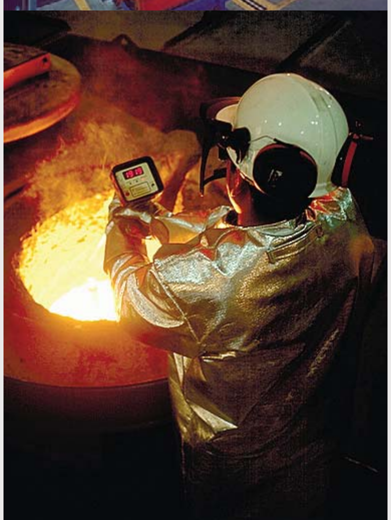
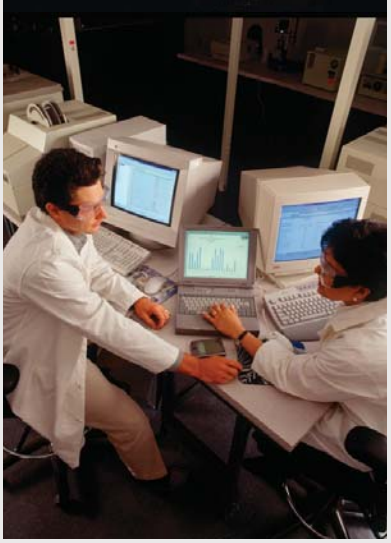
Casting Emission Reduction Program
www.cerp-us.org





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Pouring, Cooling, Shakeout, Iron, Step Core, BeachBox® Binder, Comparison to Test GZ

1412-116 HD

November 2006
(Revised for public distribution - June 2007)

CISA Casting Industry Suppliers Association
AFS American Foundry Society
Armament Research, Development & Engineering Center Picatinny, NJ
USCAR United States Council for Automotive Research
DaimlerChrysler Ford GM General Motors

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Pouring, Cooling, Shakeout, Iron, Step Core, BeachBox® Binder, Comparison to Test GZ

1412-116 HD

This report has been reviewed for completeness and accuracy and approved for release by the following:

Senior Scientist	*//Original Signed//* Sue Anne Sheya, PhD	Date
V.P. Operations	*//Original Signed* George Crandell	Date

The data contained in this report were developed to assess the relative emissions profile of the product or process being evaluated. You may not obtain the same results in your facility. Data were not collected to assess cost or producability.

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EXECUTIVE SUMMARY

This report contains the results of Test HD, an investigation and evaluation of the pouring, cooling, and shakeout airborne emissions, as well as internal surface casting quality comparisons, from a low emission iron core-binder system in greensand molds with no seacoal. Cores were made with a hot-air cured silicate salt low emission binder (Beach Box® LK700-403, Laempe), at 2.5% based on sand (BOS). All results of this test were compared to Test GZ. Test GZ was a core reference test for greensand with no seacoal, which also used a sodium silicate core binder (Corosil®, Hill & Griffith) activated with CO_2, but at 5.0% BOS. The Corosil® binder contains a sugar additive for shakeout enhancement.

The testing performed involved the continuous collection of air samples over a seventy-five minute period, encompassing the mold pouring, cooling, shakeout, and post shakeout processes for nine molds using the 4-on step core pattern.

The emissions results are reported in both pounds of analyte per pound of binder (lb/lb) and pounds of analyte per ton of metal poured (lb/ton). The relative percent difference calculated in lb/ton of metal for this product for the Emission Indicators (presented in Table 1) averaged 68% lower when compared to Test GZ. Comparing to a phenolic urethane core baseline indicates approximate reductions of over 90%. On a lb/lb of binder basis, emissions were lower by an average of 35% for the three emissions indicators shown to have a statistically relevant change when compared to the reference Test GZ. These include TGOC as Propane and the Sums of Target Organic Analytes and HAPs. TGOC as Propane results include all exempted compounds including methane and, at present, the methane contribution has not been determined or removed.

Table 1 Average Emissions Indicators Summary

	Lb/Tn Metal		Lb/Lb Binder	
Analyte Name	**Test GZ Average**	**Test HD Average**	**Test GZ Average**	**Test HD Average**
Emission Indicators				
TGOC as Propane	0.1844	0.0575	0.0078	0.0056
Sum of Target Organic HAPs	0.0311	0.0084	0.0013	0.0008
Sum of Target POMs	0.0017	0.0006	0.0001	0.0001

In the data validation, verification and reporting of results from this test, an analyte is defined as non-detect if its concentration is below the experimentally measured limit of detection (practical quantitation limit, PQL). In individual runs where an analyte is below this limit, the value which is non-detect is substituted by the value of zero. If an analyte average concentration falls below the PQL when all runs are averaged over the entire test (in this case there are nine runs which are averaged together), the test average for that analyte is shown as ND in the Tables and Figures of this report.

The internal surface quality for each of the conditioning run castings was assessed qualitatively relative to each other. A photographic record was made of the twelve coated core castings produced from the three molds poured during the sand conditioning runs. Pictures of best, median and worst casting quality are shown in Appendix C. The castings were also compared to and ranked with those from Test GZ. The coating used with each binder was selected by the vendor. The castings from the BeachBox® cores exhibited a rougher surface most likely due to the thickness of the coating. Both castings displayed veining, but it was more pronounced in the BeachBox® cores. The veining lowered the BeachBox® cores' casting quality surface ranking relative to the coated castings from the Corosil® binder used in Test GZ.

Emission results from the testing performed and described herein are not suitable for use as emission factors or for purposes other than evaluating the relative emission reductions associated with the use of alternative materials, equipment, or processes. The emissions measurements are unique to the specific castings produced, materials used, and testing methodology associated with these tests. These measurements should not be used as the basis for estimating emissions from actual commercial foundry applications.

1.0 Introduction

1.1. Background

Technikon LLC is a privately held contract research organization located in McClellan, California, a suburb of Sacramento. Technikon offers emissions research services to industrial and government clients specializing in the metal casting and point source emissions areas. Technikon operates the Casting Emission Reduction Program (CERP). CERP is a cooperative initiative between the Department of Defense (US Army) and the United States Council for Automotive Research (USCAR). The parties to the CERP Cooperative Research and Development Agreement (CRADA) include The Environmental Leadership Council of USCAR, a Michigan partnership of DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation; the U.S. Army Research, Development, and Engineering Command (RDECOM-ARDEC); the American Foundry Society (AFS); and the Casting Industry Suppliers Association (CISA). The US Environmental Protection Agency (US EPA) and the California Air Resources Board (CARB) also have been participants in the CERP program and rely on CERP published reports for regulatory compliance data. All published reports are available on the CERP web site at www.cerp-us.org.

1.2. CERP/Technikon Objectives

The primary objective of CERP is to evaluate materials, equipment, and processes used in the production of metal castings. Technikon's facility was designed to evaluate alternate materials and production processes designed to achieve significant air emission reductions. The facility's principal testing arena is designed to measure airborne emissions from individually poured molds. This testing facility enables the repeatable collection and evaluation of airborne emissions and associated process data.

1.3. Report Organization

This report has been written to document the methodology and results of a specific test plan that was used to evaluate the pouring, cooling and shakeout emissions from an uncoated hot-air cured inorganic sodium silicate core binder (Beach Box® LK700-403, Laempe) in a greensand mold with no seacoal and poured with iron. Emission results are then compared to Test GZ, an iron silicate salt (with additives), core reference. Test GZ evaluated emissions from greensand molds with no seacoal containing uncoated cores made with a CO_2 cured sodium silicate core binder (Corosil®, Hill & Griffith) containing additives. Binder amounts were different for each test.

Section 2.0 of this report includes a summary of the methodologies used for data collection and analysis, procedures for emission calculations, QA/QC procedures, and data management and reduction methods. Specific data collected during this test are summarized in Section 3 of this report, with detailed data included in the appendices of this report. Section 4 of this report contains a discussion of the results.

The raw data for this test series are archived at the Technikon facility.

1.4. SPECIFIC TEST PLAN AND OBJECTIVES

Table 1-1 provides a summary of the test plan. The details of the approved test plan are included in Appendix A.

Table 1-1 Test Plan Summary

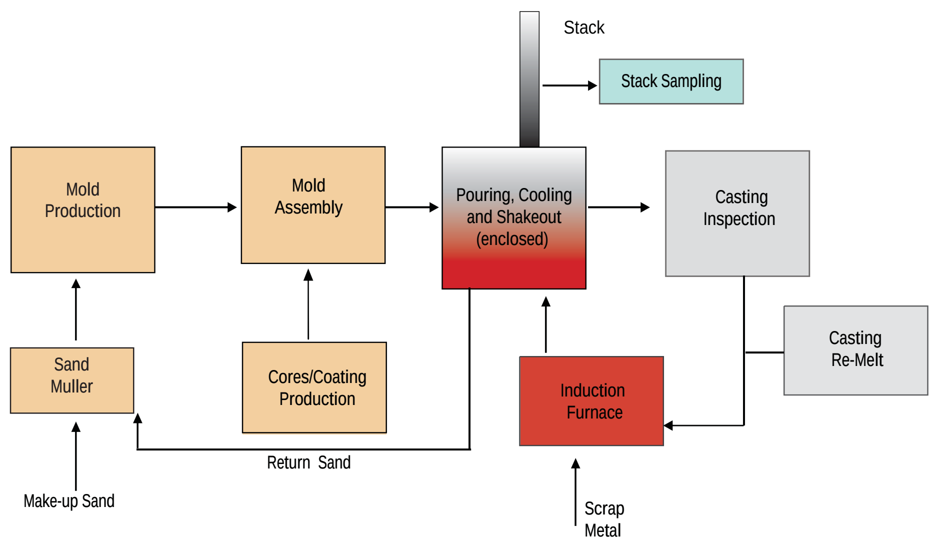
Test Plan Number	1412-122 GZ	1412-116 HD
Type of Process Tested	Pouring, cooling, shakeout baseline, uncoated Hill and Griffith Corosil® sodium silicate core in greensand.	Pouring, cooling, shakeout: uncoated Laempe BeachBox® LK700-403 cores in greensand.
Metal Poured	Class 30 gray iron.	Class 30 gray Iron
Mold Type	4-on step core greensand with no seacoal.	4-on stepcore greensand with no seacoal
Sand System	Wexford 450 sand, western and southern bentonite in a 5:2 ratio to yield 7.0 +/- 0.5% MB clay, no seacoal	Wexford 450 sand, western and southern bentonite in a 5:2 ratio to yield 7.0 +/- 0.5% MB clay, no seacoal
Core Type	Step; Wedron 530 sand; 5.0% (BOS) Hill & Griffith Corosil® binder, CO_2 activated.	Step; Wedron 530 sand; 2.5% (BOS) BeachBox® LK700-403, hot air cured
Core Coating	Foseco RHEOTEC® for conditioning runs, Foseco Isomol® for casting quality runs, none for emission runs	Ashland Weissfilm® for casting quality/conditioning runs, none for emission runs
Number of Molds Poured	3 engineering/conditioning + 9 Sampling + 3 casting quality	3 engineering/conditioning, 9 sampling
Test Dates	December 12, 2005 through December 21, 2005	April 10, 2006 through April 13, 2006
Emissions Measured	55 target analytes and TGOC as propane, CO, CO_2, NOx, SO_2	55 target analytes and TGOC as propane, CO, CO_2, NOx, SO_2
Process Parameters Measured	Total casting, mold, and binder weights; metallurgical data, % LOI, sand temperature; stack temperature, moisture content, pressure, and volumetric flow rate	Total casting, mold, and binder weights; metallurgical data, % LOI, sand temperature; stack temperature, moisture content, pressure, and volumetric flow rate

2.0 TEST METHODOLOGY

2.1. DESCRIPTION OF PROCESS AND TESTING EQUIPMENT

Figure 2-1 is a diagram of the Research Foundry test process.

Figure 2-1 Research Foundry Layout Diagram



2.2. DESCRIPTION OF TESTING PROGRAM

The testing program encompasses the foundry process and emissions testing, both of which are rigorously controlled. Parameters are monitored and recorded prior to and during the emission tests. Process measurements included the weights of the casting and mold sand, loss on ignition (LOI) values for the mold and core prior to the test, and relevant metallurgical data. Measured source parameters included stack temperature, pressure, volumetric flow rate, and moisture content. All parameters were maintained within prescribed ranges to ensure the reproducibility of the test runs.

Emission testing for organic hydrocarbons included several methods. Method 18 is one of the US Environmental Protection Agency (EPA) reference methods for volatile organic carbon (VOC) analysis. The method is a guideline and a system of quality assurance checks (QA) for VOC analysis rather than a rigorous, explicit manual for sampling or analysis.

Method 18 is generally used to identify and/or measure as many compounds as possible in order to calculate actual VOC emissions from other measurements (e.g., EPA Method 25 or 25A).

As described in the method, sampling can be conducted using a Volatile Organic Sampling Train (VOST), which was the technique used for sampling for the tests described in these reports. A sample gas stream was extracted from the source and then routed using the train through tubes containing adsorbents, which are the collection materials upon which the organic analytes are deposited. Adsorption tube samples were collected and analyzed for fifty-six target organic compounds using procedures based on approved federal methods, including those of the EPA.

Two methods were employed to measure undifferentiated hydrocarbon emissions as Emission Indicators: TGOC as Propane, performed in accordance with EPA Method 25A, and HC as Hexane.

Method 25A is an instrumental based method in which the stack gas is introduced directly to a flame ionization detector (FID) without first separating the components. In Method 25A, sampling is accomplished by extracting a gas stream from the stack effluent and transferring it via heated non-reactive tubing to the FID analyzer under very controlled temperature and pressure conditions. The FID measures the quantity of carbon containing molecules, and is calibrated by a gas standard, which in this case is the three carbon alkane, propane (C_3H_8). The FID will give a response relative to the calibration standard and results are expressed in terms of the gas used for calibration.

Because the FID responds to all carbon containing compounds, methane (CH_4) and other exempt compounds are included in the results, as per the method design. For this test, these compounds have not been determined or removed from the averaged results.

The HC as Hexane method is based on NIOSH methods 1500-1550, and represents the sum of all detected hydrocarbon compounds in the carbon range between C_6 and C_{16}, expressed in terms of the calibration compound, which in this case is the six-carbon alkane, hexane (C_6H_{14}). Results are determined by the summation of all chromatographic peak areas which fall between the elution time of hexane through the elution time of hexadecane ($C_{16}H_{34}$) on the chromatogram. The quantity of hydrocarbons (HC) is determined by dividing the total summed area count by the area of hexane calculated from the initial calibration curve that is derived from a five point calibration.

Continuous on-line monitoring of select criteria pollutant and greenhouse gases such as carbon dioxide (CO_2), carbon monoxide (CO), and nitrogen oxide (NOx) concentrations was conducted according to US EPA Methods, 3A, 10, and 7E respectively.

Mass emission rates for all analytes were calculated using continuous monitoring or laboratory analytical results, measured source data and appropriate process data. Detailed emission results are presented in Appendix B. Individual analyte emissions were calculated in addition to five "Emission Indicators": TGOC as Propane, HC as Hexane, Sum of Target Organic Analytes, Sum of Target Organic Hazardous Air Pollutants (HAPs), and the Sum of Target Polycyclic Organic Matter (POMs). Full descriptions of these indicators can be found in Section 3.0 of this report.

The specific steps used in this sampling program are summarized below.

2.2.1. Test Plan Review and Approval

The proposed test plan was reviewed and approved by the Technikon staff.

2.2.2. Mold, Core and Metal Preparation

In Technikon's Research foundry, castings were produced individually in discrete manually constructed mold packages, each of which consists of four cavities. The step-core pattern built to evaluate core emissions was used. The molds and cores (Figure 2-2 and 2-3) were prepared to a standard composition

Figure 2-2 Step Cores in Mold

Figure 2-3 Coated Step Cores

by the Technikon production team. Relevant process data were collected and recorded. The total amount of metal melted was determined from the expected poured weight of the castings and the number of molds to be poured. The weight of metal poured into each mold was recorded on the process data summary sheet.

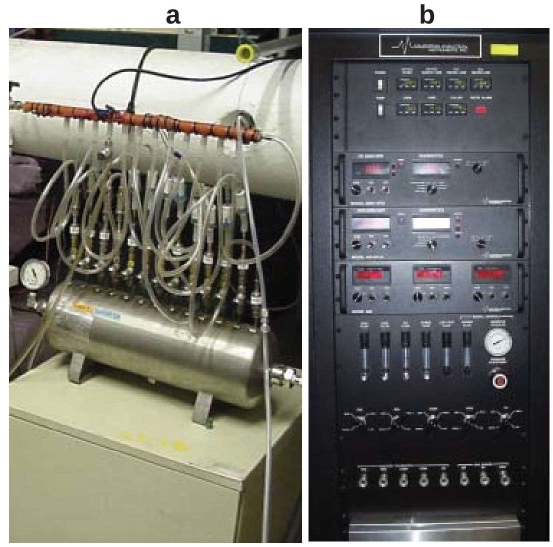
Figure 2-4 Pouring Metal into Mold in Total Enclosure Hood

2.2.3. Individual Sampling Events

Replicate runs were performed on nine (9) mold packages. For Test HD, three (3) conditioning cycles were run to condition the sand and to produce the coated castings used for surface quality comparisons. Prior to pouring and emission sampling for each run, one mold package was placed onto a shake-out table contained within a hooded enclosure designed to meet the requirements of EPA Method 204 for a total temporary enclosure. The enclosed test stand was pre-heated to approximately 85°F. The flow rate of the emission capture air was nominally 300 scfm. Iron at approximately 2630°F was poured through an opening in the top of the emission enclosure, after which the opening was closed (Figure 2-4).

Figure 2-5 Stack Sampling Equipment

a **b**



The emissions generated are transported through an insulated six (6) inch duct (stack) located at the top of the enclosure. Heated sample probes inserted into the stack at relevant locations determined by EPA Method 1 enabled collection of total emissions from all phases of the casting process. One probe provided gases for the VOST (Figure 2-5a). Another probe in the stack was used to continuously draw effluent samples and transport them via a forty-seven (47) ft heated sample line to an emissions console, containing a battery of gas analyzers (Figure 2-5b), located in Technikon's laboratory. This console, or emissions bench, consists of a total hydrocarbon analyzer for TGOC analysis, two infra-red analyzers (for CO and CO_2) and a chemiluminescence analyzer for NOx.

Continuous air samples were collected during the forty-five minute pouring and cooling phase, during the five minute shakeout of the mold, and for an additional twenty five minute cooling period following shakeout. The total sampling time was seventy-five minutes.

2.2.4. Process Parameter Measurements

Table 2-1 lists the process parameters that are monitored during each test. The analytical equipment and methods used are also listed.

Table 2-1 Process Equipment and Methods

Process Parameter	Equipment and Method(s)
Mold Weight	Cardinal 748E platform scale (Gravimetric)
Casting Weight	Ohaus MP2 Scale
Muller water weight	Ohaus MP2 Scale
Binder Weight	MyWeigh i2600
Core Weight	Mettler SB12001 Digital Scale (Gravimetric)
Volatiles	Mettler PB302 Scale (AFS Procedure 2213-00-S)
LOI, % at Mold	Denver Instruments XE-100 Analytical Scale (AFS procedure 5100-00-S)
Metallurgical Parameter	
Pouring Temperature	Electro-Nite DT 260 (T/C Immersion Pyrometer)
Mold Compactability	Dietert 319A Sand Squeezer (AFS Procedure 2221-00-S)

2.2.5. Air Emissions Analysis

The specific sampling and analytical methods used in the Research Foundry tests are based on federal reference methods shown in Table 2-2. The details of the specific testing procedures and their variance from the reference methods are included in the Technikon Standard Operating Procedures.

Table 2-2 Emission Sampling and Analytical Methods

Measurement Parameter	Test Method(s)
Port Location	US EPA Method 1
Number of Traverse Points	US EPA Method 1
Gas Velocity and Temperature	US EPA Method 2
Gas Density and Molecular Weight	US EPA Method 3a
Gas Moisture	US EPA Method 4 (Gravimetric)
Target VOCs and HAPs	US EPA Methods TO17, TO11; NIOSH Methods 1500, 2002
TGOC	US EPA Method 25A
CO	US EPA Method 10
CO_2	US EPA Method 3A
NOx	US EPA Method 7E
SO_2	OSHA ID 200

Some methods modified to meet specific CERP test objectives.

2.2.6. Data Reduction, Tabulation and Preliminary Report Preparation

Data calculations for determining emission concentrations resulting from the specific test plan outlined in Appendix A are based on process and emission parameters. The analytical results of the emissions tests provide the mass of each analyte in the sample. The total mass of the analyte emitted is calculated by multiplying the mass of analyte in the sample by the ratio of total stack gas volume to sample volume. The total stack gas volume is calculated from the measured stack gas velocity and duct diameter and corrected to dry standard conditions using the measured stack pressures, temperatures, gas molecular weight and moisture content. The total mass of analyte is then divided by the weight of the casting poured or weight of binder to provide emissions data in pounds of analyte per ton of metal or pounds of analyte per pound of binder.

Individual concentration and reporting limit results for each analyte for all sampling runs are included in Appendix B of this report. Average results for the test are given in Section 3.0, Table 3-1a and 3-1b.

2.2.7. Report Preparation and Review

The Preliminary Draft Report is created and reviewed by Process Team and Emissions Team members to ensure its completeness, consistency with the test plan, and adherence to the prescribed QA/QC procedures. Appropriate observations, conclusions and recommendations are added to the report to produce a Draft Report. The Draft Report is then reviewed by senior management and comments are incorporated into a draft Final Report prior to final signature approval and distribution.

2.3. QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC) PROCEDURES

Detailed QA/QC and data validation procedures for the process parameters, stack measurements, and laboratory analytical procedures are included in the "Technikon Emissions Testing and Analytical Testing Standard Operating Procedures" publication. In order to ensure the timely review of critical quality control parameters, the following procedures are followed:

- Immediately following the individual sampling events performed for each test, specific process parameters are reviewed by the Process Engineer to ensure that the parameters are maintained within the prescribed control ranges. Where data are not within the prescribed ranges, the Manager of Process Engineering and the Vice President of Operations determine whether the individual test samples should be invalidated or flagged for further analysis following review of the laboratory data.

- The source (stack) and sampling parameters, analytical results and corresponding laboratory QA/QC data are reviewed by the Emissions Measurement Team to confirm the validity of the data. The Manager of Measurement Technologies reviews and approves the recommendation, if any, that individual sample data should be invalidated. Invalidated data are not used in subsequent calculations.

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3.0 TEST RESULTS

As previously reported, changes from reports prior to July 2006 have been implemented in the text and tables to clarify emission related terminology. Terminology has been changed and results have been recalculated for the reference Test GZ to enable a direct comparison to the current test, Test HD.

The full description of changes may be found in the report for 1412-113, Test HE.

The Beach Box® binder used in Test HD for iron castings was a comparatively low emitting binder system. The average emission results for individual target analytes and emission indicators for Test HD are presented in Table 3-1a in lb/ton of metal and Table 3-1b in lb/lb of binder.

Table 3-1a Comparison Summary of Top 95% Targeted Organic Analytes for Reference Test GZ with Test HD Average Results - Lb/Tn Metal

Analyte Name	Test GZ Average	Test HD Average	Percent Change from Test GZ
Emission Indicators			
TGOC as Propane	0.1844	0.0575	**-69**
HC as Hexane	0.0394	0.0167	**-58**
Sum of Target Organic Analytes	0.0354	0.0099	**-72**
Sum of Target Organic HAPs	0.0311	0.0084	**-74**
Sum of Target POMs	0.0017	0.0006	**-68**
Selected Target Organic HAPs and POMs			
Acetaldehyde	0.0104	0.0027	**-74**
Benzene	0.0081	0.0024	**-71**
Toluene	0.0036	0.0008	**-77**
Xylenes	0.0027	0.0005	**-82**
Formaldehyde	0.0013	0.0011	**-20**
Propionaldehyde (Propanal)	0.0013	0.0003	**-77**
Methylnaphthalenes	0.0009	0.0004	**-56**
Additional Selected Target Organic Analytes			
Trimethylbenzenes	0.0013	0.0012	-1
Butyraldehyde/Methacrolein	0.0004	0.0003	**-25**
Criteria Pollutants and Greenhouse Gases			
Carbon Dioxide	4.0596	2.1289	**-48**
Carbon Monoxide	1.3975	1.2705	**-9**
Nitrogen Oxides	ND	ND	NA
Sulfur Dioxide	0.0060	0.0078	**29**

NA = Not Applicable

NT = Not Tested

ND = Not Detected

<0.0001 = less than reporting limit of 0.0001 lb/ton metal

Notes:

- Selected Results >95% of mass of all detected target analytes for Test HD
- Results recalculated for the Test GZ to enable a direct comparison to Test HD
- Names in italics are not included in top 95% of target analyte mass for Test GZ.
- Bold numbers = compounds with calculated t-statistics significant at alpha=0.05

Table 3-1b Comparison Summary of Top 95% Targeted Organic Analytes for Reference Test GZ with Test HD Average Results - Lb/Lb Binder

Analyte Name	Test GZ Average	Test HD Average	Percent Change from Test GZ
Emission Indicators			
TGOC as Propane	0.0078	0.0056	**-29**
HC as Hexane	0.0017	0.0016	-4
Sum of Target Organic Analytes	0.0015	0.0010	**-35**
Sum of Target Organic HAPs	0.0013	0.0008	**-40**
Sum of Target POMs	0.0001	0.0001	-26
Selected Target Organic HAPs and POMs			
Acetaldehyde	0.0004	0.0003	**-41**
Benzene	0.0003	0.0002	**-33**
Toluene	0.0001	0.0001	**-48**
Xylenes	0.0001	<0.0001	NA
Formaldehyde	0.0001	0.0001	**83**
Propionaldehyde (Propanal)	0.0001	<0.0001	NA
Methylnaphthalenes	<0.0001	<0.0001	NA
Additional Selected Target Organic Analytes			
Trimethylbenzenes	0.0001	0.0001	**125**
Butyraldehyde/Methacrolein	<0.0001	<0.0001	NA
Criteria Pollutants and Greenhouse Gases			
Carbon Dioxide	0.1713	0.2053	**20**
Carbon Monoxide	0.0589	0.1226	**108**
Nitrogen Oxides	ND	ND	NA
Sulfur Dioxide	0.0003	0.0002	**-35**

NA = Not Applicable

NT = Not Tested

ND = Not Detected

<0.0001 = less than reporting limit of 0.0001 lb/ton metal

Notes:

- Selected Results >95% of mass of all detected target analytes for Test HD
- Results recalculated for the Test GZ to enable a direct comparison to Test HD
- Names in italics are not included in top 95% of target analyte mass for Test GZ.
- Bold numbers = compounds with calculated t-statistics significant at alpha=0.05

Relative reductions in the pounds of emissions for CERP's Emission Indicators were measured using this product. On a basis of pounds of emissions per ton of metal poured, emission indicator reductions of 58% to 74% were calculated as compared to Test GZ. Although binder concentrations were twice as high for Test GZ (5% vs. 2.5% BOS for Test HD), statistically relevant reductions on a lb/lb binder basis were still noted for TGOC as Propane, the Sum of Target Organic Analytes, and the Sum of Target Organic HAPs of 29, 35, and 40%, respectively. A detailed discussion of results can be found in Section 4.0 of this report.

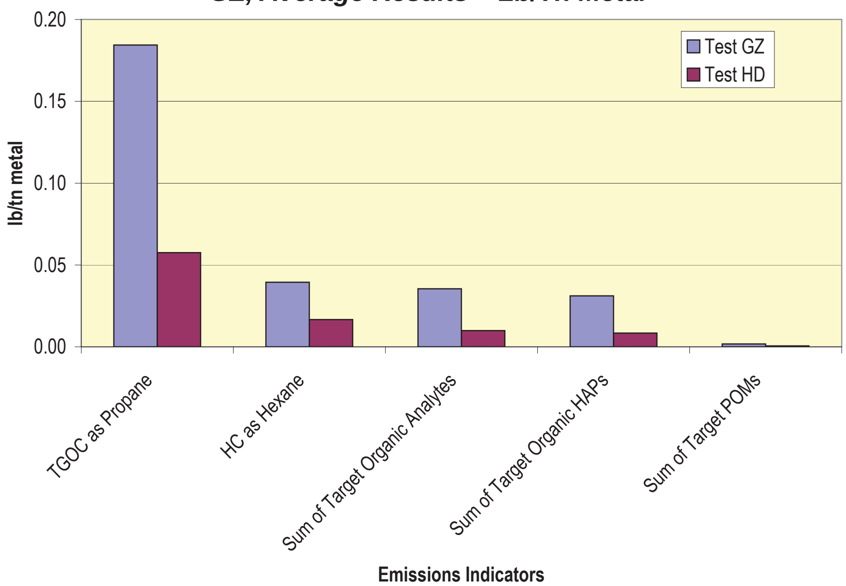
Individual target compounds or isomer classes included in the tables are those that comprise at least 95% of the total targeted organic analytes measured, as well as the "Sum of Target Organic Analytes", the "Sum of Target Organic HAPs", and the "Sum of Target POMs". These three analyte sums are part of the group termed "Emission Indicators." Also included in this group and reported on the tables are "TGOC as Propane" and "HC as Hexane". In addition, the average values for selected criteria and greenhouse gases such as carbon monoxide, carbon dioxide, sulfur dioxide and nitrogen oxides are given. This table also includes the relative percent change in emissions from Test GZ (the reference test) to Test HD. The relative percent change in this case is defined as the difference in concentrations between the current test and reference test, divided by the reference test concentration and expressed as a percentage.

The average reported values for those analytes measured continuously on-line in real time at Technikon during Test HD presented in the tables have been background corrected. These include CO, CO_2, NOx and TGOC as propane. Integrated adsorption tube samples have not been background corrected with the exception of HC as Hexane.

In the data validation, verification and reporting of results from this test, an analyte is defined as non-detect if its concentration is below the experimentally measured limit of detection (practical quantitation limit, PQL). The PQL is statistically related to the detection limitations of an analytical method and the capabilities of analytical instrumentation. In individual runs where an analyte is reported as below this limit, the non-detect value is substituted by the value of zero for calculation purposes. If an analyte average concentration falls below the PQL when all individual runs are averaged over the entire test (in this case there are nine runs which are averaged together), the test average for that analyte is shown as ND in the Tables and Figures of this report.

Compounds that are structural isomers have been grouped together and are reported as a single isomer class. For example: ortho-, meta-, and para-xylene are the three structural isomers of dimethyl benzene and their sum is reported as xylenes. All other isomers such as trimethylbenzenes, dimethylphenols, and several other compound classes are also treated and reported in a similar manner.

Figure 3-1a Emissions Indicators Comparison of Test HD to Test GZ, Average Results – Lb/Tn Metal



Figures 3-1a to 3-3b graphically present the data from the tables for Test HD of the five emissions indicators as well as selected individual HAP, organic analyte, and criteria pollutant and greenhouse gas emissions data relative to Test GZ as both lb/ton of metal and lb/lb of binder.

Figure 3-1b Emissions Indicators Comparison of Test HD to Test GZ, Average Results – Lb/Lb Binder

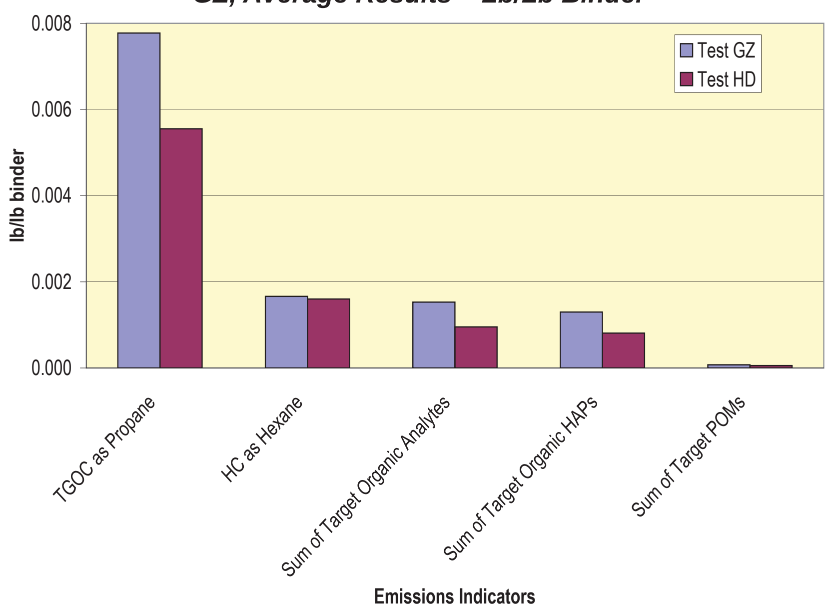


Figure 3-2a Selected Organic HAP and POM Emissions Comparison of Test HD to Test GZ, Average Results – Lb/Tn Metal

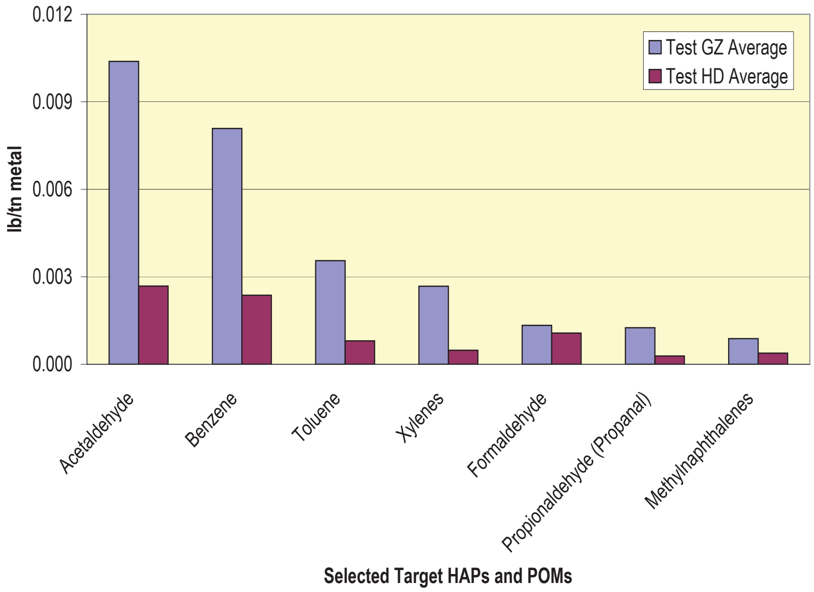


Figure 3-2b Selected Organic HAP and POM Emissions Comparison of Test HD to Test GZ, Average Results – Lb/Lb Binder

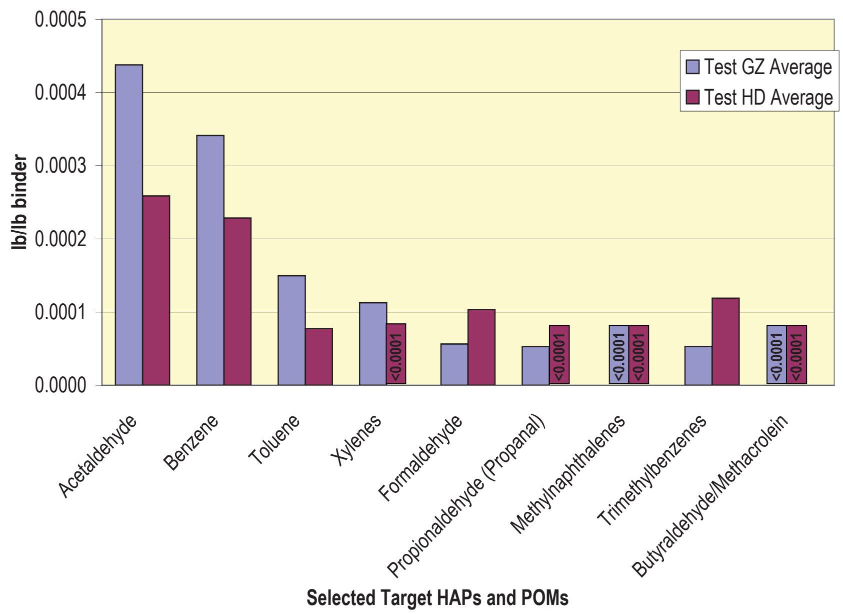


Figure 3-3a Criteria Pollutants and Greenhouse Gases Comparison of Test HD to Test GZ, Average Results – Lb/Tn Metal

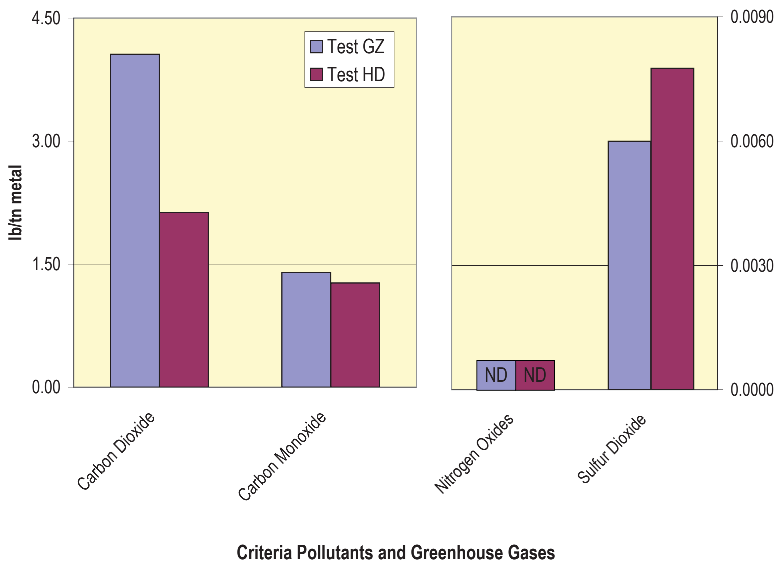
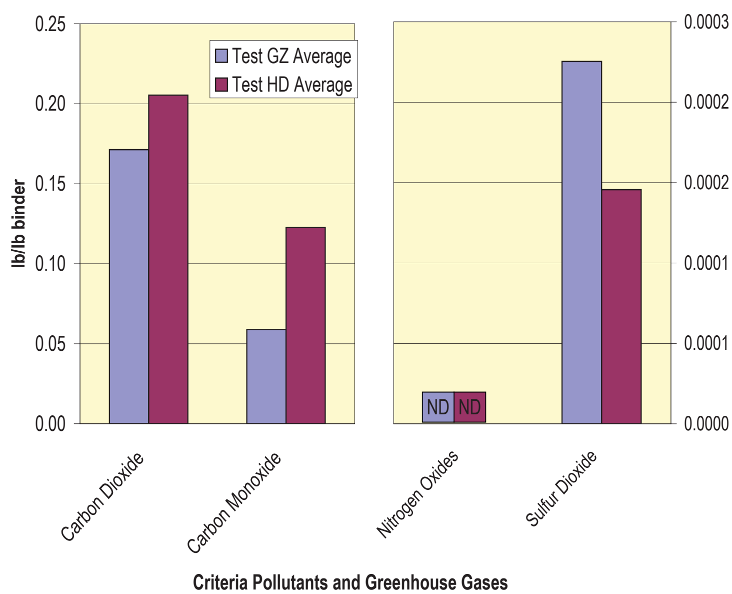


Figure 3-3b Pollutants and Greenhouse Gases Comparison of HD to GZ, Average Results – Lb/Lb Binder



Compounds which were chosen for analysis based on chemical and operational parameters are the target analytes. The emissions indicator called the "Sum of Target Organic Analytes" is the sum of all individual organic analytes targeted for collection and analysis that were detected at a level above the practical quantitation limit. The sum includes compounds which may also be defined as HAPs and POMs. By definition, HAPs are specific compounds listed in the Clean Air Act Amendments of 1990. The term POM defines not one compound, but a broad class of compounds based on chemical structure and boiling point. POMs as a class are a listed HAP. A subset of organic compounds from the current list of EPA HAPs was targeted for collection and analysis. These individual target HAPs (which may also be POMs by nature of their chemical properties) detected in the samples are summed together and defined as the "Sum of Target Organic HAPs", while the "Sum of Target POMs" only sums those organic HAPs that are also defined as POMs.

In Table 3-2 the tensile strength of the LaempeKuhs BeachBox® and Hill and Griffith Corosil® binders are compared to the strength of a generic phenolic urethane cold box binder. As is standard practice, dogbone tensile strength is taken at intervals of 5 minutes, 2 hours, and 24 hours. Additionally, a 24 hour test was performed in a 100% relative humidity environment.

Table 3-2 Dogbone Tensile Strength Comparison - psi

	Corosil® Test GZ	BeachBox® Test HD	Phenolic Urethane (Generic)
Concentration (BOS)	**5.0%**	**2.5%**	**1.1%**
5 minutes	27.3	63.0	177.2
2 hours	20.9	218.0	283.9
24 hour	54.6	151.0	230.6
24 hour with 100% humidity	14.2	0	140.6

The comparative rankings of casting appearance for each casting made with coated cores used in the three conditioning runs for Test HD, and coated cores poured after the three conditioning runs and the emission test runs for Test GZ are shown in Table 3-3. Each of the four castings from the molds of the three conditioning runs was assessed and compared relative to each other. The comparison consisted initially of a visual examination of major and minor surface defects such as burn-in, gas holes or scabbing. Castings were first ranked according to those defects. To further differentiate surface quality among castings, the finish was tested by touch for smoothness. The smoothest casting with the fewest visual surface defects received the highest ranking. Three benchmark visual casting quality rankings consisting of the best, the median, and the worst casting are assigned to three of the castings. The "best" designation means that the internal surface of a casting is the best appearing of the lot of twelve, and is given an in-series rank of "1". The "median" designation, given an in-series rank of "6", means that five castings are better in appearance and six are worse. The "worst" designation is assigned to that casting which is of the poorest quality, and is assigned an in-series rank of "12". The remaining castings are then compared to these three benchmarks and ranked accordingly. The three-benchmark castings from Test GZ were then compared to and collated with the benchmark castings from Test HD.

Table 3-3 Casting Quality Rank Order

Rank Order	Mold Number	Cavity Number	Test GZ	Test HD
Rank 1	GZ013	4	Best	
Rank 2	GZ013	1	Median	
Rank 3	HDCR2	3		Best
Rank 4	HDCR1	1		
Rank 5	GZ014	2	Worst	
Rank 6	HDCR1	2		
Rank 7	HDCR3	2		
Rank 8	HDCR1	3		
Rank 9	HDCR1	4		Median
Rank 10	HDCR3	3		
Rank 11	HDCR3	1		
Rank 12	HDCR2	4		
Rank 13	HDCR2	1		
Rank 14	HDCR2	2		
Rank 15	HDCR3	4		Worst

Rank Order of Appearance = Overall Best Casting to Overall Worst Casting

The coated castings produced were used for surface finish quality comparisons only. No emissions from these runs were sampled and are therefore not included in the emission results reported here.

The average process parameters are reported in Table 3-4 and Appendix C.

Table 3-4 Summary of Test Plan Average Process Parameters

	Test GZ	Test HD
Test Dates	**12/12/05-12/21/05**	**4/10/06-4/13/06**
Test Type	PCS Uncoated Corosil® Silicate Cores in Greensand.	PCS Uncoated BeachBox® Silicate Cores in Greensand.
Cast Weight, lbs.	118.91	124.28
Pouring Time, sec.	12.67	13.56
Pouring Temp ,°F	2632	2626
Pour Hood Air Temp at Start of Pour, °F	87	86
Mixer Auto Dispensed Sand Weight, lbs	50.00	50.17
Core Binder Weight, lbs	2.51	1.26
% Core Binder (BOS)	5.01	2.50
% Core Binder, Actual	4.77	2.44
Total Core Weight in Mold, lbs.	29.52	26.37
Total Binder Weight in Mold, lbs.	1.41	0.64
Core LOI, %	0.85	0.19
Core Dogbone Tensile, psi	27	63
Core Age, hrs.	195	168
Muller Batch Weight, lbs.	901	904
GS Mold Sand Weight, lbs.	645	636
Mold Temperature, °F	73	82
Average Green Compression , psi	22.71	22.51
GS Compactability, %	39	43
GS Moisture Content, %	2.11	2.05
GS MB Clay Content, %	7.17	6.95
MB Clay Reagent, ml	36.6	39.2
1800°F LOI - Mold Sand, %	0.86	0.74
900°F Volatiles , %	0.28	0.25
Permeability Index	239	252
Sand Temperature, °F	78	78

The four appendices in this report contain detailed information regarding testing, sampling, data collection and results for each sampling event. Appendix A contains test plans, instructions and the sampling plan for Test HD. Appendix B contains detailed emissions data and average results for all targeted analytes. Target analyte practical quantitation reporting limits expressed in both lb/lb binder and lb/ton metal are also shown in Appendix B. Appendix C contains detailed process data and the pictorial casting record. Appendix D contains continuous monitor charts. The charts are presented to show TGOC, carbon monoxide, carbon dioxide, and oxides of nitrogen time-dependent emissions profiles for each individual emissions test pour. Charts have not been background corrected. Appendix E contains acronyms and abbreviations.

4.0 DISCUSSION OF RESULTS

The individual chemical compounds from airborne emissions targeted for collection and analyses for this test were chosen based on the chemistry of the binder under investigation as well as analytes historically targeted. The analyte lists were identical for Test HD and the reference Test GZ.

Examination of measured process parameters indicated that both tests were run within acceptable ranges and limits. In each individual run, the principal causes and secondary influences of the emissions are fixed between the reference test and the comparative test so that for pouring, cooling, and shakeout, the emissions reflect only the difference in the materials being tested. A statistical determination of whether the means of emissions of the baseline test and the current test were different was made by calculating a T-test at a 95% significance level (α=0.05). Results at this significance level indicate that there is a 95% probability that the mean values for Test HD are not equivalent to those of Test GZ. Therefore, it may be said that the differences in the average emission values are real differences, and not due to test, sampling, or analysis methodologies. This difference is indicated in Tables 3-1a and 3-1b in the column labeled “Percent Change from Test GZ”. Values in this column presented in **bold font** indicate a greater than 95% probability that the two tests are statistically different.

In general, emissions for both Test HD and Test GZ were low compared to traditional organic binder systems. Comparing to a phenolic urethane core baseline indicates approximate reductions of over 90%. Emission Indicator results expressed as lb/ton show statistically relevant percent differences of 58 to 74% comparing Test HD to Test GZ. Reductions of 20% to 82% were also calculated for individual analytes.

Binder percentages influence emissions on a relative basis when calculated as lb/lb binder. When comparing emissions on a lb/lb binder basis for the Emission Indicators, decreases of 29, 35 and 40% in TGOC as Propane and in the Sums of Target Organic Analytes and HAPs, respectively, were calculated as can be seen in Table 3-1b. Results for individual analytes for the test calculated averages which were low relative to the stated reporting limit of 0.0001 lb/lb binder are shown as < 0.0001 on Table 3-1b. In this circumstance, the relative percent difference between the two tests then becomes NA (not applicable). The exceptions are for acetaldehyde, benzene, toluene, and formaldehyde which showed 41%, 33%, 48% and 83% decrease, respectively, from Test GZ to Test HD.

Nine (9) organic analytes and isomer classes accounted for more than 95% of the concentration of all emitted targeted organic analytes detected from Test HD when calculated as both lb/ton of metal and lb/lb of binder. Acetaldehyde and benzene were responsible for 27% and 24% of emissions, respectively. Trimethylbenzenes contributed 12%, and formaldehyde contributed the fourth highest at 11%. The remaining six analytes contributed 8% and less.

The BeachBox® tensile bars show better strength than those made with Corosil® in all cases except for the 24 hour humidity test. The tensile specimens collapsed under their own weight in that test, resulting in a tensile strength of 0 psi. It is important to note that even though BeachBox® tensile specimens were made at 2.5% (BOS) binder as opposed to 5.0% (BOS) binder for the Corosil® specimens, they had higher tensile strengths. Both the Corosil® and the BeachBox® binders show considerably less strength than generic phenolic urethane binders.

The castings from Test GZ had a smoother surface than those from Test HD. The castings from Test GZ also had less burn-in. The casting surface appearance from both of these tests could be due to the core wash used.

APPENDIX A TEST & SAMPLE PLANS AND PROCESS INSTRUCTIONS

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TECHNIKON TEST PLAN

- **CONTRACT NUMBER:** 1412 **TASK NUMBER:** 1.2.2 **SERIES:** GZ
- **SITE:** Research Foundry
- **TEST TYPE:** Pouring, cooling, shakeout baseline, uncoated Hill and Griffith Corosil® sodium silicate core in greensand.
- **METAL TYPE:** Class 30, gray iron.
- **MOLD TYPE:** 4-on step core greensand with no seacoal.
- **NUMBER OF MOLDS:** 3 engineering/conditioning + 9 Sampling + 3 casting quality.
- **CORE TYPE:** Step; Wedron 530 sand; 5.0 % (BOS) Hill & Griffith Corosil® binder, CO_2 activated.
- **CORE COATING:** Foseco RHEOTEC® for conditioning runs, Foseco Isomol® for casting quality runs, none for emission runs
- **SAMPLE EVENTS:** 9
- **ANALYTE LIST** List G, CO/CO_2, NO_x, SO_2, TGOC
- **TEST DATE:** **START**: 12 Dec 2005

  FINISHED: 21 Dec 2005

TEST OBJECTIVES:

Measure selected PCS HAP & VOC emissions, CO, CO_2, NO_x, and TGOC from Hill & Griffith Corosil® binder activated with CO_2 in greensand with no seacoal to update the core baseline to include washed cores for casting internal surface comparisons.

VARIABLES:

The pattern will be the 4-on step core. The mold will be made with Wexford 450 sand, western and southern bentonite in a 5:2 ratio to yield 7.0 +/- 0.5% MB Clay, no seacoal, and tempered to 40-45% compactability, mechanically compacted. The molds will be maintained at 70-90^{o}F prior to pouring. The sand heap will be maintained at 900 pounds. Molds will be poured with iron at 2630 +/- 10^{o}F. Mold cooling will be 45 minutes followed by 15 minutes of shakeout, or until no more material remains to be shaken out, followed by 15 minutes additional sampling for a total of 75 minutes.

BRIEF OVERVIEW:

These greensand molds will be produced on mechanically assisted Osborne molding machines. (Ref. CERP test FH). The 4-on step-core standard mold is a 24 x 24 x 10/10 inch 4-on array of standard AFS, drag only, step core castings against which other binder systems can be compared. The cores will be manufactured at Technikon.

SPECIAL CONDITIONS:

The process will include rigorous maintenance of the size of sand heap and maintenance of the material and environmental testing temperatures to reduce seasonal and daily temperature dependent influence on the emissions. Initially a 1200 pound greensand heap will be created from a single muller batch. Nine hundred pounds will become the re-circulating heap. The balance will be used to makeup for attrition. Cores will be produced with Wedron 530 silica sand. The cores shall be bagged in plastic. Coated and dried cores will be bagged as soon as sufficiently cooled. The cores for the runs GZ013-015 will be dipped to provide 12 castings with an internal surface available for comparison to as best, average, and worst by other coated cores made with other core binders.

TECHNIKON TEST PLAN

- **CONTRACT NUMBER:** 1412 **TASK NUMBER** 116 **SERIES** HD
- **SITE:** Research Foundry
- **TEST TYPE:** Pouring, cooling, shakeout: uncoated Laempe BeachBox® LK700-403 cores in greensand.
- **METAL TYPE:** Class 30 gray Iron
- **MOLD TYPE:** 4-on stepcore greensand with no seacoal
- **NUMBER OF MOLDS:** 3 engineering/conditioning, 9 sampling
- **CORE TYPE:** Step; Wedron 530 sand; 2.5% (BOS) LK700-403, hot air cured
- **CORE COATING:** Ashland Weissfilm® for casting quality/conditioning runs, none for emission runs.
- **SAMPLE EVENTS:** 9
- **TEST DATE(S):** **START:** 10 Apr 2006
  FINISH: 13 Apr 2006

TEST OBJECTIVES:

Measure selected PCS HAP & VOC emissions, CO, CO_2, NOx, and TGOC from Laempe BeachBox® LK700-403 core binder in greensand with no seacoal compared to Test GZ, the core baseline, to include washed cores for casting internal surface comparisons. Results will be calculated in pounds of emissions per pound of binder and pounds of emissions per ton of metal poured.

VARIABLES:

The pattern will be the 4-on step core. The mold will be made with Wexford 450 sand, western and southern bentonite in a 5:2 ratio to yield 7.0 ± 0.5% MB Clay, no seacoal, and tempered to 40-45% compactability, mechanically compacted. The molds will be maintained at 70-90°F prior to pouring. The sand heap will be maintained at 900 pounds. Molds will be poured with Class 30 gray iron at 2630 ± 10°F. Mold cooling will be 45 minutes followed by 15 minutes of shakeout, or until no more material remains to be shaken out, followed by 15 minutes additional sampling for a total of 75 minutes.

BRIEF OVERVIEW:

These greensand molds will be produced on mechanically assisted Osborne molding machines. (Ref. CERP test FH). The 4-on step-core standard mold is a 24 x 24 x 10/10 inch 4-on array of standard AFS, drag only, step core castings against which other binder systems can be compared. The cores will be manufactured at Technikon.

SPECIAL CONDITIONS:

The process will include rigorous maintenance of the size of sand heap and maintenance of the material and environmental testing temperatures to reduce seasonal and daily temperature dependent influence on the emissions. Initially a 1200 pound greensand heap will be created from a single muller batch. Nine hundred pounds will become the re-circulating heap. The balance will be used to makeup for attrition. Cores will be produced with Wedron 530 silica sand. The cores shall be bagged in plastic. Coated and dried cores will be bagged as soon as sufficiently cooled. The cores for the engineering runs HDER1-3 will be dipped to provide 12 castings with an internal surface available for comparison to as best, average, and worst by other coated cores made with other core binders.

RESEARCH FOUNDRY GZ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/12/2005											
CONDITIONING - 1											
THC, CO, CO_2 & NOx	GZ CR-1	X									TOTAL

RESEARCH FOUNDRY GZ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/12/2005											
CONDITIONING - 2											
THC, CO, CO_2 & NOx	GZ CR-2	X									TOTAL

RESEARCH FOUNDRY GZ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/12/2005											
CONDITIONING - 3											
THC, CO, CO_2 & NOx	GZ CR-3	X									TOTAL

RESEARCH FOUNDRY GZ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/13/2005											
THC, CO, CO_2 & NOx	GZ001	X									TOTAL
TO-17	GZ00101		1						60	1	Carbopak charcoal
TO-17	GZ00102				1				0		Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								500	4	Excess
	Excess								500	5	Excess
OSHA ID200	GZ00103		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GZ00104				1				0		100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GZ00105		1						1000	8	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	GZ00106				1				0		100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GZ00107		1						1000	10	DNPH Silica Gel (SKC 226-119)
TO11	GZ00108				1				0		DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GZ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
12/13/2005											
THC, CO, CO_2 & NOx	GZ002	X									TOTAL
TO-17	GZ00201		1						60	1	Carbopak charcoal
TO-17	GZ00202			1					60	2	Carbopak charcoal
	Excess								60	3	Excess
	Excess								500	4	Excess
	Excess								500	5	Excess
OSHA ID200	GZ00203		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GZ00204			1					1000	7	100/50 mg Carbon Bead (SKC 226-80)
NIOSH 1500	GZ00205		1						1000	8	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	GZ00206			1					1000	9	100/50 mg Charcoal (SKC 226-01)
TO11	GZ00207		1						1000	10	DNPH Silica Gel (SKC 226-119)
TO11	GZ00208			1					1000	11	DNPH Silica Gel (SKC 226-119)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GZ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/13/2005											
THC, CO, CO_2 & NOx	GZ003	X									TOTAL
TO-17	GZ00301		1						60	1	Carbopak charcoal
TO-17 MS	GZ00302		1						60	2	Carbopak charcoal
TO-17 MS	GZ00303			1					60	3	Carbopak charcoal
	Excess								500	4	Excess
	Excess								500	5	Excess
OSHA ID200	GZ00304		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GZ00305		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GZ00306		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GZ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
12/14/2005											
THC, CO, CO_2 & NOx	GZ004	X									TOTAL
TO-17	GZ00401		1						60	1	Carbopak charcoal
TO-17	GZ00402					1			60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								500	4	Excess
	Excess								500	5	Excess
OSHA ID200	GZ00403		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GZ00404		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GZ00405		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GZ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/14/2005											
THC, CO, CO_2 & NOx	GZ005	X									TOTAL
TO-17	GZ00501		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								500	4	Excess
	Excess								500	5	Excess
OSHA ID200	GZ00502		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GZ00503		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GZ00504		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GZ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/14/2005											
THC, CO, CO_2 & NOx	GZ006	X									TOTAL
TO-17	GZ00601		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								500	4	Excess
	Excess								500	5	Excess
OSHA ID200	GZ00602		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GZ00603		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GZ00604		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GZ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/15/2005											
THC, CO, CO_2 & NOx	GZ007	X									TOTAL
TO-17	GZ00701		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								500	4	Excess
	Excess								500	5	Excess
OSHA ID200	GZ00702		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GZ00703		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GZ00704		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GZ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
12/15/2005											
THC, CO, CO_2 & NOx	GZ008	X									TOTAL
TO-17	GZ00801		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								500	4	Excess
	Excess								500	5	Excess
OSHA ID200	GZ00802		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GZ00803		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GZ00804		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GZ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
12/15/2005											
THC, CO, CO_2 & NOx	GZ009	X									TOTAL
TO-17	GZ00901		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								500	4	Excess
	Excess								500	5	Excess
OSHA ID200	GZ00902		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GZ00903		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GZ00904		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HD - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
4/10/2006											
CONDITIONING - 1											
THC, CO, CO2 & NOx	HD CR-1	X									TOTAL

RESEARCH FOUNDRY HD - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
4/10/2006											
CONDITIONING - 2											
THC, CO, CO2 & NOx	HD CR-2	X									TOTAL

RESEARCH FOUNDRY HD - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
4/10/2006											
CONDITIONING - 3											
THC, CO, CO2 & NOx	HD CR-3	X									TOTAL

RESEARCH FOUNDRY HD - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
4/11/2006											
THC, CO, CO2 & NOx	HD001	X									TOTAL
TO-17	HD00101		1						60	1	Carbopak charcoal
TO-17	HD00102				1				0		Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HD00103		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	HD00104				1				0		100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HD00105		1						1000	8	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	HD00106				1				0		100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HD00107		1						1000	10	DNPH Silica Gel (SKC 226-119)
TO11	HD00108				1				0		DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HD - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
4/11/2006											
THC, CO, CO2 & NOx	HD002	X									TOTAL
TO-17	HD00201		1						60	1	Carbopak charcoal
TO-17	HD00202			1					60	2	Carbopak charcoal
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HD00203		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	HD00204			1					1000	7	100/50 mg Carbon Bead (SKC 226-80)
NIOSH 1500	HD00205		1						1000	8	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	HD00206			1					1000	9	100/50 mg Charcoal (SKC 226-01)
TO11	HD00207		1						1000	10	DNPH Silica Gel (SKC 226-119)
TO11	HD00208			1					1000	11	DNPH Silica Gel (SKC 226-119)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HD - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
4/11/2006											
THC, CO, CO2 & NOx	HD003	X									TOTAL
TO-17	HD00301		1						60	1	Carbopak charcoal
TO-17 MS	HD00302		1						60	2	Carbopak charcoal
TO-17 MS	HD00303			1					60	3	Carbopak charcoal
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HD00304		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HD00305		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HD00306		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HD - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
4/12/2006											
THC, CO, CO2 & NOx	HD004	X									TOTAL
TO-17	HD00401		1						60	1	Carbopak charcoal
TO-17	HD00402					1			60	1	Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HD00403		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HD00404		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HD00405		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HD - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
4/12/2006											
THC, CO, CO2 & NOx	HD005	X									TOTAL
TO-17	HD00501		1						60	1	Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HD00502		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HD00503		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HD00504		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HD - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
4/12/2006											
THC, CO, CO2 & NOx	HD006	X									TOTAL
TO-17	HD00601		1						60	1	Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HD00602		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HD00603		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HD00604		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HD - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
4/13/2006											
THC, CO, CO2 & NOx	HD007	X									TOTAL
TO-17	HD00701		1						60	1	Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HD00702		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HD00703		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HD00704		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HD - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
4/13/2006											
THC, CO, CO2 & NOx	HD008	X									TOTAL
TO-17	HD00801		1						60	1	Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HD00802		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HD00803		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HD00804		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HD - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
4/13/2006											
THC, CO, CO2 & NOx	HD009	X									TOTAL
TO-17	HD00901		1						60	1	Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HD00902		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HD00903		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HD00904		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

1412-1.2.2-GZ

PCS Baseline: Greensand Uncoated Core with Hill and Griffith Corosil Core Binder & Mechanized Molding

Process Instructions

A. Experiment

1. Baseline emissions measurement from a greensand mold, with CO_2 cured Hill and Griffith Corosil cores, made with all virgin Wexford W450 sand, bonded with western & southern bentonite in the ratio of 5:2 to yield 7.0 +/- 0.5% MB Clay, and no seacoal. The molds shall be tempered with potable water to 40-45% compactability, poured at constant weight, temperature, surface area, & shape factor. This test will recycle the same mold material, replacing burned clay with new materials after each casting cycle and providing clay for the retained core sand.

B. Materials

1. Mold sand

a. Virgin mix of Wexford W450 lake sand, western and southern bentonites in ratio of 5:2, and potable water per recipe.

2. Core

a. Uncoated step core (for emisson runs GZ001-GZ009) made with virgin Wedron 530 silica sand and 5.0% (BOS) Hill and Griffith Corosil, CO_2 cured.

3. Core coating

a. Foseco RHEOTEC™ for engineering runs GZER1-3 and Foseco IsoMol® for production runs GZ013-GZ015 only, none for engineering runs GZ001-GZ009.

4. Metal

a. Class 30, gray cast iron poured at 2630 +/- 10°F.

5. Pattern release

a. Black Diamond, hand wiped.

6. 20 pores per inch (ppi) 2 x 2 x 0.5 ceramic foam filter.

C. Briefing

1. The Process Engineer, Emissions Engineer, and the area Supervisor will brief the operating personnel on the requirements of the test at least one (1) day prior to the test.

Caution

Observe all safety precautions attendant to these operations as delineated in the Pre-production operating and safety instruction manual.

D. Silicate Cores

1. Core sand mixing

a. Clean the core sand mixer.
b. Add 50 pounds of virgin Wedron 530 to the running mixer.
c. Slowly pour 2.5 +/- .03 pounds of sodium silicate resin into the sand. Distribute the resin as it is poured. Avoid pouring the resin on the plows or walls of the mixer or in one location or resin balling will occur preventing proper mixing.
d. Mix for three minutes after the resin is all in.
e. One batch will make about 6 cores.

2. Making step cores

a. Place the core box on a flat surface large open side up.
b. Place about 2 inches of sand in the bottom of the step section. Firmly tamp the sand into the 1inch diameter bottom using a ½ inch diameter rod.
c. Place a few more inches of sand in the core box and compact it. Take care to avoid parting planes. Repeat until the box is full.
d. Scrape off the excess. Remove the unused sand away from the gassing area.
e. Place a gassing plate on the open end of the core box.
f. Hold the plate down and gas the core for 30 seconds on each of the two gas holes with 20 PSI CO_2 gas.
g. Dry the cores for two hours at 250°F and allow them to cool.
h. Bag the cores in moisture proof bags for storage.
i. Identify each bag by batch number.
j. Record the date, batch number, the batch mix time, sand batch weight, resin weight, the gassing time, the gas pressure, individual dried core weight, good core count from each batch.

3. Core coating for runs GZER-1 to GZER-3

a. Store the client supplied core coating at 70-80 °F for 24 hours prior to use.
b. Vigorously stir the client supplied core coating.
c. Test and record the Baumé scale reading.
d. Measure and record the coating temperature.
e. Dip the core in the tip-down position to within ½ inch of the blow end.
  1) The tip of an un-dipped core can be used as a substitute for the LOI test sample for the engineering runs.

f. Quickly set the core into the oven.
g. Dry the coated core at 230°F for 1 hour. Measure and record un-dipped and dried dipped weight.
h. Re-bag the cores.

4. Core coating for runs GZER-13 to GZER-15
  a. Store the Isomol core coating at 70-80°F for 24 hours prior to use.
  b. Vigorously stir the client supplied core coating.
  c. Add 90% or greater IPA to the coating until the Baumé is between 45 and 50.
  d. Test and record the Baumé scale reading.
  e. Measure and record the coating temperature.
  f. Dip the core in the tip-down position to within ½ inch of the blow end.
    1) The tip of an un-dipped core can be used as a substitute for the LOI test sample for the engineering runs.
  g. Allow the coating to stop running and begin dripping, then shake the core a couple of times and set it aside tip up.
  h. Dry the coated core at 325°F for 1 hour. Measure and record un-dipped and dried dipped weight.
  i. Re-bag the cores.

5. Dog Bone Manufacture
  a. Hook up the CO_2 to the small Redford Carver Machine
  b. Set the parameters per the AFS Procedure
  c. If available, use the sand/sodium silicate mixture from core making; Proceed to step D.4.e
  d. Use the KitchenAid® mixer
    1) Add 5 pounds of lake sand to the running mixer.
    2) Slowly pour .25 +/- .03 pounds of sodium silicate resin into the sand. Distribute the resin as it is poured. Avoid pouring the resin on the plows or walls of the mixer or in one location or resin balling will occur preventing proper mixing.
    3) Mix for three minutes after the resin is all in.

  e. Power machine on.
  f. Fill the sand head with the sand/sodium silicate mix.
  g. Depress the horizontal clamp start buttons until the horizontal clamp engaged light comes on.
  h. Place the sand head above the dog bone boxes
  i. Clamp down on the head by pulling the slot machine–like arm.
  j. Press the blow start button
  k. Remove the sand head and replace it with the gas head.
  l. Clamp down on the head by pulling the slot machine–like arm.
  m. Open the gas valve and close after 15 seconds.
  n. Remove the gas head
  o. After the clamps open remove and inspect the dog bones for completeness, if need be adjust the settings on the machine, and discard the dog bones.
  p. Record the time and settings from when the dog bones were made and store the dog bones in a desiccator.
  q. Repeat from step D.4.e until there are 30 dog bones made for a 5 minute, 2 hour, 24

hour and 24 hour with 100% humidity tensile test.

E. Sand preparation

1. Start up batch: make 1, GZER1.

- **a.** Thoroughly clean the pre-production muller elevator and molding hoppers.
- **b.** Weigh and add 1130 +/-10 pounds of new Wexford W450 lake sand, per the recipe, to the running pre-production muller to make a 1200 batch.
- **c.** Add 5 pounds of potable water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
- **d.** Add the clays slowly to the muller to allow them to be distributed throughout the sand mass in proportion to the sand weight per the recipe for this test.
- **e.** Dry mull for about 3 minutes to allow distribution and some grinding of the clays to occur.
- **f.** Temper the sand-clay mixture slowly, with potable water, to allow for distribution.
- **g.** After about 16 pounds of water have been added allow 30 seconds of mixing then start taking compactability test samples.
- **h.** Based on each test add water incrementally to adjust the temper. Allow 1 minute of mixing. Retest. Repeat until the compactability, as would be measured at the mold, is in the range 40-45%.
- **i.** Discharge the sand into the mold station elevator.
- **j.** Grab sufficient sample after the final compactability test to fill a quart zip-lock bag. Label bag with the test series and sequence number, date, and time of day and deliver it immediately to the sand lab for analysis
- **k.** Record the total sand mixed in the batch, the total of each type of clay added to the batch, the amount of water added, the total mix time, the final compactability and sand temperature at discharge into the mold. The sand will be characterized for Methylene Blue Clay, AFS clay, Moisture content, Compactability, Green Compression strength, Permeability 1800 °F loss on ignition (LOI), and 900°F volatiles. Each volatile test requires a separate 50 gram sample from the collected sand. Each LOI test requires 3 separate 30 gram samples from the collected sand.
- **l.** Empty the extra greensand from the mold hopper into a clean empty dump hopper whose tare weight is known. Set this sand aside to be used to maintain the recycled batch at 900+/-10 pounds

2. Re-mulling: GZER2

- **a.** Add to the sand recovered from poured mold GZER1 sufficient pre-blended sand so that the sand batch weight is 900 +/- 10 pounds. Record the sand weight.
- **b.** Return the sand to the muller and dry blend for about one minute.
- **c.** Add the clays, as directed by the process engineering staff, slowly to the muller to allow them to be distributed throughout the sand mass.
- **d.** Add 5 pounds of water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
- **e.** Follow the above procedure beginning at E.1.f.

3. Re-mulling: GZER3, GZ004-GZ015
   a. Add to the sand recovered from the previous poured mold, mold machine spill sand, the residual mold hopper sand and sufficient pre-blended sand to total 900 +/- 10 pounds.
   b. Return the sand to the muller and dry blend for about one minute.
   c. Add the clays, as directed by the process engineering staff, slowly to the muller to allow them to be distributed throughout the sand mass.
   d. Add 5 pounds of water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
   e. Follow the above procedure beginning at E.1.f.

F. Molding

1. Step core pattern.
   a. Pattern preparation
      1) Inspect and tighten all loose pattern and gating pieces.
      2) Repair any damaged pattern or gating parts.

2. Making the green sand mold.
   a. Mount the drag pattern on one Osborne Whisper Ram molding machine and mount the cope pattern on the other Osborne machine.
   b. Lightly rub parting oil from a damp oil rag on the pattern particularly in the corners and recesses.

Caution

Do not pour gross amounts of parting oil on the pattern to be blown off with air. This practice will leave sufficient oil at the parting line to be adsorbed by the sand weakening it and the burning oil will be detected by the emission samplers.

   c. Use the overhead crane to place the pre-weighed drag/cope flask on the mold machine table, parting line surface down.
   d. Locate a 24 x 24 x 4 inch deep wood upset on top of the flask.
   e. Make the green sand mold cope or drag on the Osborn Whisper Ram Jolt-Squeeze mold machine.

WARNING

Only properly trained personnel may operate this machine.
Proper personal protective equipment must be worn at all times while operating this equipment, including safety glasses with side shields and a properly fitting hard hat. Industrial type boots are highly recommended.

WARNING

Stand clear of the mold machine table and swinging head during the following operation or serious injury or death could result.

f. Open the air supply to the mold machine.

WARNING
The squeeze head may suddenly swing to the outboard side or forward.
Do not stand in the outer corners of the molding enclosure.

g. On the operator's panel turn the POWER switch to ON.
h. Turn the RAM-JOLT-SQUEEZE switch to ON.
i. Turn the DRAW UP switch to AUTO.
j. Set the PRE-JOLT timer to 4-5 seconds.
k. Set the squeeze timer to 8 seconds.
l. Set the crow-footed gagger on the support bar. Verify that it is at least ½ inch away from any pattern parts.
m. Manually spread one to two inches or so of sand over the pattern using a shovel. Source the sand from the overhead mold sand hopper by actuating the hopper gate valve with the lever located under the operators panel.
n. Fill the center potion of the flask.
o. Manually move sand from the center portion to the outboard areas and hand tuck the sand.
p. Finish filling the 24 x 24 x 10 inch flask and the upset with greensand from the overhead molding hopper.
q. Manually level the sand in the upset. By experience manually adjust the sand depth so that the resulting compacted mold is fractionally above the flask only height.
r. The operator will grab a sand sample for the Lab. The sand technician will quickly measure the sand temperature and compactability and record the results.
s. Initiate the settling of the sand in the flask by pressing the PRE-JOLT push button. Allow this cycle to stop before proceeding.
t. Remove the upset and set it aside.

WARNING
Failure to stand clear of the molding table and flasks in the following operations could result in serious injury as this equipment is about to move up and down with great force.

WARNING
Stand clear of the entire mold machine during the following operations.
Several of the machine parts will be moving.
Failure to stand clear could result in severe injury even death.

u. Using both hands initiate the automatic machine sequence by simultaneously pressing, holding for 2-3 seconds, and releasing the green push buttons on either side of the operators panel. The machine will squeeze and jolt the sand in the flask and then move the squeeze head to the side.

WARNING

Do no re-approach the machine until the squeeze head has stopped at the side of the machine.

- **v.** Screed the bottom of the drag mold flat to the bottom of the flask if required.
- **w.** Press and release the LOWER DRAW/STOP push button to separate the flask and mold from the pattern.
- **x.** Use the overhead crane to lift the mold half and remove it from the machine. If the mold half is a drag, roll it parting line side up, set it on the floor, blow it out.
- **y.** Finally, press and release the DRAW DOWN pushbutton to cause the draw frame to return to the start position.
- **z.** Set four (4) step cores that have been weighed and logged into the drag. Verify that the cores are fully set and flush with the parting line and insert foam filter into its receiver.
- **aa.** Close the cope over the drag being careful not to crush anything.
- **bb.** Clamp the flask halves together.
- **cc.** Weigh and record the weight of the closed un-poured mold, the pre-weighed flask, the uncoated cores, and the sand weight by difference.
- **dd.** Measure and record the sand temperature.
- **ee.** Deliver the mold to the previously cleaned shakeout to be poured.
- **ff.** Cover the mold with the emission hood.

G. Pig molds

- **1.** Each day make a 900 pound capacity pig mold for the following day's use.

H. Emission hood

- **1.** Loading.
  - **a.** Hoist the mold onto the shakeout deck within the emission hood.
  - **b.** Close, seal, and lock the emission hood.
  - **c.** Adjust the ambient air heater control so that the measured temperature of the blended air within the hood is 85-90°F at the start of the test run.

I. Shakeout.

- **1.** After the 45 minute cooling time prescribed in the emission sample plan has elapsed turn on the shakeout unit and run for it the 15 minutes prescribed in the emission sample plan or until the sand has all fallen through the grating.
- **2.** Turn off the shakeout.
- **3.** Sample the emissions for 30 minutes after the start of shakeout, a total of 75 minutes.
  - **a.** When the emission sampling is completed remove the flask, with casting, and recover the sand from the hopper and surrounding floor.

- **4.** Weigh and record the metal poured and the total sand weight recovered and rejoined with the left over mold sand from the molding hopper, spilled molding sand, and sand loosely adhered to the casting.

5. Add sufficient unused premixed sand to the recycled sand to return the sand heap to 900 +/- 10 pounds.

J. Melting.

1. Initial iron charge
    - **a.** Charge the furnace according to the heat recipe.
    - **b.** Place part of the steel scrap on the bottom, followed by carbon alloys, and the balance of the steel.
    - **c.** Place a pig on top of the other materials.
    - **d.** Bring the furnace contents to the point of beginning to melt over a period of 1 hour at reduced power.
    - **e.** Add the balance of the metallics under full power until all is melted and the temperature has reached 2600 to 2700°F.
    - **f.** Slag the furnace and add the balance of the alloys.
    - **g.** Raise the temperature of the melt to 2700°F and take a DataCast 2000 sample. The temperature of the primary liquidus (TPL) must be in the range of 2200-2350°F.
    - **h.** Hold the furnace at 2500-2550°F until near ready to tap.
    - **i.** When ready to tap raise the temperature to 2700°F and slag the furnace.
    - **j.** Record all metallic and alloy additions to the furnace, tap temperature, and pour temperature. Record all furnace activities with an associated time.

2. Back charging.
    - **a.** Back charge the furnace according to the heat recipe.
    - **b.** Charge a few pieces of steel first to make a splash barrier, followed by the carbon alloys.
    - **c.** Follow the above steps beginning with J.1.e

K. Emptying the furnace.

1. Pig the extra metal only after the last emission measurement is complete to avoid contaminating the air sample.
2. Cover the empty furnace with ceramic blanket to cool.

L. Pouring

1. Preheat the ladle.
    - **a.** Tap 400 pounds more or less of 2700°F iron into the cold ladle.
    - **b.** Carefully pour the metal back into the furnace.
    - **c.** Cover the ladle.
    - **d.** Reheat the metal to 2780 +/- 20°F.
    - **e.** Tap 450 pounds of iron into the ladle while pouring inoculating alloys onto the metal stream near its base.

1412-1.1.6-HD

PCS Product Test: Uncoated Core with Laempe BeachBox® LK700-403 Core Binder in Greensand & Mechanized Molding

Process Instructions

A. Experiment:

1. Product emissions measurement from a greensand mold, with hot air cured Laempe BeachBox® LK700-403 cores, made with all virgin Wexford W450 sand, bonded with Western & Southern Bentonite in the ratio of 5:2 to yield 7.0 +/- 0.5 % MB Clay, & no seacoal. The molds shall be tempered with potable water to 40-45% compactability, poured at constant weight, temperature, surface area, & shape factor. This test will recycle the same mold material, replacing burned clay with new materials after each casting cycle and providing clay for the retained core sand.

B. Materials:

1. Mold sand:

a) Virgin mix of Wexford W450 lake sand, western and southern bentonites in ratio of 5:2, and potable water per recipe.

2. Core:

a) Uncoated step core (for engineering runs HD001-HD009) made with virgin Wedron 530 silica sand and 2.5% (BOS) Laempe BeachBox® LK700-403, hot air cured.

3. Core coating:

a) Customer choice for engineering runs HDER1-3 only, none for engineering runs HD001-HD009.

4. Metal:

a) Class-30 gray iron poured at 2630 ± 10°F.

5. Pattern release:

a) Black Diamond, hand wiped.

b) 20 pores per inch (ppi) 2 x 2 x 0.5 ceramic foam filter.

C. Briefing:

1. The Process Engineer, Emissions Engineer, and the area Supervisor will brief the operating personnel on the requirements of the test at least one (1) day prior to the test.

Caution

Observe all safety precautions attendant to these operations as delineated in the Pre-production operating and safety instruction manual.

D. Laempe BeachBox® Cores:

1. Klein vibratory core sand mixer.

a) The binder components should be 75-85°F.

b) Calibrate the Klein mixer sand batch size.

i) Calibrate sand.

- Turn the AUTO/MAN switch to MANUAL on main control panel.
- Zero a container on the scale.
- Put the same container below the mixing bowl to catch the sand.
- Open a few bags of WEDRON 530 sand into the sand hopper and manually fill batch hopper using max. and min. proximity switches.
- Discharge the sand from the batch hopper using the single cycle push button. Catch the sand as it leaves the batch hopper and record the net weight and the dispensing time.
- Repeat 3 times to determine the weight variation. The sand should be 75-85°F.

c) Stir binder for 10 minutes prior to use, and 2 minutes per hour during use.

d) Pre-weigh 2.5% (BOS) of the binder into a non-absorbing container for addition to the mixer.

e) Turn on the mixer and turn the AUTO/MAN switch to AUTO.

f) Press the SINGLE CYCLE push button on the operator's station to make a batch of sand. As soon as the sand enters the mixer chamber pour the pre-weighed binder through the open top front half of the mixing chamber.

g) Make three (3) batches to start the Redford Carver core machine.

h) Make a batch of sand for every 7 core machine cycles when using the step core. About two (2) batches will be retained in the core machine sand magazine.

i) Clean the mixer bowl when done.

Caution:
Do not make more sand than sand magazine will hold plus one (1) batch. If too much sand is made it will shorten the sand bench life

2. Redford/Carver core machine.

a) Mount the Step-Core core box on the Carver/Redford core machine.

b) Start the core machine auxiliary equipment per the Production Foundry OSI for that equipment.

c) Set up the core machine in the warm box mode with gassing and working pressures and gas and purge time according to the core recipe sheet.

i) Core process setup

- Set the core box heaters to 300°F
- Set the blow pressure to 50+/-2 psi for 3 seconds (R/C).
- Set the gas time to 0 seconds.

- Set the purge for 210 seconds(R/C).
- Total cycle time approximately 4 minutes.

d) Run the core machine for three (3) cycles and discard the cores. When the cores appear good begin test core manufacture. Five (5) good cores are required for each mold. Make five (5) additional 50 pound sand batches and run the sand out making core. A minimum of 60 cores are required.

e) The sand lab will sample one (1) core from the core rack for each mold produced just prior to the emission test to represent the four (4) cores placed in that mold. Those cores will be tested for LOI using the standard 1800 °F core LOI test method and reported out associated with the test mold it is to represent.

3. Dog Bone Manufacture

a) Set the parameters per the AFS Procedure

b) Use the Kitchen Aid® mixer

i) Add 5 pounds of Wedron 530 to the running mixer.

ii) Slowly pour 2.5% of sodium silicate resin into the sand. Distribute the resin as it is poured. Avoid pouring the resin on the plows or walls of the mixer or in one location or resin balling will occur preventing proper mixing.

iii) Mix for three minutes after the resin is all in.

c) Fill the sand head with sand and place it under the blow head

d) Compress the sand head with the lever and hit the blow button

e) Gas the samples in the same manner until hardened

f) Immediately put the samples in a desiccator and take them to the green room and tensile test them.

E. Sand preparation

1. Start up batch: make 1, HDER1.

a) Thoroughly clean the pre-production muller elevator and molding hoppers.

b) Weigh and add 1130 +/-10 pounds of new Wexford W450 lake sand, per the recipe, to the running pre-production muller to make a 1200 batch.

c) Add 5 pounds of potable water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.

d) Add the clays slowly to the muller to allow them to be distributed throughout the sand mass in proportion to the sand weight per the recipe for this test.

e) Dry mull for about 3 minutes to allow distribution and some grinding of the clays to occur.

f) Temper the sand-clay mixture slowly, with potable water, to allow for distribution.

g) After about 16 pounds of water have been added allow 30 seconds of mixing then start taking compactability test samples.

h) Based on each test add water incrementally to adjust the temper. Allow 1 minute of mixing. Retest. Repeat until the compactability, as would be measured at the mold, is in the range 40-45%.

i) Discharge the sand into the mold station elevator.

j) Record the total sand mixed in the batch, the total of each type of clay added to the batch, the amount of water added, the total mix time, the final compactability and sand temperature at discharge into the mold. The sand will be characterized for Methylene Blue Clay, AFS clay, Moisture content, Compactability, Green Compression strength, Permeability 1500°F loss on ignition (LOI), and 900°F volatiles. Each volatile test requires a separate 50 gram sample from the collected sand. Each LOI test requires 3 separate 30 gram samples from the collected sand.

k) Empty the extra greensand from the mold hopper into a clean empty dump hopper whose tare weight is known. Set this sand aside to be used to maintain the recycled batch at 900+/-10 pounds

2. Re-mulling: HDER2

a) Add to the sand recovered from poured mold HDER1 sufficient pre-blended sand so that the sand batch weight is 900 +/- 10 pounds. Record the sand weight.

b) Return the sand to the muller and dry blend for about one minute.

c) Add the clays, as directed by the process engineering staff, slowly to the muller to allow them to be distributed throughout the sand mass.

d) Add 5 pounds of water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.

e) Follow the above procedure beginning at E.1.f.

3. Re-mulling: HDER3, HD001-HD009

a) Add to the sand recovered from the previous poured mold, mold machine spill sand, the residual mold hopper sand and sufficient pre-blended sand to total 900 +/- 10 pounds.

b) Return the sand to the muller and dry blend for about one minute.

c) Add the clays, as directed by the process engineering staff, slowly to the muller to allow them to be distributed throughout the sand mass.

d) Add 5 pounds of water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.

e) Follow the above procedure beginning at E.1.f.

F. Molding:

1. Step core pattern.

a) Pattern preparation:

i) Inspect and tighten all loose pattern and gating pieces.

ii) Repair any damaged pattern or gating parts.

2. Making the green sand mold.

a) Mount the drag pattern on one Osborne Whisper Ram molding machine and mount the cope pattern on the other Osborne machine.

b) Lightly rub parting oil from a damp oil rag on the pattern particularly in the corners and recesses.

Caution:
Do not pour gross amounts of parting oil on the pattern to be blown off with air. This practice will leave sufficient oil at the parting line to be adsorbed by the sand weakening it and the burning oil will be detected by the emission samplers.

c) Use the overhead crane to place the pre-weighed drag/cope flask on the mold machine table, parting line surface down.
d) Locate a 24 x 24 x 4 inch deep wood upset on top of the flask.
e) Make the green sand mold cope or drag on the Osborn Whisper Ram Jolt-Squeeze mold machine.

WARNING
Only properly trained personnel may operate this machine.
Proper personal protective equipment must be worn at all times while operating this equipment, including safety glasses with side shields and a properly fitting hard hat.
Industrial type boots are highly recommended.

WARNING
Stand clear of the mold machine table and swinging head during the following operation or serious injury or death could result.

f) Open the air supply to the mold machine.

WARNING
The squeeze head may suddenly swing to the outboard side or forward.
Do not stand in the outer corners of the molding enclosure.

g) On the operator's panel turn the POWER switch to ON.
h) Turn the RAM-JOLT-SQUEEZE switch to ON.
i) Turn the DRAW UP switch to AUTO.
j) Set the PRE-JOLT timer to 4-5 seconds.
k) Set the squeeze timer to 8 seconds.
l) Set the crow-footed gagger on the support bar. Verify that it is at least ½ inch away from any pattern parts.
m) Manually spread one to two inches or so of sand over the pattern using a shovel. Source the sand from the overhead mold sand hopper by actuating the hopper gate valve with the lever located under the operators panel.
n) Fill the center potion of the flask.

o) Manually move sand from the center portion to the outboard areas and hand tuck the sand.
p) Finish filling the 24 x 24 x 10 inch flask and the upset with greensand from the overhead molding hopper.
q) Grab a sufficient sample of sand to fill a quart zip-lock bag. Label bag with the test series and sequence number, date, and time of day and deliver it immediately to the sand lab for analysis
r) Manually level the sand in the upset. By experience manually adjust the sand depth so that the resulting compacted mold is fractionally above the flask only height.
s) The operator will grab a sand sample for the Lab. The sand technician will quickly measure the sand temperature and compactability and record the results.
t) Initiate the settling of the sand in the flask by pressing the PRE-JOLT push button. Allow this cycle to stop before proceeding.
u) Remove the upset and set it aside.

WARNING
Failure to stand clear of the molding table and flasks in the following operations could result in serious injury as this equipment is about to move up and down with great force.

WARNING
Stand clear of the entire mold machine during the following operations.
Several of the machine parts will be moving.
Failure to stand clear could result in severe injury even death.

v) Using both hands initiate the automatic machine sequence by simultaneously pressing, holding for 2-3 seconds, and releasing the green push buttons on either side of the operators panel. The machine will squeeze and jolt the sand in the flask and then move the squeeze head to the side.

WARNING
Do not re-approach the machine until the squeeze head has stopped at the side of the machine.

w) Screed the bottom of the drag mold flat to the bottom of the flask if required.
x) Press and release the LOWER DRAW/STOP push button to separate the flask and mold from the pattern.
y) Use the overhead crane to lift the mold half and remove it from the machine. If the mold half is a drag, roll it parting line side up, set it on the floor, blow it out.
z) Finally, press and release the DRAW DOWN pushbutton to cause the draw frame to return to the start position.
aa) Set four (4) step cores that have been weighed and logged into the drag. Verify that the cores are fully set and flush with the parting line and insert foam filter into its

receiver.

bb) Close the cope over the drag being careful not to crush anything.
cc) Clamp the flask halves together.
dd) Weigh and record the weight of the closed un-poured mold, the pre-weighed flask, the uncoated cores, and the sand weight by difference.
ee) Measure and record the sand temperature.
ff) Deliver the mold to the previously cleaned shakeout to be poured.
gg) Cover the mold with the emission hood.

G. Emission hood:

1. Loading.

a) Hoist the mold onto the shakeout deck within the emission hood.
b) Close, seal, and lock the emission hood.
c) Adjust the ambient air heater control so that the measured temperature of the blended air within the hood is 85-90°F at the start of the test run.

H. Shakeout.

1. After the 45 minute cooling time prescribed in the emission sample plan has elapsed turn on the shakeout unit and run for it the 15 minutes prescribed in the emission sample plan or until the sand has all fallen through the grating.
2. Turn off the shakeout.
3. Sample the emissions for 30 minutes after the start of shakeout, a total of 75 minutes.

a) When the emission sampling is completed remove the flask, with casting, and recover the sand from the hopper and surrounding floor.

4. Weigh and record the metal poured and the total sand weight recovered and rejoined with the left over mold sand from the molding hopper, spilled molding sand, and sand loosely adhered to the casting.
5. Add sufficient unused premixed sand to the recycled sand to return the sand heap to 900 +/- 10 pounds.

I. Melting:

1. Initial iron charge:

a) Charge the furnace according to the heat recipe.
b) Place part of the steel scrap on the bottom, followed by carbon alloys, and the balance of the steel.
c) Place a pig on top of the other materials.
d) Bring the furnace contents to the point of beginning to melt over a period of 1 hour at reduced power.
e) Add the balance of the metallics under full power until all is melted and the temperature has reached 2600 to 2700°F.
f) Slag the furnace and add the balance of the alloys.

- **g)** Raise the temperature of the melt to 2700°F and take a DataCast 2000 sample. The temperature of the primary liquidus (TPL) must be in the range of 2200-2350°F.
- **h)** Hold the furnace at 2500-2550°F until near ready to tap.
- **i)** When ready to tap raise the temperature to 2700°F and slag the furnace.
- **j)** Record all metallic and alloy additions to the furnace, tap temperature, and pour temperature. Record all furnace activities with an associated time.

2. Back charging.
- **a)** Back charge the furnace according to the heat recipe.
- **b)** Charge a few pieces of steel first to make a splash barrier, followed by the carbon alloys.
- **c)** Follow the above steps beginning with I.1.e

J. Emptying the furnace.
- **1.** Pig the extra metal only after the last emission measurement is complete to avoid contaminating the air sample.
- **2.** Cover the empty furnace with ceramic blanket to cool.

K. Pouring:
1. Preheat the ladle.
- **a)** Tap 400 pounds more or less of 2700°F iron into the cold ladle.
- **b)** Carefully pour the metal back into the furnace.
- **c)** Cover the ladle.
- **d)** Reheat the metal to 2780 +/- 20°F.
- **e)** Tap 450 pounds of iron into the ladle while pouring inoculating alloys onto the metal stream near its base.
- **f)** Cover the ladle to conserve heat.
- **g)** Move the ladle to the pour position and wait until the metal temperature reaches 2630 +/- 10°F.
- **h)** Commence pouring keeping the sprue full.
- **i)** Upon completion, return the extra metal to the furnace and cover the ladle.
- **j)** Record the pour temperature and pour time on the heat log.

L. Shot Blasting
- **1.** All castings from emission runs HDER1-HDER3 will be shot blasted for 8 minutes at 12 amps, weighed and the weight recorded, and saved for evaluation.
- **2.** All castings from emission runs HD001-HD009 will be shot blasted for 8 minutes at 12 amps, weighed and the weight recorded, and recycled.

M. Rank order evaluation.
- **1.** The supervisor shall select a group of up to five persons to make a collective subjective judgment of the casting relative surface appearance.

2. The rank order evaluation for cored castings shall be done on castings from the Engineering/ conditioning runs HDER1-3, with coated cores, only.
3. Review the general appearance of the interior of the castings and select specific casting features to compare.
4. For each cavity 1-4 :
   a) Place each casting initially in sequential mold number order.
   b) Beginning with the casting from mold HDER1, compare it to castings from mold HDER2.
   c) Place the better appearing casting in the first position and the lesser appearing casting in the second position.
   d) Repeat this procedure with HDER1 to its nearest neighbors until all castings closer to the beginning of the line are better appearing than HDER1 and the next casting farther down the line is inferior.
   e) Repeat this comparison to next neighbors for each casting number.
   f) When all casting numbers have been compared go to the beginning of the line and begin again comparing each casting to its nearest neighbor. Move the castings so that each casting is inferior to the next one closer to the beginning of the line and superior to the one next toward the tail of the line.
   g) Repeat this comparison until all concur with the ranking order.

5. Record mold number by rank-order series for this cavity.
6. Compare the castings to the best, median, and worst rated castings for test GZ.

Thomas J Fennell Jr.
Process Engineer

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APPENDIX B DETAILED EMISSION RESULTS AND QUANTITATION LIMITS

Test GZ - Detailed Emissions Data - Lb/Tn Metal

Organic Analytes	POM	HAP		GZ001	GZ002	GZ003	GZ004	GZ005	GZ006	GZ007	GZ008	GZ009	Average	Standard Deviation
			Test Dates	**13-Dec-05**	**13-Dec-05**	**13-Dec-05**	**14-Dec-05**	**14-Dec-05**	**14-Dec-05**	**15-Dec-05**	**15-Dec-05**	**15-Dec-05**	—	—
Emission Indicators														
			TGOC as Propane	1.49E-01	1.50E-01	1.86E-01	1.71E-01	2.00E-01	1.94E-01	1.94E-01	2.03E-01	2.12E-01	1.84E-01	2.28E-02
			HC as Hexane	2.89E-02	3.37E-02	1.91E-02	3.64E-02	5.06E-02	5.06E-02	3.62E-02	3.72E-02	6.20E-02	3.94E-02	1.29E-02
			Sum of Target VOCs	2.79E-02	3.02E-02	3.64E-02	3.38E-02	4.02E-02	4.05E-02	4.10E-02	3.87E-02	3.80E-02	3.64E-02	4.71E-03
			Sum of Target HAPs	2.58E-02	2.64E-02	3.13E-02	3.02E-02	3.43E-02	3.46E-02	3.64E-02	3.42E-02	3.36E-02	3.19E-02	3.74E-03
			Sum of Target POMs	1.36E-03	1.27E-03	1.97E-03	1.61E-03	2.15E-03	2.15E-03	1.51E-03	2.00E-03	1.70E-03	1.75E-03	3.33E-04
Selected Target Organic HAPs and POMs														
O		H	Acetaldehyde	8.98E-03	9.06E-03	1.09E-02	9.97E-03	1.07E-02	1.07E-02	1.12E-02	1.10E-02	1.10E-02	1.04E-02	8.45E-04
O		H	Benzene	6.46E-03	6.54E-03	7.54E-03	7.56E-03	8.48E-03	8.72E-03	9.93E-03	8.76E-03	8.77E-03	8.09E-03	1.15E-03
O		H	Toluene	3.02E-03	2.79E-03	3.32E-03	3.39E-03	3.80E-03	3.80E-03	4.15E-03	3.84E-03	3.86E-03	3.55E-03	4.46E-04
O		H	Xylene, mp-	1.54E-03	1.51E-03	1.78E-03	2.05E-03	2.32E-03	2.32E-03	2.32E-03	2.26E-03	2.22E-03	2.03E-03	3.37E-04
O		H	Phenol	1.10E-03	1.01E-03	1.23E-03	1.23E-03	1.93E-03	1.93E-03	2.07E-03	1.11E-03	9.92E-04	1.40E-03	4.44E-04
O		H	Formaldehyde	1.31E-03	1.26E-03	1.35E-03	1.47E-03	1.42E-03	1.42E-03	1.40E-03	1.16E-03	1.24E-03	1.34E-03	1.02E-04
O		H	Propionaldehyde (Propanal)	9.82E-04	1.01E-03	1.22E-03	1.12E-03	1.26E-03	1.26E-03	1.44E-03	1.41E-03	1.57E-03	1.25E-03	1.97E-04
O	P	H	Naphthalene	5.40E-04	5.74E-04	7.82E-04	5.89E-04	9.18E-04	9.18E-04	6.95E-04	8.36E-04	7.19E-04	7.30E-04	1.44E-04
O		H	Hexane	I	9.58E-04	5.91E-04	4.62E-04	6.39E-04	6.39E-04	7.18E-04	1.00E-03	5.45E-04	6.95E-04	1.92E-04
O		H	Xylene, o-	5.24E-04	4.95E-04	5.40E-04	6.23E-04	7.32E-04	7.32E-04	7.23E-04	6.85E-04	7.14E-04	6.41E-04	9.75E-05
O	P	H	Methylnaphthalene, 2-	4.52E-04	4.79E-04	6.87E-04	6.00E-04	7.26E-04	7.26E-04	5.45E-04	6.50E-04	5.61E-04	6.03E-04	1.02E-04
O		H	Styrene	2.52E-04	2.53E-04	4.80E-04	3.39E-04	4.91E-04	4.91E-04	5.19E-04	5.29E-04	5.04E-04	4.29E-04	1.14E-04
O		H	Ethylbenzene	2.85E-04	2.70E-04	3.29E-04	3.81E-04	4.40E-04	4.40E-04	4.90E-04	4.53E-04	4.66E-04	3.95E-04	8.21E-05
O	P	H	Methylnaphthalene, 1-	2.10E-04	2.19E-04	3.17E-04	2.61E-04	3.19E-04	3.19E-04	2.74E-04	3.17E-04	2.49E-04	2.76E-04	4.42E-05
O	P	H	Dimethylnaphthalene, 1,3-	1.54E-04	ND	1.87E-04	1.62E-04	1.84E-04	1.84E-04	ND	1.98E-04	1.74E-04	1.38E-04	7.94E-05
O	P	H	Acenaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 1,2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 1,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 1,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 1,8-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 2,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 2,7-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Trimethylnaphthalene, 2,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O		H	Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O		H	Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O		H	Cresol, mp-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O		H	Cresol, o-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA

NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

Test GZ - Detailed Emissions Data - Lb/Tn Metal

Organic Analytes	POM	HAP		GZ001	GZ002	GZ003	GZ004	GZ005	GZ006	GZ007	GZ008	GZ009	Average	Standard Deviation
			Test Dates	**13-Dec-05**	**13-Dec-05**	**13-Dec-05**	**14-Dec-05**	**14-Dec-05**	**14-Dec-05**	**15-Dec-05**	**15-Dec-05**	**15-Dec-05**	—	—
Additional Selected Target Organic Analytes														
O			Trimethylbenzene, 1,2,4-	6.00E-04	1.08E-03	9.85E-04	8.00E-04	1.39E-03	1.39E-03	9.99E-04	8.01E-04	8.06E-04	9.84E-04	2.70E-04
O			2-Butanone (MEK)	6.85E-04	8.07E-04	1.04E-03	8.27E-04	9.81E-04	9.81E-04	9.79E-04	1.22E-03	1.23E-03	9.73E-04	1.83E-04
O			Heptane	ND	ND	8.39E-04	6.39E-04	9.12E-04	9.12E-04	7.64E-04	8.53E-04	8.01E-04	6.35E-04	3.70E-04
O			Benzaldehyde	3.85E-04	4.22E-04	5.28E-04	4.47E-04	5.09E-04	5.09E-04	4.53E-04	5.36E-04	5.31E-04	4.80E-04	5.48E-05
O			Butyraldehyde/Methacrolein	2.85E-04	3.09E-04	3.58E-04	3.59E-04	3.83E-04	3.83E-04	3.90E-04	3.72E-04	3.84E-04	3.58E-04	3.70E-05
O			Ethyltoluene, 3-	ND	7.11E-04	6.19E-04	ND	8.83E-04	8.83E-04	ND	ND	ND	3.44E-04	4.16E-04
O			Trimethylbenzene, 1,2,3-	ND	2.77E-04	3.25E-04	1.86E-04	4.25E-04	4.25E-04	2.85E-04	2.90E-04	2.48E-04	2.74E-04	1.29E-04
O			Crotonaldehyde	1.47E-04	1.56E-04	2.29E-04	1.67E-04	1.89E-04	1.89E-04	1.76E-04	2.03E-04	2.07E-04	1.85E-04	2.62E-05
O			Pentanal (Valeraldehyde)	ND	ND	2.23E-04	2.01E-04	2.32E-04	2.32E-04	1.99E-04	2.24E-04	2.03E-04	1.68E-04	9.62E-05
O			o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	3.50E-04	ND	ND	3.89E-05	1.17E-04
O			Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Diethylbenzene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Dimethylphenol, 2,4-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Dimethylphenol, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Dodecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Ethyltoluene, 2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Hexaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Propylbenzene, n-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Trimethylbenzene, 1,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Undecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Indene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
Criteria Pollutants and Greenhouse Gases														
			Carbon Dioxide	3.99E+00	4.26E+00	3.62E+00	4.78E+00	4.10E+00	3.83E+00	4.51E+00	3.70E+00	3.75E+00	4.06E+00	3.93E-01
			Carbon Monoxide	1.43E+00	1.23E+00	1.44E+00	1.38E+00	1.31E+00	1.47E+00	1.59E+00	1.28E+00	1.44E+00	1.40E+00	1.11E-01
			Sulfur Dioxide	I	6.69E-03	5.39E-03	6.91E-03	6.62E-03	6.62E-03	5.35E-03	4.99E-03	5.43E-03	6.00E-03	7.76E-04
			Nitrogen Oxides	2.62E-03	1.17E-03	8.61E-04	I	1.18E-03	1.43E-03	1.76E-03	2.07E-03	1.39E-03	1.56E-03	5.66E-04

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Test GZ - Detailed Emissions Data - Lb/Lb Binder

Organic Analytes	POM	HAP		GZ001	GZ002	GZ003	GZ004	GZ005	GZ006	GZ007	GZ008	GZ009	Average	Standard Deviation
			Test Dates	13-Dec-05	13-Dec-05	13-Dec-05	14-Dec-05	14-Dec-05	14-Dec-05	15-Dec-05	15-Dec-05	15-Dec-05	—	—
Emission Indicators														
			TGOC as Propane	6.24E-03	6.43E-03	7.90E-03	7.42E-03	8.30E-03	8.18E-03	8.01E-03	8.44E-03	9.06E-03	7.78E-03	9.29E-04
			HC as Hexane	1.21E-03	1.44E-03	8.12E-04	1.60E-03	2.10E-03	2.10E-03	1.50E-03	1.54E-03	2.65E-03	1.66E-03	5.46E-04
			Sum of Target VOCs	1.24E-03	1.29E-03	1.55E-03	1.48E-03	1.67E-03	1.69E-03	1.70E-03	1.60E-03	1.62E-03	1.54E-03	1.71E-04
			Sum of Target HAPs	1.15E-03	1.13E-03	1.33E-03	1.32E-03	1.43E-03	1.44E-03	1.51E-03	1.41E-03	1.44E-03	1.35E-03	1.33E-04
			Sum of Target POMs	5.70E-05	5.43E-05	8.38E-05	7.07E-05	8.92E-05	8.92E-05	6.28E-05	8.28E-05	7.28E-05	7.36E-05	1.35E-05
Selected Target Organic HAPs and POMs														
O		H	Acetaldehyde	3.77E-04	3.87E-04	4.65E-04	4.37E-04	4.44E-04	4.44E-04	4.63E-04	4.54E-04	4.70E-04	4.38E-04	3.37E-05
O		H	Benzene	2.71E-04	2.79E-04	3.20E-04	3.31E-04	3.53E-04	3.67E-04	4.12E-04	3.62E-04	3.75E-04	3.41E-04	4.56E-05
O		H	Toluene	1.27E-04	1.19E-04	1.41E-04	1.49E-04	1.58E-04	1.58E-04	1.72E-04	1.59E-04	1.65E-04	1.50E-04	1.76E-05
O		H	Xylene, mp-	6.46E-05	6.44E-05	7.58E-05	8.96E-05	9.63E-05	9.63E-05	9.62E-05	9.33E-05	9.47E-05	8.57E-05	1.36E-05
O		H	Phenol	4.61E-05	4.30E-05	5.21E-05	5.38E-05	8.04E-05	8.04E-05	8.60E-05	4.58E-05	4.24E-05	5.89E-05	1.80E-05
O		H	Formaldehyde	5.49E-05	5.37E-05	5.73E-05	6.45E-05	5.89E-05	5.89E-05	5.80E-05	4.79E-05	5.31E-05	5.64E-05	4.67E-06
O		H	Propionaldehyde (Propanal)	4.12E-05	4.31E-05	5.18E-05	4.90E-05	5.26E-05	5.26E-05	5.96E-05	5.85E-05	6.69E-05	5.28E-05	8.06E-06
O		H	Hexane	6.60E-05	4.09E-05	2.51E-05	2.03E-05	2.66E-05	2.66E-05	2.98E-05	4.15E-05	2.33E-05	3.33E-05	1.43E-05
O	P	H	Naphthalene	2.27E-05	2.45E-05	3.32E-05	2.58E-05	3.82E-05	3.82E-05	2.88E-05	3.46E-05	3.07E-05	3.07E-05	5.73E-06
O		H	Xylene, o-	2.20E-05	2.11E-05	2.29E-05	2.73E-05	3.04E-05	3.04E-05	3.00E-05	2.83E-05	3.05E-05	2.70E-05	3.92E-06
O	P	H	Methylnaphthalene, 2-	1.90E-05	2.04E-05	2.92E-05	2.63E-05	3.02E-05	3.02E-05	2.26E-05	2.69E-05	2.40E-05	2.54E-05	4.16E-06
O		H	Styrene	1.06E-05	1.08E-05	2.04E-05	1.49E-05	2.04E-05	2.04E-05	2.15E-05	2.19E-05	2.15E-05	1.80E-05	4.67E-06
O		H	Ethylbenzene	1.20E-05	1.15E-05	1.40E-05	1.67E-05	1.83E-05	1.83E-05	2.03E-05	1.87E-05	1.99E-05	1.66E-05	3.35E-06
O	P	H	Methylnaphthalene, 1-	8.84E-06	9.35E-06	1.35E-05	1.14E-05	1.33E-05	1.33E-05	1.14E-05	1.31E-05	1.06E-05	1.16E-05	1.77E-06
O	P	H	Dimethylnaphthalene, 1,3-	6.48E-06	ND	7.94E-06	7.11E-06	7.63E-06	7.63E-06	ND	8.21E-06	7.42E-06	5.82E-06	3.34E-06
O	P	H	Acenaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 1,2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 1,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 1,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 1,8-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 2,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Dimethylnaphthalene, 2,7-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O	P	H	Trimethylnaphthalene, 2,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O		H	Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O		H	Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O		H	Cresol, mp-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O		H	Cresol, o-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA

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Test GZ - Detailed Emissions Data - Lb/Lb Binder

Organic Analytes	POM	HAP	Test Dates	GZ001 13-Dec-05	GZ002 13-Dec-05	GZ003 13-Dec-05	GZ004 14-Dec-05	GZ005 14-Dec-05	GZ006 14-Dec-05	GZ007 15-Dec-05	GZ008 15-Dec-05	GZ009 15-Dec-05	Average —	Standard Deviation —
Additional Selected Target Organic Analytes														
O			Trimethylbenzene, 1,2,4-	2.52E-05	4.62E-05	4.18E-05	3.51E-05	5.77E-05	5.77E-05	4.14E-05	3.31E-05	3.44E-05	4.14E-05	1.10E-05
O			2-Butanone (MEK)	2.88E-05	3.44E-05	4.43E-05	3.62E-05	4.08E-05	4.08E-05	4.06E-05	5.05E-05	5.27E-05	4.10E-05	7.53E-06
O			Heptane	ND	ND	3.56E-05	2.80E-05	3.79E-05	3.79E-05	3.17E-05	3.53E-05	3.42E-05	2.67E-05	1.55E-05
O			Benzaldehyde	1.62E-05	1.80E-05	ND	1.96E-05	2.12E-05	2.12E-05	1.88E-05	2.22E-05	2.27E-05	1.78E-05	6.98E-06
O			Butyraldehyde/Methacrolein	1.20E-05	1.32E-05	1.52E-05	1.57E-05	1.59E-05	1.59E-05	1.62E-05	1.54E-05	1.64E-05	1.51E-05	1.51E-06
O			Ethyltoluene, 3-	ND	3.03E-05	2.63E-05	ND	3.67E-05	3.67E-05	ND	ND	ND	1.44E-05	1.74E-05
O			Trimethylbenzene, 1,2,3-	ND	1.18E-05	1.38E-05	8.16E-06	1.77E-05	1.77E-05	1.18E-05	1.20E-05	1.06E-05	1.15E-05	5.32E-06
O			Crotonaldehyde	6.19E-06	6.64E-06	9.74E-06	7.31E-06	7.85E-06	7.85E-06	7.30E-06	8.39E-06	8.85E-06	7.79E-06	1.10E-06
O			Pentanal (Valeraldehyde)	ND	ND	9.46E-06	8.79E-06	9.64E-06	9.64E-06	8.26E-06	9.25E-06	8.69E-06	7.08E-06	4.04E-06
O			Indene	ND	ND	2.41E-05	ND	ND	ND	ND	ND	ND	2.68E-06	8.05E-06
O			o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	1.45E-05	ND	ND	1.61E-06	4.84E-06
O			Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Diethylbenzene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Dimethylphenol, 2,4-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Dimethylphenol, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Dodecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Ethyltoluene, 2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Hexaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Propylbenzene, n-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Trimethylbenzene, 1,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
O			Undecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
Criteria Pollutants and Greenhouse Gases														
			Carbon Dioxide	1.67E-01	1.82E-01	1.53E-01	2.08E-01	1.70E-01	1.62E-01	1.86E-01	1.54E-01	1.60E-01	1.71E-01	1.77E-02
			Carbon Monoxide	5.99E-02	5.25E-02	6.11E-02	6.01E-02	5.45E-02	6.20E-02	6.57E-02	5.31E-02	6.15E-02	5.89E-02	4.52E-03
			Sulfur Dioxide	4.07E-04	2.85E-04	2.29E-04	3.03E-04	2.75E-04	2.75E-04	2.22E-04	2.06E-04	2.32E-04	2.70E-04	6.08E-05
			Nitrogen Oxides	1.10E-04	5.01E-05	3.65E-05	1.47E-04	4.90E-05	6.04E-05	7.23E-05	8.59E-05	5.93E-05	7.44E-05	3.48E-05

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Test HD - Detailed Emissions Data - Lb/Tn Metal

Organic Analytes	POM	HAP		HD001	HD002	HD003	HD004	HD005	HD006	HD007	HD008	HD009	Average	Standard Deviation
			Test Dates	**11-Apr-06**	**11-Apr-06**	**11-Apr-06**	**12-Apr-06**	**12-Apr-06**	**12-Apr-06**	**13-Apr-06**	**13-Apr-06**	**13-Apr-06**	—	—
Emission Indicators														
			TGOC as Propane	6.67E-02	5.30E-02	5.28E-02	5.71E-02	5.21E-02	4.91E-02	7.02E-02	5.66E-02	6.03E-02	5.75E-02	7.03E-03
			HC as Hexane	2.22E-02	2.16E-02	1.23E-02	1.72E-02	2.10E-02	2.11E-02	1.22E-02	1.07E-02	1.17E-02	1.67E-02	4.91E-03
			Sum of Target Organic Analytes	1.16E-02	1.25E-02	9.22E-03	7.24E-03	1.22E-02	1.20E-02	9.70E-03	9.92E-03	8.94E-03	1.04E-02	1.80E-03
			Sum of Target HAPs	8.44E-03	9.30E-03	7.91E-03	6.46E-03	9.00E-03	8.45E-03	8.82E-03	8.81E-03	8.29E-03	8.39E-03	8.31E-04
			Sum of Target POMs	4.83E-04	8.58E-04	4.97E-04	3.36E-04	9.62E-04	7.11E-04	7.07E-04	3.68E-04	1.77E-04	5.67E-04	2.59E-04
Selected Target Organic HAPs and POMs														
O		H	Acetaldehyde	2.70E-03	2.72E-03	2.64E-03	2.70E-03	2.77E-03	2.67E-03	2.70E-03	2.68E-03	2.57E-03	2.68E-03	5.36E-05
O		H	Benzene	2.17E-03	2.68E-03	2.14E-03	1.40E-03	2.37E-03	2.48E-03	2.56E-03	2.78E-03	2.71E-03	2.37E-03	4.28E-04
O		H	Formaldehyde	1.14E-03	1.11E-03	1.07E-03	1.01E-03	1.33E-03	1.03E-03	9.73E-04	9.82E-04	1.00E-03	1.07E-03	1.13E-04
O		H	Toluene	9.12E-04	9.39E-04	7.51E-04	4.85E-04	7.59E-04	7.69E-04	8.47E-04	9.13E-04	8.52E-04	8.03E-04	1.39E-04
O		H	Xylene, mp-	4.69E-04	4.17E-04	3.73E-04	2.57E-04	3.76E-04	3.89E-04	4.53E-04	5.35E-04	4.08E-04	4.08E-04	7.68E-05
O	P	H	Methylnaphthalene, 2-	2.91E-04	3.88E-04	2.21E-04	2.14E-04	4.49E-04	3.42E-04	3.64E-04	2.49E-04	1.77E-04	2.99E-04	9.16E-05
O		H	Propionaldehyde (Propanal)	2.88E-04	2.82E-04	2.87E-04	2.83E-04	3.04E-04	2.77E-04	2.90E-04	2.82E-04	2.73E-04	2.85E-04	9.01E-06
O	P	H	Naphthalene	1.92E-04	3.18E-04	1.25E-04	1.21E-04	3.31E-04	2.40E-04	2.04E-04	1.19E-04	0.00E+00	1.83E-04	1.05E-04
O		H	Hexane	1.41E-04	1.56E-04	1.49E-04	0.00E+00	1.21E-04	1.27E-04	1.77E-04	1.46E-04	1.78E-04	1.33E-04	5.35E-05
O	P	H	Methylnaphthalene, 1-	ND	1.52E-04	1.51E-04	ND	1.83E-04	1.29E-04	1.40E-04	ND	ND	8.39E-05	8.08E-05
O		H	Xylene, o-	1.42E-04	1.49E-04	ND	ND	ND	ND	1.18E-04	1.26E-04	1.05E-04	7.12E-05	6.87E-05
O	P	H	Acenaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 1,2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 1,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 1,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 1,8-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 2,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 2,7-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Trimethylnaphthalene, 2,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Cresol, mp-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Cresol, o-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Phenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

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Test HD - Detailed Emissions Data - Lb/Tn Metal

Organic Analytes	POM	HAP		HD001	HD002	HD003	HD004	HD005	HD006	HD007	HD008	HD009	Average	Standard Deviation
			Test Dates	**11-Apr-06**	**11-Apr-06**	**11-Apr-06**	**12-Apr-06**	**12-Apr-06**	**12-Apr-06**	**13-Apr-06**	**13-Apr-06**	**13-Apr-06**	—	—
Additional Selected Target Organic Analytes														
O			Trimethylbenzene, 1,2,4-	9.01E-04	9.57E-04	4.26E-04	3.66E-04	1.20E-03	9.12E-04	3.12E-04	2.81E-04	1.36E-04	6.10E-04	3.80E-04
O			Trimethylbenzene, 1,3,5-	1.10E-03	1.12E-03	4.31E-04	1.50E-04	5.41E-04	4.55E-04	3.13E-04	6.06E-04	2.15E-04	5.47E-04	3.49E-04
O			Ethyltoluene, 3-	6.18E-04	6.27E-04	ND	ND	8.12E-04	5.99E-04	ND	ND	ND	2.95E-04	3.55E-04
O			Butyraldehyde/Methacrolein	3.11E-04	2.82E-04	3.06E-04	2.60E-04	2.63E-04	2.25E-04	2.51E-04	2.23E-04	3.03E-04	2.69E-04	3.34E-05
O			Heptane	ND	ND	ND	ND	ND	1.20E-03	ND	ND	ND	1.34E-04	4.01E-04
O			Trimethylbenzene, 1,2,3-	1.51E-04	1.72E-04	ND	ND	2.64E-04	1.83E-04	ND	ND	ND	8.56E-05	1.06E-04
O			Benzaldehyde	1.23E-04	ND	1.46E-04	ND	ND	ND	ND	ND	ND	2.98E-05	5.95E-05
O			Crotonaldehyde	ND	ND	ND	ND	1.16E-04	ND	ND	ND	ND	1.29E-05	3.86E-05
O			2-Butanone (MEK)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Diethylbenzene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Dimethylphenol, 2,4-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Dimethylphenol, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Dodecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Ethyltoluene, 2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Hexaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Indene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Pentanal (Valeraldehyde)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Propylbenzene, n-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Undecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
Criteria Pollutants and Greenhouse Gases														
			Carbon Dioxide	2.69E+00	1.78E+00	1.78E+00	2.13E+00	1.92E+00	2.06E+00	2.58E+00	2.27E+00	1.95E+00	2.13E+00	3.27E-01
			Carbon Monoxide	1.34E+00	1.22E+00	1.19E+00	1.30E+00	1.25E+00	1.30E+00	1.29E+00	1.27E+00	1.29E+00	1.27E+00	4.61E-02
			Sulfur Dioxide	8.93E-03	7.04E-03	6.78E-03	7.29E-03	1.03E-02	7.95E-03	7.02E-03	7.10E-03	7.39E-03	7.76E-03	1.16E-03
			Nitrogen Oxides	3.02E-03	1.76E-03	1.68E-03	1.46E-03	1.95E-03	1.50E-03	2.47E-03	1.22E-03	1.27E-03	1.82E-03	5.91E-04

ND= Not Detected
NA= Not Applicable
I=Invalidated Data

Test HD - Detail Emissions Data - Lb/Lb Binder

Organic Analytes	POM	HAP	0	HD001	HD002	HD003	HD004	HD005	HD006	HD007	HD008	HD009	Average	Standard Deviation
			Test Dates	11-Apr-06	11-Apr-06	11-Apr-06	12-Apr-06	12-Apr-06	12-Apr-06	13-Apr-06	13-Apr-06	13-Apr-06	—	—
Emission Indicators														
			TGOC as Propane	6.26E-03	4.92E-03	5.08E-03	5.50E-03	5.10E-03	4.73E-03	6.85E-03	5.51E-03	6.01E-03	5.55E-03	6.98E-04
			HC as Hexane	2.08E-03	2.00E-03	1.18E-03	1.66E-03	2.06E-03	2.03E-03	1.18E-03	1.04E-03	1.17E-03	1.60E-03	4.52E-04
			Sum of Target Organic Analytes	1.09E-03	1.16E-03	8.86E-04	6.99E-04	1.19E-03	1.16E-03	9.46E-04	9.66E-04	8.92E-04	9.99E-04	1.64E-04
			Sum of Target HAPs	7.93E-04	8.64E-04	7.60E-04	6.24E-04	8.82E-04	8.14E-04	8.60E-04	8.58E-04	8.27E-04	8.09E-04	7.95E-05
			Sum of Target POMs	4.53E-05	7.97E-05	4.78E-05	3.24E-05	9.43E-05	6.84E-05	6.89E-05	3.58E-05	1.77E-05	5.45E-05	2.49E-05
Selected Target Organic HAPs and POMs														
O		H	Acetaldehyde	2.53E-04	2.52E-04	2.54E-04	2.60E-04	2.71E-04	2.57E-04	2.63E-04	2.61E-04	2.57E-04	2.59E-04	5.94E-06
O		H	Benzene	2.04E-04	2.49E-04	2.06E-04	1.35E-04	2.33E-04	2.39E-04	2.50E-04	2.70E-04	2.71E-04	2.28E-04	4.24E-05
O		H	Formaldehyde	1.07E-04	1.03E-04	1.03E-04	9.73E-05	1.31E-04	9.88E-05	9.48E-05	9.56E-05	1.00E-04	1.03E-04	1.09E-05
O		H	Toluene	8.57E-05	8.72E-05	7.22E-05	4.68E-05	7.44E-05	7.40E-05	8.26E-05	8.89E-05	8.51E-05	7.74E-05	1.31E-05
O		H	Xylene, mp-	4.40E-05	3.87E-05	3.59E-05	2.48E-05	3.69E-05	3.74E-05	4.42E-05	5.21E-05	4.07E-05	3.94E-05	7.44E-06
O	P	H	Methylnaphthalene, 2-	2.73E-05	3.60E-05	2.12E-05	2.07E-05	4.40E-05	3.29E-05	3.55E-05	2.42E-05	1.77E-05	2.88E-05	8.76E-06
O		H	Propionaldehyde (Propanal)	2.70E-05	2.61E-05	2.76E-05	2.73E-05	2.98E-05	2.66E-05	2.83E-05	2.74E-05	2.72E-05	2.75E-05	1.05E-06
O	P	H	Naphthalene	1.80E-05	2.95E-05	1.20E-05	1.17E-05	3.24E-05	2.31E-05	1.98E-05	1.16E-05	ND	1.76E-05	1.01E-05
O		H	Hexane	1.33E-05	1.45E-05	1.43E-05	ND	1.19E-05	1.23E-05	1.73E-05	1.42E-05	1.78E-05	1.28E-05	5.21E-06
O	P	H	Methylnaphthalene, 1-	ND	1.41E-05	1.45E-05	ND	1.79E-05	1.24E-05	1.36E-05	ND	ND	8.07E-06	7.79E-06
O		H	Xylene, o-	1.33E-05	1.38E-05	ND	ND	ND	ND	1.15E-05	1.23E-05	1.05E-05	6.83E-06	6.55E-06
O	P	H	Acenaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 1,2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 1,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 1,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 1,8-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 2,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Dimethylnaphthalene, 2,7-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O	P	H	Trimethylnaphthalene, 2,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Cresol, mp-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Cresol, o-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Phenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O		H	Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

NT=Not Tested
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Test HD - Detail Emissions Data - Lb/Lb Binder

Organic Analytes	POM	HAP	0	HD001	HD002	HD003	HD004	HD005	HD006	HD007	HD008	HD009	Average	Standard Deviation
			Test Dates	11-Apr-06	11-Apr-06	11-Apr-06	12-Apr-06	12-Apr-06	12-Apr-06	13-Apr-06	13-Apr-06	13-Apr-06	—	—
Additional Selected Target Organic Analytes														
O			Trimethylbenzene, 1,2,4-	8.46E-05	8.88E-05	4.10E-05	3.53E-05	1.18E-04	8.78E-05	3.05E-05	2.74E-05	1.36E-05	5.85E-05	3.63E-05
O			Trimethylbenzene, 1,3,5-	1.03E-04	1.04E-04	4.14E-05	1.45E-05	5.30E-05	4.39E-05	3.05E-05	5.91E-05	2.15E-05	5.23E-05	3.22E-05
O			Ethyltoluene, 3-	5.80E-05	5.82E-05	ND	ND	7.96E-05	5.76E-05	ND	ND	ND	2.82E-05	3.41E-05
O			Butyraldehyde/Methacrolein	2.92E-05	2.61E-05	2.95E-05	2.51E-05	2.57E-05	2.17E-05	2.44E-05	2.17E-05	3.02E-05	2.60E-05	3.17E-06
O			Heptane	ND	ND	ND	ND	ND	1.16E-04	ND	ND	ND	1.29E-05	3.86E-05
O			Trimethylbenzene, 1,2,3-	1.42E-05	1.60E-05	ND	ND	2.59E-05	1.77E-05	ND	ND	ND	8.19E-06	1.02E-05
O			Benzaldehyde	1.15E-05	ND	1.40E-05	ND	ND	ND	ND	ND	ND	2.84E-06	5.67E-06
O			Crotonaldehyde	ND	ND	ND	ND	1.13E-05	ND	ND	ND	ND	1.26E-06	3.78E-06
O			2-Butanone (MEK)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Diethylbenzene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Dimethylphenol, 2,4-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Dimethylphenol, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Dodecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Ethyltoluene, 2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Hexaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Indene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Pentanal (Valeraldehyde)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Propylbenzene, n-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
O			Undecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
Criteria Pollutants and Greenhouse Gases														
			Carbon Dioxide	2.53E-01	1.65E-01	1.71E-01	2.06E-01	1.88E-01	1.98E-01	2.51E-01	2.21E-01	1.95E-01	2.05E-01	3.12E-02
			Carbon Monoxide	1.26E-01	1.13E-01	1.14E-01	1.25E-01	1.22E-01	1.25E-01	1.26E-01	1.24E-01	1.29E-01	1.23E-01	5.48E-03
			Sulfur Dioxide	8.38E-04	6.54E-04	6.52E-04	7.03E-04	1.01E-03	7.65E-04	6.84E-04	6.92E-04	7.37E-04	7.49E-04	1.15E-04
			Nitrogen Oxides	2.83E-04	1.64E-04	1.61E-04	1.41E-04	1.91E-04	1.44E-04	2.41E-04	1.19E-04	1.27E-04	1.75E-04	5.51E-05

NT=Not Tested
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Test GZ - Practical Reporting Limits

Analyte	Lb/Tn Metal	Analyte	Lb/Tn Metal
Carbon Monoxide	2.69E-02	Ethyltoluene, 2-	1.80E-04
Carbon Dioxide	4.23E-02	Ethyltoluene, 3-	9.00E-04
Nitrogen Oxides	2.89E-02	Formaldehyde	1.73E-04
TGOC as Propane	4.23E-02	Heptane	9.00E-04
2-Butanone (MEK)	1.73E-04	Hexaldehyde	1.73E-04
Acenaphthalene	9.00E-04	Hexane	1.80E-04
Acetaldehyde	1.73E-04	Indan	9.00E-04
Acetone	1.73E-04	Indene	9.00E-04
Acrolein	1.73E-04	Methylnaphthalene, 1-	1.80E-04
Benzaldehyde	1.73E-04	Methylnaphthalene, 2-	1.80E-04
Benzene	1.80E-04	Naphthalene	1.80E-04
Biphenyl	9.00E-04	Nonane	9.00E-04
Butyraldehyde/Methacrolein	2.88E-04	o,m,p-Tolualdehyde	4.61E-04
Cresol, mp-	9.00E-04	Octane	9.00E-04
Cresol, o-	9.00E-04	Pentanal (Valeraldehyde)	1.73E-04
Crotonaldehyde	1.73E-04	Phenol	9.00E-04
Cyclohexane	9.00E-04	Propionaldehyde (Propanal)	1.73E-04
Decane	9.00E-04	Propylbenzene, n-	9.00E-04
Diethylbenzene, 1,3-	9.00E-04	Styrene	1.80E-04
Dimethylnaphthalene, 1,2-	9.00E-04	Sulfur Dioxide	2.26E-03
Dimethylnaphthalene, 1,3-	1.80E-04	Tetradecane	9.00E-04
Dimethylnaphthalene, 1,5-	9.00E-04	THC as Undecane	9.00E-04
Dimethylnaphthalene, 1,6-	9.00E-04	THCs as n-Hexane	5.44E-03
Dimethylnaphthalene, 1,8-	9.00E-04	Toluene	1.80E-04
Dimethylnaphthalene, 2,3-	9.00E-04	Trimethylbenzene, 1,2,3-	1.80E-04
Dimethylnaphthalene, 2,6-	9.00E-04	Trimethylbenzene, 1,2,4-	1.80E-04
Dimethylnaphthalene, 2,7-	9.00E-04	Trimethylbenzene, 1,3,5-	1.80E-04
Dimethylphenol, 2,4-	9.00E-04	Trimethylnaphthalene, 2,3,5-	9.00E-04
Dimethylphenol, 2,6-	9.00E-04	Undecane	1.80E-04
Dodecane	9.00E-04	Xylene, mp-	1.80E-04
Ethylbenzene	1.80E-04	Xylene, o-	1.80E-04

Analyte	Lb/Lb Binder	Analyte	Lb/Lb Binder
Carbon Monoxide	1.14E-03	Ethyltoluene, 2-	4.79E-06
Carbon Dioxide	1.79E-03	Ethyltoluene, 3-	2.39E-05
Nitrogen Oxides	1.22E-03	Formaldehyde	4.60E-06
TGOC as Propane	1.79E-03	Heptane	2.39E-05
2-Butanone (MEK)	4.60E-06	Hexaldehyde	4.60E-06
Acenaphthalene	2.39E-05	Hexane	4.79E-06
Acetaldehyde	4.60E-06	Indan	2.39E-05
Acetone	4.60E-06	Indene	2.39E-05
Acrolein	4.60E-06	Methylnaphthalene, 1-	4.79E-06
Benzaldehyde	4.60E-06	Methylnaphthalene, 2-	4.79E-06
Benzene	4.79E-06	Naphthalene	4.79E-06
Biphenyl	2.39E-05	Nonane	2.39E-05
Butyraldehyde/Methacrolein	7.67E-06	o,m,p-Tolualdehyde	1.23E-05
Cresol, mp-	2.39E-05	Octane	2.39E-05
Cresol, o-	2.39E-05	Pentanal (Valeraldehyde)	4.60E-06
Crotonaldehyde	4.60E-06	Phenol	2.39E-05
Cyclohexane	2.39E-05	Propionaldehyde (Propanal)	4.60E-06
Decane	2.39E-05	Propylbenzene, n-	2.39E-05
Diethylbenzene, 1,3-	2.39E-05	Styrene	4.79E-06
Dimethylnaphthalene, 1,2-	2.39E-05	Sulfur Dioxide	6.01E-05
Dimethylnaphthalene, 1,3-	4.79E-06	Tetradecane	2.39E-05
Dimethylnaphthalene, 1,5-	2.39E-05	THC as Undecane	2.39E-05
Dimethylnaphthalene, 1,6-	2.39E-05	THCs as n-Hexane	1.45E-04
Dimethylnaphthalene, 1,8-	2.39E-05	Toluene	4.79E-06
Dimethylnaphthalene, 2,3-	2.39E-05	Trimethylbenzene, 1,2,3-	4.79E-06
Dimethylnaphthalene, 2,6-	2.39E-05	Trimethylbenzene, 1,2,4-	4.79E-06
Dimethylnaphthalene, 2,7-	2.39E-05	Trimethylbenzene, 1,3,5-	4.79E-06
Dimethylphenol, 2,4-	2.39E-05	Trimethylnaphthalene, 2,3,5-	2.39E-05
Dimethylphenol, 2,6-	2.39E-05	Undecane	4.79E-06
Dodecane	2.39E-05	Xylene, mp-	4.79E-06
Ethylbenzene	4.79E-06	Xylene, o-	4.79E-06

Test HD - Practical Reporting Limits

Analyte	Lb/Tn Metal	Analyte	Lb/Tn Metal
Carbon Monoxide	2.64E-02	Ethyltoluene, 2-	1.10E-04
Carbon Dioxide	4.14E-02	Ethyltoluene, 3-	5.49E-04
Nitrogen Oxides	2.82E-02	Formaldehyde	1.05E-04
THC as Propane	4.14E-02	Heptane	5.49E-04
2-Butanone (MEK)	1.05E-04	Hexaldehyde	1.05E-04
Acenaphthalene	5.49E-04	Hexane	1.10E-04
Acetaldehyde	1.05E-04	Indan	5.49E-04
Acrolein	1.05E-04	Indene	5.49E-04
Benzaldehyde	1.05E-04	Methylnaphthalene, 1-	1.10E-04
Benzene	1.10E-04	Methylnaphthalene, 2-	1.10E-04
Biphenyl	5.49E-04	Naphthalene	1.10E-04
Butyraldehyde/Methacrolein	1.75E-04	Nonane	5.49E-04
Cresol, mp-	5.49E-04	o,m,p-Tolualdehyde	2.80E-04
Cresol, o-	5.49E-04	Octane	5.49E-04
Crotonaldehyde	1.05E-04	Pentanal (Valeraldehyde)	1.05E-04
Cyclohexane	5.49E-04	Phenol	5.49E-04
Decane	5.49E-04	Propionaldehyde (Propanal)	1.05E-04
Diethylbenzene, 1,3-	5.49E-04	Propylbenzene, n-	5.49E-04
Dimethylnaphthalene, 1,2-	5.49E-04	Styrene	1.10E-04
Dimethylnaphthalene, 1,3-	1.10E-04	Sulfur Dioxide	1.39E-03
Dimethylnaphthalene, 1,5-	5.49E-04	Tetradecane	5.49E-04
Dimethylnaphthalene, 1,6-	5.49E-04	HC as n-Hexane	3.33E-03
Dimethylnaphthalene, 1,8-	5.49E-04	Toluene	1.10E-04
Dimethylnaphthalene, 2,3-	5.49E-04	Trimethylbenzene, 1,2,3-	1.10E-04
Dimethylnaphthalene, 2,6-	5.49E-04	Trimethylbenzene, 1,2,4-	1.10E-04
Dimethylnaphthalene, 2,7-	5.49E-04	Trimethylbenzene, 1,3,5-	1.10E-04
Dimethylphenol, 2,4-	5.49E-04	Trimethylnaphthalene, 2,3,5-	5.49E-04
Dimethylphenol, 2,6-	5.49E-04	Undecane	1.10E-04
Dodecane	5.49E-04	Xylene, mp-	1.10E-04
Ethylbenzene	1.10E-04	Xylene, o-	1.10E-04

Analyte	Lb/Lb Binder	Analyte	Lb/Lb Binder
Carbon Monoxide	2.54E-03	Ethyltoluene, 2-	1.06E-05
Carbon Dioxide	3.99E-03	Ethyltoluene, 3-	5.30E-05
Nitrogen Oxides	2.72E-03	Formaldehyde	1.01E-05
THC as Propane	3.99E-03	Heptane	5.30E-05
2-Butanone (MEK)	1.01E-05	Hexaldehyde	1.01E-05
Acenaphthalene	5.30E-05	Hexane	1.06E-05
Acetaldehyde	1.01E-05	Indan	5.30E-05
Acrolein	1.01E-05	Indene	5.30E-05
Benzaldehyde	1.01E-05	Methylnaphthalene, 1-	1.06E-05
Benzene	1.06E-05	Methylnaphthalene, 2-	1.06E-05
Biphenyl	5.30E-05	Naphthalene	1.06E-05
Butyraldehyde/Methacrolein	1.69E-05	Nonane	5.30E-05
Cresol, mp-	5.30E-05	o,m,p-Tolualdehyde	2.70E-05
Cresol, o-	5.30E-05	Octane	5.30E-05
Crotonaldehyde	1.01E-05	Pentanal (Valeraldehyde)	1.01E-05
Cyclohexane	5.30E-05	Phenol	5.30E-05
Decane	5.30E-05	Propionaldehyde (Propanal)	1.01E-05
Diethylbenzene, 1,3-	5.30E-05	Propylbenzene, n-	5.30E-05
Dimethylnaphthalene, 1,2-	5.30E-05	Styrene	1.06E-05
Dimethylnaphthalene, 1,3-	1.06E-05	Sulfur Dioxide	1.34E-04
Dimethylnaphthalene, 1,5-	5.30E-05	Tetradecane	5.30E-05
Dimethylnaphthalene, 1,6-	5.30E-05	HC as n-Hexane	3.21E-04
Dimethylnaphthalene, 1,8-	5.30E-05	Toluene	1.06E-05
Dimethylnaphthalene, 2,3-	5.30E-05	Trimethylbenzene, 1,2,3-	1.06E-05
Dimethylnaphthalene, 2,6-	5.30E-05	Trimethylbenzene, 1,2,4-	1.06E-05
Dimethylnaphthalene, 2,7-	5.30E-05	Trimethylbenzene, 1,3,5-	1.06E-05
Dimethylphenol, 2,4-	5.30E-05	Trimethylnaphthalene, 2,3,5-	5.30E-05
Dimethylphenol, 2,6-	5.30E-05	Undecane	1.06E-05
Dodecane	5.30E-05	Xylene, mp-	1.06E-05
Ethylbenzene	1.06E-05	Xylene, o-	1.06E-05

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Appendix C Detailed Process Data and Casting Quality Photos

Test GZ - Detailed Process Data

Greensand PCS																
Test Dates	**12/12/2005**	**12/12/2005**	**12/12/2005**	**12/13/2005**	**12/13/2005**	**12/13/2005**	**12/14/2005**	**12/14/2005**	**12/14/2005**	**12/15/2005**	**12/15/2005**	**12/15/2005**	**Averages**	**12/21/2005**	**12/21/2005**	**12/21/2005**
Emissions Sample #	**GZER1**	**GZER2**	**GZER3**	**GZ001**	**GZ002**	**GZ003**	**GZ004**	**GZ005**	**GZ006**	**GZ007**	**GZ008**	**GZ009**				
Production Sample #	**GZ001**	**GZ002**	**GZ003**	**GZ004**	**GZ005**	**GZ006**	**GZ007**	**GZ008**	**GZ009**	**GZ010**	**GZ011**	**GZ012**		**GZ013**	**GZ014**	**GZ015**
Cast Weight, Lbs.	120.35	120.95	122.80	118.40	118.60	119.75	123.55	117.25	118.60	117.00	116.60	120.45	**118.9**	127.20	118.60	117.50
Pouring Time, sec.	13	12	14	13	12	12	10	13	14	15	13	12	**13**	11	12	13
Pouring Temp ,°F	2629	2624	2625	2627	2626	2636	2634	2625	2641	2641	2624	2636	**2632**	2637	2618	2624
Pour Hood Process Air Temp at Start of Pour, °F	86	87	87	87	87	88	88	88	86	86	87	86	**87**	86	87	88
Sand in Sodium Silicate Sand mix, lbs	50.10	50.05	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	ND	**50.0**	50.00	50.00	50.00
Sodium Silicate in Sodium Silicate Core Sand Mix,lbs	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	ND	**2.5**	2.5	2.5	2.5
Sodium Silicate Core CO2 Gassing Pressure, PSI	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	**20.0**	20.0	20.0	20.0
Sodium Silicate Core CO2 Gassing Time, sec	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	**30.0**	30.0	30.0	30.0
Sodium Silicate Content, % (BOS)	5.00	5.00	5.01	5.04	5.02	5.00	5.01	5.02	5.01	5.01	5.01	ND	**5.01**	5.02	5.00	5.00
Sodium Silicate Content, % of Sand Mix	4.76	4.76	4.77	4.79	4.78	4.76	4.77	4.78	4.77	4.78	4.77	ND	**4.77**	4.78	4.76	4.76
Total Weight of Baked Cores in Mold, Lbs.	29.15	29.15	29.39	29.46	29.02	29.69	29.77	29.56	29.53	29.74	29.40	29.50	**29.5**	29.66	30.01	30.08
Binder Weight in Mold, Lbs	1.39	1.39	1.40	1.41	1.39	1.41	1.42	1.41	1.41	1.42	1.40	ND	**1.41**	1.42	1.43	1.43
Baking Oven nominal temperature, °F	250	250	250	250	250	250	250	250	250	250	250	250	**250.0**	250	250	250
Average heated investment time, Minutes	120	120	120	120	120	120	120	120	120	120	120	120	**120.0**	120	120	120
Core LOI, %	ND	ND	ND	0.84	0.84	0.84	0.85	0.84	0.84	0.89	0.85	0.86	**0.9**	ND	ND	ND
Core dogbone tensile, psi	27	27	27	27	27	27	27	27	27	27	27	27	**27**	0	0	0
Core age, hrs.	164.1	165.3	167.9	185.0	171.3	173.3	191.3	193.2	195.4	213.5	216.0	218.0	**195**	46.7	48.0	48.5
Muller Batch Weight, Lbs.	1000	900	900	900	900	890	900	900	900	910	910	900	**901**	900	900	900
GS Mold Sand Weight, Lbs.	651	647	652	655	646	638	652	644	646	640	644	637	**645**	631	642	623
Mold Temperature, °F	72	75	76	69	78	79	70	69	77	67	76	72	**73**	76	79	82
Average Green Compression , psi	16.87	18.87	18.61	20.46	19.75	18.25	23.63	21.75	23.81	26.01	25.54	25.21	**22.71**	ND	ND	ND
GS Compactability, %	57	47	38	30	41	42	41	34	45	36	38	40	**39**	42	43	46
GS Moisture Content, %	2.26	2.06	2.00	1.88	2.10	2.68	2.06	1.96	1.96	2.16	2.16	2.08	**2.11**	ND	ND	ND
GS MB Clay Content, %	7.11	7.61	8.10	7.51	6.91	7.31	6.91	7.51	6.81	7.20	7.20	7.20	**7.17**	ND	ND	ND
MB Clay reagent, ml	36.0	38.5	41.0	38.0	35.0	37.0	35.0	38.0	35.0	37.0	37.0	37.0	**36.6**	ND	ND	ND
1800°F LOI - Mold Sand, %	0.86	0.88	0.84	1.02	0.83	0.83	0.77	0.85	0.87	0.88	0.80	0.89	**0.86**	ND	ND	ND
900°F Volatiles , %	0.34	0.38	0.32	0.34	0.30	0.24	0.28	0.30	0.22	0.26	0.30	0.28	**0.28**	ND	ND	ND
Permeability index	270	248	235	215	251	240	231	230	250	240	245	249	**239**	ND	ND	ND
Sand Temperature, °F	75	80	79	72	81	82	74	79	81	75	78	80	**78**	ND	ND	ND

Notes:

Runs GZ013-GZ015 were only done as casting qualtiy runs. The first three runs normally are used for casting quality , but the core coating was applied improperly and caused a casting that would not be representative of the coating if apllied correctly. More cores were made, and coated correctly. The rankings shown are with the seconc

There is no data for the reported for the mixing of the cores for batch GZ012, because no data was recorded

There is no data for the LOI for the cores for runs GZ001-GZ003 because the cores were coated and the coating would affect the LOI

Test HD - Detailed Process Data

Greensand PCS													
Test Dates	**4/10/2006**	**4/10/2006**	**4/10/2006**	**4/11/2006**	**4/11/2006**	**4/11/2006**	**4/12/2006**	**4/12/2006**	**4/12/2006**	**4/13/2006**	**4/13/2006**	**4/13/2006**	**Averages**
Emissions Sample #	**HDCR1**	**HDCR2**	**HDCR3**	**HD001**	**HD002**	**HD003**	**HD004**	**HD005**	**HD006**	**HD007**	**HD008**	**HD009**	
Production Sample #	**HDCR1**	**HDCR2**	**HDCR3**	**HD001**	**HD002**	**HD003**	**HD004**	**HD005**	**HD006**	**HD007**	**HD008**	**HD009**	
Cast Weight, Lbs.	116.55	120.25	119.10	122.85	120.70	124.05	123.90	126.20	124.05	125.35	124.10	127.35	**124.3**
Pouring Time, sec.	16	13	13	14	12	14	13	17	13	12	13	14	**14**
Pouring Temp ,°F	2630	2641	2636	2623	2626	2620	2622	2620	2622	2624	2637	2639	**2626**
Pour Hood Process Air Temp at Start of Pour, °F	89	86	86	87	85	86	87	86	86	87	86	86	**86**
Mixer auto dispensed sand weight, Lbs	50.17	50.17	50.17	50.17	50.17	50.17	50.17	50.17	50.17	50.17	50.17	50.17	**50.17**
Core binder weight, Lbs	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	**1.3**
% core binder (BOS)	2.50	2.51	2.51	2.52	2.51	2.50	2.50	2.50	2.51	2.50	2.50	2.50	**2.50**
% core binder, actual	2.44	2.45	2.45	2.45	2.45	2.44	2.44	2.44	2.44	2.44	2.44	2.44	**2.44**
Total core weight in mold, Lbs.	28.05	28.01	28.07	26.65	26.52	26.43	26.31	26.39	26.36	26.37	26.15	26.19	**26.37**
Total binder weight in mold, Lbs.	NT	NT	NT	0.654	0.650	0.645	0.642	0.644	0.644	0.643	0.637	0.638	**0.644**
Core LOI, %	NT	NT	NT	0.20	0.18	0.17	0.17	0.29	0.18	0.17	0.18	0.19	**0.2**
Core dogbone tensile, psi (5 min duration)	63	63	63	63	63	63	63	63	63	63	63	63	**63**
Core age, hrs.	119	122	124	143	145	147	165	167	169	188	191	193	**168**
Muller Batch Weight, Lbs.	1000	910	900	900	910	900	900	890	900	900	940	900	**904**
GS Mold Sand Weight, Lbs.	635	646	628	639	641	639	635	639	634	638	632	629	**636**
Mold Temperature, °F	70	78	84	78	83	87	76	85	84	77	84	89	**82**
Average Green Compression , psi	19.17	19.33	21.01	19.38	20.36	21.27	23.13	22.54	23.54	23.19	23.85	25.34	**22.51**
GS Compactability, %	53	44	45	42	42	45	46	45	43	38	39	47	**43**
GS Moisture Content, %	2.12	2.46	1.80	2.00	1.75	2.00	1.98	2.10	2.04	2.10	2.16	2.33	**2.05**
GS MB Clay Content, %	7.09	7.35	7.44	6.91	6.91	6.73	7.09	6.73	6.73	6.91	7.44	7.09	**6.95**
MB Clay reagent, ml	40.0	41.5	42.0	39.0	39.0	38.0	40.0	38.0	38.0	39.0	42.0	40.0	**39.2**
1800°F LOI - Mold Sand, %	NT	NT	NT	0.67	0.71	0.76	0.71	0.71	0.72	0.84	0.79	0.73	**0.74**
900°F Volatiles , %	NT	NT	NT	0.24	0.22	0.28	0.30	0.26	0.22	0.34	0.18	0.20	**0.25**
Permeability index	249	238	248	240	245	255	240	251	258	252	260	265	**252**
Sand Temperature, °F	73	82	83	76	78	78	76	78	78	76	79	79	**78**

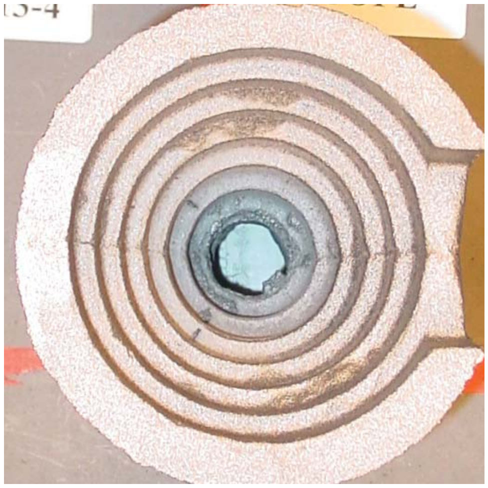
Notes:

NT=not tested. The core coating could have affected the correct value.

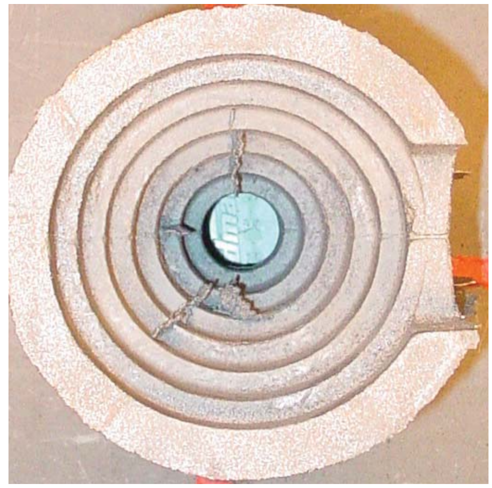
The dogbones were made with the same binder percent as the cores. One batch of sand was made for the whole test

Casting Surface Quality Comparison Photos

Best



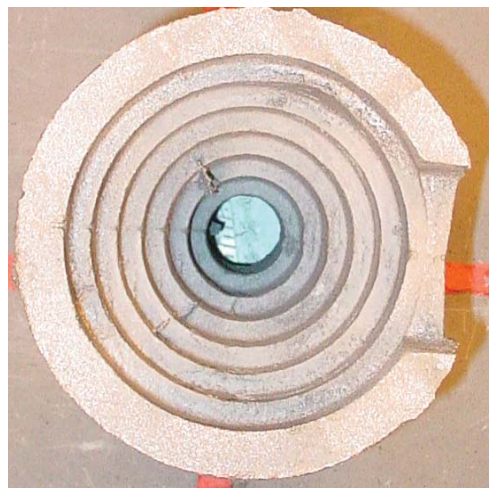
GZ 013 Cavity 4



HD CR2 Cavity 3

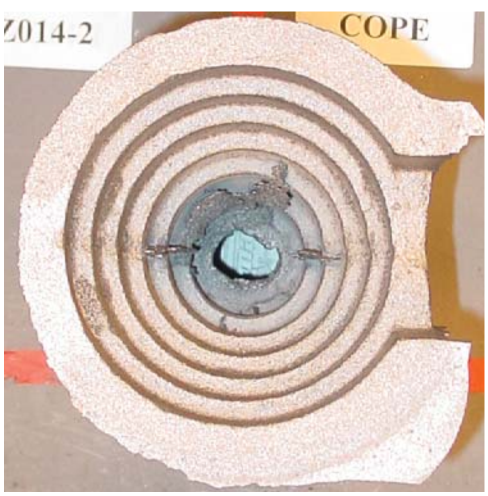
Median

GZ 013 Cavity 1



HD CR1 Cavity 4

Worst



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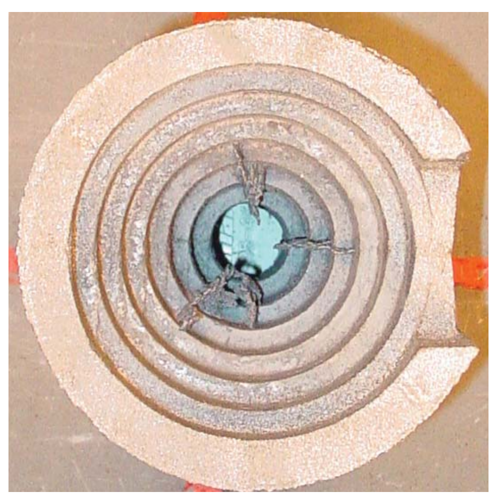

HD CR3 Cavity 4

APPENDIX D CONTINUOUS EMISSION CHARTS

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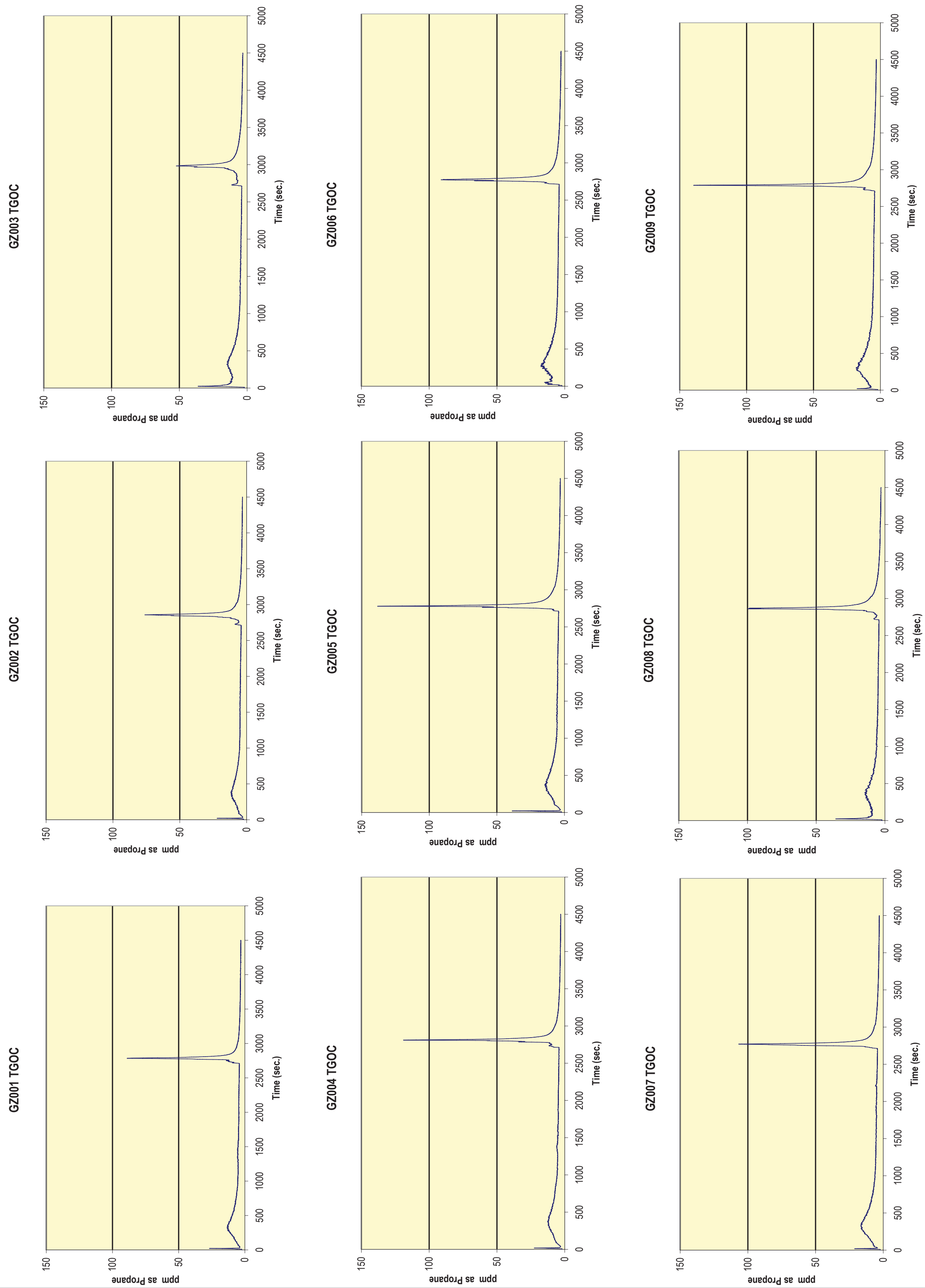
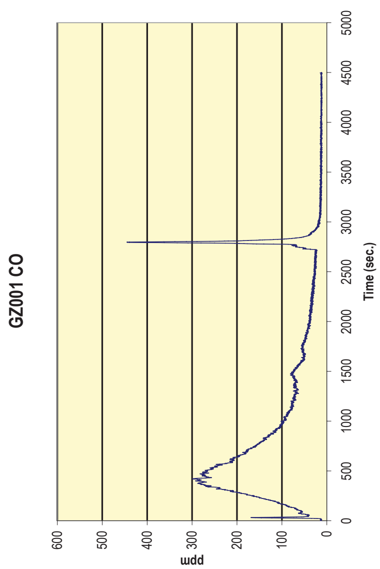
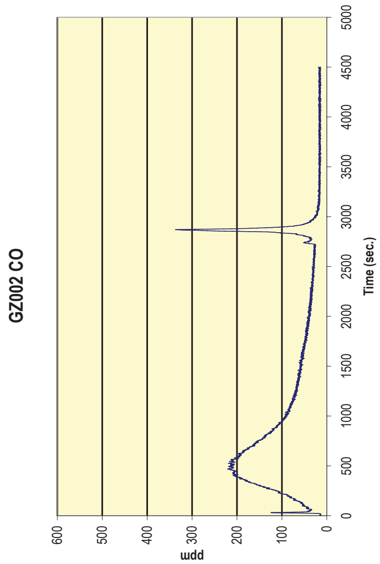
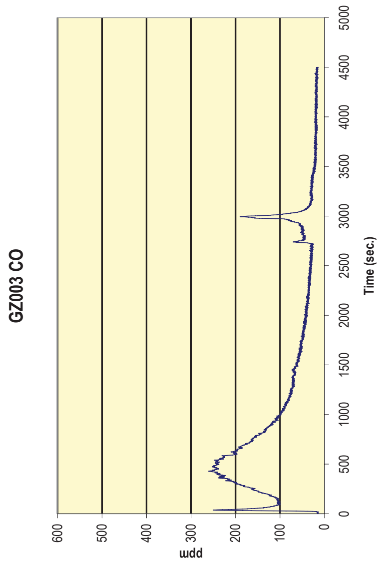
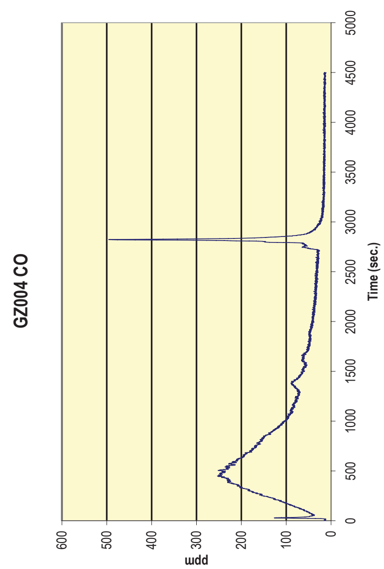
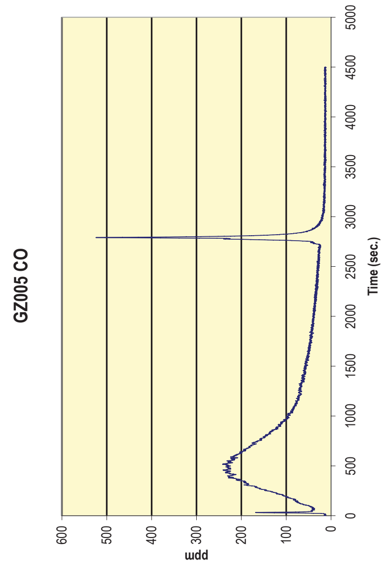

GZ001 TGOC
GZ002 TGOC
GZ003 TGOC
GZ004 TGOC
GZ005 TGOC
GZ006 TGOC
GZ007 TGOC
GZ008 TGOC
GZ009 TGOC
ppm as Propane
Time (sec.)


GZ001 CO
ppm
Time (sec.)


GZ002 CO
ppm
Time (sec.)


GZ003 CO
ppm
Time (sec.)


GZ004 CO
ppm
Time (sec.)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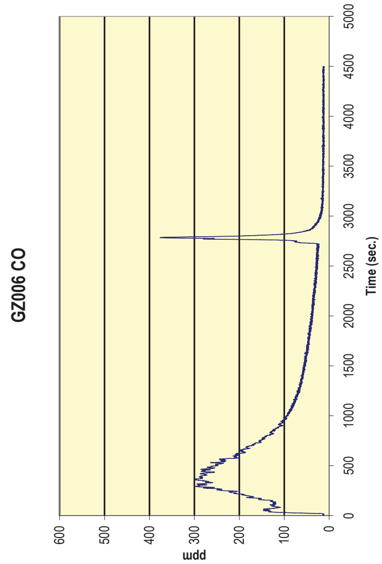
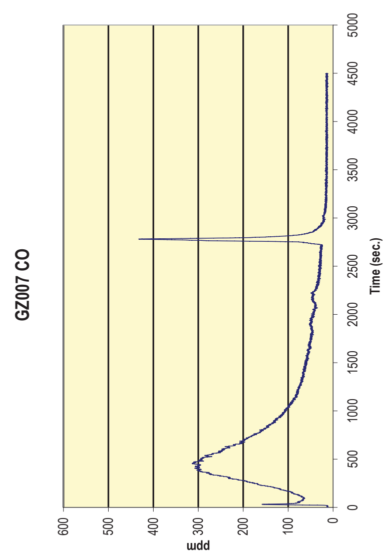

GZ006 CO
ppm
Time (sec.)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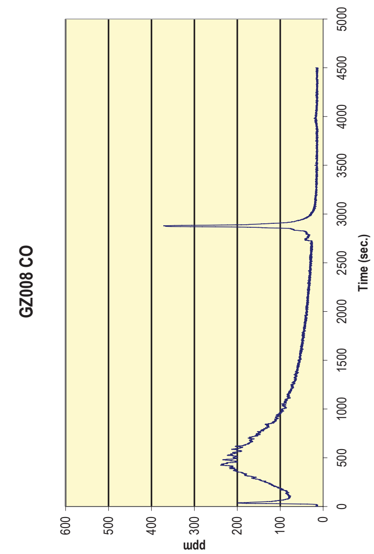
ppm
Time (sec.)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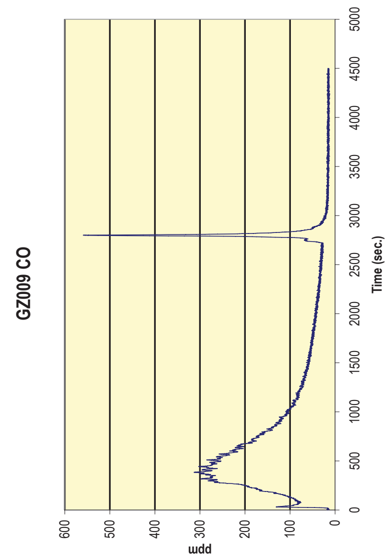
GZ009 CO
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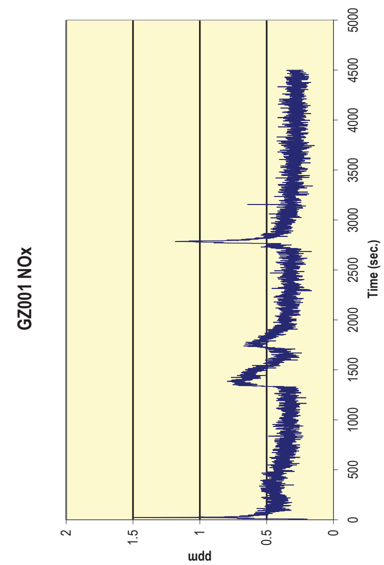
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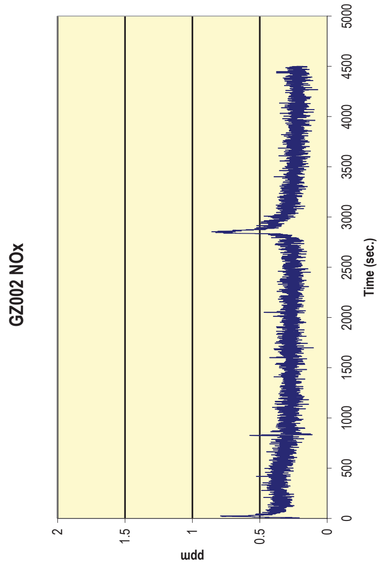
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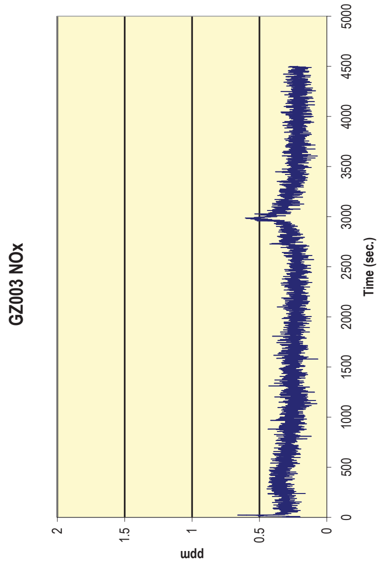
GZ003 NOx
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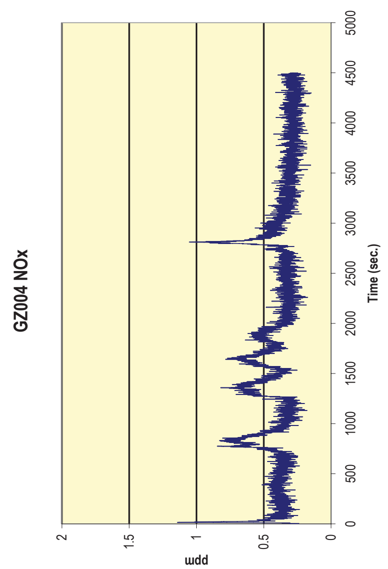
Time (sec.)


GZ004 NOx
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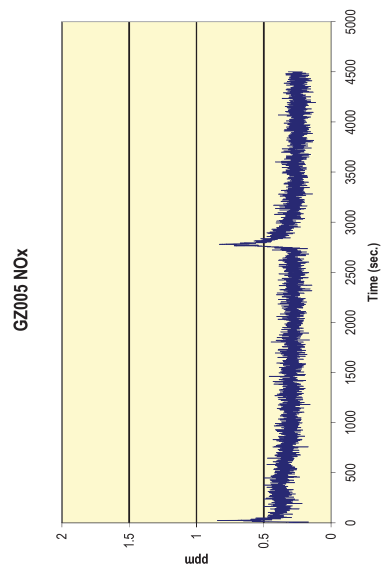
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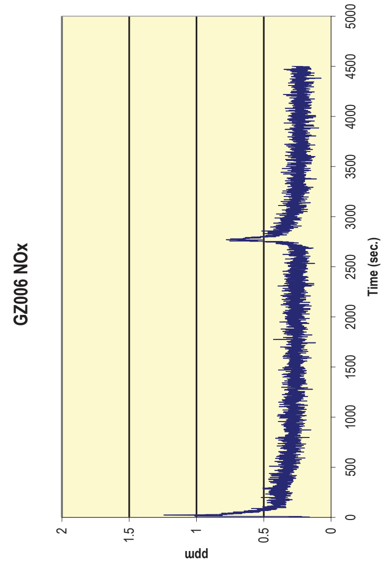
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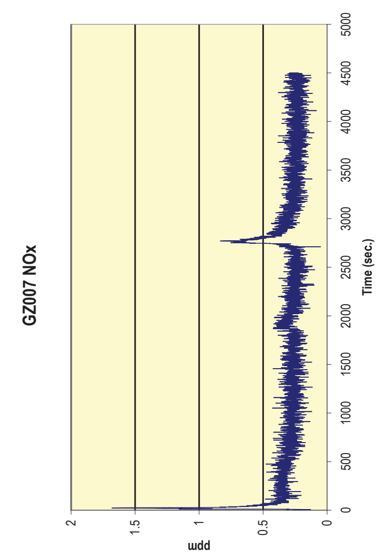
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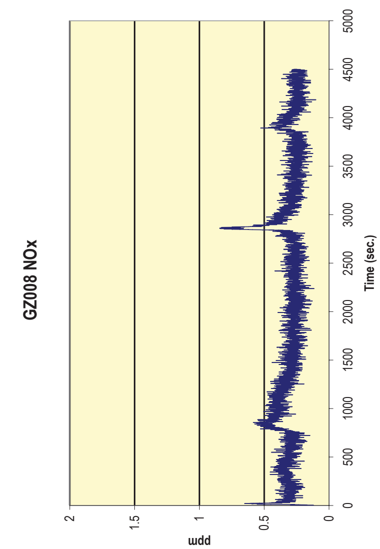
GZ008 NOx
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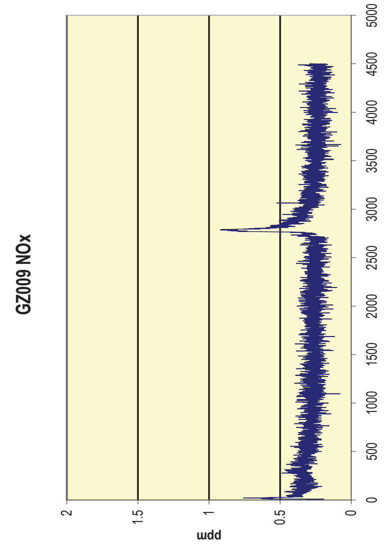
GZ009 NOx
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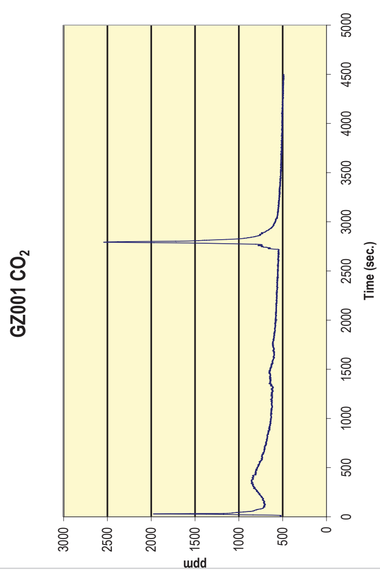
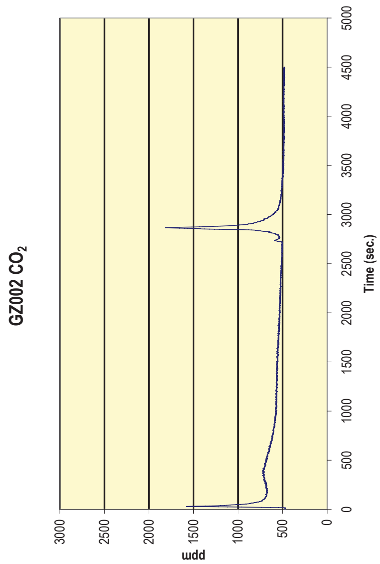

GZ001 CO2
ppm
Time (sec.)


GZ002 CO2
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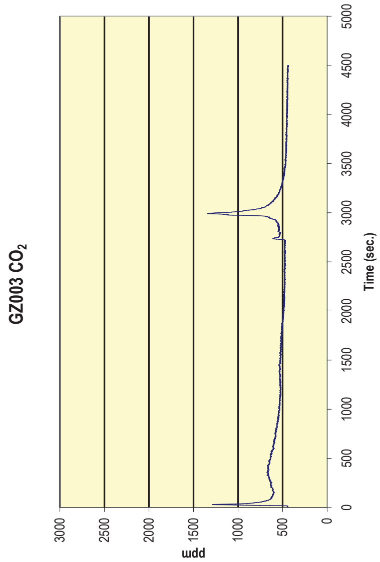
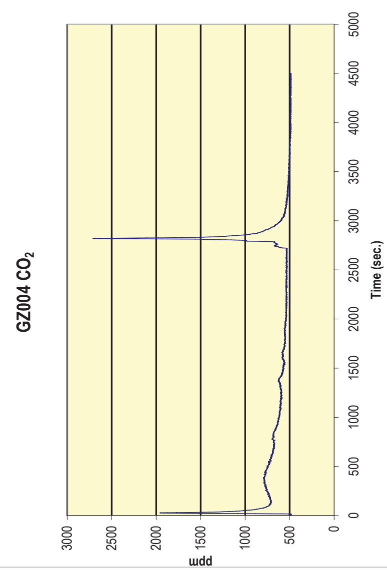
Time (sec.)


GZ003 CO2
ppm
Time (sec.)


GZ004 CO2
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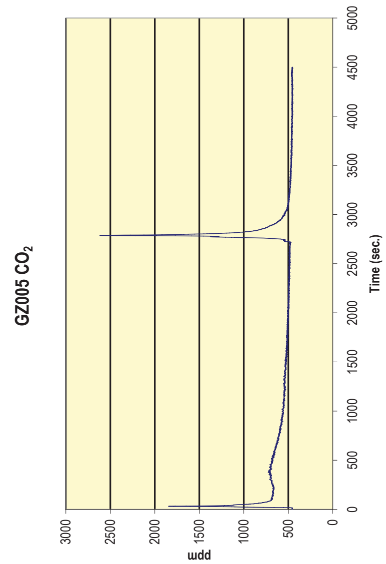
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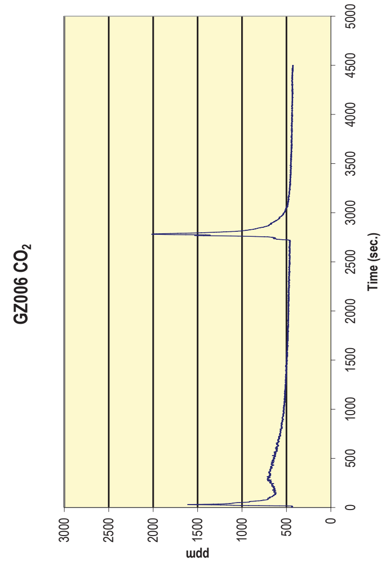
GZ006 CO2
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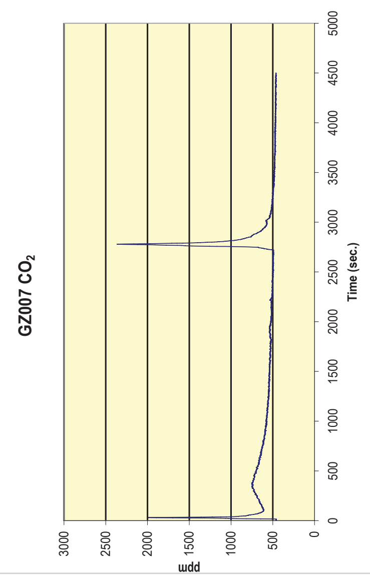
Time (sec.)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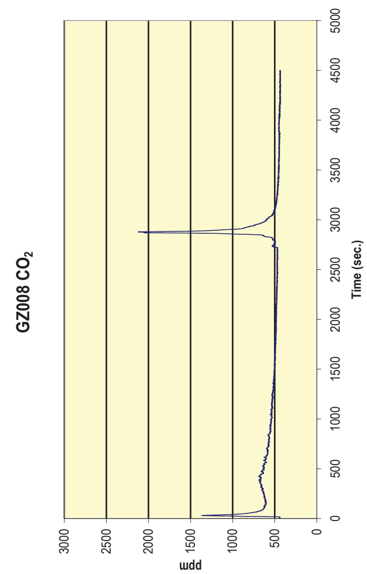
Time (sec.)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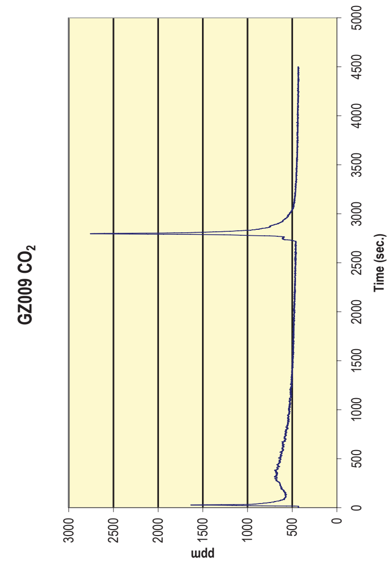
GZ009 CO2
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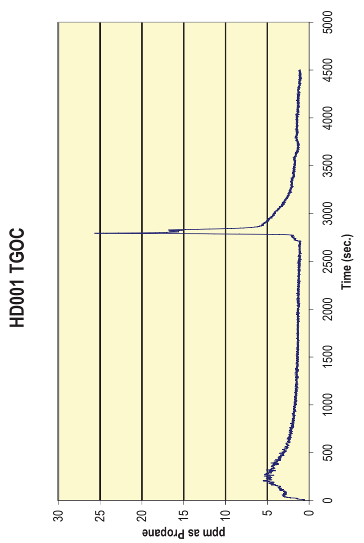
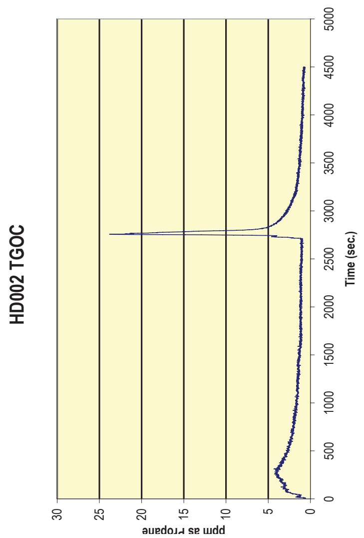
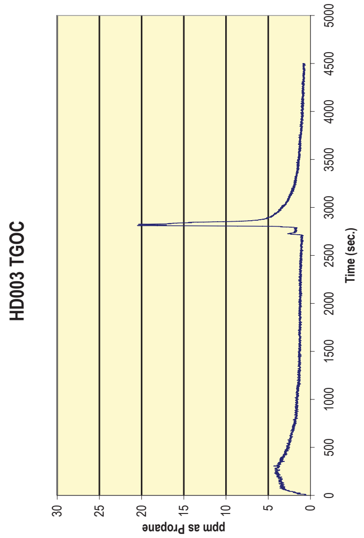
Time (sec.)


HD001 TGOC
ppm as Propane
Time (sec.)


HD002 TGOC
ppm as Propane
Time (sec.)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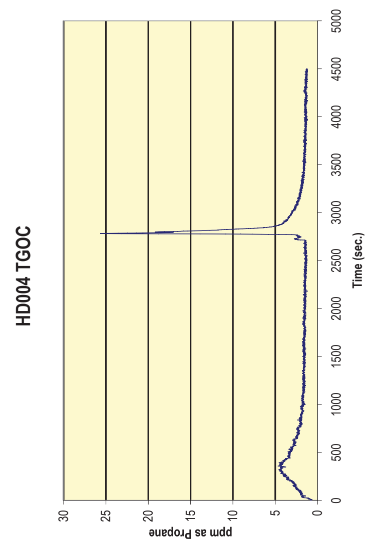
ppm as Propane
Time (sec.)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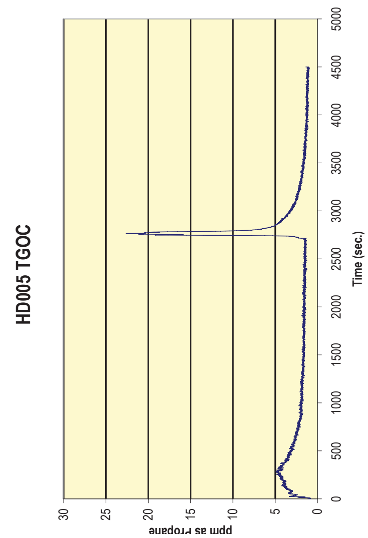
Time (sec.)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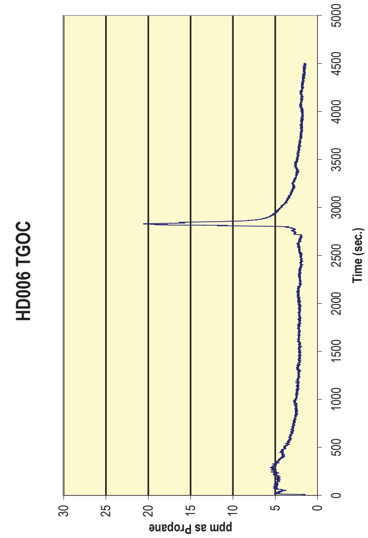
Time (sec.)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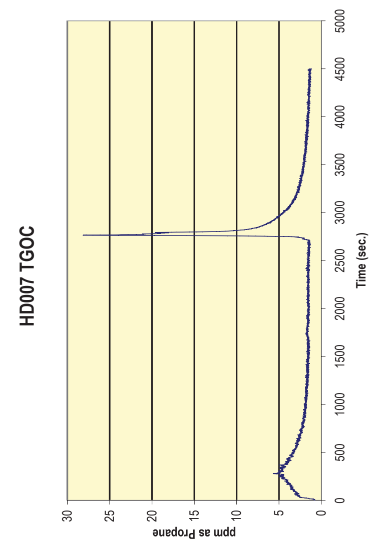
ppm as Propane
Time (sec.)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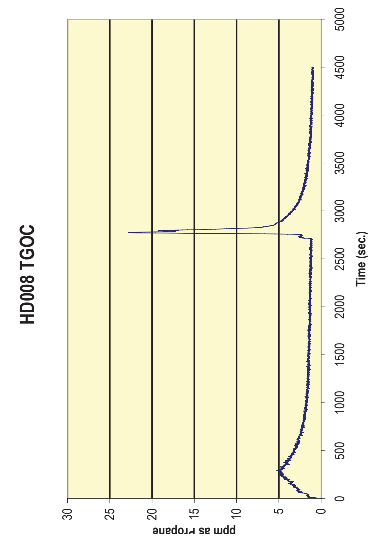
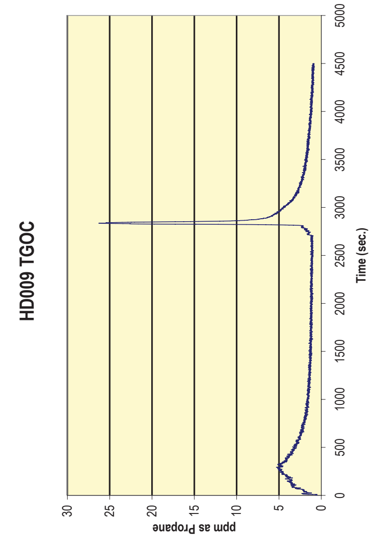
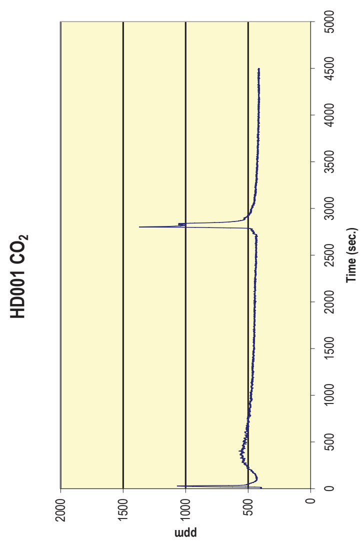
Time (sec.)


HD008 TGOC
ppm as Propane
Time (sec.)


HD009 TGOC
ppm as Propane
Time (sec.)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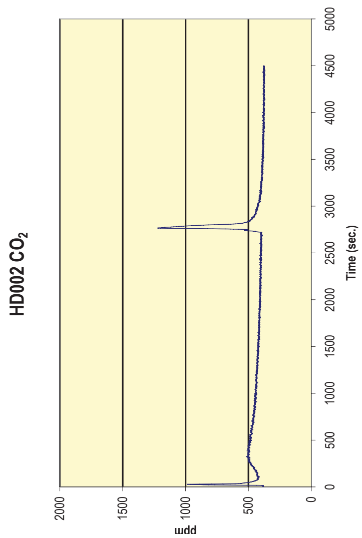
ppm
Time (sec.)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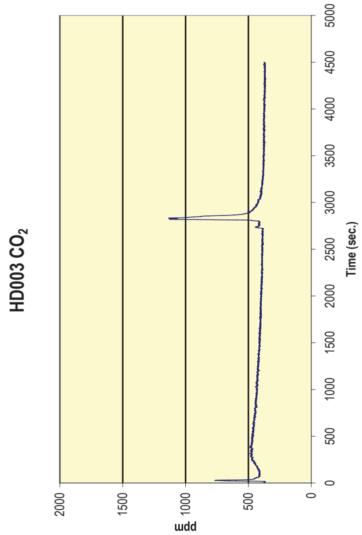
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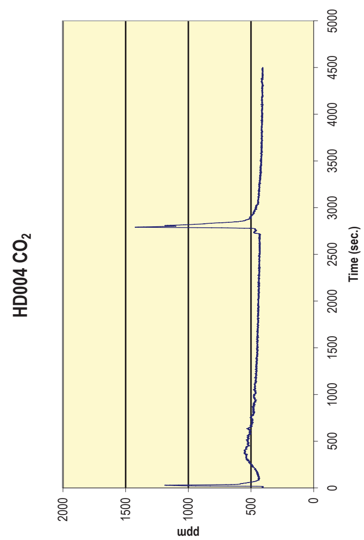
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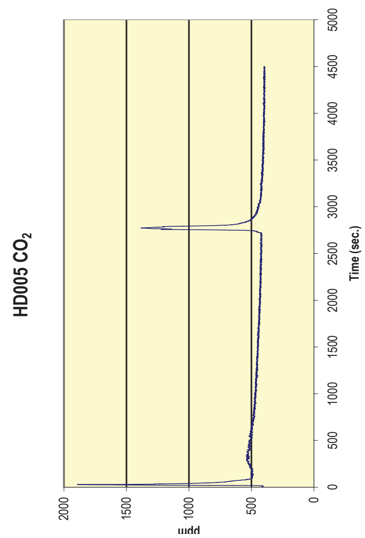
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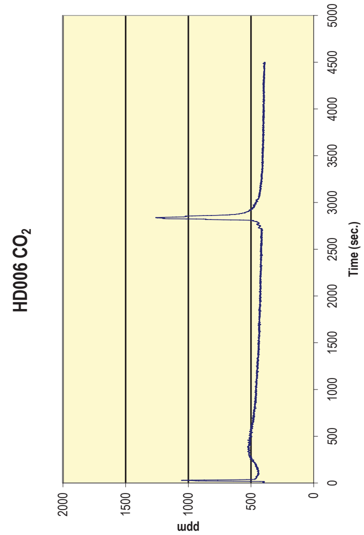
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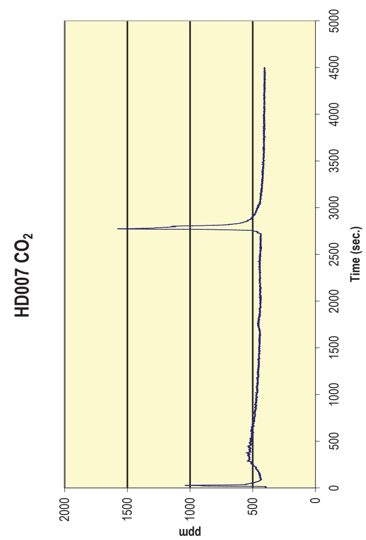
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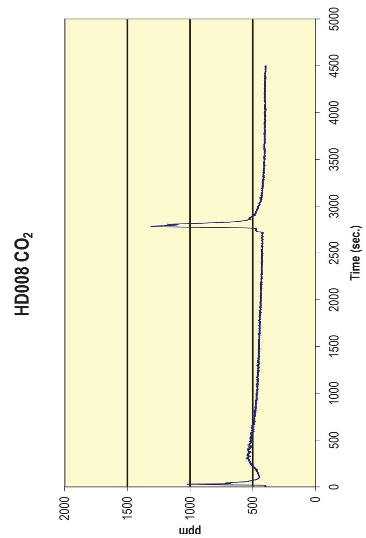
Time (sec.)


HD008 CO_2
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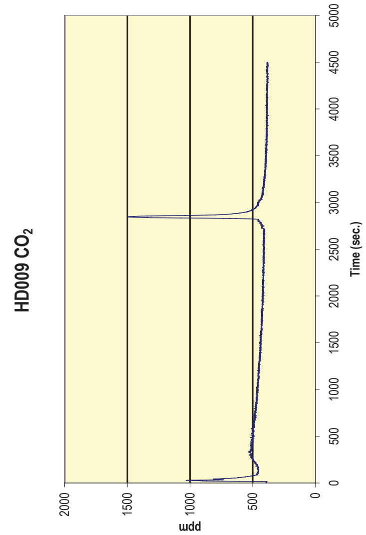
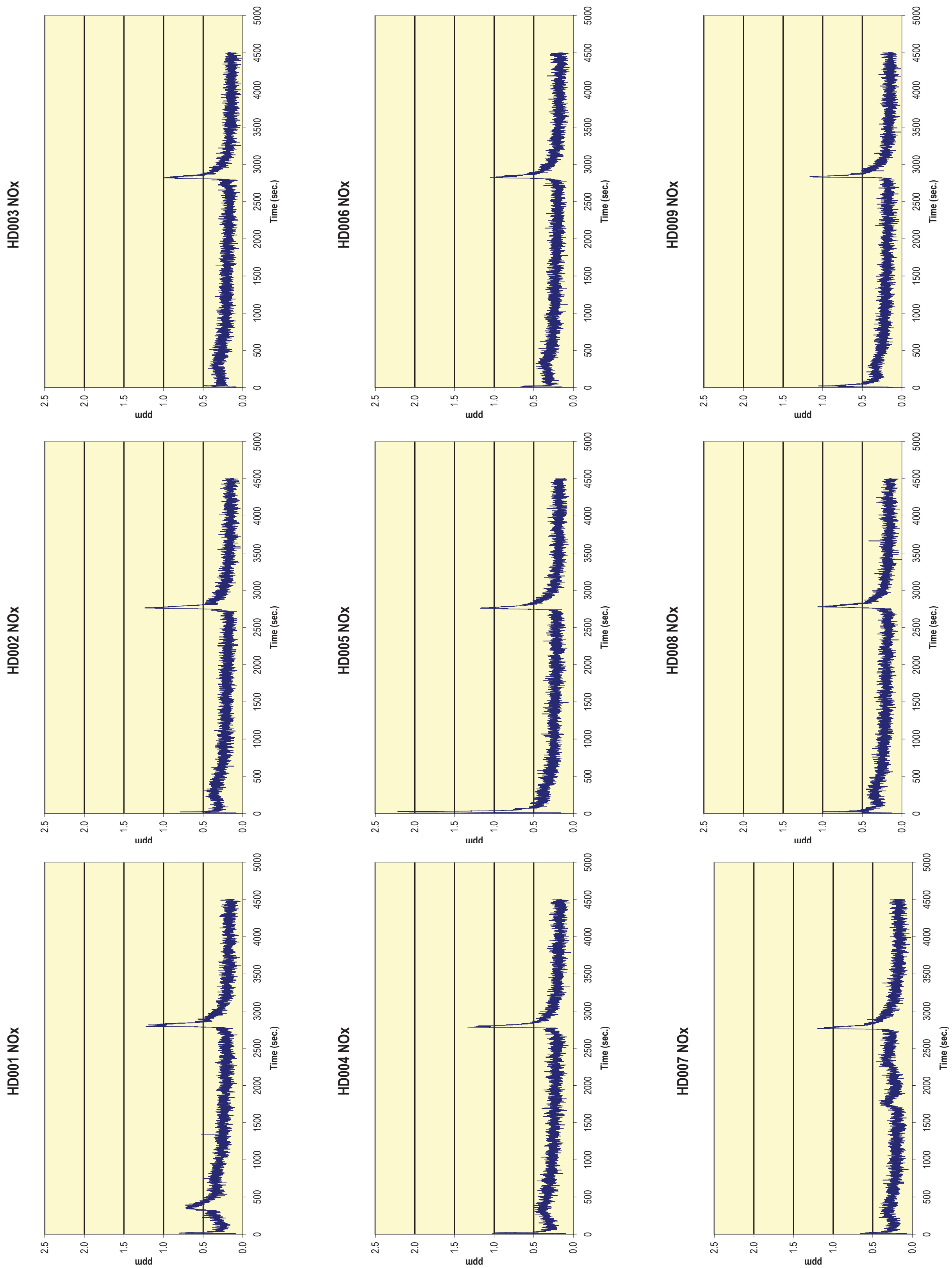
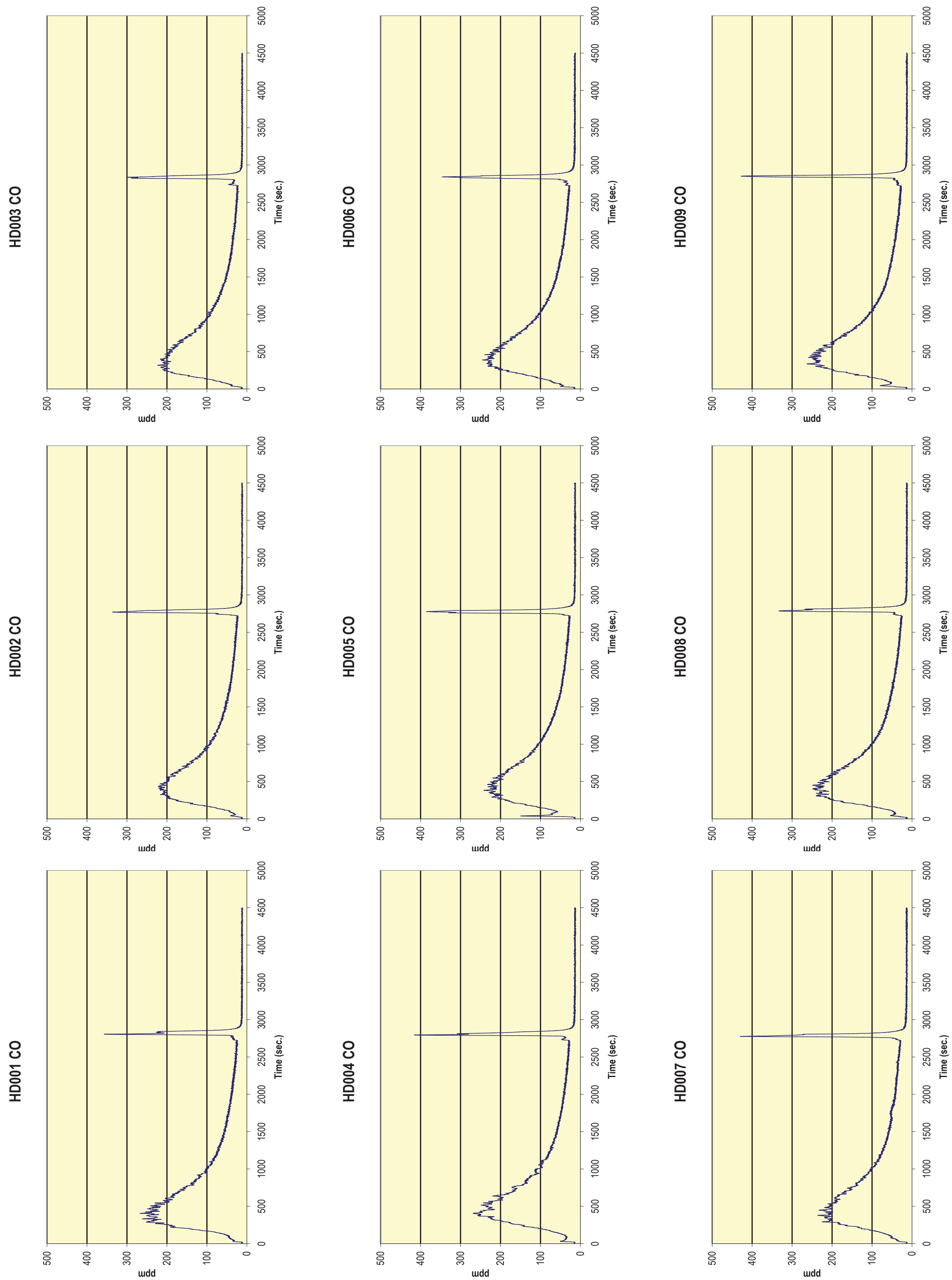
Time (sec.)


HD009 CO_2
ppm
Time (sec.)


HD001 NOx
HD002 NOx
HD003 NOx
HD004 NOx
HD005 NOx
HD006 NOx
HD007 NOx
HD008 NOx
HD009 NOx
ppm
Time (sec.)


HD001 CO
HD002 CO
HD003 CO
HD004 CO
HD005 CO
HD006 CO
HD007 CO
HD008 CO
HD009 CO
ppm
Time (sec.)

APPENDIX E ACRONYMS AND ABBREVIATIONS

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ACRONYMS & ABBREVIATIONS

AFS	American Foundry Society
ARDEC	(US) Army Armament Research, Development and Engineering Center
BO	Based on ( ).
BOS	Based on Sand.
CAAA	Clean Air Act Amendments of 1990
CARB	California Air Resources Board
CERP	Casting Emission Reduction Program
CFR	Code of Federal Regulations
CISA	Casting Industry Suppliers Association
CO_2	Carbon Dioxide
CRADA	Cooperative Research and Development Agreement
DOD	Department of Defense
DOE	Department of Energy
EPA	Environmental Protection Agency
ERC	Environmental Research Consortium
FID	Flame Ionization Detector
GS	Greensand
HAP	Hazardous Air Pollutant defined by the 1990 Clean Air Act Amendment
HC	Hydrocarbon
I	Invalidated Data
Lb/Lb	Pound per Pound of Binder used
Lb/Tn	Pound per Ton of Metal poured
LOI	Loss on Ignition
MB	Methylene Blue
NA	Not Applicable; Not Available
ND	Non-Detect
NOx	Oxides of Nitrogen
NT	Not Tested
OA	Organic Analytes
PCS	Pouring, Cooling, Shakeout
POM	Polycyclic Organic Matter
PQL/PRL	Practical Quantitation Limit/ Practical Reporting Limit

QA/QC	Quality Assurance/Quality Control
SO_2	Sulfur Dioxide
TGOC	Total Gaseous Organic Concentration
THC	Total Hydrocarbon Concentration
US EPA	United States Environmental Protection Agency
USCAR	United States Council for Automotive Research
VOC	Volatile Organic Compound
VOST	Volatile Organic Sampling Train
WBS	Work Breakdown Structure