GAS TECHNOLOGY INSTITUTE

# Cement-Lock® Technology for Decontaminating Dredged Estuarine Sediments

## PLANT OPERATIONS REPORT
### December 2003 – March 2005


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Submitted to:

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**Brookhaven Science Associates, L.L.C.**
Upton, New York 11973-5000
Brookhaven Contract No. 725043


July 2005



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# CEMENT-LOCK® TECHNOLOGY FOR DECONTAMINATING DREDGED ESTUARINE SEDIMENTS

# PHASE V – OPERATION OF THE CEMENT-LOCK DEMONSTRATION FACILITY

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Brookhaven Contract No. 725043
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# EXECUTIVE SUMMARY

This report documents the operations of the Cement-Lock® demonstration plant at the International Matex Tank Terminal (IMTT) in Bayonne, New Jersey since the completion of start-up and commissioning activities in December 2003 through the end of March 2005. This work was conducted under Phase V – Operation of the Cement-Lock Demonstration Facility – of the Brookhaven National Laboratory sponsored program (BNL Contract No.: 725043) for "Cement-Lock® Technology for Decontaminating Dredged Estuarine Sediments." Other funding for this program has been provided by the New Jersey Department of Transportation Office of Maritime Resources (NJ-DOT/OMR) and the Gas Research Institute (GRI, Des Plaines, IL).

Cement-Lock Technology is a thermo-chemical manufacturing process – developed by the Gas Technology Institute (GTI, Des Plaines, IL) and Unitel Technologies (Mount Prospect, IL) – that not only decontaminates dredged sediment but also converts it into construction-grade cement. The technology can treat all types of contaminants (organic as well as inorganic) at widely varying concentrations. The technology is applicable to a variety of wastes including contaminated soils and sediments, debris from brownfields, industrial chemical wastes, sludges, and incinerator residues among others. During processing, all of the waste is converted to cement, which is suitable for use in general construction projects where ordinary Portland cement is used.

As part of the overall program, the Cement-Lock Technology demonstration plant has been designed, fabricated, and constructed at IMTT in Bayonne, New Jersey. The demo plant is owned by ENDESCO Clean Harbors, L.L.C. (ECH) – a GTI subsidiary. During shakedown and commissioning, numerous equipment problems, malfunctions, and failures were encountered that delayed the project, including a significant temperature excursion in the activated carbon adsorber bed, two plant-wide power outages, and the deleterious effects of inclement weather.

Start-up of the demo plant was initiated in mid November 2003. By early December, we began feeding a mixture of sediment and modifiers to the rotary kiln melting system. Approximately 5 cubic yards ($yd^3$) of sediment and modifier mixture were fed to the system on a batch-wise basis over 2 days. The first samples of Ecomelt were collected from the Cement-Lock demo plant on December 10 at about 3:10 p.m.

As the campaign progressed, solidified slag accumulated in the drop-out box and began to occlude the opening through which the melt normally flowed. By late evening on December 10, slag had accumulated to such an extent that the granulator drag conveyor jammed. After this initial successful start-up, the Cement-Lock demo plant was shut down so that the accumulated slag could be removed from the drop-out box and granulator.

The initial sample of Ecomelt was subjected to the EPA TCLP leaching test and found to be essentially non-leachable. None of the priority elements analyzed was detected in the TCLP leachate. The Ecomelt was also converted into construction-grade cement and tested for compressive strength. At the end of the 28-days test, the compressive strength of the construction-grade cement was measured to be 5190 psi, which is well above the ASTM C-150 requirement for Portland cement (4060 psi) and the ASTM C-595 requirement for blended cement (3480 psi).

During 2004, GTI and its team conducted four tests in the Cement-Lock demo plant under slagging conditions. Ecomelt was produced in three of these tests. In the fourth test, the drag conveyor in the granulator jammed due to an equipment problem before sediment feeding was initiated and the test was terminated.

Also during 2004, GTI and its team implemented numerous changes and modifications to enhance the overall operability of the demo plant. These changes and modifications included installing additional burners in the drop-out box, air-drying the sediment and blending modifiers with the sediment prior to feeding, and conducting additional instrument calibrations. However, none of the mechanical or operational changes implemented were successful in eliminating the slag accumulation problem in the drop-out box.

In December 2004, the project sponsors, GTI and ECH management decided to complete the program by operating the Cement-Lock demo plant under non-slagging conditions. In March 2005, the non-slagging campaign was initiated after needed winterization activities were completed. Also during this campaign, the U.S. EPA SITE program sampling team collected environmental and stack samples to characterize the technology under these conditions. The non-slagging campaign was conducted at 1835°F in the rotary kiln and 2115°F in the secondary combustion chamber. The nominal sediment-modifier feed rate was 1,000 pounds per hour. About 80 $yd^3$ of sediment-modifier mixture was processed through the plant during the campaign.

Overall, the non-slagging test generated a remediated product – called EcoAggMat (for Ecological Aggregate Material) – that was essentially devoid of any of the original organic contamination. Also, the EcoAggMat did not leach metals above the TCLP or MEP criteria. EcoAggMat can be beneficially used as clean fill or as a partial replacement for sand in concrete.

The air data collected under the EPA SITE program showed emission rates of $SO_2$ of <0.024 lb/hour (< 0.8 ppmdv @ 7% $O_2$), NOx of 1.53 lb/hour (76 ppmdv @ 7% $O_2$), CO of 0.02 lb/hour (0.98 ppmdv @ 7% $O_2$), and total hydrocarbons (as methane) of < 0.01 lb/hour (< 0.05 ppmwv @ 7% $O_2$). These data are well within the NJ-DEP Air Quality Permit limits for the plant.

The emission of PCDD and PCDF in the stack was measured at 0.35 ng/dscm. For comparison, the EPA New Source Performance Standard for dioxins and furans emitted from large municipal waste incinerators is 30 ng/dscm.

The concentration of mercury entering the activated carbon bed was 14.6 µg/acm, while that from the stack measured 0.14 µg/acm. This represents 99 percent collection efficiency across the activated carbon adsorber bed. The NJ-DEP Air Quality Permit requires a minimum of 70 percent collection efficiency.

The beneficial use of the EcoAggMat will be demonstrated in two ways: 1) as a partial replacement for sand in concrete used to produce foam-core wall panels for construction, and 2) as clean fill at a site remediation project in South Kearny, New Jersey (BASF Company).

As another demonstration of the beneficial use, Ecomelt produced during the slagging tests will be ground to cement fineness (< 50 micrometers) and shipped to a local ready mix company. The ground Ecomelt will then be used as a partial replacement for Portland cement in the manufacture of concrete for a length of sidewalk at Montclair State University.

This phase of the Cement-Lock demo plant operations has been completed.

# TABLE OF CONTENTS

## TABLE OF CONTENTS (Continued)

## TABLE OF CONTENTS (Continued)

# LIST OF FIGURES

## LIST OF FIGURES (Continued)



## LIST OF TABLES

# I. INTRODUCTION

The Gas Technology Institute (GTI, Des Plaines, IL) and Unitel Technologies (Mount Prospect, IL) developed the Cement-Lock®*[1] Technology in response to the need identified by the U.S. Environmental Protection Agency (Region 2) and the U.S. Army Corps of Engineers (New York District) under a mandate from the federal Water Resource Development Act (WRDA). The overall objective of the WRDA Program was to bring fast-track sediment decontamination technologies to the commercial market to decontaminate sediment from the New York/New Jersey waterways and to find beneficial uses for these sediments.

**Cement-Lock Technology®**

The Cement-Lock Technology is a thermo-chemical remediation technology that converts contaminated sediments, soils, sludges and other waste materials into construction-grade cement – a marketable product for beneficial use. The construction-grade blended cement from the Cement-Lock Technology has properties similar to those of ordinary Portland cement. Under the WRDA program, GTI conducted tests at the bench-scale as well as at continuously operating pilot-scale using Newtown Creek (New York) sediment to illustrate the concept of the technology. The results of these tests were very encouraging. All the organic contaminants present in the sediment were destroyed and the inorganic contaminants were immobilized in the cement matrix. The construction-grade cement produced from these tests surpassed the compressive strength requirements for Portland as well as blended cements as required by ASTM (American Society for Testing and Materials) standards.

The mixture of sediment and modifiers is conveyed to the rotary kiln melter (Ecomelt® Generator) by screw conveyor. The Ecomelt Generator itself is maintained at a temperature in the range of 2500° to 2600°F by combustion of natural gas or other fuel with air. This temperature is sufficient to yield a melt with a manageable viscosity and cause the minerals in the sediment and modifier mixture to react together. During processing, the sediment-modifier blend is thermo-chemically transformed from the recognizable materials in the feed to a homogeneous melt. All nonvolatile heavy metals originally present in the sediment are

[1] Cement-Lock® consulting services for waste treatment available from Cement-Lock Group, L.L.C.

incorporated into the melt matrix via an ionic replacement mechanism. The molten material moves through and exits the Ecomelt Generator by kiln rotation and gravity. It then falls into a plenum through high-pressure streams of water, which immediately quenches and granulates the melt. The quenched and granulated material is called Ecomelt®. The Ecomelt is removed from the quench granulator by a drag conveyor, which also partially dewaters it.

A portion of the quench water vaporizes during the quenching operation. Makeup water required is provided from a local supply of process water.

Flue gas from the Ecomelt Generator flows into the Secondary Combustion Chamber (SCC), which provides an additional 2 seconds of residence time at a minimum temperature of 2200°F to ensure complete destruction of any organic compounds that survive the severe thermal conditions in the Ecomelt Generator. Effluent gas from the SCC is rapidly cooled via direct water injection to prevent the formation or recombination of dioxin or furan precursors. Powdered lime is injected into the cooled gas to capture sulfur compounds and sodium and potassium chloride (NaCl and KCl) from seawater. The sulfur/salt/lime mixture is removed from the flue gas stream by a baghouse. The collected baghouse material is containerized and shipped off-site in an ordinary landfill. This material represents less than 2 percent of the raw sediment volume. Volatile heavy metals – such as mercury – are removed from the flue gas as it passes through a fixed bed of activated carbon pellets. The charge of activated carbon in the fixed bed is more than sufficient to capture the mercury from the approximately 350 $yd^3$ of sediment allocated for the pilot demonstration project. Cleaned flue gas is vented to the atmosphere at about 350°F via an I.D. (induced draft) fan.

After the demonstration, the activated carbon pellets will be analyzed for mercury content. If the carbon has reached its capacity, it will be removed and sent to an appropriate spent activated carbon reprocessor.

The Cement-Lock demonstration plant incorporates all of the major equipment components needed to demonstrate and characterize the process. The final steps in producing the Cement-Lock construction-grade cement, namely, grinding and blending the Ecomelt with ordinary Portland cement or another lime source will be done at an off-site facility. A simplified process flow diagram of the Cement-Lock demonstration facility is presented in Figure 1.

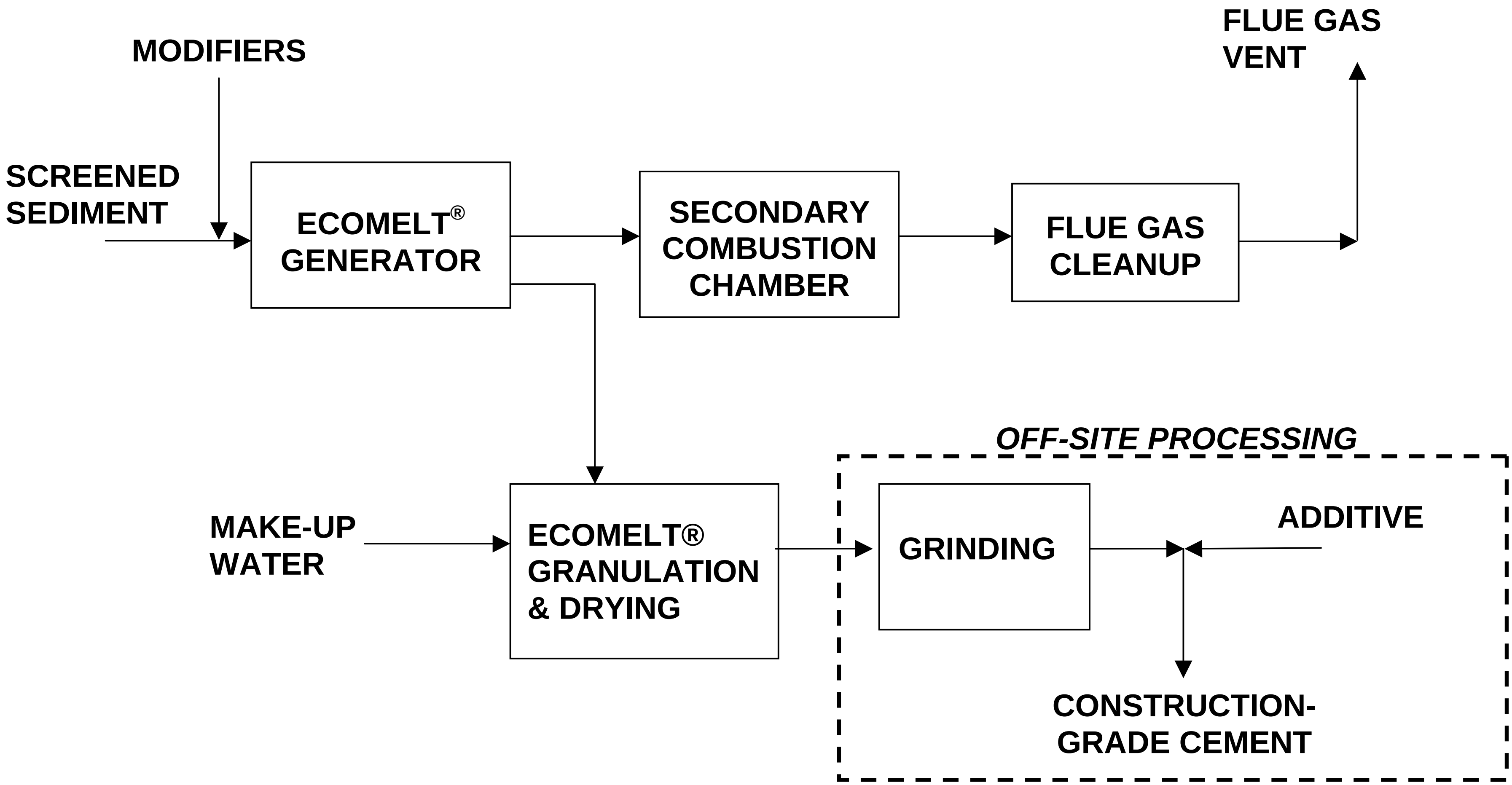



Figure 1. Process Flow Diagram for Cement-Lock Demonstration Plant

**New Jersey State Sediment Decontamination Demonstration Project**

The Cement-Lock Technology was also selected by the New Jersey Dredging Project Facilitation Task Force (appointed by then New Jersey Governor Christine Todd Whitman) to process a minimum of 30,000 $yd^3$ of contaminated sediment. The successful demonstration will be followed by construction of a 500,000-$yd^3$ per year contaminated sediment treatment facility.

A public-private partnership was created to carry out the demonstration project. Specifically, ENDESCO Clean Harbors, L.L.C. (ECH – a subsidiary of GTI) licensed to transact business in New Jersey was formed as a separate entity with a mandate to demonstrate Cement-Lock Technology on harbor sediment. ECH owns the demonstration plant equipment and also holds license to use the Cement-Lock Technology from Cement-Lock Group, L.L.C. Other parties to this partnership include the natural gas industry represented by the Gas Research Institute (GRI), ENDESCO Services, Inc. (a wholly owned subsidiary of GTI), the U.S. Environmental Protection Agency Region 2, U.S. Army Corps of Engineers – New York District with technical and management support from Brookhaven National Laboratory (BNL), tentatively, a cement/concrete manufacturing company, and the State of New Jersey Office of Maritime Resources (NJ-DOT/OMR).

Technical support in the areas of product development and product utilization has been provided by Construction Technology Laboratories (Skokie, IL – the independent research arm of the Portland Cement Association), a private cement company, and the New Jersey Department of Transportation. Anderson 2000 Inc. (A2K, Peachtree City, GA) provided engineering, equipment construction, equipment installation, training, and start-up services.

This report documents the operations of the Cement-Lock® demonstration plant at the International Matex Tank Terminal (IMTT) in Bayonne, New Jersey since the completion of start-up and commissioning activities in December 2003 through the end of March 2005. This work was conducted under Phase V – Operation of the Cement-Lock Demonstration Facility – of the Brookhaven National Laboratory sponsored program (Brookhaven Contract No.: 725043) for "Cement-Lock® Technology for Decontaminating Dredged Estuarine Sediments." Other funding for this program has been provided by the NJ-DOT/OMR and the Gas Research Institute (GRI, Des Plaines, IL).

# II. NEW JERSEY PERMITTING

Prior to the construction and initial operations of the Cement-Lock demo plant, ENDESCO Clean Harbors applied for and obtained an Air Quality Permit and an Acceptable Use Determination (AUD) from the New Jersey Department of Environmental Protection (NJ-DEP). During the operations phase of the project, ECH was required to obtain a revised AUD as the beneficial use of the non-slagged EcoAggMat product was different from that of the Ecomelt product generated under slagging conditions. The original AUD and the revised AUD are described below.

**Original Acceptable Use Determination (AUD)** – The original AUD was issued by the NJ-DEP Office of Dredging and Sediment Technology (File No. 0714-99-0001.1. The major points of the AUD covered the following:

1) Storage of up to 500 $yd^3$ of sediment from the Stratus Petroleum Newark Terminal berthing area in lined and covered roll-offs at the Passaic Valley Sewerage Commissioners (PVSC) location in Newark
2) Transport and off-loading of the sediment into the lined and bermed sediment storage area at IMTT
3) Construction of the Cement-Lock demonstration plant
4) Operation of the Cement-Lock demonstration plant with the stored sediment, and
5) Beneficial use of the Ecomelt product in suitable construction projects.

**Revised Acceptable Use Determination** – As the project developed, it became necessary for ECH to request a modification to the existing AUD in February 2005 to accommodate the operation of the Cement-Lock demo plant in non-slagging mode. As Ecomelt is only produced under slagging conditions, the beneficial use of the thermally treated product – EcoAggMat – needed to be defined and included in the AUD. Letters were secured from BASF Corporation, Florham Park, NJ and EnCap Golf Holdings, East Rutherford, NJ in which these companies agreed to accept the thermally treated material if it met specific placement criteria. These letters as well as the revised AUD from NJ-DEP issued to ECH are included in Appendix A.

# III.  EQUIPMENT CONSTRUCTION AND INSTALLATION

The equipment for the Cement-Lock demonstration plant was originally fabricated for the specific application of medical waste incineration in non-slagging (or ashing mode).  The rotary kiln system was subsequently obtained by A2K during an acquisition.  A2K modified the equipment for the Cement-Lock Technology, which included means for maintaining the molten slag exiting the rotary kiln in a fluid state.  Construction of the Cement-Lock demo plant was completed at IMTT in July 2003.  Start-up and commissioning activities commenced immediately thereafter.

The equipment construction and installation activities have been described in detail in the "Plant Shakedown Report," which was submitted to BNL in January 2004.  These activities are briefly described below.

### Infrastructure

Actual construction activities were initiated in June 2002 with the installation of a 10-foot high, chain-link fence around the leased property perimeter on the IMTT facility.  Other construction-related activities included:

1) Preparing the subsurface ground for the several monolithic concrete slabs
2) Excavating the soil where the foundation pads would be poured
3) Installing framing and pouring concrete for the foundation pads
4) Receiving equipment deliveries, including structural steel, vessels, motors, piping, ductwork, etc. for the plant.
5) Installing and connecting each piece of equipment as designed
6) Installing the needed utility infrastructure
7) Installing the electrical power and instrumentation.

### Foundations and Foundation Design

The objectives of this task were to design and install foundations for the Cement-Lock demonstration plant equipment, the sediment storage hopper, modifier hoppers, Cement-Lock product storage hopper, and other ancillary equipment items (screw conveyors, compressor, bins, motor control center, etc) to accommodate the plant. The throughput capacity of the plant had been increased from 10,000 to 30,000 $yd^3$ per year of sediment when the EPA Region 2/BNL and NJ-DOT/OMR project objectives were combined.

Increasing the overall plant throughput capacity can be achieved by increasing the sizes of certain equipment as well as using oxygen-enriched air for combustion. Using oxygen-enriched air significantly reduces the quantity of flue gases that must be heated to Ecomelt Generator temperature (2500° to 2600°F) thereby saving fuel costs. However, oxygen enrichment was not included in the Phase I effort.

The main pad, which supports the charging platform, the rotary kiln plus refractory and motor drive, the secondary combustion chamber, the drop-out box, and the water spray quencher is a concrete monolith 88 feet long and 32 feet wide and 2 feet 9 inches thick. It has rebar installed.

**Utility Requirements**

The utility requirements for the Cement-Lock demonstration plant were estimated by A2K for the plant operating at its full design capacity of about 2931 pounds of sediment (containing 60 weight percent water) per hour plus appropriate amounts of Modifier 1 and 2. The electrical requirements are 1200 amps at 480 volts (576 kW). The natural gas requirement is 40 million Btu/hour (maximum) and 30 million Btu/hour (nominal). The water requirements were estimated as 1) Ecomelt granulator evaporation of 7 gpm, 2) Flue gas quencher water of 35 gpm, and 3) Fire protection for Activated Carbon adsorber bed of 75 gpm for a total of 117 gpm. A2K recommended a nominal water supply of 200 gpm to establish the water utility for the plant. Natural gas, electricity, and water were availability at the site.

**Installing Refractory and Insulation**

Because of weight and durability concerns associated with the high-temperature refractory, most of the refractory was installed at the site after the equipment had been set in place. The primary equipment for which refractory is needed includes the Ecomelt Generator, the secondary combustion chamber (SCC), and the interconnecting piping between the SCC and the flue gas quencher. The refractory work was completed by Lynn Whitsett Company (GA).

Two major equipment items were delivered to the plant site with some refractory already installed: The drop-out box, which had been "gunned" on-site at A2K. The nose ring and tail ring of the rotary kiln (Novacon 95), which had been cast on-site at A2K.

For cold weather-related reasons, it was necessary to insulate some of the equipment and piping to prevent freezing as well as condensation. The primary piece of equipment requiring insulation is the baghouse. Similarly, pipes handling water-bearing gases or liquids were insulated.

**Plant Standard Operating Procedures**

The operating and maintenance (O&M) procedures developed by A2K were reviewed by GTI staff. Comments and suggestions were incorporated into the final O&M document. Also, per the recommendation of RPMS and A2K, a series of Standard Operating Procedures (S.O.P.s) were developed for the Cement-Lock demo plant. The S.O.P.s include the following: Start-up and shut-down procedures, plant operations management, general start-up and operations procedure, solids feed systems operating procedures, fuel gas system operating procedures, Ecomelt system operating procedures, Ecomelt off gas systems operating procedures, Ecomelt dryer off gas systems operating procedures, plant support systems operating procedures, overall plant maintenance procedures.

**Temporary Buildings**

Several temporary buildings or trailers were required for the Cement-Lock demo plant facility. These include office space, locker room, motor control center, and storage locker. The motor control center (MCC) was housed in a building that has controlled temperature and atmosphere so that the PLC (Programmable Logic Controller) does not get too hot or too cold, or have to endure severe fluctuations in humidity.

**Equipment Rental**

ECH opted to rent several equipment items rather than incur the capital costs associated with each, including:

- Two trailers for control room and staff, storage container (Williams Scotsman)
- Sanitary facilities (Mr. John)

- Emergency Generator and Automatic Transfer Switch (Foley Inc.)
- Man-lift, front-end loader, skidsteer, and fork lift (Foley Inc.

The equipment was rented as needed and then returned to the rental agency when not needed. Currently, the only items continuing to be rented are the control room trailer and the storage container.

### Haz-Op Review Sessions

Prior to completing plant construction and installation, representatives from GTI, A2K, RPMS, and Hazen Research met at the offices of RPMS to anticipate potential hazards and assess the overall operability of the plant. The Haz-Op review sessions focused on the Piping & Instrument Drawings prepared by A2K and modified by RPMS to include additional needed instrumentation. Specific items recommended during the Haz-Op sessions were implemented in the Cement-Lock demo plant.

### Electrical and Instrumentation

Bid packages for the electrical and instrumentation work required for the plant were prepared and submitted by RPMS to several local contractors. Bids were received and evaluated and the subcontract for the work was let. The contractor began installing the electrical conduit and trays in late April 2003. Part of the delay in beginning this work was due to delays in getting electrical drawings from A2K.

### Equipment Installation and Deficiencies

The first delivery of equipment to the plant site (a truckload of structural steel, the rotary kiln, and the sediment storage bin) was made on September 18, 2002. The rotary kiln could not be set on its trunnions that day due to a misalignment between the twenty 1½-inch diameter bolts set in each of the trunnion pedestals and the corresponding 1⅝-inch diameter holes in the trunnion baseplate. The twenty holes in each trunnion baseplate needed to be enlarged to accommodate the tight bolt pattern. The drum of the rotary kiln was then set on its trunnions two days later on September 20. The last delivery of a major equipment item was the motor control center (MCC) building, which was delivered to the plant site on January 24, 2003.

As equipment deliveries and installation progressed, many deficiencies were noted in structural steel, several inoperative motors, rusted or broken parts, and other items. In total, 117 deficiencies were documented during construction. Per prior agreement, these deficiencies were noted and brought to A2K's attention. Correcting these deficiencies caused delays and extra costs to the overall project.

### Summary of Construction and Installation

Construction and installation of the Cement-Lock demonstration plant was completed on July 26, 2003. Shakedown and commissioning activities commenced on Monday July 29, 2003.

# IV. PLANT SHAKEDOWN AND COMMISSIONING

The objective of shakedown and commissioning activities was to ensure that all of the individual equipment items associated with the Cement-Lock demonstration plant were in proper working order. Another objective was to ensure that each subsystem (designated collection of individual equipment items) was also working in together with the other subsystems. A third objective was to insure that all data acquisition and control equipment (instruments, wiring, PLC, etc.) was working properly and communicating with the computers in the control room.

The plant shakedown and commissioning activities are discussed in detail in the "Plant Shakedown Report," which was submitted to BNL in January 2004. These activities are briefly described below.

### Shakedown and Commissioning Team

Plant shakedown and commissioning activities were performed under the guidance and direction of A2K. A2K initially contracted GreenTree Services (Exton, PA) to begin the shakedown and commissioning activities and then later sent their own commissioning engineer to complete the work. RPMS's subcontractors provided labor for welding, cutting, rewiring, adjusting, monitoring, etc. during the shakedown and commissioning activities. To serve as site monitors on behalf of GTI and ECH, Steve Calderone and Todd Harvey (Unitel Technologies, Mount Prospect, IL) were at the plant site from May 8 through September 4, 2003 GTI staff, including Bob Sheng, Mike Mensinger, and Dave Bowen, also served stints on-site during the remainder of the shakedown and commissioning activities.

### Subsystem Testing

Each Cement-Lock demo plant equipment subsystem was checked for proper connection and operation by the shakedown and commissioning team in a systematic manner, including:

- Sediment hoppers, augers, feed systems, motors, conveyors, instrumentation
- Modifiers 1 and 2 hoppers, feed systems, rotary valves, motors, conveyors, instrumentation
- Rotary kiln melter (Ecomelt generator), drive motor, burner, natural gas supply, combustion air blowers, refractory, alignment, instrumentation

- Secondary combustion chamber system, burner, natural gas supply, combustion air blower, refractory, instrumentation
- Natural gas burner systems (main, secondary, melt, and Ecomelt dryer)
- Ecomelt granulator and conveyor system, water sprays, drag conveyor motor, instrumentation.
- Ecomelt conveyor, dryer, and storage system, conveyors, motors, instrumentation
- Flue gas quench system, water sprays, water storage tank, pumps, instrumentation
- Lime injection system, lime hopper, blower and motor, rotary valve, instrumentation
- Baghouse dust collection, compressed air system, rotary valve, dust collection, instrumentation
- Activated carbon adsorber bed system, carbon, fire suppression system, instrumentation
- Induced draft (I.D.) fan, motor, damper, instrumentation
- Computer data acquisition and control system, PLC (Programmable Logic Controller)
- Safety interlocks
- Natural gas supply system, natural gas compressor, instrumentation.

At a minimum all electrical connections were checked for continuity and accuracy. All electrical connections were checked for proper polarity. Electric motors were checked for proper voltage, wiring, and rotation. Pumps (and associated motors) were checked for proper wiring, rotation, and lose connections, leaks, etc. Connecting lines and nozzles were checked for blockages, obstructions, leaks, etc. Safety switches were checked for proper operation. All conveyors were checked for proper rotation, correct installation of keys, obstructions, etc. Natural gas lines were checked for leaks, proper connection to safety controls. Natural gas burners were checked for operability, safety controls. Computer signals from the field were checked for proper connection to the PLC, and for communication with the computer control system.

Refractory Curing: Concurrent with the equipment calibrations, the refractory bricks in the kiln, the gunned refractory in the secondary combustion chamber, and the ductwork were cured in the manner specified by the manufacturer. The curing operation involves heating the refractory in stages to specified increasing temperatures and maintaining those temperatures for specific time periods. Curing is necessary to drive off surface moisture as well as moisture that is variously combined with the refractory components. The refractory curing requires slow and steady heating over a period of several days.

Once the refractory has been maintained at temperature for the specified time, it was planned to continue with actual operations to save time. In the original start-up plans, A2K recommended that the kiln temperature be brought back down to ambient so that the refractory could be examined for problems and/or defects. In the interest of saving time, this step was by-passed.

### Electrical Components

All of the electrical installation work was completed prior to shakedown and commissioning. Cable trays and conduit were installed. All electric motors in the demo plant were wired to appropriate motor starters in the Motor Control Center (MCC). During shakedown, each motor was tested for proper wiring and “bumped” for proper rotation. Several motors were found to be inoperative. These motors were removed and replaced with new motors.

### Instrumentation

All instruments were checked for proper polarity, connection, continuity, and operation at the instrument itself, at the PLC (Programmable Logic Controller), and at the HMI (Human Machine Interface otherwise known as a PC). Some instrument loops were checked from the PLC directly. Instruments include thermometers, thermocouples, and temperature indicating transmitters, pressure indicators (gauges), pressure indicating transmitters, flow meters, flow indicating transmitters, and digital inputs and digital outputs were checked for proper connection and calibrations and limits as needed.

### Sediment Feed System

The sediment feed system consists of the following equipment items: 100-$yd^3$ capacity main Storage Hopper (T-101), alternate Storage Hopper (T-102), sediment conveyors C-101, C-102, the Pug Mill Mixer (C-131), sediment Weigh Feeder (C-112), and water-cooled Auger/Screw Feeder (C-151). Conveyor C-101 is a metering conveyor that controls the flow of sediment to the Weigh Feeder (C-112). Based on the Weigh Feeder indication of sediment flow, the proper quantities of Modifier 1 and Modifier 2 are fed from their respective feed systems.

All of these equipment items in this subsystem were tested and their operation confirmed. Even though the load cells were calibrated, the sediment feeding tests through the weigh feeder yielded inconsistent results. It was concluded that the sticky nature of the sediment caused it to accumulate within the Weigh Conveyor rather than pass readily through. This prompted the sediment and modifier premixing approach (see following discussion).

The initial attempts to calibrate the main sediment feed conveyor (C-101) resulted in sediment completely plugging and jamming the conveyor. With all four of the augers turning in the main Sediment Hopper (T-101), it appeared that too much sediment was being fed to the main feed conveyor. Also, the consistency of the sediment was such that it stuck to the flights of the screw conveyor. Very little material actually made it out of the screw conveyor and into the pug mill (M-131). The operators had to remove the segmented covers to the conveyor and manually removed the sediment from the flights.

Another approach involved premixing the sediment and modifiers solids together in measured batches (according to the desired Ecomelt recipe) in the sediment storage area. Several batches of premixed sediment and modifiers were manually prepared area using a rototiller. These batches were covered with tarps in the sediment storage area.

### Modifier Feed System

The modifier feed systems include the Modifier 1 Hopper (T-103), Feeder (F-103), Conveyor (C-103), Modifier 2 Hopper (T-104), and Feeder (F-104). When the Modifier 1 and 2 feeding systems were initially tested, it was found that neither was in the proper range for the demo project. Both were feeding much more modifier than expected or appropriate for the demo. Modifications needed to achieve the proper range for each feed system were installed.

### Lime Feed System

The lime feed system includes the Lime Hopper (T-302), Feeder (F-302), Lime Feeder Airlock (F-302A), and Lime Eduction Blower (B-302). The lime feed system was calibrated according to the calibration procedure prepared by A2K. To convey the lime into the flue gas upstream of the baghouse, a slipstream of ambient air was used as motive gas.

## Flue Gas Quencher

The flue gas quencher system includes the Flue Gas Quencher (Z-301), double tipping valves (KV-301 and KV-302), the Quencher Water Tank (T-301), Quencher Water Pump (P-301), air compressor (P-305), and Water Flow Control Valve (TV-301). The Flue Gas Quencher must operate properly to protect the downstream air pollution control equipment, specifically the baghouse and activated carbon bed, from temperature excursions. The bags in the baghouse are capable of operating at temperatures up to 500°F (Huyglas®); however the design temperature (per A2K) is 400°F.

## Baghouse

The particulate filtration/collection subsystem consists of the Baghouse (S-303), the dust discharge Rotary Feeder (F-303), and a means for collecting the dust. The system also incorporates a reverse pulse compressed air system to clean the accumulated dust from the bags when the pressure drop exceeds the manufacturer's recommendation.

## Activated Carbon Adsorber Bed

The Activated Carbon Adsorber bed (A-304) is an air pollution control device designed to capture volatilized heavy metals, such as mercury, that may be present in dredged sediment. The activated carbon adsorber bed consists of two 2-foot thick beds of activated carbon pellets within a single steel vessel. The total quantity of activated carbon pellets in the two beds was about 24,000 pounds. . The carbon in the activated carbon bed is specified to operate at 350°F.

## Induced Draft (I.D.) Fan

While commissioning the I.D. fan and motor, the pneumatic actuator for the air damper failed to respond properly. The actuator had been incorrectly connected to the high-pressure air line from the compressor rather than the low-pressure instrument signal line, which damaged the diaphragm. A replacement actuator was ordered and installed. However, the new actuator was not strong enough to adjust the air damper under the full load of the I.D. fan. A larger replacement was obtained by A2K, installed, and tested for proper function.

### Emergency Stack Cap

The emergency stack cap is located at the top of the refractory-lined duct leading from the Secondary Combustion Chamber into the Flue Gas Quencher. When initially tested, the stack cap would not open completely. The chain that reaches from the stack cap to ground level was too long. At ground level, a personnel guard rail was installed around the counterweight to prevent accidents. At top level, the grating interfered with the movement of the chain. The grating was adjusted to allow free movement of the chain.

### Natural Gas Supply System

The natural gas supply system consists of the natural gas booster compressor and the supply lines to the different process burners. The natural gas line was successfully leak/pressure tested from the spud up to the natural gas booster (the test gas was nitrogen). The natural gas compressor was commissioned and, after some adjustment of its internal PLC programming parameters, operated as designed.

### Natural Gas Burners

Four main burner systems were originally installed in the Cement-Lock demo facility: 1) Primary Burner (30 million Btu/hour – HX-201) for the Ecomelt Generator, 2) Secondary combustion chamber burner (6 million Btu/hour – HX-202), 3) Melt burners (three nominal 0.5 million Btu/hour – HX-203A, B, and C), and 4) Ecomelt dryer burner (0.9 million Btu/hour – HX-206). Each burner system is equipped with safety, flow control, and flame detection systems.

### Ecomelt Generator

The Ecomelt Generator subsystem consists of the Ecomelt Generator (R-201), Secondary Combustion Chamber (R-202), and the refractory, motor drive, and combustion air blowers.

### Refractory Curing

Refractory curing was initiated on October 13, 2003. The temperature in the rotary kiln was brought up slowly according to the curing schedule recommended by A2K. However, while attempting to light the burners, it was determined that the ultraviolet flame detectors had failed. The UV flame detectors had to be replaced. Curing was continued until a temperature excursion occurred in the Activated Carbon Adsorber bed. The temperature excursion and resulting damage to the system are described in detail in the "Plant Shakedown Report," which was submitted to BNL in January 2004.

**Ecomelt Granulator**

The Ecomelt Granulator subsystem consists of the Ecomelt Granulator (C-203), Granulator water Recirculation Tank (T-203), the Ecomelt drag conveyor, and the Granulator Recirculation Pump (P-203) and its backup (P-203A).

**Ecomelt Dryer and Storage**

The Ecomelt Dryer and Storage subsystem consists of the Ecomelt Dryer (D-206), Rotary Feeder (F-206), Dried Ecomelt Conveyor (C-216), Bucket Elevator (C-217), Ecomelt Hopper (T-219), Rotary Feeder (F-219), Dried Ecomelt Product Conveyor (C-219), Dryer Cyclone Separator (M-401), Bag Filter (S-402), and Ecomelt Dryer I.D. Fan (B-402).

**Continuous Emissions Monitoring System (CEMS) Testing**

The Continuous Emissions Monitor System (CEMS) is capable of measuring the oxygen ($O_2$) and carbon monoxide (CO) contents of the flue gas as well as opacity. All three of these parameters are required to be measured and recorded as stipulated by the Air Quality permit issued by the NJ-DEP. The CEMS was successfully activated and calibrated with special protocol calibration gases. The protocol calibrations for the CO and $O_2$ and the analysis of the nitrogen (zero gas) are included in Appendix B.

**Summary of Shakedown and Commissioning**

During shakedown and commissioning, numerous equipment failures and problems were encountered that delayed the project, including a temperature excursion in the activated carbon bed, two power outages, and the deleterious effects of inclement weather.

# V. OPERATOR TRAINING AND SAFETY

The plant operators have undergone both classroom as well as hands-on training in the proper function of the demo plant equipment. Also, as part of the overall focus on safety at the plant during construction as well as operations, the plant manager and all shift supervisors as well as GTI project staff underwent health and safety training to enable them to safely assist RPMS staff in the operation of the plant on an "as needed" basis. Training and safety-related activities are described below.

On September 3 and 4, 2003, A2K conducted classroom training for the Cement-Lock demonstration plant at IMTT facilities. Tom Van Remmen, A2K Vice President of Sales and Marketing presented the training material, which was abstracted from the Cement-Lock demo plant Operations & Maintenance Manual. Safe operation of the plant was stressed during the training session as being of paramount importance.

The A2K Commissioning Engineer, Nelson Carswell, provided hands-on plant operations training of the plant manager, shift supervisors, and laborers. The RPMS plant manager, shift supervisors, and GTI staff attended safety orientation training and awareness seminar presented by the Safety Department of IMTT. Supervisory staff and operators underwent scaffolding use and safety awareness training. The 4-hour session was conducted by a representative from Emilcott Associates. Each attendee received a diploma certifying that they had attended the session.

Further, a detailed, site-specific Health and Safety Plan (HASP) was prepared and submitted to BNL as a deliverable for the project.

Overall, during the construction, installation, shakedown and commissioning, initial operation, continuing operation, and non-slagging activities at the plant, there have been <u>no</u> significant or lost time injuries.

# VI. START UP AND INITIAL OPERATION

The start-up and initial operation of the Cement-Lock demo plant was completed in early December 2003. The first Ecomelt from Stratus Petroleum sediment was generated at the demo plant on December 9, 2003. The Ecomelt was tested and found to be appropriate for use as a partial replacement for Portland cement in concrete. Subsequently, GTI and the plant operating team worked to remedy problems in efficiently feeding sediment and modifiers to and discharging slag from the system.

The following described briefly the activities during the initial start-up.

**Test No. 1 (December 9-10, 2003)**

On the morning of December 9, the kiln temperature had been brought up to 2425°F. The Secondary Combustion Chamber (SCC) temperature was 2290°F. At 9:15 a.m., we began feeding the premixed sediment-modifier mixture to the kiln through an opening in the main conveyor (C-101). The sediment-modifier mixture was manually fed at a rate estimated to be about 600 pounds per hour. The readings obtained from the weigh conveyer (C-112) were not reliable due to the sticky nature of the sediment. Several batches of premixed feed material were fed manually during the day.

Feeding was halted that night for safety concerns. The operators prepared additional batches of premixed feed materials. Other operating parameters were maintained at steady conditions.

Although molten slag was observed to be dripping from the "ceiling" of the rotary kiln (Figure 2), no Ecomelt was discharged from the Cement-Lock demo plant on December 9. It was estimated that several batches of premixed feed material would be required to coat the refractory with a layer of slag.

On December 10, feeding resumed around 9:00 a.m. Shortly thereafter, the water-cooled auger/screw (C-151) jammed. This auger runs at a fixed speed and was being fed more material than it could effectively convey into the rotary kiln. This imbalance resulted in "flooding or choking" in the pug mill discharge (the connecting plenum between the pug mill and the auger/screw).

Figure 2. Molten Slag Dripping From the Kiln "Ceiling" During December 2003 Campaign

Operating conditions in the Cement-Lock demo plant were steady when the material was fed into the C-101 conveyor. Natural gas flows to the main kiln burner averaged 19.9 million Btu/hour during the operating test period. The flow of combustion air to the main burner averaged 229,776 ACFH. Temperature in the Secondary Combustion Chamber averaged 2390°F and the natural gas flow averaged 856,000 Btu/hour. Combustion air to the SCC averaged 9257 ACFH. The temperature at the melt burner averaged 1924°F. Natural gas flow to the melt burners were not recorded. Other conditions were steady. The temperature of flue gases flowing into the activated carbon bed was 350°F. The time-temperature history of the initial start-up of the Cement-Lock demo plant is presented in Figure 3. Temperatures for the Ecomelt Generator, SCC, Flue Gas Quencher outlet, Activated Carbon bed outlet, and Main Flue Gas Vent (stack) are presented. Major process flows from the test are presented in Figure 4.

The presence of rocks in the feed material caused the inclined screw conveyor (C-101) to jam several times. Although the operators had removed oversized materials by hand, some tramp materials were missed. The conveyor system had to be stopped, the motors locked out, and the lids to the conveyor removed so that the blockage could be cleared.

Feeding resumed at 2:00 p.m. At this point, the kiln temperature had been increased to 2515°F. By visual observation, the molten slag in the kiln appeared to be less viscous than that from the pilot-scale testing at Hazen Research.

At 3:10 p.m., the first sample of Ecomelt from Stratus Petroleum sediment was conveyed out of the granulator (Figure 5). Samples were taken for visual and microscopic examination. Under cross-polarized light, the desired non-crystalline (glassy) phases appear dark (Figure 6). The

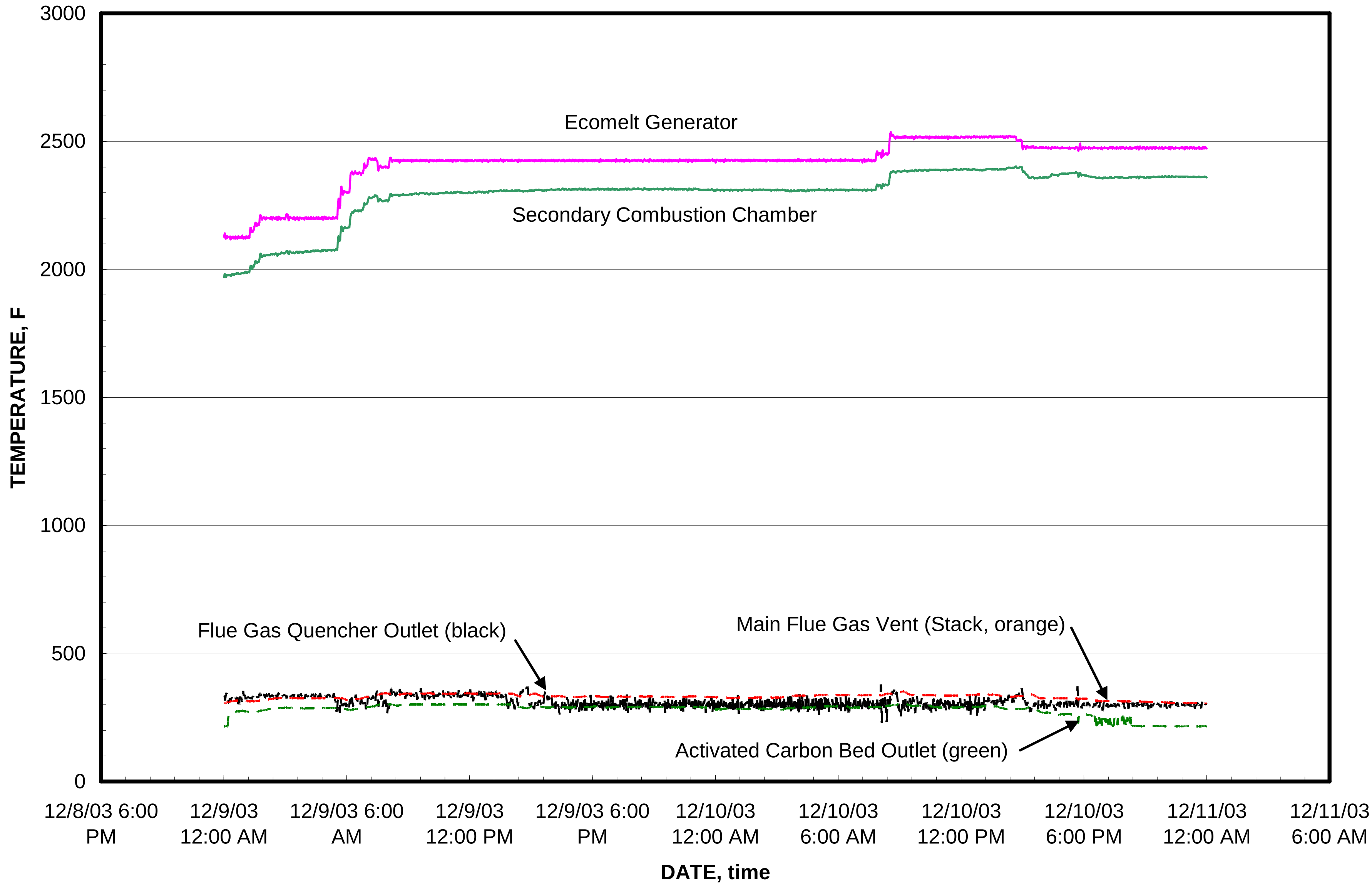



Figure 3. Time-Temperature History of the Initial Startup (Test No. 1, December 9-10, 2003) of the Cement-Lock Demo Plant

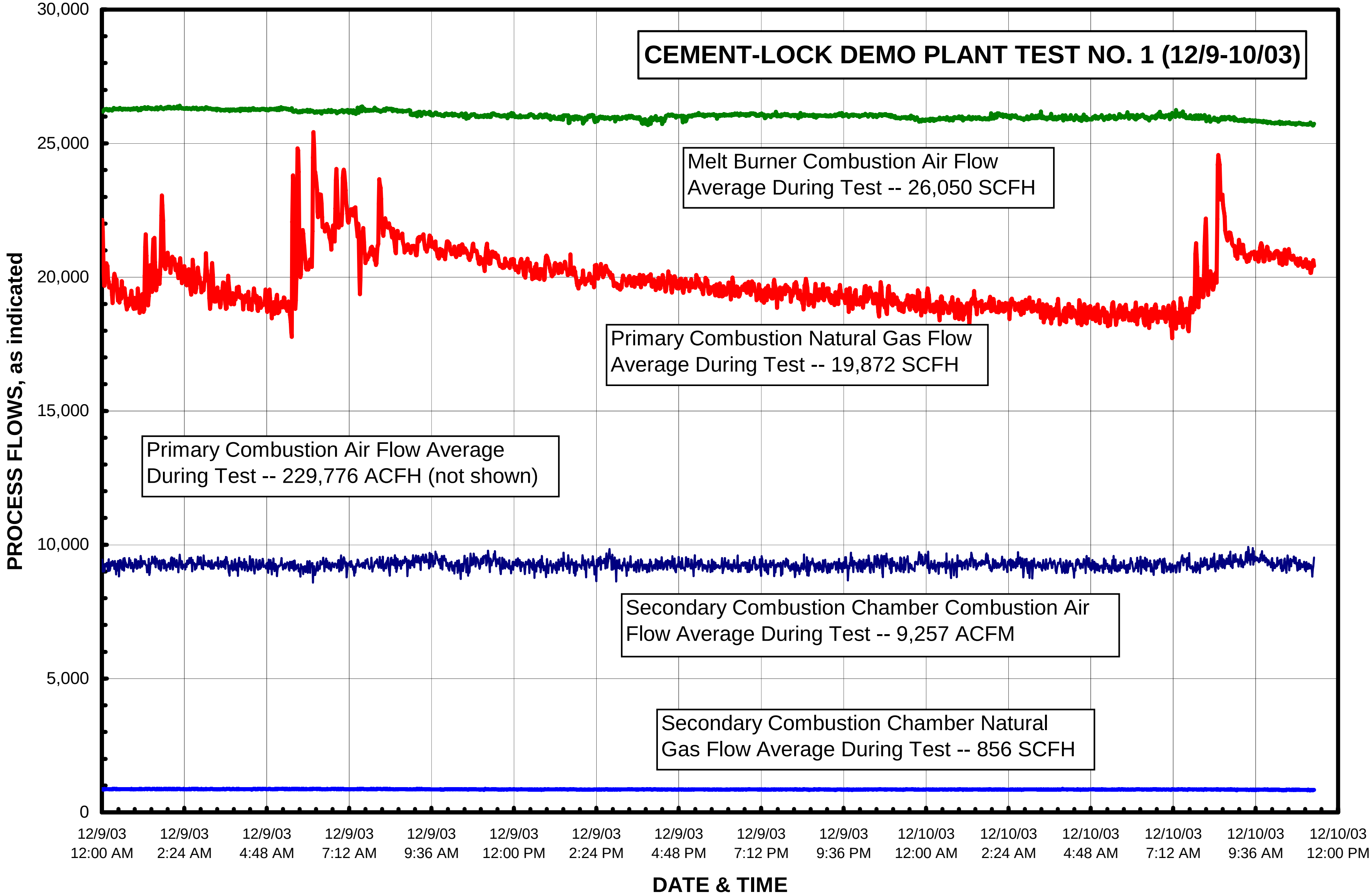



Figure 4. Major Process Flows Recorded During the Initial Startup
(Test No. 1, December 9-10, 2003) of the Cement-Lock Demo Plant

Figure 5. Initial Ecomelt Produced From Stratus Petroleum Sediment – Collected December 10, 2003.

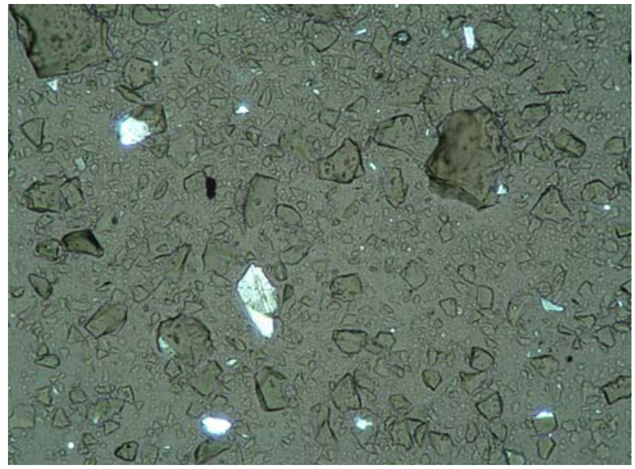


Figure 6. Ecomelt Viewed Under Cross-Polarized Light, the Desired Glassy (Dark) Phase Predominates. Bright Spots are Undesired Crystalline Phases.

undesired crystalline phases appear as bright spots. The estimated desired glassy composition of the Ecomelt sample was over 90 percent. Manual feeding was halted just after 3:00 p.m. as the operators changed shifts. Feeding was resumed at 4:00 p.m.

When viewed through the two view ports on the drop-out box, the molten slag appeared to be more viscous around the kiln discharge than in the main part of the rotary kiln. Slag buildup on the ceramic pusher tiles and drop-out box section was also observed. The three melt burners were constantly fired at their maximum output. However, there is speculation that the melt burners were under-fired due to insufficient natural gas pressure to the burners. The length of the main burner flame was increased to convey more heat toward the drop-out box and possibly clear the slag buildup. This was not effective and the slag continued to accumulate. By 6:00 p.m., the slag buildup had blocked the entire south view port and half of the north view port. At this point, solids feeding was halted.

At about 12:00 midnight, the shift supervisor reported that the drag conveyor in the Ecomelt granulator had jammed. Attempts to clear the jam were not successful. The kiln was maintained at about 2500°F overnight.

The next day, the kiln temperature was reduced according to the prescribed rate. After the system had cooled sufficiently, the tiles were withdrawn so that the condition of the drop-out box could be evaluated. The granulator and drop-out box were filled with accumulated slag. The operators worked to remove the slag from the drop-out box and granulator using a pneumatic jackhammer until the vessel was cleared on December 24. The slag was collected in five 55-gallon drums and the Ecomelt was collected in two partially filled 55-gallon drums.

A debriefing meeting was held at the plant site to discuss the possible causes of the slag accumulation in the drop-out box area and to recommend possible solutions. Other aspects of plant operation were discussed as well. The major recommendations from the debriefing were to 1) repair the kiln seals to minimize the influx of cool air into the drop-out box, 2) add additional burners to the drop-out box area (either as movable lances or permanently installed equipment), 3) add additional view ports to the drop-out box, 4) increase the rotational speed of the C-151 screw/auger, 5) enable forward/reverse operation for the sediment feed conveyors, and 6) add a condensate collection tank and recirculation pump to the Flue Gas Quencher bottom.

A sample of Ecomelt from the initial operation of the Cement-Lock demo plant was submitted to CTL for testing. CTL conducted x-ray diffraction (XRD) on samples of raw sediment and Ecomelt. The results of the XRD analysis on the sample of sediment (Figure 7) show the presence of numerous peaks of undesired crystal phases (typically quartz). The results of the XRD analysis on the sample of Ecomelt (Figure 8) show the smooth characteristic hill indicating the desired glassy (amorphous) nature of Ecomelt.

CTL performed the ASTM test for slag hydraulic activity (C-1073) on the Ecomelt sample. In this test, a sample of pozzolanic material (Ecomelt) is mixed with prescribed amounts of sand and a 20 wt% solution of sodium hydroxide (NaOH). The mixture is formed into 2-inch cubes and the cubes of mortar are then cured at 55°C for 24 hours. After the curing period, the samples are tested for compressive strength. The results of this test showed that the Ecomelt was hydraulically active and achieved a compressive strength of 4,380 psi. Please note that the original laboratory-scale sample of Ecomelt achieved a 1-day compressive strength of 3100 psi.

CTL also conducted tests to determine the compressive strength per ASTM Standard C-109 for comparison with the requirements for Portland cement of ASTM C-150. The results of these tests showed compressive strengths after 3, 7, and 28 days of curing of 1765, 2910, and 5190 psi, respectively, which compares very favorably with previous results. Details are summarized in Section X of the report.

**Sediment**

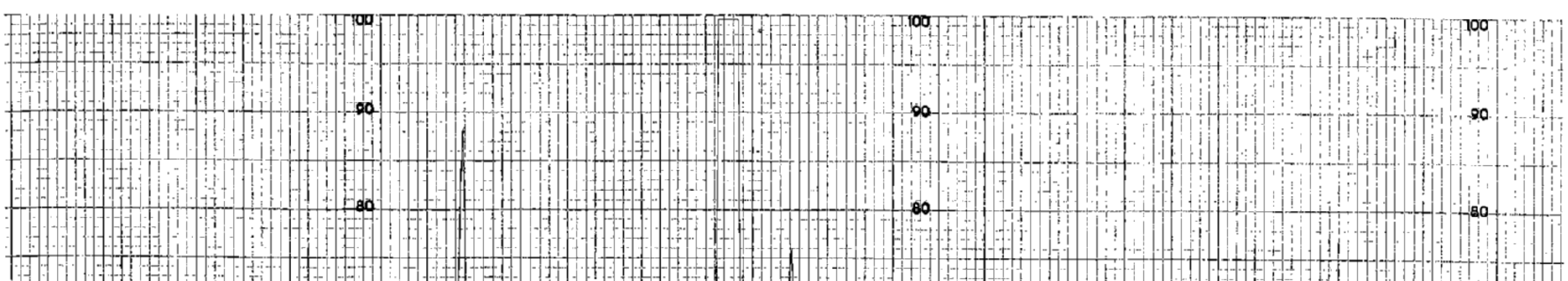


Figure 7. X-Ray Diffraction of Dredged Sediment from Stratus Petroleum –
Peaks Indicate Crystalline Phases of Mineral Matter

**Ecomelt**

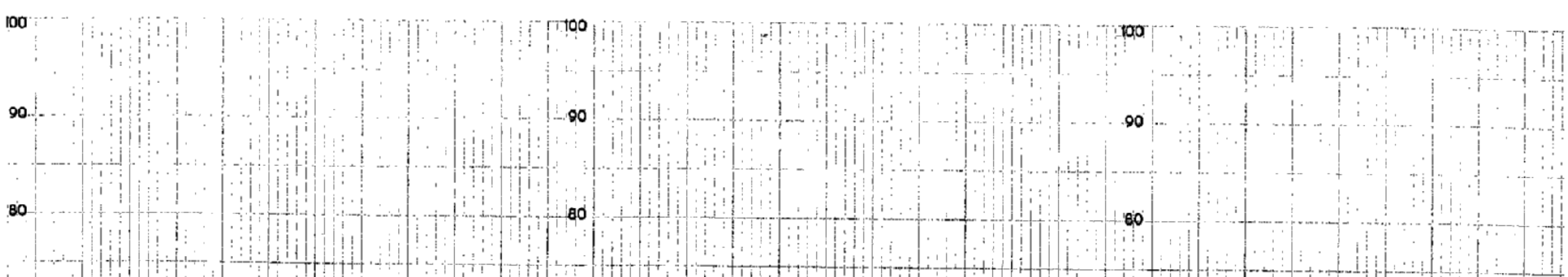


Figure 8. X-Ray Diffraction of Ecomelt from Stratus Petroleum Sediment – Lack of Peaks Indicates Desired Glassy Nature

# VII. IMPROVING PLANT OPERABILITY

The problems encountered during the initial start-up of the Cement-Lock demonstration plant in December 2003 led to the involuntary shutdown of the Cement-Lock demo plant. The implementation of the following mechanical or operational solutions were expected to enhance the overall operability of the demo plant. Activities and tests conducted since the initial start-up through the non-slagging test campaign conducted in March 2005, represent the bulk of the operations covered under this report on plant operations.

Several equipment-related problems contributed to the involuntary shutdown during initial start-up in December 2003. These problems are categorized into four major sections:

1. Feed Solids Handling
2. Ecomelt Generator and Drop-Out Box
3. Gas Cleanup, and
4. Miscellaneous Repairs / Retrofits

Among the problems identified were the inability to consistently and uniformly feed sediment into the system, inadequate air seal around the rotary kiln at the drop-out box, insufficient thermal energy input to the drop-out box, and insufficient real-time information on the situation developing in the drop-out box. Other problems related to sediment handling and feeding included sticking of sediment to and jamming of the sediment feed screw (C-101). Problems related to gas cleanup included inadequate atomization of the flue gas quencher water and excessive production of condensate from the flue gas quencher.

**Process Improvements and Enhancements**

The proposed solutions to problems identified after the December 2003 campaign and the actions taken are listed below. Please note that some of the proposed solutions were not instituted. After careful consideration, these were judged to be not cost-effective for the benefit that was originally conceived. Those proposed solutions are marked “not done” and are followed with a brief explanation.

**Feed Solids Handling**

- Install a tent to cover the raw sediment storage area. The purpose was to keep air-dried and pre-mixed sediment and modifiers from becoming rewetted due to incident rainfall. – Complete
- Spread the raw sediment over the ground (under the tent) to reduce its moisture content by air drying. By turning the sediment under the tent with a rototiller, more surface area would be exposed speeding the air-drying. – Complete
- Blend predetermined amounts of modifier solids with air-dried sediment. Blending dry modifiers with air-dried sediment would further reduce the water content of the air-dried premixed material. – Complete
- Install a removable cover on top of main sediment storage hopper (T-101). We were planning to feed the air-dried premixed material from the main sediment storage hopper. The steel covers originally fabricated for the hopper had never been installed, we decided to erect a tent-like structure over the sediment hopper that could be opened and closed with guy lines. – Complete
- Install variable speed drive on the four conveyor motors of the main sediment storage hopper (T-101). With this addition, the air-dried sediment-modifier mixture could be metered from the sediment storage area. – Complete
- Install forward/reverse switches on sediment feed conveyors (C-101 and C-112). This would facilitate cleaning of the inclined conveyor (C-101) and the weigh conveyor (C-11). If either of these conveyors were to become jammed or stuck, reversing the motor may help to free up the obstruction. – Complete
- Increase the speed of the water-cooled screw/auger (C-151). It was intended that increasing the rotational speed of the water-cooled screw/auger would convey the feed material more efficiently into the melter. – Complete
- Install a discharge chute on the main sediment feed conveyor (C-101). As the weigh conveyor (C-112) was not accurately providing information on the rate of sediment feed to the system, we opted to install a chute on the main conveyor so that a "bucket and stopwatch approach could be used to measure the feed rate. – Complete
- Install removable covers on the sediment feed conveyor (C-101). The purpose for this modification was to facilitate clearing of the flights of the inclined conveyor in the event of sediment caking. – Complete

These modifications were intended to enable the sediment or sediment-modifier mixture to be fed more consistently and uniformly into the system via the existing screw conveyors.

Installing a tent over the sediment storage area significantly improved the feed preparation activities. The tent was 90 feet long and 60 feet wide. It was 24 feet tall at its highest point. The tent has 6 support poles located within the covered sediment storage area.

The removable cover on the main sediment hopper (T-101) consists of plastic tarps draped over a central horizontal pole and tied down with guy lines. When the hopper was being loaded, the guy lines were used to retract a portion of the tarp exposing the material in the hopper below.

Air drying of raw sediment and premixing of dried sediment with modifier solids will greatly improve the operability of the feed handling system. Adding forward/reverse motor switches to the conveyors will also improve the operability of the conveyors.

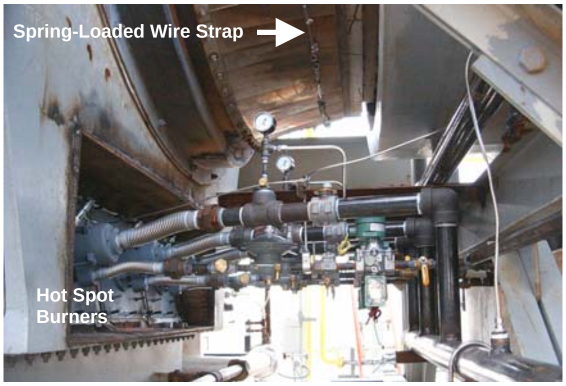
The fixed-speed drive of the water-cooled screw/auger C-151 was converted to a variable-speed drive. The original specification for screw/auger C-151 called for it to deliver 117 cubic feet (4⅓ $yd^3$) per hour of sediment and modifier mixture. This relates to a throughput capacity of 30,000 $yd^3$ per year of sediment, which is significantly higher than the target feed rate for demo plant testing. The variable-speed drive allows the conveyor to be set at a specified feed rate. If material begins to accumulate in the plenum above the C-151 screw/auger, the speed can be increased.

### Ecomelt Generation and Drop-Out Box

- Repair air seal (overlapping leaf seals) assembly at kiln discharge. This was a significant source of excess air infiltration – Complete
- Seal weld gaps in seal frame around kiln discharge. This was another source of excess air infiltration – Complete
- Repair and retune existing melt burners and air/fuel trains as needed. It had been observed that the original melt burners were operating very lean. – Complete
- Remove pusher plate/tile assembly and its cooling water supply and return system – Complete
- Install refractory lined wall to replace pusher plate/tile – Complete
- Install 5 melt burners at strategic locations around the kiln discharge. These burners were sized to supplement the calculated radiant heat loss and excess air infiltration. – Complete
- Install air and fuel gas trains and control panel for new melt burners – Complete

- Install combustion air blower system for new melt burners (including motor control center switch addition) – Complete
- Install flue gas sampling nozzles at kiln discharge for CO & $O_2$ measurement. This enabled us to reduce excess combustion air to the primary burner. – Complete
- Install 2 view ports at kiln discharge including safety blast gates and air purge. One view port was directed at the kiln nose; the other at the kiln lip. – Complete
- Install TV camera and monitor system at kiln discharge – Not done
- Replace damaged thermocouples at kiln discharge – Complete
- Install forward/reverse switch on granulator conveyor (C-203). The intent of this change was to enable "jogging" of the conveyor in the event that it became jammed. It was never intended for operating the conveyor in reverse for any appreciable length of time. A2K had cautioned that operation of the drag conveyor in reverse could result is severe damage to the system. – Complete
- Verify settings of all existing and new burners (North American Manufacturing Co., Ltd.) – Complete
- Install operator access port (manway) at kiln discharge. Since the movable tiles and assembly were eliminated, a means of entering the drop-out box and rotary kiln was needed – Complete

These modifications and retrofits will minimize the heat loss from the kiln discharge and provide additional thermal input so that the slag discharged from the kiln can be kept in a fluid molten state. The photograph (below left) shows the three new North American Manufacturing Co. Hot Spot burners installed at the drop-out box and connected to the natural gas and air supplies. The photograph (below right) shows the high-velocity Tempest burner installed on the north wall of the drop-out box (a second burner is installed on the south wall).




The air seal was improved by the simple addition of a wire strap wrapped circumferentially around the individual steel leaves connected with a spring (photograph above left). The spring keeps the wire taut and the leaves from flapping.

The new nozzle on the west side of the drop-out box enables the concentrations of $O_2$ and CO of the flue gases exiting the rotary kiln to be measured to facilitate the settings of natural gas and air inputs and to improve combustion efficiency and reduce excess air (which saves fuel).

The two new sight ports were installed on the west wall of the drop-out box. These will enable operators to visually note conditions where the slag exits the kiln and enters the drop-out box.

After considerable discussion, it was decided that a camera would add only limited benefit to the operation of the rotary kiln melter system during this phase of testing. In addition to its initial acquisition cost, costs would be incurred to install and connect the camera to electrical and water utilities (it needs to be water cooled because of the local temperature) and lead the video feed to the monitor in the trailer. Additional manpower would be needed to maintain the camera and to monitor its output, which would detract from other staff duties. Another view port would be required for direct viewing if a camera were to be mounted on an existing view port. Taken together, these costs were considered too much for this phase of the project. For the extended operation of the Phase II effort, which will process up to 2,500 $yd^3$ of sediment, a camera could be useful.

The new operator access door (manway) was installed on the west wall of the drop-out box just below the level of the two new sight ports. The access is 27 inches wide and 24 inches tall.

**Gas Clean-Up**

- Remove the double tipping valves at the bottom of the flue gas quencher. – Complete
- Install condensate surge tank and recirculating pump on the exit of flue gas quencher (Z-301) – Not done
- Relocate spray nozzles in throat of flue gas quencher – Complete
- Install pressure indicators on air/water lines to spray nozzles of flue gas quencher – Complete
- Repipe air and water to the spray nozzles eliminating all of the solenoid valves and the by-pass air lines – Complete

- Install backup thermocouple at outlet of flue gas quencher – Not done
- Locate and repair air leakage in I.D. fan expansion joint – Complete
- Repair the Continuous Emissions Monitoring System – Complete
- Replace/repair ID fan expansion joint – Not done

These modifications will enhance the performance of the flue gas quenching system, reduce pressure fluctuations, and reduce the amount of excess air leaking into the system.

The double tipping valves were removed. A simple flange was fabricated to cover the opening left by removing the double-tipping valves. Instead of installing a condensate surge tank with recirculating pump as originally proposed, we decided to route any condensate from the bottom of the flue gas quencher directly to the granulator recirculation tank (T-203). Both water sources are "contact" water, meaning that they have been in contact with process gases and, as such, cannot be disposed of without treatment. This was a logical and less expensive solution to this particular problem.

The four spray nozzles in the throat of the flue gas quencher generated a considerable amount of condensate during operation. To reduce or eliminate this unwanted situation, the spray nozzles were completely disconnected from the nozzle header and were then rewelded so that they extended about 3 inches farther into the spray plenum than before. This was sufficient to insure that the spray would not come into contact with the walls. Also, pressure gages were installed on each water header so that the water pressure as well as the air pressure could be monitored and adjusted according to the manufacturer's specifications for proper spray development. During subsequent operation, the quantity of condensate generated as well as the pressure and temperature fluctuations in the flue gas quencher were significantly reduced.

The damage to the I.D. fan expansion joint due to the temperature excursion that occurred October 2003 was determined to be superficial. No air leakage was detected and no further action was taken.

**Miscellaneous Repairs / Retrofits**

- Recalibrate all flow transmitters – Complete

- Repair water supply leaks at the hot box, trailers, safety shower, and conveyor C-151 – Complete
- Repair Continuous Emission Monitoring System – Complete

These modifications will ensure that the flow measurement devices are properly working and providing accurate information to the computer data acquisition and control system. A total of 18 instruments were recalibrated by KGB Controls (Tyrone, GA). These instruments are listed below.

| | |
|---|---|
| FIT-203 | Flow transmitter for water to granulator sprays (C-203) |
| FIT-502 | Flow transmitter for natural gas to plant |
| FIT-511 | Flow transmitter for natural gas to primary burner |
| FIT-570 | Flow transmitter for natural gas to melt burners |
| FIT-164 | Flow transmitter for air to melt burners |
| FIT-105 | Flow transmitter for air to primary burner |
| TT-303 | Temperature transmitter for baghouse outlet |
| TT-301 | Temperature transmitter for flue gas quencher outlet |
| TT-206 | Temperature transmitter for dryer outlet |
| TT-304 | Temperature transmitter for activated carbon bed outlet |
| TT-305 | Temperature transmitter for flue gas at stack outlet |
| TT-404 | Temperature transmitter for water from C-151 (water-cooled screw) |
| TT-202B | Temperature transmitter for secondary combustion chamber (backup) |
| TT-202A | Temperature transmitter for secondary combustion chamber (primary) |
| TT-201B | Temperature transmitter for rotary kiln (backup) |
| TT-206A | Temperature transmitter for dryer combustion chamber |
| TT-203 | Temperature transmitter for drop-out box (Z-203) |
| TT-201A | Temperature transmitter for rotary kiln (primary) |

The report prepared by KGB for the calibration work is presented in Appendix C.

Information collected by the CEMS is crucial to the operation of the plant as the oxygen and carbon monoxide contents in the flue gas are limited by the NJ-DEP Air Quality Permit. While the CO monitor was being repaired by Rosemount Analytical, we rented another unit from Clean Air Rentals (Palatine, IL). The repaired CO monitor was returned and reinstalled in the CEMS cabinet and is fully functional.

## III. CONTINUING SLAGGING OPERATIONS

After the equipment retrofits and process enhancements were in place, ECH and its operating team prepared the system for start-up.

**Preparations for Plant Operations**

Prior to the first demo plant test, GTI conducted laboratory-scale tests to determine how much drying was required to improve the flowability and conveyability of sediment feed material. The test results showed that an air-dried sediment and modifier mixture with a net moisture content of about 20 weight percent (or lower) would be conveyable. Based on these results, the operating crew prepared several large batches of air-dried sediment blended with specific quantities of modifier solids. The bobcat was used to scoop up a known volume of sediment (about 1000 pounds), and then a rototiller was used to blend the modifiers into the sediment. The individual modifiers were weighed using an electronic scale. The batches of air-dried sediment and modifiers were stored under the tent.

North American Manufacturing Co., Ltd. dispatched their service technician to the plant to tune the new burner system and check the operation of the other existing burners. Mr. Tamas Nemeth spent four days at the plant site (July 7-10, 2004) troubleshooting and tuning the burners. He found several items that needed to be rewired and control piping that needed to be installed. His report (included in Appendix D) indicated that the natural gas supply to the original melt burners was restricted by an undersized regulator. Thus, these burners could only be fired at about 240,000 Btu/hour instead of the design rate of 500,000 Btu/hour each. To overcome this limiting restriction, RPMS installed a manual bypass around the limiting regulator.

Trace Environmental Systems (TES) set up and confirmed the operation of the Continuous Emissions Monitoring System (CEMS). The original CO analyzer did not function properly and was removed and taken back to TES's shop for evaluation. In the meantime, GTI rented a CO analyzer from Clean Air Rentals (Palatine, IL). On July 13 TES's service technician returned to the plant to install and calibrate the rented CO monitor.

The emergency diesel generator was reconnected to the plant power system and successfully tested. It had been disconnected and removed after the December 2003 campaign.

The rotary discharge feeder on the baghouse had rusted solid and could not be freed up. FMW (subcontractor to RPMS) removed the rotary feeder and replaced it with another 6-inch rotary feeder borrowed from the Ecomelt dryer baghouse that was not being used.

On July 13, we began calibrating the four augers in the main sediment hopper (T-101). The augers are driven by new variable-speed motors that can be adjusted to deliver the desired amount of material to the main sediment conveyor (C-101). C-101 is operated at a constant speed to deliver the feed material to the weigh conveyor (C-112) and then to the pug mill (M-131). Two loads of pre-blended feedstock were charged to the main sediment storage hopper (T-101) for the calibrations. During the calibration, it was observed that the four augers were not turning in the proper direction to propel the feed material toward the discharge end. This wiring problem was subsequently corrected by SM Electric.

The pre-blended feed material could be conveyed much more readily than the raw, wet sediment tested in December 2003. The calibration showed that at 33 percent (20 Hz), the nominal feed rate was 330 pounds per hour. At 100 percent (60 Hz), the nominal feed rate averaged about 1500 pounds per hour.

To keep rainwater out of the main sediment hopper (T-101), water-proof tarps were draped over the hopper over a central pipe in a tent-like structure. The tarps are held in place by guy ropes. When material is charged to the hopper, the tarps were pulled back.

The operators devised a high-pressure air lance to disrupt “rat-holing” and bridging in the T-101 sediment hopper. This was to facilitate consistent feeding from the hopper. The operator directed the high-pressure air stream at material in the hopper that had bridged.

Refractory curing was initiated at a low heat-up rate for the new refractory “lip” and new refractory around the new Hot Spot and Tempest burners. The curing rate was specified by Harbison-Walker Refractories Co. The primary burner on low fire was used for this operation.

## Ecomelt Generation (Slagging) Tests

The following tests were conducted in the Cement-Lock demo plant with equipment retrofits and process enhancements in place under slagging conditions.

- Test No. 2 (July 16-17, 2004)
- Test No. 3 (July 22-23, 2004)
- Test No. 4 (September 22, 2004)
- Test No. 5 (October 27-28, 2004)

The operating conditions and results of each test are described in detail below.

**Test No. 2 (July 16-17, 2004)**

The objective of this test was to operate the Cement-Lock demo plant with the newly installed process enhancements and equipment retrofits in place and begin processing the pre-blended sediment-modifiers mixture.

Prior to test initiation, the temperatures in the rotary kiln (TIC-201) and secondary combustion chamber (SCC) (TIC-202) were measured at 2400° and 2250°F, respectively.

Temperatures of the refractory lining at various locations in the rotary kiln and drop-out box were also measured by hand-held pyrometer. These temperature readings showed that the fire bricks near the rotary kiln discharge were about 150°F higher than the reading indicated by TIC-201, which was measured by a thermocouple (TE-201) located on the ceiling of the drop-out box. The refractory "lip" in the drop-out box was about 100°F hotter than the TE-203 readings measured by a thermocouple located on the west wall of the drop-out box.

The flow of natural gas to the primary burner averaged 13,338 SCFH (or about 13.3 million Btu/hr). The flow of combustion air averaged 123,983 SCFH. The SCC burner was not fired during the test. As the temperature of the SCC was significantly higher than the minimum permitted level of 2100°F, it was not considered necessary.

The water flow to the granulator sprays was reduced from 55 to 40 gpm and the flow of water to the weir was reduced to 60 gpm. As a result of these flow reductions, the drop-out box temperature (TIC-203) increased from 1780° to 1845°F.

The test was initiated at 10:00 am when the four augers in T-101 were started at 67 percent (40 Hz) or a nominal feed rate of about 1000 pounds per hour.

During the initial part of the test, the oxygen concentration in the flue gas exiting the system through the vent stack averaged 7 mole percent (dry basis)  By the end of the test, the $O_2$ concentration had been brought down to about 5.5 mole percent by adjusting excess air.  The carbon monoxide concentration in the flue gas averaged 2.8 ppm during the initial part of the test and then increased to about 3.5 ppm for the remainder of the test.

As in Test No. 1 (December 2003), it took several hours of feeding before molten slag completely coated the surface of the rotary kiln and Ecomelt began to flow out of the Ecomelt granulator.  The Ecomelt was black and granular with numerous -¼-inch spherical pieces.  It resembled the Ecomelt generated during the pilot test at Hazen Research.

During the test, slag "rain" was observed to continuously fall from the ceiling of the kiln as it rotated.  The presence of "rain" indicates that the viscosity of the slag was too high.  Under the desired conditions, molten slag would form a rivulet flowing down the middle of the kiln floor. Slag "rain" was also observed during Test No. 1.

At about 2:30 pm, we increased the kiln temperature to 2450°F.  Also, we took a feed rate measurement using the newly installed chute in C-101.  The feed rate was determined to be about 1800 pounds per hour.  The operator's air-lancing technique in the feed hopper was more efficient than expected.  The auger speed rate was reduced to compensate.

Within about 15 minutes, the drop-out box temperature (TIC-203) began to increase.  After about one hour (3:30 pm), the drop-out box temperature had reached 2200°F.  Achieving a higher drop-out box temperature was one of the test objectives; however, it appeared to coincide with the accumulation of slag in the drop-out box.

At about 4:30 pm, we experienced a jam in the conveyor (C-205) that feeds the Ecomelt dryer as oversized slag material was being brought up by the Ecomelt granulator conveyor (C-203).  As the conveyor jammed, the drive belt connecting its motor to the C-205 conveyor failed.  Still hot slag material had to be extracted manually from the 6-inch diameter sample port on the C-205 granulator conveyor.

Feed was discontinued shortly thereafter (at 4:30 pm). Kiln rotation was reduced from 0.4 to 0.3 rpm to reduce the flow rate of slag to the drop-out box. The melt burners were fired continuously and the temperature of the drop-out box increased from 2200° to over 2600°F by 7:30 pm. The kiln temperature was maintained overnight at 2450°F in hope that the blockage would clear; however, it did not. On July 17, the test was terminated and the temperature in the rotary kiln was brought down per the prescribed rate of about 100°F per hour.



On July 20, the system had cooled sufficiently for personnel to enter and make a photographic record of the slag accumulation in the drop-out box. The photo (above left) shows that the top level of the slag was uniformly flat. It had completely covered over the granulator opening just below the new Hot Spot melt burners. The photo (above right) shows slag had begun to fill the nozzle of the Hot Spot burner under the new refractory "lip". As mentioned above, the drop-out box had been heated by the melt burners overnight at about 2600°F and the slag had flowed to a uniformly flat level. Thin layers of slag also flaked from the walls and kiln as shown in the photo.

Operating staff entered the drop-out box with a jackhammer and began chipping away at the slag. Within two hours, the slag had been completely broken up. Shards of slag were removed from the granulator through the sample port at the entrance to the C-205 conveyor. Later, to facilitate removal of any oversize slag in future tests, FMW installed an access/clean out port on the upper end of the C-203 conveyor. Figure 9 shows the time-temperature history of Test No. 2 of the Cement-Lock demo plant from July 16 to 17, 2004 with retrofits and enhancements in

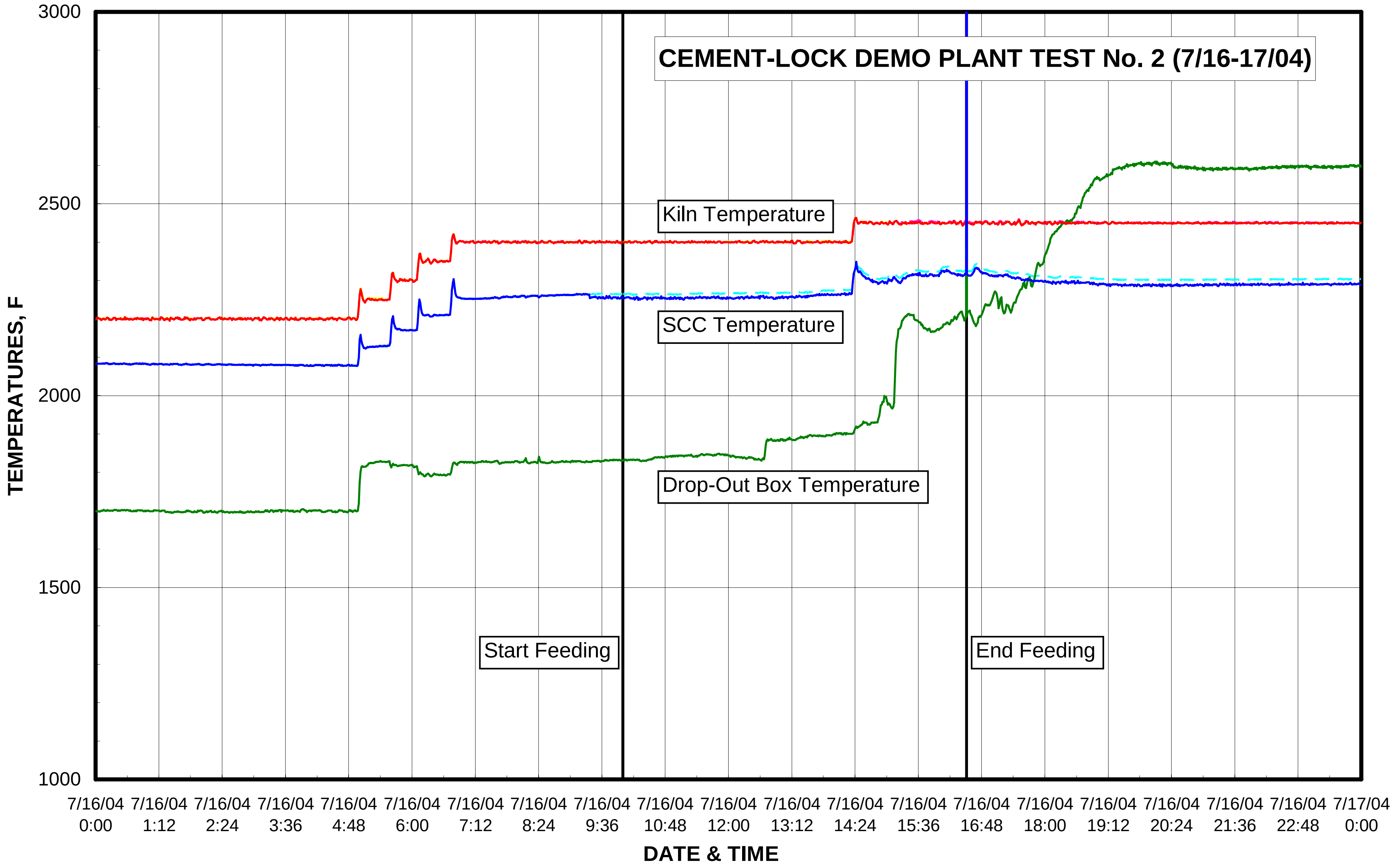



Figure 9. Time-Temperature History of Cement-Lock Demo Plant Test No. 2
With Retrofits and Enhancements (July 16-17, 2004)

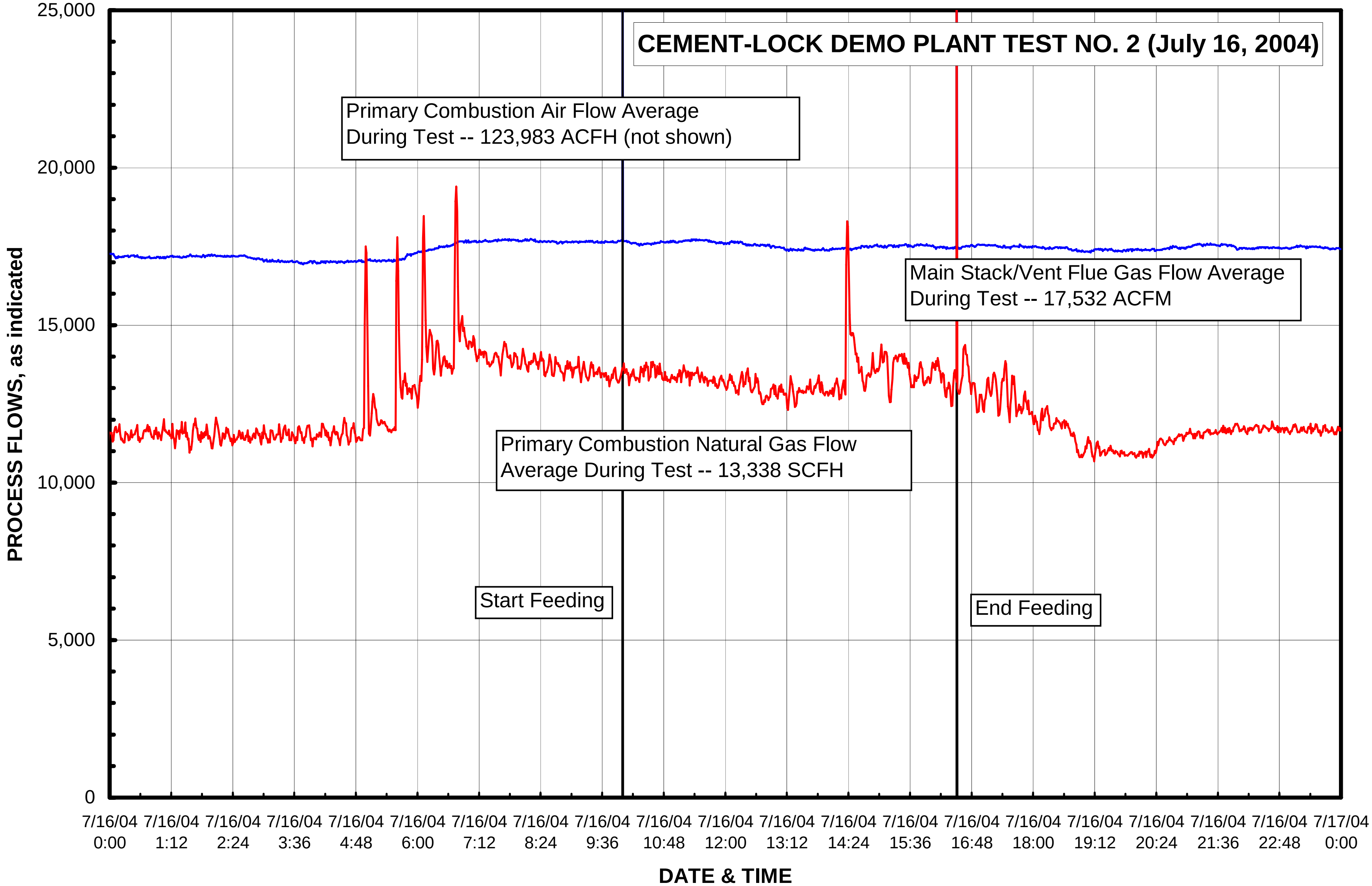



Figure 10. Major Process Flows Recorded During Cement-Lock Demo Plant Test No. 2 With Retrofits and Enhancements (July 16-17, 2004)

place. Major process flows from the test are shown in Figure 10. The primary combustion air to the rotary kiln averaged 123,983 ACFH. The average flow of natural gas to the rotary kiln was 13.3 million Btu/hour. The flow of flue gases from the main vent stack averaged 17,532 ACFM during the test.

**Test No. 3 (July 21-22, 2004)**

The objective of this test was to operate the Cement-Lock demo plant at conditions that would minimize slag accumulation including increasing the temperature of the drop-out box and adding additional modifiers and flux to the feed. The combined effects were to improve slag fluidity.

Prior to test initiation, the temperatures in the rotary kiln (TIC-201) and secondary combustion chamber (SCC) (TIC-202) were measured at 2450° and 2285°F, respectively. The flow of natural gas to the primary burner averaged 14,513 SCFH (or about 14.5 million Btu/hr). The flow of combustion air averaged 142,446 SCFH. The SCC burner was also not fired during this test.

The water flow to the granulator sprays was reduced from 40 to 8 gpm and the flow of water to the weir was reduced from 60 to 15 gpm. Reducing the water flows was expected to reduce the amount of steam generated in the drop-out box area. As a result of these flow reductions, the drop-out box temperature (TIC-203) increased from 1845° to 2210°F.

Test No. 3 was initiated at 3:30 pm when the four augers in T-101 were started at 33 percent (20 Hz) or a nominal feed rate of about 500 pounds per hour. Additional modifier (limestone) and flux (fluorspar) were added to the feed material to decrease its viscosity when molten.

During the test, the oxygen concentration in the flue gas exiting the system through the vent stack averaged 7 mole percent (dry basis). The carbon monoxide concentration in the flue gas averaged 3 ppm during the test.

After several hours of feeding, Ecomelt began to flow out of the Ecomelt granulator. As in Test No. 2, the Ecomelt was black and granular with numerous minus ¼-inch spherical pieces.

Slag "rain" was also observed to fall from the ceiling of the kiln as it rotated during this test. Figure 11 shows the time-temperature history of Test No. 3 of the Cement-Lock demo plant from

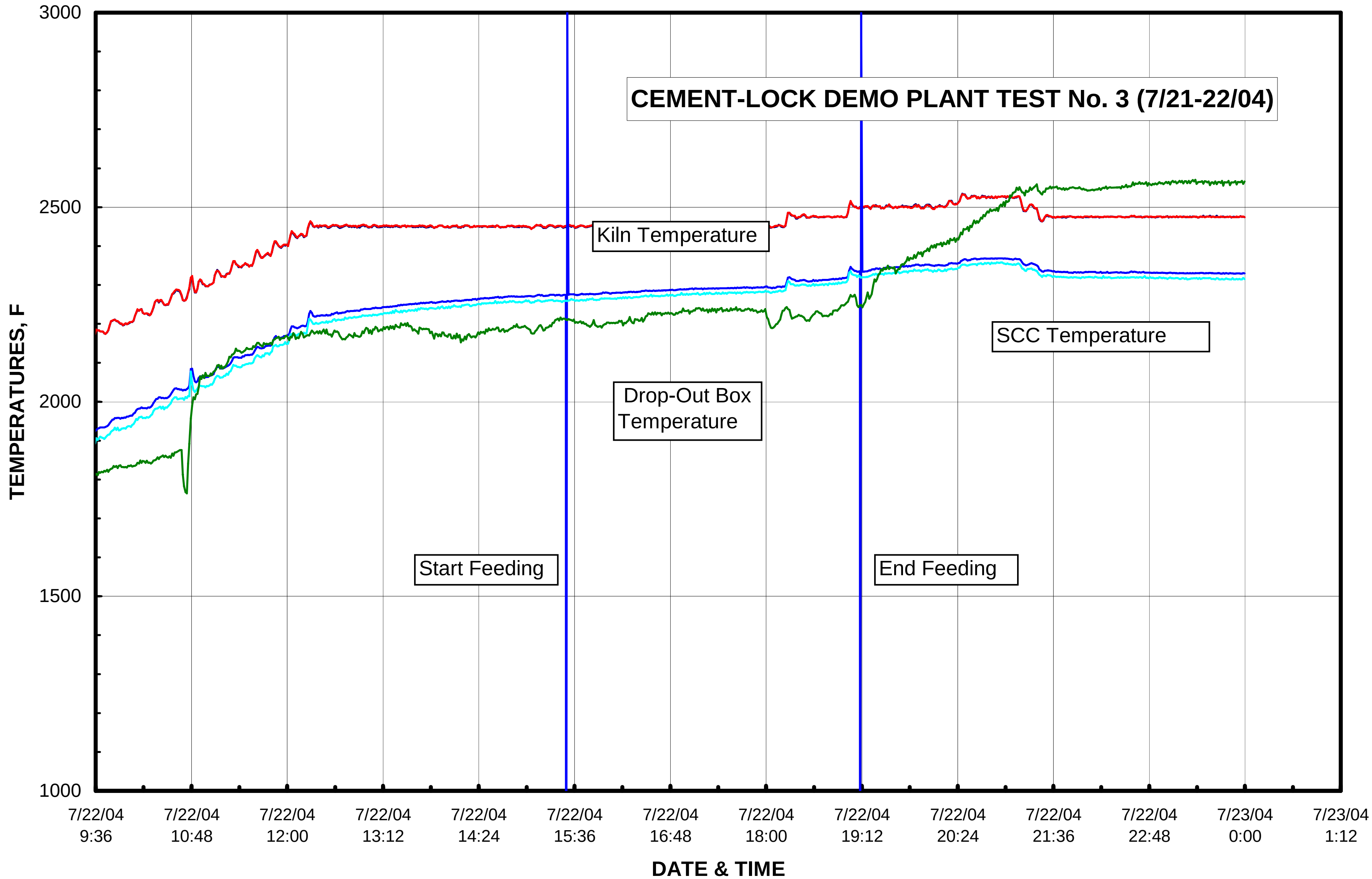



Figure 11. Time-Temperature History of Cement-Lock Demo Plant Test No. 3
With Retrofits and Enhancements (July 21-22, 2004)

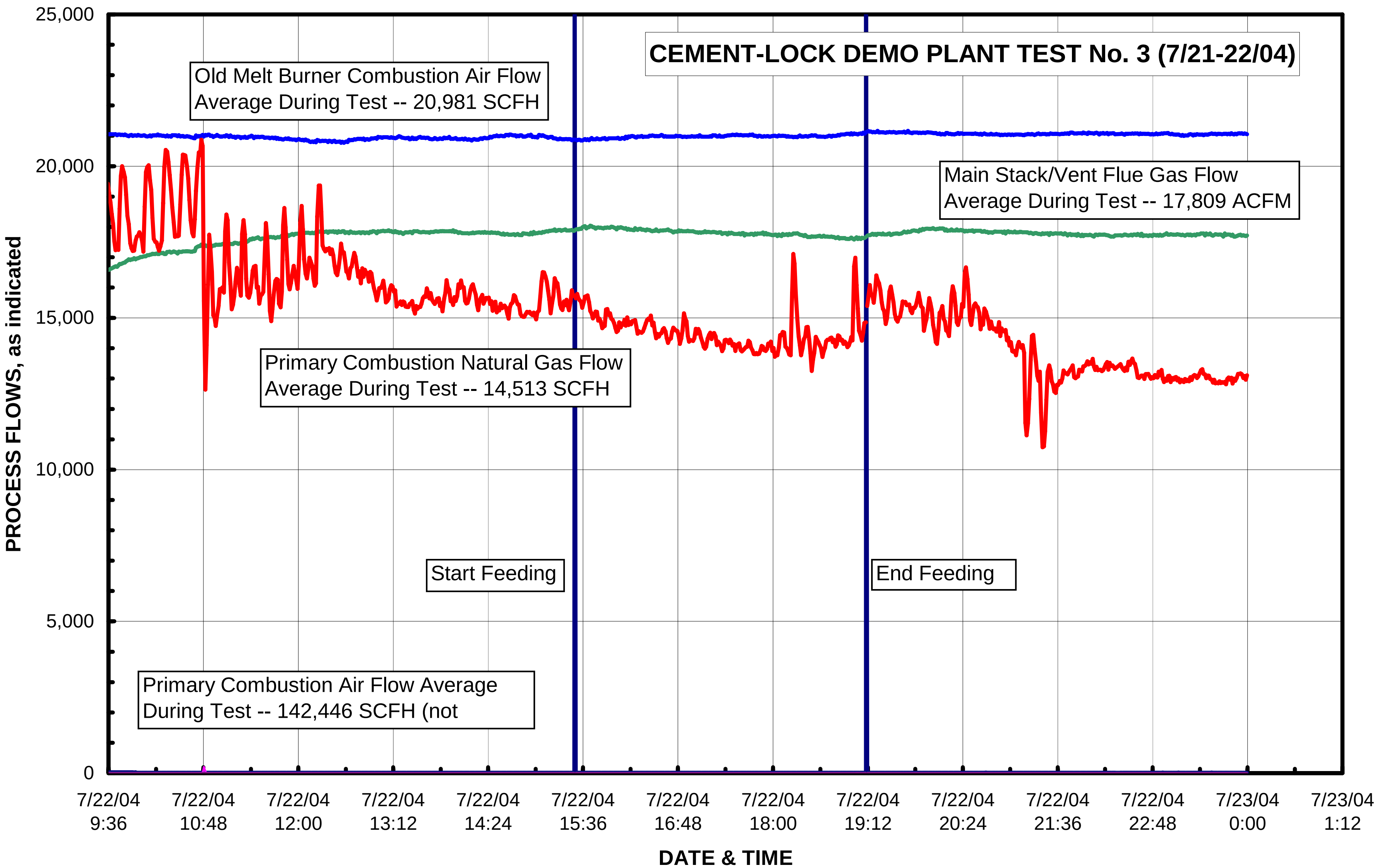



Figure 12. Major Process Flows Recorded During Cement-Lock Demo Plant Test No. 3 With Retrofits and Enhancements (July 21-22, 2004)

July 21 to 22, 2004 with retrofits and enhancements in place. Major process flows are presented in Figure 12. The primary combustion air to the rotary kiln averaged 142,446 ACFH. The average flow of natural gas to the rotary kiln was 14.5 million Btu/hour. The flow of flue gases from the main vent stack averaged 17,532 ACFM during the test.

We increased the kiln temperature (TIC-201) to 2475°F at about 6:15 pm and then to 2500°F at about 7:00 pm. The objective of these operating changes was to decrease the slag viscosity in the kiln. Over the same time period, the drop-out box temperature (TIC-203) increased from about 2235° to about 2275°F.

At about 7:10 pm, we experienced a jam in the granulator conveyor (C-205) as oversized slag material was being brought up the granulator. The C-205 conveyor was halted. Hot slag had to be extracted manually from the port cut in the C-203 granulator conveyor plenum. Feed was discontinued at about 7:15 pm.

At about 8:30 pm, we increased the kiln temperature to 2550°F in an attempt to disrupt the drop-out box blockage; however, there was no effect. By 9:15 pm, the drop-out box temperature had reached 2550°F and the kiln temperature was reduced to 2475°F. These conditions were held constant overnight.

The next morning (July 23), the temperature of the drop-out box had risen to 2620°F and the granulator water temperature had cooled to 180°F. In an effort to break the slag blockage, we momentarily opened the weir and spray water valves full in an attempt to fracture the blockage with cold water/steam impingement. There was no apparent effect of this action and the valves were closed. It was decided to terminate the test so that the slag in the drop-out box could be cleared. The demo plant system was cooled per the prescribed procedure.

**Post-Test Evaluation (Tests No. 2 & 3)**

On July 26, the slag blocking the exit was removed using a jackhammer as before. Before the slag was broken, two adjacent 1-foot diameter holes were observed in the slag covering the drop-out box. These could have resulted from the water weir/spray action described above.

During inspection of the rotary kiln refractory, we noticed that part of the cast refractory of the kiln “nose” at the discharge end of the kiln had cracked and spalled. The refractory contractor was brought back on-site to repair the damaged area and to touch up” two other problem areas in the kiln.

Even though process operating conditions were adjusted from the first test to minimize slag accumulation, the second test was terminated for essentially the same reason. The drop-out box was too cool to allow the molten slag to readily flow into the granulator.

For the next test, we had planned to increase both the kiln and drop-out box temperatures to 2500°F to further reduce the viscosity of the melt in the kiln and improve the fluidity of the slag flowing through the drop-out box. However, it was apparent that merely changing the operating conditions (e.g., increasing the kiln temperature and/or adding more flux) would not provide a positive means of clearing accumulated slag and ensuring sustained operation. More aggressive actions were needed to assure a successful test. Specifically, a mechanical means of breaking or disrupting slag was needed before another test would be attempted.

**Slag Breakers –** Several approaches to slag breaking were considered. For example, one suggestion was to use pneumatic or electrically operated chisels inserted into the dropout box through the water-cooled transition section between the drop-out box and the granulator. The chisels would be activated when slag began to accumulate on the drop-out box walls. It was concluded that the angle of chisel insertion and the maneuvering space were limited which would reduce the effectiveness of this approach.

Another approach was a “see-saw” slag breaker. This approach was determined to be feasible and several conceptual configurations were prepared. One slag breaker arm each would be installed at the north and south end of the granulator just under the weir trough. The breaker arms would be attached to pivot pipes that could be pushed in or pulled out to access the entire width of the drop-out box opening. The breaker arms would be long enough to reach the edge of the kiln nose when rotated. When not in use, the breaker arms would be retracted up against the east and west walls of the overflow weir. The pivot pipes and breaker arms would be cooled in part by the existing water sprays. External handles would be used to activate the breaker arms individually. Two mechanical slag breakers each consist of a 2-inch-diameter stainless steel pipe, 4½ feet long were fabricated and installed.

**View Port Installation –** A new view port was installed on the upper north side of the drop-out box for observing the discharge of slag from the kiln into the granulator (the photo below was taken from the new view port).

**Granulator Discharge Modifications –** A GTI consultant proffered that excessive steam generation from the Ecomelt quencher was cooling the slag. He suggested that the cross-sectional area of the drop-out box opening be reduced to limit radiation heat transfer to the quench water below. Reducing the radiation heat transfer would reduce steam formation. Therefore, we blocked off a portion of the drop-out box discharge area to limit heat loss to the granulator water due to radiation. To accomplish this, ⅜- and ¼-inch thick steel plates were installed lengthwise across the drop-out box discharge. Refractory bricks left over from the rotary kiln refractory repair were layered on top of the steel plates for insulation. The open area was reduced by about 50 percent from 72 x 21 inches to 72 x 10½ inches. The water spray nozzles and water header on the west wall of the drop-out box were removed to accommodate the bricks. The photo at right (Figure 13) shows the reduced area at the discharge of the drop-out box. The rotary kiln nose and extended lip are indicated with arrows. The two drop-out box thermocouples (T.C.) can also be seen at right. The slag breakers (not visible) are operable within this reduced open area.

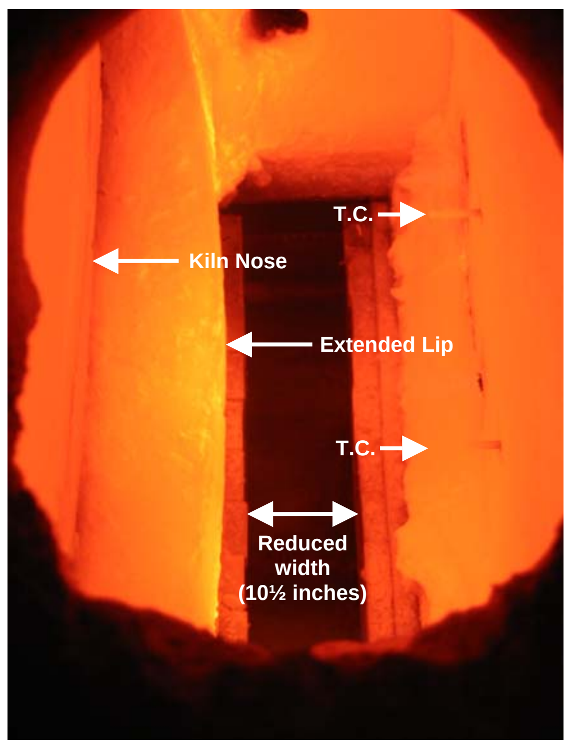



Figure 13. View of Kiln Nose, Extended Lip, and Reduced Drop-Out Box Area.

The lower screw section of conveyor C-205 was removed and the opening under the discharge of the granulator drag conveyor was enlarged to accommodate Ecomelt and chunks of oversized slag.

**Miscellaneous Equipment-Related Repairs –** The timer on the baghouse back-pulsing system had been set with a 0-second delay at the factory. As a result, all six banks (with 3 rows per bank) of air headers back-pulsed simultaneously. This caused wide pressure fluctuations in the downstream air pollution control equipment. The timer was reset for a 30-second delay between back-pulsing for each of the six banks to reduce the magnitude of back-pulsing pressure fluctuations.

Also, by-pass piping was installed around an undersized pressure regulator that limited the amount of natural gas that could be fed to the original melt burners. These melt burners were adjusted using the by-pass to increase the gas supply. As a result, each burner produced a high-velocity flame that extended completely across the drop-out box and impinged on the east wall.

**Test No. 4 (September 22, 2004)**

Another recommendation made following Tests No. 2 and 3 was to operate the kiln with less excess air to the primary burner. Reducing excess air to the primary kiln burner has the benefit of reducing fuel consumption, thereby improving process efficiency. Prior to conducting Test No. 4, we conducted the following test to determine the effect of excess-air minimization tests.

**Excess-Air Minimization Tests –** Previous CEMS readings had shown that the kiln had been operating with significant excess air. To measure the excess air content in the flue gas exiting the kiln, we employed a portable $CO/CO_2/O_2$ monitor. The hot flue gas sample was taken using a 2-inch diameter and 12-foot long water-cooled stainless steel sample probe. The sample probe was inserted into a 2½-inch nozzle at the west end of the kiln (upper drop-out box) and extended into the drop-out box plenum about 6 feet.

The excess-air minimization tests were conducted when the system was operating at a kiln temperature of 2500°F. No sediment was fed to the system during these tests. The initial $O_2$ content of the flue gas exiting the kiln was measured at 12.0 mole percent (dry basis) with a CO content of 20 ppm. For combustion of natural gas (methane) with air, this value represents 120 percent excess air. The excess air ratio was reduced in steps using the computer control system until the $O_2$ concentration measured at the kiln exit had reached 4.0 mole percent. This represents about 20 percent excess air. At these conditions, the CO content in the kiln exit increased to 130 ppm. At the same time, the $O_2$ and CO contents in the vent stack measured 6.4 mole percent and 6.6 ppm, respectively. Thus, the overall excess air in the Cement-Lock system was about 40 percent.

As expected, as the ratio of excess air to natural gas was reduced, the concentration of $O_2$ in the flue gas exiting the rotary kiln decreased and the concentration of CO in the flue gas increased. Flue gases passing from the kiln into the secondary combustion chamber encounter additional fuel and air that provide an additional 2 seconds of residence time at temperature to complete the burnout of products of incomplete combustion (PICs).

The results of these tests show that the system can be operated at an $O_2$ content exiting the kiln as low as 4.0 percent without experiencing flame instability or elevated CO levels in the vent stack.

**CO Excursion and Visible Flame –** After the excess air minimization tests were completed, the kiln temperature was reduced at the prescribed rate of 100°F per hour to the overnight "idling" temperature of 1800°F.

At about 2:00 a.m. (morning of September 22) per instructions, the shift supervisor began to increase the temperature of the rotary kiln from its idling temperature of 1800°F at a rate of 100°F per hour. At this rate of heating, the kiln temperature would be 2500°F by about 9:00 a.m.. Each time the shift supervisor increased the temperature setting on the controller (TIC-201), the valve controlling the flow of natural gas opened and a surge of natural gas was admitted to the primary kiln burner. At the same time, the flow of combustion air to the system was increased proportionately as well. As the temperature reached its new set point, the natural gas flow to the burner was reduced and the ratio of air-to-natural gas was balanced.

However, because the ratio of air-to-natural gas had been reduced during the earlier excess air minimization experiments, each time the shift supervisor increased the temperature there was a momentary episode of incomplete combustion of the natural gas. This led to transient CO increases that were recorded by the CEMS. During the early stages of heat up, the CO excursions were small; however at about 6:30 a.m. on September 22, flames were visible around the periphery of the emergency stack cap. At that time, the kiln temperature was about 2200ºF.

Within a few minutes, IMTT's Safety Manager arrived at the plant and instructed the shift supervisor to immediately shut down the kiln and melt burners. The shift supervisor proceeded accordingly. The flame emanating from in the emergency stack cap was extinguished immediately when the natural gas supply to the system was shut off.

The unburned CO in the flue gas was apparently ignited by the hot refractory lining in the emergency stack cap located at the outlet of the secondary combustion chamber. The spontaneous ignition temperature of CO is 1128°F (Perry's Chemical Engineers' Handbook).

**Safety and Oversight Proposal:** Because there was a visible flame, IMTT requested a detailed plan from ECH to ensure that this would not happen again. Therefore, a safety and oversight proposal was developed by GTI and ECH and submitted to IMTT for review on October 12. On October 21, Mr. Jamie Coleman, President, IMTT – Bayonne informed us that the safety and oversight proposal had been accepted. With the acceptance of the plan, we had the approval of IMTT to proceed with the next test. The safety and oversight plan specifies that during operation of the Cement-Lock demo plant, the operation must be monitored by GTI staff knowledgeable in the process and equipment (a copy of the incident report and the safety and oversight plan is included in Appendix E).

As part of the requirements in the safety and oversight plan, during the next startup, we provided refresher training and safety reviews for the shift supervisors and laborers. This included rules and regulations on personal protective equipment (PPE), no smoking regulations, prohibition on cell phone use on IMTT property, confined space procedures, fire extinguisher use, emergency marshaling and evacuation planning, and plant shut-down procedures.

**Sediment Feeding Test:** After a review and diagnostic of the system following the CO excursion, we restarted and began reheating the system (September 22). The target temperature of 2500°F was reached in the rotary kiln. The temperature of the drop-out box reached 2450°F. In previous tests, the drop-out box temperature lagged below the kiln temperature by as much as several hundred degrees.

At 6:30 pm, sediment feeding was initiated at a rate of 500 pounds per hour. The objective of this test was to operate the Cement-Lock demo plant with the new auxiliary burner system and other mechanical improvements – including slag breakers – in place. The preblended mixture of sediment began to enter the kiln a short while later.

However, at 8:00 p.m. the computer control system indicated a slow speed on the granulator drag conveyor – it had jammed. Attempts to clear the jam in the conveyor and restart the motor were unsuccessful. Also, the torque arm support for the motor and gear reducers that drive the drag conveyor had bent 90°. As the torque arm bent, the motor mounting bracket rotated and the motor impacted the granulator housing. The motor casing separated from the gear reducer housing. The run was terminated involuntarily. No Ecomelt® was produced. As it was unclear where the jam occurred, the temperature of the kiln was brought down at the prescribed rate and allowed to cool so that repairs could be implemented.

Upon opening the granulator on September 27, RPMS observed that no large chunks of slag or refractory were responsible for jamming drag conveyor. The jam had apparently been caused by slack in the chain links of the drag conveyor that jammed the downstream (compression) side of the circuit. RPMS had previously eliminated slack in the drag conveyor chain by removing several links. The drag conveyor chain had been re-tensioned; however, chain wear and/or possible loosening of the motor support bracket resulted in enough slack to cause the jam. The motor and its gear reducer were dismantled and sent to a motor repair shop for evaluation and repair.

**Equipment Repairs:** The damaged gear reducer and motor that drives the granulator drag chain conveyor (C-203) were replaced. As the delivery time for replacement parts for the original gear reducer and motor was about six weeks, we opted to obtain a comparably specified gear reducer and motor. These items were delivered, installed, and tested for proper operability. A new torsion bar was installed to replace the one that was bent during the previous test. The tension in the granulator drag chain conveyor was adjusted and the conveyor was operated for several hours to run it in. The refractory contractor repaired two loose refractory rings in the main section of the rotary kiln and repaired some damage to the nose ring refractory. Also, the rotary feeder that discharges spent lime from baghouse was repaired and reinstalled. It had become jammed.

**Test No. 5 (October 27-28, 2004)**

For this test, the drop-out box was in the same configuration as that for Test No. 4 (September 22). The open area of the drop-out box was about one-half its original size with refractory bricks layered on steel platforms. Mechanical slag breakers were installed – one on the south and one on the north side of the drop-out box.

The primary objectives of the test were to evaluate 1) the impact of the reduced open area of the drop-out box bottom on its temperatures, 2) the effectiveness of the slag breakers, and 3) the impact of the tuned melt burners on drop-out box temperature.

**System Start-Up:** We initiated system start-up with around-the-clock operation on October 26. The temperature of the rotary kiln was brought up to operating temperature at the prescribed rate of 100°F per hour. Overnight, we maintained the rotary kiln at its "idling" temperature of 1800°F to conserve fuel and equipment.

The target temperature of 2450°F was reached in the rotary kiln at about 10:00 a.m. on October 27. At that time, the temperature of the drop-out box was 2420°F. The temperature in the drop-out box was higher than that of the previous tests. The temperature increase resulted from one or a combination of the following actions: 1) The open area of drop-out box bottom was decreased by 50 percent (reducing radiation heat loss), 2) three melt burners on the west wall were repaired and tuned, and the thermal input to the dropout box was increased, and 3) water spray to the drop-out box was removed.

The kiln temperature was selected to conserve the equipment and refractory while providing a relatively low viscosity melt. At this temperature, the slag viscosity would be close to the targeted viscosity (< 100 poise) according to the study performed by Hazen Research for ECH. The temperatures in the kiln and dropout box could be increased if slag began to accumulate.

At 11:00 a.m., we began feeding the premixed blend of air-dried sediment and modifiers at a rate of 500 pounds per hour. The premixed blend of sediment began to enter the kiln a short while later. We monitored the progression of the molten slag through the kiln thereafter. Slag slowly progressed through the kiln as it first coated the refractory walls. The slag "rain" phenomenon was again observed indicating that the viscosity of the melt was still too high to enable it to roll down the kiln wall. The pressure in the kiln was maintained at a slight vacuum of -0.3 inches (water gauge). The oxygen content of the flue gas exiting the stack was about 8 mole percent (dry basis).

At about 3:20 p.m. the first samples of Ecomelt began to exit from the granulator. The Ecomelt was in the shape of small (less than ¼ inch) irregularly shaped particles, dark brown to black in color. At about 3:45 p.m. slag was observed to be flowing over the bricks on the reduced open area and the slag breakers were activated. The slag breaker on the south side was operated almost continuously as directed by the observer at the upper view port. The action of the south slag breaker caused some bricks on the southeast wall to move away from the platform. By 4:00 p.m. slag began accumulating in the bottom of the drop-out box and on top of the south slag breaker. The north side slag breaker was moved from under the bricks on the west side of the drop-out box. However, as the slag breaker was moved toward the east, it caused the bricks above to migrate toward the east as well reducing the throat area even more. This rendered the north slag breaker ineffective and it was returned under the bricks on the west wall.

At 4:15 p.m. feed to the kiln was discontinued. At 5:00 p.m. the kiln temperature (TIC-201) was increased to 2500°F. At about 5:30 p.m. the throat had become almost completed filled with slag. By 7:00 p.m. slag was covering almost the entire drop-out box. The south slag breaker became ineffective as it was covered with slag and could not be freed up (Figure 14). As the test could not be continued under these conditions, we began to cool the system at about 11:00 p.m.

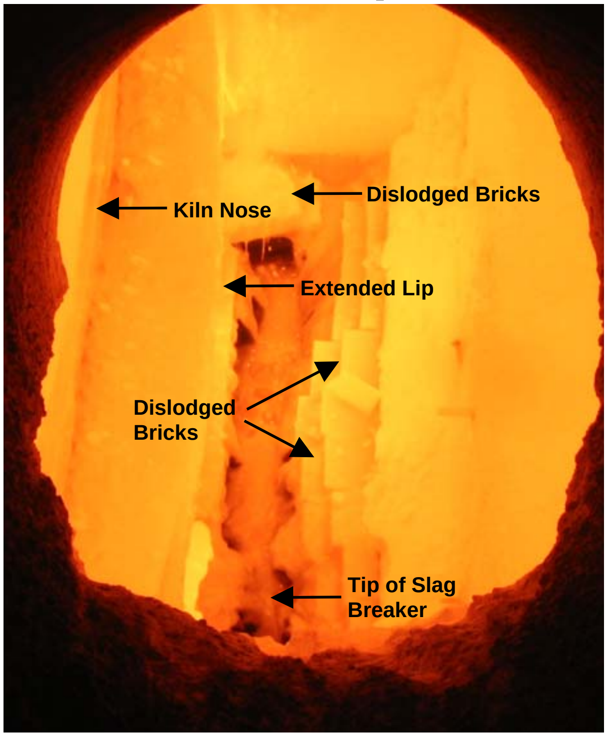



Figure 14. View of Slag Accumulated on Bricks and Slag Breaker After Test No. 5 (lighter colors are relatively hotter than darker colors)

The molten slag flowing over the bricks at the throat of the drop-out box appeared to be much more viscous than the molten slag flowing in the kiln and over the nose and lip. Observations also confirmed that the more viscous molten slag over and down from the bricks precipitated the slag accumulation and the eventual plug up.

A total of 849 pounds of Ecomelt was produced during the test. The time-temperature history of this test is presented in Figure 15. Major process flows from the test are presented in Figure 16. The primary combustion air to the rotary kiln averaged 143,141 ACFH. The average flow of natural gas to the rotary kiln was 14.2 million Btu/hour. The flow of flue gases from the main vent stack averaged 17,311 ACFM during the test.

**Post-Test Evaluation**

When the system was cool enough to open, the following observations were made. The opening of the drop-out box just above the granulator was completely covered with slag. The location, shape and appearance of the slag were similar to those of previous tests. There were numerous cracks noted in the refractory lining. The burner tile of the south Hot Spot burner on the east wall was cracked. The burner tile of the center Hot Spot burner was also cracked and protruded slightly. However, both burner nozzles appear to be intact. The south slag breaker was severely warped and concaved (crescent-shaped).

The following recommendations were made based on the above observations:

<u>Remove the bricks added to the water trough:</u> The bricks were added to decrease the opening area of the drop-out box and reduce the radiation heat loss to the water. The drop-out box temperatures did increase; however, the heat input of the original melt burners was also increased and the water spray to the drop-out box was deleted. Therefore, the precise impact of the bricks can not be determined. The lower bricks were less than 9 inches above the granulator water. As measured by pyrometer, these bricks were 300°F lower in temperature than the drop-out box temperature. Molten slag adhered, cooled and solidified over these bricks, precipitating slag accumulation.

<u>Reconsider effectiveness of slag breakers:</u> As the slag cools, its viscosity increases significantly. The slag has the consistency of taffy and does not shatter upon impact. The slag breakers must be operated almost continuously, otherwise they will become ineffective as slag freezes on top of

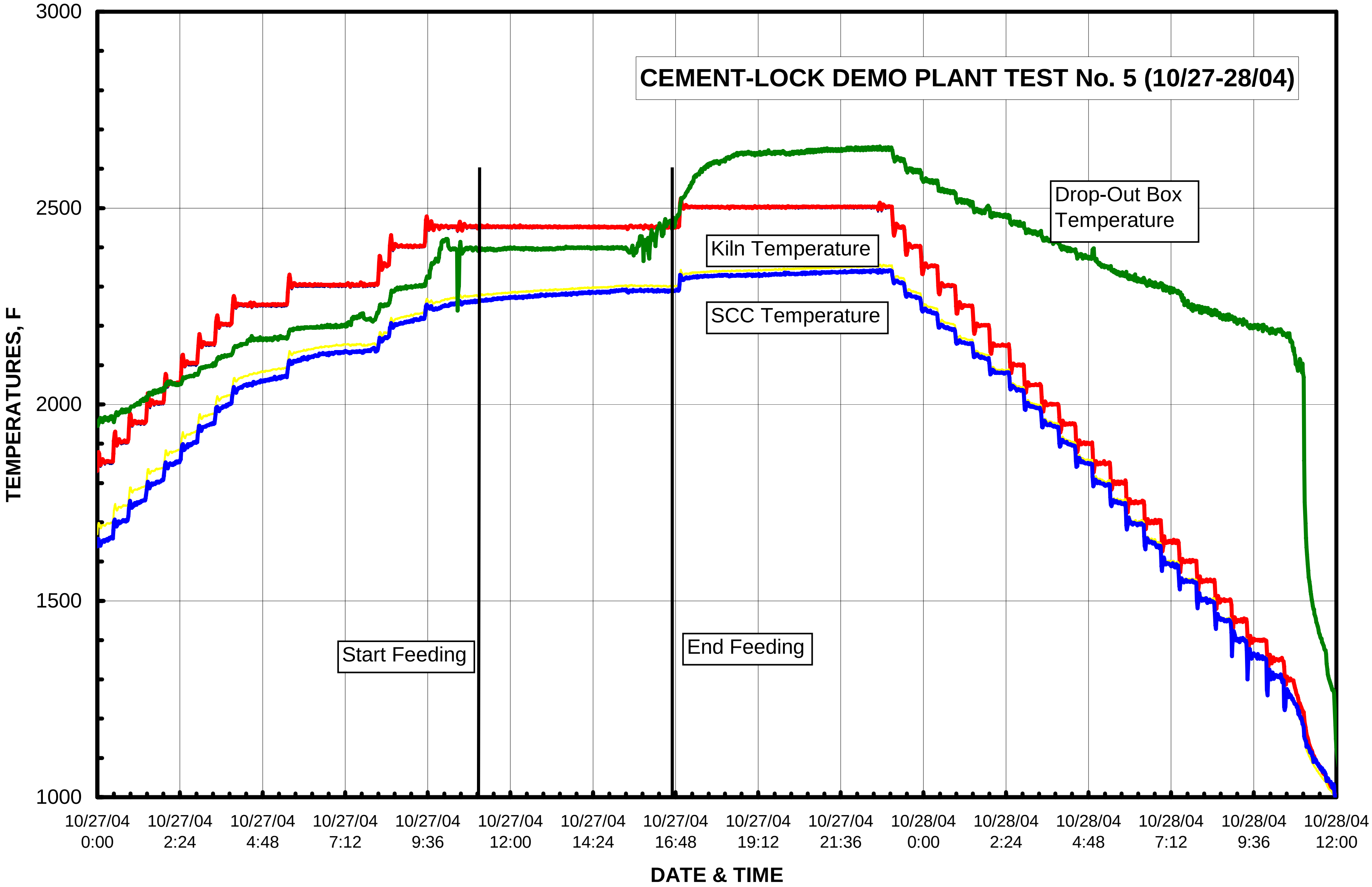



Figure 15. Time-Temperature History of Cement-Lock Demo Plant
Test No. 5 (October 27-28, 2004)

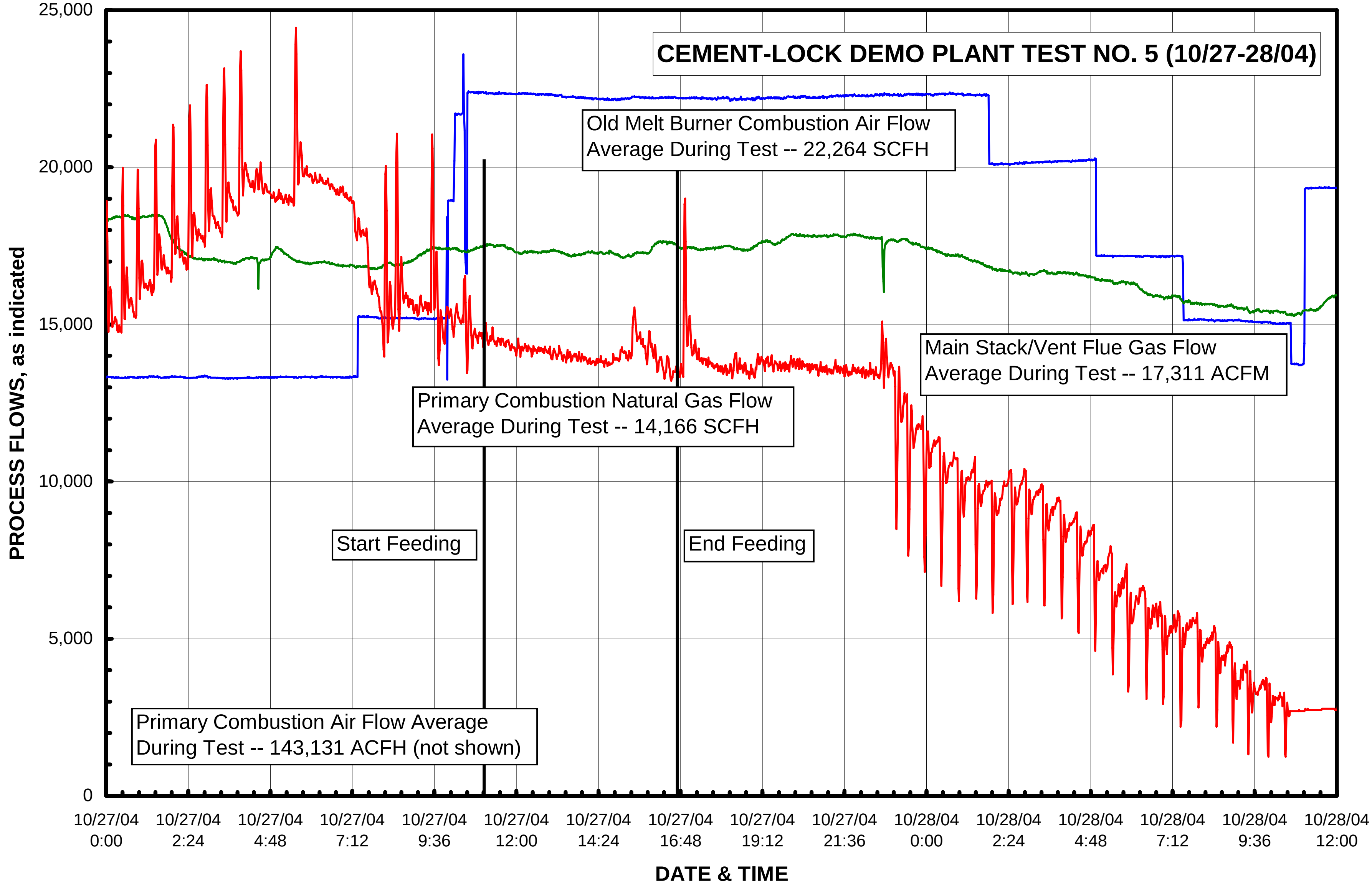



Figure 16. Major Process Flows Recorded During Cement-Lock Demo Plant Test No. 5 (October 27-28, 2004)

them. As the slag was accumulating, the breakers were more difficult to move and less effective. They are also labor intensive.

Extend the weir: The height of the existing overflow weir should be raised to just under the bottom of the drop-out box such that the overflow water will continuously cover these vertical walls. Based on experience from the Hazen pilot plant test and all the demo plant tests, slag does not accumulate on water-covered walls. With this arrangement, the molten slag would fall directly into the water, and minimize the chances of sticking to the walls or bricks, thereby minimize slag accumulation.

Increase kiln and dropout box temperatures to 2600°F or higher: Increasing temperature will reduce slag viscosity, minimize slag rain, and improve slag discharging from the kiln. The key issue is whether the temperature at the bottom of the drop-out box can be increased to over 2450°F where the slag viscosity would be about 100 poise.

Extend the kiln lip well over the throat of the drop-out box: The accumulation of slag occurs primarily from the south and east walls of the drop-out box. By extending the lip to the midpoint of the open area will minimize slag sticking on the walls of the drop-out box. The lip can be kept clear (and hot) by the north and south Tempest burners.

**Equipment Turnaround:** After Test No. 5 was completed, the drop-out box was cleared of accumulated slag, which took about two hours. Other work performed included removal of the refractory bricks that had been installed in the drop-out box to reduce the area of the throat. The steel plate supports as well as the south slag breaker were also removed.

The refractory contractor (Duddy Contracting) repaired loose bricks near the primary burner and filled various cracks that had developed in the rotary kiln after Test No. 5. The refractory supplier (Harbison-Walker Refractories) evaluated the kiln bricks and castable. His opinion was that the kiln bricks were in fairly good shape. He noted that the castable kiln nose ring had deteriorated and would eventually fail. An indication of failure would be spalling of a large chunk of castable from the nose ring. It would require replacement at that time.

The granulator drag conveyor chain was tightened. Also, the 60 x 90 foot Century tent that had been used to cover the sediment storage area since June 2004 was removed by the rental company. Plastic tarps were used to keep the piles of sediment and sediment modifier mixtures covered in lieu of the tent.

**Revised drop-out box configuration and implementation:** After considerable additional discussion about the slag accumulation problem, it was decided to extend the lip of the kiln past the midpoint of the granulator opening. This concept had been discussed previously, but was rejected in favor of reducing the open area and installing mechanical slag breakers. There had been concerns in the past about the potential for the extended lip to fail with large chunks of refractory falling into the granulator. When this approach was revisited with the refractory installer, he said that the kiln lip could be extended about 8 inches past the existing lip and it would be self-supporting. This would put the edge of the lip about one-half the way across the open throat of the drop-out box. The southern-most part of the lip would extend upward in an arc about four feet above the lowest point of the lip. This arc would include a trough-like depression that would allow slag to flow downward toward the central part of the extended lip and then overflow.

The existing refractory was demolished and forms for the new "extended lip" were installed. The new refractory, Novacon 95, was poured on November 19 and electric heaters were installed in the kiln to maintain the temperature at about 65°F to facilitate curing. The forms were removed on November 24. Testing of the revised configuration was planned to be initiated on November 29 just after the Thanksgiving holidays.

### Plant Assessment and Reconfiguration Plan With Volcano Partners

Representatives from the NJ-DOT/OMR, EPA Region 2, BNL, and ECH/GTI met at NJ-DOT/OMR offices on November 18, 2004 for a project review meeting. The objective of the meeting was to discuss project progress and achievements including the persistent problem of slag accumulation in the drop-out box and to develop a plan for completing the Phase I project successfully and in a cost-effective timely manner. A schedule proposed by NJ-DOT/OMR called for project participants to complete an overall evaluation of the Cement-Lock demo plant with problem resolution recommendations by December 15. These recommendations were to ensure a high probability of success and were to be implemented immediately so that operations could resume by January 5, 2005. The Phase I testing could possibly be completed by January 17, 2005 with Phase II operations following shortly thereafter.

After the November 18 meeting, GTI and Volcano Partners, L.L.C. (Volcano, Key Biscayne, FL) agreed to work together to develop the overall plan to complete the Phase I project. The primary goals of the ECH/Volcano Study were to 1) evaluate the current status of the Cement-Lock demo plant, 2) provide advice on actions that would enable the plant to operate successfully for the Phase I testing and, 3) provide advice on actions for successful treatment of dredged sediment for Phase II of the project.

This effort was cost-shared by ECH and Volcano and was initiated on November 29, 2004. As part of the study, participants met at the demo plant on December 7 for a site tour and to discuss equipment modification options. The overall project was completed on December 15, 2004 as scheduled. The final report was transmitted to project sponsors for consideration and action.

Recommendations for major equipment modifications (including nose ring refractory, drop-out box, granulator, lime feeding system, sediment feeding system, plant winterization, and operational changes (e.g., kiln operating temperature) as determined by the Volcano Study are summarized below.

Kiln Nose Ring Refractory – As mentioned above, the kiln nose ring refractory exhibits cracking that will eventually result in its failure during operation. The refractory supplier recommended that no action be taken at the present time. He did recommend that during operations the nose ring should be frequently inspected for signs of impending failure. Depending upon availability of materials, replacement of the nose ring refractory could require up to 4 months.

Drop-Out Box (DOB) – The study recommended that any surface that slag could impinge below the rotary kiln should be eliminated. Several alternate DOB configurations were proposed during the study. The study concluded that the granulator should be moved under the nose of the kiln so that slag would flow directly into the water below. This modification would entail considerable metal and refractory re-working. However, it was considered to have a high probability of performing as designed.

Granulator Modifications – The study noted that a sizable piece of refractory could become dislodged from the kiln nose ring and fall into the granulator. If this were to happen, it could jam the drag conveyor in the granulator resulting in an involuntary shut-down. A solution would be to install a grizzly screen under the water in the granulator above the drag conveyor blades. Should a piece of refractory break loose, it would be caught by the grizzly. Ecomelt would continue to fall through the grizzly screen into the granulator below.

Lime Feeding System – The lime feeding system has not consistently fed lime to the duct upstream of the baghouse. It was suggested that air sparging taps be installed around the live bottom of the hopper, which would permit the lime to be "fluffed" to provide more consistent flow. Also, a partial load of limestone was mistakenly unloaded into the lime hopper, which must be removed and replaced prior to the next test.

Sediment Feeding System – To facilitate feeding possibly frozen sediment-modifier mixture, an ALLU SML screening bucket would be procured. This device can crush and size frozen material as well as wet material. A conveyor belt would be rented that extended from the sediment storage area to the feed system so that frozen material could be metered and fed.

Plant Winterization – Equipment winterization will be necessary regardless of the modifications.

Operation of the West Wall Melt Burners – The melt burners on the west wall of the DOB would continue to be operated to make up, at least in part, the loss of the heat from the 3 Hot-Spot burners that were to be removed from the east wall. These burners would be operated under fuel-rich conditions to minimize flow of excess air into the system.

Kiln Operating Temperature – Increasing the kiln temperature (as indicated and controlled by TIC-201) to 2600°F was recommended for the next test. This would reduce slag viscosity to a honey-like flowability.

**Path Forward for the Demo Project**

The results of the ECH/Volcano Study were presented to the project sponsors. All agreed that the results presented a viable short-term solution to the problem of slag accumulation in the DOB. However, funding for the recommended equipment modifications was not available.

Therefore, alternatives for the path forward needed to be developed. The alternatives were discussed at a meeting held on December 28, 2004 in Newark, NJ with NJ-DOT/OMR, U.S. EPA Region 2, Brookhaven National Laboratory, and ECH/GTI. The consensus of the meeting was that to complete the current project, the Cement-Lock demo plant would be operated in non-slagging (or ashing) mode. Project participants agreed that this would be the favored approach given the lack of funds for implementing the equipment modifications recommended in the ECH/Volcano Study. Steps were immediately initiated to implement this approach.

# IX. NON-SLAGGING OPERATION

Pursuing the non-slagging courses of operation to complete the Cement-Lock demo project involved 1) a preliminary laboratory-scale evaluation, 2) planning for non-slagging operation in the demo plant, and 3) sustained non-slagging operation. These steps are discussed below.

**Laboratory-Scale Evaluation**

The laboratory-scale evaluation included a determination of the ash fusion characteristics of the sediment-modifier mixture and unmixed sediment, a batch test with the sediment-modifier mixture under non-slagging conditions, and an environmental evaluation of the thermally treated product from the batch test to determine organic destruction as well as leaching characteristics. The results are discussed below.

To determine the appropriate temperature at which to operate the rotary kiln, we performed ash fusion tests on samples of the sediment-modifier mixture and unmixed sediment. The results of these tests presented below show that the initial deformation temperature of the sediment-modifier mixture is 2140°F or about 140°F lower than that of the unmixed sediment. The initial deformation temperature provides an indication of the temperature at which particles may begin to stick together and agglomerate into larger particles. The fluid temperatures for the sediment-modifier mixture and unmixed sediment are 2180° and 2455°F, respectively. Based on these results, the operating temperature for the rotary kiln will be in the range of 1800° to 1900°F to provide an operating margin.

| Sample | Sediment-Modifier Mixture | Unmixed Sediment |
|---|---|---|
| | -- Ash Fusion Temperature (Oxidizing), °F -- | |
| Initial Deformation (IT) | 2140 | 2280 |
| Softening (ST) | 2155 | 2325 |
| Hemispherical (HT) | 2165 | 2370 |
| Fluid (FT) | 2180 | 2455 |

A laboratory-scale batch test was conducted to determine if the conditions for non-slagging demo plant operation would achieve the desired organic destruction and reduce leachability of the treated product. The conditions for the laboratory-scale test were a nominal 1800°F and a one-hour solids residence time at temperature.

Prior to the test, a sample of wet sediment was blended with modifiers according to the Cement-Lock recipe. Much of the sediment on-site had been premixed with modifiers previously so air-dried and premixed sediment was prepared for the batch test.

About one kilogram of the premixed sample was partially dried to reduce its moisture content. The feed material was gray in color. During drying, the sample shrank and formed irregular clumps. These clumps were manually broken to about -½ inch, which exposed additional surface area for treatment. It is expected that during the demo plant test, the rotation of the kiln will cause the blended sediment-modifier mixture to break up into smaller particles as well. The partially dried sample was then put into the furnace that had been heated to 1800°F. After one hour at temperature, the power to the furnace was shut off and the sample was allowed to cool.

As shown in Figure 17 (below), the thermally treated material from the laboratory-scale test had a uniformly rusty (reddish) color, probably from iron oxide. Also visible in the clumps were inclusions of limestone ($CaCO_3$), most of which had calcined to lime ($CaO$) during treatment. Smaller size particles are also present in the photo.


Figure 17. Photo of EcoAggMat Produced in Laboratory-Scale Furnace

Upon breaking, the exposed fresh surface of the clumps has the same color as the external surface indicating that the treatment was uniform.

Samples of the sediment-modifier mixture and the thermally treated product were submitted for analysis of volatile and semi-volatile organic constituents and metals (As, Ba, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, and Zn). The thermally treated product was also subjected to the TCLP (Toxicity Characteristic Leaching Procedure) and MEP (Multiple Extraction Procedure) leachability tests. The results of these metals and organic analyses are presented in Table 1. The results of leaching tests are presented in Table 2.

Table 1. Results of Non-Slagging Laboratory-Scale Test
With Sediment-Modifier Mixture

| Sample | Feed Sediment-Modifier Mixture | Product EcoAggMat | Analytical Reporting Limit |
|---|---|---|---|
| **Detected Organic Compounds** | -------------------- µg/kg -------------------- | | |
| Acetone | ND* | 42* | 10 |
| 2 Butanone | 57 | ND | 10 |
| 2-Hexanone | 15 | ND | 10 |
| Chloromethane | 28 | ND | 5 |
| Methyl Acetate | 18 | ND | 5 |
| Toluene | 800 | 76 | 120/5 |
| Isopropyl Benzene | 500 | ND | 120 |
| Benzo (a) Anthracene | 630 | ND | 330 |
| Benzo (a) Pyrene | 730 | ND | 330 |
| Benzo (b) Fluoranthene | 670 | ND | 330 |
| Benzo (g,h,i) Perylene | 500 | ND | 330 |
| Benzo (k) Fluoranthene | 810 | ND | 330 |
| Bis (2-Ethylhexyl) Phthalate | 3300 | ND | 330 |
| Chrysene | 790 | ND | 330 |
| Fluoranthene | 810 | ND | 330 |
| Indeno (1,2,3-CD) Pyrene | 420 | ND | 330 |
| Pyrene | 860 | ND | 330 |
| | | | |
| **Priority Trace Elements** | -------------------- mg/kg -------------------- | | |
| Arsenic | 8.4 | ND | 0.75 |
| Barium | 94 | 47 | 0.15 |
| Cadmium | 0.94 | 0.41 | 0.15 |
| Chromium | 97 | 12 | 0.75 |
| Copper | 98 | 27 | 0.75 |
| Lead | 87 | 13 | 0.75 |
| Nickel | 25 | 8.2 | 0.75 |
| Selenium | 1.9 | ND | 0.75 |
| Silver | 2.0 | ND | 0.75 |
| Zinc | 140 | 28 | 3 |
| Mercury | 3.4 | ND | 0.1 |

* ND = Not detected above the analytical detection limit
** Possible laboratory contamination

Table 2. Results of TCLP and MEP Leaching Tests on EcoAggMat
From Non-Slagging Laboratory-Scale Test

| | TCLP* | ------------------------------- MEP** ------------------------------- | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sampling Day | | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 | Day 8 |
| **Component** | ------------------------------------ mg/L ------------------------------------ | | | | | | | | |
| Arsenic | ND** | ND | ND | ND | ND | ND | ND | ND | ND |
| Barium | 0.42 | 0.29 | ND | ND | ND | ND | ND | ND | ND |
| Cadmium | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Chromium | 0.79 | ND | 0.075 | ND | ND | ND | ND | ND | ND |
| Lead | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Selenium | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Silver | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Mercury | ND | ND | ND | ND | ND | ND | ND | ND | ND |

* Toxicity Characteristic Leaching Procedure is conducted with dilute acetic acid solution.
** MEP extractions are conducted with dilute nitric and sulfuric acid solutions.
+ ND = Not detected above the analytical detection limit.

The results in Table 1 show that the proposed kiln operating conditions of 1800°F and one hour residence time will be adequate for destroying organic compounds found in the sediment. The presence of volatile toluene and isopropyl benzene in the feed and toluene in the product is unexpected since these compounds were not reported in previous analyses. The results in Table 2 show that the thermally treated product EcoAggMat was essentially non-leachable. For example, the TCLP leachability of Barium from the EcoAggMat was 0.42 mg/L. The TCLP regulatory limit for Barium leachability from material destined for a landfill is 100 mg/L. The TCLP leachability of Chromium from the EcoAggMat was 0.79 mg/L. The TCLP regulatory limit for Cr leachability from material destined for a landfill is 5 mg/L. The other TCLP results were below the analytical detection limit.

The results of the MEP procedure showed that none of the priority metals leached from the EcoAggMat sample past Day 2. It is interesting to note that Cr was detected in the leachate on Day 2, but not Day 1. The detection limit for Cr was 0.05 mg/L.

**Planning for Non-Slagging Demo Plant Operations**

Other conditions will be maintained as if the system were being operating in slagging mode. For example, the secondary combustion chamber (SCC) will be maintained at a temperature in the range of 2100° to 2200°F. The air pollution control equipment (flue gas quencher, lime feeder, baghouse, and activated carbon bed) will be operated as before.

Operating the demo plant under non-slagging conditions requires several operational changes compared with slagging operation. The most significant is to reduce the temperature of the rotary kiln to prevent the sediment-modifier mixture from incipient melting and agglomerating into larger particles as it tumbles through the kiln. The temperature must be high enough to ensure that organic contaminants present are completely destroyed. During processing, the material will tumble through the rotary kiln, exit the drop-out box, and fall into the granulator, where the thermally treated product – EcoAggMat – will be cooled with water. The wet EcoAggMat will be conveyed out of the granulator via the drag conveyor and collected directly in Super Sacks with plastic liners. The Super Sacks (about one $yd^3$ capacity) will be stored on-site pending shipment to the off-site location for beneficial use.

The melt burners and the auxiliary burners installed in the drop-out box will not be fired during non-slagging operations. This is to conserve energy and to ensure that the treated product does not begin to melt.

The target feed rate of the sediment-modifier mixture was 2,000 pounds per hour. The limiting factor in the system throughput capacity is the SCC burner. The SCC burner is needed to increase the temperature of the rotary kiln flue gas to the required range to achieve complete burnout. Please note that in previous tests conducted under slagging conditions, the SCC temperature remained at an elevated level without having to fire the SCC burner.

Table 3 summarizes the effect increasing the rotary kiln temperature on the estimated processing capacity of the overall system. The maximum firing capacity of the SCC burner is 6 million Btu/hour. The data in the table shows that if the kiln temperature is 1700°F and the SCC temperature is 2100°F, the maximum feed rate (wet sediment plus modifiers) is 2,376 lb/hour. Increasing the kiln temperature to 1900°F increases the maximum feed rate to 4,631 lb/hour. Therefore, reducing the SCC temperature to a range of 2100 to 2200°F increases throughput capacity, while at the same time meets the NJ-DEP Air Quality Permit requirement (SCC temperature must be > 2100°F while feeding sediment). Overall, the nominal feed rate that can be sustained under non-slagging conditions is about 1 to 2 tons per hour.

Table 3. Effect of Increasing the Rotary Kiln Temperature on Feed Mixture Processing Capacity

| **Calculated Case No.** | B-6 | B-5 | B-7 | B-8 |
|---|---|---|---|---|
| Rotary kiln temperature, °F | 1700 | 1800 | 1900 | 2000 |
| SCC temperature, °F | 2100 | 2100 | 2100 | 2100 |
| Feed mixture to kiln, lb/hr | 2,376 | 3,085 | 4,631 | 6,428 |
| Moisture in feed mixture, wt % | 31 | 31 | 31 | 31 |
| Sediment to kiln, lb/hr | 1,850 | 2,400 | 3,600 | 5,000 |
| Estimated moisture in sediment, wt % | 40 | 40 | 40 | 40 |
| Limestone to kiln, lb/hr | 456 | 592 | 888 | 1233 |
| Alumina to kiln, lb/hr | 28 | 37 | 57 | 78 |
| Fluorspar to kiln, lb/hr | 42 | 56 | 86 | 117 |
| Nat Gas to kiln, million Btu/hr (HHV) | 8.42 | 11.05 | 16.62 | 24.27 |
| Nat Gas to SCC, million Btu/hr (HHV) | 6.08 | 6.04 | 6.06 | 5.16 |
| Gas residence time in kiln, sec | 11.6 | 8.5 | 5.4 | 3.6 |
| Gas residence time in SCC, sec | 4.4 | 3.7 | 2.5 | 2.0 |
| Oxygen in kiln off-gas, vol % (dry basis) | 4.00 | 4.01 | 4.01 | 4.01 |
| Quencher off-gas flow rate, lb/hr | 21,600 | 25,900 | 35,300 | 46,600 |
| Lime to quencher off-gas, lb/hr | 32 | 42 | 63 | 87 |
| Spent lime from baghouse, lb/hr | 51 | 66 | 98 | 137 |
| Wet EcoAggMat from granulator, lb/hr | 1,488 | 1,932 | 2,902 | 4,028 |

**Beneficial use and Acceptable Use Determination:** As the product from the non-slagging test was not Ecomelt, but EcoAggMat, a revised Acceptable Use Determination (AUD) was required from the NJ-DEP. Two viable beneficial uses for EcoAggMat were defined. The first is as a partial replacement for aggregate in BASF Corporation's foam core concrete construction panels. The second is for clean fill at the BASF site restoration project in Kearny, NJ. Material that was not thermally treated could be used as fill at the EnCap Golf site at the Meadowlands, NJ.

As mentioned in Section III (New Jersey Permitting), ECH received letters from BASF and EnCap Golf confirming that they would take the thermally treated product (BASF) or the untreated sediment (EnCap) from the Cement-Lock test provided that each met appropriate specifications. ECH subsequently received a revised AUD from NJ-DEP.

**Quality Assurance Project Plan (QAPP):** The quality assurance project plan (QAPP) originally prepared by the EPA SITE (Superfund Innovative Technology Evaluation) program in conjunction with GTI and ECH required modification and approval as a result of the non-slagging operation of the Cement-Lock demo plant. GTI worked with EPA SITE to accommodate the changes required in the QAPP (the revised QAPP is in Appendix F).

**Non-Slagging Demo Plant Operations**

Beginning in early January 2005, RPMS and their mechanical, electrical, and insulating contractors worked to prepare the Cement-Lock demo plant for non-slagging operations. The work included repair of frozen/cracked piping, addition of insulation and heat tracing, installation of a conveyor belt system and electrical hookup, recalibration of selected instruments, and preparation of EcoAggMat collection stands.

Around-the-clock plant operation was initiated on March 5. Plant operations continued until March 21, when it was decided to stop feeding and begin to cool the system. These activities are described in more detail below.

**Plant winterization:** Winterization of the plant equipment included repairing the damage to the water supply system that resulted in a leak in December 2004. FMW repaired the broken pipe and damage to the backflow preventer in the hot box. They also installed water drain valves on strategic water lines in the plant. These valves will enable each line to be readily drained in the event of freezing weather. The water supply line was successfully tested up to the main header.

SM Electric checked out the circuitry for the heaters on the Flue Gas Quencher water storage tank. This heating system had never been connected. They connected the control panel to power and confirmed the operation of the system. SM Electric also confirmed the operation of the other heat tracing systems or repaired and ran additional heat tracing as required.

The air receiver tank from the compressor, air control piping, and the exposed air and water piping on the top of the Flue Gas Quencher were insulated. The plant experienced a major snow event the weekend of January 22, 2005. Several days of work were devoted to snow removal around the plant so that contractors could continue their work. A skidsteer (similar to a bobcat) was rented to facilitate snow removal.

**Sediment feed system:** For feeding the frozen sediment-modifier mixture to the plant during cold weather, a hydraulically operated crushing, sizing, and screening bucket – ALLU SML –

was procured. According to the manufacturer, the ALLU bucket can perform as a conventional bucket to load sediment. It can also crush and size frozen material. If needed, it can also feed and size wet material. The ALLU bucket will be used to meter the sediment-modifier mixture onto a rented belt conveyor. The belt conveyor will extend 80 feet from the sediment storage area to the alternate feed hopper (T-102). The speed of the ribbon blenders in the alternate feed hopper will be reduced by installation of a variable-speed drive to match the feed rate.

Originally, we had considered discharging the belt conveyor directly above the main sediment conveyor (C-101); however, the structural steel and close quarters in the vicinity rendered this approach infeasible.

**Lime hopper feed system:** The lime feeding system has not consistently fed lime to the duct upstream of the baghouse in recent tests. One explanation is that the lime may have absorbed moisture from the air and partially caked in the hopper. One approach would be to install air spargers around the bottom of the hopper to dry out the lime. However, for the non-slagging campaign it was decided to clean the flights and recalibrate the lime feeder system.

**EcoAggMat Collection:** We designed and FMW fabricated two stands to collect EcoAggMat as it was discharged from the inclined drag conveyor (C-203) discharge chute. Having two stands

enabled us to recycle the first stand while the other was collecting EcoAggMat. When the Super sack was filled, the drag conveyor would be momentarily shut down. The photo above left shows one stand as built. The photo above right shows the stand with Super sack in place in position under the C-203 discharge chute. The Super sacks were 39 inches by 39 inches by 36 inches tall with duffle top openings. Each Super sack had a plastic liner to prevent any excess moisture from leaking out of the Super sack onto the ground. This arrangement worked very well during the non-slagging campaign.

**Around-the-Clock Operations:** Staffing for around-the-clock operations included a plant manager, and a shift supervisor and 3 laborers each shift. Supervisor shifts were 12 hours. Laborers worked an 8-hour shift. The required safety and oversight staffing was provided around the clock by GTI.

The primary and SCC burners were initially ignited on March 3. A problem with the low-gas pressure switch prevented the system from being heated to temperature. This problem was corrected and the system was heated to 1800°F at the prescribed rate of 100°F per hour. Although the rotary kiln temperature was readily achieved, the SCC temperature could not be readily increased above 1800°F. Numerous approaches to increasing the SCC temperature were tried, but did not work. A restriction orifice in the natural gas feed line to the SCC burner was limiting the flow. It was removed after consultation with North American Manufacturing Company. Also, we increased the rotary kiln temperature to 1835°F to reduce the load on the SCC burner. Together these changes enabled the SCC temperature to reach 2115°F. The time-temperature history of the campaign is presented in Figure 18. Major process flows are presented in Figure 19. The flow of combustion air to the primary burner (Ecomelt generator) averaged 139,953 ACFH during the campaign. The flow of natural gas to the primary burner average 9,260 SCFH (or about 9.3 million Btu/hr). The flow of flue gases out the stack/vent averaged 15,518 ACFM during the period.

On the morning of March 6, when the rotary kiln temperature was about 1200°F, chunks of the new extended lip (refer to discussion on page 57) detached from the drop-out box and plunged into the granulator quencher. The chunks were dragged out of the granulator by the drag conveyor. A total of 475 pounds of refractory was collected. Fortunately, no other damage to the internals of the kiln or the drop-out box was sustained. It was decided that this would not prevent the operation of the system in non-slagging mode so operations continued. A piece of wood (5 feet x 2 inches x 8 inches) that had been installed by the refractory installed to support the extended lip also fell into the granulator on top of the slag breakers. By reducing the water level in the granulator, enough ambient air was drawn into the granulator to burn the wood piece. It eventually broke up and was removed from the back (north side) of the granulator.

A problem occurred during the initial operation of the ALLU SML mechanical bucket that precluded its being used for the duration of the non-slagging campaign. Later, it was decided to return the ALLU to the manufacturer.

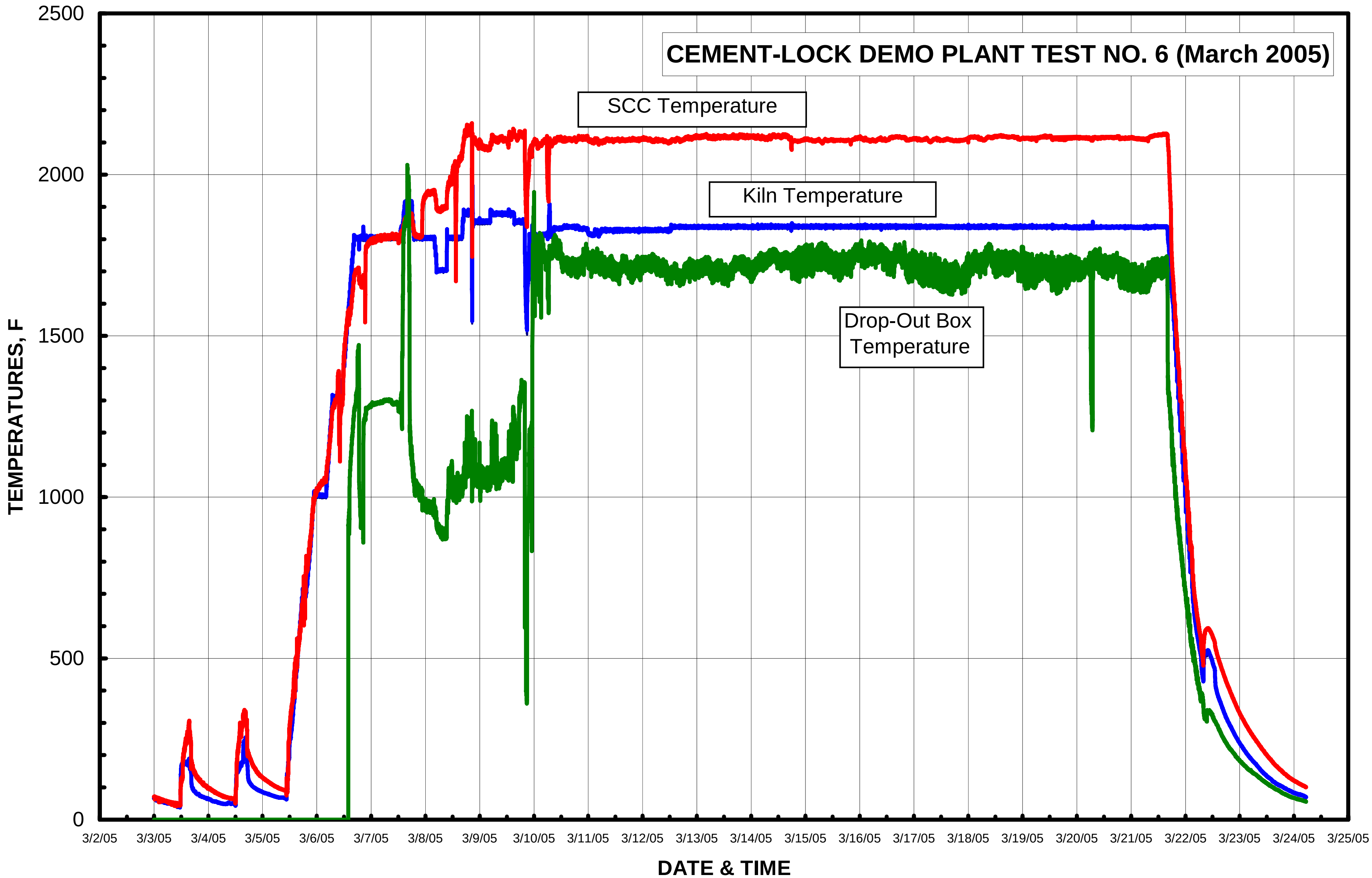



Figure 18. Time-Temperature History of Cement-Lock Demo Plant
Test No. 6 – Non-Slagging Mode (March 2005)

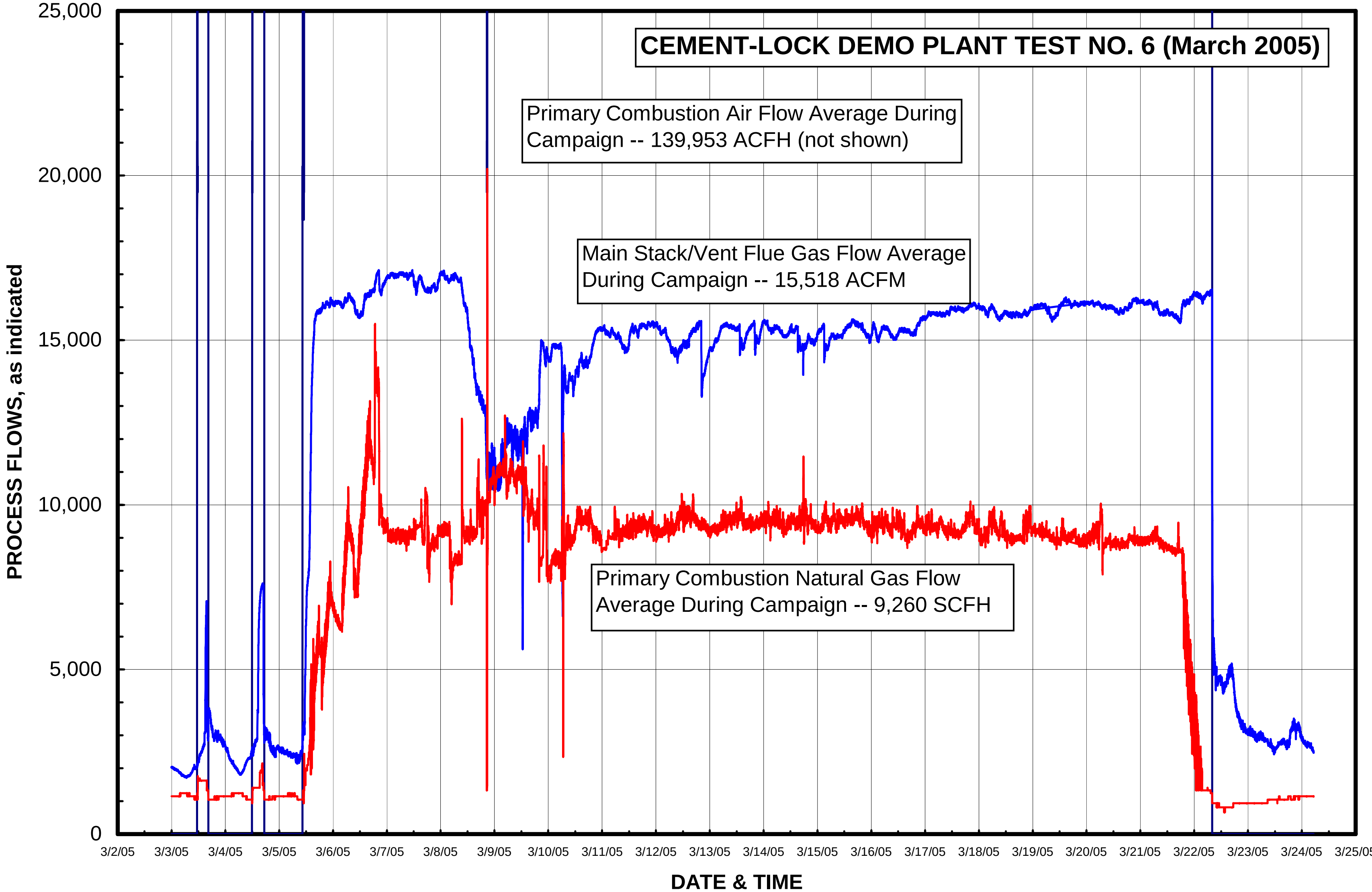



Figure 19. Major Process Flows Recorded During Cement-Lock Demo Plant Test No. 6 – Non-Slagging Mode (March 2005)

Some preliminary sediment-modifier mixture feeding tests were conducted to determine appropriate feeding techniques for the air-dried, but frozen material. Frozen material became caked around the main feed conveyor (C-101), which needed to be opened and cleared by hand.

Overnight the temperatures in the area fell below freezing during the campaign. This required the operating staff to check the condition of the compressor air receiver drain/discharge as well as several key equipment items every 5-10 minutes to ensure that they did not freeze up. A protocol and check list was prepared and followed during freezing conditions.


Thermally treated material flowing from the kiln was generally in the shape of small irregularly shaped particles, spheres, or oblate spheroids. The size ranged from sand to about 1 inch in size (Photo at right shows EcoAggMat collected in a Super Sack). On several occasions, material tumbling in the kiln agglomerated into larger chunks that resemble logs or pancakes. These were described as being typical of non-slagging kiln operation by Dr. Paul Queneau (consultant). One log about 4 feet long and 8 inches in diameter successfully passed through the kiln and broke up as it dropped into the granulator. On another occasion, a pancake about 2½ feet in diameter and 8 inches thick dropped into the granulator and caused the drag conveyor to jam. Fortunately, the pancake was accessible from the back of the granulator and it readily broke up when manipulated with a poker. Pieces of the pancake were withdrawn from the granulator by the drag conveyor.

**EPA SITE Program Sampling:** Beginning on March 10, 2005 at about 10:15 a.m. the EPA SITE program sampling team began their sampling work. The sampling team had arrived at the plant site a few days earlier so that they could attend IMTT Safety Orientation training. Operating conditions during the sampling were a feed rate of 500 pounds per hour, a kiln temperature of 1835°F (T-201), a SCC temperature of 2115°F (T-202), and kiln rotation rate of 0.4 rpm. These conditions were maintained consistently during the sampling activities.

Consistent feeding of the sediment-modifier mixture was achieved by manually loading the material into the C-151 access/view port from a 5-gallon pail. Manual feeding was selected over mechanical feeding (i.e., using the T-102 hopper, the C-102 and C-101 conveyors) to ensure consistent conditions during EPA sampling.

EPA SITE Program sampling continued on March 11, beginning about 8:00 a.m. They finished sampling about 6:00 p.m. They then packed their equipment and departed.

**Continuing Non-Slagging Operation:** After the EPA SITE sampling was completed, we continued feeding the sediment-modifier mixture to the system. However, we increased the feed rate to 1,000 pounds per hour, which was equivalent to one Bobcat bucket of sediment-modifier mixture per hour. The EcoAggMat product was collected in 1-$yd^3$ capacity Super sacks and as each sack was filled it was logged, weighed, and relocated to storage in the west part of the property.

Three 5-gallon pails of EcoAggMat were delivered to BASF Company for their beneficial use evaluation.

Freezing temperature continued to plague operations during the late evening and overnight hours. Some evenings, it was all the operating staff could do but keep the equipment from freezing up. Also, the alternate feed hopper (T-102), which had been used as the surge hopper for material being fed from the sediment storage area onto the belt conveyor began to experience packing of sediment-modifier mixture in its discharge conveyor (C-102). When this small conveyor plugged, it took several hours to unplug. As the material from the conveyor belt continued to fill the alternate feed hopper until the plug was detected, the extra material then backed up into the alternate feed hopper and plugged it. Later we decided to bypass the alternate feed hopper (T-102) and deposit feed material directly into the C-101 conveyor. This simplified the operation somewhat, but made the operation more labor intensive.

Sediment-modifier mixture also plugged the water-cooled screw conveyor (C-151) several times during the campaign. This was usually the result of overfeeding the material into the C-101 conveyor, which fed the C-112 Weigh Hopper, which fed the M-131 Pug Mill.

We took precautions to avoid overfeeding this conveyor, including taking preventive maintenance steps once per shift to clear C-151, run it forward and reverse for 10 to 15 minutes then close it up. Nevertheless, the water-cooled screw auger continued to plug.

Material continued to accumulate around the water-cooled auger shaft as well as on the interior of the feeding tube. Material became caked on the bottom of the feed tube and displaced the rotating auger up against the top of the feed tube. The added friction of the rotating screw against the feed tube surface caused the water-cooled screw auger motor to overheat. We tried reducing the caking in the bottom of the feed tube using water sprays as well as water dumped directly into the C-151 access/view port. These steps were moderately successful in reducing the motor load; however, within a short time, the motor would again begin to heat up.

The diaphragm in the vacuum pump in the CEMS cabinet also failed during the campaign. Trace Environmental Systems came out to the plant and repaired the pump and did maintenance work on the stack sampling lines. A few lines had become overheated during the campaign and had developed a leak. The CEMS was repaired and put back into service.

The filter screens that protect the granulator recirculation water pump began to accumulate fine particles of lime over time. We would switch from one duplex screen to the other at least once per shift. The filter screen not in use would be cleaned of lime and replaced. The source of the lime was limestone that had been premixed into the sediment prior to feeding. When subjected to the temperature in the kiln, the limestone would calcine into lime. At least a portion of the lime would dissolve into the granulator water.

By March 20, the motor overheating experienced with water-cooled screw auger C-151 continued to worsen. Adding water to the C-151 access/view port did not relieve the overheating. Running the auger in reverse also had limited effect. The screw auger needed to be pulled out of the kiln feed tube so that it could be thoroughly cleaned and evaluated. This would necessitate shutting down the plant.

At 3:30 p.m. on March 21, after discussing the situation with ECH/GTI management and project sponsors, we decided to discontinue attempts to feed and begin cooling the system.

On March 22, the system had cooled sufficiently that FMW could pull the water-cooled screw auger out of its feed tube for inspection. The auger showed signs of friction-induced deformation that progressively worsened closer to the discharge end.

As the major objective of the non-slagging campaign had been achieved, we decided to begin returning the rental equipment and begin planning for Phase II of the overall project.

Overall, we estimate that about 80 $yd^3$ of sediment-modifier mixture was processed through the Cement-Lock demo plant system from March 5 through 21, 2005. The EcoAggMat was collected in 107 Super sacks (see photo below).

Currently, the rental equipment has been returned and the EcoAggMat as well as the remainder of untreated sediment and sediment-modifier mixture is awaiting beneficial use disposition.

# X. DISCUSSION OF RESULTS

The Cement-Lock demo plant began shakedown and commissioning in July 2003. Since then a total of six tests have been conducted in the unit. Five tests were conducted in slagging mode with the objective of producing Ecomelt – a beneficial use product with pozzolanic properties that can be converted into construction-grade cement. One test was conducted in non-slagging mode. The objective of this test was to remediate the sediment and to generate a beneficial use product that could be used as a partial replacement for aggregate in concrete or as clean fill.

The following discusses the 1) Demo plant tests operating conditions and results, 2) the EPA SITE Program air emissions data from the demo plant, 3) the available environmental data on Ecomelt and EcoAggMat from the demo plant, 4) the cement testing properties of Ecomelt, and 5) the available physical properties data on EcoAggMat.

**Demo Plant Tests Operating Conditions and Results**

As mentioned above, a total of six tests were conducted in the Cement Lock demonstration plant. The system was operated in slagging mode for five tests conducted on December 10, 2003, July 16, July 22, September 22, and October 27, 2004. These tests were terminated involuntarily due to slag buildup in the discharge section of the kiln. However, short steady-state operation periods were achieved for these tests and the data analysis is presented below. Also, the kiln was operated in non-slagging mode for 17 days during March 2005 and that test was terminated voluntarily. The steady state operation period on March 11, 2005 was selected for data analysis because of the availability of EPA stack gas analysis.

The key operating conditions of the Cement-Lock demo plant tests are summarized in Table 4. As Test No. 4 was not successful in producing Ecomelt, the complete results are omitted from the table. The significant conclusions are:

1. For all slagging tests, the kiln operating temperature was maintained above 2400°F measured by thermocouples TE-201A and B. The thermocouples were located at the discharge end of the kiln and the measured the gas-phase temperatures. The temperatures of the refractory-lined walls of the kiln were measured by an optical pyrometer and found to be 50° to 100°F higher than the control thermocouple readings.

2. The operating temperature of the kiln was reduced to 1825°F for the non-slagging test conducted in March 2005.

3. The averaged pressure in the kiln was maintained at negative 0.3 inch water gauge for the slagging tests and it was increased to negative 0.1 inch water gauge for the non-slagging test to reduce the air leakage into the kiln.

4. The speed of the kiln was maintained in the range of 0.3 to 0.4 rpm for the tests.

5. The solids residence time in the kiln was maintained at about 80 minutes for all tests.

6. The gas residence time in the kiln was maintained at 3.2 to 3.5 seconds for the slagging tests. The gas residence time in the kiln for the non-slagging test was unable to be determined because of a malfunction of the flow measurement instrument.

7. For Test No. 3 on July 22, 2004, the flow rate of water to the overflow weir and sprays was decreased from 90 to 20 gpm. This resulted in an increase of the averaged drop-out box temperatures from 1850° to 2200°F.

8. For Test No. 5 on October 27, 2004, the faulty components of the melt burner system were repaired and the opening area of the dropout box was decreased by about 50 percent. This resulted in an increase of the averaged drop-out box temperature from 2200° to 2400°F.

9. The secondary combustion chamber (SCC) burner was not fired for the slagging tests because the temperatures of the flue gas entering the SCC already exceeded the required temperatures for the destruction of contaminants. The temperature in the SCC was maintained above 2300°F for all slagging tests.

10. The SCC burner was fired for the non-slagging test and the average temperature in the SCC was maintained above 2110°F.

11. The gas residence time in the SCC was maintained at over 2.2 seconds for all tests.

12. The oxygen and carbon monoxide concentrations in the stack gas were above 7 volume percent and 3 ppmv (dry basis), respectively, for the slagging tests measured by the CEMS. This high concentration of oxygen showed high amount of ambient air was leaked mostly into the kiln through the solids inlet and air seal assemblies of the kiln.

13. The oxygen concentration in the stack gas increased to 12.5 volume percent for the non-slagging test. This was a result of ambient air leaking into the system through the open covers of the solids feeding equipment. Excess air leaked into the kiln.

Table 4. Operating Conditions of Cement-Lock Demo Plant Tests

| Test No. | 1 | 2 | 3 | 5 | 6 |
|---|---|---|---|---|---|
| Test Date | 12/10/03 | 7/16/04 | 7/22/04 | 10/27/04 | 3/11/05 |
| Kiln | | | | | |
| Operating Mode | ---------------- Slagging ---------------- | | | | Non-Slagging |
| Temperature, °F | 2425 | 2400 | 2455 | 2450 | 1825 |
| Pressure, inches W.G. | -0.3 | -0.4 | -0.3 | -0.3 | -0.1 |
| Drop-Out Box Temperature, °F | 1909 | 1855 | 2218 | 2400 | 1720 |
| Kiln Speed, rpm | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 |
| Gas Residence Time, sc | 3.5 | 3.5 | 3.3 | 3.2 | N/A |
| Solids Residence Time, min. | 80 | 80 | 80 | 80 | 80 |
| SCC | | | | | |
| SCC Burner | ------------------ Off ------------------ | | | | On |
| Temperature, °F | 2309 | 2260 | 2280 | 2285 | 2110 |
| Gas Residence Time, sec. | 2.5 | 2.5 | 2.3 | 2.3 | 2.2 |
| Granulator Temperature, °F | 150 | 185 | 182 | 170 | 170 |
| Quencher Outlet Temperature, °F | 300 | 335 | 335 | 320 | 320 |
| Baghouse Outlet Temperature, °F | 333 | 285 | 292 | 280 | 270 |
| Ac Bed Outlet Temperature, °F | 289 | 217* | 216* | 215* | 230 |
| Stack Gas Temperature, °F | 335 | 297 | 302 | 292 | 245 |
| Stack Gas Composition, dry basis | | | | | |
| $O_2$, Vol % | 14.05 | 7.15 | 6.94 | 8.39 | 12.50 |
| CO, ppmv | 3 | 3 | 3 | | < 1 |
| $CO_2$, vol% | N/A | N/A | N/A | N/A | 4.5 |
| NOx, ppmv | N/A | N/A | N/A | N/A | 45 |
| $SO_2$, ppmv | N/A | N/A | N/A | N/A | < 1 |
| THC, ppmv | N/A | N/A | N/A | N/A | < 1 |

*Unresolved low temperature of Activated Carbon Adsorber Bed outlet temperature.

Heat and mass balances were calculated for the Cement-Lock demo plant tests and the results are summarized in Tables 5 to 8. The significant conclusions are:

1. The non-slagging test has better heat and mass balance closures than all slagging tests. This is mainly because a detailed stack gas analysis was available for the non-slagging test such that the flow rate of air leakage could be more accurately estimated by using a forced nitrogen balance.

2. The flow rates of air leakage for all slagging testes were estimated by matching the calculated oxygen concentrations in the stack gas against the concentrations measured by the

CEMS. The results were then confirmed by pressure drop calculations across the solids feeder and air seals of the kiln. This approach involved more input and output streams and it was less accurate than using the forced nitrogen balance since nitrogen is an inert species and can be used as a tracer through the system.

3. The mass balance shows high air leakage for all tests. This means a high amount of excess air was present in the kiln and SCC. Solids feeding devices with improved air seals must be used in future tests to minimize air leakage and reduce natural gas consumption. This will also increase the plant capacity and thermal efficiency.

4. The fraction of air leakage to the processing equipment downstream of the kiln was estimated by assuming the oxygen concentrations at the kiln exit were about 2% less than that in the stack gas based on the experimental results of on-line sampling of the kiln exit gas using a GTI specialized hot-gas sampling probe.

5. The basis for the heat balance is 70°F and liquid water. The high heating value of natural gas was 23,058 Btu/lb and the natural gas was assumed to be 100% methane. The high heating value of raw sediment was 420 Btu/lb (dry basis), and the heat of limestone calcination was 768 Btu/lb.

6. Measured external shell temperatures of the kiln, SCC, flue gas quencher, baghouse, and activated carbon bed were used to calculate the heat losses from the equipment vessels. Ambient temperatures of 70° and 40°F were assumed for the slagging and non-slagging test, respectively, zero wind speed, and an emissivity of 0.96 were used to determine the heat transfer coefficients.

The calculated material balances ranged from 102.8 to 111.9 percent. The calculated energy balances ranged from 99.3 to 110.8 percent.

Table 5. Heat and Mass Balance for Cement-Lock Test No. 2 on 7/16/04

From 7/16/04 10:00 To 7/16/04 14:00

| INPUT STREAMS | lb/hr | Btu/hr | OUTPUT STREAMS | lb/hr | Btu/hr |
|---|---|---|---|---|---|
| Sediment/Modifiers to Kiln | 1,000 | 160,991 | Stack Gas | 37,903 | 19,228,928 |
| Natural Gas to Kiln & SCC | 844 | 19,468,496 | Ecomelt | 610 | 23,790 |
| Combustion Air to Kiln & SCC | 11,643 | 0 | Total Heat Loss | | 2,497,954 |
| Air Leakage | 7,400 | 0 | | | |
| Water to Granulator | 500 | 0 | | | |
| Water to Quencher | 11,500 | 0 | | | |
| Air to Quencher | 2,000 | 0 | | | |
| TOTAL | 34,887 | 19,629,487 | TOTAL | 38,513 | 21,750,672 |

| | |
|---|---|
| % Mass Balance (Out/In) | 110.4 |
| % Heat Balance (Out/In) | 110.8 |

Table 6. Heat and Mass Balance for Cement-Lock Test No. 3 on 7/22/04

From 7/22/04 15:00 To 7/22/04 19:00

| INPUT STREAMS | lb/hr | Btu/hr | OUTPUT STREAMS | lb/hr | Btu/hr |
|---|---|---|---|---|---|
| Sediment/Modifiers to Kiln | 500 | 80,321 | Stack Gas | 39,425 | 19,504,388 |
| Natural Gas to Kiln & SCC | 887 | 20,441,921 | Ecomelt | 300 | 11,700 |
| Combustion Air to Kiln & SCC | 12,403 | 0 | Total Heat Loss | | 2,497,954 |
| Air Leakage | 7,700 | 0 | | | |
| Water to Granulator | 500 | 0 | | | |
| Water to Quencher | 11,500 | 0 | | | |
| Air to Quencher | 2,000 | 0 | | | |
| TOTAL | 35,490 | 20,522,242 | TOTAL | 39,725 | 22,014,042 |

| | |
|---|---|
| % Mass Balance (Out/In) | 111.9 |
| % Heat Balance (Out/In) | 107.3 |

Table 7. Heat and Mass Balance for Cement-Lock Test No. 5 on 10/27/04

From 10/27/04 11:00 To 10/27/04 16:00

| INPUT STREAMS | Lb/hr | Btu/hr | OUTPUT STREAMS | lb/hr | Btu/hr |
|---|---|---|---|---|---|
| Sediment/Modifiers to Kiln | 600 | 94,210 | Stack Gas | 39,930 | 18,592,625 |
| Natural Gas to Kiln & SCC | 887 | 20,441,921 | Ecomelt | 370 | 14,430 |
| Combustion Air to Kiln & SCC | 13,164 | 0 | Total Heat Loss | | 2,497,954 |
| Air Leakage | 8,600 | 0 | | | |
| Water to Granulator | 500 | 0 | | | |
| Water to Quencher | 11,000 | 0 | | | |
| Air to Quencher | 2,000 | 0 | | | |
| TOTAL | 36,751 | 20,536,131 | TOTAL | 40,300 | 21,105,009 |

| | |
|---|---|
| % Mass Balance (Out/In) | 109.7 |
| % Heat Balance (Out/In) | 102.8 |

Table 8. Heat and Mass Balance for Cement-Lock Test No. 6 on 3/11/05

From 3/11/05 07:00 To 3/11/05 19:00

| INPUT STREAMS | lb/hr | Btu/hr | OUTPUT STREAMS | lb/hr | Btu/hr |
|---|---|---|---|---|---|
| Sediment/Modifiers to Kiln | 1,000 | 250,917 | Stack Gas | 43,709 | 15,784,216 |
| Natural Gas to Kiln & SCC | 802 | 18,495,071 | EcoAggMat | 615 | 20,295 |
| Combustion Air to Kiln & SCC | 12,272 | -92,038 | Total Heat Loss | | 2,388,626 |
| Air Leakage | 17,258 | -129,434 | | | |
| Water to Granulator | 500 | -10,000 | | | |
| Water to Quencher | 8,750 | -175,000 | | | |
| Air to Quencher | 616 | -4,623 | | | |
| Air to Baghouse | 1,933 | -14,495 | | | |
| TOTAL | 43,131 | 18,320,398 | TOTAL | 44,324 | 18,193,137 |

% Mass Balance (Out/In) 102.8

% Heat Balance (Out/In) 99.3

## EPA SITE Program Air Emission Data

The EPA SITE Program conducted environmental sampling of the stack as well as feeds and products during the non-slagging test on March 10 and 11, 2005. The complete results of the air emissions sampling are included in Appendix G. The flue gas from the stack was sampled for the following components: CO, $O_2$, $CO_2$, HCl, $Cl_2$, NOx, $SO_2$, THC (total hydrocarbons), PAHs, PCBs, and dioxins and furans. Also, the inlet to the activated carbon bed was sampled for the same components to determine collection efficiency across the bed.

The results are presented below in Table 9.

Table 9. Summary of Air Emission Data From Non-Slagging Cement-Lock Demo Plant Test (March 2005)

| **Sample Location** | **Inlet to Activated Carbon Bed (A-304)** | **System Outlet Stack (S-304)** |
|---|---|---|
| Components | | |
| $O_2$ | NA | 12.6 mol % |
| $CO_2$ | NA | 4.5 mol % |
| CO | NA | 1.7 ppmdv @ 7% $O_2$<br>0.02 lb/hr |
| HCl | 0.9 ppm<br>0.023 lb/hr | 17.5 ppm<br>0.37 lb/hr |
| NOx | NA | 76 ppmdv @ 7% $O_2$<br>1.53 lb/hr |
| $SO_2$ | NA | < 0.8 ppmdv @ 7% $O_2$<br>< 0.024 lb/hr |
| THC | NA | < 1.4 ppmdv @ 7% $O_2$<br>< 0.01 lb/hr |
| HCl | 1.5 ppmd @ 7% $O_2$<br>0.023 lb/hr | 23.4 ppmd @ 7% $O_2$<br>0.37 lb/hr |
| Mercury | 14.6 µg/acm<br>$6.79 \times 10^{-4}$ lb/hr | 0.14 µg/acm<br>$5.61 \times 10^{-6}$ lb/hr |
| Arsenic | < 0.112 µg/acm<br>< $5.20 \times 10^{-6}$ lb/hr | 0.29 µg/acm<br>$1.18 \times 10^{-5}$ lb/hr |
| Barium | 0.70 µg/acm<br>$3.27 \times 10^{-5}$ lb/hr | 3.05 µg/acm<br>$1.23 \times 10^{-4}$ lb/hr |
| Cadmium | 1.04 µg/acm<br>$4.77 \times 10^{-5}$ lb/hr | 0.15 µg/acm<br>$6.17 \times 10^{-6}$ lb/hr |

| **Sample Location** | **Inlet to Activated Carbon Bed (A-304)** | **System Outlet Stack (S-304)** |
|---|---|---|
| Chromium | 0.47 μg/acm<br>$1.71 \times 10^{-5}$ lb/hr | 2.75 μg/acm<br>$1.11 \times 10^{-4}$ lb/hr |
| Copper | 0.23 μg/acm<br>$1.07 \times 10^{-5}$ lb/hr | 4.23 μg/acm<br>$1.7 \times 10^{-4}$ lb/hr |
| Lead | 0.10 μg/acm<br>$4.75 \times 10^{-6}$ lb/hr | 6.11 μg/acm<br>$2.46 \times 10^{-4}$ lb/hr |
| Nickel | 0.72 μg/acm<br>$3.3 \times 10^{-5}$ lb/hr | 2.20 μg/acm<br>$8.85 \times 10^{-5}$ lb/hr |
| Selenium | < 0.112 μg/acm<br>$< 5.2 \times 10^{-6}$ lb/hr | < 0.126 μg/acm<br>$< 5.07 \times 10^{-6}$ lb/hr |
| Silver | < 0.112 μg/acm<br>$< 5.2 \times 10^{-6}$ lb/hr | 0.32 μg/acm<br>$1.29 \times 10^{-5}$ lb/hr |
| Zinc | 7.9 μg/acm<br>$3.64 \times 10^{-4}$ lb/hr | 5.44 μg/acm<br>$2.18 \times 10^{-4}$ lb/hr |
| Benzo (a) Anthracene | $< 3.83 \times 10^{-6}$ lb/hr | $< 3.53 \times 10^{-6}$ lb/hr |
| Benzo (a) Pyrene | $< 3.83 \times 10^{-6}$ lb/hr | $< 3.53 \times 10^{-6}$ lb/hr |
| Benzo (b) Fluoranthene | $< 3.83 \times 10^{-6}$ lb/hr | $< 3.53 \times 10^{-6}$ lb/hr |
| Benzo (k) Fluoranthene | $< 3.83 \times 10^{-6}$ lb/hr | $< 3.53 \times 10^{-6}$ lb/hr |
| Bis (2-Ethylhexyl) Phthalate | $1.41 \times 10^{-4}$ lb/hr | $3.24 \times 10^{-4}$ lb/hr |
| Chrysene | $< 3.83 \times 10^{-6}$ lb/hr | $< 3.53 \times 10^{-6}$ lb/hr |
| Indeno (1,2,3-c,d) Pyrene | $< 3.83 \times 10^{-6}$ lb/hr | $< 3.53 \times 10^{-6}$ lb/hr |
| Total Dioxins/Furans | 4.0 ng/dscm @ 7% $O_2$<br>$3.72 \times 10^{-8}$ lb/hr | 0.35 ng/dscm @ 7% $O_2$<br>$2.86 \times 10^{-9}$ lb/hr |
| Total PCBs | 0.14 μg/dscm @ 7% $O_2$<br>$1.49 \times 10^{-6}$ lb/hr | 0.13 μg/dscm @ 7% $O_2$<br>$1.42 \times 10^{-6}$ lb/hr |

The data show that CO emissions were very low and averaged only 1.7 ppm (corrected to 7% $O_2$). The emission of NOx was also low (76 ppmdv corrected to 7% $O_2$) considering that no specific NOx control equipment is included in the demo plant.

The mercury capture efficiency of the activated carbon bed was calculated to be about 99 percent. This is well above the NJ Air Quality Permit minimum requirement of 70 percent removal efficiency. The emission of dioxins and furans from the system stack was measured at 0.35 ng/dscm (corrected to 7% $O_2$). This is significantly lower than the EPA's New Source

Performance Standard for emissions of dioxins and furans from large municipal waste incineration facilities of 30 ng/dscm.

The measured emissions of PAHs (polycyclic aromatic hydrocarbons) were below detection limits. It is interesting to note that Bis (2-Ethylhexyl) Phthalate was detected in the duct upstream as well as downstream of the activated carbon bed. This compound was also detected in the stack from the pilot-scale test conducted at Hazen Research.

**Environmental Data on Ecomelt and EcoAggMat**

The TCLP leachability of the Ecomelt sample generated during the demo plant test No. 1 is compared with that of the EcoAggMat from the laboratory-scale test in Table 10. The results show that the EcoAggMat leached Barium and Chromium at 0.42 and 0.79 mg/L, respectively. These are both well below the regulatory limit of materials destined for a landfill. The sample of Ecomelt from demo plant Test No. 1 did not leach any priority metals above the analytical detection limits. Additional environmental data from the EPA SITE Program sampling will be included in this report when available.

Table 10. Results of TCLP Tests on Ecomelt From Demo Plant Test No. 1
and EcoAggMat From Non-Slagging Laboratory-Scale Test

| Sampling Day | Ecomelt (Test No. 1) | | EcoAggMat (lab-scale) | | TCLP Regulatory Limit |
|---|---|---|---|---|---|
| **Component** | mg/kg | TCLP, mg/L | mg/kg | TCLP,** mg/L | mg/L |
| Arsenic | 2.3 | ND* | ND | ND | 5 |
| Barium | 240 | ND | 47 | 0.42 | 100 |
| Cadmium | ND | ND | 0.41 | ND | 1 |
| Chromium | 100 | ND | 12 | 0.79 | 5 |
| Lead | 19 | ND | 13 | ND | 5 |
| Selenium | ND | ND | ND | ND | 1 |
| Silver | ND | ND | ND | ND | 5 |
| Mercury | ND | ND | ND | ND | 0.2 |
| Copper | -- | -- | 27 | -- | -- |
| Nickel | -- | -- | 8.2 | -- | -- |
| Zinc | -- | -- | 28 | -- | -- |

*ND = Not detected above the analytical detection limit.
**Data reproduced from Table 2 (page 64).

## Cement Properties of Ecomelt

A sample of Ecomelt from Test No. 1 (slagging test, December 10, 2003) was submitted to Construction Technology Laboratories for evaluation. CTL conducted XRD tests on the untreated sediment (Figure 7) for comparison with the Ecomelt (Figure 8). As presented previously in Section VI, the results showed that the Ecomelt was amorphous, glassy material, whereas the sediment had specific crystalline components.

CTL also conducted tests to determine the compressive strength of the Ecomelt according to ASTM C-109. The results are compared with the compressive strength requirements of Portland cement per ASTM C-150 in Table 11. The results of these tests showed compressive strengths after 1, 3, 7, and 28 days of curing of 750, 1765, 2910, and 5190 psi, respectively, which compares very favorably with previous results. Please note that there is no 1-day compressive strength requirement in the ASTM standard. CTL determined this value to gauge the initial curing rate of the Ecomelt sample. Also, the 28-day compressive strength requirements are listed in the optional table of ASTM C-150. The compressive strength results exceed the ASTM requirements for both Portland and blended cements after 7 and 28 days of curing. After 3 days of curing, the compressive strength of Cement-Lock cement was less than that required for blended cements (C-595), but greater than that required for Portland cement (C-150). The results of the ASTM C-1073 (hydraulic activity of ground Ecomelt in 20 weight percent NaOH solution cured at 55°C for 1 day) was 4380 psi (30.2 MPa).

Table 11. Comparison of Compressive Strength of Ecomelt From Demo Plant Test No. 1 with ASTM Standard Requirements

| Test Period Days | Cement-Lock Demo Plant Test No. 1 | ASTM Cement Requirements C-595 Blended | ASTM Cement Requirements C-150 Portland |
|---|---|---|---|
| | psi | psi | psi |
| 1 | 750 | NA | NA |
| 3 | 1765 | 1890 | 1740 |
| 7 | 2910 | 2900 | 2760 |
| 28 | 5190 | 3480 | 4060 |

*NA = there is no 1-day compressive strength requirement under these ASTM standards

## Physical Properties of EcoAggMat

The physical properties of the EcoAggMat generated during the March 2005 campaign will affect its ultimate beneficial use. EcoAggMat will be used as clean fill at BASF location in Kearny, NJ and as a replacement for aggregate in BASF's foam core building panels. The bulk density of the EcoAggMat from the laboratory-scale test was about 35 $lb/ft^3$. This is roughly the same bulk density as other samples vendors' "light-weight" aggregate product. Other physical properties of EcoAggMat determined by EPA SITE Program as well as CTL will be presented when available.

# XI. PLANS FOR BENEFICIAL USE OF PRODUCT

The beneficial use of the EcoAggMat generated during the March 2005 campaign will be demonstrated in two ways: 1) as a partial replacement for sand/aggregate in concrete used to produce BASF's foam-core wall panels for construction, and 2) as clean fill at a site remediation project in South Kearny, New Jersey also for BASF.

As another beneficial use demonstration, Ecomelt produced during the earlier slagging tests will consolidated as appropriate and then ground to cement fineness (< 50 micrometers). Grinding companies have been identified for this activity. Once the Ecomelt has been ground, a sample will be sent to CTL to develop a mix design for its ultimate use. With the mix design, the bulk sample of ground Ecomelt will be shipped to a local (NJ) ready mix company. The ground Ecomelt will then be used as a partial replacement for Portland cement in the manufacture of concrete for a length of sidewalk at Montclair State University.

Untreated sediment and sediment mixed with modifiers will be beneficially used as fill at the EnCap Golf Holdings location at the Meadowlands, NJ.

# XII. CONCLUSIONS AND RECOMMENDATIONS

This report presents the results of operations conducted at the Cement-Lock demo plant in Bayonne, New Jersey at the International Matex Tank Terminal location. The demo plant is a "first-of-a-kind" large-scale solids-and-fluid-processing plant for converting contaminated sediment into a beneficial-use product, namely construction-grade cement. As documented above, the construction, shakedown and commissioning, and operation of the Cement-Lock demo plant in both slagging and non-slagging modes has been quite challenging. Most of those challenges have been successfully met. However, more work needs to be done to prepare the demo plant for successful slagging operation for the planned Phase II project in which 2,500 $yd^3$ of sediment from the Passaic River are planned to be processed. Conclusions and recommendations from the Phase I project operations conducted to date are presented below.

**Conclusions**

- The existing sediment and modifier conveying, blending, and feeding systems are not adequate for sustained and consistent feeding of wet sediment and modifiers.
- The existing rotary kiln system can operate at the elevated temperatures required for slagging operation.
- The drop-out box system is not adequate for sustained slagging operation.
- The pollution control equipment (including SCC, flue gas quencher, baghouse, and activated carbon bed) performed as designed to limit emissions from this thermal system.
- The plant can be operated in non-slagging mode for an extended period of time; however, even under those relatively mild conditions the plant showed signs of wear and fatigue.
- The winterization work completed on the plant prior to the non-slagging operation in March was not adequate for the weather that was encountered.
- The EcoAggMat produced in the laboratory under non-slagging conditions was essentially non-leachable under the conditions of the TCLP and MEP. It was also essentially devoid of organic contaminants.
- The Cement-Lock construction-grade cement (from Ecomelt) exhibited compressive strength that exceeded ASTM requirements for Portland as well as blended cements.
- The Ecomelt produced was essentially non-leachable under the conditions of the TCLP.

## Recommendations

- The existing sediment and modifier feeding systems, kiln discharge, and drop-out box systems should be thoroughly evaluated by a company or companies with direct sediment handling and slagging kiln design, construction, and operating experience.

- Based on the above plant system evaluation, the modifications needed to ensure successful and prolonged operation of the Cement-Lock demo plant under slagging conditions should be developed. The plans for the modifications should include detailed designs and a firm cost estimate and schedule to implement the modifications.

## Appendix A.

**NEW JERSEY ACCEPTABLE USE DETERMINATION FOR ECOMELT AND ECOAGGMAT AND RELATED CORRESPONDENCE**

## Appendix B.

**CERTIFIED PROTOCOL GAS CALIBRATIONS**

(Spectra Gases, Inc., Branchburg, NJ)

**SPECTRA GASES INC.**
3434 Route 22 West • Branchburg, NJ 08876 USA Tel.: (908) 252-9300 • (800) 932-0624 • Fax: (908) 252-0811
Shipped From: 80 Industrial Drive • Alpha, NJ 08865 www.spectra-gases.com

## CERTIFICATE OF ANALYSIS

## EPA PROTOCOL MIXTURE
**PROCEDURE # : G1**

**CUSTOMER:** Gas Technology Institute
**SGI ORDER # :** 0041590
**ITEM# :** 2
**P.O.# :** W24054

**CYLINDER # :** CC-17723
**CYLINDER PRES:** 2000 PSIG
**CGA OUTLET:** 350

**CERTIFICATION DATE:** 9/5/2003
**EXPIRATION DATE:** 9/5/2006

**CERTIFICATION HISTORY**

| COMPONENT | DATE OF ASSAY | MEAN CONCENTRATION | CERTIFIED CONCENTRATION | ANALYTICAL ACCURACY |
|---|---|---|---|---|
| Carbon Monoxide | 8/21/2003<br>9/5/2003 | 162.0 ppm<br>162.1 ppm | 162.1 ppm | +/- 1% |
| | | | | |
| | | | | |
| | | | | |

**BALANCE** Nitrogen

**PREVIOUS CERTIFICATION DATES:** None

**REFERENCE STANDARDS**

| COMPONENT | SRM/NTRM# | CYLINDER# | CONCENTRATION |
|---|---|---|---|
| Carbon Monoxide | GMIS-1 | CC-94868 | 505 ppm |
| | | | |
| | | | |
| | | | |

**INSTRUMENTATION**

| COMPONENT | MAKE/MODEL | SERIAL # | DETECTOR | CALIBRATION DATE(S) |
|---|---|---|---|---|
| Carbon Monoxide | Horiba VIA-510 | 570423011 | NDIR | 8/20/2003 |
| | | | | |
| | | | | |
| | | | | |

**THIS STANDARD IS NIST TRACEABLE. IT WAS CERTIFIED ACCORDING TO THE EPA PROTOCOL PROCEDURES.**
**DO NOT USE THIS STANDARD IF THE CYLINDER PRESSURE IS LESS THAN 150 PSIG.**

ANALYST: Cheryl Patino
CHERYL PATINO

DATE: 9/5/2003

**SPECTRA GASES INC.**

3434 Route 22 West • Branchburg, NJ 08876 USA Tel.: (908) 252-9300 • (800) 932-0624 • Fax: (908) 252-0811
Shipped From: 80 Industrial Drive • Alpha, NJ 08865
www.spectra-gases.com

## CERTIFICATE OF ANALYSIS

## EPA PROTOCOL MIXTURE

**PROCEDURE # :** G1

| | | | |
|---|---|---|---|
| **CUSTOMER:** | Gas Technology Institute | **CYLINDER # :** | CC-126794 |
| **SGI ORDER # :** | 0041590 | **CYLINDER PRES:** | 2000 PSIG |
| **ITEM# :** | 3 | **CGA OUTLET:** | 350 |
| **P.O.# :** | W24054 | | |

**CERTIFICATION DATE:** 9/5/2003
**EXPIRATION DATE:** 9/5/2006

**CERTIFICATION HISTORY**

| COMPONENT | DATE OF ASSAY | MEAN CONCENTRATION | CERTIFIED CONCENTRATION | ANALYTICAL ACCURACY |
|---|---|---|---|---|
| Carbon Monoxide | 8/27/2003<br>9/5/2003 | 2371 ppm<br>2379 ppm | 2375 ppm | +/- 1% |
| | | | | |
| | | | | |
| | | | | |

**BALANCE** Nitrogen

**PREVIOUS CERTIFICATION DATES:** None

**REFERENCE STANDARDS**

| COMPONENT | SRM/NTRM# | CYLINDER# | CONCENTRATION |
|---|---|---|---|
| Carbon Monoxide | SRM-2638a | FF23332 | 4966 ppm |
| | | | |
| | | | |
| | | | |

**INSTRUMENTATION**

| COMPONENT | MAKE/MODEL | SERIAL # | DETECTOR | CALIBRATION DATE(S) |
|---|---|---|---|---|
| Carbon Monoxide | Horiba VIA-510 | 42331960012 | NDIR | 8/27/2003 |
| | | | | |
| | | | | |
| | | | | |

**THIS STANDARD IS NIST TRACEABLE. IT WAS CERTIFIED ACCORDING TO THE EPA PROTOCOL PROCEDURES. DO NOT USE THIS STANDARD IF THE CYLINDER PRESSURE IS LESS THAN 150 PSIG.**

ANALYST: Cheryl Patino
CHERYL PATINO

DATE: 9/5/2003

SPECTRA GASES
3434 Route 22 West • Branchburg, NJ 08876 USA Tel: (908) 252-9300 • (800) 932-0624 • Fax: (908) 252-0811
Website: http://www.spectra-gases.com

SHIPPED FROM: 80 INDUSTRIAL DRIVE ALPHA, N.J. 08865 TEL: (908) 454-7455

**SHIPPED TO:** Gas Technology Institute
250 E. 22nd Street
Bayonne, NJ 07002

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| **SGI ORDER # :** | 0041590 | | |
| **ITEM# :** | 1 | **CYLINDER # :** | CC-20231 |
| **CERTIFICATION DATE:** | 9/3/2003 | **CYLINDER PRES:** | 2000 psig |
| **P.O.#:** | W24054 | **CYLINDER VALVE:** | CGA 580 |
| **GRADE:** | CEM ZERO NITROGEN | | |

| COMPONENT | REQUESTED GAS GRADE |
|---|---|
| NITROGEN | 99.9995 % |

| | |
|---|---|
| CO | ≤ 0.5 ppm |
| $CO_2$ | ≤ 1.0 ppm |
| $H_2O$ | ≤ 4.0 ppm |
| NOx | ≤ 0.1 ppm |
| $O_2$ | ≤ 0.5 ppm |
| $SO_2$ | ≤ 0.1 ppm |
| THC | ≤ 0.1 ppm |

ANALYST: Cheryl Patino
Cheryl Patino

DATE: 9/3/2003

USA • United Kingdom • Germany • Japan
ISO 9001

## Appendix C.

**INSTRUMENTATION CALIBRATION REPORTS**

KGB Controls
Tyrone, GA
June 30, 2004

Omni Instrumentation Services, Inc.
Linden, NJ
February 28, 2005

# Appendix D.

## NORTH AMERICAN MANUFACTURING BURNER TUNING REPORT

## Appendix E.

**INCIDENT REPORT (SEPTEMBER 22, 2004)
AND SAFETY AND OVERSIGHT PROPOSAL**

## Appendix F.

**REVISED EPA SITE PROGRAM QUALITY ASSURANCE PROJECT PLAN**

## Appendix G.

**EPA SITE PROGRAM ENVIRONMENTAL SAMPLING REPORTS**