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**Innovative Fossil Fuel Fired Vitrification
Technology for Soil Remediation
Phase I**

Topical Report

Work Performed Under Contract No.: DE-AC21-92MC29120

**U.S. Department of Energy
Office of Environmental Management
Office of Technology Development
1000 Independence Avenue
Washington, DC 20585**

For

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NOTICE

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1.0 EXECUTIVE SUMMARY

Vortec has successfully completed Phase 1 of the "Innovative Fossil Fuel Fired Vitrification Technology for Soil Remediation" program under Contract No. DE-AC21-92MC29120 with the Department of Energy (DOE) Morgantown Energy Technology Center (METC). The Combustion and Melting System (CMS) has processed 7000 pounds of material representative of contaminated soil that is found at DOE sites. The soil was spiked with Resource Conservation and Recovery Act (RCRA) metals surrogates, an organic contaminant, and a surrogate radionuclide. The samples taken during the tests confirmed that virtually all of the radionuclide was retained in the glass and that it did not leach to the environment—as confirmed by both ANS 16.1 and Toxicity Characteristic Leaching Procedure (TCLP) testing. The organic contaminant, anthracene, was destroyed during the test with a Destruction and Removal Efficiency (DRE) of at least 99.99%. RCRA metal surrogates, that were in the vitrified product, were retained and did not leach to the environment—as confirmed by the TCLP testing. Semi-volatile RCRA metal surrogates were captured by the Air Pollution Control (APC) system, and data on the amount of metal oxide particulate and the chemical composition of the particulate were established for use in the Phase 2 APC subsystem design.

In addition to the testing accomplished during Phase 1, a preliminary design and cost study was completed for the Phase 2 Transportable Demonstration Plant. The baseline plant has a capacity of 25 tons per day (TPD) of dried waste (2,000 lbs/hr), and the system configuration includes the soil preparation, CMS, and APC subsystems. The baseline configuration for the soil preparation subsystem is composed of grinding and drying equipment that produces a dry granulate soil for transport to the CMS combustor. The baseline configuration for the APC subsystem has a baghouse as its principal component followed by high energy particulate air (HEPA) filters. As alternatives, a wet soil preparation subsystem was developed that could transport soil to the CMS combustor as a slurry. In addition, an alternative APC subsystem was designed that would use a wet electrostatic precipitator (WESP). These alternatives were suggested during discussions with the potential sites' technical staff.

The installed costs, that is, the cost to purchase and install the equipment, as developed during the preliminary design effort being reported here for the Demonstration Plant, are as follows:

1. Baseline 25 TPD System—Dry Soil Preparation, Dry APC	\$3.7 Million
2. Alternative 1: 25 TPD System—Wet Soil Preparation, Dry APC	\$4.2 Million
3. Alternative 2: 25 TPD System—Dry Soil Preparation, Wet APC	\$4.6 Million

It should be noted here that an installed cost includes only the equipment cost and the cost to install the equipment; not included are the design, permitting, program management, and operating costs.

Vortec contacted six DOE sites to determine their interest in hosting the Phase 2 demonstration plant. Five of these are definitely interested; they are the:

- Hanford Site,
- Savannah River Site,
- Oak Ridge National Laboratory,
- Idaho National Engineering Laboratory, (INEL) and
- Component Development Integration Facility (CDIF).

Vortec has visited these sites and made presentations outlining the proposed Phase 2 program. The staff at each of these sites has expressed their interest in the Phase 2 program directly to DOE METC's Gary Nelkin and DOE Headquarters' Paul Hart.

This topical report will present a summary of the activities conducted during Phase 1 of the "Innovative Fossil Fuel Fired Vitrification Technology for Soil Remediation" program. The report includes the detailed technical data generated during the experimental program, and the design and cost data for the preliminary Demonstration Plant developed during this phase of the program.

Information developed throughout Phase 1 concerning the preferences and needs of the sites lead to changes in the demonstration plant's configuration. Thus, the demonstration plant configuration proposed by Vortec for the second phase of this program, and described in our Phase 2 proposal to DOE, is a modification and extension of the plant configuration developed during Phase 1. The revised plant configuration described in the Phase 2 proposal has the capability to supply both dry and slurry feed to the combustor. In addition, the revised plant configuration described in the Phase 2 proposal has the capability to use either wet or dry APC technology to clean the combustion gases.

Vortec is recommending that the program be continued into Phase 2. However, some changes to the scope of work are suggested. In particular, verification testing at the University of Pittsburgh Applied Research Center (U-PARC), using surrogates, is recommended to establish the optimum feedstock composition once the site soil is established. A detailed design and cost analysis and the permitting activities should be completed in Phase 2. Phase 3 should then be concerned with the construction and operation of the demonstration plant.

Data presented in this report is current as of September 30, 1993.

2.0 INTRODUCTION

Vortec has successfully completed the demonstration testing and preliminary baseline plant design required in the Phase 1 program. Vortec will continue the development of the CMS with the construction and demonstration of the Phase 2 integrated facility at a DOE site. 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 CMS technology, in plant sizes up to 200 TPD, have been made during the last year.

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, itself, not present any major obstacles to its own safe decontamination and decommissioning.

During the Phase 1 effort, Vortec has demonstrated the CMS technology's ability to vitrify soil contaminated with radionuclides, heavy metals, and organic materials. In Phase 1, a surrogate soil was defined using data obtained from site ER&WM organizations, and this soil was used for testing at the Vortec test facility. In addition, this phase of the program developed preliminary estimates of the cost for a 25 TPD Demonstration Plant system (2,000 lbs/hr of dried and sized waste soil into the combustor). The baseline plant design included a feedstock preparation subsystem that processed soil in a dry condition and an air pollution control (APC) subsystem that handled the flue gas with a dry clean-up process. Discussions with the sites indicated that material preparation and flue gas clean up in the wet conditions should also be investigated. As a result, two optional system configurations were included; that is, a wet material preparation system that can feed material to the combustor as a slurry, and a wet APC option that included a wet electrostatic precipitator (WESP) component.

During Phase 1, Vortec made presentations to five DOE laboratories - Hanford, Oak Ridge, Savannah River, INEL, and CDIF—to establish their interest in hosting the Phase 2 demonstration site. All sites expressed interest and have been in contact with METC and/or DOE Headquarters to confirm their interest.

The unique features of the proposed CMS technology should make it a particularly cost-effective process for the vitrification of soils, sediments, sludges, and mill tailings 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 would include:

1. The ability to produce a product which immobilizes heavy metals, toxic inorganics, and radionuclides over the long-term.

2. Its flexibility with respect to the types of materials which can be processed allows for accommodation of variations in feedstock composition and provides for a broad range of hazardous material applications.
3. The potential for oxidizing and vitrifying materials introduced as a slurry provides the capability for mixing contaminated or waste oils with various types of hazardous solids, such as soils, soil wash process sediments, and mill tailings. The CMS has demonstrated the capability of processing soil-water slurry and water soluble waste streams.
4. The 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.
5. The water-cooled components can continue to operate in the event that unusual wear or separation of refractory occurs, until such time as the unit can be safely shut down.
6. The potential application of automated, in-situ ceramic welding of refractory would allow for online maintenance, which reduces radiation exposure hazards to personnel, eliminates the need to remove and dispose of contaminated refractory, and increases the unit's availability and service life.
7. Its small physical size reduces the decommissioning and disposal costs of the process equipment at the end of its useful life.

This Final Report summarizes the activities that have occurred during Phase 1 of the Vortec/METC Soil Remediation Program.

3.0 PROGRAM OBJECTIVES

The principal objective of the DOE/METC program is to develop and demonstrate the effectiveness of the Vortec CMS in remediating soils contaminated with both hazardous materials and low levels of radionuclides. To convincingly demonstrate the CMS's capability, the following objectives will be met during the 3-phase program.

1. Determine the glass chemistry requirements to achieve vitrification of typical contaminated soils likely to be found at DOE sites; that is, given a specific soil, determine how its oxide composition must be modified to produce a vitrified product that will immobilize contaminants over the long-term.
2. Determine the extent to which complete silica dissolution is necessary to produce a glass product that will satisfy the glass stability and leachability criteria for containing hazardous and radionuclide materials.
3. Determine the glass residence time requirements (and therefore melter-reservoir configuration) to achieve the desired degree of silica dissolution.
4. Determine the 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 subsystems.
5. Determine the DRE of the CMS for organic contaminants likely to be found in soil from DOE sites requiring remediation.
6. Demonstrate that the CMS technology has the capability to produce a vitrified product that will immobilize the hazardous and radionuclide materials consistent with the needs of the specific DOE waste repositories. In Phase 1, the demonstration will be conducted using soil contaminated with surrogate materials and processed at the Vortec test facility at U-PARC. In the subsequent phases of the program, a facility will be constructed and operated at a DOE site.
7. Establish the quantity and chemical composition of the gaseous and particulate carryover and the size distribution of the particulate carryover from the CMS process, so that valid designs and cost estimates can be made for the flue gas clean-up systems.
8. Establish the cost of a fully-integrated soil vitrification CMS, with a 25-TPD capacity.
9. Conduct start-up, shake-down, and feasibility demonstrations using the fully-integrated plant, with a capacity of 25 TPD, constructed at a DOE site.
10. Establish the technical content of Phase 3.

Phase 1 of the METC/Vortec program has accomplished a significant portion of the first eight of these objectives. Once a DOE site is selected for Phase 2, the remaining objectives can be addressed—and definitive answers that account for the site's soil composition and the site management's preference will be possible.

4.0 ISSUES ADDRESSED BY PHASE 1

In order to partially fulfill the first 8 objectives listed in Section 2.0, the Phase 1 program plan included the following six tasks:

Task 1.1. National Environmental Policy Act (NEPA) Documentation

Task 1.2. Contaminated Soil Characteristics

Task 1.3. Synthetic Soil Definition & Preparation

Task 1.4. Subscale CMS Testing

Task 1.5. Subscale Integrated System Conceptual Design

Task 1.6. Program Management

Based on the NEPA documentation developed under Task 1.1, the Phase 1 program was granted a categorical exclusion by DOE for Phase 1 testing at U-PARC. To establish the plausible soil characteristics for DOE sites, Vortec, under Task 1.2, contacted the ER&WM managers at different sites for information on their soil's chemical composition and contamination levels. A bibliography of the material obtained from the sites is included in Appendix A. A composite of these data was used to define a surrogate soil, and the surrogate was used for the Phase 1 demonstration testing.

Having established the soil composition and its contaminant levels, Vortec initiated a laboratory program in Task 1.3 that included melt tests to define the glass-making additives required to produce a vitrified product. Given the soil composition, the addition of limestone, at 35 wt%, produced a satisfactory vitrified product with a melting temperature of approximately 2600°F.

Sub-scale testing, Task 1.4, was initiated with Test 1 using 2000 lbs of the soil and glass-making additives, but without the contaminants. The feedstock particle size was established at a mean of 600 microns with a top size of 1000 microns. Test results indicated that the SiO_2 was not fully reacted and that additional residence time of approximately 2 to 3 hours would be required for complete dissolution. The objective of Test 2 was to increase the particle size in an attempt to define the maximum particle size that could be melted. However, since the residence time of the pilot plant's reservoir is limited to 1 to 2 hours and since the reservoir configuration could not be modified within the scope of the present program, Test 2 was canceled in favor of continuing with Tests 3 and 4. Test 1 did indicate that particle sizes up to 1000 microns could be processed if sufficient residence time was available for complete dissolution of the silicates. This test also indicated that no change in the feedstock composition was needed to produce an acceptable vitrified product.

Tests 3 and 4 were conducted with all of the surrogate contaminants included in the feedstock. The tests produced 5000 pounds of vitrified product and samples were taken of all of the influent and effluent streams. The test results indicate that:

1. All of the vitrified product passed TCLP for cadmium and lead,
2. Essentially all of the zirconium and most of the potassium remained in the glass,
3. The DRE for the anthracene was greater than 99.99%, and
4. The quantities and characteristics of the semi-volatile metals in the flue gas stream were determined for use in the APC subsystem design.

Task 1.5 required the preliminary design and cost estimate for the integrated demonstration plant. Vortec contracted with Roy F. Weston Inc. to assist in the details of this design effort. Discussions with prospective sites indicated that a 25 TPD transportable design would be acceptable. The baseline preliminary design included a pneumatic feed system with a dry soil feed to the Vortec CMS and a dry APC subsystem featuring a baghouse and HEPA filters. However, expressions of concern from some DOE laboratory technical staff members prompted the investigation and costing of a wet (slurry) feedstock preparation subsystem and a wet air pollution control subsystem (APCS) as alternatives.

The baseline system developed during the Phase 1 preliminary design is considered transportable. Roy F. Weston Inc., the country's leading designer and operator of transportable thermal remediation equipment, assisted in the design; and they found no significant problems associated with a transportable plant design of this size.

The preliminary plant design developed in this first phase processes 25 TPD of dried and sized contaminated soil. The installed cost of the plant is estimated to be \$3.7 million. The installed cost of Alternative I, which includes the wet feed preparation system with a dry APC, is \$4.2 million. Alternative II, a dry feed and wet APCS, was also included for completeness, and its installed cost is estimated to be \$4.6 million.

The program management task included contacting the potential laboratory sites to determine if they had an interest in hosting the Phase 2 demonstration plant. Visits were made to:

1. Savannah River Site—Aiken, SC;
2. Hanford Site—Richland, WA;
3. Oak Ridge National Laboratory—TN;
4. Idaho National Engineering Laboratory—ID; and
5. CDIF—Butte, MT.

All of these sites expressed interest in hosting the demonstration facility. However, a definitive site for the Phase 2 Demonstration Test has not been established. This site selection is critical to continued progress in Phase 2.

5.0 CMS PROCESS DESCRIPTION

The following section will describe the CMS process and the 15-TPD test facility at U-PARC. Appendix B presents the complete test plan for the Phase 1 experimental program, including a more detailed description of the test facility, the test facility's instrumentation, and the sampling protocol. It should be noted that the existing test facility configuration is less comprehensive than the complete plant design discussed later in this report.

5.1 VORTEC'S 15 TPD TEST FACILITY AT U-PARC

The primary components of the basic CMS are a counter-rotating vortex (CRV) combustor and a cyclone melter. Figure 5.1-1 is an artist's rendering of the basic CMS concept. A unique feature of the process is the rapid suspension heating and oxidation of feedstock materials in the CRV heater 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 CRV 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 heater. Any organic contaminants in the feedstocks are also effectively oxidized.

The melted product formed in the cyclone melter, and the combustion products, exit through a tangential channel and enter a separator/reservoir (not shown in the figure) where a pool of the melted material is collected. The vitrified material exits the reservoir through a bottom or side tap, and the flue gases exhaust to a water quench/electrostatic precipitator (ESP) 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 (APC) 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. In most applications, the total amount of uncontrolled particulate carryover is less than 4% of the total mass feedstock into the process.

In applications where additional combustion residence time is required, precombustor assemblies upstream of the CRV heater inlet arms are added to the basic process system. (An alternative means of achieving additional residence time and improved combustion efficiency is through the use of oxygen enrichment of the combustion air stream.)

An isometric depiction of the test configuration which was used for the experimental program is shown in Figure 5.1-2. In the system configuration used for this test, the precombustors introduced only preheated air into the combustor. High local flame temperatures ($>4000^{\circ}\text{F}$) can be achieved in the Vortec process, since preheated combustion air at a temperature of approximately 1200°F can be used in the process. In spite of the high local flame temperatures, NO_x emissions have been demonstrated to be low; that is, typically less than 100-200 ppm.

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

Figure 5.1-1. Artist's Rendering of Basic Combustion/Melting System

Figure 5.1-2. Isometric Sketch of Vortec's Pilot Plant Configuration

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. 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 pilot plant typically ranged between 3.5 to 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. Recent tests, using Hanford's low level tank waste simulant, demonstrated the CRV combustor's ability to successfully process a feedstream containing up to 30% water.

Most of the tests to date have used a dry, shredded, or pulverized (< 400 microns particle size) feedstock pneumatically transported and injected into the CMS, and have used natural gas and/or coal as the fuel. During the Phase 1 tests, a feedstock, with a top particle size of 1 millimeter in diameter, was vitrified using the CMS process. When using a feedstock with this top size distribution, additional residence time is required to produce a fully reacted glass.

The CMS pilot system has demonstrated NO_x emissions of less than 4 lbs per ton of vitrified product, meeting the California emission standard for glass melting furnaces—currently the most stringent in the U.S. With natural gas as the primary fuel, the NO_x emissions, calculated as NO₂, have typically been approximately 2 lbs 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 municipal solid waste incineration (MSWI) flyash and fiberglass waste, the uncontrolled emissions levels have typically been in the range from 1% to 2%. However, Vortec is investigating proprietary concepts for the recycling of these particulates into the system.

5.2 PREVIOUS RESEARCH ACCOMPLISHED AT THE U-PARC FACILITY

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:

- Utility flyash,
- Fiberglass waste with organic contaminants,
- Municipal solid waste incinerator (MSWI) flyash, and
- Dusts containing heavy metals and organic materials.

Appendix C is a partial listing of the recent contracts completed by Vortec related to CMS test and development activities.

6.0 EXPERIMENTAL PROGRAM RESULTS

The following sections describe the results of the Phase 1 experimental program. As previously indicated, based on the NEPA documentation developed in Task 1.1, the Vortec test facility was granted a categorical exclusion by DOE.

6.1 SURROGATE SOIL DEFINITION

The objective of this task was to identify the physical and chemical properties of soils likely to require remediation at DOE sites and to provide information to define the surrogate soil contaminants. Available publications and reports by DOE site contractors were reviewed to accomplish the objective of this task. Table 1 lists the individuals that were contacted as well as those who contributed either information or documentation. Soils were characterized with respect to:

- Oxide content,
- Toxic organic and inorganic content,
- Radioactive constituents, and
- Particle size distribution.

Documents reviewed for soil characteristics data are listed in Appendix A.

Table 1. Vortec Contacts to Establish Soil Composition at DOE Sites

Contact	Location
Larry Voorhease	DOE Oak Ridge
Lisa Wachter	Oak Ridge (Martin-Marietta)
Hal Davidson	Oak Ridge (Martin-Marietta)
Ron Rhea	Oak Ridge (Martin-Marietta)
Marilyn Tober-Smith	DOE Headquarters
Mark Triplate	PNL Richland
Steve Short	PNL Richland
Jeff England	DOE Savannah River Project
Jack Nyhan	DOE Los Alamos
Will Polser	DOE Los Alamos
Ralph Koenig	Merlin Company, Boulder, CO
Anthony Eicher	Focus Engineering, Knoxville, TN

To establish the variability within a particular site, it is likely that many samples per site would be necessary. However, collecting and analyzing multiple samples from several possible sites was beyond the scope of this project.

Table 2 is a matrix of reported soil oxide content as a function of site location. As additional data on site soils were obtained from the Environmental Restoration organizations at each site, they were compared to Table 2 to establish any significant differences.

Table 2. Typical Soil Composition at Selected DOE Sites

Composition, Wt%

Location	Soil Type	K ₂ O	Na ₂ O	Al ₂ O ₃	CaO	Fe ₂ O ₃	MgO	SiO ₂	TiO ₂ , P ₂ O ₃ , ZrO ₂
Barnwell	Fugay	0.20	0.24	9.26	0.04	2.75	0.12	86.7	0.68
Hanford	-	1.80	3.02	13.6	6.00	9.55	2.88	60.9	1.95
Idaho (INEL)	-	2.52	1.35	11.4	9.97	4.07	-	69.6	1.07
LANL	Carjo	2.82	2.73	12.4	0.94	2.93	0.60	76.8	0.78
	Puye	3.39	3.87	13	0.51	2.38	0.37	76.1	0.45
	Tuff	4.44	4.44	12.3	0.46	1.23	-	76.9	0.16
Maxey Flats	Tilsit	1.12	0.44	7.79	0.06	3.13	0.43	85.5	1.52
NTS	Beatty	3.88	3.54	13.6	2.89	2.87	1.25	71.3	0.74
ORNL	-	2.55	0.32	17.3	0.11	11.0	0.97	66.5	1.28
Sheffield	Fayette	1.97	1.60	10.8	0.78	3.82	0.87	79.1	0.96
WVNS	Churchville	2.69	1.09	14.2	3.22	5.01	2.03	70.4	1.29

Source: J. L. Buelt et.al., "In-situ Vitrification of Transuranic Waste": PNL-4800, March 1987.

Information on soil moisture content and particle size distribution was lacking at most sites. However, this lack of information did not have a significant impact on establishing the surrogate soil definition. Soil size distribution ranged from rocks with effective diameters of several inches to fines. In all cases raw soil size, as randomly removed from a proposed site, is expected to be significantly larger than can be accommodated by the CMS system without a soil preparation step. Moisture content also would have a large variability, as would be expected for soil randomly removed from a proposed site, and will require a drying step to be pneumatically transportable.

Table 3 presents the surrogate soil composition derived by Vortec, based on: data given in Table 2, review of additional data supplied by the site ER&WM managers, and recommendations by Vortec's glass scientists. Also included in the table is the surrogate soil defined by EPA used for studies in their Superfund Innovative Technologies Evaluation (SITE) program. In the SITE program, a large number of Superfund sites were surveyed, and the composite soil defined in Table 3 was established. The only significant difference between the SITE soil and the surrogate defined for the DOE sites is the amount of CaO included in the SITE soil. A large number of the Superfund sites were waste sites containing significant

Table 3. Recommended Soil Composition for the METC Phase 1 Demonstration

Compound	DOE SITE SOIL Wt%	EPA SITE SOIL Wt%
SiO ₂	75.30	57.43
Al ₂ O ₃	11.00	11.74
K ₂ O	2.10	1.55
Na ₂ O	1.80	0.84
Ca O	3.10	20.26
Fe ₂ O ₃	5.10	2.32
MgO	0.70	5.29
Other Oxides	0.90	0.57

amounts of acid waste. Attempts were made to neutralize the acid using limestone and this accounts for the higher levels of CaO.

6.2 FEEDSTOCK PREPARATION

In order to establish the correct glass-making additives needed to make a suitable glass matrix, which would retain the contaminants, laboratory melt tests were conducted at Vortec's laboratory facility in Collegeville, PA. A mixture of the surrogate soil and 35% weight limestone produced a satisfactory glass.

Actual inorganic, organic, and radionuclide contaminants were simulated with: lead oxide, cadmium oxide, anthracene, potassium carbonate, and zirconium oxide, based on data from the site ER&WM managers and additional information describing the contaminants found at Superfund sites.

Table 4 lists the types and amounts of compounds that were added to the soil to represent the hazardous and radionuclide contaminants expected in the soil. Simulated radionuclides are non-radioactive metals, which simulate the true behavior of radionuclide species in the CMS process. To complete the feedstock formulation, limestone was added to the soil for all of the tests as the glass-making additive, at 35 weight %. Prior to the day of the test, blending of the surrogate soil was completed at Vortec's U-PARC facility.

Table 4. Concentration of Contaminant Compounds

Compound	Concentration of Element in Soil (PPM)
Heavy Metals	
Lead Oxide	1000
Cadmium Oxide	1000
Volatiles	
Anthracene	1000
Radionuclides	
Potassium Carbonate	1000
Zirconium Oxide	1000

The cadmium and lead represent volatile RCRA heavy metals; anthracene represents a semi-volatile organic compound; and zirconium is representative of plutonium and strontium at low temperatures and in the presence of water. The anthracene was chosen as the organic simulant for two reasons. First, it is considered a difficult compound to incinerate and has been used by DOE as the principal organic constituent for combustion testing. Secondly, its physical properties are well suited to Vortec's feedstock preparation needs. Since Vortec prepares, samples, and stores test feedstock in a separate facility several days prior to actual testing, using a volatile material in a liquid form could cause problems: it would compromise the mixing process; and the amount of organic actually in the feedstock at the time of the test would be unknown. Because anthracene is a non-volatile solid at room temperature and pressure, it works well as the organic simulant under the conditions found at the U-PARC facility.

For Test 1, 2000 lbs of feedstock were prepared, without hazardous constituents added to the soil. Figure 6.2-1 indicates the size distribution; these data indicate that the mean size of the surrogate soil was 600 microns, as specified, with a top size of approximately 1000 microns. Figure 6.2-2 indicates the size distribution of the soil used in Test 3 and Test 4.

Figure 6.2-1. Particle Size Distribution for METC Test 1

Figure 6.2-2. Particle Size Distribution for METC Tests 3 and 4

6.3 CMS TESTING

As already indicated, Tests 1, 3, and 4 of the test plan were completed. Test 1 was initiated using feedstock materials with a top size of 1000 microns and was run to determine if the large particles could successfully make a fully-reacted glass using the CMS system. Significant amounts of undissolved silica were observed in the glass, and its presence and composition were confirmed by Corning's petrographic analysis. Vortec's laboratory determined that the additional residence time at melt temperature required to completely dissolve the silica was approximately 2 to 3 hours. This amount of time at melt temperature was not possible with the CMS system configuration presently available at the test facility. Test 2, as originally planned, would have used larger particle sizes than Test 1; therefore, it was not conducted; and the decision to use particle size distributions within our experience-base lead to proceeding with Tests 3 and 4.

Tests 3 and 4 of the Phase 1 experimental program were conducted during the week of June 14, 1993, at Vortec's U-PARC test facility. The surrogate soil used had a top particle size of approximately 420 microns, and the soil was spiked with the surrogate contaminants as listed in Section 6.2.

The flowrate of feedstock to the CMS during the tests was determined by measuring the difference in the feed tank weight over time. The feed tank weight time histories are presented in Figures 6.3-1 through 6.3-3. Glass and water samples were taken simultaneously with an EPA Method 5 sampling procedure being conducted on the flue gas. The glass samples were sent to the CELS laboratory for metals, ANS 16.1, and petrographic analysis and to Blue Marsh Laboratory, Inc., Douglassville, PA, for TCLP analysis. Spray channel water samples were also sent to Blue Marsh Laboratory, Inc. for metals analysis. The Method 5 sampling was performed by Energy Systems Associates (ESA), Pittsburgh, PA.

Figure 6.3-1. Feedstock Flow Time History—Test 1

Figure 6.3-2. Feedstock Flow Time History—Test 3

Figure 6.3-3. Feedstock Flow Time History—Test 4

Table 5 presents a run-time log and indicates the times when measurements and samples were taken.

Table 5. Run-Time Log for Test 1, Test 3, and Test 4

TIME		BATCH FLOW
Test 1		
22:50	Batch ON	
00:01	Glass sample taken	500 lbs/hr
01:01	Sample taken	1000 lbs/hr
01:58	Batch OFF	
Test 3		
8:40	Batch ON—Start Test 3	Average feedstock
10:22	Batch STOPPED—ESA having difficulty	flowrate:
12:05	Batch ON	819 lbs/hr
12:40	ESA Tests—Start data collection	
13:45	ESA Tests—Finish data collection	
13:50	Batch OFF—End of Test 3	
Test 4		Average feedstock
15:38	Batch ON—O ₂ Test commenced—Start Test 4	flowrate:
17:15	ESA Tests—Start data collection	535 lbs/hr
18:10	ESA Tests—Finish data collection	
19:36	Batch OFF—End of Test 4	

6.3.1 Glass Characterization

Glass samples were taken directly from the molten glass stream leaving the tap hole at the time indicated in Table 5. Corning conducted petrographic analyses on the two Test 1 samples. The amount of undissolved silica was approximately the same for both samples. Figure 6.3.1-1 is a photomicrograph, taken by Corning, of a Test 1 glass sample, indicating an undissolved silica particle with a maximum dimension of approximately 660 microns.

Vortec evaluated samples of the vitrified product from the Test 1 to determine the additional time at melt temperature required to completely dissolve the residue of the 1000 micron silicon dioxide particles remaining in the glass. Samples were reheated to their melting temperature in a laboratory furnace and held for varying lengths of time. Test results indicate that a fully-reacted glass can be produced if the molten glass is held at approximately 2500°F for an additional 2.5 to 3.0 hours. It should be noted that the importance of having a fully-reacted glass, that is, the complete dissolution of the silicon dioxide, on the leachability of the radionuclides is not known. Discussion with glass technologists at Hanford and Savannah River indicated that if the glass could pass the leachability test, ANS 16.1 or its equivalent, it would be considered a satisfactory waste form. It should also be noted here that a fully-reacted glass was produced during Test 3 and Test 4, simply by reducing the top size of the silicon dioxide to 420 microns. No other changes were needed and there were no changes in the feedstock composition.

Figure 6.3.1-1. Photomicrograph of Glass Sample from METC Test 1

Table 6 presents the data generated by Corning's laboratory using the leaching test procedure defined in ANS 16.1. As already indicated, the surrogate used for plutonium was non-activated zirconium, and at a concentration of 1000 ppm in the soil it was expected that enough would leach from the glass to be detectable by the plasma emission spectroscopy methods used by Corning. However, Corning reported non-detectable levels for all time intervals and this result was simply reported in Table 6. Since the zirconium was not activated, scintillation detection methods capable of identifying much lower levels of activity in the leachate were not applicable.

The glass produced during Tests 3 and 4 was analyzed for the heavy metal surrogates by Corning. Table 7 presents those metals analyses results.

The relatively low concentrations of cadmium and lead in the glass were not unexpected, for both heavy metals are volatile at the melting temperature of the glass. Previous tests with feedstocks containing these metals have produced similar results. Further testing with lower operating temperatures are expected to reduce the volatilization of these metals.

The concentration of potassium in the glass is higher than one would expect if the soil contained only 1000 ppm of potassium. However, the actual concentration of potassium in the soil is much higher since the Nepheline Syenite, a component used to form the proper chemical composition of the surrogate soil, contained about 5% K_2O . In any event, the majority of the potassium was retained in the glass and did not leach.

Table 6. ANS 16.1 Leachability Test Results for Glass Processed in Vortec's CMS

Time (hours)	Zirconium Amount Leached* (PPM)
0	not detected
2	not detected
7	not detected
24	not detected
48	not detected
72	not detected
96	not detected
120	not detected

*Detection Limit <0.003 ppm

Table 7. Glass Characteristics for Tests 3 & 4

SURROGATE CONTAMINANT	Test 3		Test 4	
	Concentration in Glass			
	Wt %	Glass / Feed %	Wt %	Glass / Feed %
CdO	0.0048	5.3	0.0044	4.8
K ₂ O	1.76	98.0	1.71	95.0
PbO	0.021	24.0	0.012	14.0
ZrO ₂	0.235	>100	0.165	>100

The zirconium concentration in the glass is also higher than expected; this is due to the absorption of some zirconium from the AZS (alumina-zirconia-silica) refractory present in the CMS pilot unit. As indicated by the ANS 16.1 and TCLP test results, the zirconium contained in the glass did not leach.

Table 8 displays the results of TCLP tests performed on the feedstock and the glass samples collected during Test 3. For the glass, the concentrations of the cadmium and lead in the leachate are below their allowable maximum levels, as defined in Table I of 40 CFR, part 261.24; that is, 1 ppm and 5 ppm respectively. The feedstock materials for both tests would have been judged hazardous by characteristic.

Table 8. Glass and Feedstock TCLP Results

Metal	Glass (mg/l)	Feedstock Sample 1 (mg/l)	Feedstock Sample 2 (mg/l)
Cadmium	0.11	35.45	34.80
Lead	ND	16.6	22.7
Potassium	ND	35.	21.3
Zirconium	ND	ND	ND

6.3.2 Flue Gas Characterization

ESA sampled the flue gas effluent using Method 5 procedures for particulate, cadmium, lead, potassium and zirconium. The sampling location for the Method 5 test is immediately after the spray channel quench system and before the wet ESP. The particulates were sampled isokinetically using the standard EPA sampling train configuration. Table 9 presents the data obtained during the Method 5 test conducted during Tests 3 and 4. The particulate mass loading reported during Test 3 was 2.22 lbs/hr; and during Test 4, the loading was reported as 1.65 lbs/hr.

Table 9. Particulate Mass Loading Summary for Tests 3 & 4

Test:	Test 3	Test 4
Particulate Loading Results		
Particulate Loading (grains/dscf)	0.31	0.41
Particulate Loading (lb/dscf)	4.39E-05	5.81E-05
Particulate Emission Rate (lbs/hr)	2.22	1.65

The particulate captured during the Method 5 test was also analyzed for the surrogate radionuclides and heavy metals. Table 10 displays the flue gas mass loading or emissions for the cadmium, lead, potassium and zirconium for Tests 3 and 4. Emission rates for cadmium and lead during Test 4 are not consistent with Test 3, or previous experience. Immediately after the Method 5 test procedure was completed, a modified Method 5 procedure was initiated to capture any anthracene in the flue gas.

Table 10. Metals Mass Loading Summary for Tests 3 & 4

Test:	Test 3 Emission Rate (lb/h)	Test 4
Cadmium	0.415	0.190
Lead	0.297	0.139
Potassium	0.319	0.324
Zirconium	0.006	0.002

Table 11 presents the anthracene data from the modified Method 5 test performed during Tests 3 and 4. The anthracene mass loading reported during Test 3 was 1.68E-7 lbs/hr and during Test 4 was 1.68E-7 lbs/hr. The DRE for both tests was well beyond 99.99%.

Table 12 displays the flue gas emissions data as determined by Vortec's online gas analyzers. The only significant change in the flue gas emissions between Test 3 and Test 4 is the increase in the NO_x levels during Test 4. This is due to the higher flame temperature within the CRV when using oxygen enriched air, which increases the thermal NO_x production.

Table 11. Anthracene Mass Loading Summary for Tests 3 & 4

Test:	Test 3	Test 4
Anthracene Loading Results		
Anthracene Loading (grains/dscf)	2.33E-08	4.15E-08
Anthracene Loading (lb/dscf)	3.33E-12	5.92E-12
Anthracene Concentration (ppm)	7.20E-03	1.28E-05
Anthracene Emission Rate (lbs/hr)	1.68E-07	1.68E-07

Table 12. Flue Gas Emission Data*

Test:	Test 3	Test 4
% O ₂	4.13	5.11
ppm NO _x	309	850
ppm CO	159	190
ppm SO ₂	6.67	10.2

* Note: As indicated in Table 5, test data were taken during two intervals for Test 3 and Test 4. The SO_x, NO_x, CO and % O₂ measurements are recorded automatically during the test run at 1-minute intervals. During the data reduction procedure, these data are time-averaged and reported over the duration that the flue gas Method 5 data and glass samples were obtained. Table 12 reports these are the time-averaged values.

6.3.3 Spray Channel Characterization

Since the Method 5 test sampling location is immediately after the spray quench system and before the wet ESP, the spray channel water and any particulate matter captured by the water must be analyzed for the surrogate radionuclides, heavy metals and anthracene. (See Appendix B for instrument and sampling locations.)

Table 13 shows the flow rates of the spray channel water and the particulate captured by the quench water. Table 14 shows the concentrations of anthracene and metals in the spray channel water and the spray channel water particulates.

Table 13. Spray Channel Water and Particulate Flow Rates (lbs/hr)

Test:	Test 3	Test 4
Quench Water	3165	4728
Particulate	8.88	6.24

Table 14. Spray Channel Water and Particulate Composition

Test:	Test 3	Test 4
SPRAY CHANNEL WATER (mg/l)		
Anthracene	ND	ND
Cadmium	ND	ND
Lead	2.0	6.1
Potassium	44.9	23.0
Zirconium	ND	ND
SPRAY CHANNEL SEDIMENT (mg/kg)		
Anthracene	ND	ND
Cadmium	5900.	9696.
Lead	10400.	12700.
Potassium	190.	116.
Zirconium	2150.	2490.

6.3.4 System Performance

The heat and mass balances for Tests 3 and 4 are presented in Figures 6.3.4-1 and 6.3.4-2, respectively.

The objective in running these two tests was to demonstrate the effect of oxygen enrichment on flue gas flow rate and glass quality. The oxygen content of the combustion air was increased from 23% in Test 3 to 30% in Test 4.¹

The heat and mass balance data presented indicate that the increase in oxygen will produce a decrease of 32% in the flue gas flow rate, a 50% increase in gas residence time and a 28% reduction in heat rate. The principal advantage in using high levels of oxygen enrichment is that it reduces flue gas flow rates which, in turn, increases the residence time of the gases in the CMS. This increase in residence time could be beneficial in the destruction of semi-volatile organics. NO_x production will also be reduced when nearly 100% O₂ is used.

A mass balance on the surrogate materials (the surrogate radionuclides, heavy metals, and anthracene) was performed for both Tests 3 and 4. The mass balance data are shown in Tables 15 and 16. The accuracy of the flue gas data collected is sufficient to report an anthracene DRE of 99.9999% for both tests. The mass balances on the semi-volatile heavy metals indicate that the majority of these compounds exit the CMS as a particulate in the flue gas. These particulate materials may be recycled into the glass through a proprietary technology presently being developed by Vortec; however, the recycling was not within the scope of work for this Phase 1 research.

¹ **Note:** At 30% enrichment, the oxygen system was operating at maximum capacity. Additional capacity is available for higher levels of enrichment, but line, valve and regulator changes will be required.

Figure 6.3.4-1. Heat and Mass Balance for Test 3

Figure 6.3.4-2. Heat and Mass Balance for Test 4

Table 15. Mass Balance on Surrogate Materials for Test 3 (lbs/hr)

Surrogate Compound	Feed-stock In	Glass out	Flue Gas out	Quench Water out	Quench Particulate out	Percent Not Accounted For
Anthracene	0.530	ND	1.68E-07	ND	ND	NA
Cadmium	0.530	0.0283	0.415	ND	0.0524	6.47
Lead	0.530	0.131	0.297	0.00633	0.0924	0.59
Potassium	10.07	9.87	0.319	0.142	0.00169	-2.56
Zirconium	0.530	1.17	0.00560	ND	0.0191	NA

Table 16. Mass Balance on Surrogate Materials for Test 4 (lbs/hr)

Surrogate Compound	Feed-stock In	Glass out	Flue Gas out	Quench Water out	Quench Particulate out	Percent Not Accounted For
Anthracene	0.347	ND	1.68E-7	ND	ND	NA
Cadmium	0.347	0.0170	0.190	ND	0.0605	22.9
Lead	0.347	0.0489	0.139	0.0288	0.0792	14.7
Potassium	6.59	6.27	0.324	0.109	0.000724	-1.62
Zirconium	0.347	0.537	0.00194	ND	0.0155	NA

The mass balances on the potassium and zirconium show that significant fractions (>95%) of the potassium and zirconium remain in the glass. The quantity of potassium fed to the CMS is much larger than the 1000 ppm originally intended. This is due to the presence of potassium in the surrogate soil—about 5% K₂O. However, the mass balances performed account for all of the potassium fed to the CMS, and indicate that the majority will be retained in the glass.

It should be noted that the quantity of zirconium exiting the CMS is greater than the quantity entering the unit. This is due to the absorption of zirconium into the glass from the AZS refractory lining of the separator reservoir.

7.0 PRELIMINARY CONCEPTUAL DESIGN

The preliminary design completed during Phase 1 was accomplished simultaneously with interactions with the site's technical staff. The preliminary conceptual design baseline configuration was modified consistent with the input from other sites. The site's interests and preferences resulted in two alternative configurations being costed in addition to the baseline configuration.

By way of clarification, it should be noted that system configuration discussed in Vortec's Phase 2 proposal combined the baseline and both options into a single system configuration. This combination is expected to improve the versatility of the system, thereby reducing technical risk and providing a system that can process a wide variety of waste streams.

7.1 INTEGRATED SYSTEM CONCEPTUAL DESIGN—BASELINE

Phase 1, Task 1.5, required the preliminary design and estimated cost of a fully integrated plant that is to be built and operated at a DOE site to remediate actual contaminated soil. This section of the Topical Report will define the baseline 25 TPD system that was developed during Phase 1. Discussions with the sites indicated that a significant variability in the feedstream is likely. In addition, some sites had very definite opinions on the technology they would accept in the plant design. As a result, the baseline plant with two alternatives is defined here, and the installed cost for the baseline plant and the alternatives are presented. The plant designs are labeled as follows:

- 25 TPD Dry Preparation-Dry APC—Baseline
- 25 TPD Wet Preparation-Dry APC—Alternative I
- 25 TPD Dry Preparation-Wet APC—Alternative II

7.1.1 System Requirements

The system requirements for the Baseline facility are as follows:

1. Waste soil input will be approximately 25 TPD of dried and sized material.
2. Facility will be transportable, allowing for its use at multiple DOE sites and/or multiple locations at a single site. Only minor design modifications are needed to develop a transportable facility versus a fixed-location facility (e.g., replacing welded connections with flanges). Process equipment will be skid-mounted which can be attached to concrete pad foundations or other transportable foundation structures.
3. The facility will be capable of processing mixed wastes. Mixed wastes are soils, sediments, and/or sludges contaminated with hazardous wastes and low-level radioactive wastes. Any organic contamination (solvents, fuels, etc.) is assumed to contain chlorine at concentrations requiring acid gas (HCl) neutralization as part of the flue gas treatment system. Both volatile (cesium) and nonvolatile (uranium and plutonium) radionuclides may be present in the waste stream.
4. The entering waste stream will be fed, in dry form, to the CRV combustor with a particle size no greater than 500 microns and a moisture content that enables the material to flow freely (approximately 0 to 10 percent). When the optional slurry feed system is being considered, the wet feed stream will require a similar

particle size and a liquid content that enables the material to be pumped (approximately 40 to 50 % water).

5. The APC subsystem will be required to meet DOE/EPA standards for the removal of hazardous material and radionuclides.
6. Spent "equipment" generated as a result of testing will be disposed on-site, or at an approved DOE low-level radioactive waste-disposal facility, and will be the responsibility of the DOE facility. These wastes may include but are not limited to:
 - Personnel protective equipment
 - HEPA filters
 - Treated scrubber/ESP water
 - Spent ion exchange equipment

Vitrified product will be returned to the area on the site from which it was removed, or be placed in a repository as directed by the site personnel.

7. It is assumed that the DOE site selected is a Comprehensive Environmental Responsibility, compensation and Liability Act (CERCLA) site and is included on EPA's National Priorities List (NPL). CERCLA hazardous waste sites do not require permits for performing remedial activities (although the substantive requirements of the permit must be met). It is further assumed that initial testing will be performed with CERCLA hazardous waste only, thereby minimizing requirements for EPA or state permits. When radioactive wastes are processed, additional permitting requirements will be necessary depending on the DOE facility and the State in which it operates.
8. Upon completion of testing, the facility will be decontaminated, decommissioned, and stored at the DOE site. The test site will be restored to the original condition before the test.

7.1.2 Material Balances

The material balances for the complete Baseline facility is included as Figures 7.1.2-1a and 7.1.2-1b. The material balance is used to properly size the process equipment and helps in understanding the flow of process materials (including contaminants) through the system. The assumptions used in developing this material balance include:

- The material balance for the dry feed system is independent of the CMS feed system.
- The feed hopper will supply wastes to the impact hammer mill at a maximum rate of 4,000 lbs/hr with a moisture content of 20%.
- The waste feed has a volatile radionuclide concentration of 3×10^{-7} ppm of Cs-137. Non-volatile radionuclides like U-238 or Th-230 are not critical to the sizing of process equipment.
- The waste feed also has an organic chlorine content of 1,000 ppm, which is used to evaluate acid gas neutralization equipment.
- The waste stream conveyed to the CRV will consist of 25% by weight limestone and 75% waste material. (Note: Surrogate soil tests, reflecting later data from DOE sites, resulted in 35% limestone and 65% waste for the experimental tests.)
- The dust loading from the CMS has been conservatively estimated at 10% of the feed rate. The dust loading from the materials-handling cyclone separator has also been estimated at 10% of the hopper feed rate.

Figure 7.1.2-1a. Phase 2 Baseline Facility Material Balance (p. 1 of 4)

Figure 7.1.2-1b. Phase 2 Baseline Facility Material Balance (p. 2 of 4)

Stream I.D. #	1	2	3	4	5	6	7	8	9	10
Stream Description	Hopper Feed	Mill Exit	Dried & Sized Waste	Limestone Addition	Feed to CRV	Molten Exit	Glassified Residual	Off-Gases from Recuperation	Spray Tower Exit	Baghouse Exit
Flow Rate in ACFM (gpm)	-	-	-	-	-	-	-	10,150	7,130	7,560
Temperature in °F	60	250	100	60	75	2400	200	2000	400	375
Pressure in inches W.C. (psig)	-	-	-	-	-	0	0	-1	-2	-7
Mass Flow in lbs/hr	4,000	3,200	2,085	520	2,605	2,335	2,335	8,940	15,660	17,400
Composition in Wt %										
- CO ₂	-	-	-	-	-	-	-	12.2	7.0	6.2
- H ₂ O	20	-	20	20	20	-	20	18.5	43.4	39.1
- N ₂	-	-	-	-	-	-	-	66.2	45.5	48.7
- O ₂	-	-	-	-	-	-	-	3.0	4.0	5.9
- HCl	-	-	-	-	-	-	-	0.1	0.1	0.1
Radioactivity (Cs-137)(pCi/gm)	26.1	32.6	32.6	0	22.8	0	0	6.33	3.62	3.26
Dust Loading (lb/hr)	-	-	-	-	-	-	-	310	310	3.1
Stream I.D. #	11	12	13	14	15	16	17	18	19	20
Stream Description	HEPA Filter Exit	Scrubber Exit	Stack Exit	Cyclone Separator Exit	I.D. Fan Exit	I.D. Fan Recycle	Baghouse Exit	HEPA Filter	Carbon Bed Exit	Cooling Tower Influent
Flow Rate in ACFM (gpm)	7,560	6,190	6,190	1,930	1,930	0	2,090	2,010	2,010	(61)
Temperature in °F	375	175	175	200	200	0	190	180	180	110
Pressure in inches W.C. (psig)	-10	-14	0	-2	-2	0	-2	-3	0	(30)
Mass Flow in lbs/hr	17,400	18,480	18,480	7,008	7,008	0	7,570	7,570	7,570	30,440
Composition in Wt %										
- CO ₂	6.2	5.9	5.9	-	-	-	-	-	-	0
- H ₂ O	39.1	42.8	42.8	-	-	-	-	-	-	100
- N ₂	48.7	45.8	45.8	-	-	-	-	-	-	0
- O ₂	5.9	5.5	5.5	-	-	-	-	-	-	0
- HCl	0.1	0	0	-	-	-	-	-	-	0
Radioactivity (Cs-137)(pCi/gm)	3.26	0	0	0	0	0	0	0	0	0
Dust Loading (lb/hr)	0	0	0	320	320	0	3.2	0	0	0

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Figure 7.1.2-1c. Phase 2 Baseline Facility Material Balance (p. 3 of 4)

Stream Description	20 Cooling Tower Exit	21 Natural Gas to CRV	22 Natural Gas to Air Heater	24 Pre- heated Combust- ion Air	25 Water to Spray Tower	26 Water to Quench Tank	27 Water to Quencher/ Absorber	28 Caustic Addition	29 Scrubber Blow- down	30 Scrubber Recycle
Flow Rate in ACFM (gpm)	(61)	94	10	3,220	(10.3)	(5.0)	(2.6)	(0.1)	(0.4)	(300)
Temperature in °F	85	68	68	1,200	70	70	70	70	175	175
Pressure in inches W.C. (psig)	(30)	(100)	(10)	(10)	(80)	(25)	(30)	(30)	(30)	(30)
Mass Flow in lbs/hr	30,440	400	43	7720	5160	2500	50	50	220	165,000
<u>Composition in Wt %</u>										
- CO ₂	0	-	-	1	0	0	0	0	0	0
- H ₂ O	100	-	-	0	100	100	75	75	94	94
- N ₂	0	-	-	78	0	0	0	0	0	0
- O ₂	0	-	-	21	0	0	0	0	0	0
- HCl	0	-	-	0	0	0	0	0	0	0
Radioactivity (Cs-137)(pCi/gm)	0	0	0	0	0	0	0	0	0	5.14
Dust Loading (lb/hr)	0	0	0	0	0	0	0	0	0	0

Figure 7.1.2-1d. Phase 2 Baseline Facility Material Balance (p. 4 of 4)

- This material balance assumes no recycle of the materials handling off-gases back into the impact dryer mill (Stream 16).
- The maximum dissolved solids concentration in the scrubber blowdown will be 6% by weight (Streams 29 and 30).
- The caustic solution added to the absorber will be 25% sodium hydroxide (NaOH).
- The "Composition by Wt %" description is primarily intended for the characterization of the flue gases (Streams 8 through 13) and is not calculated for each individual stream.

The material balance indicates a waste processing rate of 4,000 lbs/hr. Preprocessed solid wastes are then stored in a silo and fed to the feedstock mixing tank at an approximate rate of 2,085 lbs/hr. Off-gases from the materials handling system are exhausted to the atmosphere at a rate of 1,910 acfm and a temperature of 180°F.

Feedstock to the CRV (waste materials plus limestone) is conveyed at a rate of 2,605 lbs/hr. Molten material exits the separator-reservoir at a rate of 2,335 lbs/hr and a temperature of approximately 2,400°F. Flue gases are treated through air pollution control equipment and discharged to the atmosphere at a rate of approximately 6,190 acfm and a temperature of 175°F. Scrubber water would be blowdown from the system at a rate of 0.4 gpm.

7.1.3 Plant Layout

The baseline facility has been conceptually designed as a transportable system; that is, the individual components of the process have the capability to be transported by truck to the site, erected, and when operation is complete, dismantled, decontaminated, loaded back onto trucks, and hauled off-site.

Figure 7.3-1 shows the overall plant layout, designed to accommodate truck traffic into and out of the plant. Trucks delivering supplies or raw materials to the site will enter from the north, along the gravel access road, and check-in at the office trailer. Office deliveries or limestone deliveries can be made from on or just off the gravel access road, minimizing vehicle contamination. Roll-offs containing frit can also be managed from just off the gravel access road.

The waste feed staging area is located in the southwest corner of the plant, away from the most active work areas because of increased exposure potential associated with the wastes. Dump trucks carrying wastes to the plant travel a separate gravel access road to the waste feed staging area. Dump trucks will be decontaminated prior to leaving the staging area.

The feed hopper and impact dryer mill are located on a single, bermed skid adjacent to the waste feed staging area. The waste feed storage tank, limestone tank, and feedstock mixing tank are all on one skid. The melting system and the individual flue gas treatment system components will each have separate skid configurations.

Health and safety work zones (e.g., exclusion zone, support zone) will be established once a particular facility is identified and more site-specific information is obtained (e.g., climatic data, waste characterization data, etc.). The site health and safety requirements may dictate the degree of containment required in the soil preparation facility.

Figure 7.1.3-1. Phase 2 Baseline Facility—Plant Layout

Facility Site Criteria

Both DOE and Vortec are currently evaluating potential sites for testing the CMS. Candidate sites are DOE facilities with large quantities of mixed wastes (hazardous and low-level radioactive wastes) including: Hanford, WA; Savannah River, SC; Oak Ridge, TN; and possibly Idaho Falls, ID. The CDIF at Butte, MT has also expressed interest.

One feature that makes the sub-scale vitrification facility testing more attractive to candidates is its transportability. When testing is completed in a given area, the facility can be removed from that area. Permitting requirements are often less stringent for a transportable facility.

Permits may be required from the U.S. EPA, the state environmental agency, and the DOE. From a hazardous waste standpoint, the assumption is that testing would be performed at a CERCLA site which would eliminate the need for permits. If a CERCLA site is not available, the facility would most likely be permitted as a RCRA research and development facility. It is not anticipated that a RCRA Part B permit application would be required due to the limited time of facility operation.

From a low-level radioactive standpoint, it is assumed that DOE, as the owner, accepts responsibility for operation of the facility. Under this arrangement, radiation issues are regulated under DOE authority.

Preliminary site selection criteria have been established by DOE, and are presented in Appendix D.

7.1.4 Baseline System Description

The description of the baseline facility is divided into three primary subsections. Subsection 7.1.4.1 presents an overall process description which shows how each of the process components fit into the overall system. Next, Subsection 7.1.4.2 discusses the primary process areas in detail. Finally, Subsection 7.1.4.3 lists the vitrification facility equipment.

Figure 7.3-1 showed the overall plant layout schematic, and Figure 7.1.4-1 shows the flow diagram for the baseline facility. The 25 TPD (2,085 lbs/hr dry soil into the combustor) baseline conceptual design to be presented here includes a dry feed system (using the impact dryer mill) and a dry flue gas treatment train (baghouse option). The wet feed and wet flue gas options were evaluated as variations to the baseline design and are designated Alternative I and Alternative II, respectively.

7.1.4.1 Overall Process Description

The baseline facility will be installed and operated at a DOE facility that requires some form of soil remediation. To demonstrate the effectiveness of the technology, 400 hours of start-up and functional testing are planned followed by a 30-day period of continuous testing. Processing will be performed on soils contaminated with hazardous and/or radioactive materials.

The vitrification process begins with the preparation of the waste stream to be treated. Contaminated soils will be excavated and transported to a stockpiling location adjacent to the vitrification facility. From the stockpile area,

Figure 7.1.4-1. Phase 2 Baseline Facility Process Flow Diagram

contaminated materials will be transported by front-end loader to a screened feed hopper. Material is deposited into the screened feed hopper where particles greater than 1.0 inch in diameter are removed. The screened material is transported by screw conveyor from the bottom of the hopper to the impact dryer mill. The impact dryer mill simultaneously pulverizes and dries the material; heat from the drying operation is supplied by a gas-fired burner. The dried, fine grained material is pneumatically transported out of the mill and into a cyclone separator where the solid material is separated from the transport air. The solid material drops from the cyclone into a storage silo before being processed through Vortec's CMS.

Off-gases from the pneumatic transport system will require treatment due to the possible volatilization of organic compounds during the drying process. As waste material is heated, volatile organics will be stripped off; however, volatile radionuclides are not expected to be stripped off at the temperatures present in the dryer (less than 500°F). From the induced draft fan, pneumatic transport air is passed through a baghouse for particulate removal, a HEPA filter for very fine particulate removal, and a vapor-phase activated-carbon bed for volatile organics removal. An available option is to recycle a portion of the pneumatic air stream back to the impact dryer mill, thus reducing the volume of air requiring treatment.

The dry, pulverized feed material is transported pneumatically to a feedstock mixing tank where limestone is added as a glass fluxing agent. From the feedstock mixing tank, the waste/limestone mixture is transported pneumatically to the CMS. The CMS consists of three major components; the CRV combustor, the cyclone melter, and the separator-reservoir. The feed material, natural gas, and pre-heated combustion air are injected into the CRV combustor. The CRV heats the wastes to temperatures in excess of 2400°F, where organic components are incinerated, and the inorganic components are heated. After the combustor, the feedstock enters the cyclone melter. In the melter, material is transported to the liquid layer on the walls by centrifugal action. Glass-forming reactions occur in the liquid layer to form the vitrified product. Molten materials flow through the separator-reservoir before exiting into a quench tank.

Flue gases from the CMS pass through a recuperator (heat exchanger) where combustion air is pre-heated to 1100°F. Flue gases within the recuperator are cooled from 2560°F to 2000°F. From the recuperator, flue gases enter a spray tower which cools the gases from 2000°F to 400°F to avoid damage to the downstream air pollution control equipment. Cooled flue gases enter a baghouse and a HEPA filter for particulate removal. From the HEPA filter, flue gases enter a quencher/absorber for neutralization of any acid gases before being exhausted out a stack. Scrubber blowdown from the absorber may contain volatile radioactive metals and will be treated using ion exchange. Flyash collected within the baghouse is transported pneumatically to a waste storage silo for reprocessing.

7.1.4.2 Detailed Process Description

Feedstock Preparation and Handling System

Wastes will be excavated and placed into plastic-lined and covered dump trucks for transport to the waste staging area. The staging area will be constructed of

natural soils covered with a 40-mil HDPE liner. On three sides of the staging area 3-foot berms will be constructed for containment purposes. The staging area will be sloped to a corner sump to collect any free liquids that may accumulate. The approximate size of the staging area will be 25 ft x 25 ft, with one side open for equipment access. The open side of the staging area will be ramped as opposed to bermed to allow equipment access. Tarps may be required to cover waste piles during extended periods of rain. Similarly, dust control may be required during extended dry periods. Collected storm water will be used for dust control if needed.

Wastes in the staging area are transported via front-end loader to the feed hopper. The feed hopper is equipped with a screen across the entire opening to reject all material over 1 inch in diameter. At the base of the hopper is a screw conveyor, which conveys the screened feed material to the impact dryer mill. Oversized material that does not pass through the screen will not be processed through the system. Oversized material will be loaded into a separate roll-off container and managed separately. The hopper size is approximately 12 ft long by 6 ft wide and 8 ft deep. The screw conveyor is 9 inches in diameter and operated by a 3-hp motor.

Feed material will be fed to the impact dryer mill at a maximum rate of 2 tons per hour. The feed rate into the hopper is independent of the feed rate into the CMS. Waste materials will be fed into the hopper to keep an adequate supply material of sized feedstock in the waste feed silo. Wastes are pulverized by rotating hammers within the mill and pass through a velocity separator where an accurate size classification is made. Oversized material in the separator falls back into the grinding chamber for additional size reduction. The mill is operated by a 15-hp motor. The velocity separator is 2.5 ft in diameter and is operated by a 3-hp motor. The air heater is a gas-fired unit, with a 1.5 MBTU/hr capacity.

The sized wastes are pneumatically conveyed through the velocity separator to a cyclone separator where the sized waste feed is separated from the transport air. The feedstock then enters the Blending Subsystem.

Off-gases from the pneumatic transport of the dry feed material exit the cyclone separator and are exhausted through air pollution control equipment. The majority of the off-gases flow through a series of air pollution control equipment, while a portion of the off-gases are recycled back into the impact dryer mill. Off-gases to be treated will first encounter a baghouse for particulate removal, followed by a HEPA filter for very fine particulate removal, and a vapor-phase activated-carbon bed for removal of any organics that may have vaporized as a result of the heating/drying process. A second fan will be needed to discharge clean gases and evaporated moisture from the system. The main materials handling fan is driven by a 30 hp motor, while the smaller discharge fan is driven by a 5 hp motor.

Blending Subsystem

In the blending subsystem, the prepared waste material is mixed with limestone to produce a glass forming mixture. After blending, it is stored for introduction into the CMS. From the storage tank, the material flows into a continuous loss-in-weight feeder.

The Blending Subsystem consists of a storage silo mounted under the cyclone separator, a limestone storage tank, a blending tank, and a continuous loss-in-weight feeder with air lock metering to provide continuous flow to the CMS. From the storage silo, wastes are pneumatically conveyed to a batch tank where they are mixed with limestone. Limestone is also conveyed pneumatically from a limestone storage tank. The limestone storage tank is periodically filled using tanker trucks that transport the crushed limestone to the facility. Limestone is added to the waste (approximately 20% by weight) to enhance glass-forming properties. After thorough mixing, the contents of the batch tank are pneumatically conveyed to the CMS. The waste storage silo is a carbon steel vessel, 10 ft in diameter and 15 ft high with a cone-shaped bottom to allow for pneumatic withdrawal of the waste. The cyclonic separator is 5 ft in diameter, approximately 12 ft in total height and is constructed of carbon steel. The limestone storage tank is similar to the waste storage tank in size and construction. The batch mixing tank is 6 ft in diameter and 10 ft high with a cone-shaped bottom. The cyclone separator, waste storage silo, limestone storage tank and batch mixing tank are each equipped with a bottom-mounted rotary valve with a 0.5 hp gear motor and chain drive.

Combustion and Melting System

The CMS consists of an in-flight suspension feedstock preheater and a cyclone melter. The suspension preheater is a CRV combustor designed to provide suspension preheating of the materials, as well as secondary combustion of volatiles in the contaminated soil. The average gas-solids suspension temperature leaving the CRV combustor chamber is typically on the order of 2200°F to 2700°F.

The CRV combustor is a refractory lined, water cooled steel vessel. If unusual wear or separation of refractory occurs during operation, a thin layer of glass will solidify on the wall and protect the surface until repair of the refractory can be accomplished. The higher temperature and intense turbulence generated in the CRV combustor should reduce the residence time requirements for effective hazardous waste incineration, when compared to conventional solid/hazardous waste incinerators, such as fluidized beds and rotating kilns. However, if longer residence times are required, this can be achieved by running the unit at reduced thermal load, by making the vessels slightly larger, by extending the length of the cyclone exit assembly, or by combinations of these options.

The preheated solid materials exit the CRV combustor enter the cyclone melter, where they are separated to the chamber walls to form a molten glass layer. The glass product and the exhaust gases exit the cyclone melter through a tangential exit channel and enter a separator/reservoir assembly.

The separator/reservoir is a carbon steel, refractory-lined tank approximately 14 ft long x 6 ft wide x 8 ft high. Its primary functions are to separate the combustion products from the melted material and to provide an interface with a Vitrified Product Handling System. Additionally, the separator can be used to recycle solid waste material from the gas cleanup subsystem back into the glass. The hot exhaust products exit the separator through an exhaust port located on the side or top.

This port also interfaces with a recuperator (heat exchanger), which is a conventional radiation type recuperator, typical of the type used in the glass industry. Air is preheated to 1100°F and flue gases are cooled from 2560°F to 2000°F. From the recuperator, the gases enter the Air Pollution Control System.

Air Pollution Control Subsystem (APCS)

The first component of the APCS train is a spray tower which is used to cool the flue gas exiting the recuperator. Gases enter the spray tower at a flow rate of approximately 10,150 acfm and temperature of 2,000°F and are cooled to approximately 400°F. The spray tower is refractory lined carbon steel with an inside diameter of approximately 7 ft and a height of 25 ft. Duct work from the recuperator to the spray tower will also be refractory-lined.

Directly downstream of the spray tower, a baghouse provides particulate removal. Flue gas enters the bottom of the baghouse, flows through filter bags where particulate is captured, and exits from the top of the baghouse. Filter bags are periodically pulsed with compressed air to remove built-up particulate. This material is then collected and pneumatically conveyed to the waste storage silo. The baghouse has been sized to handle 8,000 acfm at 400°F. Overall dimensions for the baghouse are approximately 9 ft long x 9 ft wide x 35 ft high including the structural steel support. From the baghouse, flue gas passes through a bank of HEPA filters to remove sub-micron radioactive particulates. A bank of four HEPA filters will be required to satisfy the flow rate, and the actual location in the APCS is still under consideration.

The filtered flue gas then passes through a liquid quench/absorber for neutralization of any acid gases that may have formed as a result of the combustion process. The hot flue gas is immediately quenched from 375°F to 175°F to prevent damage to the fiberglass-reinforced plastic (FRP) materials of construction.

From the quencher, the flue gas enters the horizontal packed-bed absorber where a 25% caustic solution is injected as a fine mist through the packing medium to neutralize the acid gases into salts and water. The caustic scrubber solution is continually recycled through the absorber until the dissolved solids concentration reaches approximately 6%. At 6% dissolved solids, the scrubber solution must be blown down (removed from the system) to prevent potential operational/ maintenance problems associated with scrubbing solutions with a high dissolved solids content. Scrubber blowdown will be treated via ion exchange resins to remove radioactive metals that may be present.

After neutralization, the flue gas passes through the induced draft fan, up the stack, and into the atmosphere.

Vitrified Product Handling System

The Vitrified Product Handling System collects molten glass from the separator/reservoir and quenches the hot product for disposal. Molten glass exits the separator/reservoir and is water cooled as it travels down a cullet chute and into a quench tank. As the molten material cools, it forms glass pellets (frit). A steel drag conveyor will be located at the bottom of the quench tank to remove the frit as it enters the tank. The conveyor travels the length of the

quench tank bottom, up one side of the tank and continues upward to a height of 12 feet above ground surface where it discharges into a flatbed, truck-mounted, roll-off container for disposal.

Because of the volume of frit being generated and the continuous nature of the operation (2,334 lbs/hr), an automated system was recommended for frit formation and disposal. It consists of the following process components:

- Quench tank for cooling of the molten residuals exiting the vitrification unit,
- Drag conveyor for removing the vitreous frit from the quench tank,
- Roll-off containers for storing and transporting the vitreous frit, and
- Make-up water feed pump.

Being completely automated, the system minimizes worker exposure to the very hot molten material. As a roll-off container is filled to capacity, the conveyor is briefly stopped, the roll-off is moved to a staging area by truck, and an empty roll-off is positioned to receive the vitreous frit once the conveyor is restarted. Assuming continuous operation, each roll-off will be filled to capacity (20 tons) approximately every 17 hours.

The quench tank will be trapezoidal and positioned under the separator-reservoir. The sides of the quench tank will be sloped towards each other with depth. The tank will be constructed of carbon steel and sized to contain approximately 1500 gallons of quench water. A steel drag conveyor will be positioned at the bottom of the quench tank to remove the frit as it enters the tank. The conveyor travels the length of the quench tank bottom, up one side of the tank, and continues upward to a height of 12 feet above ground surface, where it discharges into a flatbed truck-mounted roll-off container. Roll-off containers will be steel construction with a 20-ton capacity. The roll-off containers will be sloped to a small sump to drain/collect free-standing water.

Make-up water will be continually added to the system through the cullet chute to control the temperature of the quench water. If additional cooling of quench water is necessary, a recirculation loop using the CMS cooling tower (Subsection 4.2.7) could be included.

Process Monitoring and Control System

The primary operator interface for control of the process will be located on a central control panel in the control room.

Table 17 lists components found on the control panel; and Figure 7.1.4.2-1 depicts the process monitoring and control system architecture.

Table 17. Control Panel Components

Loop controllers <i>for analog control and information functions</i>	<p>All modulating control (e.g., flow control through control valve or variable drive pump) will be performed by standard configurable single and/or multiple loop controllers.</p> <p>All variable inputs (e.g., pressure and temperature readings) will be visible to the operator using loop indicators (similar to loop controllers except that there are only inputs and no outputs).</p>
Pushbuttons, selector switches, and indicator lights <i>for discrete control functions</i>	<p>Discrete control for open/close block valves and operator selections will be performed by momentary pushbuttons and selector switches located on the control panel. The discrete control devices from the panel will be wired to inputs on a PLC, where the signals will be processed. The signal will then be transmitted via PLC outputs to the final destination devices.</p> <p>Discrete control for motors will be performed by operator start/stop momentary pushbuttons located on the control panel. The pushbuttons will be wired directly into the motor starter circuitry. Any automatic pump start/stop sequencing or motor interlocking will be wired into the motor starter circuitry from PLC outputs.</p> <p>Discrete input devices (e.g., pump status, valve position status) will be wired to inputs on the PLC. The status will then be transmitted, via PLC output, to the control panel.</p>
Alarm annunciator <i>for displaying alarming and status information</i>	<p>All analog alarms (e.g., level, flow alarming) will be set in the individual loop controllers. The loop controllers will then transmit these signals, via dry relay contacts, to the alarm annunciator.</p> <p>All discrete alarms (e.g., pressure, temperature switches) will be wired to the PLC as inputs. The PLC will then transmit these signals, via PLC outputs, to the alarm annunciator.</p> <p>No redundancy will be provided for any of the functions.</p>
Data acquisition	<p>Historical data collection, trending, and customized data processing will be performed on a personal computer (PC) located in the control room. The analog data from the loop controllers will be brought into the PC data collection system via a local controller data highway interface. All discrete field instrumentation wired to the PLC will be brought into the PC data collection system via a PLC data highway interface.</p>

Figure 7.1.4.2-1. Process Monitoring and Control System Architecture

Continuous Emissions Monitoring (CEM) System

The CEM system is used to sample, monitor, and report flue gas data. The CEM system includes analyzers for monitoring carbon monoxide (CO), carbon dioxide (CO₂), oxygen (O₂), oxides of nitrogen (NO_x), hydrogen chloride (HCl), and opacity.

Flue gas samples will be extracted from the ducting downstream of the recuperator by low-volume pumps housed within the individual analyzers. Depending on the analyzer, the sample may be conditioned by removing excess heat, particulate, and/or moisture. Once conditioned, the individual flue gas samples will pass through their respective analyzers. Instrument exhausts are tied together in a common vent line, which allows the gases to exit the instrument cabinet.

The CEM system data and monitoring functions will be performed by the Programmable Logical Controller (PLC). The PLC will be programmed to process data output from the CEM system and provide summary reports as needed.

The PLC will also monitor all CEM system temperature sensors, pressure sensors, and flow switches. At given intervals, the PLC will initiate CEM system calibration.

Support Services and Facilities

Several support services and facilities are required for the proper operation of the vitrification plant. The major services and facilities are: cooling tower, site utilities, structural steel, control room/office trailer, and decontamination facilities.

A cooling tower will be required to cool process water within the plant. The primary plant area requiring cooling water is the melting system, where water is used to cool the outside skin of the CMS. A 50-ton-per-hour cooling tower has been specified for the conceptual design. This unit is approximately 10 ft long, 7 ft width, and 7 ft high. The attached blower is operated by a 5 hp motor. The cooling tower was oversized by 25% to account for other potential uses for cooling water within the plant.

Site utilities will be necessary for construction and operation of the plant. Critical utilities required on-site include water, natural gas, electricity, telephone, and sanitary services. When possible, existing DOE facility utilities will be used.

Structural steel will be required for support of process equipment and connecting piping/ducting. The majority of the structural steel will be associated with the melting system and the flue gas treatment system.

The control room/office trailer will be the focal point of all site activities. A portion of the trailer will be dedicated to process control. Process control and data acquisition stations will be manned by a control room operator. The other main function of the trailer is to provide administrative support to the field effort.

Decontamination facilities for both personnel and equipment will also be required on-site. Personnel decontamination stations are established between the exclusion, or "contaminated" area, and the support area to eliminate the transport of contaminants into the support area. Decontamination trailers may be needed to accommodate showering and changing from street clothes to work clothes. Equipment decontamination pads will be constructed to minimize the transport of contamination on equipment, particularly vehicles. Wash water will be collected and containerized on-site, and used for dust control where possible.

7.1.4.3 Equipment List

A summary of the major equipment discussed above are presented in Appendix E. The list is divided into process areas similar to those used in Subsection 7.1.4.2. Final equipment sizing will be accomplished during the detailed design phase. Equipment purchases will be made only after preparation of equipment data sheets and specifications based upon finalized engineering flow diagrams.

7.2 ALTERNATIVE SYSTEM CONFIGURATIONS

Two alternatives to the baseline system, already presented, are discussed here. They are a wet feedstock preparation subsystem Alternative I, and a wet APCS, and Alternative II.

7.2.1 Feed Subsystem

Baseline

The dry feedstock preparation and handling system, described in Section 7.1.4.2, includes the necessary equipment to prepare dry site wastes in a form acceptable for feeding to the CMS. Figure 7.2.1-1 presents a subsystem flow diagram.

Wet Feed—Alternative I

A wet or slurry feed subsystem was considered as an alternative to the baseline dry subsystem in an attempt to minimize the formation of potentially contaminated emissions during materials handling activities and to reduce the need for drying wastes prior to introduction into the CMS. The wet feed subsystem would slurry wastes to an approximate moisture content of 40% before pumping them through a wet grinder and into a second slurry tank. Limestone (glass formers) and additional water are added to the tank increasing the moisture content to approximately 50% before being pumped to a storage tank for feeding into the CMS. A block flow diagram of the wet feed subsystem is shown in Figure 7.2.1-2.

The wet feed subsystem would consist of the following components:

- Feed hopper for screening oversized material (diameter > 2.0 inches),
- Slurry tank for mixing wastes and water to create slurry for pumping,
- Slurry pump for transferring wastes from the slurry tank to the wet grinder,
- Wet grinder (ball mill) for size reduction of wastes to be treated, and
- Slurry tank for storage of sized-slurried wastes for feeding into the feedstock mixing tank for limestone addition.

LEGEND
—— Solids
..... Gases

Figure 7.2.1-1. Baseline Feed System Block Flow Diagram

Figure 7.2.1-2. Wet Feed Subsystem Block Flow Diagram—Alternative I

The wet feed subsystem is capable of accepting both wet and dry soil. As an aqueous (or semi-aqueous) process with no pneumatic transport, emissions are virtually eliminated; however, the CMS operating efficiency is reduced due to the increased moisture content of the waste feed. Also, difficulties could arise in handling and storage of the sized-slurried soil. Continuous agitation of the slurried feedstock would be required to prevent gravity separation and solidification of the feedstock prior to feeding to the melter (especially with the addition of limestone to the slurry). Slurry tanks would be approximately 5,000 gallons in capacity, requiring large mixers and high energy outputs to keep the slurry homogeneous. In addition to slurry handling problems, the sizing of the CMS and the downstream flue gas treatment equipment would be significantly increased to account for the increased water loading. The size of the CMS would almost double to handle the same quantity of waste for the wet feed option as opposed to the dry option. The flue gas requiring treatment would increase by over 60% (8,950 lbs/hr of flue gas using a dry feed subsystem versus 13,830 lbs/hr of flue gas using a wet feed subsystem).

After evaluating both the wet and dry feed subsystems, the dry feed subsystem was selected as the baseline feedstock preparation and handling system; however, there may be some beneficial applications of the wet subsystem as well. The dry subsystem is all-inclusive, combining heating, grinding, and material transport into one package and can handle a variety of feedstocks. Material would be transported pneumatically, which is commonplace for handling fine-grained material. The major drawback with the dry subsystem is that off-gases from the pneumatic system would have to be collected and treated due to potential contamination.

The wet feed subsystem may be advantageous when dealing with homogeneous and/or moist feedstocks like lagoon sediments or sludges. Homogeneous feedstocks can be slurried and pumped easily without major buildup or clogging. Feedstocks that are already moist are ideal candidates for slurrying. Also, equipment and operating costs associated with materials handling air pollution control devices are eliminated. The major drawback with the wet feed subsystem is the reduction in overall efficiency of the CMS due to the water addition for slurrying.

A cost comparison of the dry feed subsystem versus the wet feed subsystem is presented in Section 6.6. From this comparison, the dry feed subsystem equipment costs are less than the wet feed system costs. The total cost to construct the demonstration system with the dry feed subsystem baseline, is approximately \$3.7 million, as compared with \$4.2 million for the wet feed subsystem, Alternative I. Although operational costs are not included in this report, it is expected that long-term operation would increase the overall costs of a wet feed subsystem as opposed to the dry feed subsystem, due to increases in electricity and natural gas consumption.

7.2.2 Air Pollution Control Subsystem Options

Baseline

The dry APCS, described in Section 7.1.4.2, includes the necessary equipment to process flue gas using a baghouse followed by a HEPA filter. Figure 7.2.2-1 presents a subsystem flow diagram.

Figure 7.2.2-1. Baseline Flue Gas Treatment Block Flow Diagram

APCS—Alternative II

Figure 7.2.2-2 is a block flow diagram for the wet flue gas treatment option. This alternative consists of: a spray tower for quenching, Venturi scrubber and cyclonic separator for coarse particulate control, two wet ESPs in parallel for fine particulate control, a quencher/absorber vessel to cool and neutralize any acid gases, a reheater to raise the off-gas temperature above its dew point, a HEPA filter, ID fan, and stack. In addition to the ion exchange unit for blowdown treatment, a settling/ recirculation tank will be used to collect particulate from both the Venturi scrubber and wet ESPs. Effluent from the tank clearwell will be recirculated back through the wet ESP for reuse. Supernatant from the tank will be pumped to the ion exchange unit for treatment prior to disposal. Collected particulate will be manually transported to the impact dryer mill.

Cooled off-gases from the spray tower enter the top of the Venturi scrubber and are introduced to the scrubbing liquid. The Venturi section "squeezes" the gas and liquid into the throat area which can be a fixed or adjustable size. Within the throat, gases and liquids are thoroughly mixed at a predetermined pressure drop. The saturated gases laden with the entrained particulate are then allowed to expand, where the particulate drops to the bottom of the scrubber for collection and the treated off-gases are directed through the top of the scrubber.

Venturi scrubbers are frequently used for particulate control in both hazardous and low-level radioactive thermal treatment systems. Venturi scrubbers are not as effective as baghouses in removing fine particulate, although they can effectively remove coarse particulate.

In addition to the Venturi scrubber, wet ESPs are used to capture fine particulate. Wet ESPs use water sprays to saturate the incoming gas stream. The electric field within the ESP charges the liquid droplets. The liquid droplets charge, collect, and wash away the particulates from the gas stream. Maintaining the proper liquid-to-gas ratio (typically 5 gallons per 1000 scf) is essential for the effective operation of the equipment.

Wet ESPs are used infrequently in both hazardous and low-level radioactive waste thermal treatment applications. They are large and generally used in large, fixed applications (i.e., coal-fired power plants, trash-to-steam facilities, etc.). From an operational standpoint, a wet ESP can offer very high particulate removal efficiencies even for very small particles and may represent a preferred option at some DOE facilities. Removal efficiencies of 99.9% on 0.5 microns or larger particles can be achieved with a pressure drop of only 1" W.C.

After comparing the advantages and disadvantages of each of the options discussed above, the dry option is believed to be the best flue gas treatment system for this application. The baghouse offers excellent particulate control at reasonable energy requirements. Baghouses are moderately sized, moderately priced, and are transportable. Also, baghouses do not require the use of water, thus eliminating the creation of another waste stream. The major disadvantages of the baghouse option are the moisture and temperature restrictions on the off-gases entering the baghouse; however, these restrictions can be overcome through proper design and operation of the spray tower.

Figure 7.2.2-2. Wet Flue Gas Treatment Block Flow Diagram—Alternative II

The wet option requires a more complicated air pollution control train with increased capital costs and increased operational problems; however, if collected particulate is desired in a wet/moist form (and not as a dry dust), the wet option may be a viable option. Capital costs for the vitrification system using the dry flue gas treatment train are approximately \$3.7 million, as compared to capital costs of approximately \$4.6 million using the wet flue gas treatment system. Detailed cost estimates for each option are included in Section 7.3.

7.3 INTEGRATED SYSTEM CONCEPTUAL DESIGN—INSTALLED COST

As part of this Preliminary Conceptual Design, three cost estimates have been prepared. The primary cost estimate was developed for the baseline system, which utilizes a dry feed system and a dry flue gas treatment system. Secondary cost estimates were developed as alternatives to the baseline system. The first alternative utilizes a wet or slurry feed system and is designated Alternative I.

The second alternative utilizes a wet flue gas treatment train and is designated Alternative II. Cost estimates for each of the alternatives take into account purchase and installation of equipment.

Table 18 details the installed cost estimate associated with the baseline system. Tables 19 and 20 detail the installed cost estimates associated with the alternative systems. Costing assumptions are discussed in the paragraphs which follow the tables.

Table 18. Cost Estimate for Baseline System

Site work:	\$ 60,100
Structural support:	\$ 132,400
Major equipment:	\$1,560,900
Mechanical and piping:	\$ 218,100
Electrical and instrumentation:	\$ 347,400
Subcontracts:	\$ 60,000
Other project direct and indirect costs:	\$ 318,800
Project and construction contract costs:	<u>\$ 492,700</u>
Subtotal	\$3,190,400
Contingency at 15%	<u>\$ 478,600</u>
Total	\$3,669,000

Table 19. Cost Estimate for Wet/Slurry Feed Subsystem—Alternative I

Site work:	\$ 60,100
Structural support:	\$ 132,400
Major equipment:	\$1,895,500
Mechanical and piping:	\$ 218,200
Electrical and instrumentation:	\$ 347,400
Subcontracts:	\$ 60,000
Other project direct and indirect costs:	\$ 360,400
Project and construction contract costs:	<u>\$ 561,400</u>
Subtotal	\$3,635,200
Contingency at 15%	<u>\$ 545,300</u>
Total	\$ 4,180,500

Table 20. Cost Estimate for Wet Flue Gas Treatment Subsystem—Alternative II

Site work:	\$ 60,100
Structural support:	\$ 132,400
Major equipment:	\$2,178,340
Mechanical and piping:	\$ 235,00
Electrical and instrumentation:	\$ 301,900
Subcontracts:	\$ 60,000
Other project direct and indirect costs:	\$ 394,100
Project and construction contract costs:	<u>\$ 614,060</u>
Subtotal	\$3,975,900
Contingency at 15%	<u>\$ 596,400</u>
Total	\$4,572,300

Major capital equipment costs for the dry feed subsystem were developed from vendor quotes that were obtained as part of the engineering evaluation. Miscellaneous equipment costs were obtained from equipment catalogs. Cost estimates for structural steel and instrumentation were based on the combined experience of Vortec and Weston engineering personnel. Installation costs for equipment were based on an estimate of required man-hours and labor rates.

The cost estimate for the wet feed subsystem—Alternative I (Table 19) was based on applying a scale-up factor to the dry feed cost estimate to account for the increase in equipment sizes. In addition, the materials handling equipment for the wet feed subsystem (slurry type equipment) differed from the dry feed system equipment (pneumatic type equipment), which influenced the system economics.

Costing assumptions built into Tables 18 through 20 are discussed below:

- A four-acre site would be necessary for facility construction and would require cleaning/grading.
- The waste stockpile area will be approximately 50 ft x 50 ft x 4 ft deep, and constructed of earthen berms with a high density polyethylene (HDPE) liner and leachate/stormwater collection sump.
- Cast-in-place concrete foundations have been specified for many facility components. A yardage of concrete has been estimated for each piece of equipment.
- Structural steel (columns, beams, base plates) has been estimated at 29 tons. Also included in the structural steel estimate are stair treads, grating, and handrails with toe-plates.
- It is assumed that utility lines will be extended to the site a distance of 300 linear feet from an existing source. This includes water, process/sanitary drains, and natural gas.
- Mechanical interconnecting piping with diameters less than 2 inches has been estimated at 600 linear ft. Piping with diameters greater than 2 inches has been estimated at 460 linear ft.
- Breeching and combustion gas ducting and lagging has been estimated at 200 linear feet.
- Electrical work was estimated as a lump sum (labor + materials + equipment).
- Instrumentation costs were based on:
 - Control panel with programmable loop controllers, annunciators and start/stop pushbuttons, selector switches, and indicators (lump sum);
 - PC based data acquisition system with printer (lump sum);
 - Programmable logic controller (PLC) (lump sum);
 - Instrument I/O listing;
 - Software/training (lump sum);
 - Continuous emissions monitoring system (lump sum).
- Subcontractors have been identified for painting/coatings, equipment and piping/breeching insulation, and refractory installation.

The complete details of the cost categories can be found in Weston's Phase 1 Conceptual Engineering Report, Appendix F.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Both feasibility testing and a preliminary system design were completed during the Phase 1 program. The conclusions and recommendations generated from these two activities are presented in this section.

8.1 FEASIBILITY TESTING

In Phase 1, Vortec demonstrated the feasibility of producing a vitrified product from a surrogate soil representative of the class of soils found at DOE sites. Vortec conducted a survey of DOE site remediation managers, requesting data on the chemical composition of the their site's soil that was designated for remediation. To define a surrogate soil, these compositions were averaged and compared with EPA's surrogate soil, and adjusted where necessary. Having defined a soil, and the heavy metals and radionuclides that it contained, Vortec prepared a feedstock combining the soil with suitable glass additives. In order to establish the quantity and type of glass-making additive required, this feedstock was first vitrified in the laboratory. For these tests, 35% by weight limestone was the only additive needed. However, the actual site soil will probably require a slightly different additive, and could require a reduced amount of glass-making fluxes.

Vortec prepared approximately 2000 pounds of the feedstock, without contaminants, with a mean particle size of approximately 1000 microns. The 2000 pounds were vitrified in the CMS test facility and the glass was analyzed for undissolved silica. The results of the first test indicate that without changing the feedstock composition, but with a reduced particle size (average reduced from 1000 microns to 600 microns) the CMS, in its present configuration, would successfully vitrified the surrogate soil. An additional 5000 pounds of soil were prepared and spiked with surrogate heavy metals (Cd, Pb), a surrogate organic compound (anthracene), and a surrogate radionuclide (zirconium) and two additional tests were conducted.

The results of the test program can be summarized as follows.

1. By selecting the proper soil particle size distribution and glass making additives, a satisfactory glass waste form was produced.
2. The soil, which contained the surrogates heavy metals, and would not pass TCLP prior to vitrification, produced a product that did pass TCLP after vitrification.
3. Approximately 1500 ppm of zirconium were present in the glass produced during Test 3. The ANS 16.1 test, to establish the leachability of the glass waste form, did not detect zirconium in the leachate. (Detection limit for zirconium in the leachate: < .003ppm.)
4. Approximately 1000 ppm of the organic compound Anthracene were present in the soil. The destruction and removal efficiency for this compound was at least 99.99%.
5. Volatile heavy metals will be carried over from the CMS and must be removed by the air pollution control system. Several operational factors will help reduce the amount of carry over.
 - a. Lowering the operating temperature in the combustor will reduce the amount of volatilization.
 - b. The soil chemistry will be a determining factor in selecting, the proper glass-making additives which intern will determine the optimum operating temperature for vitrification.

- c. Oxygen enrichment of the combustion air reduces the total flow rate of the flue gasses. In the limit, 100% oxygen enrichment could reduce the flue gas flow rate by approximately 80%, thereby reducing the size of the APCS significantly.

8.2 PRELIMINARY DESIGN

Vortec, in conjunction with Roy F. Weston Inc., conducted a preliminary design and cost estimate for a 25 TPD, fully-integrated plant that would process the type of soil defined above for the feasibility tests. The plant's baseline design included the preparation of soil in a dry form, followed by pneumatic conveyance of the soil to the CMS for vitrification. The Air Pollution Control subsystem featured a dry process consisting of a bag house, HEPA filters and a quencher / absorber for acid gas treatment. The installed cost was estimated to be approximately \$3.7 Million for this baseline system.

Two alternatives were also considered. The first alternative replaced the dry feed preparation subsystem with a wet, slurry feed subsystem, leaving the remaining subsystems unchanged from the baseline configuration. The second alternative replaced the dry APC subsystem with a wet APC subsystem, leaving all other subsystems unchanged from the baseline configuration. The cost of these two alternatives was estimated to be \$4.1 Million and \$4.6 Million respectively.

In preparation for the preliminary design, Vortec surveyed potential DOE sites to determine their interest in hosting the demonstration plant. Presentations were made at the sites describing the CMS technology and the preliminary design. Valuable insights were obtained regarding the site's needs, concerns, as well as the restrictions and deadlines imposed on them by the local regulators. In fact, the information obtained during these interactions with the sites caused Vortec to modify its Demonstration Plant design. It is the modified plant design that is described in Vortec's Phase 2 proposal.

Important insights from the site meetings can be summarized as follows.

1. Each site has contaminated soil exhibiting a diversity in chemical composition, moisture level, and contaminant content. Most of the sites that require remediation have not been completely characterized with regard to oxide and contaminant content. The cost of sampling and analyzing a site's contaminated (radioactive) soil is significant.
2. Each site has well established process technologies and procedures for handling their contaminated soils. The procedures are generally based on the physical state of the contaminated soil requiring remediation. Some sites preferred handling their soil as a slurry, other as a dry material. In general, all the sites emphasized that the more comprehensive the soil preparation and feed system design is the more likely the subsystem will be able to cope with the wide variety of material characteristics it will receive.
3. Each site has specific EPA, DOE, State and local environmental regulations that will have to be met by the demonstration plant. However, the interaction with the local regulators and the regulatory climate was significantly different from site to site. Each site recommended that the interaction with the local regulators is best handled by the M&O contractor at the site that regularly handles these affairs.
4. Each site indicated that the demonstration plant should be of sufficient size to actually process a major fraction of some existing waste streams. The sites were of the

opinion that a 10-15 TPD minimal demonstration effort as originally proposed was not an acceptable plan. They preferred a transportable 25-50 TPD plant, designed for maximum flexibility of use, that would be available at the site for continued testing once the 30-day demonstration was completed. The site's reasons are:

- a. Permitting is complex and expensive regardless of the plant size or duration of intended use.
- b. Processing of hazardous and mixed waste required extensive health, safety, and environmental safeguards that could not be waved or modified for short term demonstration testing. (Regulations comparable to EPA's Treatability exemptions do not exist.)
- c. Once the plant processed mixed waste there was no simple way to decontaminate it. Therefore, the preferred plan would be to continue using it.

Based on the interaction with the sites that occurred throughout Phase 1, significant changes and modification to the preliminary plant design, completed in Phase 1, were included in Vortec's Phase 2 proposal. Since the Phase 2 plant is to be considered a permanent test (processing) facility capable of handling a wide variety of waste streams, the Phase 2 plant was proposed assuming the following design criteria.

1. Process 25-50 TPD of mixed waste materials.
2. Feed preparation subsystem will be capable of handing both dry and wet waste feed streams.
3. Flue gas clean-up subsystem will include both wet and dry processes and also includes an acid-gas clean-up technology. NO_x reductions technologies may also be required.
4. Design the systems to perform satisfactorily well beyond the 30 days required for the Demonstration Test.

8.3 RECOMMENDATION FOR PHASE 2

Vortec concluded from its interaction with the site that support from the site will be necessary to comply with the applicable permitting tasks, to characterize the site's soil, and to comply with other site specific requirements. Indeed, a number of these requirements will not be satisfactorily accomplished unless the site takes the responsibility for interacting with the local agencies. These required activities, as outline by site personnel to Vortec are:

- 1 Preparation of NEPA Documentation
2. Preparation of DOE-Site Permits
3. Soil Characterization
4. Preparation of EPA-Permits
5. Satisfaction of the site's Safety and Health Requirements
6. Satisfaction of the site's Security Requirements
7. Satisfaction of the site's Environmental Requirements
8. Satisfaction of the site's Quality Assurance Requirements
9. Satisfaction of the site's Criticality Requirements.

In general the site should have the primary responsibility for permitting. The site will require the assistance from Vortec in providing information on the CMS's performance, effluents, and requirements to complete the following activities.

1. **Permit applications**
 - a. Air Quality Permits
 - b. Waste Water Permits
 - c. Storm Water (NPDES)
 - d. Sewage Permits
 - e. National Environmental Protection Permit (NEPA)
2. **CERCLA documentation**—If a CERCLA site is selected for the demonstration, the following CERCLA documentation will be required:
 - a. Treatability Study Workplan
 - b. Interim Action Proposed Plan (IAPP)
 - c. Interim Record of Decision (ROD)
 - d. Treatability Study Report
3. **Collection and analysis of the Soil Characterization Samples**—for Metals, Gamma PHA, Ra, U, Tritium, Sr-90, Pu-239, Neptunium, Am-241, Cs-137, and organic content, oxide content, particle size, and moisture content
 - a. Preparation of the soil sampling plan
 - b. Collect soil samples
 - c. Chemical analysis of the soil samples
 - d. Geotechnical characterization of the soil samples
4. **Analysis of the CMS effluent samples**—for Metals, Gamma PHA, Ra, U, Tritium, Sr-90, Pu-239, Neptunium, Am-241, Cs-137, organic content
 - a. Analysis of glass product
 - b. Analysis of CMS effluent streams samples taken during test operations
5. **Site Preparation**
 - a. Clean and grade site
 - b. Erosion control
 - c. Provide power to the site
 - d. Provide water to the site
 - e. Provide a fuel supply to the site
6. **Health and Safety Support**
 - a. Prepare Health and Safety plan
 - b. Provide Health and Safety monitoring during construction and operation
7. **Facility Support**
 - a. Provide site support during mobilization, construction, and operation
 - b. Decontamination if required
 - c. Final disposal of vitrified product after testing

Vortec made recommendations to METC regarding a revised work statement for the Phase 2 and Phase 3. Phase 2 includes tasks to: assist DOE in selecting a site; assist the site in defining the specific site-soil characteristics; conduct design verification and optimization testing; prepare a final design for the 25-30 TPD transportable CMS vitrification plant.

Phase 3 as now proposed will include tasks to construct and test the demonstration plant at the DOE site.

Phase 4 will consist of tasks to incorporate system improvements and conduct operational and training for site personnel.

Vortec recommends continued development and demonstration of the Vortec CMS applied to the remediation of mixed-waste contaminated soils found at DOE sites.

LIST OF ACRONYMS

Acronym or Unit of Measure	Definition
acfm	Actual cubic feet per minute
ANS	American National Standard
APC	Air Pollution Control
APCS	Air Pollution Control Subsystem
AZS	Alumina-zirconia-silica
BTU	British Thermal Units
CDIF	Component Development Integration Facility
CELS	Corning Engineering Laboratory Services
CEM	Continuous Emissions Monitoring
CERCLA	Comprehensive Environmental Responsibility, Compensation and Liability Act
CM	Cyclone melter
CMS	Combustion and melting system
CRV	Counter-rotating vortex
dcscf	Dry standard cubic feet
DOE	U.S. Department of Energy
DRE	Destruction and Removal Efficiency
EPA	U.S. Environmental Protection Agency
ER&WM	Environmental Restoration and Waste Management
ESA	Energy Systems Associates
ESP	Electrostatic precipitator
gpm	Gallons per minute
HDPE (liner)	High density polyethylene
HEPA	High efficiency particulate air
hp	horse power
IAPP	Interim Action Proposed Plan
ID	Induced draft
INEL	Idaho National Engineering Laboratory
METC	Morgantown Energy Technology Center
MSWI	Municipal Solid Waste Incineration
NEPA	National Environmental Policy Act
NPL	National Priorities List
PC	Personal computer
PLC	Programmable logic controller
PLC	Programmable Logical Controller
ppm	parts per million
RCRA	Resource Conservation & Recovery Act
ROD	Record of Decision
scf	standard cubic feet
SITE	Superfund Innovative Technologies Evaluation
TCLP	Toxicity Characteristic Leaching Procedure
TPD	Tons per day
U-PARC	University of Pittsburgh's Applied Research Center
W.C.	Water column
WESP	Wet electrostatic precipitator

Appendix A

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92-086M/0992: Tables A-9 through A-31.

Appendix B

METC Phase 1 Test Plan

PHASE I TEST PLAN

INNOVATIVE FOSSIL FUEL-FIRED VITRIFICATION TECHNOLOGY FOR SOIL REMEDIATION

DOE/METC Contract No. DE-AC21-92MC29120

**PREPARED FOR
THE U.S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
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**REVISION 2
22 APRIL 1993**

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1.0 INTRODUCTION

This test plan has been prepared in partial fulfillment of the contract requirements of DOE/METC Contract No. DE-AC21-92MC29120. The test plan presented here represents an update of the preliminary test plan included in the Vortec Proposal No. 01-03-05-1235, December 13, 1991. This research and development program represents the first phase of a three phase development program applying the Vortec Combustion and Melting System (CMS) process to the remediation of soils contaminated with low level rad waste.

In accordance with the National Environmental Policy Act (NEPA), Vortec has submitted an Environmental Assessment (EA) for the proposed work. The Environmental Assessment was approved by DOE, effective January 22, 1993.

2.0 PROGRAM TEST OBJECTIVES & SCOPE

The testing to be performed under the contract is composed of two test series. The first test series (Preliminary Testing) is to provide a database on the performance and operation of the CMS when vitrifying surrogate soil feedstocks having different mean particle sizes. The initial test will use a mean particle size for the uncontaminated soil of 600 microns. The primary purpose of the first test in the sequence is to evaluate the melting performance and to define the expected range of flue gas emissions from the Vortec (CMS) when processing surrogate soil feedstocks. Success is measured by the formation of a vitrified product free of any undissolved crystalline products. If the initial test is successful a second test will run using a feedstock with a larger mean particle size. If the initial test is not successful a second test will run using a feedstock with a smaller mean particle size.

The second series of tests will use the feedstock having the optimum particle size distribution developed in the previous two tests, plus it will be contaminated with organic, inorganic, and radionuclide surrogates. Samples of the effluent streams will be taken to establish the partitioning of the contaminants.

3.0 TEST MATRIX & TEST SCHEDULE

The proposed test matrix for the Phase I program is summarized in Table 3.0-1. The test program will consist of 4 test runs, with run times in the range of 6-8 hrs at a nominal feed rate of 1000 lbs/hr. All tests will be performed with natural gas as the fuel.

The primary objective of the first two tests is to obtain experience in surrogate soil processing, defining the largest mean particle size of the feedstock that can be successfully melted, and obtaining baseline emissions data when using the surrogate soil as a feedstock. The first test will use a feedstock with a mean particle size of 600 microns. Initially the glass will exit the separator reservoir at the tap hole closest to the melter exit. Steady state glass flow will be established and allowed to flow from this port for approximately 1.5 hours with samples taken every 30 minutes. After 1.5 hours this tap hole will be closed and a second one, at the end of the separator reservoir, will be opened. There is a two-hour delay time required for the separator reservoir to fill, and this added residence time should improve the glass quality. Glass will be allowed to flow from the second tap hole for 1.5 hours with samples taken at half-hour intervals.

The glass samples taken during the preliminary tests will be analyzed petrographically to determine the extent of undissolved feedstock material remaining in the glass. By analyzing the samples from the two different locations, the influence of the additional residence time can be determined. If there are undissolved materials remaining in the glass, the mean particle size for

the next test will be reduced. If all the feedstock materials are fully dissolved, the feedstock's mean particle size will be increased. The increase or decrease amount will be judged from the petrographic analysis results.

Table 3.0-1. Test Matrix and Schedule

RUN NO.	TEST DURATION (HRS)	FEEDSTOCKS	FUEL/OXIDIZER	TEST SCHEDULE
1	8	Clean Soil-600 Microns Mean Particle Size	NATURAL GAS-AIR	May 1, 1993
2	8	Clean Soil-Adjusted Mean Particle Size	NATURAL GAS-AIR	May 15, 1993
3	8	Soil contaminated with surrogate Organic, Inorganic, and Radionuclides	NATURAL GAS-AIR	June 1, 1993
4	8	Soil contaminated with surrogate Organic, Inorganic, and Radionuclides	NATURAL GAS-AIR	June 15, 1993

Having established the optimum particle size for the CMS combustor, the third and fourth tests will be run to establish the effectiveness of the CMS at capturing the compounds that represent the surrogate heavy metals, radionuclides, and organic contaminants.

4.0 SOIL SOURCE AND PREPARATION

Table 4.0-1 summarizes the soil composition data obtained from DOE sites. Ideally, the selection of a site would allow the use of the clean soil from that site during the Vortec Phase 1 testing program. However, Vortec understands that the Phase 2 site selection is to be resolved between METC and DOE headquarters. The program will use the data presented in Table 4.0-1 to define a soil composition for the surrogate tests.

Table 4.0-2 lists Vortec's recommended surrogate soil composition. Melt tests at Vortec's laboratory facility have established the flux addition needed to make a suitable glass matrix to contain the contaminants.

Table 4.0-3 lists the types and amounts of compounds that will be added to the soil to represent the contaminants expected in the soil. Simulated radionuclides are non-radioactive metals, the behavior of which in the CMS process will simulate the true radionuclide species. Based on the data received to date and additional information describing the contaminants found by EPA in its Superfund sites, lead oxide, cadmium sulfate, anthracene, potassium carbonate, and zirconium dioxide will be used to represent typical inorganic, organic, and radionuclide contaminants.

**Table 4.0-1. Soil Composition-DOE Sites*
(Wt %)**

Location	Soil Type	K2O	Na2O	Al2O3	CaO	Fe2O3	MgO	SiO2	TiO2, P2O3, ZrO2
Barnwell	Fugay	0.20	0.24	9.26	0.04	2.75	0.12	86.70	0.68
Hanford	-	1.80	3.02	13.60	6.00	9.55	2.88	60.90	1.95
Idaho (INEL)	-	2.52	1.35	11.40	9.97	4.07	-	69.60	1.07
LANL	Carjo	2.82	2.73	12.40	0.94	2.93	0.60	76.80	0.78
	Puye	3.39	3.87	13.00	0.51	2.38	0.37	76.10	0.45
	Tuff	4.44	4.44	12.30	0.46	1.23	-	76.90	0.16
Maxey Flats	Tilsit	1.12	0.44	7.79	0.06	3.13	0.43	85.50	1.52
NTS	Beatty	3.88	3.54	13.60	2.89	2.87	1.25	71.30	0.74
ORNL	-	2.55	0.32	17.30	0.11	11.00	0.97	66.50	1.28
Sheffield	Fayette	1.97	1.60	10.80	0.78	3.82	0.87	79.10	0.96
WVNS	Church ville	2.69	1.09	14.20	3.22	5.01	2.03	70.40	1.29

* PNL-4800 "In Situ Vitrification of Transuranic Wastes," J.L.Buelt, et.al., March 1987.

Table 4.0-2. Recommended Soil Composition for Phase 1 Test

	Wt%	Wt%
SiO2	75.30	
Al2O3	11.00	
K2O	2.10	
Na2O	1.80	
Ca O	3.10	
Fe2O3	5.10	
MgO	0.70	
Other Oxides	0.90	
Total Soil	100.00	
Soil		65.00
Glass Fluxes		35.00

Table 4.0-3. Concentration of Contaminant Compounds

Compound	Concentration of Element in Soil (PPM)
Heavy Metals	
Lead Oxide	1000
Cadmium Sulfate	1000
Semi-Volatiles	
Anthracene	1000
Radionuclide Surrogates	
Potassium Carbonate	1000
Zirconium Dioxide	1000

Compounds of the lead and cadmium will be used to represent these RCRA heavy metals. Lead represents a heavy metal with a relatively high volatility.

Potassium is selected as a surrogate for the volatile radionuclides such a cesium (Non- activated cesium is to expensive to use directly). Zirconium is an excellent surrogate for the activated forms of thorium and uranium having approximately the same volatility and chemical behavior.

The parameter used to evaluate the destruction of organic compounds during demonstration tests is the Destruction and Removal Efficiency (DRE). Anthracene is a representative stable organic compound and has been selected as the prncipal organic constituent (POHC) to be used during testing because it is difficult to destroy. It is, therefore, the compound used in the DRE computation, and if the DRE for anthracene is satisfactory, then the more volatile compounds will also be destroyed effectively.

The soil components will be blended at the Vortec UPARC facility at a convenient time prior to the test schedule. Just prior to the test, the surrogate contaminants will be blended into the soil and the contaminated soil will be stored in 500 lb supersacks.

5.0 PROCESS DESCRIPTION AND OPERATING CONDITIONS

The primary components of the basic CMS are a counter-rotating vortex (CRV) feedstock heater and a cyclone reactor (melter). An artist's rendering of the basic CMS concept is shown in Figure 5.0-1. A unique feature of the process is the rapid suspension heating and oxidation of feedstock materials in the CRV heater prior to the physical and chemical melting processes which occur within the cyclone reactor. The use of the Vortec CRV feedstock heater in conjunction with a cyclone reactor distinguishes the Vortec combustion/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 heater, along with a 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. Both convection and radiation heat transfer mechanisms contribute to the rapid heating of the feedstock materials within the CRV heater.

Figure 5.0-1. Artist Rendering of Basic Combustion/Melting System

Any organic contaminants in the feedstocks are also effectively oxidized. As a result of the unique features of the CRV heater, the Vortec process is able to rapidly heat inert solids to melting temperatures at solids-to-gas mass ratios on the order of 1:1.

The melted product formed in the cyclone reactor, and the combustion products, exit through a tangential channel and enter a separator/reservoir (not shown in the figure) where a pool of the melted material is collected. The vitrified material exits the reservoir through a bottom or side tap, and the flue gases exhaust to a water quench/Electrostatic Precipitator (ESP) assembly or an optional heat recovery unit for combustion air preheating.

The flue gases exiting the separator/reservoir are treated in an air pollution control (APC) 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. In most applications, the total amount of uncontrolled particulate carryover is less than 4% of the total mass feedstock into the process.

In applications where additional combustion residence time is required, precombustor assemblies upstream of the CRV heater inlet arms are added to the basic process system. (An alternative means of achieving additional residence time and improved combustion efficiency is through the use of oxygen enrichment of the combustion air stream.)

An engineering drawing of a system configuration with twin precombustors is shown in Figure 5.0-2. An isometric depiction of the pilot configuration which will be used for the proposed test program is shown in Figure 5.0-3. In this system configuration, waste oxidation is initiated in the precombustors and is completed in the CRV heater. High local flame temperatures ($>4000^{\circ}\text{F}$) can be achieved in the Vortec process, since preheated combustion air at a temperature of approximately 1200°F can be used in the process. In spite of the high local flame temperatures, NO_x emissions have been demonstrated to be low; that is, typically less than 100-200 ppm. The NO_x control capability is due to the rapid temperature quenching by the particulates and the staged combustion which occurs within the process.

The average gas-solids suspension temperature leaving the CRV combustor chamber is typically on the order of 2000°F to 2700°F , depending on 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.

6.0 TEST PARAMETERS AND DATA

Figure 6.0-1 is a process schematic of the Vortec test facility at UPARC. Included, with numerical designators, are the locations of the instruments used to control and assess the thermodynamic performance of the system. Table 6.0-1 presents the instrumentation type and its system location. The measurement procedures routinely applied to the operation of the Vortec CMS are described in the ensuing sections of this test plan.

6.1 Flue Gas Sampling (Combustion Products)

Two flue gas sampling systems are available for the measurement of the combustion products. Figure 6.1-1 shows a schematic of the sampling flow-train. The first sampling system is shown in solid lines and the second with dashed line.

Figure 5.0-2. Combustion/Melting System Configuration with Twin Pre-Combustors
 (Engineering Drawing)

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Figure 5.0-3. Isometric Sketch of Pilot Plant Test Configuration

Figure 6.0-1. Process Schematic of Vortec Test Facility

Table 6.0-1. Test Facility Instrumentation

Process Instrumentation

NOTE: Work with sketch DMB-070291.

System	Station No.	Sub-system/ Component	Measurement	Instrument	Location	Recorded by
Process Air Supply and Preheat Air	1	Lamson Blower	Pressure Temperature Flow	Pressure Transmitter Pressure Gauge K thermocouple Dial thermometer Orifice plate	Blower outlet Blower outlet Blower outlet	Data Logger Reference only Data Logger Reference only Data Logger
	2	Air Heater	Temperature	K thermocouple	Heater outlet	Data Logger
Batch Supply/Feed	3	Batch Tank	Weight Coal Flow	Load cells Load cells	Tank supports Tank supports	Data Logger Manual - loss in weight calc.
	4	Transport Air	Pressure Temperature Flow	Pressure transmitter K thermocouple Orifice plate	Air supply line Air supply line Air supply line	Data Logger Data Logger Data Logger
CMS	5A and 5B	Precombustors	Inlet Air Temperature Inlet Air Pressure Refractory Temperature Gas Temperature Gas Pressure	K Thermocouple Pressure transmitter S Thermocouples S Thermocouple Pressure transmitter	Inlet arm Inlet arm Embedded in refractory Combustor sidewall Viewport	Data Logger Data Logger Data Logger Data Logger Data Logger
	6	CRV	Gas Temperature Gas Pressure Refractory Temperature	S Thermocouple S Thermocouple S Thermocouple Pressure transmitter S Thermocouples	Inlet arm Combustor sidewall CRV outlet Viewpoint Embedded in refractory at CRV outlet	Data Logger Data Logger Data Logger Data Logger Data Logger
	7	Cyclone Melter	Gas Temperature Gas Pressure	S Thermocouple Pressure transmitter	Cyclone melter endwall Viewpoint	Data Logger Data Logger
	8	Natural Gas	Pressure Temperature Flow	Pressure transmitter K thermocouple Orifice plate	Process gas supply line Process gas supply line Process gas supply line	Data Logger Data Logger Data Logger
Conditioning	9	Separator/Reservoir	Gas Temperature Refractory Temperature Glass temperature Gas Pressure	S Thermocouple S Thermocouple S Thermocouple Pressure transmitter	Inlet Embedded in refractory Tap hole block Viewpoint	Data Logger Data Logger Data Logger Data Logger
	10	Natural Gas	Pressure Temperature Flow	Pressure transmitter K thermocouple Orifice plate	Burner gas supply line Burner gas supply line Burner gas supply line	Data Logger Data Logger Data Logger
	11	Combustion air	Pressure Temperature Flow	Pressure transmitter K thermocouple Orifice plate	Eclipse blower outlet Eclipse blower outlet Eclipse blower outlet	Data Logger Data Logger Data Logger
Flue Gas/Quench	12	Stack	Flue gas temperature	S Thermocouple K Thermocouple Dial thermometer	Spray channel inlet Scrubber outlet Scrubber outlet	Data logger Data logger Reference
	13	Spray Channel	Excess oxygen	Beckmann Model 755 Oxygen Analyzer	Spray Channel Inlet	Data Logger
	14	CMS Outlet	CO NO/NOx SOx	Beckmann Model 870 Non-Dispersive Infrared Analyzer Beckmann Model 951A NO/NOx Analyzer Beckmann Model 880 Non-Dispersive Infrared Analyzer	Spray Channel Inlet Spray Channel Inlet Spray Channel Inlet	Data Logger Data Logger Data Logger
	15	Stack	Particulate	Anderson Analyzer	Stack	Manual
	16	Scrubber	Particulate	Grab Sample	Scrubber Drain	Manual
Cooling Water	17	Global view	Supply Temperature	K Thermocouple Dial Thermometer	Supply water header Supply water header	Data Logger Manual
	18	Global View	Ave. return temperature	K Thermocouple	Return water header	Data Logger
	Not Shown	Individual Circuit	Temperature Flow	K Thermocouple Dial Thermometer Rotameter	Component exit Component exit Component entrance	Data Logger Manual Manual

Figure 6.1-1. Instrumentation Process Schematic

With the first system, the sample gas passes through a cooling coil, where most of the condensate is drained, and a particulate filter prior to the vacuum pump. After the vacuum pump, there is a dryer which is electrically heated to remove residual moisture in the sample stream. The moisture and particulate-free sample stream then goes to the control room to be analyzed. Nitrogen purge is used on the sampling probes to remove possible material build-up.

The second system uses a heated sampling line directly to a Perma Pure sampling system and shares the same vacuum pump used with the first system. Because the sample gas has been conditioned by the Perma Pure system, the dryers and filters down stream of the vacuum filter are bypassed. The Perma Pure system is designed to condition the gas and vapor streams by continuous selective removal of particulates and water vapor, without loss of the gases being measured. Continuous filtration of gas sample streams that contain a high percentage of solids is made with a high-efficiency bypass filter. The gas sample passes through the inside surface of the filter at a high velocity through a teflon eductor. Particulates and condensable vapors are bypassed, and the sample stream will contain particulates smaller than one micron. When sulfuric acid is present, the bypass filter is heated to prevent condensation and corrosion of the filter. A second high-efficiency, coalescing filter at a slightly lower temperature takes out fine particulates while a dryer selectively removes the water vapor.

The flue gas sample is analyzed using Beckman series analyzers (Models 755, 870, 951, and 880 for O₂, CO, NO/NO_x, and SO_x). The analyzers are calibrated for zero and span gases according to manufacturer recommended procedures prior to each test as well as during the test if such calibration appears to be necessary. Measurement of total hydrocarbon and other chemical species may be performed depending upon the objectives of the test.

6.2 Air Pollution Control System (APC)

The APC system consists of a flue gas quench assembly, Venturi Scrubber ESP, a recirculation tank that allows the particulate to settle out of the quench water, and a water pump. Provisions have been made to use clean city water as the collection medium during sampling of the water passing through the quench system. When the particulate flow in the quench system is to be sampled the recirculating flow, that carries particulate to the settling tank, can be interrupted by starting the city water pump and passing clean water through the spray nozzles of the quench system. The three way valve is used to divert all of the flow from the quench system exit line into the container used to collect the water. The collection process should last approximately five minutes. The three-way valve is then closed and the city water pump is shut down, placing the system back in the recirculation mode.

The time to fill a 55-gal. container will be measured with a stop watch. Once the container has been filled to capacity it will be sealed and the next measurement will be made using another container. After the test is completed, each container will be weighed. The flow rate is the quotient of net weight and time to fill.

The containers will be set aside for several days to allow the solids to settle out, after which the solids will be filtered from the water. The solids will be dried and weighed. Again the flow rate is the quotient of net weight and time to fill the container.

6.3 Feedstock Flow Measurement

The batch tank weighing system uses a Hardy Instruments weight controller in conjunction with three strain gage load cells. The system was initially calibrated by suspending known weights, traceable to the NBS standards, from the tank itself. The system was checked for zero, span, and linearity by varying the weights attached in increments of 3000 pounds, from 0 to 9000 pounds. The calibration of the weighing system is checked at the beginning of each test when the known amounts of batch material are added to the tank, and the output from the weighing system is checked to see if it agrees with the weight added. If the difference is greater than 2% the system is recalibrated.

The time history of the batch tank weight, as recorded by the data acquisition system, will be used to generate flow rates for the feedstock.

6.4 Instrument Monitoring and Control System

The Vortec test facility is extensively instrumented. The facility uses a PC-based computer system to simultaneously operate the system, monitor the system's performance, and record time histories of selected system parameters. Four types of measurement time histories are made; namely: pressures, temperatures, weights, and flows. In addition, concentrations of excess O₂, CO, NO_x, and SO_x are recorded.

The supervisory control and data acquisition (SCADA) system's architecture is based on the following components.

1. Measuring Element
2. Measurement Transmitter/Transducer
3. Analog to Digital (or D/A) Interface Hardware
4. Computer Monitor

A five-point calibration procedure is performed for each component in each data channel when the components are initially installed. This five-point procedure involves monitoring the output of each component at 0, 25, 50, 75 and 100 per cent of the input range, and is conducted in both directions, that is, with an increasing input signal and then with a decreasing input signal. The same five point calibration procedure is conducted on each complete data channel at selected intervals; usually at the beginning of a new test program and if and when there is a question about data quality.

The calibration procedure for each sensor type is described in the following sections.

6.4.1 Pressure/Differential Pressure

Each pressure measuring channel is calibrated using a two-step procedures as follows. A Thommen pneumatic micro manometer is used to apply a known pressure into the pressure transmitter/transducer. The output is measured using a Beckman Digital Multimeter and checked for zero, span, and linearity. The transmitter/transducer output signal, normally connected to the analog-to-digital interface, is replaced with a Transmation Digital Calibrator. The Transmation Digital Calibrator generates a known signal that is then monitored in the control room to assure that the data channel is reading accurately. At selected intervals, usually at the beginning of a test program, the system is calibrated by applying a known pressure to the transducer and monitoring the output at the computer. The system is checked for zero, span, and linearity.

6.4.2 Temperature

When the thermocouple circuits are first installed, the EMF output from the individual thermocouples is simulated using a known milli-volt input signal connected to the analog-to-digital interface. The five-point calibration procedure, described above, is used and the actual values are recorded in the computer in the control room. The system is checked for zero, span, and linearity. At selected intervals, usually at the beginning of a test program, the system is calibrated by disconnecting the thermocouple at their connectors and applying a known milli-volt signal to the thermocouple leads. The output is monitored at the control-room computer.

6.4.3 Batch Tank Weights

The batch tank weighing system uses a Hardy Instruments weight controller in conjunction with three strain-gage load cells. The controller accepts the milli-volt signals from the load cells and digitizes them for transmission to an Allen-Bradley PLC-5 logic feeding system. The 16 BIT words of the PLC-5 are read by our SADA system using a data highway communications interface. The system was initially calibrated by suspending known weights, traceable to the NBS standards, from the tank itself. The system was checked for zero, span, and linearity by varying the weights attached in increments of 3000 pounds.; 0, 3000, 6000, and 9000 pounds.

The calibration of the weighing system is checked when adding known amounts of feedstock material and checking for agreement. If the difference is greater than 2%, the system will be recalibrated.

6.4.4 Gas Analyzers

The Beckman Industrial gas analyzers are calibrated before and during the tests according to the manufacturer's procedure, which requires the use of high-purity bottled calibration gases. The sample gas is delivered to the instrument and the instrument is adjusted to read the sample concentration. Sample gas concentrations are selected to allow high span and low span for each instrument.

6.4.5 Gas Flow Rates

Gas flow rates are measured using orifice plates in the air and gas supply lines. These measurements rely on the difference of an upstream and downstream pressure measurement. The installation of the plate follows the standard ASME procedures for the location of the pressure taps, and the calibration of the pressure-measuring system has been described above.

Orifice plates are purchased for specific flow conditions:

1. $F1$ = Design flow rate (Lbs / Hr),
2. $SP1$ = Design pressure (Lbs / In ²),
3. $T1$ = Design temperature (Degrees Fahrenheit).

These conditions will produce a design differential pressure of $\Delta P1$ inches of water. To find the actual flow rate the following relation is used:

$$F2 = F1 \sqrt{(\Delta P2/\Delta P1 * SP2/SP1 * T1/T2)}$$

where $F2$ = New flow (Lbs /Hr)
 $\Delta P2$ = New differential Pressure (Inches of Water)
 $SP2$ = New design pressure (Lbs / In ²),
 $T2$ = New temperature (Degrees Fahrenheit)

The flow rate's accuracy has been determined to be within 1/2% at the low end of the flow range.

7.0 SAMPLING PLAN FOR FEEDSTOCK/VITRIFIED PRODUCT STREAMS

The experimental system at UPARC provides for relatively easy access to feedstock materials (surrogate soil), vitrified products, and stack gas effluents. Feedstock and vitrified product samples will be collected in appropriate vessels (e.g., glass, polypropylene, polyethylene, stainless steel). Stack gas effluent samples will be obtained, at a location already in use for this purpose, directly ahead of the ID fan.

The sampling point locations are indicated on Figure 6.0-1 with the designators S1, S2, S3, S4, and S5. These locations were selected because they are truly representative of the process inlet and exit state points and will represent the true potential of the system to physically alter the surrogate soil. Selection of sampling points elsewhere in the system would not be representative of the process's performance.

The following sections present the sampling procedures based on the guidelines set forth in the Table 9-7 Sample Summary Matrix US EPA SW-846, "Testing Methods for Evaluating Solid Waste," third edition, November 1986. A description is given of the method to be used in obtaining each sample at the locations where surrogate soil is introduced into the vitrification process and where the product is removed, as well as at alternate paths of escape for the heavy metals through the exhaust gas and the waste water effluent streams.

Preparation for sampling includes the acquisition of all necessary sampling equipment and site-specific information to perform the required sampling. Vortec will supply sample containers prelabelled and containing the necessary preservatives. For solid samples, no preservatives are required. For liquid samples, the preservative is HNO_3 to pH less than 2.0. Experience with the SITE tests indicates that the particulate taken from the ESP system should be separated and the water fraction should be preserved with the HNO_3 .

The Vortec QA Manager will instruct all test personnel on the sampling procedures to be followed. The Vortec Laboratory Coordinator will verify that all of the sampling containers needed for shipping the samples to the analytical laboratory are available prior to the test initiation.

7.1 Bulk Sampling of Surrogate Soil

Table 7.1-1 lists the frequency with which samples will be taken from the input stream during the vitrification process. The surrogate soil will be in a dry granulated form and will be introduced into the process pneumatically from a batch tank. The batch material will include specified amounts of the surrogate soil as well as glass making additives. The batch material will be brought to the batch tank in "super sacks" capable of holding 1000 pounds of material. Each sack will be sampled just prior to being emptied into the batch feed system. The samples will be taken using the thief type equipment as indicated in Table 9-7 of US EPA SW-846. Two samples will be taken from each super sack and placed into a stainless steel bucket. The contents of the bucket will be thoroughly homogenized by mixing with a stainless steel spoon, and approximately eight ounces will be spooned into the laboratory prepared sample bottles, placed in a cooler, and maintained at approximately 4 degrees Celsius to be shipped. Each sample will be analyzed for lead, cadmium, zirconium, and potassium, as well as the organic constituent anthracene.

7.2 Bulk Sampling of Vitrified Product

Table 7.1-1 lists the frequency with which samples will be taken of the vitrified product that is being produced by the Vortec CMS. This material will be sampled at location S2: 1) as a molten liquid leaving the separator-reservoir, and 2) again as a granular solid in the cullet cart once the material has been quenched in water. A steel ladle will be used to sample the molten glass by catching approximately one (1) pound of the material as it exits the separator-reservoir. This material will be allowed to air-cool on a stainless steel plate. As the glass cools, internal stresses will cause the sample to break into several pieces. Approximately 8 ounces will be spooned into the laboratory prepared sample bottles, placed in a cooler, and maintained at approximately 4 degrees Celsius to be shipped. Samples will be taken from the molten glass stream once every half hour after steady state glass flow has been established.

Samples will also be taken from the cullet cart using the auger type equipment described in EPA-846. The cart holds approximately 1500 lbs of material and will be sampled after it is full and is being removed from the process line. The cart will be removed approximately once every hour. Eight subcells will be identified for the vitrified product collected in each cullet cart, and a sample collected from each subcell. A stainless steel bucket auger will be used to penetrate the entire depth of the cullet pile. The sample will be removed from the bucket auger using a stainless steel spoon and placed into a stainless steel bucket. After sampling is completed, the entire contents of the bucket will be thoroughly homogenized by mixing with a stainless steel spoon. Approximately 8 ounces will be spooned into the laboratory prepared sample bottles, placed in a cooler, and maintained at approximately 4 degrees Celsius to be shipped.

Table 7.1-1. Sampling Schedule

SUMMARY OF CRITICAL AND NON-CRITICAL MEASUREMENTS

MEASUREMENT	MEASUREMENT CLASSIFICATION	SAMPLE SITE	MEASUREMENT FREQUENCY	REMARKS	ANALYSES
Soil Flow (Super sack weight)	Critical	Batch Tower (S1)	Each sack prior to being emptied	Batch tower is instrumented to weigh loss in weight to 1%	Cd, K, Pb, Zr, Anthracene
Soil composition	Critical	Batch Tower (S1)	Each sack prior to being emptied	Sampled prior to being placed into batch tank	"
Glass flow	Critical	Cullet Cart (S2)	Each cart when full and removed from the line	Weighed using crane scale	"
Glass composition	Critical	Cullet Cart (S2)	Each cart when full and removed from the line	Four auger sample samples per cart will be composited	"
Cullet water flow	Critical	Cullet Cart (S3)	30-minute intervals	Measured time to fill known volume	"
Cullet water composition	Critical	Cullet Cart (S3)	30-minute intervals	Samples taken as flow rate is measured	"
Wet ESP water flow	Critical	ESP Exit (5)	30-minute intervals	measured time to fill known volume	"
Water composition	Critical	Scrubber Exit (S5)	30-minute intervals	Samples taken as flow rate is measured	"
Wet ESP particulate composition	Critical	Scrubber Exit (S5)	Once at end of test	Once after particulate removed and dried	"
Exhaust gas metals Metals composition & Flow	Critical	Exhaust stack (S4)	Once per test	EPA / 530 - 91 - 010	Monitored by system computer
O2	Non-Critical	Exhaust stack (S4)	Continuously		
N2	Non-Critical	Exhaust stack (S4)	Continuously		
CO2	Non-Critical	Exhaust stack (S4)	Continuously		
CO	Non-Critical	Exhaust stack (S4)	Continuously		
System Temperatures Pressures Flows	Non-Critical Non-Critical Non-Critical	See Figure 6.0-1			Monitored by system computer

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Sampling of the vitrified product will not start until steady state glass making has been achieved in the CMS which will occur approximately two hours after the commencement of the batch feeding. Each sample will be analyzed for lead, cadmium, zirconium, and potassium, as well as the organic constituent anthracene.

7.3 Sampling of the Flue Gas for Heavy Metals and Organics

Stack gas sampling will be conducted by a qualified analytical laboratory, such as Geraghty & Miller or Energy Systems Associates, using the protocol described in Section 3.0 of the *Methods Manual for Compliance with the Boiler and Industrial Furnace Regulations*. This particular section is entitled "Sampling and Analytical Methods" and describes the sampling and analytical procedure for determining the metals content of the flue gas. In particular, the method is designed to determine the quantities of potassium, cadmium, lead, zirconium, and the organic compound anthracene. The laboratory analytical procedures to determine the metals content of the samples are consistent with and refer to the methods described in SW-846.

7.4 Post Sampling Procedures

Vortec will supply sample containers prelabeled and containing any required preservative. Immediately after collection, samples will be transferred to properly labeled sample containers with all necessary preservatives added. For solid samples, no preservatives are required. For liquid samples, the preservative is HNO_3 to a pH less than 2.0. Samples requiring refrigeration for preservation will be immediately transferred to coolers packed with ice or ice packs. Tables 7.4-1 through 7.4-4 identify the laboratory testing that will be conducted on individual samples taken from the effluent and influent streams.

7.5 Sample Custody

The primary objective of sample custody procedures is to create an accurate written record of the possession and handling of all samples—from the moment of their collection, through analysis, until their final disposition. Custody for samples collected during this investigation will be maintained by the Field Operations Manager (FOM) or the field personnel collecting the samples. The FOM or the field personnel will be responsible for documenting each sample transfer and maintaining custody of all samples until they are shipped to the laboratory.

Vortec will supply all necessary sample containers and preservatives. All necessary chemical preservatives will be added to the bottles prior to the sampling event. Custody of the sample bottles will be maintained by the FOM. Sample bottles needed for a specific sampling task will then be relinquished by the FOM to the sampling team after the FOM has verified the integrity of the bottles and ensured that the proper bottles have been assigned to the task to be conducted.

A self-adhesive sample label will be affixed to each container before sample collection. At a minimum, the sample label will contain the following information.

- Client - Job Name (Vortec SITE 04)
- Sample Number
- Sample identification - place of sampling
- Data and time collected
- Sampler's name
- Testing required
- Preservatives added

Table 7.4-1. Laboratory Tests Required

Test Matrix
Effluent and Influent Streams
Test 1 - Duration 6 Hours

Stream	Particulate Size	Petrographic Analysis	Metal Concentration	Organic Concentration	Leachability
Feedstock	yes	-	-	yes	-
Glass	-	yes	-	-	-
Cullet	-	yes	-	-	-
CC Water	-	-	-	-	-
ESP Water	-	-	-	-	-
ESP Particulate	yes	-	-	-	-
Flue Gas	yes	-	-	yes	-

Table 7.4-2. Laboratory Tests Required

Test Matrix
Effluent and Influent Streams
Test 2 - Duration 6 Hours

Stream	Particulate Size	Petrographic Analysis	Metal Concentration	Organic Concentration	Leachability
Feedstock	yes	-	-	yes	-
Glass	-	yes	-	-	-
Cullet	-	yes	-	-	-
CC Water	-	-	-	-	-
ESP Water	-	-	-	-	-
ESP Particulate	yes	-	-	-	-
Flue Gas	yes	-	-	yes	-

Table 7.4-3. Laboratory Tests Required

Test Matrix
Effluent and Influent Streams
Test 3 - Duration 4 Hours

Stream	Particulate Size	Petrographic Analysis	Metal Concentration	Organic Concentration	Leachability
Feedstock	yes	-	yes	yes	TCLP
Glass	-	yes	yes	yes	TCLP, ANS 16.1
Cullet	-	yes	yes	yes	TCLP, ANS 16.1
CC Water	-	-	yes	yes	-
ESP Water	-	-	yes	yes	-
ESP Particulate	yes	-	yes	yes	-
Flue Gas	yes	-	yes	yes	-

Table 7.4-4. Laboratory Tests Required

Test Matrix
Effluent and Influent Streams
Test 4 - Duration 4 Hours

Stream	Particulate Size	Petrographic Analysis	Metal Concentration	Organic Concentration	Leachability
Feedstock	yes	-	yes	yes	TCLP
Glass	-	yes	yes	yes	TCLP, ANS 16.1
Cullet	-	yes	yes	yes	TCLP, ANS 16.1
CC Water	-	-	yes	yes	-
ESP Water	-	-	yes	yes	-
ESP Particulate	yes	-	yes	yes	-
Flue Gas	yes	-	yes	yes	-

Immediately after sample collection, each sample bottle will be sealed in an individual plastic bag. Samples will then be placed immediately into an insulated cooler to maintain them at approximately 4 degrees Celsius for shipment to the laboratory. Each cooler will contain sufficient ice and/or ice packs to ensure that proper temperature is maintained and will be packed in a manner to prevent damage to sample containers. All coolers will be shipped by an overnight courier according to current U.S. DOT regulations.

8.0 METHODS FOR DATA ACQUISITION

The heart of the control system and data logging system is an IBM-486 computer which is dedicated to operating the Genesis control series program. The computer communicates with the subsystems through digital and analog input/output and data highway communications cards.

The Genesis control series program uses drivers to facilitate communications between the computer and the input/output hardware connections. Using available data, Genesis runs a developed control strategy designed to provide the following functions: data acquisition, recording, trending, mathematical, logical, indication, status, digital control, analog control, alarming, sequencing, timing, reporting, and user intervention.

Initially, the process control system required that individual systems be started and stopped manually; the Genesis control package only controlled process air flow, natural gas flow, batch flow, coal flow, and provided data acquisition and trending analysis. As experience was gained in the operation, more systems were automated. Ultimately, the startup, shutdown, and continuous operation functions were automatic, and became a part of the Genesis control logic.

9.0 TEST DATA EVALUATION

To evaluate the test data, a complete heat and mass balance of the system, based on combustion chemistry and thermodynamics, is performed for each test using a proprietary computer program developed by Vortec. This test-data analysis program is used to validate the data measured and to identify any possible unaccounted for heat and mass streams. The data analysis is also able to provide information with regard to the composition of the flue gas and the volume and enthalpy associated with each of the species. A typical system heat and mass balance diagram is illustrated in Figure 9.0-1.

Based on the test data, the fluid dynamic characteristics of the CMS are analyzed for both the gaseous phase and the liquid glass phase. As a result, the velocity and residence time of the combustion products at different locations in the CMS are determined. The glass layer thickness in the CRV is also calculated.

Figure 9.0-1. Example of a Heat and Mass Balance Diagram

Appendix C

Vortec Programs/History

Vortec has been the prime contractor of several recent R&D programs involving the design and testing of advanced glass melting and waste vitrification processes. Brief descriptions of some of these contracts follow.

Westinghouse Hanford Company, MJB-SVV-096473. Westinghouse Hanford is evaluating Vortec's vitrification technology for the safe disposal of national defense wastes stored at the U.S. DOE's Hanford Site. A "proof-of-principle" test run, at Vortec's U-PARC facility, simulated low-level radioactive waste injection into the Vortec Combustion and Melting System. The test demonstrated that Vortec's compactly designed CMS—with its high capacity and ability to accommodate diverse wastes—is able to make glass from sodium wastes and accept high volumes of liquid in the waste. The rate at which this was accomplished (500lbs/hr) was significantly greater than melters using an electric arc.

*Advanced Coal-Fired Glass Melting Process Heater Program; DOE Contracts DE-AC22-87PC79651 and DE-AC22-91PC91161; \$7.5 million; 3/87 to 9/94—*As prime contractor, Vortec is developing a multi-fuel capable advanced high temperature process heater for melting and other high temperature industrial applications, based on patents previously developed by Vortec. We designed, fabricated, and installed a nominal 15-20 TPD advanced process heater test loop. The system has been used to test the melting of waste glass, waste fiberglass contaminated with organics, utility flyash, and waste dust. The DOE technical project officer is Philip Goldberg, telephone (412) 892-5806.

*Advanced Vitrification Technology for Waste Treatment, EPA SITE-04 Program; Assistance No. CR818194-01-0; \$300,000; 6/91 to 6/93—*The objective of this program is to verify the effectiveness of our patented Combustion/Melting system for the oxidation and vitrification of soils in dry and slurry form representative of EPA superfund sites. The technical project officer for EPA is Ms. Teri (Shearer) Richardson (513) 569-7949.

*Innovative Fossil-Fuel-Fired Vitrification Technology for Soil Remediation; DOE, Morgantown Energy Research Center; Contract DE-AC21-92MC29120; \$10.7 million; 9/92 to 8/97—*As prime contractor, Vortec is developing a multi-fuel capable advanced vitrification process for the remediation of soil contaminated with hazardous materials and low levels of radiation waste. Vortec's nominal 15-20 TPD pilot plant will be used for testing during Phase 1. Program Phases 2 and 3 will design, construct, and operate a DOE-site plant, and demonstrate the remediation of actual site soil. The DOE technical project officer is Gary Nelkin, telephone (304)-291-4171.

*Rapid Glass Refiner Development Program; DOE Grant DE-FC07-90ID12911; \$2.3 million (Phase I); 10/89 to 11/94—*Vortec is the prime contractor on this three-phase program to develop a rapid glass-refining (RGR) technology which will significantly enhance the productivity and competitiveness of the U.S. glass industry. The program is currently in Phase I, the objective of which is to build and test an experimental scale RGR system integrated with Vortec's pilot-scale CMS. The technical project officer for DOE is Richard Loop, telephone (208) 526-0350.

*Innovative Coal-Fired Incineration Technology for Waste Fiberglass Recycling; DOE SBIR Grant DE-FG01-90ER80856; \$50,000 (Phase I) and \$459,193 (Phase II); 8/89 to 5/92—*Vortec was the prime contractor for this program. Phase I of the program demonstrated the feasibility of using our advanced combustion and melting process fired with coal as the primary fuel, through experimental testing in our nominal 15-20 TPD test facility, to oxidize the organic contaminants in waste insulation fiberglass material, and produce a cullet suitable for recycling to a manufacturer's furnace. Phase II of the program optimized the

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process for recycling several classes of waste insulation fiberglass materials and demonstrated satisfactory process control to proceed to a field demonstration phase of the program. The DOE technical project officer was John Winslow, telephone (412) 892-6290.

Innovative Incineration Technology for Fiberglass Manufacturing Solid and Hazardous Waste Disposal/Recycling; EPA SBIR Contracts 68D90120 and 68D00052; \$200,000; 9/89 to 10/91—Vortec Corporation completed the two-phase program which demonstrated the feasibility of using our advanced melting process with natural gas as the primary fuel, through experimental testing using our nominal 15 - 20 TPD test system, to oxidize the organic contaminants in waste insulation fiberglass material and produce a cullet suitable for recycling to a manufacturer's furnace.

Advanced Vitrification Technology for Waste Treatment, EPA SITE-04 Program; Assistance No. CR818194-01-0; \$300,000; 6/91 to 6/93—The objective of this program is to verify the effectiveness of our patented Combustion/Melting system for the oxidation and vitrification of soils in dry and slurry form representative of EPA Superfund sites. The technical project officer for EPA is Ms. Teri (Shearer) Richardson (513) 569-7949.

Appendix D

Preliminary Site Selection Criteria

**MORGANTOWN ENERGY TECHNOLOGY CENTER
DEMONSTRATION SITE SELECTION CRITERIA
FOR
ENVIRONMENTAL RESTORATION & WASTE MANAGEMENT
TECHNOLOGY DEVELOPMENT PROJECTS**

INTRODUCTION

DOE's Morgantown Energy Technology Center (METC) supports the Environmental Restoration and Waste Management (EM) - Office of Technology Development (EM-50) by contracting for research and development of technologies for waste site characterization and cleanup. The goal of this program is to develop and demonstrate new or improved technologies for addressing DOE's ER&WM needs and to make those technologies known and available where needed across the DOE complex. METC responsibilities in this program include technology needs identification, procurement, project management, field demonstration, technology transfer, and support to transfer of technologies to the commercial sector. Project success will ultimately require demonstration of the technology at an appropriate DOE site.

Demonstration site selection is a key decision in obtaining programmatic success since it impacts on all aspects of each project, it guides the planning in the initial project phase, provides a basis for Go/No-Go decisions for continuation of the project, and drives the planning for subsequent phases. Therefore, site identification, negotiation, and planning must be made as early in the project life cycle as possible. It is the objective of METC to initiate the site selection process during Phase I of a project. Where possible, site selection will be made at the close of Phase I. In other cases, the close of Phase I will support the evaluation of alternative demonstration sites, and site selection will be made subsequent to Phase I but prior to award and implementation of Phases II and III.

Site selection involves the consideration, evaluation, and weighing of a variety of issues, goals and objectives, and must be directed by appropriate and sound criteria. This document identifies the major criteria, and discusses their application.

SELECTION CRITERIA

Seven primary criteria have been identified for selection of a demonstration site. While all of the seven criteria are considered to be important, they are not listed in order of priority. An overriding order of priority has not been established, because the relative importance of any criterion may vary from project to project, depending on the nature

of the demonstration project and/or the technology involved. Thus, prioritization of site-selection criteria will receive consideration upon initiation of the site selection process.

The seven criteria are:

1. There must be a defined and documented site need for the technology.
2. The technical approach must be applicable and feasible for efficient performance at the site.
3. The regulatory status of the facility and compatibility of established regulatory schedules and constraints that apply to the site must not unreasonably limit the feasibility of a successful project demonstration.
4. Technical, scientific, commercial and operational factors that lead to the preference of a specific site by the technology development contractor must be considered.
5. The potential for the demonstration to show applicability of the technology at other sites or throughout the weapons complex must be determined, and considered.
6. The costs associated with conduct of demonstration at alternative sites must be considered in order to assure cost effectiveness. The availability and source of funding must be established.
7. The site must demonstrate its willingness, technical ability, and adequate organizational structure to support the demonstration project.

The following discussion elaborates on each of the above criteria.

CRITERION 1.

There must be a defined and documented site need for the technology.

In order to support a decision to commit funding and resources to an on-site small scale and eventual full scale demonstration, it is necessary to establish that the basis of the proposed project will provide for resolution of an identified need. By clearly defining the needs of the end user, clear objectives and performance goals by which the success of the demonstration can be measured will be established. A major criterion must be that the technology can be applied to resolution of an identified problem. The test plan can then be developed so that the maximum probability of transferring a proven technology to a practical field application is assured.

CRITERION2.

The technical approach must be applicable and feasible for efficient performance at the site.

The technical applicability and feasibility of demonstrating the project technology at the site must be considered and verified. A technology that potentially will work very well at one site may well be a failure at another due to differences in site conditions. Differences in site conditions could include, for example, waste matrices, range of contaminants, contaminant concentrations and characteristics, geological and meteorological conditions, and clean-up levels or goals.

CRITERION3.

The regulatory status of the facility and compatibility of established regulatory schedules and constraints that apply to the site must not unreasonably limit the feasibility of a successful project demonstration.

The regulatory status of the potential site and the compatibility of the technology development project schedule with the site schedules for regulatory compliance, including characterization and remediation, must be evaluated and properly weighed in site selection decisions. The need and ability to obtain the necessary regulatory permits, whether the site is under CERCLA or RCRA, the requirements for NEPA documentation, and the requirements of a Federal Facility Compliance Agreement will all affect site selection

CRITERION4.

Technical, scientific, commercial and operational factors that lead to the preference of a specific site by the technology development contractor must be considered.

In certain cases, a technology development contractor may have previously established a strong understanding of the requirements of a specific site remediation program and the prevailing site conditions, and may have previously structured his research and development program to address the specific concerns. This situation is particularly apparent if a contractor has been working at a site utilizing the existing state-of-the-art, and has developed more advanced concepts. A contractor may also make the case that the conditions at the proposed site offer the greatest potential for developing a commercially viable (profitable) piece of equipment, instrument, or treatment process.

CRITERION5.

The potential for the demonstration to show applicability of the technology at other sites or throughout the weapons complex must be determined, and considered.

An important consideration in site selection is the multiple applicability of a technology to the DOE complex resulting from a demonstration at a given site. Would the demonstration results be applicable to a variety of needs at a number of sites, or would it only solve a limited or specific problem? To the extent that multiple applicability has been identified, site selection should lead to the development of a Demonstration Test Plan that will ensure the generation of adequate data to support a determination that the technology has applicability to other sites across the DOE complex, and that the results of the demonstration can be applied to other sites.

CRITERION 6.

The costs associated with conduct of demonstration at alternative sites must be considered in order to assure cost effectiveness. The availability and source of funding must be established.

It is recognized that life cycle costs associated with the conduct of a demonstration may significantly differ between sites. Such differences may derive from costs for utilities, logistics, permitting, sampling and analysis, mobilization, etc. These differences may affect the cost-effectiveness of the demonstration. In addition, the site-specific demonstration costs must be evaluated in comparison with the availability of budgeted funding.

CRITERION 7.

The site must demonstrate its willingness, technical ability, and adequate organizational structure to support the demonstration project

Successful demonstration of a technology project requires active and effective support from DOE management at the facility, the Management and Operating contractor, and other support organizations. Accordingly, a particular site's technical or scientific background relative to the nature of the problem and the proposed technology application must be considered. The facility's technical and administrative resources and past experience in demonstrating projects of similar scope and complexity will be considered to be an important element in the ultimate success of the demonstration project.

SITE SELECTION PROCESS

In order to ensure that the application of new technologies will receive the acceptance and support of all affected parties, it is essential that a process of open discussion and involvement in the process is adopted. The active support of many organizations across the DOE complex facilitates and accelerates the successful demonstration of a technology development project. The comments and recommendations of all affected parties will be actively sought throughout the demonstration site selection process, and will be appropriately utilized for all METC site decisions. Affected parties include,

but may not be limited to: the technology development contractor, Environmental Restoration or Waste Management division at the DOE Operations Office, Technology Development division at the DOE Operations Office, EM-30 or EM-40, EM-50, Site M & O or ERM contractor, and Stakeholders and Regulators.

In particular, it must be recognized that the Regulators and the Stakeholders will have a significant impact on the final selection, since the ultimate use of the technology at a particular site must receive their approval. It also must be recognized that there are significant differences in the administrative approach of the different regions of the U.S. EPA, and in the states towards the adoption and implementation of innovative technologies at DOE sites.

Each technology project must be viewed as unique as the site selection process continues to a decision. The major criteria form the basis for guiding this process and for moving forward. Final site Selection will be made based upon METC's assessment of the optimum potential for project success and maximum benefit to the goals of the ERWM program.

Appendix E

Major Equipment List—Phase I Integrated System Design

Table E-1. Phase I Integrated System Design Equipment List

Feedstock Preparation and Handling System

- Waste Staging Area
 - 3 ft soil berms with 40-mil HDPE liner
 - 2 ft x 2 ft sump
 - Synthetic tarp (30 ft x 30 ft) for dust control
- Front-End Loader
- Dump Trucks
- Feed Hopper
 - 2.5 inch screen across entire opening
 - 12 ft x 6 ft x 8 ft deep
 - 9 inch diameter screw conveyor with 3 hp motor
- Impact Dryer Mill
 - Feed rate of 2 tons/hour
 - Hammer mill with 15 hp motor
 - Velocity separator; 2.5 ft in diameter with variable speed drive with 3-hp motor
 - High static induced draft fans (2)
 - Cyclone separator; 5 ft in diameter with rotary valve and drive motor
 - Gas fired air heater; 1,500,000 Btu/hour
 - Baghouse with 16 oz. woven Dacron bags; reverse jet blowers; pneumatic conveyor discharge and rotary valve
- Waste Storage Silo
 - 10 ft diameter; 20 ft height with conical bottom
 - Rotary valve
 - Carbon steel construction
- HEPA Filter
 - 2 ft x 2 ft x 1 ft deep; wood frame
 - Carbon steel housing
 - 2,000 ACFM capacity at 2 inches W.C.
- Vapor Phase Carbon
 - 13,000 lbs of carbon
 - 22 ft x 8 ft x 8 ft in height
 - Rated for 2,000 ACFM at 1 inch W.C.
 - Housing is epoxy-coated carbon steel
- Batch Mixing Tank
- Limestone Storage Tank
- Pneumatic Transport System
- Oversized Feed Roll-Off Container
 - 20 ton capacity
 - Carbon steel construction

Table E-1. Phase I Integrated System Design Equipment List

- Stormwater Collection Tank
 - Carbon steel construction
 - 3,000 gallon capacity

Cyclone Melting System

- Combustion Air Assembly
 - Blower Assembly with silencer and 40 hp motor
 - Piping from recuperator to CRV
- CRV Assembly
 - CRV
 - Refractory
- Melter Assembly
 - Glass melter
 - Refractory
- Separator-Reservoir
 - Separator-Reservoir
 - Refractory
- Gas Distribution
 - Main gas controls and flame safety

Heat Recovery System

- Recuperator
 - Recuperator; 15 ft height and 4 ft diameter
 - Refractory

Flue Gas Treatment System

- Spray Tower
 - Flow rate of 10,150 acfm at 2,000°F
 - Water requirement of 10 gpm
 - Refractory-lined carbon steel
 - 7 ft diameter and 25 ft height
- Baghouse
 - Flow rate of 7,130 acfm at 400°F
 - Effective cloth area of 2,233 sq. ft.
 - Compressed air cleaning system
 - 9 ft x 9 ft x 35 ft height
 - Fly ash pneumatically transported back to waste storage silo
- HEPA Filter
 - Flow rate of 7,560 acfm at 375°F
 - Four filters required at 2000 acfm each
 - Each filter is 2 ft x 2 ft x 1 ft deep
 - Carbon steel housing; silicone seals

Table E-1. Phase I Integrated System Design Equipment List

- **Quencher/Absorber**
 - Quench vessel is 10 ft height by 3 ft diameter; carbon steel construction
 - Horizontal absorber is 18 ft length by 10 ft height; FRP construction
- **Caustic Storage Tank**
 - Carbon steel construction
 - 8 ft diameter and 16 ft height
 - Internal heating elements
- **Caustic Recycle Pumps**
 - Centrifugal type
 - 3 hp motor
- **Water Supply Pumps**
 - Centrifugal type
 - 3 hp motor
- **Scrubber Recycle Pumps**
 - Centrifugal type
 - 3 hp motor
- **Ion Exchange Unit**
 - FRP pressure vessel; 1 ft diameter by 4 ft height
 - 2 cubic ft of cation exchange resin
 - Radiation meter
- **Induced Draft Fan**
 - Pressure drop requirement of 14 inches W.C.
 - Driven by 50 hp motor
- **Exhaust Stack**
 - FRP construction
 - 2 ft diameter and 40 ft height

Vitrified Glass Handling System

- **Quench Tank**
 - Carbon steel construction; trapezoidal shape
 - Continuous supply of make-up water required
 - Tank capacity approximately 1,500 gallons
- **Drag Conveyor**
 - 1 ft wide, providing > 12 ft elevation of material
 - Carbon steel construction
 - Removal rate of approximately 2,000 lbs/hr of frit
- **Roll-Off Containers**
 - Carbon steel construction; 20 ton capacity
 - Sloped bottom to a sump to collect free liquids
 - Approximate dimensions 10 ft x 25 ft x 8 ft height

Table E-1. Phase I Integrated System Design Equipment List

- Make-up Water Feed Pump
 - Centrifugal type
 - 3 hp motor

Process Monitoring and Control System

- Process Control
 - Central control panel located in control room
 - Programmable loop controllers for analog control (21 control loops estimated)
 - Programmable logic controller (PLC) for discrete control
- Data Collection
 - PC based data collection located in control room
 - Log and alarm printer
- CEM Analyzers
 - Oxygen analyzer
 - Carbon monoxide analyzer
 - Carbon dioxide analyzer
 - Oxides of nitrogen (NOx) analyzer
 - Opacity analyzer

Support Services and Facilities

- Cooling Tower
 - 50 ton per hour unit
 - 10 ft x 7 ft x 7 ft height
 - Attached blower operated by 5 hp motor
- Cooling Water Recirculation Pump
 - Centrifugal type - 60 gpm
 - 5-10 hp motor
- Control Room/Office Trailer
 - Double-wide (~15 ft) x 40 ft length
- Decontamination Facilities
 - Decon trailer
 - Decon pad

Appendix F

Weston's Conceptual Engineering Report

Revision: 1
Date: 02 July 1993

**INNOVATIVE FOSSIL FUEL FIRED VITRIFICATION FACILITY
FOR SOIL REMEDIATION**

CONCEPTUAL ENGINEERING REPORT

July 1993

Prepared by:

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Prepared for:

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Work Order No. 10189-001-001

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SECTION 1

INTRODUCTION

1.1 BACKGROUND

Vortec Corporation (Vortec) of Collegeville, PA has developed an innovative fossil fuel fired vitrification technology for ex situ soil remediation. The Department of Energy (DOE) is currently evaluating the technology for treatment of mixed wastes (i.e., a combination of hazardous waste and low-level radioactive wastes) through the Morgantown Energy Technology Center (METC). Vortec's existing contract with METC consists of three phases:

- Phase I: Sub-scale major component testing at Vortec's University of Pittsburgh Applied Research Center (U-PARC) facility. Four tests are anticipated, 6 to 8 hours each with a throughput rate of approximately 15 tons/day.
- Phase II: Sub-scale integrated system testing at a selected DOE facility. Testing is anticipated for 30 days at a throughput of 25 tons/day.
- Phase III: Full-scale integrated system testing at a selected DOE facility. Long-term testing is anticipated with an approximate throughput of 100 tons/day.

The Vortec vitrification technology is capable of treating a wide variety of contaminated soils and sludges. The heart of the process is Vortec's proprietary cyclone melting system (CMS) which is used to accomplish both thermal destruction and vitrification process steps. Waste materials are injected into a counter rotating vortex (CRV) combustor wherein organic contaminants are thermally destroyed and the inorganic components are heated in suspension to the appropriate temperature necessary for melting of the material. The hot, molten, inorganic waste is then collected in a melt chamber before exiting the CMS. Commercially available heat recovery and flue gas cleanup subsystems are utilized for downstream flue gas processing. The vitrified products generated consistently pass toxicity

characteristic leaching procedure (TCLP), minimizing the disposal restrictions placed on the "glass" produced.

Vortec is currently near completion of Phase I testing at their U-PARC facility and is discussing with the DOE potential sites for Phase II testing using a 25 ton/day sub-scale system. Initial indications are that there may be multiple candidate sites where ex situ vitrification would be applicable. For this reason, Vortec has recommended the design of a transportable system, utilizing skid-mounted equipment, capable of being transported by multiple flatbed semi-trailers or railcars. A DOE decision on site location is not expected until the fall of 1993.

1.2 PURPOSE

Roy F. Weston, Inc. (WESTON.) has been contracted by Vortec to assist in developing a conceptual design of the sub-scale integrated system (25 tons/day) to a sufficient level of detail to support development of cost estimates for Phase II of the project. Specifically, WESTON has been tasked to perform the following activities:

- 1) Support Vortec in conducting a systems analysis to establish the integrated system design criteria.
- 2) Develop sub-system and component design criteria for the balance of plant components.
- 3) Develop a major component equipment list, a layout drawing showing the general location and outline of major equipment, a flow diagram for major subsystems, subsystem descriptions, and conceptual equipment specifications.
- 4) Develop a conceptual cost estimate for the sub-scale integrated system project (Phase II). The Phase II cost estimate includes only capital costs associated with purchase and installation of the sub-scale system.

Operating costs during startup, shakedown and demonstration testing will be estimated during preliminary Phase II activities.

The sub-scale vitrification facility has been designed in part by Vortec and in part by WESTON. Vortec's primary design responsibilities included the waste feed system, the melting system, and the heat recovery system. WESTON's primary design responsibilities included the waste preparation system, the flue gas handling system, the vitrified glass handling system, the process monitoring and control system, and any support services and facilities required. Interaction between Vortec and WESTON has occurred throughout the concept design process to assure compatibility at system interfaces.

The purpose of this Conceptual Engineering Report is to discuss the various design options that were evaluated, and recommend an integrated design based on effectiveness, implementability, and economics. The recommended design is described in detail and includes a process flow diagram and a material balance. A layout of the major process equipment is also included. Ultimately, the concept design was used to support the development of a cost estimate for the sub-scale system. This cost estimate is included in Section 7.

SECTION 2

SYSTEM REQUIREMENTS

The system requirements for the sub-scale vitrification facility have been developed based on the following project criteria or assumptions:

- Facility throughput will be approximately 25 tons/day based on laboratory testing performed by Vortec.
- Facility will be transportable, allowing for its use at multiple DOE sites. Only minor design modifications are needed to develop a transportable facility versus a fixed-location facility (e.g., replacing welded connections with flanges). Process equipment will be skid-mounted for structural support, as opposed to being mounted to concrete pad foundations.
- The facility is capable of processing mixed wastes. Mixed wastes are soils, sediments, and/or sludges contaminated with hazardous wastes and low-level radioactive wastes. Organic contamination (solvents, fuels, etc.) contains chlorine at concentrations requiring acid gas (HCl) neutralization as part of the flue gas treatment system. Both volatile (cesium) and nonvolatile (uranium and plutonium) radionuclides may be present in the waste stream.
- Wastes fed in dry form to the CRV combustor will require a particle size of no greater than 500 microns (μm) and a moisture content that enables the material to free flow (approximately 0 to 10 percent). Wastes fed in wet form will require a similar particle size and a moisture content that enables the material to be pumpable (approximately 40 to 50 percent).
- Wastes generated as a result of testing will be disposed on-site, or at an approved DOE low-level radioactive waste disposal facility, and will be the responsibility of the DOE facility. These waste streams may include but are not limited to:
 - Personnel protective equipment
 - High efficiency particulate air (HEPA) filters
 - Treated scrubber blowdown water
 - Spent ion exchange equipment
 - Classified product
- The DOE site selected is a CERCLA site and is included on EPA's National Priorities List (NPL). CERCLA hazardous waste sites do not require permits for performing remedial activities (although the substantive requirements of

the permit must be met). It is assumed that initial testing will be with CERCLA hazardous waste only, thereby minimizing requirements for EPA or state permits. If radioactive waste are processed, additional permitting requirements will be necessary depending on the DOE facility and the State in which it operates.

Upon completion of testing, the facility will be decontaminated, dismantled and either hauled off-site, or stored within the DOE facility. The test site will be restored to its existing condition.

SECTION 3

PROCESS EVALUATION

Before the overall design of the sub-scale vitrification facility could be established, a process evaluation was performed to outline the most feasible components of the system. WESTON's process evaluation involved comparing the trade-offs of various pieces of equipment that had similar capabilities. This evaluation started with a working meeting between Vortec and WESTON project personnel. Various concepts were discussed in an attempt to find the best engineering solution for a given process area. At the conclusion of the meeting, the most promising two or three suggestions were identified for each process area. An evaluation of these concepts is presented below along with the recommended concept design for each process area. The two process areas that required evaluation included the feedstock (waste) preparation and handling system, and the flue gas treatment system. Other systems, such as the vitrified glass handling system and the process monitoring and control system that did not require a preliminary process evaluation are discussed in Section 4.

3.1 FEEDSTOCK PREPARATION AND HANDLING COMPARISON

The feedstock preparation and handling system includes the necessary equipment to prepare the site wastes in a form acceptable for feeding to the melting system. Possible scenarios include a dry feed system where wastes are dried and transported either pneumatically or mechanically; or a wet feed system where wastes are slurried and transported via pumping. An evaluation of a dry feed system versus a wet feed system is discussed below.

Option 1 - Dry Feed System

The dry feed system must screen site wastes to a maximum diameter of 2 inches, pulverize the wastes to a 500 μ m particle size, dry the pulverized waste to a "flowable" consistency, and then transport the processed waste to a storage silo. An impact dryer mill was selected

as the main component of such a system. The impact dryer mill is a commercially proven technology that can perform all of these tasks with one integrated system. A block flow diagram of the dry feed system that incorporates the impact dryer mill is shown as Figure 3-1. This dry feed system consists of the following process components:

- Feed hopper with 2.5 inch screen on top and a screw conveyor to convey the screened waste to the mill.
- Impact dryer mill reduces feed to the desired product size (i.e., size less than 500 μm) while simultaneously, hot gases injected into the mill remove moisture from the waste.
- High static pressure fan draws pulverized material into a velocity separator, where particles that have been reduced to the proper size are air-conveyed out of the mill.
- Cyclone separator removes product-sized material from the air stream. A storage silo would be located under the cyclone separator for product collection.
- Baghouse removes airborne fines entrained in the exhaust gas. Fines would be pneumatically transported to the storage silo.
- HEPA filter and vapor-phase carbon beds would be included for final polishing of exhaust gases before being vented to the atmosphere.
- Gas fired air heater supplies heated air to the impact dryer mill. The high static pressure fan discussed above would be used to draw air through the heater and into the mill.

The dry system also includes a batch mixing tank and a limestone storage silo that are being designed by Vortec.

This dry feed system has been evaluated as a stand alone system, that is, it could operate without the CMS or flue gas treatment systems in operation. This design approach allows for increased flexibility during operations. This concept could be modified further to increase flexibility by allowing the option to use waste heat from the recuperator to dry the wastes in the impact dryer mill, and vent off-gases from the pneumatic waste handling

FIGURE 3-1 DRY FEED SYSTEM BLOCK FLOW DIAGRAM

system to the CMS eliminating the need for off-gas treatment (i.e., baghouse, HEPA filter, and carbon beds).

Option 2 - Wet Feed System

A wet or slurry feed system was considered as an alternative to the dry system in an attempt to minimize the formation of potentially contaminated emissions during materials handling activities and reduce the need for having to dry wastes prior to introduction into the CMS. The wet feed system would slurry wastes to an approximate moisture content of 40% before pumping them through a wet grinder and into a second slurry tank. Limestone (glass formers) and additional water are added to the tank increasing the moisture content to approximately 50% before being pumped to a feed tank for feeding to the furnace. A block flow diagram of the wet feed system is included as Figure 3-2. The wet feed system would consist of the following components:

- Feed hopper for screening oversized material (greater than 2.5 inches in diameter).
- Slurry tank for mixing wastes and water to create slurry for pumping.
- Slurry pump for transferring wastes from the slurry tank to the wet grinder.
- Wet grinder (ball mill) for size reduction of wastes to be treated.
- Slurry tank for storage of sized, slurried wastes for feeding into the batch mixing tank for limestone addition.

The wet feed system is capable of accepting both wet and dry feedstocks. As an aqueous (or semi-aqueous) process with no pneumatic transport, emissions are virtually eliminated; however, the CMS operating efficiency is reduced due to the increased moisture content of the waste feed. Also, difficulties could arise in handling and storage of the sized, slurried soil. Continued agitation of the slurried wastes would be required to prevent gravity separation and "setting up" of the wastes prior to feeding to the furnace (especially with the

FIGURE 3-2 WET FEED SYSTEM BLOCK FLOW DIAGRAM

addition of limestone to the slurry). Slurry tanks would be approximately 5,000 gallons in capacity, requiring large mixers and high energy outputs to keep the slurry homogeneous.

In addition to slurry handling problems, the sizing of the CMS and the downstream flue gas treatment equipment would have to be significantly increased to account for the increased water load. The size of the CMS would almost double to handle the same quantity of waste for the wet feed system as opposed to the dry system. The flue gas requiring treatment would increase by over 60% (8,950 lb/hr of flue gas using a dry feed system versus 13,830 lb/hr of flue gas using a wet feed system).

Recommendation

After evaluating both the wet and dry feed systems, the dry feed system has been selected as the baseline feedstock preparation and handling system based on versatility; however, there may be some beneficial applications of the wet system as well. The dry system is all-inclusive, combining heating, grinding, and material transport into one package and can handle a variety of feed stocks. Material would be transported pneumatically, which is commonplace for handling fine-grained material. The major drawback with the dry system is that off-gases from the pneumatic system would have to be collected and treated due to potential contamination.

The wet feed system may be advantageous when dealing with homogeneous and/or moist feedstocks like lagoon sediments or sludges. Homogeneous feedstocks can be slurried and pumped easily without major buildup or clogging. Feedstocks that are already moist are ideal candidates for slurrying. Also equipment and operating costs associated with materials handling air pollution control devices are eliminated. The major drawback with the wet feed system is the reduction in overall efficiency of the CMS due to the water addition for slurrying.

The size of the CMS accepting slurried waste would have to increase significantly to handle the same waste flow rate from a dry waste feed system. Similarly, the downstream flue gas treatment equipment would also require upscaling to account for the increase in water vapor generated.

A cost comparison of the dry feed system versus the wet feed system is presented in Section 7. From this comparison the dry feed system equipment costs are less than the wet feed system costs. The total cost to construct the sub-scale system with the dry feed system is approximately \$3,669,000, as compared with \$4,180,500 for the wet feed system. Although operational costs are not included in this report, it is expected that long-term operation would increase the overall costs of a wet feed system as opposed to the dry feed system due to increases in electricity and natural gas consumption.

3.2 FLUE GAS TREATMENT EQUIPMENT COMPARISON

Two flue gas treatment trains were initially thought to be applicable in treating off-gases generated from the vitrification process; a dry flue gas treatment system and a wet flue gas treatment system. These trains were developed based on WESTON's thermal treatment experience, Vortec's vitrification experience, and guidance from EPA's Radiation and Mixed Waste Incineration Document (EPA, 1991). The two flue gas treatment trains vary primarily in the method of particulate control, i.e., the dry system uses a baghouse versus a venturi scrubber and wet electrostatic precipitators (ESP) for the wet system. Both the dry and wet systems includes a bank of HEPA filters, a packed-bed absorption unit, an induced draft (ID) fan, and a stack. The pack-bed absorption unit is included in each option for neutralization of any acid gases that may form as a result of combustion. Block flow diagrams for both of the flue gas treatment options are included as Figures 3-3 and 3-4.

The evaluation for the flue gas treatment system options focused on the selection of the most appropriate particulate removal technology, that is, a comparison between a dry system

FIGURE 3-3 DRY FLUE GAS TREATMENT SYSTEM BLOCK FLOW DIAGRAM - BAGHOUSE OPTION

FIGURE 3-4 WET FLUE GAS TREATMENT SYSTEM BLOCK FLOW DIAGRAM - VENTURI SCRUBBER AND WET ESP OPTION

using a baghouse and a wet system using a venturi scrubber and wet ESP. The remainder of each train is relatively similar.

Dry Option - Baghouse

The dry option consists of a spray tower to quench hot off-gases from the recuperator, a baghouse to remove particulate, a HEPA filter to remove any very fine particulate that may have escaped the baghouse, a quencher/absorber vessel to cool and neutralize any acid gases, an ID fan to draw the off-gases through the system, and a stack to disperse the off-gases to the atmosphere. A 25% caustic solution is added to the absorber to aid in the neutralization of acid gases. Blowdown from the system will be passed through an ion exchange unit to remove radioactive metals (such as Cs-137).

The spray tower and baghouse are what differentiate this option from the other two. The spray tower is a refractory lined vessel that injects water into the off-gas stream for cooling. Off-gases enter the spray tower at approximately 2,000 °F and must be cooled to a temperature of 400 °F prior to entering the baghouse. Proper design and operation of the spray tower is essential because baghouses are moisture and temperature sensitive. Too much water injected into the off-gas stream may cause excessive cooling, and the carry-over of water droplets to the baghouse, causing the filters to clog. Insufficient water injected into the off-gas stream may not provide adequate cooling resulting in the overheating of the baghouse and potential fire. WESTON's experience has been that baghouse temperatures should be kept below 500 °F to prevent fire hazards without having to use exotic bag materials (i.e., Teflon).

Baghouses are frequently used for particulate control in both hazardous and low-level radioactive waste thermal treatment systems. Baghouses offer very high particulate removal efficiencies even for very small particles. Removal efficiencies of 99.9% on 0.5 μm or larger particles can be achieved with a pressure drop of 4 to 6" of water column (W.C.). Collected particulate would be transported pneumatically to the waste storage silo on a batch basis.

Baghouses can be easily transported via flatbed semi-trailers or railcars. Baghouse capital costs are low to moderate, ranging from \$25,000 to \$40,000 for a unit sized for the sub-scale system (approximately 8,000 acfm).

Wet Option - Venturi Scrubber and Wet ESP

The wet option consists of a spray tower for quenching, venturi scrubber and cyclonic separator for coarse particulate control, two wet ESPs in parallel for fine particulate control, a quencher/absorber vessel to cool and neutralize any acid gases, an air reheater to raise the off-gas temperature above its dew point, and a HEPA filter, ID fan, and stack as discussed in the dry option. In addition to the ion exchange unit for blowdown treatment, a settling/recirculation tank will be used to collect particulate from both the venturi scrubber and wet ESPs. Effluent from the tank clearwell will be recirculated back through the wet ESP for reuse. Supernatant from the tank will be pumped to the ion exchange unit for treatment prior to disposal. Collected particulate will be manually transported to the impact dryer mill.

The major variations from Option 1 are the addition of the venturi scrubber, wet ESPs, settling/recirculation tank, and air reheater, and the removal of the baghouse. Cooled off-gases from the spray tower enter the top of the venturi scrubber and are introduced to the scrubbing liquid. The venturi section "squeezes" the gas and liquid into the throat area which can be a fixed or adjustable size. Within the throat gases and liquids are thoroughly mixed at a predetermined pressure drop. The saturated gases laden with the entrained particulate are then allowed to expand where the particulate drops to the bottom of the scrubber for collection while the treated off-gases are directed through the top of the scrubber.

Venturi scrubbers are frequently used for particulate control in both hazardous and low-level radioactive thermal treatment systems. Venturi scrubbers are not as effective as baghouses in removing fine particulate although they can effectively remove coarse

particulate. Venturi scrubber systems can be easily transported via flatbed semi-trailers or railcars. Capital costs for venturi scrubbers are low to moderate, ranging from \$20,000 to \$50,000, depending on the materials of construction used.

In addition to the venturi scrubber, Vortec has recommended using wet ESPs to capture fine particulate. Wet ESPs use water sprays to saturate the incoming gas stream. The electric field within the ESP charges the liquid droplets. The liquid droplets charge, collect, and wash away the particulates from the gas stream. Maintaining the proper liquid-to-gas ratio (typically 5 gallons per 1000 scf) is essential for the effective operation of the equipment.

Two wet ESPs are recommended, operating in parallel to allow for washdown/maintenance of a unit while continuing operation. Vortec has experienced "particulate build-up" problems on their existing pilot-scale wet ESP during previous vitrification tests causing test interruptions for cleaning.

Wet ESPs are used infrequently in both hazardous and low-level radioactive waste thermal treatment applications. ESPs are generally large and expensive (both capital and O&M) pieces of air pollution control equipment and are normally used in large fixed applications (i.e., coal-fired power plants, trash-to-steam facilities, etc.). Hazardous waste and low-level radioactive waste treatment facilities are typically smaller in scale, even transportable, often times making ESPs prohibitively expensive. However, from an operational standpoint, a wet ESP can offer very high particulate removal efficiencies even for very small particles and may represent a preferred option at some DOE facilities. Removal efficiencies of 99.9% on 0.5 μm or larger particles can be achieved with a pressure drop of only 1" W.C. Capital costs associated with a pair of wet ESPs are high, approaching \$500,000.

Recommendation

After comparing the advantages and disadvantages of each of the options discussed above, the dry option is believed to be the best flue gas treatment system for this application. The

baghouse offers excellent particulate control at reasonable energy requirements. Baghouses are moderately sized, moderately priced, and are transportable. Also, baghouses do not require the use of water, thus eliminating the creation of another waste stream. The major disadvantages of the baghouse option are the moisture and temperature restrictions on the off-gases entering the baghouse; however, these restrictions can be overcome through the proper design and operation of the spray tower.

The wet option requires a more complicated air pollution control train requiring increased capital costs and increased operational problems; however, if collected particulate is desired in a wet/moist form (and not as a dry dust), the wet option may be a viable option. Capital costs for the dry flue gas treatment train are approximately \$3,669,000. Capital costs for the wet flue gas treatment system are approximately \$4,572,300. Detailed costs estimates for each option are included in Section 7. The baseline system design discussed in Sections 4 and 5 will include the dry (baghouse) flue gas treatment train.

SECTION 4

PROCESS DESCRIPTION

4.1 INTRODUCTION

The process description of the sub-scale vitrification facility is divided into three primary subsections. This initial subsection presents an overall process description allowing the reader to understand how each of the process components fit into the overall system. The second subsection (Subsection 4.2) discusses the primary process areas in some detail. An equipment listing is provided in the third subsection (Subsection 4.3). The overall flow diagram for the sub-scale vitrification facility is included as Figure 4-1. The baseline conceptual design to be discussed below includes a dry feed system (using the impact dryer mill) and a dry flue gas treatment train (baghouse option). The wet feed and wet flue gas options were evaluated as variations to the baseline design and are not evaluated further with the exception of the cost estimates presented in Section 7.

The sub-scale vitrification facility will be installed and operated at a DOE facility for site remediation. Testing is planned for a 30-day period to demonstrate the effectiveness of the technology. Testing will be performed on soils, sediments, and/or sludges contaminated with hazardous and/or radioactive materials. The overall process description is discussed below.

The ex situ vitrification process begins with the preparation and handling of the waste stream to be treated. Contaminated soils, sediments, or sludges would be excavated and transported to a stockpiling location adjacent to the vitrification facility. From the stockpile area, contaminated materials will be transported by front-end loader to a screened feed hopper. Material is deposited into the screened feed hopper where material greater than 2.5 inches in diameter is removed. Material is screw conveyed from the hopper bottom to the impact dryer mill. The impact dryer mill simultaneously pulverizes and dries the material; heat from the drying operation is supplied by a gas-fired burner. The dried, fine

Figure 4-1. Vitrification Facility Process Flow (p. 1 of 2)

Figure 4-1. Vitrification Facility Process Flow (p. 2 of 2)

grained material is pneumatically transported out of the mill and into a cyclone separator where the solid material is separated from the transport air. The solid material drops from the cyclone into a storage silo before being processed through Vortec's patented cyclone melting system (CMS).

Off-gases from the pneumatic transport system will require treatment due to the possible volatilization of organic compounds during the drying process. As waste material is heated, volatile organics would tend to be stripped off; however, volatile radionuclides are not expected to be stripped off at the temperatures present in the dryer (less than 500°F). From the induced draft fan, pneumatic transport air is passed through a baghouse for particulate removal, a HEPA filter for very fine particulate removal, and a vapor-phase carbon bed for volatile organics removal. The option is available for recycling a portion of the pneumatic air stream back to the impact dryer mill reducing the volume of air requiring treatment.

After drying and pulverizing the feed material, it is transported pneumatically to a batch mixing tank where limestone is added. Limestone is added to enhance the quality of the glass formed. From the batch mixing tank, the waste feed/limestone is transported pneumatically to the CMS. The CMS consists of three major components; the CRV combustor, the cyclone melter, and the separator-reservoir. The feed material, along with natural gas and pre-heated combustion air, is injected into the CRV combustor. The CRV acts as a pre-heater, heating the wastes to temperatures in excess of 2,200 °F wherein organic components are incinerated and the inorganic components are heated in suspension for melting of the materials. Solid material begins to melt as it passes through the CRV combustor and into the cyclone melter. Molten residuals flow through the separator-reservoir before exiting down a water-cooled cullet chute into a quench tank. Upon cooling in the quench tank the molten material glassifies, forming a frit. The frit can be drag conveyed out of the quench tank and placed in roll-off containers for disposal.

Flue gases from the CMS are passed through a recuperator (heat exchanger) where combustion air is pre-heated to 1,100 °F. Flue gases within the recuperator are cooled from 2,560 °F to 2,000 °F. From the recuperator, flue gases enter a spray tower to cool the gases from 2,000 °F to 400 °F to avoid damage to the downstream air pollution control equipment. Cooled flue gases enter a baghouse and a HEPA filter for particulate removal. From the HEPA filter flue gases enter a quencher/absorber for neutralization of any acid gases before being exhausted out a stack. Scrubber blowdown from the absorber may contain volatile radioactive metals and will be treated using ion exchange. Fly ash collected within the baghouse is transported pneumatically to the waste storage silo for reprocessing.

4.2 DETAILED PROCESS DESCRIPTION

4.2.1 Feedstock Preparation and Handling System

Wastes to be treated as part of this technology evaluation may come from a variety of locations within the selected DOE facility. Typical wastes may include contaminated soils, sediments from streams or ponds, or sludges from lagoons or tanks. Wastes will be excavated and placed into plastic-lined dump trucks for transport to the waste staging area. The staging area will be constructed of natural soils covered with a 40-mil HDPE liner. Three-foot berms will be constructed on three sides of the staging area for containment purposes. The staging area will be sloped to a corner sump to collect any free liquids that may accumulate. The approximate size of the staging area will be 25 ft x 25 ft, with one side open for equipment access. The open side of the staging area will be ramped as opposed to bermed to allow equipment access. Tarps may be required to cover waste piles during extended periods of rain. Similarly, dust control may be required during extended dry periods. Collected storm water will be used for dust control if needed.

Wastes in the staging area are transported via front-end loader to the feed hopper. The feed hopper is equipped with a 2.5 inch square hole screen across the entire opening. At the base of the hopper is a screw conveyor, which conveys the screened feed material to the impact dryer mill. Oversized material that does not pass through the screen will not be

processed through the system. Oversized material be loaded into a separate roll-off container and managed separately. The hopper size is approximately 12 feet in length by 6 feet in width and 8 feet deep. The screw conveyor is 9 inches in diameter and operated by a 3 hp motor.

Feed material will be fed to the impact dryer mill at a maximum rate of 2 tons per hour. The feed rate into the hopper is independent of the feed rate into the CMS. Material will be fed into the hopper as needed to keep an adequate supply of feed material in the waste feed silo. Wastes are pulverized by rotating hammers within the mill. Hot gases are injected into the mill to promote drying of the feed material. Controlled air flow in the mill enables the flow of hot gas to selectively air-convey particles, ground to the proper size, up and out of the grinding chamber. The ground product, suspended in air, passes through a velocity separator where an accurate size classification is made. Oversized material in the separator falls back into the grinding chamber for additional size reduction. The mill is operated by a 15 hp motor. The velocity separator is 2.5 feet in diameter and is operated by a 3 hp motor. The air heater is gas-fired, with a 1.5 MBTU/hr capacity unit.

The sized wastes are pneumatically conveyed through the velocity separator to a cyclone separator. Within the cyclone separator the dried, sized waste feed is separated from the transport air. The waste feed falls from the cyclone into a silo where the wastes are stored prior to processing via the CMS. The cyclone separator is mounted on top of the storage silo. From the storage silo, wastes are pneumatically conveyed to a batch tank where they are mixed with limestone. Limestone is also conveyed pneumatically from a limestone storage tank. The limestone storage tank is periodically filled using tanker trucks that transport the crushed limestone to the facility. Limestone is added to the waste (approximately 20% by weight) to enhance glass-forming properties. After thorough mixing, the contents of the batch tank are pneumatically conveyed to the CMS. The waste storage silo is a carbon steel vessel, 10 feet in diameter and 15 feet in height with a cone-shaped bottom to allow for pneumatic withdrawal of the waste. The cyclonic separator is 5 feet in diameter, approximately 12 feet in total height and is constructed of carbon steel. The

limestone storage tank is similar to the waste storage tank in size and construction. The batch mixing tank is 6 feet in diameter and 10 feet in height with a cone-shaped bottom. The cyclone separator, waste storage silo, limestone storage tank and batch mixing tank are each equipped with a bottom-mounted rotary valve with a 0.5 hp gear motor and chain drive.

Off-gases from the pneumatic transport of the dry feed material exit the cyclone separator and are exhausted through air pollution control equipment using an induced draft fan. This fan is used to pull the ground waste materials out of the impact dryer mill into the cyclone separator and ultimately into the storage silo. The exhaust side of the fan transports the majority of the off-gases through a series of air pollution control equipment while a portion of the off-gases are recycled back into the impact dryer mill. Off-gases to be treated will first encounter a baghouse for particulate removal, followed by a HEPA filter for very fine particulate removal, and a vapor-phase carbon bed for removal of any organics that may have volatilized as a result of the heating/drying process. A second fan will be needed to discharge clean gases and evaporated moisture from the system. The main materials handling fan is driven by a 30 hp motor, while the smaller discharge fan is driven by a 5 hp motor. The baghouse is sized to contain 500 sq. ft. of effective cloth area to treat 2,090 acfm (air-to-cloth ratio of 4.18) of transport air. The bags will be made of polyester or Nomex. Cages and the housing will be made of carbon steel. Approximate dimensions of the housing are 4 feet in length by 4 feet in width by 14 feet in height. The HEPA filter is rated for 2,000 acfm at 1.5 inches of water. The filter is 2 feet in height by 2 feet in length, by 1 foot in depth with a woodboard frame and synthetic gasket. The housing for the HEPA filter will be constructed of carbon steel. The vapor-phase carbon bed will contain two separate adsorber beds each with approximately 6,500 pounds of carbon. Depending on VOC concentrations, the beds can be used one at a time (keeping one off-line) or both beds can be operated in parallel and used simultaneously. The vessel dimensions are approximately 22 feet in length by 8 feet in width by 8 feet in height, and is constructed of epoxy-coated carbon steel. At a volumetric flow rate of 2,000 acfm the pressure drop is only 1 inch of water. It should be noted that in evaluating the carbon usage rate, a concentration

of 4 lbs/hr of VOC's has been assumed. The 4 lbs/hr feed rate was calculated from an assumed VOC concentration in the waste of 1,000 ppm multiplied by a feed rate of 4,000 lbs/hr. Actual carbon usage will depend on the actual VOC concentration in the wastes being treated.

4.2.2 Cyclone Melting System

VORTEC TO PROVIDE

4.2.3 Heat Recovery System

VORTEC TO PROVIDE

4.2.4 Flue Gas Treatment System

Flue gases exiting the recuperator will be subjected to a series of flue gas control equipment prior to being exhausted out the stack. The first component of the flue gas control train is a spray tower which is used to cool flue gases exiting the recuperator. Gases enter the spray tower at a flow rate of approximately 10,150 acfm and temperature of 2,000 °F. A series of spray nozzles inject water into the flue gas causing the formation of water vapor and a reduction in gas temperature. Flue gases exit the spray tower at a temperature of approximately 400 °F. The spray tower will be constructed of refractory-lined carbon steel with an inside diameter of approximately 7 feet and a height of 25 feet. Duct work from the recuperator to the spray tower will also require refractory lining. Structural steel support will also be required.

Directly downstream of the spray tower, a baghouse provides particulate removal. Flue gases enter the bottom of the baghouse and flow through filter bags where particulate is captured. Filtered flue gases exit from the top of the baghouse. Filter bags are periodically pulsed with compressed air to remove built-up particulate; this material is then collected and

pneumatically conveyed to the waste storage silo discussed in Subsection 4.2.1. The baghouse has been sized to contain 2233 sq. ft. of effective cloth area and handle 8,000 acfm at 400 °F (air-to-cloth ratio of 3.58). Overall dimensions for the baghouse are approximately 9 feet in length by 9 feet in width by 35 feet in height (includes structural steel support). Particulate removal efficiencies of 99.9% for particles of 0.5 μm or larger can be expected with a pressure drop of 5 inches of water.

HEPA filters are also included in the flue gas treatment system because of the potential for sub-micron radioactive particulate being present. From the baghouse, flue gases will pass through a bank of HEPA filters. Because the standard high-volume HEPA filter has a capacity of only 2,000 acfm, a bank of four HEPA filters will be required to satisfy the flow rate of 7,560 acfm out of the baghouse. The four filters will be stacked in a two by two matrix, all enclosed within a single housing. Each filter is 2 feet in height by 2 feet in width by 1 foot in depth. The seals between the filters and the housing will be constructed of silicon because flue gas temperatures will be above 200 °F. HEPA filters are designed for a particulate removal efficiency of 99.99% for 0.3 μm particles or larger with a pressure drop of 2 inches of water.

The filtered flue gas then passes through a liquid quench/absorber for neutralization of any acid gases that may have formed as a result of the combustion process. A skid-mounted horizontal quencher/absorber is conceptualized to ease in transportation, installation, and maintenance. The hot flue gases (375 °F) are immediately quenched to prevent damage to the fiberglass-reinforced plastic (FRP) materials of construction. Inside the quencher, water is injected into the flue gas stream using a series of nozzles to cool the gas to approximately 175 °F. From the quencher, the flue gas enters the horizontal packed absorber where a 25% caustic solution is injected as a fine mist through the packing medium. The flue gas dissolves in the caustic solution causing a chemical reaction, neutralizing the acid gases into salts and water. The caustic scrubber solution is continually recycled through the absorber until the dissolved solids concentration reaches approximately 6%. At 6% dissolved solids the scrubber solution must be blowdown (removed from the

system) to prevent potential operational/maintenance problems associated with scrubbing solutions with a high dissolved solids content. Scrubber blowdown will be treated via ion exchange resins to remove radioactive metals that may be present. The quench vessel is approximately 10 feet in height, 3 feet in diameter and constructed of carbon steel. The horizontal absorber is 18 feet in length, 10 feet in height and constructed of FRP. The scrubber solution recirculation pumps will be 15 hp centrifugal type. The caustic solution storage tank will be 8 feet in diameter, 16 feet in height, and constructed of carbon steel. The tank may require heating depending on the climatic conditions during testing. The caustic addition pumps will be 3 hp centrifugal type. The ion exchange unit will consist of an FRP pressure vessel (1 foot in diameter) and approximately 2 cubic feet of cation exchange resin. Radiation detectors will monitor the radioactivity of the resins throughout operations.

After neutralization, the flue gas passes through the induced draft fan, up the stack and into the atmosphere. The fan will be powered by a 50 hp motor based on a system pressure drop of approximately 14 inches of water. The fan housing will be constructed of rubber-lined carbon steel. Critical fan internals like the wheel will be stainless steel. The stack will be constructed of FRP, have a diameter of 2 feet, and a length of approximately 40 feet.

4.2.5 Vitrified Glass Handling System

The vitrified glass handling system collects molten residuals from the CMS and forms a glass product for disposal. Molten material exits the separator-reservoir and is water cooled as it travels down a cullet chute and into a quench tank. As the molten material cools it forms glass pellets, or frit. The frit is then separated from the water and disposed of.

Cullet carts containing quench water had been used in previous laboratory tests to cool the molten material and form the frit. Because of the increased volume of frit being generated and the continuous nature of the operation (2,334 lbs/hr), a more automated system was

recommended for frit formation and disposal. This system consists of the following process components:

- Quench tank for cooling of the molten residuals exiting the vitrification unit.
- Drag conveyor for removing the glassified frit from the quench tank.
- Roll-off containers for storing and transporting the glassified frit.
- Make-up water feed pump.

This vitrified glass handling system has been conceptualized as being completely automated, minimizing worker exposure to the very hot molten material. As a roll-off container is filled to capacity, the conveyor is briefly stopped and the roll-off is moved to a staging area by truck and an empty roll-off is positioned to receive the glassified frit once the conveyor is restarted. Assuming continuous operation, each roll-off will be filled to capacity (20 tons) approximately every 17 hours.

The quench tank will be trapezoidal in shape and positioned under the separator-reservoir. The sides of the quench tank will be sloped towards each other with depth. The tank will be constructed of carbon steel and sized to contain approximately 1500 gallons of quench water. A steel drag conveyor will be positioned at the bottom of the quench tank to remove the frit as it enters the tank. The conveyor travels the length of the quench tank bottom, up one side of the tank and continues upward to a height of 12 feet aboveground surface where it discharges into a flatbed truck-mounted roll-off container. Roll-off containers will be steel construction with a 20 ton capacity. The roll-off containers will be sloped to a small sump to drain/collect free-standing water.

Make-up water will be continually added to the system via the cullet chute to control the temperature of the quench. If additional cooling of quench water is necessary, a recirculation loop using the CMS cooling tower (Subsection 4.2.7) could be included.

4.2.6 Process Monitoring and Control System

4.2.6.1 Process Monitoring and Control

The primary operator interface for control of the process will be performed on a central control panel process will be performed on a central control panel located in the control room. The architecture of the process monitoring and control system is depicted in Figure 4-2. The control panel will include:

- **Loop controllers for analog control and information functions.**
 - All modulating control (e.g., flow control via control valve or variable drive pump) will be performed by standard configurable single and/or multiple loop controllers.
 - All variable inputs (e.g., pressure and temperature readings) will be visible to the operator using loop indicators (similar to loop controllers except that there are only inputs and no outputs).
- **Pushbuttons, selector switches and indicator lights for discrete control functions.**
 - Discrete control for open/close block valves and operator selections will be performed by momentary pushbuttons and selector switches located on the control panel. The discrete control devices from the panel will be wired to inputs on a programmable logic controller (PLC) where the signals will be processed. The signal will then be transmitted via PLC outputs to the final destination devices.
 - Discrete control for motors will be performed by operator start/stop momentary pushbuttons located on the control panel. The pushbuttons will be wired directly into the motor starter circuitry. Any automatic pump start/stop sequencing or motor interlocking will be wired into the motor starter circuitry from PLC outputs.
 - Discrete input devices (e.g., pump status, valve position status) will be wired to inputs on the PLC. The status will then be transmitted, via PLC output, to the control panel.
- **Alarm annunciator for displaying alarming and status information.**
 - All analog alarms (e.g., level, flow alarming) will be set in the individual loop controllers. The loop controllers will then transmit these signals, via dry relay contacts, to the alarm annunciator.

FIGURE 4-2 PROCESS MONITORING AND CONTROL SYSTEM SCHEMATIC DIAGRAM

- All discrete alarms (e.g., pressure, temperature switches) will be wired to the PLC as inputs. The PLC will then transmit these signals, via PLC outputs, to the alarm annunciator.

No redundancy will be provided for any of the functions.

4.2.6.2 Data Acquisition

Historical data collection, trending, and customized data processing will be performed on a personal computer (PC) located in the control room. The analog data from the loop controllers will be brought into the PC data collection system via a local controller data highway interface. All discrete field instrumentation wired to the PLC will be brought into the PC data collection system via a PLC data highway interface.

4.2.6.3 Continuous Emissions Monitoring (CEM) System

The CEM system is used to monitor flue gases as a result of the combustion process. The CEM system includes analyzers for monitoring carbon monoxide (CO), carbon dioxide (CO₂), oxygen (O₂), oxides of nitrogen (NO_x), and opacity.

The primary functions of a CEM system include:

- Flue gas sample extraction.
- Flue gas sample conditioning.
- Flue gas sample analysis.
- Data control and reporting.

Flue gas samples will be extracted from the ducting downstream of the recuperator by low-volume pumps housed within the individual analyzers. Depending on the analyzer, the sample may be conditioned by removing excess heat, particulate, and/or moisture. Once conditioned the individual flue gas samples pass through their respective analyzers. Instrument exhausts are tied together in a common vent line exiting the instrument cabinet.

The CEM system data and monitoring functions will be performed by the PLC. The PLC will be programmed to process data output from the CEM system and provide summary reports as needed. The PLC will also monitor all CEM system temperature sensors, pressure sensors, and flow switches. At given intervals, the PLC will initiate CEM system calibration.

4.2.7 Support Services and Facilities

A number of support services and facilities are required for the proper operation of the sub-scale vitrification plant. The following are of primary concern and are discussed in subsequent paragraphs:

- Cooling tower
- Site utilities
- Structural steel
- Control room/office trailer
- Decontamination facilities

A cooling tower will be required to cool process water within the plant. The primary plant area requiring cooling water is the melting system where water is used to cool the outside skin of the CMS. A 50 ton per hour cooling tower has been specified for the conceptual design. This unit is approximately 10 feet in length by 7 feet in width by 7 feet in height. The attached blower is operated by a 5 hp motor. The cooling tower was oversized by 25% to account for other potential uses for cooling water within the plant.

Site utilities will be necessary for construction and operation of the plant. Critical utilities required on-site include water, natural gas, electricity, telephone and sanitary services. When possible, existing DOE facility utilities will be used.

Structural steel will be required for support of process equipment and connecting piping/ducting. The majority of the structural steel will be associated with the melting system and the flue gas treatment system.

The control room/office trailer will be the focal point of all site activities. A portion of the trailer will be dedicated to process control. Process control and data acquisition stations will be manned by a control room operator. The other main function of the trailer is to provide administrative support to the field effort.

Decontamination facilities for both personnel and equipment will also be required on-site. Personnel decontamination stations are established between the exclusion, or "contaminated" area, and the support area to minimize the transport of contamination into the support area. Decontamination trailers may be needed to accommodate showering and changing from street clothes to work clothes. Equipment decontamination pads will be constructed to minimize the transport of contamination on equipment, particularly vehicles. Wash water will be collected and containerized on-site, and used for dust control where possible.

4.3 EQUIPMENT LIST

A summary of the major equipment discussed above are presented in Table 4-1. The list is divided into process areas similar to those used in Subsection 4.2. Equipment sizing is subject to modifications during the detailed design phase. Equipment purchases should be made only after preparation of equipment data sheets and specifications based upon finalized engineering flow diagrams.

Table 4-1

**Sub-Scale Vitrification Facility
Equipment List**

Feedstock Preparation and Handling System

- **Waste Staging Area**
 - 3 ft soil berms with 40-mil HDPE liner
 - 2 ft x 2 ft sump
 - Synthetic tarp (30 ft x 30 ft) for dust control
- **Front-End Loader**
- **Dump Trucks**
- **Feed Hopper**
 - 2.5 inch screen across entire opening
 - 12 ft x 6 ft x 8 ft deep
 - 9 inch diameter screw conveyor with 3 hp motor
- **Impact Dryer Mill**
 - Feed rate of 2 tons/hour
 - Hammer mill with 15 hp motor
 - Velocity separator; 2.5 ft in diameter with variable speed drive with 3 hp motor
 - High static induced draft fans (2)
 - Cyclone separator; 5 ft in diameter with rotary valve and drive motor
 - Gas fired air heater; 1,500,000 Btu/hour
 - Baghouse with 16 oz. woven Dacron bags; reverse jet blowers; pneumatic conveyor discharge and rotary valve
- **Waste Storage Silo**
 - 10 ft diameter; 20 ft height with conical bottom
 - Rotary valve
 - Carbon steel construction

Table 4-1

**Sub-Scale Vitrification Facility
Equipment List
(continued)**

- **HEPA Filter**
 - 2 ft x 2 ft x 1 ft deep; wood frame
 - Carbon steel housing
 - 2,000 ACFM capacity at 2 inches W.C.
- **Vapor Phase Carbon**
 - 13,000 lbs of carbon
 - 22 ft x 8 ft x 8 ft in height
 - Rated for 2,000 ACFM at 1 inch W.C.
 - Housing is epoxy-coated carbon steel
- **Batch Mixing Tank**
- **Limestone Storage Tank**
- **Pneumatic Transport System**
- **Oversized Feed Roll-Off Container**
 - 20 ton capacity
 - Carbon steel construction
- **Stormwater Collection Tank**
 - Carbon steel construction
 - 3,000 gallon capacity

Cyclone Melting System

- **Combustion Air Assembly**
 - Blower Assembly with silencer and 40 hp motor
 - Piping from recuperator to CRV

Table 4-1

**Sub-Scale Vitrification Facility
Equipment List
(continued)**

- **CRV Assembly**
 - **CRV**
 - **Refractory**
- **Melter Assembly**
 - **Glass melter**
 - **Refractory**
- **Separator-Reservoir**
 - **Separator-Reservoir**
 - **Refractory**
- **Gas Distribution**
 - **Main gas controls and flame safety**

Heat Recovery System

- **Recuperator**
 - **Recuperator; 15 ft height and 4 ft diameter**
 - **Refractory**

Flue Gas Treatment System

- **Spray Tower**
 - **Flow rate of 10,150 acfm at 2,000°F**
 - **Water requirement of 10 gpm**
 - **Refractory-lined carbon steel**
 - **7 ft diameter and 25 ft height**
- **Baghouse**
 - **Flow rate of 7,130 acfm at 400°F**
 - **Effective cloth area of 2,233 sq. ft.**
 - **Compressed air cleaning system**

Table 4-1

**Sub-Scale Vitrification Facility
Equipment List
(continued)**

- 9 ft x 9 ft x 35 ft height
- Fly ash pneumatically transported back to waste storage silo
- **HEPA Filter**
 - Flow rate of 7,560 acfm at 375°F
 - Four filters required at 2000 acfm each
 - Each filter is 2 ft x 2 ft x 1 ft deep
 - Carbon steel housing; silicone seals
- **Quencher/Absorber**
 - Quench vessel is 10 ft height by 3 ft diameter; carbon steel construction
 - Horizontal absorber is 18 ft length by 10 ft height; FRP construction
- **Caustic Storage Tank**
 - Carbon steel construction
 - 8 ft diameter and 16 ft height
 - Internal heating elements
- **Caustic Recycle Pumps**
 - Centrifugal type
 - 3 hp motor
- **Water Supply Pumps**
 - Centrifugal type
 - 3 hp motor
- **Scrubber Recycle Pumps**
 - Centrifugal type
 - 3 hp motor

Table 4-1

**Sub-Scale Vitrification Facility
Equipment List
(continued)**

- **Ion Exchange Unit**
 - FRP pressure vessel; 1 ft diameter by 4 ft height
 - 2 cubic ft of cation exchange resin
 - Radiation meter
- **Induced Draft Fan**
 - Pressure drop requirement of 14 inches W.C.
 - Driven by 50 hp motor
- **Exhaust Stack**
 - FRP construction
 - 2 ft diameter and 40 ft height

Vitrified Glass Handling System

- **Quench Tank**
 - Carbon steel construction; trapezoidal shape
 - Continuous supply of make-up water required
 - Tank capacity approximately 1,500 gallons
- **Drag Conveyor**
 - 1 ft wide, providing > 12 ft elevation of material
 - Carbon steel construction
 - Removal rate of approximately 2,000 lbs/hr of frit
- **Roll-Off Containers**
 - Carbon steel construction; 20 ton capacity
 - Sloped bottom to a sump to collect free liquids
 - Approximate dimensions 10 ft x 25 ft x 8 ft height
- **Make-up Water Feed Pump**
 - Centrifugal type
 - 3 hp motor

Table 4-1

**Sub-Scale Vitrification Facility
Equipment List
(continued)**

Process Monitoring and Control System

- **Process Control**
 - Central control panel located in control room
 - Programmable loop controllers for analog control (21 control loops estimated)
 - Programmable logic controller (PLC) for discrete control
- **Data Collection**
 - PC based data collection located in control room
 - Log and alarm printer
- **CEM Analyzers**
 - Oxygen analyzer
 - Carbon monoxide analyzer
 - Carbon dioxide analyzer
 - Oxides of nitrogen (NO_x) analyzer
 - Opacity analyzer

Support Services and Facilities

- **Cooling Tower**
 - 50 ton per hour unit
 - 10 ft x 7 ft x 7 ft height
 - Attached blower operated by 5 hp motor
- **Cooling Water Recirculation Pump**
 - Centrifugal type - 60 gpm
 - 5-10 hp motor

Table 4-1

**Sub-Scale Vitrification Facility
Equipment List
(continued)**

- **Control Room/Office Trailer**
 - **Double-wide (~15 ft) x 40 ft length**
- **Decontamination Facilities**
 - **Decon trailer**
 - **Decon pad**

SECTION 5

MATERIAL BALANCE

The conceptual material balance for the sub-scale vitrification facility is included as Figure 5-1. The material balance is used to properly size the process equipment and helps in understanding the flow of process materials (including contaminants) through the system.

The assumptions used in developing this material balance include:

- The material balance for the dry feed system is independent of the CMS feed system.
- The feed hopper will supply wastes to the impact hammer mill at a maximum rate of 4,000 lbs per hour with a moisture content of 20%.
- The waste feed has a volatile radionuclide concentration of 3×10^{-7} ppm of Cs-137. Non-volatile radionuclides like U-238 or TH-230 are not critical to the sizing of process equipment and have therefore been omitted.
- The waste feed also has an organic chlorine content of 1,000 ppm, which is used to evaluate acid gas neutralization equipment.
- The wastestream conveyed to the CRV will consist of 20% by weight limestone and 80% waste material.
- The dust loading from the CMS has been conservatively estimated at 10% of the feed rate. The dust loading from the materials handling cyclone has also been estimated at 10% of the hopper feed rate.
- This material balance assumes no recycle of the materials handling off-gases back into the impact dryer mill (Stream 16).
- The maximum dissolved solids concentration in the scrubber blowdown will be 6% by weight (Streams 29 and 30).
- The caustic solution added to the absorber will be 25% sodium hydroxide (NaOH).
- The "Composition by Wt %" description is primarily intended for the characterization of the flue gases (Streams 8 through 13) and is not calculated for each individual stream.

Figure 5-1. Vitrification Facility Material Balance (p. 1 of 2)

Figure 5-1. Vitrification Facility Material Balance (p. 2 of 2)

Stream I.D. #	1	2	3	4	5	6	7	8	9	10
Stream Description	Hopper Feed	Mill Exit	Dried & Sized Waste	Limestone Addition	Feed to CRV	Molten Exit	Glassified Residual	Off-Gases from Recuperation	Spray Tower Exit	Baghouse Exit
Flow Rate in ACFM (gpm)	-	-	-	-	-	-	-	10,150	7,130	7,560
Temperature in °F	60	250	100	60	75	2400	200	2000	400	375
Pressure in inches W.C. (psig)	-	-	-	-	-	0	0	-1	-2	-7
Mass Flow in lbs/hr	4,000	3,200	2,085	520	2,605	2,335	2,335	8,940	15,660	17,400
<u>Composition in Wt %</u>										
- CO ₂	-	-	-	-	-	-	-	12.2	7.0	6.2
- H ₂ O	20	-	20	20	20	-	20	18.5	43.4	39.1
- N ₂	-	-	-	-	-	-	-	66.2	45.5	48.7
- O ₂	-	-	-	-	-	-	-	3.0	4.0	5.9
- HCl	-	-	-	-	-	-	-	0.1	0.1	0.1
Radioactivity (Cs-137)(pCi/gm)	26.1	32.6	32.6	0	22.8	0	0	6.33	3.62	3.26
Dust Loading (lb/hr)	-	-	-	-	-	-	-	310	310	3.1
Stream I.D. #	11	12	13	14	15	16	17	18	19	20
Stream Description	HEPA Filter Exit	Scrubber Exit	Stack Exit	Cyclone Separator Exit	I.D. Fan Exit	I.D. Fan Recycle	Baghouse Exit	HEPA Filter	Carbon Bed Exit	Cooling Tower Influent
Flow Rate in ACFM (gpm)	7,560	6,190	6,190	1,930	1,930	0	2,090	2,010	2,010	(61)
Temperature in °F	375	175	175	200	200	0	190	180	180	110
Pressure in inches W.C. (psig)	-10	-14	0	-2	-2	0	-2	-3	0	(30)
Mass Flow in lbs/hr	17,400	18,480	18,480	7,008	7,008	0	7,570	7,570	7,570	30,440
<u>Composition in Wt %</u>										
- CO ₂	6.2	5.9	5.9	-	-	-	-	-	-	0
- H ₂ O	39.1	42.8	42.8	-	-	-	-	-	-	100
- N ₂	48.7	45.8	45.8	-	-	-	-	-	-	0
- O ₂	5.9	5.5	5.5	-	-	-	-	-	-	0
- HCl	0.1	0	0	-	-	-	-	-	-	0
Radioactivity (Cs-137)(pCi/gm)	3.26	0	0	0	0	0	0	0	0	0
Dust Loading (lb/hr)	0	0	0	320	320	0	3.2	0	0	0

Figure 5-1. Vitrification Facility Material Balance (Continued)

Stream ID: 8	21	22	23	24	25	26	27	28	29	30
Stream Description	Cooling Tower Exit	Natural Gas to CRV	Natural Gas to Air Heater	Pre-heated Combustion Air	Water to Spray Tower	Water to Quench Tank	Water to Quencher/Absorber	Caustic Addition	Scrubber Blow-down	Scrubber Recycle
Flow Rate in ACFM (gpm)	(61)	94	10	3,220	(10.3)	(5.0)	(2.6)	(0.1)	(0.4)	(300)
Temperature in °F	85	68	68	1,200	70	70	70	70	175	175
Pressure in inches W.C. (psig)	(30)	(100)	(10)	(10)	(80)	(25)	(30)	(30)	(30)	(30)
Mass Flow in lbs/hr	30,440	400	43	7720	5160	2500	50	50	220	165,000
<u>Composition in Wt %</u>										
- CO ₂	0	-	-	1	0	0	0	0	0	0
- H ₂ O	100	-	-	0	100	100	75	75	94	94
- N ₂	0	-	-	78	0	0	0	0	0	0
- O ₂	0	-	-	21	0	0	0	0	0	0
- HCl	0	-	-	0	0	0	0	0	0	0
Radioactivity (Cs-137)(pCi/gm)	0	0	0	0	0	0	0	0	0	5.14
Dust Loading (lb/hr)	0	0	0	0	0	0	0	0	0	0

Figure 5-1. Vitrification Facility Material Balance (Continued)

- The "dashed" values indicate parameters that are not applicable for the stream identified.

The material balance indicates a feedstock processing rate of 4,000 lbs per hour. Preprocessed solid wastes are then stored in a silo and fed to the batch mixing tank at an approximate rate of 2,085 lbs per hour. Off-gases from the materials handling system are exhausted to the atmosphere at a rate of 1,910 acfm and a temperature of 180 °F.

Feed to the CRV (waste materials plus limestone) is conveyed at a rate of 2,605 lbs per hour. Molten material exits the separator-reservoir at a rate of 2,335 lbs per hour and a temperature of 2,400° F. Flue gases are treated through a series of air pollution control equipment and discharged to the atmosphere at a rate of approximately 6,190 acfm and a temperature of 175° F. Scrubber water would be blowdown from the system at a rate of 0.4 gpm.

SECTION 6

PLANT LAYOUT

6.1 PHYSICAL PLANT AND FACILITIES

The sub-scale vitrification facility has been conceptually designed as a transportable system, that is, the individual components of the process have the capability to be transported by truck to the site, erected, and when operation is complete, dismantled, decontaminated, loaded back onto trucks, and hauled off-site. Each piece of equipment will be skid-mounted, in order to eliminate the extensive permitting requirements that are associated with constructing concrete foundations.

The overall layout of the plant is included as Figure 6-1. The layout was designed to accommodate truck traffic into and out of the plant. Trucks to the site delivering supplies or raw materials will enter from the north along the gravel access road and check-in at the office trailer. Office deliveries or limestone deliveries can be made from on or just off the gravel access road minimizing vehicle contamination. Roll-offs containing frit can also be managed from just off the gravel access road.

The waste feed staging area is located in the southwest corner of the plant away from the most active work areas because of increased exposure potential associated with the wastes. Dump trucks carrying wastes to the plant travel a separate gravel access road to the waste feed staging area. Dump trucks will be decontaminated prior to leaving the staging area.

The feed hopper and impact dryer mill are located on a single bermed skid adjacent to the waste feed staging area. The waste feed storage tank, limestone tank and batch mixing tank are all on one skid. The melting system and the individual flue gas treatment system components will each have separate skid configurations.

FIGURE 6-1 SUB-SCALE VITRIFICATION FACILITY LAYOUT

Health and safety work zones (e.g., exclusion zone, support zone) will be established once a particular facility is identified and more site specific information is obtained (e.g., climatic data, waste characterization data, etc.).

6.2 FACILITY SITING CRITERIA

The DOE and Vortec are currently evaluating potential sites for testing of the sub-scale vitrification facility. Candidate sites would be DOE facilities with large quantities of mixed wastes (hazardous and low-level radioactive wastes) including: Hanford, WA; Fernald, OH; Mound, OH; Savanna River, SC; and Oak Ridge, TN. Site selection is expected later this year.

Because the sub-scale vitrification facility is transportable, siting should be made easier due to the fact that when testing is completed in a given area, the facility can be removed from that area. Permitting requirements are often less stringent for a transportable facility as well. Permits may be required from the U.S. EPA, the State environmental agency, and the DOE. From a hazardous waste standpoint, the working assumption is that testing would be performed at a CERCLA site, eliminating the need for RCRA permits. If a CERCLA site is not available, the facility would most likely be permitted as a RCRA research and development facility, even processing 25 tons per day of waste material. It is not anticipated that a RCRA Part B permit application would be prepared due to the limited time of operation of the facility.

From a low-level radioactive standpoint, it is assumed that, as the owner, DOE accepts responsibility for operation of the facility. Under this arrangement, radiation issues are regulated under DOE authority. If Vortec were to accept responsibility for operation of the facility, additional licensing requirements would be necessary before testing could commence.

SECTION 7

COST ESTIMATES

Three cost estimates have been prepared as part of this Conceptual Engineering Report. The primary cost estimate was developed for the baseline system which utilizes a dry feed system and a dry flue gas treatment system. Secondary cost estimates were developed as alternatives to the baseline system. The cost estimate for the first alternative utilizes a wet or slurry feed system. The cost estimate for the second alternative utilizes a wet flue gas treatment train. Each of these estimates takes into account purchase and installation of equipment. Table 7-1 details the cost estimate associated with the baseline system. Tables 7-2 and 7-3 detail the cost estimates associated with the alternative systems.

The baseline design cost estimate can be broken out as follows:

• Site work:	\$ 60,100
• Structural support:	\$ 132,400
• Major equipment:	\$1,560,900
• Mechanical and piping:	\$ 218,100
• Electrical and instrumentation:	\$ 347,400
• Subcontracts:	\$ 60,000
• Other project direct and indirect costs:	\$ 318,800
• Project and construction contract costs:	<u>\$ 492,700</u>
Subtotal	\$3,190,400
Contingency at 15%	<u>\$ 478,600</u>
Total	\$3,669,000

The total cost associated with the wet/slurry feed system alternative is \$4,180,500. The total cost associated with the wet flue gas treatment system alternative is \$4,572,300.

Major capital equipment costs for the dry feed system were developed from vendor quotes that were obtained as part of the engineering evaluation. Miscellaneous equipment costs were obtained from equipment catalogs. Cost estimates for structural steel and

instrumentation were based on the combined experience of Vortec and WESTON engineering personnel. Installation costs for equipment were based on an estimate of required manhours and labor rates as outlined in estimating guidance documents.

The cost estimate for the wet feed system (Table 7-2) was based on applying a scale-up factor to the dry feed cost estimate to account for the increase in equipment sizes. A quantity scale-up factor of 0.37658 was calculated as shown on page 7-22 of Table 7-2, and applied to the dry feed system cost estimate. In addition to the scale-up factor, the materials handling equipment for the wet feed system (slurry type equipment) vary from the dry feed system equipment (pneumatic type equipment) which in turn alters the economics.

The costing assumptions built into Tables 7-1 through 7-3 are discussed below:

- A four acre site would be necessary for facility construction and would require cleaning/grading.
- The waste stockpile area will be approximately 50 ft x 50 ft x 4 ft deep, and constructed of earthen berms with an HDPE liner and leachate/stormwater collection sump.
- Cast-in-place concrete foundations have been specified for many facility components. A yardage of concrete has been estimated for each piece of equipment.
- Structural steel (columns, beams, base plates) has been estimated at 29 tons. Also included in the structural steel estimate are stair treads, grating and handrails with toe-plates.
- It is assumed that utility lines will be extended to the site a distance of 300 linear feet from an existing source. This includes water, process/sanitary drains, and natural gas.
- Mechanical interconnecting piping less than 2" in diameter has been estimated at 600 linear ft. Piping greater than 2" in diameter has been estimated at 460 linear ft.
- Breeching and combustion gas ducting and lagging has been estimated to 200 linear feet.

- Electrical work was estimated as a lump sum (labor + materials + equipment).
- Instrumentation costs based on:
 - Control panel with programmable loop controllers, annunciators and start/stop pushbuttons, selector switches, and indicators (lump sum).
 - PC based data acquisition system with printer (lump sum).
 - Programmable logic controller (PLC) (lump sum).
 - Instrument I/O listing.
 - Software/training (lump sum)
 - Continuous emissions monitoring system (lump sum)
- Subcontractors have been identified for painting/coatings, equipment and piping/breeching insulation, and refractory installation.

Table 7-1
Cost Estimate for Baseline System -
Dry Feed/Dry Flue Gas Treatment

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECV.MK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, DRY FEED ALTERNATIVE SHEET SUMMARY													
	TOTAL FROM SHEET 3 - SITE WORK				401.1		12031.65		21572.98		0.00	10000.00	16500.00	60,104.63
	TOTAL FROM SHEET 4 - STRUCTURAL				1628.7		48861.12		74930.31		0.00	8601.00	0.00	132,392.43
	TOTAL FROM SHEET 5 - MAJOR EQUIPMENT				533.9		16017.50		32882.81		187960.00	0.00	8200.00	245,060.31
	TOTAL FROM SHEET 6 - MAJOR EQUIPMENT				593.3		17798.75		17202.16		59976.00	0.00	5300.00	100,276.91
	TOTAL FROM SHEET 7 - MAJOR EQUIPMENT				556.0		16678.61		33138.38		43051.75	0.00	0.00	92,868.74
	TOTAL FROM SHEET 8 - MAJOR EQUIPMENT				563.5		16905.00		16413.25		72441.25	0.00	7200.00	112,959.50
	TOTAL FROM SHEET 9 - MAJOR EQUIPMENT				340.0		10199.27		26153.01		21096.75	12750.00	5000.00	75,199.03
	TOTAL FROM SHEET 10 - MAJOR EQUIPMENT				611.1		18332.50		25607.44		25831.25	5000.00	5000.00	79,771.19
	TOTAL FROM SHEET 11 - MAJOR EQUIPMENT				101.5		3045.00		3956.88		17465.63	0.00	0.00	24,467.50
	TOTAL FROM SHEET 12 - MAJOR EQUIPMENT				2356.8		70703.25		218545.00		490700.00	50250.00	0.00	830,198.25
	TOTAL FROM SHEET 13 - MECHANICAL AND PIPING				2968.8		89062.50		107772.50		0.00	9800.00	11500.00	218,135.00
	TOTAL FROM SHEET 14 - ELECTRICAL AND INSTR.				1990.5		59715.00		27250.00		113250.00	142200.00	5000.00	347,415.00
	TOTAL FROM SHEET 15 - SUBCONTRACTS				0.0		0.00		0.00		0.00	60000.00	0.00	60,000.00
	SUMMARY TOTAL SHEET 2				12645.0		379350.15		605426.70		1031772.63	298601.00	63700.00	2,378,848.47

FILENAME: VORTECV.WK1

[illegible]

FILENAME: VORTECV.WC1

[illegible]

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECV.MKT

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, DRY FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
III	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
1.	IMPACT HAMMER DRYER MILL SEE WILLIAMS PATENT CRUSHER AND PULVERIZER CO., INC. PROPOSAL Q-930238 TYPE AND SIZE: GP-15122 IMPACT DRYER MILL WEIGHT: APPROXIMATELY 20,000 LBS. FEED RATE: 4,000 NET POUNDS PER HOUR COMPRISED OF THE FOLLOWING COMPONENTS:	1.00	LS		0.0		0.00		0.00	187960.00	187960.00			187,960.00
A	1 - GP-1512 IMPACT DRYER MILL WITH STRUCTURAL STEEL BASE, V-BELT DRIVE AND OSHA GUARD				0.0		0.00		0.00		0.00			0.00
B	1 - 9" ROTARY SCREW FEEDER ASSY WITH 1 HP DRIVE WITH MOTOR AND 150 CF FEED BIN				0.0		0.00		0.00		0.00			0.00
C	1 - 2.5 FT. DIA. SPINNER SEPARATOR WITH VARIABLE SPEED DRIVE WITH MOTOR				0.0		0.00		0.00		0.00			0.00
D	1 - 13" HD HIGH STATIC FANS WITH V-BELT DRIVE				0.0		0.00		0.00		0.00			0.00
E	1 - 5.0' DIA. HD VACUUM TYPE CYCLONE COLLECTOR WITH ROTARY VALVE AND DRIVE MOTOR				0.0		0.00		0.00		0.00			0.00
F	1 - LOT 13" DIA. AIR DUCT TO SET CYCLONE COLLECTOR WITHIN 35.0' OF MILL BASE				0.0		0.00		0.00		0.00			0.00
G	1 - GAS FIRED AIR HEATER, 1.5 X 10'6 BTU/HR. WITH AUTO IGNITION, ELECTRONIC FLAME SAFEGUARD, AUTOMATIC TEMP CONTROLLER AND RECORDER; CONTROLS MOUNTED IN NEMA 12 PANEL, WIRED, PIPED AND SHIPPED COMPLETE WITH REFRACTORY				0.0		0.00		0.00		0.00			0.00
H	1 - 96ST36 DUST COLLECTOR WITH 16 OZ MOVEN DACRON BAGS, COMPLETE WITH REVERSE JET BLOWERS, WITH SCREW CONVEYOR DISCHARGE AND ROTARY VALVE				0.0		0.00		0.00		0.00			0.00
I	1 - LOT 8" DIA. AIR DUCT TO SET AIR FAN AND BAGHOUSE WITHIN 35.0' OF MILL BASE				0.0		0.00		0.00		0.00			0.00
J	ITEMS NOT INCLUDED IN OFFERED QUOTATION: CONCRETE FOUNDATION(S) AND ANCHOR BOLTS	54.17	CY	5.50	297.9	30.00	8937.50	111.38	6032.81		0.00			14,970.31
2	FIELD PIPING FOR LUBRICATION SYSTEM, SUPPLY(S) AND RETURN(S)	1.00	LS	80.00	80.0	30.00	2400.00	5750.00	5750.00		0.00			8,150.00
3	PLATFORMS AND LADDERS	1.00	LS	64.00	64.0	30.00	1920.00	7500.00	7500.00		0.00		3500.00	12,920.00
4	SURGE BINS FOR FEED OR PRODUCTS (SEE NO. 6)	1.00	LS		0.0		0.00		0.00		0.00			0.00
5	MOTOR STARTERS	1.00	LS		0.0		0.00	5000.00	5000.00		0.00			5,000.00
6	FREIGHT	1.00	LS		0.0		0.00		0.00		0.00		4700.00	4,700.00
7	CYCLONES AND AIR PIPE SUPPORTS	1.00	LS	92.00	92.0	30.00	2760.00	8600.00	8600.00		0.00			11,360.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
	TOTAL SHEET 5				533.9		16017.50		52882.81		187960.00	0.00	8200.00	245,600.31

FILENAME: VORTECV.WK1

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COS. MATL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, DRY FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
111	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
2.	VAPOR-PHASE CARBON ADSORPTION SYSTEM:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	24.00	24.0	30.00	720.00	200.00	200.00	25000.00	25000.00			25,920.00
	CALGON VAPOR-PAC 10				0.0		0.00		0.00		0.00			0.00
	TWO(2) MONTH RENTAL COMPLETE WITH 12,500 LB				0.0		0.00		0.00		0.00			0.00
	CARBON INVENTORY, SAMPLING AND ANALYSIS,				0.0		0.00		0.00		0.00			0.00
	PICKUP AND DELIVERY COMPLETE				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	10.42	CY	5.50	57.3	30.00	1718.75	111.38	1160.16		0.00			2,878.91
	VALVES AND PIPING SPECIALTIES	1.00	LS	32.00	32.0	30.00	960.00	2040.00	2040.00		0.00			3,000.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
					0.0		0.00		0.00		0.00			0.00
3	BAG HOUSE:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	192.00	192.0	30.00	5760.00	3500.00	3500.00	15400.00	15400.00			24,660.00
	INLET FLOW: 1,800 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 250 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -3				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-4,000 LBS/MR				0.0		0.00		0.00		0.00			0.00
	TYPE - REVERSE AIR, WITH DUST COLLECTION				0.0		0.00		0.00		0.00			0.00
	HOPPERS AND RECOVERY SYSTEM				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	16.00	CY	5.50	88.0	30.00	2640.00	111.38	1782.00		0.00			4,422.00
	VALVES AND PIPING SPECIALTIES	1.00	LS	24.00	24.0	30.00	720.00	1520.00	1520.00		0.00			2,240.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
	FREIGHT	1.00	LS		0.0		0.00		0.00		0.00		1500.00	1,500.00
	STARTUP ASSISTANCE	1.00	LS		0.0		0.00		0.00		0.00		3800.00	3,800.00
					0.0		0.00		0.00		0.00			0.00
4	HEPA FILTER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	2.00	EA	32.00	64.0	30.00	1920.00	100.00	200.00	3388.00	6776.00			8,896.00
	INLET FLOW: 1,800 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 250 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -5				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-4,000 LBS/MR				0.0		0.00		0.00		0.00			0.00
	TYPE - HIGH ENERGY PARTICULATE AIR FILTER				0.0		0.00		0.00		0.00			0.00
	WITH PARTICULATE MATTER RECOVERY				0.0		0.00		0.00		0.00			0.00
	HIGH TEMPERATURE FRAMES AND GASKETS	4.00	EA	16.00	64.0	30.00	1920.00	100.00	400.00	3200.00	12800.00			

FILENAME: VORTECV.MK1

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, DRY FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
111	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
5	INDUCED AIR(ID) FAN: (MATERIALS HANDLING) QUANTITY:	1.00	EA	24.00	24.0	30.00	720.00	150.00	150.00	11896.75	11896.75			12,766.75
	INLET FLOW: 1,900 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 200 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -5				0.0		0.00		0.00		0.20			0.00
	MASS FLOW: +/-4,000 LBS/MR				0.0		0.00		0.00		0.00			0.00
	TYPE - HORIZONTAL SHAFT, CENTRIFUGAL				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	2.37	CY	5.50	13.0	30.00	391.11	74.25	176.00		0.00			567.11
	VALVES AND PIPING SPECIALTIES/DAMPERS	1.00	LS	48.00	48.0	30.00	1440.00	4025.00	4025.00		0.00			5,465.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
6	WASTE STORAGE SILO: QUANTITY:	1.00	EA	48.00	48.0	30.00	1440.00	500.00	500.00	12500.00	12500.00			14,440.00
	TYPE: VERTICAL DRY STORAGE TANK/VESSEL				0.0		0.00		0.00		0.00			0.00
	DIMENSIONS: 10.0' X 20.0' HT				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	8.00	CY	5.50	44.0	30.00	1320.00	74.25	594.00		0.00			1,914.00
	VALVES AND PIPING SPECIALTIES	1.00	LS	48.00	48.0	30.00	1440.00	4025.00	4025.00		0.00			5,465.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	4800.00	4800.00		0.00			5,520.00
7	COOLING TOWER: QUANTITY:	1.00	EA	64.00	64.0	30.00	1920.00	500.00	500.00	3500.00	3500.00			5,920.00
	TYPE: FORCED DRAFT COOLING TOWER				0.0		0.00		0.00		0.00			0.00
	SIZE: 50 TONS PER HOUR, 50 DEG F. DT				0.0		0.00		0.00		0.00			0.00
	SEE SPECIFICATIONS - DELTA COOLING TOWERS				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	6.67	CY	5.50	36.7	30.00	1100.00	74.25	495.00		0.00			1,595.00
	VALVES AND PIPING SPECIALTIES	1.00	LS	48.00	48.0	30.00	1440.00	4025.00	4025.00		0.00			5,465.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	4800.00	4800.00		0.00			5,520.00
8	SPRAY QUENCH TOWER: QUANTITY:	1.00	EA	24.00	24.0	30.00	720.00	200.00	200.00	15155.00	15155.00			16,075.00
	INLET FLOW: 11,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 2,000 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -1				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: 9,000 LBS/MR				0.0		0.00		0.00		0.00			0.00
	TYPE - VERTICAL, TANGENTIAL INLET, COUNTER-CURRENT FLOW, TOP-HAT OUTLET				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	5.50	CY	5.50	30.3	30.00	907.50	74.25	408.38		0.00			1,315.00
	VALVES AND PIPING SPECIALTIES	1.00	LS	32.00	32.0	30.00	960.00	2040.00	2040.00		0.00			3,000.00
	INSTRUMENTATION	1.00</												

FILENAME: VORTCV.WK1

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER HR \$/HR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, DRY FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
111	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
9	BAG HOUSE:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	192.00	192.00	30.00	5760.00	3500.00	3500.00	35437.00	35437.00			44,697.00
	INLET FLOW: 8,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 400 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -3				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-18,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - REVERSE AIR, WITH DUST COLLECTION				0.0		0.00		0.00		0.00			0.00
	HOPPERS AND RECOVERY SYSTEM				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	16.00	CY	5.50	88.0	30.00	2640.00	111.38	1782.00					4,432.00
	VALVES AND PIPING SPECIALTIES	1.00	LS	24.00	24.0	30.00	720.00	1520.00	1520.00					2,340.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00					3,920.00
	FREIGHT	1.00	LS		0.0		0.00		0.00				3400.00	3,400.00
	STARTUP ASSISTANCE	1.00	LS		0.0		0.00		0.00				3000.00	3,000.00
10	HEPA FILTER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	2.00	EA	32.00	64.0	30.00	1920.00	100.00	200.00	3386.00	6776.00			8,096.00
	INLET FLOW: 8,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 400 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -7				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-18,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - HIGH ENERGY PARTICULATE AIR FILTER				0.0		0.00		0.00		0.00			0.00
	WITH PARTICULATE MATTER RECOVERY				0.0		0.00		0.00		0.00			0.00
	HIGH TEMPERATURE FRAMES AND GASKETS	4.00	EA	16.00	64.0	30.00	1920.00	100.00	400.00	3200.00	12800.00			15,120.00
11	FLUE GAS QUENCHER/ABSORBER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	24.00	24.0	30.00	720.00	200.00	200.00	17428.25	17428.25			18,348.25
	INLET FLOW: 7,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 350 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: 0.0				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: 20,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - PACKED TOWER/BED, COUNTER-CURRENT FLOW				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	5.00	CY	5.50	27.5	30.00	825.00	74.25	371.25					1,196.25
	VALVES AND PIPING SPECIALTIES	1.00	LS	32.00	32.0	30.00	960.00	2040.00	2040.00					3,000.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00					3,920.00
					0.0		0.00		0.00		0.00			0.

FILENAME: VORTECV.LM1

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	HANDERS	LABOR RATE PER HR \$/HR	DIRECT LABOR \$	UNIT COST MATL \$/EA	MATERIAL \$	UNIT COST PM PLY EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, DRY NEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
111	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
12	INDUCED AIR(10) FAN:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	24.00	24.0	30.00	720.00	150.00	150.00	11006.75	11006.75			12,766.75
	INLET FLOW: 7,000 ACPH				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 200 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, IN/WC: -14				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: 20,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - HORIZONTAL SHAFT, CENTRIFUGAL				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	2.37	CY	5.50	15.0	30.00	391.11	74.25	176.00					567.11
	VALVES AND PIPING SPECIALTIES/DAMPERS	1.00	LS	48.00	48.0	30.00	1440.00	4825.00	4825.00					5,465.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3000.00	3200.00					3,920.00
13	STACK:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA		0.0		0.00		0.00		0.00	12750.00		12,750.00
	INLET FLOW: 7,000 ACPH				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 200 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, IN/WC: 1				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: 20,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - VERTICAL SINGLE FLUE, +/-50.0' HT				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	4.00	CY	5.50	22.0	30.00	660.00	74.25	297.00				5000.00	5,957.00
	INSTRUMENTATION, CEN (WITH INSTRUMENTATION)	1.00	LS	64.00	64.0	30.00	1920.00	4800.00	4800.00					6,720.00
14	ION EXCHANGER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	8.00	8.0	30.00	240.00	100.00	100.00	3000.00	3000.00			3,340.00
	INLET FLOW: 3 GPM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 180 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE: 30 PSIG				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: 1710 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - ANION/CATION EXCHANGER TO TREAT				0.0		0.00		0.00		0.00			0.00
	NET SCRUBBER EFFLUENT				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	1.00	CY	5.50	5.5	30.00	165.00	111.30	111.30					276.30
	VALVES AND PIPING SPECIALTIES	1.00	LS	16.00	16.0	30.00	480.00	3150.00	3150.00					3,630.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00					3,920.00
15	CAUSTIC STORAGE TANK:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	32.00	32.0	30.00	960.00	200.00	200.00	4200.00	4200.00			7,360.00
	CAPACITY: 6,000 GALLONS				0.0		0.00		0.00		0.00			0.00

CLIENT : VORTEC CORPORATION
LOCATION : 10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT HOURS	HOURS	LABOR RATE PER HR \$/HR	DIRECT LABOR \$	UNIT COST MATL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMMENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
III	VITRIFICATION FACILITY, DRY FEED ALTERNATIVE MAJOR EQUIPMENT													
16	FLUE GAS SCRAMBLER CAUSTIC FEED PUMPS: CAPACITY: 40 GPM @ 60.0' TON MOTOR: 1 HP TYPE: CENTRIFUGAL CAST-IN-PLACE CONCRETE FOUNDATION VALVES AND PIPING SPECIALTIES	2.00	EA	24.00	48.0	30.00	1440.00	100.00	200.00	1293.75	2587.50			6,227.50
17	QUENCH TOWER WATER/CAUSTIC SLURRY FEED PUMPS: CAPACITY: 100 GPM @ 60.0' TON MOTOR: 5 HP TYPE: CENTRIFUGAL, LINED CAST-IN-PLACE CONCRETE FOUNDATION VALVES AND PIPING SPECIALTIES	1.00 1.00	CT LS	5.50 16.00	5.5 16.0	30.00 30.00	165.00 480.00	111.38 3150.00	111.38 3150.00					276.38 3,630.00
18	QUENCHED MATERIALS REMOVAL CONVEYOR: QUANTITY: TYPE: DRAG FLIGHT CAPACITY: AS REQUIRED MOTOR: 5 HP WITH GEAR REDUCING DRIVE UNIT MISCELLANEOUS STEEL AND PLATE FOR INCLINED DISCHARGE TROUGH AND DISCHARGE CHUTE	1.00	EA	128.00	128.0	30.00	3840.00	500.00	500.00	11600.00	11600.00			15,940.00
19	QUENCH TANK: QUANTITY: TYPE: ABOVE GRADE, CARBON STEEL CONSTRUCTION DIMENSIONS: +/- 20'-0" LG X 4'-0" W 4'-0" SHD + FB SLOPED SIDEWALLS TO COLLECTION TROUGH CAST-IN-PLACE CONCRETE FOUNDATION VALVES AND PIPING SPECIALTIES	1.00	EA	224.00	224.0	30.00	6720.00	6005.00	6005.00				2500.00	16,105.00
20	ROLL-OFF CONTAINER: QUANTITY: CAPACITY: 20 TON RENTAL/LEASE AGREEMENT AND DEPOSIT	5.83 1.00	CT LS	5.50 16.00	32.1 16.0	30.00 30.00	962.50 480.00	111.38 3150.00	649.69 3150.00			5000.00		7,500.00
	TOTAL SHEET 10				611.1		18332.50		25607.44		25831.25	5000.00	5000.00	79,771.19

FILENAME: VORTECV.MK1

[illegible]

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECV.WK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, DRY FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
IV	METC COMBUSTION EQUIPMENT				0.0		0.00		0.00		0.00			0.00
1	METC 25 TONS PER DAY (TPD) VITRIFICATION FACILITY: SEE VORTEC CORRESPONDENCE DATED MAY 24, 1993				0.0		0.00		0.00		0.00			0.00
	COMBUSTION AIR SUBSYSTEM -				0.0		0.00		0.00		0.00			0.00
A	BLOWER ASSEMBLY - BLOWER, BASEPLATE, CPLG AND GUARD, FILTER AND SILENCER AND DAMPER, 40 HP	1.00	EA	48.00	48.0	30.00	1440.00	200.00	200.00	13300.00	13300.00			14,940.00
	460 VAC, 3 PHASE, 60 HZ TEFC MOTOR				0.0		0.00		0.00		0.00			0.00
B	PIPING - RECUPERATOR TO CRV	1.00	LS	128.00	128.0	30.00	3840.00	20000.00	20000.00			4000.00		27,840.00
C	EXPANSION JOINT	1.00	EA	12.00	12.0	30.00	360.00	5300.00	5300.00					5,660.00
D	BALANCE VALVES - COMPLETE	2.00	EA	16.00	32.0	30.00	960.00	1766.00	3532.00					4,492.00
E	BLEED VALVE WITH ACTUATOR	1.00	EA	12.00	12.0	30.00	360.00	3095.00	3095.00					3,455.00
F	COMBUSTION AIR FLOW TO CRV	1.00	EA	22.50	22.5	30.00	675.00	3800.00	3800.00					4,475.00
G	COMBUSTION AIR FLOW TO RECUPERATOR	1.00	EA	22.50	22.5	30.00	675.00	3000.00	3000.00					3,675.00
H	COMBUSTION AIR FLOW TO PILOT BURNER	1.00	EA	28.50	28.5	30.00	855.00	5320.00	5320.00					6,175.00
	CRV ASSEMBLY -				0.0		0.00		0.00		0.00			0.00
I	CRV	1.00	EA	239.25	239.3	30.00	7177.50	500.00	500.00	20475.00	20475.00			28,152.50
J	REFRACTORY	1.00	LOT		0.0		0.00	43740.00	43740.00			9975.00		53,715.00
K	CRV SUPPORTS	3.00	EA	16.00	48.0	30.00	1440.00	409.67	1229.00					2,669.00
L	MISCELLANEOUS	1.00	LS	35.50	35.5	30.00	1065.00	7753.00	7753.00					8,818.00
	CYCLONE MELTER ASSEMBLY -				0.0		0.00		0.00		0.00			0.00
M	GLASS MELTER	1.00	EA	184.88	184.9	30.00	5546.25	500.00	500.00	15225.00	15225.00			21,271.25
N	SUPPORTS	4.00	EA	8.00	32.0	30.00	960.00	100.75	403.00					1,363.00
O	REFRACTORY	1.00	LOT		0.0		0.00	22084.00	22084.00			9975.00		32,059.00
P	MISCELLANEOUS	1.00	LS	27.50	27.5	30.00	825.00	3423.00	3423.00					4,248.00
	SEPARATOR/RESERVOIR -				0.0		0.00		0.00		0.00			0.00
Q	STEEL WELDMENT/FABRICATION	1.00	EA	239.25	239.3	30.00	7177.50	200.00	200.00	11500.00	11500.00			18,877.50
R	REFRACTORY	1.00	LOT		0.0		0.00	55200.00	55200.00			24800.00		80,000.00
S	BURNER AND APPURTENANCES	1.00	LS	80.00	80.0	30.00	2400.00	500.00	500.00	25000.00	25000.00			27,900.00
T	HEATING ELEMENTS AND CONTROLS	1.00	LS	96.00	96.0	30.00	2880.00	5156.00	5156.00	20000.00	20000.00			28,036.00
	FLUE GAS SUBSYSTEM -				0.0		0.00		0.00		0.00			0.00
U	RECUPERATOR ASSEMBLY	1.00	LS	52.80	52.8	30.00	1584.00	300.00	300.00	64200.00	64200.00			66,084.00
	BATCH HANDLING/FEEDING SUBSYSTEM -				0.0		0.00		0.00		0.00			0.00
V	BATCH EQUIPMENT - SKID MOUNTED	4.00	ASSY	64.00	256.0	30.00	7680.00	300.00	1200.00	73000.00	292000.00			300,880.00
W	BATCH TRANSPORT AIR FLOW MEASUREMENT	1.00	LS	18.00	18.0	30.00	540.00	2810.00	2810.00					3,350.00
	GAS DISTRIBUTION SUBSYSTEM -				0.0		0.00		0.00		0.00			0.00
X	MAIN GAS CONTROLS AND FLAME SAFETY	1.00	ASSY	96.00	96.0	30.00	2880.00	500.00	500.00	29000.00	29000.00			32,380.00
Y	GAS FLOW MEASUREMENT	1.00	LS	24.00	24.0	30.00	720.00	2810.00	2810.00					3,530.00
	COOLING WATER CIRCULATING SUBSYSTEM -				0.0		0.00		0.00		0.00			0.00
Z	RUBBER HOSE	2400.00	LF	0.10	228.0	30.00	6840.00	1.00	2600.00					9,260.00
AA	HOSE FITTINGS, CLAMPS AND VALVES	1.00	LS	159.60	159.6	30.00	4788.00	7140.00	7140.00					11,928.00
AB	COOLING SYSTEM DEVICES	1.00	LS	72.00	72.0	30.00	2160.00	10275.00	10275.00					12,435.00
	SUPPLEMENTARY SUPPORT STEEL	5.00	TONS	32.50	162.5	30.00	4875.00	1235.00	6175.00			1500.00		12,550.00
	TOTAL SHEET 12				2356.8		70703.25		218545.00		490700.00	50250.00	0.00	830,198.25

FILENAME: VORTECV.WK1

[illegible]

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECV.WK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATL \$/EA	MATERIAL \$	UNIT COST PW PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
V	VITRIFICATION FACILITY, DRY FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
	ELECTRICAL AND INSTRUMENTATION				0.0		0.00		0.00		0.00			0.00
1	ELECTRICAL WORK AS REQUIRED:	1.00	LS	960.00	960.0	30.00	28800.00	22250.00	22250.00	63250.00	63250.00		5000.00	119,300.00
	FEEDER CIRCUITS, CONDUIT AND TRAY				0.0		0.00		0.00		0.00			0.00
	BRANCH CIRCUITS, CONDUIT AND TRAY				0.0		0.00		0.00		0.00			0.00
	WIRE AND CABLE				0.0		0.00		0.00		0.00			0.00
	DEVICES				0.0		0.00		0.00		0.00			0.00
	FIXTURES				0.0		0.00		0.00		0.00			0.00
	PANELS, LIGHTING AND OTHER				0.0		0.00		0.00		0.00			0.00
	MOTOR CONTROL CENTER				0.0		0.00		0.00		0.00			0.00
	SUBSTATION AND SWITCHGEAR				0.0		0.00		0.00		0.00			0.00
	LIGHTING				0.0		0.00		0.00		0.00			0.00
	GROUNDING				0.0		0.00		0.00		0.00			0.00
	LIGHTNING PROTECTION				0.0		0.00		0.00		0.00			0.00
	HEAT TRACING				0.0		0.00		0.00		0.00			0.00
2	INSTRUMENTATION:				0.0		0.00		0.00		0.00			0.00
A	CENTRAL CONTROL PANEL WITH PROGRAMMABLE LOOP	1.00	LS		0.0		0.00		0.00		0.00	45000.00		45,000.00
	CONTROLLERS, ANNUNCIATORS AND STOP/START				0.0		0.00		0.00		0.00			0.00
	PUSHBUTTONS, SELECTOR SWITCHES, AND				0.0		0.00		0.00		0.00			0.00
	INDICATORS				0.0		0.00		0.00		0.00			0.00
B	PC BASED DATA ACQUISITION SYSTEM WITH PRINTER	1.00	LS		0.0		0.00		0.00		0.00	10000.00		10,000.00
C	PROGRAMMABLE LOGIC CONTROLLER(S) (PLC)	1.00	LS		0.0		0.00		0.00		0.00	32200.00		32,200.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
	INSTRUMENT I/O LISTING				0.0		0.00		0.00		0.00			0.00
	ANALOG INPUT (AI)	59.00	EA	2.50	147.5	30.00	4425.00		0.00		0.00			4,425.00
	ANALOG OUTPUT (AO)	17.00	EA	2.50	42.5	30.00	1275.00		0.00		0.00			1,275.00
	DIGITAL INPUT, 24 VDC (DI)	46.00	EA	2.50	115.0	30.00	3450.00		0.00		0.00			3,450.00
	DIGITAL INPUT, 110 VAC (DI)	23.00	EA	2.50	57.5	30.00	1725.00		0.00		0.00			1,725.00
	DRY RELAY OUTPUTS	51.00	EA	4.00	204.0	30.00	6120.00		0.00		0.00			6,120.00
	TOTAL CONTROL LOOPS	21.00	EA	16.00	336.0	30.00	10080.00		0.00		0.00			10,080.00
D	SOFTWARE	1.00	LS		0.0		0.00		0.00		0.00	40000.00		40,000.00
E	INSTRUMENT CALIBRATION	1.00	LS		0.0		0.00		0.00		0.00	15000.00		15,000.00
F	CONTINUOUS EMISSION MONITORING SYSTEM (CEM)	1.00	LS	128.00	128.0	30.00	3840.00	5000.00	5000.00	50000.00	50000.00			58,840.00
	(O2, CO, NOX, CO2, AND OPACITY)				0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
	NOTE: ABOVE COSTS ALLOWS FOR 25%				0.0		0.00		0.00		0.00			0.00
	ADDITIONAL INPUTS				0.0		0.00		0.00		0.00			0.00
	TOTAL SHEET 14				1990.5		59715.00		27250.00		113250.00	142200.00	5000.00	347,415.00

FILENAME: VORTECV.WK1

[illegible]

Table 7-2
Cost Estimate for Alternative 1 -
Wet Feed/Dry Flue Gas Treatment

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECX.WK1

CLIENT :VORTEC CORPORATION
LOCATION :COLLEGEVILLE, PENNSYLVANIA
W. O. NO.:10189-001-001-0001-00

ESTIMATOR: MGA
ESTIMATE BASIS: CONCEPTUAL/PRELIMINARY

ESTIMATE ACCURACY: +30% TO -15%

COST/ITEM CODE	DESCRIPTION	30-Jun-93 07:39 AM	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATL \$/EA	MATERIAL \$	UNIT COST PW PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
I	VITRIFICATION FACILITY PROJECT SUMMARY (WET FEED ALTERNATIVE) FIRST COST SUBTOTAL (FROM SHEET SUMMARY, SHEET NO. 2)					13816.7		408441.27		678031.36		1249768.75	322325.57	54794.28	2,713,361.23
II	OTHER PROJECT DIRECT AND INDIRECT COSTS:														
1	PROJECT CONSTRUCTION FACILITIES														149,230.00
2	CONSTRUCTION EQUIPMENT														122,100.00
3	MOBILIZATION AND DEMOBILIZATION														24,510.00
4	SMALL TOOLS AND CONSUMABLE ITEMS														30,638.00
5	PERMITS AND FEES														33,920.00
	SUBTOTAL														3,073,750.00
III	PROJECT AND CONSTRUCTION CONTRACT COSTS:														
1	GENERAL AND ADMINISTRATIVE COSTS														261,270.00
2	CONTRACTOR MARKUP AND FEE														380,150.00
	SUBTOTAL														3,635,170.00
IV	CONTINGENCY @ 15%														545,280.00
V	TOTAL (ROUNDED)														4,180,500.00
	SHEET 1														

7-21

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECK.MK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, WET FEED ALTERNATIVE SHEET SUMMARY													
	TOTAL FROM SHEET 3 - SITE WORK				401.1		12031.65		21572.98		0.00	10000.00	16500.00	60,104.63
	TOTAL FROM SHEET 4 - STRUCTURAL				1628.7		48861.12		74930.31		0.00	8601.00	0.00	132,392.43
	TOTAL FROM SHEET 5 - MAJOR EQUIPMENT				1048.3		31450.21		37022.89		259250.00	0.00	0.00	327,723.09
	TOTAL FROM SHEET 6 - MAJOR EQUIPMENT				0.0		0.00		0.00		0.00	0.00	0.00	0.00
	TOTAL FROM SHEET 7 - MAJOR EQUIPMENT				282.9		8487.50		15668.38		18655.00	0.00	0.00	42,810.88
	TOTAL FROM SHEET 8 - MAJOR EQUIPMENT				563.5		16905.00		16413.25		72441.25	0.00	7200.00	112,959.50
	TOTAL FROM SHEET 9 - MAJOR EQUIPMENT				340.0		10199.27		26153.01		21096.75	12750.00	5000.00	75,199.03
	TOTAL FROM SHEET 10 - MAJOR EQUIPMENT				611.1		18332.50		25607.44		25831.25	5000.00	5000.00	79,771.19
	TOTAL FROM SHEET 11 - MAJOR EQUIPMENT				101.5		3045.00		3956.88		17465.63	0.00	0.00	24,467.50
	TOTAL FROM SHEET 12 - MAJOR EQUIPMENT				2356.8		70703.25		218545.00		490700.00	50250.00	0.00	830,198.25
	TOTAL FROM SHEET 13 - MECHANICAL AND PIPING				2968.8		89062.50		107772.50		0.00	9800.00	11500.00	218,135.00
	TOTAL FROM SHEET 14 - ELECTRICAL AND INSTR.				1990.5		59715.00		27250.00		113250.00	142200.00	5000.00	347,415.00
	TOTAL FROM SHEET 15 - SUBCONTRACTS				0.0		0.00		0.00		0.00	60000.00	0.00	60,000.00
	SCALE UP FACTOR FOR INCREASE IN COMBUSTOR SIZE RELATING TO THE UTILIZATION OF WET SLURRY FEED SYSTEM - SCALE UP AT AN INCREASE OF 60% ADDITIONAL AIR FLOW IN CFM AND HEAT REQUIRED TO TREAT INCREASED MOISTURE CONTENT. DRY FEED/AIR FLOW RATE - 4,000 LBS/HR & 8,000 CFM WET FEED/AIR FLOW RATE - (COMPUTED) 6,400 LBS/HR & 12,800 CFM COMPUTED SCALE-UP FACTOR: (((6400*12800)/(4000*8000))^0.68)-1 =	0.3765804												
	ADDITIONAL COSTS FOR INCREASES IN EQUIPMENT PERFORMANCE, APPLIED TO TOTAL FROM SHEET 12 AND OTHER EQUIPMENT COMPONENTS				1321.61		39648.28		103138.74		231078.88	23724.57	4594.28	402,184.75
	SUMMARY TOTAL SHEET 2				13614.7		408441.27		678031.36		1249768.75	322325.57	54794.28	2,713,361.23

FILENAME: VORTEX.WK1

[illegible]

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECX.WK1

CLIENT : VORTEC CORPORATION
LOCATION : 10189-001-001-0001-00

[illegible]

FILENAME: VORTECX.WK1

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	\$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, WET FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
III	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
1.	WET FEED EQUIPMENT				0.0		0.00		0.00		0.00			0.00
A	WET GRINDER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	320.00	320.0	30.00	9600.00	2500.00	2500.00	160000.00	160000.00			172,100.00
	CAPACITY: 4,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	WATER FLOW INPUT: 5 - 10 GPM				0.0		0.00		0.00		0.00			0.00
	SIZE REDUCTION: FROM +1/2" TO <1/2"				0.0		0.00		0.00		0.00			0.00
	ALLIS MINERAL SYSTEM; BALL MILL				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	2.96	CY	5.50	16.3	30.00	488.89	111.38	330.00		0.00			818.89
	VALVES AND PIPING SPECIALTIES	1.00	LS	32.00	32.0	30.00	960.00	2040.00	2040.00		0.00			3,000.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
B	TRANSFER SLURRY PUMP:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	2.00	EA	80.00	160.0	30.00	4800.00	500.00	1000.00	19800.00	39600.00			45,400.00
	TYPE: PNEUMATIC DIAPHRAGM				0.0		0.00		0.00		0.00			0.00
	CAPACITY: 5 - 10 GPM				0.0		0.00		0.00		0.00			0.00
	MOTOR: PNEUMATIC				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	0.83	CY	5.50	4.6	30.00	137.50	111.38	92.81		0.00			230.31
	VALVES AND PIPING SPECIALTIES	1.00	LS	32.00	32.0	30.00	960.00	2040.00	2040.00		0.00			3,000.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
C	SLURRY TANK NO.1				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	32.00	32.0	30.00	960.00	200.00	200.00	5750.00	5750.00			6,910.00
	CAPACITY: 5,000 GALLONS				0.0		0.00		0.00		0.00			0.00
	SIZE: 8.0' DIA. X 14.0' HT. VERTICAL				0.0		0.00		0.00		0.00			0.00
	TYPE: VERTICAL ATMOSPHERIC STORAGE TANK				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	3.53	CY	5.50	19.4	30.00	583.16	111.38	393.63		0.00			976.79
	VALVES AND PIPING SPECIALTIES	1.00	LS	16.00	16.0	30.00	480.00	3150.00	3150.00		0.00			3,630.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
D	AGITATOR - VERTICAL SHAFT	1.00	EA	16.00	16.0	30.00	480.00	1200.00	1200.00	4275.00	4275.00			5,955.00
	METERING TRANSFER SLURRY PUMP:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	2.00	EA	80.00	160.0	30.00	4800.00	500.00	1000.00	19800.00	39600.00			45,400.00
	TYPE: PNEUMATIC DIAPHRAGM				0.0		0.00		0.00		0.00			0.00
	CAPACITY: 5 GPM				0.0		0.00		0.00		0.00			0.00
	MOTOR: PNEUMATIC				0.0		0.00							

FILENAME: VORTECX.MK1

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, WET FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
111	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
2.	VAPOR-PHASE CARBON ADSORPTION SYSTEM:	(DELETED)			0.0		0.00		0.00		0.00			0.00
	QUANTITY:	0.00	EA	24.00	0.0	30.00	0.00	200.00	0.00	25000.00	0.00			0.00
	CALGON VAPOR-PAC 10				0.0		0.00		0.00		0.00			0.00
	TWO(2) MONTH RENTAL COMPLETE WITH 12,500 LB				0.0		0.00		0.00		0.00			0.00
	CARBON INVENTORY, SAMPLING AND ANALYSIS,				0.0		0.00		0.00		0.00			0.00
	PICKUP AND DELIVERY COMPLETE				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	0.00	CY	5.50	0.0	30.00	0.00	111.38	0.00		0.00			0.00
	VALVES AND PIPING SPECIALTIES	0.00	LS	32.00	0.0	30.00	0.00	2040.00	0.00		0.00			0.00
	INSTRUMENTATION	0.00	LS	24.00	0.0	30.00	0.00	3200.00	0.00		0.00			0.00
3	BAG HOUSE:	(DELETED)			0.0		0.00		0.00		0.00			0.00
	QUANTITY:	0.00	EA	192.00	0.0	30.00	0.00	3500.00	0.00	15400.00	0.00			0.00
	INLET FLOW: 1,800 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 250 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -3				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-4,000 LBS/MR				0.0		0.00		0.00		0.00			0.00
	TYPE - REVERSE AIR, WITH DUST COLLECTION				0.0		0.00		0.00		0.00			0.00
	HOPPERS AND RECOVERY SYSTEM				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	0.00	CY	5.50	0.0	30.00	0.00	111.38	0.00		0.00			0.00
	VALVES AND PIPING SPECIALTIES	0.00	LS	24.00	0.0	30.00	0.00	1520.00	0.00		0.00			0.00
	INSTRUMENTATION	0.00	LS	24.00	0.0	30.00	0.00	3200.00	0.00		0.00			0.00
	FREIGHT	0.00	LS		0.0		0.00		0.00		0.00		0.00	0.00
	STARTUP ASSISTANCE	0.00	LS		0.0		0.00		0.00		0.00		0.00	0.00
4	HEPA FILTER:	(DELETED)			0.0		0.00		0.00		0.00			0.00
	QUANTITY:	0.00	EA	32.00	0.0	30.00	0.00	100.00	0.00	3388.00	0.00			0.00
	INLET FLOW: 1,800 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 250 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -5				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-4,000 LBS/MR				0.0		0.00		0.00		0.00			0.00
	TYPE - HIGH ENERGY PARTICULATE AIR FILTER				0.0		0.00		0.00		0.00			0.00
	WITH PARTICULATE MATTER RECOVERY				0.0		0.00		0.00		0.00			0.00
	HIGH TEMPERATURE FRAMES AND GASKETS	0.00	EA	16.00	0.0	30.00	0.00	100.00	0.00	3200.00	0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00

FILENAME: VORTECX.WK1

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	\$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, WET FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
111	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
5	INDUCED AIR(ID) FAN: (MATERIALS HANDLING)	(DELETED)	EA	24.00	0.0	30.00	0.00	150.00	0.00	11896.75	0.00			0.00
	QUANTITY:	0.00			0.0		0.00		0.00		0.00			0.00
	INLET FLOW: 1,900 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 200 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/wc: -5				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-4,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - HORIZONTAL SHAFT, CENTRIFUGAL				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	0.00	CY	5.50	0.0	30.00	0.00	74.25	0.00		0.00			0.00
	VALVES AND PIPING SPECIALTIES/DAMPERS	0.00	LS	48.00	0.0	30.00	0.00	4025.00	0.00		0.00			0.00
	INSTRUMENTATION	0.00	LS	24.00	0.0	30.00	0.00	3200.00	0.00		0.00			0.00
6	WASTE STORAGE SILO:	(DELETED)	EA	48.00	0.0	30.00	0.00	500.00	0.00	12500.00	0.00			0.00
	QUANTITY:	0.00			0.0		0.00		0.00		0.00			0.00
	TYPE: VERTICAL DRY STORAGE TANK/VESSEL				0.0		0.00		0.00		0.00			0.00
	DIMENSIONS: 10.0' X 20.0' HT				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	0.00	CY	5.50	0.0	30.00	0.00	74.25	0.00		0.00			0.00
	VALVES AND PIPING SPECIALTIES	0.00	LS	48.00	0.0	30.00	0.00	4025.00	0.00		0.00			0.00
	INSTRUMENTATION	0.00	LS	24.00	0.0	30.00	0.00	4800.00	0.00		0.00			0.00
7	COOLING TOWER:		EA	64.00	64.0	30.00	1920.00	500.00	500.00	3500.00	3500.00			5,920.00
	QUANTITY:	1.00			0.0		0.00		0.00		0.00			0.00
	TYPE: FORCED DRAFT COOLING TOWER				0.0		0.00		0.00		0.00			0.00
	SIZE: 50 TONS PER HOUR, 50 DEG F. DT				0.0		0.00		0.00		0.00			0.00
	SEE SPECIFICATIONS - DELTA COOLING TOWERS				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	6.67	CY	5.50	36.7	30.00	1100.00	74.25	495.00		0.00			1,595.00
	VALVES AND PIPING SPECIALTIES	1.00	LS	48.00	48.0	30.00	1440.00	4025.00	4025.00		0.00			5,465.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	4800.00	4800.00		0.00			5,520.00
8	SPRAY QUENCH TOWER:		EA	24.00	24.0	30.00	720.00	200.00	200.00	15155.00	15155.00			16,075.00
	QUANTITY:	1.00			0.0		0.00		0.00		0.00			0.00
	INLET FLOW: 11,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 2,000 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/wc: -1				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: 9,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - VERTICAL, TANGENTIAL INLET,				0.0		0.00		0.00		0.00			0.00
	COUNTER-CURRENT FLOW, TOP-NAT OUTLET				0.0									

FILENAME: VORTCH.MCT

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER HHR \$/HHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PER PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, WET FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
III	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
9	BAG HOUSE:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	192.00	192.0	30.00	5760.00	3500.00	3500.00	35437.00	35437.00			44,097.00
	INLET FLOW: 8,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 400 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -3				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-18,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - REVERSE AIR, WITH DUST COLLECTION				0.0		0.00		0.00		0.00			0.00
	HOPPERS AND RECOVERY SYSTEM				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	16.00	CY	5.50	88.0	30.00	2640.00	111.38	1782.00		0.00			4,422.00
	VALVES AND PIPING SPECIALTIES	1.00	LS	24.00	24.0	30.00	720.00	1520.00	1520.00		0.00			2,240.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
	FREIGHT	1.00	LS		0.0		0.00		0.00		0.00		3400.00	3,400.00
	STARTUP ASSISTANCE	1.00	LS		0.0		0.00		0.00		0.00		3000.00	3,000.00
10	HEPA FILTER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	2.00	EA	32.00	64.0	30.00	1920.00	100.00	200.00	3388.00	6776.00			8,096.00
	INLET FLOW: 8,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 400 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -7				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-18,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - HIGH ENERGY PARTICULATE AIR FILTER				0.0		0.00		0.00		0.00			0.00
	WITH PARTICULATE MATTER RECOVERY				0.0		0.00		0.00		0.00			0.00
	HIGH TEMPERATURE FRAMES AND GASKETS	4.00	EA	16.00	64.0	30.00	1920.00	100.00	400.00	3200.00	12000.00			15,120.00
11	FLUE GAS QUENCHER/ABSORBER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	24.00	24.0	30.00	720.00	200.00	200.00	17428.25	17428.25			18,348.25
	INLET FLOW: 7,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 350 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: 0.0				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: 20,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - PACKED TOWER/BED, COUNTER-CURRENT FLOW				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	5.00	CY	5.50	27.5	30.00	825.00	74.25	371.25		0.00			1,196.25
	VALVES AND PIPING SPECIALTIES	1.00	LS	32.00	32.0	30.00	960.00	2040.00	2040.00		0.00			3,000.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
					0.0		0.00							

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECK.WK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001 00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MTRL \$/EA	MATERIAL \$	UNIT COST PW PLY EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, WET FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
III	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
12	INDUCED AIR(ID) FAN: QUANTITY: INLET FLOW: 7,000 ACFM INLET TEMPERATURE: 200 F INLET PRESSURE, in/WC: -14 MASS FLOW: 20,000 LBS/HR TYPE - HORIZONTAL SHAFT, CENTRIFUGAL	1.00	EA	24.00	24.0	30.00	720.00	150.00	150.00	11896.75	11896.75			12,766.75
	CAST-IN-PLACE CONCRETE FOUNDATION	2.37	CY	5.50	13.0	30.00	391.11	74.25	176.00		0.00			567.11
	VALVES AND PIPING SPECIALTIES/DAMPERS	1.00	LS	48.00	48.0	30.00	1440.00	4025.00	4025.00		0.00			5,465.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
13	STACK: QUANTITY: INLET FLOW: 7,000 ACFM INLET TEMPERATURE: 200 F INLET PRESSURE, in/WC: 1 MASS FLOW: 20,000 LBS/HR TYPE - VERTICAL SINGLE FLUE, +/-50.0' HT	1.00	EA		0.0		0.00		0.00		0.00	12750.00		12,750.00
	CAST-IN-PLACE CONCRETE FOUNDATION	4.00	CY	5.50	22.0	30.00	660.00	74.25	297.00		0.00		5000.00	5,957.00
	INSTRUMENTATION, CEM (WITH INSTRUMENTATION)	1.00	LS	64.00	64.0	30.00	1920.00	4800.00	4800.00		0.00			6,720.00
14	ION EXCHANGER: QUANTITY: INLET FLOW: 3 GPM INLET TEMPERATURE: 180 F INLET PRESSURE: 30 PSIG MASS FLOW: 1710 LBS/HR TYPE - ANION/CATION EXCHANGER TO TREAT WET SCRUBBER EFFLUENT	1.00	EA	8.00	8.0	30.00	240.00	100.00	100.00	3000.00	3000.00			3,340.00
	CAST-IN-PLACE CONCRETE FOUNDATION	1.00	CY	5.50	5.5	30.00	165.00	111.38	111.38		0.00			276.38
	VALVES AND PIPING SPECIALTIES	1.00	LS	16.00	16.0	30.00	480.00	3150.00	3150.00		0.00			3,630.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
15	CAUSTIC STORAGE TANK: QUANTITY: CAPACITY: 6,000 GALLONS SIZE: 8.0' DIA. X 16.0' HT. VERTICAL TYPE: VERTICAL ATMOSPHERIC STORAGE TANK	1.00	EA	32.00	32.0	30.00	960.00	200.00	200.00	6200.00	6200.00			7,360.00
	CAST-IN-PLACE CONCRETE FOUNDATION	3.53	CY	5.50	19.4	30.00	583.16	111.38	393.63		0.00			976.77
	VALVES AND PIPING SPECIALTIES	1.00	LS	16.00	16.0	30.00	480.00	3150.00	3150.00		0.00			3,630.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
	TOTAL SHEET 9				340.0		10199.27		26153.01		21096.75	12750.00	5000.00	75,199.03

AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

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FILENAME: VORTECX.WK1

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATL \$/EA	MATERIAL \$	UNIT COST PM P/LT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, WET FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
III	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
16	FLUE GAS SCRUBBER CAUSTIC FEED PUMPS:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	2.00	EA	24.00	48.0	30.00	1440.00	100.00	200.00	1293.75	2587.50			4,227.50
	CAPACITY: 40 GPM @ 60.0' TDH				0.0		0.00		0.00		0.00			0.00
	MOTOR: 1 HP				0.0		0.00		0.00		0.00			0.00
	TYPE: CENTRIFUGAL				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	1.00	CY	5.50	5.5	30.00	165.00	111.38	111.38		0.00			276.38
	VALVES AND PIPING SPECIALTIES	1.00	LS	16.00	16.0	30.00	480.00	3150.00	3150.00		0.00			3,630.00
					0.0		0.00		0.00		0.00			0.00
17	QUENCH TOWER WATER/CAUSTIC SLURRY FEED PUMPS:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	2.00	EA	24.00	48.0	30.00	1440.00	100.00	200.00	5821.88	11643.75			13,283.75
	CAPACITY: 100 GPM @ 60.0' TDH				0.0		0.00		0.00		0.00			0.00
	MOTOR: 5 HP				0.0		0.00		0.00		0.00			0.00
	TYPE: CENTRIFUGAL, LINED				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	1.00	CY	5.50	5.5	30.00	165.00	111.38	111.38		0.00			276.38
	VALVES AND PIPING SPECIALTIES	1.00	LS	16.00	16.0	30.00	480.00	3150.00	3150.00		0.00			3,630.00
					0.0		0.00		0.00		0.00			0.00
18	QUENCHED MATERIALS REMOVAL CONVEYOR:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	128.00	128.0	30.00	3840.00	500.00	500.00	11600.00	11600.00			15,940.00
	TYPE: DRAG FLIGHT				0.0		0.00		0.00		0.00			0.00
	CAPACITY: AS REQUIRED				0.0		0.00		0.00		0.00			0.00
	MOTOR: 5 HP WITH GEAR REDUCING DRIVE UNIT				0.0		0.00		0.00		0.00			0.00
	MISCELLANEOUS STEEL AND PLATE FOR INCLINED DISCHARGE TROUGH AND DISCHARGE CHUTE	1.00	LS	72.00	72.0	30.00	2160.00	7500.00	7500.00		0.00			9,660.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
19	QUENCH TANK:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	224.00	224.0	30.00	6720.00	6885.00	6885.00		0.00		2500.00	16,105.00
	TYPE: ABOVE GRADE, CARBON STEEL CONSTRUCTION				0.0		0.00		0.00		0.00			0.00
	CAPACITY:				0.0		0.00		0.00		0.00			0.00
	DIMENSIONS: +/-20.0'LG X 4.0'X 4.0'SMD + FB SLOPED SIDEWALLS TO COLLECTION TROUGH				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	5.83	CY	5.50	32.1	30.00	962.50	111.38	649.69		0.00			1,612.19
	VALVES AND PIPING SPECIALTIES	1.00	LS	16.00	16.0	30.00	480.00	3150.00	3150.00		0.00			3,630.00
					0.0		0.00		0.00		0.00			0.00
20	ROLL-OFF CONTAINER:				0.0		0.00		0.00					

FILENAME: VORTEX.WK1

[illegible]

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECK.WK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, WET FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
IV	METC COMBUSTION EQUIPMENT				0.0		0.00		0.00		0.00			0.00
1	METC 25 TONS PER DAY (TPD) VITRIFICATION FACILITY: SEE VORTEC CORRESPONDENCE DATED MAY 24, 1993				0.0		0.00		0.00		0.00			0.00
	COMBUSTION AIR SUBSYSTEM -				0.0		0.00		0.00		0.00			0.00
A	BLOWER ASSEMBLY - BLOWER, BASEPLATE, CPLG AND GUARD, FILTER AND SILENCER AND DAMPER, 40 HP 460 VAC, 3 PHASE, 60 HZ TEFC MOTOR	1.00	EA	48.00	48.0	30.00	1440.00	200.00	200.00	13300.00	13300.00			14,940.00
	PIPING - RECUPERATOR TO CRV	1.00	LS	128.00	128.0	30.00	3840.00	20000.00	20000.00			4000.00		27,840.00
B	EXPANSION JOINT	1.00	EA	12.00	12.0	30.00	360.00	5300.00	5300.00					5,660.00
D	BALANCE VALVES - COMPLETE	2.00	EA	16.00	32.0	30.00	960.00	1766.00	3532.00					4,492.00
E	BLEED VALVE WITH ACTUATOR	1.00	EA	12.00	12.0	30.00	360.00	3095.00	3095.00					3,455.00
F	COMBUSTION AIR FLOW TO CRV	1.00	EA	22.50	22.5	30.00	675.00	3800.00	3800.00					4,475.00
G	COMBUSTION AIR FLOW TO RECUPERATOR	1.00	EA	22.50	22.5	30.00	675.00	3000.00	3000.00					3,675.00
H	COMBUSTION AIR FLOW TO PILOT BURNER CRV ASSEMBLY -	1.00	EA	28.50	28.5	30.00	855.00	5320.00	5320.00					6,175.00
I	CRV	1.00	EA	239.25	239.3	30.00	7177.50	500.00	500.00	20475.00	20475.00			28,152.50
J	REFRACTORY	1.00	LOT		0.0		0.00	43740.00	43740.00			9975.00		53,715.00
K	CRV SUPPORTS	3.00	EA	16.00	48.0	30.00	1440.00	409.67	1229.00					2,669.00
L	MISCELLANEOUS	1.00	LS	35.50	35.5	30.00	1065.00	7753.00	7753.00					8,818.00
	CYCLONE MELTER ASSEMBLY -				0.0		0.00		0.00					0.00
M	GLASS MELTER	1.00	EA	184.88	184.9	30.00	5546.25	500.00	500.00	15225.00	15225.00			21,271.25
N	SUPPORTS	4.00	EA	8.00	32.0	30.00	960.00	100.75	403.00					1,363.00
O	REFRACTORY	1.00	LOT		0.0		0.00	22084.00	22084.00			9975.00		32,059.00
P	MISCELLANEOUS	1.00	LS	27.50	27.5	30.00	825.00	3423.00	3423.00					4,248.00
	SEPARATOR/RESERVOIR -				0.0		0.00		0.00					0.00
Q	STEEL WELDMENT/FABRICATION	1.00	EA	239.25	239.3	30.00	7177.50	200.00	200.00	11500.00	11500.00			18,877.50
R	REFRACTORY	1.00	LOT		0.0		0.00	55200.00	55200.00			24800.00		80,000.00
S	BURNER AND APPURTENANCES	1.00	LS	80.00	80.0	30.00	2400.00	500.00	500.00	25000.00	25000.00			27,900.00
T	HEATING ELEMENTS AND CONTROLS FLUE GAS SUBSYSTEM -	1.00	LS	96.00	96.0	30.00	2880.00	5156.00	5156.00	20000.00	20000.00			28,036.00
U	RECUPERATOR ASSEMBLY	1.00	LS	52.80	52.8	30.00	1584.00	300.00	300.00	64200.00	64200.00			66,084.00
	BATCH HANDLING/FEEDING SUBSYSTEM -				0.0		0.00		0.00					0.00
V	BATCH EQUIPMENT - SKID MOUNTED	4.00	ASSY	64.00	256.0	30.00	7680.00	300.00	1200.00	73000.00	292000.00			300,880.00
W	BATCH TRANSPORT AIR FLOW MEASUREMENT	1.00	LS	18.00	18.0	30.00	540.00	2810.00	2810.00					3,350.00
	GAS DISTRIBUTION SUBSYSTEM -				0.0		0.00		0.00					0.00
X	MAIN GAS CONTROLS AND FLAME SAFETY	1.00	ASSY	96.00	96.0	30.00	2880.00	500.00	500.00	29000.00	29000.00			32,380.00
Y	GAS FLOW MEASUREMENT	1.00	LS	24.00	24.0	30.00	720.00	2810.00	2810.00					3,530.00
	COOLING WATER CIRCULATING SUBSYSTEM -				0.0		0.00		0.00					0.00
Z	RUBBER HOSE	2400.00	LF	0.10	228.0	30.00	6840.00	1.00	2400.00					9,240.00
AA	HOSE FITTINGS, CLAMPS AND VALVES	1.00	LS	159.60	159.6	30.00	4788.00	7140.00	7140.00					11,928.00
AB	COOLING SYSTEM DEVICES	1.00	LS	72.00	72.0	30.00	2160.00	10275.00	10275.00					12,435.00
	SUPPLEMENTARY SUPPORT STEEL	5.00	TONS	32.50	162.5	30.00	4875.00	1235.00	6175.00			1500.00		12,550.00
	TOTAL SHEET 12				2356.8		70703.25		218545.00		490700.00	50250.00	0.00	830,198.25

FILENAME: VORTECX.WK1

[illegible]

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECX.WK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY, WET FEED ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
V	ELECTRICAL AND INSTRUMENTATION				0.0		0.00		0.00		0.00			0.00
1	ELECTRICAL WORK AS REQUIRED: FEEDER CIRCUITS, CONDUIT AND TRAY BRANCH CIRCUITS, CONDUIT AND TRAY WIRE AND CABLE DEVICES FIXTURES PANELS, LIGHTING AND OTHER MOTOR CONTROL CENTER SUBSTATION AND SWITCHGEAR LIGHTING GROUNDING LIGHTNING PROTECTION HEAT TRACING	1.00	LS	960.00	960.0	30.00	28800.00	22250.00	22250.00	63250.00	63250.00		5000.00	119,300.00
2	INSTRUMENTATION: CENTRAL CONTROL PANEL WITH PROGRAMMABLE LOOP CONTROLLERS, ANNUNCIATORS AND STOP/START PUSHBUTTONS, SELECTOR SWITCHES, AND INDICATORS	1.00	LS		0.0		0.00	0.00	0.00		0.00	45000.00		45,000.00
B	PC BASED DATA ACQUISITION SYSTEM WITH PRINTER	1.00	LS		0.0		0.00	0.00	0.00		0.00	10000.00		10,000.00
C	PROGRAMMABLE LOGIC CONTROLLER(S) (PLC)	1.00	LS		0.0		0.00	0.00	0.00		0.00	32200.00		32,200.00
	INSTRUMENT I/O LISTING				0.0		0.00	0.00	0.00		0.00			0.00
	ANALOG INPUT (AI)	59.00	EA	2.50	147.5	30.00	4425.00	0.00	0.00		0.00			4,425.00
	ANALOG OUTPUT (AO)	17.00	EA	2.50	42.5	30.00	1275.00	0.00	0.00		0.00			1,275.00
	DIGITAL INPUT, 24 VDC (DI)	46.00	EA	2.50	115.0	30.00	3450.00	0.00	0.00		0.00			3,450.00
	DIGITAL INPUT, 110 VAC (DI)	23.00	EA	2.50	57.5	30.00	1725.00	0.00	0.00		0.00			1,725.00
	DRY RELAY OUTPUTS	51.00	EA	4.00	204.0	30.00	6120.00	0.00	0.00		0.00			6,120.00
	TOTAL CONTROL LOOPS	21.00	EA	16.00	336.0	30.00	10080.00	0.00	0.00		0.00			10,080.00
D	SOFTWARE	1.00	LS		0.0		0.00	0.00	0.00		0.00	40000.00		40,000.00
E	INSTRUMENT CALIBRATION	1.00	LS		0.0		0.00	0.00	0.00		0.00	15000.00		15,000.00
F	CONTINUOUS EMISSION MONITORING SYSTEM (CEM) (O2, CO, NOX, CO2, AND OPACITY)	1.00	LS	128.00	128.0	30.00	3840.00	5000.00	5000.00	50000.00	50000.00			58,840.00
	NOTE: ABOVE COSTS ALLOWS FOR 25% ADDITIONAL INPUTS				0.0		0.00	0.00	0.00		0.00			0.00
	TOTAL SHEET 14				1990.5		59715.00		27250.00		113250.00	142200.00	5000.00	347,415.00

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FILENAME: VORTECX.WK1

[illegible]

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Table 7-3
Cost Estimate for Alternative 2
Dry Feed/Wet Flue Gas Treatment

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECY.WK1

CLIENT :VORTEC CORPORATION
LOCATION :COLLEGEVILLE, PENNSYLVANIA
W. O. NO.:10189-001-001-0001-00

ESTIMATOR: NGA
ESTIMATE BASIS: CONCEPTUAL/PRELIMINARY

ESTIMATE ACCURACY: +30% TO -15%

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MTRL \$/EA	MATERIAL \$	UNIT COST PH PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
I	VITRIFICATION FACILITY PROJECT SUMMARY (DRY FEED,WET SCRUBBER ALTERNATIVE) FIRST COST SUBTOTAL (FROM SHEET SUMMARY, SHEET NO. 2)				14883.8		446514.15		644298.40		1464110.63	313601.00	99200.00	2,967,724.17
II	OTHER PROJECT DIRECT AND INDIRECT COSTS:													163,220.00
1	PROJECT CONSTRUCTION FACILITIES													133,550.00
2	CONSTRUCTION EQUIPMENT													26,790.00
3	MOBILIZATION AND DEMOBILIZATION													33,490.00
4	SMALL TOOLS AND CONSUMABLE ITEMS													37,100.00
5	PERMITS AND FEES													
	SUBTOTAL													3,361,870.00
III	PROJECT AND CONSTRUCTION CONTRACT COSTS:													285,760.00
1	GENERAL AND ADMINISTRATIVE COSTS													328,290.00
2	CONTRACTOR MARKUP AND FEE													
	SUBTOTAL													3,975,920.00
IV	CONTINGENCY @ 15%													596,390.00
V	TOTAL (ROUNDED)													4,572,300.00
	SHEET 1													

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ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECY.WK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY DRY FEED, WET SCRUBBER ALTERNATIVE SHEET SUMMARY				401.1		12031.65		21572.98		0.00	10000.00	16500.00	60,104.63
	TOTAL FROM SHEET 3 - SITE WORK													
	TOTAL FROM SHEET 4 - STRUCTURAL				1628.7		48861.12		74930.31		0.00	8601.00	0.00	132,392.43
	TOTAL FROM SHEET 5 - MAJOR EQUIPMENT				533.9		16017.50		32882.81		187960.00	0.00	8200.00	245,060.31
	TOTAL FROM SHEET 6 - MAJOR EQUIPMENT				593.3		17798.75		17202.16		59976.00	0.00	5300.00	100,276.91
	TOTAL FROM SHEET 7 - MAJOR EQUIPMENT				556.0		16678.61		33138.38		43051.75	0.00	0.00	92,868.74
	TOTAL FROM SHEET 8 - MAJOR EQUIPMENT				235.5		7065.00		6411.25		37004.25	0.00	0.00	50,480.50
	TOTAL FROM SHEET 9 - MAJOR EQUIPMENT				340.0		10199.27		26153.01		21096.75	12750.00	5000.00	75,199.03
	TOTAL FROM SHEET 10 - MAJOR EQUIPMENT				611.1		18332.50		25607.44		25831.25	5000.00	5000.00	79,771.19
	TOTAL FROM SHEET 11 - MAJOR EQUIPMENT				2300.3		69009.00		42586.58		485240.63	15000.00	42700.00	654,536.20
	TOTAL FROM SHEET 12 - MAJOR EQUIPMENT				2356.8		70703.25		218545.00		490700.00	50250.00	0.00	830,198.25
	TOTAL FROM SHEET 13 - MECHANICAL AND PIPING				3188.8		95662.50		118018.50		0.00	9800.00	11500.00	234,981.00
	TOTAL FROM SHEET 14 - ELECTRICAL AND INSTR.				2138.5		64155.00		27250.00		113250.00	142200.00	5000.00	351,855.00
	TOTAL FROM SHEET 15 - SUBCONTRACTS				0.0		0.00		0.00		0.00	60000.00	0.00	60,000.00
	SUMMARY TOTAL SHEET 2				14883.8		446514.15		644298.40		1464110.63	313601.00	99200.00	2,967,724.17

FILENAME: VORTECY.WK1

[illegible]

FILENAME: VORTECY.WK1

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
II	VITRIFICATION FACILITY				0.0		0.00		0.00		0.00			0.00
	DRY FEED,WET SCRUBBER ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
	STRUCTURAL				0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			9.00
					0.0		0.00		0.00		0.00			0.00
	1 COMBUSTOR AND ANCILLARIES SUPPORT STRUCTURE:				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	77.88	CY	5.50	428.3	30.00	12850.29	111.38	8673.95		0.00			21,524.24
	+/-23.0' X 53.0' PLUS STAIR TOWER				0.0		0.00		0.00		0.00			0.00
	STRUCTURAL STEEL - ASTM A36				0.0		0.00		0.00		0.00			0.00
	6 EA. COLUMNS - W12X65 X 24.0'	4.68	TONS		0.0		0.00		0.00		0.00			0.00
	6 EA. BASE PLATES - 3/4"PL-14" X 1'2"	0.12	TONS		0.0		0.00		0.00		0.00			0.00
	HORIZONTAL MEMBERS - LONG AXIS				0.0		0.00		0.00		0.00			0.00
	12 EA. BEAMS - W14X68 X 16.5'	6.73	TONS		0.0		0.00		0.00		0.00			0.00
	12 EA. BEAMS - W8X17 X 16.5'	1.68	TONS		0.0		0.00		0.00		0.00			0.00
	HORIZONTAL MEMBERS - SHORT AXIS				0.0		0.00		0.00		0.00			0.00
	8 EA. BEAMS - W14X68 X 20.0'	5.44	TONS		0.0		0.00		0.00		0.00			0.00
	8 EA. BEAMS - W8X17 X 20.0'	1.36	TONS		0.0		0.00		0.00		0.00			0.00
	STAIR TOWER				0.0		0.00		0.00		0.00			0.00
	2 EA. COLUMNS - W8X31 X 24.0'	0.74	TONS		0.0		0.00		0.00		0.00			0.00
	2 EA. BASE PLATES - 3/4"PL-14" X 1'2"	0.04	TONS		0.0		0.00		0.00		0.00			0.00
	HORIZONTAL MEMBERS - LONG AXIS				0.0		0.00		0.00		0.00			0.00
	6 EA. BEAMS - W8X17 X 16.5'	0.84	TONS		0.0		0.00		0.00		0.00			0.00
	HORIZONTAL MEMBERS - SHORT AXIS				0.0		0.00		0.00		0.00			0.00
	16 EA. BEAMS - W8X17 X 9.5'	1.29	TONS		0.0		0.00		0.00		0.00			0.00
	MISCELLANEOUS, DIAGONALS AND STIFFENERS	5.73	TONS		0.0		0.00		0.00		0.00			0.00
	TOTAL STRUCTURAL STEEL	28.67	TONS	32.50	931.9	30.00	27957.03	1235.00	35412.24		0.00	8601.00		71,970.26
					0.0		0.00		0.00		0.00			0.00
	STAIR TREADS 3.5' LONG	32.00	EA	0.75	24.0	30.00	720.00	55.00	1760.00		0.00			2,480.00
	GRATING	2170.00	SF	0.05	108.5	30.00	3255.00	10.41	22595.13		0.00			25,850.13
	HANDRAIL WITH TOE-PL	412.00	LF	0.33	136.0	30.00	4078.80	15.75	6489.00		0.00			10,567.80
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00							

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECY.WK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
III	VITRIFICATION FACILITY				0.0		0.00		0.00		0.00			0.00
	DRY FEED, WET SCRUBBER ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
1.	IMPACT HAMMER DRYER MILL				0.0		0.00		0.00		0.00			0.00
	SEE WILLIAMS PATENT CRUSHER AND				0.0		0.00		0.00		0.00			0.00
	PULVERIZER CO., INC. PROPOSAL 0-930238	1.00	LS		0.0		0.00		0.00	187960.00	187960.00			187,960.00
	TYPE AND SIZE: GP-15122 IMPACT DRYER MILL				0.0		0.00		0.00		0.00			0.00
	WEIGHT: APPROXIMATELY 20,000 LBS.				0.0		0.00		0.00		0.00			0.00
	FEED RATE: 4,000 WET POUNDS PER HOUR				0.0		0.00		0.00		0.00			0.00
	COMPRISED OF THE FOLLOWING COMPONENTS:				0.0		0.00		0.00		0.00			0.00
A	1 - GP-1512 IMPACT DRYER MILL WITH STRUCTURAL				0.0		0.00		0.00		0.00			0.00
	STEEL BASE, V-BELT DRIVE AND OSHA GUARD				0.0		0.00		0.00		0.00			0.00
B	1 - 9" ROTARY SCREW FEEDER ASSY WITH 1 HP				0.0		0.00		0.00		0.00			0.00
	DRIVE WITH MOTOR AND 150 CF FEED BIN				0.0		0.00		0.00		0.00			0.00
C	1 - 2.5 FT. DIA. SPINNER SEPARATOR WITH				0.0		0.00		0.00		0.00			0.00
	VARIABLE SPEED DRIVE WITH MOTOR				0.0		0.00		0.00		0.00			0.00
D	1 - 13" HD HIGH STATIC FANS WITH V-BELT				0.0		0.00		0.00		0.00			0.00
	DRIVE				0.0		0.00		0.00		0.00			0.00
E	1 - 5.0' DIA. HD VACUUM TYPE CYCLONE				0.0		0.00		0.00		0.00			0.00
	COLLECTOR WITH ROTARY VALVE AND DRIVE MOTOR				0.0		0.00		0.00		0.00			0.00
F	1 - LOT 13" DIA. AIR DUCT TO SET CYCLONE				0.0		0.00		0.00		0.00			0.00
	COLLECTOR WITHIN 35.0' OF MILL BASE				0.0		0.00		0.00		0.00			0.00
G	1 - GAS FIRED AIR HEATER, 1.5 X 10 ⁶ BTU/HR.				0.0		0.00		0.00		0.00			0.00
	WITH AUTO IGNITION, ELECTRONIC FLAME				0.0		0.00		0.00		0.00			0.00
	SAFEGUARD, AUTOMATIC TEMP CONTROLLER AND				0.0		0.00		0.00		0.00			0.00
	RECORDER; CONTROLS MOUNTED IN NEMA 12 PANEL,				0.0		0.00		0.00		0.00			0.00
	WIRED, PIPED AND SHIPPED COMPLETE WITH				0.0		0.00		0.00		0.00			0.00
	REFRACTORY				0.0		0.00		0.00		0.00			0.00
H	1 - 965136 DUST COLLECTOR WITH 16 OZ WOVEN				0.0		0.00		0.00		0.00			0.00
	DACRON BAGS, COMPLETE WITH REVERSE JET				0.0		0.00		0.00		0.00			0.00
	BLOWERS, WITH SCREW CONVEYOR DISCHARGE AND				0.0		0.00		0.00		0.00			0.00
	ROTARY VALVE				0.0		0.00		0.00		0.00			0.00
I	1 - LOT 8" DIA. AIR DUCT TO SET AIR FAN AND				0.0		0.00		0.00		0.00			0.00
	BAGHOUSE WITHIN 35.0' OF MILL BASE				0.0		0.00		0.00		0.00			0.00
J	ITEMS NOT INCLUDED IN OFFERED QUOTATION:				0.0		0.00		0.00		0.00			0.00
	CONCRETE FOUNDATION(S) AND ANCHOR BOLTS	54.17	CY	5.50	297.9	30.00	8937.50	111.38	6032.81		0.00			14,970.31
2	FIELD PIPING FOR LUBRICATION SYSTEM,	1.00	LS	80.00	80.0	30.00	2400.00	5750.00	5750.00		0.00			8,150.00
	SUPPLY(S) AND RETURN(S)				0.0		0.00		0.00		0.00			0.00
3	PLATFORMS AND LADDERS	1.00	LS	64.00	64.0	30.00	1920.00	7500.00	7500.00		0.00		3500.00	12,920.00
4	SURGE BINS FOR FEED OR PRODUCTS (SEE NO. 6)	1.00	LS		0.0		0.00		0.00		0.00			0.00
5	MOTOR STARTERS	1.00	LS		0.0		0.00	5000.00	5000.00		0.00			5,000.00
6	FREIGHT	1.00	LS		0.0		0.00		0.00		0.00		4700.00	4,700.00
7	CYCLONES AND AIR PIPE SUPPORTS	1.00	LS	92.00	92.0	30.00	2760.00	8600.00	8600.00		0.00			11,360.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
	TOTAL SHEET 5				533.9		16017.50		32882.81		187960.00	0.00	8200.00	245,060.31

FILENAME: VORTECY.WK1

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY				0.0		0.00		0.00		0.00			0.00
	DRY FEED, WET SCRUBBER ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
III	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
2.	VAPOR-PHASE CARBON ADSORPTION SYSTEM:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	24.00	24.0	30.00	720.00	200.00	200.00	25000.00	25000.00			25,920.00
	CALGON VAPOR-PAC 10				0.0		0.00		0.00		0.00			0.00
	TWO(2) MONTH RENTAL COMPLETE WITH 12,500 LB				0.0		0.00		0.00		0.00			0.00
	CARBON INVENTORY, SAMPLING AND ANALYSIS,				0.0		0.00		0.00		0.00			0.00
	PICKUP AND DELIVERY COMPLETE				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	10.42	CY	5.50	57.3	30.00	1718.75	111.38	1160.16		0.00			2,878.91
	VALVES AND PIPING SPECIALTIES	1.00	LS	32.00	32.0	30.00	960.00	2040.00	2040.00		0.00			3,000.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
					0.0		0.00		0.00		0.00			0.00
3	BAG HOUSE:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	192.00	192.0	30.00	5760.00	3500.00	3500.00	15400.00	15400.00			24,660.00
	INLET FLOW: 1,800 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 250 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -3				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-4,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - REVERSE AIR, WITH DUST COLLECTION				0.0		0.00		0.00		0.00			0.00
	HOPPERS AND RECOVERY SYSTEM				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	16.00	CY	5.50	88.0	30.00	2640.00	111.38	1782.00		0.00			4,422.00
	VALVES AND PIPING SPECIALTIES	1.00	LS	24.00	24.0	30.00	720.00	1520.00	1520.00		0.00			2,240.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
	FREIGHT	1.00	LS		0.0		0.00		0.00		0.00		1500.00	1,500.00
	STARTUP ASSISTANCE	1.00	LS		0.0		0.00		0.00		0.00		3800.00	3,800.00
					0.0		0.00		0.00		0.00			0.00
4	HEPA FILTER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	2.00	EA	32.00	64.0	30.00	1920.00	100.00	200.00	3388.00	6776.00			8,896.00
	INLET FLOW: 1,800 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 250 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -5				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-4,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - HIGH ENERGY PARTICULATE AIR FILTER				0.0		0.00		0.00		0.00			0.00
	WITH PARTICULATE MATTER RECOVERY				0.0									

FILENAME: VORTECY.WK1

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY				0.0		0.00		0.00		0.00			0.00
	DRY FEED, WET SCRUBBER ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
III	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
5	INDUCED AIR(ID) FAN: (MATERIALS HANDLING)				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	24.00	24.0	30.00	720.00	150.00	150.00	11896.75	11896.75			12,766.75
	INLET FLOW: 1,900 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 200 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -5				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-4,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - HORIZONTAL SHAFT, CENTRIFUGAL				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	2.37	CY	5.50	13.0	30.00	391.11	74.25	176.00		0.00			567.11
	VALVES AND PIPING SPECIALTIES/DAMPERS	1.00	LS	48.00	48.0	30.00	1440.00	4025.00	4025.00		0.00			5,465.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
6	WASTE STORAGE SILO:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	48.00	48.0	30.00	1440.00	500.00	500.00	12500.00	12500.00			14,440.00
	TYPE: VERTICAL DRY STORAGE TANK/VESSEL				0.0		0.00		0.00		0.00			0.00
	DIMENSIONS: 10.0' X 20.0' HT				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	8.00	CY	5.50	44.0	30.00	1320.00	74.25	594.00		0.00			1,914.00
	VALVES AND PIPING SPECIALTIES	1.00	LS	48.00	48.0	30.00	1440.00	4025.00	4025.00		0.00			5,465.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	4800.00	4800.00		0.00			5,520.00
7	COOLING TOWER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	64.00	64.0	30.00	1920.00	500.00	500.00	3500.00	3500.00			5,920.00
	TYPE: FORCED DRAFT COOLING TOWER				0.0		0.00		0.00		0.00			0.00
	SIZE: 50 TONS PER HOUR, 50 DEG F. DT				0.0		0.00		0.00		0.00			0.00
	SEE SPECIFICATIONS - DELTA COOLING TOWERS				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	6.67	CY	5.50	36.7	30.00	1100.00	74.25	495.00		0.00			1,595.00
	VALVES AND PIPING SPECIALTIES	1.00	LS	48.00	48.0	30.00	1440.00	4025.00	4025.00		0.00			5,465.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	4800.00	4800.00		0.00			5,520.00
8	SPRAY QUENCH TOWER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	24.00	24.0	30.00	720.00	200.00	200.00	15155.00	15155.00			16,075.00
	INLET FLOW: 11,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 2,000 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -1				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: 9,000 LBS/HR				0.0		0.00		0.0					

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECY.WK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
III	VITRIFICATION FACILITY				0.0		0.00		0.00		0.00			0.00
	DRY FEED, WET SCRUBBER ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
	9 BAG HOUSE: (DELETED FOR THIS OPTION)				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	0.00	EA	192.00		30.00		3500.00		35437.00				0.00
	INLET FLOW: 8,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 400 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -3				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-18,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - REVERSE AIR, WITH DUST COLLECTION				0.0		0.00		0.00		0.00			0.00
	HOPPERS AND RECOVERY SYSTEM				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	0.00	CY	5.50		30.00		111.38						0.00
	VALVES AND PIPING SPECIALTIES	0.00	LS	24.00		30.00		1520.00						0.00
	INSTRUMENTATION	0.00	LS	24.00		30.00		3200.00					0.00	0.00
	FREIGHT	1.00	LS				0.00		0.00		0.00			0.00
	STARTUP ASSISTANCE	1.00	LS				0.00		0.00		0.00		0.00	0.00
					0.0		0.00		0.00		0.00			0.00
	10 HEPA FILTER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	2.00	EA	32.00	64.0	30.00	1920.00	100.00	200.00	3388.00	6776.00			8,896.00
	INLET FLOW: 8,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 400 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -7				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-18,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - HIGH ENERGY PARTICULATE AIR FILTER				0.0		0.00		0.00		0.00			0.00
	WITH PARTICULATE MATTER RECOVERY				0.0		0.00		0.00		0.00			0.00
	HIGH TEMPERATURE FRAMES AND GASKETS	4.00	EA	16.00	64.0	30.00	1920.00	100.00	400.00	3200.00	12800.00			15,120.00
					0.0		0.00		0.00		0.00			0.00
	11 FLUE GAS QUENCHER/ABSORBER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	24.00	24.0	30.00	720.00	200.00	200.00	17428.25	17428.25			18,348.25
	INLET FLOW: 7,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 350 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: 0.0				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: 20,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - PACKED TOWER/BED, COUNTER-CURRENT FLOW				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	5.00	CY	5.50	27.5	30.00	825.00	74.25	371.25		0.00			1,196.25
	VALVES AND PIPING SPECIALTIES	1.00	LS	32.00	32.0	30.00	960.00	2040.00	2040.00		0.00			3,000.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
TOTAL SHEET 8					235.5		7065.00		6411.25		37004.25	0.00	0.00	50,480.50

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ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECY.WK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
111	VITRIFICATION FACILITY				0.0		0.00		0.00		0.00			0.00
	DRY FEED, WET SCRUBBER ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
12	INDUCED AIR(ID) FAN:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	24.00	24.0	30.00	720.00	150.00	150.00	11896.75	11896.75			12,766.75
	INLET FLOW: 7,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 200 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: -14				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: 20,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - HORIZONTAL SHAFT, CENTRIFUGAL				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	2.37	CY	5.50	13.0	30.00	391.11	74.25	176.00		0.00			567.11
	VALVES AND PIPING SPECIALTIES/DAMPERS	1.00	LS	48.00	48.0	30.00	1440.00	4025.00	4025.00		0.00			5,465.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
					0.0		0.00		0.00		0.00			0.00
13	STACK:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA		0.0		0.00		0.00		0.00	12750.00		12,750.00
	INLET FLOW: 7,000 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 200 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/WC: 1				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: 20,000 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - VERTICAL SINGLE FLUE, +/-50.0' HT				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	4.00	CY	5.50	22.0	30.00	660.00	74.25	297.00		0.00		5000.00	5,957.00
	INSTRUMENTATION, CEM (WITH INSTRUMENTATION)	1.00	LS	64.00	64.0	30.00	1920.00	4800.00	4800.00		0.00			6,720.00
					0.0		0.00		0.00		0.00			0.00
14	ION EXCHANGER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	8.00	8.0	30.00	240.00	100.00	100.00	3000.00	3000.00			3,340.00
	INLET FLOW: 3 GPM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 180 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE: 30 PSIG				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: 1710 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - ANION/CATION EXCHANGER TO TREAT				0.0		0.00		0.00		0.00			0.00
	WET SCRUBBER EFFLUENT				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	1.00	CY	5.50	5.5	30.00	165.00	111.38	111.38		0.00			276.38
	VALVES AND PIPING SPECIALTIES	1.00	LS	16.00	16.0	30.00	480.00	3150.00	3150.00		0.00			3,630.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
					0.0		0.00		0.00		0.00			0.00
15	CAUSTIC STORAGE TANK:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	32.00	32.0	30.00	960.00	200.00	200.00	6200.00	6200.00			7,360.00
	CAPACITY: 6,000 GALLONS				0.0		0.00		0.00		0.00			0.00
	SIZE: 8.0' DIA. X 16.0' HT. VERTICAL				0.0		0.00		0.00		0.00			0.00
	TYPE: VERTICAL ATMOSPHERIC STORAGE TANK				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	3.53	CY	5.50	19.4	30.00	583.16	111.38	393.63		0.00			976.79
	VALVES AND PIPING SPECIALTIES	1.00	LS	16.00	16.0	30.00	480.00	3150.00	3150.00		0.00			3,630.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
	TOTAL SHEET 9				340.0		10199.27		26153.01		21096.75	12750.00	5000.00	75,199.03

FILENAME: VORTECY.WK1

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MAT'L \$/EA	MATERIAL \$	UNIT COST PM PLY EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY				0.0		0.00		0.00		0.00			0.00
	DRY FEED, WET SCRUBBER ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
111	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
16	FLUE GAS SCRUBBER CAUSTIC FEED PUMPS:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	2.00	EA	24.00	48.0	30.00	1440.00	100.00	200.00	1293.75	2587.50			4,227.50
	CAPACITY: 40 GPM @ 60.0' TDH				0.0		0.00		0.00		0.00			0.00
	MOTOR: 1 HP				0.0		0.00		0.00		0.00			0.00
	TYPE: CENTRIFUGAL				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	1.00	CY	5.50	5.5	30.00	165.00	111.38	111.38		0.00			276.38
	VALVES AND PIPING SPECIALTIES	1.00	LS	16.00	16.0	30.00	480.00	3150.00	3150.00		0.00			3,630.00
					0.0		0.00		0.00		0.00			0.00
17	QUENCH TOWER WATER/CAUSTIC SLURRY FEED PUMPS:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	2.00	EA	24.00	48.0	30.00	1440.00	100.00	200.00	5821.88	11643.75			13,283.75
	CAPACITY: 100 GPM @ 60.0' TDH				0.0		0.00		0.00		0.00			0.00
	MOTOR: 5 HP				0.0		0.00		0.00		0.00			0.00
	TYPE: CENTRIFUGAL, LINED				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	1.00	CY	5.50	5.5	30.00	165.00	111.38	111.38		0.00			276.38
	VALVES AND PIPING SPECIALTIES	1.00	LS	16.00	16.0	30.00	480.00	3150.00	3150.00		0.00			3,630.00
					0.0		0.00		0.00		0.00			0.00
18	QUENCHED MATERIALS REMOVAL CONVEYOR:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	128.00	128.0	30.00	3840.00	500.00	500.00	11600.00	11600.00			15,940.00
	TYPE: DRAG FLIGHT				0.0		0.00		0.00		0.00			0.00
	CAPACITY: AS REQUIRED				0.0		0.00		0.00		0.00			0.00
	MOTOR: 5 HP WITH GEAR REDUCING DRIVE UNIT				0.0		0.00		0.00		0.00			0.00
	MISCELLANEOUS STEEL AND PLATE FOR INCLINED	1.00	LS	72.00	72.0	30.00	2160.00	7500.00	7500.00		0.00			9,660.00
	DISCHARGE TROUGH AND DISCHARGE CHUTE				0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
19	QUENCH TANK:				0.0		0.00		0.00		0.00		2500.00	0.00
	QUANTITY:	1.00	EA	224.00	224.0	30.00	6720.00	6885.00	6885.00		0.00			16,105.00
	TYPE: ABOVE GRADE, CARBON STEEL CONSTRUCTION				0.0		0.00		0.00		0.00			0.00
	CAPACITY:				0.0		0.00		0.00		0.00			0.00
	DIMENSIONS: +/- 20.0' LG X 4.0' X 4.0' SMD + FB				0.0		0.00		0.00		0.00			0.00
	SLOPED SIDEWALLS TO COLLECTION TROUGH				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	5.83	CY	5.50	32.1	30.00	962.50	111.38	649.69		0.00			1,612.19
	VALVES AND P													

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECY.WK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
III	VITRIFICATION FACILITY				0.0		0.00		0.00		0.00			0.00
	DRY FEED, WET SCRUBBER ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
	MAJOR EQUIPMENT				0.0		0.00		0.00		0.00			0.00
21	AIR COMPRESSOR:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	42.00	42.0	30.00	1260.00	250.00	250.00	17465.63	17465.63			18,975.63
	CAPACITY: 75 CFM @ 100 PSIG				0.0		0.00		0.00		0.00			0.00
	MOTOR: 5 HP				0.0		0.00		0.00		0.00			0.00
	TYPE: CENTRIFUGAL, COMPLETE W/RECIEVER				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	5.00	CY	5.50	27.5	30.00	825.00	111.38	556.88		0.00			1,381.88
	VALVES AND PIPING SPECIALTIES	1.00	LS	32.00	32.0	30.00	960.00	3150.00	3150.00		0.00			4,110.00
					0.0		0.00		0.00		0.00			0.00
22	VENTURI SCRUBBER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	288.00	288.0	30.00	8640.00	3500.00	3500.00	35000.00	35000.00			47,140.00
	INLET FLOW: 3,600 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 400 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/VC: -3				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-8,700 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - VENTURI SCRUBBER WITH ALL ANCILLARY				0.0		0.00		0.00		0.00			0.00
	SUPPORT SYSTEMS AND VENDOR CONTROLS				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	20.00	CY	5.50	110.0	30.00	3300.00	111.38	2227.50		0.00			5,527.50
	VALVES AND PIPING SPECIALTIES	1.00	LS	24.00	24.0	30.00	720.00	1520.00	1520.00		0.00			2,240.00
	INSTRUMENTATION	1.00	LS	24.00	24.0	30.00	720.00	3200.00	3200.00		0.00			3,920.00
	FREIGHT	1.00	LS		0.0		0.00		0.00		0.00		3300.00	3,300.00
	STARTUP ASSISTANCE	1.00	LS		0.0		0.00		0.00		0.00		3800.00	3,800.00
					0.0		0.00		0.00		0.00			0.00
23	WET ELECTROSTATIC PRECIPITATORS:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	2.00	EA	512.00	1024.0	30.00	30720.00	5000.00	10000.00	200000.00	400000.00			440,720.00
	INLET FLOW: 3,600 ACFM				0.0		0.00		0.00		0.00			0.00
	INLET TEMPERATURE: 400 F				0.0		0.00		0.00		0.00			0.00
	INLET PRESSURE, in/VC: -3				0.0		0.00		0.00		0.00			0.00
	MASS FLOW: +/-8,700 LBS/HR				0.0		0.00		0.00		0.00			0.00
	TYPE - WET/MOIST AIR INLET ELECTOSTATIC				0.0		0.00		0.00		0.00			0.00
	PRECIPITATORS WITH ANCILLARIES				0.0		0.00		0.00		0.00			0.00
	CAST-IN-PLACE CONCRETE FOUNDATION	33.60	CY	5.50	184.8	30.00	5544.00	111.38	3742.20		0.00			9,286.20
	VALVES AND PIPING SPECIALTIES	2.00	LS	24.00	48.0	30.00	1440.00	1520.00	3040.00		0.00			4,480.00
	INSTRUMENTATION	2.00	LS	24.00	48.0	30.00	1440.00	3200.00	6400.00		0.00			7,840.00
	FREIGHT	1.00	LS		0.0		0.00		0.00		0.00		18000.00	18,000.00
	STARTUP ASSISTANCE	1.00	LS		0.0		0.00		0.00		0.00		7600.00	7,600.00
					0.0		0.00		0.00		0.00			0.00
24	AIR REHEATER:				0.0		0.00		0.00		0.00			0.00
	QUANTITY:	1.00	EA	448.00	448.0	30.00	13440.00	5000.00	5000.00	32775.00	32775.00	15000.00	10000.00	76,215.00
	ALLOWANCE FOR AIR HEATER TO RAISE PARTIALLY				0.0		0.00		0.00		0.00			0.00
	TREATED COMBUSTION GASES TO ABOVE 400 DEGREES				0.0		0.00		0.00		0.00			0.00
	FOR ADDITIONAL DOWNSTREAM TREATMENT.				0.0		0.00		0.00		0.00			0.00
	(ALLOWANCE)				0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
	TOTAL SHEET 11				2300.3		69009.00		42586.58		485240.63	15000.00	42700.00	654,536.20

7-47

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECY.WK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MHR \$/MHR	DIRECT LABOR \$	UNIT COST MATERIAL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY				0.0		0.00		0.00		0.00			0.00
	DRY FEED, WET SCRUBBER ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
	METC COMBUSTION EQUIPMENT				0.0		0.00		0.00		0.00			0.00
IV					0.0		0.00		0.00		0.00			0.00
1	METC 25 TONS PER DAY (TPD) VITRIFICATION FACILITY: SEE VORTEC CORRESPONDENCE DATED MAY 24, 1993				0.0		0.00		0.00		0.00			0.00
	COMBUSTION AIR SUBSYSTEM -				0.0		0.00		0.00		0.00			0.00
A	BLOWER ASSEMBLY - BLOWER, BASEPLATE, CPLG AND GUARD, FILTER AND SILENCER AND DAMPER, 40 HP 460 VAC, 3 PHASE, 60 HZ TEFC MOTOR	1.00	EA	48.00	48.0	30.00	1440.00	200.00	200.00	13300.00	13300.00			14,960.00
					0.0		0.00		0.00		0.00			0.00
B	PIPING - RECUPERATOR TO CRV	1.00	LS	128.00	128.0	30.00	3840.00	20000.00	20000.00			4000.00		27,840.00
C	EXPANSION JOINT	1.00	EA	12.00	12.0	30.00	360.00	5300.00	5300.00					5,660.00
D	BALANCE VALVES - COMPLETE	2.00	EA	16.00	32.0	30.00	960.00	1766.00	3532.00					4,492.00
E	BLEED VALVE WITH ACTUATOR	1.00	EA	12.00	12.0	30.00	360.00	3095.00	3095.00					3,455.00
F	COMBUSTION AIR FLOW TO CRV	1.00	EA	22.50	22.5	30.00	675.00	3800.00	3800.00					4,475.00
G	COMBUSTION AIR FLOW TO RECUPERATOR	1.00	EA	22.50	22.5	30.00	675.00	3000.00	3000.00					3,675.00
H	COMBUSTION AIR FLOW TO PILOT BURNER CRV ASSEMBLY -	1.00	EA	28.50	28.5	30.00	855.00	5320.00	5320.00					6,175.00
					0.0		0.00		0.00		0.00			0.00
J	CRV	1.00	EA	239.25	239.3	30.00	7177.50	500.00	500.00	20475.00	20475.00			28,152.50
J	REFRACTORY	1.00	LOT		0.0		0.00	43740.00	43740.00			9975.00		53,715.00
K	CRV SUPPORTS	3.00	EA	16.00	48.0	30.00	1440.00	409.67	1229.00					2,669.00
L	MISCELLANEOUS	1.00	LS	35.50	35.5	30.00	1065.00	7753.00	7753.00					8,818.00
	CYCLONE MELTER ASSEMBLY -				0.0		0.00		0.00		0.00			0.00
M	GLASS MELTER	1.00	EA	184.88	184.9	30.00	5546.25	500.00	500.00	15225.00	15225.00			21,271.25
N	SUPPORTS	4.00	EA	8.00	32.0	30.00	960.00	100.75	403.00					1,363.00
O	REFRACTORY	1.00	LOT		0.0		0.00	22084.00	22084.00			9975.00		32,059.00
P	MISCELLANEOUS	1.00	LS	27.50	27.5	30.00	825.00	3423.00	3423.00					4,248.00
	SEPARATOR/RESERVOIR -				0.0		0.00		0.00		0.00			0.00
Q	STEEL WELDMENT/FABRICATION	1.00	EA	239.25	239.3	30.00	7177.50	200.00	200.00	11500.00	11500.00			18,877.50
R	REFRACTORY	1.00	LOT		0.0		0.00	55200.00	55200.00			24800.00		80,000.00
S	BURNER AND APPURTENANCES	1.00	LS	80.00	80.0	30.00	2400.00	500.00	500.00	25000.00	25000.00			27,900.00
T	HEATING ELEMENTS AND CONTROLS	1.00	LS	96.00	96.0	30.00	2880.00	5156.00	5156.00	20000.00	20000.00			28,036.00
	FLUE GAS SUBSYSTEM -				0.0		0.00		0.00		0.00			0.00
U	RECUPERATOR ASSEMBLY	1.00	LS	52.80	52.8	30.00	1584.00	300.00	300.00	64200.00	64200.00			66,084.00
	BATCH HANDLING/FEEDING SUBSYSTEM -				0.0		0.00		0.00		0.00			0.00
V	BATCH EQUIPMENT - SKID MOUNTED	4.00	ASSY	64.00	256.0	30.00	7680.00	300.00	1200.00	73000.00	292000.00			300,880.00
W	BATCH TRANSPORT AIR FLOW MEASUREMENT	1.00	LS	18.00	18.0	30.00	540.00	2810.00	2810.00					3,350.00
	GAS DISTRIBUTION SUBSYSTEM -				0.0		0.00		0.00		0.00			0.00
X	MAIN GAS CONTROLS AND FLAME SAFETY	1.00	ASSY	96.00	96.0	30.00	2880.00	500.00	500.00	29000.00	29000.00			32,380.00
Y	GAS FLOW MEASUREMENT	1.00	LS	24.00	24.0	30.00	720.00	2810.00	2810.00					3,530.00
	COOLING WATER CIRCULATING SUBSYSTEM -				0.0		0.00		0.00		0.00			0.00
Z	RUBBER HOSE	2400.00	LF	0.10	228.0	30.00	6840.00	1.00	2400.00					9,240.00
AA	HOSE FITTINGS, CLAMPS AND VALVES	1.00	LS	159.60	159.6	30.00	4788.00	7140.00	7140.00					11,928.00
AB	COOLING SYSTEM DEVICES	1.00	LS	72.00	72.0	30.00	2160.00	10275.00	10275.00					12,435.00
					0.0		0.00		0.00		0.00			0.00
	SUPPLEMENTARY SUPPORT STEEL	5.00	TONS	32.50	162.5	30.00	4875.00	1235.00	6175.00			1500.00		12,550.00
	TOTAL SHEET 12				2356.8		70703.25		218545.00		490700.00	50250.00	0.00	830,198.25

FILENAME: VORTECY.WK1

[illegible]

ROY F. WESTON, INC.
WEST CHESTER, PENNSYLVANIA

FILENAME: VORTECY.WK1

CLIENT :VORTEC CORPORATION
LOCATION :10189-001-001-0001-00

COST/ITEM CODE	DESCRIPTION	QUANTITY	UNIT	UNIT MAN HOURS	MANHOURS	LABOR RATE PER MNR \$/MNR	DIRECT LABOR \$	UNIT COST MATEL \$/EA	MATERIAL \$	UNIT COST PM PLT EQUIP \$/EA	PERMANENT PLANT EQUIP \$	SUBCONTRACTS \$	MISC OTHER COSTS \$	TOTAL \$
	VITRIFICATION FACILITY				0.0		0.00		0.00		0.00			0.00
	DRY FEED, WET SCRUBBER ALTERNATIVE				0.0		0.00		0.00		0.00			0.00
	ELECTRICAL AND INSTRUMENTATION				0.0		0.00		0.00		0.00			0.00
V					0.0		0.00		0.00		0.00			0.00
1	ELECTRICAL WORK AS REQUIRED:	1.00	LS	960.00	960.0	30.00	28800.00	22250.00	22250.00	63250.00	63250.00		5000.00	119,300.00
	FEEDER CIRCUITS, CONDUIT AND TRAY				0.0		0.00		0.00		0.00			0.00
	BRANCH CIRCUITS, CONDUIT AND TRAY				0.0		0.00		0.00		0.00			0.00
	WIRE AND CABLE				0.0		0.00		0.00		0.00			0.00
	DEVICES				0.0		0.00		0.00		0.00			0.00
	FIXTURES				0.0		0.00		0.00		0.00			0.00
	PANELS, LIGHTING AND OTHER				0.0		0.00		0.00		0.00			0.00
	MOTOR CONTROL CENTER				0.0		0.00		0.00		0.00			0.00
	SUBSTATION AND SWITCHGEAR				0.0		0.00		0.00		0.00			0.00
	LIGHTING				0.0		0.00		0.00		0.00			0.00
	GROUNDING				0.0		0.00		0.00		0.00			0.00
	LIGHTNING PROTECTION				0.0		0.00		0.00		0.00			0.00
	HEAT TRACING				0.0		0.00		0.00		0.00			0.00
2	INSTRUMENTATION:				0.0		0.00		0.00		0.00			0.00
A	CENTRAL CONTROL PANEL WITH PROGRAMMABLE LOOP	1.00	LS		0.0		0.00		0.00		0.00	45000.00		45,000.00
	CONTROLLERS, ANNUNCIATORS AND STOP/START				0.0		0.00		0.00		0.00			0.00
	PUSHBUTTONS, SELECTOR SWITCHES, AND				0.0		0.00		0.00		0.00			0.00
	INDICATORS				0.0		0.00		0.00		0.00			0.00
B	PC BASED DATA ACQUISITION SYSTEM WITH PRINTER	1.00	LS		0.0		0.00		0.00		0.00	10000.00		10,000.00
C	PROGRAMMABLE LOGIC CONTROLLER(S) (PLC)	1.00	LS		0.0		0.00		0.00		0.00	32200.00		32,200.00
					0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
	INSTRUMENT I/O LISTING				0.0		0.00		0.00		0.00			0.00
	ANALOG INPUT (AI)	65.00	EA	2.50	162.5	30.00	4875.00		0.00		0.00			4,875.00
	ANALOG OUTPUT (AO)	23.00	EA	2.50	57.5	30.00	1725.00		0.00		0.00			1,725.00
	DIGITAL INPUT, 24 VDC (DI)	52.00	EA	2.50	130.0	30.00	3900.00		0.00		0.00			3,900.00
	DIGITAL INPUT, 110 VAC (DI)	29.00	EA	2.50	72.5	30.00	2175.00		0.00		0.00			2,175.00
	DRY RELAY OUTPUTS	57.00	EA	4.00	228.0	30.00	6840.00		0.00		0.00			6,840.00
	TOTAL CONTROL LOOPS	25.00	EA	16.00	400.0	30.00	12000.00		0.00		0.00			12,000.00
D	SOFTWARE	1.00	LS		0.0		0.00		0.00		0.00	40000.00		40,000.00
E	INSTRUMENT CALIBRATION	1.00	LS		0.0		0.00		0.00		0.00	15000.00		15,000.00
F	CONTINUOUS EMISSION MONITORING SYSTEM (CEM)	1.00	LS	128.00	128.0	30.00	3840.00	5000.00	5000.00	50000.00	50000.00			58,840.00
	(O2, CO, NOX, CO2, AND OPACITY)				0.0		0.00		0.00		0.00			0.00
					0.0		0.00		0.00		0.00			0.00
	NOTE: ABOVE COSTS ALLOWS FOR 25%				0.0		0.00		0.00		0.00			0.00
	ADDITIONAL INPUTS				0.0		0.00		0.00		0.00			0.00
	TOTAL SHEET 14				2138.5		64155.00		27250.00		113250.00	142200.00	5000.00	351,855.00

FILENAME: VORTECY.WK1

[illegible]

SECTION 8

REFERENCES

U.S. EPA, 1991. Radiation and Mixed Waste Incineration: Background Information Document. Air and Radiation Research and Development, EPA 520/1-91-010-1, May 1991.

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