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

CONTRACT DE-AC22-91PC91161

APRIL 1992 - JUNE 1992

PREPARED FOR

U.S. DEPARTMENT OF ENERGY
PITTSBURGH ENERGY TECHNOLOGY CENTER

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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 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 concepts to be developed are based on advanced glass melting and ore smelting furnaces developed and patented by Vortec Corporation. 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 current reporting period, approval of Vortec's Environmental Assessment (EA) required under the National Environmental Policy Act (NEPA) was approved. The EA approval cycle took approximately 9 months. The preliminary test program which was being held in abeyance pending approval of the EA was initiated. Six preliminary test runs were successfully competed during the period.

Engineering and design activities in support of the Phase III proof of concept are continuing, and modifications to the existing test system configuration to allow performance of the preliminary tests were completed. The purchase orders for the design of the wet ESP and recuperator were issued. Release of the equipment for fabrication will be done upon receipt of the remaining FY 92 funding obligation from DOE,

The economic evaluation of commercial scale CMS processes is continuing. Preliminary designs for 15, 25, 100 and 400 ton/day systems are in progress. This data will serve as input data to the life cycle cost analysis which will be an integral part of the CMS commercialization plan.

Vortec's property management reporting procedures were updated and submitted to DOE for approval. A property audit was performed by DOE audit and all requirements were found to be satisfactory.

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 NOx, SOx 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 2-1.

Rapid temperature quenching of the combustion products by the inert waste glass particles and staged combustion are the primary means of limiting NOx emissions. Experimental data obtained during the course of feasibility experiments with the pilot-scale CMS indicate NOx 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 NOx are currently the most stringent in the United States.

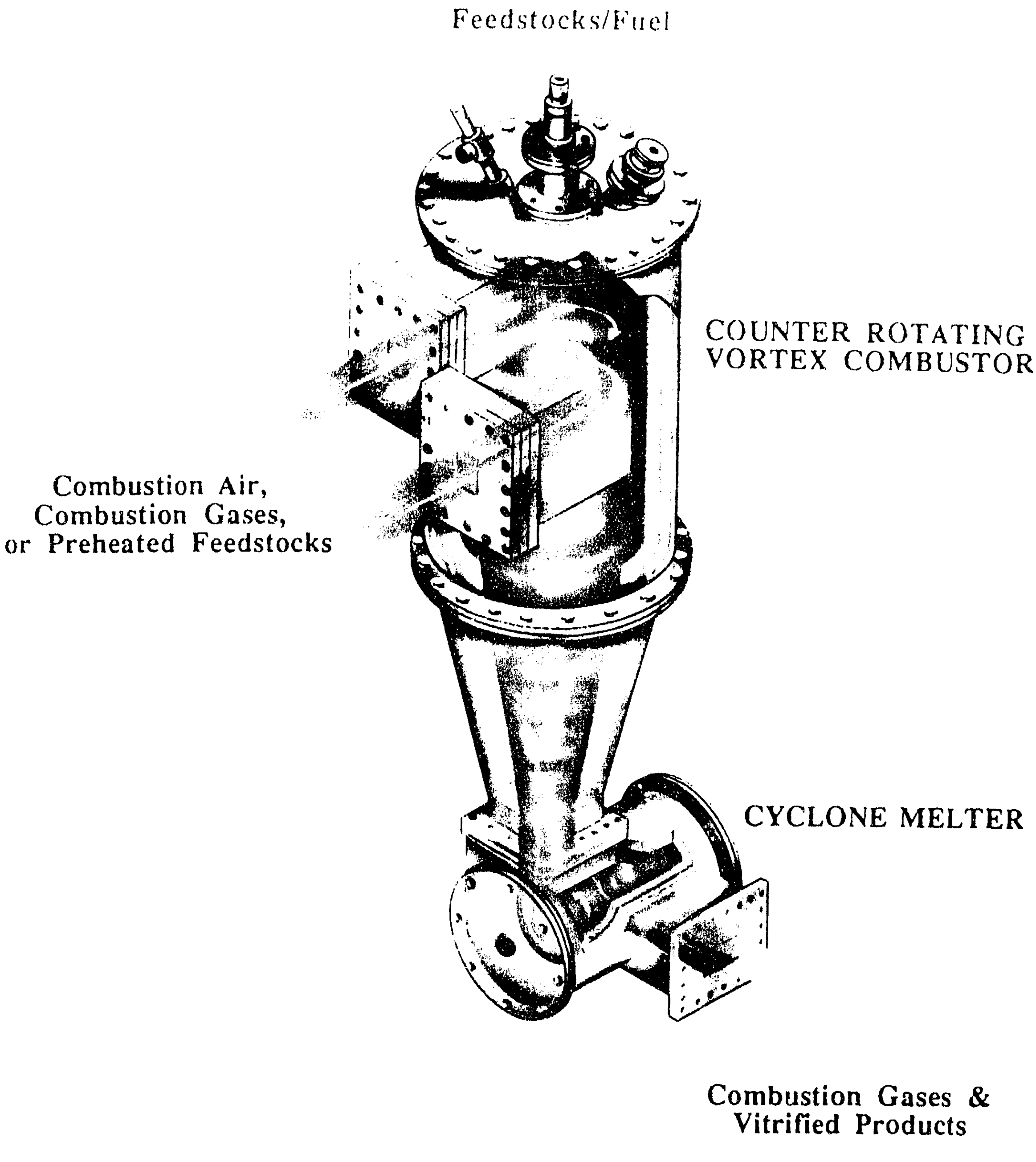

Figure 2-1. Artist Rendering of Basic CMS

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.

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

1. The Vortec multi-fuel 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.

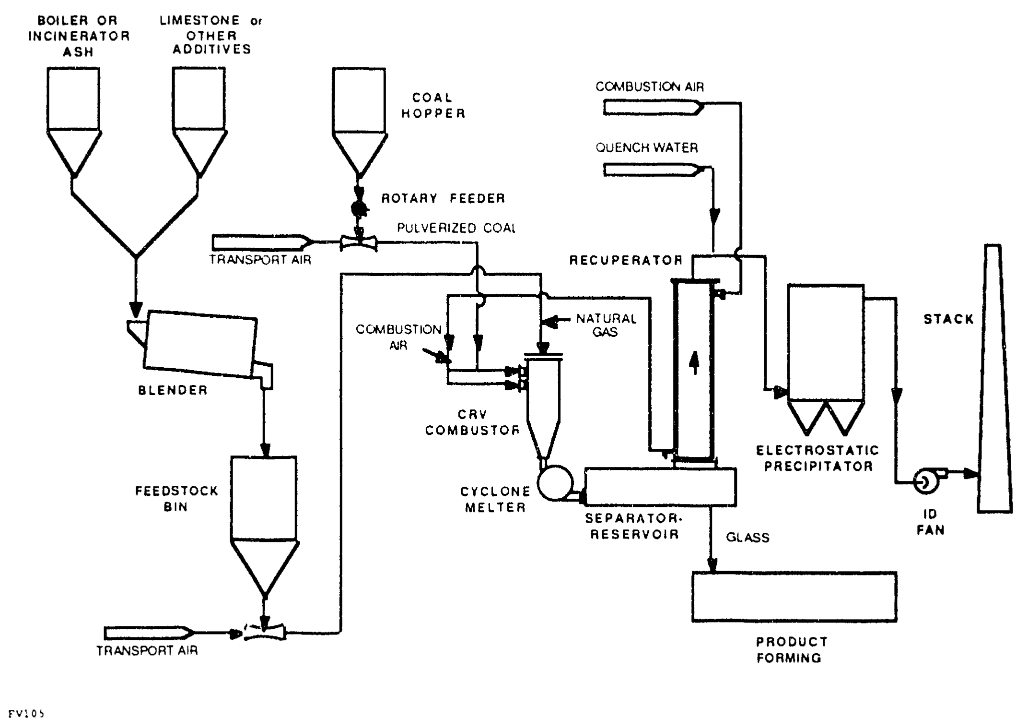

Figure 2-2. Vortec Ash Vitrification And Recycling System

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.

Final 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 CMS indicate that NO_x emissions with coal combustion are lower than the California emission standards 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 SO_2 or HCl emissions can be reduced using existing 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 cyclone 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.

Boiler or incinerator ash is delivered to storage bins located within the processing facility. Additives required to provide a feedstock suitable for the product to be produced 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.

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. 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.

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 10^6 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. As 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 produced 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 six (6) technical tasks and a program management task distributed over 36 months as shown in Figure 3-1. The tasks in the contract's Statement of Work are provided below in Table 3-1.

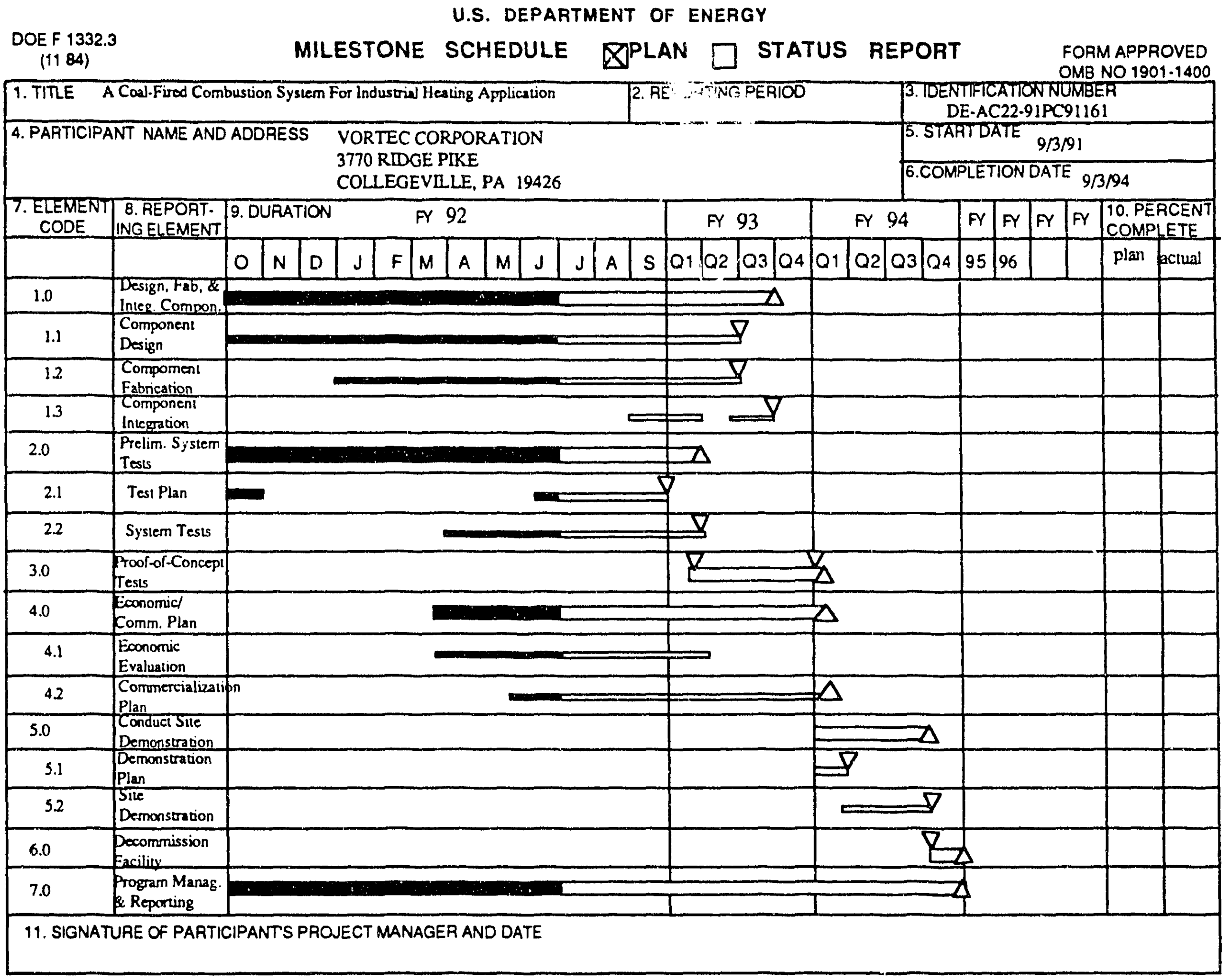

Figure 3-1. Phase III Program Schedule

Table 3-1. 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

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.

4.0 PROJECT STATUS

During the past quarter (the third quarter of the contract performance period), effort has been concentrated on modifying the pilot scale combustion and melting system (CMS) test facility for preliminary performance testing, conducting preliminary vitrification performance tests with selected ash and industrial waste materials, developing preliminary designs and cost estimates for commercial scale systems, and continuation of commercialization planning. A summary of the activities performed during this reporting period is presented below.

4.1 Design, Fabrication, Component Integration

Modifications, repairs and upgrades of the Combustion and Melting System (CMS) facility were performed in preparation of the preliminary waste processing tests to be performed under this phase of the development program.

CMS Refractory Repairs

Prior to initiation of the preliminary test campaign, an inspection of the Combustion and Melting System (CMS) components indicated the condition of most of the existing refractories were acceptable for continuing operations. Some of the refractory on the side wall of the Counter Rotating Vortec Combustor (CRV) required replacement. The melter refractory, however, remained in good shape. Therefore, it was decided to replace only the CRV refractory. The CRV and melter were removed from the test structure, and the CRV was disassembled. After documenting the refractory wear, the CRV refractory was removed. Because previous refractory testing showed that a chrome based refractory resists corrosion better than an AZS when melting ash, it was decided to replace the hot liner with a chrome based refractory. The hot face refractory selected was Zedcor CR-30 manufactured by Zedmark Corporation. The CR-30 is a plastic ram refractory consisting of 68% Al_2O_3, 30% Cr_2O_3, and 1% SiO_2.

The installation of the refractory was conducted by LVR, a refractory installation company, and Zedmark, the refractory supplier. The refractory liner consisted of a hot liner of CR-30 followed by a ceramic fiberboard insulation. The insulation was use to used to offset the high thermal conductivity of the CR-30. The fiberboard was installed first against the steel shell of the CRV. A wooden mold of the CRV interior was then placed, centered axially, inside the CRV shell. The CR-30 was then rammed into the annulus between the fiberboard and the mold using pneumatic hammers. After the CR-30 had air dried for approximately 24 hours,the mold was removed and the CRV was reassembled.

The CRV lid required special attention so that the uncured refractory would not separate from the hangers attached to the lid. Because of this, the lid was shipped to LVR's facility for relining and curing prior to CRV assembly. The CRV was completely reassembled and reinstalled in the test tower. The refractory was then cured in place using the externally fired air heater and the CRV natural gas burner.

Gas Sampling Flow-Train Modification

One of the difficulties in obtaining continuous flue gas measurements has been the inability to sample the exhaust gases over a long period of time without the sample flow-train filters and piping becoming plugged with carryover particulates. When this occurs, the filters and often times the piping, must be removed, cleaned and reinstalled. Also, after the flow-train is reassembled, the system often has ambient air leaks which must be traced and sealed before accurate data can be collected. This periodic cleaning requirement is time consuming and leaves gaps in the recorded data. Initial results of Computational Fluid Dynamic (CFD) modeling analysis (reported last period) indicated that particles larger than 20 microns do not enter the sampling system. An analysis of the plugging material confirmed that it was made up of very fine particulates. Based on the review of these data, it was decided to evaluate commercially available sampling flow trains capable of continuously sampling a flue gas containing a high percentage of fine particulates and condensed water vapor.

The results of this evaluation indicated that Perma Pure Products, Inc. had a system which could potentially solve the sampling problem. The Perma Pure system is designed to condition the gas and vapor streams by continuous selective removal of particulates, condensates, and water vapor, without loss of the gases being measured. If a small quantity of the selected gas is removed from the sample, this loss can be quantitatively measured differentially by using a calibration gas.

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 via a Teflon eductor. Particulates and condensable liquids are bypassed, and the sample stream will contain particulates smaller then 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 lower temperature takes out the acid mist and fine particulates while a dryer selectively removes the water vapor.

Based on the evaluation of the Perma Pure system, it was decided to initiate a modification to the sampling system. Figure 4-1 shows the modified sampling flow-train. The original sampling system is shown in solid lines with the modification shown as a dashed line. With the original system, the sample gas passes through a cooling coil, where the condensate is drained, and a particulate filter prior to the vacuum pump. After the vacuum pump, there is a dryer and a second cooling coil and filter. The modified system uses a heated sampling line directly to the Perma Pure sampling system and shares the same vacuum pump used with the original system. Because the sample gas has been conditioned by the Perma Pure system, the dryers and filter down steam of the vacuum filter are bypassed.

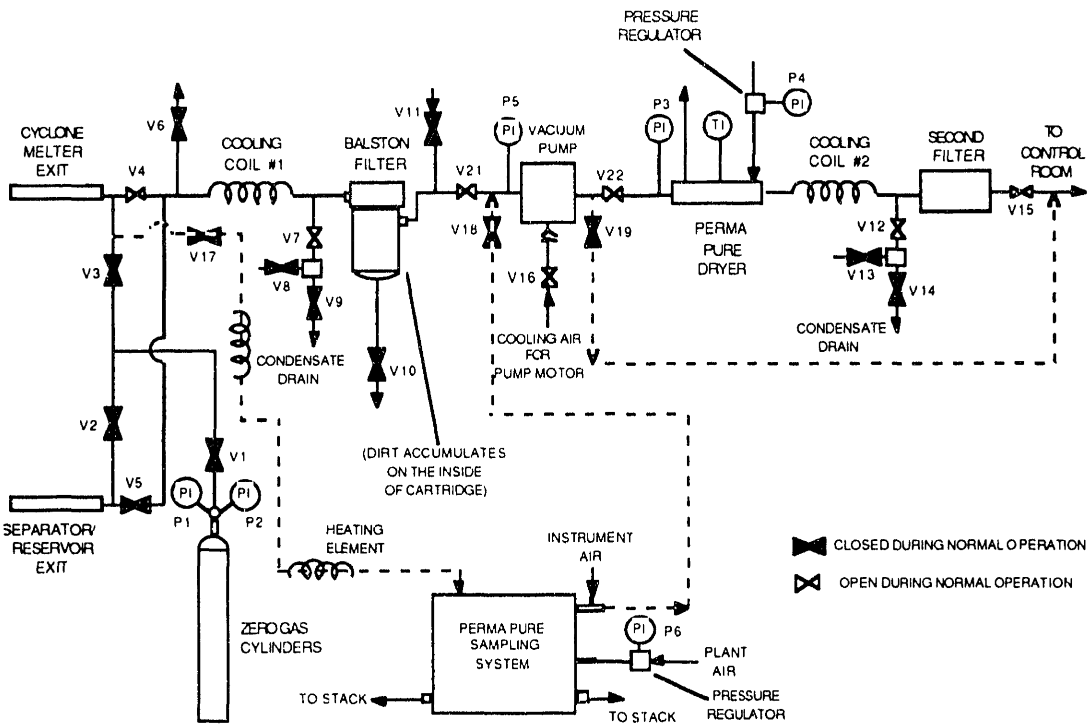

Figure 4-1. Flue Gas Sampling System

It is anticipated that the Perma Pure system will be installed parallel with the original system so that a comparison between the two system can be made. If the Perma Pure system proves to be superior, the original system will be removed.

Air Pollution Control

In the prior reporting period a technology assessment was performed upon the various flue gas clean-up systems currently available. As reported in the quarterly report, the outcome of the assessment indicated that a wet electrostatic precipitator (WESP) would best serve the needs of the Phase III test loop. Specifications for a WESP were prepared and competitive bids were solicited.

In April, a bid evaluation of the three proposals received was completed. Bids were received from Beltran, NAPCO, and Sonic. Of the three proposals, NAPCO was the lowest technically acceptable bidder.

Also in April, a design review package was submitted to DOE PETC which included: a summary of the bid evaluation, the technical assessment performed in the previous reporting period, and a copy of the WESP purchase specification. Upon review of the documents, it was found that the selected particulate control technology appeared suitable for its intended application and the cost for the WESP was within our original cost estimate. Approval for the purchase and subsequent installation of the WESP was given.

In May a purchase order was given to NAPCO for the WESP. Due to possible program funding constraints for FY1993, the purchase order authorized the design of the WESP only, fabrication of the unit has been placed on hold pending resolution of funding constraints. WESP drawings were delivered in June and installation studies for integration of the unit with the test loop were initiated.

The WESP is a variation of the standard ESP design which lends itself to the collection of particulate which are adhesive or moist. The WESP can handle high concentrations of submicron particles and is not highly sensitive to particle composition. The style of WESP considered for this application is the tubular type, consisting of square or hexagonal tubes with rigid electrode masts in the center of each tube. The WESP requires a saturated gas and, therefore, is typically located downstream of a wet scrubber. Removal of large particulates in this way is more economical than providing for additional WESP capacity. Additionally, the existing test loop has a Fisher Klosterman wet venturi scrubber which will be suitable for integration with the WESP. The charged particles are collected on the walls of the tubes and are cleaned via irrigation with water which is collected with the particulate, and through periodic flushing of the collecting walls by auxiliary cleaning sprays. The selected unit is an upflow design utilizing 116 tubes, each collector is a 6 inch hexagonal x 60 inch long collecting tubes. The unit provides a total collection area of 100 sq. ft. A rod deck venturi scrubber will be provided at the inlet even though the WESP has been sized to accommodate a design dust loading of 17.43 Gr/DSCF (200 lbs/hr). For the CMS pilot system the WESP will handle the widest variation of possible particulate and will provide the best range of clean-up for the test loop.

<u>Heat Recovery Subsystem</u>

In the prior reporting period, specifications for a heat recovery subsystem were prepared and competitive bids were received, and a bid evaluation was initiated. In April, a bid evaluation of the three proposals received was completed. Bids were received from American Schack, ECT Inc., and Thermal Transfer. Of the three proposals, ECT Inc. was the lowest technically acceptable bidder.

Also in April, a design review package was submitted to DOE PETC which included a summary of the bid evaluation. Upon review of the documents, it was found that the selected recuperator appeared suitable for its intended application and the cost was within original budget estimates. Approval from DOE was obtained for the purchase and subsequent installation of the selected heat recovery subsystem.

In May a purchase order was given to ECT Inc. for the recuperator. Due to possible program funding constraints for FY1993, the purchase order authorized the design of the unit only, fabrication has been placed on hold pending resolution of funding constraints. Preliminary recuperator drawings were delivered in June and installation studies for integration of the unit with the test loop were initiated. Final drawings are expected to be received in July.

4.1.2 Component Fabrication

No major components were fabricated during this reporting period.

4.1.3 Component Integration

Control System

The PETC Phase II test loop has been controlled with an AT type personal computer (PC) programmed with Genesis control software. Interface between the PC and I & C system of the test loop has been via Input/Output (I/O) hardware manufactured by Digitronics and MetraByte. Originally the I/O boards were 100% MetraByte, but these boards presented some incompatibility problems with the test loop controls. The Digitronics I/O boards have eliminated some interface problems and appear to be more reliable than the other boards. Consequently, as old boards fail, the replacement boards are upgraded to the Digitronics. During this reporting period two new boards were incorporated into the computer control system.

The control logic for the test loop has grown considerably since the system was originally installed. As a consequence, it takes longer for the computer to scan the control logic and to read and record all the data acquisition points. The AT PC had a 12 MHz clock speed and an apparent slowdown of the control process could be observed when entering control parameters and while printing out data files. The AT machine was also breaking down frequently, so a new 486 PC with a 33 MHz clock speed was integrated into the test loop.

The Genesis control software was several revisions old and was designed for an AT type PC. Since a newer computer was integrated into the control system, the latest revision of Genesis was also purchased to take advantage of the faster machine speed and extended memory of the new computer. After the initial debugging of both the hardware and the software, a significant improvement could be seen in the overall performance of the control system

ID Fan

Since the testing emphasis has shifted from glass batch materials to fly ash and waste materials, carryover problems have increased. A wet ESP will be added to the Phase III test loop in 1993 to eliminate stack emission problems. However, for the interim preliminary testing period, modifications were made to the existing system to increase the efficiency of the existing air pollution clean-up (APC) system.

The existing Phase II APC system consists of a wet venturi scrubber with a recirculation water spray loop. The maximum pressure drop across the scrubber has been about 12 in. wg. under normal operating conditions. The system was modified by grinding back a stop on the variable venturi inlet to allow it to close down to a full shut-off condition. The speed of the ID fan was also increased to the maximum speed allowable by the fan manufacturer. With these two changes in place, the maximum pressure drop across the scrubber has increased to 19 in. wg. under normal operating conditions.

Separator/Reservoir Drain System

The separator/reservoir holds approximately 2400 pounds of glass during normal operation. This reservoir of glass provides residence time for fining (elimination of glass seeds) to occur. At the end of a test run, the reservoir must be emptied by opening a drain hole in the bottom of the reservoir which allows the molten glass to flow down a cullet chute then into a cullet cart full of quench water.

To allow the direct draining of the glass into a cullet cart, a modified hot glass draining system was incorporated during this report period. The assemblies consists of a 3 cu. yd. cullet cart with extended sides located directly below the drain hole. Figure 4-2 presents a sketch of the system. The cullet cart is three times larger than required to hold the glass contents of the reservoir. Prior to draining the reservoir, the cart is filled with water. The extended sides, added by Vortec, prevent water from splashing over the sides while the hot glass is being quenched. After the reservoir has emptied and the water has cooled, the cart is drained of water and the glass cullet is dumped out. The new system was used in the following test series and it performed without incident.

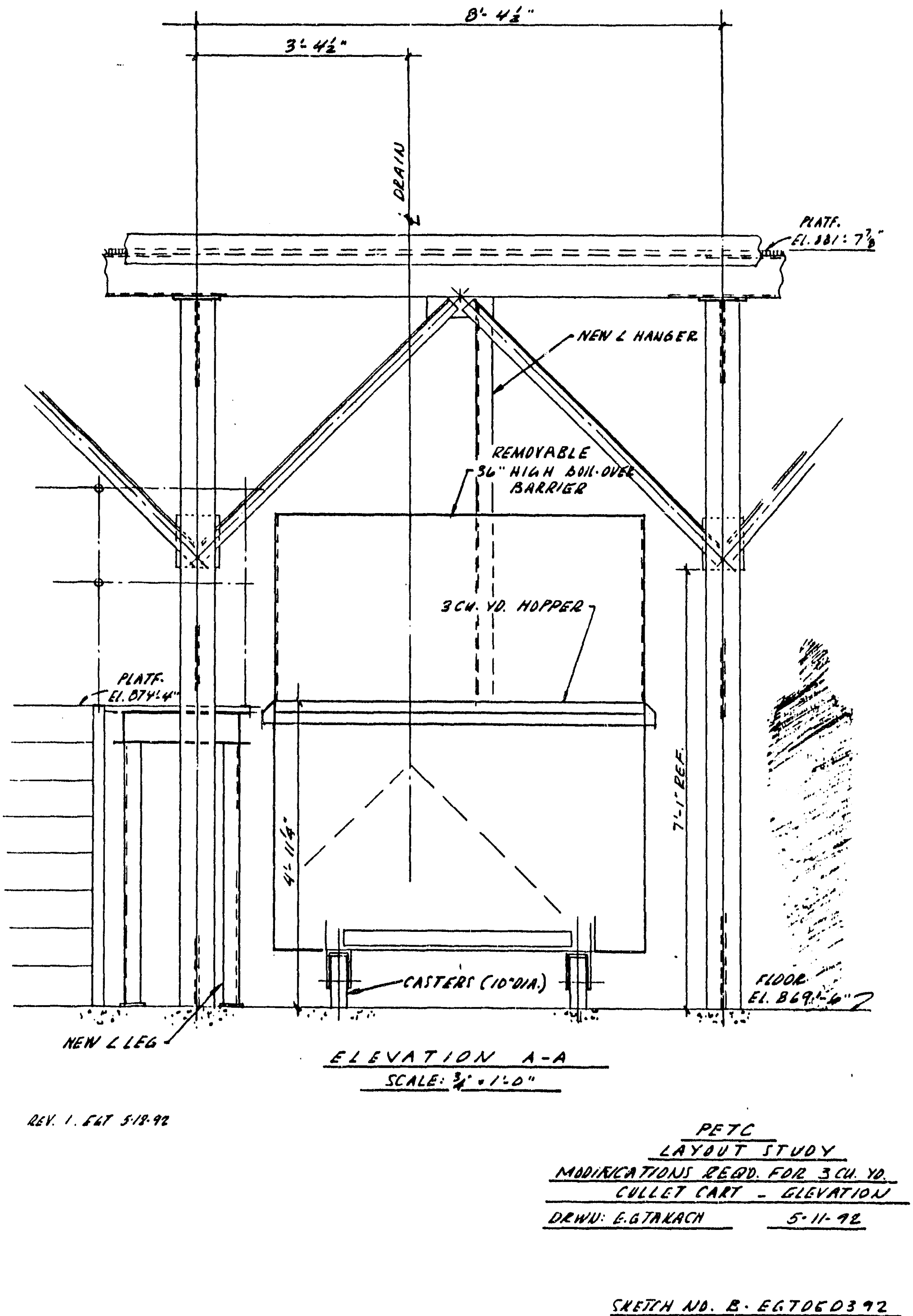

Figure 4-2. New Separator/Reservoir Drain Layout

4.2 Test Operations

Six preliminary gas-fired tests were performed during this period. Testing prior to this time was held in abeyance pending approval of the environmental assessment submitted to the Department of Energy at the beginning of the contract. The primary objectives of the preliminary tests were to obtain baseline information on the melting performance of the candidate waste materials to be processed under the proof of concept testing and to characterize flue gas emissions for future installation of supplemental air pollution control equipment. A total of 37 hours of process heating operation were accumulated during the preliminary test runs. Table 4-1 summarizes the principal test parameters of the tests which were performed. Method 5 analyses were performed for the measurement of particulate emissions during steady state operation of the test runs and was performed by an independent environmental company. NOx, SO_2, O_2, CO_2 and CO measurements were measured by Vortec using an on-line emissions analysis sampling train. A Genesis computer package is used for the data logging of all thermocouple, pressure, and flow measurements made in the course of a typical test run. Manual data logs are also kept for critical process information. A 7.5 HP Palla vibrating ball mill and NBE 24 cu.ft. blender are also installed at the U-PARC facility for feedstock preparation. Complete data analyses on all of the test runs has not yet been completed. Therefore, the data presented herein should be considered preliminary in nature.

Test No. 29 examined the melting of a utility boiler flyash when blended with 40% limestone. The flyash utilized was obtained from the Duquesne Light Company Cheswick plant. The mixture ratio of limestone to flyash was based on the melting characteristics as determined by laboratory crucible melts and previous pilot scale test operations. The vitrified product melt temperature for this test run was nominally 2700°F. The nominal heat input during the test run was 3.85 million Btu/hr with a feedstock flow rate of 778 lb/hr and an excess air level of 6%. The total uncontrolled particulate emissions amounted to 2.28 % of the total solids feedstock delivered to the CMS. A majority of the carryover from the process was captured in the venturi scrubber located downstream of the reservoir. With the addition of the wet electrostatic precipitator, the carryover of particulates is projected to be less than 0.001 gr/dscf. The NOx, SO2 and CO levels measured during the test were 264, 107 and 515 ppmv, respectively.

Test Run No.	Date	Fuel Type	Combustion Air			Feedstock		Test Length	Glass		Emissions*				Heat Rate	
			Nominal Rate (MM Btu/Hr)	Excess Air (Nominal)	Preheat Temp. (Nominal, °F)	Type	Rate (lb/hr)	Test Duration (hrs.)	Qty Melted (lbs)	Temperature (°F)	NOx (ppmv)	SO2 (ppmv)	CO (ppmv)	Particulates % of Feed	MM Btu/ ton of batch	MM Btu/ ton of glass
29	9/16/91	Natural Gas	3.85	6%	1050	Duquesne 60% utility FA 40% limestone 7% L.O.I.	778	10	7134	2700	264.2	107.5	515.7	2.28	9.90	12.66
30	10/10/91	Natural Gas	4.02	24%	1100	Res Fiberglass 6% L.O.I.	1600	4	4287	2200-2300	NA	NA	47.3	7.77	5.03	5.35
31	4/29/92	Natural Gas	3.691	31.40%	1102	Sewage Sludge Ash 5% L.O.I. 15% Water	961	7.5	3602	2320	168.9	19.78	1309	1.53	7.68	9.60
32	4/29/92	Natural Gas	3.34	45%	1104	MSW Flyash Northeast 7.5% L.O.I. 0.5% Water	818	6	3644	2320	27.2	76.2	28.02	4.2	8.17	8.88
33	4/30/92	Natural Gas	3.542	40%	1103.5	Consumer Waste Cullet	1034	4.5	4160	2310	82.1	4.2	1567.3	0.38	6.85	6.88
34	6/17/92	Natural Gas & Oxygen	3.185	43%	1071	Consumer Waste Cullet	1103	5	1714	2393	1296.9	14.8	127.1	NA	5.78	5.78
37**	7/22/92	Coal Char	1.5	10%	1100	Industrial Boiler Flyash HC - Narrows	1000	5	-	2500	-	-	-	-	-	-
42**	9/16/92	Coal	4	10%	1100	Sewer Sludge Ash (Alcosan)	1000	4	-	2400	-	-	-	-	-	-
44**	9/17/92	Coal	4	10%	1100	Cullet	1000	4	-	2400	-	-	-	-	-	-

* Emission data corrected to 3% oxygen, dry gas
** Planned Coal-Fired Tests
NA=Not Available

Table 4-1. Summary of Preliminary Test Operations

Test No. 30 examined the vitrification/recycling of residential fiberglass wastes. The waste materials, and cost sharing support for the test were provided by a major glass manufacturer. Approximately approximately 3.2 tons of residential insulation fiberglass batting with 3-6% binder, backed with kraft paper and asphalt adhesives were processed at an average feed rate of about 1600 lb/hr. One major objective of the test was to evaluate the oxidation/vitrification capacity of the Vortec CMS when processing waste insulation fiberglass materials. Because insulation fiberglass contains sodium and boron based species which tend to volatilize to some extent during glass melting operations, the partial volatilization of these species was anticipated. The measurement of the total particulate emissions was also another major test objective. Te ensure the effective oxidation of the organics contained in the fiberglass binders, the excess air ratio was increased relative to the utility flyash material processed under Run No. 29. The pneumatic feeding system used to transport the waste material to the CMS accounted for a significant portion of the excess air delivered to the process. As a result of the glass fluxes contained in the waste material, the vitrified product formed had a relatively low melting temperature (i.e., ca. 2200 - 2300°F). NOx and SO_2 measurements are not reported because of sampling and instrumentation problems. The recorded CO levels were measured to be 47 ppmv, suggesting good oxidation of the phenolic binders. The total uncontrolled particulate emissions are estimated to be 7.7% of the total total feedstock input to the process. The particulate emissions were found to be predominantly less than 5 microns in size. The fuel inputs requirements for processing the waste material amounted to about 5 million Btu/ton of waste. Some of the energy requirements for processing the waste material were derived from oxidation of the phenolic binders, paper and asphalt contained in the insulation bats.

Test Run 31 evaluated the vitrification of an incinerator ash generated by the incineration of sewage sludge. Sewage sludge incinerator ash vitrification represents an additional potential market for coal-fired operation not originally identified. It is estimated that approximately 42 pounds of organic dry solids of wastewater sludge are generated annually per inhabitant. Thus, in the United States, about 4.6 million tons of organic dry solids of wastewater sludge are produced. Of this total, about 4 million dry tons of sewage sludge are generated in U.S. municipal wastewater plants each year. Approximately 25% of the material is currently incinerated. As a result of the incineration of the more than 4 million tons of dry solids and more than 400,000 tons of ash are generated annually which must be disposed of in an environmentally acceptable manner. Municipal sludge ash is normally exempted from regulation as a solid waste. The sewage sludge incinerator flyash with an SiO_2 concentration of 39.5%, Al_2O_3 of 9.3% and CaO of 14.0% was found to melt readily by modest increases in the glass modifier concentrations. TCLP tests performed with the sewage sludge incinerator flyash and vitrified product indicated that all the RCRA metals readily passed the leaching test requirements. During the testing of the sewage sludge ash, approximately 3600 lbs of ash were melter over a 7.5 hr test period. During the period when the EPA Method 5 measurements were made, the feedstock feed rate was 961 lbs/hr and the fuel input requirement for melting amounted to 7.7 million Btu per ton of waste input. The excess air during combustion amounted to 31.4 %. The NOx, SO_2 and CO levels during the test run were measured to be 169, 20 and 1309 ppmv, respectively. The high CO level experienced during this test is thought to be caused by the high (15%) water content in the ash. In addition to the quenching effect of batch feed, evaporation of the water from the batch could further lower the flame temperature resulting in CO generation from the delayed ignition of the unburned carbon found in the ash (4.9%) and the natural gas fuel. The total uncontrolled particulate carryover was 1.53% of the feedstock feed rate. Most of the particulates were collected in the venturi scrubber (1.27% of feedstock) while 0.20% was carried over into the stack. With the addition of a wet electrostatic precipitator, it is estimated the stack emissions with typical sewage sludge incinerator ashes will be less than 0.003 gr/dscf. The NOx and SOx emissions were measured to be 0.321 and 0.052 lb/million Btu, respectively.

Test Run No. 32 evaluated the performance of the CMS when processing a municipal incinerator flyash. The flyash tested was from an incinerator located in the Northeastern section of the United States (NE-1). The average particle diameter of the NE-1 ash is approximately 70 microns with 90% being less than 250 microns. Compared to the coal-fired boiler flyash, the MSWI ash was found to have lower SiO_2 concentrations (29.5%), lower Al_2O_3 levels (11.6%), lower Fe_2O_3 levels (2.8%), higher CaO levels (28.2%) and higher K_2O/Na_2O concentrations (5.6% combined). The higher glass modifier concentrations in these ashes reduced the amount of additives required to achieve reasonable glass fluid properties. For the NE-1 ash with 28.2% CaO, no additional modifiers were required to suitably melt the flyash. Three test runs were performed with the pilot scale CMS using the three different MSWI ashes. Test operations with the NE-1 ash were performed at a feed rate of 818 lb/hr and thermal input of 3.41 mm Btu/hr. The uncontrolled particulate emissions amounted to 4.24% of the total feedstock input. The particulates collected in the venturi scrubber were 0.28% of the feed, while the stack emissions were 3.96%. The higher stack emissions for the MSWI are primarily due to the finer size distribution of the particulates generated during the vitrification of MSWI ash. It is conjectured that the finer size distribution of these particulates is due to volatilization and subsequent recondensation of chloride salts. This has been reported by other researchers in the waste incineration field; however, a complete data analysis of our test is not yet available to confirm this. Chemical compositions of the carryover collected in the scrubber and by the stack gas Method 5 sampling indicate the scrubber, sediment were found to consist primarily of SiO_2 (9.2%), Fe_2O_3 (4.4%) and PbO (40.5%). In contrast, the stack particulates had relatively high concentrations of K_2O (17.6%) and Na_2O (28.9%). The lead oxide concentration in the stack gas (5.2%) was considerably lower than in the scrubber sediment. With the addition of a wet electrostatic precipitator, the particulate emissions with MSWI incinerator ash are projected to be less than 0.006 gr/dscf.

Test Runs No. 33 and 34 were conducted using a commercially processed container glass cullet which was spiked with metals to assess the ability of the CMS to oxidize metal contaminants and to assess the oxidation/redox state of the glass produced. The primary metal of concern is aluminum, since magnetic separation cannot be used with non-ferrous metals and the contaminant pieces are often too small to be effectively removed by eddy current separators. Test Run No. 33 was performed using combustion air preheated to 1100°F as the oxidizer. During this test run, a dark red cullet frit was produced suggesting that complete oxidation of the metals did not occur. Test Run No. 34 was essentially a repeat of the previous test, except oxygen enrichment was utilized to enhance the metal oxidation rates. During this second test run, there was a noticeable increase in the combustion intensity and temperature within the CRV indicating an increase in the combustion intensity as a result of the increased oxygen concentration. The maximum oxygen enrichment level during the test run was 40%. The color of the frit produced was again dark suggesting that metal oxidation has not been effectively completed. Data on the chemical oxygen demand (COD) and the Beta ratios for these tests have not yet been received from our glass industry partner. Therefore, only subjective data on the oxidation capability of the process when processing glass contaminated with aluminum can be ascertained. During both tests, the feedstock flow rates were in excess of 1000 lb/hr. With preheated air as the oxidizer, the NO_x, SO_2 and CO levels during the Test Run No. 33 were measured to be 82, 4 and 1567 ppmv, respectively. The high CO level during this test can be attributed to contamination in the CO sampling train The total uncontrolled particulate carryover was 0.38% of the feedstock feed rate. The heat rate for the test run was determined to be about 6.9 million Btu/ton with a glass melt temperature of 2310°F. During Run No. 34 when oxygen enrichment was utilized, the energy requirement for melting dropped to about 5.8 million Btu/ton and the CO emission levels were 127 ppmv. The NOx emissions increase from 82 ppmv to 1296 ppmv can be attributed, in part, to the higher process temperatures as is evidenced by the elevated glass temperature. The slightly higher SO_2 level measured during the oxygen enrichment test (15 versus 4 ppmv) could possibly be attributed to slight variations in feedstock composition or an increase in the level of SO_2 out gassing from the glass as a result of the elevated glass melt temperature.

The preliminary gas-fired testing performed has helped to establish the melting performance of the waste materials of interest for near term commercialization. The emissions data provides a basis for assessing the influence of fossil fuel type on NO, SO_2, CO and particulate emissions.

During the next reporting period, three major coal-fired tests are planned. The first scheduled test will use coal char/flyash from a coal-fired industrial boiler as the fuel/feedstock. The primary objective of this test is to evaluate the burning, melting, and emission characteristics of a low volatile coal char ash of an eastern bituminous. A Loss on Ignition (LOI) has been conducted on the feedstock and indicates that the coal char/flyash feedstock contains approximately 40% by weight of unburned carbon. It is anticipated that this should provide sufficient thermal input so that no additional fuel will be required to vitrify the remaining inorganics. It is also anticipated that because of the low volatile nature of the coal, some oxygen enrichment may be necessary to complete the burnout of the char given the existing CRV residence time.

The second coal-fired test run scheduled will use sewer sludge ash as the feedstock and a washed Upper Elkhorn as the fuel. This test will be conducted in conjunction with a DOE SBIR program to evaluate the use of the CMS as a coal-fired sewer sludge vitrification system. Vortec has been contacted by several municipalities to provide information and cost quotations for a vitrification system which can transform their sludge ash into a value added product. They are being driven to evaluate this alternative because of decreasing landfill space, increasing landfill costs, and local and state regulations. It is anticipated that this test will demonstrate the feasibility of using a coal-fired CMS for this application.

The third test will evaluate injecting coal coaxially with the batch directly into the CRV. The primary objective of this test is to evaluate the burning characteristics of the coal (beneficiated Upper Elkhorn seam coal) when injected directly into the CRV and to see if complete burnout of the coal can be obtained prior to interaction with the glass. The feedstock for this test will be a glass cullet and oxidation state of the glass produced will be tested to determine the effectiveness of this injection configuration.

4.3 Commercialization Planning

Significant progress has been made in the development of a commercialization plan. The commercialization planning efforts have included identification of target markets, establishment of a basic marketing approach, development of an initial market penetration strategy, identification of potential customers and potential demonstration sites. A business plan to raise capital via limited equity or private placement offerings is being prepared. Potential investors are being sought and discussions are being held regarding the formulation of commercial corporation to process various waste materials using the CMS technology.

Commercial System Heat and Mass Balances

Heat loss calculations were conducted for various refractory configurations for a commercial 15 ton/day system. Because long refractory life is a primary requirement of a commercial system, the refractory configuration will, in most cases, incorporate fused cast refractory as the hot liner. The fused cast material, however, has a much higher thermal conductivity than the bonded refractory currently used in the test unit. Therefore, the hot liner will be thicker, and will be backed by a layer of thermal insulating fiberfrax. The heat loss calculations indicate the heat rate for a given configuration and allow the calculation of gas flow rates and system heat and mass balances. This information allows the determination of the optimum refractory configuration for a given commercial application. It also allows for an accurate estimate of the refractory weight and cost, and the system's life cycle cost.

Figures 4-3 and 4-4 are two heat and mass balances for a commercial 15 ton per day ash vitrification system. Figure 4-3 represents a system design with the CRV and cyclone melter lined with 9 inches of fused cast refractory backed with 1 inch of insulating ceramic fiber blanket. For this case, the required heat input is only 3.08×10^6 Btu/hr corresponding to a heat rate of 4.1×10^6 Btu/ton of glass produced.

Figure 4-4 shows the results of a heat balance for the CRV and melter lined with 4.5 inches of fused cast refractory and no insulating blanket. For this case, the required thermal input is 5.73×10^6 Btu/hr corresponding to a heat rate of 7.7×10^6 Btu/ton of glass produced. Although this configuration has a lower a thermal efficiency, it may be desirable for

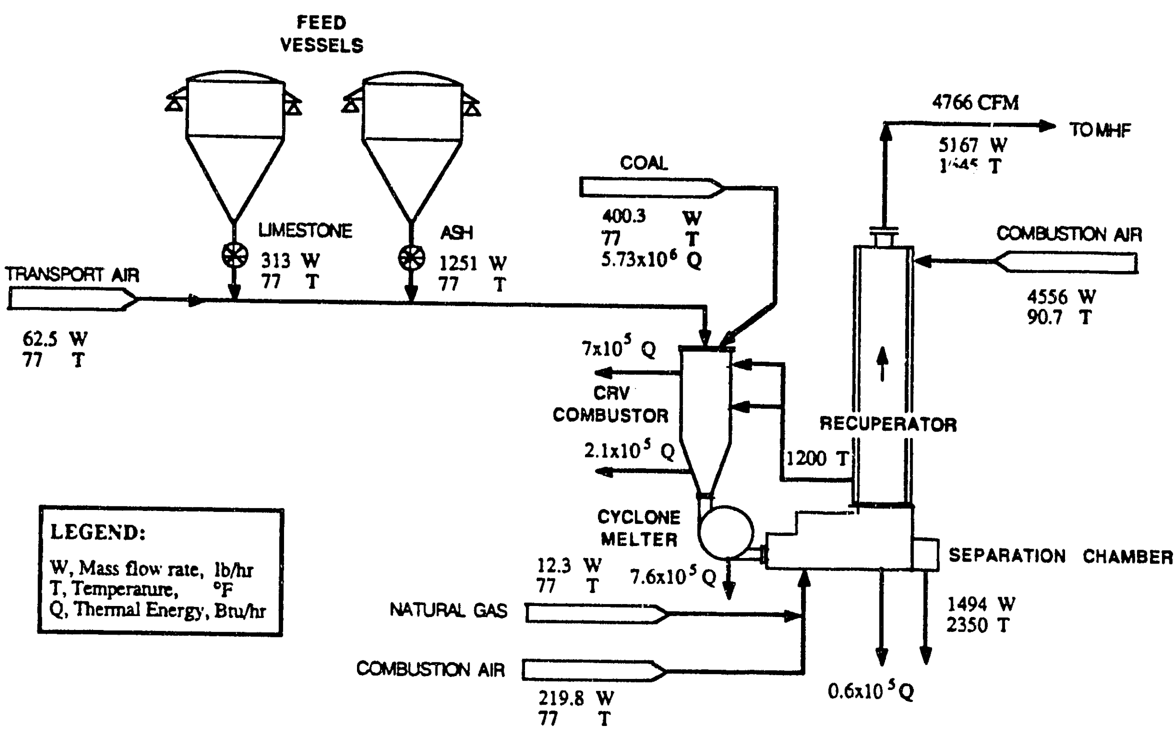

Figure 4-3.
15 ton/day Commercial System Heat and Mass Balance (9 " liner)

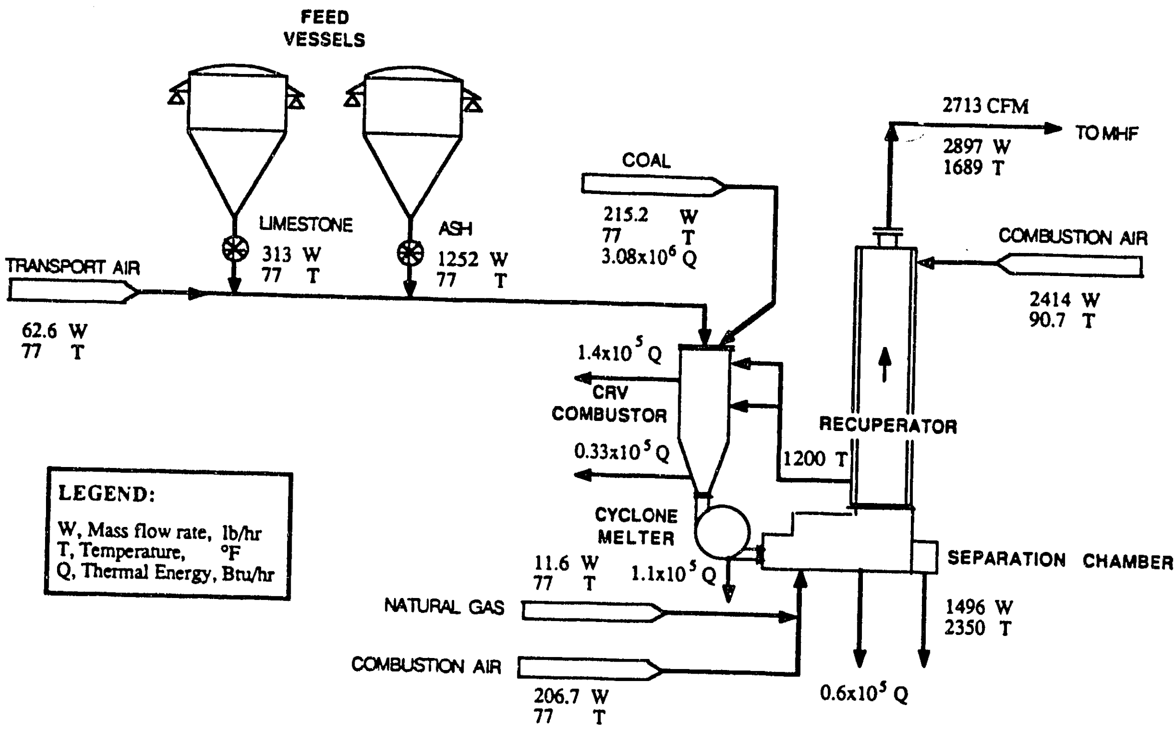

Figure 4-4.
15 ton/day Commercial System Heat and Mass Balance (4.5" liner)

commercial systems using very corrosive feedstocks since the refractory wear will be reduced by the active cooling of the hot liner.

From a system design perspective, both design concepts are being carried for potential commercial applications. In the future, additional commercial heat and mass balances will be produced for 25, 50, and 100 ton/day commercial systems.

Part of the Phase III research is to establish installed costs for commercial units. These costs would then be utilized in techno-economic analysis to establish life cycle costs for a commercial plant. In order to establish pricing within 10% to 20% of the actual cost, it is necessary to prepare preliminary designs of an actual commercial layout. A preliminary design will provide an estimator with more accurate information concerning quantity of steel, size of foundations and footers, building or enclosure requirements, access and clearances for equipment installation, platform and stairway requirements, lighting requirements, etc. Preliminary layouts for 25 TPD, 100 TPD, and 400 TPD units were initiated. For the purpose of these studies, it was assumed that the CRV would be fired by direct injection of coal rather than utilizing precombustors. This method of operation should be satisfactory for mineral wool production and vitrification of waste products. The layout studies were then used to complete preliminary structural steel and foundation designs. These preliminary designs were then used to establish installation costs for the support structure of several commercial units under Task 4.

A typical layout study for a 100 TPD waste vitrification unit is shown in Figures 4-5 to 4-7. Figure 4-5 shows an elevation view of the major components of a 100 TPD commercial unit with a low height building, while Figure 4-6 is a cross-section showing the CRV and cyclone melter only. In this concept the main work area is indoors with the building kept to a minimum to keep the costs down. Material handling equipment, fans, and air pollution control equipment would be located outdoors. Figure 4-7 is the same concept except the building now encloses the major components.

4.4 Project Management

The environmental assessment required under the National Environmental Policy Act (NEPA) has been satisfactorily completed by DOE, and Vortec has been released to work on all the tasks specified by the contract.

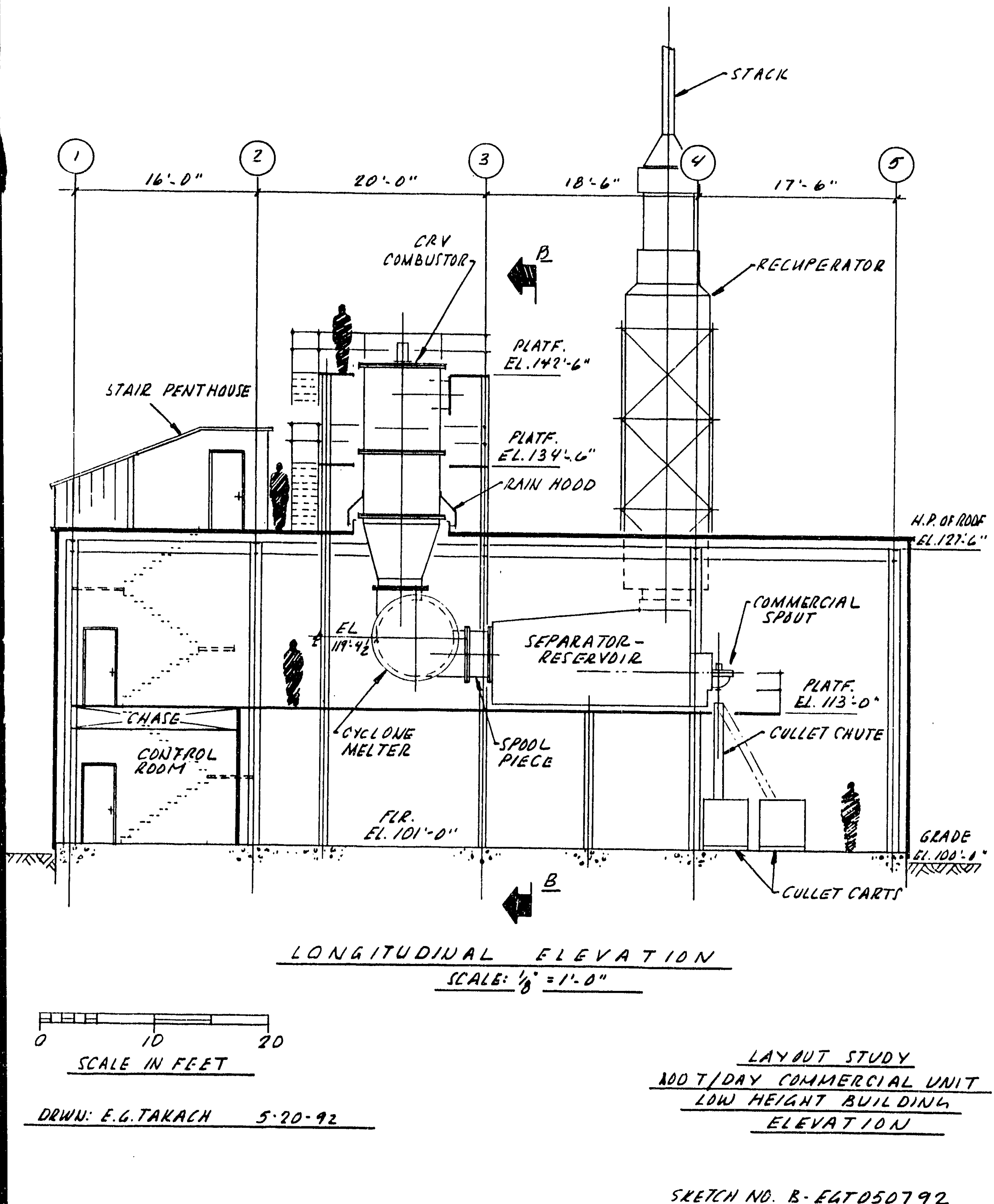

Figure 4-5. 100 Ton/Day Commercial Unit - Low Height Building

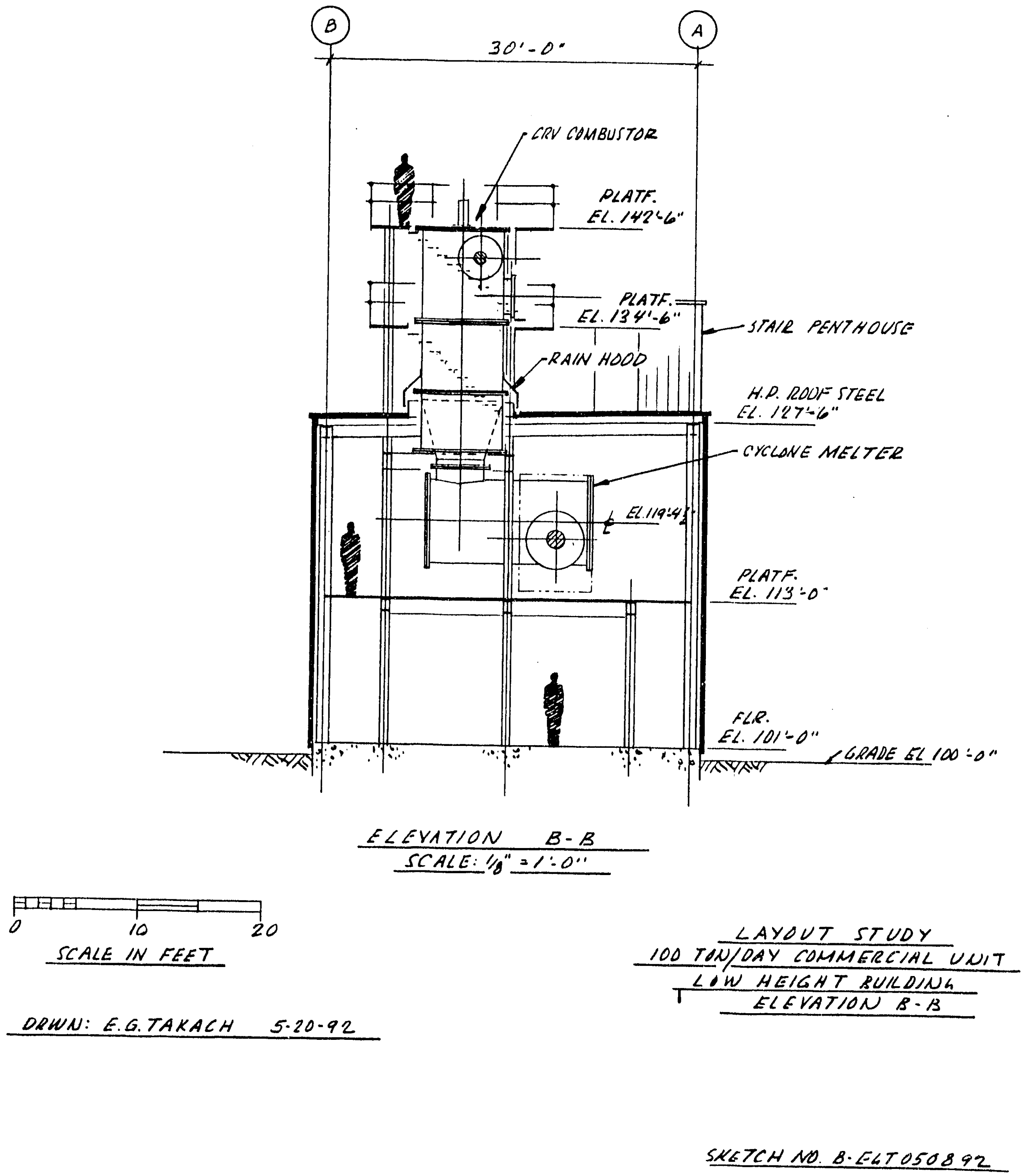

Figure 4-6. 100 Ton/Day Commercial Unit - Low Height Building-Section B-B

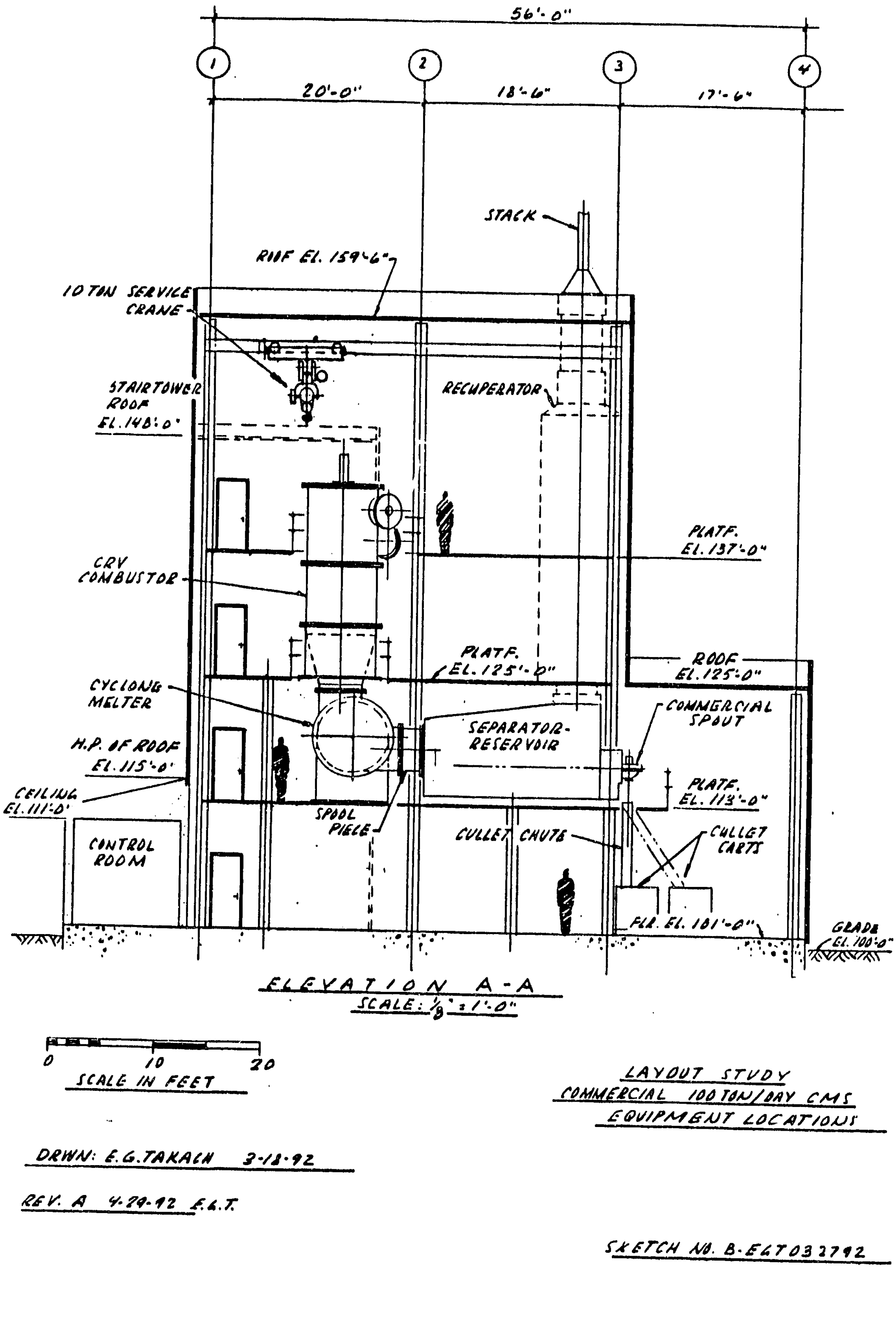

Figure 4-7. 100 Ton/Day Commercial Unit - High Building

The Vortec Property Management Plan was submitted and approved by PETC. Additionally, a property management audit was conducted June 3rd at the U-PARC facility and no discrepancies were noted.

The manuscript for the PETC contractors conference was completed and submitted to DOE. A summary of the project progress will be presented at the DOE/PETC contractors conference to be held in July 1992.

5.0 PLANNED ACTIVITIES

5.1 Task - 1 Design, Fabricate, and Integrate Components

During the next reporting period the major emphasis of the engineering design and fabrication activities will be directed toward completing the design of the ESP installation interfaces. Procurement of long lead time items and the fabrication of the ESP will be initiated.

The designs of additional spool pieces for the CRV will be developed and evaluated. The objective of the spool pieces will be to provide additional residence time for coal and char burnout when injecting coal directly into the CRV. This method of operation is preferred when processing feedstocks which are not impacted by coal ash contamination. Examples where coal ash contamination is not a quality control consideration include the vitrification and recycling of boiler ash and incinerator ashes into value added products. The design analysis will be supported by heat transfer and computational fluid dynamics modeling.

New control logic is being developed using an updated version of Genesis control software. Additional control system hardware (controller boards and power supplies) were also installed in anticipation of the installation of the recuperator and ESP. As-built drawings of the existing control system will be produced and later updated to reflect the new configuration.

Integration requirements for the APC assembly will be defined and detailed engineering drawings showing the layout and interconnection of all components and utilities will be developed. Equipment foundation designs will be developed and site work will begin.

5.2 Task 2 - Perform Preliminary System Tests

Preliminary coal-fired testing of the CMS will be initiated. During the next reporting period, two major coal fired test runs are planned. The first test will include the combustion and vitrification of a coal char from an eastern l . minous coal. The coal char will be provided by major chemical manufacturer. The objective of this test will be to assess the carbon burnout performance of the CMS with and without oxygen enrichment. Crucible melts of the coal char will be performed to establish the loss on ignition (L.O.I) and the melting characteristics of the ash. The coal char samples will be sent to outside laboratories to establish the carbon content of the char relative to the ash. Preliminary analysis indicates that the coal char could have in the range of 25% 50 40% unburned carbon. Under these circumstances, the use of supplemental fuel for vitrification of the ash will likely not be necessary.

The second coal-fired test will examine the vitrification of a sewage sludge ash when using a beneficiated Upper Elkhorn coal. The objective of this test will be examine the melting characteristics of the ash when using coal as the primary fuel and to compare the flue gas emissions of the process relative to gas fired operation. The pulverized coal will be introduced concurrent with the ash into the CRV. Oxygen injection will be used during the test run to assess the impact of oxygen enrichment on combustion efficiency and NO_X formation.

5.3 Task 4 - Evaluate Economics/Prepare Commercialization Plan

Preliminary foundation and structural steel designs have been completed and the support steel has been sized for the 100 ton per day commercial CMS. This information will be used to develop the costs for the structural steel. These costs will then be used as input data to the CMS system cost data base currently being developed.

Heat loss calculations will be conducted for various refractory configurations for a commercial 15 ton/day system. Because long refractory life is a primary requirement of a commercial system, the refractory configuration will, in most cases, incorporate fused cast refractory as the hot liner. The fused cast material, however, has a much higher thermal conductivity than the bonded refractory currently used in the test unit. Therefore, the hot liner will be thicker, and will be backed by a layer of thermal insulating fiberfrax. The heat loss calculations will indicate the heat rate for a given configuration and this will allow the calculation of gas flow rates and system heat and mass balances. This information will allow the determination of the optimum refractory configuration for a given commercial application. It will also allow for an accurate estimate of the refractory weight and cost, and the system's life cycle cost.

6.0 SUMMARY

The design modifications are proceeding as planned. Purchases orders for the design of the APC system and the recuperator were issued. Release of the purchase orders for fabrication are being held in abeyance pending receipt of budgeted funding obligations from DOE/PETC. Modifications modifications and maintenance on the test facility were performed in preparation of the preliminary test program.

Approval of the environmental assessment has been obtained in accordance with the requirements of National Environmental Policy Act (NEPA). Preliminary tests with various waste feedstock materials were initiated. A total of six preliminary gas-fired test runs totaling 37 hours of melting operations were performed during this reporting period. During the next reporting period, several major coal-fired tests are planned. One test will involve the processing of coal char from an industrial boiler. The other major test will be a vitrification test run with a sewage sludge incinerator ash using a beneficiated coal as the primary fuel.

Significant progress has been made in the commercialization planning task. Cost sharing support for the test operations is being provided by several waste generators and preliminary plans are being developed for commercial demonstration systems.

7.0 REPORT DISTRIBUTION LIST

The report distribution list as specified in the contract is as follows:

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