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**QUARTERLY TECHNICAL PROGRESS REPORT
FOR THE DEVELOPMENT
OF "A COAL-FIRED COMBUSTION SYSTEM FOR
INDUSTRIAL PROCESS HEATING APPLICATIONS"**

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CONTRACT DE-AC22-91PC91161

APRIL 1995 - JUNE 1995

PREPARED FOR

**U.S. DEPARTMENT OF ENERGY
PITTSBURGH ENERGY TECHNOLOGY CENTER**

PREPARED BY

**VORTEC CORPORATION
3770 RIDGE PIKE
COLLEGEVILLE, PA 19426**

AUGUST 1995

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This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

1.0 EXECUTIVE SUMMARY

PETC has implemented a number of advanced combustion research projects that will lead to the establishment of a broad, commercially acceptable engineering data base for the advancement of coal as the fuel of choice for boilers, furnaces, and process heaters. Vortec Corporation's Phase III development contract DE-AC22-91PC91161 for a "Coal-Fired Combustion System for Industrial Process Heating Applications" is a project funded under the DOE/PETC advanced combustion program.

This advanced combustion system research program is for the development of innovative coal-fired process heaters which can be used for high temperature melting, smelting and waste vitrification processes. The process heater systems to be developed have multiple use applications; however, the Phase III research effort is being focused on the development of a process heater system to be used for producing value added vitrified glass products from boiler/incinerator ashes and industrial wastes. The primary objective of the Phase III project is to develop and integrate all the system components, from fuel through total system controls, and then test the complete system in order to evaluate its potential marketability.

During the past quarter, the major effort was concentrated on conducting the 100 hour demonstration test. The test was successfully conducted from September 12th through the 16th.

The test program consisted of one test run, with a duration of 100 hours at a nominal feed rate of 1000 lbs/hr. Throughout the test, the CMS was fired with coal and a coal by-product (i.e. coal-fired boiler flyash) as the primary fuels. Natural gas was used as an auxiliary fuel as necessary to provide process trim. The feedstock consisted of a coal-fired utility boiler flyash and dolomite and produced a stable, fully-reacted vitrified product. The fly ash, supplied by PENELEC, contained between 6 and 12% by weight of carbon because of the low NO_x burners on the PENELEC boilers. Therefore, a substantial portion of the required thermal input came from the flyash.

The data from the test was reduced and was incorporated into a comprehensive Final Report. A draft of the Final Report has been submitted to DOE for review.

2.0 INTRODUCTION/BACKGROUND

2.1 Introduction

The Pittsburgh Energy Technology Center (PETC) of the U.S. Department of Energy awarded Vortec Corporation this Phase III contract (No. DE-AC22-91PC91161) for the development of "A Coal-Fired Combustion System for Industrial Process Heating Applications". The effective contract start date was September 3, 1991. The contract period of performance is 36 months. The program established by this contract is described below.

2.2 Background

PETC has implemented a number of advanced combustion research projects that will lead to the establishment of a broad, commercially acceptable engineering data base for the advancement of coal as the fuel of choice for boilers, furnaces, and process heaters. This includes new installations and those existing installations that were originally designed for oil or gas firing. The data generated by these projects must be sufficient for private-sector decisions on the feasibility of using coal as the fuel of choice. This work should also provide incentives for the private sector to continue and expand the development, demonstration, and application of these combustion systems. Vortec Corporation's Coal-Fired Combustion System for Industrial Process Heating Applications is being developed under contract DE-AC22-91PC91161 as part of this DOE development program. The current contract represents the third phase of a three-phase development program. Phase I of the program addressed the technical and economic feasibility of the process, and was initiated in 1987 and completed 1989. Phase II was initiated in 1989 and completed in 1990. During Phase II of the development, design improvements were made to critical components and the test program addressed the performance of the process using several different feedstocks. Phase III of the program was initiated September 1991 and is scheduled for completion in 1994. The Phase III research effort is being focused on the development of a process heater system to be used for producing value-added vitrified glass products from boiler/incinerator ashes and selected industrial wastes.

This coal-fired process heater system is unique in several important aspects. The important advantages of the technology are as follows:

1. Significantly lower capital cost as compared to conventional gas/oil-fired and electric furnaces.
2. Substantially higher thermal efficiency as compared to conventional gas/oil-fired melting furnaces.
3. Satisfaction of projected future emission requirements for NO_x, SO_x and particulates.
4. The process heater system has a degree of operational flexibility unmatched by conventional fossil fuel fired glass melting or mineral wool systems. Several of the unique operational capabilities of this innovative technology include: multi-fuel use capability (including coal, coal slurry, petro-coke, oil and gas), rapid product changeover, and rapid startup/shutdown.

The primary components of the CMS are a counter-rotating suspension preheater and a cyclone melter. An artist rendering of the basic CMS concept is shown in Figure 2.2-1.

Coal combustion and in-flight suspension preheating of the batch ingredients take place in a counter-rotating vortex (CRV) combustion preheater. The ash and other feedstock materials are introduced into the CRV preheater through an injector assembly and are rapidly heated in the flame zone. Any unburned carbonaceous materials are rapidly volatilized and incinerated. The inert materials are heated to nominally 2200°F to 2900°F, depending on the feedstocks utilized, prior to entering the cyclone melter. Combustion air preheated to nominally 1000°F to 1400°F is used in the process. Therefore, high local flame temperatures (>4000°F) are achieved in the CRV preheater. However, NO_x emissions have been demonstrated in the pilot scale CMS to be low; typically less than 200 ppm.

Rapid temperature quenching of the combustion products by the inert waste glass particles and staged combustion provide an effective means of limiting NO_x emissions. The system also has the capability of utilizing natural gas reburning for additional NO_x control. The rapid temperature quenching and the staged combustion which occurs within the CMS are perceived to be the primary controlling mechanisms for reduced NO_x emissions. Experimental data obtained during the course of feasibility experiments with the pilot-scale

Figure 2.2-1. Artist Rendering of Basic CMS

CMS indicate NO_x emissions are lower than the California emission standards (4.5 lbs per ton of glass produced) for glass melting furnaces. In this regard, it should be noted that the California glass melting emission standards for NO_x are currently the most stringent in the United States.

The use of low sulfur or beneficiated coals is the initial approach for the control of SO_x emissions. However, since sodium containing compounds and limestone are ingredients used as fluxes for melting the incinerator ash, there are demonstrated reductions of SO_x emissions from the combustion of medium or high sulfur coals in the recycling system by sodium or limestone injection. The sulfates formed can be effectively removed by an electrostatic precipitator, bag house, or flue gas scrubber. Residual SO₂ or HCl emissions can be reduced using commercially available downstream acid gas scrubbers.

The preheated solid materials from the CRV preheater enter the cyclone melter where they are distributed to the chamber walls by cyclonic action to form a molten glass layer. The glass produced and the exhaust products exit the cyclone melter through a tangential exit channel and enter the separator/reservoir. The separator/reservoir separates the combustion products from the melted glass and provides a reservoir of hot glass for proper interfacing with product forming equipment. The hot exhaust products exit through an exhaust port which ties into a conventional radiation type recuperator with a nominal 1000°F to 1400°F delivered air preheat capability.

The particulate removal/stack assembly quenches the flue gas temperature exiting the radiation recuperator to 700-750°F by use of a water quench or air dilution system. Commercially available particulate control devices are incorporated into the design as dictated by local environmental regulations. The uncontrolled particulate emission levels of the CMS are about the same as conventional gas-fired glass melting furnaces. Therefore, the use of commercially available particulate control devices will be incorporated into the design as dictated by local flue gas emission regulations. Pilot plant testing to date indicates that a venturi scrubber will be suitable for some applications; however, wet or dry electrostatic precipitators may be necessary to achieve higher levels of particulate emissions control.

A process diagram of a Vortec CMS-based commercial ash vitrification and recycling system is shown in Figure 2.2-2. The basic elements of a commercial ash vitrification and recycling system include:

1. The Vortec multifuel-capable Combustion and Melting System (CMS), consisting of a counter-rotating vortex (CRV) combustor and a cyclone melter;
2. an upstream storage and feeding subsystem;
3. a separator/reservoir assembly;
4. a cullet handling and delivery subsystem;
5. a heat recovery subsystem;
6. a flue gas conditioning/distribution assembly; and
7. a particulate removal/stack assembly.

FV105

Figure 2.2-2. Vortec Ash Vitrification And Recycling System

Except for the CMS and the separator/reservoir, all other subsystems or assemblies are commercially available or modified versions of commercially available equipment. The basic CMS can be modified to accommodate the use of a variety of fuels, including pulverized coal, coal slurry fuels, natural gas, and oil. In some coal-fired applications, pulverized coal can be injected and burned directly in the counter-rotating vortex (CRV) preheater. In other coal-fired applications, the use of a pulverized coal precombustor is advantageous.

Boiler or incinerator ash is delivered to storage bins located within the processing facility. Additives required to produce a suitable product are stored in separate storage bins. The ash and additives are mixed on a batch basis and stored in a feedstock storage bin. The feedstock is then delivered via pneumatic transport or other means to the CMS. Pulverized coal, when used as the primary fuel, is delivered to the process facility in pneumatic transport vehicles and stored in a storage bin. The coal is then delivered via pneumatic transport to the CMS.

2.3 Objectives

This contract is the third phase of a three-phase R&D program which was initiated during March 1987. The objective of the program is to develop an advanced industrial process heater capable of using pulverized coal or coal-derived fuels as the primary fuel.

The objective of Phase I of the program was to verify the technical feasibility and economic benefits of Vortec's advanced Combustion and Melting System (CMS) technology using coal as the fuel of choice. Phase I consisted of two segments, Phase I-A and Phase I-B. During Phase I-A, detailed designs of a proof-of-concept scale coal-fired CMS and the supporting test facilities were completed. It also included tradeoff studies and techno-economic studies to cost optimize the advanced process heater and to evaluate the technical and economic feasibility of the process heater system. In Phase I-B of the program, critical components were tested to validate the feasibility of the Vortec process heater for glass melting with coal as the primary fuel. This phase involved the fabrication, installation and operation of a 3 to 5 x 10⁶ Btu/hr coal-fired CMS test loop at Vortec's high temperature process test facility in Harmarville, PA. Glass melting with 100% coal firing was effectively demonstrated with minimal contamination effects. Glass cullet was the primary process feedstock during the Phase I test program. A conceptual design of a commercial scale CMS glass melter was also developed and techno-economic studies were continued.

The primary objective of the Phase II effort was to improve the performance of the primary components and demonstrate the effective operation of a subscale process heater system integrated with a glass separator/reservoir. The impact of coal ash on glass production quality was assessed and the melting of more complex glasses was evaluated during this phase. Additionally, due to Vortec's commitment to commercialize the process heater technology it is developing with DOE's support, we have analyzed several different markets, particularly in the areas of waste material recycling, in which the Vortec process heater system will offer unique technical and cost advantages. Some preliminary testing was performed using Vortec's pilot scale test system to demonstrate the feasibility of application of the Vortec process heater to these markets with encouraging results.

The primary objective of the Phase III project is to develop and integrate all the system components, from fuel through total system controls, and then test the complete system in order to evaluate its potential marketability. Vortec's primary target market for Phase III is boiler/incinerator ash vitrification. A secondary market application is the oxidation/vitrification of waste glass materials into glass frits which can be recycled into existing glass furnace operations. Potential end uses of the glass products include: mineral fiber manufacturing, glass frits, and aggregates. The glass frits produced can be used as filler for road base asphalt, granules for asphalt shingles and filler for bricks and concrete blocks. Aggregates can also be produced for landscaping and backfill applications.

3.0 PROJECT DESCRIPTION

3.1 Program Description

To accomplish objectives outlined in Section 2.3, Vortec will supply all the necessary personnel, facilities, materials, and services to execute the tasks in the contract Statement of Work. The program is divided into seven (7) technical tasks and a program management task distributed over 36 months as shown in Figure 3.1-1. The tasks in the contract's Statement of Work are provided below in Table 3.1-1.

DOE F 1332.3 (11 84)		U.S. DEPARTMENT OF ENERGY MILESTONE SCHEDULE ☐ PLAN ☒ STATUS REPORT		FORM APPROVED OME NO 1901-1400																											
1. TITLE A Coal-Fired Combustion System For Industrial Heating Applications		2. REPORTING PERIOD 10/1/94-12/31/94		3. IDENTIFICATION NUMBER DE-AC22-91PC21161																											
4. PARTICIPANT NAME AND ADDRESS VORTEC CORPORATION 3770 RIDGE PIKE COLLEGEVILLE, PA 19426		5. START DATE 9/3/91		6. COMPLETION DATE 6/30/95																											
7. ELEMENT CODE	8. REPORTING ELEMENT	9. DURATION												10. PERCENT COMPLETE																	
		FY 94												FY 95				FY 96													
		O	N	D	J	F	M	A	M	J	J	A	S	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4					plan	actual				
1.0	Design, Fab. & Integ. Component	████████████████████																													
1.1	Component Design	████████████████████																													
1.2	Component Fabrication	████████████████████																													
1.3	Component Integration	████████████████████																													
2.0	Prelim. System Tests	████████████████████																													
2.1	Test Plan	████████████████████																													
2.2	System Tests	████████████████████																													
3.0	Proof-of-Concept Tests	████████████████████																													
4.0	Economic/Comm. Plan	████████████████████																													
4.1	Economic Evaluation	████████████████████																													
4.2	Commercialization Plan	████████████████████																													
5.0	Conduct Site Demonstration	████████████████████																													
5.1	Demonstration Plan	████████████████████																													
5.2	Site Demonstration	████████████████████																													
6.0	Decommission Facility	████████████████████																													
7.0	Program Manag. & Reporting	████████████████████																													
8.0	TSCA Ash Testing	████████████████████																													
11. SIGNATURE OF PARTICIPANT'S PROJECT MANAGER AND DATE																															

Figure 3.1-1. Phase III Program Schedule

Vortec Corporation

Table 3.1-1. Phase III Work Breakdown Structure

Task 1 -	Design, Fabricate, and Integrate Components
	Subtask 1.1 - Component Design
	Subtask 1.2 - Component Fabrication
	Subtask 1.3 - Component Integration
Task 2 -	Perform Preliminary System Tests
Task 3 -	Perform Proof-of-Concept System Tests
Task 4 -	Evaluate Economics/Prepare Commercialization Plan
	Subtask 4.1 - Economic Evaluation
	Subtask 4.2 - Commercialization Plan
Task 5 -	Conduct Site Demonstration
	Subtask 5.1 - Demonstration Plan
	Subtask 5.2 - Site Demonstration
Task 6 -	Decommission Test Facility
Task 7 -	Program Management and Reporting
Task 8 -	TSCA Ash Testing
	Subtask 8.1 - Laboratory Analysis & Surrogate Definition
	Subtask 8.2 - Pilot-Scale Testing

3.2 Background Patents and Proprietary Data

The basic elements of the proposed coal-fired Vortec Process heater are embodied in U. S. Patent 4,544,394 dated Oct. 1, 1985 and U.S. Patent 4,553,997 dated Nov. 19, 1985. Patent No. 4,957,527, dated September 18, 1990 was filed in accordance with OMB Circ. A-127 Trans. Memo No. 1, patent rights small business firms or non-profit organizations (April 1984). Vortec Corporation has elected to retain title licensing and royalty rights to this patent as per provisions under Contract No. DE-AC22-87PC79651, dated March 11, 1987. Vortec Corporation is in the process of filing additional patents for its process heaters, and will use proprietary information in the execution of this program. Procedures for protecting this proprietary information have been implemented with our subcontractors and consultants via non-disclosure/patent agreements.

Vortec Corporation

4.0 PROJECT STATUS

During the past quarter, the major effort has focused on completing the final technical report. The following is a summary of the work completed.

Vortec Corporation and the Department of Energy, Pittsburgh Energy Technology Center (PETC), have completed a three phase research and development program which has resulted in the development and commercialization of a process heater, capable of being fueled by pulverized coal, natural gas, and other solid, gaseous, or liquid fuels, for the vitrification of industrial wastes.

Phase I of the program, initiated in 1987 and completed in 1989, addressed the technical and economic feasibility of the process via the design, fabrication, installation, and feasibility testing of a nominal 15 ton/day system. Phase II of the program, initiated in 1989 and completed in 1990, implemented design improvements to critical components and addressed the performance of the process using several different feedstocks. The Phase III research effort, which began in 1991 and culminated in a 105 hour demonstration test in September 1994, focused on the development of a process heater system to be used for producing value added glass products from the vitrification of boiler/incinerator ashes and industrial wastes. The primary objective of the Phase III project was to develop and integrate all the system components, from fuel through total system controls, and then test the complete system in order to evaluate its potential for successful commercialization.

Ninety-seven major tests have been performed on the nominal 15 ton/day advanced combustion and melting system (CMSTTM) since its construction in 1989, as shown in Table 4.0-1. The system has been operated for more than 835 hours processing more than 457,500 lbs of glass and waste materials listed in Table 4.0-2. Seventy-five tests were performed during the Phase III performance period with 22 of those supported by the DOE/PETC program. Phase III culminated with an extended duration demonstration test of the 15 ton/day CMSTTM.

The demonstration test consisted of one test run, with a duration of 105 hours, approx. one-half (46 hours) performed with coal as the primary fuel source (70% to 100%), the other half with natural gas. Approximately 50 hours of melting operation were performed vitrifying approx. 25 tons of coal-fired utility boiler flyash/dolomite mixture, producing a fully-reacted vitrified product. The flyash, supplied by Pennsylvania Electric Company (PENELEC), contained approximately 4% by weight of carbon. Therefore, the flyash/dolomite mixture (60%/40% by weight) provided approximately 10% of the total energy input to the vitrification system.

Table 4.0-1
Vortec Subscale CMS™ Test Operations Summary

VORTEC PILOT SCALE CMS - TEST OPERATIONS SUMMARY						
Test Run Number	Date	Fuel Type	Oxidant	Feedstock	Test Duration (hrs.)	Batch Quantity Melted (lbs)
1	5/17/89	Nat. Gas	Air	Bassichis GL-70 Cullet	1.0	1,000
2	5/31/89	Nat. Gas	Air	Bassichis GL-70 Cullet	4.0	3,680
3	6/14/89	Nat. Gas	Air	Bassichis GL-70 Cullet	6.0	7,873
4	6/22/89	Nat. Gas	Air	Potter's D-Dust	4.5	5,016
5	6/29/89	Nat. Gas	Air	Potter's D-Dust	5.5	8,340
6	7/11/89	Nat. Gas	Air	Potter's D-Dust	6.0	9,148
7	7/18/89	Nat. Gas	Air	Potter's D-Dust	8.0	9,148
8	8/29/89	Nat. Gas & Coal	Air	Bassichis GL-70 Cullet	5.5	5,700
9	9/7/89	Nat. Gas & Coal	Air	Bassichis GL-70 Cullet	6.5	4,200
10	9/14/89	Nat. Gas & Coal	Air	Bassichis GL-70 Cullet	9.0	5,653
11	9/28/89	Nat. Gas & Coal	Air	Bassichis GL-70 Cullet	4.0	7,300
12	10/25/89	Nat. Gas & Coal	Air	Fiberglass Blowing Wool	2.8	2,000
13	10/30/89	Nat. Gas	Air	Fiberglass Blowing Wool	8.0	3,350
14	11/21/89	Nat. Gas	Air	Bassichis GL-70 Cullet & Fiberglass Blowing Wool	4.5	4,360
15	12/7/89	Nat. Gas & Coal	Air	Ground Fiberglass Blowing Wool	7.5	640
16	12/14/89	Nat. Gas & Coal	Air	Blowing Wool	3.5	0
17	1/17/90	Nat. Gas	Air	Potters Roth Bros.	5.0	3,870

Table 4.0-1
Vortec Subscale CMS™ Test Operations Summary
(Continued)

VORTEC PILOT SCALE CMS - TEST OPERATIONS SUMMARY						
Test Run Number	Date	Fuel Type	Oxidant	Feedstock	Test Duration (hrs.)	Batch Quantity Melted (lbs)
18	2/13/90	Nat. Gas & Coal	Air	Duquesne Flyash	2.8	1,262
19	2/20/90	Nat. Gas & Coal	Air	Flyash & GL-70 cullet	4.5	4,215
20	3/15/90	Nat. Gas & Coal	Air	Flyash	2.3	2,000
21	11/13/90 11/16/90	Nat. Gas & Coal	Air	Soda Ash & Silica Sand	60.0	8,335
22A	12/17/90 thru 12/18/90	Nat. Gas	Air	Blowing Wool	17.5	622
22B	12/17/90 thru 12/18/90	Nat. Gas	Air	Blowing Wool	x	x
23	1/21/91	Nat. Gas	Air	Blowing Wool	8.0	700
24	4/24/91 thru 4/26/91	Nat. Gas & Coal	Air	Wool/Board	32.0	3,750
25	5/23/91	Nat. Gas & Coal	Air	Foil board	5.3	2,500
26.1	6/26/91	Nat. Gas	Air	Duquesne 70% utility FA 30% limestone	7.5	5,865
26.2	6/26/91 thru 6/27/91	Nat. Gas	Air	Duquesne 70% utility FA 30% limestone	3.0	x
27	8/21/91	Nat. Gas	Air	Duquesne 60% utility FA 40% limestone	8.0	8,300
28	SEPARATOR / RESERVOIR MELT OUT					
29	9/16/91	Nat. Gas	Air	Duquesne 60% utility FA 40% limestone	10.0	7,134
30	10/10/91	Nat. Gas	Air	Res Fiberglass	4.0	668
31	4/29/92	Nat. Gas	Air	Sewage Sludge Ash	7.5	3,602
32	4/29/92	Nat. Gas	Air	MSW Flyash Northeast	6.0	3,644

Table 4.0-1
Vortec Subscale CMS™ Test Operations Summary
(Continued)

VORTEC PILOT SCALE CMS - TEST OPERATIONS SUMMARY						
Test Run Number	Date	Fuel Type	Oxidant	Feedstock	Test Duration (hrs.)	Batch Quantity Melted (lbs)
33	4/30/92	Nat. Gas	Air	Consumer Waste Cullet	5.5	4,160
34	6/17/92	Nat. Gas & Oxy	Oxygen	Consumer Waste Cullet	5.0	1,714
35	6/17/92	Nat. Gas	Air	Textile Fiber-glass Waste	4.0	4,800
36.1 36.2	6/18/92	Nat. Gas	Air	Surrogate Soil Site-4	6.0	4,818
37	7/22/92	Coal Char	Air	Industrial Boiler Flyash HC - Narrows	9.0	4,908
38	7/22/92	Nat. Gas	Air	MSW Incinerator Ash (RWS)	2.0	1,904
39	CANCELLED					
40	7/23/92	Nat. Gas	Air	Waste Fiberglass		450 (Unisol @ 25lb/2min)
41	9/15/92 thru 9/16/92	Nat. Gas	Air	Waste Fiberglass	8.5	4,400
42	9/16/92	Nat. Gas & Coal	Air	Alcosan Sewage Sludge Ash	6.8	3,252
43	9/16/92 thru 9/17/92	Nat. Gas	Air	Lead Reinjection w/ Glass Cullet	3.8	3,500
44	9/17/92	Nat. Gas	Air	Lead Reinjection w/ Canadian MSW Flyash	1.0	654
45	9/17/92	Coal	Air	Glass Cullet	7.3	4,232
46	12/7/92 thru 12/9/92	Nat. Gas	Air	Vetrotex Waste Fiber Glass	43.5	14,270
47	1/6/93	Nat. Gas	Air	Plate Glass Cullet	11.0	10,450
48	12/9/92	Nat. Gas	Air	EPA Site 04 Slurry Sys. Test	2.0	0
49	CANCELLED					

Table 4.0-1
Vortec Subscale CMS™ Test Operations Summary
(Continued)

VORTEC PILOT SCALE CMS - TEST OPERATIONS SUMMARY						
Test Run Number	Date	Fuel Type	Oxidant	Feedstock	Test Duration (hrs.)	Batch Quantity Melted (lbs)
50	2/5/93 2/6/93	Nat. Gas & Coal	Air	HC Flyash w/ swarf	1.0	700
51	3/8/93 3/9/93	Nat. Gas	Air	RGR Container Cullet	25.0	22,500
52	3/9/93 3/10/93	Nat. Gas	Air	RGR Vetrotex Textile Fiber	14.0	12,600
53	4/6/93	Nat. Gas	Air	CertainTeed Waste Fiberglass	8.0	2,400
54	4/7/93	Nat. Gas	Air	SITE 04 Slurry Sys. Test	1.5	900
55	5/4/93	Nat. Gas	Air	Ormet Surrogate Potliners Anthracite Mixed 10 % by weight	10.0	1,820
56	CANCELLED					
57	5/4/93 5/5/93	Nat. Gas	Air	METC Surrogate Soil	3.0	1,950
58	5/5/93	Nat. Gas	Air	SITE 04	7.0	2,100
59	5/7/93	Nat. Gas	Air	CertainTeed Fiberglass Acoustical Board	3.0	3,000
60	6/14/93	Nat. Gas	Air	Ben Franklin 20% Virgin & 80% Virgin	19.0	15,200
61a	6/15/93	Nat. Gas	Air	METC Contaminated Soil	7.0	3,000
61b	6/15/93	Nat. Gas	Air	METC Contaminated Soil	4.0	2,000
62	6/16/93	Nat. Gas	Air	Ormet SPL	3.0	918
63	7/13/93 to 7/15/93	Nat. Gas	Air	Hanford Simulate Dry & Liquid Utility Metal	9.5	5,800
64	7/20/93	Nat. Gas	Air	Soda Ash, Zn Sulfate, Cu Carb., Ni Carb.	3.5	3,000
65	7/20/93	Nat. Gas	Air	Utility Metal Soda Ash, Cu Carbonate	2.0	1,600

Table 4.0-1
Vortec Subscale CMS™ Test Operations Summary
(Continued)

VORTEC PILOT SCALE CMS - TEST OPERATIONS SUMMARY						
Test Run Number	Date	Fuel Type	Oxidant	Feedstock	Test Duration (hrs.)	Batch Quantity Melted (lbs)
66	7/21/93	Nat. Gas	Air	Utility Metal Soda Ash, Ni Carbonate	4.5	1,400
67	7/21/93	Nat. Gas	Air	Utility Metal Soda Ash, Zn Sulfate	3.5	2,500
68	8/17/93	Nat. Gas	Air	Ormet SPL	3.0	700
69	8/18/93	Nat. Gas	Air	Ormet SPL	4.0	750
70	8/19/93	Nat. Gas	Air	Ormet SPL	3.0	700
71	8/19/93	Nat. Gas	Air	Hoechst Celanese	2.8	900
72	9/14/93	Nat. Gas	Air	CertainTeed Fiberglass Acoustical Brd, Sludge, Paper	11.0	8,000
73	28-Sep to 9/29/93	Nat. Gas	Air	Ferro Soft & Hard Frit, Borax	21.0	5,500
74	12/6/93	Nat. Gas	Air	System Flush Cullet & Soda Ash	5.0	4,000
75	12/7/93	Nat. Gas	Air	TSCA RWS Flyash & NE MSWI Flyash	10.0	5,116
76	12/8/93	Nat. Gas	Air	TSCA RWS Flyash & NE MSWI Flyash	9.5	4,872
77	12/9/93	Nat. Gas	Air	Ormet SPL, Limestone, Cullet, Sand	4.5	2,700
78	1/11/94 1/12/94	Nat. Gas	Air	Batch feed testing Duquesne Light & Limestone	14.0	3,000
79	4/12/94	Nat. Gas	Air	50% Container Batch, 50% Container Cullet	20.5	16,500
80	5/17/94	Nat. Gas	Air	Flint Container Cullet	4.0	4,000
81	5/18/94	Nat. Gas	Air	50% Container Batch, 50% Container Cullet	11.6	8,400
82	5/19/94	Nat. Gas	Air	Sodium Silicate Batch	8.0	3,000

Table 4.0-1
Vortec Subscale CMS™ Test Operations Summary
(Continued)

VORTEC PILOT SCALE CMS - TEST OPERATIONS SUMMARY						
Test Run Number	Date	Fuel Type	Oxidant	Feedstock	Test Duration (hrs.)	Batch Quantity Melted (lbs)
83	6/7/94	Nat. Gas	Air	ASR Ash	2.7	1,250
84	6/7/94	Nat. Gas	Air	60% Penelec Ash 40% Dolomite	4.0	4,000
85	6/8/94	Nat. Gas	Air	74% Soil, 15% Soda Ash, 11% Limestone	7.0	7,000
86	6/9/94	Nat. Gas	Air	74% Soil, 15% Soda Ash, 11% Limestone	7.5	7,000
87	7/20/94	Nat. Gas	Air	ASR Ash	6.5	3,900
88	7/20/94	Nat. Gas	Air	ASR Ash + 25% EAF Dust	5.0	2,150
89	7/20/94	Nat. Gas	Air	ASR Ash + 35% EAF Dust	6.0	1,600
90	7/21/94	Nat. Gas	Air	Soil / Carryover Reinjection	7.5	6,900
91	8/11/94	Coal	Air	60% Penelec Ash, 40% Dolomite	3.0	1,250
92	8/11/94	Coal	Air	None	6.0	0
93	9/12/94 to 9/16/94	Coal & Nat. Gas	Air	60% Penelec Ash, 40% Dolomite	105.0	50,000
94	10/5/94	Nat. Gas	Air	Simulated Soil	6.5	5,000
95	10/6/94	Nat. Gas	Air	Simulated Soil	6.5	6,300
96	10/25/94	Nat. Gas	Air	Waste Fiber Glass	7.0	4,500
97	10/25/94	Nat. Gas	Air	Waste Fiber Glass	2.5	2,300
98	10/26/94	Nat. Gas	Oxygen	Waste Fiber Glass	6.0	4,200
99	10/26/94	Nat. Gas	Oxygen	Waste Fiber Glass	2.0	1,250
100		Nat. Gas	Air	Duquesne 70% utility FA 30% limestone		
TOTALS					835.8	457,513

Table 4.0-2
Materials Melted in Vortec's 15 ton/day CMS Test Facility

Waste Post Consumer Glass
Industry Waste Glass Powder
Insulation Fiberglass Blanket Manufacturing Waste
Insulation Fiberglass Board Manufacturing Waste
Fiberglass Acoustical Board Manufacturing Waste
Waste Blowing Wool
Hazardous Metals Recycling Baghouse Dust
Electric Utility Coal-fired Boiler Flyash
Industrial Coal-fired Boiler Flyash
Soda-Lime-Silica Glass Raw Materials
Sewage Sludge Incinerator Ash
Municipal Solid Waste Incinerator Flyash
Municipal Solid Waste Incinerator Combined Ash
Textile Fiberglass Manufacturing Waste
Textile Fiberglass Manufacturing Raw Materials
Surrogates for Soils (Dry) Contaminated with RCRA Metals
Surrogates for Soils (Slurry) Contaminated with RCRA Metals
Surrogates for Soils with Low Level Radioactive and RCRA Metals Contaminants
Spent Potliner from Aluminum Manufacturing
Surrogates for High Sodium Content, Low Level Radioactive Tank Waste
Surrogates for Metals Plating Industry Waste
Surrogate for TSCA Incinerator Ash
Sodium Silicate Glass Raw Materials
Ash from Automobile Shredder Residue Gasifier
Automobile Shredder Residue Gasifier Ash Mixed with Electric Arc Furnace (EAF) Dust

The test demonstrated the commercial viability of the CMS™ for the vitrification of industrial wastes by producing a consistent vitrified product from coal-fired boiler flyash over an extended duration. It also provided data useful for the design of refractories and flue gas conditioning subsystems for commercial systems.

Based on the results of tests conducted under this R&D program, Vortec has been able to assess the potential markets for the technology. The most promising markets are related to the production of glass products from industrial wastes and the remediation of wastes containing hazardous and low level radioactive contaminants. The primary advantages of the CMS™ technology relative to current technologies are its ability to rapidly melt inorganic constituents in feedstock using a variety of fuels and efficiently oxidize organic constituents which could otherwise be hazardous pollutants. The rapid melting capability is provided by the efficient heating of feedstock in suspension with combustion gases in the process. As a result, the high temperature components comprising the process are smaller in physical size than conventional melting components and thus have lower structural heat losses. This results in higher thermal efficiencies and lower capital and operating costs.

Vortec has negotiated a sales & licensing agreement with Ormet Primary Aluminum for the construction of a CMS™ based spent potliner vitrification process at Ormet's Hannibal, Ohio, aluminum reduction plant. Spent potliner (SPL) is generated during the production of aluminum using the Hall-Heroult Process, which is currently used in all primary aluminum reduction operations. In removing the liner from the pot, the insulating bricks and pot liner itself are often mixed or co-mingled, resulting in a hazardous waste which consists of a mixture of the carbon based liner, barrier brick, and the insulation brick. Carbon liners can be anthracite or graphite based. The CMS technology has the advantage, relative to conventional technologies, of being able to process the entire mixture, oxidizing the carbon in the liner and rapidly melting the refractory (brick) material to produce an oxidized glass frit. The ORMET system will process approximately 34 tons/day of spent potliner producing a glass frit which will be sold to a glass manufacturer for use as an additive to other glass making ingredients. The total investment in the process is expected to be approximately \$8 million, inclusive of engineering and design, equipment for all major and support systems, site modifications, construction, and start-up operations. Total processing cost is anticipated to be on the order of \$100/ton. Ormet expects to sell the glass frit for \$10 to \$30/ton. It currently costs Ormet approximately \$350/ton to dispose of their potliner. Therefore, a net savings on the order of \$270/ton will be realized through

vitrification with the CMS™ technology. This provides a payback on capital investment of less than 3 years.

Vortec currently has a contract with DOE/METC for the construction and operation of a 25 ton/day CMS™ field demonstration process for remediation of soils and other wastes containing hazardous and radioactive constituents at DOE's Paducah Gaseous Diffusion Plant in Paducah, Kentucky. The primary advantages of the CMS™ technology relative to competing technologies, primarily joule-heated melters and plasma arc melters, are its ability to cost effectively vitrify large volumes of waste (several hundred tons/day with a single unit) and efficiently destruct hazardous organic constituents in the waste. Additionally, the CMS™ technology can produce a homogeneous glass product from wastes containing higher concentrations of iron and other metals which tend to form immiscible layers in pool type melters. Processing costs with the CMS™ technology are expected to be in the range from \$100 to \$200 per ton compared to \$300 to \$400 per ton for competing technologies.

Vortec has also prepared a commercialization/business plan for the construction and operation of glass/ceramic tile manufacturing plants using coal-fired boiler flyash and/or other waste as the feedstock. The cost of raw materials for existing clay-based ceramic tile manufacturing represents from 15% to 35% of the cost of manufacturing. The use of waste materials as a feedstock has the potential for not just reducing the raw material costs but providing a source of income in terms of tipping fees for some wastes. Manufacturing cost savings of 25% to 50% are estimated for a CMS based ceramic tile manufacturing process relative to existing clay-based manufacturing operations. Coal-fired boiler flyash represents a unique opportunity for this process application. First, the oxide constituents of coal ash are essentially the same as many commercial glasses. Second, there are essentially unlimited supplies of the feedstock. Third, it is possible to receive a tipping fee for the feedstock. Fourth, the ash can serve as an energy source for the process. and Fifth, the recycling of residual and industrial waste materials will alleviate a substantial number of environmental problems associated with landfilling.

Based on the results of tests conducted under this R&D program, Vortec has been able to assess the potential markets for the technology. The most promising markets are industrial solid waste recycling into value-added products, remediation of hazardous and radioactive wastes, and commercial glass melting and waste glass recycling. The primary advantages of the CMS™ technology relative to current technologies are its ability to rapidly melt

inorganic constituents in feedstock using a variety of fuels and efficiently oxidize organic constituents which could otherwise be hazardous pollutants. The rapid melting capability is provided by the efficient heating of feedstock in suspension with combustion gases in the process. As a result, the high temperature components comprising the process are smaller in physical size than conventional melting components and thus have lower structural heat losses. This results in higher thermal efficiencies and lower capital and operating costs.

Vortec has negotiated a sales & licensing agreement with Ormet Primary Aluminum for the construction of a CMS™ based spent potliner vitrification process at Ormet's Hannibal, Ohio, aluminum reduction plant. Spent potliner (SPL) is generated during the production of aluminum using the Hall-Heroult Process, which is currently used in all primary aluminum reduction operations. In removing the liner from the pot, the insulating bricks and pot liner itself are often mixed or co-mingled, resulting in a hazardous waste which consists of a mixture of the carbon based liner, barrier brick, and the insulation brick. Carbon liners can be anthracite or graphite based. The CMS technology has the advantage, relative to conventional technologies, of being able to process the entire mixture, oxidizing the carbon in the liner and rapidly melting the refractory (brick) material to produce an oxidized glass frit. The ORMET system will process approximately 34 tons/day of spent potliner producing a glass frit which will be sold to a glass manufacturer for use as an additive to other glass making ingredients. The total investment in the process is expected to be approximately \$8 million, inclusive of engineering and design, equipment for all major and support systems, site modifications, construction, and start-up operations. Total processing cost is anticipated to be approximately \$80/ton. Ormet expects sell the glass frit for \$10 to \$30/ton. It currently costs Ormet approximately \$350/ton to dispose of their potliner. Therefore, a net savings on the order of \$290/ton will be realized through vitrification with the CMS™ technology. This provides a payback on capital investment of less than 3 years.

Vortec has also prepared a commercialization/business plan for the construction and operation of glass/ceramic tile manufacturing plants using coal-fired boiler flyash and/or other waste as the feedstock. The cost of raw materials for existing clay-based ceramic tile manufacturing represents from 15% to 35% of the cost of manufacturing. The use of waste materials as a feedstock has the potential for not just reducing the raw material costs but providing a source of income in terms of tipping fees for some wastes. Manufacturing cost savings of 25% to 50% are estimated for a CMS based ceramic tile manufacturing process relative to existing clay-based manufacturing operations. Coal-fired boiler flyash

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Commercialization of the CMS™ technology in the glass industry for waste glass recycling and primary glass melting provides the potential for melting energy savings of more than 20 trillion Btu/yr (>30%), energy cost savings of over \$70 million/yr, and total manufacturing cost savings of over \$300 million/yr.

This report provides a detailed description of the activities and accomplishments of Phase III of the program performed under Contract No. DE-AC22-91PC91161.

5.0 PLANNED ACTIVITIES

The Final Report is being completed and is currently undergoing internal review. A no-cost contract extension until September 30, 1995 has been approved by DOE to allow for submission of the Final Report.