Capture and Use of Coal Mine Ventilation Air Methane

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ABSTRACT

CONSOL Energy Inc., in conjunction with MEGTEC Systems, Inc., and the U.S. Department of Energy with the U.S. Environmental Protection Agency, designed, built, and operated a commercial-size thermal flow reversal reactor (TFRR) to evaluate its suitability to oxidize coal mine ventilation air methane (VAM). Coal mining, and particularly coal mine ventilation air, is a major source of anthropogenic methane emissions, a greenhouse gas. Ventilation air volumes are large and the concentration of methane in the ventilation air is low; thus making it difficult to use or abate these emissions. This test program was conducted with simulated coal mine VAM in advance of deploying the technology on active coal mine ventilation fans. The demonstration project team installed and operated a 30,000 cfm MEGTEC VOCSIDIZER oxidation system on an inactive coal mine in West Liberty, WV. The performance of the unit was monitored and evaluated during months of unmanned operation at mostly constant conditions. The operating and maintenance history and how it impacts the implementation of the technology on mine fans were investigated. Emission tests showed very low levels of all criteria pollutants at the stack. Parametric studies showed that the equipment can successfully operate at the design specification limits. The results verified the ability of the TFRR to oxidize ≥95% of the low and variable concentration of methane in the ventilation air. This technology provides new opportunities to reduce greenhouse gas emissions by the reduction of methane emissions from coal mine ventilation air. A large commercial-size installation (180,000 cfm) on a single typical mine ventilation bleeder fan would reduce methane emissions by 11,000 to 22,100 short tons per year (the equivalent of 183,000 to 366,000 metric tonnes carbon dioxide).

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1. INTRODUCTION

Methane is the second most important non-water greenhouse gas (GHG). Coal mining, and particularly coal mine ventilation air, is a major source of anthropogenic methane emissions. For example, the ventilation air methane (VAM) coming from mine ventilation fans accounted for 89 billion cubic feet (bcf) of the 151 bcf of coal mine methane (CMM) emitted in the United States in the year 2000. The capture and use of VAM is problematic because of the large volumes of mine ventilation air and its low methane concentration, typically 0.3% to 1.5%.

A thermal flow reversal reactor (TFRR) system (specifically, the MEGTEC VOCSIDIZER™ oxidation system) can oxidize and destroy the dilute methane in the mine ventilation air. The equipment is self-sustaining at low methane concentrations (0.2%-1.2%), without reliance on another source of heat. The system will convert the methane to carbon dioxide and produce essentially no SO_x, NO_x, or particulate, and only very minor quantities of CO. Because methane has a 21-times greater radiative forcing factor than carbon dioxide (over a 100-year time frame), this process will substantially reduce the effective greenhouse gas emissions to the atmosphere. In addition, with the integration of a heat recovery system, the TFRR can be used to recover useful energy, thus avoiding the GHG emissions associated with the avoided fuel. Even though a commercial-size unit has not been applied to a U.S. coal mine, the oxidation technology is a proven system for destroying volatile organic compounds in over 600 applications around the world.

The original purpose of this project was to demonstrate the operation of a full-scale commercial TFRR system on a mine ventilation fan from an active U.S. coal mine. However, certain issues caused us to take an alternative approach to simulate coal mine ventilation air methane using coal mine methane emissions from a bore hole of a closed coal mine. The objectives of the alternative approach were to: 1) design an effective interface between the TFRR and a mine ventilation system that does not compromise mine safety, 2) convert the low and variable concentrations of methane contained in the coal mine ventilation air to carbon dioxide effectively and economically by simulating the ventilation air stream using diluted coal mine methane, and 3) determine the quantity of useful energy that can be economically produced when processing ventilation air from a working coal mine and perform an engineering/economic evaluation of the concept.

2. EXECUTIVE SUMMARY

CONSOL Energy Inc., with assistance from MEGTEC Systems, Inc. and the United States Department of Energy, successfully demonstrated a thermal flow reversal reactor (TFRR) system (specifically, the MEGTEC VOCSIDIZER™ oxidation system) using simulated ventilation air methane. While simulating the ventilation air stream using diluted coal mine methane, the key objectives of this project were to demonstrate that the low and variable concentrations of methane contained in the coal mine ventilation air can be converted to carbon dioxide effectively and economically; to determine the quantity of useful energy that can be economically produced when processing ventilation air from a working coal mine; and to perform an engineering/economic evaluation of the concept.

The location for the field demonstration was West Liberty, Brooke County, West Virginia, at a coal mine methane vent from the abandoned Windsor Mine. The initial tasks were to test the vent to determine if there was sufficient methane to conduct the demonstration project, determine if an air permit was required, and to determine the structural integrity of the soil to support the equipment. From the testing, it was determined that the vent could emit up to 1MM ft^3/day of gas containing 43% methane which was sufficient to demonstrate a single VOCSIDIZER unit. Based on the expected emissions of the process, it was determined that no air permit was required from the West Virginia Department of Environmental Protection. The existing soil was not sufficiently competent to support the equipment weight of 58.2 tons and the civil design selected used structured back-fill under concrete slabs for the support system.

Once the subcontract with MEGTEC Systems was finalized, it took less than a year to fabricate the equipment, install the system, and introduce methane to the unit. Fabrication of the equipment required about five months and, during that time, the site preparation was initiated. Equipment foundations and 3-phase power were the primary resources required to support the equipment. The VOCSIDIZER, fan, and control room arrived on site pre-assembled on skids, which minimized field installation time. In order to complete the system, a gas train to simulate ventilation air methane was built, and the power and control wiring were connected to the unit and the instrumentation. This installation required more instrumentation and safeties than what would typically be on a mine ventilation fan because simulated ventilation air methane had to be produced.

On February 11, 2007, the check-out was complete and simulated mine ventilation air methane entered the VOCSIDIZER for the first time. Unmanned operation of the equipment had three areas of focus. The first area was to conduct parametric tests to measure the ability of the unit to convert methane at the limits of the equipment. The tests were to determine the effects of the mine ventilation air flow rate and VAM concentration on the response of the TFRR and methane conversion. One set of parametric tests were conducted the week of April 9, 2007, and a second set of tests were conducted the week of April 28, 2008. All tests showed that operation was sustainable at low (0.3%) and high (0.8%-1.0%) methane concentrations entering the VOCSIDIZER and low (15,000 scfm) and high (30,000 scfm) air flow into the

VOCSIDIZER. Only one of the eleven tests, which was conducted at 1.0% methane and 15,000 scfm, failed to meet the manufacturer's guarantee of greater than 95% methane conversion.

The second area of focus during the operating phase was to conduct air emission tests to determine the composition of the air emitted from the stack and to verify the performance of the unit. Three campaigns were completed; August 7-9, 2007, August 5-7, 2008, and September 8-10, 2008. Considering all test results from the three campaigns, the typical measured concentration for each criteria pollutant were: 0-0.12 ppmv NO_x, 0-1.19 ppmv SO_2, 1.32-2.01 ppmv CO, and 0.06-2.81 lb/hr particulate matter. The low SO_2 levels were assumed to represent uncertainty in the measurement. The particulate matter was assumed to primarily be dust from the ceramic media. All other criteria pollutants were below the manufacturer's guarantee. The emissions of methane were from 126-186 ppmv which calculated to greater than 95% methane conversion.

The third area of focus was to conduct long-term testing at one set of conditions that are representative of a mine ventilation fans. During long-term testing, operating data were collected daily to review the operation of the system. Long-term operability of the equipment and maintenance issues were the two areas that were evaluated during the testing.

Two campaigns were run, with revisions made between campaigns to improve operability. In the first campaign from May 9, 2007, to November 30, 2007, there were 1300 unmanned hours logged on the equipment. In the second campaign, from May 1, 2008, to October 31, 2008, there were 2833 hours logged on the equipment. The second campaign showed a significant uptime improvement to 64.4%. Considering only core problems, the uptime on the equipment was 84.1%. The core problem was a loss of media at the corners of the bed, which caused the corner temperatures to drop and shut down the system. During the operating periods when the corner temperatures were dropping, the equipment continued to maintain methane conversions greater than 95%. After viewing the results from the initial campaign, the manufacturer changed the equipment specification and lowered the maximum methane concentrations that could be processed in the bed from 1.2% to 0.8%.

The equipment problems that caused downtime were failures of the air compressor, methane analyzers, flow meter, and bed thermocouples. It is critical that the methane analyzer measuring the inlet methane concentration to the VOCSIDIZER have a quick response with a high level of accuracy for safety reasons. Because the original analyzer did not meet the specification, it was replaced with a second analyzer from a different manufacturer. The replacement analyzer accurately measured methane with a response time from 5 to 6 seconds, depending on the probe length.

In addition to the mechanical problems, there were challenges to operating the equipment unmanned, in a remote location, without an operator available 24 hours a

day. This contributed to downtime. Having an alarm call-out system was helpful in responding to problems in a timely manner.

When this technology is advanced to a mine ventilation fan, a typical abatement-only installation would consist of six beds the size of the demonstration unit that would capture 180,000 scfm of ventilation air. This system is only economically feasible when there is value for greenhouse gas emission reduction. Our baseline assumptions for the economic analysis are: a complete installation would cost $5.412MM, the maintenance costs are 5% of capital, the sales price for electricity is $0.058/kWh, manpower costs are $40/man-hour, the overall methane destruction is 95%, methane concentration is 0.6%, equipment availability is 97%, the equipment life is ten years on a single fan, and the carbon credit is $7.00/tonne CO_2e, The baseline case has an internal rate of return (IRR) of 2.5%. If optimistic conditions were selected, to achieve a 15% IRR, the value of the carbon credit would have to increase to $8.60/tonne CO_2e.

Considering a 180,000 scfm system having heat recovery with power generation , the capital investment increased to $15.335MM. Changes to the abatement-only baseline assumptions in the economic analysis included: the maintenance costs are $0.015/kWh, a full time onsite operator at $40/man-hour is required, and electrical efficiency is 28% on a LHV basis. The base case produced 3.07 MW of electricity with a 2.8% IRR. If optimistic conditions were selected, a 15% IRR could be achieved if the value of the carbon credit increased to $14.70/tonne CO_2e. High methane concentrations and high value of the generated electricity are favorable for considering power generation with the TFRR system.

The single bed unit, operating at 30,000 scfm and 0.6% methane at Windsor Mine, reduced methane emissions by 894 short tons during the 13 months of operation which is equivalent to 14,849 metric tonne of carbon dioxide. A large commercial-size installation (180,000 scfm) of TFRR technology on a single typical mine ventilation bleeder fan could reduce methane emissions between 11,000 and 22,100 ton per year (the equivalent of 183,000 to 366,000 tonne carbon dioxide) depending on the methane concentration. Adding power generation to the system would reduce the demand on fossil fuel generating stations, thus reducing the emissions of SO_2, NO_X, CO, and other criteria pollutants and CO_2. The system could produce 3.3-8.2 MW of electricity or 11-27 MW of thermal power.

Based on this demonstration project, the TFRR technology appears to be a viable technology to mitigate ventilation air methane. CONSOL Energy is interested in advancing this technology to an active mine site by initially relocating the existing VOCSIDIZER unit to a mine fan under the Mine Safety and Health Administration's (MSHA) guidelines. MEGTEC Systems is continuing to improve the equipment to obtain a more robust system and improve its operability. In a carbon-constrained world, this technology provides the capability of utilizing a waste stream to reduce green house gases as well as the potential to produce useful energy.

3. TECHNOLOGY DESCRIPTION

3.1 Principle of Operation

The VOCIDIZER installed at CONSOL for the demonstration project is shown in Figure 1. It consisted of a bed of ceramic material contained in an airtight steel container resting on a sturdy steel frame, see Figure 2. Commercial VOCSIDIZERs are usually installed as multi-bed systems. In the current project, we used a full-size single bed system that processed 30,000 scfm of mine ventilation air. Above and below the bed were air plenum chambers to provide even distribution of the inlet air. The granular ceramic bed material ensured even flow and temperature distribution over the bed. Electrical heating elements were placed in the bed to obtain the required start-up temperature (1832ºF or 1000ºC). The process fan at the inlet side of the VOCSIDIZER forced the feed air, via pneumatically actuated valves, into the plenum and through the preheated bed where the air is heated to a temperature at which methane is completely oxidized. The thermal energy released during methane oxidization was recovered by the bed media as the air moved to the outlet side of the bed. The exhaust air was released to the atmosphere at a temperature higher than the incoming process air. The exact temperature depended on the methane concentration in the mine ventilation air and flow rate of air. (This would also be affected by a heat recovery system in the bed.) Thermocouples in the bed were tied to the programmable logic controller (PLC) system that monitored the temperature profile of the bed and the movement of the high-temperature zone, which moved toward the outlet of the ceramic bed.

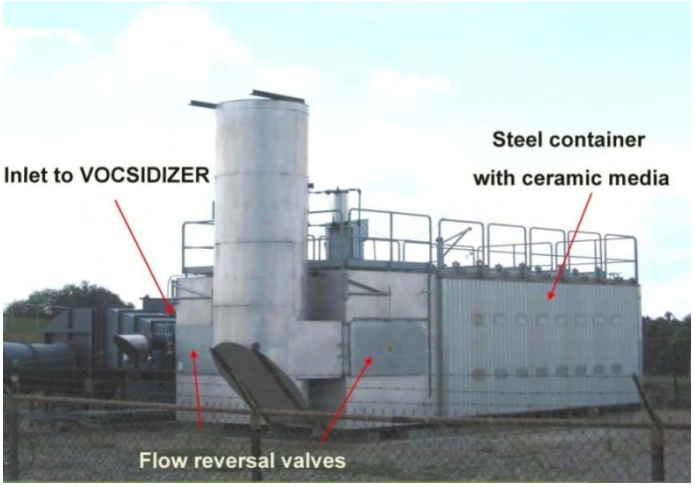

Figure 1. Full Size Single Bed Unit

To maintain the high-temperature zone within the ceramic bed, large switching valves reversed the air flow through the bed periodically. The PLC program optimized valve switching intervals using time and temperature to maximize energy efficiency. After the valves were switched and reversed the direction of air flow through the bed, the energy that was recovered and stored in one side of the bed heated the incoming process air to oxidation temperature. The high temperature zone in the bed moved toward the new outlet and the process repeated. In operation, the VOCSIDIZER typically changed air flow direction through the bed every few minutes. The reaction zone at the oxidation temperature was sustained near the center of the bed by optimizing the regenerative heat exchange between the ventilation air and the ceramic bed. Figure 3 shows the reversal of air flow through the bed as the valve position switches.

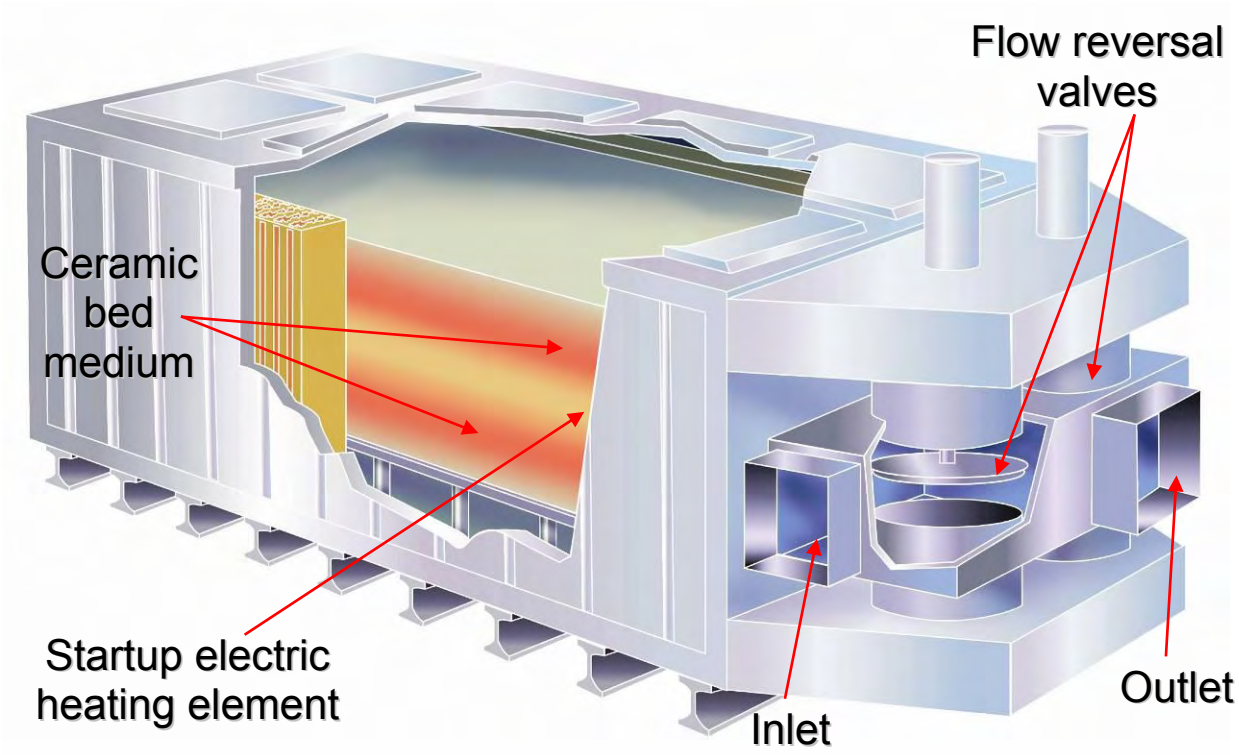

Figure 2. VOCSIDIZER Cut-Away Showing Internal Components

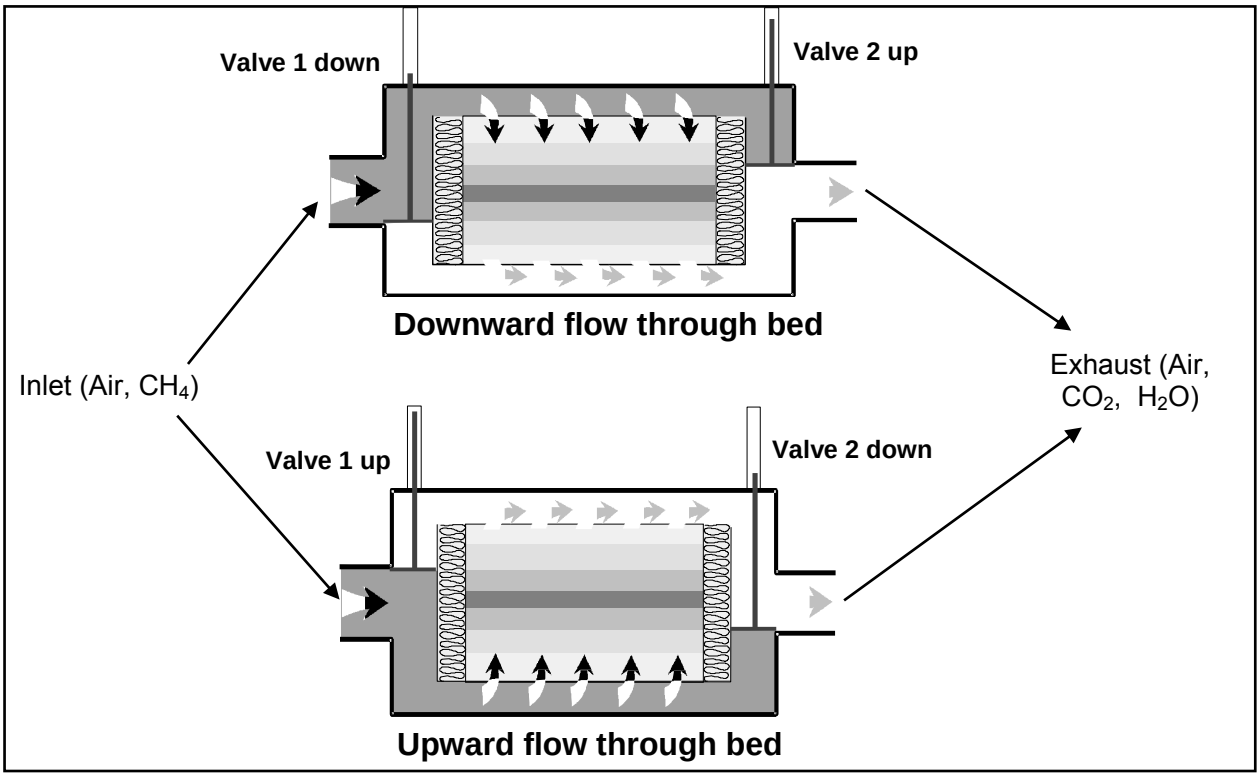

Figure 3. Flow Reversal in VOCSIDIZER

The programmable logic controller also provides logic and sequence controls, and monitors various plant/process parameters. The safety and alarm functions incorporated into the system include high and low bed temperatures, high exhaust temperatures, low compressed air pressure, and high methane concentration. In alarm mode, the fan is shut off and the dampers are shut to isolate the unit from the gas source. Because the unit has rugged construction, few moving parts, and advanced control, it is expected that the system will require little maintenance and maintain reliable emission control performance. The guaranteed methane conversion is 95%. However, MEGTEC expects methane conversion rates to be higher.

3.2 Competing Technology

There are several technologies in use to remove volatile organic compounds from chemical operations. Listed below are some technologies that have been developed for VAM applications.

A Canadian company, Biothermica Technologies Inc. has developed a regenerative thermal oxidation (RTO) system, VAMOX, to mitigate the dilute methane emissions released by ventilation systems of underground mines. The system utilizes two separate media beds and the oxidation reaction occurs in an open chamber above the media. A propane burner brings the unit up to temperature. The VAMOX can process methane levels from 0.2% to 1.2%. Whenever the concentration is above 0.25%, it is possible for the heat to be recovered as hot water, low grade steam, or electricity produced from superheated steam. According to Biothermica's literature, a single unit is projected to process up to 100,000 ft^3/min of ventilation air. The expected methane destruction efficiency according to the literature is up to 98% at an oxidation temperature as low as 1472˚F. The first demonstration of this technology is on a Jim Water Resources, Inc. active mine No. 4 in Brookwood, Alabama. A 30,000 ft^3/min unit was commissioned January 2009.

CANMET (Canadian Mineral and Energy Technologies) Energy Technology Center (CETC-Varennes) has developed a catalytic flow reversal reactor (CH4MIN) to treat the methane in coal mine ventilation air. The development comprised of computer simulations, pilot-scale trials, and a catalyst compatibility test at the Phalen coal mine (Nova Scotia, Canada). The unit consists of a reactor, two pairs of valves, and a heat removal system in the central region separating the catalyst bed in two parts. At both ends of the reactor, an inert material bed is present and acts as a thermal accumulator. Flow reversal is controlled by the two sets of valves. An external heat source is required to bring the inert and catalyst beds up to an appropriate reaction temperature. The catalyst reduces the auto-ignition temperature of the methane by several hundred degrees to 662˚F (350˚C). The excess heat generated by the exothermic chemical reaction is withdrawn by the heat removal system in the mid-section of the reactor. The equipment can process dilute methane streams from 0.1% to 1.0% methane. At concentrations between 0.3% to 1.0% methane it is possible to recover the reaction heat as a high-quality hot air stream (i.e., from 1112-1472˚F) at a heat recovery efficiency between 50% and 95%. For a typical coal mine concentration of 0.5%

methane the heat recovery efficiency is 75%. Because the reaction temperature is below 1472˚F the outlet gas and extracted hot air do not contain nitrogen oxides. In 2003, CETC-Varennes began working with a Canadian equipment manufacturer Lefebvre Frères Ltée, to commercialize the CH4MIN technology. A demonstration unit capable of process 10,600 cfm is being planned for a China coal mine. A full scale commercial system is expected to process 210,000 cfm of ventilation air methane.

Durr Systems, Inc. has developed an Ecopure RTO or regenerative thermal oxidation system to purify exhaust gases from chemical and pharmaceutical plants, paint finishing and coating plants, and printing presses. The process consists of regenerator columns, combustion chamber with a burner system, and air-directing system with valves and fan. The regenerator columns are filled with ceramic packing material which acts as a heat exchanger. The combustion chamber connects the individual regenerator columns with each other. The gas is transferred through the Ecopure RTO by a fan, and is directed through the valves by timer system alternately into one of the regenerator columns. The gas flows through the hot packed beds from the bottom to top, and is pre-heated in the process. If necessary, a burner heats up the raw gas to the final combustion temperature. The purified hot exhaust air then flows through the heat exchanger in column two from top to bottom, transmitting its heat to the packed bed while doing so. When the packed bed reaches a certain optimum heat storage point the direction of flow through the columns is changed. The system is constantly switched over to ensure optimum heat exchanger performance and raw gas cleaning efficiency. There is no published information regarding use of this technology on a ventilation air methane application.

4. EXPERIMENTAL

4.1 Project Plan

The original project approach was to install a VOCSIDIZER system, capable of oxidizing 60,000 scfm of ventilation air methane, on an operating mine ventilation fan at an active mine in Northern Appalachia. The criteria being used to determine the ideal site location for the VOCSIDIZER was to have 1) sufficient acreage to install the equipment, 2) adequate topography to minimize site preparation, 3) an existing mine ventilation fan that will release sufficient concentration of methane, 4) site that had over 60,000 scfm mine ventilation air. A suitable site that met the project criteria was identified in southwest Pennsylvania. The fan at the site had been in operation since 1999 with an average flow rate of 210,000 cfm. The methane concentration ranged from 0.9% to 1.5 % in 2002. It was located outside of the active underground mining area, which would reduce the potential dust particles in the air stream.

The next task was the permitting process. The Mine Safety and Health Administration (MSHA) ruled that the new installation would be under their jurisdiction on the surface of the coal mine. Therefore, the design for the oxidation system and mine/oxidizer interface had to be acceptable to MSHA. It was determined that the vehicle for design approval was through a 101(c) Petition for Modification to MSHA. This document

explained the safety features of the equipment that would prevent a hazardous situation from occurring to the underground mining operating. This was the first time this technology had been presented to the regulatory organization.

After several months of work to obtain approval, it was recognized that the approval process could significantly delay the project. The approach to put it on an active mine was terminated and a new approach was initiated. The following time line shows milestones that were reached that transformed the project from an active mine to a closed mine.

- **October 1, 2002** - Cooperative Agreement awarded.
- NETL and CONSOL agree to add NEPA compliance task to the proposed and amended SOW pending information supplied by CONSOL concerning noise abatement of existing mine fan and MSHA regulation.
- **February 10, 2003** - PA Department of Environmental Protection exempted the project from the Plan Approval/Operating Permit requirements under 25 PA Code §127.14(8).
- **March 21, 2003** – A 101(c) Petition for Modification of Application of Mandatory Safety Standard was filed with MSHA's Office of Regulations, Variances and Standards in Arlington, Virginia.
- **March 31, 2003** - Major subcontract with MEGTEC Systems was signed.
- **May 21, 2003** - Pre-Investigation Meeting held with MSHA to discuss the allegations on 101(c) Petition for Modification.
- **July 29, 2003** - CONSOL withdrew Petition for Modification.
- **January 9, 2004** - Alternative approach discussed with DOE.
- **February 12, 2004** - DOE accepted alternative approach in principal.
- **May 21, 2004** - Meeting with MSHA in Arlington to reopen the discussions on the original approach for the VOCSIDIZER.
- **July 9, 2004** - Letter from MSHA received, stating their expectation that the project would be regulated under both surface and underground standards.
- **September 16, 2004** - CONSOL formally requested an in-scope modification to the contract including a budgetary increase and a time extension for the alternative approach.

The new approach was to locate the equipment at a shaft or bore hole of a closed coal mine or a sealed area of an active mine. The mine ventilation air methane would be simulated by blending methane emissions from the mine vent with ambient air. The advantages of this approach were to be able to test the equipment without impacting the operation of an active coal mine. This would allow hands-on experience with the technology. MSHA would be able to observe the operation and become more familiar with the technology. Safety data and operability data could be collected on the equipment. It would be the first step for future installation on a mine ventilation fan. All the original objectives of the project could still be accomplished with the added benefit of no risk for the mining operation and better flexibility to test different operating conditions.

4.2 New Site

The new design presented challenges to be overcome. The abandoned substation at the closed Windsor Mine portal at West Liberty, West Virginia, was selected as the demonstration site. It is located in the northern panhandle of West Virginia close to the Ohio/Brooke county line. The site selection was based on the following characteristics; sufficient acreage, adequate topography, low dust from the mine, low risk of mine flooding (hence, a stable supply of gas), road access, ownership of surface, coal, and gas, and 3-phase power available. The required production rate was from 150-300 scfm of methane at a concentration from 30% to 100% methane.

The first step was to verify the quantity and quality of the methane from the vent hole at Windsor. A capacity test was conducted in February 2005 which consisted of pulling the gas from the vent hole for a month while monitoring the flow and concentration during that period of time. If there is a significant decline in methane concentration or decline in flow rate over the duration of the test, then the vent would not be sufficient to sustain extended use of the gas. Figure 4 shows the recorded rate of gas from the vent hole and Table 1 shows the concentration of gas samples that were collected during the testing period. The test confirmed that the vent was capable of producing one million cubic feet a day of mine gas containing 43% methane. The other components by analysis included 51% nitrogen, 3.8% carbon dioxide, 1.4% oxygen, and 0.3% ethane. This quantity and quality of gas was within the requirements to operate the demonstration equipment.

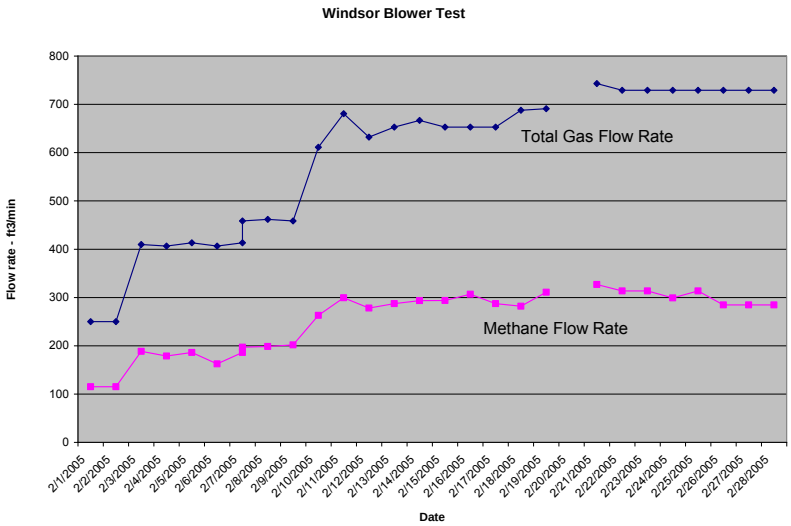

Figure 4. Gas Flow Rate during One-Month Blower Test on Windsor Vent Hole

Table 1. Gas Chromatography Analysis of Gas Samples Taken During Vent Capacity Tests

Sample date	2/7/2005	2/16/2005	2/28/2005
Component	**Volume %**	**Volume %**	**Volume %**
Methane	44	42	40
Ethane	0.26	0.26	0.21
C3+	0.06	0.07	0.06
Nitrogen	50	52	53
Carbon dioxide	4.0	3.6	4.1
Oxygen	1.1	1.7	1.9

The next step was to determine the risk of the mine flooding. Flooding of the mine would prevent the methane from being liberated from the coal. There were three locations where the water level was being monitored in the mine. As seen in Figure 5, the West Liberty location, around 800 feet above sea level, was dry from 2003 to 2005. The only water present in the mine was at 675 feet with a slow increase of one foot per month. Therefore there was little risk that there would be flooding at the West Liberty location during the duration of the project.

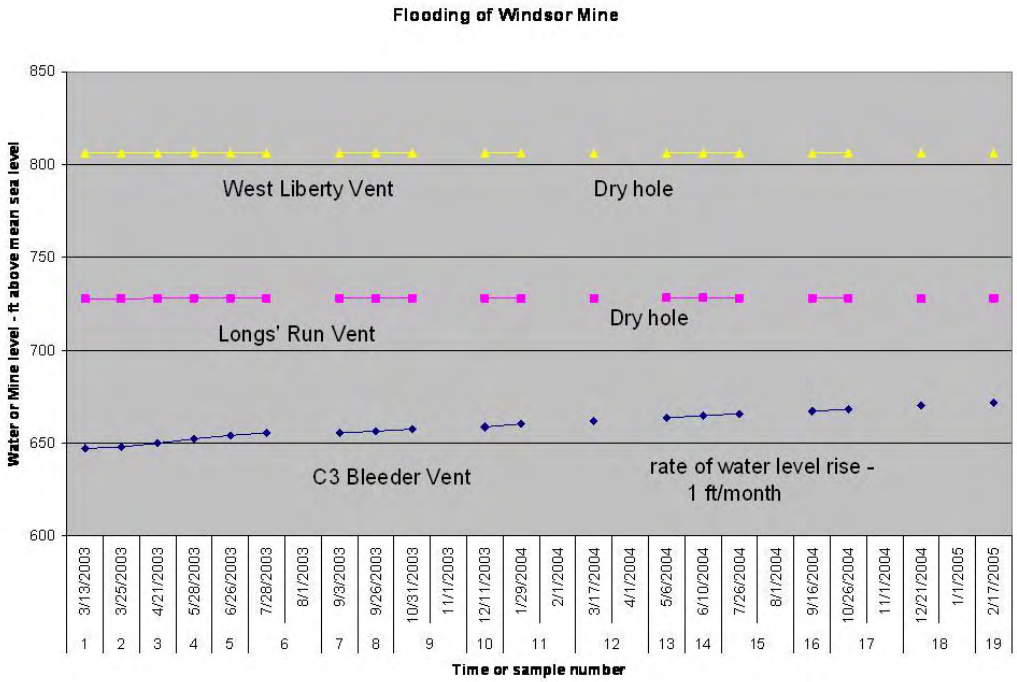

Figure 5. Reported Water Levels in Windsor Mine

The next challenge that had to be resolved was the lack of 3-phase power at the site. Changing the land use from coal mining to light industry and donating the property to West Liberty College opened the door for American Electric Power (AEP) to provide 3-phase power to the site. During the time the power issue was being resolved, it was determined that an Environmental Assessment was not required for the Windsor Mine site.

The specific sequence of events taken to assure that the site was viable for the demonstration project is listed below in chronological order.

- **February 2005** - Capacity test on potential vent hole at Windsor Mine in WV showed sufficient methane for demonstration with 43% methane at 1 MM cubic feet per day
- **April 19, 2005** - CONSOL submitted a Land Use Change permit revision for the Windsor Mine West Liberty Portal area to the WV DEP, as a first step to obtain 3-phase power.
- **May 3, 2005** - CONSOL submitted a revised NEPA Environmental Questionnaire to DOE for the new project site at Windsor Mine.

- **June 29, 2005** - NEPA Compliance Officer signed off on a Categorical Exclusion for the alternative approach. Therefore, an Environmental Assessment (optional Task 2) will not be required for the Windsor Mine site.
- **June 17, 2005** - CONSOL revised the request for an in-scope modification to the contract, including a new budget and schedule for the alternative approach.
- CONSOL partitioned the Windsor Portal site so that the unneeded part of the site could be donated to West Liberty State College.
- **September 14, 2005** - CONSOL received the "Land Use Change" permit for the Windsor Mine West Liberty Portal to become permitted for light industry.
- **November 10, 2005** – A "Termination of Jurisdiction" was approved by the WV DEP for the Windsor Portal site as a second step to obtain 3-phase power.
- **November 21, 2005** – Local power company, AEP, agreed to provide three-phase power to the site with no installation costs to the project.

4.3 Project Tasks

On January 17, 2006, DOE officially accepted the in-scope modification for the alternative approach and the project plan was implemented. The work tasks included permitting, detailed design of the oxidation system, procurement of the unit and auxiliary equipment, preparation of the Windsor site, installation of the system, start-up and commissioning of equipment, operation, data analysis, and documentation. The following paragraphs provide more details on the activities that occurred during each project task.

4.3.1 Permitting

Permitting at the Windsor site was simplified since MSHA approval was no longer required. State and local regulatory agencies were involved in two areas; air emissions and local building codes. A Permit Determination Form was submitted to West Virginia Department of Environmental Protection on August 17, 2005, to determine if an air permit was required for the new site location. It was determined by the WVDEP that an air permit was not required for the project based on the fact the expected emissions from the equipment would not exceed 2 lbs/hr or 5 tons/year of total Hazardous Air Pollutants (HAPs) or 6 lbs/hour and 10 tons/year of any regulated pollutant. There were no water discharges from the site so no water permit was required. The local municipality was informed of the project and no building constraints were imposed.

4.3.2 Detailed Design

The design for the installation at the Windsor site consisted of simulating ventilation air methane by diluting coal mine methane from the closed mine vent hole with ambient air to obtain methane concentration from 0.2%-1.2% (0.8%). Figure 6 is a simplified process flow schematic showing the 45%-60% methane from the vent hole going through a sparger where it is diluted to mine ventilation air methane concentrations. This simulated VAM is then pulled by the process fan into the VOCSIDIZER.

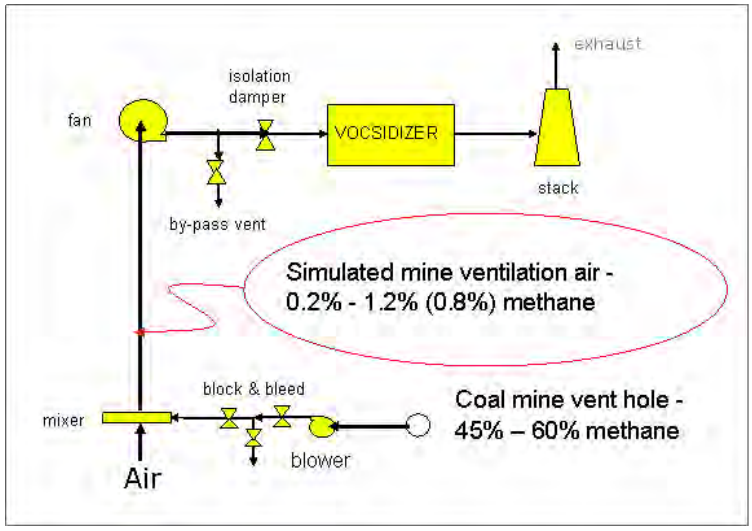

Figure 6. Field Trial Schematic Diagram

The major components of the design included:

- Mine gas blower with variable speed drive
- Methane dilution system
- Fan with variable speed drive
- Purge damper
- Single-bed thermal flow reversal reactor
- Vent stack
- PLC controls
- Air compressor for instrument air

The detailed process and instrumentation diagram is provided in Confidential Appendix F. The following paragraphs provide more detail on the process flow.

MEGTEC's standard design for installation of the VOCSIDIZER had to be modified to accommodate the capability of simulating ventilation air methane. This required a means of mixing the mine gas with fresh air to create concentrations between 0.2 volume percent and 1.2 volume percent (0.8%) methane. The design allowed the concentration to be controlled by the operator. The mine gas supply line could be thought of as a typical gas train. Stepping through the components of the line, it began with an isolation valve at the mine, a check valve to prevent backflow of mine gas, and a rupture disc to relieve excess pressure in the line. The next component was a knock-out pot and filter that removed any water droplets and dust from the mine gas. Since the mine gas flow was affected by the barometric pressure, a mine gas blower that allowed the amount of gas emitted from the vent to be controlled was installed as part of the gas train. Downstream of the mine gas blower was a gas meter that measured the flow rate of mine gas. A double block and bleed system was installed in the piping to isolate the mine gas when the system was shutdown. As part of the system safety

features, an orifice plate and two pressure switches were installed to alarm for high gas flow. The six-inch gas pipe then penetrated the main 47-inch air duct to make an air sparger. One-inch holes were drilled perpendicular to the flow in the six-inch pipe that extended the diameter of the duct. This allowed the mine gas to be dispersed with fresh air and produce dilute mixtures of methane. A series of mixing vanes were installed in the air duct to improve the mixing of the mine gas with the fresh air. The volume of fresh air was controlled by the main fan and variable speed drive on the motor. The fan has a 200 hp motor capable of moving 30,000 scfm of air. A flow meter in the duct measures the volume of the simulated ventilation air methane that entered the VOCSIDIZER. The concentration of the simulation ventilation air methane was measured with a methane analyzer on a sample pulled from the duct.

The remaining components of the design included dampers, the VOCSIDIZER, and the stack. Part of the duct design includes a purge damper that is used to purge the duct and VOCSIDIZER at startup and to dump the air if there is a shutdown. There is an isolation damper at the inlet of the VOCSIDIZER to block the entrance to the unit when required. The outlet to the VOCSIDIZER is a stack that is 55 inches internal diameter and 19.7 feet above the base of the unit. The programmable logic controller is housed in the control room. An instrument air compressor generates the air to control the reversal valves and other air operated equipment.

Many safety features are incorporated into the VOCSIDIZER design to assure that any malfunction would be contained within the equipment and not extend to the mining operation or other gas source. One main operating constraint is that the fan and the electric heater cannot be running at the same time. The electric heaters must shut off before any methane can be introduced into the bed. Another safety feature is to prevent a methane concentration greater than 1.2% (0.8%) from entering the VOCSIDIZER. The primary mechanism for preventing this is by measuring the inlet concentration with a methane detector. The detector must be capable of accurately measuring the methane concentration and have a fast response time to signal an unacceptable methane level. The electronic signal from the detector sends an alarm to the PLC when the concentration is above the limit and the equipment shuts down. Other safety features stop the process when specific operating parameters exceed the equipment specification. Operating parameters that can indicate an operating problem are the temperature and differential pressure across the bed. The temperature can be any thermocouple in the bed reading above its high temperature set point. There are redundant thermocouples in the bed and all thermocouples are dual-wired for additional safety. A greater-than-specified temperature on the inlet or exit of the bed can cause the equipment to shut down. Some of the shutdowns are hard-wired while others are soft-wired through the PLC. The shutdowns are signaled to the operator through four tiers of alarms based on severity. The types of shutdown are listed in Table 2, which indicates how the mode of equipment shutdown is impacted by the alarm condition. In alarm Type C, the electric heaters come on automatically after the fan is shutdown to keep the bed warm and shorten the time to return to operation.

Table 2. Type of Alarm Shutdowns

Alarm Type	Shutdown mode	Condition equipment in	Number of conditions causing Alarm
Type A	Emergency Stop Lock-out all active operating modes	Control power OFF Electric heaters OFF All prime movers to fail-safe position	4
Type B	Lock-out all operating modes except "Alarm Shutdown"	Electric heaters OFF All prime movers to fail-safe position	19
Type C	Interlock all operating modes	Electric heaters ON	52
Warning	Unit continues running	Running	12

When a shutdown occurs the following actions are initiated: the flow reversal valves close, the isolation damper closes, the purge damper opens, and the fan shuts down. All the valves have a fail-safe position to assure proper position during a shutdown.

4.3.3 Future Design

Applying this technology to an active mine ventilation fan will require taking the ventilation air methane directly from the mine fan as it is exhausted into the atmosphere. The gas train as described above will not be part of the design. Ambient air dilution will only be required to maintain methane concentrations below 0.8%. The additional safeties that will be part of the design include; shutdown of the VOCSDIZIER must have no impact on the mine operation, the shutdown of the mine ventilation fan will shutdown the VOCSIDIZER, the thermocouples will be replaced on a yearly basis, and the methane analyzer will be calibrated monthly. The one added component that was not part of the demonstration project will be an interface between the ventilation fan and the inlet ductwork to the VOCSIDIZER. The interface must not have any impact to the operation of the mine ventilation fan. It must have a sufficiently close connection to the exhaust to prevent dilution of the methane, and it must not have a hard connection to the exit of the mine fan. A preliminary design was completed for extracting 60,000 scfm from a typical mine ventilation fan. It was found that backpressure created from an interface in front of the fan's exhaust is negligible so long as the available flow area is not restricted. However, placement of the inlet duct is critical if it is to perform effectively. The finite element model showed that being as close as possible to the exhaust louvers at an angle would meet the guidelines. The complete report "VOCSIDIZER Duct Inlet Specification" is provided in Appendix A.

4.3.4 Equipment Fabrication/Site Preparation/System Installation

Once DOE officially accepted the in-scope modification for the alternative approach on January 17, 2006, the major subcontract with MEGTEC Systems was revised and

reissued reflecting the alternative approach. On March 27, 2006, the green light was given to proceed with the procurement of the equipment. The fabrication of the VOCSIDIZER took about five months. Site preparation required about two months of field work and field hookups required two to three months. The construction activities started in June 2006 and continued until February 2007. The milestone dates listed below show the key accomplishments during this time. The construction time was longer than expected because of delays from contractor availability, delivery of instruments, rework of misaligned piping, and inclement weather. Details of the construction work follow.

- March 27, 2006 — A project "GO" decision was made between CONSOL Energy, MEGTEC Systems, and DOE.
- June 1, 2006 — Construction activities begin
- August 1, 2006 — Field construction work began
- October 1, 2006 — Major equipment arrived on site
- January 1, 2007 — Mechanical construction completed
- January 4, 2007 — Local utility energized 3-phase electrical service
- January 15, 2007 — MEGTEC field technicians began equipment checkout.
- February 1, 2007 — Electrical construction completed.
- February 11, 2007 — Simulated ventilation air methane introduced to VOCSIDIZER

Initial construction included preparation of the site for the equipment. This required work in two main areas; installation of foundations to support the equipment and installation of 3-phase electrical power to the site.

Before foundations could be installed, the site had to be evaluated for strength. A civil design engineering firm was contracted to evaluate the soil conditions and provide a foundation design to support the equipment. Four exploratory bore holes were drilled at the site and a geotechnical analysis was completed. The results showed the site had soft soil fill material that would not support the weight of the VOCSIDIZER. To support the equipment, the civil design included over-excavation of the area and backfilling with a structural fill to support the slabs of concrete on grade.

The civil work was completed in the field from mid-August to early-September 2006. An area measuring 47 feet by 41 feet was excavated, backfilled, and compacted with structural fill. Two large, eight-inch thick, concrete slabs were poured on which to set the equipment. The pad supporting the 116,400-pound VOCSIDIZER was 16 feet by 30 feet and the pad for the fan and control room skid was 10 feet by 28 feet. A smaller pad for the mine gas blower, as well as small pads to support the duct and piping, were poured.

As previously stated, the site did not have any three-phase power available. It was necessary for the power company to install a new 3-phase line from the substation in West Liberty to the site, which was a couple miles away. Other components that were required included a 500 KVA transformer at the site and a metering box that served as a junction point for distributing the 480 volt power to the VOCSIDIZER. Existing underground cable was used to connect the power from the source to the site. The main power was brought into the motor control center (MCC) housed in the control room. Other electrical work included installing an electrical grounding system that was tied into the existing system at the site.

The main equipment arrived at the site in pre-assembled sections to minimize field installation time. The VOCSIDIZER shipped as one unit and the fan with the MCC were on a second skid. The components that required mechanical field installation were the stack, flow reversal valve air cylinders, VOCSIDIZER top railing, and duct work with damper valves. The gas train was shipped as individual components that required field piping to connect the mine vent to the duct. The air compressor was also shipped separately. The mechanical field hook-ups including installing the instrument air lines and piping the gas train.

The remaining electrical work included running the power and communication wires to all field instrumentation and bed heaters, and heat tracing. The power and control conduit were installed from the MCC to three areas: the junction boxes located on top of the VOCSIDIZER, the gas train pad, and the VOCSIDIZER bed heaters. Heat tracing and insulation on the gas train and the gas sampling lines to the methane detectors was required to prevent condensate from freezing. Figure 7 is a photograph of the complete field installation of the VOCSIDIZER at West Liberty, West Virginia.

Figure 7. Completed Installation at West Liberty, WV

4.3.5 Startup and Commissioning

MEGTEC Systems' field technicians arrived on site on January 15, 2007, to begin the startup. Once the technicians completed the final wire terminations on the instruments, the performance of each device was proven. Each instrument was systematically checked to assure the device was properly powered and the electronic signal was communicated to the

programmable logic controller (PLC). Any device that malfunctioned during startup was replaced. Some modifications to the operating logic were required in order to add safety features. These included adding the operation of the automatic mine shutoff valve into the operating sequence, adding the rupture disc release to the shutdown logic, and adding a low methane concentration shutdown at 30% methane.

The equipment was then started up and stepped through normal operating sequencing to check operation, test the control loops, and verify all shutdown alarms. The first step of operation, the purge cycle, was successfully demonstrated. The next step, the heating cycle of the VOCSIDIZER bed with the electrical heating coils, was proven operational. The electric heaters were on for 48 hours from a first cold start before the temperature was reached that permits methane into the bed. On February 11, 2007, the mine vent was opened and simulated mine ventilation air methane entered the VOCSIDIZER for the first time. The separate control loops were then tested including the mine gas blower control, the main fan control, and control of the concentration of methane entering the VOCSIDIZER. The shutdown alarm conditions on the pressure switches, the flow switches, and the methane detectors were all successfully set. Despite the coldest and snowiest weather of the winter, the system was fully operational at full capacity with 1.0% methane.

The equipment operated successfully during startup except for the methane sampling systems. After field checks with a handheld methane detector and a field flame ionization detection (FID) device, it was determined that the methane sampling systems had several problems. There are two methane analyzers, one measuring the methane concentration in the mine gas and the other measuring the simulated ventilation air methane concentration in the duct. Both units were a Cirrus Fixed Point Infrared Flammable Gas Detector from Crowcon Detection Instruments. The problems included the long response time on both systems, an inaccurate methane reading on the mine gas detector, and uncertainty that the sampling location in the duct provided a representative sample of the VOCSIDIZER inlet concentration at all flow conditions. Without the methane analyzers operating properly, the system could not be run unattended.

MEGTEC Systems technical support personnel returned to the site on April 9, 2007, and again on May 2, 2007, to finish commissioning the equipment and making modifications to allow unattended operation. The three areas of the operation targeted as important at this point included improving the methane detection system, improving the mixing and velocity profile in the duct, and adding additional safety shutdowns.

To improve the accuracy and response time of the methane detection systems, mechanical changes were made to the methane sampling systems. The following items were done to reduce the response time of the methane analyzers: 1) both units were relocated closer to the sampling points; 2) the rotometers in the sampling lines were replaced to increase the sampling rate; 3) the volume percent analyzer was replaced with a different model that has a faster response time. The following items were done to improve accuracy of the methane detectors: 1) pressure control devices were installed

on both sampling systems to provide constant pressure during all sampling conditions; 2) the sampling point for the mine gas was relocated to improve the representativeness of the sample taken; 3) baffles were installed in the inlet duct to improve the mixing of the mine gas with the fresh air to reduce the possibility of withdrawing an unrepresentative sample from the air stream. Despite all the changes, the analyzers still do not meet the project specifications. The improvements that were made showed that the methane analyzer measuring the mine gas was inaccurate despite a fast response; whereas the methane analyzer measuring the simulated mine ventilation air was accurate despite a slow response.

Since the problems with the methane analyzers were not resolved completely, MEGTEC Systems added redundant hard-wire safeties and software safety shutdowns to protect the system from unsafe mixtures in the duct. The safety interlocks physically restricted the ratio of air and mine gas that could enter the VOCSIDIZER such that an explosive mixture could not be created. The CONSOL R&D Safety Review process determined that there were sufficient safeties to allow the equipment to operate unattended. Finally on May 9, 2007 the equipment was ready for unattended operation.

4.3.6 Operation

Unmanned operation of the equipment had three areas of focus. The first area was to conduct parametric tests to measure the ability of the unit to convert methane at the limits of the equipment. The tests were to determine the effects of the mine ventilation air flow rate and VAM concentration on the response of the TFRR and methane conversion. The second area of focus was to conduct air emission tests to determine the composition of the air emitted from the stack and to verify the performance of the unit. The third area was to conduct long-term testing at one set of conditions that are representative of a mine ventilation fan.

Operating for a proposed eight to twelve months would allow time to evaluate operation and maintenance of the equipment. During long-term testing, operating data were collected daily so that the operation of the system could be reviewed continuously. Table 3 and Table 4 summarize data collected from the main operating parameters and the frequency at which they were collected.

Table 3. Monitored Operating Parameters for Temperature

Type of Measurement	Location	Instrument ID	Units	Frequency	Frequency
				Phase I	**Phase II**
Temperature	Center of Bed	TE101	˚F	5 min	5 min/1sec
	Center of Bed	TE104	˚F	5 min	5 min/1sec
	NE Corner of Bed	TE111A	˚F	5 min	5 min/1sec
	SE Corner of Bed	TE111B	˚F	5 min	5 min/1sec
	SW Corner of Bed	TE111C	˚F	5 min	5 min/1 sec
	NW Corner of Bed	TE111D	˚F	5 min	5 min/1 sec
	Top Plenum	TE110-1	˚F	5 min/5 sec	5 min/5 sec
	Bottom Plenum	TE110-2	˚F	5 min/5 sec	5 min/5 sec
	Inlet VOCSIDIZER	TE126	˚F	5 sec	5 sec
	Outlet VOCSIDIZER	TE123A	˚F	5 sec	5 sec

Table 4. Monitored Operating Parameters for Flow, Concentration, and Pressure

Type of Measurement	Location	Instrument ID	Units	Frequency	Frequency
				Phase I	Phase II
Flow	Inlet Duct VOCSIDIZER	FI240	scfm	5 min	5 min
	Inlet Duct VOCSIDIZER	FI240	%	5 sec/1 sec	5 sec/1 sec
	Process Fan Motor Speed	SIC240	%	5 sec/1 sec	5 sec/1 sec
	Mine Gas	FI409	scfm	5 min	5 min/5 sec
	Mine Fan Motor Speed	SIC428	%	1 sec	5 sec
Methane Concentration	Inlet Duct VOCSIDIZER	AI432	% LEL	5 min/5 sec/1 sec	5 min/5 sec/1 sec
	% CH_4 Mine Gas	AI403	Volume %	1 sec	1 min
Pressure	Differential across Bed	PI421	Inches WC	5 min	5 min
	Mine Gas	PI429	Inches WC	5 min/1 sec	5 min/5 sec
Miscellaneous	Electric Heaters Powered	EH101	%	5 min	5 min

Two primary variables that were tracked to monitor effects of continuous operation were bed temperatures and pressure drop. The bed temperatures were monitored to assure oxidation of methane. The pressure drop across the TFRR bed was monitored to determine any long-term change, such as might be caused by dust accumulation. Over 450,000 data points per day were collected through the programmable logic controller system from May to October 2008.

The long-term testing was divided into two phases separated by a rebuild of the bed, which was initiated by a mechanical failure of the heater coupled with non-reliable performance. Parametric tests were conducted during the first phase and repeated on the modified bed design. One set of emission tests were conducted during phase one and two sets completed during the second phase. Long-term operation for the first phase was seven months from May 2007 through November 2007 and for the second phase was six months from May 2008 through October 2008.

5. RESULTS AND DISCUSSION

5.1 Parametric Test Plan – Phase I

The Phase I parametric test plan for the VOCSIDIZER, which was conducted during the week of April 9, 2007, consisted of six test runs to measure the effect of methane concentration and flow rate on the bed temperature, methane conversion, and bed pressure drop. The specific test runs are listed in Table 5. The test conditions bracketed the operating limits of the equipment. Each test run required the unit to operate for up to three hours at steady state conditions. Gas samples were obtained at the stack, inlet to the VOCSIDIZER, and the mine vent three times during the steady state operation.

Table 5. Phase I Parametric Test Plan

Test Run ID	Methane Concentration (%)	Process Air Flow Rate (scfm)
TEST A	0.3	15,000
TEST B	1.0	15,000
TEST C	0.3	30,000
TEST D	1.0	30,000
TEST E	1.0	22,500
TEST F	0.6	22,500

The plan required gas methane concentrations at the stack to be measured using the integrated bag procedure outlined in EPA Method 18, which consisted of a stainless steel sampling probe, moisture knock-out impinger (empty impinger in an ice bath),

leak-proof Teflon-coated sampling pump, low-range flowmeter, and leak-tested Tedlar bags. Teflon tubing was used for all transport lines. The system was leak-tested before sampling started by plugging off the inlet and noting the rotometer activity. After conducting the leak check, the probe was inserted in the stack and the system was flushed for five minutes. At the start of the test, a 25 L Tedlar sample bag was connected to the pump discharge and the flow rate was adjusted to uniformly fill the bag. Bag samples were also taken from the other two locations simultaneously. The contents of all bags were analyzed using gas chromatography at CONSOL's R&D Laboratory.

5.1.1. Results on Parametric Testing – Phase I

The VOCSIDIZER was capable of operating at all six test conditions. The conditions demonstrated operation was successful at low (0.3%) and high (0.9%) methane concentrations entering the VOCSIDIZER and low (15,000 scfm) and high (30,000 scfm) air flow into the VOCSIDIZER. Mid-point conditions of 21,000 scfm air and 0.6% methane were also tested. The gas samples from the VOCSIDIZER inlet and stack, analyzed using gas chromatography, were used to determine the methane conversion at each test condition.

Table 6 summarizes the results from the six experimental tests. The values reflect the average of the three sets of gas samples that were taken for each test condition over a three-hour period of time. All but one test resulted in methane conversions greater than the vendor's emission guarantee of 95% methane reduction rate. The data show that as the flow rate of air and the concentration of methane increase, the temperature of the bed and the pressure drop across the bed increase.

Table 6. Phase I Parametric Test Plan Results

	Test A	Test C	Test D	Test B	Test E	Test F[1]
Target % CH4	0.3	0.3	1.0	1.0	1.0	0.6
Actual % CH4	0.3	0.35	0.85	1.0	0.94	0.64
Target flow, scfm	15,000	30,000	30,000	15,000	22,500	22,500
Actual flow, scfm	14,750	29,572	31,178	14,650	22,000	21,609
Temp of stack, ˚F	209	229	524	523	529	379
Delta T bed, ˚F	129	171	451	444	449	329
Delta P bed, "WC[2]	0.39R	1.00R	1.37R	0.47R	0.77R	0.72R
Maximum bed temp, ˚F	1863	1974	2113	2017	2049	2007
% CH4 Conversion	96.4	97.7	95.4	91.5	95.7	96.6

[1] Results reflect average of two tests. Third test was discarded since unit not at steady state conditions.

[2] Reference pressure is pressure drop across the bed during Phase I at operating conditions of 0.3% CH_4 and 30,000 scfm

5.2 Parametric Test Plan - Phase II

Table 7. Phase II Parametric Test Plan

Test Run ID	Methane Concentration (%)	Process Air Flow Rate (scfm)
TEST A	0.3	15,000
TEST B	0.8	15,000
TEST C	0.3	30,000
TEST D	0.8	30,000
TEST F	0.6	22,500

The parametric test plan was repeated on the rebuilt VOCSIDIZER the week of April 28, 2008 to confirm operability of the modified equipment. The maximum methane concentration tested was lowered from 1.0% to 0.8% methane due to the new manufacturer's specification for the equipment. The originally planned Test E at high methane concentration and mid-range air flow rate was eliminated from the plan as testing proceeded. The test plan is shown in Table 7.

The same field sampling method used in Phase I was repeated for the Phase II parametric tests. In brief summary, a test includes three half-hour sampling periods when the equipment has reached steady-state at the desired operating conditions. Gas bag samples are collected at the stack, inlet to the VOCSIDIZER, and the mine vent simultaneously during the sampling period. The contents of the bags are analyzed using gas chromatography at CONSOL's R&D Laboratory.

Besides monitoring the inlet methane concentration of the VOCSIDIZER with the new in-line AcuPro LEL analyzer, a temporary continuous sampling system was setup. The sampling system included a heated probe, sample conditioner, sample and calibration gas transport lines, calibration gases, and a portable flame ionization detector (FID). The probe was inserted into the VOCSIDIZER inlet near the flow reversal valve. The measured methane readings were manually recorded from the analyzer during the test period.

5.2.1 Results on Parametric Testing - Phase II

The system was successfully operated at the five test conditions. The conditions demonstrated operation of the VOCSIDIZER at low (0.3%) and high (0.8%) methane concentrations entering the bed and low (15,000 scfm) and high (30,000 scfm) air flow into the unit. Mid-point conditions of 22,500 scfm air and 0.6% methane were also tested. The VOCSIDIZER inlet gas and stack samples collected were analyzed using gas chromatography to determine the methane conversion. The inlet methane concentration was continuously monitored with the FID during the test periods and compared to the inline AcuPro methane analyzer readings and hand-held methane meter readings to assure the inlet concentrations were at the desired targets. There were slight discrepancies between all measuring devices, but the FID method is considered to be the most reliable for measuring methane.

Table 8 summarizes the results from the five parametric tests. The values reflect the average value of the data collected for the three individual sample periods for each test. Appendix B provides graphical representations of the operating and process data that were automatically recorded through the PLC during the test periods. All tests resulted

in methane conversions greater than the vendor's emission guarantee of 95% methane reduction rate.

Table 8. Phase II Parametric Test Plan Results

Date	4/30/08 PM	5/1/08 AM	4/30/08 AM	5/1/08 PM	4/29/08 AM
Test ID	**Test A**	**Test B**	**Test C**	**Test D**	**Test F**
Target % CH_4	0.3	0.8	0.3	0.8	0.6
Actual % CH_4 by FID	0.29	0.70	0.30	0.79	0.62
Actual % CH_4 by GC	0.23	0.58	0.22	0.60	0.50
Target flow, scfm	15,000	15,000	30,000	30,000	22,500
Actual flow, scfm	16,738	16,530	29,812	29,824	21,689
Temperature stack, ˚F	196	388	192	453	327
Delta T bed, ˚F	133	333	133	364	266
Delta P bed, "WC[1]	0.51R	0.67R	1.25R	1.56R	0.94R
Maximum bed temp, ˚F	1897	2023	1945	2095	2034
Fan Speed (% of max)	52	58	86	95	69
% CH_4 Conversion (based on GC results)	97.9	97.0	98.8	97.8	98.2

[1] Reference pressure is pressure drop across the bed during Phase I at operating conditions of 0.3% CH_4 and 30,000 scfm

The data show similar trends from the original test plan: as the flow rate of air and the concentration of methane increases, the temperature of the bed and the pressure drop across the bed increases. Confidential Appendix G provides more details on the parameter relationships. Confidential Appendix H provides MEGTEC's detailed analysis of the parametric tests. One difference between the data on the rebuilt bed was that the pressure drop increased on average 28% with the new bed configuration.

5.3 Emission Test Plan

The emission testing plan for the VOCSIDIZER consists of testing the emissions three times throughout the duration of project operation. The purpose of the tests is to measure nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2), volatile organic compounds (VOCs), particulate matter (PM), and methane (CH_4) that are emitted from the stack during normal operating conditions. Each campaign consists of three one-hour test periods using EPA-style emission measurement equipment to manually sample and analyze the emissions from the VOCSIDIZER. The first set of tests or campaign was conducted August 7-9, 2007. The second campaign was conducted August 5-7, 2008 and the third campaign was conducted September 8-10, 2008.

A continuous emission monitoring (CEM) system was used for measuring the SO_2, NO_x, CO, CO_2, O_2, and total VOC concentrations at the stack of the VOCSIDIZER. The system was comprised of a heated probe, heated out-of-stack filter, sample conditioner (cryogenic moisture removal), sample and calibration gas transport lines, sample manifold, CEMs, programmable logic controller, calibration gases, and computer-

controlled data acquisition system. The CEM equipment was maintained in a 24' mobile, self-contained, laboratory trailer and was operated by the CONSOL R&D gas sampling team on site.

The test required a sample to be continuously extracted from the gas stream; a portion of the sample stream is conveyed to each CEM for simultaneous analysis. Table 9, below, summarizes the separate analyzers and methods used to individually measure each component. With this system, all QA/QC procedures are computer controlled, along with the sample acquisition and reporting. The emission data were automatically recorded and the final data were corrected for span and zero drift, as specified in EPA Method 6C. The sampling points used for the particulate matter (PM) and velocity determinations at the stack were selected as outlined in EPA Method 1.

To measure the gas methane concentration according to EPA Method 18, a bag sampling system was integrated into the total VOC CEM sampling system. The gas sample was extracted through the heated sample line into a 25 L Tedlar sample bag. At the completion of the test, the contents of the bag were analyzed using gas chromatography with equipment at CONSOL's R&D Laboratory. Besides collecting a gas sample from the stack, bag samples of the mine gas and inlet gas to the VOCSIDIZER were collected to determine methane conversion.

Table 9. Equipment and Methods for Gas Analysis

Component	Analyzer Manufacturer	Model	Type	Testing Method
CO	Rosemount Analytical	880A	Non-Dispersive Infrared Analysis (NDIR)	EPA Method 10
O_2	Maihak	OXOR 610	Paramagnetic Analysis	EPA Method 3A
CO_2	Horiba Instruments	PIR-2000	Non-Dispersive Infrared Analysis (NDIR)	EPA Method 3A
SO_2	Bovar Engineered Products-Western Research	721AT2	Ultraviolet Analysis	EPA Reference Method 6C
NO_x	Teledyne-API	200EH	Chemiluminescence Analysis	EPA Reference Method 7E
Total VOC	JUM Engineering	VE-7	Flame Ionization Detector Analysis	EPA Method 25A
PM	Thermo-Andersen Instruments	2010A	Isokinetic	EPA Method 5
CH_4	Varian	CP 4900	Gas Chromatography	EPA Method 18

In addition to the computer controlled sample acquisition and reporting system as part of the emission measurement equipment, a second data logging device was connected in series during the second and third test campaigns. This provided the capability of collecting data at a shorter frequency to better capture the behavior of the equipment when the flow reversal valves switch.

5.3.1 Results on Emission Testing

The first set of tests conducted on August 7-9, 2007, tested the performance of the original bed configuration. The second and third set of tests conducted on August 5-7, 2008, and September 8-10, 2008, respectfully, were conducted on the rebuilt equipment.

5.3.1.1 Emission Campaign 1

Table 10 below summarizes the detailed results obtained during the first campaign conducted from August 7-9, 2007. During the campaign, the operating conditions at the inlet of the VOCSIDIZER were controlled at 30,000 scfm and 0.6% methane. All recorded CEM gas measured concentrations were corrected for instrument calibration using EPA Method 7E. The full report is provided in Appendix C. Methane was measured via gas chromatography on a bag sample collected over an approximately one-hour period. The other species were measured with continuous monitors over the same duration. The analytical data showed all criteria pollutants and methane conversions were within the manufacturer's specifications.

Table 10. Results from Emission Tests August 7-9, 2007

		Test 1	Test 2	Test 3	Average of all valid Tests
Components in Stack		**Concentration in stack**			
O_2	%	19.9	20.0	21.1 [1]	20.0
CO_2	%	0.67	0.55	0.62 [1]	0.61
NOx	ppmv	0.25	0.10	-0.1 [4]	0.12
SO_2	ppmv	2.37 [2]	0.00	-0.1 [1]	1.19 [2]
CO	ppmv	-0.1 [4]	1.32	2.34	1.22
THC [3]	ppmv	12.1	13.9	13.0 [1]	13.0
Methane	ppmv	212	197	149	186
% CH_4 Conversion	%	95.7	95.9	96.8	96.1

[1] Test was invalid due to sampling measuring equipment overheating. Values were eliminated from average.

[2] No sulfur is expected in the gas. Potential contamination in sampling equipment.

[3] Total hydrocarbon values from the monitor were not consistent with methane values obtained from the bag samples, and we consider them to be invalid.

[4] Negative values reflect noise in the measuring system.

Problems that were encountered during Test 3 were the result of the instruments in the trailer becoming overheated. An auxiliary electric generator was required at the site to power the trailer housing the continuous emission monitoring system due to insufficient and unstable power available at the site. As a result, the trailer air conditioner malfunctioned and due to excessive ambient temperatures, the trailer got too warm and caused the instruments to fail during the QA/QC calibration procedures. Hence, not all the data from Test 3 could be used.

There is no sulfur expected to be present in the coal mine gas. Therefore, the number reported in the first test showing sulfur is suspect and is believed to be caused from contamination in the sampling equipment. The negative values that are reported in the table for NO_x, SO_x, and CO are the result of noise in the measuring system. When the component concentrations are near zero, noise is noticeable.

The values for the total hydrocarbons were not consistent with the methane values obtained from the bag samples and were considered to be invalid. This was due to the frequency at which the data was reported in the data acquisition system. The data acquisition system was only capable of logging a value for total hydrocarbons every minute. Meanwhile, the flow reversal valves switched every couple of minutes. When the valves switched, there was an opportunity for the incoming feed to bypass the bed and exit out of the stack since the pressure drop across the bed was greater than the open stack. This caused unreacted methane to exit the stack and show up as spikes in the emission data. Even though these spikes were visible on the continuous emission monitors, the logging apparatus was not fast enough to record them.

The particulate loading was 0.0003 grains/dscf (dry standard cubic feet) or 0.06 lb/hr. This low value was expected since the incoming methane from the coal mine was diluted with ambient air and an inactive mine would contain little mining dust.

5.3.1.2 Emission Campaign 2

Table 11 summarizes the detailed results obtained during the second emission tests conducted August 5, 2008. The full report is provided in Appendix D. The VOCSIDIZER operation was very stable at 0.6% methane and 30,000 scfm of total flow during the testing period. Methane was measured via gas chromatography on a bag sample collected over an approximately one-hour period. The other species were measured with continuous monitors over the same duration.

Table 11. Results from Emission Tests Campaign 2 - August 6-7, 2008

		Test 1 Aug-1	Test 2 Aug-2	Test 3 Aug-3	Average of all Tests
Components in stack		**Concentration in stack**			
O_2	% dry	19.8	19.8	19.7	19.8
CO_2	% dry	0.67	0.67	0.62	0.65
NOx	ppmv	0.00	0.00	-0.10 [2]	-0.03 [2]
SO_2	ppmv	-1.08 [2]	-1.34 [2]	-0.64 [2]	-1.02 [2]
CO	ppmv	2.76	2.04	1.22	2.01
THC	ppmv	64.2	66.7	62.5	64.4
Methane	ppmv	152 [1]	188 [1]	132 [1]	157 [1]
% CH_4 Conversion	%	96.8	95.9	97.2	96.6
[1] Data from GC analysis, all other data from CEM					
[2] Negative values reflect noise in the measuring system.					

Use of the data logger provided a more representative measurement of the volatile organic compounds and resulted in a better comparison to the gas chromatography analysis. Figure 8 illustrates the spikes of increased VOC concentration every time the flow reversal valves would switch. The VOCs are reported on a dry propane-equivalency basis. The analytical results showed all criteria pollutants were within the manufacturer's specifications. The average methane conversion for all three tests was 96.6%, which was above the manufacturer's guarantee.

Measuring particulate matter emissions based on EPA Method 5 provided a thorough method for determining solid emissions. A 12-point traverse with six points in each of the two stack ports yielded a representative sampling of the stack. The average particulate loading was 0.006 grains/dscf or 1.96 lb/hr. We believe this is the result of the powdered media from the lower plenum being carried out the stack. This dust formation was worse than the expected performance of the media and caused MEGTEC to investigate the source of the problem.

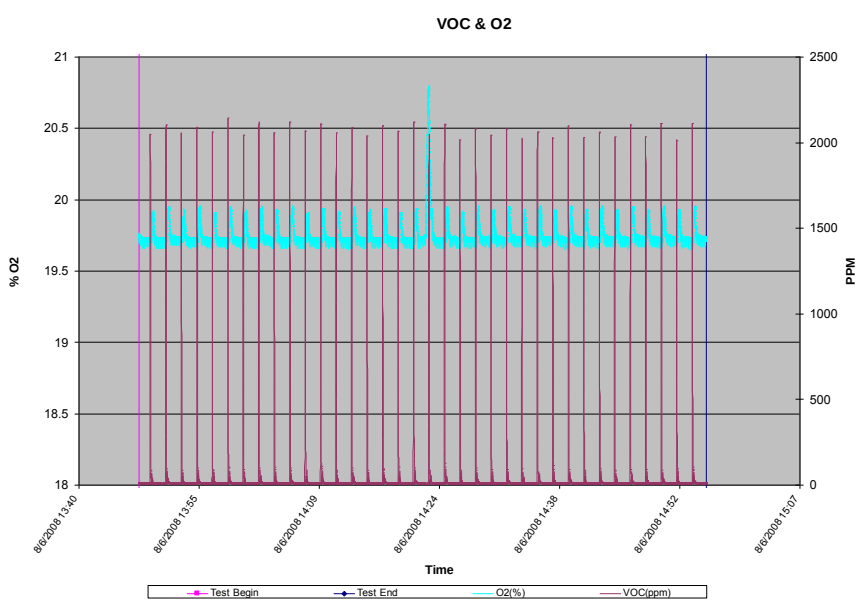

Figure 8. Emissions during Campaign 2 Run ID Aug-2

5.3.1.3 Emission Campaign 3

Table 12 shows the results from the third series of emission tests conducted September 8-10, 2008. The full report is provided in Appendix D. The tests were conducted using the same procedures followed for the second series of emission tests. The procedure included three one-hour tests in which the team continuously sampled and analyzed the emissions from the stack. The VOCSIDIZER operation was stable during the testing period.

Table 12. Results from Emission Tests Campaign 3 - September 9 - 10, 2008

		Test 1 Sept-1	Test 2 Sept-2	Test 3 Sept-3	Average of all Tests
Components in stack		**Concentration in stack**			
O_2	% dry	19.9	19.9	19.9	19.9
CO_2	% dry	0.58	0.58	0.58	0.58
NO_x	ppmv	-0.10 [2]	-0.64 [2]	-0.06 [2]	-0.27 [2]
SO_2	ppmv	-1.52 [2]	-0.91 [2]	-0.98 [2]	-1.14 [2]
CO	ppmv	1.64	1.65	1.28	1.52
THC	ppmv	59.3	61.3	63.7	61.4
Methane	ppmv	121 [1]	139 [1]	119 [1]	126 [1]
% CH_4 Conversion	%	97.3	96.7	97.0	97.0

[1] Data from GC analysis, all other data from CEM

[2] Negative values reflect noise in the measuring system.

The results were very similar to the results from the second emission test. All criteria pollutants met the manufacturer's specification and the average methane conversion for all three tests was 96.4%, which was above the manufacturer's guarantee. The particulate loading was 0.009 grains/dscf or 2.81 lb/hr. This was slightly greater than the results from the second series of tests. As in Test 2, we believe this particulate to be dust from abraded ceramic media. Insufficient material was available to conduct any laboratory analysis.

5.4 Long-Term Testing – Phase I

The first phase of long-term testing at one set of conditions went from May 9, 2007, until November 16, 2007. The conditions that were chosen to operate are 0.6% methane concentration (typical of a mine ventilation fan) and 30,000 scfm of total flow (full flow for a single bed). The system logged 1300 unmanned hours from May 2007 through November 2007. This represented 26.4% uptime on the equipment. The specific operating hours for each month are:

- May 2007 436 operating hours
- June 2007 116 operating hours
- July 2007 119 operating hours
- August 2007 267 operating hours
- September 2007 56 operating hours

- October 2007 277 operating hours
- November 2007 30 operating hours

Some shutdowns occurred due to equipment problems and others were operational problems. Prior to November 30, 2007, corrective action was taken after each shutdown, which resulted in successfully returning the equipment to operation. A call-out system was installed so that immediate notification of the alarm condition was sent to the responsible team. This was helpful in responding to the different types of alarms in a timely manner.

The major sources of equipment problems were the methane detector and the compressed air system. As discussed in Startup and Commissioning, Section 4.8, the original methane detectors were not sufficiently accurate and were too slow to respond to changes. Even after the modifications made during commissioning, they continued to be problematic. The compressor air system problems resulted from mechanical failure of component parts. The major sources of operating problems were power outages and settling of the bed media.

Quantifying the amount of time resulting from each type of shutdown alarm is subject to interpretation. Many shutdowns had multiple causes. Once the system shut down, our safety rules required a manual restart. Sometimes, the re-start was delayed due to the remote location of the facility. If the re-start was not effected quickly, the bed cooled and reheating the bed added to the downtime. The length of down time would have been reduced if on-site operators checked the equipment daily. Figure 9 shows the operating time for each month from May 2008 through November 2008 with a breakdown of down time due to each type of problem. Figure 10 graphically shows how each type of shutdown contributed to the amount of total downtime on the equipment. Table 13 provides the number of downtime hours that each cause shutdown represented. The downtime represented 73.6% of the maximum potential operating time. If all the problems that were “non-core” were not considered, the availability improved to 46.1%. Specific details follow on the changes made for each of the shutdown causes in order to increase the run time on the equipment.

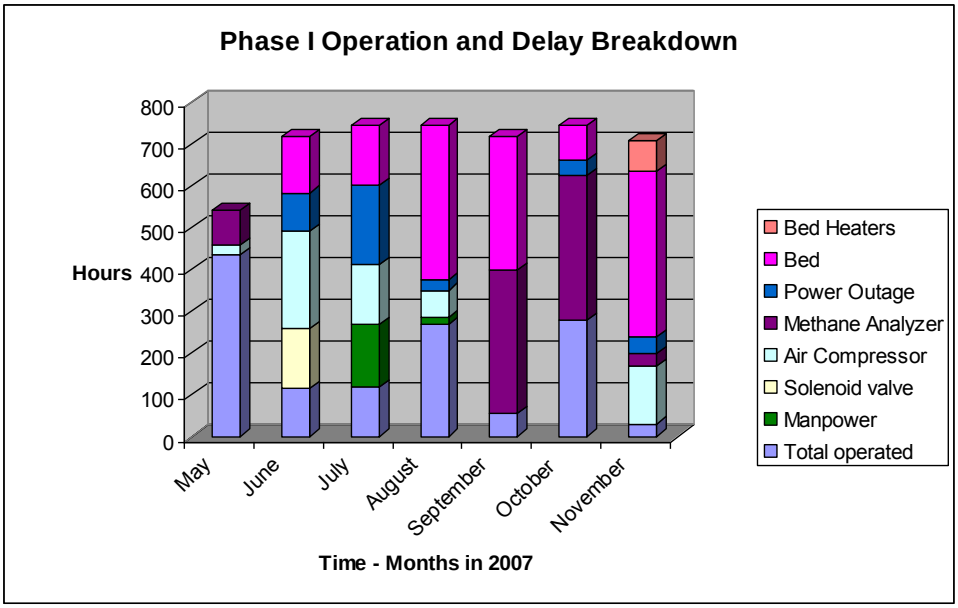

Figure 9. Monthly Operating Time during Phase I

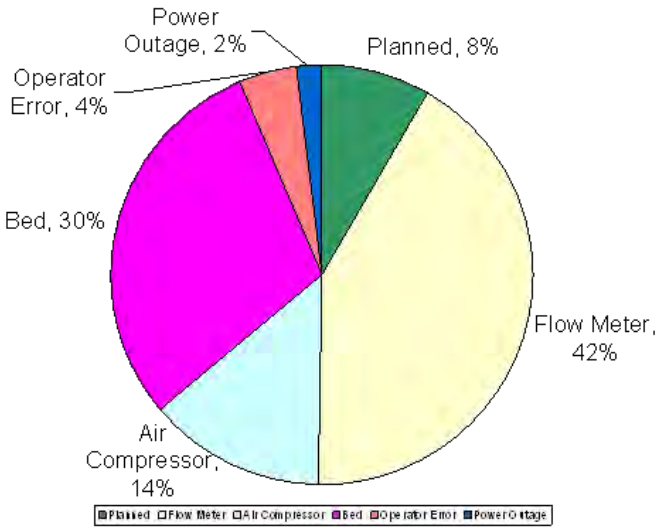

Figure 10. Causes Contributing to Downtime on VOCSIDIZER – Phase I

Table 13. Causes of Operation Shutdowns

Cause	Hours Down	% of Total Down Time
Methane analyzer	802	22.1
Air Compressor	607	16.8
Solenoid Valve	142	3.9
Power Outage	381	10.5
Manpower	167	4.6
Bed	1446	39.9
Bed Heaters	76	2.1
Total down time	3621	100

5.4.1 Equipment Problems – Phase I

Even after the changes made on the methane analyzing system during commissioning, the methane analyzer measuring the inlet duct concentration continued to cause problems that prevented the system from operating. The most common alarm condition was "Low Concentration Mine Gas", which was caused by the LEL analyzer reporting an erroneously low reading of the methane entering the VOCSIDIZER. This resulted in an erroneously low back-calculated value (below 30% methane) of mine gas concentration. CONSOL's safety requirements are that the mine vent must be closed if the actual concentration of methane in the mine gas is below 30%. Sampling of the mine gas and the inlet to the VOCSIDIZER verified that the concentration of the methane in the mine had not changed from 45% to 50% methane since the beginning of the long-term testing. . The LEL sampling system, from the probe inside the duct to the detector, was disassembled and cleaned. The calibration of the detector was checked. The source of the problem was dirt in the flow switch that restricted the flow of the sample gas and gave an erroneously low measurement of methane.

The most common alarm that shutdown the air compressor system was "Low Pressure Compressed Air". The low compressed air pressure shutdowns were the result of problems with the 1) compressed air piping system including faulty solenoid valves and leaking pipes, 2) serious mechanical failure of the compressor, and 3) mechanical failure of the regenerative dryers.

Corrective action that was taken on the air piping included replacing a faulty solenoid valve in the air delivery system, adjusting the manual air valve on the inlet flow reversal valve to allow positive closure of the flow reversal valve, and repairing leaks in the air line. It was also theorized that the pressure drop across the compressor discharge filters increased, which reduced the available pressure at the flow reversal valves. Adjusting the compressor pressure switch by five psig was sufficient to prevent the low pressure shutdown. Since the low pressure alarm was noticed when the flow reversal valves switched, a delay timer was added into the control logic so the instantaneous demand on the compressor would not trip the low pressure sensor. Adjustment of the

compressor discharge and increasing the delay time were required a second time after additional run time on the equipment.

Serious mechanical repairs on the compressor included replacing a faulty check valve on the compressor tank and replacing a broken air compressor intercooler that required a new unit from the compressor manufacturer. Other modifications made to the compressor were modifying the inlet air piping so it would have more flexibility and realigning the compressor to handle vibration better.

The malfunctioning of the regenerative dryers on the discharge of the air compressor was due to failure of the purge valve on the dryers, which prevented the canisters from switching. The principle of operation of the dryers is to flow the compressed air through one canister to remove moisture while the second canister is regenerating. An automatic timer causes the canisters to switch and continuously dry the compressed air. When the canisters did not switch, the air line filled with moisture; this reduced the pressure and caused a low compressed air pressure shutdown alarm. The purge valve on the dryers was replaced and the compressed air lines were blown dry of water to correct the problem.

5.4.2 Operational Problems – Phase I

Operating problems that caused shutdown included: 1) power outages due to thunderstorms; 2) limited manpower; 3) temperature sensing problem in bed; 4) settling of bed packing affecting thermocouples; 5) failure of the heating elements.

Through the summer months the site was vulnerable to power outages caused by local thunderstorms and unstable utility power. A power outage caused the unit to go into an "Emergency Shutdown" which put the system into a cold shutdown that de-energized the electric heaters. This extended the shutdown period because the bed would have to be reheated to oxidation temperatures before introducing the mine methane. The most cost effective method of dealing with this type of shutdown was to install a call-out system. Instantaneously making the operator aware of a loss of power reduced the time to respond to the shutdown and often prevented the bed heat from cooling too much.

The down time due to an emergency shutdown could have also been reduced if an operator was located at the site. In some cases when the equipment was at oxidation temperatures the introduction of methane was delayed due to the availability of on-site trained manpower. Even though all down time was extended by the remote location and available personnel, it specifically was responsible for 5% of the down time.

The majority of the down time was associated with the operation of the bed. There were several problems associated with the bed operation. The main alarm that continued to occur was "Low Temperature Corner". There were several causes for the erratic temperature readings. Initially the focus was on the temperature sensing equipment. Corrective action that was taken included: the height of the thermocouples were adjusted to assure the proper bed depth were being measured, the electrical

connections were rechecked to assure the wires were not damaged, and suspect thermocouples were replaced. A damaged ceramic sheath around one corner thermocouple was replaced.

The next area of focus to explain the low corner temperatures was the integrity of the bed media. Observation of the bed packing repeatedly showed settling in the corners, along the walls, and through the middle of the bed. Inspection of the lower plenums showed an excess amount of ceramic debris ranging in particle size from dust to large pieces of ceramic packing. Samples of the media were collected and sent to MEGTEC for analysis. All analyzes conducted on the bed material showed that the ceramic material met the chemical composition and strength specifications. Internal inspection of the bed support structure was conducted and found no significant damage. The only observation made that related to any potential cause of the debris was small gaps between the support plate and frame. The corrective action taken was to weld extensions onto the frame at the corners and the center of the bed to eliminate the gaps. The other action taken was to fill the cavities in the bed corners with fresh ceramic material in order to prevent the problem from reoccurring. However, refilling the ceramic media was repeated several times during the course of five months but it was not successful in preventing the unit from shutting down on low corner temperatures.

The electric bed heaters caused a serious problem in November 2007. The heating bar above the bed, which is connected to the bed heating elements, cracked. This was successfully repaired in place but evidence showed more damage existed on the heating elements submerged in the bed. When the electric heaters were turned on to begin the heat up process, one section of the bed heaters failed completely. The repair of the damaged heating elements is a major job that would require removal of half of the bed media at a major expense. It therefore required the team to determine if it would be cost effective to repair the damages or rebuild the bed to address the problems.

5.4.3 Rebuild Design

Since the performance of the bed had not met expectations, MEGTEC proposed to rebuild the internals of the bed. On November 30, 2007, it was decided to shutdown the equipment and focus on rebuilding the bed internals. The design for the rebuild was modified to improve the operation of the equipment. Details of the design are in Confidential Appendix I. MEGTEC changed the rebuilt equipment specification by reducing the maximum allowable concentration of methane that could be introduced into the VOCSIDIZER from 1.2 volume percent methane to 0.8 volume percent methane. The constraint on maximum methane concentration was established to ensure the unit operates within an acceptable temperature range to enhance long-term durability. DOE approved a no-cost extension on February 5, 2008, to rebuild the bed internals. The modified contract with MEGTEC Systems was signed on March 14, 2008, to proceed with the construction.

The rebuild required two to three weeks of field work, which began in April, 2008. Besides making repairs to the bed, other equipment was replaced that had caused

significant down time during Phase I, including the methane monitors and the air compressor. The methane monitor measuring the percent LEL entering the VOCSIDIZER was replaced with a Control Instruments' AcuPro IR Sensor and the methane monitor measuring the mine gas concentration was replaced with a Rel-Tek Gas Boss100 sensor. The air compressor was replaced with an Ingersoll-Rand screw-type compressor.

Additional miscellaneous construction activities were completed to improve the operation of the system. New electric heaters were installed. New thermocouples with protective sleeves were installed in the corners and center of the bed. New gasket material was used to seal the top lids. The deflection of the flow reversal valves was checked to assure they were sealing properly.

On April 18, 2008, the heaters were turned on to begin heating up the bed slowly. The objective was to assure the moisture was removed from the bed and the insulation was dried before methane was introduced. All the safety shutdowns that were impacted by the rebuild were retested. On April 24, 2008, mine gas was successfully introduced to the bed. During the week of April 28, 2008, a series of test runs were completed to determine the performance of the rebuilt bed (see Parametric Testing – Phase II, Section 5.2.)

5.5 Long-Term Testing - Phase II

The system began operating unattended for the second phase of long-term testing on May 1, 2008. The operating conditions chosen for the long-term test remained unchanged at 0.6% methane concentration (typical of a mine ventilation fan) and 30,000 cfm of total flow (full flow for a single bed). The system logged 2833 unmanned hours from May 1, 2008 through October 31, 2008. The specific operating hours for each month during Phase II are:

- May 2008 699 operating hours
- June 2008 433 operating hours
- July 2008 223 operating hours
- August 2008 466 operating hours
- September 2008 357 operating hours
- October 2008 655 operating hours

There was a significant improvement in the number of hours the equipment operated compared to the first phase of operation: the equipment availability in 2007 was 26.4% versus 64.4% in 2008. The new LEL analyzer was reliable with better accuracy and a faster response time (see Response Test on Methane Analyzer, Section 6.4) than the original analyzer. Equipment problems and operational problems were greatly reduced, but continued to be the source of shutdowns. The equipment problems were due to the main fan air flow meter and the air compressor. The operational problems were caused by power outages, operator error, and settling of the bed media.

Figure 11 shows the operating and downtime for each month in 2008 during Phase II of operation. Table 14 quantifies the hours attributed to each type of shutdown. In a great improvement over Phase I operation, the problems with the methane analyzer were eliminated; however, problems with the air flow meter appeared. There was less down time due to power outages and no down time directly attributed to manpower availability. Some of the other problems from Phase I, such as the air compressor and bed media problems continued to persist through Phase II. Figure 12 graphically shows the percent each type of downtime contributed to the total down time. Overall the total downtime was much lower than Phase I: 35.6% of the maximum potential run time in Phase II versus 73.6% in Phase I. If everything that was repairable (that is, non-core problems) was removed from consideration, the availability was 84.1% compared to 46.1% during Phase I. This shows that the modified bed design made a significant improvement in the operation of the system.

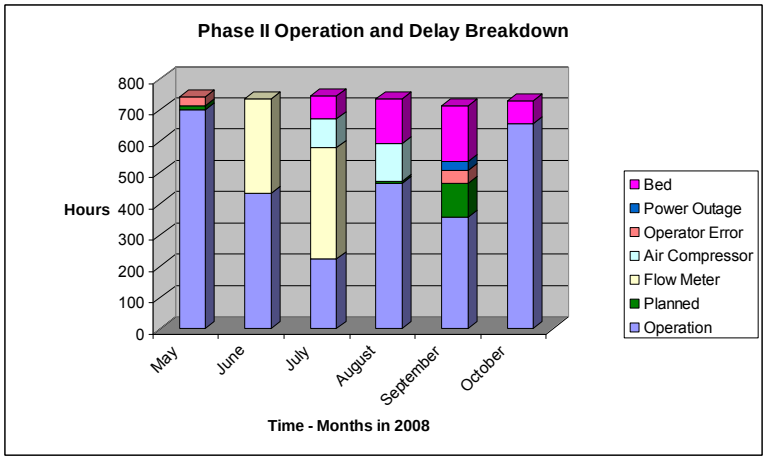

Figure 11. Monthly Operating Time during Phase II

Table 14. Causes of Operation Shutdowns Phase II

Cause	Hours Down	% of Total Down Time
Flow Meter	656	41.9
Air Compressor	213	13.6
Bed	467	29.9
Operator Error	70	4.5
Power Outage	29	1.9
Planned	130	8.3
Total down time	1565	100

Throughout Phase II the root causes of the shutdowns were determined and corrective actions were taken to resolve the problems and allow continued unmanned operation of the VOCSIDIZER. Equipment modifications continued to develop a more robust system that operated without operator interaction for an extended period of time. Specific details follow on the changes made for the major shutdown causes in order to increase the run time on the equipment.

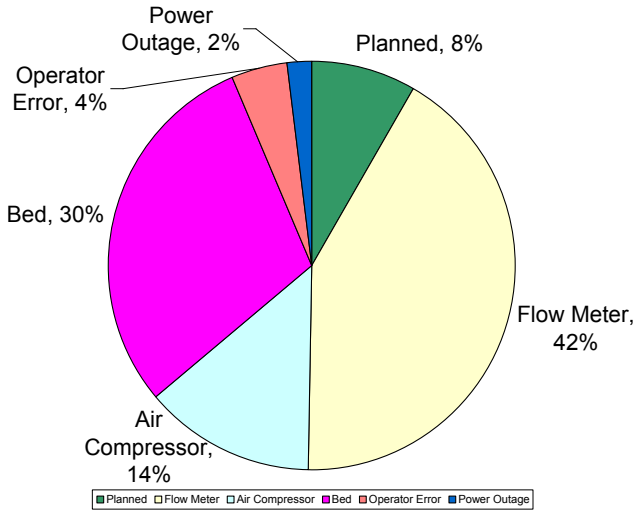

Figure 12. Causes Contributing to Downtime on VOCSIDIZER - Phase II

5.5.1 Equipment Problems – Phase II

There were several problems with the main fan air flow meter. The air flow rate is part of the control loop for the mine gas booster such that as the air flow increases/decreases the mine gas flow also increases/decreases to maintain the desired methane concentration setpoint entering the VOCSIDIZER. Initially the meter showed erroneously low air flow rate readings, which caused the mine gas flow rate to reduce and allow the methane concentrations to go below the setpoint. Removing and cleaning the flow meter corrected the readings and resulted in better control of the methane concentration at 0.6%, but for only a short time. Then, the meter readings became erratic, which caused the fan speed and mine gas flow to be unstable. The resulting effect was that the unit shut down on high LEL. The flow meter also lost communication with the PLC, which contributed to the shutdown problems. Tightening loose wires on the meter improved the operation of the meter and stabilized the flow rate into the VOCSIDIZER and appeared to correct the problem initially. The meter then repeatedly read erroneously high readings, which appeared to be associated with rain events. It was speculated the high readings were due to impingement of water droplets on the thermal dispersion probe that extends into the duct to measure the air flow. This caused a high LEL in the duct and the methane analyzer shut the system down.

Since moisture was the source of the erroneous readings on the flow meter, added concern was placed on the functionality of the safety flow switches in the duct that operated with the same principle of flow measurement. It was decided to replace the safety switches with a pressure differential type switch that protects the system in a low-flow condition. Modifications were also made to the operating logic to put the main fan on a fixed speed in order to continue the long-term testing and prevent erroneous readings of the flow meter from shutting the system down. A replacement flow meter was installed but the same behavior occurred during rainy weather. This means that rain droplets are problematic to this type of flow meter. However, it is expected that this instrument would not be a problem on a mine site, since the ventilation air methane will

not have water droplets in the gas. The flow meter will require routine maintenance to clean the probe from accumulated dirt in order to avoid erroneous flow rate readings.

Low compressed air pressure alarms continued to shutdown the system even though the original air compressor was replaced during the rebuild of the VOCSIDIZER. One area of concern was the amount of oil the new compressor discharged into the compressed air stream, which could contribute to an increased backpressure in the air line. Items that were changed included; replacing the oil separator inside the compressor cabinet, installing a new filter in the separator upstream of the regenerative dryers, and replacing the desiccant in the regenerative dryers with new material. The purge drain timer on the separator was also adjusted to minimize the loss of air pressure. These changes appeared to have corrected the alarm condition for a while. After two weeks of operation the problem reoccurred and the new corrective action taken was to replace and relocate the low pressure switch on the compressed air system. The automatic drain valves on the air surge tank and air filter were shut off. A leaking pressure regulator was replaced. Based on recommendations from the compressor manufacturer it was decided to run the compressor continuously to reduce wear on the equipment and to maintain a more stable pressure in the air system. Weekly maintenance checks require oil usage to be monitored to determine if any compressor components have failed.

5.5.2 Operational Problems- Phase II

Settling of the bed packing and lower corner temperatures were first noticed at the end of July, which was after three months of operation. The top plenum of the VOCSIDIZER was opened and the bed corners were inspected. Cavities in the bed media had formed in the corners around the thermocouples. These cavities could be the cause of the lower recorded temperatures in the corners. Fresh media was used to fill in the corners and level the surface of the bed. In mid-August erratic temperature swings in the bed corner thermocouples were beginning to impact the ability to operate the unit continuously. Low bed corner temperatures shut the unit down and caused difficulty in starting the equipment back up. The bed internals were inspected; cavities were found in the corners and a layer of stuck-together media was noticed. The bottom plenum had a layer of powder that appeared to increase with every inspection. To help understand the behavior of the corners, replacement corner ceramic media were painted. During the next bed inspection the colored media appeared to remain in the corners but had settled. There was no sign that the corner colored media had dispersed in the bed to indicate excessive fluidization in the corners. Confidential Appendix J provides more details on the fluctuations of the corner bed temperatures throughout the operating period.

Unreliable utility power still contributed to downtime and caused emergency shutdowns. The reduced amount of downtime it caused during this phase was because the operator was able to respond to the shutdown more quickly with the call-out system operational. Operator error was another cause of shutdowns during this phase that contributed to the downtime. There were also planned shutdowns that were used to inspect the bed internals and conduct equipment checks.

6. OPERATION EVALUATION

6.1 Startup and Shutdown Period

One aspect of the operation that plays a role in both operating time and down time is the time required for heating up and cooling down the bed. These periods contribute to the time the bed is not oxidizing methane. The rate of heating and cooling the bed impacts the required operator responsiveness, the operating costs, and maintenance requirements.

During the commissioning of the equipment when the heat was initially introduced to the bed, the heat-up was slow in order to dry out all the moisture in the bed. A slow heat-up evaporated all the water in the bed insulation and the media. The process took a couple days to assure there was no structural damage to the media.

The heat-up required the 175 kW electric heaters to be on at full load until the center of the bed reached the methane oxidation temperature. There were setpoints within the PLC logic, which the operator could not change, that controlled the cycling operation of the electric heaters. Once the oxidation temperature was reached, the function of the heaters was to maintain the hot zone until methane could be introduced into the bed. Figure 13 shows a startup with the electric heaters in a cyclic pattern. A typical cycle

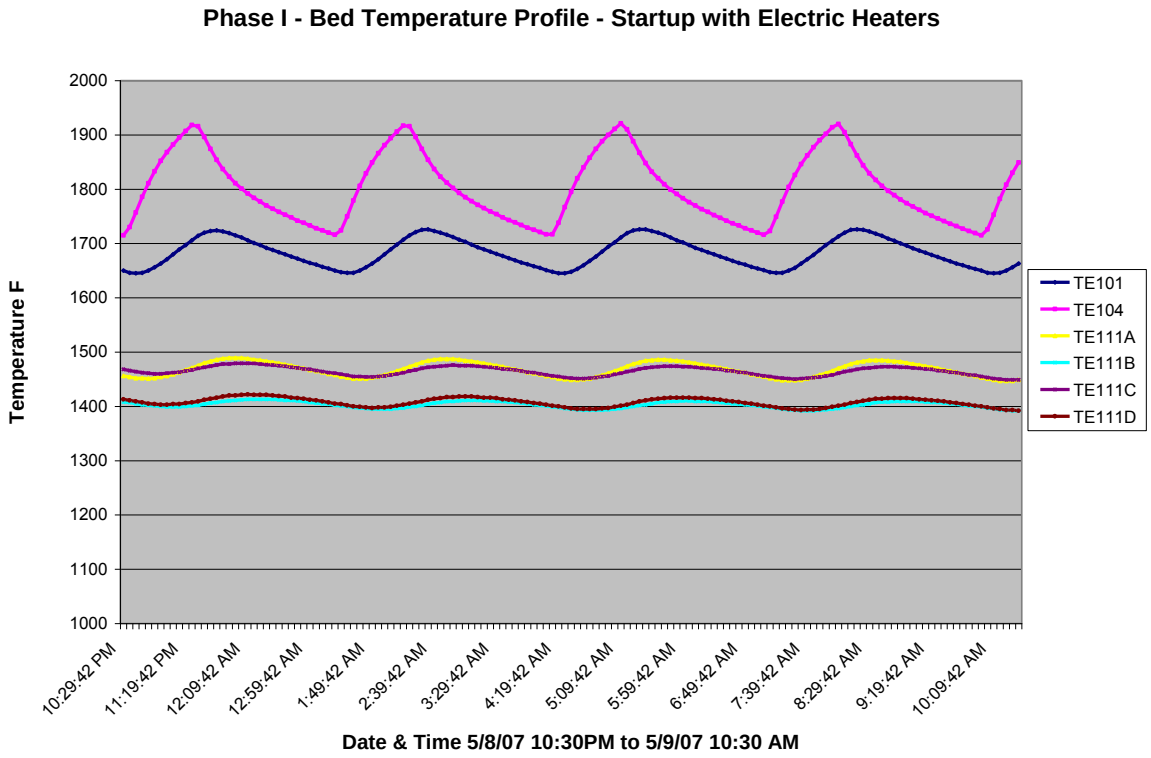

Figure 13. Startup of VOCSIDIZER on Electric Heaters

was a 55-minute period with the heaters “ON”, followed by a 1-hour, 55-minute period with the electric heaters “OFF”.

During operation of the equipment the time to cool down the bed was important in responding to alarm situations. During a Type C shutdown the electric heaters would automatically turn on when the center of the bed reached a predetermined set point. It took about 17 hours for the bed to naturally cool down to where the electric heaters turn on. This cool-down time became very important when there was a Type A or Type B alarm and the electric heaters did not come on automatically. Therefore, if the operator had not responded to the alarm situation within 17 hours, there was a potential that the bed temperature profile would become irregular and unsuitable to allow methane to be introduced into the unit. During times when the corner temperatures became unstable, the time to respond was even less than 17 hours before the electric heaters where unable to heat the bed uniformly. The corrective action at this point was to cool down the bed below 250 degrees F and begin the heat up process again. This caused more down time.

The other situation when cool down and heat up time was important was when the unit had to be shut down for maintenance. The condition that required operator intervention was when the corner temperatures were erratic and decreasing. Corrective action was for the operator to enter the upper bed plenum and install new media in the corners and level off the bed cavities.

To naturally cool down the bed so it could be opened for maintenance took about three to four days. This was a loss of operating time that was unacceptable. Therefore a procedure was developed to decrease the time it took to cool down and purge the system. Modifying the time the flow reversal valves switched allowed a controlled bed cool-down that minimized damage to the ceramic media. Using the main fan to purge the bed with ambient air was successful in cooling the bed internals to ambient temperature in about 24 hours.

The heating time to bring the bed up to temperature with the electric heaters was about 32 hours. To provide optimum performance of the bed, the operating practice was to wait for the heaters to cycle at least two times before introducing methane to assure stable temperatures throughout the bed. Figure 14 shows the temperature profile of the bed during a typical startup. The temperature zigzag on the graph is the result of the electric heaters turning on and off. Once methane was introduced, it took about 3.25 hours for the bed to reach steady state temperatures.

Continuous monitoring of the system operating parameters provided data that assisted in trouble-shooting the alarm shutdowns and upfront awareness of potential operating problems before they occurred.

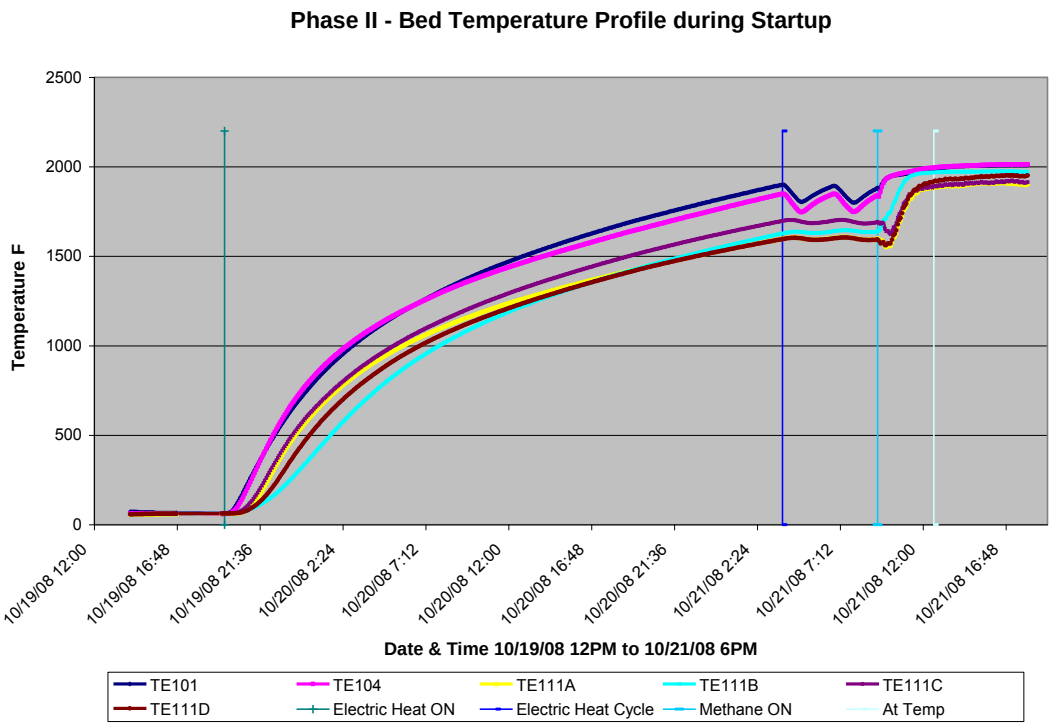

Figure 14. Cold Startup of VOCSIDIZER from Electric Heaters to Methane Gas

6.2 Performance of Equipment

As stated under Operation, Section 4.3.6, the system operating parameters were continuously monitored. The collected data assisted in trouble-shooting the alarm shutdowns and provided upfront awareness of potential operating problems before they occurred. The following figures are graphical representations of several of the operating parameters listed in Tables 3 and 4, Section 4.3.6. The graphs plot data from the Emission Campaign 2, Run ID: Aug-2, which is a good illustration of steady state operation of the VOCSIDIZER.

The main parameter monitored was the bed temperature profile. The temperature profile is flat with the center bed temperatures slightly higher than the corner temperatures. This is expected since the center bed thermocouples are embedded deeper in the middle of the bed. The corner thermocouples are located in the corners where the equipment walls affect the temperature. Figure 15 shows that there is at most only 100 degree difference between the center and the corners and all temperatures are above the oxidation temperature of methane.

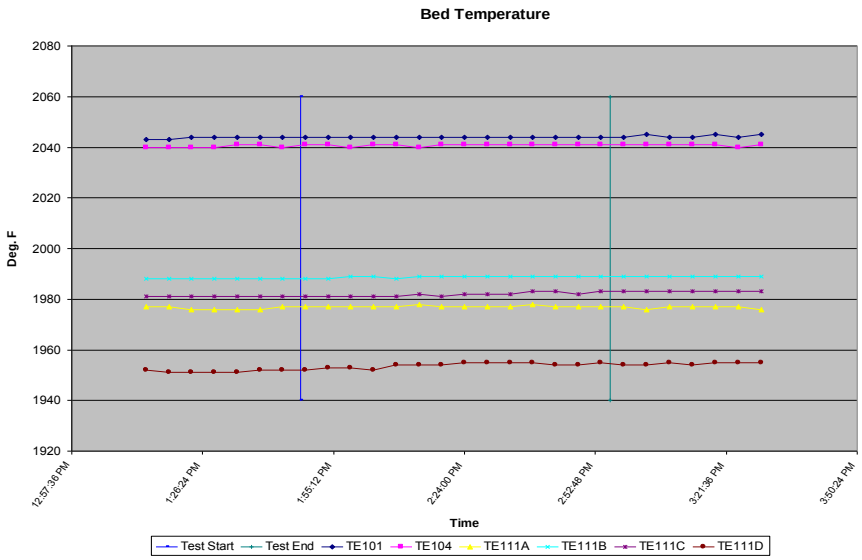

Figure 15. Temperature Profile of VOCSIDIZER during Steady-State Operation on 8/6/2008

Flow rates of the air entering the VOCSIDIZER and of the mine gas were both continuously monitored. The rates were important in maintaining the desired methane concentration entering the VOCSIDIZER. During typical operations, the flow rate of the main fan was held constant while the flow rate of the mine gas could vary if the concentration of the inlet duct did not meet the desired setpoint. As seen in Figure 16, the mine gas rate was stable at around 300 scfm and the air flow was on average 28,600 scfm. The percent methane, recorded in terms of Lower Explosive Limit (% LEL) was mainly held at 12% LEL but occasionally would drop to 11% LEL. The

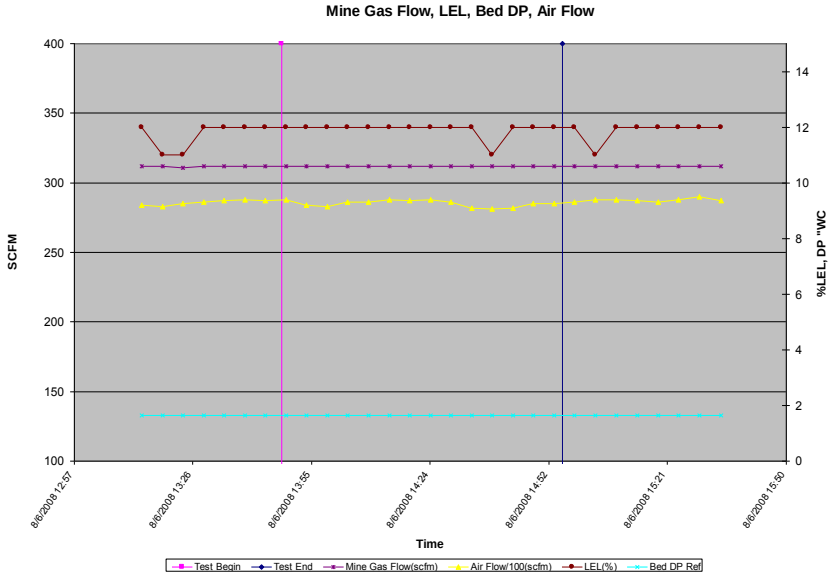

Figure 16. Typical Flow Rates, Pressure Drop and Methane Concentration in VOCSIDIZER, 5-Minute Data

pressure drop across the bed was constant at 1.64 times the reference pressure measured during operation at 6% LEL and 30,000 scfm in inches of water column (WC).

In general the main fan air flow was stable. Looking at the main fan at a more frequent data logging collection rate (5 seconds versus 5 minutes), shows more precisely what is occurring. In Figure 17, the data show the fluctuations in the flow rate due to the

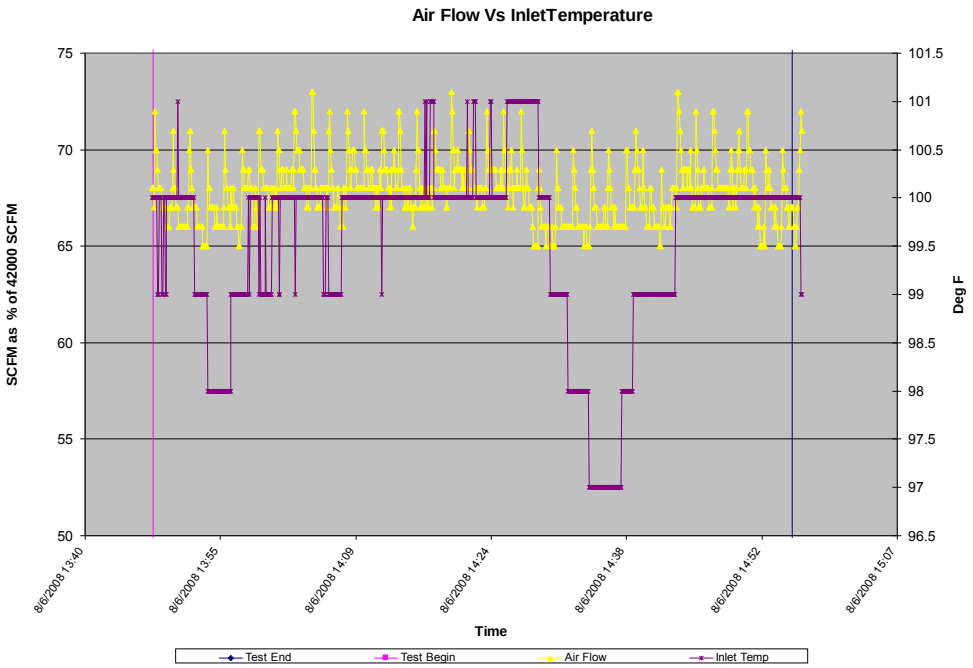

Figure 17. Air Flow Rate through VOCSIDIZER at More Frequent Data Collection (5-Second Data)

switching of the flow reversal valves. Every valve switch allows more air to be pulled through the fan because there is less resistance in the bed. The peaks are so quick that it does not affect the overall stability of the air flow through the fan. Graphing air flow with ambient air temperature shows there may be some affect of volume due to temperature.

The LEL value also fluctuates as the flow reversal valves switch. It makes sense that as the fan pulls more air through the duct on a momentary basis, the methane concentration in the duct would momentarily decrease. The control loop for the booster mine fan responding to the change in LEL is slower than the peaks and is not intended to react to these fluctuations in the LEL. Figure 18 shows the spikes in LEL during the duration of the emission test.

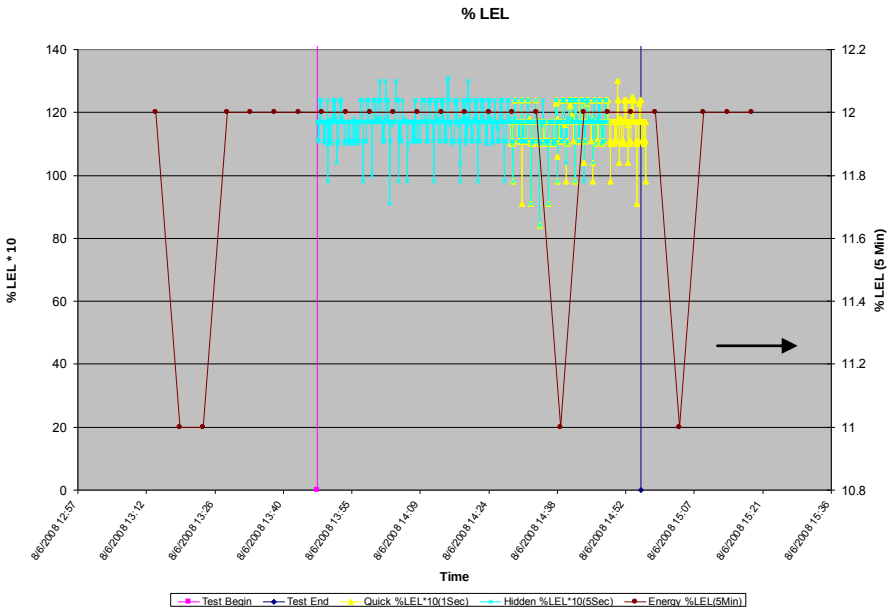

Figure 18. Variation of VOCSIDIZER Inlet Methane Concentration Due to Data Collection Method

This graph is another illustration of how the frequency and accuracy of the data collected can provide a different perspective of the operation. The data collected every five minutes are average values truncated to two significant figures and they show a step change in LEL from 11% to 12%. The one second and five second data are recorded with three significant figures and show the drop in LEL during the flow reversal valve switch. The range in concentration was from 8.4% to 13.0% LEL with an average of 11.6% LEL. There was no significant difference between the one and five second readings. Even though our objective was to have a constant duct concentration it varied by the nature of the design. This level of variability in the methane concentration may be present in a ventilation mine fan. Since the instability of the inlet concentration did not affect the operation of the bed, it is a good indication that the equipment will be able to handle any similar fluctuations on an active mine.

The one trend that most distinctively shows how the performance of the bed changes during a flow reversal valve switch is the temperature of the outlet of the VOCSIDIZER. The purpose of the valve switch is to maintain the hot reaction zone in the middle of the bed and prevent the heat from exiting the bed. Figure 19 shows the outlet temperature measured at the stack in relationship to the inlet temperature. The inlet temperature is relatively constant from 97˚F to 101˚F. The outlet temperature changes from 266˚F to 501˚F, with an average temperature of 357˚F. Each spike represents a valve switch and a change in air flow direction in the bed. The flow downward through the bed has a slightly higher peak temperature by about 30 degrees.

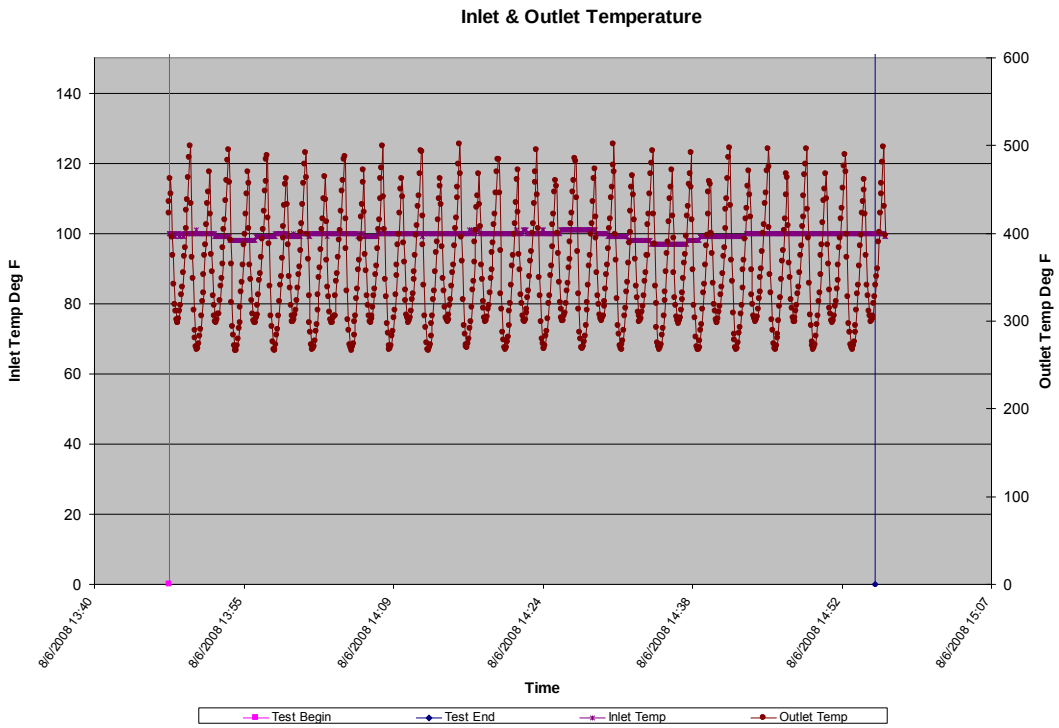

Figure 19. Temperature of Inlet and Outlet to VOCSIDIZER

Figure 20 shows the flow reversal valve switch in more detail and illustrates how the bed plenum temperatures also fluctuate with each switch. The graph again shows the stable inlet temperature of the gas and the fluctuating temperature of the outlet. The upper and lower plenum temperatures fluctuate with each switch, which indicates which direction the flow is in the bed. The other two variables plotted on the graph are the

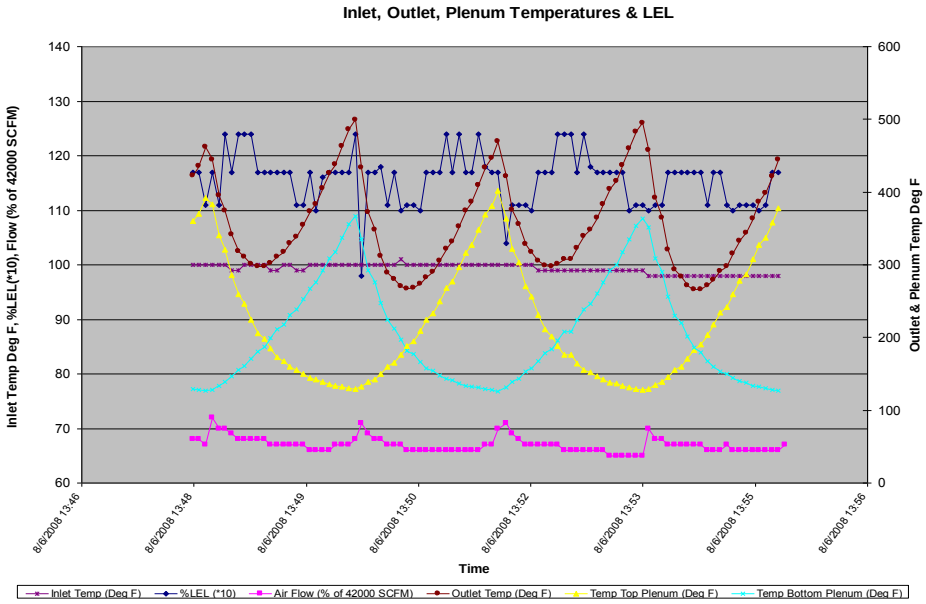

Figure 20. VOCSIDIZER Operation During a Flow Reversal Valve Switch

flow rate of air and the inlet duct methane concentration as % LEL. During the valve switch, the duct methane concentration goes down and the air flow rate peaks up as previously discussed. Even though these changes occur continually, the overall operation of the bed is very stable.

6.3 Performance Test at Low Corner Temperatures

As discussed in Operational Problems, Sections 5.4.2 and 5.5.2, unstable corner temperatures where observed during both phases of operation. It was of concern whether the methane conversion in the bed was impacted by the erratic corner temperatures that repeatedly shut down the unit. A performance test was conducted on the equipment during a period of time when the temperature profile of the bed was unstable (see Figure 21). It is more desirable to maintain a more uniform temperature profile as observed during the Emission Campaign 2 (see Figure 15). The amount of methane unreacted in the stack gas was the primary focus of the test. On October 7, 2008, field testing equipment and procedures similar to those used for the parametric tests were used for the performance test at low corner temperatures. Bag samples were collected from the inlet of the VOCSIDIZER and at the stack during two, half-hour periods and one, one-hour period. Samples were analyzed for methane using gas chromatography. Results summarized in Table 15 show that the performance of the bed still met the performance criteria even though the temperatures in the corners were fluctuating and at most 700˚F colder than the center temperatures.

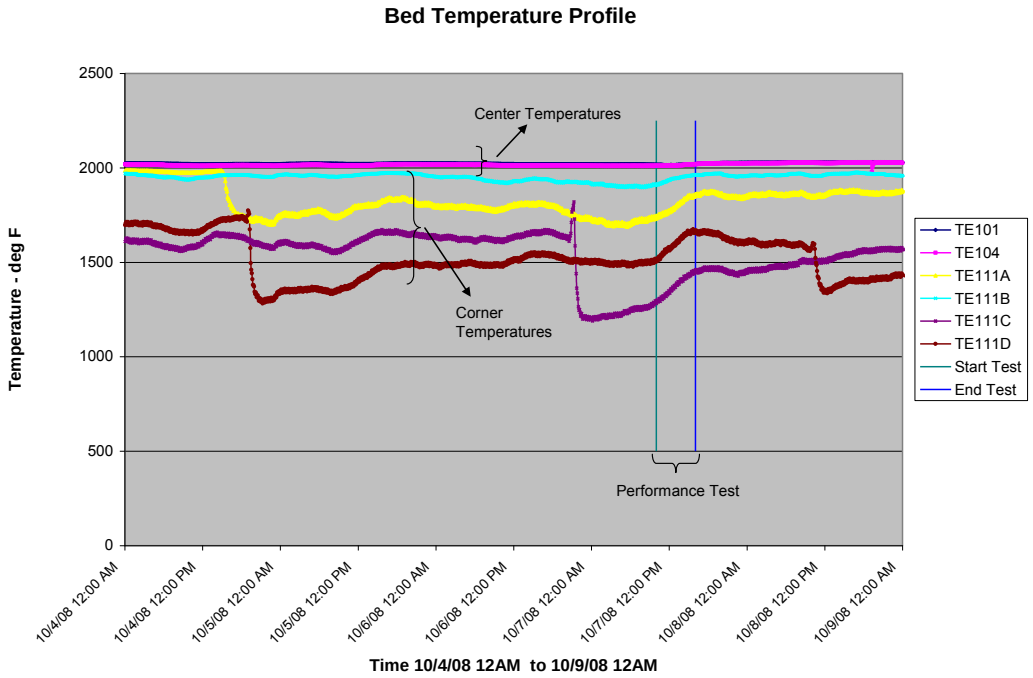

Figure 21. Erratic Temperature Profile of VOCSIDIZER

Table 15. Conversion Test Conducted on 10/7/08 With Undesirable Bed Temperature Profile

		Test 1	Test 2	Test 3	
Time		**11:00-11:35**	**12:00-12:30**	**13:10-14:12**	
	Average Inlet composition	**Stack composition**	**Stack composition**	**Stack composition**	**Average Stack composition**
CH_4%	0.44	0.0116	0.0109	0.0115	0.0113
C_2H_6%	<0.01	<0.01	<0.01	<0.01	<0.01
CO_2%	0.10	0.56	0.56	0.57	0.56
O_2%	20.72	19.97	19.96	19.94	19.96
N_2%	77.94	78.64	78.65	78.67	78.65
% Methane Conversion		97.3	97.6	97.4	97.4

6.4 Response Test on Methane Analyzer

The methane analyzer for measuring the methane concentrations in the duct at levels below 1.2% was a key component for the safe operation of the system. As mentioned in Startup and Commissioning, Section 4.3.5, the ability to measure accurately and quickly were important criteria to detect out-of-range methane concentrations and shutdown the equipment. The original unit was a Cirrus Fixed Point Infrared Flammable Gas Detector from Crowcon Detection Instruments. The instrument specification lists a response time of T90 less than ten seconds and a repeatability of ± 2%. The inability of the equipment to meet those specifications delayed our ability to operate the equipment unmanned and contributed to 22% of the down time in Phase I of the long-term operation.

During Phase II of the long-term operation, the instrument used for measuring the low methane concentration entering the VOCSIDIZER was replaced with an Acupro Infrared Process Analyzer – Model 610 Series from Control Instruments Corporation. The manufacturer's specifications include a response time of T90 less than three second to 90% of final reading, an accuracy of ±3% of full scale, or 10% of applied gas concentrations, whichever is greater, a repeatability of ±1% of measurement range, a zero stability of ±1% in 30 days, and a span stability of ±5% per year.

The principle of operation of the instrument is that the gas sample is drawn into the analyzer's optical cell by suction produced by an air aspirator. The aspirator runs from a regulated supply at constant pressure on the air inlet. Flammable gases and vapors in the sample absorb energy from an infrared source. Detectors located opposite the infrared source convert the resulting energy change into an electrical signal, which is proportional to the concentration of flammable gas from 0 to 100% of the Lower Flammable Limit (LFL or LEL). The optical cell has inlet and exhaust flame arrestors to

prevent flame propagation out of the optical cell. Disposable filters inside the flame arrestors keep the sensor flow path clean.

The instrument was calibrated on a monthly basis using “zero” air with no flammables, and “span” gas containing 50% LEL. The calibration was controlled electronically through the operating panel of the analyzer. There was very little drift in the calibration from month to month.

In September 2008, after four-and-a-half months of operation, MEGTEC Systems and Control Instruments inspected the unit and conducted a response time test. Modifications were made to the sample collection system at that time to allow proper outdoor housing of the instrument. Inspection of the internal filters showed no debris, and no other instrument problems were identified. The purpose of the response test was to measure the time it took for a known concentration sample to read 90% of its maximum value on the instrument. This is known as the response time at T90.

The response test on the analyzer was conducted by placing a bag of 50% LEL calibration gas at the end of a standard length sample probe. The time the analyzer read a specific methane concentration was recorded using an electronic switch and electronic data collection system. The probe length and calibration gas concentration were varied to see the effect on response time of the instrument.

The response time published by the instrument manufacturer is a T90 of less than three seconds to 90% of final reading, plus a sample transport time of one second. One second is to be added for every additional 6 feet of ¼ inch OD sample tubing used. The results summarized in Table 16 appear to meet the manufacturer’s specifications. The time to reach T60, or 60% of the maximum value, was also recorded. As seen in Figure 22, there is a step change in the methane concentration measured on the instrument which implies the electronics do not update as fast as the instrument is measuring. The average response time measured at T90 for each set of conditions tested ranged from 4.8 to 5.7 seconds.

Table 16. LEL Analyzer Response Times at Varying Sample Probe Lengths with 50% LEL Calibration Gas

			Test 1 for each Setup		Test 2 for each Setup		Test 3 for each Setup		Test 4 for each Setup		Average for each Setup	
	Length of probe, inches		Response time, sec		Response time, sec		Response time, sec		Response time, sec		Response time, sec	
	3/8” tube	¼” tube	T60	T90	T60	T90	T60	T90	T60	T90	T60	T90
Setup 1	60	36	4.5	6.5	5.1	5.1	5.7	5.8	5.2	5.2	5.1	5.7
Setup 2	32	36	4	6	5.8	5.8	4.8	4.8			4.9	5.5
Setup 3	24	4	3.7	5.7	5	5	4.5	4.6			4.4	5.1
Setup 4	2	4	5.1	5.1	4.4	4.4	4.8	4.8			4.8	4.8

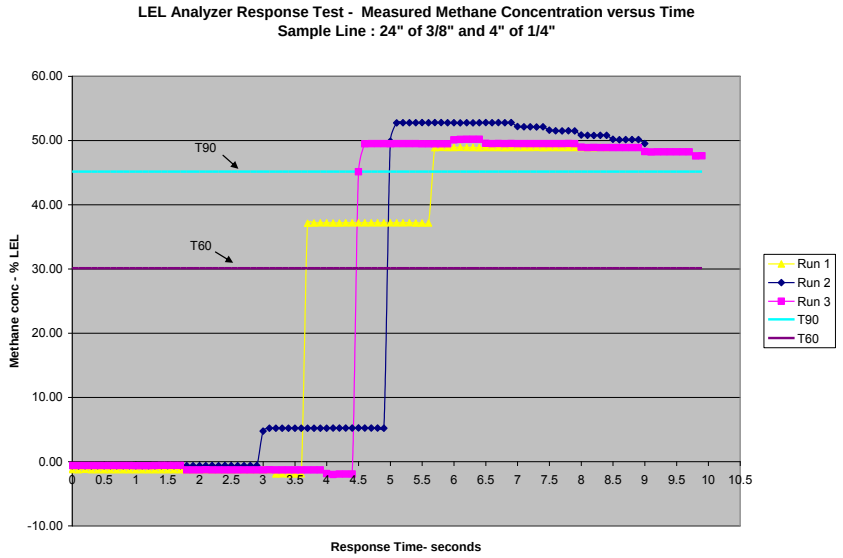

Figure 22. Results from Analyzer Response Test

The results show that the shorter the sampling probe the faster the response time, see Figure 23. The sample probe in our demonstration site is a 3/8 inch tube that extends across the width of the duct. We chose this design to provide a more representative sample of the simulated mine ventilation air methane.

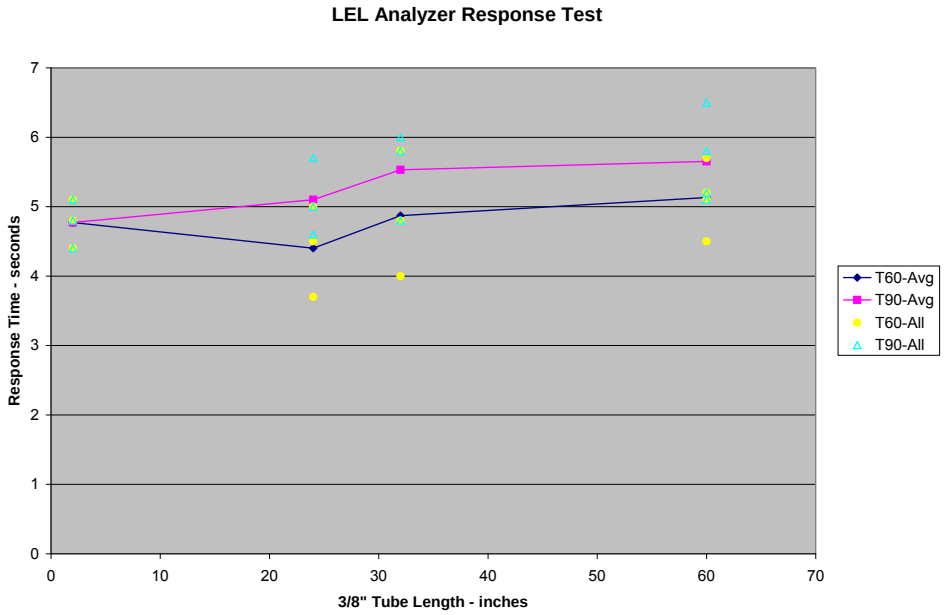

Figure 23. Effect of Sampling Probe Length on Methane Analyzer Response Time

The analyzer response time is important for the implementation of the TFRR technology to a mine ventilation fan. One of the safety features at a mine installation is to assure

that gas above a predetermined concentration is not permitted to enter the high temperature VOCSIDIZER. The response time of the instrument becomes important in designing the duct and locating the measuring point to prevent the high concentration gas from entering the VOCSIDIZER. Besides the infrared technology, a flame based sensor such as a flame ionization detector has high accuracy with fast response times but has restrictions from MSHA due to the flame. Laser based sensors are another technology that could be investigated in the future for application to a mine fan.

6.5 Public Communications

The technology concepts and project accomplishments have been presented to the public in several venues throughout the duration of the project. In total, eight presentations, three published papers in conference proceedings, two posters, and five organized site tours have been shared with the public. The details on each presentation are provided.

A paper entitled "Capture and Use of Coal Mine Ventilation Air Methane" was presented at the Second Annual Conference on Carbon Sequestration in May 2003 in Alexandria, Virginia.

A paper entitled "Capture and Use of Coal Mine Ventilation Air Methane" was published in the proceedings of the Twentieth Annual International Pittsburgh Coal Conference, September 2003. A poster illustrating this project was presented at the conference. The poster presentation garnered an Award for Honorable Mention-Technical Poster from the conference.

A presentation entitled "Capture and Use of Coal Mine Ventilation Air Methane" was presented to a joint meeting of the Northern West Virginia Association for the Advancement of Cost Engineering (AACE) International & Morgantown Chapter of West Virginia Society of Professional Engineers on May 23, 2007.

The project was selected to be reviewed during the 2007 Carbon Sequestration Peer Review sponsored by U.S. DOE on September 18, 2007. An eleven-page Project Summary document was submitted to the review panel in late July and a presentation was made at the DOE Peer Review Meeting in Pittsburgh. The panel's requested additional information is being provided in the final project report and the techno/economic analysis at the end of the project. The recommendations did not require any changes to the project goals and objectives.

A presentation was made to the First Annual Coal Mine Methane Conference sponsored by U.S. EPA in St. Louis, MO, on September 25, 2007. Results from the experimental test program and the emission test were presented.

A presentation entitled "Oxidation Technology for Ventilation Air Methane: First U.S. Field Trial", was made at the MinExpo International 2008, September 22 - 24, 2008 in Las Vegas, Nevada.

A presentation entitled, “First U.S. Field Trial of Oxidation Technology for Coal Mine Ventilation Air Methane”, was given at the 25th Annual International Pittsburgh Coal Conference, September 29 - October 2, 2008. The corresponding paper was published in the proceedings of the conference.

A presentation entitled, “Case Study: Results from the First U.S. Field Trial of Oxidation Technology for Coal Mine Ventilation Air Methane”, was given at the U.S. EPA Coalbed Methane Outreach Program 2008 U.S. Coal Mine Methane Conference, October 28 - 30, 2008, in Pittsburgh, PA. As part of the conference, a site tour of the operating equipment was given to about 60 conference attendees and other invited guests. Posters highlighting the project accomplishments were displayed during the tour.

A presentation entitled, “Oxidation Technology for Ventilation Air Methane: First U.S. Field Trial”, was given at the Coal and the Carbon Markets Conference in Charleston, WV, on April 17, 2009.

6.6 Interaction with MSHA

Personnel from the U.S. Mine Safety and Health Administration visited the site several times during the field demonstration. The equipment was observed during pre-startup before methane was introduced and during operation when the equipment was running at 30,000 scfm and 0.6% methane. The largest MSHA group who visited the Windsor site on June 16-17, 2008, included personnel from MSHA headquarters, MSHA District 3, MSHA Technical Support, EPA Coalbed Methane Outreach Program (CMOP) team, DOE, MEGTEC, and CONSOL. The purpose of the meeting was for a technology exchange among the attendees and a discussion on MSHA‘s design guidelines for the equipment to be located on an active mine ventilation fan. During the meeting, presentations were made on the progress of the Windsor project and on MEGTEC’s Australian VOCSIDIZER system that is producing electricity from ventilation air methane.

Because of the continual transfer of information to MSHA from the initial conceptual design phase through the final operating phase, MSHA has an understanding of the system. The main concern for installation on an active coal mine is for the safety of the mining operation; the VOCSIDIZER system cannot negatively impact the mine. Key issues are the ability of the methane detection system to accurately measure methane concentrations entering the VOCSIDIZER, the ability of the system to prevent a hazardous mixture of methane from entering the VOCSIDIZER, and the ability of the system to prevent a fire from returning back to the mine. It was determined that the installation of a VOCSIDIZER system will be part of the mine ventilation plan. The plan will require approval from the MSHA District in which the installation will be placed. MSHA supports the concept of installing the units on an active mine provided all safety concerns are addressed.

7. ECONOMICS

7.1 Technical basis

An economic evaluation was performed to determine the impact of varying parameters on the internal rate of return for installation of a full-scale VOCSIDIZER system handling 180,000 scfm of ventilation air. The following information was used to provide a basis for the economics. It is assumed that the coal mine methane venting from a mine ventilation fan contains 0.6% methane with a volumetric flow of at least 180,000 scfm. It is assumed that the VOCSIDIZER system is amenable to modular construction with each unit capable of processing 30,000 scfm. Therefore, the full scale system represents six units of the same size used during the demonstration project.

An ideal site for the VOCSIDIZER would have three-phase power and telephone communication available. The site should be flat and have sufficient acreage to install six VOCSIDIZER units with auxiliary equipment and maintain a 100-foot distance from the mine ventilation fan. The site will be fenced and be accessible via a road capable of supporting trucks in and out of the site.

The economic parameters that remained constant for all cases studied include:

Equipment life - 10 years
Depreciation rate – 200% declining balance
Depreciation time – 7 years
Total ordinary tax rate - 38%
Inflation rate - 3%

The two main areas of interest to conduct an economic analysis are for an abatement-only system and a heat recovery system.

7.2 Abatement case studies

The cost components that were varied in the economic analysis for the abatement cases included; capital costs, flow rate, relocation costs, operating & maintenance costs, electricity costs, the value of carbon dioxide credits, operating availability, and methane concentration. The base case for the economics set the variable parameters at the following conditions:

Base Case, Abatement:

- VOCSIDIZER equipment capital costs - $30.1 /scfm
- Flow rate – 180,000 scfm of ventilation air
- Operating & maintenance costs –$5800 labor per year for onsite operators plus 5% of capital
- Electricity cost - $0.058/kWh
- Carbon dioxide credit value – $7.00/ tonne CO_2e
- Methane destruction - 95%
- Availability - 97%

- Methane concentration – 0.6%
- The unit would be located in one place with no relocation for 10 years

Each of these parameters was varied based on experiences with the demonstration project and MEGTEC Systems' experiences. The summary of the variables changed with the ranges selected for the sensitivity analysis are provided in Table 17. The underlined values reflect the conditions that were used for the base case in the analysis. The paragraphs following the chart describe in more detail the basis of the parameters selected and the ranges used.

Table 17. Parameters for Sensitivity Analysis

Parameter	Units	Low limit	Mid range		High limit
Ventilation air flow rate	scfm	30,000	150,000	**180,000**	300,000
Maintenance cost	% of capital	2	3	**5**	10
Labor rate	$/man-hour	25	**40**		60
Electricity cost	$/kWh	0.026	0.0438	**0.058**	0.067, 0.10
CO_2 credit value	$/tonne CO_2e	0-3	5-**7**	10-15	20
Equipment availability	%	64	84	90	**97**
Methane concentration	volume %	0.3-.05	**0.6**	0.8	0.9-1.2
Relocation cost	$M	**0**	100	250	500

The values for capital costs were indirectly changed based on the flow rate and methane concentration. The values for capital investment were extrapolations from curves MEGTEC provided. Three curves were provided that show the investment cost in Euros as a function of system flow rate at three separate methane concentrations; i.e., 0.3%, 0.75%, and 1.2% methane. The costs were converted to US dollars using the exchange rate on February 4, 2009, which was 1 Euro equals 1.28866 US dollars. Figure 1 in Confidential Appendix K is a graph of the three curves. The range of capital investment was $4.5 million for a 150,000 scfm system operating at 0.3% methane to $9.5 million for a 300,000 scfm system operating at 1.2% methane. It was assumed that for methane concentrations between 0.3% and 0.49%, the investment cost of the system would follow MEGTEC's curve at 0.3% methane. For methane concentrations from 0.50% to 0.80%, the investment cost would be taken from MEGTEC's 0.75% curve. Since the maximum allowable concentration in the VOCSIDIZER is 0.8% CH_4, the VAM from any mine fan that emits concentrations greater than 0.8% would have to be diluted with fresh air before entering the bed. Another way to express the investment cost is as a cost per scfm of ventilation air. The range of values obtained for abatement cases when considering from 150,000 scfm to 300,000 scfm of ventilation air were $31.8/scfm to $26.6/scfm with an average cost of $29.2/scfm. The VOCSIDIZER

equipment is currently fabricated in Europe. With a potential market developing in the U.S., there are discussions of expanding fabrication to the U.S. Fabrication location and the strength of the American dollar will have an impact on future costs of the equipment.

The operating and maintenance costs represent several different types of activities. There are maintenance activities that would occur during downtimes and there are normal operating activities. There are costs associated with spare or replacement parts. There are utility costs to operate the equipment. For the analysis it is assumed that maintenance activities conducted by a MEGTEC service technician would occur during the 3% down time on the unit. This corresponds to a total of 263 hours per year that the equipment is not running. It is assumed that three times per year the bed will have to be shutdown and the temperature lowered to ambient conditions in order to enter the bed internals. It is assumed that this procedure will require 60 hours which allows time to cool the bed, make the internal repairs. and bring the bed back up to combustion temperature. Besides the standard planned routine maintenance, the second type of downtime would be unplanned shutdowns caused by power outages or minor equipment problems occurring three to four times a year. Planned normal operator activities would include checking the equipment daily for 15 minutes, and conducting MSHA required safety checks and instrument calibration monthly for 6 hours. Overall the total operating and maintenance time requires 24 minutes per day or 145 man-hours per year. At the base conditions this represented $5800/year. The cost of the man-hours was varied from $25/man-hour to $60/man-hour in the analysis. The change in man-hour costs could be dependent on whether an outside contractor was hired to conduct the field checks or if a full-time mining operator did the work. To capture the costs of replacement parts, unknown maintenance, and travel time to the site, maintenance costs were also included as a percentage of capital investment. The value was changed from 2% to 10% of capital to determine the impact on the economics.

The abatement analysis assumes that the electricity to operate the equipment would be purchased from the power company. The main demand is from the fan forcing the ventilation air through the VOCSIDIZER. The existing fan at Windsor has a brake horsepower of 190, or 142 kW of electricity which is the energy required to overcome the pressure drop through the bed. For the analysis, it was assumed that the energy requirements would be six times as great since there are six beds in operation. The second energy demand is from the electric heaters used during startup. Each bed would have an electric heater demanding 175 kW during startup. Based on our field experience it is assumed that 34 hours are required to bring the bed up to temperature and assure uniform heating throughout the bed. The value of the electricity used was representative of different electricity costs CONSOL currently pays. The base case of $0.058/kWh was the average cost of electricity during five months of operation in 2009 at the Windsor Mine. The values used were $0.026/kWh (energy costs at a Pennsylvania mine), $0.0438/kWh (total costs including energy costs, demand charges, and power factor charges at that same Pennsylvania mine), $0.067/kWh (average cost at Windsor Mine in 2008), and $0.10/kWh.

The economics include the impact of a carbon credit market on the implementation of the technology. The calculation of the CO_2 equivalents is based on the amount of methane that is converted to CO_2 and water. The methane conversion used was the manufacturer's guarantee of 95%. During the demonstration project it was confirmed that this conversion was usually exceeded under all system operating conditions. The total amount of methane sent through the VOCSIDIZER to be converted to CO_2 is dependent on the concentration of VAM in ventilation air and the VOCSIDIZER fan flow rate. The base concentration for the economic analysis was 0.6% methane which was the concentration tested during the demonstration project. This quantity is expected to be an average concentration of a typical mine application. The expectation is that when the VOCSIDIZER is placed on the operating mine fan the concentration will initially be greater at 0.8% to 1.2% methane. Over time the methane concentration will reduce to less than 0.6% but never go below 0.3% methane. The total methane captured and oxidized by an 180,000 scfm VOCSIDIZER system, which would otherwise be emitted to the atmosphere, will be 523 million ft^3/year if the inlet concentration is stable at 0.6% methane. Converting this quantity to CO_2 equivalents by using a global warming equivalent of 21 and then correcting for the carbon dioxide that is emitted from the VOCSIDIZER leaves an overall global warming equivalent of 18.27. Using a methane density of 0.04217 lb/ft3 at 60˚F and 30" Hg, the methane reduction equates to a net 183,187 tonnes/year of CO_2 equivalents. The value of a CO_2 credit in dollars per metric tonne of carbon dioxide equivalent was varied in the analysis for comparison. The values used included; \$0.00/tonne CO_2e, \$2.00/tonne CO_2e, \$3.00/tonne CO_2e, \$5.00/tonne CO_2e, \$7.00/tonne CO_2e, \$10.00/tonne CO_2e, \$15.00/tonne CO_2e, and \$20.00/tonne CO_2e.

Equipment availability was assumed to be 97%. This means the equipment is down for 263 hours of the year. During the demonstration project, the availability, considering only core problems, was 84%. With an experienced operator who can readily respond to any operating problems, we believe the existing equipment could be operated at 90% availability. This would allow one shutdown per month to adjust the bed internals and continue running. MEGTEC is investigating other bed media that would require less operator attention and allow less downtime and a greater availability. There are several impacts if the equipment does not reach the 97% availability. Increased downtime reduces the amount of methane that is destroyed, which reduces the potential income from carbon credits, it increases maintenance costs if the bed internals require adjustment, it increases power costs to heat up and cool down the bed, and it adds mechanical wear on the electric heaters. We are optimistic that the availability can be improved to 97%.

The methane concentration was varied from 0.8% to 0.3%. Ventilation fans normally operate with a decaying concentration curve during the life of the fan. The bleeder fans are located close to the active longwall and are pulling ventilation air through the active mining area. As the longwall moves away from the fan, the concentration of methane decreases. After a one-year start-up period, ventilation air methane may begin at 1.5% and reduce to 0.3% before the fan is relocated to a new site. The time for the relocation

may be from 5 to 10 years depending on the location of the fan, the ventilation plan, and the mining plan.

The base case assumes that the VOCSIDIZER will remain in one place for the ten-year life of the unit. A variation to the base case was to assume the unit would be moved one time after five years at a cost of $100,000. The cost to prepare a new site and relocate the equipment was varied up to $500,000 in the analysis. Depletion of the concentration of the ventilation air methane at the mine fan would be the main reason for relocating a unit.

7.3 Heat Recovery Case Studies

An analysis was conducted to include heat energy recovery with the system. It is assumed that the heat recovered will be converted into electricity using the same basis of 0.6% methane and 180,000 scfm. The additional assumptions for the base case are as follows:

Base Case, Heat Recovery:

- VOCSIDIZER equipment and generator capital costs - $85.2/scfm
- Flow rate – 180,000 scfm of ventilation air
- Maintenance costs – $0.015/kWh plus $345,700 per year of labor for onsite operators
- Electricity cost (consumed and sold) - $0.058/kWh
- Carbon dioxide credit value – $7.00/ tonne CO_2e
- Methane destruction - 95%
- Electrical efficiency, LHV basis – 28%
- Availability - 97%
- Methane concentration – 0.6%
- The unit would be located in one place with no relocation for 10 years

The parameters were all varied according to Table 17 except for maintenance and relocation costs. The maintenance costs were changed on the basis of power generated instead of a percent of capital. The equipment was assumed to remain in one location for ten years with no relocation costs included. The other change from the abatement sensitivity analysis was that the equipment availability was held constant at 97% instead of being varied. Electrical efficiency based on the lower heating value was added as a variable to the analysis. Table 18 shows the range of values used for the changed parameters with the values underlined representing the base case. The following paragraphs discuss the parameters that are different with the heat recovery case.

Table 18. Parameters for Heat Recovery Sensitivity Analysis

Parameter	Units	Low limit	Mid range		High limit
Power Maintenance	$/kWh	.010	**0.015**	0.026	0.045
Electrical efficiency, LHV basis	%	25	**28**	30	

The information provided in a graph by MEGTEC representing the investment for power production for three concentrations of methane at various flow rates of ventilation air served as the basis for the capital costs. Methane concentration is directly related to the amount of energy available to produce electricity. An increase in potential electricity production increases the capital cost for power generation equipment. Therefore, separate equations for cost as a function of methane concentration were generated to predict costs not plotted on MEGTEC's graphs. Specifically the investment costs for 72 m^3/sec or 150,000 scfm for 0.3% CH_4, 0.75% CH_4, and 1.2% CH_4 were provided by MEGTEC's informational graph. These three values were plotted on a graph with investment cost as a function of methane concentration at a specific flow rate. A curve was fit to the points and the equation associated with that curve would serve as the calculation for any investment for various methane concentrations. This was repeated for the flow rates of 180,000 scfm and 300,000 scfm. The capital investment for the base case of 180,000 scfm and 0.6% methane was $15.3MM. This calculated to $85.2/scfm of ventilation air produced. The generated curves are plotted in Figure 2 in Confidential Appendix K.

The maintenance and operating costs are based on a combination of an estimate of undefined maintenance items and on experiences gained from units operating in the field. To address the undefined costs, a maintenance cost based on a cost per kWh was used. For the base case, $0.015/kWh was used for the undefined maintenance costs. The range of maintenance costs was from $0.010 to $0.045 per kWh. This would include materials, supplies, spare parts, replacement parts, and manpower. In Australia, at the only power-producing VAM project, one person is scheduled full time every day to do the maintenance. Operating costs are considered to be manpower required to operate the facility. It is assumed that one person is required to be at the site full-time during operation. At the plant in Australia, it is required by law that the power generation facility be manned around the clock. The assumption was made that all the required operating activities for the beds for abatement would still be necessary. For the case study, the labor costs were changed from $25/man-hour to $60/man-hour.

For the base case, the two components making up the operating and maintenance costs are summarized in Table 19. It shows that the combination of these costs represent 4.81% of the capital investment. Based on feedback from MEGTEC, it is projected that a total O&M cost would be around 2-3% of capital. Our estimate is high to compensate for a learning curve, as this will be the first project of its type in the U.S.

Table 19. Calculation of Operating and Maintenance Costs for Heat Recovery Base Case

			Cost - $	% of O&M	% of Capital
Components Used to Calculate Maintenance Costs	Maintenance cost	$.015/kWh			
	Electric power generated – kW	3071			
	Operating hrs/year	8497			
	Maintenance costs/year		$391,424	53.1%	2.55%
Components Used to Calculate Operating Costs	Operating hrs/year	8642			
	Man-hour cost	$40/man-hour			
	Operating costs/year		$345,680	46.9%	2.25%
	Total O&M costs		$737,104		4.81%
Capital Costs	Capital investment	$15,335,000			

The amount of available energy that can be converted into electricity is generated from the combustion reaction of methane to carbon dioxide and water. That reaction releases the lower heating value of 912 Btu/ft^3 of methane in the bed. It is assumed that 0.2% methane is required to maintain the reaction temperature for self-sustainability. Methane concentrations greater than 0.2% will generate excess energy available for energy recovery. The assumed method of removing the heat from the unit is through coils embedded in the bed that carry water which is vaporized to steam. Steam is then used to turn a turbine to make electricity. The efficiency in converting the energy into electricity is a function of the quality of steam, temperature, pressure, and the type of generators purchased. A more detailed cost estimate and flow diagram would be required to define the exact efficiency of the system. For this study, there is assumed a 28% rate of efficiency on a LHV basis for the base case with a range from 25-30%.

As shown in Table 20, there are several different ways to represent the quantity of energy available. This analysis assumed 3.07 MW of electricity could be generated from an 180,000 scfm system having 0.6% methane.

Table 20. Energy Available from VOCSIDIZER System

Operating Conditions	180,000 scfm, 0.6% CH4, 97% Availability, 95% Methane Conversion	
Energy	**Units**	
Heat of combustion, LHV basis	Btu/ft^3	912
Maximum potential thermal energy	MW	16.45
Electrical efficiency	%	28
Maximum electricity generated	MW	4.61
Actual thermal energy available for energy recovery	MW	10.97
Actual electricity generated	MW	3.07

Another means of extracting energy from the equipment is to utilize the thermal energy in the form of hot water. This would allow 10.97 MW of thermal energy to be available to produce hot water for public or commercial consumption. This is equivalent to 37.4MM Btu/hr of energy. This is capable of raising the temperature of 420 gpm of water from 50˚F to 200˚F. Removal of this heat would operate on the same principle of putting coils within the bed and pumping water through them to extract the heat. Another method of heat recovery is to remove the heat from the stack. This would require installing coils in the exhaust and removing heat from the hot gas. There is available about 16 MM Btu/hr of energy that could be extracted. This has the potential of heating 273 gpm of water by 100 degrees. This method of recovery heat from the system is being implemented in projects in China. These hot-water options were not considered in our economic analysis.

7.4 Results

7.4.1 Abatement cases

Table 1 in Appendix E shows the results for all the cases that were analyzed for abatement. Figure 24 graphically shows the internal rate of return (IRR) for each case analyzed. For the range of parameters that was chosen, the selling price of the carbon credits had the largest impact on the range of the profitability for the abatement case. The base case for the abatement case showed an internal rate of return of 2.5%. The following paragraphs interpret the effect each of the parameters had on the internal rate of return.

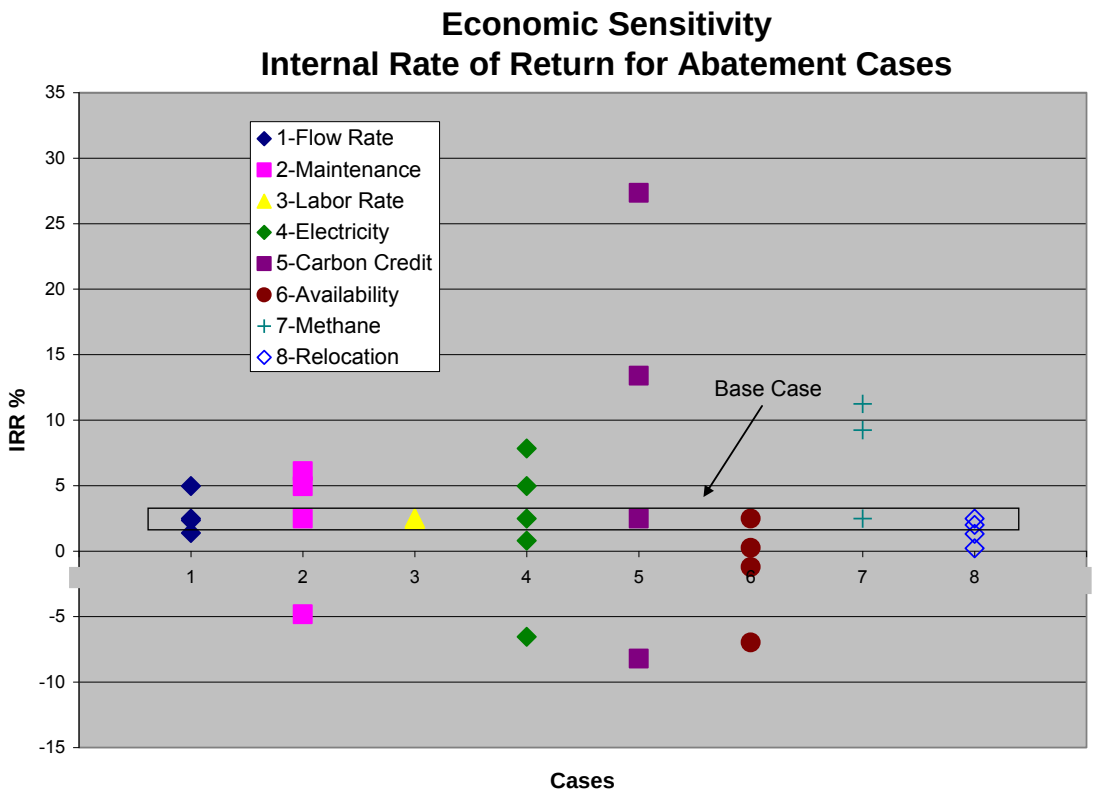

Figure 24. Economic Analysis for Full-Scale VOCSIDIZER System on Mine Fan

Flow rate changes affect the size of the abatement system and the capital investment. Increasing the flow rate of the system means increasing the size of the system. For every 30,000 scfm of flow requires another ceramic bed to be installed. For every 60,000 scfm of flow required another fan to be installed. Therefore by increasing the size of the system from 180,000 scfm to 300,000 scfm increases the number of operating beds from six to ten and the number of fans from three to five. The results showed that the return of investment increased to 5.0% when the system was increased to 300,000 scfm. The analysis assumes there is sufficient land to accommodate the equipment and the concentration of the VAM is stable at 0.6% methane.

Increasing the maintenance costs from 2% of the capital to 10% of the capital, while holding all other parameters at the base case values, decreased the internal rate of return from 6.1% to -4.8%. Changing the labor rates did not impact the results significantly. This is due to the fact that only 145 hours of manpower were specifically defined for operation. Any other manpower requirements would be absorbed in the maintenance costs as percent of capital and would not be affected by changing the cost of the labor hours. This would include costs like the operators travel time back and forth to the site.

The price of electricity is important to the economics of the project. Using a value of 2.6¢/kWh, the return on investment was 7.8%, whereas using a value of 10¢/kWh showed a -6.6% IRR when all other parameters where unchanged from the base case. The electricity is mainly used to run the VOCSIDIZER fans and represents 60.0% of the operating and maintenance costs at the base case level of 5.8¢/kWh.

The value of the CO_2 credit greatly influenced the profitability of the system. As a carbon credit market becomes enacted and the value of a carbon credit increases, the implementation of the technology on a coal mine fan becomes more economical. For the project to break even over 10 years, it requires a carbon credit value of $6.60/tonne CO_2e. At $7.00/tonne CO_2e the IRR is 2.5% and it increases to 39.3% when the value of the credit is at $20.00/tonne CO_2e.

Any reduction of uptime from the base case lowers the internal rate of return. The IRR went from 2.5% at the base of 97% uptime to –7.0% at 64% availability. The percent uptime achieved in Australia during the first year of operation of the power generating plant was around 95% with no signs of equipment problems observed during planned inspection shutdowns. CONSOL was unable to maintain that level of uptime during the demonstration project.

The concentration of the methane impacts the value of the project only if there is a carbon market. The higher methane concentration in the mine exhaust, the more methane that will be converted to carbon dioxide. The analysis assumes that the methane conversion is not impacted by the methane concentration which was confirmed during the demonstration project. The more methane that is converted to CO_2 the more the income from selling the carbon credits. The analysis assumes a slight increase in capital investment as the methane concentration increases. At methane concentrations below 0.5%, the capital cost is $5.0MM and it increases to $5.4MM when the concentration is from 0.5% to 0.8%. The increased cost in capital does not significantly impact the return because it is offset by the value of the carbon credits sold. The internal rate of return for 0.6% methane at $7.00/tonne CO_2e is 2.5% and it increases to 11.2% at 0.8% methane.

The analysis showed that if the unit was moved after five years of its ten-year life, it would decrease the IRR to 0.2% when the cost of relocation was $500,000 and all other parameters were unchanged from the base values. To minimize the relocation costs, the plan is to design skid-mounted equipment so it can be relocated easily. There may be opportunities to reduce the installation costs. The best scenario is for the ventilation fan to exhaust sufficient levels of methane to operate the VOCSIDIZER for ten years and never relocate the equipment. At the end of the ten year life, it is expected the bed internals will need to be rebuilt. This is due to a combination of wear on the bed heaters, bed media, and bed insulation. The rebuild will require a two-to three-week shutdown. All construction activities can be accomplished in the field at an estimated cost of $200,000 per bed. After the bed internals are rebuilt, the bed units should be operational for a second ten-year period.

7.4.2 Heat Recovery Cases

Table 2 in Appendix E shows the results for all the cases that were analyzed for heat recovery. Figure 25 graphically shows the internal rate of return (IRR) for each case analyzed. For the range of parameters that was chosen, the methane concentration and the carbon credit values were major influences on the profitability of a power generating system. The base case for the power generation case showed an internal rate of return of 2.8% or a pay back in the ninth year of operation.

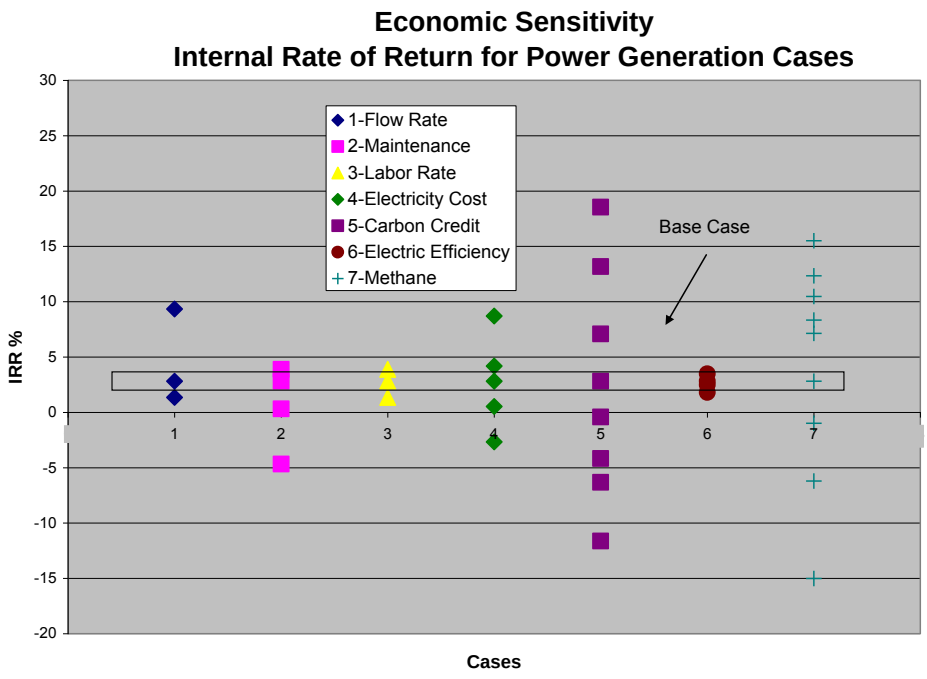

Figure 25. Economic Analysis for Full-Scale VOCSIDIZER System with Heat Recovery on Mine Fan

The capital investment to add power generation capabilities to the VOCSIDIZER system can be a three-fold increase from the abatement-only scenario. The capital investment for the base case to produce electricity was $15.3MM compared to $5.4MM for abatement case. This investment cost in terms of the quantity of electricity generated was $4993/kW based on a net 3.07MW of electricity. This is expensive compared to the average cost of traditional fossil fuel power plants. A carbon credit market could help offset the cost of the power generation from VAM.

The power generating cases showed a lower internal rate of return than abatement for most cases that had similar fixed parameters. One case where power generation showed significantly improved profitability over abatement was when the system was sized for 300,000 scfm. In that case the return was 5.0% for abatement and 9.3% for power generation when maintaining the base conditions.

Increasing the operating and maintenance costs decreased the internal rate of return. Increasing the maintenance costs from $0.010/kWh to $0.045/kWh, while holding all other parameters at the base case values, decreased the internal rate of return from 3.9% to -4.7%. Changing the labor rate impacted the IRR more for the heat recovery

cases than the abatement cases. The IRR changed from 3.9% at $25/man-hour to 1.3% at $60/man-hour. This is because, in the heat recovery analysis, we have estimated one operator will be required to man the facility for 24 hours a day.

The value of the electricity impacts the economic results. When electricity is being generated, the higher the electricity value, the better the economics. In contrast, with abatement only, the cheaper the power, the better the economics. The amount of energy required to operate the fans was treated as a parasitic load which reduced the net electricity that could be sold to the power grid. The power used by the system was not taken as an operating cost but as a loss of revenue. It is assumed that the value of the electricity is the same value whether it is bought or sold. The base case had a parasitic load of 29%. The system used 891 kW of the 3071 kW that was produced. Using a value of 2.6¢/kWh the return on investment was -2.7%, whereas 10¢/kWh showed an 8.7% IRR when all other parameters where unchanged from the base case. The power generated could also be used internally by the mine depending on the proximity to the company's internal power grid.

The value of the CO_2 credit greatly influences the economics of the system. It required a value of $5.50/tonne CO_2e for the project to break even over ten years for the base case. At $7.00/tonne CO_2e the IRR was 2.8% and it increased to 18.5% when the value of the credit is at $20.00/tonne CO_2e. The methane concentration is tied to the ability to generate carbon credits. At higher methane concentrations, more methane is available to be destroyed. Concentrations less than 0.6% do not have a positive return of investment even when $7.00/tonne CO_2e is available. As the methane concentration increases, the return on investment increases. At a VAM concentration of 0.6% methane the IRR is 2.8% and at 1.2% methane it increases to 15.5%. The value of the CO_2 credit and the concentration of methane have the biggest impact on the range of profitability of the power generation case.

Electrical efficiency has an impact on the return of investment. The efficiency is related to the capital investment and the type of equipment purchased. For this analysis we assumed that without making any capital changes to the equipment, the efficiency could vary from 25 to 30% on a LHV basis. Using this small range in efficiency the projected change in IRR was from 1.8% to 3.5%.

7.5 Cost Reduction Opportunities

Coal mines are a new application for the thermal flow reversal reactor technology. New applications for existing proven technology usually encounter higher costs initially. There is a learning curve for the operators, maintenance personnel, and engineers. Equipment modifications are often required before the problems are resolved. Systems become streamlined and costs are reduced as the problems are worked out of the system. With this in mind, the analysis was conservative with the system costs and there may be opportunities to reduce the expenses and improve the profitability of the system.

Changes in the design and manufacture of the equipment may provide opportunities to reduce the capital investment. The base cost of the VOCSIDIZER units may be reduced depending on where they are manufactured. Equipment costs will depend on the quantity of units being built, whether they are manufactured overseas or in the US, and the strength of the US dollar. If the VOCSIDIZER without heat recovery is capable of operating at concentrations greater than 0.8% methane, the system could be more economical. This assumes that the incremental cost of upgrading the materials of construction to handle the heat would be less than the value of the carbon credits. Using MEGTEC's estimate for investment costs, a system capable of operating at 1.2% methane can increase the internal rate of return from 11.2% to 20.9% when the value of the carbon credit is at $7.00/tonne CO_2e. A change in the design of the bed could increase the volumetric flow through each unit. The beds built for the Australian project were capable of handling 41,000 scfm, slightly larger than the Windsor demonstration unit at 30,000 scfm. This allowed the Australian site to contain four beds and two fans to process 165,000 scfm, which would have required six beds of our size. The reduction in the number of beds and fans has potential in reducing the capital and power consumption costs.

There may be opportunities to lower the maintenance costs. Even though a high availability was assumed in the analysis, a high level of maintenance was used due to the uncertainty of how well the equipment will operate long-term. Once any unreliable equipment is replaced and the operators establish routine maintenance practices, the maintenance costs should drop. The system has very few moving parts and should not require much repair time.

There may be an opportunity to reduce the costs of electricity when an abatement-only system is installed at a mine site. The cost of electricity is usually cheaper at the mines due to the quantity of power used at a mine in comparison to the quantity that was used at the Windsor test site.

Actual methane destruction may be greater than 95%. During our demonstration test we calculated as high as 98.8% destruction of the methane during a one-hour test. A higher destruction rate increases the amount of methane destroyed which will result in an increase in revenue from selling the equivalent carbon credit.

For a heat recovery system, there is an opportunity to increase the amount of thermal energy available. It was assumed that 0.2% methane is required to sustain the reaction (i.e., overcome energy losses) and the remaining methane is available for heat recovery. If this value is high and it is possible to remove more heat from the reactor and still sustain the operation, then it would increase the amount of electricity produced and therefore raise the revenue for the project. It is also possible for the electricity efficiency to increase to 30%.

7.6 Optimistic Cases

An optimistic set of conditions was analyzed to determine what internal rate of return could be expected from an installation of a VOCSIDIZER system on a mine in southwestern Pennsylvania. The assumptions made are that the installation is for an 180,000 scfm system with the ventilation air containing 0.6% methane. The value for the carbon credit is constant at $7.00/tonne CO_2e for the ten years of operation. It is assumed that the capital costs can be reduced by 5% from the base case, the maintenance costs are only 2% of capital, the costs for electricity are the all-in power costs being paid by one of CONSOL's Pennsylvania mines ($0.0438/kWh), and the methane destruction in the bed is 96.5%. The $40/man-hour rate and 97% equipment availability were unchanged from the base case. For an abatement-only case, the IRR increased from 2.5% at the base case conditions to 9.7% for the optimistic case as seen in Table 21. To achieve a 15% IRR, the value of the carbon credit would have to increase to $8.60/tonne CO_2e. If the assumption was made that the methane concentration from the mine was 0.9% and the equipment was capable of handling the heat, it would only require the value of the carbon credit to be $6.40/tonne CO_2e to achieve a 15% IRR, or $4.80/tonne CO_2e, if the methane concentration was 1.2%.

Table 21. Summary of Economic Analysis for Optimistic Abatement Cases

Case		500	580B	585A	585B	585C
Description		**Base Case**	**Optimistic Conditions**	**CO_2e value for 15% IRR**	**CO_2e value for 15% IRR at 1.2% CH_4**	**CO_2e value for 15% IRR at 0.9% CH_4**
Variable parameters	Units					
Methane concentration	%	0.6	0.6	0.6	1.2	0.9
Methane Conversion	%	95	96.5	96.5	96.5	96.5
Parasitic load	%	100	100	100	100	100
Carbon credit value	$/tonne CO_2e	7.00	7.00	8.60	4.80	6.40
Electricity value	$/kWh	0.058	0.0438	0.0438	0.0438	0.0438
Flow air	scfm	180,000	180,000	180,000	180,000	180,000
Total installed costs	$/scfm	30.07	28.57	28.57	32.65	32.65
Capital cost reduction	%		5	5	5	5
Total capital investment	$M	5412	5142	5142	5876	5876
Availability	%	97	97	97	97	97
O&M cost	% of cap	5	2	2	2	2
Electricity costs	$M/yr	447	338	338	338	338
O&M man-hours	hr/yr	145	145	145	145	145
Total O&M costs	$M/yr	745	460	460	475	475
Life of machine	years	10	10	10	10	10
IRR	%	2.48	9.71	15.27	15.39	15.39
Year pay back		9	7	5	5	5

For the heat-recovery case it was assumed that the maintenance costs were lowered to $0.005/kWh, the electrical efficiency was 30% on a LHV basis, and 0.18% methane was required to sustain the reaction in the bed. With all the other parameters at the optimistic conditions that were used for the abatement only case, the IRR increased from 2.8% at the base case conditions to 4.9% at the optimistic conditions. See Table 22 for the details. To achieve a 15% IRR, the value of the carbon credit would have to increase to $14.70/tonne CO_2e. If the assumption was made that the methane concentration from the mine was 0.9%, it would only require the value of the carbon credit to be $8.80/tonne CO_2e to achieve a 15% IRR, or $5.70/tonne CO_2e if the methane concentration was 1.2%. The optimistic conditions for a power generation case to be profitable include high methane concentration in the ventilation air and high value of generated electricity.

Table 22. Summary of Economic Analysis for Optimistic Heat Recovery Cases

Case		600	680B	685A	685B	685C
Description		**Base Case**	**Optimistic Conditions**	**CO_2e value for 15% IRR**	**CO_2e value for 15% IRR at 1.2% CH_4**	**CO_2e value for 15% IRR at 0.9% CH_4**
Variable parameters	Units					
Methane concentration	%	0.6	0.6	0.6	1.2	0.9
Methane Conversion	%	95	96.5	96.5	96.5	96.5
Power	kW	3071	3510	3510	8524	6017
Parasitic load	%	29	25.38	25.38	10.45	14.80
Electrical efficiency	%	28	30	30	30	30
Carbon credit value	$/tonne CO_2e	7.00	7.00	14.70	5.70	8.80
Electricity value	$/kWh	0.058	0.0438	0.0438	0.0438	0.0438
Flow air	scfm	180,000	180,000	180,000	180,000	180,000
Total installed costs	$/kW	4993	4151	4151	2255	2821
Total installed costs	$/scfm	85.20	80.94	80.94	106.78	94.31
Capital cost reduction	%		5	5	5	5
Total capital investment	$M	15335	14568	14568	19220	16976
Availability	%	97	97	97	97	97
O&M costs	$/kWh	0.015	0.005	0.005	0.005	0.005
Electricity costs	$M/yr					
O&M man-hours	hr/yr	8642	8642	8642	8642	8642
Total O&M costs	$M/yr	759	510	510	729	619
Life of machine	years	10	10	10	10	10
IRR	%	2.82	4.89	15.02	15.07	15.10
Year pay back		9	8	5	5	5

7.7 Methane Emission Reduction

The TFRR technology can provide new opportunities to reduce greenhouse gas emissions by the reduction of ventilation air methane emissions from coal mines. As shown in Table 23, the single-bed unit, operating at 30,000 scfm and 0.6% methane, reduced methane emissions by 894 short tons during the 13 months of operation, which is the equivalent of 14,849 metric tonnes of carbon dioxide. Breaking this down by year, there were 4,668 metric tonnes of CO_2e reduced in 2007 and 10,181 metric tonnes of CO_2e reduced in 2008. Because the equipment availability was less than expected, the methane reduction was less than what the technology is capable of producing. Specifically, if the equipment during Phase II long-term testing in 2008 operated at the expected 97% availability, 15,335 metric tonnes of CO_2e would have been reduced instead of 10,181 metric tonnes. If the equipment operated with all the non-core problems removed at 84.1% availability, 13,296 metric tonnes of CO_2e would have been reduced.

Another aspect of the expected performance is the manufacturer's guaranteed emissions of criteria pollutants. Using the guaranteed rate of emissions for each criteria pollutant for the actual hours of operation during both phases of operation, the equipment could have emitted 23,477 lbs of CO, 4695 lbs of NO_X, 470 lbs of particulate, and no SO_2 and still meet specifications. Based on the manufacturer's experiences from lab testing with natural gas, they expected the CO emissions to be less than the guarantee at 5469 lbs. However, assuming that the criteria pollutant emission rates that were measured during the Emission Campaigns were representative of the emissions during the total operating hours of Phase I and Phase II, then the total emissions during the demonstration project were 810-1008 lbs of CO, 52 lbs of NO_X, no measurable SO_2, and 5631-8039 lbs of particulate material.

Table 23. Comparison of Expected VOCSIDIZER Performance With Actual Windsor VOCSIDIZER Performance

	Expected Performance Phase II	Core Problem Performance Phase II	Actual Performance Phase II 2008	Actual Performance Phase I 2007	Actual Performance Phase I & II 2007 & 2008
Hours of operation (maximum/actual)	4400	4400	4400/2833	4921/1300	9321/4133
Air flow rate, scfm	30,000	30,000	30,000	30,000	30,000
Methane inlet concentration	0.6%	0.6%	0.6%	0.6%	0.6%
Methane conversion	95%	95%	95%	95%	95%
Reduction of methane emissions, MM ft^3	44	38	29	13	42
Reduction of methane emissions, short tons	923	801	613	281	894
Reduction of methane emissions, metric tonnes	839	728	557	255	812
Net reduction of equivalent carbon dioxide, metric tonnes	15,335	13,296	10,181	4668	14,849
Percent uptime	97%	84.1%	64.4%	26.4%	
Power usage, kWh	663,930	561,055	494,000	313,640	807,640
Emissions of carbon monoxide (CO), lbs guaranteed/ expected/ actual	23,845 5554 ------	20,674 4816 888-1147	15,831 3688 680-878	7646 1781 130	23,477 5469 810-1008
Emissions of NO_x, lbs guaranteed/ actual	4769 ------	4135 0	3166 0	1529 52	4695 52
Emissions of particulate, lbs guaranteed/ actual	477 -----	414 7253-10,398	317 5554-7962	153 78	470 5632-8040

The measured criteria pollutant emission rates and concentrations used to calculate the total emission weights for each pollutant are discussed below. The measured CO level of 2 ppm in the stack gas was less than the guaranteed level of 50 ppm and even lower than MEGTEC's expectation from lab testing of 10 ppm. The maximum measured NO_X value was at 0.22 mg/m^3, which was less than the guarantee of 10 mg/m^3. The measured particulate emissions were much greater than the expected values, 14.4-21.2 mg/m^3 versus 1 mg/m^3. The expected value of 1 mg/m^3 is based on the maximum allowable particulate loading entering the bed with the mine methane. In our case, the particulates were not coming from the gas entering the bed but from degradation of the bed media. The dust was visible in the lower plenum during inspections and was carried out of the stack during operation. The level of particulate emissions was undesirable and unacceptable to MEGTEC. MEGTEC is investigating alternative media that will be more resistant to the operating conditions of the bed.

A large commercial-size installation (180,000 scfm) of the TFRR technology on a single typical mine ventilation bleeder fan could reduce methane emissions between 0.52 and 1.05 billion cubic feet per year, or 11,000 and 22,100 short tons per year. This has a net equivalent global warming potential (GWP) reduction of 183,000 to 366,000 metric tonnes carbon dioxide per year (after accounting for the carbon dioxide that is emitted from the VOCSIDIZER). The assumptions used to determine these numbers are:

- Methane concentration range of 0.6% - 1.2%
- 97% equipment availability
- 95% methane destruction
- GWP of methane = 21 times CO_2
- GWP reduction of 87% upon oxidation

Added benefits result when heat recovery of the oxidation process is included with the system. The heat recovered may be utilized directly as warm air or water, or steam used to generate electricity. Generating electricity would reduce the demand on fossil fuel generating stations, thus reducing the emissions of SO_2, NO_X, CO, and other criteria pollutants. A single commercial TFRR installed on a typical mine bleeder fan unit could produce 3.3-8.2 MW of electricity or 11-27 MW of thermal power. The available energy accounts for the heat required to sustain the oxidation reaction in the bed. The parasitic load on the system to primarily operate the process fan is about 0.9 MW. This assumes an electricity efficiency of 30% on a LHV basis. If the electricity generating efficiency is assumed to be 30% on a HHV basis, the maximum gross electricity generation would be 5.5 -11.0 MW and 18-36 MW of gross thermal power.

Table 24 summarizes the impact of a specific case when the VAM concentration is 0.9% methane and a large system with heat recovery is installed. This system would abate 797 million cubic feet of methane from the atmosphere every year and generate a net 43.6 million kWh of electricity. The major pollutant that is avoided when producing electricity with the TFRR technology compared to a coal-fired power plant is sulfur dioxide. The basis for the emissions avoided with a coal fired power plant are that for every 10,000 Btu/kWh generated, the criteria pollutants will be emitted at the following rates on a lb/MMBtu basis: SO_2 – 1.2; NO_x - 0.4; particulate – 0.1; and CO – 0.07. The

carbon monoxide showed a net increase compared to a coal-fired power plant when using the guaranteed emission concentration. Based on the measured emission performance during the demonstration project, it is likely the carbon monoxide emissions would be less than from a coal-fired power plant.

Table 24. Optimistic VOCSIDIZER Performance at 180,000 scfm and Power Generation

Description	
Methane concentration	0.9%
Methane conversion	96.5%
Electrical efficiency, LHV basis	30%
Reduction of methane emissions, MM ft^3	797
Reduction of methane emissions, short tons	16,805
Reduction of methane emissions, metric tonnes	15,277
Net reduction of equivalent carbon dioxide, metric tonnes	279,119
Electricity produced, kW	6017
Electricity used, kW	890
Net electricity produced, kWh	43,557,557
Percent uptime	97%
Emissions of CO (based on 10 ppm in stack), lbs/yr	66,654
CO, tons/yr	33.327
Emissions of NO_x (based on 10 mg/m^3 in stack), lbs/yr	57,230
NO_x, tons/yr	28.615
Emissions of SO_2, lbs/yr	0
Emissions of particulate (based on 1 mg/m^3 in stack), lbs/yr	5728
particulate, tons/yr	2.86
Emissions avoided from coal fired power plant:	
CO, tons	(15.4)
NO_x, tons	73.6
SO_2, tons	306.7
Particulate, tons	22.7

8. CONCLUSION

The single-bed VOCSIDIZER equipment was successfully operated for 4133 hours, primarily at 30,000 scfm and 0.6% methane. The equipment was operated in two phases with equipment rework conducted between phases to improve operability. Equipment modifications were successful in improving the availability to 64.4%, and considering only core problems, the uptime was 84.1%.

Parametric tests were conducted during each phase of operation that tested the operability of the equipment at the limits of methane concentrations and air flow rates. Three separate emission testing campaigns were conducted throughout the operating

time. Testing showed that the VOCSIDIZER could successfully oxidize methane at the concentrations typically found in VAM. The unit successfully operated between 0.3% and 0.8% methane. The methane destruction efficiency at all conditions tested was better than 95%. Even when the bed temperature profile was erratic, the methane destruction still met the manufacture's guarantees. Carbon monoxide emissions were less than projections and there were no significant amounts of NO_x, or SO_2 in the stack gas. The particulate material emitted was greater than expected, but it was the dust from the ceramic media. MEGTEC expects that an improved media will be available for future VOCSIDIZER installations.

Oxidation of methane in the bed generates a significant amount of heat. The energy released raised the center temperature of the bed to over 2000˚F when 0.6% methane was in the feed. The temperature at the bed inlet/outlet swings from ambient to around 500˚F and back with each valve switch. These frequent changes in temperature at the upper and lower plenums caused expansion and contraction of the bed. This energy can also be a resource which can be captured for use. Recovery of the heat from the bed by raising the steam will cause smaller temperature swings and less thermal stress on the equipment.

The equipment was safely operated during the field demonstration. After several revisions, all of the mechanical and logical safeties operated according to design. The multiple levels of shutdown in the control logic proved helpful in defining the seriousness of each shutdown and the proper startup sequence that followed. The automatic safe shutdown sequence instantaneously shut the flow reversal valves, closed the inlet isolation damper to the VOCSIDIZER and released the gas in the duct through bypass damper. These steps assure that a problem in the bed does not propagate to the inlet duct and vice versa. The LEL methane analyzer measuring the inlet concentration to the VOCSIDIZER was the main component to prevent a high level of methane from entering the unit. The replacement analyzer accurately measured concentrations below 1.2% methane with a response time of 5.1 seconds when using a 24" long, 3/8" diameter sample probe in the duct. Since the site was unmanned, the automatic call-out system initiated after each shutdown was useful to respond to problems in a timely manner. Safe operation of the equipment is critical for its deployment to an active mine site.

It is clear from the demonstration test that the quality of auxiliary equipment had an impact on the operability of the system. The demonstration project had 962 hours of downtime due to the instrument air compressor, 802 hours due to the methane analyzer, and 656 hours due to a flow meter. To minimize downtime in a commercial system, the compressor must be rugged and sized properly to operate the flow reversal valves. The methane analyzer must be reliable and all instrumentation must be designed to operate over the range of local ambient conditions.

Routine maintenance on the equipment will be required when a system is deployed on an operating coal mine. The methane analyzer will have to be calibrated routinely, the flow meter will require routine cleaning, and all rotating equipment will need to be

greased. Daily visual inspections and remote cameras would be helpful in addressing system problems. Phone connections at the site are important so that on-line communication with the PLC is possible in order to make logic changes through the modems and allow MEGTEC's help-center to provide assistance when needed. Data collection of operating parameters through the phone lines is also important in understanding the equipment operation and in determining the root causes of the shutdowns.

The demonstration project reduced the economic uncertainty associated with future installation by providing more reliable capital, operating, and maintenance cost information. This information was used to conduct an economic evaluation of an 180,000 scfm system installed on a ventilation fan at an active mine. Some of the assumptions used for the analysis included that the ventilation fan would emit 0.6% methane for ten years and the site did not require major preparation to install the equipment. It is assumed that the capital costs for complete installation are $30.1/scfm or $5.412MM, the maintenance costs are 5% of capital, the cost for electricity is $0.058/kWh, manpower costs are $40/man-hour, the methane destruction in the bed is 95%, and equipment availability is 97%. If the project intention was for methane abatement only, the IRR was 2.5% when the value of the carbon credit is $7.00/tonne CO_2e. If optimistic conditions were selected so that the capital costs are lowered to $28.6/scfm or $5.142MM, the maintenance costs are only 2% of capital, the cost for electricity is lowered to $0.0438/kWh, manpower costs remain at $40/man-hour, the methane destruction in the bed increases to 96.5%, and the equipment availability stays at 97%, the IRR increased to 9.7% for the abatement only case at $7.00/tonne CO_2e. Under these optimistic conditions, to achieve a 15% IRR, the value of the carbon credit would have to increase to $8.60/tonne CO_2e.

When considering an 180,000 scfm system having heat recovery with power generation, the economic evaluation showed the capital investment increased to $85.2/scfm or $15.335MM. The analysis assumed that 0.6% methane was available for ten years and 3.07 MW of electricity was generated at 28% electrical efficiency, LHV basis. The other assumptions used in the analysis were that the maintenance costs were $0.015/kWh, a full time onsite operator at $40/man-hour was needed, the costs for electricity were $0.058/kWh, the methane destruction in the bed was 95%, and the equipment availability was 97%. The IRR for heat recovery was 2.8% when the value for the carbon credit is $7.00/tonne CO_2e. If optimistic conditions were selected, it would require the value of the carbon credit to be $14.70/tonne CO_2e to achieve a 15% IRR. High methane concentration and high value of electricity are beneficial for power generation with the TFRR system.

The single bed unit, operating at 30,000 scfm and 0.6% methane at Windsor Mine, reduced methane emissions by 894 short tons during the 13 months of operation, which is equivalent to 14,849 metric tonnes of carbon dioxide. A large commercial-size installation (180,000 scfm) of TFRR technology on a single typical mine ventilation bleeder fan could reduce methane emissions between 11,000 and 22,100 short tons per year (the equivalent of 183,000 to 366,000 tonnes carbon dioxide) depending on the

methane concentration. Adding power generation to the system would reduce the demand on fossil fuel generating stations, thus reducing the emissions of SO_2, NO_X, CO, and other criteria pollutants. The system could produce 3.3-8.2 MW of electricity or 11-27 MW of thermal power. The parasitic load on the system primarily due to the process fan is about 0.9 MW.

The TFRR technology proves to be a viable technology to mitigate ventilation air methane. Based on this demonstration project, CONSOL Energy Inc. is interested in advancing this technology to an active mine site by initially relocating the existing VOCSIDIZER unit to a mine fan under MSHA's guidelines. MEGTEC Systems, Inc. is continuing to improve the equipment to obtain a more robust system and increase its availability. In a carbon-constrained world, this technology provides the capability to utilize a waste stream to reduce greenhouse gases, as well as the potential to produce useful energy.

REFERENCES

None

LIST OF ACRONYMS AND ABBREVIATIONS

AACE	-	Association for the Advancement of Cost Engineering
acfm	-	actual cubic feet per minute (wet)
AEP	-	American Electric Power
AM	-	morning
bcf	-	billion cubic feet
Btu	-	heating value in British Thermal Units
cap	-	capital
CBM	-	coal bed methane
CEM	-	continuous emission monitor
cfm	-	cubic feet per minute
CH_4	-	methane
CMOP	-	U.S. EPA Coalbed Methane Outreach Program
CO	-	carbon monoxide
CO_2	-	carbon dioxide
CO_2e	-	carbon dioxide equivalent
DAS	-	data acquisition system
dscf	-	dry standard cubic feet

DOE	-	U.S. Department of Energy
EPA	-	U.S. Environmental Protection Agency
FID	-	flame ionization detector
ft	-	feet
ft^2	-	square feet
ft^3	-	cubic feet
g	-	grams
GC	-	gas chromatography
gpm	-	gallons per minute
GWP	-	global warming potential
H_2O	-	water
Hg	-	mercury
hp	-	horsepower
hr	-	hour
hrs	-	hours
in	-	inch
IRR	-	internal rate of return
kVA	-	kilovolt-ampere
kW	-	kilowatt
kWh	-	kilowatt hour
L	-	liter
lb	-	pound
lbs	-	pounds
lb/MMBtu	-	pounds per million British thermal units of heat input
LEL	-	Lower Explosive Limit
LFL	-	Lower Flammable Limit
LHV	-	lower heating value
M	-	thousand
m	-	meter
m^3	-	cubic meter
MCC	-	motor control center
mg	-	milligram
min	-	minute
MM	-	million
MSHA	-	Mine Safety and Health Administration
MW	-	megawatt
N_2	-	nitrogen
NO_2	-	nitrogen dioxide
NOx	-	oxides of nitrogen
O&M	-	operating and maintenance
O_2	-	oxygen
PC	-	pulverized coal
PLC	-	programable logic controller
PM	-	afternoon
PM	-	particulate matter
ppm	-	parts per million

ppmv	-	parts per million by volume
QA	-	quality assurance
QC	-	quality control
R&D	-	CONSOL Energy Inc., Research & Development
rpm	-	revolutions per minute
RTO	-	regenerative thermal oxidation
scf	-	standard cubic feet (68 ^{o}F and 29.92"Hg)
scfm	-	standard cubic feet per minute
sec	-	second
SO_2	-	sulfur dioxide
SO_x	-	oxides of sulfur
temp	-	temperature
TFRR	-	thermal flow reversal reactor
VAM	-	ventilation air methane
VOC	-	volatile organic compounds
WC	-	water column (in inches)
wt	-	weight
WVDEP	-	West Virginia Department of Environmental Protection
yr	-	year
yrs	-	years

APPENDIX A

Mine Fan Interface Design

“VOCSIDIZER Duct Inlet Specification”

CONSOL Energy Inc.

INTEROFFICE COMMUNICATION

TO : R. A. Winschel DATE : June 17, 2003

FROM : S. P. Hanson AT (OFFICE): South Park - R&D

SUBJECT : **VOCSIDIZER Duct Inlet Specification**

SUMMARY

The MEGTEC Systems VOCSIDIZER regenerative thermal oxidation system has successfully demonstrated significant methane reductions in the mine ventilation air exhaust at Australian coal mines. It is now desired to demonstrate that similar benefits may be garnered when this technology is applied to the E1 bleeder fan at Enlow Fork mine, and to identify site-specific issues with the constraint that this demonstration be accomplished without modification or disturbance to mine equipment and operations. To address this constraint, it was necessary to consider the impact that an inlet duct for the VOCSIDIZER would impose on the performance of a mine bleeder fan. Plans and photographs (provided by D. A. Kosmack) of the E1 bleeder fan, and information on CONSOL's operating practices (provided by CONSOL Coal Operations Administration - PA) were used to determine stagnation pressures and exhaust gas flows about the fan and VOCSIDIZER inlet duct. It was found that backpressure of an obstacle in front of the fan's exhaust is negligible so long as the available flow area is not restricted. However, placement of the inlet duct is critical if it is to perform effectively. Thus, it is recommended that the VOCSIDIZER inlet duct be placed as close as possible to the fan exhaust without interfering with the louvers and angled downwards.

DISCUSSION

The design of a VOCSIDIZER duct inlet for the E1 bleeder fan at Enlow Fork mine must meet two requirements. First, it must have an inconsequential impact on bleeder fan operation. Second, it must avoid dilution by ambient air of the exhaust gas.

Inlet Duct Impact on Bleeder Fan Operation

The following considerations are based on 200,000 cfm of gas exhausted from the mine through a bleeder fan and 60,000 cfm inducted to the VOCSIDIZER. Given that the fan vent is 2.5 m (8.17 ft) wide by 3.5 m (11.5 ft) high, the gas velocity normal to the exit plane is 10.8 m/s (2130 fpm). The vent louvers deflect the flow approximately 45 degrees, affecting a reduction in the cross section for exhaust gas flow and accelerating the gas to 15.3 m/s (3010 fpm). The louvers have no precise setting and are tested on a monthly basis only for closure under no-flow conditions. Louvers are usually linked and will close off as flow diminishes, but for the current status of the E1 bleeder fan under consideration, a 45-degree deflection in flow is appropriate.

As an extreme case of flow obstruction consider a vertical plate placed ½ m (1.64 ft) in front of the vent. The available area for gas flow equals that of the vent but requires the flow to turn 90 degrees. The stagnation pressure on the plate is a conservative measure of the maximum extra pressure required by the fan to overcome complete obstruction of forward flow. In practice it is impossible to position a plate this close because the louvers are 0.9 m (35 in) long so that the minimum available flow area is forced to be approximately twice the original vent area. Stagnation pressure calculated from Bernoulli's equation using an STP air density of 1.29 kg/m^3 is 75 Pa (0.3 in H_2O) for a velocity of 10.8 m/s and 150 Pa (0.6 in H_2O) for a velocity of 15.3 m/s. The difference between these pressures is equal to the extra fan pressure required to overcome the flow resistance of the louvers, and the total pressures are equivalent to the extra fan pressure necessary to overcome a 24 mph (10.8 m/s) or 34 mph (15.3 m/s) wind blowing directly at the vent.

The bleeder fans used by CONSOL Energy that are capable of handling 200,000 cfm, operate at a pressure differential of 18-22 in H_2O, and draft the recently mined longwall panels as the gob settles. The fans operate at a fixed rpm and the flow resistance for gas arriving at the fan changes as the longwall operation moves and the gob settles. In order to keep the fan operating efficiently with an 18-22 in H_2O pressure differential, barriers in the mine are moved to change the flow resistance and distribution. The gob settles over about a one-year period, after which the main fans assume the draft. The effective useful life of a bleeder fan is typically 2 to 3 years. The fan is then moved to a new ventilation shaft ahead of the longwall, while another bleeder fan located near the mining operation can exert optimal draft to the gob. Pressure drop in mufflers, louvers and other post-fan devices is about 1 in H_2O. The rest of the pressure drop occurs within the mine where compensation is routinely performed to maintain the flow to the fan.

It has been shown that any design for the VOCSIDIZER duct inlet which does not cause the open area for flow from the fan to be less than the vent area, will produce a back pressure less than 0.6 in H_2O. If there is no compensation made to flow resistance in the mine, this back pressure will reduce bleeder fan flow by no more than 1% based upon a fan operating at 18 in H_2O. This establishes a conservative constraint as to how obtrusive a device must be to affect the gas flow by 1%, and is commensurate in magnitude with the impact of environmental conditions. A VOCSIDIZER inlet duct design that incorporates the aforementioned constraint ensures an inconsequential impact on bleeder fan operation.

Inlet Duct Effectiveness

To optimize the effective capture of exhaust gas with minimal dilution by ambient air demands a more detailed knowledge of the flow field around the duct inlet. Computation of the flow field necessitates the use of finite element modeling. Finite element modeling of the gas exhausted from the vent provides insight into the proper placement of a VOCSIDIZER duct inlet. The software used for the computation was FlexPDE version 2.22, a multi-discipline/multi-physics finite element solution environment. Figure 1 shows the geometry of the simple concept design used for this study. Conditions used in the computation are as follows: average gas flow to the VOCSIDIZER is 10 m/s in a 1.83 m (72 in) diameter duct for a volumetric flow of 26.27 m^3/s (55,658 cfm), gas flow from the fan exhaust is 14.14 m/s directed downwards at an

angle of 45 degrees for a volumetric flow of 87.5 m^3/s (185402 cfm). This flow corresponds to the low end of fan operation when the impact of the VOCSIDIZER withdrawal will be greatest. The duct inlet has no obstruction on the rear and functions to prevent the spread of the exhaust gasses and to inhibit the induction of ambient air immediately in front of the duct to the VOCSIDIZER. The cross section of the duct inlet is 2 m wide by 2.5 m high by 3 m long so that it remains within the projected cross section of the vent and allows at least 0.306 m (12 in) clearance for the louvers. Figures 2 – 4 and 6 – 9 show the velocity components for three cases: no duct inlet present; the duct inlet positioned horizontally in front of the vent; the duct inlet inclined at 40 degrees relative to the front of the vent. In all computations the pressure field was weak, having a magnitude of the order of 10 Pa (0.05 in H_2O).

The unobstructed flow of exhaust gas penetrates approximately 2 meters in front of the vent (Figure 2) due to the downward deflection of the flow (Figure 3), which encounters the ground and spreads sideways (Figure 4). Examination of the ground in front of the exhaust vent, shown in Figure 5, displays this behavior as a parabolic pattern scoured in the dirt. It is clear that in order for an inlet duct to be effective it must be positioned close to the exhaust vent, but not so close as to interfere with the vent louvers or so close as to restrict the escape of exhaust gases if the inlet duct is obstructed. Neither the inlet duct positioned horizontally in front of the vent, depicted in Figures 6 and 7, nor the inclined inlet duct, depicted in Figures 8 and 9, draw any ambient air into the manifold. However, the inclined inlet duct is preferred since it takes advantage of the downward flow of exhaust gases to maximize the portion of gases captured by the duct inlet, and minimizes the obstruction to the vent. A recommended position for the inclined inlet duct would be to align the lower surface with the bottom edge of the vent with the duct's rear edge resting on the ground. A complete depiction of this configuration is shown as a rendered image with profile views, including pertinent dimensions, in Figure 10. The proposed interface duct would be 2 m wide by 3 m high by 3 m long and angled 30 degrees from vertical away from the vent, with sufficient clearance to prevent interference with movement of the louvers.

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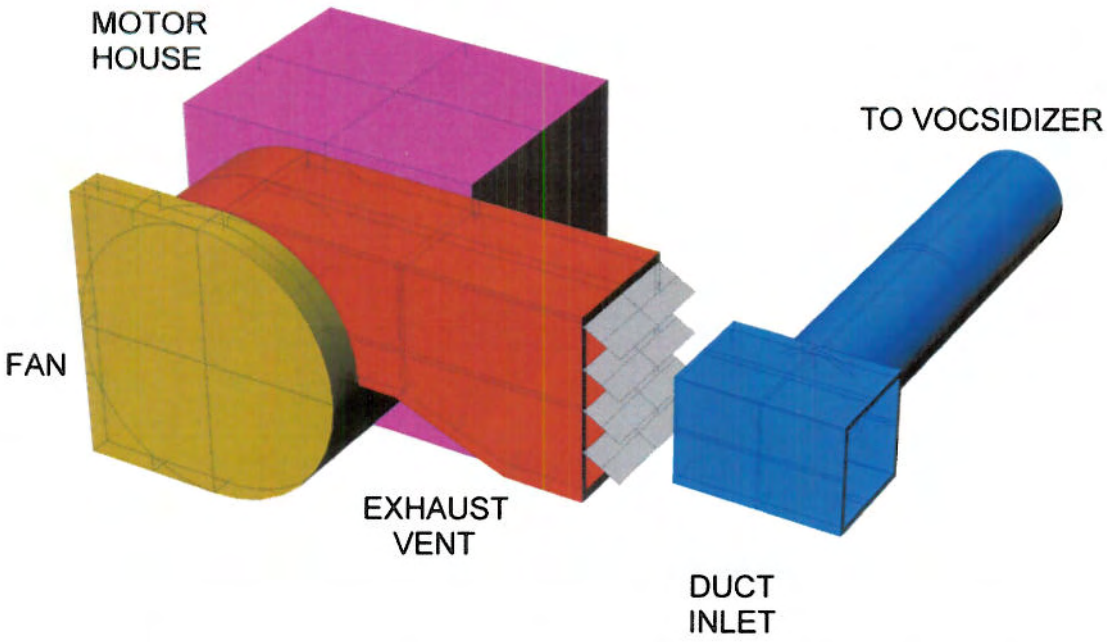


Figure 1. Bleeder Fan Exhaust and VOCSIDIZER Geometry

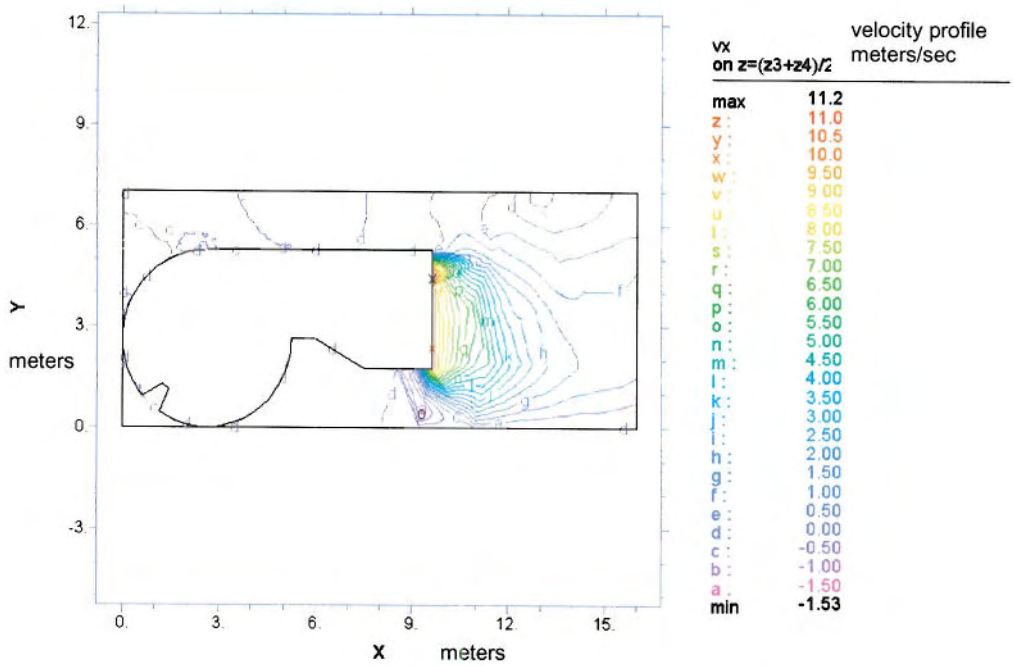


Figure 2. X-component of Velocity without VOCSIDIZER Duct on Exhaust Centerline

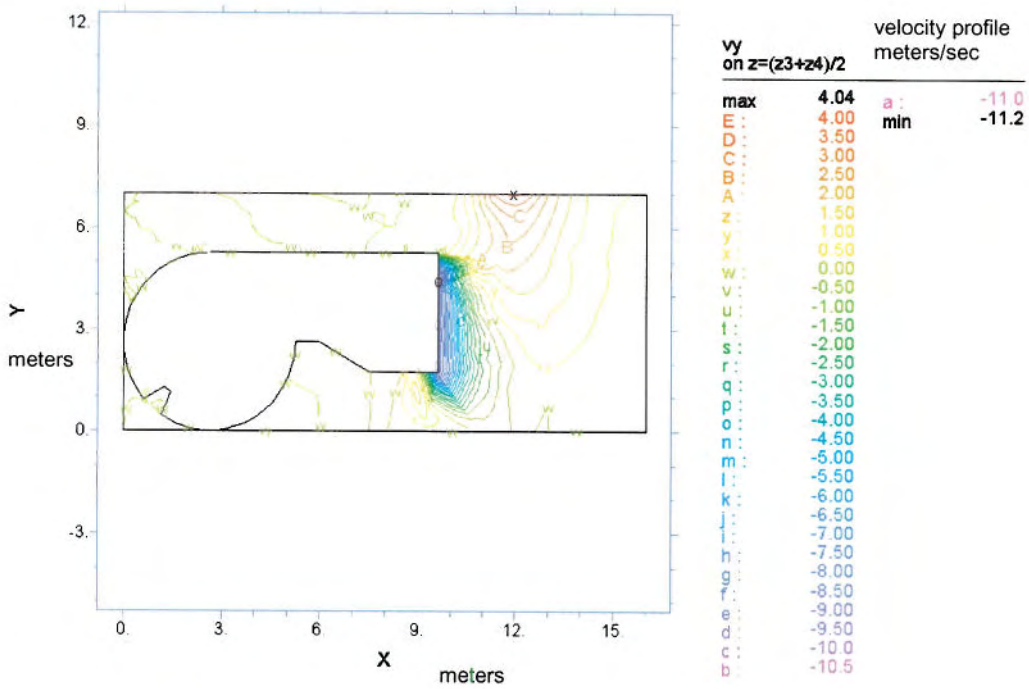


Figure 3. Y-component of Velocity without VOCSIDIZER Duct on Exhaust Centerline

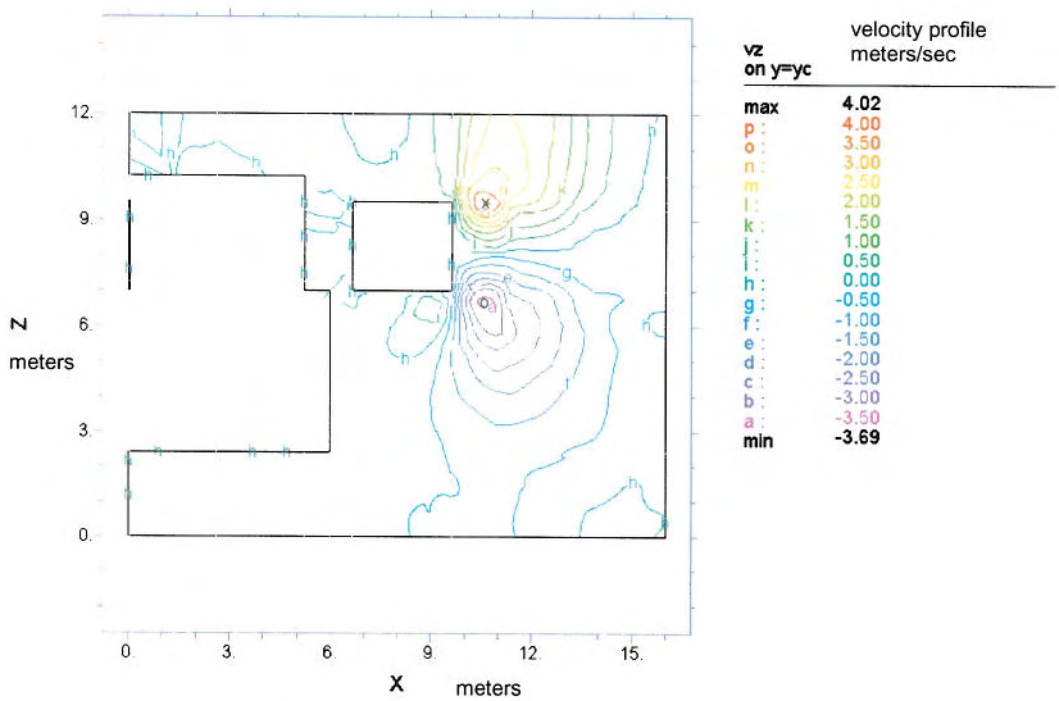


Figure 4. Z-component of Velocity without VOCSIDIZER Duct on Lower Plane of Exhaust

Figure 5. Bleeder Fan and Exhaust Vent "E1" at Enlow Fork Mine

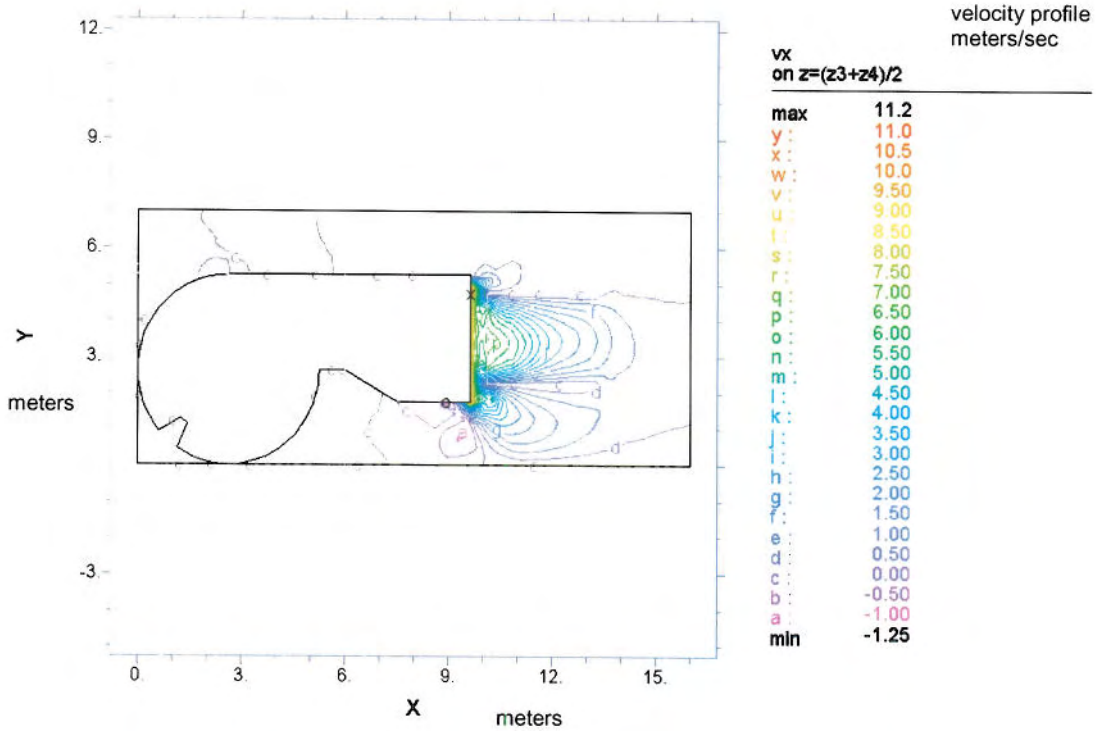


Figure 6. X-component of Velocity with Horizontal VOCSIDIZER Duct on Exhaust Centerline

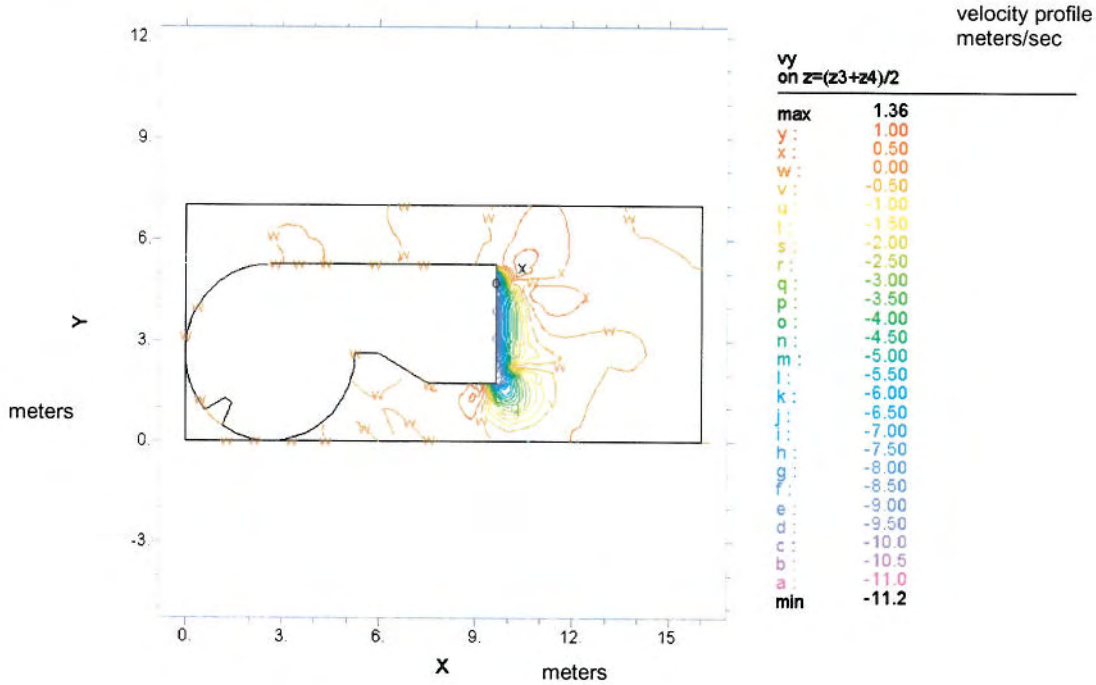


Figure 7. Y-component of Velocity with Horizontal VOCSIDIZER Duct on Exhaust Centerline

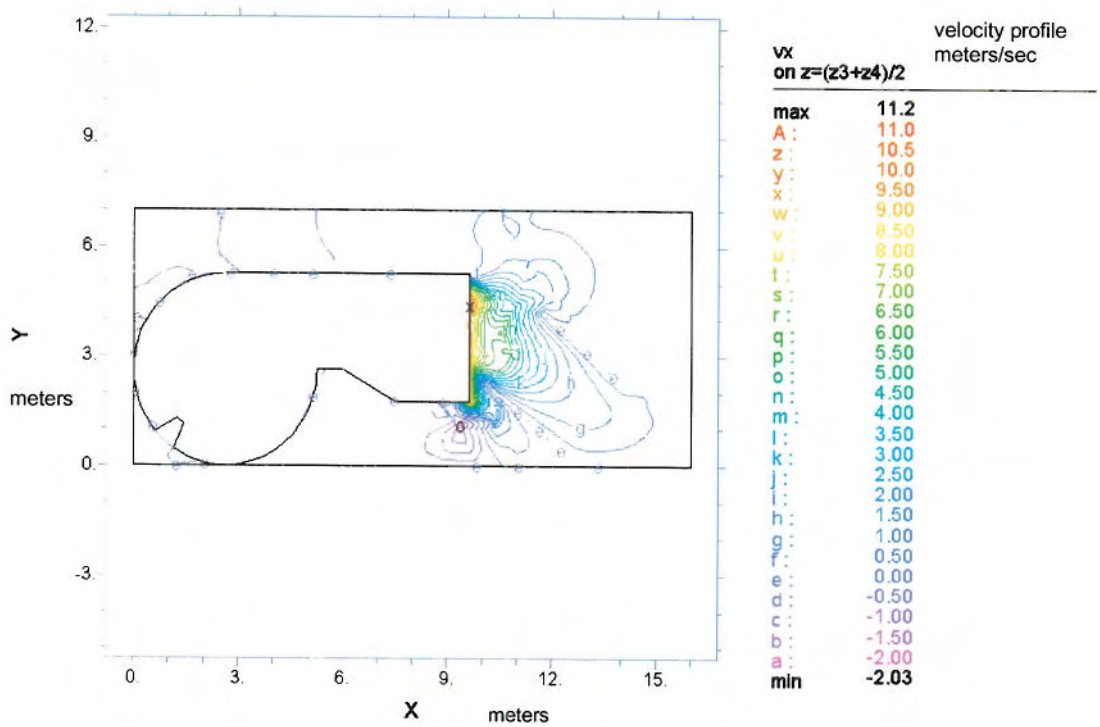


Figure 8. X-component of Velocity with Inclined VOCSIDIZER Duct on Exhaust Centerline

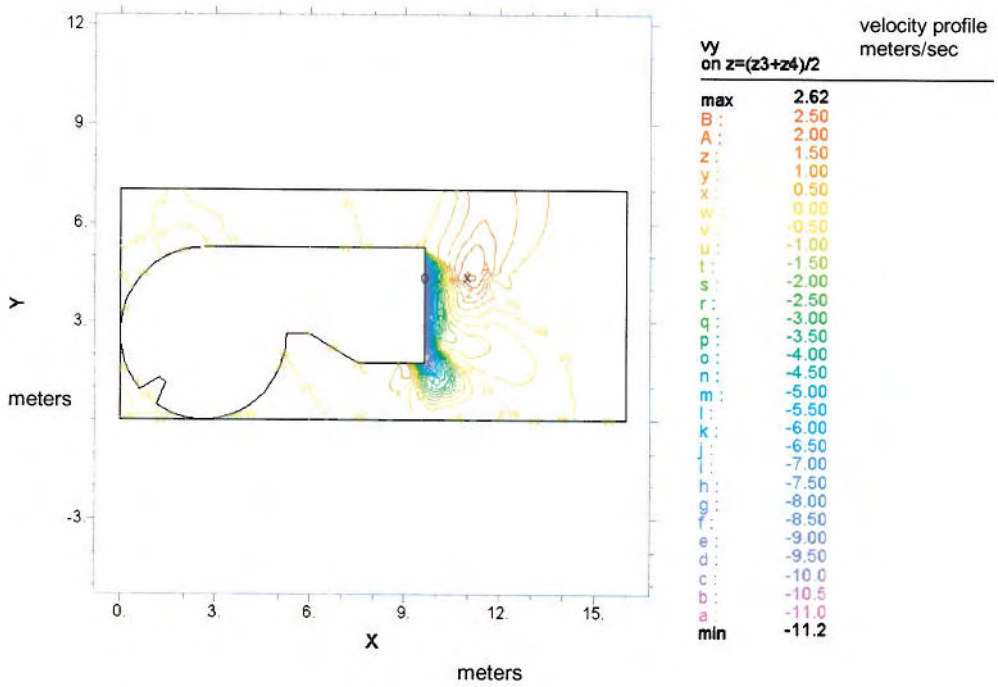


Figure 9. Y-component of Velocity with Inclined VOCSIDIZER Duct on Exhaust Centerline

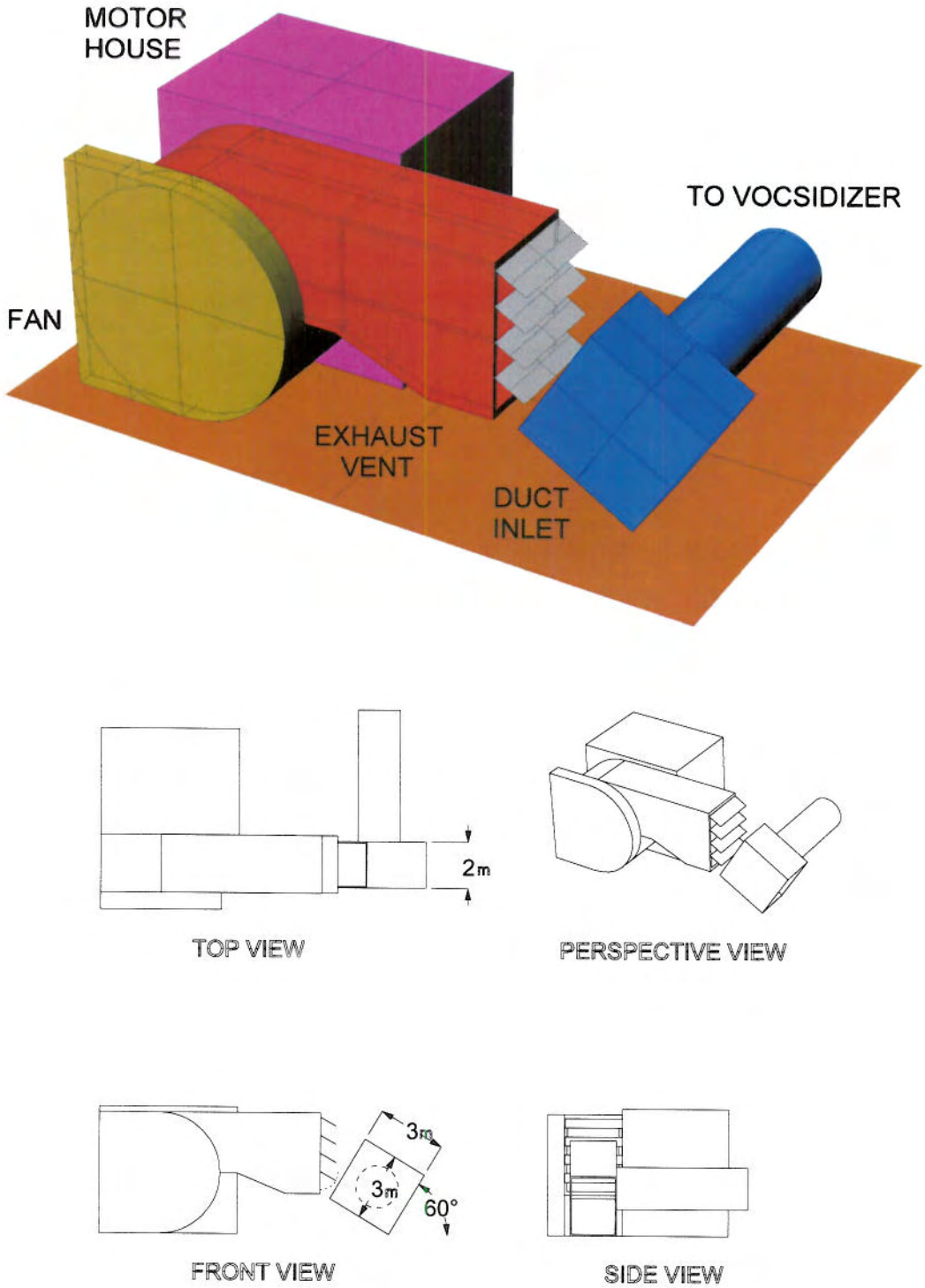


Figure 10. Rendered and Profile Views of VOCSIDIZER Duct Inlet In Recommended Situation Relative to the Bleeder Fan Exhaust

APPENDIX B

OPERATING DATA
FROM PARAMETRIC TESTING – PHASE II

OPERATING DATA FROM PARAMETRIC TESTING – PHASE II

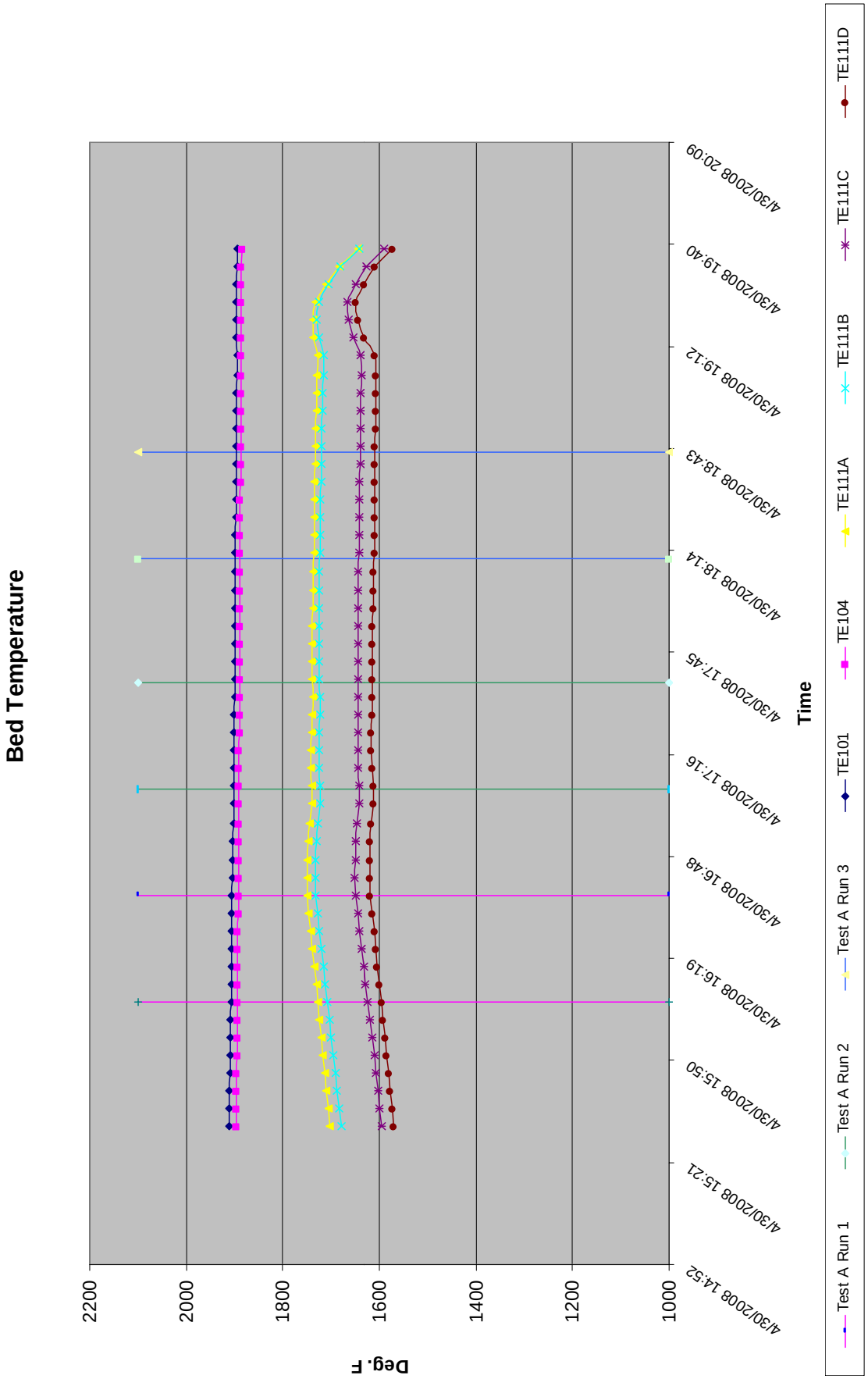
The VOCSIDIZER operating and process data were recorded automatically through the unit's data-logging system during the parametric tests. Data were recorded at regular intervals from 1 second to 5 minutes depending on the instrument as discussed in the Operation, Section 4.3.6, and detailed in Tables 3 and 4 in Section 4.3.6.

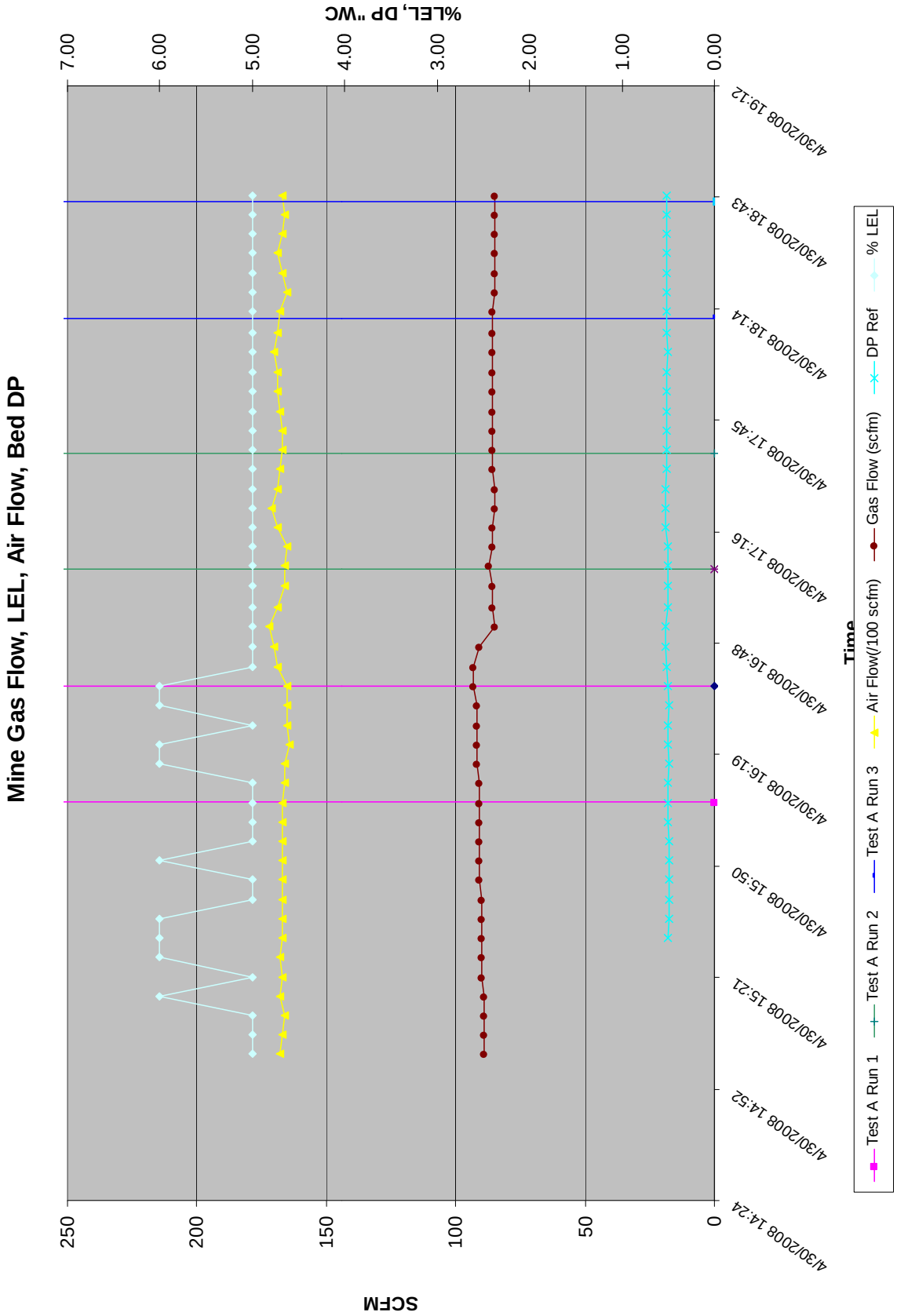
The following parameters were graphed with operating time for each parametric test; main fan air flow rate, mine gas flow rate, measured inlet methane concentration as % LEL, pressure drop across the bed against a reference value, internal bed media temperatures, bed plenum temperatures, bed inlet temperatures, and bed outlet temperatures. The following graphs are provided for each parametric test:

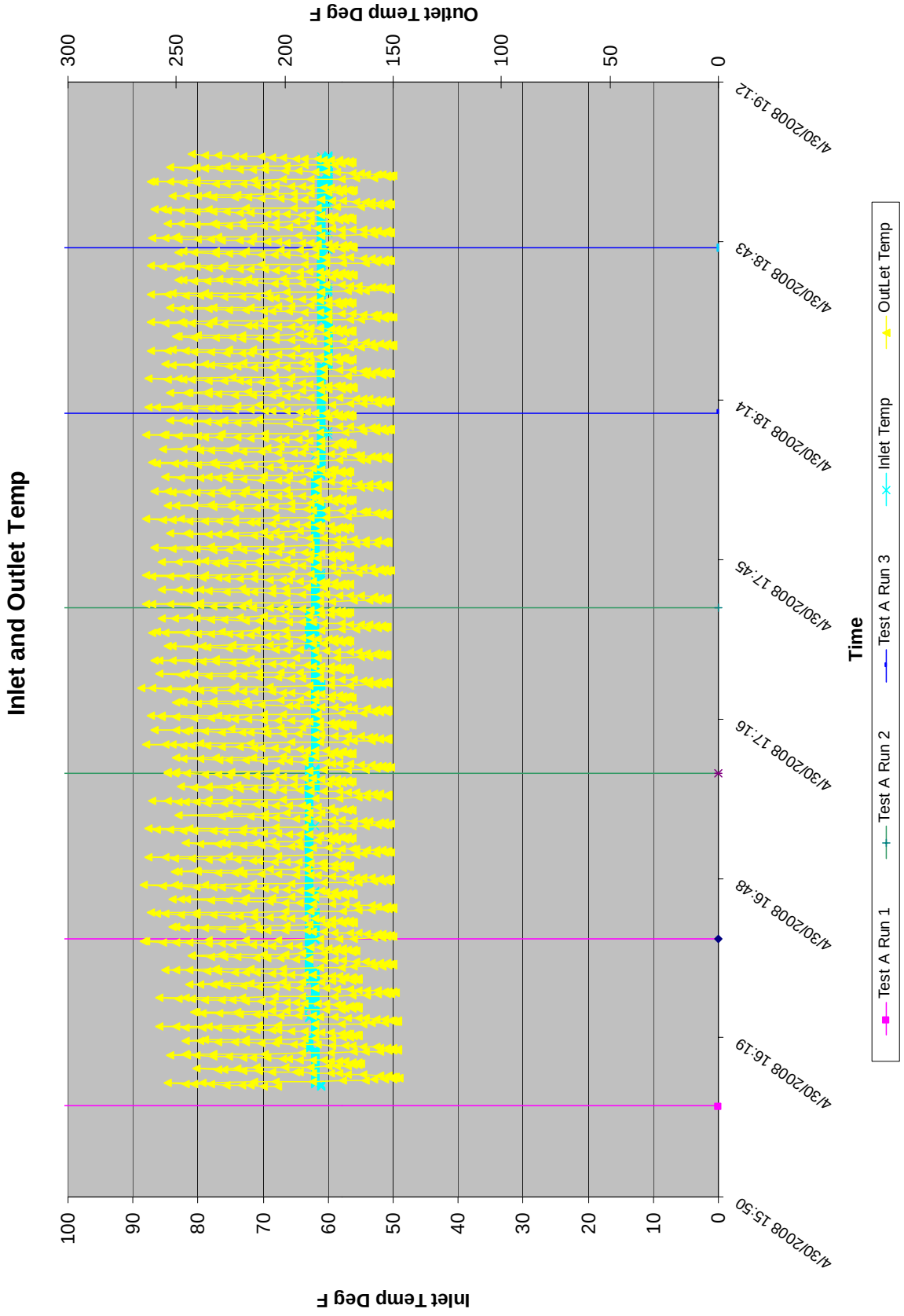
- Bed Temperature Profile
- Mine Gas Flow, LEL, Air Flow, Bed Pressure Drop
- Inlet & Outlet Temperature
- Plenum Temperatures
- Air Flow versus Inlet Temperature
- Inlet Methane Concentration – LEL

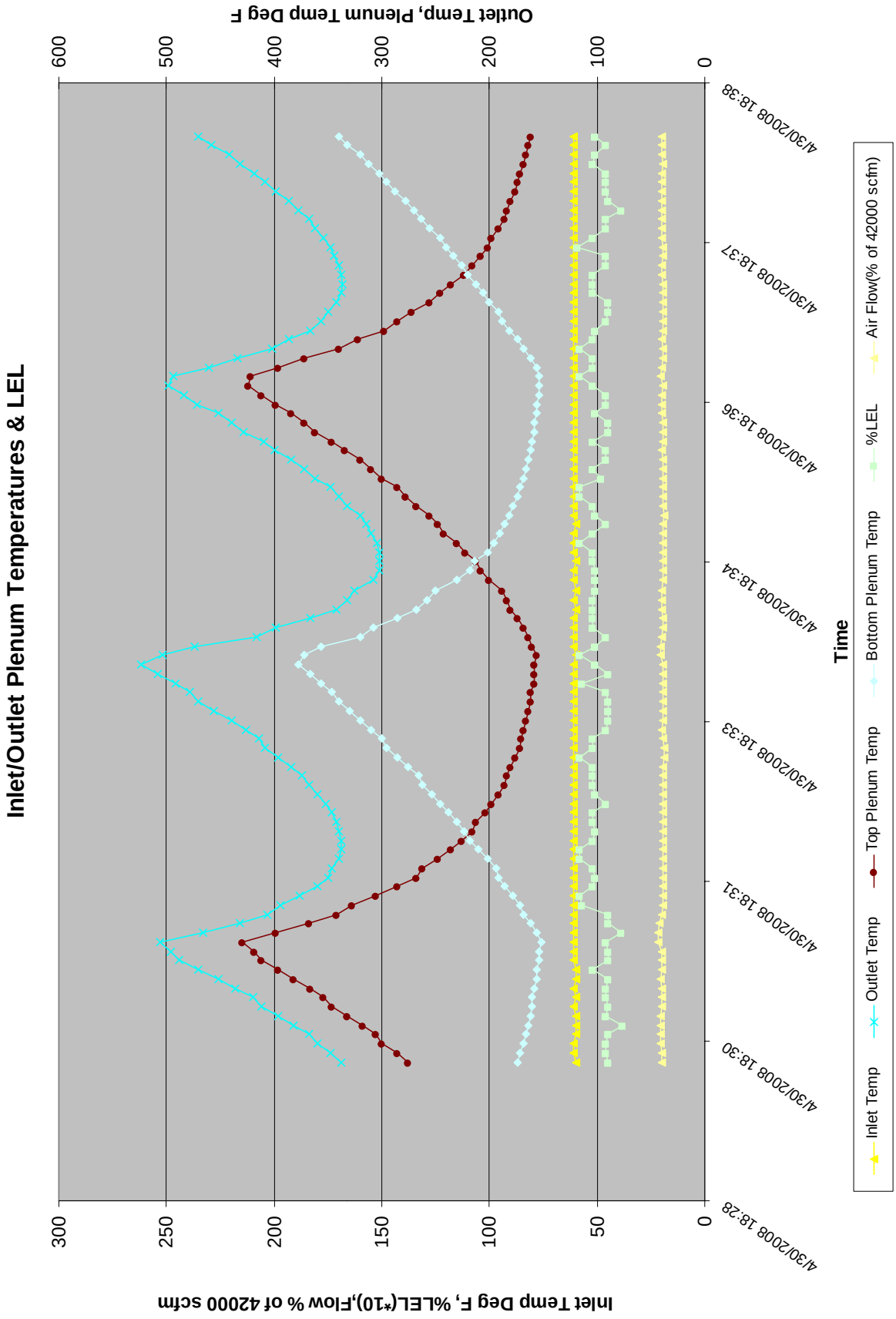
Each graph represents the total duration of the test with each half-hour sampling period labeled. The graphs show the VOCSIDIZER operation was very stable over the testing periods. For more explanation of what information can be interpreted from the graphs refer to the Performance of Equipment Section.

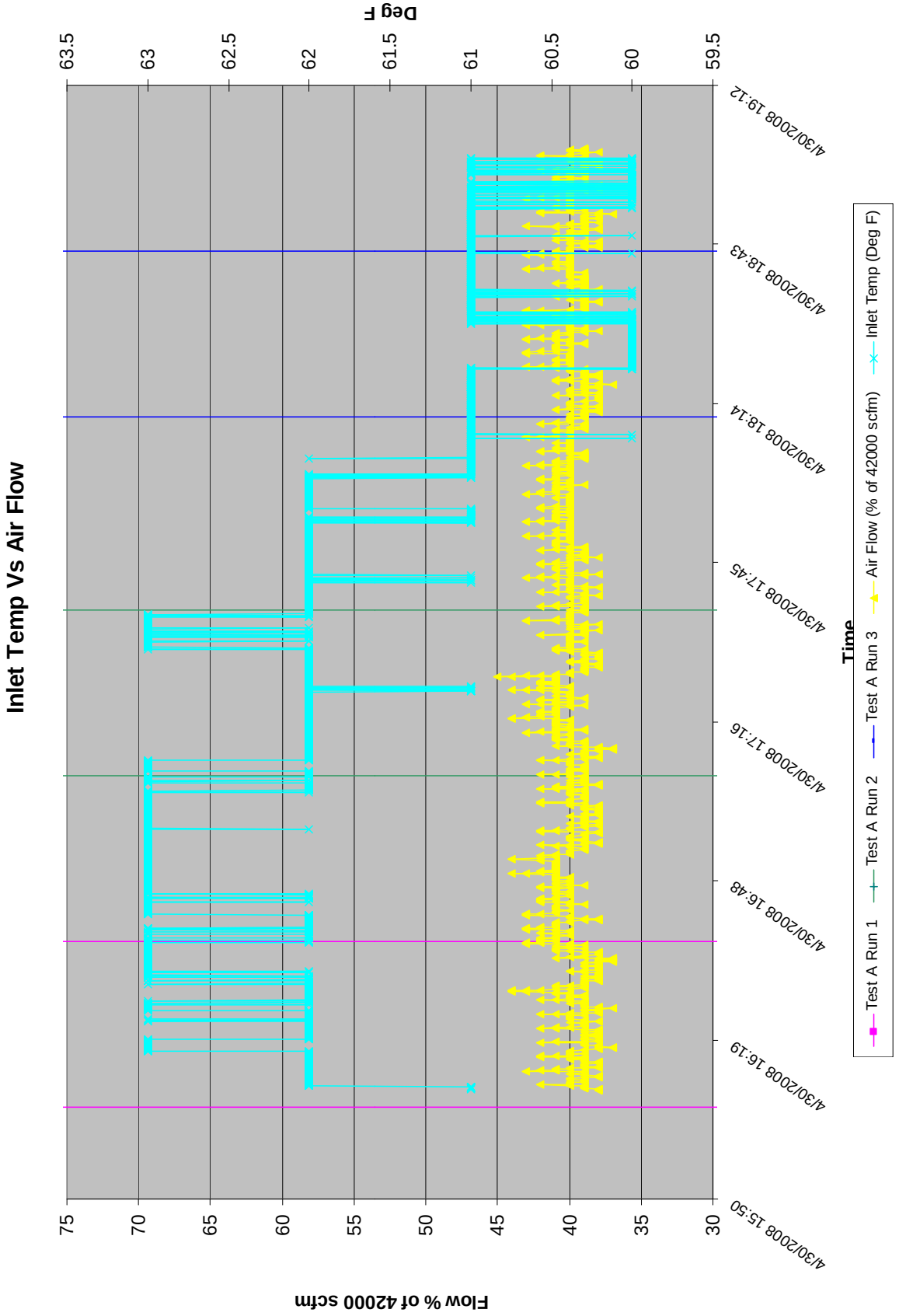
VOCSIDIZER Parametric Tests
Phase II
Test A
April 30, 2008
Run 1 - 4:07 PM to 4:37 PM
Run 2 - 5:07 PM to 5:37 PM
Run 3 - 6:12 PM to 6:42 PM

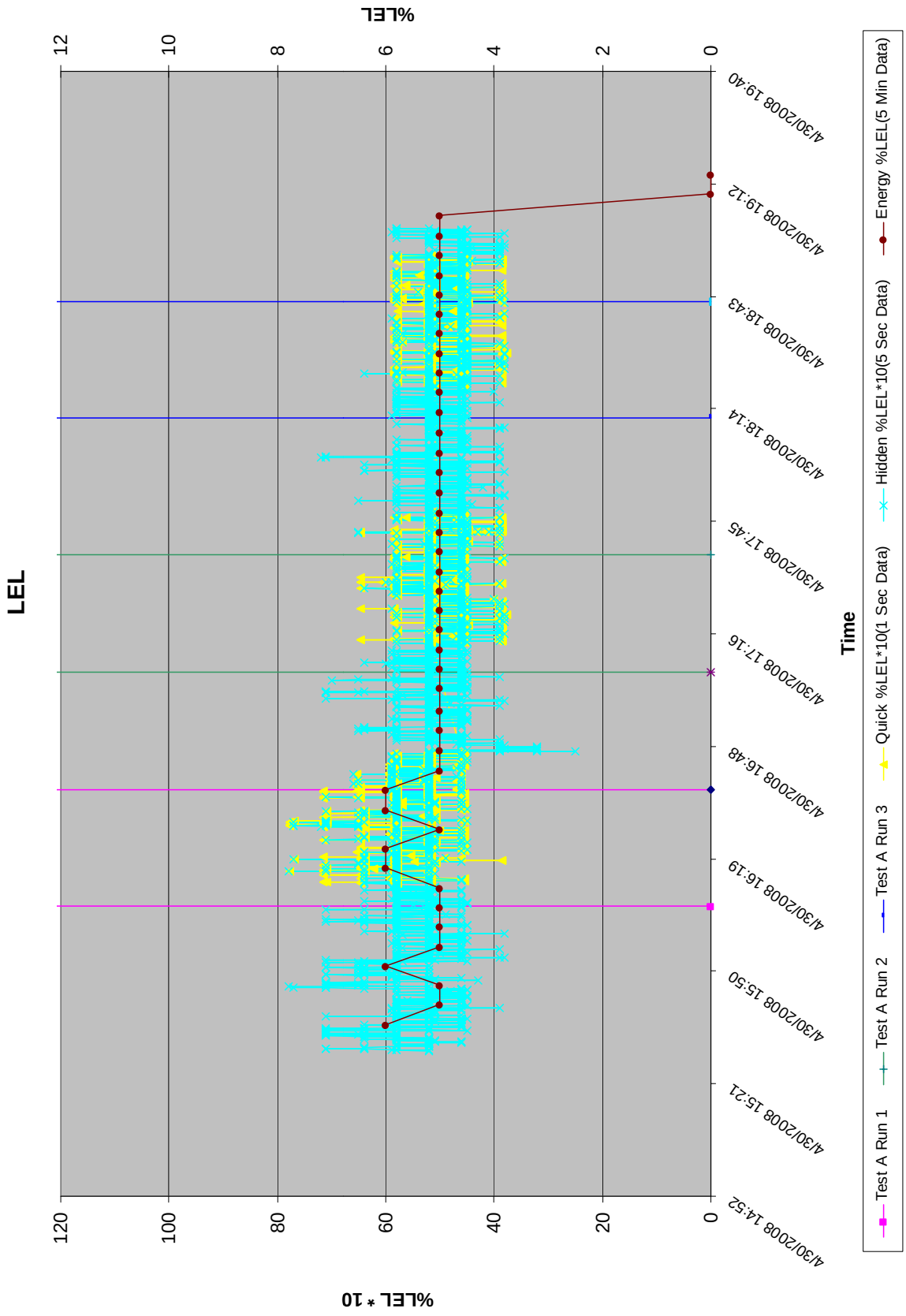

Bed Temperature
Deg. F
2200
2000
1800
1600
1400
1200
1000
4/30/2008 14:52
4/30/2008 15:21
4/30/2008 15:50
4/30/2008 16:19
4/30/2008 16:48
4/30/2008 17:16
4/30/2008 17:45
4/30/2008 18:14
4/30/2008 18:43
4/30/2008 19:12
4/30/2008 19:40
4/30/2008 20:09
Time
Test A Run 1
Test A Run 2
Test A Run 3
TE101
TE104
TE111A
TE111B
TE111C
TE111D


Mine Gas Flow, LEL, Air Flow, Bed DP
SCFM
%LEL, DP "WC
250
200
150
100
50
0
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
4/30/2008 14:24
4/30/2008 14:52
4/30/2008 15:21
4/30/2008 15:50
4/30/2008 16:19
4/30/2008 16:48
4/30/2008 17:16
4/30/2008 17:45
4/30/2008 18:14
4/30/2008 18:43
4/30/2008 19:12
Time
Test A Run 1
Test A Run 2
Test A Run 3
Air Flow(/100 scfm)
Gas Flow (scfm)
DP Ref
% LEL

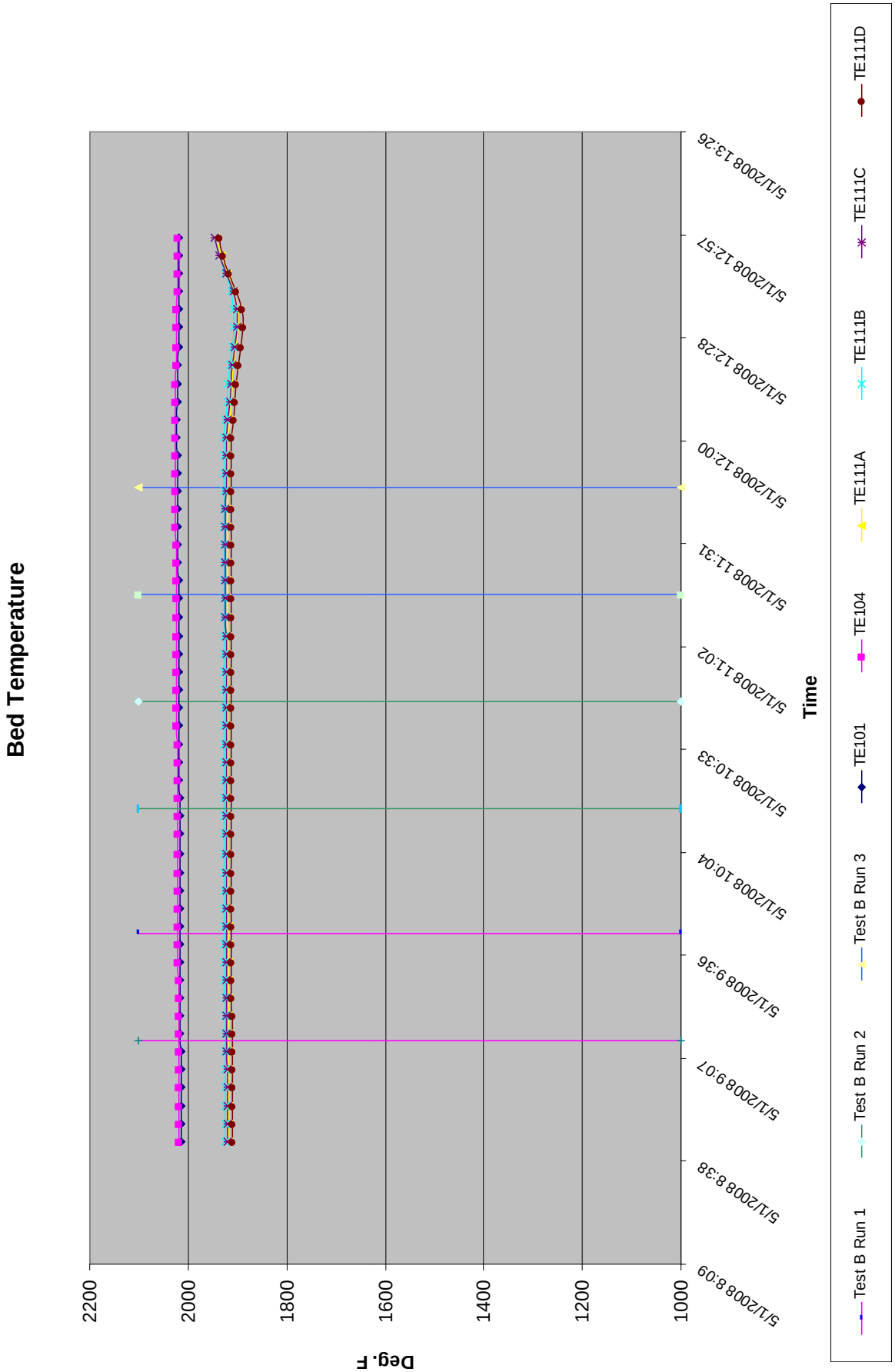

Inlet and Outlet Temp
Inlet Temp Deg F
Outlet Temp Deg F
100
90
80
70
60
50
40
30
20
10
0
300
250
200
150
100
50
0
4/30/2008 15:50
4/30/2008 16:19
4/30/2008 16:48
4/30/2008 17:16
4/30/2008 17:45
4/30/2008 18:14
4/30/2008 18:43
4/30/2008 19:12
Time
Test A Run 1
Test A Run 2
Test A Run 3
Inlet Temp
OutLet Temp

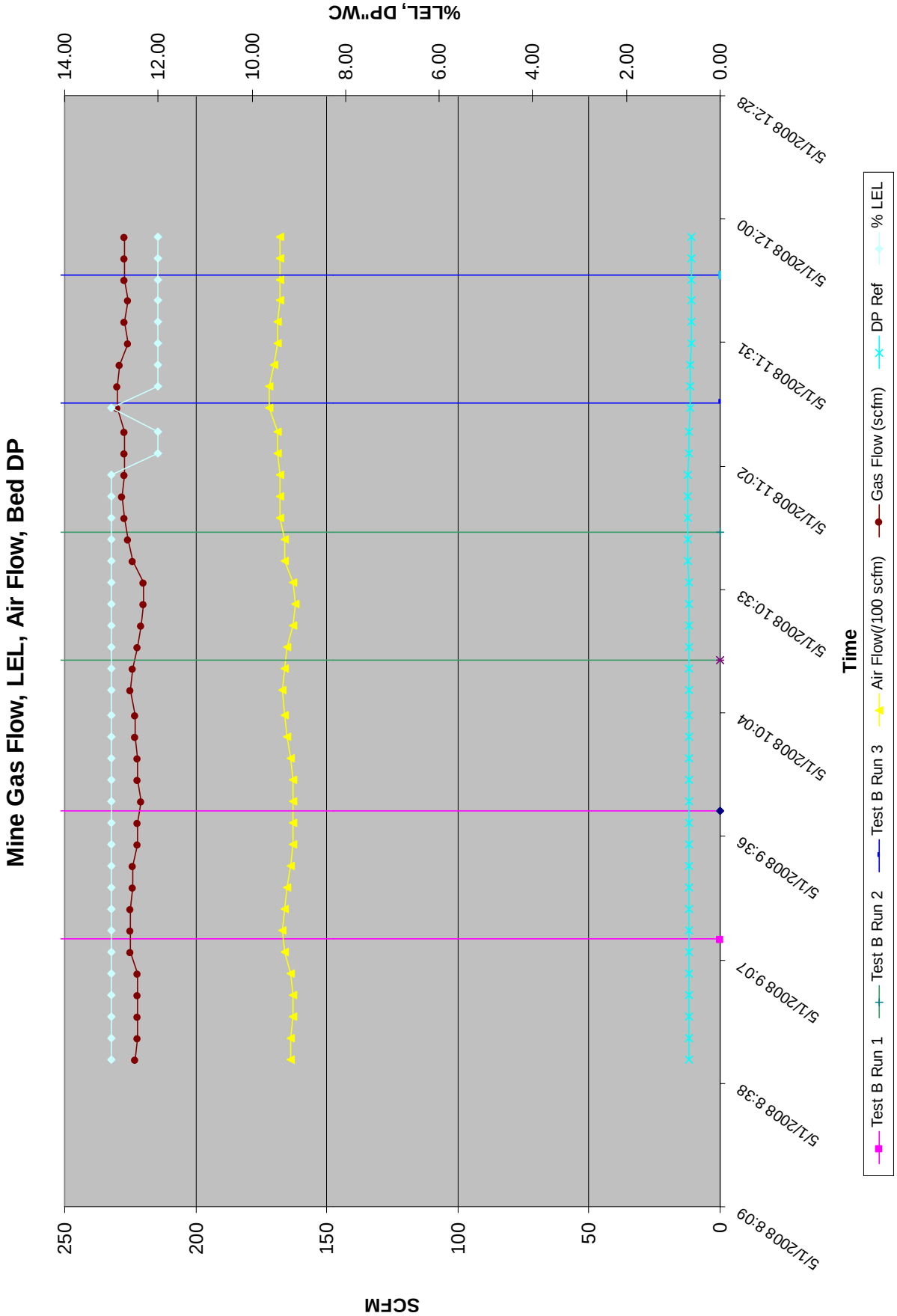

Inlet/Outlet Plenum Temperatures & LEL
Inlet Temp Deg F, %LEL(*10),Flow % of 42000 scfm
Outlet Temp, Plenum Temp Deg F
300
250
200
150
100
50
0
600
500
400
300
200
100
0
4/30/2008 18:28
4/30/2008 18:30
4/30/2008 18:31
4/30/2008 18:33
4/30/2008 18:34
4/30/2008 18:36
4/30/2008 18:37
4/30/2008 18:38
Time
Inlet Temp
Outlet Temp
Top Plenum Temp
Bottom Plenum Temp
%LEL
Air Flow(% of 42000 scfm)

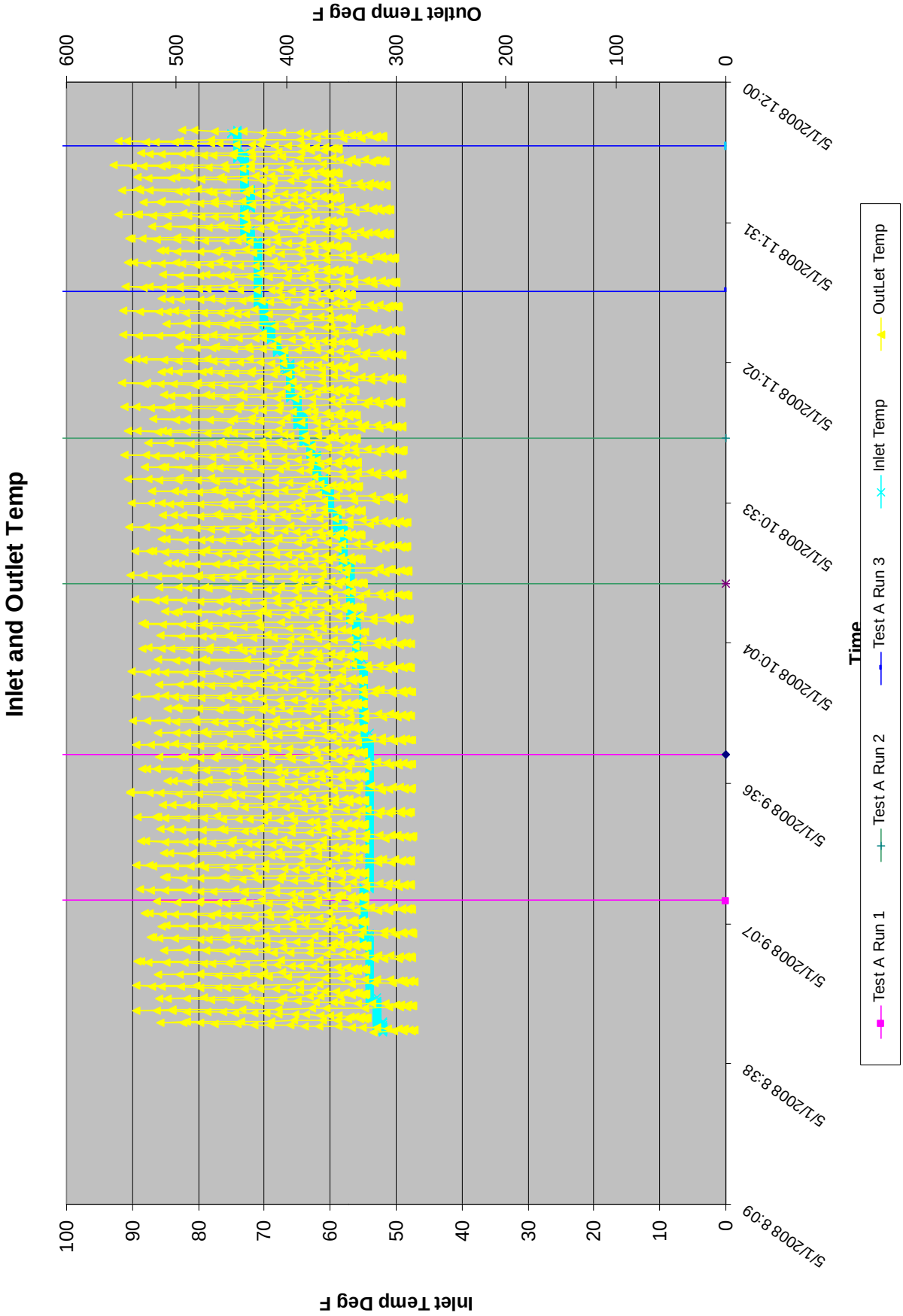

Inlet Temp Vs Air Flow
Flow % of 42000 scfm
Deg F
75
70
65
60
55
50
45
40
35
30
63.5
63
62.5
62
61.5
61
60.5
60
59.5
4/30/2008 15:50
4/30/2008 16:19
4/30/2008 16:48
4/30/2008 17:16
4/30/2008 17:45
4/30/2008 18:14
4/30/2008 18:43
4/30/2008 19:12
Time
Test A Run 1
Test A Run 2
Test A Run 3
Air Flow (% of 42000 scfm)
Inlet Temp (Deg F)

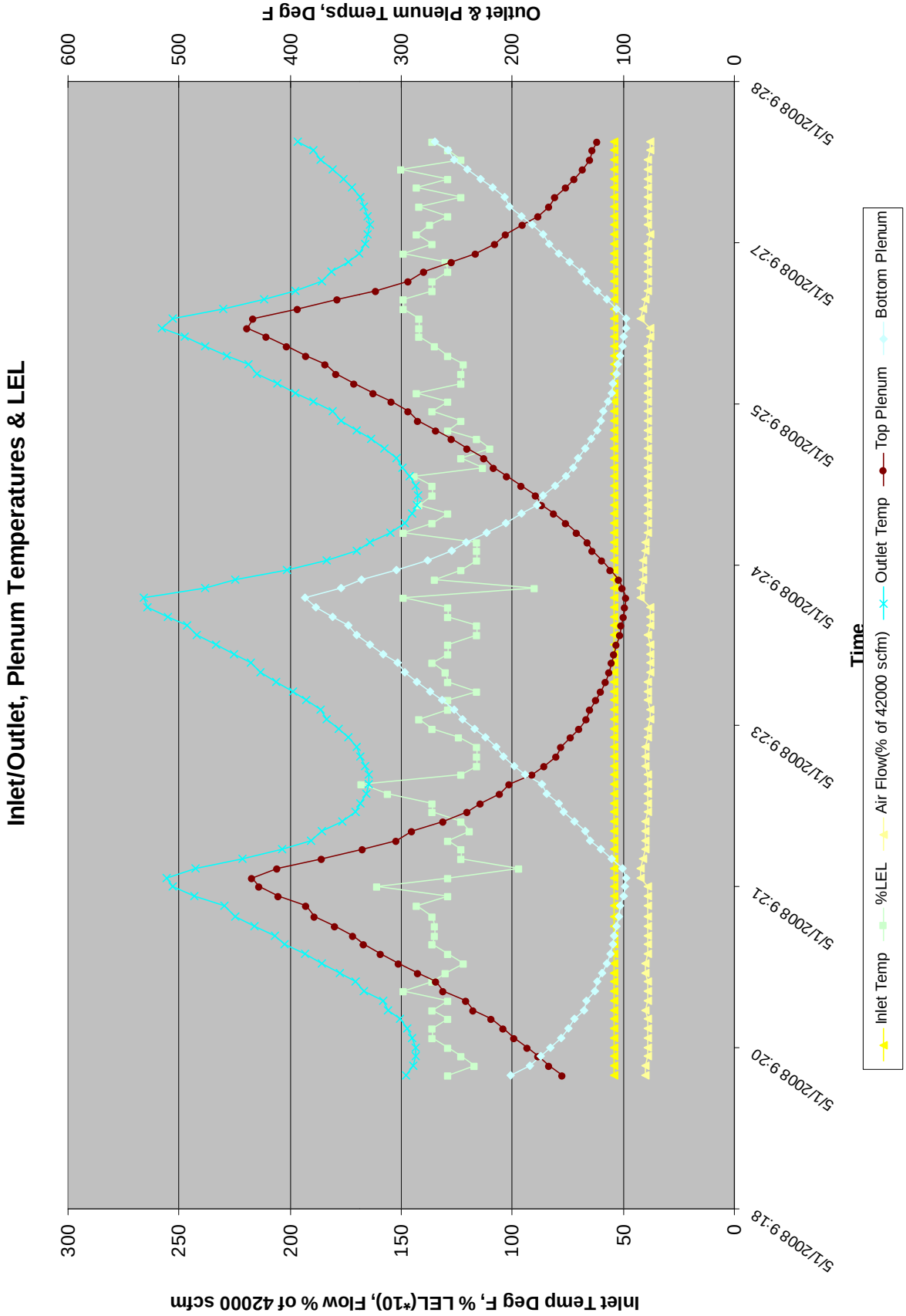

LEL
%LEL
%LEL * 10
Time
120
100
80
60
40
20
0
12
10
8
6
4
2
0
4/30/2008 14:52
4/30/2008 15:21
4/30/2008 15:50
4/30/2008 16:19
4/30/2008 16:48
4/30/2008 17:16
4/30/2008 17:45
4/30/2008 18:14
4/30/2008 18:43
4/30/2008 19:12
4/30/2008 19:40
Test A Run 1
Test A Run 2
Test A Run 3
Quick %LEL*10(1 Sec Data)
Hidden %LEL*10(5 Sec Data)
Energy %LEL(5 Min Data)

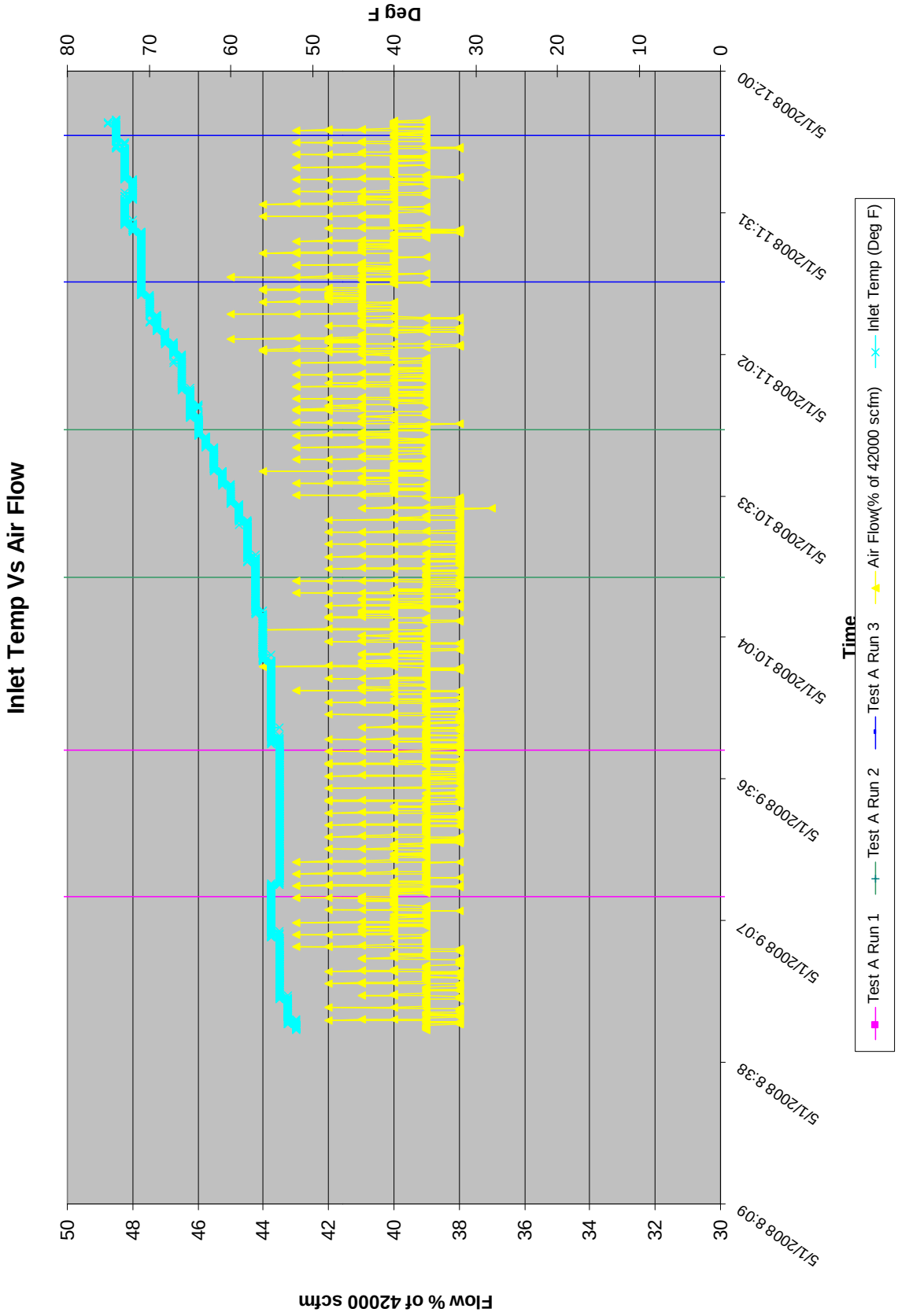
VOCSIDIZER Parametric Tests
Phase II
Test B
May 1, 2008
Run 1 - 9:12 AM to 9:42 AM
Run 2 - 10:17 AM to 10:47 AM
Run 3 – 11:17 AM to 11:47 AM

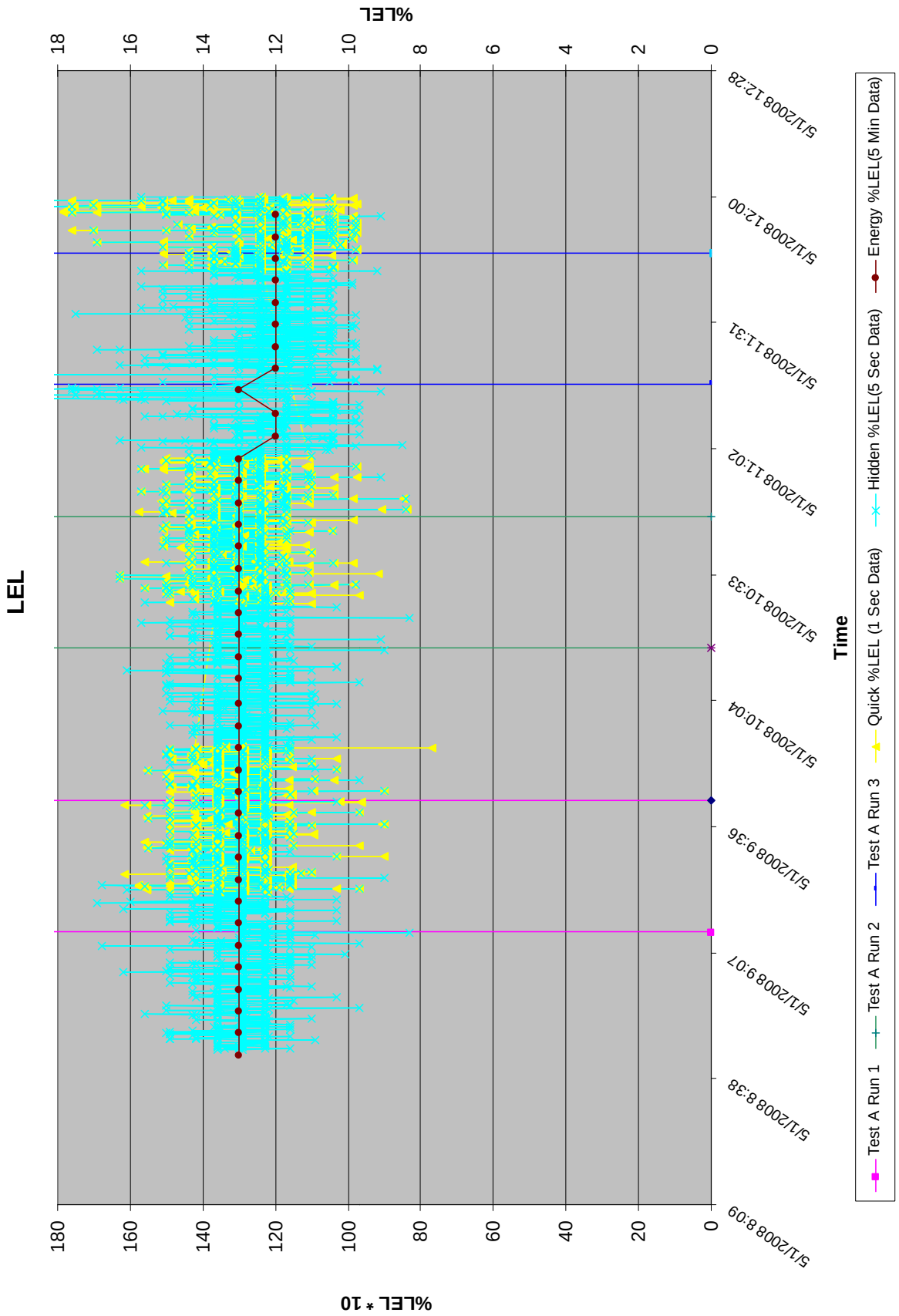

Bed Temperature
Deg. F
2200
2000
1800
1600
1400
1200
1000
5/1/2008 8:09
5/1/2008 8:38
5/1/2008 9:07
5/1/2008 9:36
5/1/2008 10:04
5/1/2008 10:33
5/1/2008 11:02
5/1/2008 11:31
5/1/2008 12:00
5/1/2008 12:28
5/1/2008 12:57
5/1/2008 13:26
Time
Test B Run 1
Test B Run 2
Test B Run 3
TE101
TE104
TE111A
TE111B
TE111C
TE111D


Mine Gas Flow, LEL, Air Flow, Bed DP
SCFM
%LEL, DP"WC
250
200
150
100
50
0
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
5/1/2008 8:09
5/1/2008 8:38
5/1/2008 9:07
5/1/2008 9:36
5/1/2008 10:04
5/1/2008 10:33
5/1/2008 11:02
5/1/2008 11:31
5/1/2008 12:00
5/1/2008 12:28
Time
Test B Run 1
Test B Run 2
Test B Run 3
Air Flow(/100 scfm)
Gas Flow (scfm)
DP Ref
% LEL

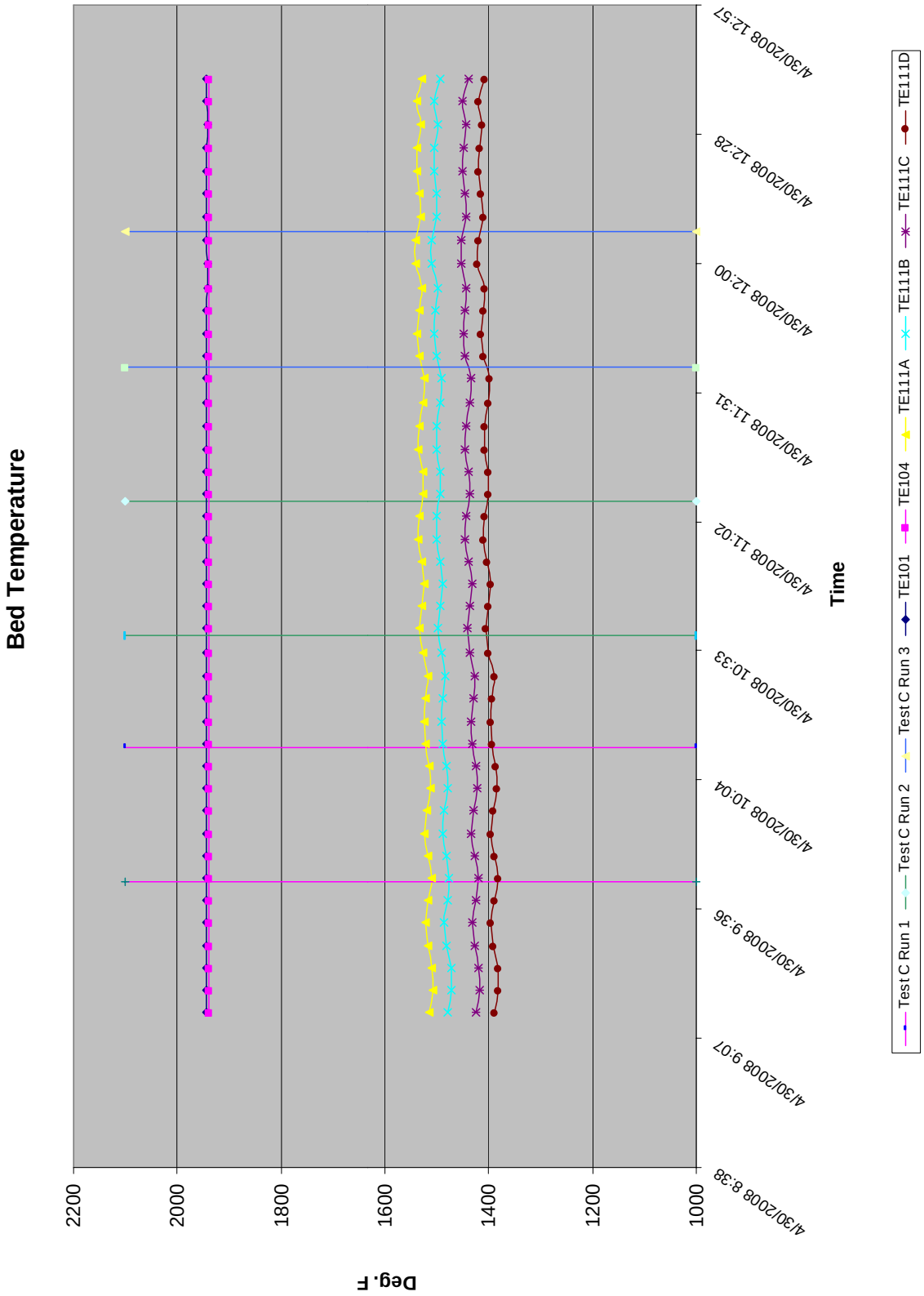

Inlet and Outlet Temp
Inlet Temp Deg F
Outlet Temp Deg F
100
90
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
5/1/2008 8:09
5/1/2008 8:38
5/1/2008 9:07
5/1/2008 9:36
5/1/2008 10:04
5/1/2008 10:33
5/1/2008 11:02
5/1/2008 11:31
5/1/2008 12:00
Time
Test A Run 1
Test A Run 2
Test A Run 3
Inlet Temp
OutLet Temp

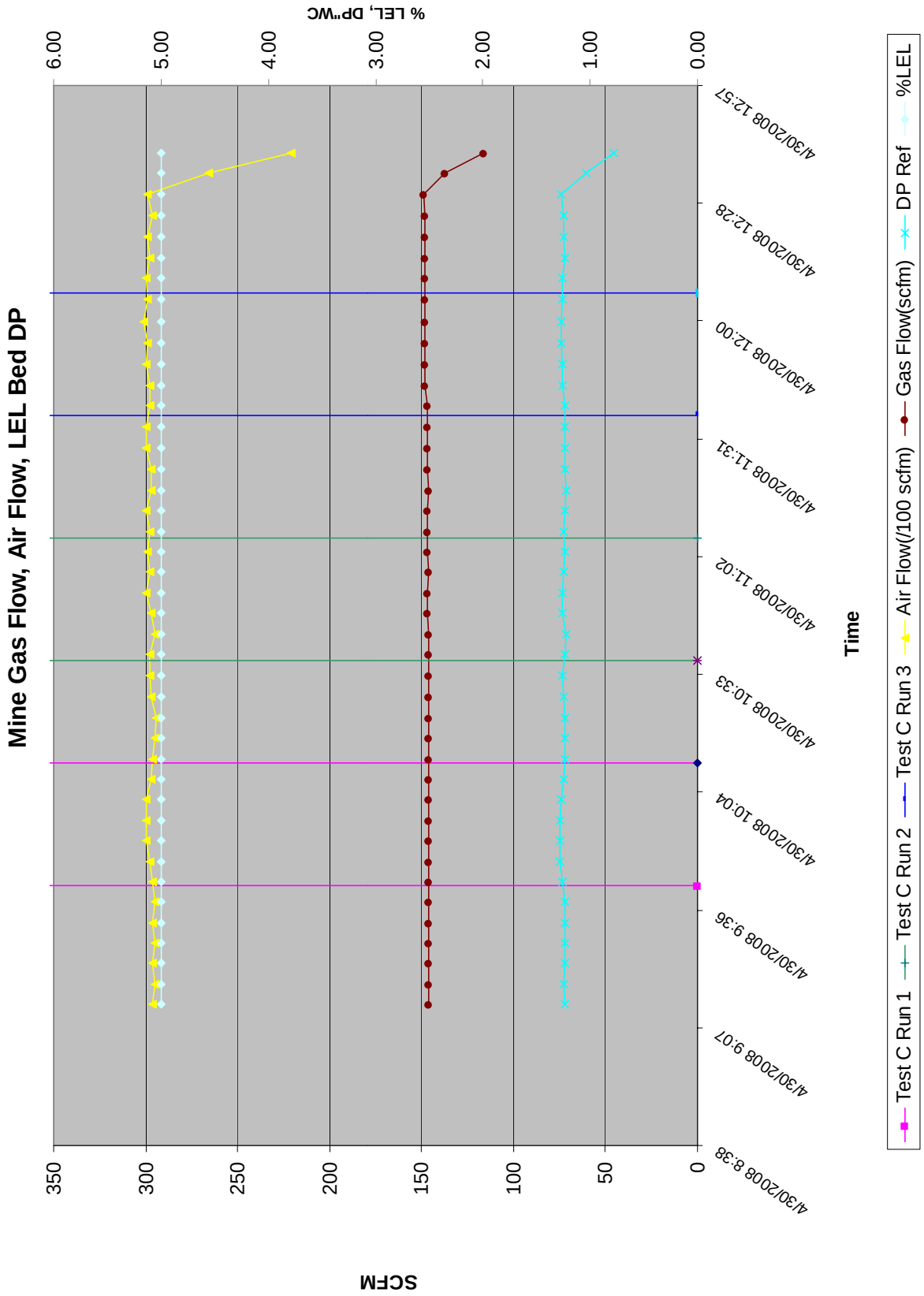

Inlet/Outlet, Plenum Temperatures & LEL
Inlet Temp Deg F, % LEL(*10), Flow % of 42000 scfm
Outlet & Plenum Temps, Deg F
300
250
200
150
100
50
0
600
500
400
300
200
100
0
5/1/2008 9:18
5/1/2008 9:20
5/1/2008 9:21
5/1/2008 9:23
5/1/2008 9:24
5/1/2008 9:25
5/1/2008 9:27
5/1/2008 9:28
Time
Inlet Temp
%LEL
Air Flow(% of 42000 scfm)
Outlet Temp
Top Plenum
Bottom Plenum

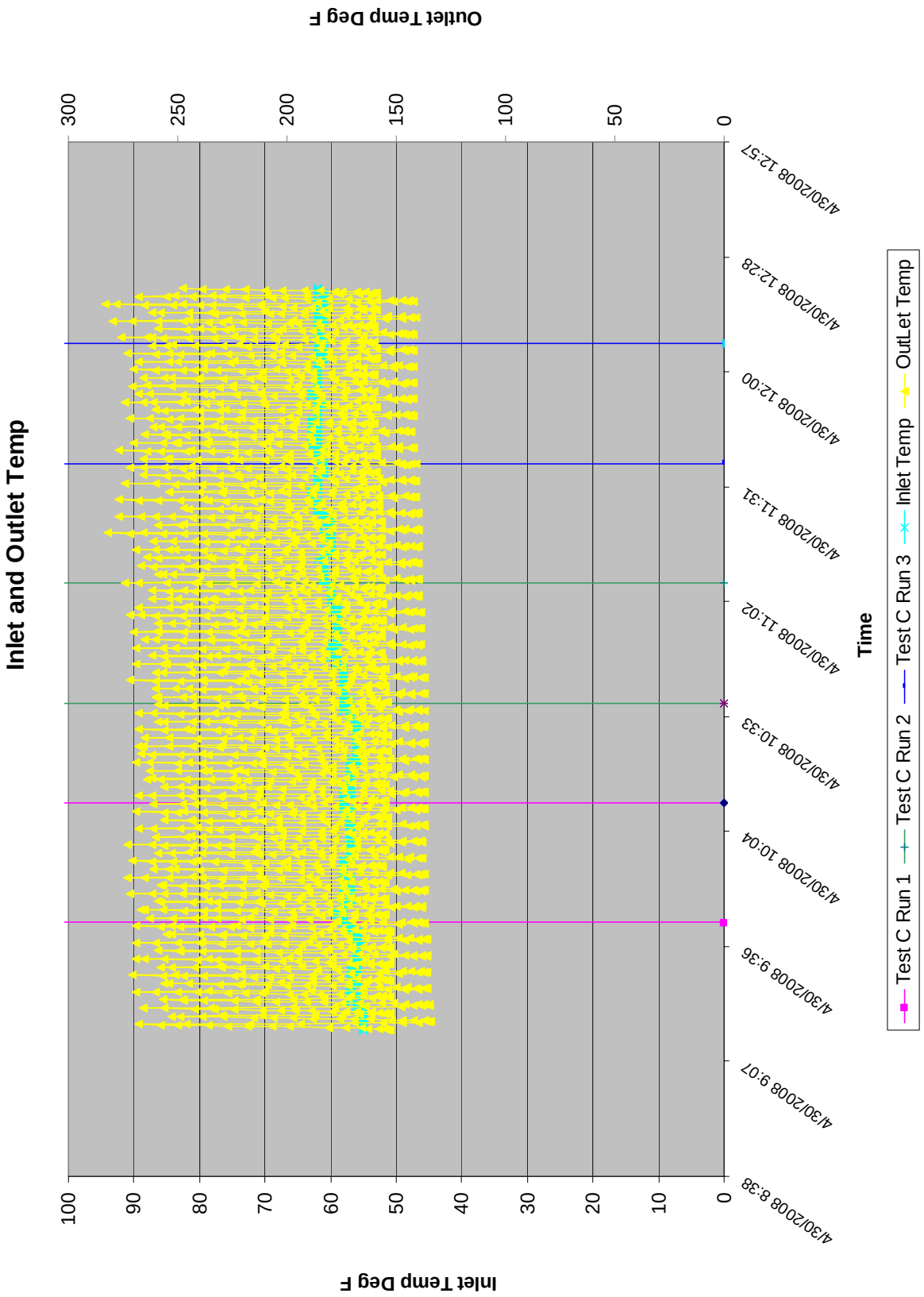

Inlet Temp Vs Air Flow
Flow % of 42000 scfm
Deg F
50
48
46
44
42
40
38
36
34
32
30
80
70
60
50
40
30
20
10
0
5/1/2008 8:09
5/1/2008 8:38
5/1/2008 9:07
5/1/2008 9:36
5/1/2008 10:04
5/1/2008 10:33
5/1/2008 11:02
5/1/2008 11:31
5/1/2008 12:00
Time
Test A Run 1
Test A Run 2
Test A Run 3
Air Flow(% of 42000 scfm)
Inlet Temp (Deg F)

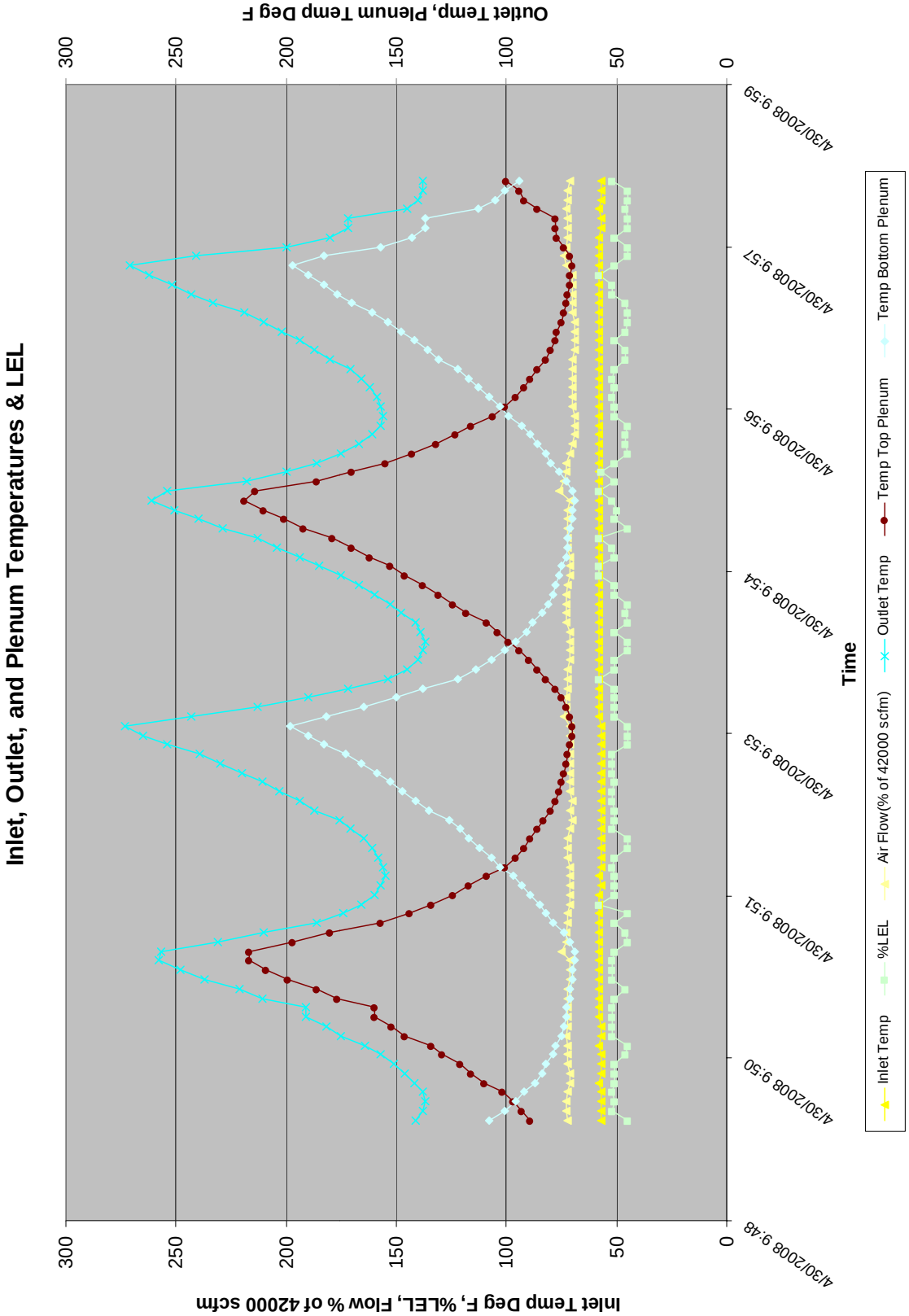

LEL
%LEL * 10
%LEL
Time
0
20
40
60
80
100
120
140
160
180
0
2
4
6
8
10
12
14
16
18
5/1/2008 8:09
5/1/2008 8:38
5/1/2008 9:07
5/1/2008 9:36
5/1/2008 10:04
5/1/2008 10:33
5/1/2008 11:02
5/1/2008 11:31
5/1/2008 12:00
5/1/2008 12:28
Test A Run 1
Test A Run 2
Test A Run 3
Quick %LEL (1 Sec Data)
Hidden %LEL(5 Sec Data)
Energy %LEL(5 Min Data)

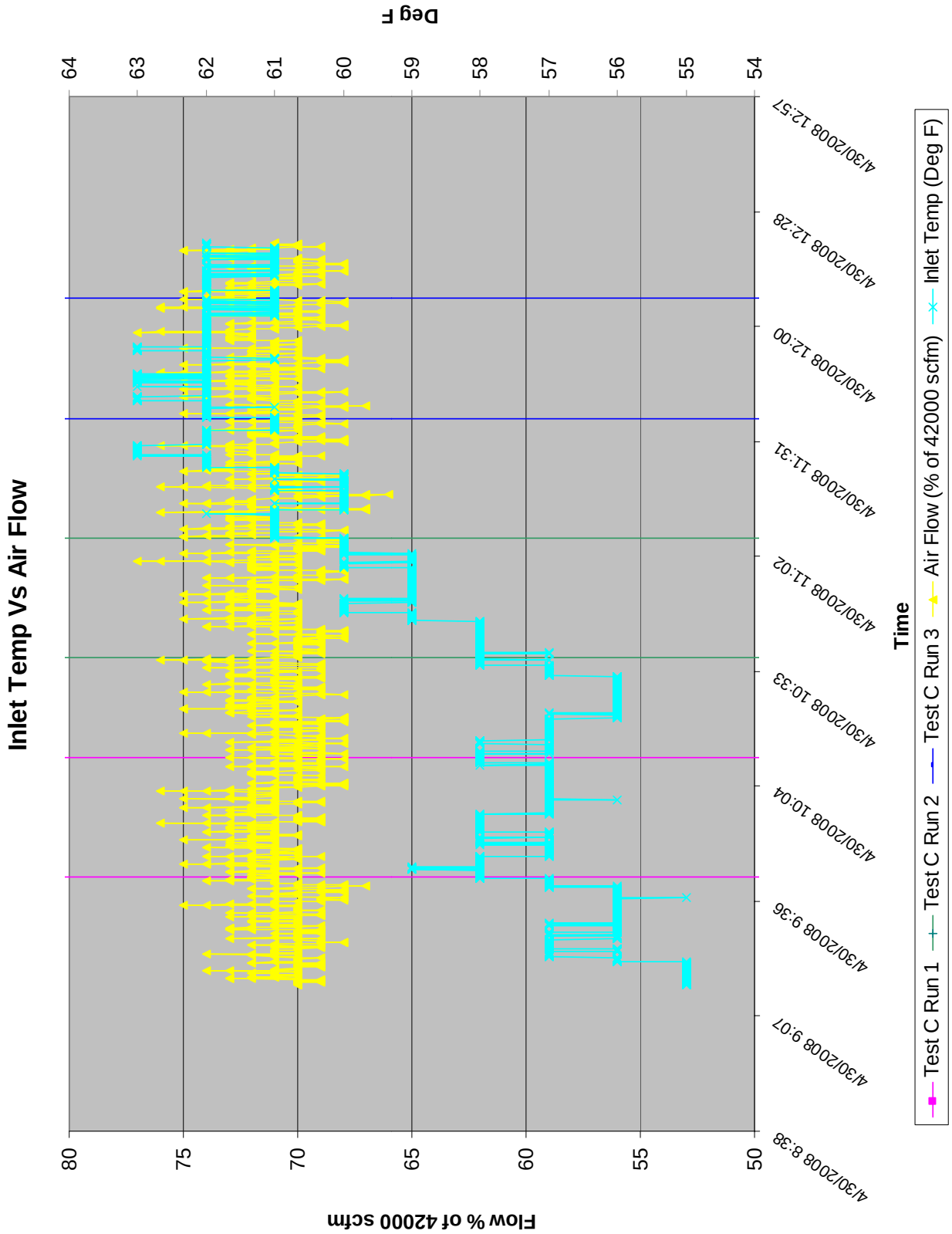
VOCSIDIZER Parametric Tests
Phase II
Test C
April 30, 2008
Run 1 - 9:42 AM to 10:12 AM
Run 2 - 10:37 AM to 11:07 AM
Run 3 – 11:37 AM to 12:07 PM

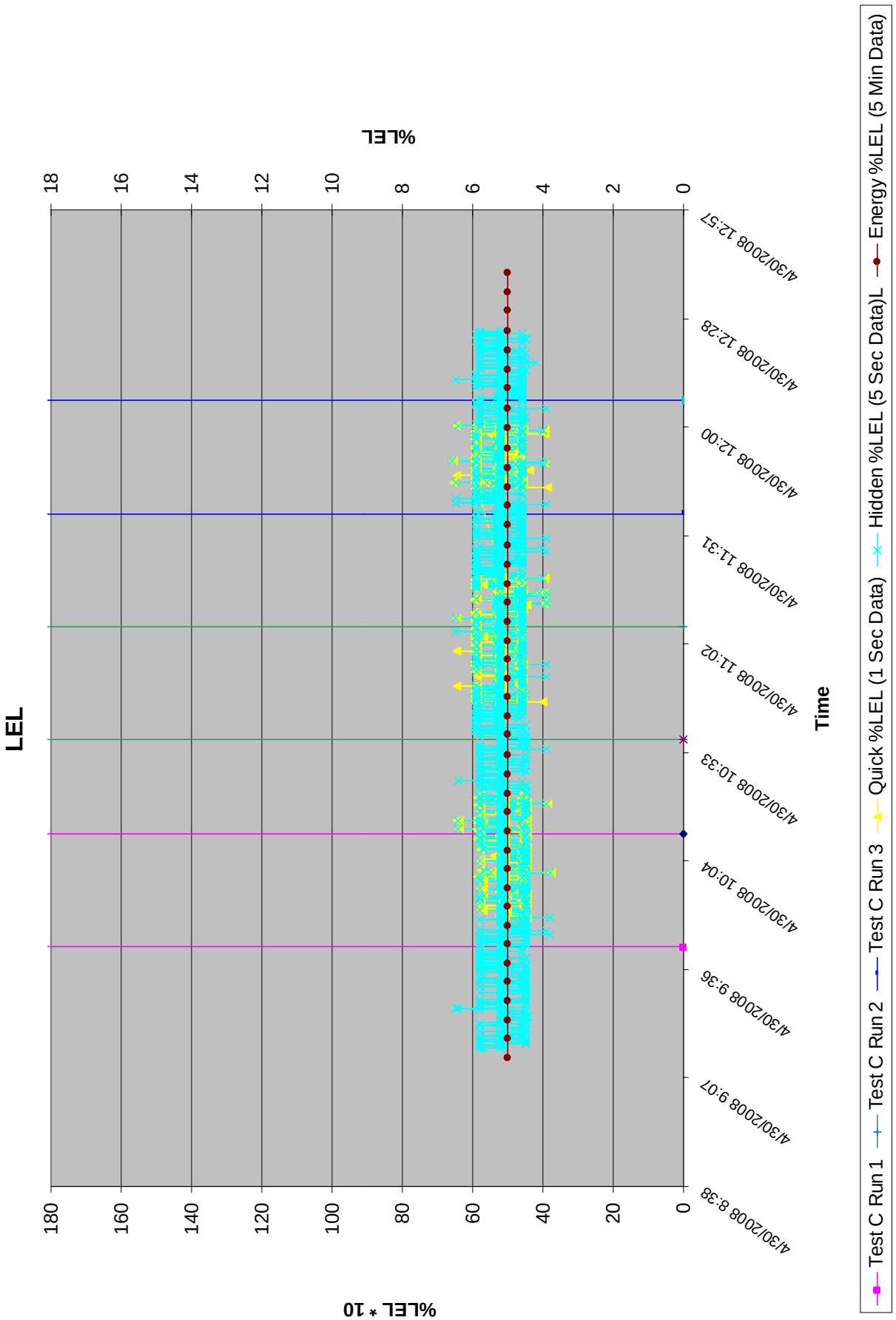

Bed Temperature
Deg. F
2200
2000
1800
1600
1400
1200
1000
4/30/2008 8:38
4/30/2008 9:07
4/30/2008 9:36
4/30/2008 10:04
4/30/2008 10:33
4/30/2008 11:02
4/30/2008 11:31
4/30/2008 12:00
4/30/2008 12:28
4/30/2008 12:57
Time
Test C Run 1
Test C Run 2
Test C Run 3
TE101
TE104
TE111A
TE111B
TE111C
TE111D


Mine Gas Flow, Air Flow, LEL Bed DP
SCFM
% LEL, DP"WC
Time
350
300
250
200
150
100
50
0
6.00
5.00
4.00
3.00
2.00
1.00
0.00
4/30/2008 8:38
4/30/2008 9:07
4/30/2008 9:36
4/30/2008 10:04
4/30/2008 10:33
4/30/2008 11:02
4/30/2008 11:31
4/30/2008 12:00
4/30/2008 12:28
4/30/2008 12:57
Test C Run 1
Test C Run 2
Test C Run 3
Air Flow(/100 scfm)
Gas Flow(scfm)
DP Ref
%LEL

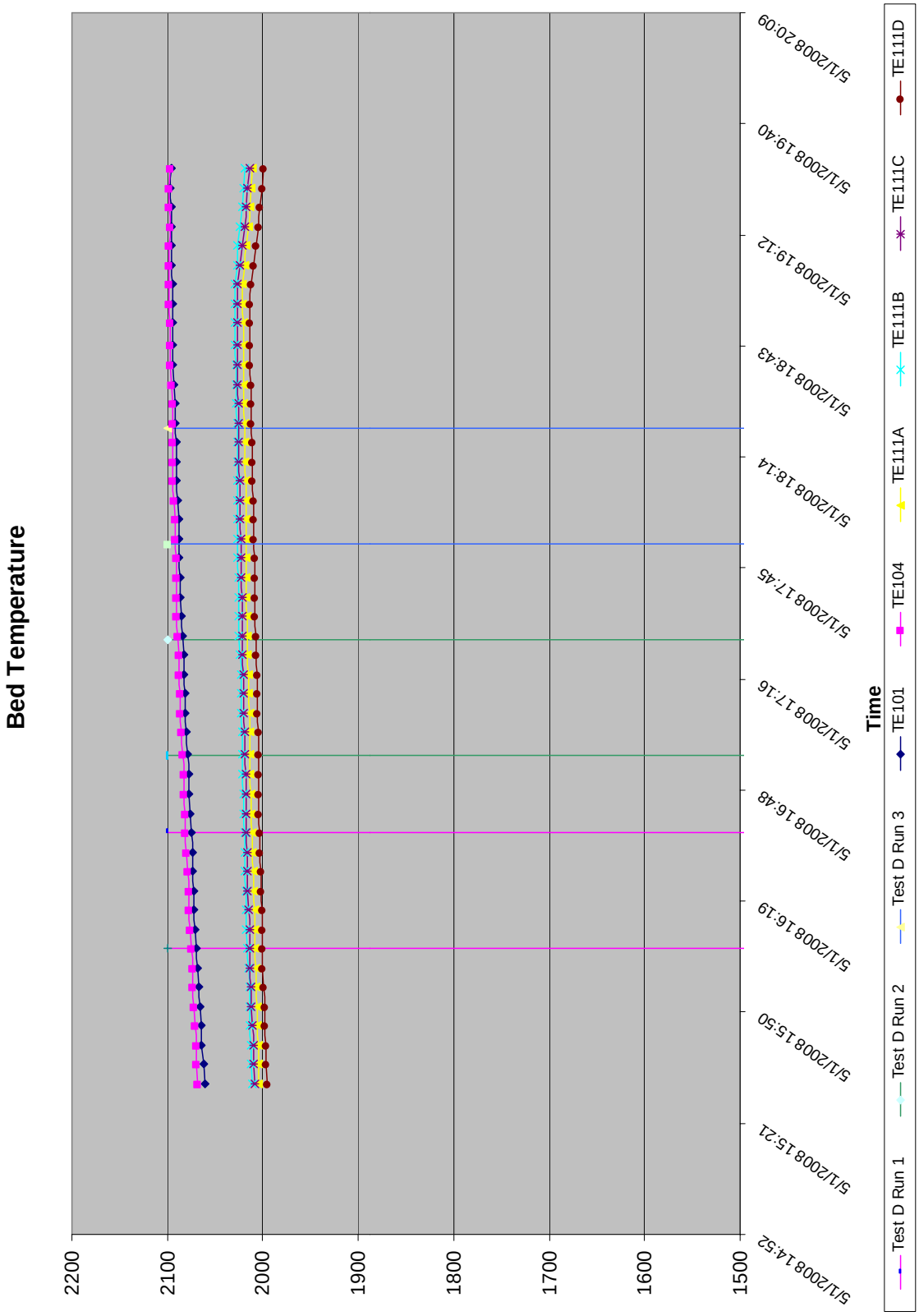

Inlet and Outlet Temp
Inlet Temp Deg F
Outlet Temp Deg F
100
90
80
70
60
50
40
30
20
10
0
300
250
200
150
100
50
0
4/30/2008 8:38
4/30/2008 9:07
4/30/2008 9:36
4/30/2008 10:04
4/30/2008 10:33
4/30/2008 11:02
4/30/2008 11:31
4/30/2008 12:00
4/30/2008 12:28
4/30/2008 12:57
Time
Test C Run 1
Test C Run 2
Test C Run 3
Inlet Temp
OutLet Temp

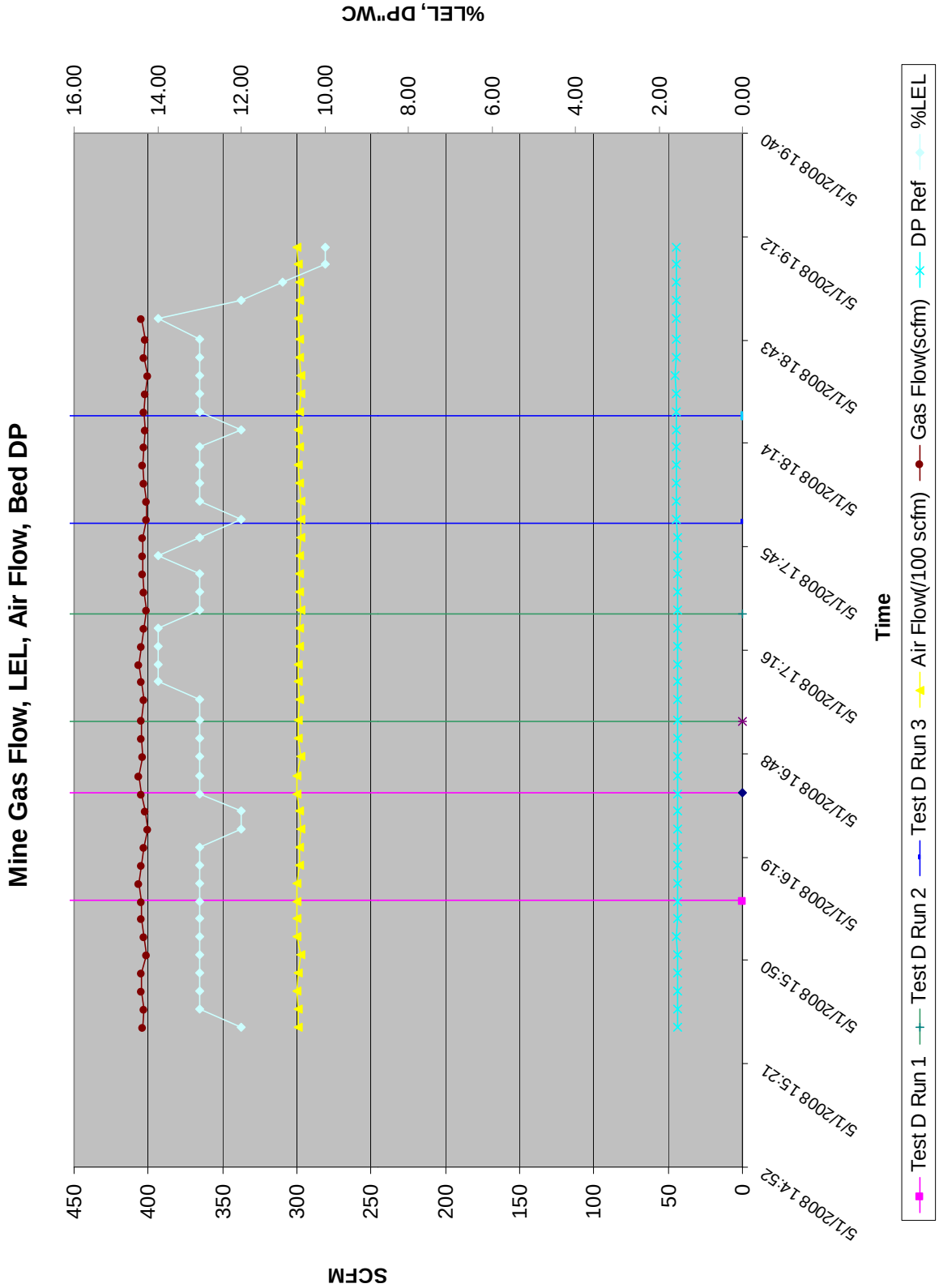

Inlet, Outlet, and Plenum Temperatures & LEL
Inlet Temp Deg F, %LEL, Flow % of 42000 scfm
Outlet Temp, Plenum Temp Deg F
300
250
200
150
100
50
0
4/30/2008 9:48
4/30/2008 9:50
4/30/2008 9:51
4/30/2008 9:53
4/30/2008 9:54
4/30/2008 9:56
4/30/2008 9:57
4/30/2008 9:59
Time
Inlet Temp
%LEL
Air Flow(% of 42000 scfm)
Outlet Temp
Temp Top Plenum
Temp Bottom Plenum

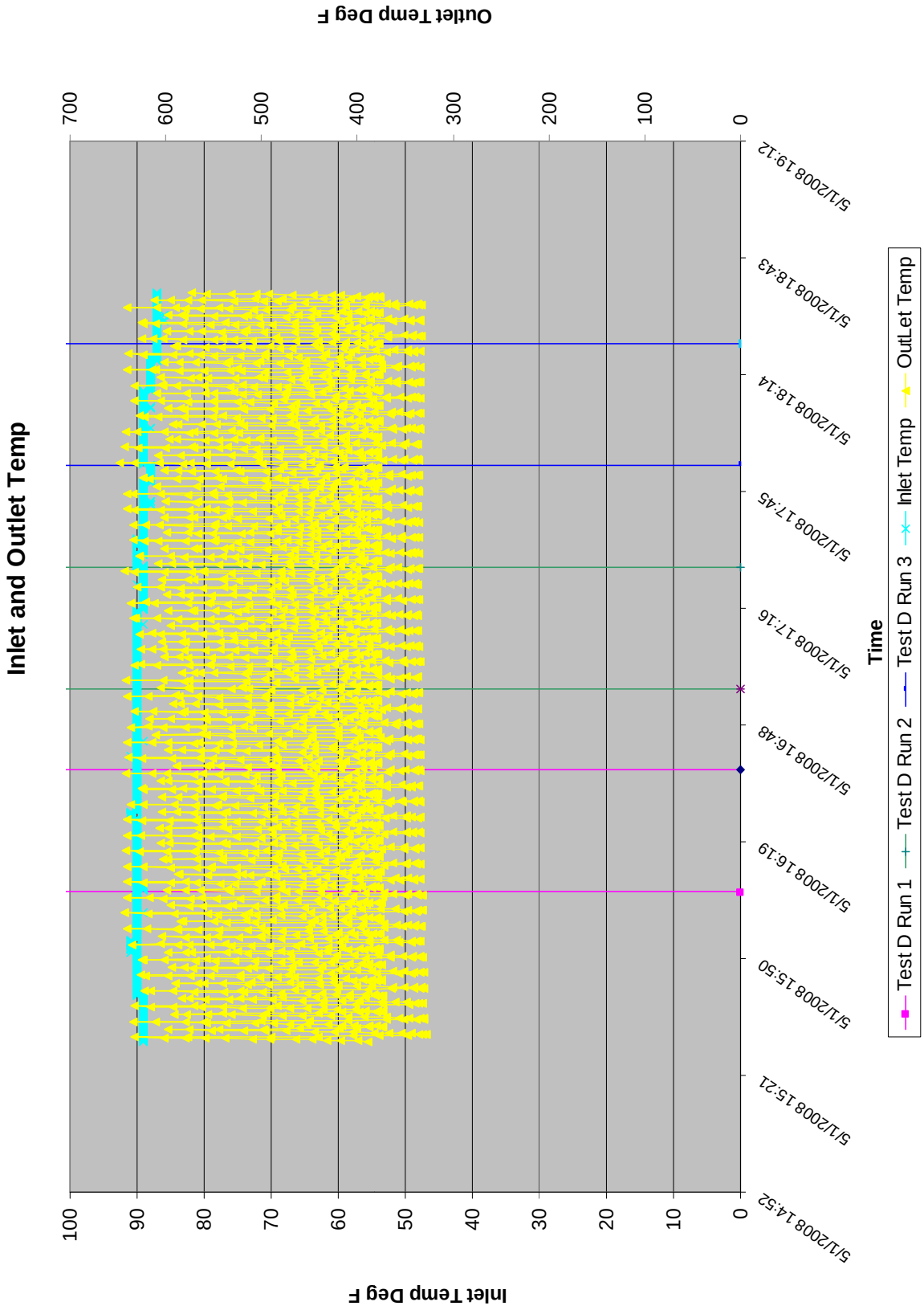

Inlet Temp Vs Air Flow
Flow % of 42000 scfm
Deg F
80
75
70
65
60
55
50
64
63
62
61
60
59
58
57
56
55
54
4/30/2008 8:38
4/30/2008 9:07
4/30/2008 9:36
4/30/2008 10:04
4/30/2008 10:33
4/30/2008 11:02
4/30/2008 11:31
4/30/2008 12:00
4/30/2008 12:28
4/30/2008 12:57
Time
Test C Run 1
Test C Run 2
Test C Run 3
Air Flow (% of 42000 scfm)
Inlet Temp (Deg F)

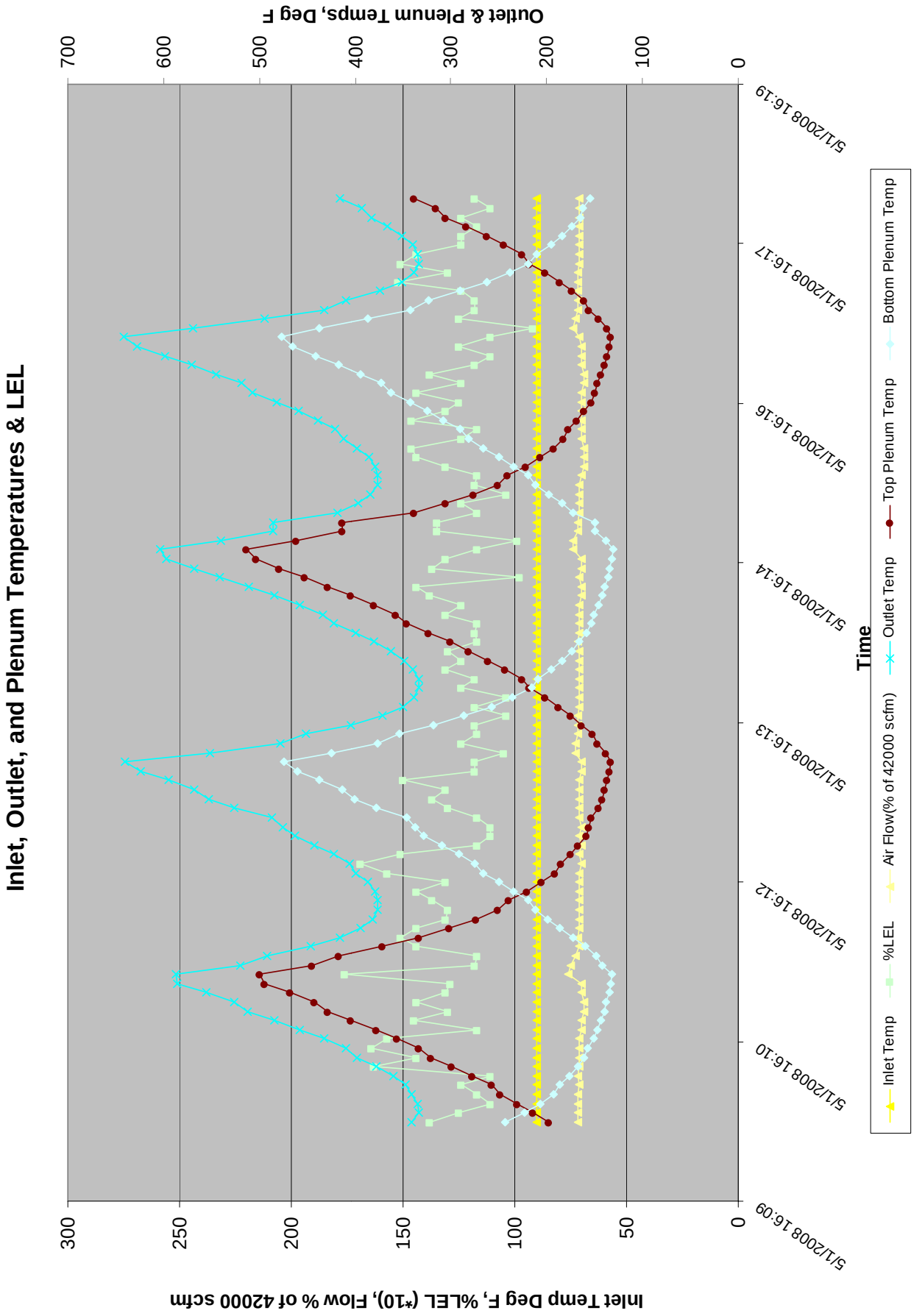

LEL
%LEL * 10
%LEL
Time
180
160
140
120
100
80
60
40
20
0
18
16
14
12
10
8
6
4
2
0
4/30/2008 8:38
4/30/2008 9:07
4/30/2008 9:36
4/30/2008 10:04
4/30/2008 10:33
4/30/2008 11:02
4/30/2008 11:31
4/30/2008 12:00
4/30/2008 12:28
4/30/2008 12:57
Test C Run 1
Test C Run 2
Test C Run 3
Quick %LEL (1 Sec Data)
Hidden %LEL (5 Sec Data)L
Energy %LEL (5 Min Data)

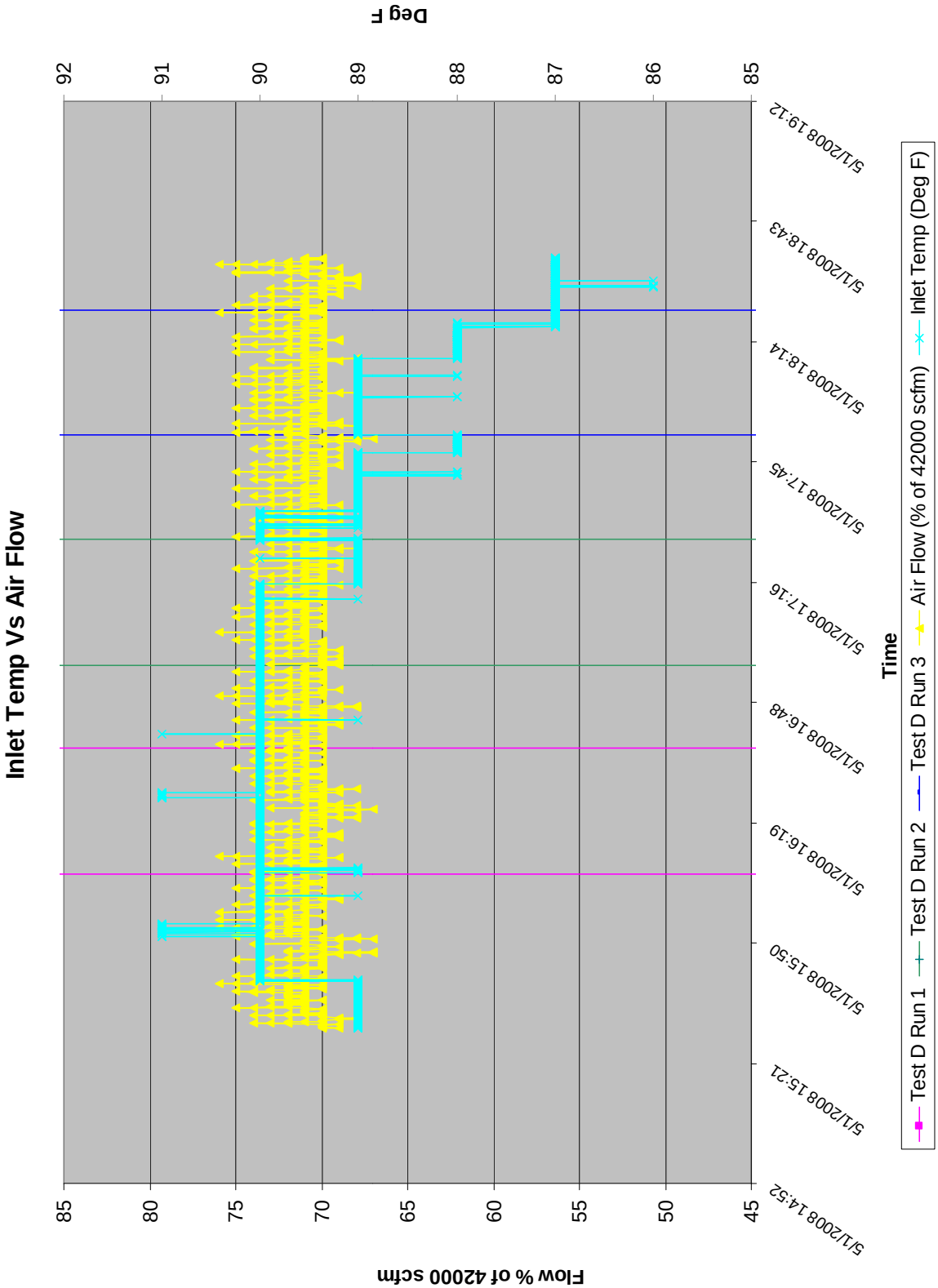
VOCSIDIZER Parametric Tests
Phase II
Test D
May 1, 2008
Run 1 – 4:07 PM to 4:37 PM
Run 2 - 4:57 PM to 5:27 PM
Run 3 – 5:52 PM to 6:22 PM

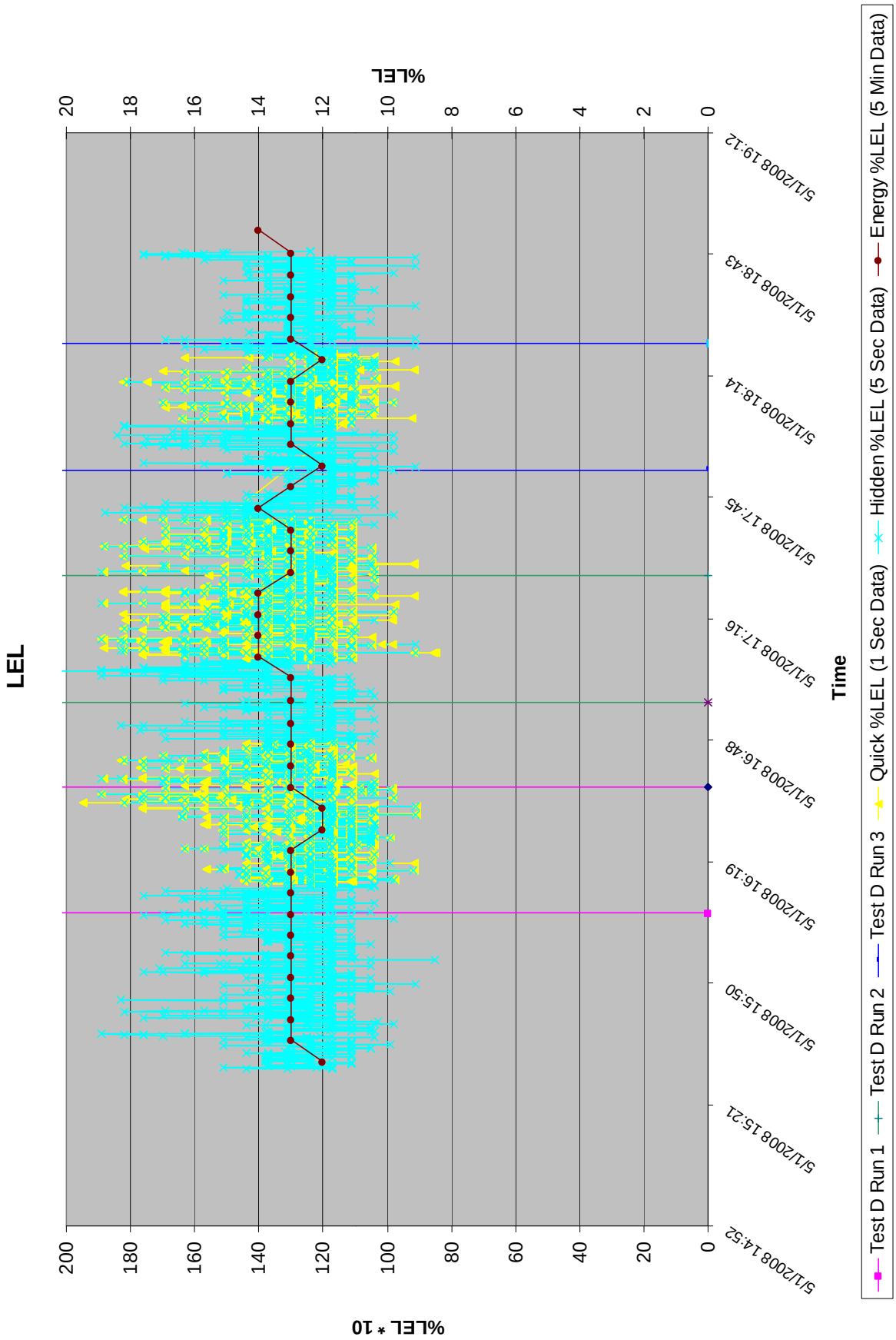

Bed Temperature
Deg. F
2200
2100
2000
1900
1800
1700
1600
1500
5/1/2008 14:52
5/1/2008 15:21
5/1/2008 15:50
5/1/2008 16:19
5/1/2008 16:48
5/1/2008 17:16
5/1/2008 17:45
5/1/2008 18:14
5/1/2008 18:43
5/1/2008 19:12
5/1/2008 19:40
5/1/2008 20:09
Time
Test D Run 1
Test D Run 2
Test D Run 3
TE101
TE104
TE111A
TE111B
TE111C
TE111D


Mine Gas Flow, LEL, Air Flow, Bed DP
SCFM
%LEL, DP"WC
450
400
350
300
250
200
150
100
50
0
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
5/1/2008 14:52
5/1/2008 15:21
5/1/2008 15:50
5/1/2008 16:19
5/1/2008 16:48
5/1/2008 17:16
5/1/2008 17:45
5/1/2008 18:14
5/1/2008 18:43
5/1/2008 19:12
5/1/2008 19:40
Time
Test D Run 1
Test D Run 2
Test D Run 3
Air Flow(/100 scfm)
Gas Flow(scfm)
DP Ref
%LEL

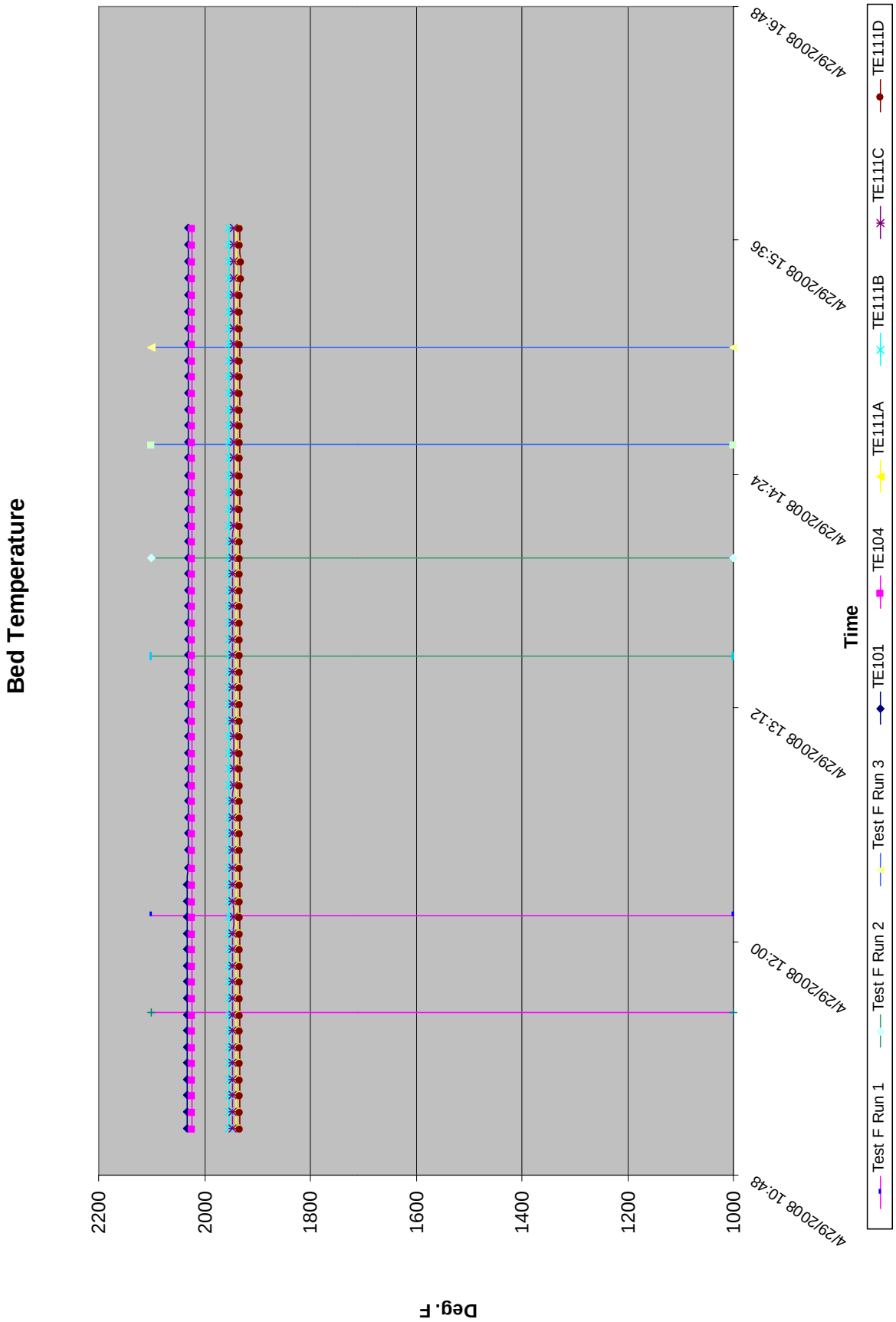

Inlet and Outlet Temp
Inlet Temp Deg F
Outlet Temp Deg F
100
90
80
70
60
50
40
30
20
10
0
700
600
500
400
300
200
100
0
5/1/2008 14:52
5/1/2008 15:21
5/1/2008 15:50
5/1/2008 16:19
5/1/2008 16:48
5/1/2008 17:16
5/1/2008 17:45
5/1/2008 18:14
5/1/2008 18:43
5/1/2008 19:12
Time
Test D Run 1
Test D Run 2
Test D Run 3
Inlet Temp
OutLet Temp

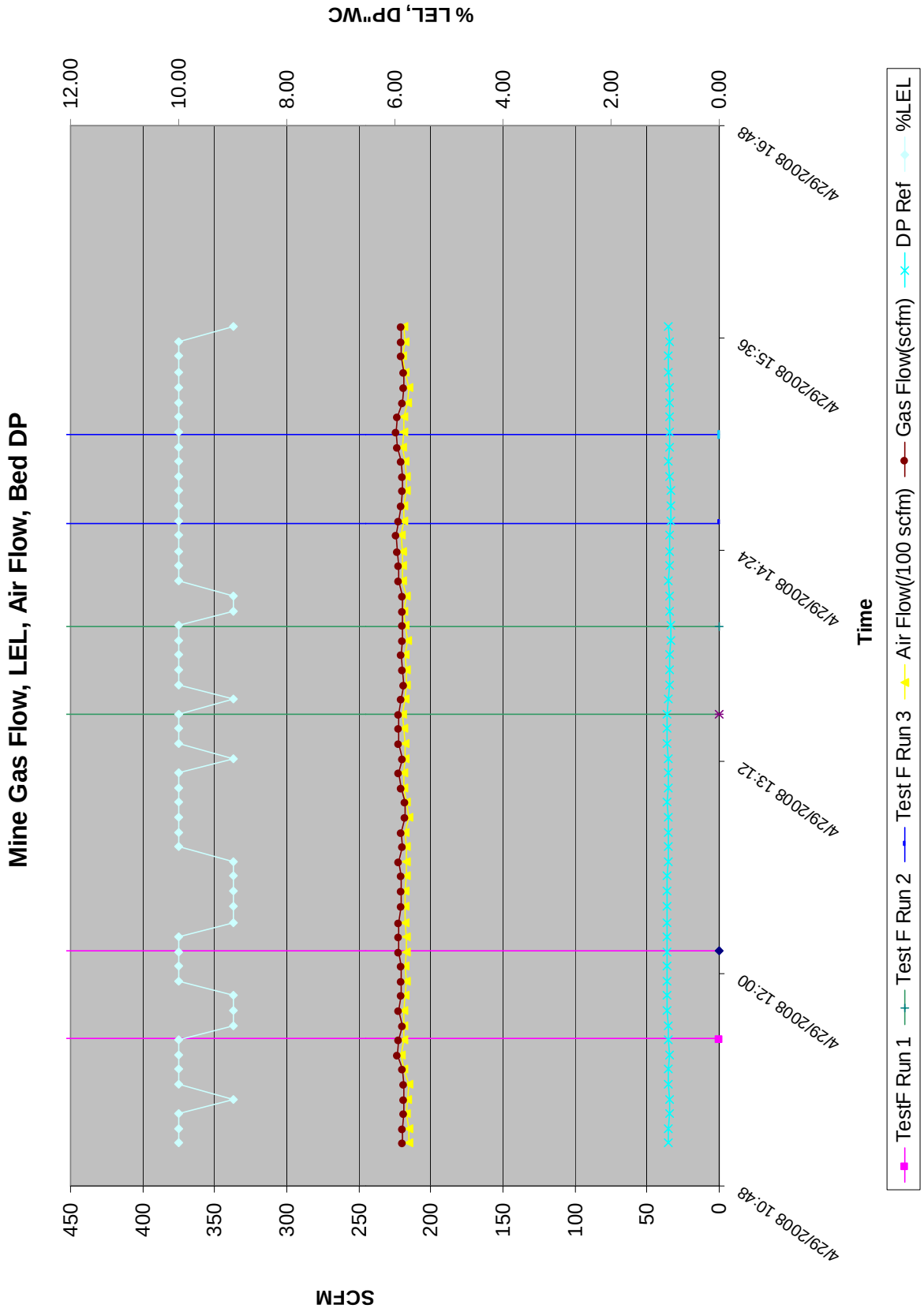

Inlet, Outlet, and Plenum Temperatures & LEL
Inlet Temp Deg F, %LEL (*10), Flow % of 42000 scfm
Outlet & Plenum Temps, Deg F
300
250
200
150
100
50
0
700
600
500
400
300
200
100
0
5/1/2008 16:09
5/1/2008 16:10
5/1/2008 16:12
5/1/2008 16:13
5/1/2008 16:14
5/1/2008 16:16
5/1/2008 16:17
5/1/2008 16:19
Time
Inlet Temp
%LEL
Air Flow(% of 42000 scfm)
Outlet Temp
Top Plenum Temp
Bottom Plenum Temp

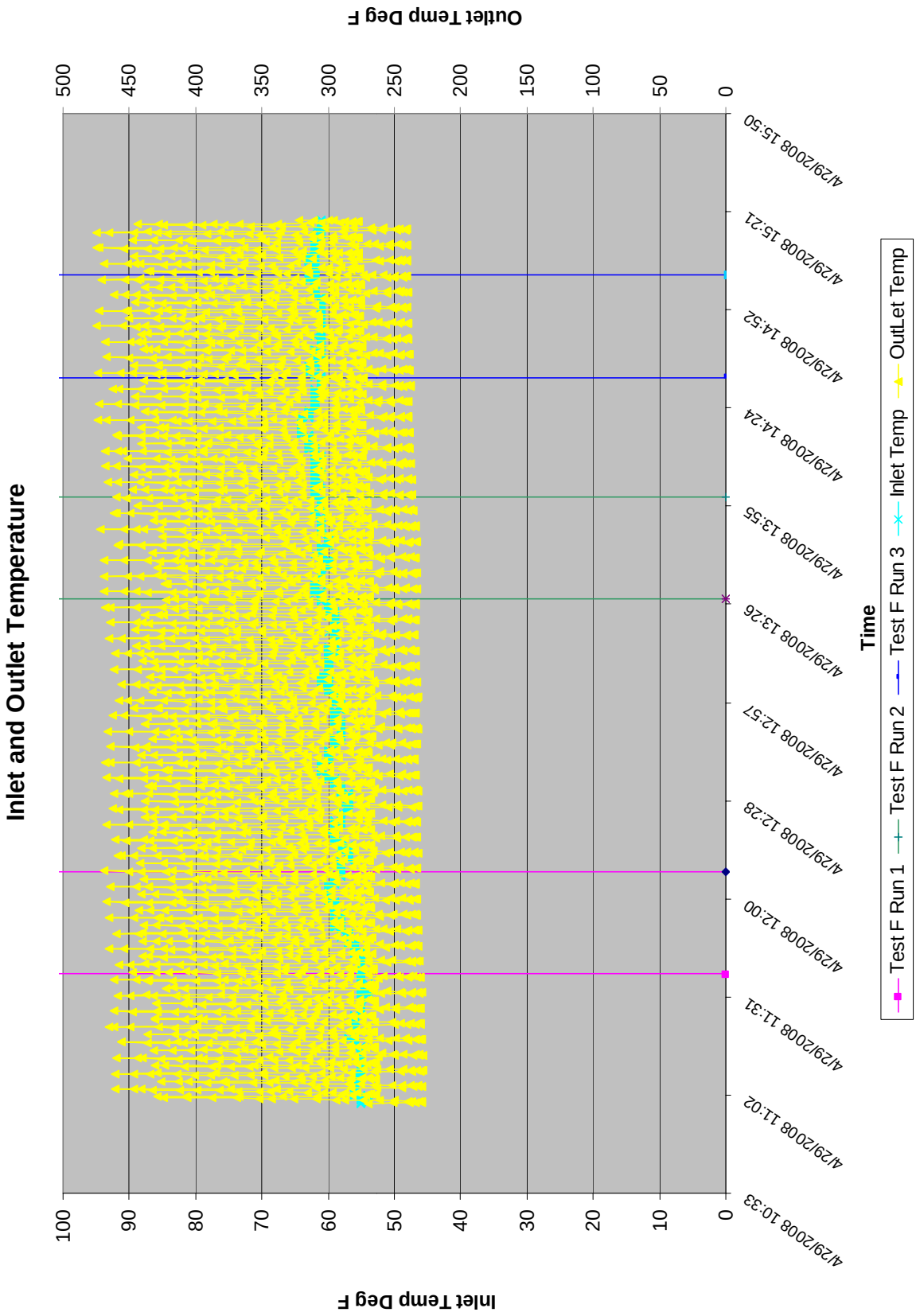

Inlet Temp Vs Air Flow
Flow % of 42000 scfm
Deg F
85
80
75
70
65
60
55
50
45
92
91
90
89
88
87
86
85
5/1/2008 14:52
5/1/2008 15:21
5/1/2008 15:50
5/1/2008 16:19
5/1/2008 16:48
5/1/2008 17:16
5/1/2008 17:45
5/1/2008 18:14
5/1/2008 18:43
5/1/2008 19:12
Time
Test D Run 1
Test D Run 2
Test D Run 3
Air Flow (% of 42000 scfm)
Inlet Temp (Deg F)

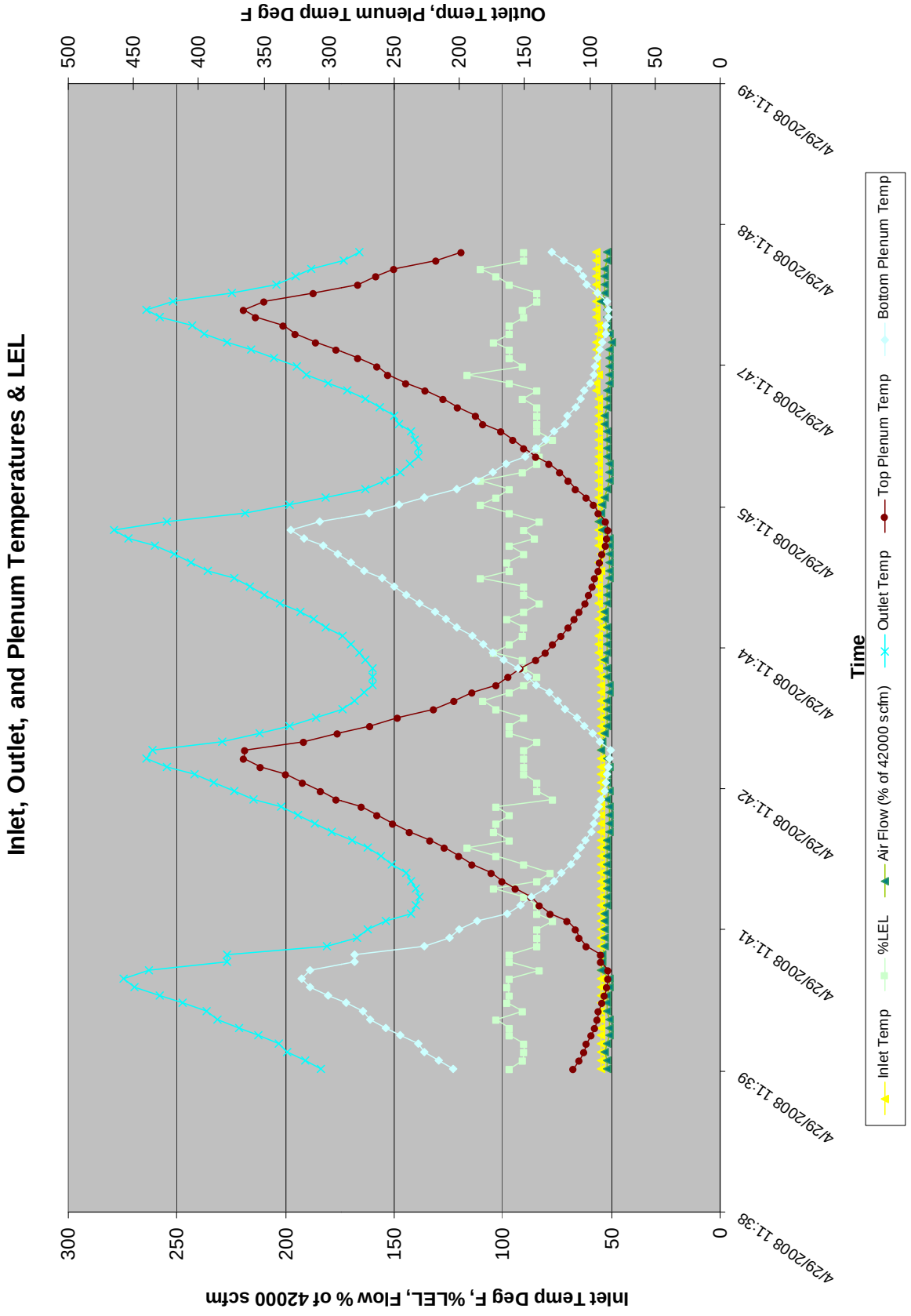

LEL
%LEL * 10
%LEL
Time
200
180
160
140
120
100
80
60
40
20
0
20
18
16
14
12
10
8
6
4
2
0
5/1/2008 14:52
5/1/2008 15:21
5/1/2008 15:50
5/1/2008 16:19
5/1/2008 16:48
5/1/2008 17:16
5/1/2008 17:45
5/1/2008 18:14
5/1/2008 18:43
5/1/2008 19:12
Test D Run 1
Test D Run 2
Test D Run 3
Quick %LEL (1 Sec Data)
Hidden %LEL (5 Sec Data)
Energy %LEL (5 Min Data)

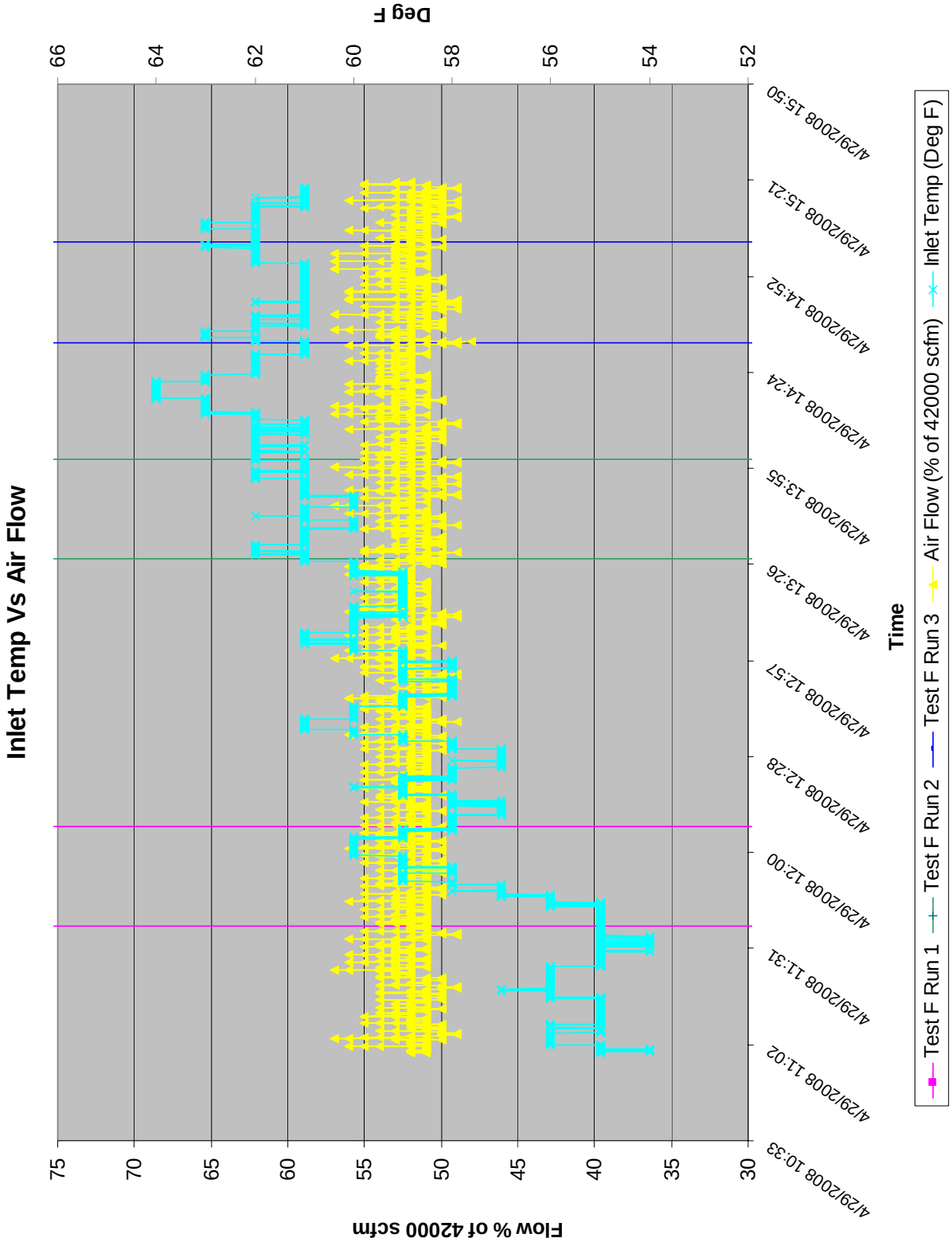
VOCSIDIZER Parametric Tests
Phase II
Test F
April 29, 2008
Run 1 – 11:38 AM to 12:08 PM
Run 2 - 1:28 PM to 1:58 PM
Run 3 – 2:33 PM to 3:03 PM

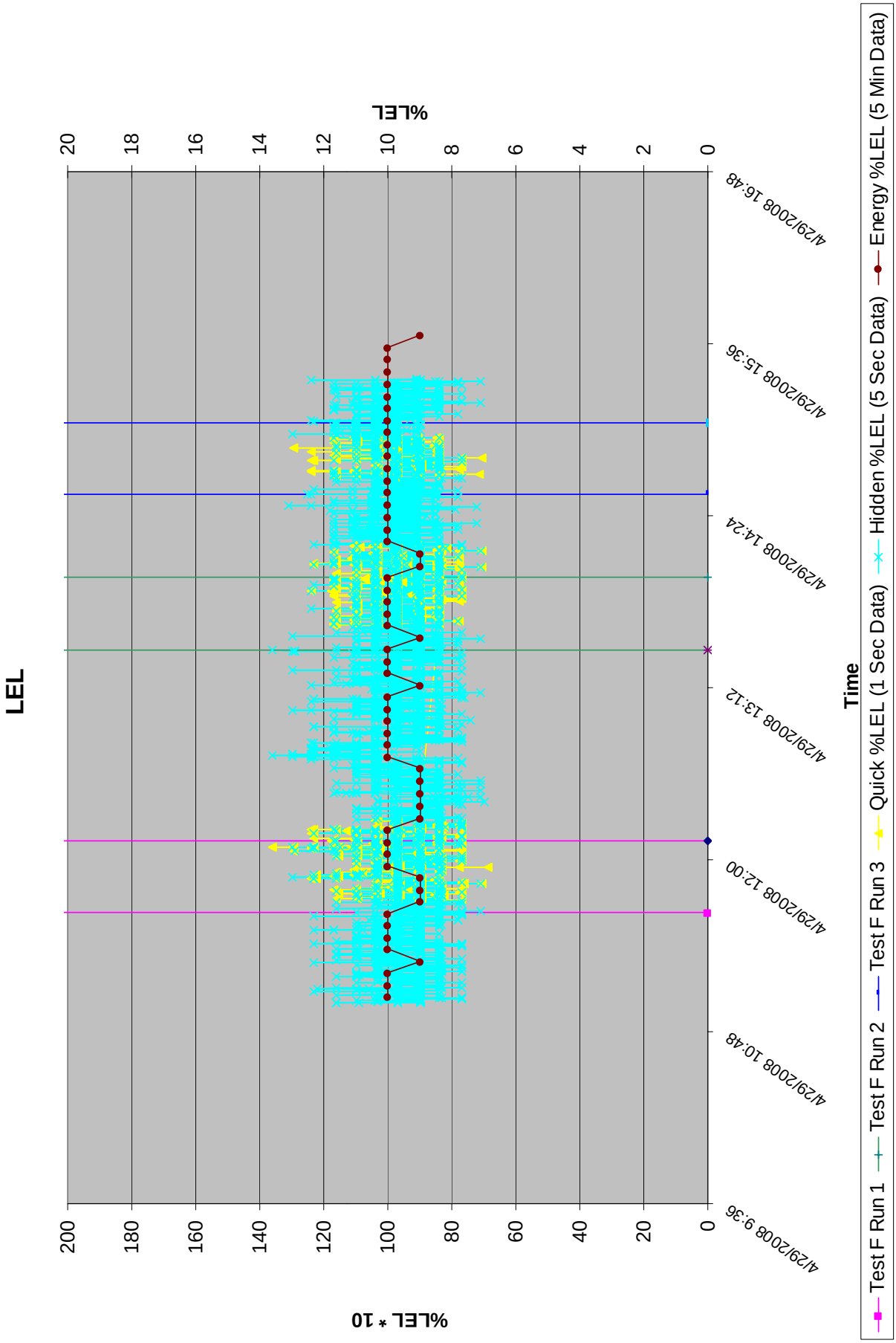

Bed Temperature
Deg. F
2200
2000
1800
1600
1400
1200
1000
4/29/2008 10:48
4/29/2008 12:00
4/29/2008 13:12
4/29/2008 14:24
4/29/2008 15:36
4/29/2008 16:48
Time
Test F Run 1
Test F Run 2
Test F Run 3
TE101
TE104
TE111A
TE111B
TE111C
TE111D


Mine Gas Flow, LEL, Air Flow, Bed DP
SCFM
% LEL, DP"WC
450
400
350
300
250
200
150
100
50
0
12.00
10.00
8.00
6.00
4.00
2.00
0.00
4/29/2008 10:48
4/29/2008 12:00
4/29/2008 13:12
4/29/2008 14:24
4/29/2008 15:36
4/29/2008 16:48
Time
TestF Run 1
Test F Run 2
Test F Run 3
Air Flow(/100 scfm)
Gas Flow(scfm)
DP Ref
%LEL


Inlet and Outlet Temperature
Inlet Temp Deg F
Outlet Temp Deg F
100
90
80
70
60
50
40
30
20
10
0
500
450
400
350
300
250
200
150
100
50
0
4/29/2008 10:33
4/29/2008 11:02
4/29/2008 11:31
4/29/2008 12:00
4/29/2008 12:28
4/29/2008 12:57
4/29/2008 13:26
4/29/2008 13:55
4/29/2008 14:24
4/29/2008 14:52
4/29/2008 15:21
4/29/2008 15:50
Time
Test F Run 1
Test F Run 2
Test F Run 3
Inlet Temp
OutLet Temp


Inlet, Outlet, and Plenum Temperatures & LEL
Inlet Temp Deg F, %LEL, Flow % of 42000 scfm
Outlet Temp, Plenum Temp Deg F
300
250
200
150
100
50
0
500
450
400
350
300
250
200
150
100
50
0
4/29/2008 11:38
4/29/2008 11:39
4/29/2008 11:41
4/29/2008 11:42
4/29/2008 11:44
4/29/2008 11:45
4/29/2008 11:47
4/29/2008 11:48
4/29/2008 11:49
Time
Inlet Temp
%LEL
Air Flow (% of 42000 scfm)
Outlet Temp
Top Plenum Temp
Bottom Plenum Temp


Inlet Temp Vs Air Flow
Flow % of 42000 scfm
Deg F
75
70
65
60
55
50
45
40
35
30
66
64
62
60
58
56
54
52
4/29/2008 10:33
4/29/2008 11:02
4/29/2008 11:31
4/29/2008 12:00
4/29/2008 12:28
4/29/2008 12:57
4/29/2008 13:26
4/29/2008 13:55
4/29/2008 14:24
4/29/2008 14:52
4/29/2008 15:21
4/29/2008 15:50
Time
Test F Run 1
Test F Run 2
Test F Run 3
Air Flow (% of 42000 scfm)
Inlet Temp (Deg F)


LEL
%LEL * 10
%LEL
Time
200
180
160
140
120
100
80
60
40
20
0
20
18
16
14
12
10
8
6
4
2
0
4/29/2008 9:36
4/29/2008 10:48
4/29/2008 12:00
4/29/2008 13:12
4/29/2008 14:24
4/29/2008 15:36
4/29/2008 16:48
Test F Run 1
Test F Run 2
Test F Run 3
Quick %LEL (1 Sec Data)
Hidden %LEL (5 Sec Data)
Energy %LEL (5 Min Data)

APPENDIX C

Test Report for Emission Campaign 1

CAPTURE AND USE OF COAL MINE VENTILATION AIR METHANE EMISSION TEST RESULTS
PM, SO_2, CO, VOC, and NO_X
U.S. Department of Energy Cooperative Agreement
DE-FC26-02NT41620

August 8 - 9, 2007

Issue Date: May 18, 2009

As Modified: September 2, 2009

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REVIEW AND CERTIFICATION

All work, calculations, and other activities and tasks performed and documented in this report were carried out under the direction and supervision of J. E. Locke, test team supervisor, CONSOL Energy Inc., Research & Development.

_____ **5/18/09**

J. E. Locke Date
Manager, Field Testing & Operations
CONSOL Energy Inc., Research & Development

This report was prepared by J. E. Locke. To the best of our knowledge, this source test report has been checked for completeness. The procedures, calculations, and emissions results contained herein are accurate, error-free, legible, and representative of the actual emissions measured during testing.

_____ 5/18/09

J. E. Locke Date
Manager, Field Testing & Operations
CONSOL Energy Inc., Research & Development

I am responsible for the generation of the analytical data presented in this source test report and to the best of my knowledge; the analytical data have been checked for completeness. The results contained herein are accurate, error-free, legible, and have been conducted in accordance with the methods in the approved protocol.

_____ 5/18/09

J. E. Locke Date
Manager, Field Testing & Operations
CONSOL Energy Inc., Research & Development

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Appendix A Raw Field Data & Tabulated Results

Appendix B Laboratory Reports (GC Analysis for Methane)

Appendix C QA/QC

Appendix D Process Operating Data

LIST OF ABBREVIATIONS

acfm	-	actual cubic feet per minute (wet)
am	-	morning
ASTM	-	American Society for Testing and Materials
Avg	-	average
Btu	-	British Thermal Units
C_3H_8	-	propane
CEM	-	continuous emission monitor
cfm	-	cubic feet per minute
CH_4	-	methane
CO	-	carbon monoxide
CO_2	-	carbon dioxide
DAS	-	data acquisition system
diff	-	difference
DOE	-	Department of Energy
dscf	-	dry standard cubic feet
dscfm	-	dry standard cubic feet per minute

dscm	-	dry standard cubic meter
dscmm	-	dry standard cubic meter per minute
EPA	-	U.S. Environmental Protection Agency
F-Factor	-	Combustion gas factor - dscf flue gas produced per mmBtu heat input
fps	-	feet per second
ft	-	feet
ft^2	-	square feet
ft^3	-	cubic feet
g	-	grams
GC	-	gas chromatography
gpm	-	gallons per minute
H_2O	-	water
HP	-	horsepower
hr	-	hour
ID	-	induced draft
in	-	inch
L	-	liter
lb	-	pound
lb/mmBtu	-	pounds per million British thermal units of heat input
m	-	meter
m^3	-	cubic meter
min	-	minute
mm	-	million
mol	-	mole
N_2	-	nitrogen
nmVOC	-	non-methane volatile organic compounds
NO_2	-	nitrogen dioxide
NOx	-	oxides of nitrogen
O_2	-	oxygen
pm	-	afternoon
PM	-	particulate matter
ppmv	-	parts per million by volume
PRSD	-	percent relative standard deviation
QA	-	quality assurance
QC	-	quality control
R&D	-	CONSOL Energy Inc., Research & Development
rpm	-	revolutions per minute
SDEV	-	standard deviation
S.P.	-	static pressure
scf	-	standard cubic feet (68 ^oF and 29.92"Hg)
scfm	-	standard cubic feet per minute
SO_2	-	sulfur dioxide
temp	-	temperature
tph	-	tons per hour
VOC	-	volatile organic compounds
w.c.	-	inches water column

wt	-	weight
WVDEP		West Virginia Department of Environmental Protection
°F	-	temperature in degrees Fahrenheit
ΔP	-	differential pressure

1.0 INTRODUCTION

The MEGTEC VOCSIDIZER is a regenerative thermal oxidizer utilized in the destruction of volatile organic compounds in a wide variety of industrial applications. CONSOL Energy R&D, in partnership with MEGTEC Systems and under U.S. Department of Energy (DOE) cooperative agreement DE-FC26-02NT41620, has applied this technology in a study to determine the system's effectiveness at destroying methane from mine ventilation air discharge streams. To verify the control capabilities, performance testing was conducted on the MEGTEC VOCSIDIZER oxidation system on August 8 and 9, 2007, to measure emissions of:

- Nitrogen oxides (NO_x),
- Sulfur dioxide (SO_2),
- Carbon monoxide (CO),
- Carbon dioxide (CO_2),
- Oxygen (O_2),
- Volatile organic compounds (VOCs), and
- Particulate matter (PM) and also
- VOCSIDIZER methane (CH_4) reduction rates.

The sampling consisted of three one-hour tests, conducted over two days. This report documents the emission rates, measurement methods, QA/QC procedures, and process conditions measured during the test program. The field sampling was conducted by personnel from the CONSOL R&D Field Testing and Operations Group. The project team leader was Brian W. Green.

The results of the analytical data showed all criteria pollutants and methane conversions were within the manufacturer's specifications. Table 1 summarizes actual emissions in comparison to the VOCSIDIZER performance guarantees.

Table 3 summarizes detailed results for all components measured. The non-methane VOC (nmVOC) results shown are questionable. This is due to the method of operation of the VOCSIDIZER in relationship to the data collection system. Gas is routed through a thermal bed vertically. After a few seconds the gas flow reverses direction. During this switch, high levels of methane exit the VOCSIDIZER, through the exhaust stack.

The VOC CEM records data once per minute and the methane sampling system extracts a continuous sample of the exhaust gas for the duration of the test period. CONSOL believes the recorded once-per-minute VOC readings did not coincide with the high methane periods created during the bed switches. The methane sample would have captured these excursions, resulting in an average methane value that exceeded the single point-in-time VOC values, creating negative nmVOC values. Consequently, CONSOL believes the reported nmVOC results are not representative of actual conditions.

Additionally, the CEM trailer air conditioning was not able to maintain stable temperatures resulting in a temperature increase that caused the O_2, CO_2, SO_2, and

VOC analyzers to experience a negative drift in excess of the method limits. The issue had an impact on the third test and on the average concentrations from the affected analyzers, mass flow rates, and mass emission rates of all measured pollutants. Therefore, throughout this report, test three averages are only included for the concentrations recorded by the unaffected analyzers.

Table 1. Emissions Guarantee and Performance Summary

Performance Category	Performance Guarantee	Measured Result[a]
Methane reduction rate	≥ 95% removal	96.1 %
Carbon monoxide concentration	< 50 mg/dscm	1.41 mg/dscm
Nitrogen oxides (expressed as nitrogen dioxide) concentration	< 10 mg/dscm	0.22 mg/dscm

[a] Measured results consist of the average of three test runs

1.1 Pollutants Tested

Pollutants and flue gas parameters, as well as equipment and methods used for sampling are summarized in the following table.

Table 2. Summary of Testing Performed

Parameter	Manufacturer	Model	Type	EPA Reference Method
CO	Rosemount Analytical	880A	NDIR	10
O_2	Maihak	OXOR 610	Paramagnetic	3A
CO_2	Horiba Instruments	PIR-2000	NDIR Analysis	3A
SO_2	Bovar – Western Research	721AT2	Ultraviolet Analysis	6C
NO_x	Teledyne-API	200EH	Chemiluminescence	7E
Total VOC	JUM Engineering	VE-7	Flame Ionization	25A
PM	Thermo-Andersen Instruments	2010A	Isokinetic	5
CH_4	Varian	CP 4900	Gas Chromatography	18

1.2 Summary of Results

A total of three emissions tests were completed on August 8 and 9, 2007. Concentrations and emissions are summarized in Table 3.

Table 3. Summary of Test Results

Note: All units reported on dry basis

Test ID	1	2	3	Averages[1]
Test Date	8/8/2007	8/9/2007	8/9/2007	
Sample Time	1610-1715	0959-1104	1153-1257	
Gas Flow, dscfm	29,500	35,300	36,200[2]	33,700
Gas Flow, dscmm	840	1,000	1,020[2]	920
CO_2, %	0.67	0.55	0.62	0.61
CO_2, lb/hr	0.14	0.13	0.15	0.13
CO_2, mg/dscm	1.22	1.00	1.13	1.11
PM, gr/dscf	0.0005	0.0000	0.0004	0.0003[3]
PM, lb/hr	0.12	000	0.12	0.06
PM, mg/dscm	1.11	0.00	0.89	0.65[3]
NO_X, ppm	0.25	0.10	0.00	0.12[3]
NO_X, lb/hr	0.05	0.03	0.00	0.04
NO_X, mg/dscm	0.48	0.19	0.00	0.22[3]
Total VOC, ppm[4]	12.1	13.9	13.0	13.0
Total VOC, lb/hr[4]	2.44	3.34	3.20	2.89
Total VOC, mg/dscm[4]	22.1	25.3	23.6	23.7
nmVOC, ppm[4]	-58.6	-51.8	-36.7	-49.0[3]
nmVOC, lb/hr[4]	-11.8	-12.5	-9.06	-12.2
nmVOC, mg/dscm[4]	-107	-94.4	-66.9	-89.4[3]
CO, ppm	0.00	1.32	2.34	1.22[3]
CO, lb/hr	0.00	0.20	0.37	0.10
CO, mg/dscm	0.00	1.53	2.71	1.41[3]
SO_2, ppm	2.37	0.00	0.00	1.19
SO_2, lb/hr	0.30	0.00	0.00	0.15
SO_2, mg/dscm	2.75	0.00	0.00	1.38

[1] – Average of tests 1 and 2 unless otherwise noted.

[2] – Oxygen analyzer drift, invalid mass flow rates.
[3] – Average of all tests.
[4] – Methane concentration was higher than Total VOC concentrations due to CEM system recording intervals resulting in negative and invalid results.
Shaded areas indicate data not considered to be trustworthy.

2.0 Description of the MEGTEC VOCSIDIZER System

The MEGTEC VOCSIDIZER system is situated on the property of the CONSOL Energy, Inc. Windsor Mine, which is no longer a producing mine. The system utilizes methane exhausted from a mine vent at a volume of approximately one million cubic feet per day at a methane concentration of approximately 43 percent. The system is designed to capture and eliminate ventilation air methane (VAM) from the exhaust of mine ventilation fans. To simulate the low methane concentration of these sites, the vent gas (45 - 60 percent methane) must be diluted with ambient air to a concentration of 0.1 - 1.2 percent methane. Following dilution, the simulated mine ventilation air is routed to the VOCSIDIZER for control. Figure 1 depicts the MEGTEC VOCSIDIZER system.

The VOCSIDIZER consists of a bed of ceramic medium contained in an airtight steel container resting on a sturdy steel frame (Figure 2). The granular ceramic bed material ensures optimum flow and temperature distribution over the bed. Air plenum chambers are located above and below the bed to provide even distribution of the inlet air. Electrical heating elements are used to obtain the required start-up bed temperature of ca. 1000 °C.

The process fan at the inlet side of the VOCSIDIZER forces the feed air via dampers into the plenum and through the preheated bed where the air is heated to a temperature at which methane is completely oxidized. The thermal energy released during methane oxidization is recovered by the bed media as the air moves to the outlet side of the bed.

Thermocouples in the bed are tied to the programmable logic controller (PLC) system that monitors the temperature profile of the bed and the movement of the high-temperature zone, which moves towards the outlet of the ceramic bed. To maintain the high-temperature zone within the ceramic bed, switching valves reverse the air flow through the bed periodically. The PLC program optimizes valve switching intervals using time and temperature to maximize energy efficiency. After the valves have switched and reversed the direction of air flow through the bed, the energy that was recovered and stored in one side of the bed heats the incoming process air to oxidation temperature. After the reversal, the high-temperature zone in the bed begins to move toward the new outlet and the process repeats.

In operation, the VOCSIDIZER typically changes air flow direction through the bed every few minutes. The reaction zone at the oxidation temperature is sustained in the center of the bed by optimizing the regenerative heat exchange between the ventilation air and the ceramic bed.

The expected methane conversion is 95%, with the capability of sustaining oxidation of methane at concentrations from 0.3 to 1.2% in air. Therefore, it is well suited to oxidize ventilation air methane into CO_2 and water.

3.0 SAMPLING AND ANALYSIS PROCEDURES

3.1 Point Selection

The sampling points used to determine the flue gas velocity in the stack were selected as outlined in EPA Method 1. Based on EPA criteria, a total of 12 sampling points (two six-point traverses) were used in making the volumetric gas flow measurements. The location of the sampling points and traverse distances are presented in Figure 2.

The samples for gas composition (O_2, CO_2, NO_X, CO, SO_2, CH_4, and total VOC) were obtained in each of the two ports located ~15' above ground level.

3.2 Verification of Axial Flow / Volumetric Gas Flow Rate

Volumetric flow rate should be determined when the stack gas flow is axial or non-cyclonic. An axial flow check was performed prior to Test 1 and resulted in an absolute "null yaw" flow angle of 0.0°, which confirms the stack gas flow was axial or non-cyclonic. EPA Method 1 states that if the average "null yaw" angle is within 20° of the vertical gas flow axis, axial flow can be assumed.

A volumetric gas flow rate determination was conducted during each of the three sampling test periods. The results of these measurements are summarized in Table 4.

3.3 Particulate Emissions Measurement

Particulate matter emissions were determined using procedures described in EPA Method 5. CONSOL used a 12 point traverse (6 points in each of two ports), sampling at each point for five minutes, which resulted in a total test time of 60 min and sample volumes >44.5 dscf. Velocity measurements were obtained at each traverse point during the PM sampling to calculate the isokinetic sampling ratio and volumetric gas flow rate. The EPA Method 5 sampling train is shown in Figure 3. Field data sheets can be found in Appendix A. Analytical summaries can be found in Appendix B. Table 4 summarizes the results of the PM sampling.

Table 4. Flue Gas Parameters and Particulate Emissions Data

Run	1	2	3	
Date	08/08/07	08/09/07	08/09/07	Avg.[1]
Avg. Stack Temp [°F]	358	372	349	360[3]
Gas Velocity [fps]	50.7	61.2	61.2	57.7[3]
Gas Flow Rate [acfm]	50,200	60,600	60,600[2]	57,200
Gas Flow Rate [dscfm]	29,500	35,300	36,200[2]	33,700
Flue Gas Moisture [%]	4.09	3.78	4.02	3.96[3]
Sample Time [min]	60	60	60	60[3]
Sample Volume [dscf]	44.5	48.4	47.7	46.9[3]
Sample Volume [dscm]	1.26	1.37	1.35	1.33[3]
PM [grains/dscf]	0.00	0.00	0.00	0.00[3]
PM [lb/hr]	0.12	0.00	0.12	0.06
PM [mg/dscm]	1.11	0.00	0.89	0.65[3]
% Isokinetic	109	98.6	94.8	101[3]

[1] – Average of tests 1 and 2 unless otherwise noted.
[2] – Oxygen analyzer drift, invalid mass flow rates.
[3] – Average of all tests.
Shaded areas indicate data not considered to be trustworthy.

3.4 Gaseous Emissions Measurement

A continuous emission monitoring (CEM) system was used to determine concentrations of O_2, CO_2, NO_X, SO_2, CO, and total VOC concentrations for this test program. The CEM data acquisition system (DAS) software records once every minute. The VOCSIDIZER unit switches flow direction through the bed approximately every 120 seconds, which results in a short-duration release of high methane concentrations. The change in emissions during this time occurs too quickly to be recorded by the CEM DAS and as a result the average total VOC concentration was low. The Method 18 sample for methane, which is collected continually, captured the high concentration "spikes". When the methane concentration was subtracted from the erroneously low total VOC value, negative non-methane VOC results were generated. Future testing will include the collection of additional Method 18 samples, which will be analyzed with the total VOC analyzer to verify the average values.

The CEM system components can be configured with two separate sampling lines; a dry sampling line for the O_2, CO_2, NO_X, SO_2, and CO analyzers; and a wet sampling line for the VOC analyzer, or as one system utilizing just the dry line, which was

incorporated in this test. The dry sampling system is equipped with a probe, heated filter, heated Teflon transport line, cryogenic moisture removal system, and a Teflon line to the CEM trailer. Inside the trailer, the gas sample enters a manifold to distribute the gas sample to the individual analyzers and gas bag port.

Calibration gases are automatically routed to the sampling probe for the sample system bias check and also directly into the analyzers for the calibration error check. All initial and final zero checks and initial and final span checks are performed by routing the calibration gases to the sampling probe. All calibrations and response time checks are computer monitored and controlled. A computer-based data acquisition system stores and reduces the field data. The system is also equipped with a dedicated printer. A schematic of the CONSOL R&D CEM system is presented in Figure 4. Specific sampling details are discussed below.

3.4.1 Oxygen and Carbon Dioxide

The O_2 and CO_2 sample was obtained and analyzed using the continuous emission monitoring (CEM) procedures outlined in EPA Method 3A and 7E, utilizing the sampling system described above. All applicable QA/QC procedures were followed including initial calibration, calibration error, initial zero and span, final zero and span, response time, and sample system bias. The QA/QC procedures are discussed in detail in Section 4.0. Supporting documentation is contained in Appendix C.

Average concentrations are summarized in Table 5. Run three is considered invalid due to excessive instrument drift. The reported averages do not include Run 3. Raw field data can be found in Appendix A.

Table 5. Oxygen and Carbon Dioxide Concentrations

Run	1	2	3	
Test Date	8/8/2007	8/9/2007	8/9/2007	Average[1]
O_2, % dry	19.9	20.0	21.1	19.9
CO_2, % dry	0.67	0.55	0.62	0.61
CO_2, mg/dscm	1.22	1.00	1.13	1.11

[1] – Average of Tests 1 and 2.
Shaded areas indicate data not considered to be trustworthy.

3.4.2 Oxides of Nitrogen

The NO_X sample was obtained and analyzed using the continuous emission monitoring (CEM) procedure outlined in EPA Method 7E, utilizing the same sampling hardware previously discussed. A portion of the stack flue gas sample is conveyed to the chemiluminescent NO_X analyzer through a manifold system. All applicable QA/QC procedures were followed including initial calibration, calibration error, initial zero and

span, final zero and span, response time, and sample system bias. The QA/QC procedures are discussed in detail in Section 4.0. Supporting documentation is contained in Appendix C.

Average concentrations are summarized in Table 6. Raw field data can be found in Appendix A.

Table 6. Oxides of Nitrogen Concentration

Run	1	2	3	
Test Date	8/8/2007	8/9/2007	8/9/2007	Average
NOx, ppmv (dry)	0.25	0.10	0.00	0.12
NOx, mg/dscm	0.48	0.19	0.00	0.22

3.4.3 Sulfur Dioxide

The SO_2 sample was obtained and analyzed using the continuous emission monitoring (CEM) procedure outlined in EPA Method 6C, utilizing the same sampling hardware previously discussed. A portion of the stack flue gas sample is conveyed to the ultraviolet fluorescence SO_2 analyzer through a manifold system. All applicable QA/QC procedures were followed including initial calibration, calibration error, initial zero and span, final zero and span, response time, and sample system bias. The QA/QC procedures are discussed in detail in Section 4.0. Supporting documentation is contained in Appendix C.

Average concentrations are summarized in Table 7. Run three is considered invalid due to excessive instrument drift. The reported averages do not include Run 3. Raw field data can be found in Appendix A.

Table 7. Sulfur Dioxide Emissions Data

Run	1	2	3	
Test Date	8/8/2007	8/9/2007	8/9/2007	Average[1]
SO_2, ppmv (dry)	2.37	0.00	0.00	1.19
SO_2, mg/dscm	2.75	0.00	0.00	1.38

[1] – Average of Tests 1 and 2.
Shaded areas indicate data not considered to be trustworthy.

3.4.4 Carbon Monoxide

The CO sample was obtained and analyzed using the continuous emission monitoring (CEM) procedure outlined in EPA Method 10, utilizing the same sampling hardware previously discussed. A portion of the stack flue gas sample is conveyed to the infrared CO analyzer through a manifold system. All applicable QA/QC procedures were followed including initial calibration, calibration error, initial zero and span, final zero and span, response time, and sample system bias. The QA/QC procedures are discussed in detail in Section 4.0. Supporting documentation is contained in Appendix C.

Average concentrations are summarized in Table 8. Raw field data can be found in Appendix A.

Table 8. Carbon Monoxide Emissions Data

Run	1	2	3	
Test Date	8/8/2007	8/9/2007	8/9/2007	Average
ppmv (dry)	0.00	1.32	2.34	1.22
mg/dscm	0.00	1.53	2.71	1.41

3.4.5 Methane

The CH_4 sample was obtained by extracting a sample from the CEM system overflow. The gas was analyzed for methane as outlined in EPA Method 18. Analytical data summaries can be found in Appendix B.

At the start of the test, a 25 L sample bag was connected to the CEM gas distribution manifold line in the CEM trailer. The flow rate through this line was adjusted to uniformly fill the bag over the entire test period.

Samples were also taken at the VOCSIDIZER inlet, where the sample gas is under positive pressure. A rotameter was used in front of the Tedlar bag to sample at a uniform rate over the hour long test period. After the test, the bag contents were analyzed for methane concentrations by gas chromatography. The samples were collected from a single-point for one-hour, coinciding with all other measurements.

The inlet and outlet CH_4 concentrations are used to calculate methane reduction during each test period. Table 9 summarizes the results. Since all bag samples were collected continuously, the results include the excursion periods, which take place when the valves switch and uncontrolled gas flows through the system. Therefore, the methane analysis for each run is the average for each sample and is a more accurate representation of VOC concentrations than results generated from the CONSOL CEM system.

Table 9. Methane Reduction Summary

Run	1	2	3	
Test Date	8/8/2007	8/9/2007	8/9/2007	Average
Inlet CH_4 concentration [ppm]	4,900	4,800	4,700	4,800
Outlet CH_4 concentration [ppm]	212	197	149	186
CH_4 reduction rate [%]	95.7	95.9	96.8	96.1

3.4.6 Total VOC

Total VOC emissions were determined using a continuous VOC analyzer and the procedure outlined in EPA Method 25A, using the common sampling system previously discussed. The VOC analyzer is equipped with a flame ionization detector, computer controlled data acquisition system, and a series of calibration gases (see Figure 4). All applicable QA/QC procedures were followed including initial calibration, calibration error, initial zero and span, final zero and span, response time, and sample system bias. The QA/QC procedures are discussed in detail in Section 4.0. Supporting documentation is contained in Appendix C.

All of the calibrations were conducted by introducing the calibration gases through a tee fitting located on the sampling probe. The total VOC concentration for each test was continuously recorded and logged. The average total VOC concentration was obtained from the values recorded by the CEM DAS. Total VOC concentrations are expressed on a propane-equivalency basis. The sample was taken at a single-point, for a period of one-hour, taken to coinciding with the other flue gas samples.

3.4.7 Non-Methane VOC

The non-methane VOC emission rate was calculated from the total VOC emissions corrected for the methane contribution as determined from the Method 18 sample bag. Total VOC results are reported on a dry, propane-equivalency basis. The methane emissions are reported on a dry basis, as methane, and converted to propane equivalence (ratio of carbon atoms in methane vs. propane), and then subtracted from the total VOC value to provide non-methane VOC emissions.

As discussed in previous sections, the measured methane values were greater than the erroneous average recorded total VOC values, which resulted in erroneous negative non-methane values. The methane results are detailed in Table 10. Raw field data can be found in Appendix A.

Table 10. Summary of Total and Non-Methane VOC Results

(VOC emissions expressed as propane equivalents)

Run	1	2	3	Average[1]
Test Date	8/8/2007	8/9/2007	8/9/2007	
Gas Flow [dscfm]	29,500	35,300	36,200[2]	33,700
Gas Flow, [dscmm]	836	999	1024[2]	930
Total VOC Emissions:				
ppmv (dry)[a]	12.1	13.9	13.0	13.0[3]
Methane:				
ppmv (dry)	212	197	149	181[3]
ppmv as C_3H_8	70.7	65.7	49.7	60.2[3]
non-Methane VOC Emissions:				
ppmv (dry)[b]	-58.6	-51.8	-36.7	-49.0 [3]
lb/hr[b]	-11.8	-12.5	-9.06	-12.2-
mg/dscm[b]	-107	-94.4	-66.9	-89.4 [3]-

[a] – Invalid results due to recording concentrations not sampled at a frequency to accurately represent total VOC emissions.

[b] – Methane concentrations were higher than the Total VOC concentration, due to CH_4 samples being collected continuously and representing an average result for the test period and the Total VOC result is an average of data points collected at one minute intervals.

[1] – Average of tests 1 and 2 unless otherwise noted.
[2] – Oxygen analyzer drift, invalid mass flow rates.
[3] – Average of all tests.
Shaded areas indicate data not considered to be trustworthy.

3.4.8 Process Data

VOCSIDIZER operating and process data were recorded automatically through the unit's data-logging system. Data were recorded at regular intervals from 1 second to 5 minutes depending on the instrument. Appendix D includes graphical representation of data collected during the second test run which was typical for the other two test periods. The following parameters were included; main fan air flow rate, mine gas flow rate, fixed mine gas concentration, measured inlet methane concentration as % CH_4, pressure drop across the bed against a reference value, internal bed media temperatures, bed plenum temperatures, bed inlet temperatures, and bed outlet temperatures.

3.5 Sampling and Lab Equipment

The CONSOL Field Sampling team used standard EPA-type sampling equipment, which conforms to all applicable test codes.

The total VOC analyzer is manufactured by J.U.M. Engineering and is a Model VE-7. Total VOC is determined by a flame ionization detector analysis based on procedures described in EPA Method 25A.

The GC used for the CH_4 analyses is a Varian CP 4900 portable micro gas chromatograph that is very versatile and was specifically configured for the gases of interest. As configured, this instrument has a minimum detection limit of 5 ppmv for methane.

A Teledyne-API 200EH continuous emission monitor measured the flue gas NOX concentration. NO_X is determined by chemiluminescence and measures total NO_X as NO_2, based on procedures described in EPA Method 7E.

A Rosemount Model 880A continuous emission monitor measured the flue gas CO concentration. CO is determined by nondispersive infrared analysis (NDIR) based on procedures described in EPA Method 10.

The CO_2 CEM analyzer is manufactured by Horiba Instruments and is Model number PIR-2000. CO_2 is determined by NDIR based on procedures described in EPA Method 3A.

The O_2 CEM analyzer is manufactured by Maihak and is Model OXOR 610. O_2 is determined by para-magnetic analysis based on procedures described in EPA Method 3A.

The CONSOL R&D CEM system includes a computer-based data acquisition system (DAS) that stores and reduces field data. All CEM gas concentrations can be displayed on tabular or strip chart forms, and a hard copy can be printed. In addition, CEM gas concentrations are corrected from a “raw” or “uncorrected” CEM reading to a “corrected” reading using EPA Method 7E, equation 7E-5.

$$C_{gas} = (C_{avg} - C_o) * C_{ma} / (C_m - C_o)$$

where: C_{gas} = corrected gas concentration, dry basis, ppm or %

C_{avg} = Average unadjusted gas concentration indicated by data recorder for the test run, ppmv or %

C_o = average of initial and final zero calibration gas readings, ppm or %

C_m = average of initial and final upscale calibration gas readings, ppm or %

C_{ma} = actual or certified concentration of upscale calibration gas, ppm or %

Within specified percent of span limits, as outlined in the applicable EPA Methods, this calculation corrects for offsets and/or drifts of the zero and/or spans during individual test periods. This correction factor was used on all reported ppmv dry concentration readings for O_2, CO_2, NO_x, SO_2, CO, and total VOC.

4.0 QA/QC

The CONSOL test manager was responsible for the implementation of the quality assurance procedures for this project. All required measuring devices, including pitot tubes, barometers, continuous gas analyzers, and the gas chromatograph were calibrated as required. Records of these calibrations are maintained in files and are included in Appendix C. All field data were recorded on standard forms, which are included in the appendices as appropriate. All of the collected data were reduced in the field to assure data quality and completeness. Methane concentrations were determined using a laboratory-quality portable gas chromatograph. Individual testing QA/QC procedures are discussed below.

4.1 Flue Gas Velocity Measurements

The flue gas volumetric flow rate is required to calculate the emission rates in mass flow units (lb/hr). Velocity measurements were made during each of the test periods. Prior to the compliance sampling, axial flow was verified at the measurement location. This survey and all subsequent measurements were made with a standard type “S” pitot tube following U.S. EPA Methods 1 and 2 criteria. The pitot tube coefficient was determined by CONSOL R&D personnel using the procedures outlined in Method 2 and an in-house wind tunnel specifically designed for Method 2 pitot calibrations. A copy of the most recent calibration is included in Appendix C. Also included are the barometer calibrations. The velocity measurements obtained during this testing are consistent with predicted flow rates for this test program.

4.2 Particulate Measurements

PM measurements were conducted using a 12 sampling point traverse, as outlined in EPA Method 1.

Leak checks were conducted on the PM sampling train for each test run prior to sampling, after the components had reached sampling temperature and a post-sampling leak check was conducted at the completion of the particulate run. Pre- and post-sampling leak checks were conducted on the pitot system. All pre- and post-sampling system leak checks were satisfactory (<0.02 cfm @ >10 “H_2O).

At the completion of the post-sampling leak check, the probe was disconnected from the filter box. Both ends of the probe (nozzle and ball cap) were sealed, and the probe was allowed to cool. The probe and nozzle were rinsed and brushed with acetone three times. The probe and nozzle rinse was caught in an approved sample container for subsequent particulate weight analysis. Protective caps were secured on the pitot tips to ensure that they were not disfigured during probe transport. The pitot tips and

sampling nozzle were inspected prior to the start of each PM run. No tip damage was observed.

CONSOL test personnel utilized a programmable calculator to determine the isokinetic sampling ratio. The isokinetic sampling ratios for all runs were calculated in the field on a daily basis to ensure that no errors were made in setting up the sampling ratio or in the sampling itself. The isokinetic sampling ratios for all tests were within the allowable range (100% ±10%).

Particulate weights were determined in the field using a Mettler electronic balance. The accuracy of this balance was verified by class "S" weights. The accuracy of the final filter weights was verified by both lab control filter blanks and field blanks.

4.3 Total VOC Measurements

Total VOC measurements were obtained with a continuous emission monitor spanned using VOC free air (0 ppmv propane) and high calibration gas (452 ppmv propane) on a 0 to 1000 ppmv scale. Linearity was verified using a low (151 ppmv propane) and middle (254 ppmv propane) calibration gases. The analyzer was checked for drift using the zero and middle (250 ppmv propane) calibration gases following each test. All calibration gases are EPA protocol gases, as documented in Appendix C. The results of the pre-test calibration, linearity check, and post- test calibration tests verified that this analyzer was operating accurately. All QA/QC documentation for the VOC analyzer is contained in Appendix C.

As previously discussed, CONSOL used a single sampling system for all gas species, consisting of a sample probe, heated filter with calibration gas port, heated Teflon transport line, cryogenic moisture trap, and a Teflon transport line. Results are transmitted from the CEM systems PLC system to a CONSOL computer, where data are recorded. During this test program the DAS was not able to record more than one reading per minute. Due to the DAS problem the Total VOC results are biased low. During the next test program at this facility extra Tedlar bag samples will be taken and analyzed for all emission parameters as well as methane concentrations. This will provide a more accurate average result of emissions during the sampling periods in conjunction with the real-time CEM data.

4.4 Methane Measurements

Methane samples were collected at three locations during the test period. VOCSIDIZER inlet and outlet concentrations were used to determine the CH_4 reduction rate. Mine gas was also sampled to verify that the proper dilution ratio was being achieved from mine gas to VOCSIDIZER inlet. The bag sampling system was leak-checked prior to sampling. The bags were leak-checked in the CONSOL lab prior to the program and again during the field sampling. The concentrations of the methane calibration gases were 100, 504, and 1000 ppmv. The calibration curve is presented in Appendix C.

4.5 NO_X Measurement

NO_X emissions were determined with a Teledyne-API chemiluminescent continuous emission monitor (CEM) spanned with a nitrogen (0 ppmv NO_X) and high calibration gas (90.8 ppmv NO_X) on a 0 to 500 ppmv scale. Linearity was verified with a middle calibration gas (49.9 ppmv NO_X). The analyzer was checked for drift using the zero and middle (50 ppmv NO_X) calibration gases following each test. All calibration gases are EPA protocol gases, as documented in Appendix C. The results of the pre-test calibration, linearity check, and post- test calibration tests verified that this analyzer was operating accurately. All of the QA/QC documentation for the NO_X analyzer is contained in Appendix C.

4.6 CO Measurement

CO emissions were determined with a Rosemount NDIR continuous emission monitor (CEM) spanned with a nitrogen (0 ppmv CO) and high calibration gas (60.0 ppmv CO) on a 0 to 1000 ppmv scale. Linearity was verified with a middle calibration gas (30.7 ppmv CO). The analyzer was checked for drift using the zero and middle (30.7 ppmv CO) calibration gases following each test. All calibration gases are EPA protocol gases, as documented in Appendix C. The results of the pre-test calibration, linearity check and post-test calibration tests verified that this analyzer was operating accurately. All of the QA/QC documentation for the CO analyzer is contained in Appendix C.

4.7 SO_2 Measurement

SO_2 emissions were determined with a Bovar chemiluminescent continuous emission monitor (CEM) spanned with a nitrogen (0 ppmv SO_2) and high calibration gas (90.ppmv SO_2) on a 0 to 200 ppmv scale. Linearity was verified with a middle calibration gas (50.7 ppmv SO_2). The analyzer was checked for drift using the zero and middle (50.7 ppmv SO_2) calibration gases following each test. All calibration gases are EPA protocol gases, as documented in Appendix C. The results of the pre-test calibration, linearity check, and post- test calibration tests verified that this analyzer was operating accurately. All of the QA/QC documentation for the SO_2 analyzer is contained in Appendix C.

4.8 QAQC Incidents

The air conditioner in the CEM trailer was unable to maintain cooling during Run 3 causing the temperature to become elevated. The temperature increase caused the O_2, CO_2, SO_2, and total VOC analyzer calibrations to drift resulting in an unacceptable post-test drift. Any data generated from calculations utilizing concentrations from these analyzers is considered to be invalid and is noted as such throughout this report.

No other QA/QC incidents were noted during this test episode.

5.0 Recommendations

The concentrations of the CEM DAS data collection did not provide accurate data of the total VOC and it is possible that the flow switching may have also impacted the results of other parameters. To improve the results, CONSOL R&D will implement the following steps in any future testing:

- Increase the data collection frequency for all CEM monitors by using a data logger with the capability of collecting data once per second, then recording a 60 second average once per minute.

- Collect additional gas bag samples for analysis by the total VOC monitor by feeding the gas directly into the sample port of the analyzer, which will provide an integrated sample for the test period.

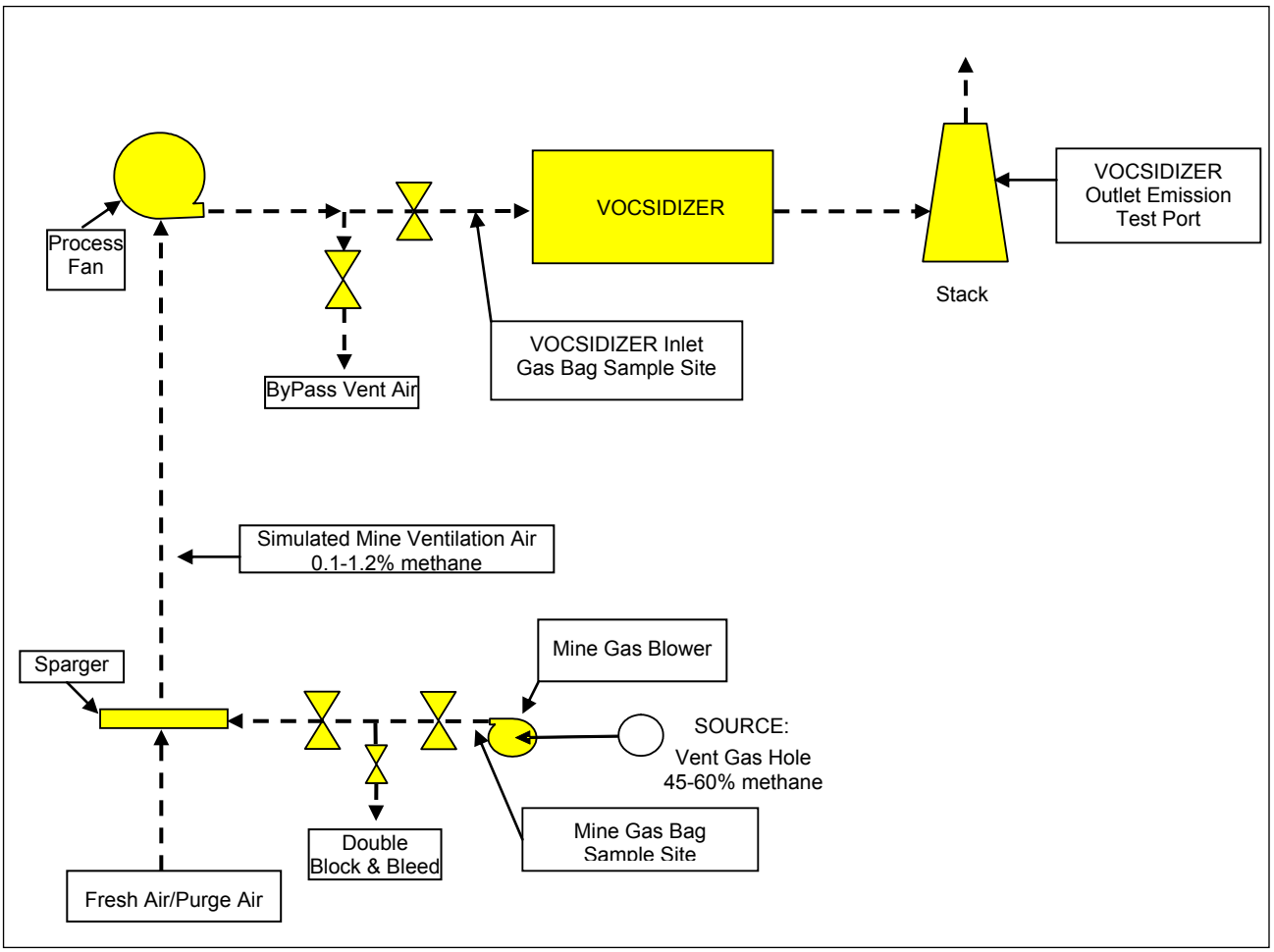


Figure 1. Process Schematic Diagram of VOCSIDIZER

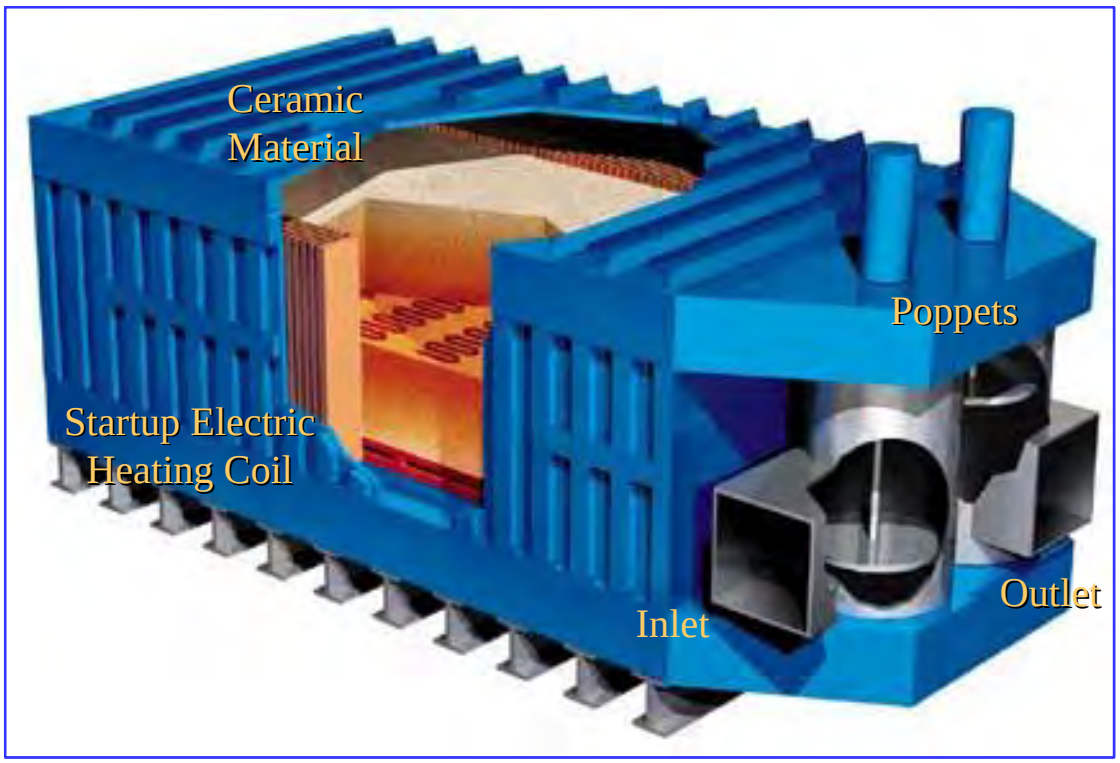
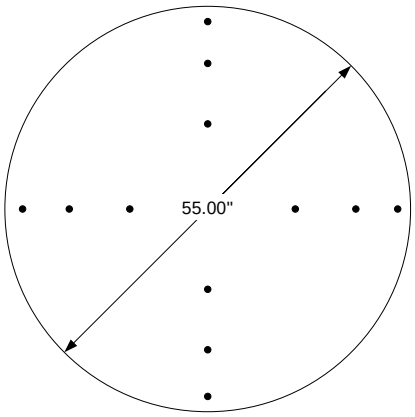


Figure 2. Internal Components of the VOCSIDIZER



Traverse Point Positions

Point No.	Location (in.)
1	2.50
2	8.00
3	16.25
4	38.75
5	47.00
6	52.50

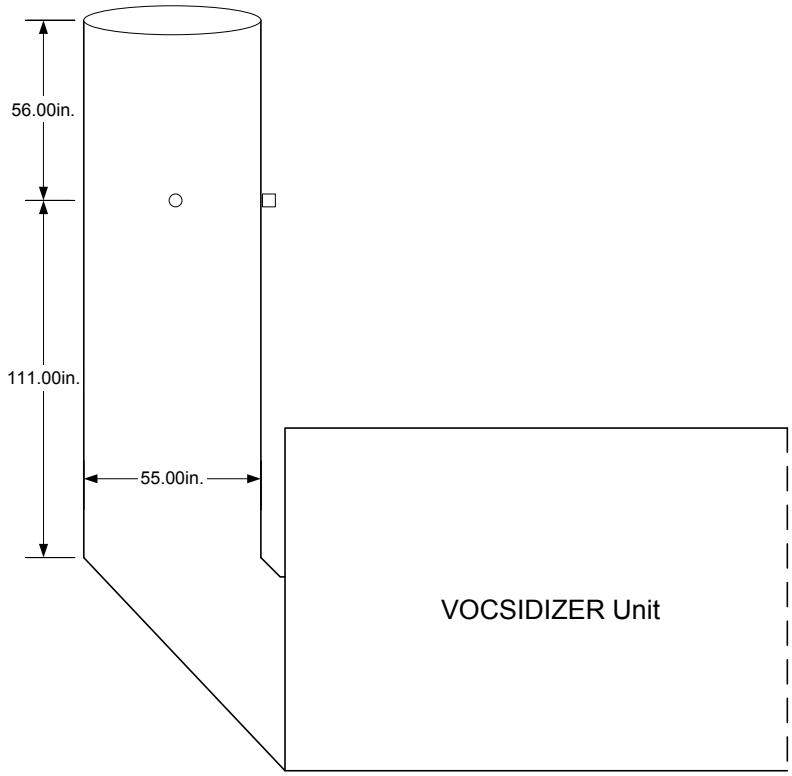


Figure 3. Schematic of the VOCSIDIZER Stack Sampling Location.

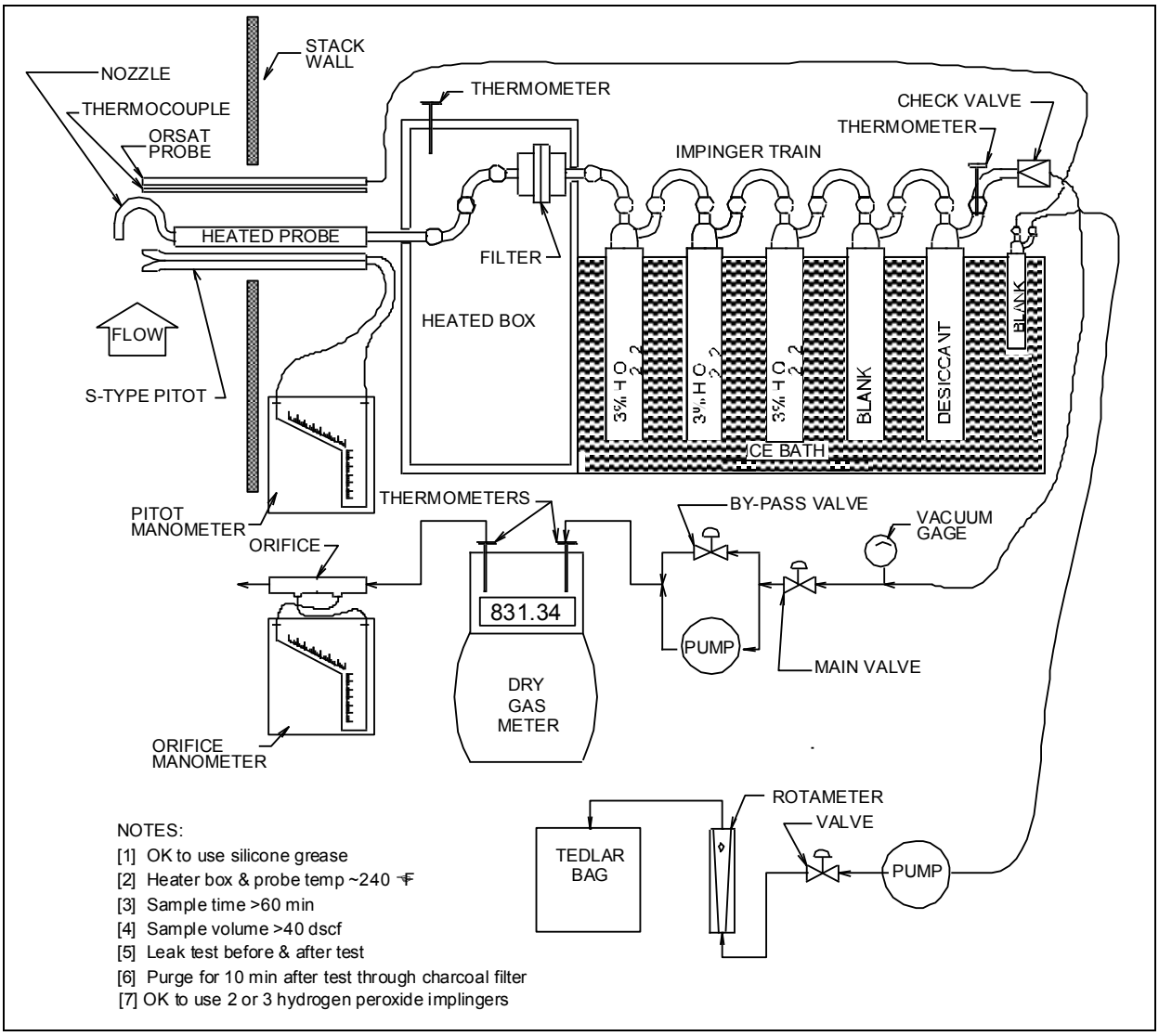


Figure 4. VOCSIDIZER PM and Orsat Sampling Train

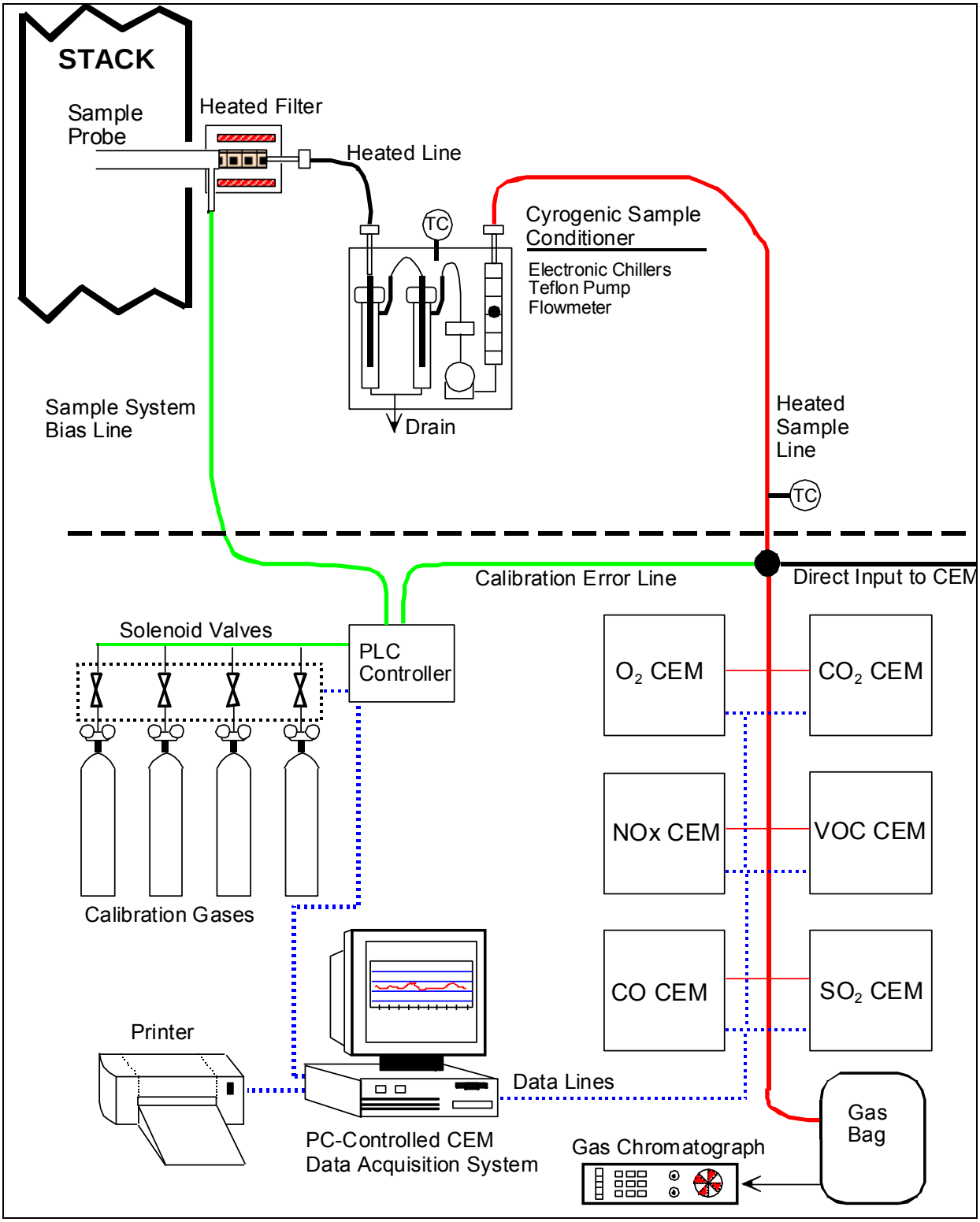


Figure 5. Schematic of CONSOL R&D CEM System

LIST OF APPENDICES

A - Raw Field Data & Tabulated Results

B - Laboratory Reports (GC Analysis for Methane)

C - QA/QC

D - Process Operating Data

APPENDIX A

Raw Field Data and Tabulated Results

- Method 5 Particulate Test Field Data Sheets
- Visible Emissions Field Data Sheets
- Total VOC Strip Chart Records
- O_2 Strip Chart Records
- CO_2 Strip Chart Records
- CO Strip Chart Records
- NO_X Strip Chart Records
- SO_2 Strip Chart Records

EPA METHOD 5 PARTICULATE SAMPLING FIELD DATA SHEET

Page _____ of _____

TEST ID	TEST # 1	METER BOX	N - 1	CAL. DATA: delta H	1.894
PLANT	WINDSOR	PITOT TUBE DESC	E - 1	Y	0.970
LOCATION	STACK 15	PROBE LENGTH [ft]	5	C(p)	
DATE	8-8-07	NOZZLE ID [inch]	1/4" c .265	FILTER BOX SETTING	~~250~~
OPERATOR(S)	BPS	%H_2O (Assumed)		PROBE HTR SETTING	250
AMBIENT TEMP [°F]	~420	FILTER ID	92	DUCT X-SECTION	circ ? / rect ? / other:
BAR. PRESS. [" Hg]	28.38	K FACTOR	2.60	DUCT DIMENSIONS	DUCT AREA
		* 0 Div	3.40		

Comments: _____

TRAVERSE POINT [port-inch]	CLOCK TIME (24-hr)	SAMPLE TIME [minute]	STATIC PRES [" H_2O]	PITOT HEAD [" H_2O]	METER DIFF PRESSURE [" H_2O]	METER VACUUM [" Hg]	METER READING [ft^3]	METER TEMP [oF] (6) inlet	METER TEMP [oF] (7) outlet	STACK TEMP [°F] (1)	PROBE TEMP [°F] (2)	FILTER BOX [°F]	LAST IMP TEMP [°F] (4)	METER EXHAUST O_2 [% vol]	METER EXHAUST CO_2 [% vol]
	1610	0					177.20								
B-1	1615	5		0.1	.26	0	178.9	94	93	440	250	NA	66		
2	1620	10	.57	0.75	2.00	5	182.7	92	94	297	250		62		
3	1625	15		0.90	2.3	5	187.0	93	94	289	250		63		
4	1630	20		0.64	1.7	6	191.1	94	94	420	252		64		
5	1635	25		0.62	1.6	5	194.8	95	94	450	253		69		
6	1640	30		0.60	2.0	4.5	199.84	96	95	301	252		71	change K factor	
A-1	~~1645~~	35		1.2	4.0	10	205.7	96	95	297	250		72		
2		40		1.2	4.0	11	211.4	97	96	357	252		73		
3		45		1.2	4.0	11	217.3	97	95	370	249		68		
4		50		.65	2.2	5	221.6	97	96	314	249		68		
5		55		.35	1.2	3	225.0	97	96	352	250		65		
6		60		.24	.82	4	227.888	96	96	410	250		63		
				.495											
AVERAGE			RMS	.648	1.71		50.688		95.1	358.1					

Sample Train Leak Checks: Pre Test OK ft^3 @ 10 in. Hg; Post Test OK ft^3 @ 12 in. Hg

Pitot Tube Leak Checks: PreTest OK @ 7 in. H_2O; Post Test OK @ 6 in. H_2O

CONSOLENERGY

EPA METHOD 5 PARTICULATE SAMPLING FIELD DATA SHEET

Page ___ of ___

TEST ID	TEST # 2
PLANT	WINDSOR
LOCATION	STACK
DATE	8-9-07
OPERATOR(S)	BPS
AMBIENT TEMP [°F]	
BAR. PRESS. [" Hg]	28.47

METER BOX	2-1
PITOT TUBE DESC	E-1
PROBE LENGTH [ft]	5
NOZZLE ID [inch]	1/4" C .245
%H_2O (Assumed)	
FILTER ID	47mm - 94
K FACTOR	~~2.60~~ 3.40

CAL. DATA: delta H	1.894
Y	0.970
C(p)	
FILTER BOX SETTING	—
PROBE HTR SETTING	250
DUCT X-SECTION	circ ? / rect ? / other:
DUCT DIMENSIONS	DUCT AREA

Comments:

TRAVERSE POINT [port-Inch]	CLOCK TIME (24-hr)	SAMPLE TIME [minute]	STATIC PRES [" H_2O]	PITOT HEAD [" H_2O]	METER DIFF PRESSURE [" H_2O]	METER VACUUM [" Hg]	METER READING [ft^3]	METER TEMP [oF] (6) inlet	METER TEMP [oF] (7) outlet	STACK TEMP [°F] (1)	PROBE TEMP [°F] (2)	FILTER BOX [°F]	LAST IMP TEMP [°F] (4)	METER EXHAUST O_2 [% vol]	METER EXHAUST CO_2 [% vol]
	0959	0					228.40								
A-1		5	.8	1.2	4.0	10	233.9	87	84	438	251	NA	63		
2		10	.77	1.0	3.4	8	239.2	91	85	365	250		52		
3		15		1.1	3.7	9	244.7	93	86	367	250		57		
4		20		.54	1.8	5	249.1	94	87	456	250		60		
5		25	.30	.30	1.0	3	252.1	95	88	392	250		61		
6		30		.20	.68	2	254.67	95	88	336	250		59		
B-1		35		1.2	4.0	11	260.4	98	91	345	252		57		
2		40		.84	2.8	7	265.5	100	92	335	252		57		
3		45		.80	2.7	7	270.2	101	93	466	251		58		
4		50		.90	3.0	8	275.3	102	95	345	252		60		
5		55		.45	1.5	5	279.1	104	96	308	250		60		
6		60		.54	1.8	5	283.038	104	97	309	250		61		
AVERAGE				.713	2.53		54.638		93.58	371.8					

Sample Train Leak Checks: Pre Test OK ft^3 @ 10 in. Hg; Post Test OK ft^3 @ 13 in. Hg

Pitot Tube Leak Checks: PreTest OK @ 7 in. H_2O; Post Test OK @ 7 in. H_2O

CONSOLENERGY

EPA METHOD 5 PARTICULATE SAMPLING FIELD DATA SHEET

Page _____ of _____

TEST ID	TEST # 3
PLANT	WINDSOR
LOCATION	STACK
DATE	8-9-07
OPERATOR(S)	BAS
AMBIENT TEMP [°F]	
BAR. PRESS. [" Hg]	28.44

METER BOX	2-1
PITOT TUBE DESC	E-1
PROBE LENGTH [ft]	5
NOZZLE ID [inch]	1/4" c .265
%H_2O (Assumed)	5
FILTER ID	95
K FACTOR	~~2.60~~ 3.4

CAL. DATA: delta H	1.894
Y	0.970
C(p)	
FILTER BOX SETTING	—
PROBE HTR SETTING	250
DUCT X-SECTION	circ ? rect ? other:
DUCT DIMENSIONS	DUCT AREA

Comments:

TRAVERSE POINT [port-inch]	CLOCK TIME (24-hr)	SAMPLE TIME [minute]	STATIC PRES [" H_2O]	PITOT HEAD [" H_2O]	METER DIFF PRESSURE [" H_2O]	METER VACUUM [" Hg]	METER READING [ft^3]	METER TEMP [oF] (6) inlet	METER TEMP [oF] (7) outlet	STACK TEMP [°F] (1)	PROBE TEMP [°F] (2)	FILTER BOX [°F]	LAST IMP TEMP [°F] (4)	METER EXHAUST O_2 [% vol]	METER EXHAUST CO_2 [% vol]
	1153	0					283.752								
B-1		5		1.1	3.7	8	289.1	103	102	386	250	NA	67		
2		10	.50	1.2	4.0	10	295.1	103	103	390	251		56		
3		15		1.0	3.4	10	300.9	104	103	294	250		62		
4		20		0.85	2.9	7	305.6	105	103	323	252		68		
5		25		0.55	1.85	5	309.6	106	104	396	253		69		
6		30		0.44	1.5	4	313.20	107	104	292	253		69		
A-1		35	.60	1.1	3.7	7	318.4	106	105	474	249		69		
2		40		1.1	3.7	8	323.9	108	105	343	251		66		
3		45		1.1	3.7	8	329.4	109	106	370	250		64		
4		50		.55	1.9	5	333.5	108	106	284	250		65		
5		55		.30	1.1	3	336.5	109	106	352	250		65		
6		60		.13	.45	1	338.803	109	106	282	250		65		
AVERAGE				.732	2.67		55.051		105.4	348.8					

Sample Train Leak Checks: Pre Test ok ft^3 @ 12 in. Hg
Post Test ok ft^3 @ 12 in. Hg

Pitot Tube Leak Checks: PreTest ok @ 6 in. H_2O
Post Test ok @ 6 in. H_2O

CONSOLENERGY

Company Name: CONSOL R&D
Location: VOCSIDIZER, Windsor
Date: 8/8/2007
Run No. One

Time	% O_2	% CO_2	ppm NOx	ppm SO_2	ppm THC	ppm CO
16:10	20.1	0.8	0.0	0.0	17.0	1.8
16:11	19.8	0.8	0.0	0.0	0.0	1.8
16:12	19.9	0.7	0.0	0.0	20.4	1.8
16:13	19.8	0.7	0.0	0.0	0.0	1.8
16:14	19.8	0.8	0.0	0.0	15.3	1.7
16:15	19.8	0.8	0.0	0.0	0.0	1.8
16:16	19.8	0.8	0.0	0.0	20.1	1.8
16:17	19.8	0.7	0.0	0.0	0.0	1.8
16:18	19.8	0.8	0.0	0.0	16.3	1.8
16:19	19.8	0.4	0.0	0.0	4.8	1.8
16:20	20.0	0.7	0.0	0.0	10.3	1.7
16:21	19.8	0.8	0.0	0.0	19.0	1.8
16:22	19.8	0.8	0.0	0.0	0.0	1.7
16:23	19.8	0.7	0.0	0.0	14.7	1.8
16:24	19.8	0.7	0.0	0.0	0.0	1.8
16:25	19.8	0.8	0.0	0.0	7.3	1.8
16:26	19.8	0.8	0.0	0.0	18.6	1.8
16:27	19.8	0.7	0.0	0.0	0.1	1.8
16:28	19.8	0.7	0.0	0.0	19.5	1.8
16:29	19.8	0.8	0.0	0.0	2.9	1.8
16:30	19.8	0.8	0.0	0.3	25.8	1.8
16:31	19.8	0.7	0.0	0.6	17.8	1.8
16:32	19.8	0.4	0.0	1.3	13.0	1.8
16:33	20.0	0.8	0.0	1.3	22.7	1.8
16:34	19.8	0.7	0.0	1.9	6.8	1.8
16:35	20.0	0.7	0.0	2.3	24.4	1.8
16:36	19.8	0.8	0.0	2.4	6.2	1.8
16:37	19.8	0.8	0.0	2.7	29.0	1.8
16:38	19.9	0.7	0.0	3.0	6.3	1.8
16:39	19.8	0.7	0.0	2.5	23.7	1.8
16:40	19.8	0.8	0.0	3.3	6.5	1.8
16:41	20.1	0.8	0.0	3.1	25.4	1.8
16:42	19.9	0.1	0.0	2.9	6.1	1.8
16:43	19.8	0.7	0.0	3.7	23.6	1.8
16:44	19.8	0.7	0.0	4.1	16.2	1.8
16:45	20.1	0.3	0.0	4.1	12.2	1.8
16:46	19.9	0.7	0.0	4.1	13.4	3.0
16:47	19.9	0.7	0.0	4.0	7.0	1.8
16:48	20.1	0.7	0.0	4.1	22.7	1.8
16:49	20.0	0.7	0.0	4.3	6.8	1.8
16:50	19.8	0.6	0.0	4.2	24.2	1.8
16:51	19.9	0.7	0.0	4.4	6.3	1.7
16:52	20.0	0.7	0.0	3.9	23.5	1.7
16:53	20.1	0.6	0.0	4.6	5.6	1.7
16:54	19.9	0.6	0.0	4.4	20.8	1.8
16:55	20.1	0.7	0.0	4.6	6.5	1.8
16:56	20.0	0.6	0.0	4.4	28.0	2.4
16:57	20.1	0.6	0.0	4.6	16.2	1.7
16:58	19.9	0.3	0.0	4.2	11.4	3.0
16:59	20.0	0.6	0.0	4.0	22.0	1.7
17:00	20.0	0.6	0.0	4.3	8.1	2.4
17:01	19.9	0.6	0.0	4.5	23.8	1.7
17:02	19.9	0.6	0.0	4.5	7.4	1.7
17:03	20.1	0.6	0.0	4.7	22.1	1.8
17:04	20.1	0.6	0.0	4.2	6.8	1.8
17:05	19.9	0.6	0.0	4.4	28.7	1.8
17:06	20.1	0.6	0.0	4.2	8.0	1.8
17:07	20.1	0.6	0.0	4.6	8.2	1.7
17:08	19.9	0.6	0.0	5.1	4.5	3.6
17:09	20.1.	0.6	0.0	4.6	4.0	3.6
Raw Average	**19.90**	**0.67**	**0.00**	**2.41**	**13.13**	**1.90**
Corrected Average	**19.94**	**0.67**	**0.25**	**2.37**	**12.10**	**-0.10**
Corrected lb/hr	**29311**	**1351**	**0.05**	**0.70**	**2.44**	**-0.01**

Company Name: CONSOL R&D
Location: VOCSIDIZER, Windsor
Date: 8/9/2007
Run No. Two

Time	% O_2	% CO_2	ppm NOx	ppm SO_2	ppm THC	ppm CO
9:59	20.0	0.6	0.0	0.0	54.5	2.8
10:00	20.0	0.6	0.0	0.0	4.2	2.9
10:01	20.0	0.5	0.0	0.0	16.4	2.9
10:02	20.1	0.5	0.0	0.0	3.8	2.9
10:03	20.0	0.6	0.0	0.0	29.9	2.9
10:04	20.0	0.5	0.0	0.0	2.7	2.8
10:05	20.0	0.5	0.0	0.0	18.7	2.8
10:06	20.1	0.5	0.0	0.0	11.3	2.9
10:07	20.2	0.3	0.0	0.0	6.1	4.1
10:08	20.0	0.3	0.0	0.0	26.6	2.9
10:09	20.2	0.5	0.0	0.0	3.2	4.1
10:10	20.1	0.5	0.0	0.0	18.5	2.3
10:11	20.1	0.5	0.0	0.0	5.0	2.9
10:12	20.1	0.6	0.0	0.0	30.8	2.2
10:13	20.0	0.5	0.0	0.0	4.3	2.2
10:14	20.1	0.6	0.0	0.0	31.2	1.6
10:15	20.1	0.5	0.0	0.0	5.9	2.8
10:16	20.0	0.5	0.0	0.0	35.8	2.8
10:17	20.0	0.5	0.0	0.0	4.2	2.9
10:18	20.0	0.5	0.0	0.0	14.5	2.8
10:19	20.1	0.6	0.0	0.0	22.5	2.9
10:20	20.0	0.5	0.0	0.0	12.3	4.1
10:21	20.1	0.5	0.0	0.0	15.0	2.2
10:22	20.2	0.5	0.0	0.0	4.0	3.4
10:23	20.0	0.4	0.0	0.0	16.4	2.8
10:24	20.1	0.5	0.0	0.0	5.6	2.2
10:25	20.1	0.5	0.0	0.0	18.4	2.7
10:26	20.0	0.5	0.0	0.0	5.4	2.8
10:27	20.0	0.6	0.0	0.0	15.3	2.2
10:28	20.8	0.5	0.0	0.0	3.4	2.8
10:29	19.9	0.5	0.0	0.0	16.5	2.8
10:30	19.8	0.5	0.0	0.0	4.3	3.5
10:31	19.9	0.4	0.0	0.0	37.3	1.6
10:32	19.9	0.5	0.0	0.0	7.5	3.4
10:33	20.1	0.5	0.0	0.0	12.4	2.9
10:34	19.8	0.5	0.0	0.0	34.6	4.0
10:35	19.9	0.5	0.0	0.0	5.6	2.9
10:36	19.9	0.7	0.0	0.0	35.3	2.8
10:37	19.8	0.5	0.0	0.0	2.3	2.8
10:38	19.8	0.6	0.0	0.0	18.9	2.8
10:39	19.8	0.6	0.0	0.0	2.5	2.8
10:40	19.9	0.6	0.0	0.0	34.4	2.3
10:41	19.8	0.7	0.0	0.6	3.5	2.8
10:42	19.8	0.6	0.0	0.7	19.5	2.8
10:43	19.8	0.6	0.0	0.0	1.9	2.8
10:44	19.8	0.6	0.0	0.4	19.9	2.8
10:45	20.0	0.6	0.0	0.4	4.2	5.8
10:46	19.8	0.7	0.0	0.0	18.1	2.8
10:47	19.8	0.6	0.0	0.0	17.0	2.8
10:48	19.8	0.6	0.0	0.4	2.7	4.1
10:49	19.8	0.6	0.0	0.1	20.1	2.8
10:50	19.9	0.7	0.0	0.1	2.1	2.8
10:51	19.8	0.6	0.0	0.1	16.9	2.9
10:52	19.8	0.6	0.0	0.1	1.2	2.8
10:53	19.8	0.6	0.0	0.1	34.9	2.8
10:54	19.9	0.7	0.0	0.2	2.6	2.8
10:55	19.8	0.6	0.0	0.0	16.4	2.8
10:56	19.8	0.6	0.0	0.1	1.2	2.9
10:57	19.8	0.6	0.0	0.0	18.4	2.9
10:58	19.9	0.5	0.0	0.0	11.3	2.9
Raw Average	**19.97**	**0.55**	**0.00**	**0.06**	**14.49**	**2.91**
Corrected Average	**20.00**	**0.55**	**0.10**	**0.00**	**13.88**	**1.32**
Corrected lb/hr	**35142**	**1316**	**0.04**	**0.00**	**4.88**	**0.47**

Company Name: CONSOL R&D
Location: VOCSIDIZER, Windsor
Date: 8/9/2007
Run No. Three

Time	% O_2	% CO_2	ppm NOx	ppm SO_2	ppm THC	ppm CO
11:53	19.8	0.6	0.0	0.0	1.4	1.6
11:54	19.8	0.6	0.0	0.0	20.3	1.6
11:55	19.8	0.6	0.0	0.0	1.1	1.6
11:56	19.8	0.7	0.0	0.0	22.2	1.7
11:57	19.8	0.7	0.0	0.0	0.6	1.6
11:58	19.8	0.6	0.0	0.0	18.0	1.6
11:59	19.8	0.6	0.0	0.0	0.0	1.6
12:00	19.9	0.6	0.0	0.0	21.6	1.5
12:01	19.8	0.6	0.0	0.0	2.4	1.6
12:02	19.8	0.3	0.0	0.0	13.2	1.6
12:03	19.8	0.6	0.0	0.0	16.7	2.8
12:04	19.8	0.7	0.0	0.0	2.6	3.4
12:05	20.0	0.6	0.0	0.0	15.7	1.6
12:06	19.8	0.7	0.0	0.0	0.2	1.5
12:07	19.8	0.7	0.0	0.0	17.1	1.6
12:08	19.8	0.7	0.0	0.0	0.0	1.6
12:09	19.9	0.6	0.0	0.0	14.8	1.6
12:10	19.8	0.7	0.0	0.0	0.0	1.6
12:11	19.8	0.7	0.0	0.0	14.4	1.7
12:12	19.8	0.6	0.0	0.0	0.0	1.7
12:13	19.8	0.6	0.0	0.0	14.9	1.7
12:14	19.8	0.7	0.0	0.0	0.0	1.7
12:15	19.8	0.7	0.0	0.0	14.9	2.9
12:16	19.8	0.7	0.0	0.0	0.0	1.6
12:17	19.8	0.7	0.0	0.0	12.3	1.6
12:18	19.8	0.5	0.0	0.0	0.0	1.6
12:19	19.8	0.7	0.0	0.0	31.1	1.6
12:20	19.8	0.7	0.0	0.0	0.0	1.5
12:21	19.8	0.7	0.0	0.0	14.4	1.7
12:22	19.9	0.7	0.0	0.0	0.0	1.7
12:23	19.8	0.6	0.0	0.0	13.5	1.7
12:24	19.8	0.6	0.0	0.0	0.0	1.7
12:25	19.8	0.6	0.0	0.0	13.2	1.8
12:26	19.8	0.6	0.0	0.0	5.8	1.7
12:27	19.8	0.1	0.0	0.0	12.2	1.7
12:28	20.0	0.5	0.0	0.0	7.1	1.6
12:29	19.8	0.4	0.0	0.0	0.0	1.6
12:30	19.8	0.5	0.0	0.0	22.5	1.6
12:31	19.8	0.4	0.0	0.0	0.0	1.7
12:32	19.8	0.5	0.0	0.0	23.7	1.6
12:33	19.8	0.5	0.0	0.0	0.0	1.7
12:34	19.8	0.5	0.0	0.0	6.8	1.7
12:35	19.8	0.5	0.0	0.0	21.0	1.7
12:36	19.8	0.5	0.0	0.0	0.0	1.7
12:37	19.8	0.5	0.0	0.0	9.2	1.7
12:38	20.1	0.5	0.0	0.0	3.7	1.7
12:39	20.0	0.5	0.0	0.0	9.8	1.7
12:40	19.9	0.5	0.0	0.0	26.4	1.7
12:41	20.0	0.5	0.0	0.0	2.1	1.7
12:42	20.0	0.4	0.0	0.0	14.2	1.7
12:43	20.2	0.6	0.0	0.0	0.3	1.7
12:44	19.9	0.5	0.0	0.0	25.6	1.7
12:45	20.1	0.5	0.0	0.0	0.0	1.6
12:46	20.1	0.5	0.0	0.0	14.3	1.7
12:47	19.9	0.5	0.0	0.0	0.0	1.7
12:48	20.0	0.5	0.0	0.0	25.6	1.7
12:49	20.1	0.5	0.0	0.0	0.0	1.7
12:50	20.2	0.5	0.0	0.0	14.3	1.7
12:51	20.0	0.5	0.0	0.0	0.0	1.7
12:52	20.0	0.3	0.0	0.0	26.9	1.7
Raw Average	**19.87**	**0.56**	**0.00**	**0.00**	**9.47**	**1.72**
Corrected Average	**21.12**	**0.62**	**-0.05**	**-0.11**	**12.96**	**2.34**
Corrected lb/hr	**37994**	**1526**	**-0.02**	**-0.04**	**4.66**	**0.84**

APPENDIX B

Laboratory Reports

- PM Analyses
- Gas Chromatograph Analyses for Methane
- Coal Analyses

EPA Method 5 Sample Train Analyses

Plant: Vocsidizer
Test Location: Stack
Test Date: 8/8/2007
Test No.: 1
Time: 1610-1715

Impinger Volumes

	Impinger				Totals
	1	2	3	Sil Gel	
Final, ml or g					
Initial, ml or g					
Gain, ml or g	0	0	0	0	0

Probe Rinse N/A

Final Wt., mg:
Tare Wt., mg:
Gain, mg: 0

Filter No.: 0092-47
Final Wt., mg: 0.151
Tare Wt., mg: 0.1496
Gain, mg: 0.0014

Total Particulate Wt., mg: 0.0014

Analyst: B.W. Green

EPA Method 5 Sample Train Analyses

Plant: Vocsidizer
Test Location: Stack
Test Date: 8/9/2007
Test No.: 2
Time: 0959-1104

Impinger Volumes

	Impinger				Totals
	1	2	3	Sil Gel	
Final, ml or g					
Initial, ml or g					
Gain, ml or g	0	0	0	0	0

Probe Rinse N/A

Filter No.: 0094-47

Final Wt., mg:
Tare Wt., mg:
Gain, mg: 0

Final Wt., mg: 0.1501
Tare Wt., mg: 0.1501
Gain, mg: 0

Total Particulate Wt., mg: 0

Analyst: B.W. Green

EPA Method 5 Sample Train Analyses

Plant: Vocsidizer
Test Location: Stack
Test Date: 8/9/2007
Test No.: 3
Time: 1153-1257

Impinger Volumes

	Impinger				Totals
	1	2	3	Sil Gel	
Final, ml or g					
Initial, ml or g					
Gain, ml or g	0	0	0	0	0

Probe Rinse N/A

Filter No.: 0095-47

Final Wt., mg:
Tare Wt., mg:
Gain, mg: 0

Final Wt., mg: 0.1506
Tare Wt., mg: 0.1494
Gain, mg: 0.0012

Total Particulate Wt., mg: 0.0012

Analyst: B.W. Green

APPENDIX C

QA/QC

- Axial Flow Check
- Pitot Tube Calibration
- Sampling Nozzle Calibration
- Dry Gas Meter Calibration
- Methane Calibration Curve for GC Analysis
- Methane QA/QC Check Samples
- Certificate of Accuracy for CEM Protocol Calibration Gases
- CEM Sample System Bias Test Data
- CEM Calibration Error Test Data
- CEM System Calibration and Drift Test Data for Each Run
- CEM Response Time Checks

Axial Flow Check

Location	Windsor	Duct Ht, "		Barometric	29.38
Date	8-8-07	Duct ID,"		Static	
Time	1510 - 1516	Duct Area	16.5 ft^2	Dry Bulb	
Tube I.D.	S-56	% O_2		Wet Bulb	
C-Factor	0.819	% CO_2		% H_20	
Operator(s)	BLG + BPS	% N_2		W.M.Wt	

PORT/ POINT	DISTANCE [" From Wall]	TEMP [°F]	DELTA P [" H_2O]	VELOCITY [Ft/Sec]	Null Angle
B- 1		412	0.70		≈ 0
2		308	2.1		≈ 0
3		300	2.2		≈ 0
4		400	1.6		≈ 0
5		440	1.6		≈ 0
6		376	2.0		≈ 0
A 1		300	3.8		≈ 0
2		325	3.9		≈ 0
3		360	3.9		≈ 0
4		325	2.2		≈ 0
5		354	1.3		≈ 0
6		400	0.96		≈ 0
Average					
Maximum					
Minimum					
SDEV					

DATA SUMMARY	
Velocity, [fps]	
acfm	
scfm	
dscfm	
Ex Air Free cfm	
Est. MM Btu/hr Heat Input	
Est. Firing Rate, lb/hr	

PITOT TUBE CALIBRATIONS

PITOT TUBE ID NUMBER- E-1
PITOT TUBE DESCRIPTION- 7-1/2" Probe tip
DATE CALIBRATED- 01/11/07
CALIBRATED BY- RPD BPS

VELOCITY RANGE	SAMPLE NUMBER	SIDE	STANDARD READINGS [" of H20]	S-TUBE READINGS [" of H20]	INDIVIDUAL C FACTOR	AVG OF INDIVIDUAL C FACTOR	DEVIATION	APPROX VELOCITY [FT/SEC]
LOW	1	A	0.1800	0.2400	0.857	0.857	0.000	28
	2		0.1800	0.2400	0.857			
	3		0.1800	0.2400	0.857			
LOW	1	B	0.1900	0.2800	0.816	0.823	0.009	29
	2		0.1900	0.2800	0.816			
	3		0.2000	0.2800	0.837			
MEDIUM	1	A	0.4600	0.7000	0.803	0.806	0.003	44
	2		0.4600	0.6900	0.808			
	3		0.4600	0.6900	0.808			
MEDIUM	1	B	0.4500	0.6700	0.811	0.807	0.003	44
	2		0.4500	0.6800	0.805			
	3		0.4500	0.6800	0.805			
HIGH	1	A	0.9600	1.2900	0.854	0.853	0.001	64
	2		0.9600	1.3000	0.851			
	3		0.9600	1.2900	0.854			
HIGH	1	B	0.9700	1.3300	0.845	0.845	0.000	64
	2		0.9700	1.3300	0.845			
	3		0.9700	1.3300	0.845			

AVERAGE CALCULATIONS OVER ENTIRE VELOCITY RANGES

SIDE	C-FACTOR	DEVIATION
A	0.839	0.022
B	0.825	0.014

[NOTE: USE DIFFERENT C-FACTORS FOR 10, 20, & 33 FT/SEC VELOCITY RANGES]

[RLO,1/22/93,1000]

CONSOL Energy
EPA Method 5
Meter Box Calibration
Pre-Test Orifice Method
English Meter Box Units, English K' Factor

Filename: G:\R&D\STACK\CALIB\meters\N1\[1.29.07.xls]Cal Form
Revised: 1/12/00 Version: 2.2

Model #: 2010A
Meter #: N-1
Operator: BPS

Date: ----------> 01/29/07
Barometric Pressure: ----------> 28.94 (in. Hg)
Theoretical Critical Vacuum:---> 13.65 (in. Hg)

!!!!!!!!
IMPORTANT For valid test results, the Actual Vacuum should be 1 to 2 in. Hg greater than the Theoretical Critical Vacuum shown above.
IMPORTANT The Critical Orifice Coefficient, K', must be entered in English units, (ft)^3*(deg R)^0.5/((in.Hg)*(min)).
!!!!!!!!

---------- DRY GAS METER READINGS ----------									-CRITICAL ORIFICE READINGS-					
dH (in H2O)	Time (min)	Volume Initial (cu ft)	Volume Final (cu ft)	Volume Total (cu ft)	Initial Temps. Inlet (deg F)	Initial Temps. Outlet (deg F)	Final Temps. Inlet (deg F)	Final Temps. Outlet (deg F)	Orifice Serial# (number)	K' Orifice Coefficient (see above)	Actual Vacuum (in Hg)	-- Ambient Temperature -- Initial (deg F)	Final (deg F)	Average (deg F)
0.31	15.00	824.000	828.850	4.850	68.0	67.0	68.0	67.0	IK40	0.240	23.0	63.0	63.0	63.0
0.67	15.00	828.850	835.920	7.070	68.0	67.0	69.0	68.0	IK48	0.350	22.0	63.0	63.0	63.0
1.20	15.00	835.920	845.220	9.300	69.0	68.0	70.0	68.0	IK55	0.461	20.2	63.0	63.0	63.0
2.00	15.00	845.220	857.200	11.980	70.0	68.0	72.0	69.0	IK63	0.594	18.5	63.0	64.0	63.5
3.85	15.00	857.200	873.680	16.480	72.0	69.0	75.0	70.0	IK73	0.816	15.0	64.0	64.0	64.0

********** RESULTS **********

--- DRY GAS METER --- VOLUME CORRECTED	
Vm(std) (cu ft)	Vm(std) (liters)
4.697	133.0
6.847	193.9
9.006	255.1
11.603	328.6
15.984	452.7

--------- ORIFICE ---------		
VOLUME CORRECTED		VOLUME NOMINAL
Vcr(std) (cu ft)	Vcr(std) (liters)	Vcr (cu ft)
4.558	129.1	4.669
6.642	188.1	6.804
8.749	247.8	8.963
11.270	319.2	11.557
15.478	438.3	15.887

-- DRY GAS METER -- CALIBRATION FACTOR	
Y Value (number)	Variation (number)
0.970	0.000
0.970	0.000
0.971	0.001
0.971	0.001
0.968	-0.002
Avg Y--> 0.970	

--------- ORIFICE --------- CALIBRATION FACTOR		
dH@		
Value (in H2O)	Value (mm H2O)	Variation (in H2O)
1.801	45.74	-0.093
1.861	47.27	-0.033
1.919	48.75	0.025
1.926	48.92	0.032
1.962	49.83	0.068
Avg dH@--> 1.894	48.10	

Note: For Calibration Factor Y, the ratio of the reading of the calibration meter to the dry gas meter, acceptable tolerance of individual values from the average is +-0.02.

For Orifice Calibration Factor dH@, the orifice differential pressure in inches of H20 that equates to 0.75 cfm of air at 68 F and 29.92 inches of Hg, acceptable tolerance of individual values from the average is +-0.2.

Meterbox: N-1 **Cal. Date = 1/29/07**
Y = 0.970 **$\Delta H_@$ = 1.894**

CALIBRATION LARGE S.S. GOOSE NECK TIPS

		1	2	3	AV.	
.500 1/2"	A	.500	.501	.500	.500	
	B	.501	.502	.503	.502	
.375 7/16"		.438	.437	.438	.438	
.375 3/8"	A	.375	.374	.375	.375	
	B	.374	.375	.376	.375	
	C	.364	.365	.366	.365	
.344 11/32"	A	.345	.346	.345	.345	
	B	.338	.337	.338	.338	
.3125 5/16"	A	.312	.313	.312	.312	
	B	.314	.314	.314	.314	
	C	———	———	———	LOST	
	D	.311	.311	.311	.311	
	E	———	———	———	LOST	
.281 9/32"	A	.276	.276	.276	.276	
	B	.275	.276	.275	.275	
	C	.276	.275	.276	.276	
.266 17/64"		———	———	———	LOST	
.250 1/4"	A	.250	.249	.250	.250	
	B	.251	.252	.251	.251	NECK BAD
	C	.265	.264	.265	.265	
	D	.247	.248	.249	.248	
	E	.249	.250	.251	.250	
.219 7/32"	A	.214	.215	.214	.214	
	B	.216	.215	.216	.216	
	C	.216	.217	.218	.217	
.1875 3/16"	A	———	———	———	LOST	
	B	.186	.186	.186	.186	
	C	.194	.195	.194	.194	
	D	.189	.190	.189	.189	
	E	.183	.184	.185	.184	
.156 5/32"	A	.154	.154	.154	.154	
	B	.158	.157	.158	.158	
	C	.150	.150	.150	.150	
	D	.147	.146	.147	.147	
.125 1/8"	A	.144	.143	.144	.144	
	B	.141	.141	.141	.141	

DONE 1-8-07 B.P.S.

.250 1/4"	A	.253	.254	.254	.254

Airgas

Airgas Great Lakes, Inc.
2009 Bellaire Ave.
Royal Oak, MI 48067
Ph: (248) 399-9150
Fax: (248) 584-2540
http://www.airgas.com

CERTIFICATE OF ANALYSIS
Grade of Product: EPA Protocol

Customer:	CONSOL		
Part Number:	E02NI99E80A0239	Reference Number:	32-112572167-5
Cylinder Number:	LL34026	Cylinder Volume:	83 Cu Ft.
Laboratory:	MIC - Royal Oak - MI	Cylinder Pressure:	2215 PSIG
Analysis Date:	Jul 30, 2007	Valve Outlet:	660

Expiration Date: Jul 30, 2009

Certification performed in accordance with "EPA Traceability Protocol (Sept. 1997)" using the assay procedures listed. Analytical Methodology does not require correction for analytical interferences. This cylinder has a total analytical uncertainty as stated below with a confidence level of 95%. There are no significant impurities which affect the use of this calibration mixture. All concentrations are on a volume/volume basis unless otherwise noted.
Do Not Use This Cylinder below 150 psig.i.e. 1 Mega Pascal

ANALYTICAL RESULTS

Component	Requested Concentration	Actual Concentration	Protocol Method	Total Relative Uncertainity
SULFUR DIOXIDE	90.00 PPM	90.861 PPM	G1	+- 1% NIST Traceable
NITROGEN	Balance			

CALIBRATION STANDARDS

Type	Lot ID	Cylinder No	Concentration	Expiration Date
NTRM	04060308	XC017404	98.0PPM SULFUR DIOXIDE/NITROGEN	Apr 02, 2008

ANALYTICAL EQUIPMENT

Instrument/Make/Model	Analytical Principle	Last Multipoint Calibration
E/N 54, 100ppmFS SO2, Nicolet 6700	Fourier Transform Infrared (FTIR)	Jul 03, 2007

Triad Data Available Upon Request

Notes:ORDER# 505643

Rachelle Rudder

QA Approval

Page 1 of 32-112572167-5

AGA
Member of the Linde Gas Group

Linde

Certificate of Analysis

EPA Protocol

Performed according to EPA-600/R-97/121, Procedure G1

Notice: This Cylinder is not to be used when pressure is under 150 psig.

Manufactured and certified at:
Linde Gas LLC
Maumee Specialty Gas Plant
6421 Monclova Road
MAUMEE OH 43537
419-893-7226

Produced for customer:
LINDE GAS
LINDE PITTSBURGH INTERBRANCH
4349 WILLIAM PENN HWY
MURRYSVILLE PA 15668
724-327-1480

Material:	6154	**Blend Tolerance:**	5 % Relative
EPA CO/N2 10-99 PPM	A31	**Blend Type:**	EPA Protocol
Production #:	100107308	**Cyl. Pressure:**	2000 psig
Lot #:	02499J5220GE	**Balance Gas:**	Nitrogen
Cylinder #:	CC167379	**CGA:**	350
Expiration Date:	10/5/2008	**Analytical Accuracy:**	1.00 % Relative
Shelf Life:	36 months	**Confidence:**	95 %

CAS #	Certified Component	Requested Concentration	Concentration and Uncertainty	Date of Certification
630-08-0	Carbon Monoxide	60	60.0 +/- 0.6 ppm	10/05/2005
7727-37-9	Nitrogen		Balance	10/05/2005

CAS #	Reference Standard	Cylinder/Standard #	Concentration	Expire Date
630-08-0	Carbon Monoxide	CC7811 , GMIS	25.48 ppm	07/13/2006

Instrument	Serial #	Analytical Principle	Calibration Date
Horiba VIA-510	569466011	Non-Dispersive Infrared	09/19/2005

All analyses are performed under controlled environmental conditions.This product is manufactured using equipment which has been calibrated with NIST traceable, or equivalent, standards, weights, or equipment.

Analytical report approved by Jennifer Carney

Jennifer Carney

HiQ Analysis Certificate

Scott Specialty Gases

Shipped From: 1290 COMBERMERE STREET
TROY MI 48083
Phone: 248-589-2950 Fax: 248-589-2134

CERTIFICATE OF ANALYSIS

CONSOL, INC
J.WITHUM BLDG 13 CYL RACK
4000 BROWNSVILLE RD
RESEARCH & DEVELOPMENT
SOUTH PARK PA 15129

PROJECT #: 05-22989-001
PO#: 043014
ITEM #: 0501026 BL
DATE: 15Sep2004

CYLINDER #: BLM000255
FILL PRESSURE: 02000 PSIG

PURE MATERIAL: AIR CAS# 132259-10-0

GRADE: VOC FREE

PURITY: -

IMPURITY	MAXIMUM CONCENTRATIONS	ACTUAL CONCENTRATIONS
THC	0.01 PPM	< 0.01 PPM
CO	0.1 PPM	< 0.1 PPM
CO2	0.3 PPM	< 0.3 PPM
H2O	2.0 PPM	< 2.0 PPM
O2	20 TO 21%	< 20 TO 21%

ANALYST:

AGA
Member of the Linde Gas Group

Linde

Certificate of Analysis

EPA Protocol

Performed according to EPA-600/R-97/121, Procedure G1

Notice: This Cylinder is not to be used when pressure is under 150 psig.

Manufactured and certified at:
Linde Gas LLC
Maumee Specialty Gas Plant
6421 Monclova Road
MAUMEE OH 43537
419-893-7226

Produced for customer:
LINDE GAS
LINDE PITTSBURGH INTERBRANCH
4349 WILLIAM PENN HWY
MURRYSVILLE PA 15668
724-327-1480

Material:	2179		**Blend Tolerance:**	1 % Relative
MISC 3 COMPONENT	EPA	A31	**Blend Type:**	EPA Protocol
Production #:	100091262		**Cyl. Pressure:**	2000 psig
Lot #:	02499L4030ZD		**Balance Gas:**	Nitrogen
Cylinder #:	CC127155		**CGA:**	590
Expiration Date:	11/17/2007		**Analytical Accuracy:**	1.00 % Relative
Shelf Life:	36 months		**Confidence:**	95 %

CAS #	Certified Component	Requested Concentration	Concentration and Uncertainty	Date of Certification
124-38-9	Carbon Dioxide	2.5	2.39 +/- 0.02 %	11/17/2004
7782-44-7	Oxygen	12.5	12.3 +/- 0.1 %	11/17/2004
7727-37-9	Nitrogen		Balance	11/17/2004

CAS #	Reference Standard	Cylinder/Standard #	Concentration	Expire Date
124-38-9	Carbon Dioxide	CC76149 , GMIS	3.007 %	04/26/2006
7782-44-7	Oxygen	CC73279 , NTRM	20.89 %	10/02/2008

Instrument	Serial #	Analytical Principle	Calibration Date
Horiba VIA-510	569164052	Non-Disperisve Infrared	07/12/2004
Rosemount 755R	1000559	Paramagnetic	09/16/2004

All analyses are performed under controlled environmental conditions.This product is manufactured using equipment which has been calibrated with NIST traceable, or equivalent, standards, weights, or equipment.

Analytical report approved by Jennifer Carney

Jennifer Carney

HiQ Analysis Certificate

RATA CLASS

Scott Specialty Gases

Dual-Analyzed Calibration Standard

6141 EASTON ROAD, BLDG 1,PLUMSTEADVILLE,PA 18949-0310 Phone: 800-331-4953 Fax: 215-766-7226

CERTIFICATE OF ACCURACY: Interference Free™ EPA Protocol Gas

Assay Laboratory

SCOTT SPECIALTY GASES
6141 EASTON ROAD, BLDG 1
PLUMSTEADVILLE,PA 18949-0310

P.O. No.: 042207
Project No.: 01-85646-003

Customer

CONSOL, INC
A. SCHWALB - BLDG 13 PDU
4000 BROWNSVILLE RD
RESEARCH & DEVELOPMENT
SOUTH PARK PA 15129

ANALYTICAL INFORMATION

This certification was performed according to EPA Traceability Protocol For Assay & Certification of Gaseous Calibration Standards; Procedure G-1; September, 1997.

Cylinder Number: BLM004367 Certification Date: 19Feb2003 Exp. Date: 18Feb2005
Cylinder Pressure***: 2122 PSIA

COMPONENT	CERTIFIED CONCENTRATION (Moles)		ANALYTICAL ACCURACY**	TRACEABILITY
NITRIC OXIDE	50.3	PPM	+/- 1%	Direct NIST and NMi
NITROGEN - OXYGEN FREE		BALANCE		
TOTAL OXIDES OF NITROGEN	50.6	PPM		Reference Value Only

*Do not use when cylinder pressure is below 150 psig
**Analytical accuracy is based on the requirements of EPA Protocol Procedure G1, September 1997
Product certified as +/- 1% analytical accuracy is directly traceable to NIST or NMi standards

REFERENCE STANDARD

TYPE/SRM NO.	EXPIRATION DATE	CYLINDER NUMBER	CONCENTRATION	COMPONENT
NTRM 1684	01Aug2006	AAL0678491	97.25 PPM	NO/N2

INSTRUMENTATION

INSTRUMENT/MODEL/SERIAL#	DATE LAST CALIBRATED	ANALYTICAL PRINCIPLE
FTIR System/8220/AA89300174	03Feb2003	Scott Enhanced FTIR

ANALYZER READINGS

(Z = Zero Gas R = Reference Gas T = Test Gas r = Correlation Coefficient)

First Triad Analysis

NITRIC OXIDE

Date: 11Feb2003 Response Unit:PPM

Z1 = 0.39380	R1 = 94.73301	T1 = 50.35869
Z2 = 94.43098	Z2 = 0.31560	T2 = 50.43050
Z3 = 0.51760	T3 = 50.20871	R3 = 94.69610
Avg. Concentration:	50.35	PPM

Second Triad Analysis

Date: 19Feb2003 Response Unit: PPM

Z1 = 0.28490	R1 = 97.36921	T1 = 50.25243
R2 = 97.09148	Z2 = 0.08330	T2 = 50.27018
Z3 = 0.28980	T3 = 50.17340	R3 = 97.13928
Avg. Concentration:	50.23	PPM

Calibration Curve

Concentration = A + Bx + Cx2 + Dx3 + Ex4
r = 0.999990

Constants:	A = 0.000000
B = 1.000000	C = 0.000000
D = 0.000000	E = 0.000000

APPROVED BY: Michael A. Kohns

Michael A. Kohns

Member of the Linde Gas Group

Linde

Certificate of Analysis

EPA Protocol

Performed according to EPA-600/R-97/121, Procedure G1

Notice: This Cylinder is not to be used when pressure is under 150 psig.

Manufactured and certified at:
Linde Gas LLC
Maumee Specialty Gas Plant
6421 Monclova Road
MAUMEE OH 43537
419-893-7226

Produced for customer:
LINDE GAS
LINDE PITTSBURGH INTERBRANCH
4349 WILLIAM PENN HWY
MURRYSVILLE PA 15668
724-327-1480

Material:	3996		**Blend Tolerance:**	5 % Relative
EPA PROPANE/ZERO	AIR 100-649	A31	**Blend Type:**	Gravimetric
Production #:	100089636		**Cyl. Pressure:**	2000 psig
Lot #:	02499K4010GI		**Balance Gas:**	Air
Cylinder #:	CC183852		**CGA:**	590
Expiration Date:	10/7/2007		**Analytical Accuracy:**	1.00 % Relative
Shelf Life:	36 months		**Confidence:**	95 %

CAS #	Certified Component	Requested Concentration	Concentration and Uncertainty	Date of Certification
74-98-6	Propane	450	452 +/- 5 ppm	10/07/2004
132259-10-0	Air		Balance	10/07/2004

CAS #	Reference Standard	Cylinder/Standard #	Concentration	Expire Date
74-98-6	Propane	CC196 , GMIS	252.9 ppm	07/14/2005
74-98-6	Propane	CC197 , GMIS	510.0 ppm	07/24/2005

Instrument	Serial #	Analytical Principle	Calibration Date
Horiba FIA-510	56847471	Flame Ionization	10/05/2004

All analyses are performed under controlled environmental conditions.This product is manufactured using equipment which has been calibrated with NIST traceable, or equivalent, standards, weights, or equipment.

Analytical report approved by Jennifer Carney

Jennifer Carney

HRI Analysis Certificate

Linde Gas

Certificate of Analysis

EPA Protocol

Performed according to EPA-600/R-97/121, Procedure G1

HiQ® Certificate

Notice: This Cylinder is not to be used when pressure is under 150 psig.

Manufactured and certified at:
Linde Gas LLC
Maumee Specialty Gas Plant
6421 Monclova Road
MAUMEE OH 43537
419-893-7226

Produced for customer:
LINDE GAS
LINDE PITTSBURGH INTERBRANCH
4349 WILLIAM PENN HWY
MURRYSVILLE PA 15668
724-327-1480

Material:	9979	**Blend Tolerance:**	5 % Relative
EPA PROPANE/ZERO AIR 100-649 PPM CERTA16		**Blend Type:**	EPA Protocol
Production #:	100125184	**Cyl. Pressure:**	2000 psig
Lot #:	02499J6140ZE	**Balance Gas:**	Air
Cylinder #:	LL32699	**CGA:**	590
Expiration Date:	9/29/2009	**Analytical Accuracy:**	1.00 % Relative
Shelf Life:	36 months	**Confidence:**	95 %

CAS #	Certified Component	Requested Concentration	Concentration and Uncertainty	Date of Certification
74-98-6	Propane	150	151 +/- 1.5 ppm	09/29/2006
132259-10-0	Air		Balance	09/29/2006

CAS #	Analyzed (For Ref Use Only)	Concentration	Analysis Date
7782-44-7	Oxygen	20.8 %	09/29/2006

CAS #	Reference Standard	Cylinder/Standard #	Concentration	Expire Date
74-98-6	Propane	CC196 , GMIS	253.1 ppm	07/12/2007
74-98-6	Propane	CC148402 , GMIS	97.82 ppm	06/02/2008
7782-44-7	Oxygen	CC195913 , NTRM	20.90 %	01/01/2010

Instrument	Serial #	Analytical Principle	Calibration Date
Horiba FIA-510	56847471	Flame Ionization	09/07/2006
Rosemount 755R	1000559	Paramagnetic	09/07/2006

All analyses are performed under controlled environmental conditions.This product is manufactured using equipment which has been calibrated with NIST traceable, or equivalent, standards, weights, or equipment.

Analytical report approved by Roy Yoder

Roy Yoder

HiQ Certificate

Linde Gas

Certificate of Analysis

EPA Protocol

Performed according to EPA-600/R-97/121, Procedure G1

HiQ® Certificate

Notice: This Cylinder is not to be used when pressure is under 150 psig.

Manufactured and certified at:
Linde Gas USA LLC
Maumee Specialty Gas Plant
6421 Monclova Road
MAUMEE OH 43537
419-893-7226

Produced for customer:
LINDE GAS
LINDE PITTSBURGH INTERBRANCH
4349 WILLIAM PENN HWY
MURRYSVILLE PA 15668
724-327-1480

Material:	9979	**Blend Tolerance:**	5 % Relative
EPA PROPANE/ZERO AIR 100-649 PPM CERTA16		**Blend Type:**	EPA Protocol
Production #:	100133630	**Cyl. Pressure:**	2000 psig
Lot #:	02499C7150GE	**Balance Gas:**	Air
Cylinder #:	LL8546	**CGA:**	590
Expiration Date:	3/23/2010	**Analytical Accuracy:**	1.00 % Relative
Shelf Life:	36 months	**Confidence:**	95 %

CAS #	Certified Component	Requested Concentration	Concentration and Uncertainty	Date of Certification
74-98-6	Propane	250	254 +/- 2.5 ppm	03/23/2007
132259-10-0	Air		Balance	03/23/2007

CAS #	Analyzed (For Ref Use Only)	Concentration	Analysis Date
7782-44-7	Oxygen	20.9 %	03/23/2007

CAS #	Reference Standard	Cylinder/Standard #	Concentration	Expire Date
74-98-6	Propane	CC196 , GMIS	253.1 ppm	07/12/2007
7782-44-7	Oxygen	CC195913 , NTRM	20.90 %	01/01/2010

Instrument	Serial #	Analytical Principle	Calibration Date
Horiba FIA-510	56847471	Flame Ionization	03/07/2007
Rosemount 755R	1000559	Paramagnetic	03/06/2007

All analyses are performed under controlled environmental conditions.This product is manufactured using equipment which has been calibrated with NIST traceable, or equivalent, standards, weights, or equipment.

Analytical report approved by Roy Yoder

Roy Yoder

HiQ certificate

Linde Gas | Linde

Certificate of Analysis

EPA Protocol

Performed according to EPA-600/R-97/121, Procedure G1

Notice: This Cylinder is not to be used when pressure is under 150 psig.

Manufactured and certified at:
Linde Gas LLC
Maumee Specialty Gas Plant
6421 Monclova Road
MAUMEE OH 43537
419-893-7226

Produced for customer:
LINDE GAS
LINDE PITTSBURGH INTERBRANCH
4349 WILLIAM PENN HWY
MURRYSVILLE PA 15668
724-327-1480

Material:	6150	**Blend Tolerance:**	5 % Relative
EPA CO/N2 10-99 PPM	A16	**Blend Type:**	EPA Protocol
Production #:	100105967	**Cyl. Pressure:**	2000 psig
Lot #:	02499H5260UG	**Balance Gas:**	Nitrogen
Cylinder #:	LL35397	**CGA:**	350
Expiration Date:	9/6/2008	**Analytical Accuracy:**	1.00 % Relative
Shelf Life:	36 months	**Confidence:**	95 %

CAS #	Certified Component	Requested Concentration	Concentration and Uncertainty	Date of Certification
630-08-0	Carbon Monoxide	30	30.7 +/- 0.3 ppm	09/06/2005
7727-37-9	Nitrogen		Balance	09/06/2005

CAS #	Reference Standard	Cylinder/Standard #	Concentration	Expire Date
630-08-0	Carbon Monoxide	CC7811 , GMIS	25.48 ppm	07/13/2006

Instrument	Serial #	Analytical Principle	Calibration Date
Thermo Nicolet AEM	AET0100218	FTIR	07/05/2005

All analyses are performed under controlled environmental conditions.This product is manufactured using equipment which has been calibrated with NIST traceable, or equivalent, standards, weights, or equipment.

Analytical report approved by Jennifer Carney

Jennifer Carey

HiQ Analysis Certificate

Consol

Linde Gas | Linde

Certificate of Analysis

EPA Protocol

Performed according to EPA-600/R-97/121, Procedure G1

Notice: This Cylinder is not to be used when pressure is under 150 psig.

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419-893-7226

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4349 WILLIAM PENN HWY
MURRYSVILLE PA 15668
724-327-1480

Material:	2179		**Blend Tolerance:**	5 % Relative
MISC 3 COMPONENT	EPA	A31	**Blend Type:**	EPA Protocol
Production #:	100114186		**Cyl. Pressure:**	2000 psig
Lot #:	02499B6100GF		**Balance Gas:**	Nitrogen
Cylinder #:	CC180011		**CGA:**	590
Expiration Date:	2/17/2009		**Analytical Accuracy:**	1.00 % Relative
Shelf Life:	36 months		**Confidence:**	95 %

CAS #	Certified Component	Requested Concentration	Concentration and Uncertainty	Date of Certification
124-38-9	Carbon Dioxide	4.5	4.50 +/- 0.05 %	02/17/2006
7782-44-7	Oxygen	21	21.0 +/- 0.2 %	02/17/2006
7727-37-9	Nitrogen		Balance	02/17/2006

CAS #	Reference Standard	Cylinder/Standard #	Concentration	Expire Date
124-38-9	Carbon Dioxide	CC73495 , NTRM	3.912 %	10/02/2008
7782-44-7	Oxygen	CC73285 , NTRM	20.89 %	10/02/2008

Instrument	Serial #	Analytical Principle	Calibration Date
Thermo Nicolet AEM	AET0100218	FTIR	01/10/2006
Rosemount 755R	1000559	Paramagnetic	01/10/2006

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Analytical report approved by Jennifer Carney

Jennifer Carney

HiQ Analysis Certificate

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Certificate of Analysis

EPA Protocol

Performed according to EPA-600/R-97/121, Procedure G1

Notice: This Cylinder is not to be used when pressure is under 150 psig.

Manufactured and certified at:
Linde Gas LLC
Maumee Specialty Gas Plant
6421 Monclova Road
MAUMEE OH 43537
419-893-7226

Produced for customer:
LINDE GAS
LINDE PITTSBURGH INTERBRANCH
4349 WILLIAM PENN HWY
MURRYSVILLE PA 15668
724-327-1480

Material:	6599	**Blend Tolerance:**	5 % Relative
EPA NO/N2 50-499 PPM	A31	**Blend Type:**	EPA Protocol
Production #:	100099559	**Cyl. Pressure:**	2000 psig
Lot #:	02499D5130SE	**Balance Gas:**	Nitrogen
Cylinder #:	CC166849	**CGA:**	660
Expiration Date:	4/28/2007	**Analytical Accuracy:**	1.00 % Relative
Shelf Life:	24 months	**Confidence:**	95 %

CAS #	Certified Component	Requested Concentration	Concentration and Uncertainty	Date of Certification
10102-43-9	Nitric Oxide	90	90.0 +/- 0.9 ppm	04/28/2005
7727-37-9	Nitrogen		Balance	04/28/2005

CAS #	Analyzed (For Ref Use Only)	Concentration	Analysis Date
N/A	NOx	90.1 ppm	04/28/2005

CAS #	Reference Standard	Cylinder/Standard #	Concentration	Expire Date
10102-43-9	Nitric Oxide	CC41909 , GMIS	49.18 ppm	05/21/2006

Instrument	Serial #	Analytical Principle	Calibration Date
Horiba CLA-510SS	568093024	Chemiluminescence	02/17/2005

All analyses are performed under controlled environmental conditions.This product is manufactured using equipment which has been calibrated with NIST traceable, or equivalent, standards, weights, or equipment.

Analytical report approved by Jennifer Carney

Jennifer Carney

HiQ Analysis Certificate

Linde Gas

Certificate of Analysis

EPA Protocol

Performed according to EPA-600/R-97/121, Procedure G1

Notice: This Cylinder is not to be used when pressure is under 150 psig.

Manufactured and certified at:
Linde Gas LLC
Maumee Specialty Gas Plant
6421 Monclova Road
MAUMEE OH 43537
419-893-7226

Produced for customer:
LINDE GAS
LINDE PITTSBURGH INTERBRANCH
4349 WILLIAM PENN HWY
MURRYSVILLE PA 15668
724-327-1480

Material:	6154	**Blend Tolerance:**	5 % Relative
EPA CO/N2 10-99 PPM	A31	**Blend Type:**	EPA Protocol
Production #:	100107308	**Cyl. Pressure:**	2000 psig
Lot #:	02499J5220GE	**Balance Gas:**	Nitrogen
Cylinder #:	CC167379	**CGA:**	350
Expiration Date:	10/5/2008	**Analytical Accuracy:**	1.00 % Relative
Shelf Life:	36 months	**Confidence:**	95 %

CAS #	Certified Component	Requested Concentration	Concentration and Uncertainty	Date of Certification
630-08-0	Carbon Monoxide	60	60.0 +/- 0.6 ppm	10/05/2005
7727-37-9	Nitrogen		Balance	10/05/2005

CAS #	Reference Standard	Cylinder/Standard #	Concentration	Expire Date
630-08-0	Carbon Monoxide	CC7811 , GMIS	25.48 ppm	07/13/2006

Instrument	Serial #	Analytical Principle	Calibration Date
Horiba VIA-510	569466011	Non-Dispersive Infrared	09/19/2005

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Analytical report approved by Jennifer Carney

Jennifer Carney

HiQ Analysis Certificate

Linde Gas | Linde

Certificate of Analysis

EPA Protocol

Performed according to EPA-600/R-97/121, Procedure G1

Notice: This Cylinder is not to be used when pressure is under 150 psig.

Manufactured and certified at:
Linde Gas LLC
Maumee Specialty Gas Plant
6421 Monclova Road
MAUMEE OH 43537
419-893-7226

Produced for customer:
LINDE GAS
LINDE PITTSBURGH INTERBRANCH
4349 WILLIAM PENN HWY
MURRYSVILLE PA 15668
724-327-1480

Material:	6653	**Blend Tolerance:**	5 % Relative
EPA SO2/N2 15-99 PPM	A16	**Blend Type:**	EPA Protocol
Production #:	100123098	**Cyl. Pressure:**	2000 psig
Lot #:	02499H6010AW	**Balance Gas:**	Nitrogen
Cylinder #:	LL22809	**CGA:**	660
Expiration Date:	8/17/2007	**Analytical Accuracy:**	1.00 % Relative
Shelf Life:	12 months	**Confidence:**	95 %

CAS #	Certified Component	Requested Concentration	Concentration and Uncertainty	Date of Certification
7446-09-5	Sulfur Dioxide	50	50.9 +/- 0.5 ppm	08/17/2006
7727-37-9	Nitrogen		Balance	08/17/2006

CAS #	Reference Standard	Cylinder/Standard #	Concentration	Expire Date
7446-09-5	Sulfur Dioxide	CC35129 , GMIS	102.0 ppm	05/08/2007

Instrument	Serial #	Analytical Principle	Calibration Date
Horiba VIA-510	4131546004	Non-Dispersive Infrared	07/07/2006

All analyses are performed under controlled environmental conditions.This product is manufactured using equipment which has been calibrated with NIST traceable, or equivalent, standards, weights, or equipment.

Analytical report approved by Jennifer Carney

Jennifer Carey

HiQ Analysis Certificate

	Date:	8/8/2007		Run One		
CAL		Cal Gases	error	initial	final	% error
O2		0.0	0.0	0.2	0.2	0.0
		12.3	12.3			
	25	21.1	21.1	21.0	21.1	0.4
CO2		0.0	0.0	0.0	0	0.0
		2.3	2.3	2.3	2.3	0.0
	5	4.5	4.4			
NOx		0.0	0.1	-0.6	0.1	0.7
		50.6	50.3			
	100	90.8	90.5	90.5	89.6	-0.9
SO2		0.0	0.0	0.0	0.1	0.1
		50.7	50.6	51.0	49.9	-1.1
	100	90.9	90.0			
Voc		0.0	0.5	1.0	1.2	0.0
		151.0	151.2			
		254.0	254.7	252.5	254.9	0.5
	500	452.0	452.8			
CO		0.0	1.0	1.6	2.4	0.8
		30.7	31.2	31.7	32.6	0.9
	100	60.0	60.6			

	Date:	8/9/2007		Run Two		
CAL		Cal Gases	error	initial	final	% error
O2		0.0	0.0	0.2	0.2	0.0
		12.3	12.3			
	25	21.1	21.1	21.0	21.1	0.4
CO2		0.0	0.0	0.0	0.0	0.0
		2.3	2.3	2.3	2.3	0.0
	5	4.5	4.5			
NOx		0.0	0.1	-0.2	0.0	0.2
		50.6	50.5			
	100	90.8	90.6	90.5	90.1	-0.4
SO2		0.0	0.0	0.0	0.1	0.1
		50.6	50.6	51.0	50.6	-0.4
	100	90.9	90.7			
Voc		0.0	0.5	0.7	0.7	0.0
		151.0	151.2			
		254.0	254.2	252.8	253.4	0.1
	500	452.0	453.1			
CO		0.0	0.8	1.6	1.6	0.0
		30.7	30.9	31.7	32.0	0.3
	100	60.0	60.2			

	Date:	8/9/2007		Run Three		
CAL		Cal Gases	error	initial	final	% error
O2		0.0	0.0	0.2	0.2	0.0
		12.3	12.3			
	25	21.1	21.1	21.1	18.6	-10.0
CO2		0.0	0.0	0.0	0	0.0
		2.3	2.3	2.3	1.9	-8.0
	5	4.5	4.4			
NOx		0.0	0.1	0.0	0.1	0.1
		50.6	50.3			
	100	90.8	90.5	90.1	90	-0.1
SO2		0.0	0.0	0.1	0.1	0.0
		50.7	50.6	50.6	42.3	-8.3
	100	90.9	90.0			
Voc		0.0	0.5	0.7	-5.8	-1.3
		151.0	151.2			
		254.0	254.7	253.4	212.4	-8.2
	500	452.0	452.8			
CO		0.0	1.0	1.6	-2.8	-4.4
		30.7	31.2	31.7	27.9	-3.8
	100	60.0	60.6			

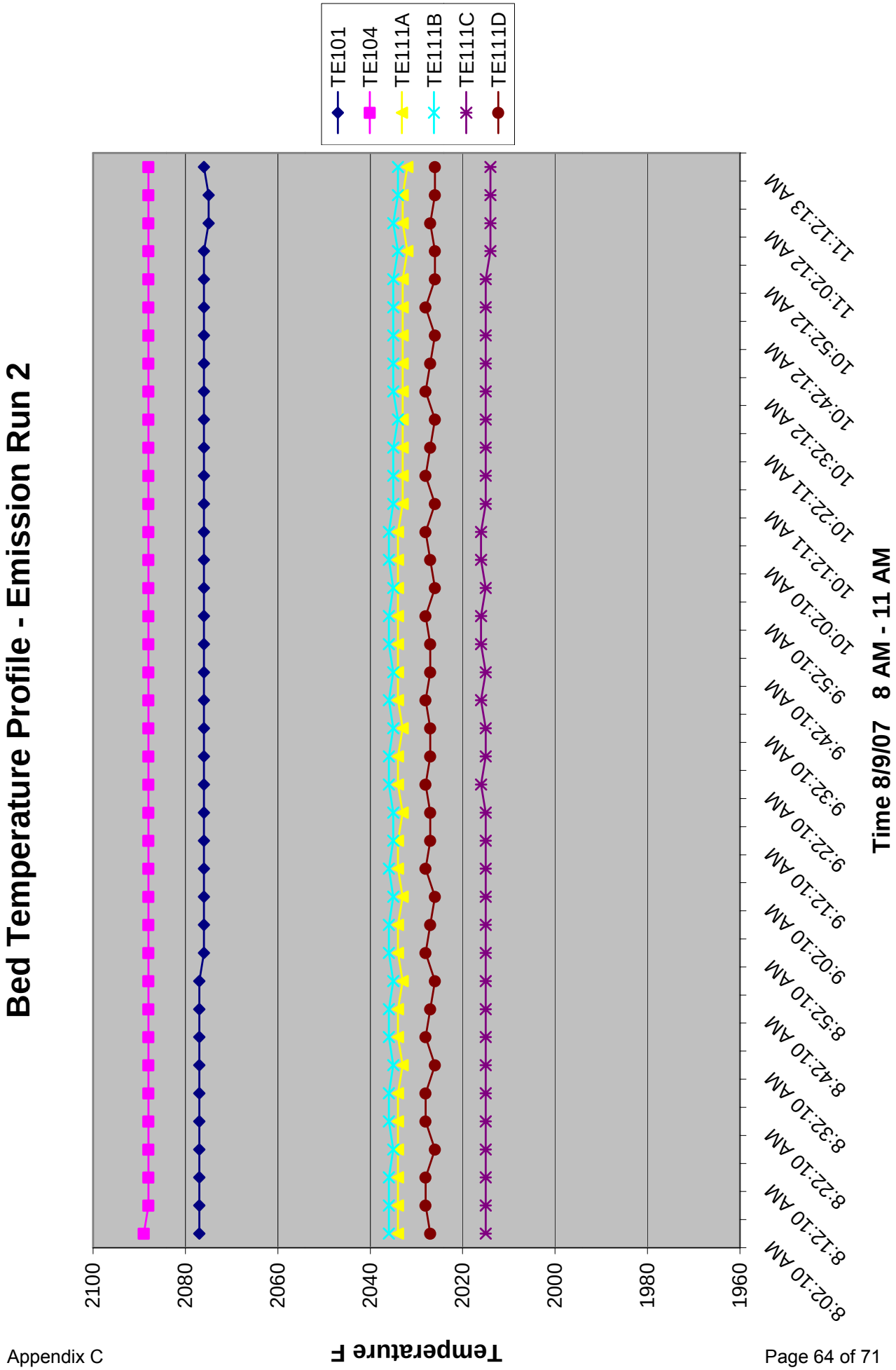
APPENDIX D

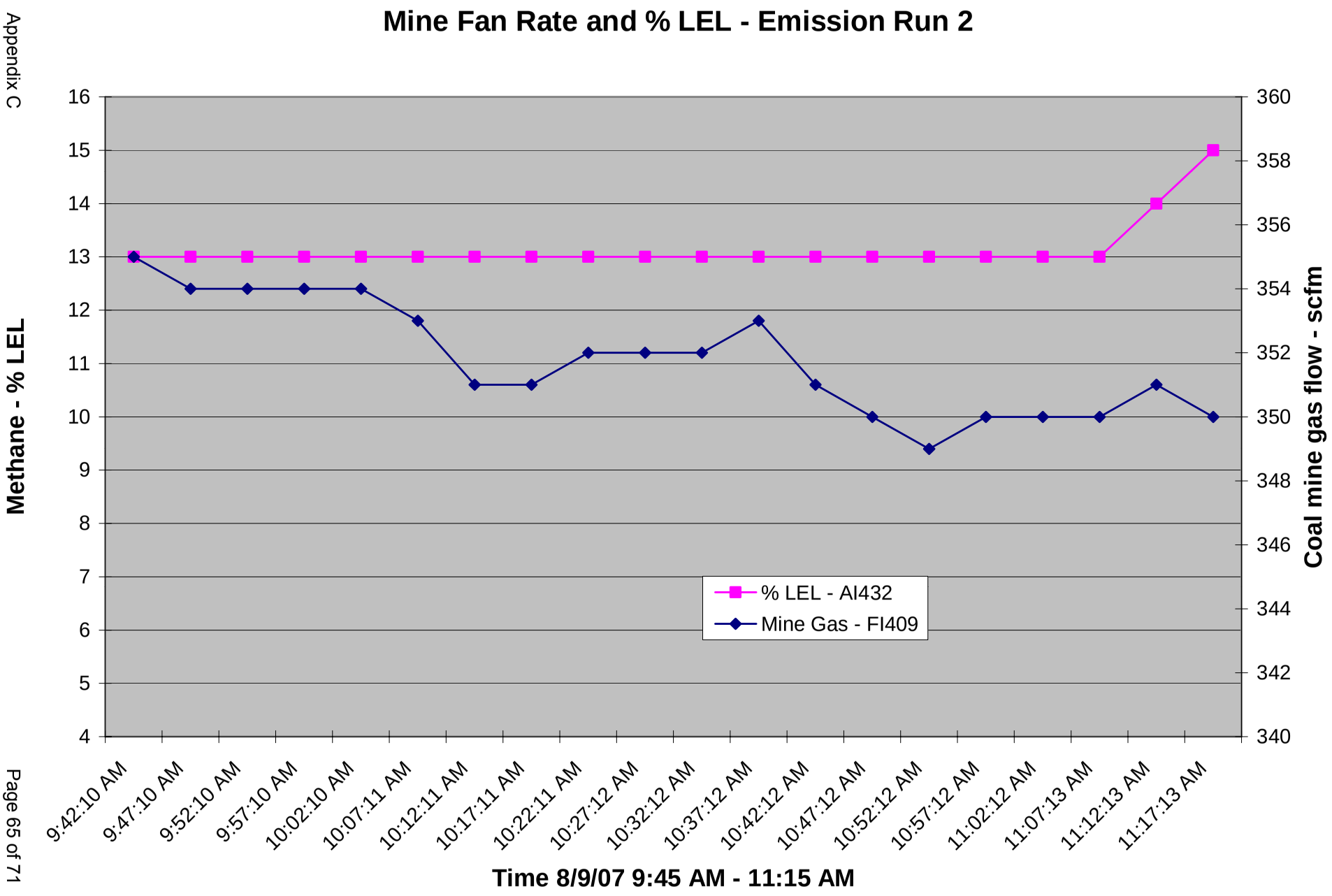
Process Operating Data

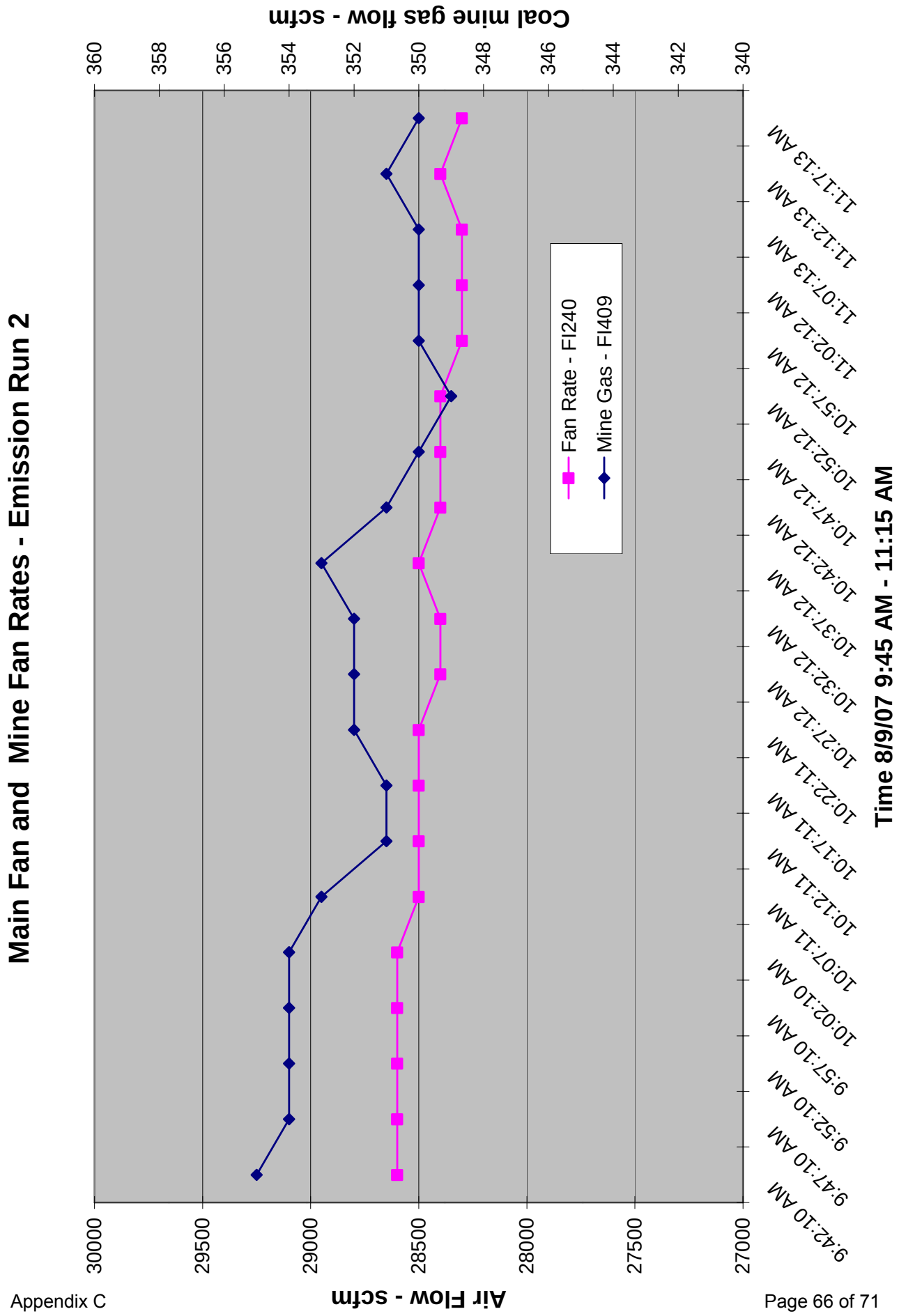
- Graphs – Emission Test Campaign 1 – Run 2

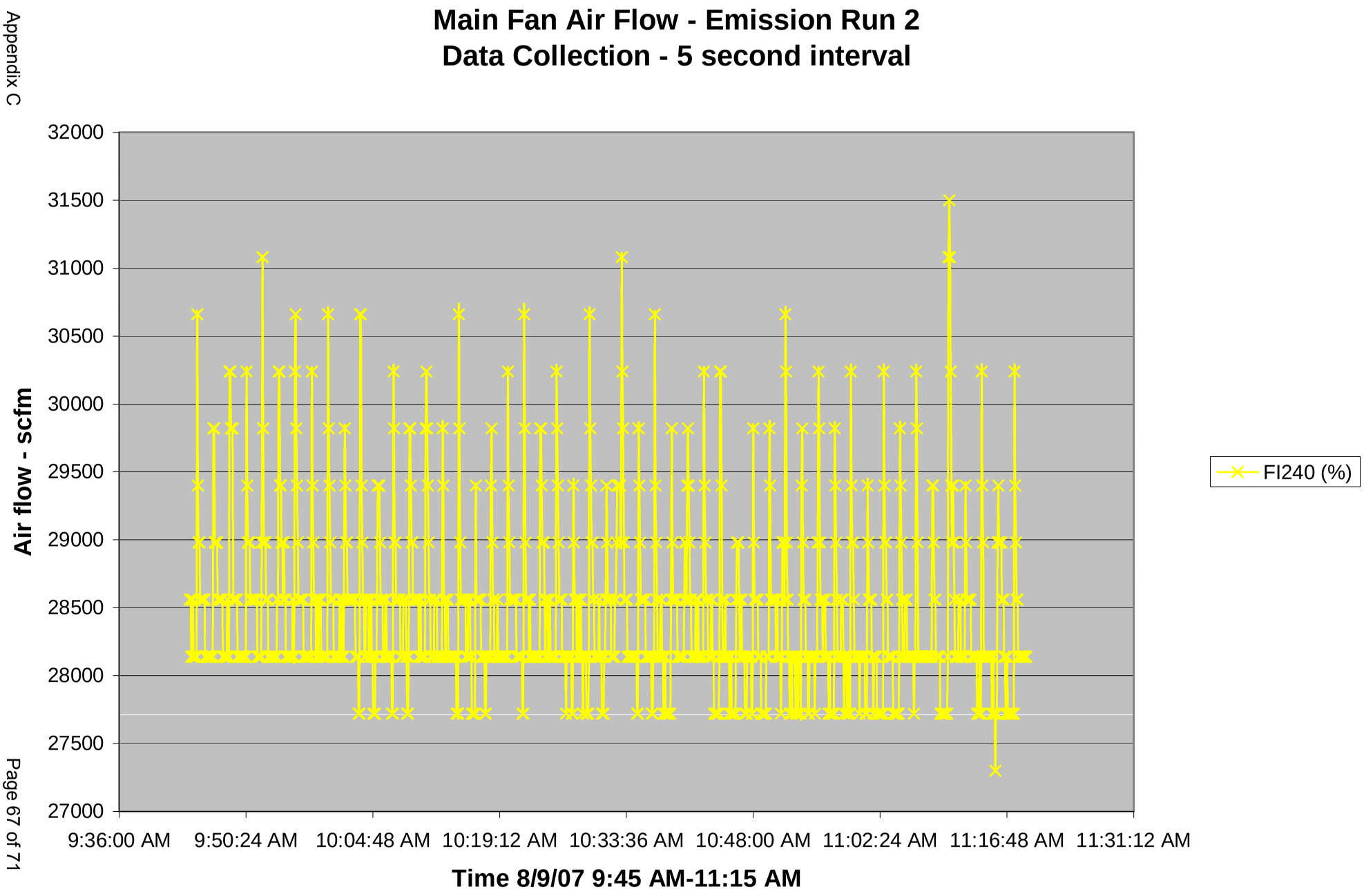
  Bed Temperature Profile
  Mine Gas Flow and % LEL
  Air Flow and Mine Gas Flow
  Main Fan Air Flow
  Bed Pressure Drop
  Plenum, Inlet, & Outlet Temperatures
  Air Flow versus Inlet Temperature
  Inlet Methane Concentration – LEL

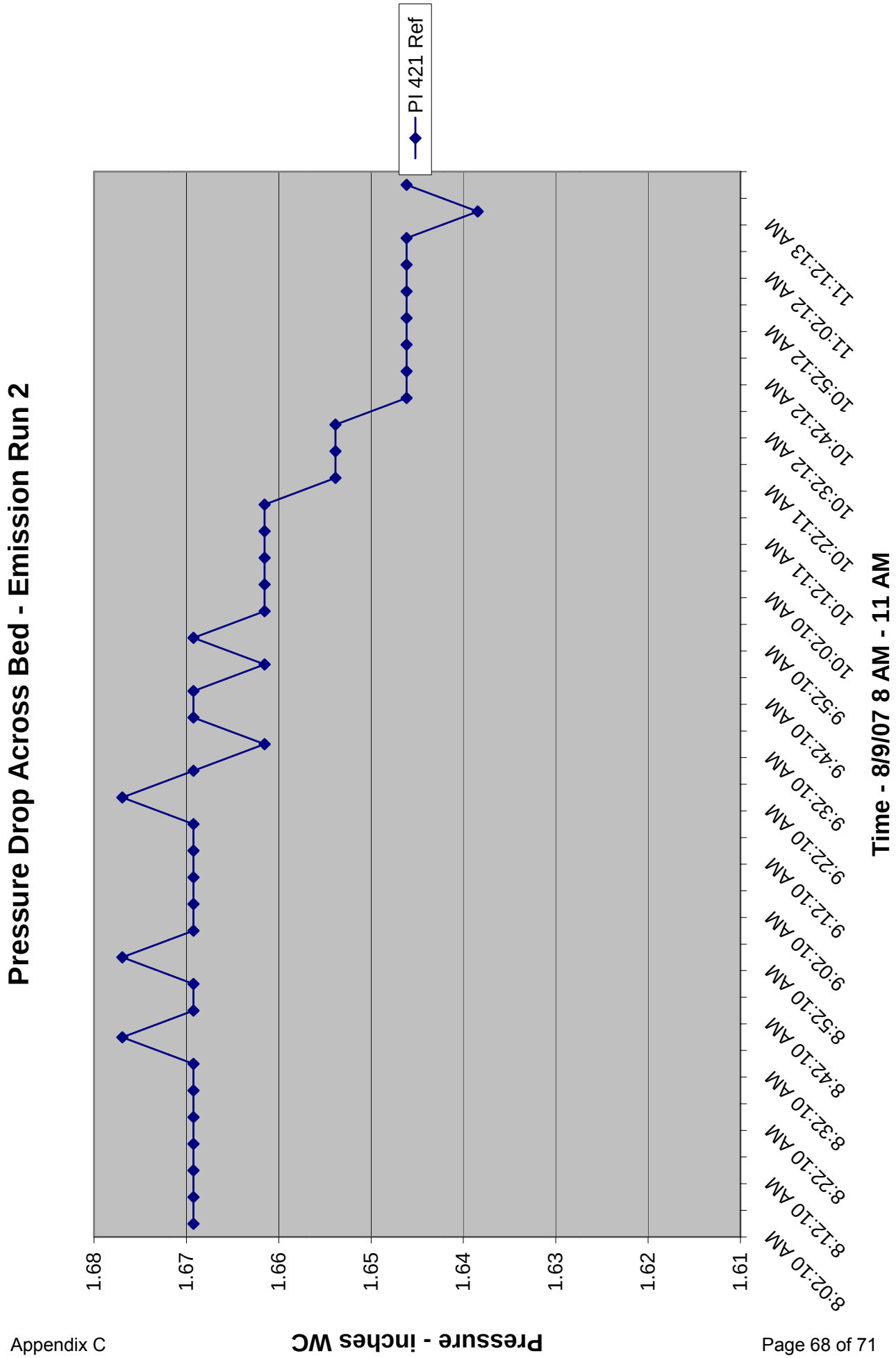
VOCSIDIZER Emission Test
Campaign 1
Run ID: 2
August 09, 2007
09:59 AM – 11:04 AM

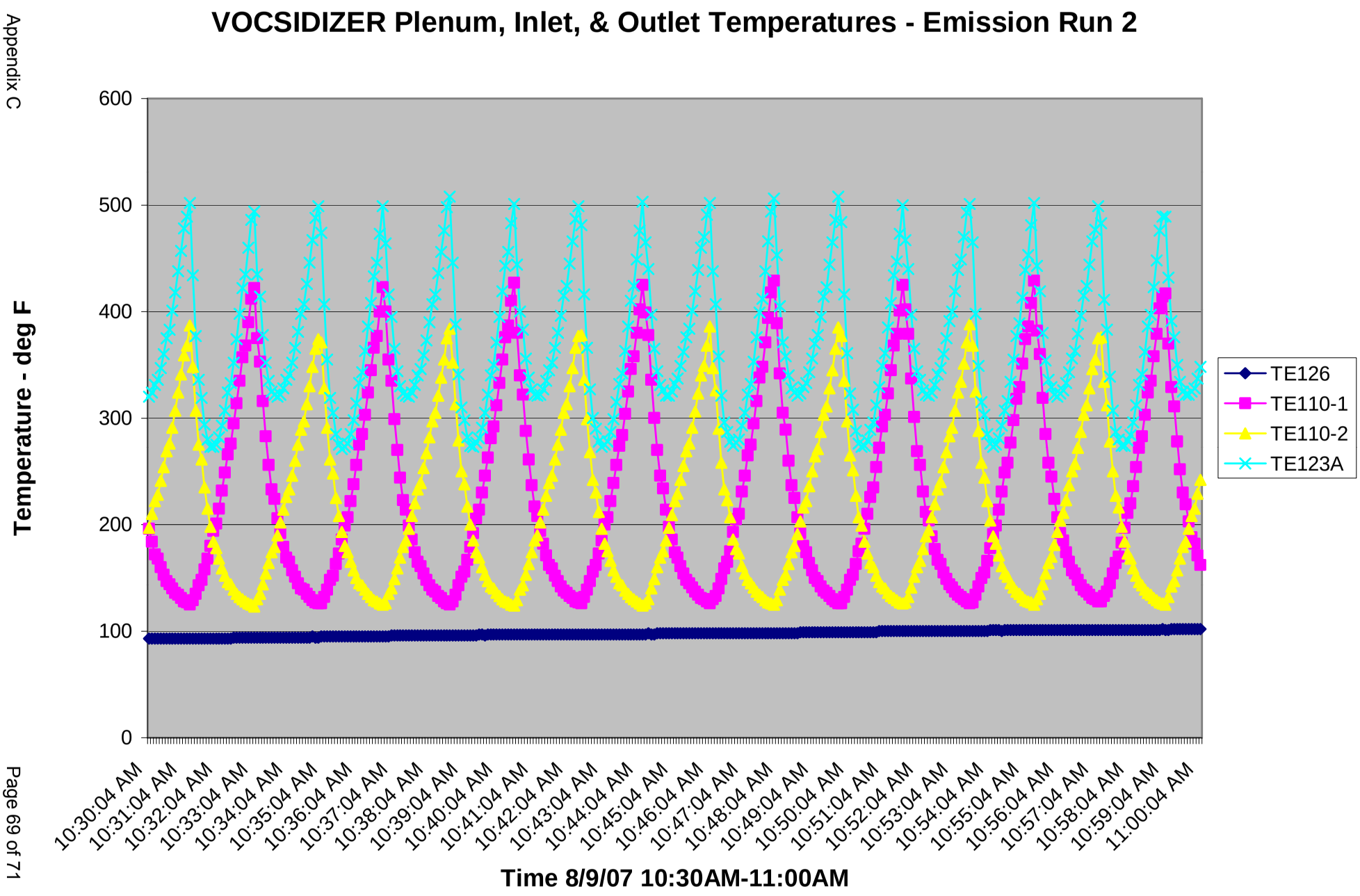

Bed Temperature Profile - Emission Run 2
TE101
TE104
TE111A
TE111B
TE111C
TE111D
2100
2080
2060
2040
2020
2000
1980
1960
Temperature F
8:02:10 AM
8:12:10 AM
8:22:10 AM
8:32:10 AM
8:42:10 AM
8:52:10 AM
9:02:10 AM
9:12:10 AM
9:22:10 AM
9:32:10 AM
9:42:10 AM
9:52:10 AM
10:02:10 AM
10:12:11 AM
10:22:11 AM
10:32:12 AM
10:42:12 AM
10:52:12 AM
11:02:12 AM
11:12:13 AM
Time 8/9/07 8 AM - 11 AM

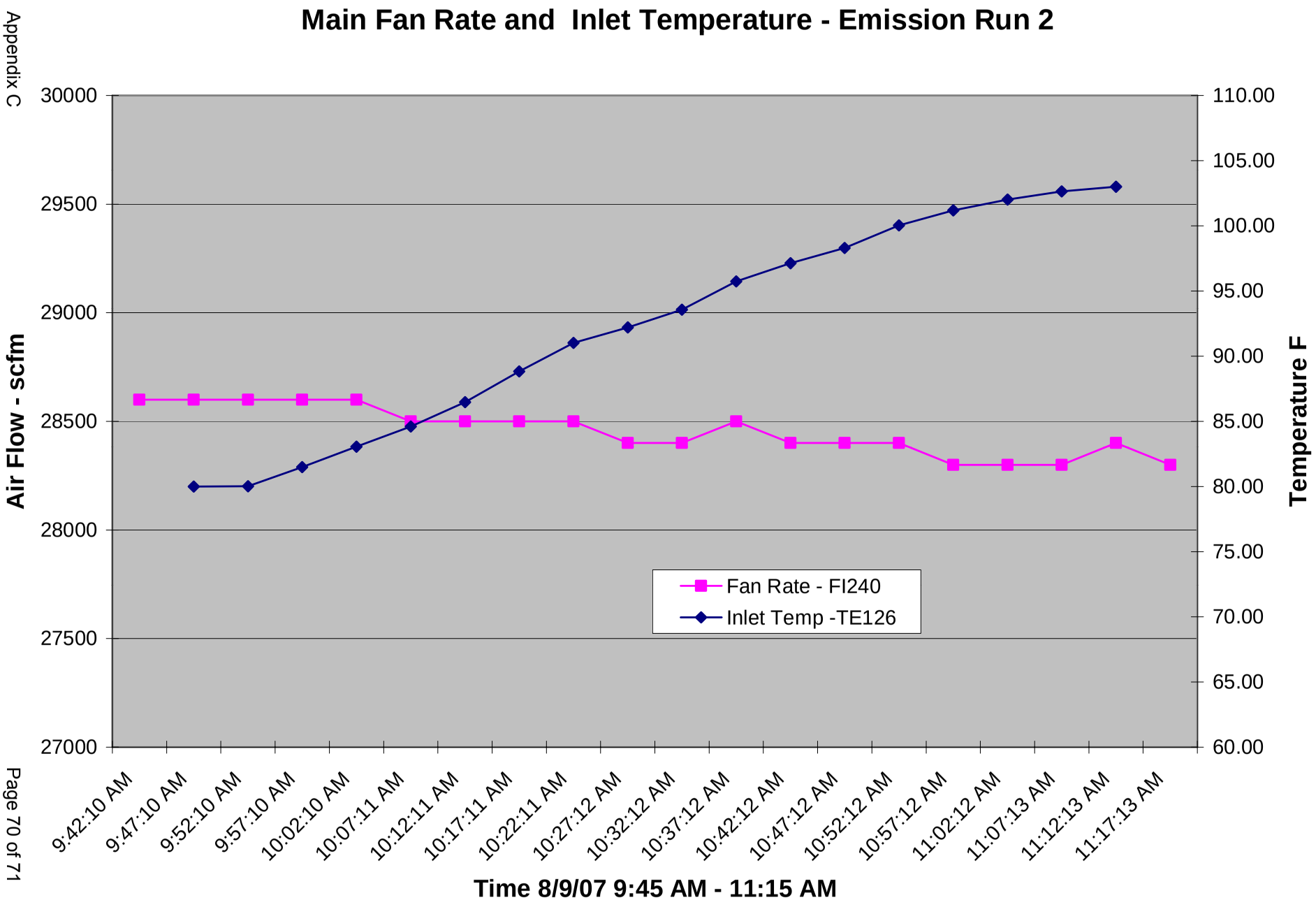

Mine Fan Rate and % LEL - Emission Run 2
Methane - % LEL
Coal mine gas flow - scfm
16
15
14
13
12
11
10
9
8
7
6
5
4
360
358
356
354
352
350
348
346
344
342
340
% LEL - AI432
Mine Gas - FI409
9:42:10 AM
9:47:10 AM
9:52:10 AM
9:57:10 AM
10:02:10 AM
10:07:11 AM
10:12:11 AM
10:17:11 AM
10:22:11 AM
10:27:12 AM
10:32:12 AM
10:37:12 AM
10:42:12 AM
10:47:12 AM
10:52:12 AM
10:57:12 AM
11:02:12 AM
11:07:13 AM
11:12:13 AM
11:17:13 AM
Time 8/9/07 9:45 AM - 11:15 AM


Main Fan and Mine Fan Rates - Emission Run 2
Air Flow - scfm
Coal mine gas flow - scfm
30000
29500
29000
28500
28000
27500
27000
360
358
356
354
352
350
348
346
344
342
340
9:42:10 AM
9:47:10 AM
9:52:10 AM
9:57:10 AM
10:02:10 AM
10:07:11 AM
10:12:11 AM
10:17:11 AM
10:22:11 AM
10:27:12 AM
10:32:12 AM
10:37:12 AM
10:42:12 AM
10:47:12 AM
10:52:12 AM
10:57:12 AM
11:02:12 AM
11:07:13 AM
11:12:13 AM
11:17:13 AM
Fan Rate - FI240
Mine Gas - FI409
Time 8/9/07 9:45 AM - 11:15 AM

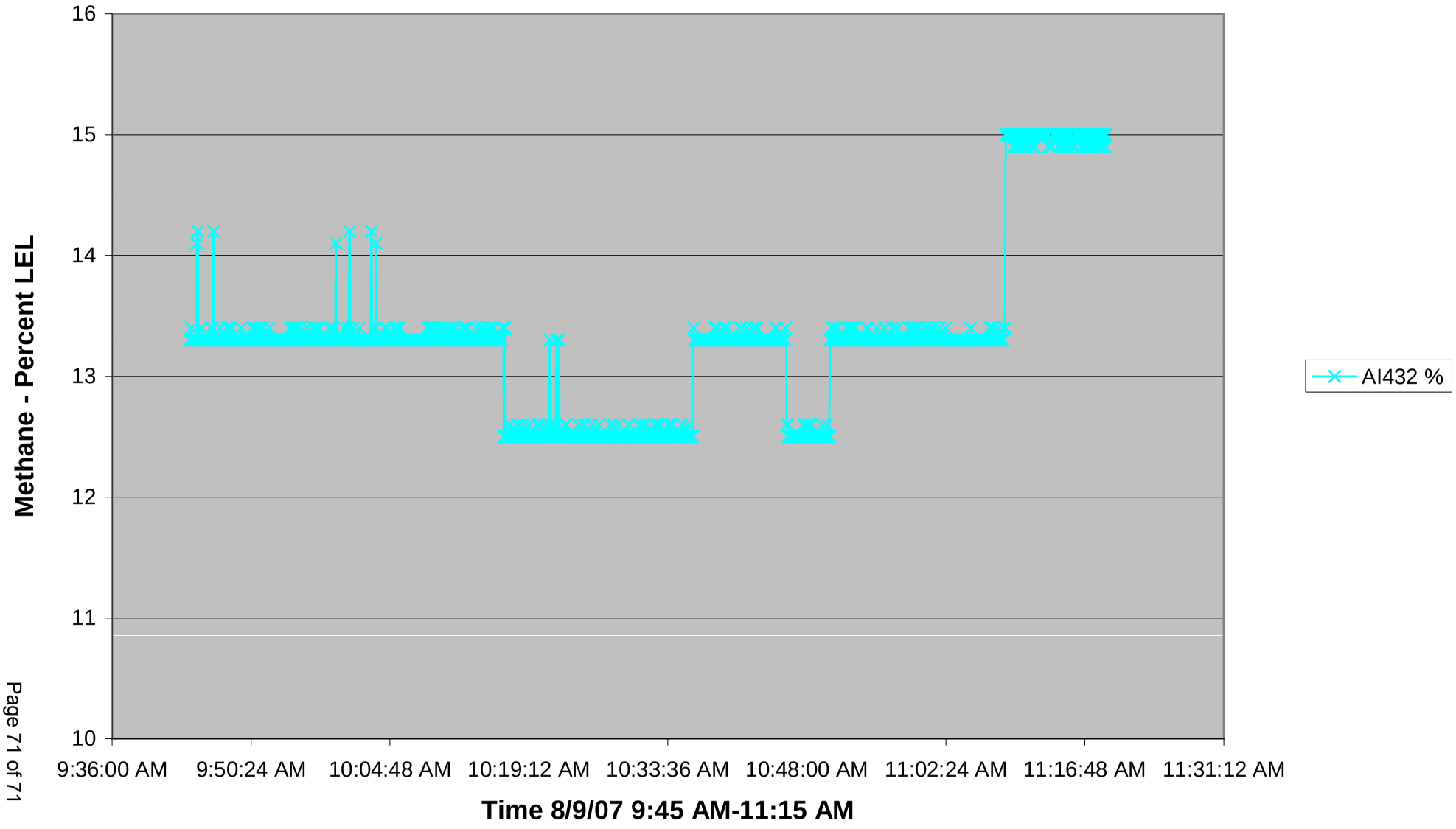

Main Fan Air Flow - Emission Run 2
Data Collection - 5 second interval
Air flow - scfm
32000
31500
31000
30500
30000
29500
29000
28500
28000
27500
27000
9:36:00 AM
9:50:24 AM
10:04:48 AM
10:19:12 AM
10:33:36 AM
10:48:00 AM
11:02:24 AM
11:16:48 AM
11:31:12 AM
Time 8/9/07 9:45 AM-11:15 AM
FI240 (%)


Pressure Drop Across Bed - Emission Run 2
PI 421 Ref
1.68
1.67
1.66
1.65
1.64
1.63
1.62
1.61
Pressure - inches WC
8:02:10 AM
8:12:10 AM
8:22:10 AM
8:32:10 AM
8:42:10 AM
8:52:10 AM
9:02:10 AM
9:12:10 AM
9:22:10 AM
9:32:10 AM
9:42:10 AM
9:52:10 AM
10:02:10 AM
10:12:11 AM
10:22:11 AM
10:32:12 AM
10:42:12 AM
10:52:12 AM
11:02:12 AM
11:12:13 AM
Time - 8/9/07 8 AM - 11 AM


VOCSIDIZER Plenum, Inlet, & Outlet Temperatures - Emission Run 2
Temperature - deg F
600
500
400
300
200
100
0
10:30:04 AM
10:31:04 AM
10:32:04 AM
10:33:04 AM
10:34:04 AM
10:35:04 AM
10:36:04 AM
10:37:04 AM
10:38:04 AM
10:39:04 AM
10:40:04 AM
10:41:04 AM
10:42:04 AM
10:43:04 AM
10:44:04 AM
10:45:04 AM
10:46:04 AM
10:47:04 AM
10:48:04 AM
10:49:04 AM
10:50:04 AM
10:51:04 AM
10:52:04 AM
10:53:04 AM
10:54:04 AM
10:55:04 AM
10:56:04 AM
10:57:04 AM
10:58:04 AM
10:59:04 AM
11:00:04 AM
Time 8/9/07 10:30AM-11:00AM
TE126
TE110-1
TE110-2
TE123A


Main Fan Rate and Inlet Temperature - Emission Run 2
Air Flow - scfm
30000
29500
29000
28500
28000
27500
27000
Temperature F
110.00
105.00
100.00
95.00
90.00
85.00
80.00
75.00
70.00
65.00
60.00
Fan Rate - FI240
Inlet Temp -TE126
9:42:10 AM
9:47:10 AM
9:52:10 AM
9:57:10 AM
10:02:10 AM
10:07:11 AM
10:12:11 AM
10:17:11 AM
10:22:11 AM
10:27:12 AM
10:32:12 AM
10:37:12 AM
10:42:12 AM
10:47:12 AM
10:52:12 AM
10:57:12 AM
11:02:12 AM
11:07:13 AM
11:12:13 AM
11:17:13 AM
Time 8/9/07 9:45 AM - 11:15 AM

Inlet Methane Concentration - Emission Run 2
% LEL Duct - 5 second interval



APPENDIX D

TEST REPORT FOR EMISSION CAMPAIGN 2 AND EMISSION CAMPAIGN 3

CAPTURE AND USE OF COAL MINE VENTILATION AIR METHANE EMISSION TEST RESULTS FOR PM, SO_2, CO, VOC, and NO_X U.S. Department of Energy Cooperative Agreement DE-FC26-02NT41620

Conducted on

August 6 - 7, 2008
and
September 9 -10, 2008

Issue Date: May 19, 2009

As Modified: September 2, 2009

Prepared By:
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REVIEW AND CERTIFICATION

All work, calculations, and other activities and tasks performed and documented in this report were carried out under the direction and supervision of J. E. Locke, test team supervisor, CONSOL Energy Inc., Research & Development.

5/19/09

J. E. Locke
Manager, Field Testing & Operations
CONSOL Energy Inc., Research & Development

Date

This report was prepared by A, R, Goodell. To the best of our knowledge, this source test report has been checked for completeness. The procedures, calculations, and emissions results contained herein are accurate, error-free, legible, and representative of the actual emissions measured during testing.

5/19/09

A. R. Goodell
Associate Engineer
Field Testing & Operations
CONSOL Energy Inc., Research & Development

Date

I am responsible for the generation of the analytical data presented in this source test report and to the best of my knowledge; the analytical data have been checked for completeness. The results contained herein are accurate, error-free, legible, and have been conducted in accordance with the methods in the approved protocol.

5/19/09

J. E. Locke
Manager, Field Testing & Operations
CONSOL Energy Inc., Research & Development

Date

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LIST OF ABBREVIATIONS AND ACRONYMS

acfm - actual cubic feet per minute (wet)
am - morning
ASTM - ASTM International, formerly American Society for Testing and Materials
Avg - average
Btu - British thermal units
C_3H_8 - propane
CEM - continuous emission monitor
cfm - cubic feet per minute
CH_4 - methane
CO - carbon monoxide
CO_2 - carbon dioxide
DAS - data acquisition system
diff - difference
DOE - Department of Energy
dscf - dry standard cubic feet

dscfm	-	dry standard cubic feet per minute
dscm	-	dry standard cubic meter
dscmm	-	dry standard cubic meter per minute
EPA	-	U.S. Environmental Protection Agency
F-Factor	-	Combustion gas factor - dscf flue gas produced per mmBtu heat input
fps	-	feet per second
ft	-	feet
ft^2	-	square feet
ft^3	-	cubic feet
g	-	grams
GC	-	gas chromatography
gpm	-	gallons per minute
H_2O	-	water
HP	-	horsepower
hr	-	hour
ID	-	induced draft
in	-	inch
L	-	liter
lb	-	pound
lb/mmBtu	-	pounds per million British thermal units of heat input
m	-	meter
m^3	-	cubic meter
min	-	minute
mm	-	million
mol	-	mole
N_2	-	nitrogen
nmVOC	-	non-methane volatile organic compounds
NO_2	-	nitrogen dioxide
NOx	-	oxides of nitrogen
O_2	-	oxygen
pm	-	afternoon
PM	-	particulate matter
ppmv	-	parts per million by volume
PRSD	-	percent relative standard deviation
QA	-	quality assurance
QC	-	quality control
R&D	-	CONSOL Energy Inc., Research & Development
rpm	-	revolutions per minute
SDEV	-	standard deviation
S.P.	-	static pressure
scf	-	standard cubic feet (68 ^oF and 29.92"Hg)
scfm	-	standard cubic feet per minute
SO_2	-	sulfur dioxide
temp	-	temperature
tph	-	tons per hour
VAM	-	ventilation air methane

VOC	-	volatile organic compounds
w.c.	-	inches water column
wt	-	weight
WVDEP		West Virginia Department of Environmental Protection
°F	-	temperature in degrees Fahrenheit
ΔP	-	differential pressure

1.0 INTRODUCTION

The MEGTEC VOCSIDIZER is a regenerative thermal oxidizer utilized in the destruction of volatile organic compounds in a wide variety of industrial applications. CONSOL Energy R&D, in partnership with MEGTEC Systems and under U.S. Department of Energy (DOE) cooperative agreement DE-FC26-02NT41620, has applied this technology in a study to determine the systems effectiveness at destroying methane from simulated mine ventilation air. To verify the control capabilities, performance testing was conducted on the MEGTEC VOCSIDIZER oxidation system on August 6 and 7, 2008, as well as September 9 and 10, 2008, to measure methane (CH_4) reduction rates and emissions of:

- Nitrogen oxides (NO_x),
- Sulfur dioxide (SO_2),
- Carbon monoxide (CO),
- Carbon dioxide (CO_2),
- Oxygen (O_2),
- Volatile organic compounds (VOCs), and
- Particulate matter (PM).

The two separate sampling events each consisted of three one-hour tests, conducted over two days each. The events represent the overall second and third emission test periods conducted on the VOCSIDIZER equipment. This report documents the emission rates, measurement methods, QA/QC procedures, and process conditions measured during the test programs. The field sampling was conducted by personnel from the CONSOL R&D Field Testing and Operations Group. The project team leader was James E. Locke.

The results of the analytical data showed all criteria pollutants and methane conversions were within the manufacturer's specifications. Table 1 summarizes actual emissions in comparison to the VOCSIDIZER performance guarantees.

Table 1. Emissions Guarantee and Performance Summary

Performance Category	Performance Guarantee	August Measured Result[a]	September Measured Result[a]
Methane reduction rate	≥ 95% removal	96.6%	97.0%
Carbon monoxide concentration	< 50 mg/dscm	2.33 mg/dscm	1.77 mg/dscm
Nitrogen oxides (expressed as nitrogen dioxide) concentration	< 10 mg/dscm	0.00 mg/dscm	0.00 mg/dscm

[a] Measured results consist of the average of three test runs

1.1 Pollutants Tested

Pollutants and flue gas components, as well as equipment and methods used for sampling are summarized in the following table.

Table 2. Summary of Testing Performed

Parameter	Manufacturer	Model	Type	EPA Reference Method
CO	Rosemount Analytical	880A	NDIR	10
O_2	Maihak	OXOR 610	Paramagnetic	3A
CO_2	Horiba Instruments	PIR-2000	NDIR Analysis	3A
SO_2	Bovar – Western Research	721AT2	Ultraviolet Analysis	6C
NO_x	Teledyne-API	200EH	Chemiluminescence	7E
Total VOC	JUM Engineering	VE-7	Flame Ionization	25A
PM	Thermo-Andersen Instruments	2010A	Isokinetic	5
CH_4	Varian	CP 4900	Gas Chromatography	18

1.2 Summary of Results

A total of three emissions tests were completed on August 6 and 7, 2008. Three additional emissions tests were completed on September 9 and 10, 2008. Concentrations and emissions are summarized in Table 3.

Table 3. Summary of Test Results

Note: All units reported on dry basis.

Test Condition	2			August Averages	3			September Averages
Run ID	Aug-1	Aug-2	Aug-3		Sep-1	Sep-2	Sep-3	
Test Date	8/6/2008	8/6/2008	8/7/2008		9/9/2008	9/10/2008	9/10/2008	
Sample Time	1106-1207	1350-1450	0931-1031		1620-1727	0937-1042	1137-1242	
Gas Flow, dscfm	35380	36040	37200	36210	35980	34900	36080	35650
Gas Flow, dscmm	1002	1021	1053	1025	1019	988	1022	1010
CO_2, %	0.67	0.67	0.62	0.65	0.58	0.58	0.58	0.58
CO_2, lb/hr	1617	1663	1566	1615	1423	1380	1427	1410
CO_2, mg/dscm	12211	12211	11300	11907	10571	10571	10571	10571
PM, gr/dscf	0.0063	0.0066	0.0061	0.0063	0.0088	0.0096	0.0436[1]	0.0092[2]
PM, lb/hr	1.90	2.02	1.95	1.96	2.73	2.88	13.5[1]	2.81[2]
PM, mg/dscm	14.4	15.0	14.0	14.4	20.3	22.0	99.9[1]	21.2[2]
NO_X, ppm	0.00	0.00	-0.10	-0.03	-0.10	-0.64	-0.06	-0.27
NO_X, lb/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NO_X, mg/dscm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total VOC, ppm	64.2	66.7	62.5	64.4	59.3	61.3	63.7	61.4
Total VOC, lb/hr	15. 5	16.4	15.9	15.9	14.6	14.6	15.7	15.0
Total VOC, mg/dscm	117	121	113	117	108	112	116	112
nmVOC, ppm	13.5	4.0	18.5	12.0	19.0	15.0	24.0	19.3
nmVOC, lb/hr	3.26	0.99	4.69	2.98	4.66	3.57	5.92	4.72
nmVOC, mg/dscm	24.6	7.3	33.6	21.9	34.6	27.3	43.9	35.2
CO, ppm	2.76	2.04	1.22	2.01	1.64	1.65	1.28	1.52
CO, lb/hr	0.42	0.32	0.20	0.31	0.26	0.25	0.20	0.24
CO, mg/dscm	3.20	2.37	1.41	2.33	1.90	1.91	1.48	1.77
SO_2, ppm	-1.08	-1.34	-0.64	-1.02	-1.52	-0.91	-0.98	-1.14
SO_2, lb/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SO_2, mg/dscm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[1] *Particles from bed degradation are the likely cause of this high value.*

[2] *Sep-3 value not included in average*

2.0 Description of the MEGTEC VOCSIDIZER System

The MEGTEC VOCSIDIZER system is located on the property of the CONSOL Energy, Inc. Windsor Mine, which is no longer a producing mine. The system is designed to capture and eliminate ventilation air methane (VAM) from the exhaust of mine ventilation fans. In this demonstration, the VAM is being simulated by diluting the vent gas (45-60% methane) from an abandoned power bore hole on the property with ambient air to a concentration of 0.1 - 1.2 percent methane. Following dilution, the simulated mine ventilation air is routed to the VOCSIDIZER for oxidation. Figure 1 depicts the MEGTEC VOCSIDIZER system.

The VOCSIDIZER consists of a bed of ceramic medium contained in an airtight steel container resting on a sturdy steel frame (Figure 2). The granular ceramic bed material ensures optimum flow and temperature distribution over the bed. Air plenum chambers are located above and below the bed to provide even distribution of the inlet air. Electrical heating elements are used to obtain the required start-up bed temperature of ca. 1000 °C.

The process fan at the inlet side of the VOCSIDIZER forces the feed air via dampers into the plenum and through the preheated bed where the air is heated to a temperature at which methane is completely oxidized. The thermal energy released during methane oxidization is recovered by the bed media as the air moves to the outlet side of the bed.

Thermocouples in the bed are tied to the programmable logic controller (PLC) system that monitors the temperature profile of the bed and the movement of the high-temperature zone, which moves towards the outlet of the ceramic bed. To maintain the high-temperature zone within the ceramic bed, switching valves reverse the air flow through the bed periodically. The PLC program optimizes valve switching intervals using time and temperature to maximize energy efficiency. After the valves have switched and reversed the direction of air flow through the bed, the energy that was recovered and stored in one side of the bed heats the incoming process air to oxidation temperature. After the reversal, the high-temperature zone in the bed begins to move toward the new outlet and the process repeats.

In operation, the VOCSIDIZER typically changes air flow direction through the bed every few minutes. The reaction zone at the oxidation temperature is sustained in the center of the bed by optimizing the regenerative heat exchange between the ventilation air and the ceramic bed.

The expected methane conversion is 95%, with the capability of sustaining oxidation of methane at concentrations from 0.3 to 0.8% in air or 0.3 to 1.2% if heat removal is included. Therefore, it is well suited to oxidize ventilation air methane into CO_2 and water.

3.0 SAMPLING AND ANALYSIS PROCEDURES

3.1 Point Selection

The sampling points used to determine the flue gas velocity in the stack were selected as outlined in EPA Method 1. Based on EPA criteria, a total of 12 sampling points (two 6-point traverses) were used in making the volumetric gas flow measurements. The location of the sampling points and traverse distances are presented in Figure 3.

The samples for gas composition (O_2, CO_2, NO_X, CO, SO_2, CH_4, and total VOC) were obtained in each of the two ports located ~15' above ground level.

3.2 Verification of Axial Flow / Volumetric Gas Flow Rate

An axial flow check was performed prior to Test 1 of the initial testing program at this location in August 2007, and resulted in an absolute "null yaw" flow angle of 0.0°, which confirms the stack gas flow was axial or non-cyclonic. EPA Method 1 states that if the average "null yaw" angle is within 20° of the vertical gas flow axis, axial flow can be assumed. As no physical or operational alterations were made at the sampling location since the initial axial flow check, and since no flow rate changes were noted during the test periods referenced in this report, no change to axial flow was assumed.

A volumetric gas flow rate determination was conducted during each of the six sampling test periods. The results of these measurements are summarized in Table 4.

3.3 Particulate Emissions Measurement

Particulate matter emissions were determined using procedures described in EPA Method 5. CONSOL used a 12 point traverse (6 points in each of two ports), sampling at each point for five minutes, which resulted in a total test time of 60 min and sample volumes >47.5 dscf. Velocity measurements were obtained at each traverse point during the PM sampling to calculate the isokinetic sampling ratio and volumetric gas flow rate. All isokinetic sampling ratios fell within acceptable limits of 90%-110%. The EPA Method 5 sampling train is shown in Figure 4. Field data sheets can be found in Appendix A. Analytical summaries can be found in Appendix B. Table 4 summarizes the results of the PM sampling.

Table 4. Flue Gas Parameters and Particulate Emissions Data

Test Condition	2				3			
Run ID	Aug-1	Aug-2	Aug-3	August Avg.	Sep-1	Sep-2	Sep-3	September Avg.
Date	08/06/08	08/06/08	08/07/08		9/9/08	9/10/08	9/10/08	
Avg. Stack Temp [°F]	357	350	352	353	327	323	302	317
Gas Velocity [fps]	59.8	60.2	62.2	60.7	58.0	55.5	55.6	56.4
Gas Flow Rate [acfm]	59250	59650	61530	60143	57455	54955	55067	55826
Gas Flow Rate [dscfm]	35380	36040	37200	36210	35980	34900	36080	35650
Flue Gas Moisture [%]	3.11	2.77	2.44	2.77	2.12	1.73	1.56	1.80
Sample Time [min]	60	60	60	60	60	60	60	60
Sample Volume [dscf]	49.2	49.5	50.5	49.7	49.69	47.62	49.50	48.94
Sample Volume [dscm]	1.39	1.40	1.43	1.41	1.41	1.35	1.40	1.39
PM [grains/dscf]	0.0063	0.0066	0.0061	0.0063	0.0088	0.0096	0.0436[1]	0.0092[2]
PM [lb/hr]	1.90	2.02	1.95	1.96	2.73	2.88	13.51[1]	2.81[2]
PM [mg/dscm]	14.4	15.0	14.0	14.4	20.3	22.0	99.9[1]	21.2[2]
% Isokinetic	96.2	95.0	93.9	95.0	95.6	94.5	95.0	95.0

1. Particles from bed degradation are the likely cause of this high value.

2. Sep-3 value not included in average

3.4 Gaseous Emissions Measurement

A continuous emission monitoring (CEM) system was used to determine concentrations of O_2, CO_2, NO_X, SO_2, CO, and total VOC concentrations for this test program. The CEM system components can be configured with two separate sampling lines; a dry sampling line for the O_2, CO_2, NO_X, SO_2, and CO analyzers; and a wet sampling line for the VOC analyzer, or as one system utilizing just the dry line, which was incorporated in this test. The dry sampling system is equipped with a probe, heated filter, heated Teflon transport line, cryogenic moisture removal system, and a Teflon line to the CEM trailer. Inside the trailer, the gas sample enters a manifold to distribute the gas sample to the individual analyzers and gas bag port.

Calibration gases are automatically routed to the sampling probe for the sample system bias check and also directly into the analyzers for the calibration error check. All initial and final zero checks and initial and final span checks are performed by routing the calibration gases to the sampling probe. All calibrations and response time checks are computer monitored and controlled. A computer-based data acquisition system stores and reduces the field data. The system is also equipped with a dedicated printer. A schematic of the CONSOL R&D CEM system is presented in Figure 5. Specific sampling details are discussed below.

3.4.1 Oxygen and Carbon Dioxide

The O_2 and CO_2 values were obtained using the continuous emission monitoring (CEM) procedures outlined in EPA Method 3A and 7E, utilizing the sampling system described above. All applicable QA/QC procedures were followed including initial calibration, calibration error, initial zero and span, final zero and span, response time, and sample system bias. The QA/QC procedures are discussed in detail in Section 4.0. Supporting documentation is contained in Appendix C.

Average measured concentrations are summarized in Table 5. Raw field data can be found in Appendix A.

Table 5. Oxygen and Carbon Dioxide Concentrations

Test Condition	2			August Average	3			September Average
Run ID	Aug-1	Aug-2	Aug-3		Sep-1	Sep-2	Sep-3	
Test Date	8/6/2008	8/6/2008	8/7/2008		9/9/08	9/10/08	9/10/08	
O_2, % dry	19.8	19.8	19.7	19.8	19.9	19.9	19.9	19.9
CO_2, % dry	0.67	0.67	0.62	0.65	0.58	0.58	0.58	0.58
CO_2, mg/dscm	12211	12211	11300	11907	10571	10571	10571	10571

3.4.2 Oxides of Nitrogen

The NO_X value was obtained using the continuous emission monitoring (CEM) procedure outlined in EPA Method 7E, utilizing the same sampling hardware previously discussed. A portion of the stack flue gas sample is conveyed to the chemiluminescent NO_X analyzer through a manifold system. All applicable QA/QC procedures were followed including initial calibration, calibration error, initial zero and span, final zero and span, response time, and sample system bias. The QA/QC procedures are discussed in detail in Section 4.0. Supporting documentation is contained in Appendix C.

The average measured concentrations are summarized in Table 6. Raw field data can be found in Appendix A. Negative values reflect noise in the measuring system.

Table 6. Oxides of Nitrogen Concentration

Test Condition	2			August Average	3			September Average
Run ID	Aug-1	Aug-2	Aug-3		Sep-1	Sep-2	Sep-3	
Test Date	8/6/2008	8/6/2008	8/7/2008		9/9/08	9/10/08	9/10/08	
NOx, ppmv (dry)	0.00	0.00	-0.10	-0.03	-0.10	-0.64	-0.06	-0.27
NOx, mg/dscm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.4.3 Sulfur Dioxide

The SO_2 value was obtained using the continuous emission monitoring (CEM) procedure outlined in EPA Method 6C, utilizing the same sampling hardware previously discussed. A portion of the stack flue gas sample is conveyed to the ultraviolet fluorescence SO_2 analyzer through a manifold system. All applicable QA/QC procedures were followed including initial calibration, calibration error, initial zero and span, final zero and span, response time, and sample system bias. The QA/QC procedures are discussed in detail in Section 4.0. Supporting documentation is contained in Appendix C.

The average measured concentrations are summarized in Table 7. Raw field data can be found in Appendix A.

Table 7. Sulfur Dioxide Emissions Data

Test Condition	2			August Average	3			September Average
Run ID	Aug-1	Aug-2	Aug-3		Sep-1	Sep-2	Sep-3	
Test Date	8/6/2008	8/6/2008	8/7/2008		9/9/08	9/10/08	9/10/08	
SO_2, ppmv (dry)	-1.08	-1.34	-0.64	-1.02	-1.52	-0.91	-0.98	-1.14
SO_2, mg/dscm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.4.4 Carbon Monoxide

The CO value was obtained using the continuous emission monitoring (CEM) procedure outlined in EPA Method 10, utilizing the same sampling hardware previously discussed. A portion of the stack flue gas sample is conveyed to the infrared CO analyzer through a manifold system. All applicable QA/QC procedures were followed including initial calibration, calibration error, initial zero and span, final zero and span, response time, and sample system bias. The QA/QC procedures are discussed in detail in Section 4.0. Supporting documentation is contained in Appendix C.

The average measured concentrations are summarized in Table 8. Raw field data can be found in Appendix A.

Table 8. Carbon Monoxide Emissions Data

Test ID	2			August Average	3			September Average
Run ID	Aug-1	Aug-2	Aug-3		Sep-1	Sep-2	Sep-3	
Test Date	8/6/2008	8/6/2008	8/7/2008		9/9/08	9/10/08	9/10/08	Test 3
ppmv (dry)	2.76	2.04	1.22	2.01	1.64	1.65	1.28	1.52
mg/dscm	3.20	2.37	1.41	2.33	1.90	1.91	1.48	1.77

3.4.5 Methane

The CH_4 outlet concentration was determined by extracting a sample from the gas bag at the CEM system sample stream. At the start of the test, a 25 L sample bag was connected to the CEM system metered pump. The flow rate was adjusted to uniformly fill the bag over the entire test period.

The gas was analyzed for methane as outlined in EPA Method 18.

Samples were also taken at the VOCSIDIZER inlet, where the sample gas is under positive pressure. A rotameter was used in front of the Tedlar bag to sample at a uniform rate over the hour long test period. After the test, the bag contents were analyzed for methane concentrations by gas chromatography. The samples were collected from a single-point for one-hour, coinciding with all other measurements.

The inlet and outlet CH_4 concentrations are used to calculate methane reduction during each test period. Table 9 summarizes the results.

Table 9. Methane Reduction Summary

Test Condition	2			August Average	3			September Average
Run ID	Aug-1	Aug-2	Aug-3		Sep-1	Sep-2	Sep-3	
Test Date	8/6/2008	8/6/2008	8/7/2008		9/9/08	9/10/08	9/10/08	
Inlet CH_4 concentration [ppm] by GC	4700	4600	4700	4667	4400	4200	4000	4200
Outlet CH_4 concentration [ppm] by GC	152	188	132	157	121	139	119	126
CH_4 reduction rate [%]	96.8	95.9	97.2	96.6	97.3	96.7	97.0	97.0

3.4.6 Total VOC

Total VOC emissions were determined using a continuous VOC analyzer and the procedure outlined in EPA Method 25A, using the common sampling system previously discussed. Additionally, due to the oscillating flow design of the VOCSIDIZER discussed in Section 2.0, an additional high frequency data acquisition module was utilized to capture any rapid changes in VOC concentration during process flow changes. The VOC analyzer is equipped with a flame ionization detector, computer controlled data acquisition system, and a series of calibration gases (see Figure 4). All applicable QA/QC procedures were followed including initial calibration, calibration error, initial zero and span, final zero and span, response time, and sample system bias. The QA/QC procedures are discussed in detail in Section 4.0. Supporting documentation is contained in Appendix C.

All of the calibrations were conducted by introducing the calibration gases through a tee fitting located on the sampling probe. The total VOC concentration for each test was continuously recorded and logged. The average total VOC concentration was obtained from the values recorded by the high frequency data acquisition module. Total VOC concentrations are expressed on a propane-equivalency basis. The sample was taken at a single point in the stack, for a period of one-hour, coinciding with the other flue gas samples.

3.4.7 Non-Methane VOC

The non-methane VOC emission rate was calculated from the total VOC emissions corrected for the methane contribution as determined from the Method 18 sample bag. Total VOC results are reported on a dry, propane-equivalency basis. The methane emissions are reported on a dry basis, as methane, and converted to propane equivalence (ratio of carbon atoms in methane vs. propane), and then subtracted from the total VOC value to provide non-methane VOC emissions.

The VOC, methane, and non-methane results are detailed in Table 10. Raw field data can be found in Appendix A.

Table 10. Summary of Total and Non-Methane VOC Results

(VOC emissions expressed as propane equivalents)

Test Condition	2			August Average	3			September Average
Run ID	Aug-1	Aug-2	Aug-3		Sep-1	Sep-2	Sep-3	
Test Date	8/6/2008	8/6/2008	8/7/2008		9/9/08	9/10/08	9/10/08	
Total VOC Emissions:								
ppmv (dry)	64.2	66.7	62.5	64.4	59.3	61.3	63.7	61.4
Methane Emissions:								
ppmv (dry)	152	188	132	157	121	139	119	126
ppmv as C_3H_8	50.7	62.7	44.0	52.3	40.3	46.3	39.7	42.1
Non-methane VOC Emissions:								
ppmv (dry)	13.5	4.0	18.5	12.0	19.0	15.0	24.0	19.3
lb/hr	3.26	0.99	4.69	2.98	4.66	3.57	5.92	4.72
mg/dscm	24.6	7.30	33.6	21.9	34.6	27.3	43.8	35.2

3.4.8 Process Data

VOCSIDIZER operating and process data were recorded automatically through the unit's data-logging system. Data were recorded at regular intervals from 1 second to 5 minutes depending on the instrument. Appendix D includes graphical representation of the data collected during each test period for the following parameters; main fan air flow rate, mine gas flow rate, fixed mine gas concentration, measured inlet methane concentration as % LEL, pressure drop across the bed against a reference value, internal bed media temperatures, bed plenum temperatures, bed inlet temperatures, and bed outlet temperatures. Graphs are also provided that show each measured emission component in the stack over the duration of each run.

3.5 Sampling and Lab Equipment

The CONSOL Field Sampling team used standard EPA-type sampling equipment, which conforms to all applicable test codes.

The total VOC analyzer is manufactured by J.U.M. Engineering and is a Model VE-7. Total VOC is determined by a flame ionization detector analysis based on procedures described in EPA Method 25A.

The GC used for the CH_4 analyses is a Varian CP 4900 portable micro gas chromatograph that is very versatile and was specifically configured for the gases of interest. As configured, this instrument has a minimum detection limit of 5 ppmv for methane.

A Teledyne-API 200EH continuous emission monitor measured the flue gas NOX concentration. NO_X is determined by chemiluminescence and measures total NO_X as NO_2, based on procedures described in EPA Method 7E.

A Rosemount Model 880A continuous emission monitor measured the flue gas CO concentration. CO is determined by nondispersive infrared analysis (NDIR) based on procedures described in EPA Method 10.

The CO_2 CEM analyzer is manufactured by Horiba Instruments and is Model number PIR-2000. CO_2 is determined by NDIR based on procedures described in EPA Method 3A.

The O_2 CEM analyzer is manufactured by Maihak and is Model OXOR 610. O_2 is determined by para-magnetic analysis based on procedures described in EPA Method 3A.

The CONSOL R&D CEM system includes a computer-based data acquisition system (DAS) that stores and reduces field data. All CEM gas concentrations can be displayed on tabular or strip chart forms, and a hard copy can be printed. In addition, CEM gas concentrations are corrected from a “raw” or “uncorrected” CEM reading to a “corrected” reading using EPA Method 7E, equation 7E-5.

$$C_{gas} = (C_{avg} - C_o) * C_{ma} / (C_m - C_o)$$

where: C_{gas} = corrected gas concentration, dry basis, ppm or %

C_{avg} = Average unadjusted gas concentration indicated by data recorder for the test run, ppmv or %

C_o = average of initial and final zero calibration gas readings, ppm or %

C_m = average of initial and final upscale calibration gas readings, ppm or %

C_{ma} = actual or certified concentration of upscale calibration gas, ppm or %

Within specified percent of span limits, as outlined in the applicable EPA Methods, this calculation corrects for offsets and/or drifts of the zero and/or spans during individual test periods. This correction factor was used on all reported ppmv dry concentration readings for O_2, CO_2, NO_x, SO_2, CO, and total VOC.

4.0 QA/QC

The CONSOL test manager was responsible for the implementation of the quality assurance procedures for this project. All required measuring devices, including pitot tubes, barometers, continuous gas analyzers, and the gas chromatograph were calibrated as required. Records of these calibrations are maintained in files and are included in Appendix C. All field data were recorded on standard forms, which are included in the appendices as appropriate. All of the collected data were reduced in the field to assure data quality and completeness. Methane concentrations were

determined using a laboratory-quality portable gas chromatograph. Individual testing QA/QC procedures are discussed below.

4.1 Flue Gas Velocity Measurements

The flue gas volumetric flow rate is required to calculate the emission rates in mass flow units (lb/hr). Velocity measurements were made during each of the test periods. Prior to the initial compliance sampling conducted in August 2007, axial flow was verified at the measurement location. This survey and all subsequent measurements were made with a standard type “S” pitot tube following U.S. EPA Methods 1 and 2 criteria. The pitot tube coefficient was determined by CONSOL R&D personnel using the procedures outlined in Method 2 and an in-house wind tunnel specifically designed for Method 2 pitot calibrations. A copy of the most recent calibration is included in Appendix C. Also included are the barometer calibrations. The velocity measurements obtained during this testing are consistent with predicted flow rates for this test program.

4.2 Particulate Measurements

PM measurements were conducted using a twelve-point sampling traverse, as outlined in EPA Method 1.

Leak checks were conducted on the PM sampling train for each test run prior to sampling, after the components had reached sampling temperature and a post-sampling leak check was conducted at the completion of the particulate run. Pre- and post-sampling leak checks were conducted on the pitot system. All pre- and post-sampling system leak checks were satisfactory (<0.02 cfm @ >10 “H_2O).

At the completion of the post-sampling leak check, the probe was disconnected from the filter box. Both ends of the probe (nozzle and ball cap) were sealed, and the probe was allowed to cool. The probe and nozzle were rinsed and brushed with acetone three times. The probe and nozzle rinse was caught in an approved sample container for subsequent particulate weight analysis. Protective caps were secured on the pitot tips to ensure that they were not disfigured during probe transport. The pitot tips and sampling nozzle were inspected prior to the start of each PM run. No tip damage was observed.

CONSOL test personnel utilized a programmable calculator to determine the isokinetic sampling ratio. The isokinetic sampling ratios for all runs were calculated in the field on a daily basis to ensure that no errors were made in setting up the sampling ratio or in the sampling itself. The isokinetic sampling ratios for all tests were within the allowable range (100% $\pm$10%).

Particulate weights were determined upon return to the laboratory using a Mettler electronic balance. The accuracy of this balance was verified by class "S" weights. The accuracy of the final filter weights was verified by both lab control filter blanks and field blanks.

4.3 Total VOC Measurements

Total VOC measurements were obtained with a continuous emission monitor spanned using VOC free air (0 ppmv propane) and high calibration gas (463.9 ppmv propane) on a 0 to 1000 ppmv scale. Linearity was verified using a low (151 ppmv propane) and middle (254 ppmv propane) calibration gases. The analyzer was checked for drift using the zero and middle (250 ppmv propane) calibration gases following each test. All calibration gases are EPA protocol gases, as documented in Appendix C. The results of the pre-test calibration, linearity check, and post- test calibration tests verified that this analyzer was operating accurately. All QA/QC documentation for the VOC analyzer is contained in Appendix C.

As previously discussed, CONSOL used a single sampling system for all gas species, consisting of a sample probe, heated filter with calibration gas port, heated Teflon transport line, cryogenic moisture trap, and a Teflon transport line. Results are transmitted from the CEM systems PLC system to a CONSOL computer, where data is recorded.

4.4 Methane Measurements

Methane samples were collected at three locations during the test period. VOCSIDIZER inlet and outlet concentrations were used to determine the CH_4 reduction rate. Mine gas was also sampled to verify that the proper dilution ratio was being achieved from mine gas to VOCSIDIZER inlet. The bag sampling system was leak-checked prior to sampling. The bags were leak-checked in the CONSOL lab prior to the program and again during the field sampling. The concentrations of the methane calibration gases were 100, 504, and 1000 ppmv.

4.5 NO_X Measurement

NO_X concentrations were determined with a Teledyne-API chemiluminescent continuous emission monitor (CEM) spanned with a nitrogen (0 ppmv NO_X) and high calibration gas (91.8 ppmv NO_X) on a 0 to 500 ppmv scale. Linearity was verified with a middle calibration gas (50.7 ppmv NO_X). The analyzer was checked for drift using the zero and middle (50.7 ppmv NO_X) calibration gases following each test. All calibration gases are EPA protocol gases, as documented in Appendix C. The results of the pre-test calibration, linearity check, and post- test calibration tests verified that this analyzer was operating accurately. All of the QA/QC documentation for the NO_X analyzer is contained in Appendix C.

4.6 CO Measurement

CO concentrations were determined with a Rosemount NDIR continuous emission monitor (CEM) spanned with a nitrogen (0 ppmv CO) and high calibration gas (60.0 ppmv CO) on a 0 to 1000 ppmv scale. Linearity was verified with a middle calibration gas (30.7 ppmv CO). The analyzer was checked for drift using the zero and middle (30.7 ppmv CO) calibration gases following each test. All calibration gases are EPA

protocol gases, as documented in Appendix C. The results of the pre-test calibration, linearity check and post-test calibration tests verified that this analyzer was operating accurately. All of the QA/QC documentation for the CO analyzer is contained in Appendix C.

4.7 SO_2 Measurement

SO_2 concentrations were determined with a Bovar chemiluminescent continuous emission monitor (CEM) spanned with a nitrogen (0 ppmv SO_2) and high calibration gas (91.8.ppmv SO_2) on a 0 to 200 ppmv scale. Linearity was verified with a middle calibration gas (50.7 ppmv SO_2). The analyzer was checked for drift using the zero and middle (50.7 ppmv SO_2) calibration gases following each test. All calibration gases are EPA protocol gases, as documented in Appendix C. The results of the pre-test calibration, linearity check, and post- test calibration tests verified that this analyzer was operating accurately. All of the QA/QC documentation for the SO_2 analyzer is contained in Appendix C.

4.8 QAQC Incidents

Prior to test run number three on September 10, 2008, the internal clock for the additional data acquisition module discussed in section 3.4.6 was not synchronized with the CEM system clock used to record official start and stop times of testing events. This resulted in a discrepancy of four hours and three minutes between official timed events for test three and the data records logged by the additional data acquisition module.

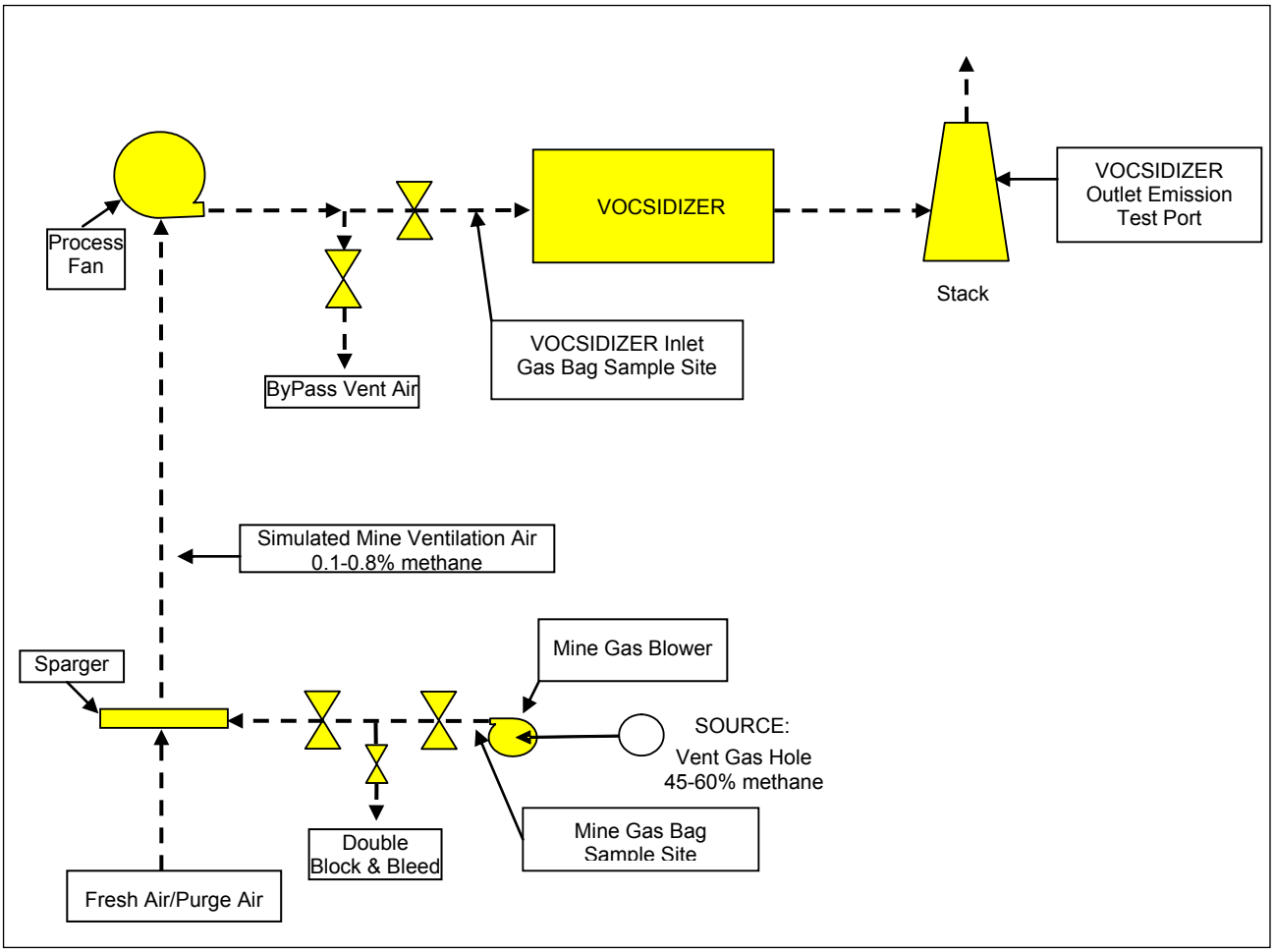


Figure 1. Process Schematic Diagram of VOCSIDIZER

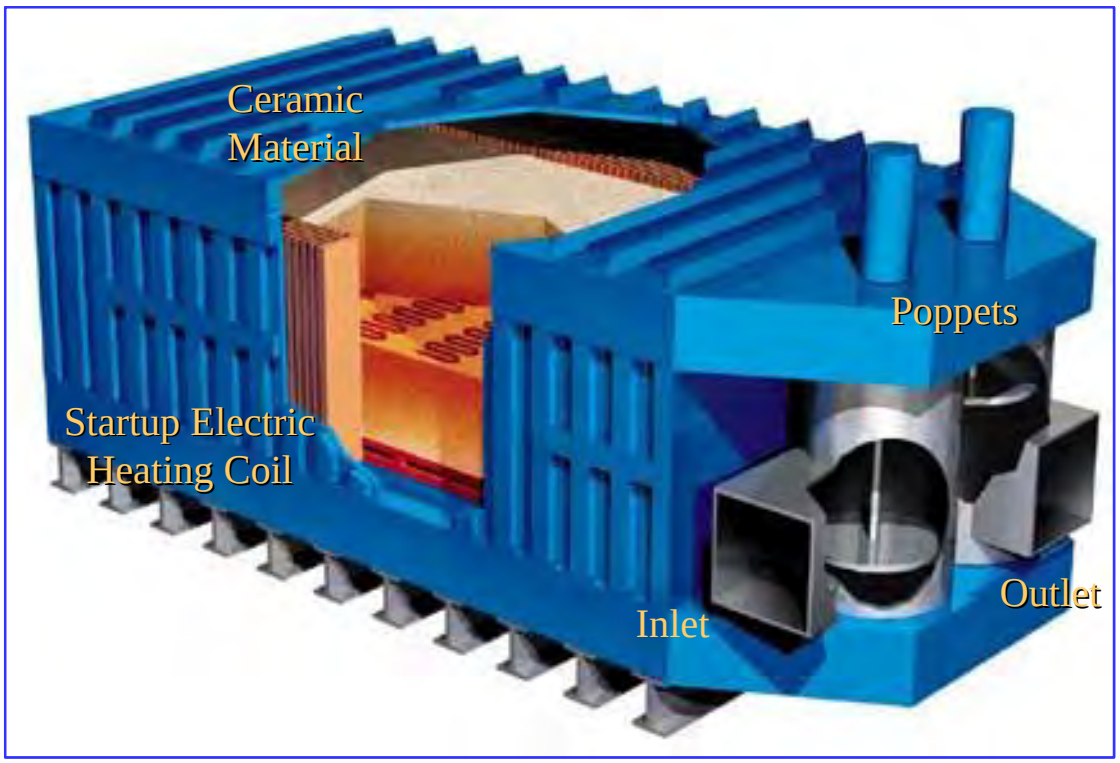
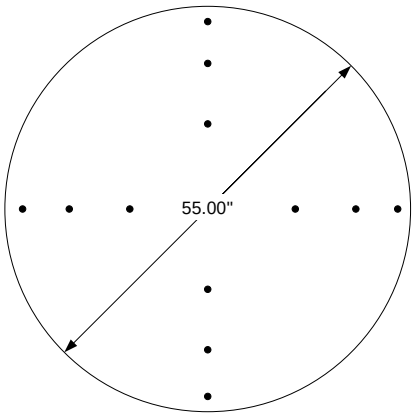


Figure 2. Internal Components of the VOCSIDIZER



Traverse Point Positions

Point No.	Location (in.)
1	2.50
2	8.00
3	16.25
4	38.75
5	47.00
6	52.50

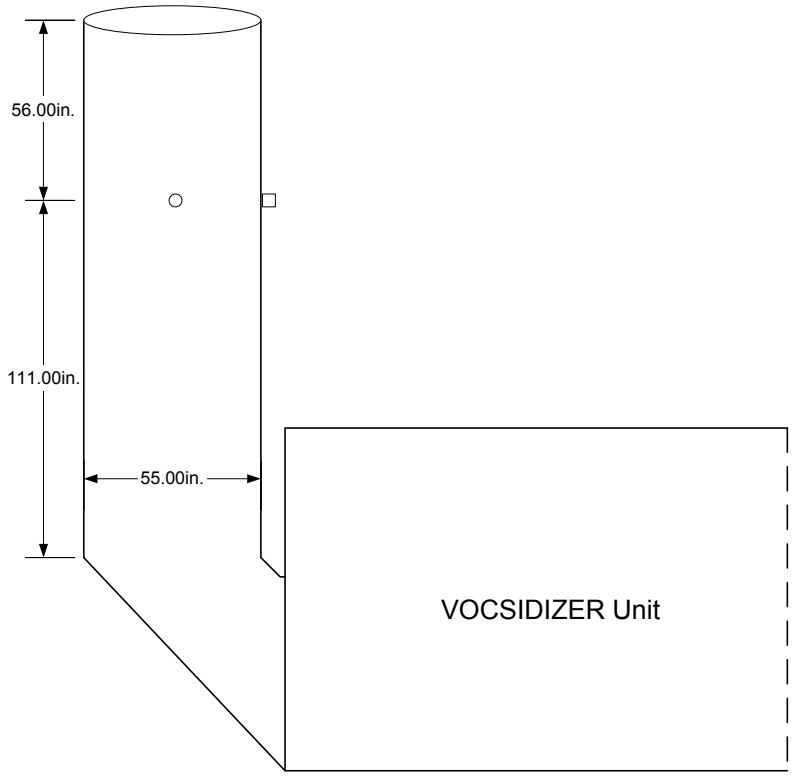


Figure 3. Schematic of the VOCSIDIZER Stack Sampling Location.

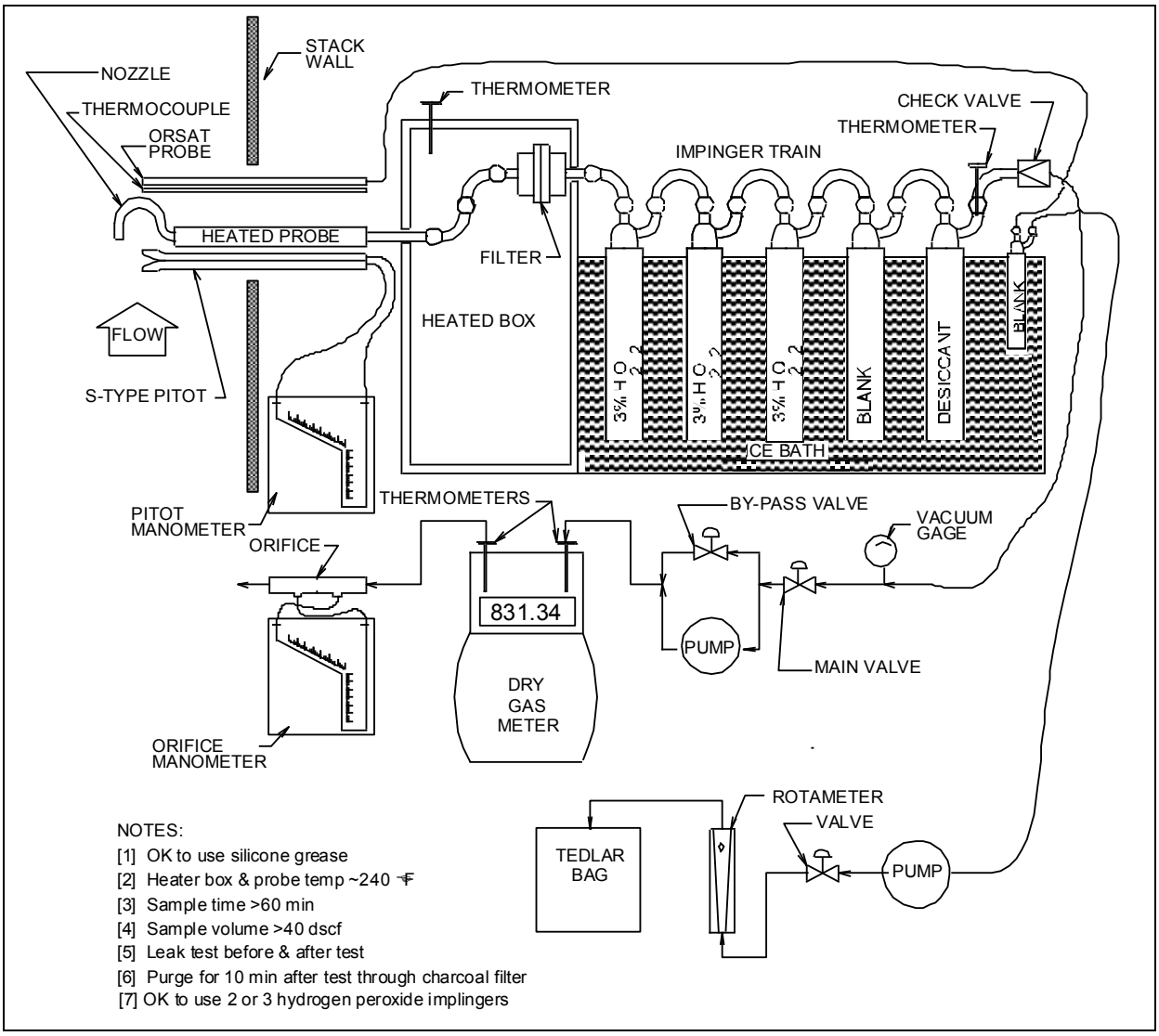


Figure 4. VOCSIDIZER PM and Orsat Sampling Train

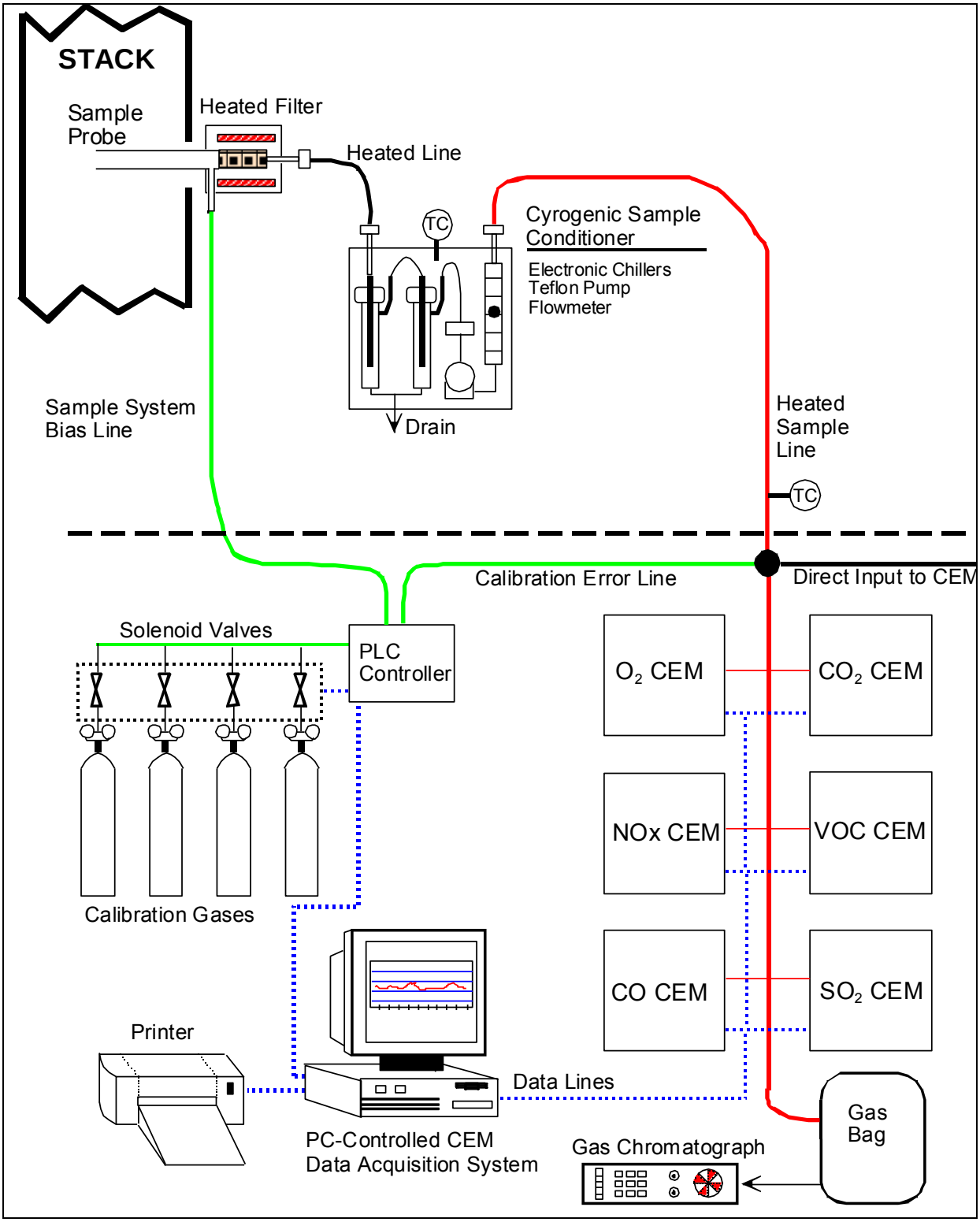


Figure 5. Schematic of CONSOL R&D CEM System

LIST OF APPENDICES

A - Raw Field Data & Tabulated Results

B - Laboratory Reports

C - QA/QC

D – Process Operating Data

APPENDIX A

Raw Field Data and Tabulated Results

- Method 5 Particulate Test Field Data Sheets
- Total VOC Strip Chart Records
- O_2 Strip Chart Records
- CO_2 Strip Chart Records
- CO Strip Chart Records
- NO_X Strip Chart Records
- SO_2 Strip Chart Records

EPA METHOD 5 PARTICULATE SAMPLING FIELD DATA SHEET

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TEST ID	Oxidizer-1
PLANT	Windsor-Metric
LOCATION	Oxidizer Outlet
DATE	3-6-03
OPERATOR(S)	BRS/AG
AMBIENT TEMP [°F]	~90°
BAR. PRESS. [" Hg]	23.50

METER BOX	N-5
PITOT TUBE DESC	E-1
PROBE LENGTH [ft]	6
NOZZLE ID [inch]	9/32 A 0.270
%H_2O (Assumed)	4.5
FILTER ID	54
K FACTOR	3.23

CAL. DATA: delta H	1.818		
Y	0.990		
C(p)	0.820		
FILTER BOX SETTING	250		
PROBE HTR SETTING	250		
DUCT X-SECTION	circ ?	rect ?	other:
DUCT DIMENSIONS		DUCT AREA	

Comments: _____

TRAVERSE POINT [port-inch]	CLOCK TIME (24-hr)	SAMPLE TIME [minute]	STATIC PRES [" H_2O]	PITOT HEAD [" H_2O]	METER DIFF PRESSURE [" H_2O]	METER VACUUM [" Hg]	METER READING [ft^3]	METER TEMP [oF] inlet	METER TEMP [oF] outlet	STACK TEMP [°F]	PROBE TEMP [°F]	FILTER BOX [°F]	LAST IMP TEMP [°F]	METER EXHAUST O_2 [% vol]	METER EXHAUST CO_2 [% vol]
	1105	0					926.10								
1		5		.38	1.25	1	929.44	92	92	360	252	251	63	—	—
2		10		.60	1.97	1	933.58	94	95	390	250	251	55	20.6	—
3		15		.75	2.46	1.5	938.24	96	96	397	251	250	56	—	—
4		20	.60	.90	2.95	2.5	943.34	99	99	387	252	251	59	20.6	—
5		25		.90	2.95	2.5	948.50	100	99	354	249	250	61	—	—
6		30		1.10	3.61	3	953.98	101	99	285	249	252	63	20.6	—
1		35		.20	.66	1	956.50	99	99	314	251	249	64	—	—
2		40		.45	1.48	1	960.12	101	101	380	251	250	54	20.6	—
3		45		.75	2.46	2	964.80	102	102	460	249	251	51	—	—
4		50	.55	.90	2.95	2.5	969.90	104	102	370	251	251	53	—	—
5		55		1.10	3.61	3	975.50	105	102	340	248	252	54	20.6	—
6	1225	60		1.10	3.61	3	981.11	106	102	270	250	250	57	—	—
				RMS											
AVERAGE			0.58	0.727	2.50		55.01	99.5		357.3				20.6	

Sample Train Leak Checks: Pre Test OK ft^3 @ 10 in. Hg; Post Test OK ft^3 @ 10 in. Hg

Pitot Tube Leak Checks: PreTest OK @ 7 in. H_2O; Post Test OK @ 7 in. H_2O

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EPA METHOD 5 PARTICULATE SAMPLING FIELD DATA SHEET

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TEST ID	VOX-2
PLANT	WINDSOR
LOCATION	VOX-OUT
DATE	8-6-08
OPERATOR(S)	BS, AG
AMBIENT TEMP [°F]	92.0
BAR. PRESS. [" Hg]	28.47

METER BOX	2-5
PITOT TUBE DESC	E-1
PROBE LENGTH [ft]	6'
NOZZLE ID [inch]	9/32 A .270
%H_2O (Assumed)	4.5
FILTER ID	55
K FACTOR	3.28

CAL. DATA: delta H	1.818
Y	.990
C(p)	.820
FILTER BOX SETTING	250
PROBE HTR SETTING	250
DUCT X-SECTION	circ ? rect ? other:
DUCT DIMENSIONS	DUCT AREA

Comments: 3

TRAVERSE POINT [port-inch]	CLOCK TIME (24-hr)	SAMPLE TIME [minute]	STATIC PRES [" H_2O]	PITOT HEAD [" H_2O]	METER DIFF PRESSURE [" H_2O]	METER VACUUM [" Hg]	METER READING [ft^3]	METER TEMP [oF] inlet	METER TEMP [oF] outlet	STACK TEMP [°F]	PROBE TEMP [°F]	FILTER BOX [°F]	LAST IMP TEMP [°F]	METER EXHAUST O_2 [% vol]	METER EXHAUST CO_2 [% vol]
	1350	0					981.50								
1		5		.35	1.15	1	984.68	90	90	320	250	251	54	—	—
2		10		.40	1.31	1	988.10	90	90	440	251	251	50	20.0	0.5
3		15		.60	1.97	1.5	992.24	93	93	300	250	251	51	—	—
4		20	.60	.90	2.95	2.5	997.28	97	95	390	250	251	54	20.0	0.5
5		25		1.10	3.61	3	002.83	99	97	314	252	249	56	—	—
6		30		1.30	4.26	4	008.86	101	98	456	252	251	60	19.9	0.6
1		35		.20	.98	1	011.85	98	98	284	252	251	60	—	—
2		40		.60	1.97	1.5	015.95	99	97	300	251	251	58	20.2	0.4
3		45		.90	2.95	2.5	020.98	101	98	335	251	251	60	—	—
4		50	.50	.90	2.95	2.5	026.02	102	98	470	251	252	60	20.2	0.4
5		55		1.10	3.61	3	031.60	104	98	305	247	250	62	—	—
6	1457	60		.90	2.95	2.5	036.65	104	98	280	249	252	64	20.2	0.4
				Rec											
AVERAGE			0.55	0.744	2.56		55.15	97.7		347.5				20.1	0.5

Sample Train Leak Checks: Pre Test OK ft^3 @ 10 in. Hg
Post Test OK ft^3 @ 10 in. Hg

Pitot Tube Leak Checks: PreTest OK @ 7 in. H_2O
Post Test OK @ 7 in. H_2O

CONSOLENERGY

1166314
0.8585-95

EPA METHOD 5 PARTICULATE SAMPLING FIELD DATA SHEET

Page ____ of ____

TEST ID	VOX-3	METER BOX	2-5	CAL. DATA: delta H	1.818	Comments:	
PLANT	WINDSOR	PITOT TUBE DESC	E-1	Y	.990		
LOCATION	VOX-OUT	PROBE LENGTH [ft]	6	C(p)	.820		
DATE	8-7-08	NOZZLE ID [inch]	9/32A .270	FILTER BOX SETTING	250		
OPERATOR(S)	BS, AG	%H_2O (Assumed)	4.5	PROBE HTR SETTING	250		
AMBIENT TEMP [°F]	~80°	FILTER ID	53	DUCT X-SECTION	circ ?	rect ?	other:
BAR. PRESS. [" Hg]	28.47	K FACTOR	3.28	DUCT DIMENSIONS		DUCT AREA	

TRAVERSE POINT [port-inch]	CLOCK TIME (24-hr)	SAMPLE TIME [minute]	STATIC PRES [" H_2O]	PITOT HEAD [" H_2O]	METER DIFF PRESSURE [" H_2O]	METER VACUUM [" Hg]	METER READING [ft^3]	METER TEMP [oF] inlet	METER TEMP [oF] outlet	STACK TEMP [°F]	PROBE TEMP [°F]	FILTER BOX [°F]	LAST IMP TEMP [°F]	METER EXHAUST O_2 [% vol]	METER EXHAUST CO_2 [% vol]
	0930	0					037.~~20~~ 40								
1		5		.30	.98	1	040.36	95	95	340	248	251	63	—	—
2		10		.60	1.97	2	044.47	97	96	400	250	251	58	20.3	0.3
3		15		.90	2.95	4	049.50	99	99	380	250	251	59	—	—
4		20	.60	1.00	3.28	5	054.82	102	101	330	250	252	60	20.3	0.3
5		25		1.10	3.61	6	060.37	104	103	295	247	251	61	—	—
6		30		.90	2.95	4.5	065.47	105	104	290	250	252	63	20.4	0.3
1		35		.35	1.15	1	068.68	104	104	430	248	251	59	—	—
2		40		.45	1.48	1.5	072.28	105	105	460	249	250	56	20.2	0.4
3		45		.80	2.62	3.5	077.06	106	105	270	250	250	55	—	—
4		50		1.10	3.61	5.5	082.64	107	105	325	250	251	56	20.2	0.4
5		55	.75	1.30	4.26	7	088.67	108	104	405	~~405~~ 250	251	57	—	—
6	1038	60		1.10	3.61	6	094.25	108	103	300	250	250	59	20.2	0.4
				RMS											
AVERAGE			0.68	0.910	2.71		56.85	102.67		352.08				20.3	

Sample Train Leak Checks: Pre Test 0.15 ft^3 @ 10 in. Hg; Post Test 0.15 ft^3 @ 10 in. Hg

Pitot Tube Leak Checks: PreTest 0.15 @ 7 in. H_2O; Post Test 0.15 @ 7 in. H_2O

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EPA METHOD 5 PARTICULATE SAMPLING FIELD DATA SHEET

Page _____ of _____

TEST ID	Test 1	METER BOX	N-5	CAL. DATA: delta H	1.818
PLANT	Windsor - Megtec	PITOT TUBE DESC	E-1	Y	.990
LOCATION	Vocsidizer Outlet	PROBE LENGTH [ft]	5'	C(p)	0.8210
DATE	9/9/08	NOZZLE ID [inch]	0.270	FILTER BOX SETTING	250
OPERATOR(S)	BS / AG	%H_2O (Assumed)	4	PROBE HTR SETTING	250
AMBIENT TEMP [°F]	~64°	FILTER ID	056	DUCT X-SECTION	circ ? / rect ? / other:
BAR. PRESS. [" Hg]	28.50	K FACTOR	3.39	DUCT DIMENSIONS	55" DUCT AREA

Comments: _____

TRAVERSE POINT [port-inch]	CLOCK TIME (24-hr)	SAMPLE TIME [minute]	STATIC PRES [" H_2O]	PITOT HEAD [" H_2O]	METER DIFF PRESSURE [" H_2O]	METER VACUUM [" Hg]	METER READING [ft^3]	METER TEMP [oF] (6) inlet	METER TEMP [oF] (7) outlet	STACK TEMP [°F] (1)	PROBE TEMP [°F] (2)	FILTER BOX [°F] (3)	LAST IMP TEMP [°F] (4)	METER EXHAUST O_2 [% vol]	METER EXHAUST CO_2 [% vol]
	1620	0					094.80								
-2.50		5		.45	1.53	1	098.25	65	65	370	251	251	51	—	—
-8.00		10		.60	2.03	1	102.26	66	66	430	250	251	49	19.9	—
-16.25		15		.80	2.71	1.5	106.90	68	68	450	251	251	50	—	—
-38.75		20	.297	.80	2.71	1.5	111.55	72	69	270	249	252	51	19.8	—
-47.00		25		1.00	3.39	2.0	116.73	74	71	300	251	253	53	—	—
-52.50		30		1.10	3.73	2.5	122.20	76	70	260	253	253	56	19.8	—
-2.50		35		.20	.68	1	124.60	72	69	320	249	250	50	—	—
-8.00		40		.35	1.19	1	127.73	74	70	273	250	250	47	20.0	—
-16.25		45		.50	1.70	1	131.40	76	70	340	249	251	46	—	—
-38.75		50	.419	1.00	3.39	2.0	136.60	77	71	380	252	252	47	19.9	—
-47.00		55		1.10	3.73	2.5	142.02	80	71	260	252	251	48	—	—
-52.50	1727	60		1.10	3.73	2.5	147.50	81	71	270	252	252	50	19.9	—
AVERAGE		-r	0.358	0.772	2.543		52.70	71.3		326.9				19.9	

Sample Train Leak Checks: Pre Test 0 K ft^3 @ 10 in. Hg; Post Test 0 K ft^3 @ 10 in. Hg

Pitot Tube Leak Checks: PreTest 0 K @ 2 in. H_2O; Post Test 0 K @ 2 in. H_2O

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EPA METHOD 5 PARTICULATE SAMPLING FIELD DATA SHEET

Page ____ of ____

TEST ID	TEST 2	METER BOX	2-5	CAL. DATA: delta H	1.818	Comments:	17.8
PLANT	Windsor - Megtec	PITOT TUBE DESC	E 1	Y	.990		
LOCATION	Vocsidizer Outlet	PROBE LENGTH [ft]	5'	C(p)	.820		
DATE	9-10-08	NOZZLE ID [inch]	0.270	FILTER BOX SETTING	250		
OPERATOR(S)	BS, AG	%H_2O (Assumed)	4	PROBE HTR SETTING	250		
AMBIENT TEMP [°F]	~630	FILTER ID	057	DUCT X-SECTION	circ ?	rect ?	other:
BAR. PRESS. [" Hg]	28.64	K FACTOR	3.39	DUCT DIMENSIONS	55"	DUCT AREA	

TRAVERSE POINT [port-inch]	CLOCK TIME (24-hr)	SAMPLE TIME [minute]	STATIC PRES [" H_2O]	PITOT HEAD [" H_2O]	METER DIFF PRESSURE [" H_2O]	METER VACUUM [" Hg]	METER READING [ft^3]	METER TEMP (6) [oF] inlet	METER TEMP (7) [oF] outlet	STACK TEMP (1) [°F]	PROBE TEMP (2) [°F]	FILTER BOX (3) [°F]	LAST IMP TEMP (4) [°F]	METER EXHAUST O_2 [% vol]	METER EXHAUST CO_2 [% vol]
	0937	0					147.70								
-2.50		5		.20	.68	1	150.07	72	68	270	251	253	49	—	—
-8.00		10		.30	1.02	1	152.95	73	70	280	251	253	46	20.4	—
-16.25		15		.50	1.70	1	156.60	75	72	300	251	254	45	—	—
-38.75		20	.784	1.00	3.39	2.5	161.75	78	72	350	251	252	48	20.4	—
-47.00		25		1.10	3.73	3	167.20	80	73	410	251	252	50	—	—
-52.50		30		1.10	3.73	3	172.65	82	74	280	249	254	55	20.5	—
-2.50		35		.35	1.19	1	175.75	80	73	330	250	253	56	—	—
-8.00		40		.50	1.70	1	179.47	80	73	260	252	253	54	20.1	—
-16.25		45		.65	2.20	1.5	183.68	80	74	370	251	253	54	—	—
-38.75		50	.475	.80	2.71	2	188.34	81	74	320	251	253	55	20.1	—
-47.00		55		.80	2.71	2	193.00	81	75	430	250	253	56	—	—
-52.50	1042	60		1.10	3.73	3	198.40	83	75	280	251	253	59	20.1	—
AVERAGE			0.630	0.659	2.374		50.70	75.8		323.3				20.3	

Sample Train Leak Checks: Pre Test OK ft^3 @ 10 in. Hg; Post Test OK ft^3 @ 10 in. Hg

Pitot Tube Leak Checks: PreTest OK @ 7 in. H_2O; Post Test OK @ 7 in. H_2O

CONSOLENERGY

EPA METHOD 5 PARTICULATE SAMPLING FIELD DATA SHEET

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TEST ID	TEST 3
PLANT	Windsor - Megtec
LOCATION	Vocsidizer Outlet
DATE	9-10-08
OPERATOR(S)	BS, AG
AMBIENT TEMP [°F]	~670
BAR. PRESS. [" Hg]	28.70

METER BOX	2-5
PITOT TUBE DESC	E1
PROBE LENGTH [ft]	5'
NOZZLE ID [inch]	0.270
%H_2O (Assumed)	4
FILTER ID	058
K FACTOR	3.39
* &	3.60

CAL. DATA: delta H	1.818		
Y	.990		
C(p)	.820		
FILTER BOX SETTING	250		
PROBE HTR SETTING	250		
DUCT X-SECTION	circ ?	rect ?	other:
DUCT DIMENSIONS	55"	DUCT AREA	

Comments: _____

TRAVERSE POINT [port-inch]	CLOCK TIME (24-hr)	SAMPLE TIME [minute]	STATIC PRES [" H_2O]	PITOT HEAD [" H_2O]	METER DIFF PRESSURE [" H_2O]	METER VACUUM [" Hg]	METER READING [ft^3]	METER TEMP [oF] (6) Inlet	(7) outlet	STACK TEMP (1) [°F]	PROBE TEMP (2) [°F]	FILTER BOX (3) [°F]	LAST IMP TEMP (4) [°F]	METER EXHAUST O_2 [% vol]	CO_2 [% vol]
	1137	0					200.50								
-2.50		5		.30	1.02	1	203.37	71	71	340	250	250	49	—	—
-8.00		10		.50	1.70	1	207.00	73	73	318	251	252	47	19.9	—
-16.25		15		.80	2.71	1.5	211.63	75	74	270	251	253	48	—	—
-38.75	*	20	.305	.85	2.88	1.5	216.45	77	75	250	249	254	49	19.8	—
-47.00	K=3.60	25		.85	3.06	1.5	221.37	79	77	400	251	254	50	—	—
-52.50		30		1.10	3.96	2.5	227.00	81	78	270	251	254	52	19.7	—
-2.50		35		.20	.72	1	229.46	78	78	266	251	252	54	—	—
-8.00		40		.30	1.08	1	232.46	79	78	270	250	253	53	20.0	—
-16.25		45		.60	2.16	1	236.61	80	79	310	~~310~~	251	54	—	—
-38.75		50	.549	1.00	3.60	2	241.96	82	77	248	251 252	254	55	20.0	—
-47.00		55		1.10	3.96	2.5	247.57	83	75	350	251	253	56	—	—
-52.50	1242	60		1.10	3.96	2.5	253.20	83	74	328	250	252	58	20.1	—
AVERAGE			0.427	0.682	2.568		52.70	77.1		301.7				19.9	

Sample Train Leak Checks: Pre Test OK ft^3 @ 10 in. Hg; Post Test OK ft^3 @ 10 in. Hg

Pitot Tube Leak Checks: PreTest OK @ 7 in. H_2O; Post Test OK @ 7 in. H_2O

CONSOLENERGY

Company Name: CONSOL R&D
Location: VOCSIDIZER, Windsor
Date: 8/6/08
Run No. One

Gas Flow (dscfm) 35376

Time	% O_2	% CO_2	ppm NOx	ppm SO_2	ppm THC	ppm CO	
11:08	19.7	0.7	0.2	0	103.0	3.2	
11:09	19.6	0.7	0.2	0	5.9	3.3	
11:10	19.6	0.7	0.2	0.1	124.0	3.1	
11:11	19.7	0.7	0.2	0	8.4	3.3	
11:12	19.6	0.7	0.2	0	108.1	3.1	
11:13	19.7	0.7	0.2	0	8.9	3.4	
11:14	19.6	0.7	0.2	0	127.2	3	
11:15	19.7	0.7	0.2	0.1	10.8	3.3	
11:16	19.6	0.7	0.2	0.1	110.0	3.1	
11:17	19.7	0.7	0.2	0.1	11.0	3.2	
11:18	19.6	0.7	0.2	0.1	130.5	3.1	
11:19	19.7	0.7	0.2	0.1	105.9	3.3	
11:20	19.6	0.7	0.2	0	18.4	3.2	
11:21	19.7	0.7	0.2	0.1	128.0	3.2	
11:22	19.6	0.7	0.2	0.1	14.3	3.2	
11:23	19.7	0.7	0.2	0.1	112.3	3	
11:24	19.7	0.7	0.2	0.1	12.6	3.3	
11:25	19.6	0.7	0.2	0	130.3	2.9	
11:26	19.7	0.7	0.2	0.1	13.4	3.1	
11:27	19.6	0.7	0.2	0	112.0	2.9	
11:28	19.7	0.7	0.2	0	12.4	3.1	
11:29	19.6	0.7	0.2	0.1	129.3	2.9	
11:30	19.7	0.7	0.2	0.1	12.7	3.1	
11:31	19.6	0.7	0.2	0.1	112.7	3.2	
11:32	19.7	0.7	0.2	0.1	116.8	3.1	
11:33	19.6	0.7	0.2	0.1	25.7	2.9	
11:34	19.7	0.7	0.2	0	110.6	3	
11:35	19.6	0.7	0.2	0.1	13.1	3.1	
11:36	19.7	0.7	0.2	0.1	127.7	2.8	
11:37	19.7	0.7	0.2	0	14.1	3	
11:38	19.7	0.7	0.2	0.1	111.7	2.9	
11:39	19.7	0.7	0.2	0.1	12.4	3.1	
11:40	19.6	0.7	0.2	0	128.9	2.8	
11:41	20	0.3	0.2	0	12.9	2.6	
11:42	20.6	0.2	0.2	0	110.1	2	Port Change
11:43	19.7	0.7	0.2	0	12.1	2.9	Data Excluded
11:44	19.6	0.7	0.2	0	126.2	2.8	
11:45	19.7	0.7	0.2	0.1	108.5	3	
11:46	19.6	0.7	0.2	0.1	15.6	3.1	
11:47	19.7	0.7	0.2	0	126.4	3	
11:48	19.6	0.7	0.2	0	14.4	3.1	
11:49	19.7	0.7	0.2	0	112.9	3	
11:50	19.7	0.7	0.2	0.1	12.4	3.2	
11:51	19.6	0.7	0.2	0.1	130.6	2.9	
11:52	19.7	0.7	0.2	0.1	13.0	3.2	
11:53	19.6	0.7	0.2	0.1	112.8	3	
11:54	19.7	0.7	0.2	0	12.2	3.2	
11:55	19.6	0.7	0.2	0	129.6	2.9	
11:56	19.7	0.7	0.2	0.1	12.6	3.1	
11:57	19.6	0.7	0.2	0	112.9	3	
11:58	19.7	0.7	0.2	0.1	123.9	3.1	
11:59	19.6	0.7	0.2	0.1	18.3	3	
12:00	19.7	0.7	0.2	0.1	112.3	3	
12:01	19.6	0.7	0.2	0	12.8	3.1	
12:02	19.7	0.7	0.2	0	127.0	2.8	
12:03	19.7	0.7	0.2	0	13.4	3.1	
12:04	19.7	0.7	0.2	0.1	112.7	2.9	
12:05	19.7	0.7	0.2	0	12.3	3.1	
12:06	19.6	0.7	0.2	0.1	128.9	2.8	
12:07	19.7	0.7	0.2	0.1	13.0	3	
12:08	19.7	0.7	0.2	0.1	113.6	2.9	
Raw Average	**19.66**	**0.69**	**0.20**	**0.06**	**69.61**	**3.05**	
Corrected Average	**19.77**	**0.67**	**0.00**	**-1.08**	**64.18**	**2.76**	
Corrected lb/hr	**34823.12**	**1616.95**	**0.00**	**-0.38**	**15.53**	**0.43**	

Company Name: CONSOL R&D
Location: VOCSIDIZER, Windsor
Date: 8/6/2008
Run No. Two

Gas Flow (dscfm) 36042

Time	% O_2	% CO_2	ppm NOx	ppm SO_2	ppm THC	ppm CO	
13:50	19.6	0.7	0.2	0	12	2.2	
13:51	19.7	0.7	0.2	0	124	2.5	
13:52	19.7	0.7	0.2	0	13	2.5	
13:53	19.7	0.7	0.2	0.1	109	2.5	
13:54	19.6	0.7	0.2	0	116	2.6	
13:55	19.7	0.7	0.2	0	19	2.6	
13:56	19.6	0.7	0.2	0.1	108	2.7	
13:57	19.7	0.7	0.2	0.1	13	2.3	
13:58	19.7	0.7	0.2	0	124	2.5	
13:59	19.6	0.7	0.2	0	14	2.3	
14:00	19.7	0.7	0.2	0	108	2.6	
14:01	19.6	0.7	0.2	0	12	2.2	
14:02	19.7	0.7	0.2	0	124	2.3	
14:03	19.6	0.7	0.2	0.1	13	2.3	
14:04	19.7	0.7	0.2	0	109	2.3	
14:05	19.6	0.7	0.2	0	12	2.2	
14:06	19.7	0.7	0.2	0.1	125	2.3	
14:07	19.6	0.7	0.2	0.1	108	2.3	
14:08	19.7	0.7	0.2	0	14	2.2	
14:09	19.6	0.7	0.2	0	123	2.4	
14:10	19.7	0.7	0.2	0.1	14	2.3	
14:11	19.7	0.7	0.2	0.1	108	2.5	
14:12	19.6	0.7	0.2	0	12	2.1	
14:13	19.7	0.7	0.2	0	123	2.5	
14:14	19.6	0.7	0.2	0	13	2.2	
14:15	19.7	0.7	0.2	0	108	2.4	
14:16	19.6	0.7	0.2	0	12	2.1	
14:17	19.7	0.7	0.2	0.1	123	2.3	
14:18	19.6	0.7	0.2	0	12	2.3	
14:19	19.7	0.7	0.2	0	109	2.2	
14:20	19.6	0.7	0.2	0	121	2.3	
14:21	19.7	0.7	0.2	0	17	2.3	
14:22	20	0.5	0.2	0	107	2	Port Change
14:23	19.6	0.7	0.2	0	13	2	Data Excluded
14:24	19.7	0.7	0.2	0	122	2.3	
14:25	19.7	0.7	0.2	0	13	2.2	
14:26	19.7	0.7	0.2	0.1	105	2.4	
14:27	19.6	0.7	0.2	0	12	2.1	
14:28	19.7	0.7	0.2	0	123	2.3	
14:29	19.7	0.7	0.2	0	13	2.2	
14:30	19.7	0.7	0.2	0.1	107	2.2	
14:31	19.6	0.7	0.2	0	12	2.1	
14:32	19.7	0.7	0.2	0.1	123	2.2	
14:33	19.7	0.7	0.2	0	105	2.3	
14:34	19.7	0.7	0.2	0	12	2.1	
14:35	19.7	0.7	0.2	0	120	2.3	
14:36	19.7	0.7	0.2	0	14	2	
14:37	19.7	0.7	0.2	0	107	2.3	
14:38	19.7	0.7	0.2	0	13	2	
14:39	19.7	0.7	0.2	0	122	2.3	
14:40	19.7	0.7	0.2	0	13	2.3	
14:41	19.7	0.7	0.2	0	107	2.2	
14:42	19.6	0.7	0.2	0	12	1.9	
14:43	19.7	0.7	0.2	0	121	2.2	
14:44	19.7	0.7	0.2	0	24	2.2	
14:45	19.7	0.7	0.2	0	95	2.1	
14:46	19.6	0.7	0.2	0	120	2	
14:47	19.7	0.7	0.2	0	15	2	
14:48	19.7	0.7	0.2	0	107	2.2	
14:49	19.7	0.7	0.2	0	13	1.9	
14:50	19.7	0.7	0.2	0	123	2.1	
Raw Average	**19.67**	**0.70**	**0.20**	**0.02**	**67.61**	**2.26**	
Corrected Average	**19.77**	**0.67**	**0.00**	**-1.34**	**66.67**	**2.04**	
Corrected lb/hr	**35482.02**	**1663.23**	**0.00**	**-0.48**	**16.44**	**0.32**	

Company Name: CONSOL R&D
Location: VOCSIDIZER, Windsor
Date: 8/7/2008
Run No. Three

Gas Flow (dscfm) 37201

Time	% O_2	% CO_2	ppm NOx	ppm SO_2	ppm THC	ppm CO	
9:31	19.7	0.6	0.2	0	122.0	1.5	
9:32	19.7	0.6	0.2	0	8.7	1.2	
9:33	19.7	0.6	0.2	0	105.7	1.5	
9:34	19.7	0.6	0.2	0	9.4	1.2	
9:35	19.7	0.6	0.2	0	125.3	1.4	
9:36	19.7	0.6	0.2	0	10.9	1.5	
9:37	19.7	0.6	0.2	0	109.1	1.5	
9:38	19.7	0.7	0.2	0	11.0	1.3	
9:39	19.7	0.6	0.2	0	126.1	1.5	
9:40	19.7	0.6	0.2	0	102.9	1.6	
9:41	19.7	0.6	0.2	0	19.4	1.4	
9:42	19.6	0.7	0.2	0	124.7	1.5	
9:43	19.7	0.6	0.2	0	14.1	1.4	
9:44	19.7	0.6	0.2	0	110.3	1.6	
9:45	19.7	0.7	0.2	0	12.3	1.3	
9:46	19.7	0.6	0.2	0	127.1	1.5	
9:47	19.7	0.6	0.2	0	13.2	1.4	
9:48	19.7	0.6	0.2	0	110.6	1.6	
9:49	19.7	0.7	0.2	0	12.2	1.4	
9:50	19.7	0.6	0.2	0	128.0	1.5	
9:51	19.7	0.7	0.2	0	12.7	1.6	
9:52	19.7	0.6	0.2	0	110.5	1.6	
9:53	19.6	0.7	0.2	0	114.7	1.4	
9:54	19.7	0.6	0.2	0	25.7	1.4	
9:55	19.7	0.6	0.2	0	108.9	1.7	
9:56	19.7	0.6	0.2	0	12.8	1.4	
9:57	19.7	0.6	0.2	0	126.3	1.6	
9:58	19.7	0.7	0.2	0	13.5	1.4	
9:59	19.7	0.6	0.2	0	110.0	1.5	
10:00	19.7	0.6	0.2	0	12.3	1.4	
10:01	19.7	0.6	0.2	0	127.5	1.6	
10:02	19.7	0.5	0.2	0	12.6	1.4	
10:03	20.6	0.1	0.2	0	11.3	0.4	Port Change
10:04	19.7	0.6	0.2	0	12.1	1.5	Data Excluded
10:05	19.7	0.6	0.2	0	125.5	1.5	
10:06	19.7	0.6	0.2	0	108.4	1.7	
10:07	19.7	0.6	0.2	0	14.7	1.5	
10:08	19.6	0.6	0.2	0	125.3	1.7	
10:09	19.7	0.6	0.2	0	14.2	1.4	
10:10	19.7	0.6	0.2	0	111.8	1.8	
10:11	19.6	0.7	0.2	0	12.5	1.4	
10:12	19.7	0.6	0.2	0	125.9	1.6	
10:13	19.7	0.6	0.2	0	12.7	1.5	
10:14	19.7	0.6	0.2	0	8.5	1.7	
10:15	19.6	0.6	0.2	0	110.9	1.5	
10:16	19.7	0.6	0.2	0	124.3	1.8	
10:17	19.7	0.7	0.2	0	11.5	1.7	
10:18	19.7	0.6	0.2	0	110.5	1.5	
10:19	19.6	0.6	0.2	0	119.5	1.5	
10:20	19.7	0.6	0.2	0	15.6	1.6	
10:21	19.7	0.6	0.2	0	108.9	1.8	
10:22	19.7	0.6	0.2	0	11.2	1.4	
10:23	19.7	0.6	0.2	0	124.5	1.7	
10:24	19.7	0.6	0.2	0	11.7	1.4	
10:25	19.7	0.6	0.2	0	110.9	1.8	
10:26	19.6	0.6	0.2	0	11.0	1.3	
10:27	19.7	0.6	0.2	0	124.5	1.5	
10:28	19.7	0.6	0.2	0	11.5	1.6	
10:29	19.7	0.6	0.2	0	109.9	1.6	
10:30	19.6	0.7	0.2	0	11.4	1.4	
10:31	19.7	0.6	0.2	0	125.5	1.5	
Raw Average	**19.69**	**0.62**	**0.20**	**0.00**	**68.59**	**1.51**	
Corrected Average	**19.73**	**0.62**	**-0.10**	**-0.64**	**62.45**	**1.22**	
Corrected lb/hr	**36552.31**	**1566.27**	**-0.03**	**-0.24**	**15.89**	**0.20**	

Company Name: CONSOL R&D
Location: VOCSIDIZER, Windsor
Date: 9/9/08
Run No. One

Gas Flow (dscfm) 35975

Time	% O_2	% CO_2	ppm NOx	ppm SO_2	ppm THC	ppm CO	
16:25	19.7	0.6	0.2	0.2	112.7	4.8	
16:26	19.6	0.6	0.2	0.3	5.0	4.9	
16:27	19.7	0.6	0.2	0.3	97.2	5.1	
16:28	19.6	0.6	0.2	0.3	2.7	4.8	
16:29	19.7	0.6	0.2	0.2	115.1	5.0	
16:30	19.6	0.6	0.2	0.3	4.2	4.8	
16:31	19.7	0.6	0.2	0.3	99.1	5.0	
16:32	19.6	0.6	0.2	0.3	3.9	4.8	
16:33	19.7	0.6	0.2	0.1	117.3	5.0	
16:34	19.6	0.6	0.2	0.2	5.4	4.9	
16:35	19.7	0.6	0.2	0.2	101.1	5.1	
16:36	19.6	0.6	0.2	0.2	6.1	4.9	
16:37	19.7	0.6	0.2	0.3	120.7	5.0	
16:38	19.6	0.6	0.2	0.2	7.6	5.0	
16:39	19.7	0.6	0.2	0.2	103.9	5.1	
16:40	19.6	0.6	0.2	0.2	8.3	4.9	
16:41	19.7	0.6	0.2	0.3	124.1	5.0	
16:42	19.7	0.6	0.2	0.2	9.3	5.1	
16:43	19.7	0.6	0.2	0.2	107.9	5.1	
16:44	19.7	0.6	0.2	0.2	9.5	5.0	
16:45	19.6	0.6	0.2	0.2	123.7	5.1	
16:46	19.7	0.6	0.2	0.3	96.4	5.1	
16:47	19.6	0.6	0.2	0.1	19.8	5.1	
16:48	19.7	0.6	0.2	0.2	119.4	5.0	
16:49	19.6	0.6	0.2	0.2	13.6	5.0	
16:50	19.7	0.6	0.2	0.2	105.5	5.2	
16:51	19.7	0.6	0.2	0.3	11.3	5.1	
16:52	19.7	0.6	0.2	0.3	9.4	4.0	
16:53	20	0.2	0.2	0.3	10.4	4.2	Port Change
16:54	20.7	0	0.2	0.1	107.5	5.2	Data Excluded
16:55	19.8	0.6	0.2	0.3	11.1	4.9	
16:56	19.7	0.6	0.2	0.2	121.7	5.2	
16:57	19.6	0.6	0.2	0.2	11.4	5.1	
16:58	19.7	0.6	0.2	0.2	108.2	5.3	
16:59	19.6	0.6	0.2	0.2	10.8	5.1	
17:00	19.7	0.6	0.2	0.2	123.3	5.3	
17:01	19.6	0.6	0.2	0.2	11.1	5.2	
17:02	19.7	0.6	0.2	0.2	107.7	5.4	
17:03	19.7	0.6	0.2	0.3	10.7	5.3	
17:04	19.7	0.6	0.2	0.2	122.3	5.5	
17:05	19.7	0.6	0.2	0.2	10.6	5.4	
17:06	19.7	0.6	0.2	0.3	107.9	5.4	
17:07	19.7	0.6	0.2	0.2	10.0	5.4	
17:08	19.6	0.6	0.2	0.2	121.9	5.5	
17:09	19.7	0.6	0.2	0.2	97.7	5.5	
17:10	19.6	0.6	0.2	0.3	18.7	5.6	
17:11	19.7	0.6	0.2	0.2	118.2	5.5	
17:12	19.6	0.6	0.2	0.1	12.4	5.5	
17:13	19.7	0.6	0.2	0.1	106.3	5.7	
17:14	19.6	0.6	0.2	0.2	9.8	5.4	
17:15	19.7	0.6	0.2	0.2	118.5	5.6	
17:16	19.6	0.6	0.2	0.2	10.5	5.5	
17:17	19.7	0.6	0.2	0.2	105.1	5.7	
17:18	19.6	0.6	0.2	0.2	9.8	5.4	
17:19	19.7	0.6	0.2	0.1	120.5	5.7	
17:20	19.6	0.6	0.2	0.2	10.7	5.6	
17:21	19.7	0.6	0.2	0.2	107.4	5.7	
17:22	19.7	0.6	0.2	0.2	10.4	5.6	
17:23	19.7	0.6	0.2	0.1	120.4	5.6	
17:24	19.6	0.6	0.2	0.2	10.7	5.5	
17:25	19.7	0.6	0.2	0.1	105.3	5.6	
17:26	19.7	0.6	0.2	0.1	10.8	5.5	
Raw Average	**19.67**	**0.60**	**0.20**	**0.21**	**60.86**	**5.22**	
Corrected Average	**19.85**	**0.58**	**-0.10**	**-1.52**	**59.30**	**1.64**	
Corrected lb/hr	**35557.33**	**1422.98**	**-0.03**	**-0.54**	**14.59**	**0.26**	

Company Name: CONSOL R&D
Location: VOCSIDIZER, Windsor
Date: 9/10/2008
Run No. Two

Gas Flow (dscfm) 34898

Time	% O_2	% CO_2	ppm NOx	ppm SO_2	ppm THC	ppm CO	
9:38	19.8	0.6	0.2	0	88	6.36	
9:39	19.8	0.6	0.2	0	6	6.33	
9:40	19.8	0.6	0.2	0	109	6.25	
9:41	19.8	0.6	0.2	0	4	6.28	
9:42	19.8	0.6	0.2	0	96	6.46	
9:43	19.8	0.6	0.2	0	2	6.27	
9:44	19.8	0.6	0.2	0	111	6.44	
9:45	19.8	0.6	0.2	0	3	6.23	
9:46	19.8	0.6	0.2	0	96	6.53	
9:47	19.8	0.6	0.2	0	2	6.25	
9:48	19.8	0.6	0.2	0	113	6.56	
9:49	19.8	0.6	0.2	0	4	6.36	
9:50	19.8	0.6	0.2	0	101	6.54	
9:51	19.8	0.6	0.2	0	4	6.42	
9:52	19.8	0.6	0.2	0	116	6.52	
9:53	19.8	0.6	0.2	0	6	6.48	
9:54	19.8	0.6	0.2	0	103	6.57	
9:55	19.8	0.6	0.2	0	7	6.45	
9:56	19.8	0.6	0.2	0	118	6.49	
9:57	19.8	0.6	0.2	0	8	6.50	
9:58	19.8	0.6	0.2	0	105	6.54	
9:59	19.8	0.6	0.2	0	9	6.49	
10:00	19.8	0.6	0.2	0	119	6.49	
10:01	19.8	0.6	0.2	0	100	6.53	
10:02	19.8	0.6	0.2	0	15	6.59	
10:03	19.8	0.6	0.2	0	118	6.52	
10:04	19.8	0.6	0.2	0	13	6.55	
10:05	19.8	0.6	0.2	0	105	6.73	
10:06	19.8	0.6	0.2	0	11	6.59	
10:07	19.8	0.6	0.2	0	120	6.67	
10:08	19.8	0.6	0.2	0	12	6.47	
10:09	19.8	0.6	0.2	0	104	6.46	
10:10	20	0.4	0.2	0	11	6.45	Port Change
10:11	19.9	0.6	0.2	0	121	6.62	Data Excluded
10:12	19.8	0.6	0.2	0	11	6.55	
10:13	19.8	0.6	0.2	0	105	6.71	
10:14	19.8	0.6	0.2	0	11	6.58	
10:15	19.8	0.6	0.2	0	122	6.67	
10:16	19.8	0.6	0.2	0	11	6.66	
10:17	19.8	0.6	0.2	0	105	6.71	
10:18	19.8	0.6	0.2	0	11	6.55	
10:19	19.8	0.6	0.2	0	121	6.60	
10:20	19.8	0.6	0.2	0	11	6.74	
10:21	19.8	0.6	0.2	0	105	6.68	
10:22	19.8	0.6	0.2	0	11	6.66	
10:23	19.8	0.6	0.2	0	121	6.75	
10:24	19.8	0.6	0.2	0	101	6.79	
10:25	19.8	0.6	0.2	0	16	6.72	
10:26	19.8	0.6	0.2	0	119	6.69	
10:27	19.8	0.6	0.2	0	13	6.73	
10:28	19.8	0.6	0.2	0	105	6.90	
10:29	19.8	0.6	0.2	0	11	6.61	
10:30	19.8	0.6	0.2	0	121	6.69	
10:31	19.8	0.6	0.2	0	12	6.59	
10:32	19.8	0.6	0.2	0	106	7.14	
10:33	19.8	0.6	0.2	0	11	6.55	
10:34	19.8	0.6	0.2	0	119	6.73	
10:35	19.8	0.6	0.2	0	11	6.67	
10:36	19.8	0.6	0.2	0	104	6.80	
10:37	19.8	0.6	0.2	0	10	6.61	
10:38	19.8	0.6	0.2	0	120	6.71	
10:39	19.8	0.6	0.2	0			
Raw Average	**19.80**	**0.60**	**0.20**	**0.00**	**62.85**	**6.57**	
Corrected Average	**19.85**	**0.58**	**-0.64**	**-0.91**	**61.25**	**1.65**	
Corrected lb/hr	**34500.62**	**1380.38**	**-0.16**	**-0.32**	**14.62**	**0.25**	

Company Name: CONSOL R&D
Location: VOCSIDIZER, Windsor
Date: 9/10/2008
Run No. Three

Gas Flow (dscfm) 36080

Time	% O_2	% CO_2	ppm NOx	ppm SO_2	ppm THC	ppm CO	
11:41	19.8	0.6	0.2	0	3	5.99	
11:42	19.8	0.6	0.2	0	115	6.19	
11:43	19.8	0.6	0.2	0	5	5.99	
11:44	19.8	0.6	0.2	0	103	6.30	
11:45	19.8	0.6	0.2	0	5	6.00	
11:46	19.8	0.6	0.2	0	120	6.06	
11:47	19.8	0.6	0.2	0	7	6.01	
11:48	19.8	0.6	0.2	0	106	6.14	
11:49	19.8	0.6	0.2	0	8	5.90	
11:50	19.8	0.6	0.2	0	121	5.95	
11:51	19.8	0.6	0.2	0	9	5.97	
11:52	19.8	0.6	0.2	0	106	5.95	
11:53	19.8	0.6	0.2	0	9	5.73	
11:54	19.8	0.6	0.2	0	124	5.80	
11:55	19.7	0.6	0.2	0	10	5.94	
11:56	19.8	0.6	0.2	0	107	5.91	
11:57	19.8	0.6	0.2	0	11	5.70	
11:58	19.8	0.6	0.2	0	125	5.72	
11:59	19.8	0.6	0.2	0	103	5.66	
12:00	19.8	0.6	0.2	0	17	5.54	
12:01	19.8	0.6	0.2	0	122	5.44	
12:02	19.8	0.6	0.2	0	14	5.41	
12:03	19.8	0.6	0.2	0	108	5.56	
12:04	19.8	0.6	0.2	0	12	5.21	
12:05	19.8	0.6	0.2	0	124	5.35	
12:06	19.8	0.6	0.2	0	12	5.08	
12:07	19.8	0.6	0.2	0	108	5.28	
12:08	19.8	0.6	0.3	0	12	4.99	
12:09	19.8	0.6	0.3	0	124	5.14	
12:10	20.1	0.4	0.3	0	12	4.96	Port Change
12:11	19.8	0.6	0.2	0	107	5.21	Data Excluded
12:12	19.8	0.6	0.2	0	11	4.56	
12:13	19.8	0.6	0.2	0	123	5.00	
12:14	19.8	0.6	0.2	0	12	5.00	
12:15	19.8	0.6	0.2	0	108	4.98	
12:16	19.8	0.6	0.2	0	11	4.79	
12:17	19.8	0.6	0.3	0	123	4.88	
12:18	19.8	0.6	0.3	0	11	4.87	
12:19	19.8	0.6	0.3	0	109	4.88	
12:20	19.8	0.6	0.3	0	11	4.79	
12:21	19.8	0.6	0.3	0	125	4.86	
12:22	19.8	0.6	0.2	0	103	4.90	
12:23	19.8	0.6	0.3	0	17	4.91	
12:24	19.8	0.6	0.3	0	121	4.72	
12:25	19.8	0.6	0.3	0	14	4.85	
12:26	19.7	0.6	0.2	0	107	4.97	
12:27	19.8	0.6	0.3	0	12	4.62	
12:28	19.8	0.6	0.3	0	123	4.81	
12:29	19.8	0.6	0.2	0	12	4.65	
12:30	19.8	0.6	0.2	0	108	4.83	
12:31	19.8	0.6	0.2	0	12	4.52	
12:32	19.8	0.6	0.3	0	122	4.64	
12:33	19.8	0.6	0.3	0	12	4.54	
12:34	19.8	0.6	0.3	0	108	4.72	
12:35	19.8	0.6	0.3	0	11	4.39	
12:36	19.8	0.6	0.3	0	124	4.56	
12:37	19.8	0.6	0.3	0	12	4.45	
12:38	19.8	0.6	0.3	0	109	4.56	
12:39	19.8	0.6	0.3	0	11	4.39	
12:40	19.8	0.6	0.3	0	125	4.50	
12:41	19.8	0.6	0.3	0	12	4.55	
12:42	19.8	0.6	0.3	0	110	4.51	
Raw Average	**19.80**	**0.60**	**0.24**	**0.00**	**65.33**	**5.20**	
Corrected Average	**19.89**	**0.58**	**-0.06**	**-0.98**	**63.73**	**1.28**	
Corrected lb/hr	**35739.82**	**1427.13**	**-0.02**	**-0.35**	**15.73**	**0.20**	

APPENDIX B

Laboratory Reports

- PM Analyses

EPA Method 5 Sample Train Analyses

Plant: Vocsidizer
Test Location: Windsor
Test Date: 8/6/2008
Test No.: 1
Time: 1105-1225

Impinger Volumes

	Impinger				Totals
	1	2	3	Sil Gel	
Final, ml or g	108	110	0	848.8	
Initial, ml or g	100	100	0	833.2	
Gain, ml or g	8	10	0	15.6	33.6

Probe Rinse

Final Wt., mg: 3720
Tare Wt., mg: 3700
Gain, mg: 20

Filter No.: 000053

Final Wt., mg: 0.3283
Tare Wt., mg: 0.329
Gain, mg: -0.0007

Total Particulate Wt., mg: 20

Analyst: A.R. Goodell

EPA Method 5 Sample Train Analyses

Plant: Vocsidizer
Test Location: Windsor
Test Date: 8/6/2008
Test No.: 2
Time: 1350-1457

Impinger Volumes

	Impinger				Totals
	1	2	3	Sil Gel	
Final, ml or g	110	108	0	860.8	
Initial, ml or g	100	100	0	848.8	
Gain, ml or g	10	8	0	12	30

Probe Rinse

Final Wt., mg: 3790
Tare Wt., mg: 3770
Gain, mg: 20

Filter No.: 000054

Final Wt., mg: 0.3267
Tare Wt., mg: 0.3257
Gain, mg: 0.001

Total Particulate Wt., mg: 20.001

Analyst: A.R. Goodell

EPA Method 5 Sample Train Analyses

Plant: Vocsidizer
Test Location: Windsor
Test Date: 8/7/2008
Test No.: 3
Time: 0930-1038

Impinger Volumes

	Impinger				Totals
	1	2	3	Sil Gel	
Final, ml or g	108	107	0	767.5	
Initial, ml or g	100	100	0	755.6	
Gain, ml or g	8	7	0	11.9	26.9

Probe Rinse

Final Wt., mg: 3850
Tare Wt., mg: 3830
Gain, mg: 20

Filter No.: 000055

Final Wt., mg: 0.3271
Tare Wt., mg: 0.3279
Gain, mg: -0.0008

Total Particulate Wt., mg: 20

Analyst: A.R. Goodell

EPA Method 5 Sample Train Analyses

Plant: Vocsidizer
Test Location: Windsor
Test Date: 9/9/2008
Test No.: 1
Time: 1620-1727

Impinger Volumes

	Impinger				Totals
	1	2	3	Sil Gel	
Final, ml or g	105	107	0	811.4	
Initial, ml or g	100	100	0	800.6	
Gain, ml or g	5	7	0	10.8	22.8

Probe Rinse

Final Wt., mg: 3726.2
Tare Wt., mg: 3697.7
Gain, mg: 28.5

Filter No.: 000056

Final Wt., mg: 326.9
Tare Wt., mg: 326.9
Gain, mg: 0

Total Particulate Wt., mg: 28.5

Analyst: ARG

EPA Method 5 Sample Train Analyses

Plant: Vocsidizer
Test Location: Windsor
Test Date: 9/10/2008
Test No.: 2
Time: 0937-1042

Impinger Volumes

	Impinger				Totals
	1	2	3	Sil Gel	
Final, ml or g	96	110	0	814.1	
Initial, ml or g	100	100	0	802.3	
Gain, ml or g	-4	10	0	11.8	17.8

Probe Rinse

Final Wt., mg: 3794
Tare Wt., mg: 3764.3
Gain, mg: 29.7

Filter No.: 000057

Final Wt., mg: 321
Tare Wt., mg: 321
Gain, mg: 0

Total Particulate Wt., mg: 29.7

Analyst: ARG

EPA Method 5 Sample Train Analyses

Plant: Vocsidizer
Test Location: Windsor
Test Date: 9/10/2008
Test No.: 3
Time: 1137-1242

Impinger Volumes

	Impinger				Totals
	1	2	3	Sil Gel	
Final, ml or g	98	108	0	826.1	
Initial, ml or g	100	100	0	815.4	
Gain, ml or g	-2	8	0	10.7	16.7

Probe Rinse

Final Wt., mg: 3835.8
Tare Wt., mg: 3697.7
Gain, mg: 138.1

Filter No.: 000058

Final Wt., mg: 326.1
Tare Wt., mg: 324.2
Gain, mg: 1.9

Total Particulate Wt., mg: 140

Analyst: ARG

APPENDIX C

QA/QC

- Pitot Tube Calibration
- Sampling Nozzle Calibration
- Dry Gas Meter Calibration
- CEM Sample System Bias Test Data
- CEM Calibration Error Test Data
- CEM System Calibration and Drift Test Data for Each Run
- CEM Response Time Checks

Test Data/Calibration Drift

Test Location: Windsor Vocsidner

Personnel: JL AG BS

Test Date: 8-6-08

Sample Run No.: 1

Pretest Zero/Span Drift Test

File Name: X1080801

Time*	Calibration Gas	Actual Concentration	Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Upscale	-0.2	0.1	1.2	3%	
	O_2 Zero	21.0	21.1	0.4	3%	
	CO_2 Upscale	0.0	0.0	0.0	3%	
	CO_2 Zero	2.7	2.7	0.0	3%	
	NOx Zero	0.2	0.4	0.2	3%	
	NOx Upscale	50.9	49.2	1.7	3%	
	SO_2 Upscale	50.1	49.2	0.9	3%	
	SO_2 Zero	0.9	0.4	0.5	3%	
	CO Upscale	30.2	29.4	0.4	3%	
	CO Zero	0.3	0.3	0.0	3%	
	VOC Upscale	464	464	0	3%	
	VOC Zero	0	0	0	3%	

Notes:

RUN EVENT LOG

Time*	Event
1104	Start Run 1
1211	End Run 1

$$(C_{mag} - C_o)\frac{C_{nm}}{C_m - C_o}$$

$$(67.7 - 5)\left(\frac{464}{472 - 5}\right) = 62.3$$

Test Data/Calibration Drift

Test Location: Voxidizer outlet

Personnel: JL, BS, AG

Test Date: 8-6-08

Sample Run No.: 1

File Name:

Start @ 1212

Posttest Zero/Span Drift Test

Time*	Calibration Gas	Actual Concentration	Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Upscale	21.0	21.1	0.0	3%	
	O_2 Zero	-0.1	0.1	0.4	3%	
	CO_2 Upscale	2.7	2.7	0.0	3%	
	CO_2 Zero	0.0	0.0	0.0	3%	
	NOx Zero	49.6	49.2	0.4	3%	
	NOx Upscale	0.2	0.4	0.0	3%	
	SO_2 Upscale	50.0	49.2	0.8	3%	
	SO_2 Zero	1.3	0.4	0.4	3%	
	CO Upscale	30.1	29.4	0.4	3%	
	CO Zero	0.3	0.3	0.0	3%	
1212	VOC Upscale	480	463	0.2	3%	
	VOC Zero	10	0	0.1	3%	

Notes:

*- If possible, initiate timed event on even minutes, with no seconds.

11:06 - 12:07 (11:41-11:42 port change)

Test Avgs. (corr.)

O_2 - 19.8

CO_2 - 0.7

NOx - 0.0

SO_2 - -1.1

CO - 2.7

THC - 67.9 ppm (corr)

Data Logger Test 1 Avg

O_2 - 19.67 %

CO_2 - 0.65 %

NOx - 0.19 ppm

SO_2 - 0.06 ppm

CO - 3.04 ppm

VOC 71 ppm

Test Data/Calibration Drift

Test Location: Uoxidizer Outlet

Personnel: JL, BS, AG

Test Date: 8-6-08

Sample Run No.: 2

Pretest Zero/Span Drift Test

File Name:

Time*	Calibration Gas	Actual Concentration	Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Upscale	21.0	21.1	0.4	3%	
	O_2 Zero	-0.1	0.1	0.8	3%	
	CO_2 Upscale	2.7	2.7	0.0	3%	
	CO_2 Zero	0.0	0.0	0.0	3%	
	NOx Zero	0.2	0.4	0.2	3%	
	NOx Upscale	50.4	48.2	1.2	3%	
	SO_2 Upscale	50.0	0.4	0.8	3%	
	SO_2 Zero	1.1	48.2	0.7	3%	
	CO Upscale	29.7	29.4	0.2	3%	
	CO Zero	0.3	0.3	0.0	3%	
	VOC Upscale	463	463	0.0	3%	
	VOC Zero	0.0	0	0.0	3%	

Notes:

RUN EVENT LOG

Time*	Event
1348	Start Run 2
1456	End Run 2
	Run Time 1350-1450 (port change @ 1422)

O_2 - 19.8
CO_2 - 0.7
SO_2 - -1.3
NOx - 0.0
CO - 2.0
THC -

Data logger avgs
O_2 - 19.65%
CO_2 - 0.67%
SO_2 - 0.03 ppm
NOx - 0.18 ppm
CO - 2.24 ppm
VOC - 67 ppm

1522 ice stop

Test Data/Calibration Drift

Test Location: Voc oxidizer outlet

Test Date: 8-6-08

Personnel: JL. AG. BS

Sample Run No.: 2

File Name:

Posttest Zero/Span Drift Test

Time*	Calibration Gas	Actual Concentration	Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Upscale	21.0	21.1	0.4	3%	
	O_2 Zero	-0.1	0.1	0.0	3%	
	CO_2 Upscale	2.7	2.7	0.0	3%	
	CO_2 Zero	0.0	0.0	0.0	3%	
	NOx Zero	0.2	0.4	0.0	3%	
	NOx Upscale	49.3	49.2	0.1	3%	
	SO_2 Upscale	49.3	49.2	0.1	3%	
	SO_2 Zero	1.5	0.4	0.6	3%	
	CO Upscale	28.7	29.4	0.4	3%	
	CO Zero	0.3	0.3	0.0	3%	
	VOC Upscale	448	463		3%	
	VOC Zero	5	0.0		3%	

Notes:

*- If possible, initiate timed event on even minutes, with no seconds.

$$(67.4 - 2.5)\left(\frac{464}{455.5 - 2.5}\right) = 66.5$$

Calibration Error/System Bias Data (EPA Daily)

Test Location: Windsor Woodstover

Personnel: JL, AG, BS

Test Date: 8-7-19

Sample Run No.: 3

File Name:

Calibration Error Test

Time*	Calibration Gas	Actual Concentration	Instrument Reading	% Error	Allowable	Pass/Fail?
	O_2 Zero	-0.1	0.0	0.4	2%	
	O_2 Mid	12.6	12.7	0.4	2%	
	O_2 High	21.0	21.1	0.4	2%	
	CO_2 Zero	0.0	0.0	0.0	2%	
	CO_2 Mid	2.7	2.6	2.0	2%	
	CO_2 High	4.6	4.7	2.0	2%	
	CO Zero		0.0			
	CO High		30.7			
	CO Zero		0.0			
	CO Mid	28.6	30.0	0.7	2%	
	NO_x Zero	0.5	0.0	0.5		
	NO_x Mid	51.0	50.7	0.3		
	NO_x High	92.9	91.3	1.1		
	SO_2 Zero	0.1	0.0	0.1		
	SO_2 Mid	49.6	50.7	1.1		
	SO_2 High	92.5	90.8	0.7		
	VOC Zero	1	0.0			
	VOC High	472	463.9			
	VOC Low	155	151		5%	
	VOC Mid	257	254		5%	

Notes:

System Bias/Response Time Test

Time*	Calibration Gas	Actual Concentration	Instrument Reading	% Error	Allowable	Pass/Fail?
	Upscale	20.9	~~20~~ 21.0	0.4		
	O_2 Zero	0.1	-0.1	0.8	5%	
	O_2 Upscale	✓	✓	✓	5%	
	Upscale					
	CO_2 Zero	0.0	0.0	0.0	5%	
	CO_2 Upscale	2.6	2.7	2.0	5%	

Notes: SO_2 Act/Exp/Err 0.7/0.1/0.6 - 48.6/49.6/1.0

NO_x Act/Exp/Err 0.3/0.5/0.2 - 49.4/51.0/1.6

Test Data/Calibration Drift

Test Location: Vocsidizer

Personnel: JL, AL, BS

Test Date: 8-7-08

Sample Run No.: 3

Pretest Zero/Span Drift Test

File Name:

Time*	Calibration Gas	Actual Concentration	Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Upscale	21.1	21.0	0.4	3%	
	O_2 Zero	0.0	-0.1	0.4	3%	
	CO_2 Upscale	2.6	2.7	2.0	3%	
	CO_2 Zero	0.0	0.0	0.0	3%	
	NOx Zero	0.3	0.5	0.2	3%	
	NOx Upscale	50.4	51.0	0.6	3%	
	SO_2 Upscale	48.4	49.6	1.2	3%	
	SO_2 Zero	0.5	0.1	0.4	3%	
	CO Upscale	29.3	28.6	0.4	3%	
	CO Zero	0.3	0.3	0.0	3%	
	VOC Upscale	472	464		3%	
	VOC Zero	1.0	0		3%	

Notes:

RUN EVENT LOG

Time*	Event
0920	Start Run 3
0931	Added 10 minutes (PM test delayed start)
1037	End Run 3
1003	Port change delete 1003 minute Reading
	931-1031

O_2 19.7%
CO_2 0.6%
SO_2 -0.6 ppm
NOx -0.1 ppm
CO 1.1 ppm
THC 60.6 ppm (corr)

Data Logger Avg

O_2 - 19.67%
CO_2 - 0.62%
SO_2 - -0.4 ppm
NOx - 0.23 ppm
CO - 1.51 ppm
VOC - 67 ppm

Test Data/Calibration Drift

Test Location: Voc oxidizer

Test Date: 8-7-08

Personnel: JL, AG, BS

Sample Run No.: 3

File Name:

Posttest Zero/Span Drift Test

Time*	Calibration Gas	Actual Concentration	Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Upscale	21.0	21.0	0.0	3%	
	O_2 Zero	0.1	-0.1	0.0	3%	
	CO_2 Upscale	2.6	2.7	2.0	3%	
	CO_2 Zero	0.0	0.0	0.0	3%	
	NOx Zero	0.3	0.5	0.0	3%	
	NOx Upscale	50.1	51.0	0.9	3%	
	SO_2 Upscale	48.5	49.6	1.1	3%	
	SO_2 Zero	0.7	0.1	0.0	3%	
	CO Upscale	31.0	28.6	1.2	3%	
	CO Zero	0.3	0.3	0.0	3%	
	VOC Upscale	470	472		3%	
	VOC Zero	11	1.0		3%	

Notes:

*- If possible, initiate timed event on even minutes, with no seconds.

$$(66.7-6)\left(\frac{464}{470-6}\right)=60.6$$

Calibration Error/System Bias Data (EPA Daily)

Test Location: Winder Incinerator Personnel: JL, BS, AG

Test Date: 8-6-08 Sample Run No.: 1

Calibration Error Test File Name:

Time*	Calibration Gas	Actual Concentration	~~Instrument~~ Expected Reading	% Error	Allowable	Pass/Fail?
~0914	O_2 Zero	0.1	0.0	0.4	2%	P
	O_2 Mid	12.7	12.7	0.0	2%	P
	O_2 High	21.1	21.1	0.0	2%	P
	CO_2 Zero	0.0	0.0	0.0	2%	P
	CO_2 Mid	2.7	2.6	2.0	2%	P
	CO_2 High	4.6	4.7	2.0	2%	P
	CO Zero	0.4	0.0			
	CO High	59.7	60.0			
	CO Zero	0.3	0.0			
	CO Mid	29.4	30.7	0.7	2%	
	NO_x Zero	0.4	0.0	0.4		P
	NO_x Mid	49.2	50.7	1.5		P
	NO_x High	93.6	91.8	1.8		P
	SO_2 Zero	0.4	0.0	0.4		P
	SO_2 Mid	49.2	50.7	1.5		P
	SO_2 High	91.8	91.8	0.0		P
	VOC Zero	0	0			
	VOC High	464	463.9			
	VOC Low	153	151.0		5%	
	VOC Mid	254	254	0	5%	

Notes:

System Bias/Response Time Test

Time*	Calibration Gas	Actual Concentration	Instrument Reading	% Error	Allowable	Pass/Fail?
	Upscale					
	O_2 Zero				5%	
	O_2 Upscale				5%	
	Upscale					
	CO_2 Zero				5%	
	CO_2 Upscale				5%	

Notes:

Calibration Error/System Bias Data (EPA Daily)

Test Location: Vocsidizer Stack

Personnel: JL, AG, BS, RS, DK

Test Date: 9-9-08

Sample Run No.: 1

Calibration Error Test

File Name:

Time*	Calibration Gas	Actual Concentration	~~Instrument~~ Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Zero	-0.1	0	0.4	2%	
	O_2 Mid	12.6	12.7	0.4	2%	
	O_2 High	21.1	21.1	0.0	2%	
	CO_2 Zero	0.0	0.0	0.0	2%	
	CO_2 Mid	2.6	2.6	0.0	2%	
	CO_2 High	4.6	4.7	2.0	2%	
	CO Zero	0.8	0.0			
	CO High	60.5	60.0			
	CO Zero		0.0			
1541	CO Mid	30.6	30.7		2%	
	NOx Zero	0.5	0.0	0.5		
	NOx Mid	50.7	50.7	0.0		
	NOx High	91.9	91.8	0.1		
	SO2 Zero	1.0	0.0	1.0		
	SO2 Mid	49.0	50.7	1.7		
	SO2 High	91.5	91.8	0.3		
	VOC Zero		0.0			
	VOC High		463.9			
	VOC Low	253.4	254	0.1	5%	
	VOC Mid	151.5	151	0.1	5%	

Notes:

System Bias/Response Time Test

Time*	Calibration Gas	Actual Concentration	Instrument Reading	% Error	Allowable	Pass/Fail?
	Upscale					
	O_2 Zero	0.1	-0.1	0.8	5%	
	O_2 Upscale	21.0	21.1	0.4	5%	
	Upscale					
	CO_2 Zero				5%	
	CO_2 Upscale				5%	

Notes: SO_2 Mid Bias Value = 48.2 PPM

Test Data/Calibration Drift

Test Location: Residual

Test Date: 9-9-09

Personnel: JL, RS, BS, DK, AG

Sample Run No.: 1

File Name:

Pretest Zero/Span Drift Test

Time*	Calibration Gas	Actual Concentration	Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Zero	0.1	-0.1	17.8	3%	
	O_2 Upscale	20.9	21.1	0.8	3%	
	CO_2 Zero	0.0	0.0	0.0	3%	
	CO_2 Upscale	2.7	2.6	2.0	3%	
	NOx Zero		0.5		3%	
	NOx Upscale		50.7		3%	
	SO_2 Zero		~~21.0~~			
	SO_2 Upscale		49.0			
	CO Upscale	32.3	30.6	0.9	3%	
	CO Zero	3.1	0.8	2.3	3%	
	VOC Upscale	464.9	463.2	0.3	3%	
	VOC Zero	-0.9	0.2	0.2	3%	

Notes:

RUN EVENT LOG

Time*	Event
1619	Start Run #1 - 1625-1726
1654-1658	Transfer port time. O_2 - 19.9% NOx - -0.1
1727	End Test CO_2 - 0.6%
	SO_2 -

Posttest Zero/Span Drift Test

Time*	Calibration Gas	Actual Concentration	Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Zero	0.1	-0.1	0.0	3%	
	O_2 Upscale	20.9	21.1	0.8	3%	
	CO_2 Zero	0.0	0.0	0.0	3%	
	CO_2 Upscale	2.7	2.6	2.0	3%	
	NOx Zero	0.3	0.5	0.0	3%	
	NOx Upscale	50.6	50.7	0.1	3%	
	SO_2 Zero	1.6	1.0	0.2	3%	
	SO_2 Upscale	47.9	49.0	1.1	3%	
	CO Upscale	33.5	30.6	1.5	3%	
	CO Zero	4.2	0.8	1.7	3%	
	VOC Upscale	452.5	463.7	2.3	3%	
	VOC Zero	6.0	0.2	1.7	3%	

Notes:

Calibration Error/System Bias Data (EPA Daily)

Test Location: Incs [illegible]

Test Date: 9.10.08

Personnel: JL, BS, [illegible], DK, RS

Sample Run No.:

File Name:

Calibration Error Test

Time*	Calibration Gas	Actual Concentration	~~Instrument~~ Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Zero	0.0	0	0.0	2%	
	O_2 Mid	12.6	12.7	0.4	2%	
	O_2 High	21.1	21.1	0.0	2%	
	CO_2 Zero	0.0	0.0	0.0	2%	
	CO_2 Mid	2.7	2.6	2.0	2%	
	CO_2 High	4.7	4.7	0.0	2%	
	CO Zero					
	CO High	60	60			
	CO Zero	1	0			
	CO Mid	31	30.7		2%	
	NOx Zero	0.5	0.0	0.5		
	NOx Mid	50.8	50.7	0.1		
	NOx High	92.7	91.8	0.9		
	SO2 Zero	0.4	0.0	0.4		
	SO2 Mid	49.4	50.7	1.3		
	SO2 High	91.8	92.8	0.4		
	VOC Zero					
	VOC High					
	VOC Low	150.7	151.0	0.0	5%	
	VOC Mid	253.0	254.0	0.2	5%	

Notes:

System Bias/Response Time Test

Time*	Calibration Gas	Actual Concentration	Instrument Reading	% Error	Allowable	Pass/Fail?
	Upscale					
	O_2 Zero	-0.1	0.0	0.4	5%	
	O_2 Upscale	21.2	21.1	0.4	5%	
	Upscale					
	CO_2 Zero	0.0	0.0	0.0	5%	
	CO_2 Upscale	2.7	2.7	0.0	5%	

Notes: Co2 zero failed first try - Manual Analyzer Cal Gas Valve open

SO2: 0.9/0.4/0.5 ~~[illegible]~~/49.4/1.3 NOx: 0.3/0.5/0.7 49.5/50.8/1.3

CO: 3/1/1.0 30/31/0.5

Test Data/Calibration Drift

Test Location: Voc oxidizer - Windsor

Personnel: JL, BS, AG, DK, RS

Test Date: 9-10-08

Sample Run No.: 2

File Name:

Pretest Zero/Span Drift Test

Time*	Calibration Gas	Actual Concentration	Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Zero	-0.1	0.0	0.4	3%	
	O_2 Upscale	21.1	21.0	0.0	3%	
	CO_2 Zero	0.0	0.0	0.0	3%	
	CO_2 Upscale	2.7	2.7	0.0	3%	
	NOx Zero	0.8	0.5	0.4	3%	
	NOx Upscale	48.4	50.8	1.0	3%	
	SO_2 Zero	0.8	0.0	0.4		
	SO_2 Upscale	48.4	49.4	1.0		
	CO Upscale	34.0	32	1.0	3%	
	CO Zero	4.8	3	0.9	3%	
	VOC Upscale	459.1	464.9	1.2	3%	
	VOC Zero	-1.1	-0.9	0.0	3%	

Notes:

RUN EVENT LOG

Time*	Event		
9:34	Start Run 2	O_2 - 19.9%	VOC - 6.6
1010-1012	- Port transfer	CO_2 - 0.6%	
1043	End Run 2	SO_2 - -0.9	
	Run Time 9:38-10:39	NOx - -0.1	

Posttest Zero/Span Drift Test

Time*	Calibration Gas	Actual Concentration	Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Zero	0.0	0.0	0.4	3%	
	O_2 Upscale	21.0	21.1	0.4	3%	
	CO_2 Zero	0.0	0.0	0.0	3%	
	CO_2 Upscale	2.7	2.7	0.0	3%	
	NOx Zero		0.5		3%	
	NOx Upscale		50.8		3%	
	SO_2 Zero	0.9	0.4	0.0		
	SO_2 Upscale	48.1	49.4	1.3		
	CO Upscale	34.6	32	1.1	3%	
	CO Zero	5.2	3	1.1	3%	
	VOC Upscale	461.9	464.9	0.6	3%	
	VOC Zero	5.8	-0.9	1.3	3%	

Notes:

Test Data/Calibration Drift

Test Location: Wastewater Windsor

Test Date: 2-10-08

Personnel: JL, BS, AK, DK, RS

Sample Run No.: 3

File Name:

Pretest Zero/Span Drift Test

Time*	Calibration Gas	Actual Concentration	Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Zero	0.0	0.0	0.0	3%	
	O_2 Upscale	21.0	21.1	0.4	3%	
	CO_2 Zero	0.0	0.0	0.0	3%	
	CO_2 Upscale	2.7	2.7	0.0	3%	
	NOx Zero	0.3	0.5	0.2	3%	
	NOx Upscale	50.3	50.8	0.5	3%	
	SO_2 Zero	0.7	0.4	0.3		
	SO_2 Upscale	47.6	49.4	1.8		
	CO Upscale	34.6	32	1.1	3%	
	CO Zero	5.2	3	1.1	3%	
	VOC Upscale	460.3	464.9	0.9	3%	
	VOC Zero	-0.2	-0.9	0.1	3%	

Notes:

RUN EVENT LOG

Time*	Event		
1137	Start Run 3	O_2 19.9%	VOC 8.4
1210 - 1211	Port transfer	CO_2 0.6%	
1247	End Run 3	SO_2 -1.0	
	Run Time: 1141-1242	NOx -0.1	

Posttest Zero/Span Drift Test

Time*	Calibration Gas	Actual Concentration	Expected Reading	% Error	Allowable	Pass/Fail?
	O_2 Zero	0.2	0.0	0.4	3%	
	O_2 Upscale	21.0	21.1	0.4	3%	
	CO_2 Zero	0.0	0.0	0.0	3%	
	CO_2 Upscale	2.7	2.7	0.0	3%	
	NOx Zero	0.3	0.5	0.0	3%	
	NOx Upscale	49.5	50.8	1.3	3%	
	SO_2 Zero	1.1	0.4	0.2		
	SO_2 Upscale	47.6	49.4	1.8		
	CO Upscale	30.9	32	0.5	3%	
	CO Zero	2.8	3	0	3%	
	VOC Upscale	454.4	464.9	2.1	3%	
	VOC Zero	6.0	-0.9	1.4	3%	

Notes:

PITOT TUBE CALIBRATIONS

PITOT TUBE ID NUMBER- E-1
PITOT TUBE DESCRIPTION- 7-1/2" Probe tip
DATE CALIBRATED- 04/21/08
CALIBRATED BY- BPS

VELOCITY RANGE	SAMPLE NUMBER	SIDE	STANDARD READINGS [" of H20]	S-TUBE READINGS [" of H20]	INDIVIDUAL C FACTOR	AVG OF INDIVIDUAL C FACTOR	DEVIATION	APPROX VELOCITY [FT/SEC]
LOW	1	A	0.1800	0.2700	0.808	0.808	0.000	28
	2		0.1800	0.2700	0.808			
	3		0.1800	0.2700	0.808			
LOW	1	B	0.1800	0.2700	0.808	0.808	0.000	28
	2		0.1800	0.2700	0.808			
	3		0.1800	0.2700	0.808			
MEDIUM	1	A	0.4600	0.6800	0.814	0.814	0.000	46
	2		0.4600	0.6800	0.814			
	3		0.4600	0.6800	0.814			
MEDIUM	1	B	0.4600	0.6800	0.814	0.814	0.000	46
	2		0.4600	0.6800	0.814			
	3		0.4600	0.6800	0.814			
HIGH	1	A	0.9000	1.2600	0.837	0.837	0.000	64
	2		0.9000	1.2600	0.837			
	3		0.9000	1.2600	0.837			
HIGH	1	B	0.9000	1.2600	0.837	0.838	0.001	64
	2		0.9000	1.2500	0.840			
	3		0.9000	1.2600	0.837			

AVERAGE CALCULATIONS OVER ENTIRE VELOCITY RANGES

SIDE	C-FACTOR	DEVIATION
A	0.820	0.011
B	0.820	0.012

[NOTE: USE DIFFERENT C-FACTORS FOR 10, 20, & 33 FT/SEC VELOCITY RANGES]

[RLO,1/22/93,1000]

Stainless Steel Nozzle Calibrations

Tip Identification			Micrometer Reading (in.)	Micrometer Reading (in.)	Micrometer Reading (in.)	Average Reading (in.)	Date
Tip Size (in.)	Tip Size (in.)	Tip Letter					
0.5000	1/2"	A	0.505	0.504	0.504	0.504	11/20/07
		B	0.506	0.504	0.505	0.505	11/20/07
0.4375	7/16"		0.440	0.440	0.438	0.439	11/20/07
0.3750	3/8"	A	0.375	0.375	0.375	0.375	11/20/07
		B	0.376	0.378	0.378	0.377	11/20/07
		C	0.372	0.372	0.373	0.372	11/20/07
0.3437	11/32"	A	0.330	0.330	0.328	0.329	11/20/07
		B	0.323	0.325	0.323	0.324	11/20/07
0.3125	5/16"	A	0.317	0.316	0.317	0.317	11/20/07
		B	0.310	0.310	0.310	0.310	11/20/07
		D	0.300	0.299	0.299	0.299	11/20/07
0.2812	9/32"	A	0.270	0.271	0.270	0.270	11/20/07
		B	0.271	0.271	0.271	0.271	11/20/07
		C	0.281	0.280	0.282	0.281	11/20/07
0.2500	1/4"	A	0.250	0.251	0.250	0.250	11/20/07
		B	0.255	0.257	0.255	0.256	11/21/07
		C	0.282	0.280	0.282	0.281	11/20/07
		D	0.260	0.260	0.260	0.260	11/20/07
0.2187	7/32"	A	0.220	0.220	0.220	0.220	11/20/07
		B	0.218	0.218	0.218	0.218	11/20/07
		C	0.211	0.211	0.211	0.211	11/20/07
0.1875	3/16"	B	0.192	0.191	0.191	0.191	11/20/07
		C	0.210	0.209	0.210	0.210	11/20/07
		D	0.189	0.189	0.190	0.189	11/20/07
		E	0.189	0.188	0.189	0.189	11/20/07
0.1562	5/32"	A	0.167	0.168	0.167	0.167	11/20/07
		B	0.170	0.170	0.170	0.170	11/20/07
		C	0.158	0.158	0.159	0.158	11/20/07
		D	0.151	0.150	0.150	0.150	11/20/07
0.1250	1/8"	A	0.150	0.150	0.150	0.150	11/20/07
		B	0.141	0.141	0.140	0.141	11/20/07

[G:\R&D\PROJECTS\STACK\calib\Nozzles\11.20.2007.xls]

APEX INSTRUMENTS METHOD 5 PRE-TEST CONSOLE CALIBRATION
USING CALIBRATED CRITICAL ORIFICES
5-POINT ENGLISH UNITS

Meter Console Information	
Console Model Number	N-5
Console Serial Number	
DGM Model Number	
DGM Serial Number	

Calibration Conditions			
Date	Time	21-Jan-08	
Barometric Pressure		30.1	in Hg
Theoretical Critical Vacuum[1]		14.2	in Hg
Calibration Technician		BWG	

Factors/Conversions		
Std Temp	528	°R
Std Press	29.92	in Hg
K_1	17.647	oR/in Hg

[1]For valid test results, the Actual Vacuum should be 1 to 2 in. Hg greater than the Theoretical Critical Vacuum shown above.

[2]The Critical Orifice Coefficient, K', must be entered in English units, $(ft^3 \cdot {}^oR^{1/2})/(in.Hg \cdot min)$.

Calibration Data

Run Time	Metering Console					Critical Orifice				
Elapsed	DGM Orifice ΔH	Volume Initial	Volume Final	Outlet Temp Initial	Outlet Temp Final	Serial Number	Coefficient	Amb Temp Initial	Amb Temp Final	Actual Vacuum
(Θ)	(P_m)	(V_{mi})	(V_{mf})	(t_{mi})	(t_{mf})		K'	(t_{amb})	(t_{amb})	
min	in H_2O	cubic feet	cubic feet	°F	°F		see above2	°F	°F	in Hg
15.0	0.3	171.002	175.652	80	80	UG40	0.2321	68	68	12
15.0	0.6	175.992	182.813	80	81	UG48	0.3421	68	68	12
15.0	1.1	182.911	191.700	81	81	UG55	0.4373	68	68	12
15.0	2.1	191.827	203.865	81	82	UG63	0.5934	68	68	12
15.0	3.6	204.006	219.901	82	81	UG73	0.7823	68	68	12

Results

Standardized Data				Dry Gas Meter				
Dry Gas Meter		Critical Orifice		Calibration Factor		Flowrate	ΔH @	
($V_{m(std)}$)	($Q_{m(std)}$)	($Vcr_{(std)}$)	($Q_{cr(std)}$)	Value (Y)	Variation (ΔY)	Std & Corr ($Q_{m(std)(corr)}$)	0.75 SCFM (ΔH@)	Variation (ΔΔH@)
cubic feet	cfm	cubic feet	cfm			cfm	in H2O	
4.577	0.305	4.561	0.304	0.996	0.006	0.304	1.620	-0.198
6.714	0.448	6.722	0.448	1.001	0.011	0.448	1.741	-0.077
8.653	0.577	8.593	0.573	0.993	0.003	0.573	1.863	0.045
11.869	0.791	11.660	0.777	0.982	-0.008	0.777	1.939	0.121
15.729	1.049	15.371	1.025	0.977	-0.013	1.025	1.926	0.109
				0.990	Y Average		1.818	ΔH@ Average

Note: For Calibration Factor Y, the ratio of the reading of the calibration meter to the dry gas meter, acceptable tolerance of individual values from the average is +-0.02.

I certify that the above Dry Gas Meter was calibrated in accordance with USEPA Methods, CFR Title 40, Part 60, Appendix A-3, Method 5, 16.2.3

Signature _____ Date _____

	Date:	8/6/2008		Run One		
CAL		Cal Gases	actual	initial	final	% error
O2		0.0	-0.1	-0.2	-0.1	0.4
		12.7	12.6			
	25	21.1	21.0	21.0	21	0.0
CO2		0.0	0.0	0.0	0	0.0
		2.6	2.7	2.7	2.7	0.0
	5	4.7	4.6			
NOx		0.0	0.5	0.2	0.2	0.0
		50.7	51.0	50.9	49.6	-1.3
	100	91.8	92.9			
SO2		0.0	0.1	0.9	1.3	0.4
		50.7	49.6	50.1	50	-0.1
	100	90.8	92.5			
Voc		0.0	1.0	0.0	10	2.0
		151.0	155.0			
		254.0	257.0			
	500	463.9	472.0	464.0	480	3.2
CO		0.0	0.0	0.3	0.3	0.0
		30.0	28.6	30.2	30.1	-0.1
	100	60.7	60.7			

	Date:	8/6/2008		Run Two		
CAL		Cal Gases	actual	initial	final	% error
O2		0.0	-0.1	-0.1	-0.1	0.0
		12.7	12.6			
	25	21.1	21.0	21.0	21	0.0
CO2		0.0	0.0	0.0	0	0.0
		2.6	2.7	2.7	2.7	0.0
	5	4.7	4.6			
NOx		0.0	0.5	0.2	0.2	0.0
		50.7	51.0	50.4	49.3	-1.1
	100	91.8	92.9			
SO2		0.0	0.1	1.1	1.5	0.4
		50.7	49.6	50.0	49.3	-0.7
	100	90.8	92.5			
Voc		0.0	1.0	0.0	5	1.0
		151.0	155.0			
		254.0	257.0			
	500	463.9	472.0	463.0	448	-3.0
CO		0.0	0.0	0.3	0.3	0.0
		30.0	28.6	29.7	28.7	-1.0
	100	60.7	60.7			

	Date:	8/7/2007		Run Three		
CAL		Cal Gases	actual	initial	final	% error
O2		0.0	-0.1	0.0	0.1	0.4
		12.7	12.6			
	25	21.1	21.0	21.1	21	-0.4
CO2		0.0	0.0	0.0	0	0.0
		2.6	2.7	2.6	2.6	0.0
	5	4.7	4.6			
NOx		0.0	0.5	0.3	0.3	0.0
		50.7	51.0	50.4	50.1	-0.3
	100	91.8	92.9			
SO2		0.0	0.1	0.5	0.7	0.2
		50.7	49.6	48.4	48.5	0.1
	100	90.8	92.5			
Voc		0.0	1.0	1.0	11	2.0
		151.0	155.0			
		254.0	257.0			
	500	463.9	472.0	472.0	470	-0.4
CO		0.0	0.0	0.3	0.3	0.0
		30.0	28.6	29.3	31	1.7
	100	60.7	60.7			

	Date:	9/9/2008		Run One		
CAL		Cal Gases	actual	initial	final	% error
O2		0.0	-0.1	0.1	0.1	0.0
		12.7	12.6			
	25	21.1	21.1	20.9	20.9	0.0
CO2		0.0	0.0	0.0	0	0.0
		2.6	2.6	2.7	2.7	0.0
	5	4.7	4.6			
NOx		0.0	0.5	0.3	0.3	0.0
		50.7	50.7	50.6	50.6	0.0
	100	91.8	91.9			
SO2		0.0	1.0	1.6	1.6	0.0
		50.7	49.0	47.9	47.9	0.0
	100	91.8	91.5			
Voc		0.0	0.2	-0.9	6	1.4
		151.0	151.5			
		254.0	253.4			
	500	463.9	463.2	464.9	452.5	-2.5
CO		0.0	0.8	3.1	4.2	1.1
		30.7	30.6	32.3	33.5	1.2
	100	60.0	60.5			

	Date:	9/10/2008		Run Two		
CAL		Cal Gases	actual	initial	final	% error
O2		0.0	-0.1	-0.1	0	0.4
		12.7	12.6			
	25	21.1	21.0	21.1	21	-0.4
CO2		0.0	0.0	0.0	0	0.0
		2.6	2.7	2.7	2.7	0.0
	5	4.7	4.7			
NOx		0.0	0.5	0.8	0.8	0.0
		50.7	50.8	48.4	48.4	0.0
	100	91.8	92.7			
SO2		0.0	0.1	0.8	0.9	0.1
		50.7	49.6	48.4	48.1	-0.3
	100	91.8	92.5			
Voc		0.0	1.0	-1.1	5.8	1.4
		151.0	151.0			
		254.0	254.0			
	500	463.9	464.9	459.1	461.9	0.6
CO		0.0	1.0	4.8	5.2	0.4
		30.7	31.0	34.0	34.6	0.6
	100	60.0	60.0			

	Date:	9/10/2008		Run Three		
CAL		Cal Gases	actual	initial	final	% error
O2		0.0	-0.1	0.0	0	0.0
		12.7	12.6			
	25	21.1	21.0	21.0	21	0.0
CO2		0.0	0.0	0.0	0	0.0
		2.6	2.7	2.7	2.7	0.0
	5	4.7	4.7			
NOx		0.0	0.5	0.3	0.3	0.0
		50.7	50.8	50.3	49.5	-0.8
	100	91.8	92.7			
SO2		0.0	0.1	0.7	1.1	0.4
		50.7	49.6	47.6	47.6	0.0
	100	91.8	92.5			
Voc		0.0	1.0	-0.2	6	1.2
		151.0	151.0			
		254.0	254.0			
	500	463.9	464.9	460.3	454.4	-1.2
CO		0.0	1.0	5.2	2.8	-2.4
		30.7	31.0	34.6	30.9	-3.7
	100	60.0	60.0			

APPENDIX D

Process Operating Data

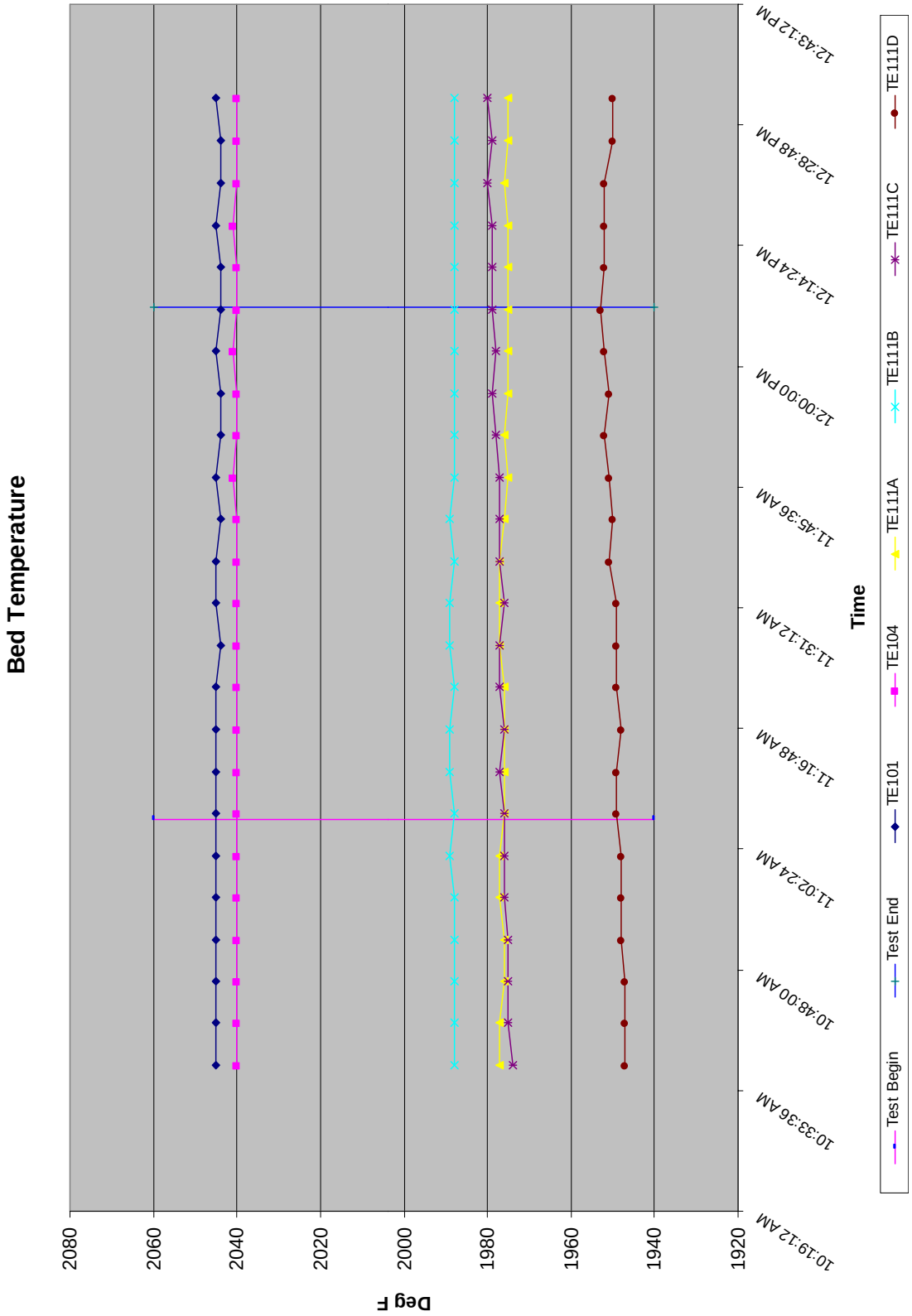
- Graphs – Emission Test Campaign 2 – Runs Aug-1, Aug-2, & Aug-3

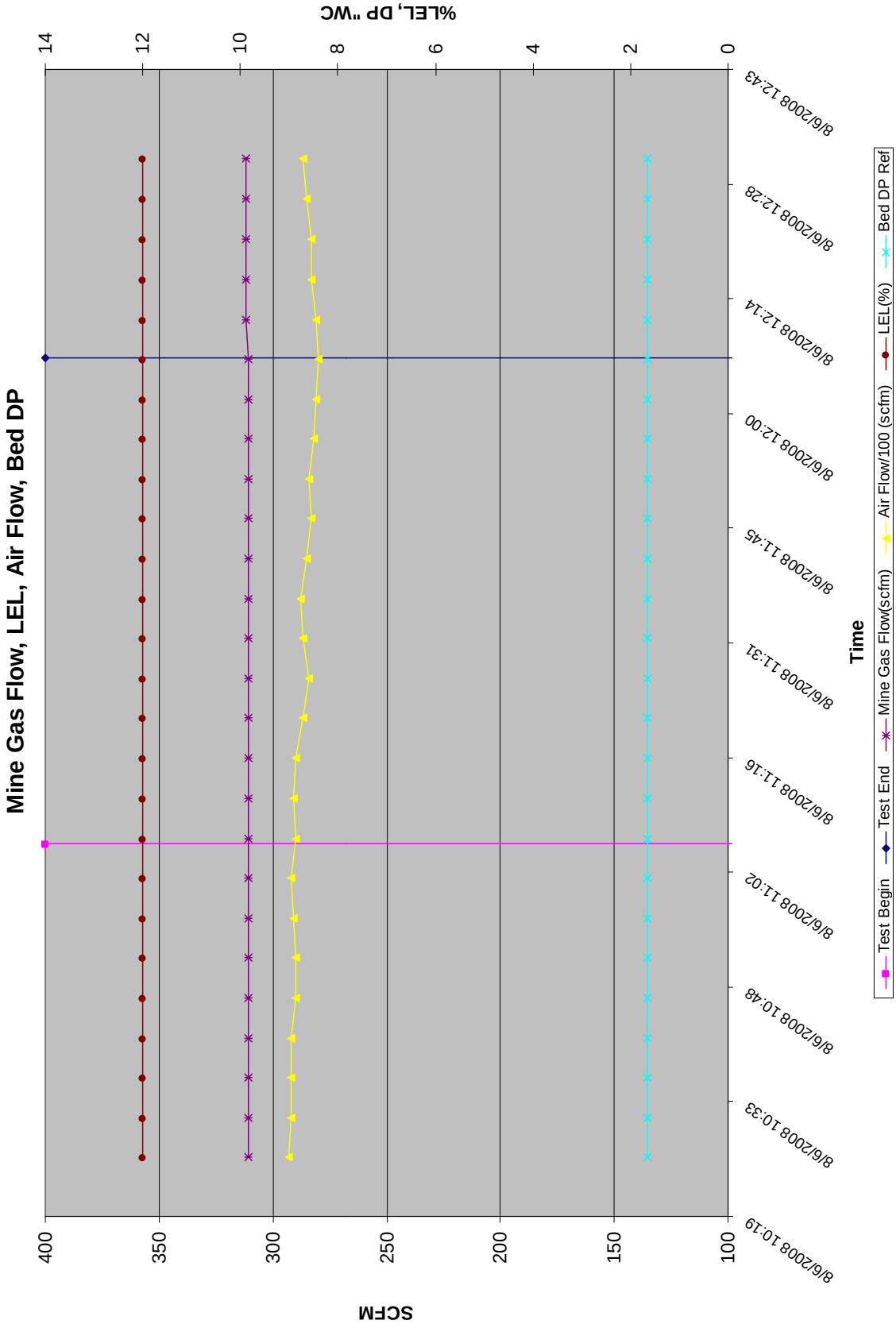
  Bed Temperature Profile
  Mine Gas Flow, LEL, Air Flow, Bed Pressure Drop
  Inlet & Outlet Temperature
  Plenum Temperatures
  Air Flow versus Inlet Temperature
  Inlet Methane Concentration – LEL
  Stack Emissions – VOC & O_2
  Stack Emissions – SO_x, NO_x, CO, & CO_2

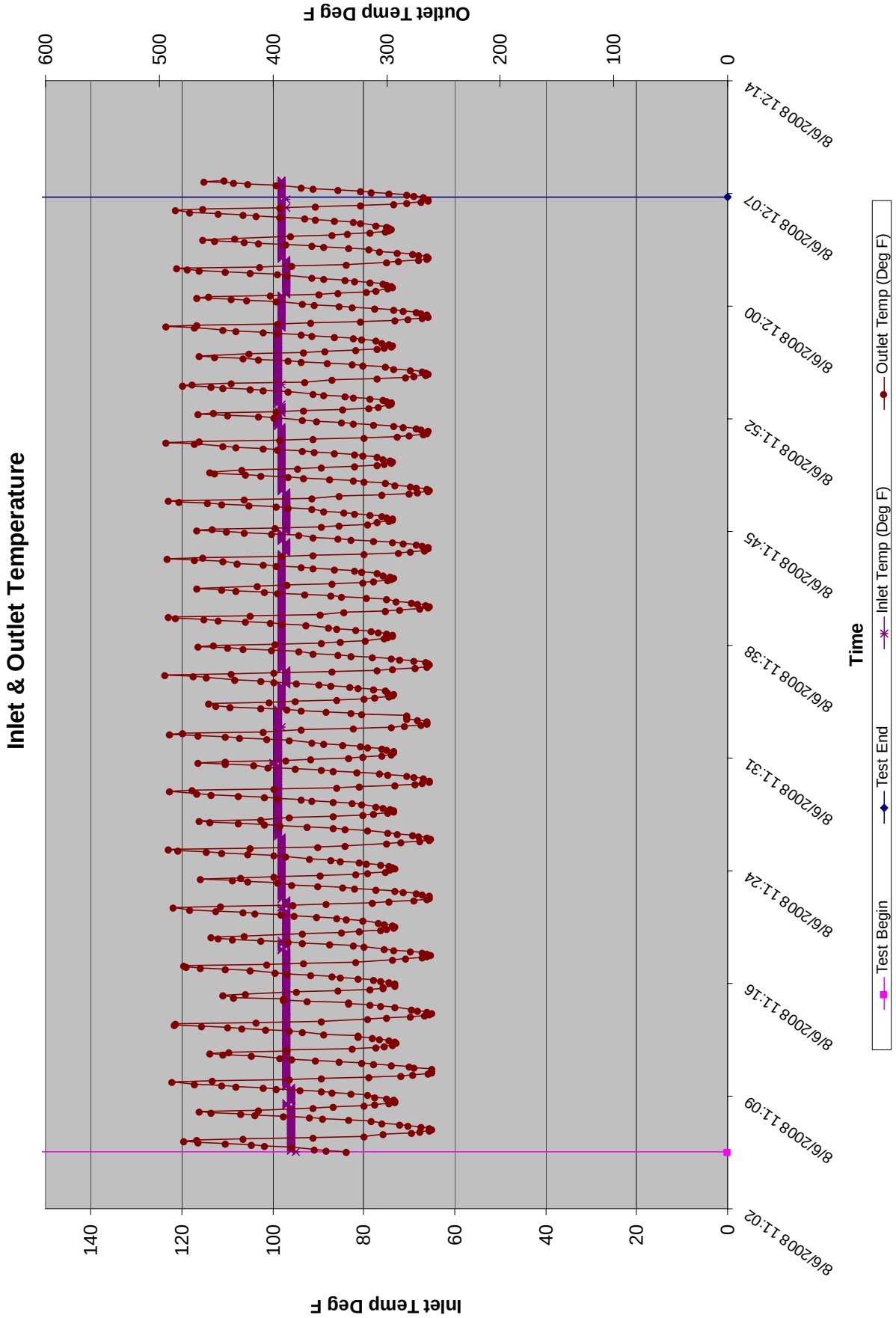
- Graphs – Emission Test Campaign 3 – Runs Sept-1, Sept-2, & Sept-3

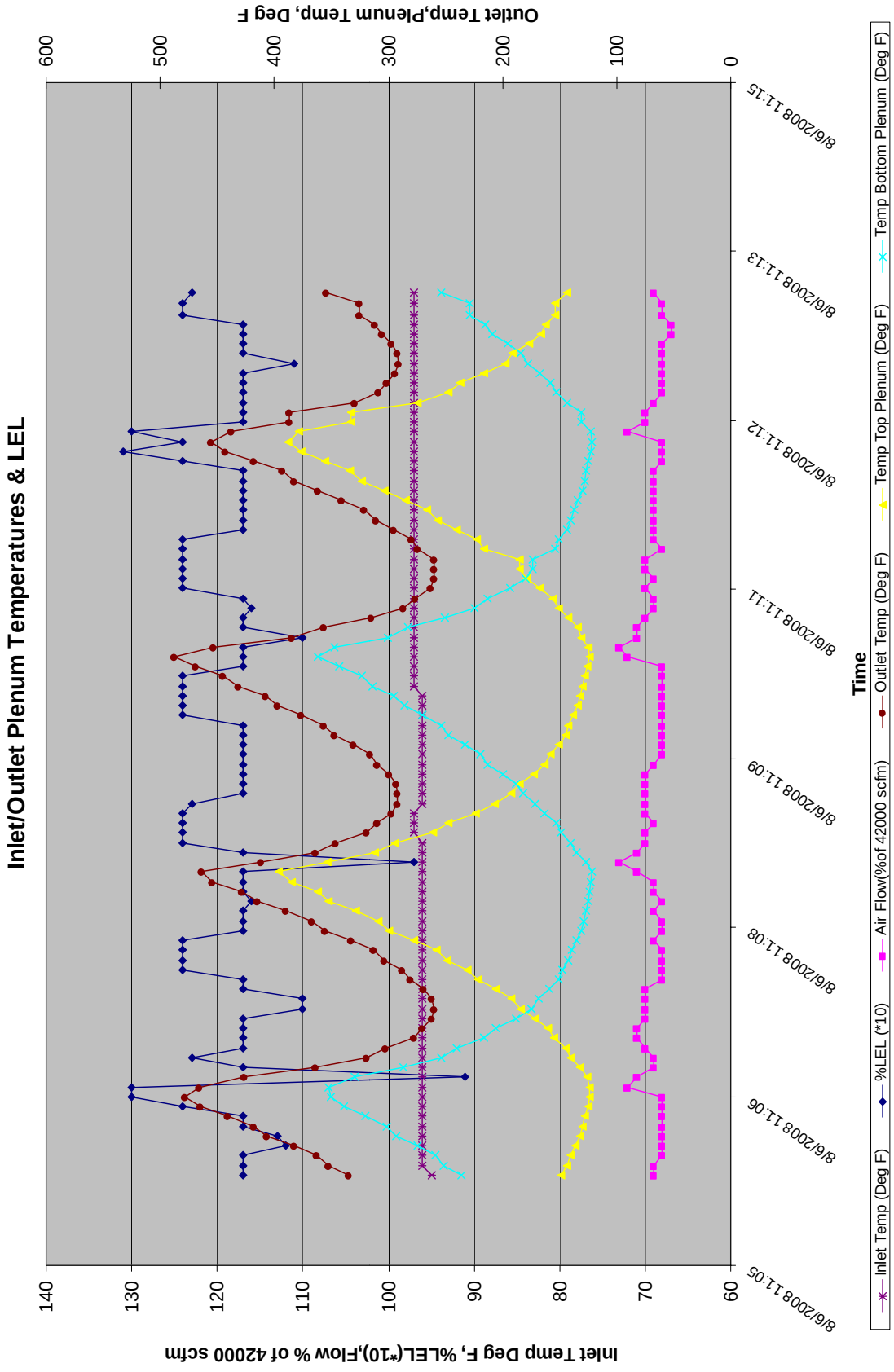
  Bed Temperature Profile
  Mine Gas Flow, LEL, Air Flow, Bed Pressure Drop
  Inlet & Outlet Temperature
  Plenum Temperatures
  Air Flow versus Inlet Temperature
  Inlet Methane Concentration – LEL
  Stack Emissions – VOC & O_2
  Stack Emissions – SO_x, NO_x, CO, & CO_2

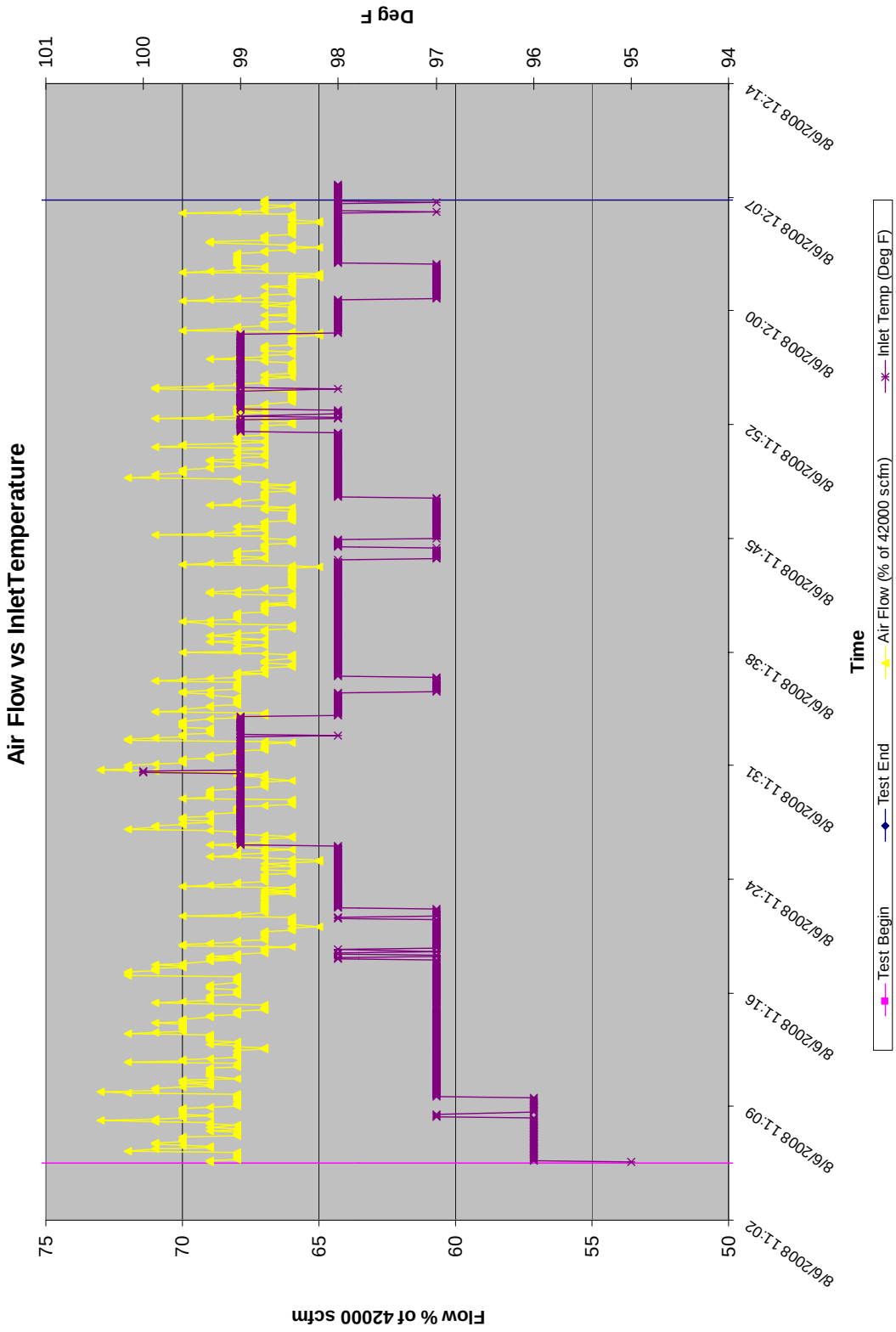
VOCSIDIZER Emission Test
Campaign 2
Run ID: Aug-1
August 06, 2008
11:06 AM – 12:07 PM

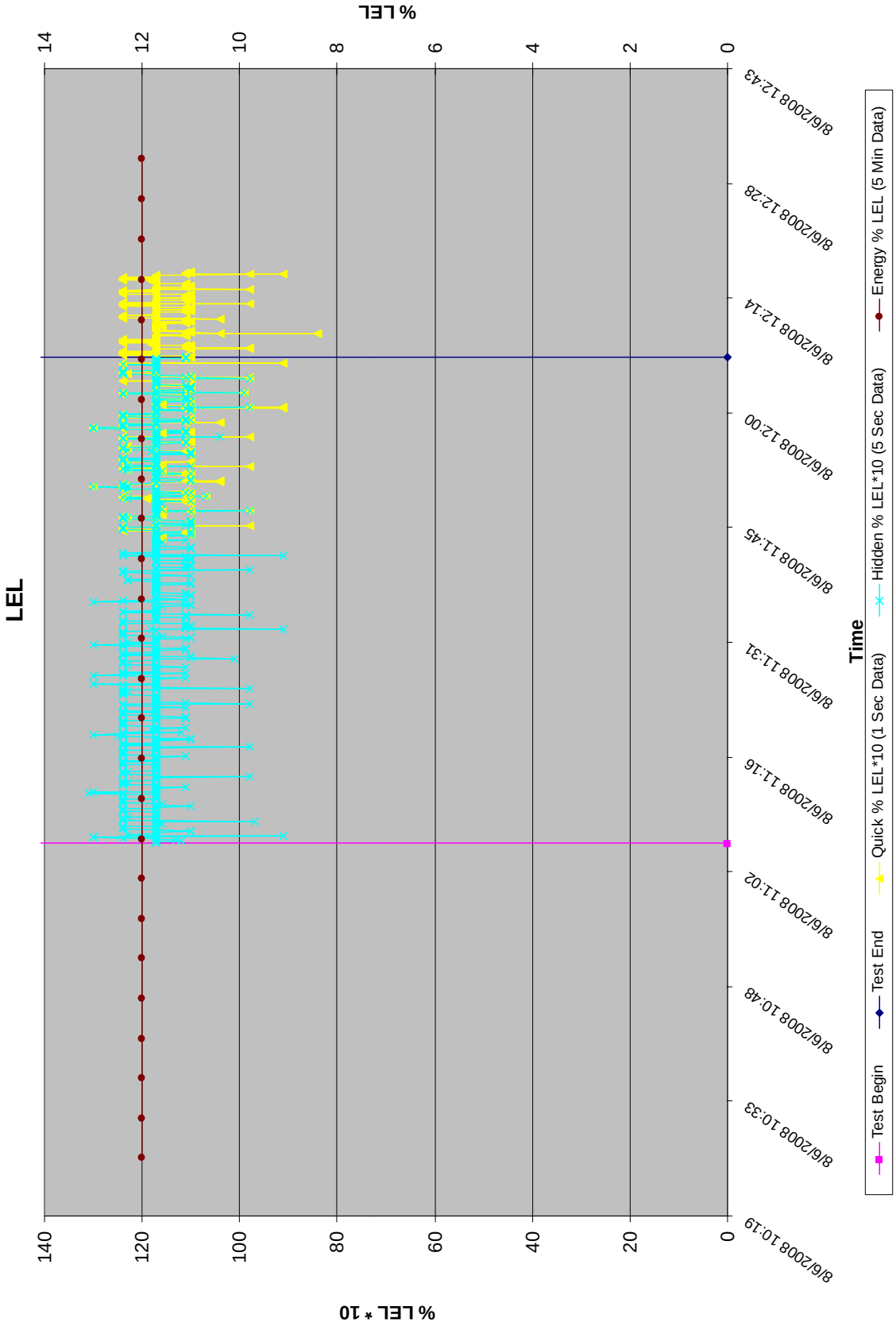

Bed Temperature
Deg F
2080
2060
2040
2020
2000
1980
1960
1940
1920
10:19:12 AM
10:33:36 AM
10:48:00 AM
11:02:24 AM
11:16:48 AM
11:31:12 AM
11:45:36 AM
12:00:00 PM
12:14:24 PM
12:28:48 PM
12:43:12 PM
Time
Test Begin
Test End
TE101
TE104
TE111A
TE111B
TE111C
TE111D

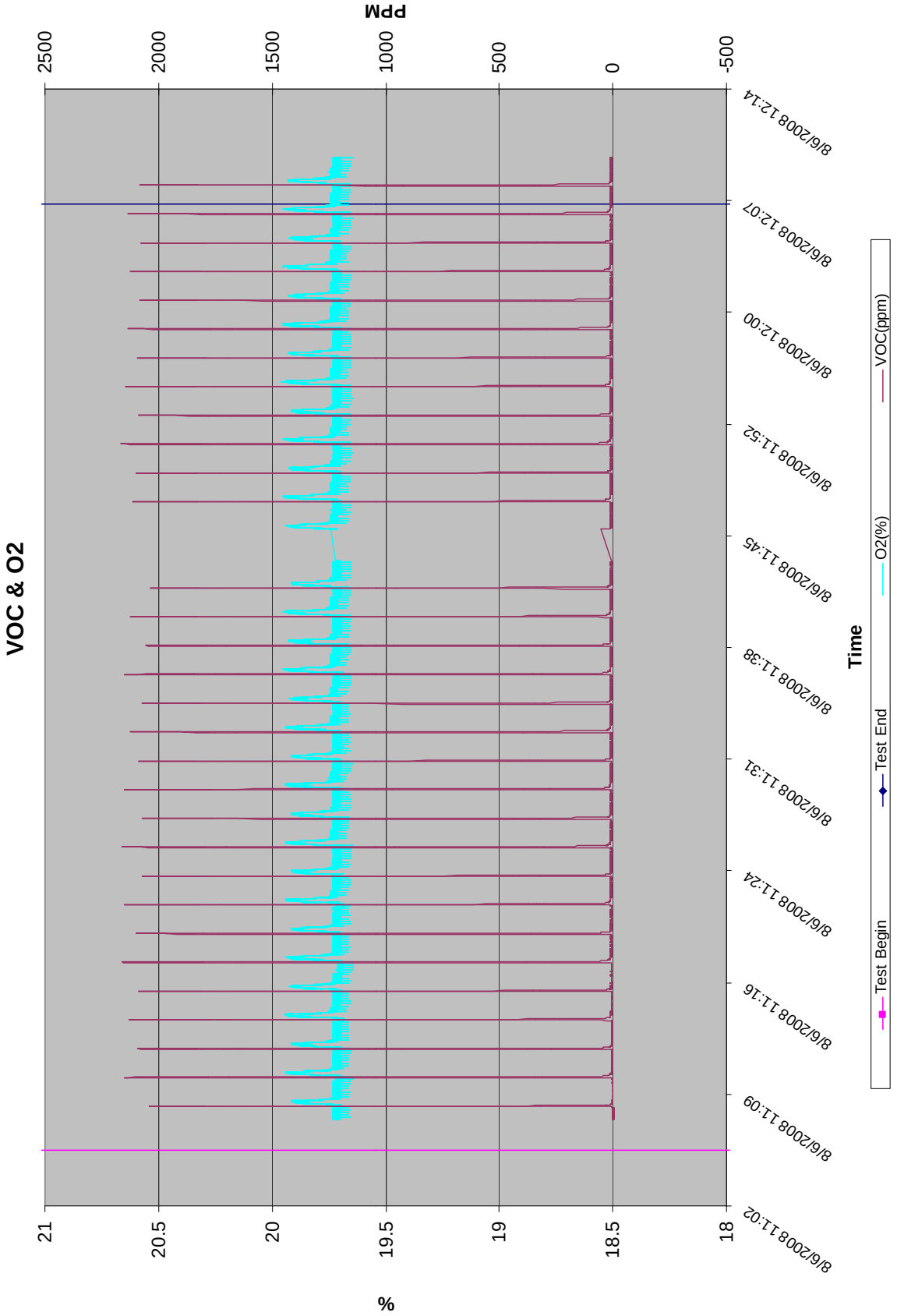

Mine Gas Flow, LEL, Air Flow, Bed DP
SCFM
%LEL, DP "WC
Time
400
350
300
250
200
150
100
14
12
10
8
6
4
2
0
8/6/2008 10:19
8/6/2008 10:33
8/6/2008 10:48
8/6/2008 11:02
8/6/2008 11:16
8/6/2008 11:31
8/6/2008 11:45
8/6/2008 12:00
8/6/2008 12:14
8/6/2008 12:28
8/6/2008 12:43
Test Begin
Test End
Mine Gas Flow(scfm)
Air Flow/100 (scfm)
LEL(%)
Bed DP Ref

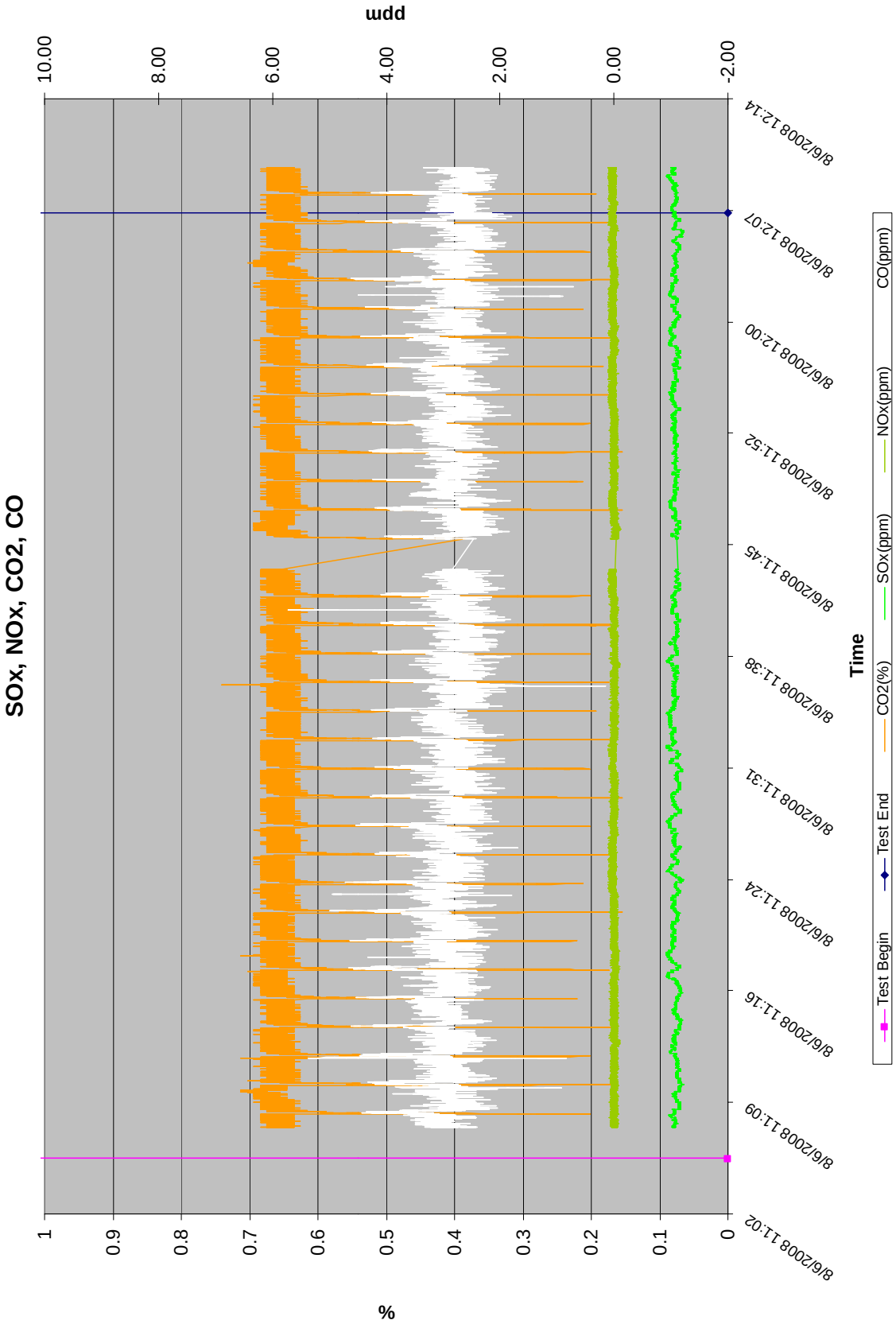

Inlet & Outlet Temperature
Inlet Temp Deg F
Outlet Temp Deg F
Time
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
8/6/2008 11:02
8/6/2008 11:09
8/6/2008 11:16
8/6/2008 11:24
8/6/2008 11:31
8/6/2008 11:38
8/6/2008 11:45
8/6/2008 11:52
8/6/2008 12:00
8/6/2008 12:07
8/6/2008 12:14
Test Begin
Test End
Inlet Temp (Deg F)
Outlet Temp (Deg F)


Inlet/Outlet Plenum Temperatures & LEL
Inlet Temp Deg F, %LEL(*10),Flow % of 42000 scfm
Outlet Temp,Plenum Temp, Deg F
140
130
120
110
100
90
80
70
60
600
500
400
300
200
100
0
8/6/2008 11:05
8/6/2008 11:06
8/6/2008 11:08
8/6/2008 11:09
8/6/2008 11:11
8/6/2008 11:12
8/6/2008 11:13
8/6/2008 11:15
Time
Inlet Temp (Deg F)
%LEL (*10)
Air Flow(%of 42000 scfm)
Outlet Temp (Deg F)
Temp Top Plenum (Deg F)
Temp Bottom Plenum (Deg F)

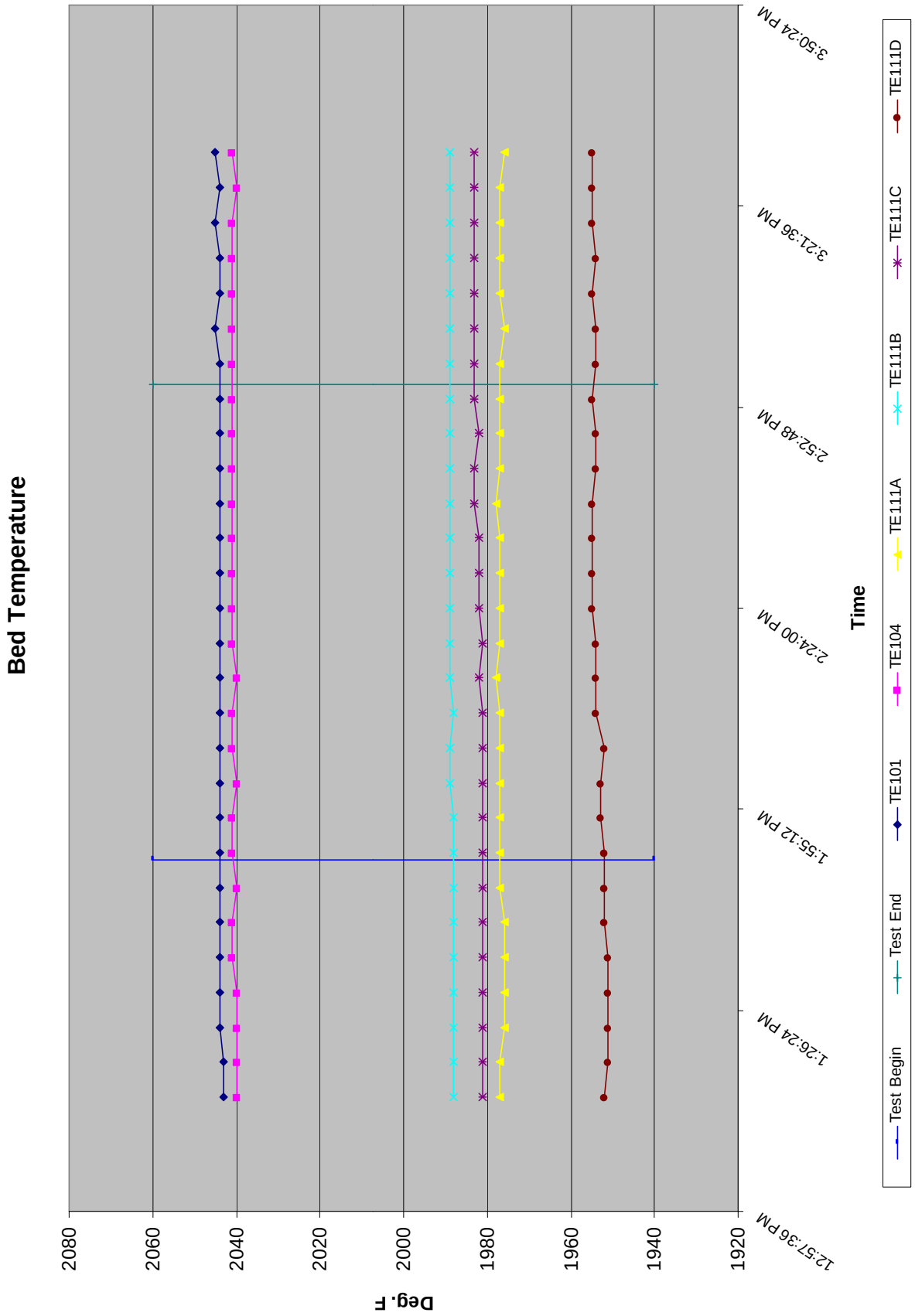

Air Flow vs InletTemperature
Flow % of 42000 scfm
Deg F
75
70
65
60
55
50
101
100
99
98
97
96
95
94
8/6/2008 11:02
8/6/2008 11:09
8/6/2008 11:16
8/6/2008 11:24
8/6/2008 11:31
8/6/2008 11:38
8/6/2008 11:45
8/6/2008 11:52
8/6/2008 12:00
8/6/2008 12:07
8/6/2008 12:14
Time
Test Begin
Test End
Air Flow (% of 42000 scfm)
Inlet Temp (Deg F)

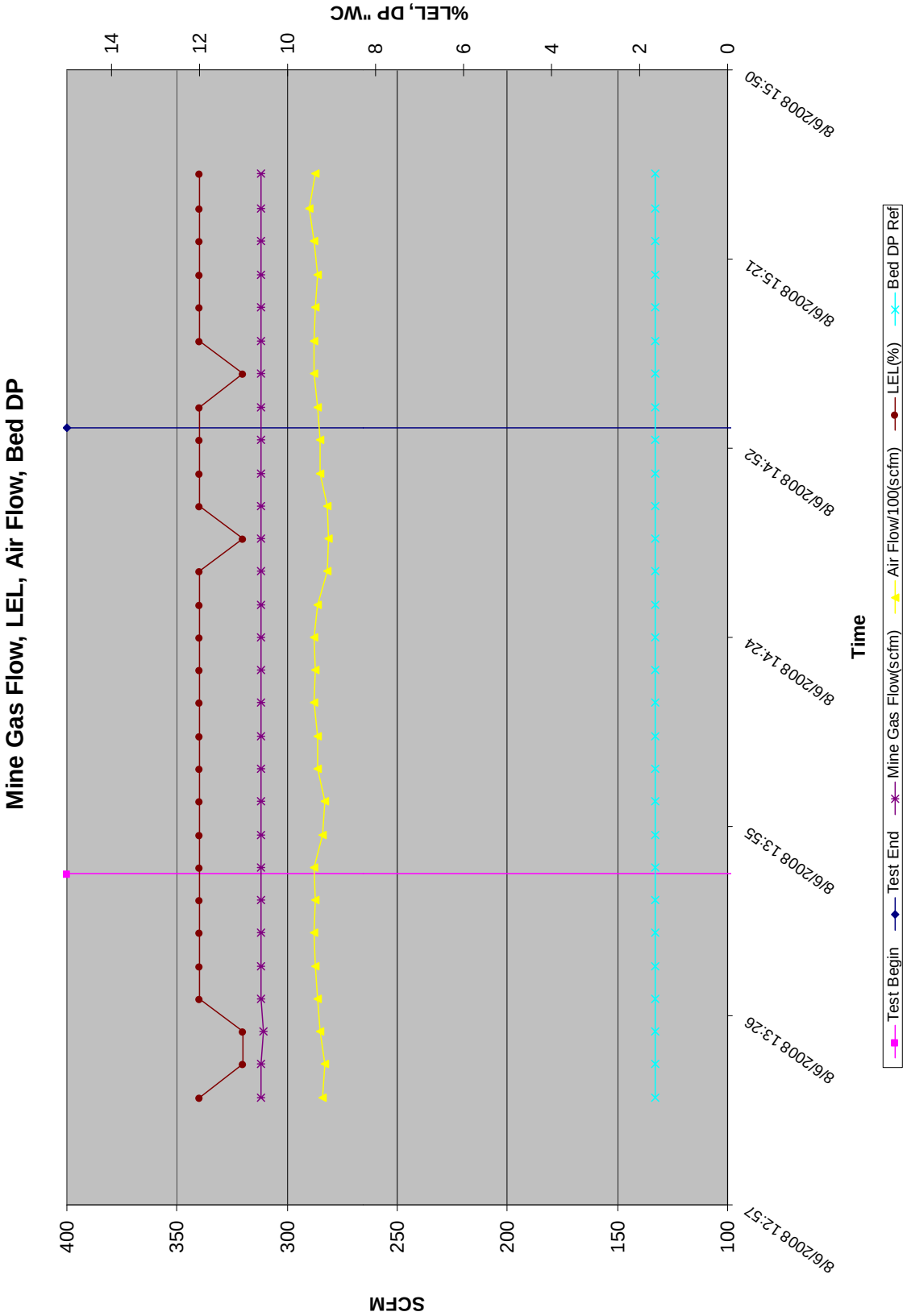

LEL
% LEL * 10
% LEL
Time
140
120
100
80
60
40
20
0
14
12
10
8
6
4
2
0
8/6/2008 10:19
8/6/2008 10:33
8/6/2008 10:48
8/6/2008 11:02
8/6/2008 11:16
8/6/2008 11:31
8/6/2008 11:45
8/6/2008 12:00
8/6/2008 12:14
8/6/2008 12:28
8/6/2008 12:43
Test Begin
Test End
Quick % LEL*10 (1 Sec Data)
Hidden % LEL*10 (5 Sec Data)
Energy % LEL (5 Min Data)

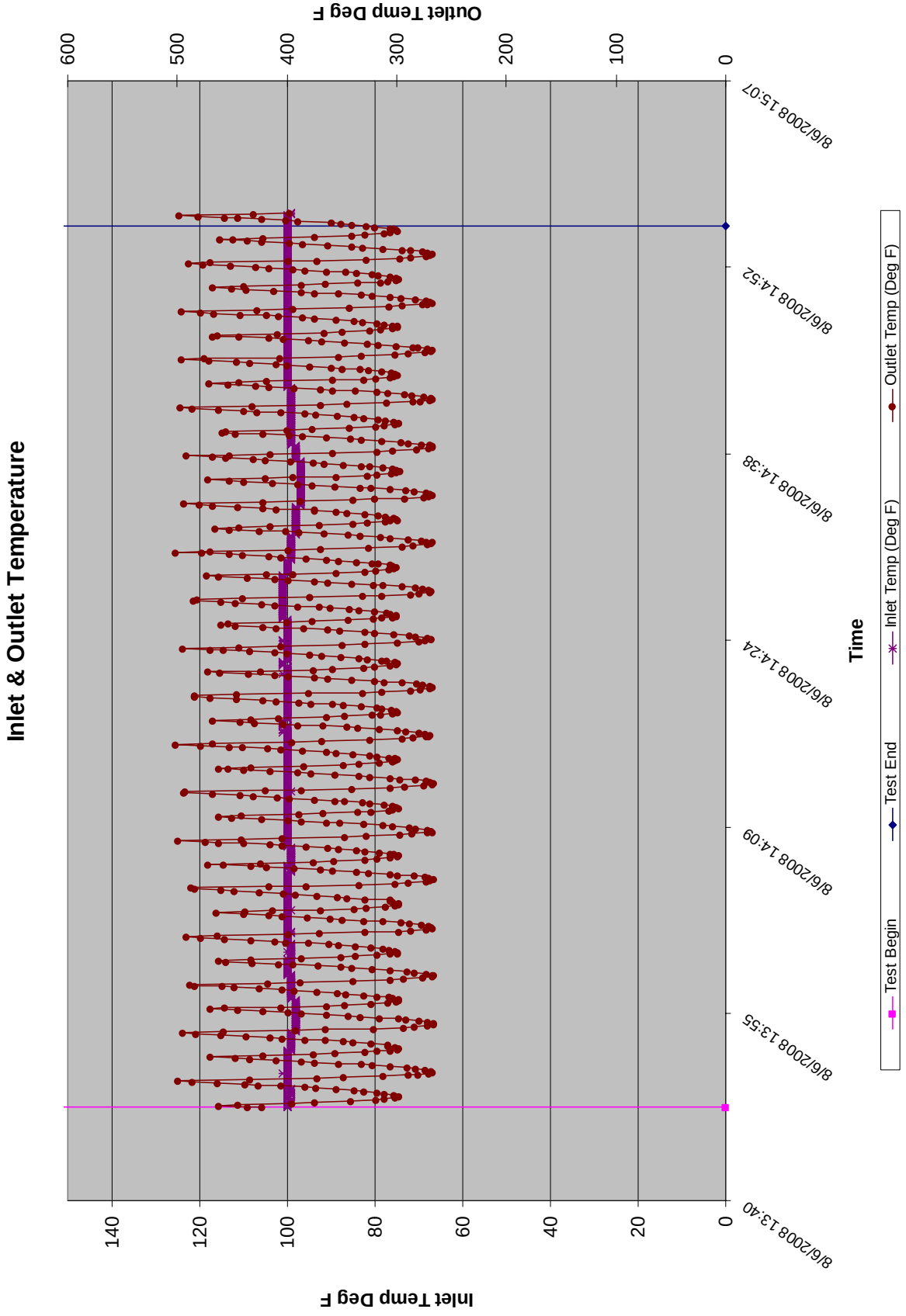

VOC & O2
ppM
2500
2000
1500
1000
500
0
-500
%
21
20.5
20
19.5
19
18.5
18
8/6/2008 11:02
8/6/2008 11:09
8/6/2008 11:16
8/6/2008 11:24
8/6/2008 11:31
8/6/2008 11:38
8/6/2008 11:45
8/6/2008 11:52
8/6/2008 12:00
8/6/2008 12:07
8/6/2008 12:14
Time
Test Begin
Test End
O2(%)
VOC(ppm)

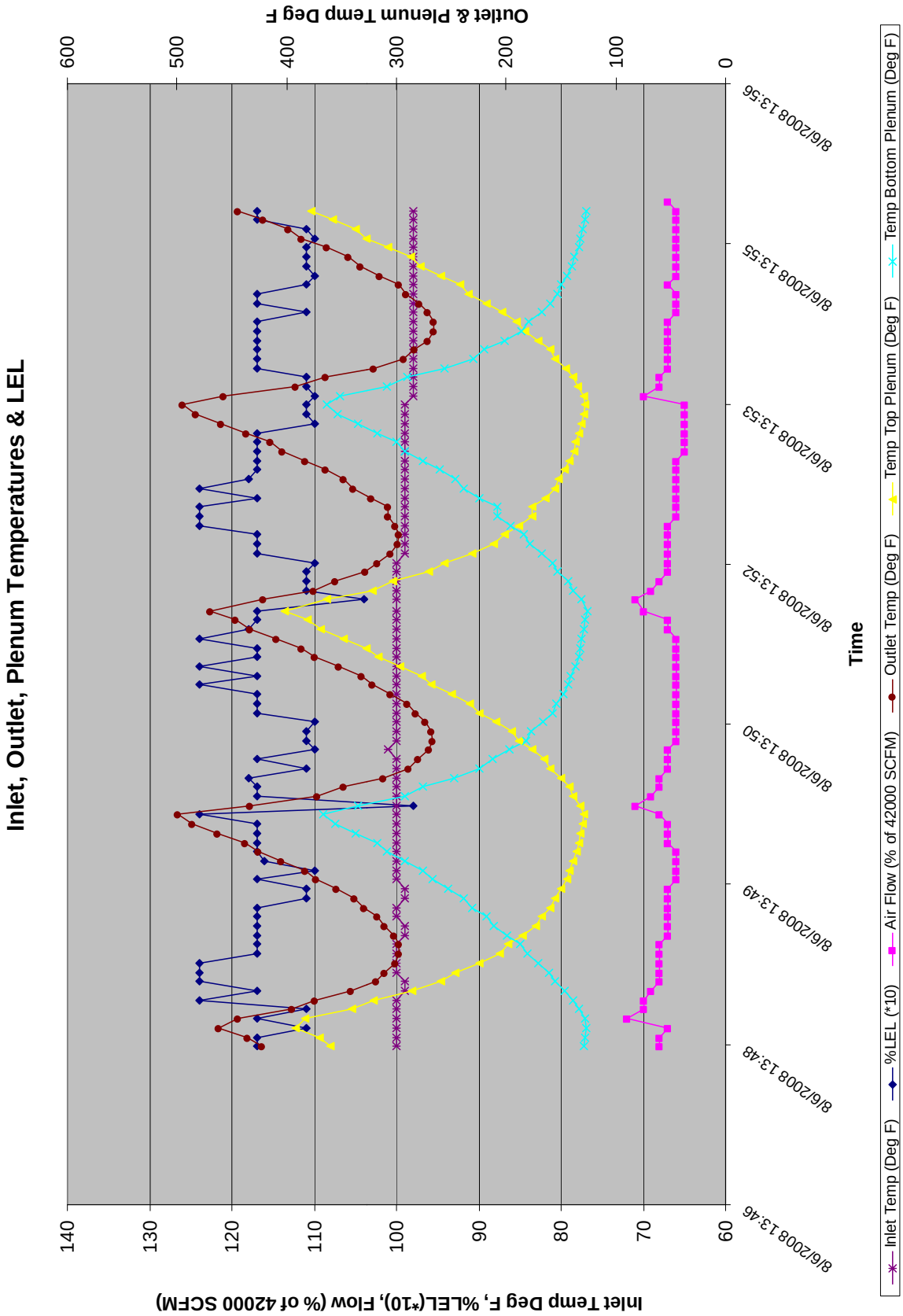

SOx, NOx, CO2, CO
ppm
%
Time
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
8/6/2008 11:02
8/6/2008 11:09
8/6/2008 11:16
8/6/2008 11:24
8/6/2008 11:31
8/6/2008 11:38
8/6/2008 11:45
8/6/2008 11:52
8/6/2008 12:00
8/6/2008 12:07
8/6/2008 12:14
Test Begin
Test End
CO2(%)
SOx(ppm)
NOx(ppm)
CO(ppm)

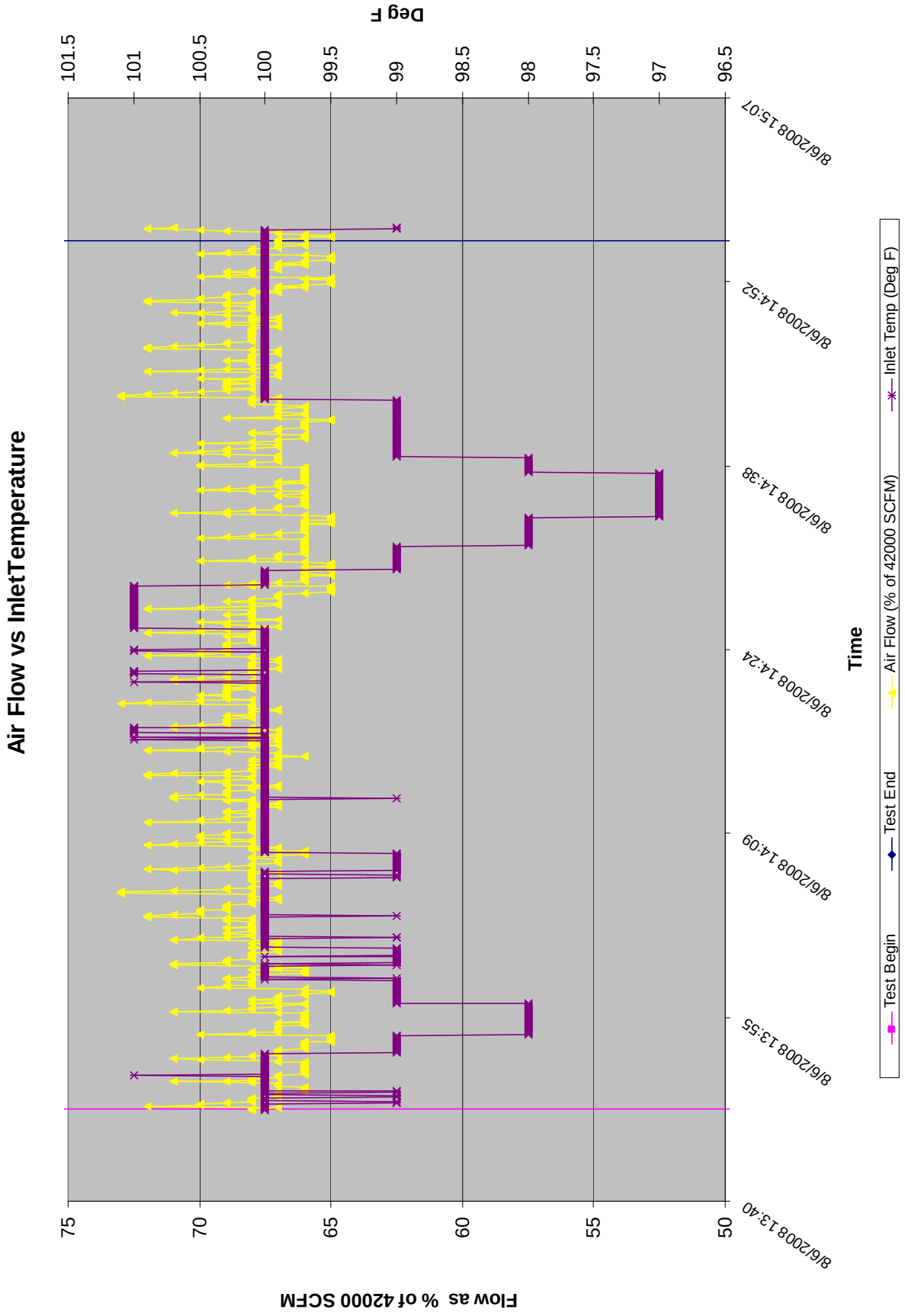
VOCSIDIZER Emission Test
Campaign 2
Run ID: Aug-2
August 06, 2008
1:38 PM – 2:56 PM

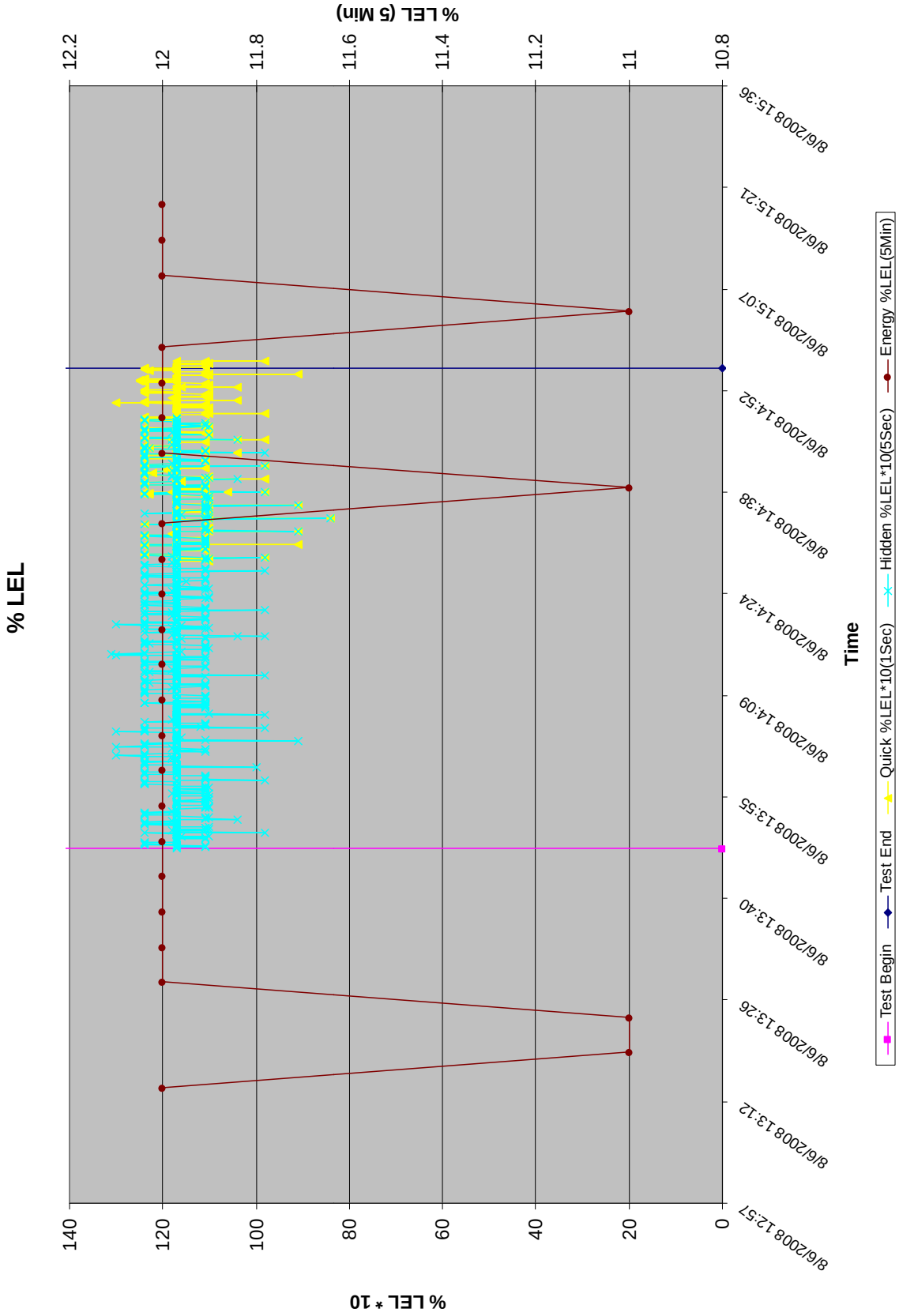

Bed Temperature
Deg. F
2080
2060
2040
2020
2000
1980
1960
1940
1920
12:57:36 PM
1:26:24 PM
1:55:12 PM
2:24:00 PM
2:52:48 PM
3:21:36 PM
3:50:24 PM
Time
Test Begin
Test End
TE101
TE104
TE111A
TE111B
TE111C
TE111D

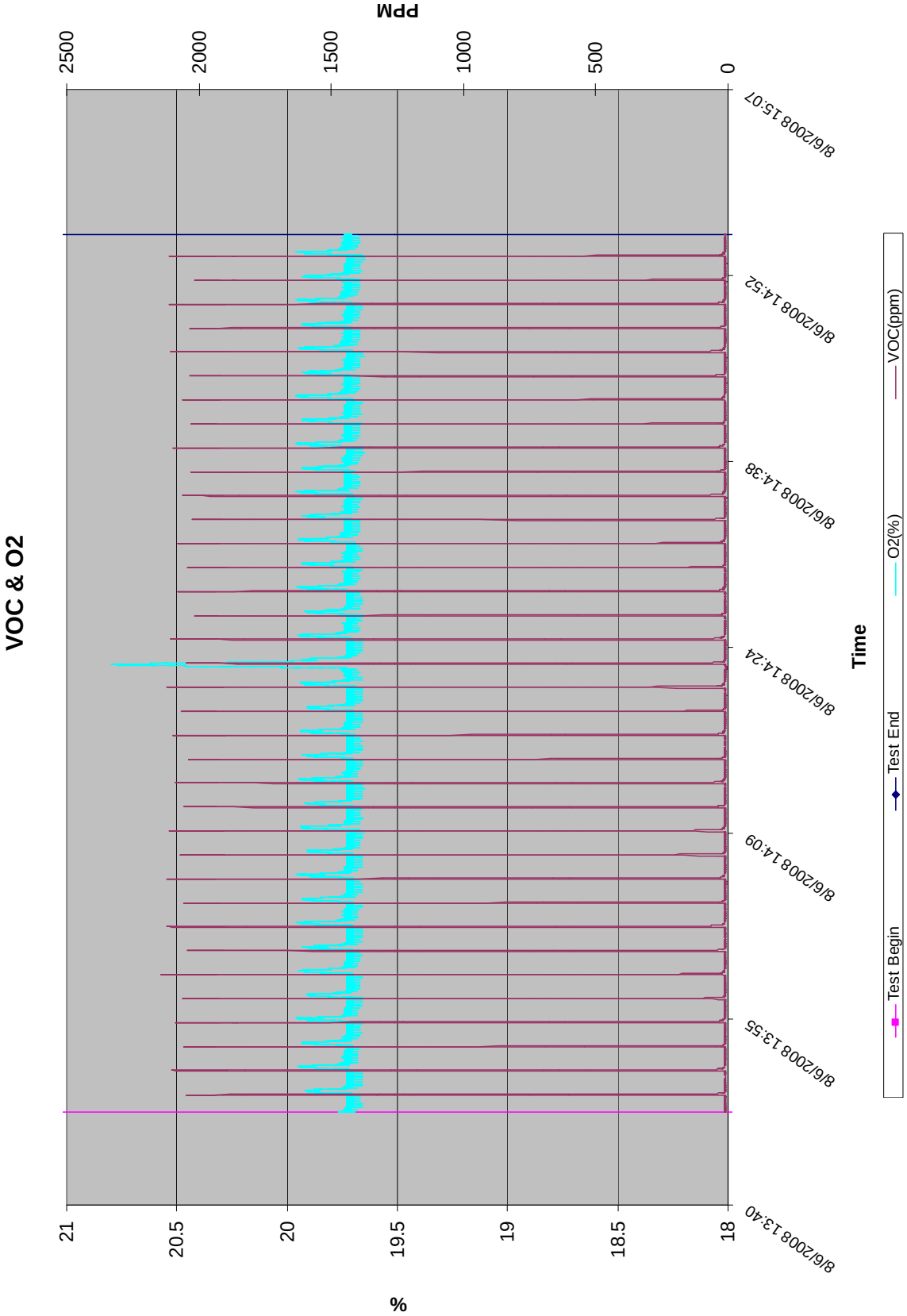

Mine Gas Flow, LEL, Air Flow, Bed DP
SCFM
%LEL, DP "WC
Time
400
350
300
250
200
150
100
14
12
10
8
6
4
2
0
8/6/2008 12:57
8/6/2008 13:26
8/6/2008 13:55
8/6/2008 14:24
8/6/2008 14:52
8/6/2008 15:21
8/6/2008 15:50
Test Begin
Test End
Mine Gas Flow(scfm)
Air Flow/100(scfm)
LEL(%)
Bed DP Ref

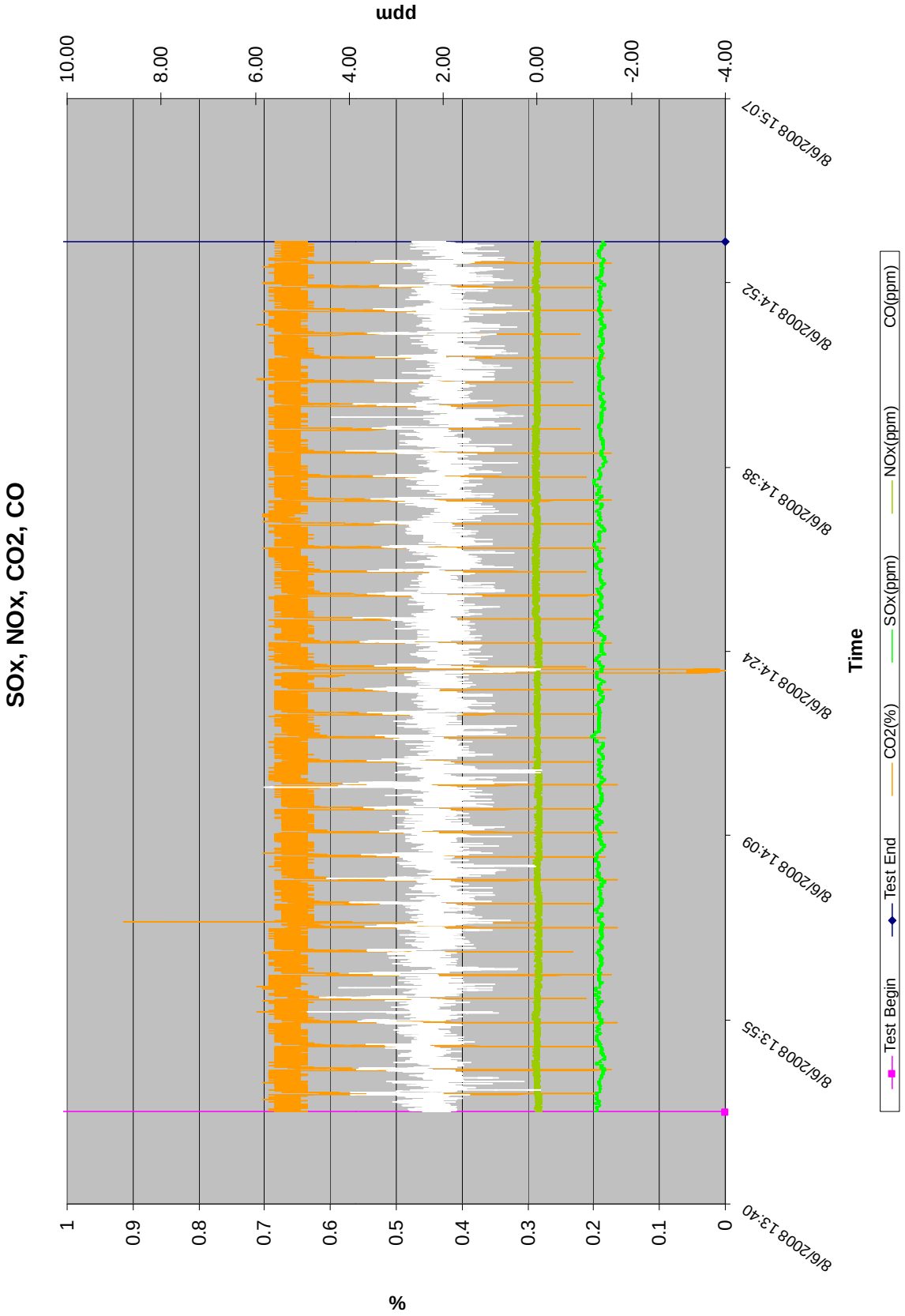

Inlet & Outlet Temperature
Inlet Temp Deg F
Outlet Temp Deg F
Time
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
8/6/2008 13:40
8/6/2008 13:55
8/6/2008 14:09
8/6/2008 14:24
8/6/2008 14:38
8/6/2008 14:52
8/6/2008 15:07
Test Begin
Test End
Inlet Temp (Deg F)
Outlet Temp (Deg F)


Inlet, Outlet, Plenum Temperatures & LEL
Inlet Temp Deg F, %LEL(*10), Flow (% of 42000 SCFM)
Outlet & Plenum Temp Deg F
140
130
120
110
100
90
80
70
60
600
500
400
300
200
100
0
8/6/2008 13:46
8/6/2008 13:48
8/6/2008 13:49
8/6/2008 13:50
8/6/2008 13:52
8/6/2008 13:53
8/6/2008 13:55
8/6/2008 13:56
Time
Inlet Temp (Deg F)
%LEL (*10)
Air Flow (% of 42000 SCFM)
Outlet Temp (Deg F)
Temp Top Plenum (Deg F)
Temp Bottom Plenum (Deg F)

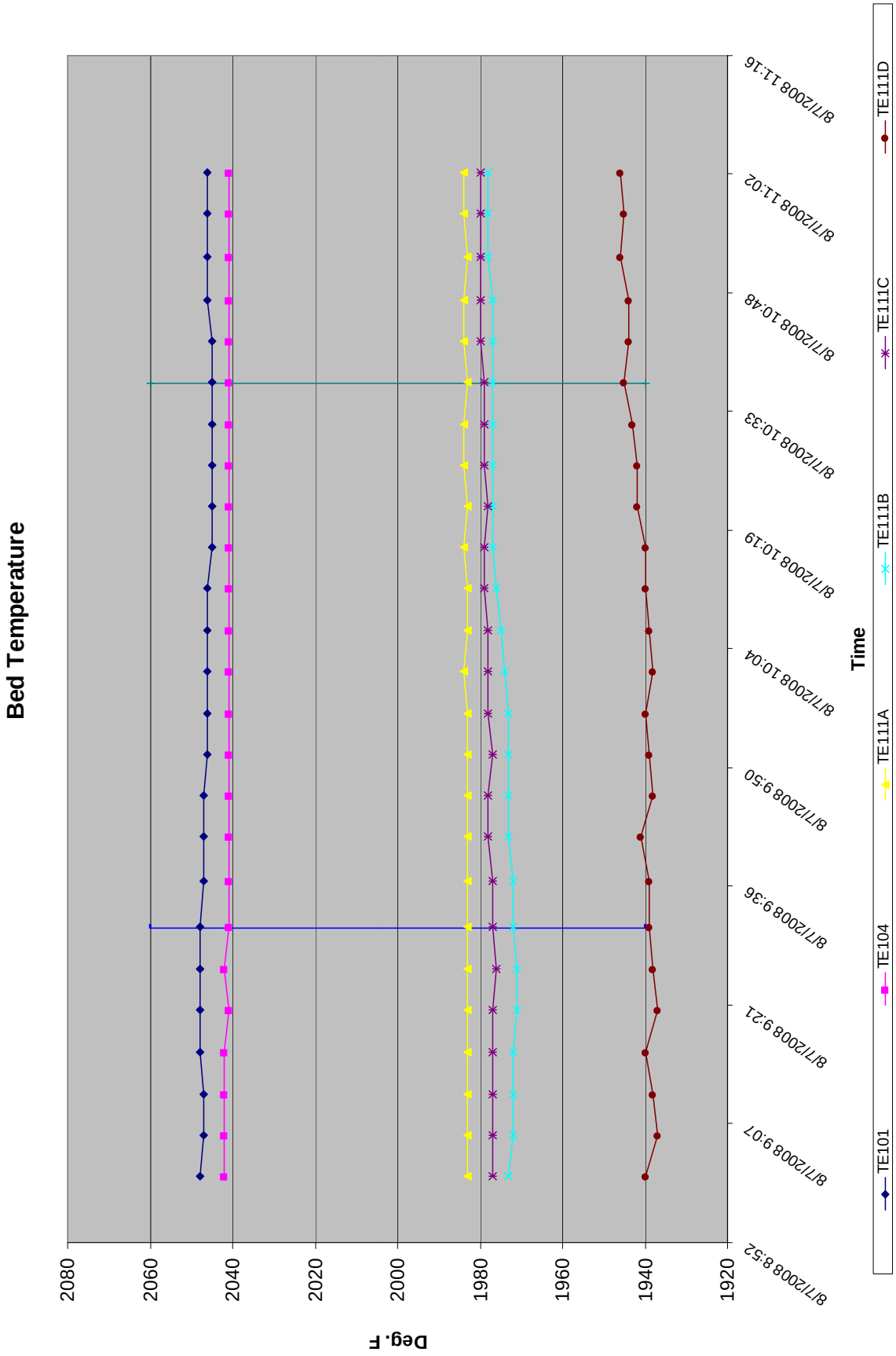

Air Flow vs InletTemperature
Deg F
101.5
101
100.5
100
99.5
99
98.5
98
97.5
97
96.5
Flow as % of 42000 SCFM
75
70
65
60
55
50
8/6/2008 13:40
8/6/2008 13:55
8/6/2008 14:09
8/6/2008 14:24
8/6/2008 14:38
8/6/2008 14:52
8/6/2008 15:07
Time
Test Begin
Test End
Air Flow (% of 42000 SCFM)
Inlet Temp (Deg F)

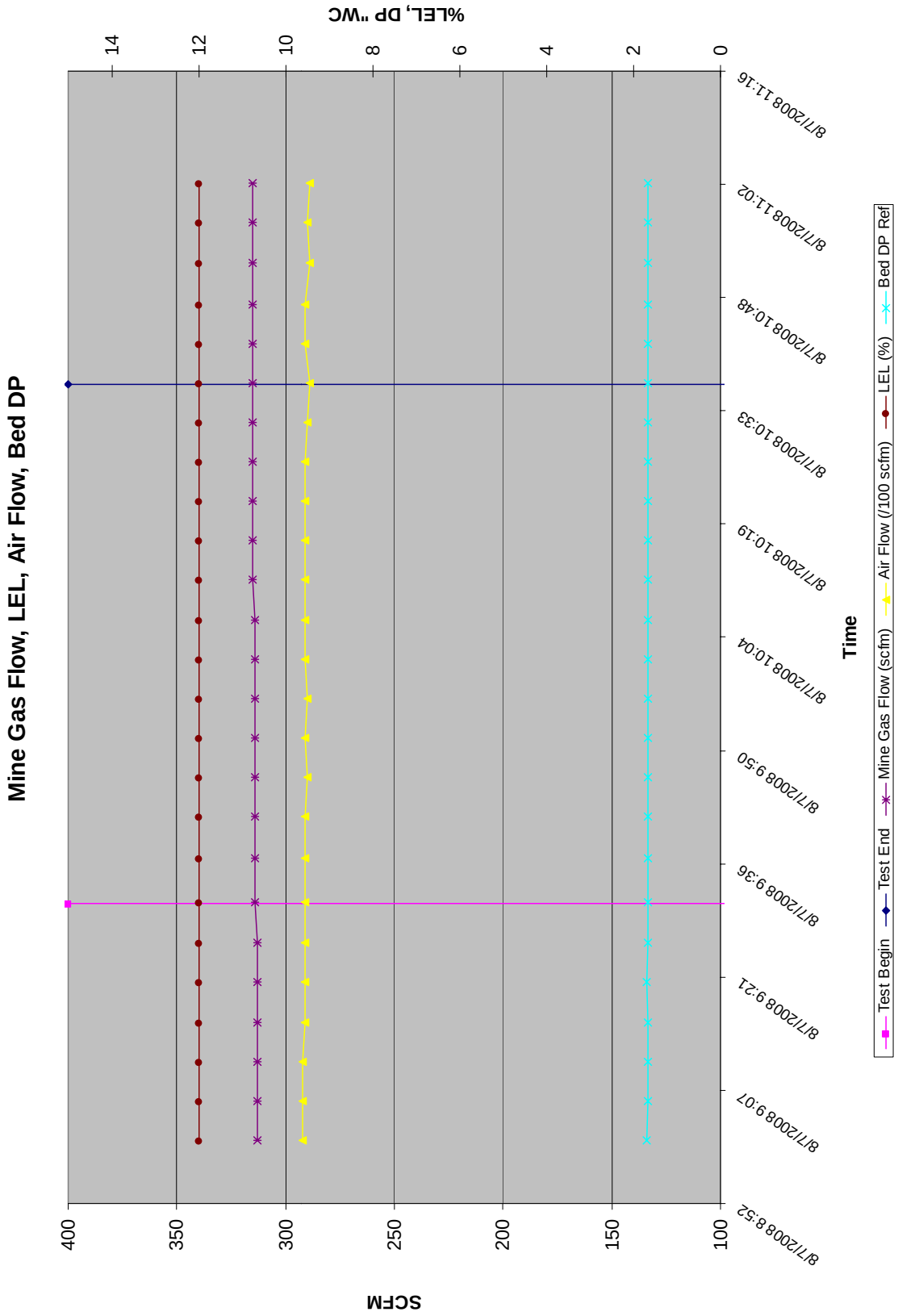

% LEL
% LEL * 10
% LEL (5 Min)
Time
140
120
100
80
60
40
20
0
12.2
12
11.8
11.6
11.4
11.2
11
10.8
8/6/2008 12:57
8/6/2008 13:12
8/6/2008 13:26
8/6/2008 13:40
8/6/2008 13:55
8/6/2008 14:09
8/6/2008 14:24
8/6/2008 14:38
8/6/2008 14:52
8/6/2008 15:07
8/6/2008 15:21
8/6/2008 15:36
Test Begin
Test End
Quick %LEL*10(1Sec)
Hidden %LEL*10(5Sec)
Energy %LEL(5Min)

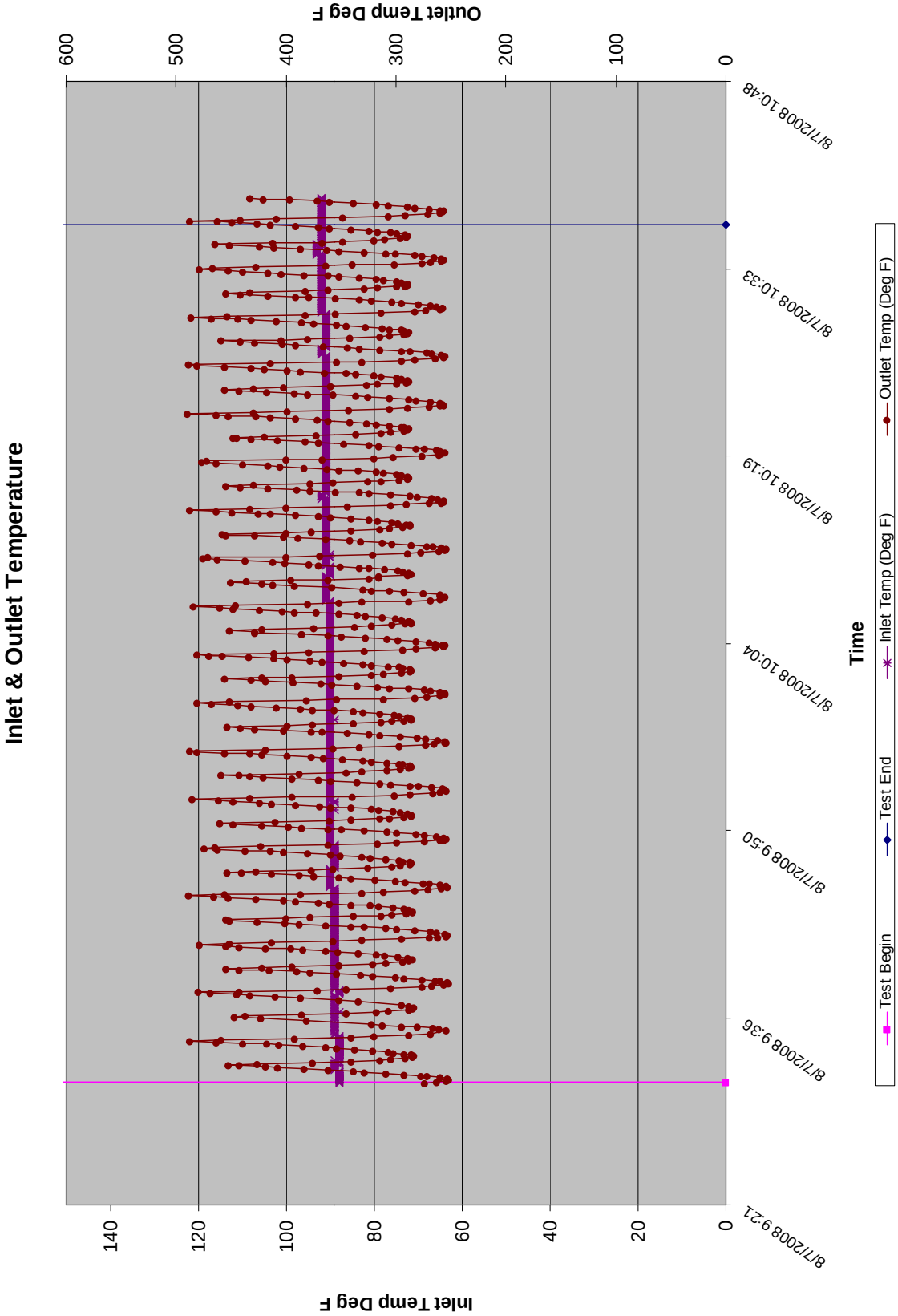

VOC & O2
ppm
2500
2000
1500
1000
500
0
%
21
20.5
20
19.5
19
18.5
18
8/6/2008 13:40
8/6/2008 13:55
8/6/2008 14:09
8/6/2008 14:24
8/6/2008 14:38
8/6/2008 14:52
8/6/2008 15:07
Time
Test Begin
Test End
O2(%)
VOC(ppm)

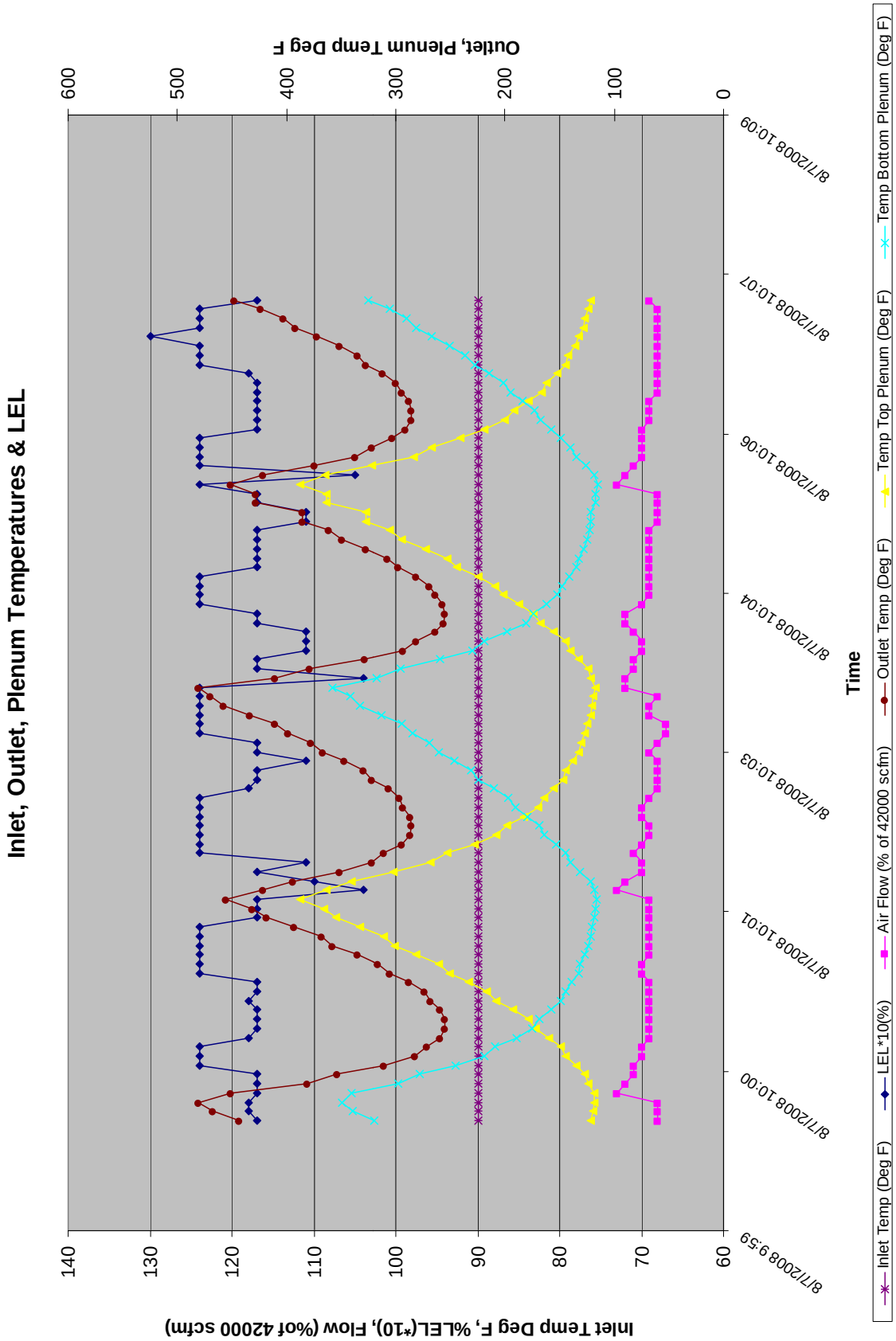

SOx, NOx, CO2, CO
ppm
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
%
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
8/6/2008 13:40
8/6/2008 13:55
8/6/2008 14:09
8/6/2008 14:24
8/6/2008 14:38
8/6/2008 14:52
8/6/2008 15:07
Time
Test Begin
Test End
CO2(%)
SOx(ppm)
NOx(ppm)
CO(ppm)

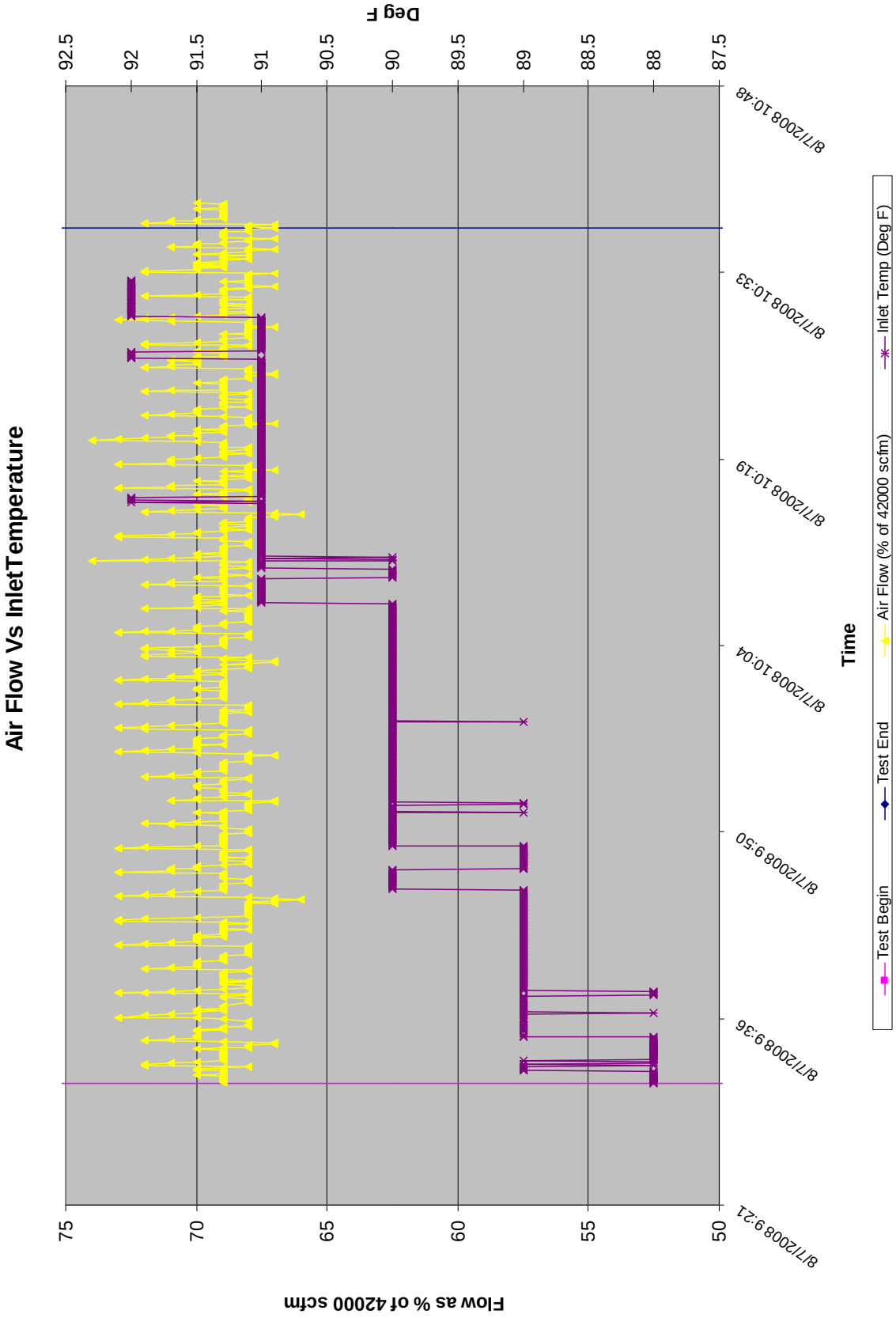
VOCSIDIZER Emission Test
Campaign 2
Run ID: Aug-3
August 07, 2008
9:30 AM – 10:37 AM

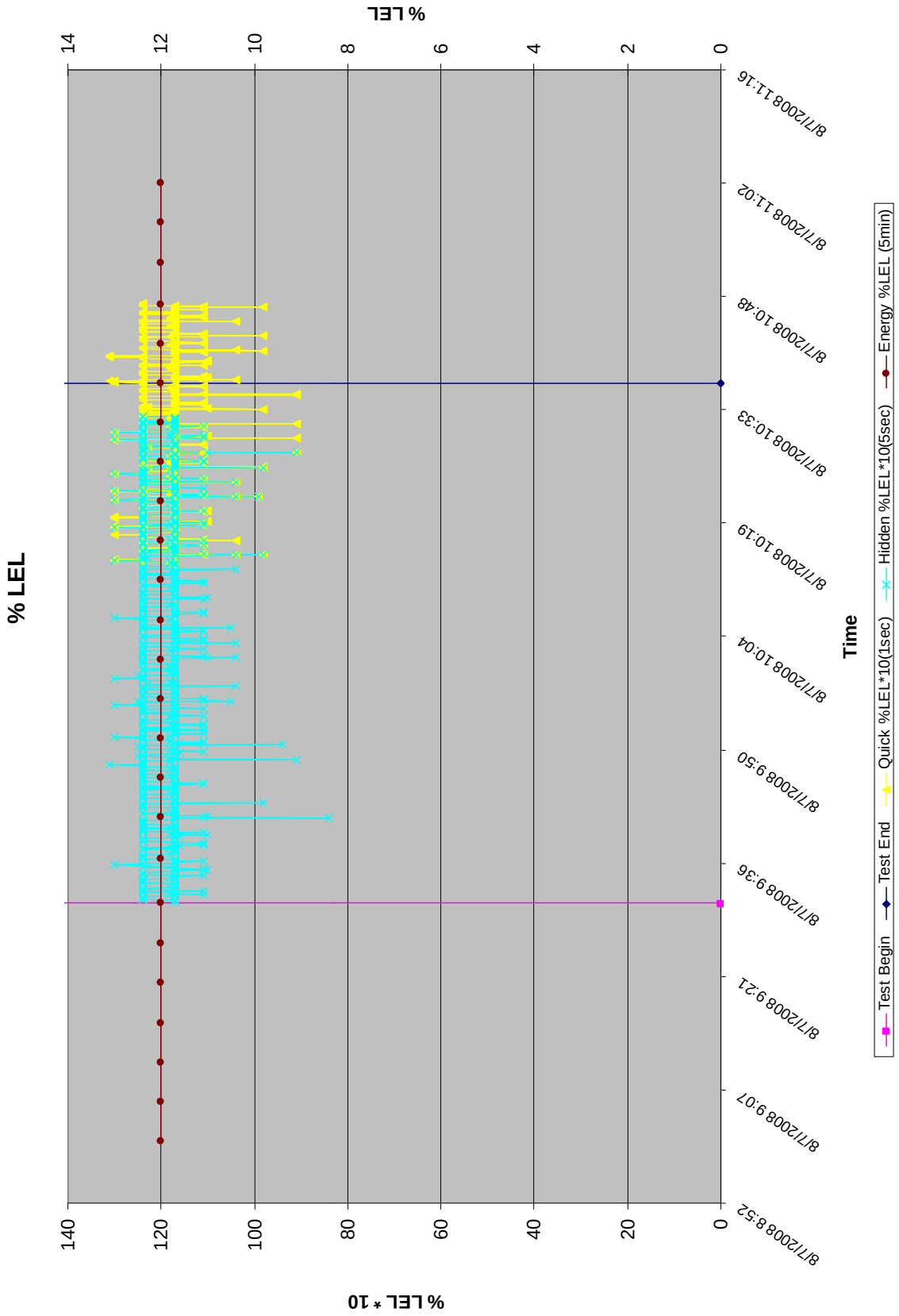

Bed Temperature
Deg. F
2080
2060
2040
2020
2000
1980
1960
1940
1920
8/7/2008 8:52
8/7/2008 9:07
8/7/2008 9:21
8/7/2008 9:36
8/7/2008 9:50
8/7/2008 10:04
8/7/2008 10:19
8/7/2008 10:33
8/7/2008 10:48
8/7/2008 11:02
8/7/2008 11:16
Time
TE101
TE104
TE111A
TE111B
TE111C
TE111D

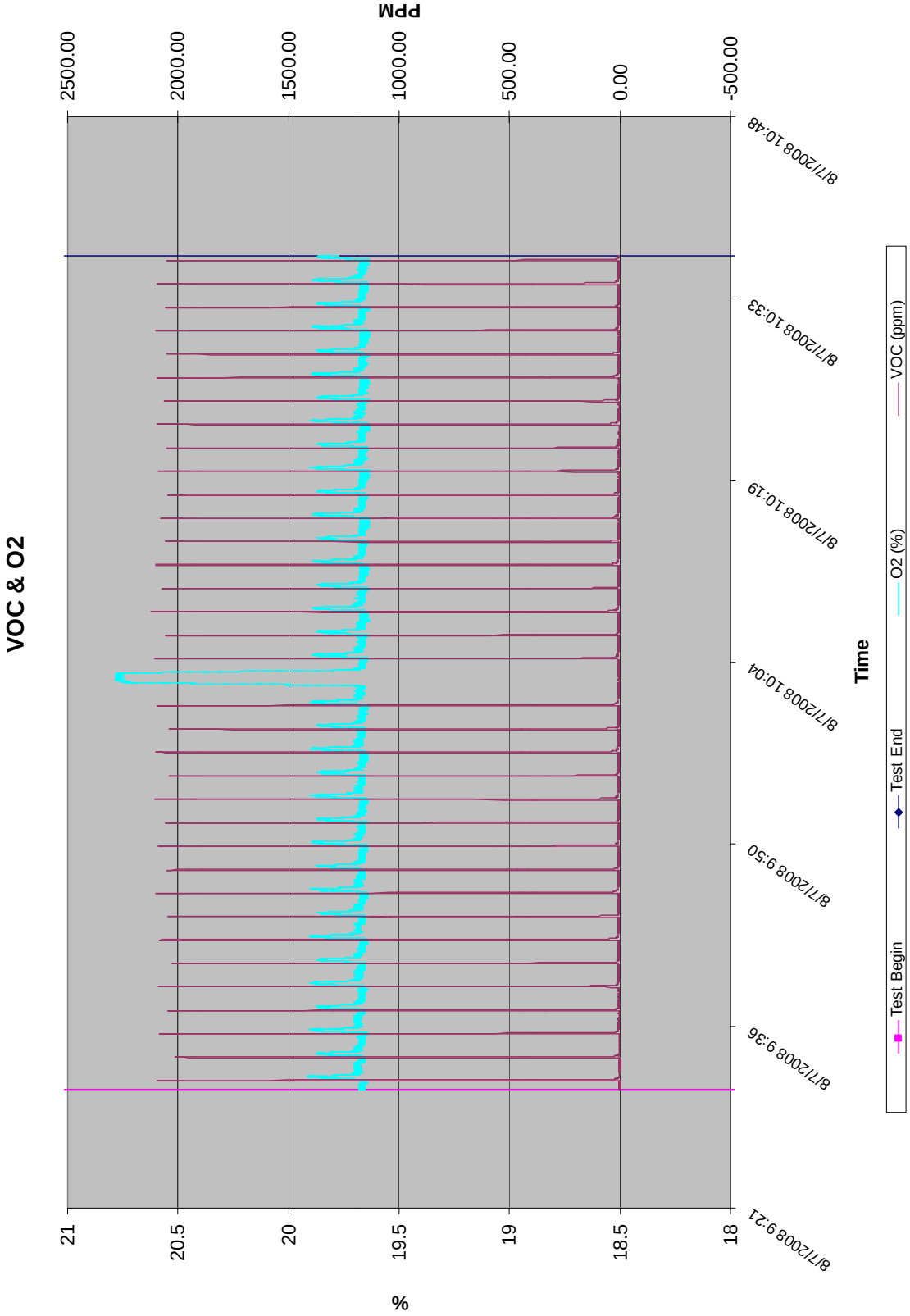

Mine Gas Flow, LEL, Air Flow, Bed DP
SCFM
%LEL, DP "WC
Time
400
350
300
250
200
150
100
14
12
10
8
6
4
2
0
8/7/2008 8:52
8/7/2008 9:07
8/7/2008 9:21
8/7/2008 9:36
8/7/2008 9:50
8/7/2008 10:04
8/7/2008 10:19
8/7/2008 10:33
8/7/2008 10:48
8/7/2008 11:02
8/7/2008 11:16
Test Begin
Test End
Mine Gas Flow (scfm)
Air Flow (/100 scfm)
LEL (%)
Bed DP Ref

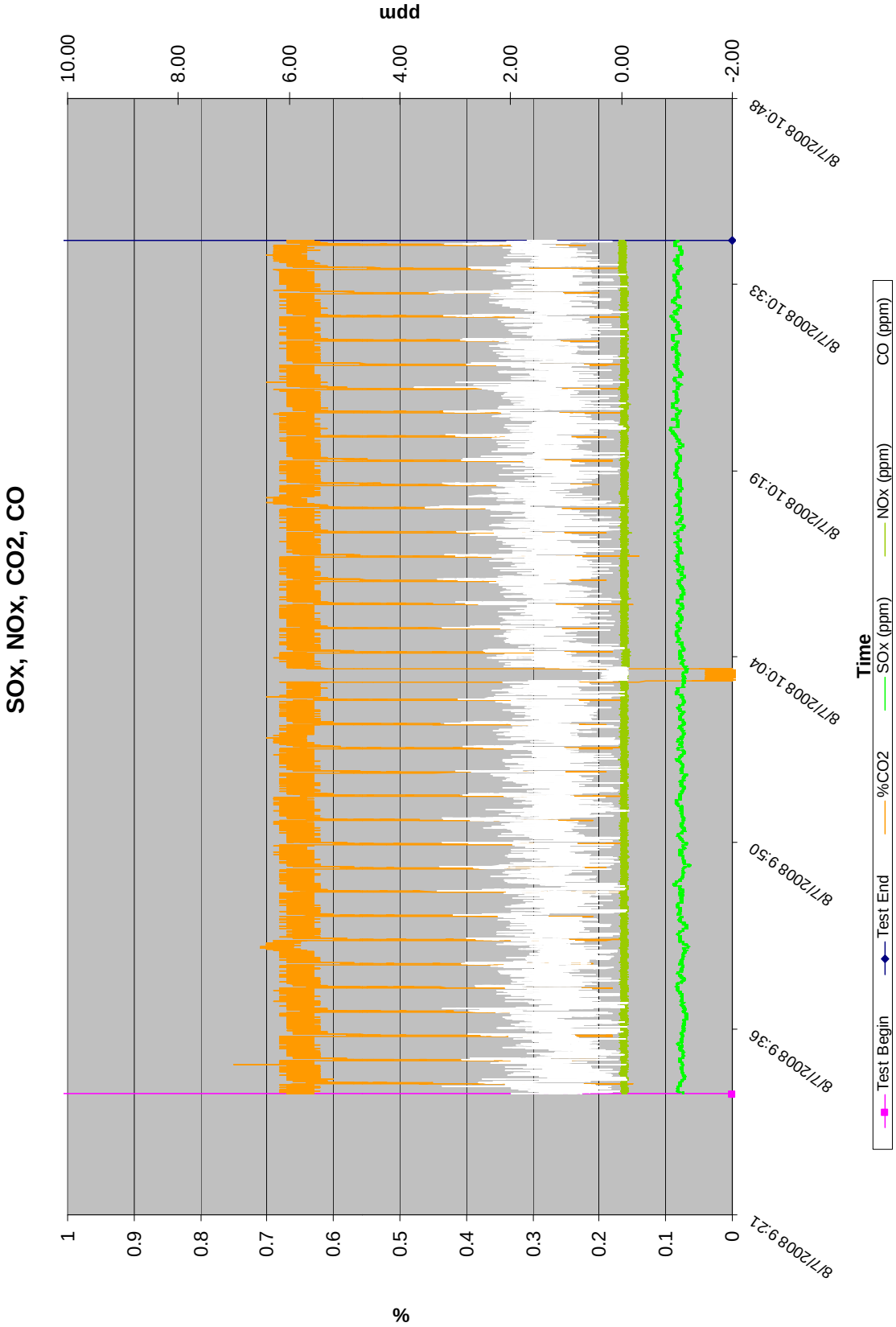

Inlet & Outlet Temperature
Inlet Temp Deg F
Outlet Temp Deg F
Time
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
8/7/2008 9:21
8/7/2008 9:36
8/7/2008 9:50
8/7/2008 10:04
8/7/2008 10:19
8/7/2008 10:33
8/7/2008 10:48
Test Begin
Test End
Inlet Temp (Deg F)
Outlet Temp (Deg F)


Inlet, Outlet, Plenum Temperatures & LEL
Inlet Temp Deg F, %LEL(*10), Flow (%of 42000 scfm)
Outlet, Plenum Temp Deg F
140
130
120
110
100
90
80
70
60
600
500
400
300
200
100
0
8/7/2008 9:59
8/7/2008 10:00
8/7/2008 10:01
8/7/2008 10:03
8/7/2008 10:04
8/7/2008 10:06
8/7/2008 10:07
8/7/2008 10:09
Time
Inlet Temp (Deg F)
LEL*10(%)
Air Flow (% of 42000 scfm)
Outlet Temp (Deg F)
Temp Top Plenum (Deg F)
Temp Bottom Plenum (Deg F)

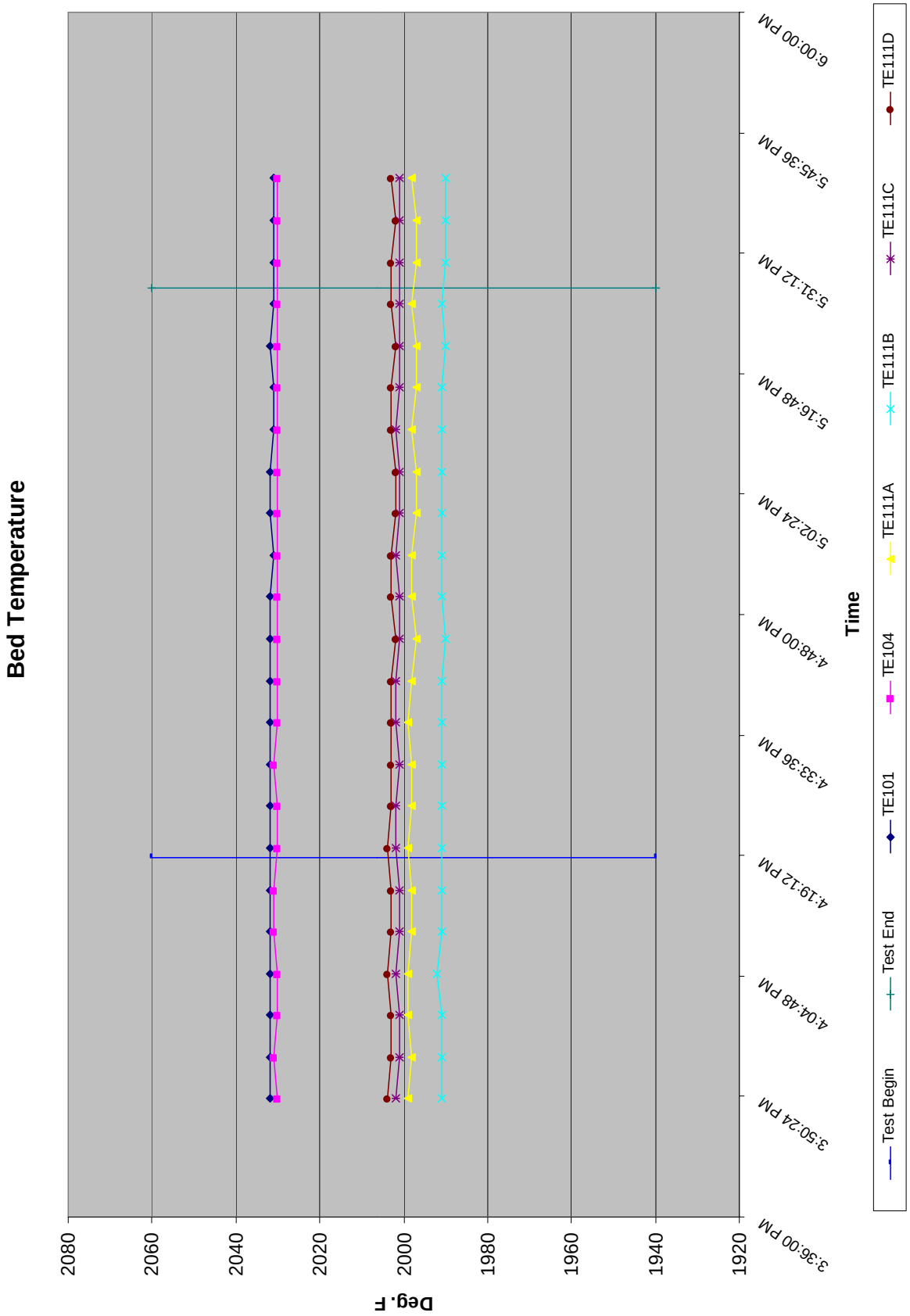

Air Flow Vs InletTemperature
Flow as % of 42000 scfm
Deg F
75
70
65
60
55
50
92.5
92
91.5
91
90.5
90
89.5
89
88.5
88
87.5
8/7/2008 9:21
8/7/2008 9:36
8/7/2008 9:50
8/7/2008 10:04
8/7/2008 10:19
8/7/2008 10:33
8/7/2008 10:48
Time
Test Begin
Test End
Air Flow (% of 42000 scfm)
Inlet Temp (Deg F)

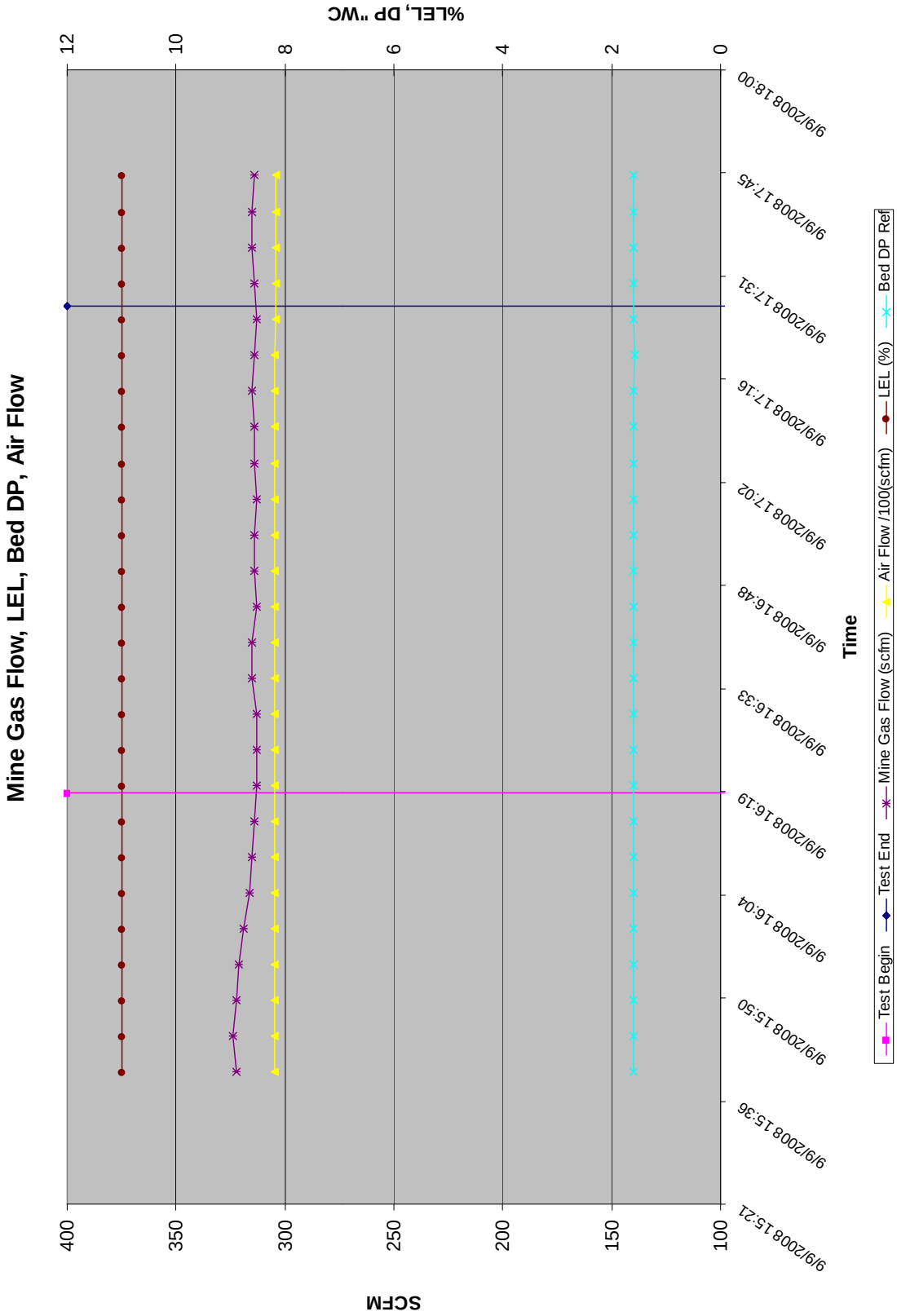

% LEL
% LEL * 10
% LEL
Time
0
20
40
60
80
100
120
140
0
2
4
6
8
10
12
14
8/7/2008 8:52
8/7/2008 9:07
8/7/2008 9:21
8/7/2008 9:36
8/7/2008 9:50
8/7/2008 10:04
8/7/2008 10:19
8/7/2008 10:33
8/7/2008 10:48
8/7/2008 11:02
8/7/2008 11:16
Test Begin
Test End
Quick %LEL*10(1sec)
Hidden %LEL*10(5sec)
Energy %LEL (5min)

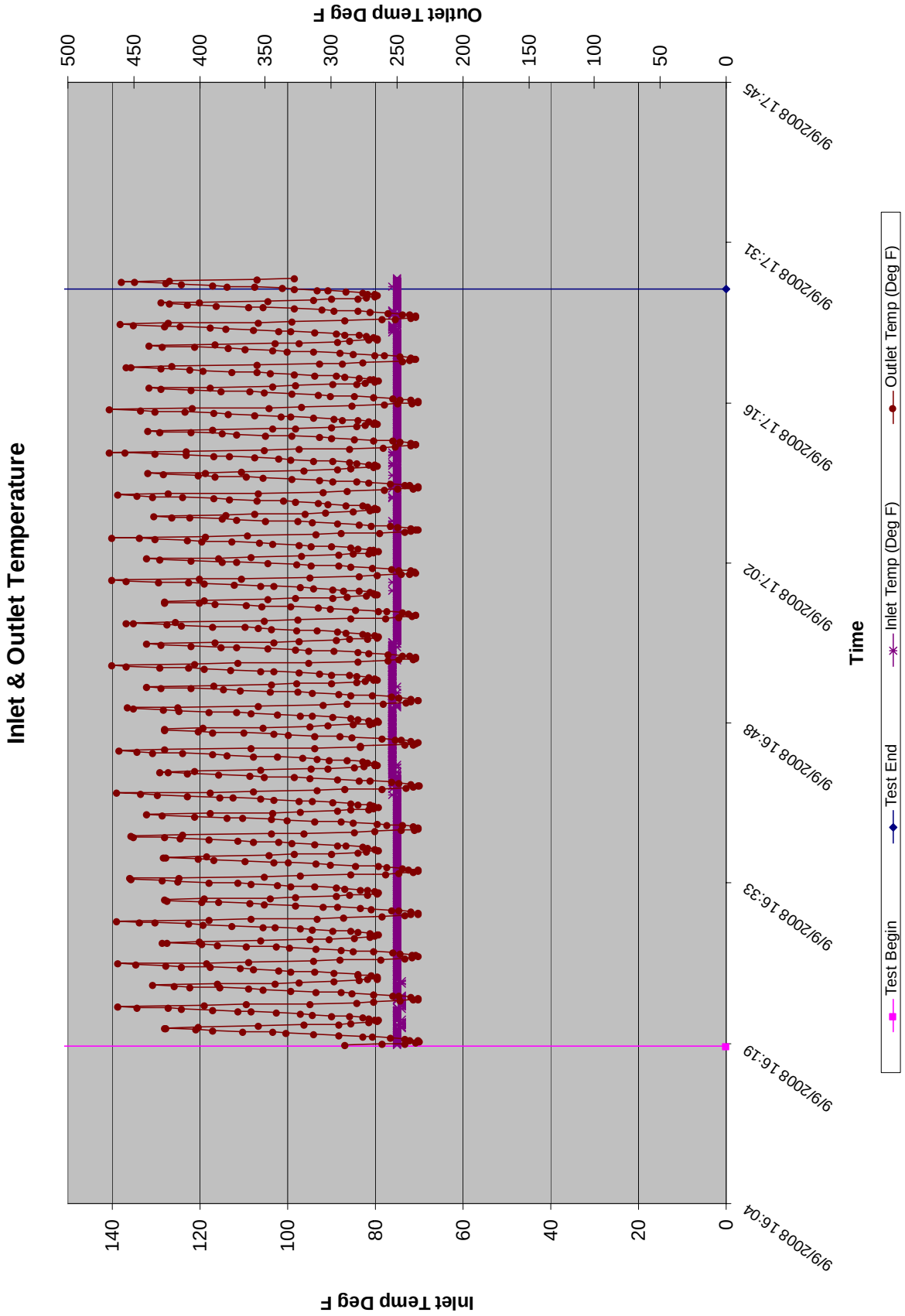

VOC & O2
ppm
2500.00
2000.00
1500.00
1000.00
500.00
0.00
-500.00
%
21
20.5
20
19.5
19
18.5
18
8/7/2008 9:21
8/7/2008 9:36
8/7/2008 9:50
8/7/2008 10:04
8/7/2008 10:19
8/7/2008 10:33
8/7/2008 10:48
Time
Test Begin
Test End
O2 (%)
VOC (ppm)

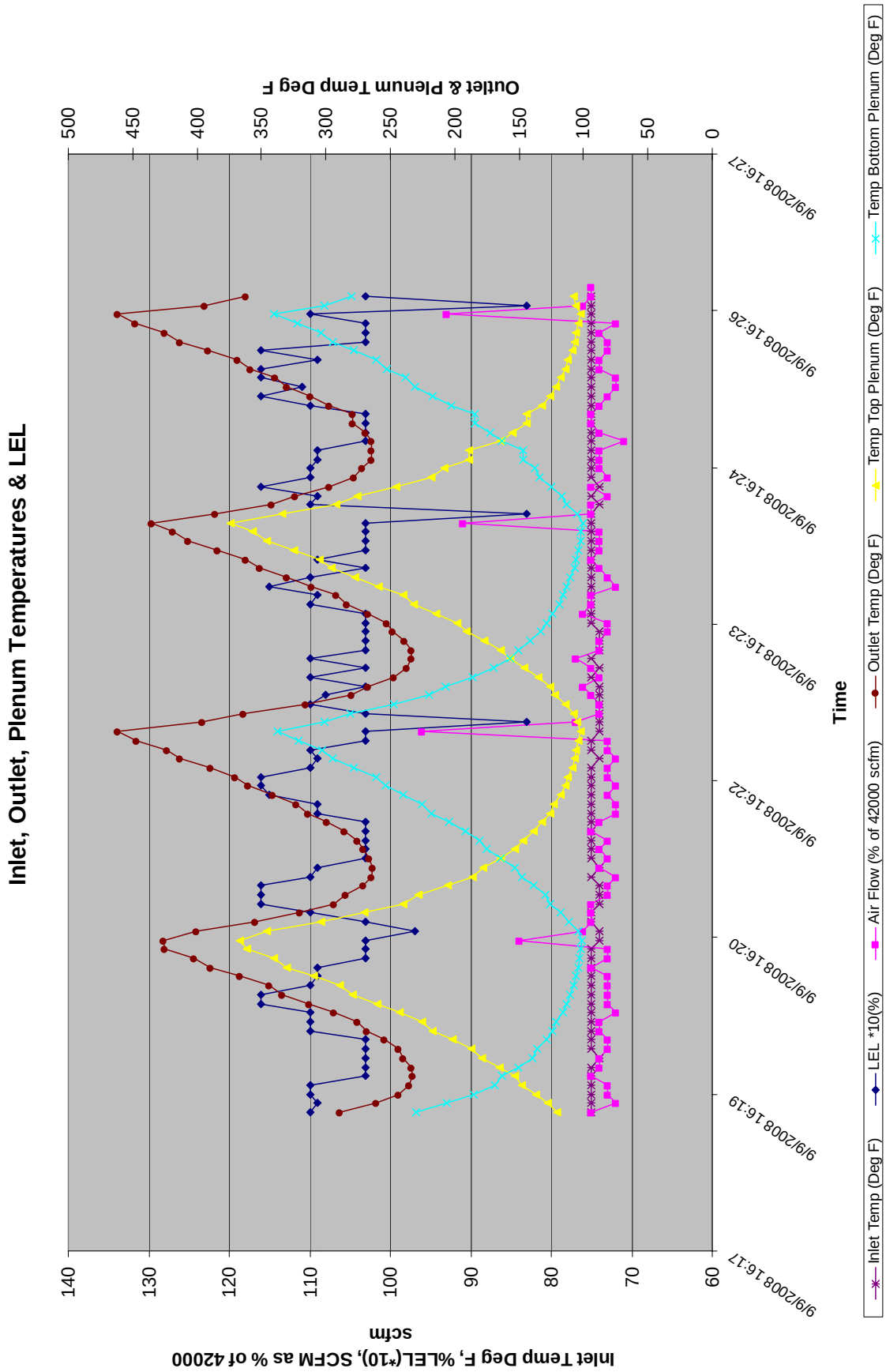

SOx, NOx, CO2, CO
ppm
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
%
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
8/7/2008 9:21
8/7/2008 9:36
8/7/2008 9:50
8/7/2008 10:04
8/7/2008 10:19
8/7/2008 10:33
8/7/2008 10:48
Time
Test Begin
Test End
%CO2
SOx (ppm)
NOx (ppm)
CO (ppm)

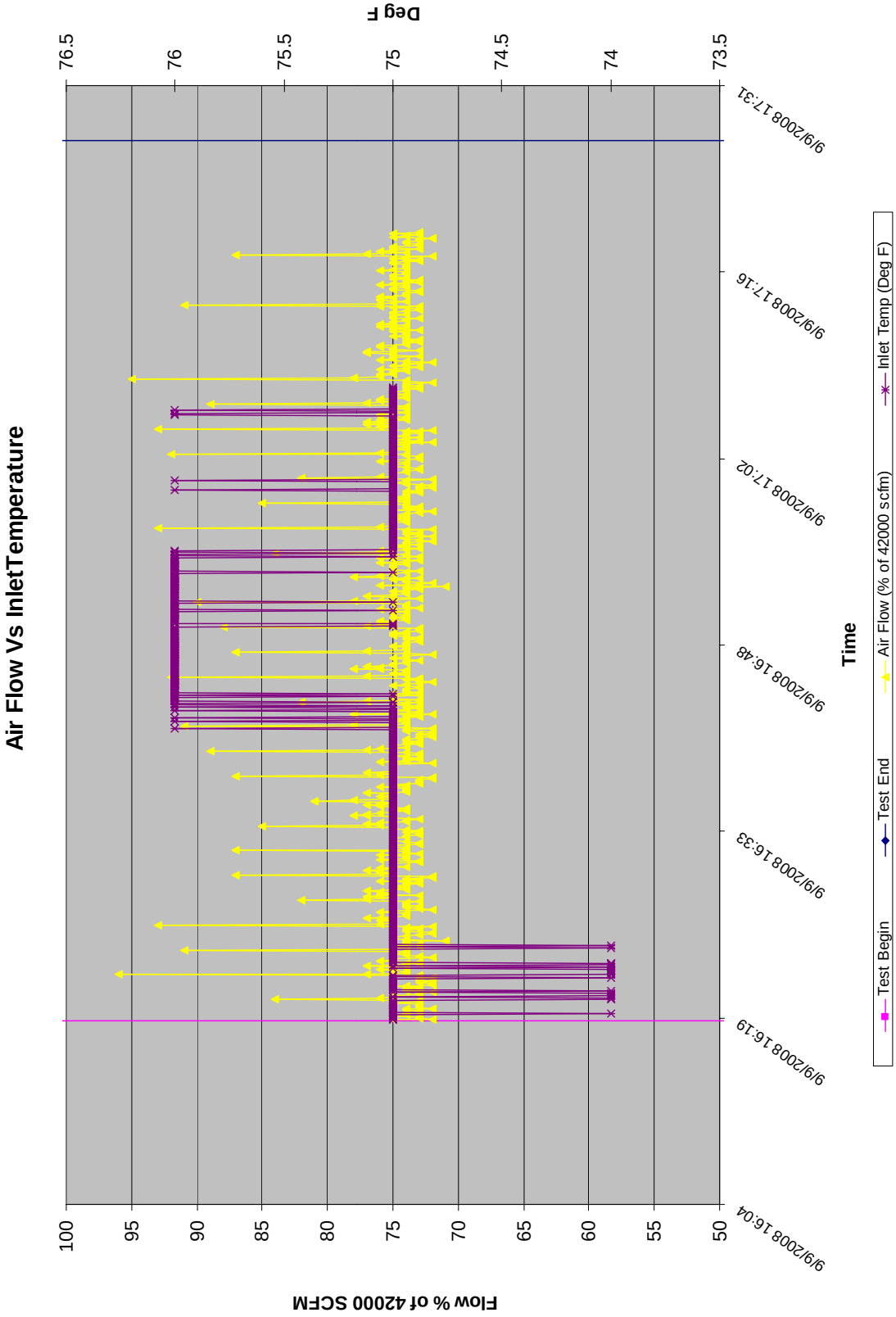
VOCSIDIZER Emission Test
Campaign 3
Run ID: Sept-1
September 09, 2008
4:20 PM – 5:27 PM

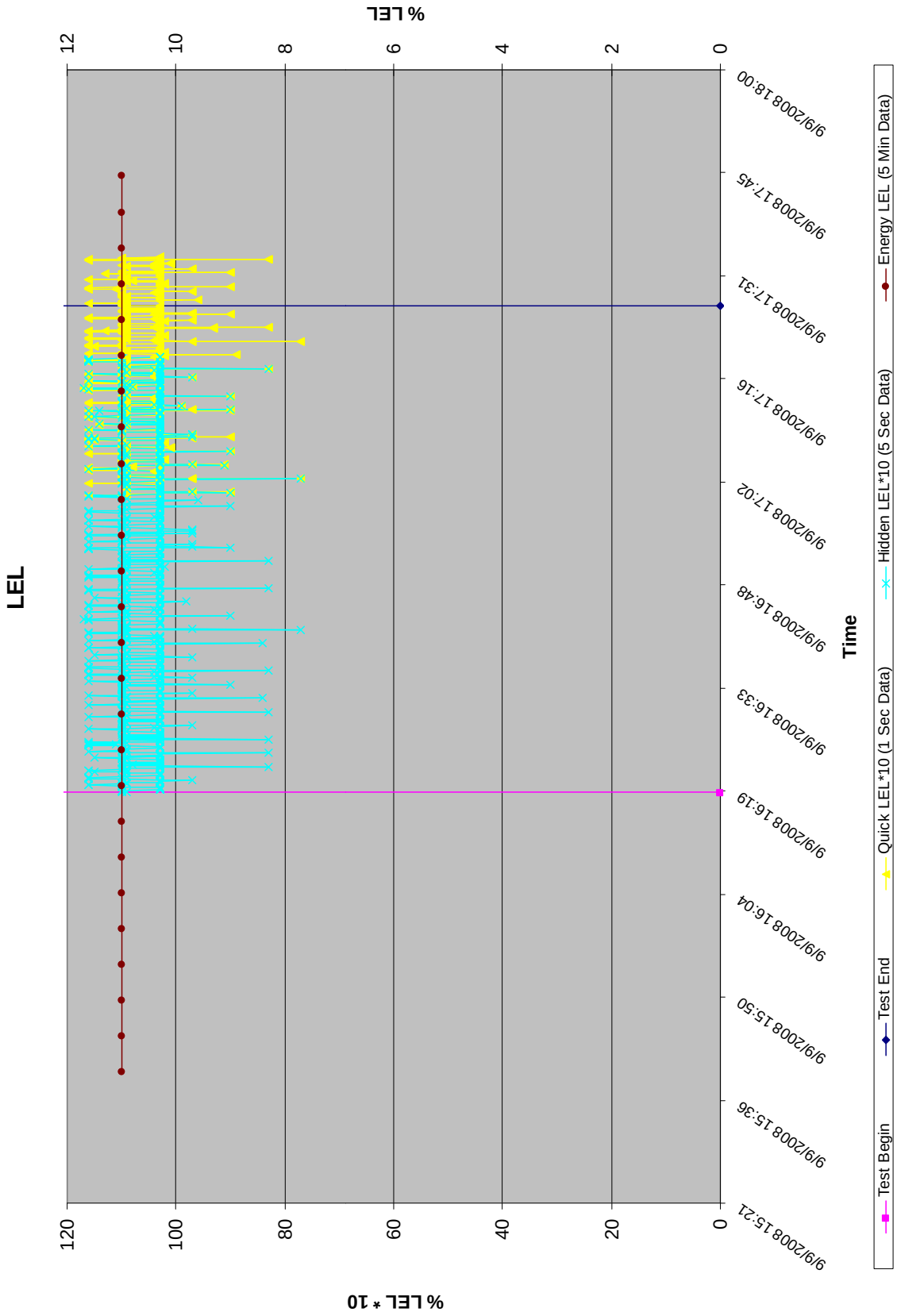

Bed Temperature
Deg. F
2080
2060
2040
2020
2000
1980
1960
1940
1920
3:36:00 PM
3:50:24 PM
4:04:48 PM
4:19:12 PM
4:33:36 PM
4:48:00 PM
5:02:24 PM
5:16:48 PM
5:31:12 PM
5:45:36 PM
6:00:00 PM
Time
Test Begin
Test End
TE101
TE104
TE111A
TE111B
TE111C
TE111D

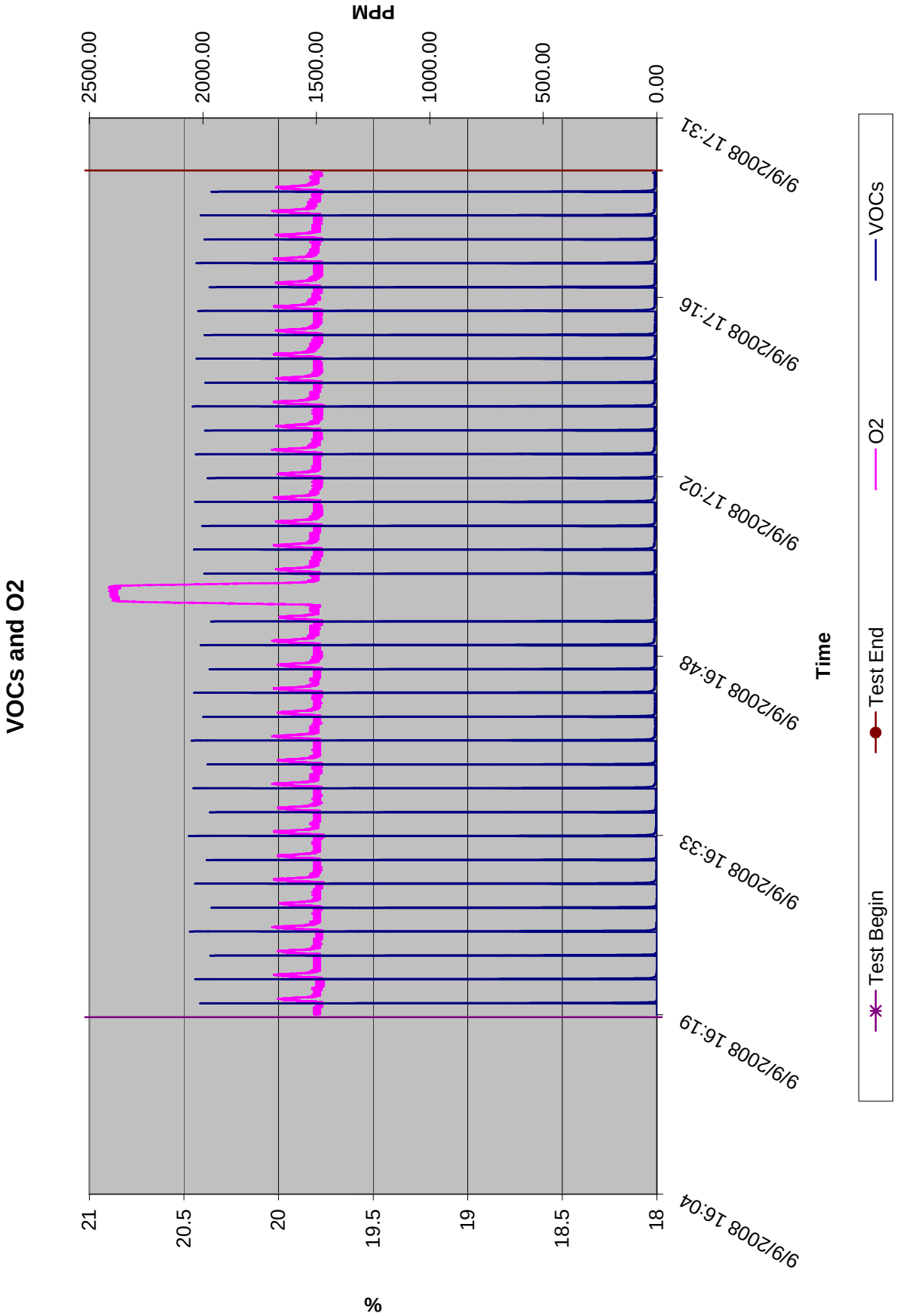

Mine Gas Flow, LEL, Bed DP, Air Flow
SCFM
%LEL, DP "WC
Time
400
350
300
250
200
150
100
12
10
8
6
4
2
0
9/9/2008 15:21
9/9/2008 15:36
9/9/2008 15:50
9/9/2008 16:04
9/9/2008 16:19
9/9/2008 16:33
9/9/2008 16:48
9/9/2008 17:02
9/9/2008 17:16
9/9/2008 17:31
9/9/2008 17:45
9/9/2008 18:00
Test Begin
Test End
Mine Gas Flow (scfm)
Air Flow /100(scfm)
LEL (%)
Bed DP Ref

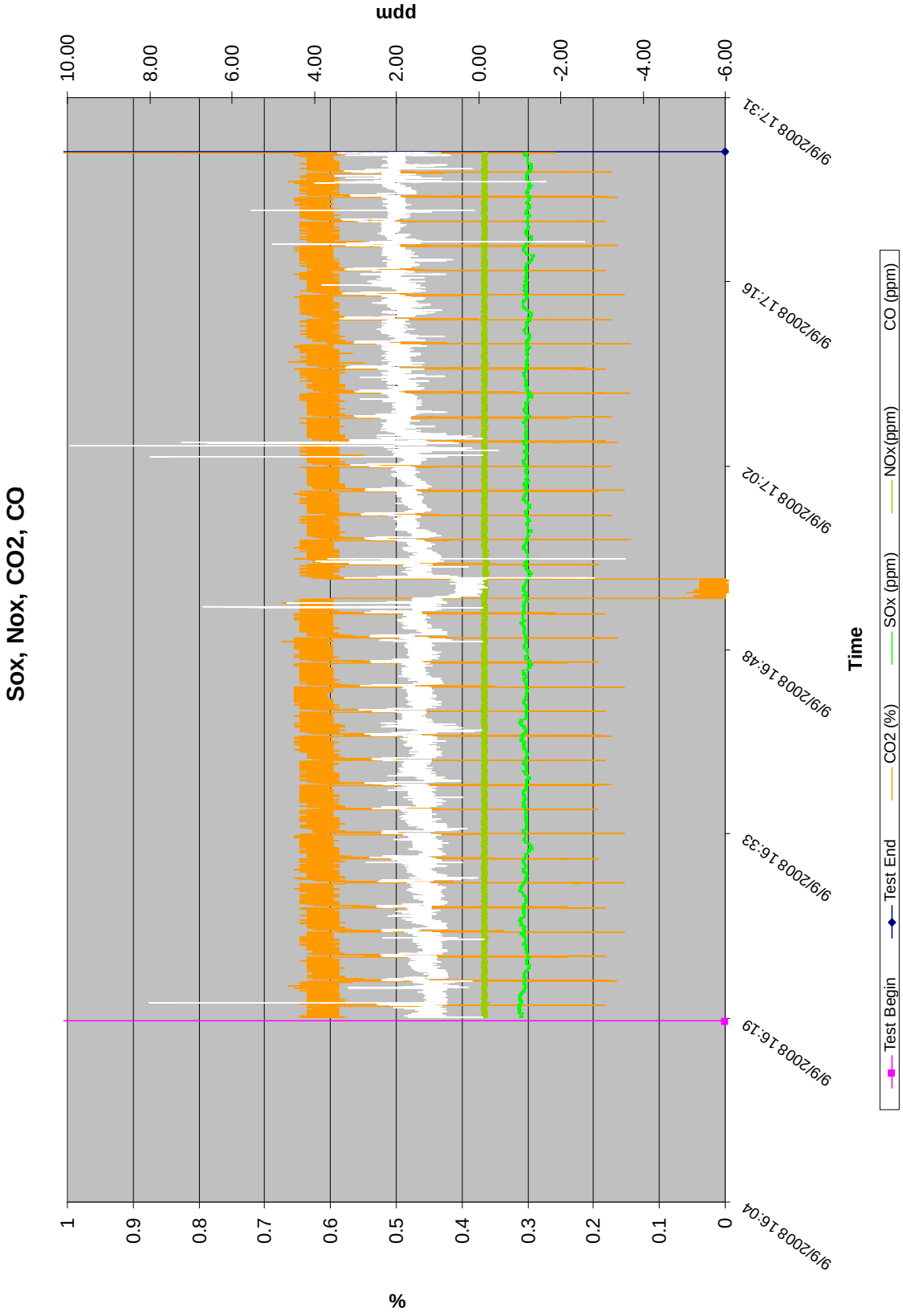

Inlet & Outlet Temperature
Inlet Temp Deg F
Outlet Temp Deg F
Time
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
450
500
9/9/2008 16:04
9/9/2008 16:19
9/9/2008 16:33
9/9/2008 16:48
9/9/2008 17:02
9/9/2008 17:16
9/9/2008 17:31
9/9/2008 17:45
Test Begin
Test End
Inlet Temp (Deg F)
Outlet Temp (Deg F)


Inlet, Outlet, Plenum Temperatures & LEL
Inlet Temp Deg F, %LEL(*10), SCFM as % of 42000 scfm
Outlet & Plenum Temp Deg F
140
130
120
110
100
90
80
70
60
500
450
400
350
300
250
200
150
100
50
0
9/9/2008 16:17
9/9/2008 16:19
9/9/2008 16:20
9/9/2008 16:22
9/9/2008 16:23
9/9/2008 16:24
9/9/2008 16:26
9/9/2008 16:27
Time
Inlet Temp (Deg F)
LEL *10(%)
Air Flow (% of 42000 scfm)
Outlet Temp (Deg F)
Temp Top Plenum (Deg F)
Temp Bottom Plenum (Deg F)

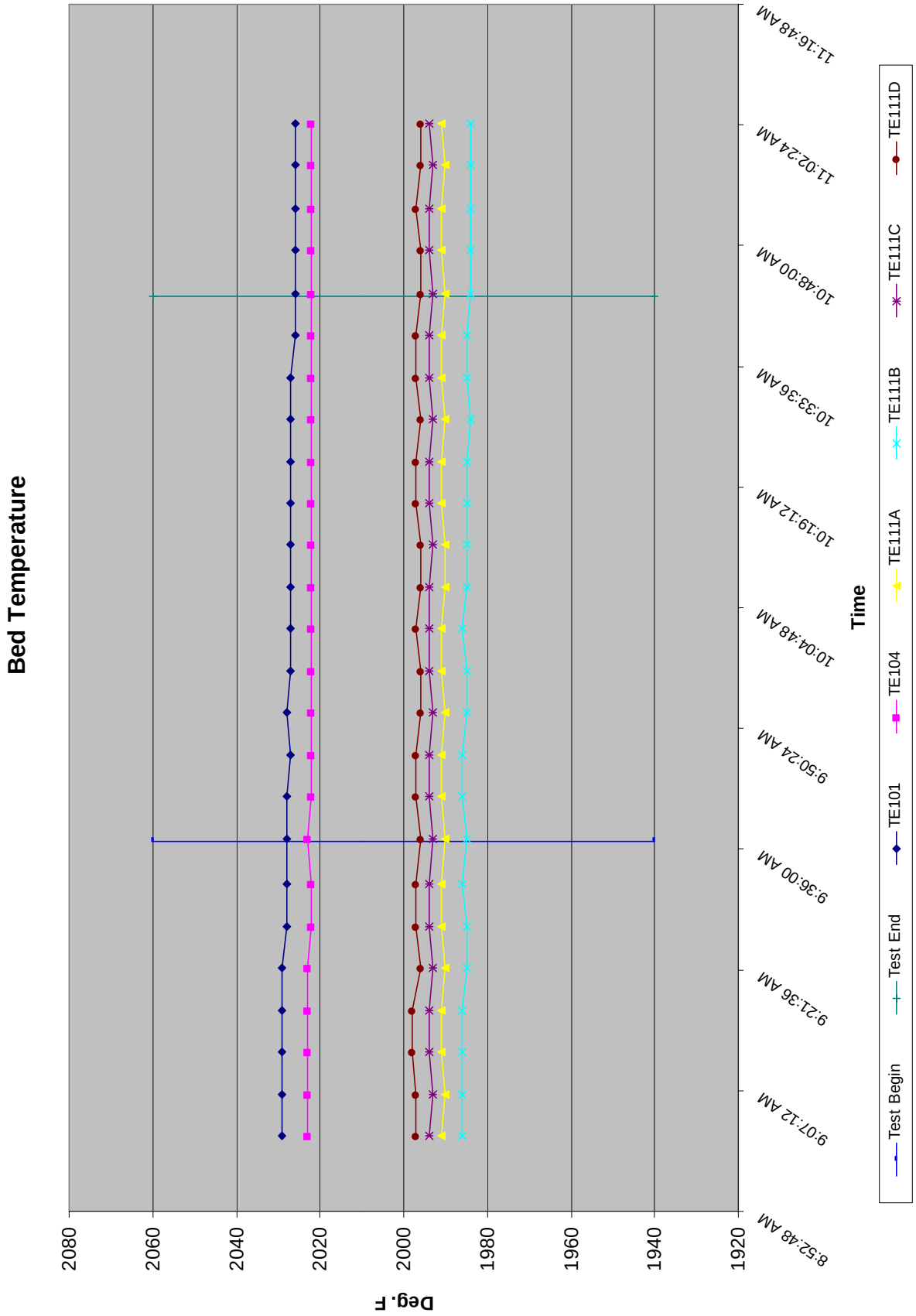

Air Flow Vs InletTemperature
Deg F
76.5
76
75.5
75
74.5
74
73.5
Flow % of 42000 SCFM
100
95
90
85
80
75
70
65
60
55
50
9/9/2008 16:04
9/9/2008 16:19
9/9/2008 16:33
9/9/2008 16:48
9/9/2008 17:02
9/9/2008 17:16
9/9/2008 17:31
Time
Test Begin
Test End
Air Flow (% of 42000 scfm)
Inlet Temp (Deg F)

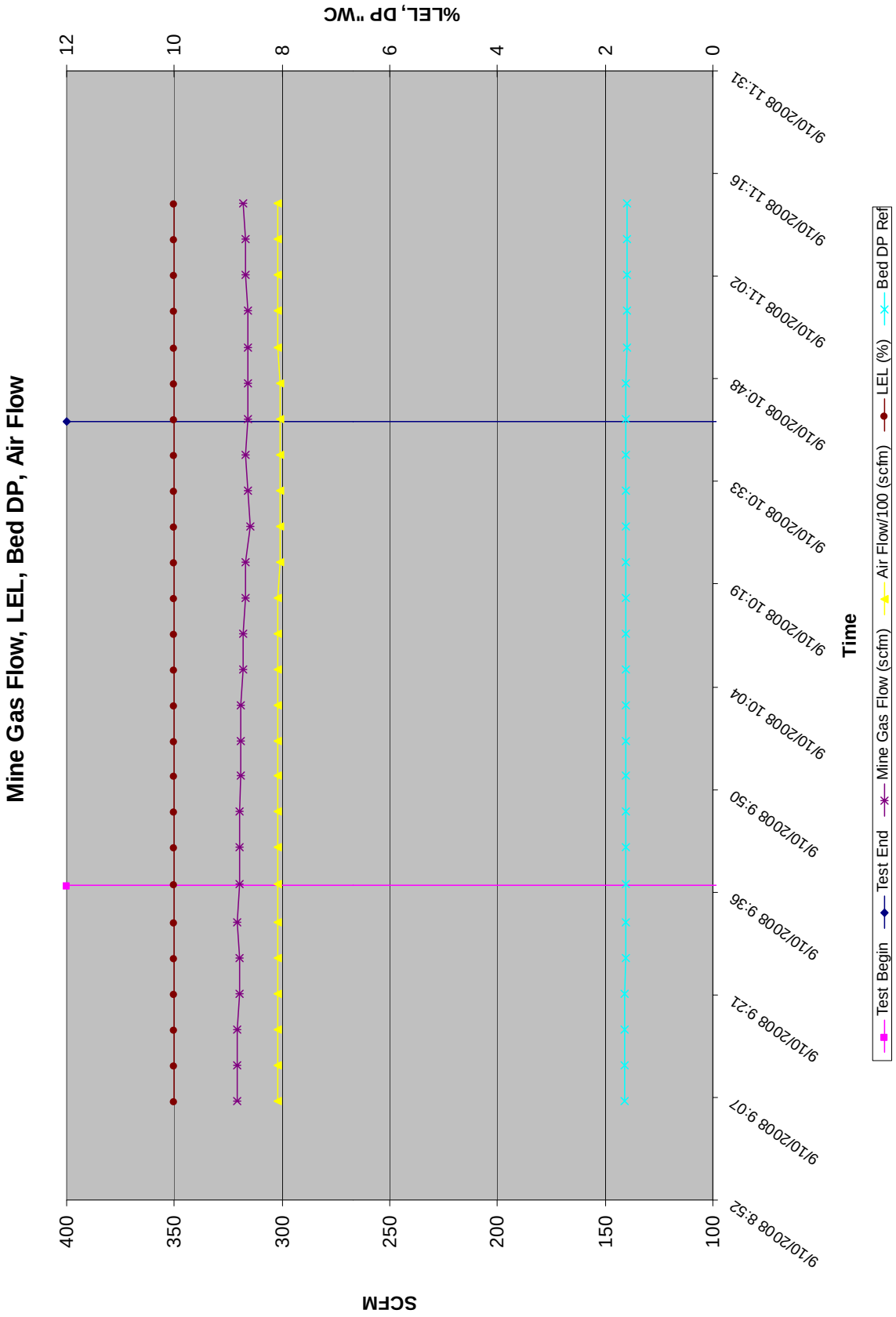

LEL
% LEL * 10
% LEL
Time
120
100
80
60
40
20
0
12
10
8
6
4
2
0
9/9/2008 15:21
9/9/2008 15:36
9/9/2008 15:50
9/9/2008 16:04
9/9/2008 16:19
9/9/2008 16:33
9/9/2008 16:48
9/9/2008 17:02
9/9/2008 17:16
9/9/2008 17:31
9/9/2008 17:45
9/9/2008 18:00
Test Begin
Test End
Quick LEL*10 (1 Sec Data)
Hidden LEL*10 (5 Sec Data)
Energy LEL (5 Min Data)

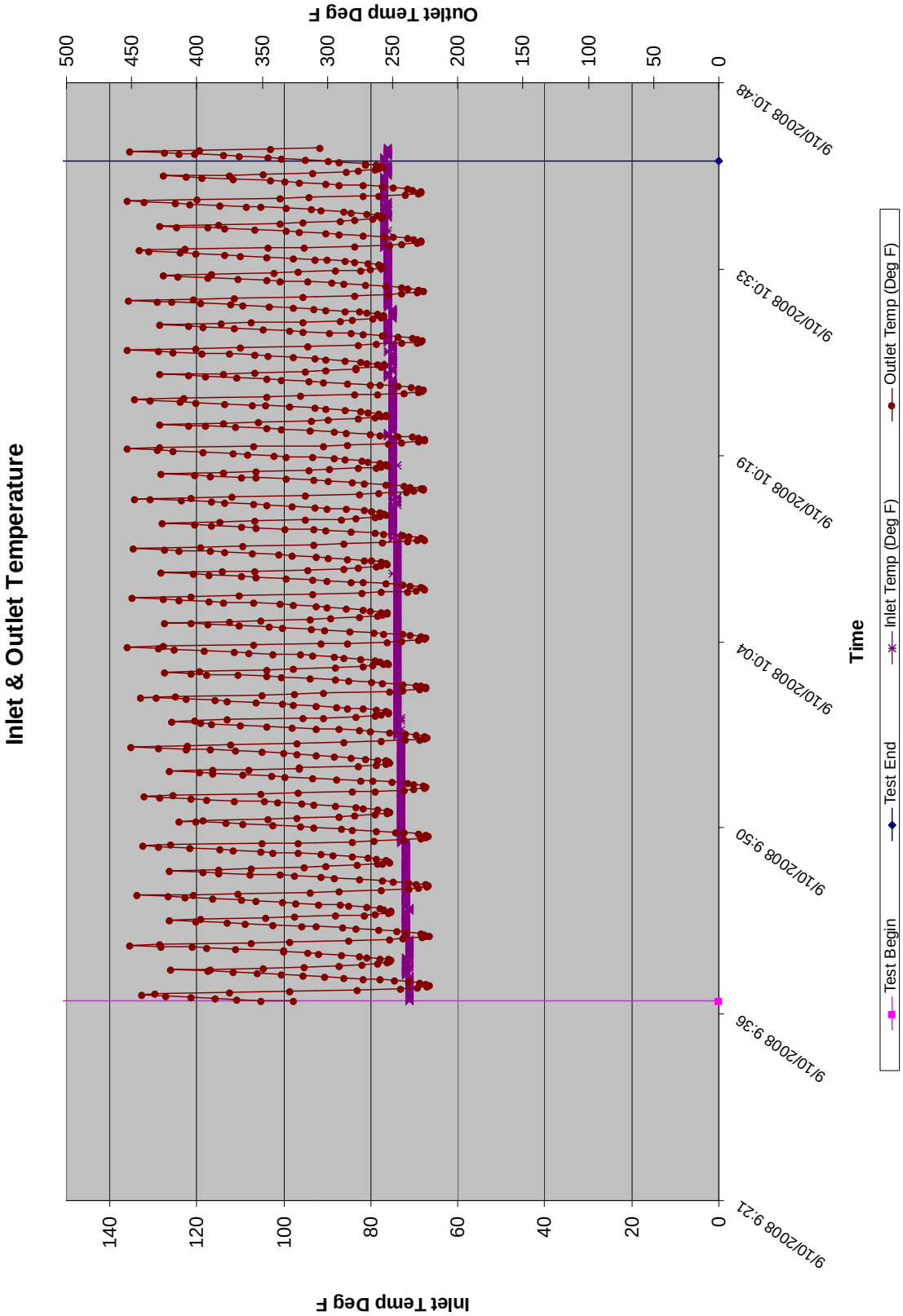

VOCs and O2
ppm
2500.00
2000.00
1500.00
1000.00
500.00
0.00
%
21
20.5
20
19.5
19
18.5
18
9/9/2008 16:04
9/9/2008 16:19
9/9/2008 16:33
9/9/2008 16:48
9/9/2008 17:02
9/9/2008 17:16
9/9/2008 17:31
Time
Test Begin
Test End
O2
VOCs

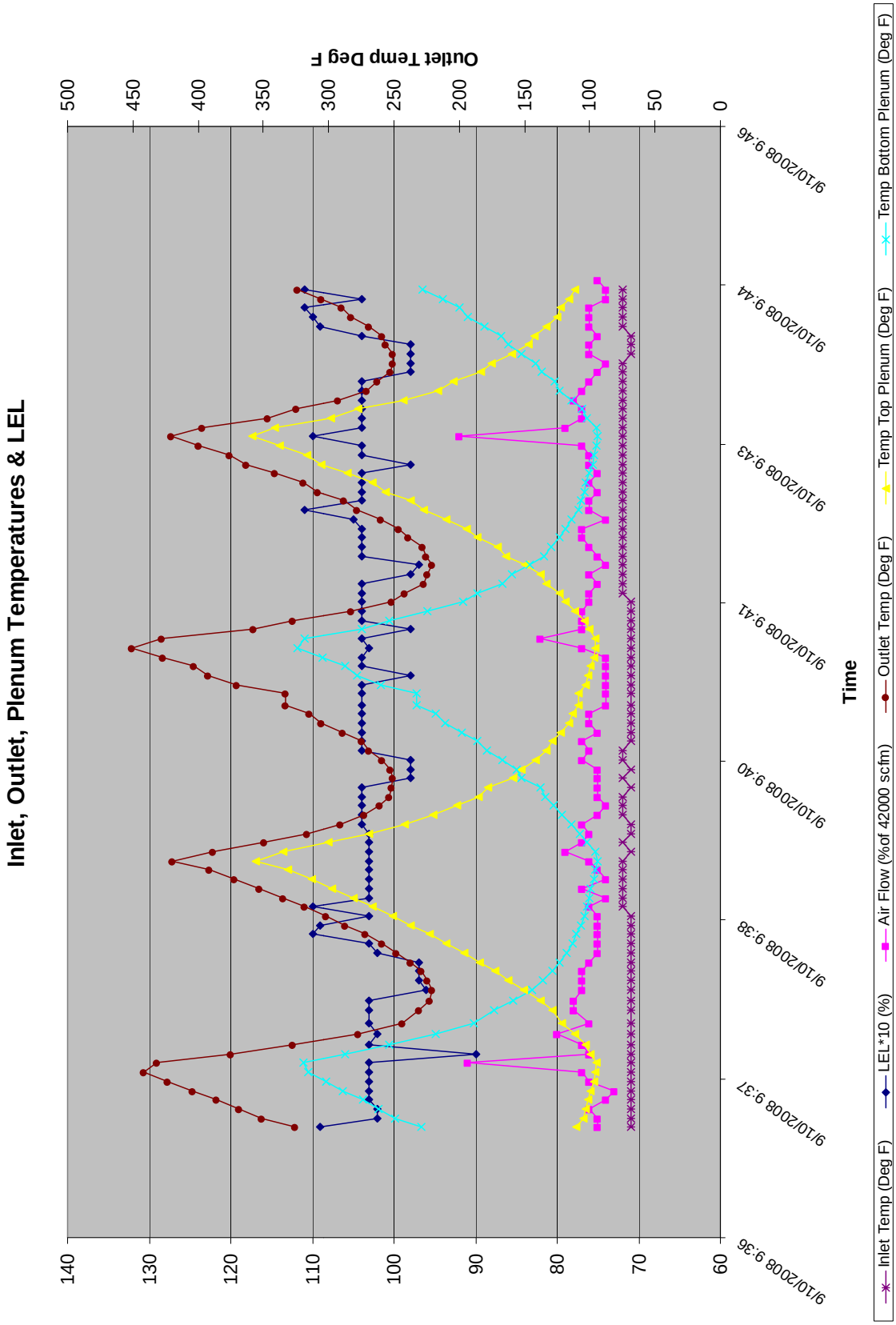

Sox, Nox, CO2, CO
ppm
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
%
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
9/9/2008 16:04
9/9/2008 16:19
9/9/2008 16:33
9/9/2008 16:48
9/9/2008 17:02
9/9/2008 17:16
9/9/2008 17:31
Time
Test Begin
Test End
CO2 (%)
SOx (ppm)
NOx(ppm)
CO (ppm)

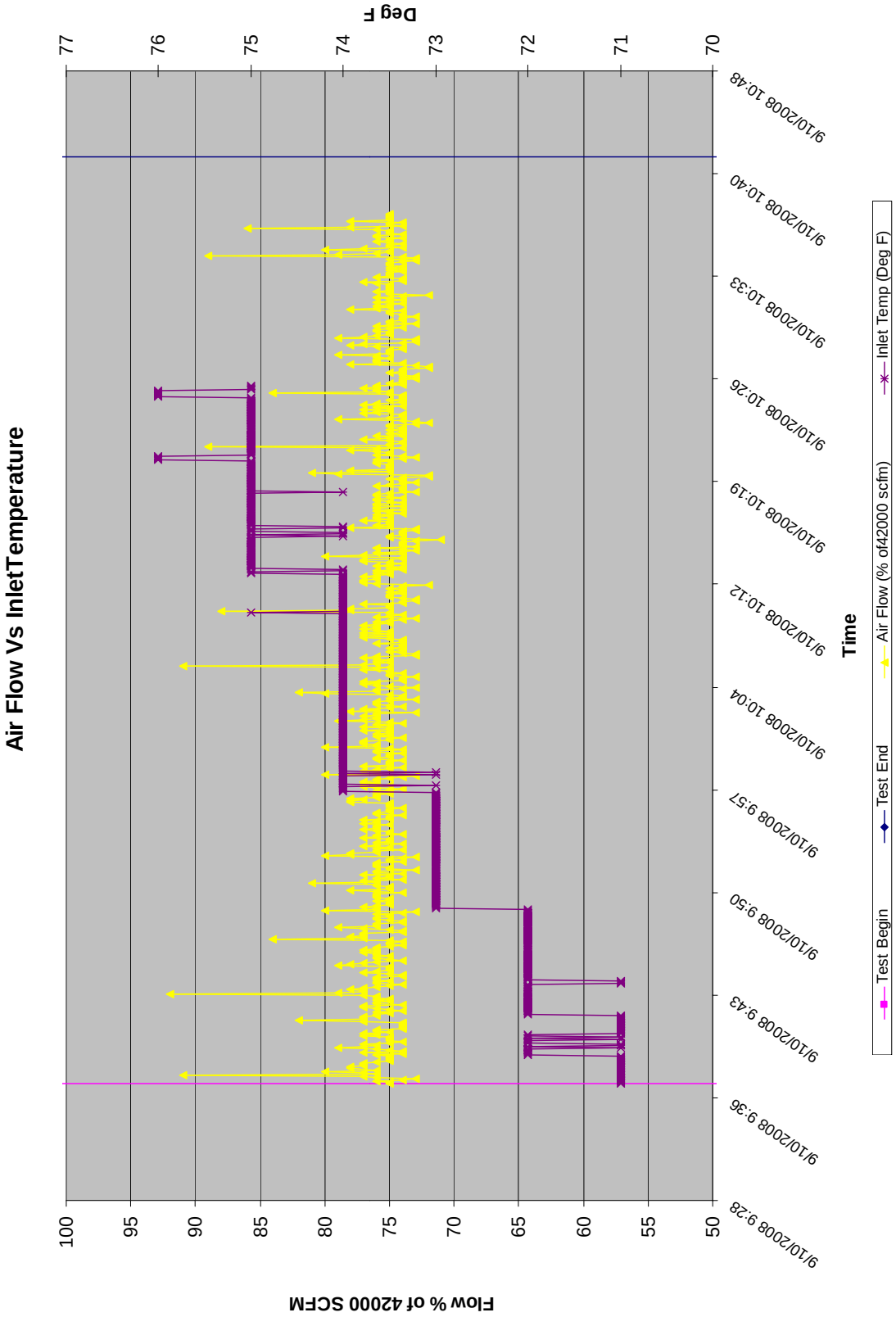
VOCSIDIZER Emission Test
Campaign 3
Run ID: Sept-2
September 10, 2008
9:37 AM – 10:42 AM

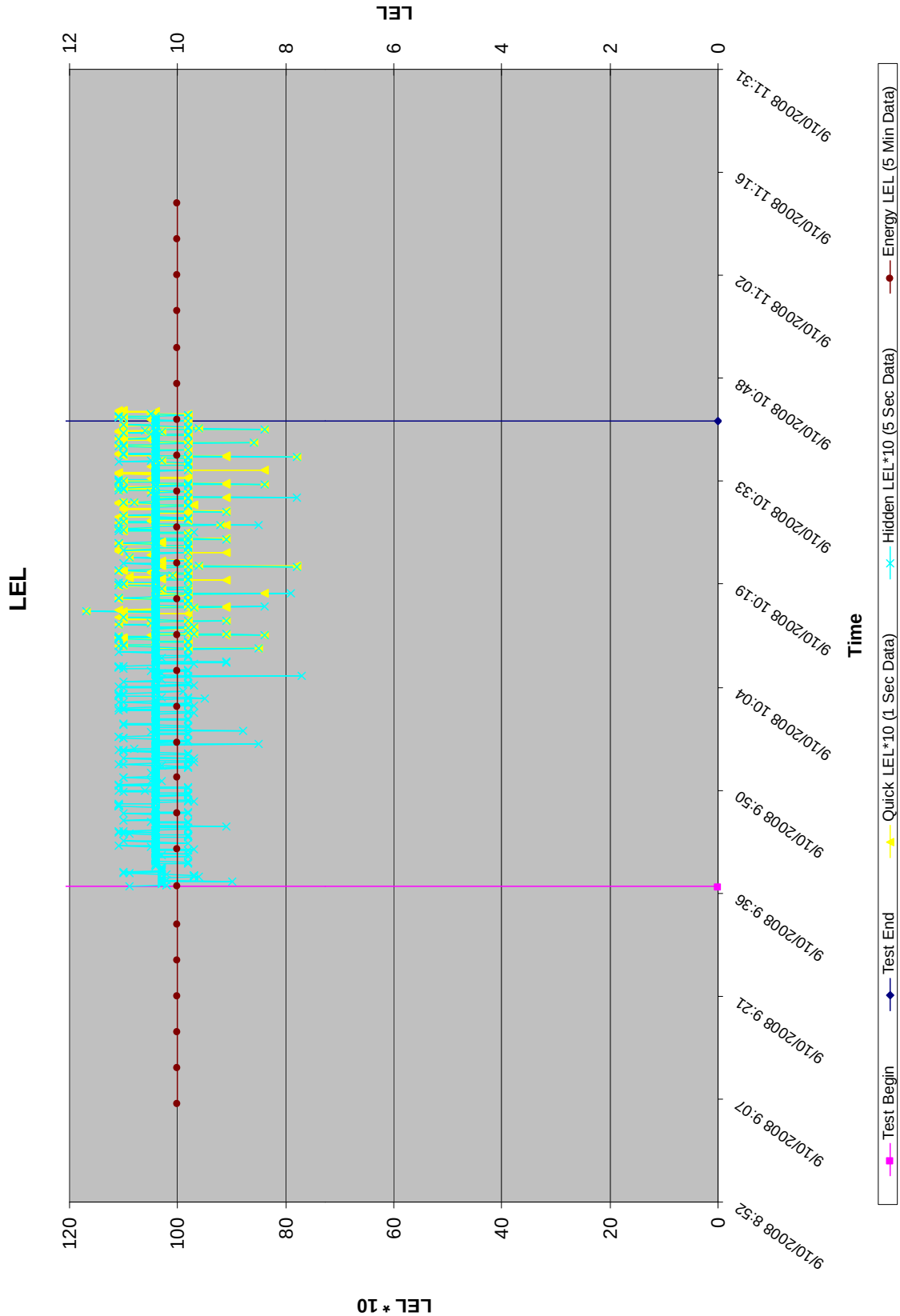

Bed Temperature
Deg. F
2080
2060
2040
2020
2000
1980
1960
1940
1920
8:52:48 AM
9:07:12 AM
9:21:36 AM
9:36:00 AM
9:50:24 AM
10:04:48 AM
10:19:12 AM
10:33:36 AM
10:48:00 AM
11:02:24 AM
11:16:48 AM
Time
Test Begin
Test End
TE101
TE104
TE111A
TE111B
TE111C
TE111D

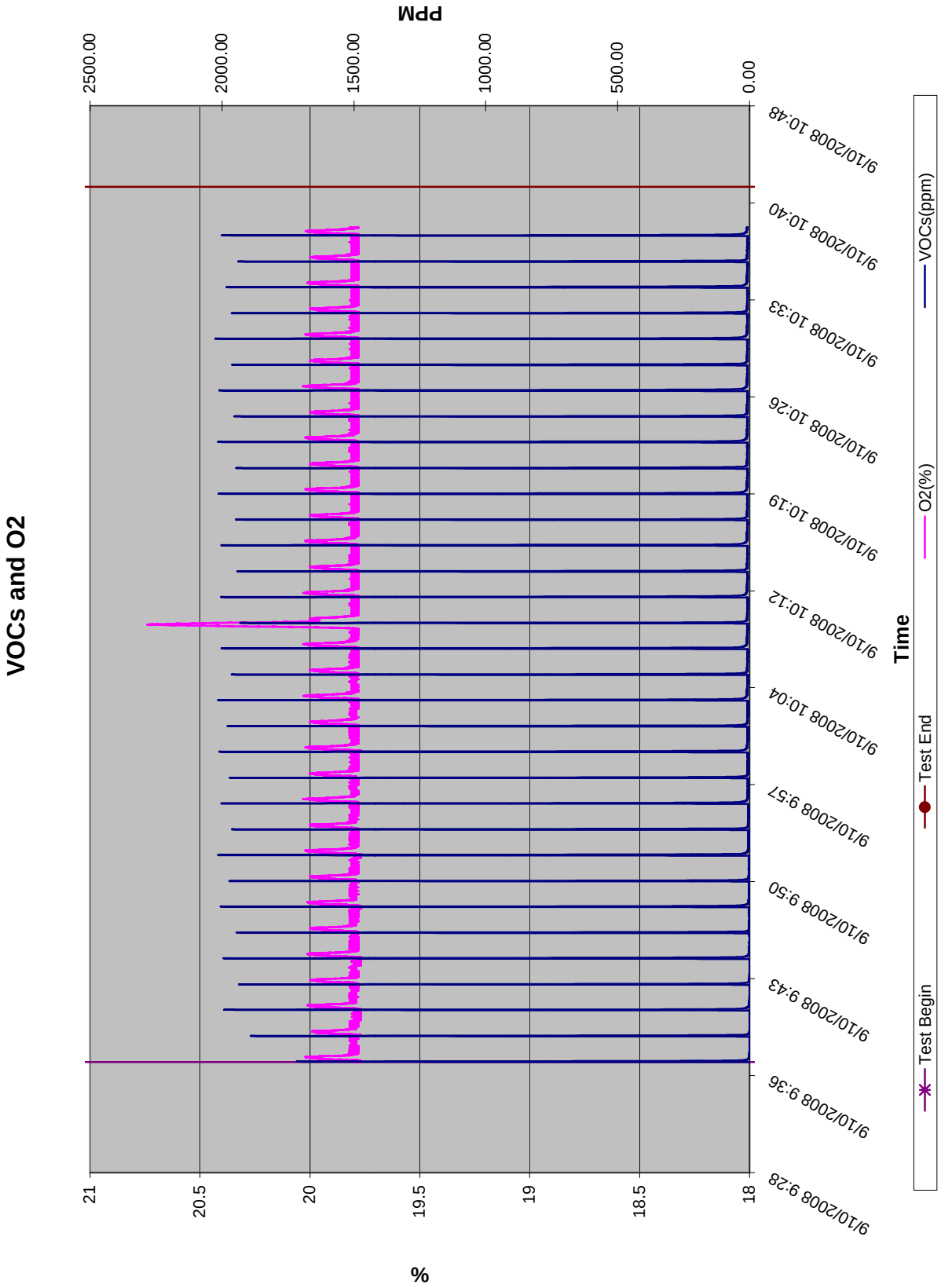

Mine Gas Flow, LEL, Bed DP, Air Flow
SCFM
%LEL, DP "WC
400
350
300
250
200
150
100
12
10
8
6
4
2
0
9/10/2008 8:52
9/10/2008 9:07
9/10/2008 9:21
9/10/2008 9:36
9/10/2008 9:50
9/10/2008 10:04
9/10/2008 10:19
9/10/2008 10:33
9/10/2008 10:48
9/10/2008 11:02
9/10/2008 11:16
9/10/2008 11:31
Time
Test Begin
Test End
Mine Gas Flow (scfm)
Air Flow/100 (scfm)
LEL (%)
Bed DP Ref

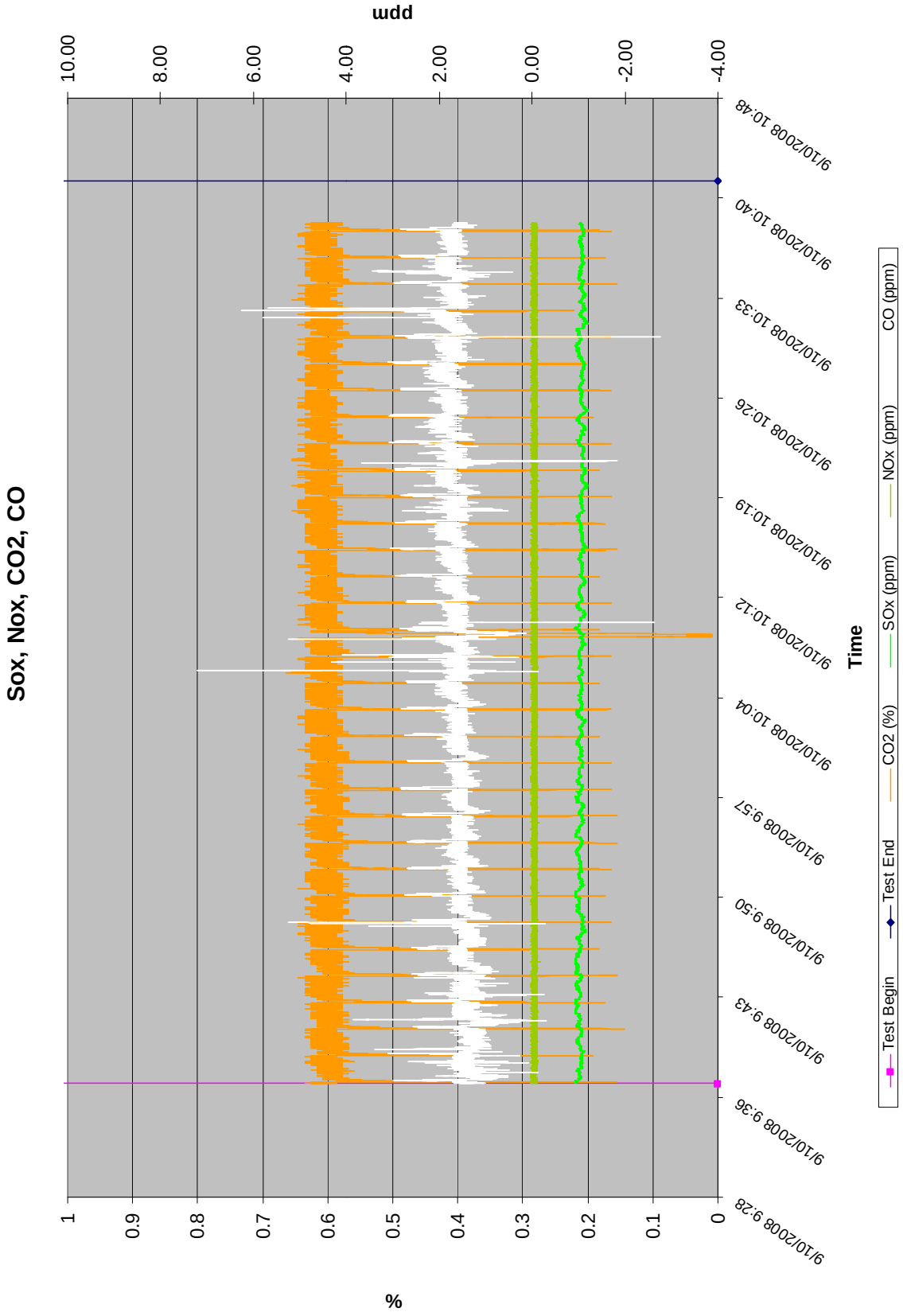

Inlet & Outlet Temperature
Inlet Temp Deg F
Outlet Temp Deg F
Time
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
450
500
9/10/2008 9:21
9/10/2008 9:36
9/10/2008 9:50
9/10/2008 10:04
9/10/2008 10:19
9/10/2008 10:33
9/10/2008 10:48
Test Begin
Test End
Inlet Temp (Deg F)
Outlet Temp (Deg F)


Inlet, Outlet, Plenum Temperatures & LEL
Inlet Temp Deg F, %LEL(*10), Flow % of 42000
Outlet Temp Deg F
140
130
120
110
100
90
80
70
60
500
450
400
350
300
250
200
150
100
50
0
9/10/2008 9:36
9/10/2008 9:37
9/10/2008 9:38
9/10/2008 9:40
9/10/2008 9:41
9/10/2008 9:43
9/10/2008 9:44
9/10/2008 9:46
Time
Inlet Temp (Deg F)
LEL*10 (%)
Air Flow (%of 42000 scfm)
Outlet Temp (Deg F)
Temp Top Plenum (Deg F)
Temp Bottom Plenum (Deg F)

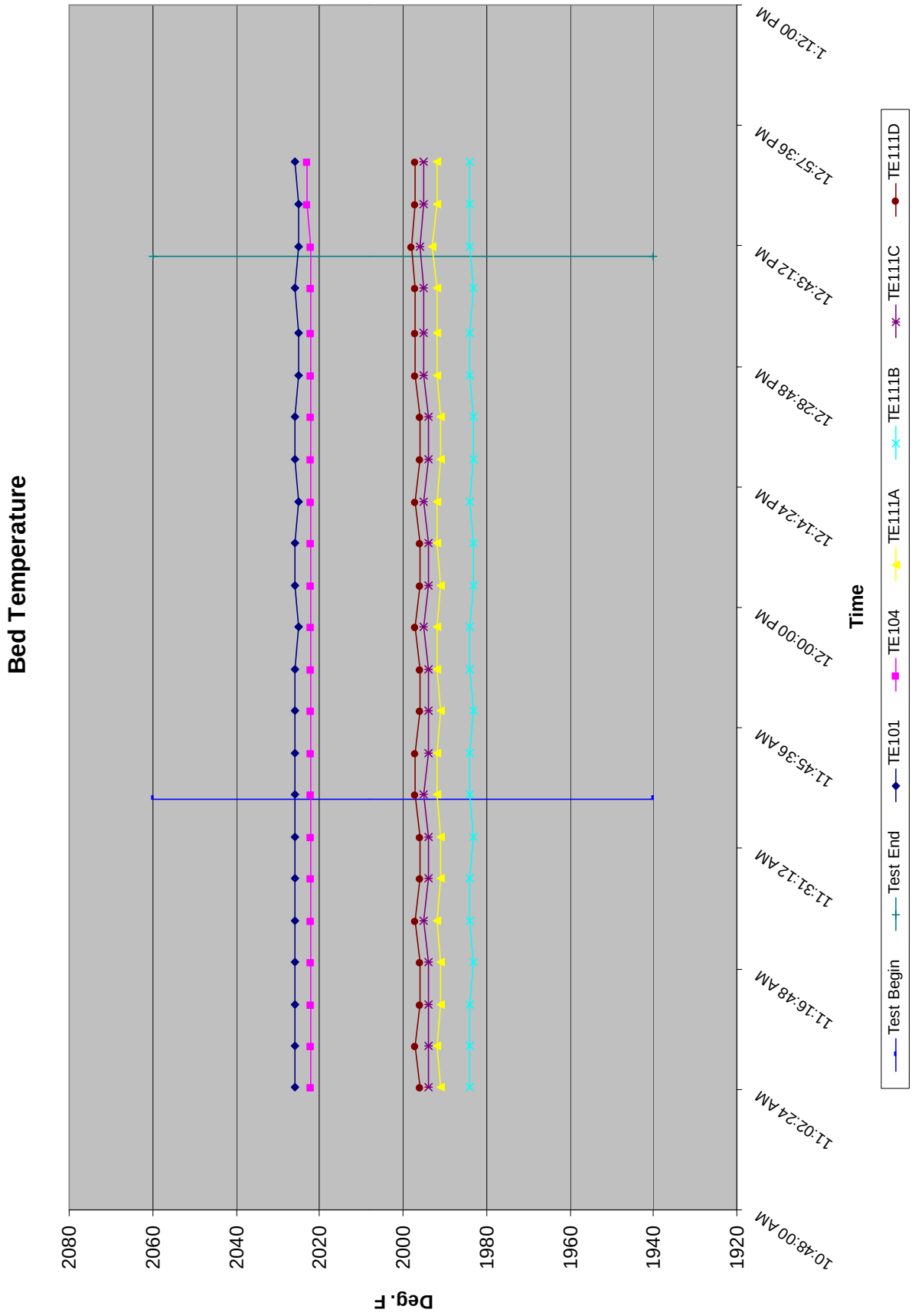

Air Flow Vs InletTemperature
Flow % of 42000 SCFM
Deg F
Time
100
95
90
85
80
75
70
65
60
55
50
77
76
75
74
73
72
71
70
9/10/2008 9:28
9/10/2008 9:36
9/10/2008 9:43
9/10/2008 9:50
9/10/2008 9:57
9/10/2008 10:04
9/10/2008 10:12
9/10/2008 10:19
9/10/2008 10:26
9/10/2008 10:33
9/10/2008 10:40
9/10/2008 10:48
Test Begin
Test End
Air Flow (% of42000 scfm)
Inlet Temp (Deg F)

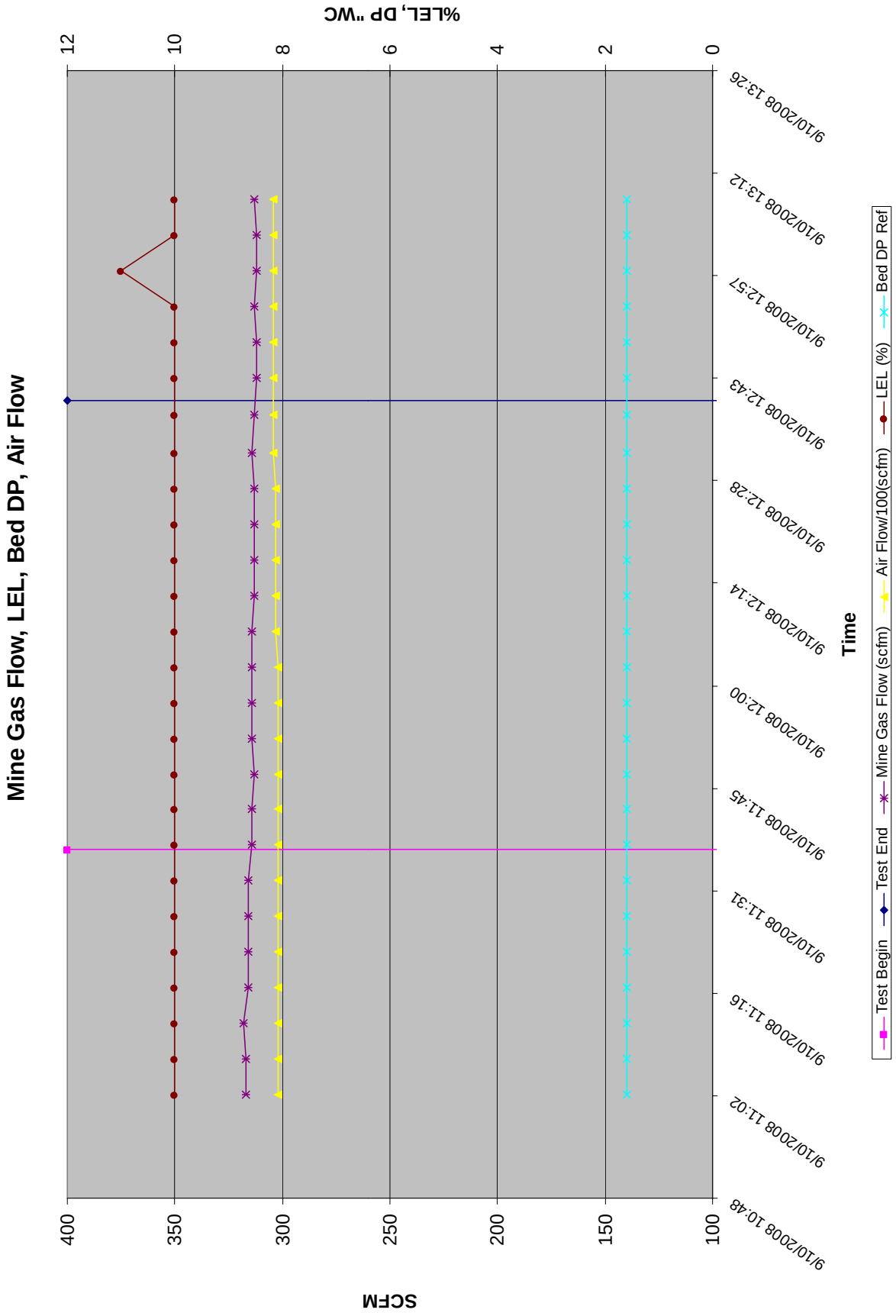

LEL
LEL * 10
120
100
80
60
40
20
0
12
10
8
6
4
2
0
9/10/2008 8:52
9/10/2008 9:07
9/10/2008 9:21
9/10/2008 9:36
9/10/2008 9:50
9/10/2008 10:04
9/10/2008 10:19
9/10/2008 10:33
9/10/2008 10:48
9/10/2008 11:02
9/10/2008 11:16
9/10/2008 11:31
Time
Test Begin
Test End
Quick LEL*10 (1 Sec Data)
Hidden LEL*10 (5 Sec Data)
Energy LEL (5 Min Data)

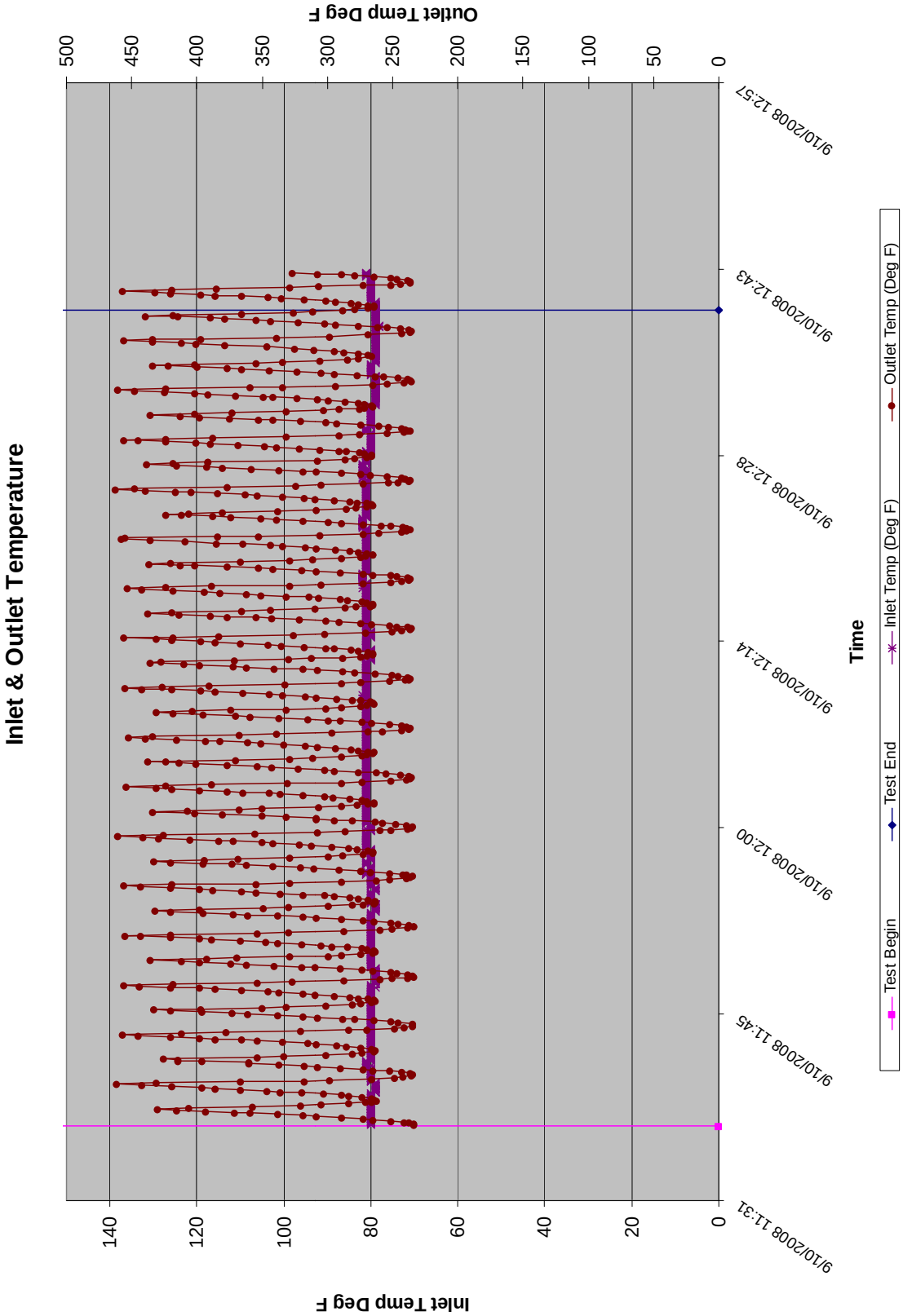

VOCs and O2
ppm
2500.00
2000.00
1500.00
1000.00
500.00
0.00
%
21
20.5
20
19.5
19
18.5
18
9/10/2008 9:28
9/10/2008 9:36
9/10/2008 9:43
9/10/2008 9:50
9/10/2008 9:57
9/10/2008 10:04
9/10/2008 10:12
9/10/2008 10:19
9/10/2008 10:26
9/10/2008 10:33
9/10/2008 10:40
9/10/2008 10:48
Time
Test Begin
Test End
O2(%)
VOCs(ppm)

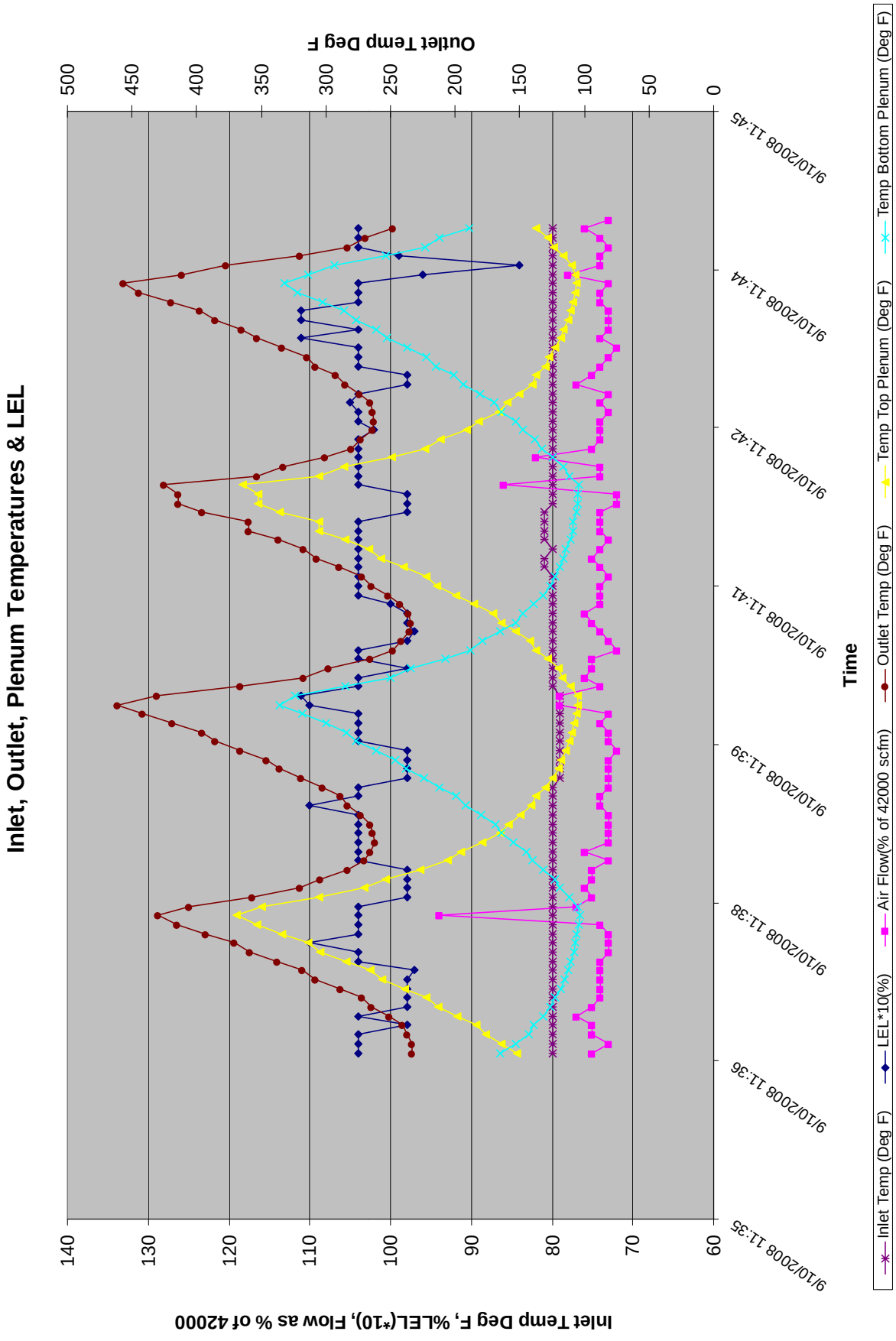

Sox, Nox, CO2, CO
ppm
%
Time
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
9/10/2008 9:28
9/10/2008 9:36
9/10/2008 9:43
9/10/2008 9:50
9/10/2008 9:57
9/10/2008 10:04
9/10/2008 10:12
9/10/2008 10:19
9/10/2008 10:26
9/10/2008 10:33
9/10/2008 10:40
9/10/2008 10:48
Test Begin
Test End
CO2 (%)
SOx (ppm)
NOx (ppm)
CO (ppm)

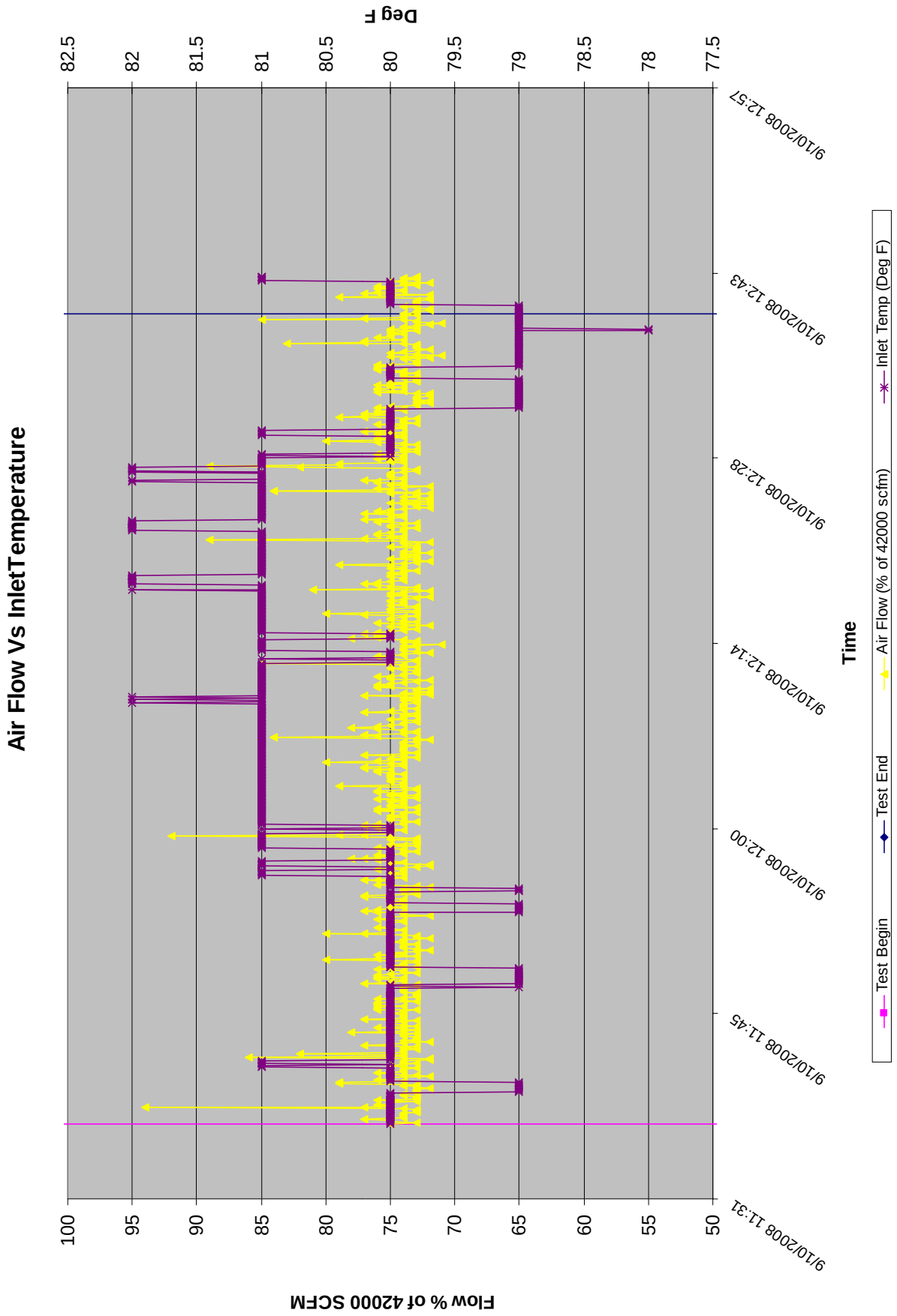
VOCSIDIZER Emission Test
Campaign 3
Run ID: Sept-3
September 10, 2008
11:37 AM – 12:42 PM

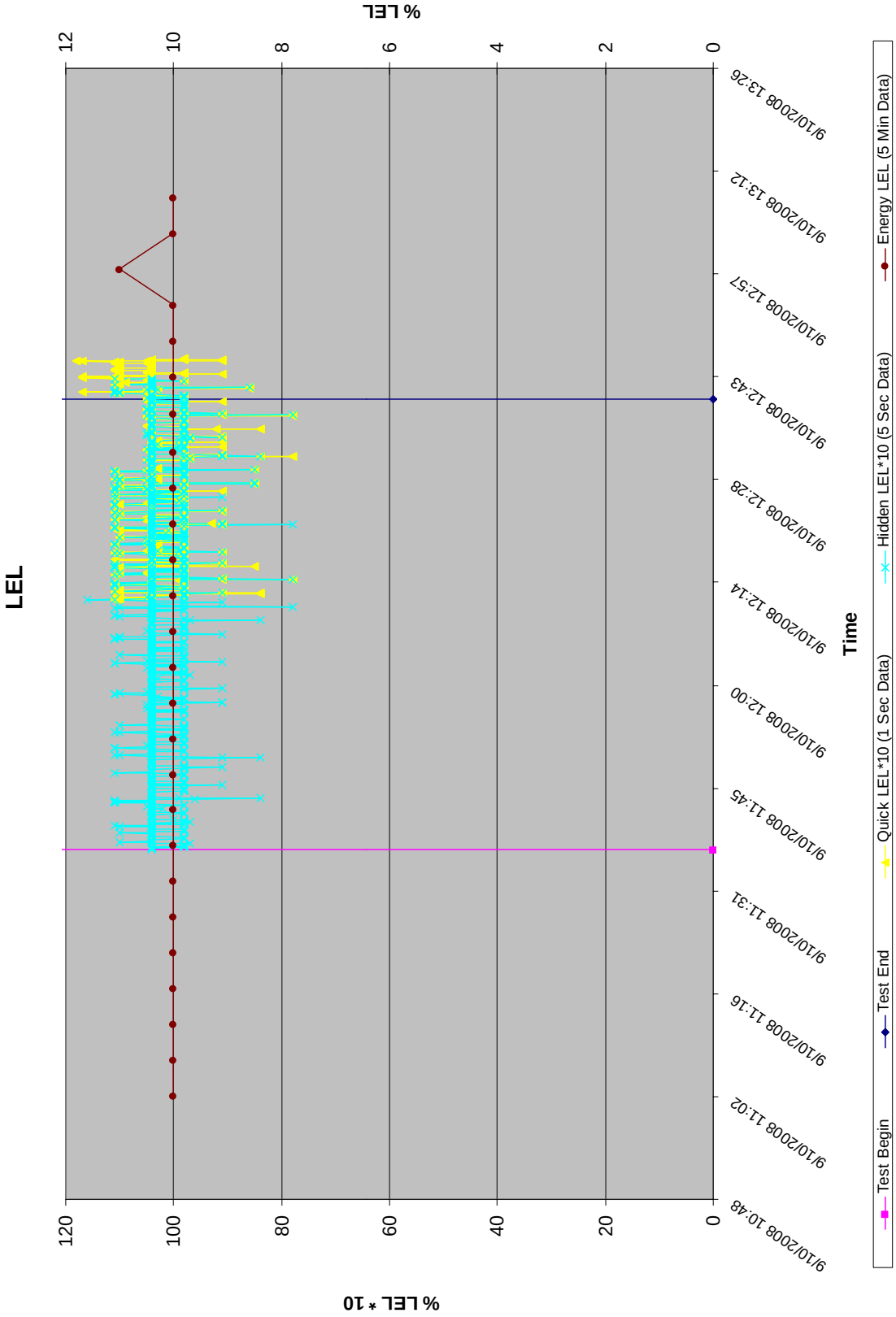

Bed Temperature
Deg. F
2080
2060
2040
2020
2000
1980
1960
1940
1920
10:48:00 AM
11:02:24 AM
11:16:48 AM
11:31:12 AM
11:45:36 AM
12:00:00 PM
12:14:24 PM
12:28:48 PM
12:43:12 PM
12:57:36 PM
1:12:00 PM
Time
Test Begin
Test End
TE101
TE104
TE111A
TE111B
TE111C
TE111D

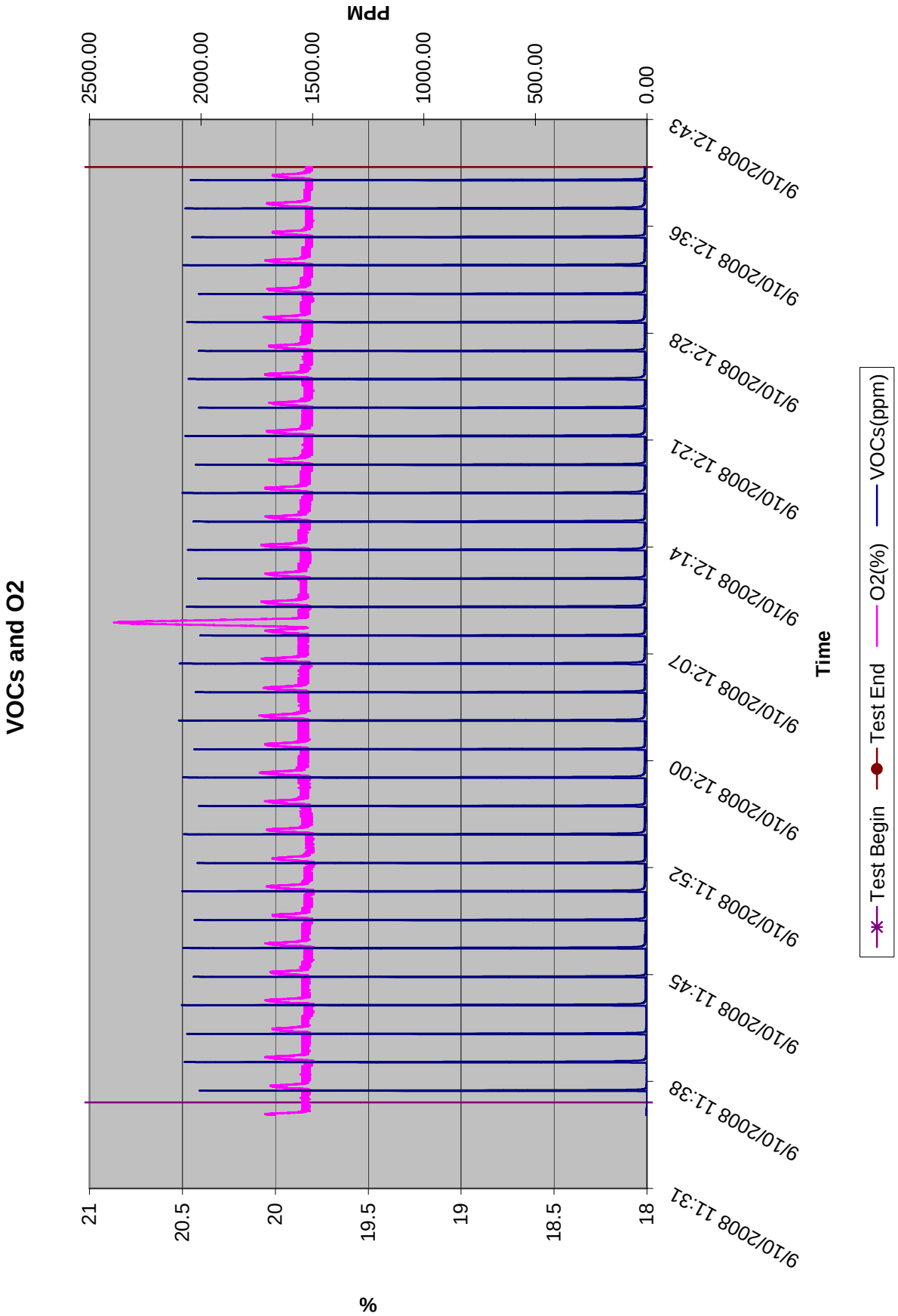

Mine Gas Flow, LEL, Bed DP, Air Flow
SCFM
%LEL, DP "WC
400
350
300
250
200
150
100
12
10
8
6
4
2
0
9/10/2008 10:48
9/10/2008 11:02
9/10/2008 11:16
9/10/2008 11:31
9/10/2008 11:45
9/10/2008 12:00
9/10/2008 12:14
9/10/2008 12:28
9/10/2008 12:43
9/10/2008 12:57
9/10/2008 13:12
9/10/2008 13:26
Time
Test Begin
Test End
Mine Gas Flow (scfm)
Air Flow/100(scfm)
LEL (%)
Bed DP Ref

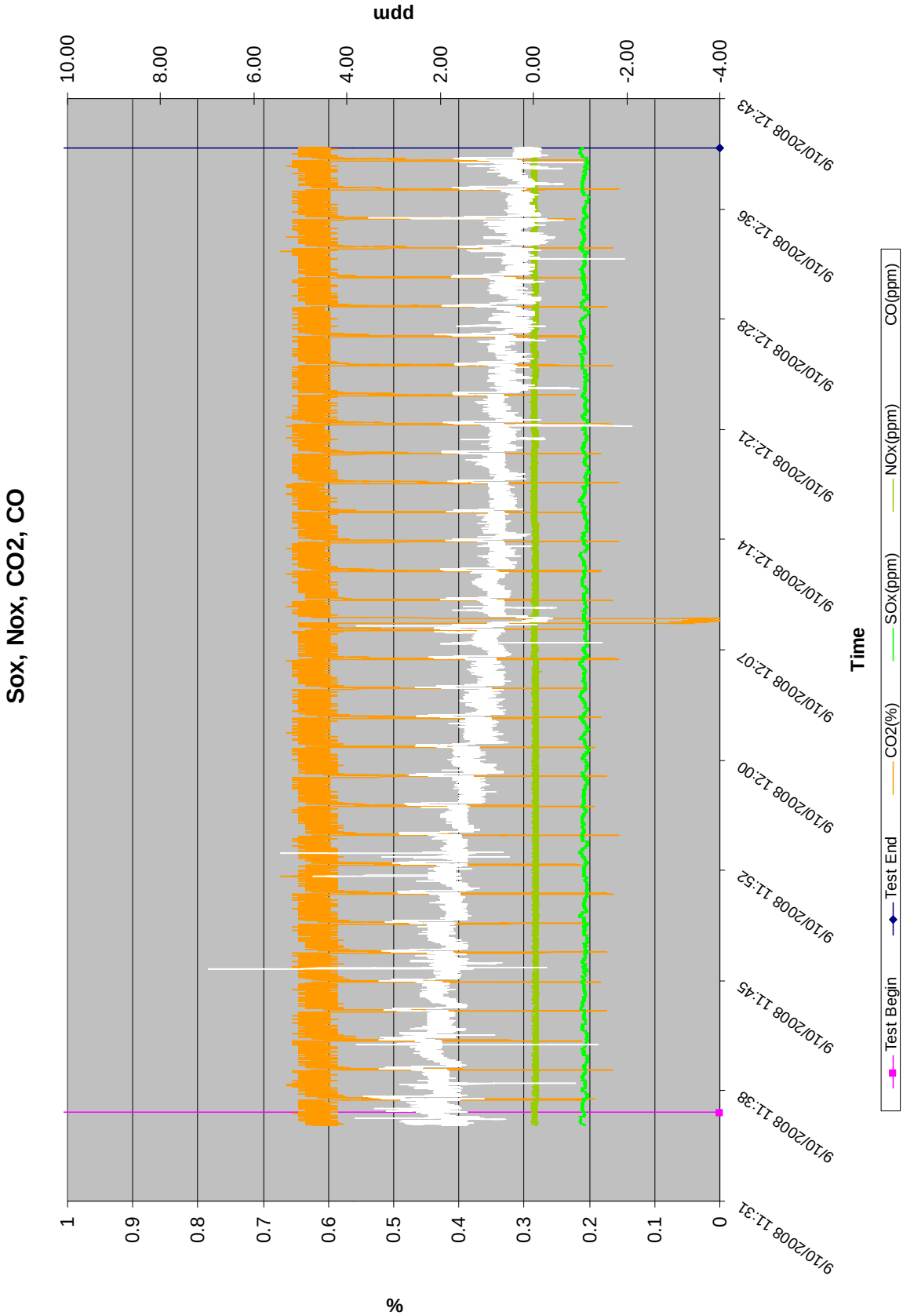

Inlet & Outlet Temperature
Inlet Temp Deg F
Outlet Temp Deg F
Time
140
120
100
80
60
40
20
0
500
450
400
350
300
250
200
150
100
50
0
9/10/2008 11:31
9/10/2008 11:45
9/10/2008 12:00
9/10/2008 12:14
9/10/2008 12:28
9/10/2008 12:43
9/10/2008 12:57
Test Begin
Test End
Inlet Temp (Deg F)
Outlet Temp (Deg F)


Inlet, Outlet, Plenum Temperatures & LEL
Inlet Temp Deg F, %LEL(*10), Flow as % of 42000
Outlet Temp Deg F
140
130
120
110
100
90
80
70
60
500
450
400
350
300
250
200
150
100
50
0
9/10/2008 11:35
9/10/2008 11:36
9/10/2008 11:38
9/10/2008 11:39
9/10/2008 11:41
9/10/2008 11:42
9/10/2008 11:44
9/10/2008 11:45
Time
Inlet Temp (Deg F)
LEL*10(%)
Air Flow(% of 42000 scfm)
Outlet Temp (Deg F)
Temp Top Plenum (Deg F)
Temp Bottom Plenum (Deg F)


Air Flow Vs InletTemperature
Flow % of 42000 SCFM
Deg F
100
95
90
85
80
75
70
65
60
55
50
82.5
82
81.5
81
80.5
80
79.5
79
78.5
78
77.5
9/10/2008 11:31
9/10/2008 11:45
9/10/2008 12:00
9/10/2008 12:14
9/10/2008 12:28
9/10/2008 12:43
9/10/2008 12:57
Time
Test Begin
Test End
Air Flow (% of 42000 scfm)
Inlet Temp (Deg F)


LEL
% LEL * 10
% LEL
Time
120
100
80
60
40
20
0
12
10
8
6
4
2
0
9/10/2008 10:48
9/10/2008 11:02
9/10/2008 11:16
9/10/2008 11:31
9/10/2008 11:45
9/10/2008 12:00
9/10/2008 12:14
9/10/2008 12:28
9/10/2008 12:43
9/10/2008 12:57
9/10/2008 13:12
9/10/2008 13:26
Test Begin
Test End
Quick LEL*10 (1 Sec Data)
Hidden LEL*10 (5 Sec Data)
Energy LEL (5 Min Data)


VOCs and O2
ppm
2500.00
2000.00
1500.00
1000.00
500.00
0.00
%
21
20.5
20
19.5
19
18.5
18
9/10/2008 11:31
9/10/2008 11:38
9/10/2008 11:45
9/10/2008 11:52
9/10/2008 12:00
9/10/2008 12:07
9/10/2008 12:14
9/10/2008 12:21
9/10/2008 12:28
9/10/2008 12:36
9/10/2008 12:43
Time
Test Begin
Test End
O2(%)
VOCs(ppm)


Sox, Nox, CO2, CO
ppm
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
%
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
9/10/2008 11:31
9/10/2008 11:38
9/10/2008 11:45
9/10/2008 11:52
9/10/2008 12:00
9/10/2008 12:07
9/10/2008 12:14
9/10/2008 12:21
9/10/2008 12:28
9/10/2008 12:36
9/10/2008 12:43
Time
Test Begin
Test End
CO2(%)
SOx(ppm)
NOx(ppm)
CO(ppm)

APPENDIX E

SUMMARY OF ECONOMIC ANALYSIS BY CASE

TABLE 1A. SUMMARY OF ECONOMIC ANALYSIS FOR VOCSIDIZER BY CASE - ABATEMENT ONLY

Full-Scale System - 180000 scfm
Capital Basis - Pick Costs from MEGTEC Graphs
Change Methane Concentration

CASE		500	500A	500B	500C	500CC	500D	500E
		Base			Change Methane			
Changing variables								
Methane concentration	%	0.6	0.3	0.75	0.8	0.9	1	1.2
Methane conversion	%	95	95	95	95	95	95	95
Power	kW	0	0	0	0	0	0	0
Parasitic load	%	100	100	100	100	100	100	100
Carbon credit	$/tonne CO2e	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Electricity value	$/kWh	0.058	0.058	0.058	0.058	0.058	0.058	0.058
Flow air	scfm	180000	180000	180000	180000	180000	180000	180000
Total installed costs	$/kW	0	0	0	0	0	0	0
Total installed costs	$/scfm	30.07	27.92	30.07	30.07	34.36	34.36	34.36
Total installed costs	$	5412000	5026000	5412000	5412000	6186000	6186000	6186000
Capital cost reduction	%							
Relocation costs	$ M	0	0	0	0	0	0	0
Time between relocations	yrs	0	0	0	0	0	0	0
Availability		97	97	97	97	97	97	97
Contract O&M costs	$/kWh	0	0	0	0	0	0	0
% Maintenance cost	% of cap	5	5	5	5	5	5	5
Maintenance cost	$M/yr	271	251	271	271	309	309	309
Power costs	$M/yr	447	447	447	447	447	447	447
Labor manhours	hrs	145	145	145	145	145	145	145
Total O&M costs	$M/yr	745	725	745	745	785	785	785
Life of machine	years	10	10	10	10	10	10	10
Labor rate	$/hr	40	40	40	40	40	40	40
IRR	%	2.48	n/a	9.24	11.23	11.78	15.02	20.94
year pay back		10		8	7	7	6	6
year pay back if investment year=0		9		7	6	6	5	5

Notes:
These use fixed lines from MEGTEC's plots
3 graphs showing capital at low methane, mid-methane, and high methane
Fixed values for capital depending on what methane concentration - only 3 different capital costs
Red data indicate a change from the base case

TABLE 1B. SUMMARY OF ECONOMIC ANALYSIS FOR VOCSIDIZER BY CASE - ABATEMENT ONLY

Full-Scale System - 180000 scfm
Capital Basis - Pick Costs from MEGTEC Graphs
Change Carbon Credit & Availability

CASE		500	510A	510B	510C	510D	510DD	510E	510F	510G	510H	520A	520B	520C
		Base	Change Carbon Credit									Change Availability		
Changing variables														
Methane concentration	%	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Methane conversion	%	95	95	95	95	95	95	95	95	95	95	95	95	95
Power	kW	0	0	0	0	0	0	0	0	0	0	0	0	0
Parasitic load	%	100	100	100	100	100	100	100	100	100	100	100	100	100
Carbon credit	$/tonne CO2e	7.00	0.00	2.00	3.00	5.00	6.60	10.00	15.00	20.00	30.00	7.00	7.00	7.00
Electricity value	$/kWh	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
Flow air	scfm	180000	180000	180000	180000	180000	180000	180000	180000	180000	180000	180000	180000	180000
Total installed costs	$/kW	0	0	0	0	0	0	0	0	0	0	0	0	0
Total installed costs	$/scfm	30.07	30.07	30.07	30.07	30.07	30.07	30.07	30.07	30.07	30.07	30.07	30.07	30.07
Total installed costs	$	5412000	5412000	5E+06	5E+06	5E+06	5E+06	5E+06	5E+06	5E+06	5E+06	5412000	5E+06	5E+06
Capital cost reduction	%													
Relocation costs	$ M	0	0	0	0	0	0	0	0	0	0	0	0	0
Time between relocations	yrs	0	0	0	0	0	0	0	0	0	0	0	0	0
Availability		97	97	97	97	97	97	97	97	97	97	90	84	64
Contract O&M costs	$/kWh	0	0	0	0	0	0	0	0	0	0	0	0	0
% Maintenance cost	% of cap	5	5	5	5	5	5	5	5	5	5	5	5	5
Maintenance cost	$M/yr	271	271	271	271	271	271	271	271	271	271	271	271	271
Power costs	$M/yr	447	447	447	447	447	447	447	447	447	447	443	416	326
Labor manhours	hrs	145	145	145	145	145	145	145	145	145	145	206	287	558
Total O&M costs	$M/yr	745	745	745	745	745	745	745	745	745	745	744	719	637
Life of machine	years	10	10	10	10	10	10	10	10	10	10	10	10	10
Labor rate	$/hr	40	40	40	40	40	40	40	40	40	40	40	40	40
IRR	%	2.48	N/A	N/A	N/A	-8.21	0.69	13.39	27.34	39.27	60.83	0.24	-1.23	-6.97
year pay back		10					11	7	5	4	3	12		
year pay back if investment year=0		9					10	6	4	3	2	11		

Notes:
These use fixed lines from MEGTEC's plots
3 graphs showing capital at low methane, mid-methane, and high methane
Fixed values for capital depending on what methane concentration - only 3 different capital costs
Red data indicate a change from the base case

TABLE 1C. SUMMARY OF ECONOMIC ANALYSIS FOR VOCSIDIZER BY CASE - ABATEMENT ONLY

Full-Scale System - 180000 scfm
Capital Basis - Pick Costs from MEGTEC Graphs
Change Air Flow Rate, Electricity Cost, & Labor Cost

CASE		500	530A	530B	530C	540A	540B	540C	540D	550A	550B
		Base	Change Flow			Change Electricity Cost				Change Labor Cost	
Changing variables											
Methane concentration	%	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Methane conversion	%	95	95	95	95	95	95	95	95	95	95
Power	kW	0	0	0	0	0	0	0	0	0	0
Parasitic load	%	100	100	100	100	100	100	100	100	100	100
Carbon credit	$/tonne CO2e	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Electricity value	$/kWh	0.058	0.058	0.058	0.058	0.026	0.0438	0.067	0.1	0.058	0.058
Flow air	scfm	180000	150000	300000	30000	180000	180000	180000	180000	180000	180000
Total installed costs	$/kW	0	0	0	0	0	0	0	0	0	0
Total installed costs	$/scfm	30.07	31.79	26.63	30.1	30.07	30.07	30.07	30.07	30.07	30.07
Total installed costs	$	5412000	4768000	7990000	903000	5412000	5412000	5412000	5412000	5412000	5412000
Capital cost reduction	%										
Relocation costs	$ M	0	0	0	0	0	0	0	0	0	0
Time between relocations	yrs	0	0	0	0	0	0	0	0	0	0
Availability		97	97	97	97	97	97	97	97	97	97
Contract O&M costs	$/kWh	0	0	0	0	0	0	0	0	0	0
% Maintenance cost	% of cap	5	5	5	5	5	5	5	5	5	5
Maintenance cost	$M/yr	271	238	399	40	271	271	271	271	271	271
Power costs	$M/yr	447	373	744	76	200	338	516	771	447	447
Labor manhours	hrs	145	145	145	145	145	145	145	145	145	145
Total O&M costs	$M/yr	745	636	1184	125	491	633	817	1079	743	748
Life of machine	years	10	10	10	10	10	10	10	10	10	10
Labor rate	$/hr	40	40	40	40	40	40	40	40	25	60
IRR	%	2.48	1.37	4.96	2.34	7.84	4.96	0.79	-6.55	2.53	2.41
year pay back		10	11	9	10	8	9	11		10	10
year pay back if investment year=0		9	10	8	9	7	8	10		9	9

Notes:
These use fixed lines from MEGTEC's plots
3 graphs showing capital at low methane, mid-methane, and high methane
Fixed values for capital depending on what methane concentration - only 3 different capital costs
Red data indicate a change from the base case

TABLE 1D. SUMMARY OF ECONOMIC ANALYSIS FOR VOCSIDIZER BY CASE - ABATEMENT ONLY

Full-Scale System - 180000 scfm
Capital Basis - Pick Costs from MEGTEC Graphs
Change Maintenance Costs, Relocation Costs, & Optimistic Conditions

CASE		500	560A	560B	560C	570A	570B	570C	580A	580B	585A	585B	585C
		Base	Change Maintenance			Change Relocation			Optimistic Conditions		Obtain 15% IRR		
Changing variables													
Methane concentration	%	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1.2	0.9
Methane conversion	%	95	95	95	95	95	95	95	96.5	96.5	96.5	96.5	96.5
Power	kW	0	0	0	0	0	0	0	0	0	0	0	0
Parasitic load	%	100	100	100	100	100	100	100	100	100	100	100	100
Carbon credit	$/tonne CO2e	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	8.60	4.80	6.40
Electricity value	$/kWh	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.0438	0.0438	0.0438	0.0438	0.0438
Flow air	scfm	180000	180000	180000	180000	180000	180000	180000	180000	180000	180000	180000	180000
Total installed costs	$/kW	0	0	0	0	0	0	0	0	0	0	0	0
Total installed costs	$/scfm	30.07	30.07	30.07	30.07	30.07	30.07	30.07	27.06	28.57	28.57	32.65	32.65
Total installed costs	$	5412000	5E+06	5E+06	5412000	5412000	5E+06	5E+06	4871000	5142000	5142000	5876000	5876000
Capital cost reduction	%								10%	5%	5%	5%	5%
Relocation costs	$ M	0	0	0	0	100	250	500	0	0	0	0	0
Time between relocations	yrs	0	0	0	0	5	5	5	0	0	0	0	0
Availability		97	97	97	97	97	97	97	97	97	97	97	97
Contract O&M costs	$/kWh	0	0	0	0	0	0	0	0	0	0	0	0
% Maintenance cost	% of cap	5	2	3	10	5	5	5	2	2	2	2	2
Maintenance cost	$M/yr	271	108	162	541	271	271	271	97	103	103	117	117
Power costs	$M/yr	447	447	447	447	447	447	447	338	338	338	338	338
Labor manhours	hrs	145	145	145	145	145	145	145	145	145	145	145	145
Total O&M costs	$M/yr	745	578	634	1024	745	745	745	454	460	460	475	475
Life of machine	years	10	10	10	10	10	10	10	10	10	10	10	10
Labor rate	$/hr	40	40	40	40	40	40	40	40	40	40	40	40
IRR	%	2.48	6.1	4.94	-4.82	2	1.31	0.21	10.76	9.71	15.27	15.39	15.39
year pay back		10	9	9		11	11	12	7	8	6	6	6
year pay back if investment year=0		9	8	8		10	10	11	6	7	5	5	5

Notes:
These use fixed lines from MEGTEC's plots
3 graphs showing capital at low methane, mid-methane, and high methane
Fixed values for capital depending on what methane concentration - only 3 different capital costs
Red data indicate a change from the base case

TABLE 2A. SUMMARY OF ECONOMIC ANALYSIS FOR VOCSIDIZER BY CASE - HEAT RECOVERY

Full-Scale System - 180000 scfm
Capital Basis - Equation as function of Methane Concentration at Specific Flow Rates
Change Methane Concentration

CASE		Base 600	600A	600A2	600A3	600B	600C	600D	600E	600F
						Change Methane				
Changing variables										
Methane concentration	%	0.6	0.3	0.4	0.5	0.75	0.8	0.9	1	1.2
Methane conversion	%	95	95	95	95	95	95	95	95	95
Power generated	kW	3071	768	1536	2303	4223	4607	5375	6143	7678
Power to grid	%	71.00	-16.01	41.99	61.33	78.91	80.66	83.43	85.5	88.4
Carbon credit	$/tonne CO2e	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Electricity value	$/kWh	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
Flow air	scfm	180000	180000	180000	180000	180000	180000	180000	180000	180000
Total installed costs	$/kW	4993	16447	8823	6274	3936	3699	3325	3040	2635
Total installed costs	$/scfm	85.2	70.16	75.28	80.29	92.35	94.69	99.27	103.76	112.4
Total installed costs	$	15335000	12629000	13550000	14452000	16624000	17044000	17869000	18676000	20232000
Capital cost reduction	%									
Relocation costs	$ M	0	0	0	0	0	0	0	0	0
Time between relocations	yrs	0	0	0	0	0	0	0	0	0
Availability		97	97	97	97	97	97	97	97	97
Contract O&M costs	$/kWh	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Total Labor manhours	hrs	8642	8642	8642	8642	8642	8642	8642	8642	8642
Operator manhours	hrs	8497	8497	8497	8497	8497	8497	8497	8497	8497
Total O&M costs	$M/yr	759	457	558	659	911	961	1062	1163	1364
Life of machine	years	10	10	10	10	10	10	10	10	10
Labor rate	$/hr	40	40	40	40	40	40	40	40	40
Parasitic load	%	29	116.01	58.01	38.67	21.09	19.34	16.57	14.5	11.6
Electrical efficiency	%	28	28	28	28	28	28	28	28	28
IRR	%	2.82	-15.01	-6.21	-0.99	7.14	8.33	10.47	12.34	15.51
year pay back		10				8	8	7	7	6
year pay back if investment year=0		9				7	7	6	6	5

Notes: Red data indicate a change from the base case

TABLE 2B. SUMMARY OF ECONOMIC ANALYSIS FOR VOCSIDIZER BY CASE - HEAT RECOVERY

Full-Scale System - 180000 scfm
Capital Basis - Equation as function of Methane Concentration at Specific Flow Rates
Change Carbon Credit & Availability

CASE		Base 600	610A	610B	610C	610D	610DD	610E	610F	610G	610H	620A	620B	620C
						Change Carbon Credit						Change Availibility		
Changing variables														
Methane concentration	%	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Methane conversion	%	95	95	95	95	95	95	95	95	95	95	95	95	95
Power generated	kW	3071	3071	3071	3071	3071	3071	3071	3071	3071	3071	3071	3071	3071
Power to grid	%	71.00	71.00	71.00	71.00	71.00	71.00	71.00	71.00	71.00	71.00	70.77	70.75	70.65
Carbon credit	$/tonne CO2e	7.00	0.00	2.00	3.00	5.00	5.50	10.00	15.00	20.00	30.00	7.00	7.00	7.00
Electricity value	$/kWh	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
Flow air	scfm	180000	180000	180000	180000	180000	180000	180000	180000	180000	180000	180000	180000	180000
Total installed costs	$/kW	4993	4993	4993	4993	4993	4993	4993	4993	4993	4993	4993	4993	4993
Total installed costs	$/scfm	85.2	85.2	85.2	85.2	85.2	85.2	85.2	85.2	85.2	85.2	85.2	85.2	85.2
Total installed costs	$	15335000	15335000	1.5E+07	1.5E+07	1.5E+07	1.5E+07	1.5E+07	1.5E+07	1.5E+07	1.5E+07	15335000	15335000	15335000
Capital cost reduction	%													
Relocation costs	$ M	0	0	0	0	0	0	0	0	0	0	0	0	0
Time between relocations	yrs	0	0	0	0	0	0	0	0	0	0	0	0	0
Availability		97	97	97	97	97	97	97	97	97	97	90	84	64
Contract O&M costs	$/kWh	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Total Labor manhours	hrs	8642	8642	8642	8642	8642	8642	8642	8642	8642	8642	8090	7646	6165
Operator manhours	hrs	8497	8497	8497	8497	8497	8497	8497	8497	8497	8497	7884	7358	5606
Total O&M costs	$M/yr	759	759	759	759	759	759	759	759	759	759	707	664	520
Life of machine	years	10	10	10	10	10	10	10	10	10	10	10	10	10
Labor rate	$/hr	40	40	40	40	40	40	40	40	40	40	40	40	40
Parasitic load	%	29	29	29	29	29	29	29	29	29	29	29.23	29.25	29.35
Electrical efficiency	%	28	28	27	27	28	28	28	28	28	28	28	28	28
IRR	%	2.82	-11.63	-6.33	-4.17	-0.42	0.43	7.08	13.18	18.54	28.01	1.78	0.86	-2.47
year pay back		10					11	8	7	6	5	11	11	
year pay back if investment year=0		9					10	7	6	5	4	10	10	

Notes: Red data indicate a change from the base case

TABLE 2C. SUMMARY OF ECONOMIC ANALYSIS FOR VOCSIDIZER BY CASE - HEAT RECOVERY

Full-Scale System - 180000 scfm
Capital Basis - Equation as function of Methane Concentration at Specific Flow Rates
Change Air Flow Rate, Electricity Cost, & Labor Cost

CASE		Base 600	630A	630B	630C	640A	640B	640C	640D	650A	650B
			Change Flow Rate			Change Power				Change Labor Rate	
Changing variables											
Methane concentration	%	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Methane conversion	%	95	95	95	95	95	95	95	95	95	95
Power generated	kW	3071	512	2559	5119	3071	3071	3071	3071	3071	3071
Power to grid	%	71.00	70.63	70.98	71.03	71.00	71.00	71.00	71.00	71.00	71.00
Carbon credit	$/tonne CO2e	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Electricity value	$/kWh	0.058	0.058	0.058	0.058	0.026	0.0438	0.067	0.1	0.058	0.058
Flow air	scfm	180000	30000	150000	300000	180000	180000	180000	180000	180000	180000
Total installed costs	$/kW	4993	1764	5348	3523	4993	4993	4993	4993	4993	4993
Total installed costs	$/scfm	85.2	30.1	91.26	60.12	85.2	85.2	85.2	85.2	85.2	85.2
Total installed costs	$	15335000	903000	13688000	18036000	15335000	15335000	15335000	1.5E+07	15335000	1.5E+07
Capital cost reduction	%										
Relocation costs	$ M	0	0	0	0	0	0	0	0	0	0
Time between relocations	yrs	0	0	0	0	0	0	0	0	0	0
Availability		97	97	97	97	97	97	97	97	97	97
Contract O&M costs	$/kWh	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Total Labor manhours	hrs	8642	8642	8642	8642	8642	8642	8642	8642	8642	8642
Operator manhours	hrs	8497	8497	8497	8497	8497	8497	8497	8497	8497	8497
Total O&M costs	$M/yr	759	423	692	1028	759	759	759	759	626	937
Life of machine	years	10	10	10	10	10	10	10	10	10	10
Labor rate	$/hr	40	40	40	40	40	40	40	40	25	60
Parasitic load	%	29	29.37	29.02	28.97	29	29	29	29	29	29
Electrical efficiency	%	28	28	28	28	27	27	27	27	27	27
IRR	%	2.82	n/a	1.34	9.33	-2.67	0.53	4.18	8.7	3.88	1.34
year pay back		10		11	8		11	9	8	9	11
year pay back if investment year=0		9		10	7		10	8	7	8	10

Notes: Red data indicate a change from the base case

TABLE 2D. SUMMARY OF ECONOMIC ANALYSIS FOR VOCSIDIZER BY CASE - HEAT RECOVERY

Full-Scale System - 180000 scfm
Capital Basis - Equation as function of Methane Concentration at Specific Flow Rates
Change Maintenance Costs & Electrical Efficiency

CASE		Base 600	660A	660B	660C	670A	670B	670C
			Change Maintenance Rate			Change Efficiency		
Changing variables								
Methane concentration	%	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Methane conversion	%	95	95	95	95	95	95	95
Power generated	kW	3071	3071	3071	3071	2742	2962	3291
Power to grid	%	71.00	71.00	71.00	71.00	67.52	69.92	72.93
Carbon credit	$/tonne CO2e	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Electricity value	$/kWh	0.058	0.058	0.058	0.058	0.058	0.058	0.058
Flow air	scfm	180000	180000	180000	180000	180000	180000	180000
Total installed costs	$/kW	4993	4993	4993	4993	5592	5178	4660
Total installed costs	$/scfm	85.2	85.2	85.2	85.2	85.2	85.2	85.2
Total installed costs	$	15335000	15335000	15335000	15335000	15335000	15335000	15335000
Capital cost reduction	%							
Relocation costs	$ M	0	0	0	0	0	0	0
Time between relocations	yrs	0	0	0	0	0	0	0
Availability		97	97	97	97	97	97	97
Contract O&M costs	$/kWh	0.015	0.01	0.026	0.045	0.015	0.015	0.015
Total Labor manhours	hrs	8642	8642	8642	8642	8642	8642	8642
Operator manhours	hrs	8497	8497	8497	8497	8497	8497	8497
Total O&M costs	$M/yr	759	625	1055	1566	716	745	788
Life of machine	years	10	10	10	10	10	10	10
Labor rate	$/hr	40	40	40	40	40	40	40
Parasitic load	%	29	29	29	29	32.48	30.08	27.07
Electrical efficiency	%	28	27	27	27	25	27	30
IRR	%	2.82	3.89	0.31	-4.68	1.8	2.48	3.48
year pay back		10	9	12		11	10	10
year pay back if investment year=0		9	8	11		10	9	9

Notes: Red data indicate a change from the base case

TABLE 2E. SUMMARY OF ECONOMIC ANALYSIS FOR VOCSIDIZER BY CASE - HEAT RECOVERY

Full-Scale System - 180000 scfm
Capital Basis - Equation as function of Methane Concentration at Specific Flow Rates
Optimistic Conditions

CASE		Base 600	680A	680B	685A	685B	685C	690A	690B
			Optimistic Conditions		CO2 to get 15% IRR			Optimistic Conditions at Higher Electricity Cost	
Changing variables									
Methane concentration	%	0.6	0.6	0.6	0.6	1.2	0.9	0.6	0.6
Methane conversion	%	95	96.5	96.5	96.5	96.5	96.5	96.5	96.5
Power generated	kW	3071	3510	3510	3510	8524	6017	3510	3510
Power to grid	%	71.00	74.62	74.62	74.62	89.55	85.20	74.62	74.62
Carbon credit	$/tonne CO2e	7.00	7.00	7.00	14.70	5.70	8.80	7.00	7.00
Electricity value	$/kWh	0.058	0.0438	0.0438	0.0438	0.0438	0.0438	0.058	0.058
Flow air	scfm	180000	180000	180000	180000	180000	180000	180000	180000
Total installed costs	$/kW	4993	4151	4151	4151	2255	2821	4151	4151
Total installed costs	$/scfm	85.2	85.01	80.94	80.94	106.78	94.31	80.94	80.94
Total installed costs	$	15335000	14568000	14568000	14568000	19220000	16976000	14568000	14568000
Capital cost reduction	%		5	5	5	5	5	5	5
Relocation costs	$ M	0	0	0	0	0	0	0	0
Time between relocations	yrs	0	0	0	0	0	0	0	0
Availability		97	97	97	97	97	97	97	97
Contract O&M costs	$/kWh	0.015	0.01	0.005	0.005	0.005	0.005	0.005	0.01
Total Labor manhours	hrs	8642	8642	8642	8642	8642	8642	8642	8642
Operator manhours	hrs	8497	8497	8497	8497	8497	8497	8497	8497
Total O&M costs	$M/yr	759	663	510	510	729	619	510	663
Life of machine	years	10	10	10	10	10	10	10	10
Labor rate	$/hr	40	40	40	40	40	40	40	40
Parasitic load	%	29	25.38	25.38	25.38	10.45	14.8	25.38	25.38
Electrical efficiency	%	28	30	30	30	30	30	30	30
IRR	%	2.82	3.64	4.89	15.02	15.07	15.1	7.38	6.22
year pay back		10	9	9	6	6	6	8	9
year pay back if investment year=0		9	8	8	5	5	5	7	8

Notes: Red data indicate a change from the base case