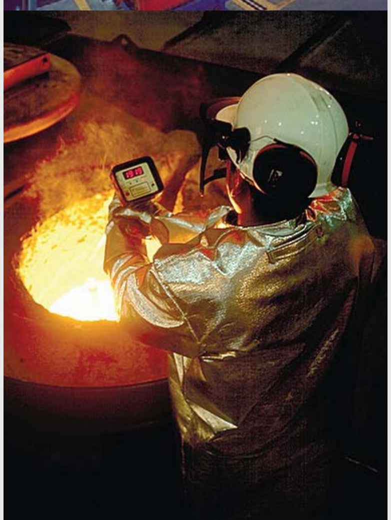
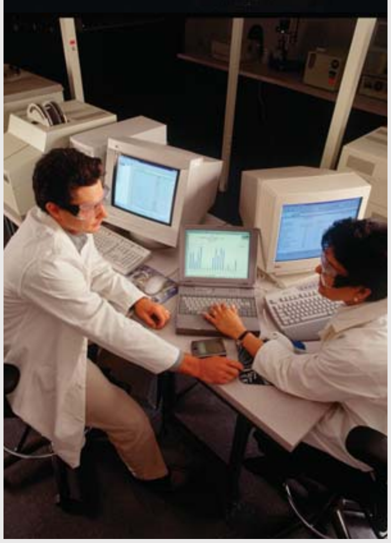
Casting Emission Reduction Program

www.cerp-us.org





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US Army Contract W15QKN-05-D-0030
FY2005 Tasks
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PCS Iron Sodium Silicate Cold Box

1412-122 GZ

May 2006
Revised for public distribution - July 2006

UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

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PCS Iron Sodium Silicate Cold Box

1412-122 GZ

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 emission testing to evaluate the pouring, cooling, and shakeout emissions from Test GZ, an uncoated sodium silicate cold box core in greensand without seacoal. The core binder for Test GZ was activated with carbon dioxide (CO_2). This report is an update and addition to the core baseline to include cores for casting internal surface comparisons. 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 testing performed involved the collection of continuous air samples over a seventy-five minute period, including the mold pouring, cooling, shakeout, and post shakeout periods for nine molds using a 4-on-step core pattern. Emission indicator results are summarized in Table 1.

Table 1 GY and GX Average Emissions Indicators Summary Table

Analyte Name	Lb/Tn Metal	Lb/Lb Binder
TGOC as Propane	0.1844	0.0078
HC as Hexane	0.0394	0.0017
Sum of Target VOCs	0.0364	0.0015
Sum of Target HAPs	0.0329	0.0014
Sum of Target POMs	0.0017	0.0001

Both process and stack parameters were monitored and recorded. Process measurements included the weights of the casting and mold sand, loss on ignition (LOI) values for the mold prior to the test, and relevant metallurgical data. Measured stack gas 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.

Adsorption tube samples were collected and analyzed for fifty-six (56) target compounds using procedures based on approved state and/or federal regulatory methods, including those of the US Environmental Protection Agency (EPA). Continuous on-line monitoring of Total Gaseous Organic Concentration (TGOC), carbon dioxide (CO_2), carbon monoxide (CO), and nitrogen oxide (NOx) concentrations was conducted according to US EPA Methods 25A, 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" which include TGOC as propane, hydrocarbons (HC) as hexane, the sum of target volatile organic compounds (VOCs), the sum of target hazardous air pollutants (HAPs), and the sum of target polycyclic organic matter (POM). Full descriptions of these indicators can be found in Section 3.0 of this report.

A photographic casting record was made of the twelve castings made with coated cores produced from the three molds poured after the emission test was completed. The surface quality for each of the conditioning run castings was assessed relative to each other. Pictures of best, medium and worst casting quality are shown in Appendix C.

It must be noted that the reported TGOC results include the exempted compound methane. At present, the methane contribution to these results has not been determined or removed. In addition, results from the testing performed are not suitable for use as emission factors or for other 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 Research Consortium (ERC), 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 arena facilitates the repeatable collection and evaluation of airborne emissions and associated process data.

1.3. REPORT ORGANIZATION

This report has been designed 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 sodium silicate cold box core, in a greensand mold with no seacoal. Section 2 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

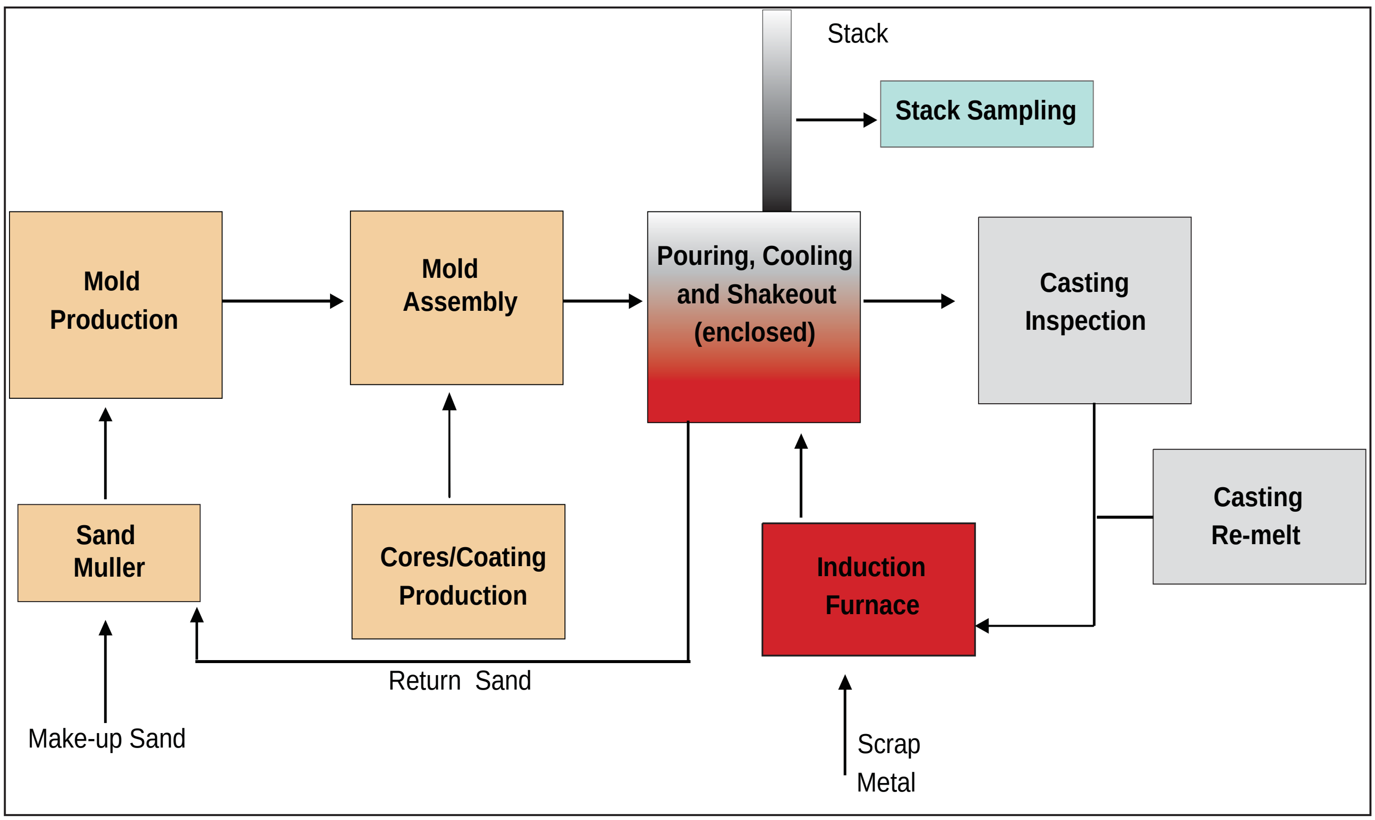
Type of Process Tested	Uncoated Sodium Silicate core in greensand without seacoal, iron, PCS
Test Plan Number	1412-122 GZ
Metal Poured	Iron
Casting Type	4-on step core
Greensand System	Wexford 450 sand, western and southern bentonite in a 5:2 ratio to yield 7.0 +/- 0.5 % MB clay, no seacoal
Core	5.0 % (BOS) Hill & Griffith Corosil®, CO_2 activated, Wedron 530 sand
Core Coating	Foseco Isomol® for casting quality runs, none for emissions sampling runs
Number of Molds Poured	3 conditioning, 9 sampling, and 3 casting quality
Test Dates	December 12, 2005 through December 21, 2005
Emissions Measured	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

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 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*

The molds and cores (Figure 2-2) were prepared to a standard composition by the Technikon production team. The cores were blown using a Redford/Carver core blower. The cores were coated with the vendor supplied core coating and dried in an OSI core drying oven (Figure 2-3). Relevant process data were collected and recorded. Iron was melted in a 1000 lb. Ajax induction furnace. The amount of metal melted was determined from the poured weight of the casting and the number of molds to be poured. The metal composition was Class-30 Gray Iron as prescribed by a metal composition worksheet. The weight of metal poured into each mold was recorded on the process data summary sheet.

Figure 2-2 Mold and Step Cores

Figure 2-3 Coated Step Cores

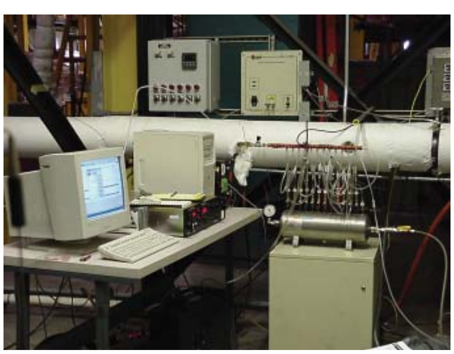
2.2.3. *Individual Sampling Events:*

Replicate runs were performed on nine (9) mold packages after the conclusion of three (3) conditioning cycles. Prior to pouring for each run, each mold package was placed into an enclosed test stand heated to approximately 85°F. The flow rate of the emission capture air was nominally 300 scfm. Iron was poured through an opening in the top of the emission enclosure, after which the opening was closed (Figure 2-4).

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

Continuous air samples were collected during the forty-five minute pouring and cooling process, during the five minute shakeout of the mold, and for an additional twenty five minute cooling period following shakeout. Figure 2-5 shows the sampling equipment used during collection of emissions. The total sampling time was

Figure 2-5 Method 25A (TGOC) and Method 18 Sampling Train



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 Parameters	
Pouring Temperature	Electro-Nite DT 260 (T/C Immersion Pyrometer)
Carbon/Silicon Fusion Temperature	Electro-Nite DataCast 2000 (Thermal Arrest)
Alloy Weights	Ohaus MP2 Scale
Mold Compactability	Dietert 319A Sand Squeezer (AFS Procedure 2221-00-S)
Carbon/Silicon	Electro-Nite DataCast 2000 (Thermal Arrest)

2.2.5. Air Emissions Analysis:

The specific sampling and analytical methods used in the Research Foundry tests are based on federal regulatory 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
NO_x	US EPA Method 7E
SO_2	OSHA ID 200

*These methods modified to meet specific CERP test objectives.

2.2.6. Data Reduction, Tabulation and Preliminary Report Preparation

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 results for each analyte for all sampling events are included in Appendix B of this report. Average results for each event are given in Section 3.0, Tables 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 Manager - Process Engineering 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 Vice President 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

The average emission results in pounds per pound (lbs/lb) of binder and pounds per ton (lbs/ton) of metal for individual target analytes and emission indicators are presented in Tables 3-1a and 3-1b. These tables include the individual target compounds or isomer classes that comprise at least 95% of the total targeted VOCs measured, as well as the "Sum of Target VOCs", the "Sum of Target HAPs", and the "Sum of Target POMs". These three analyte sums are part of a group termed "Emission Indicators". Also included in this group are TGOC as propane and HC as hexane, which are also reported in the tables. Additionally, average values for selected criteria and greenhouse gases such as carbon monoxide, carbon dioxide, sulfur dioxide and nitrogen oxides are given.

Table 3-1a Summary of Top 95% of Emission Averages - Lb/Tn Metal

Analyte Name	Average	Standard Deviation
Emission Indicators		
TGOC as Propane	0.1844	0.0228
HC as Hexane	0.0394	0.0129
Sum of Target VOCs	0.0364	0.0047
Sum of Target HAPs	0.0329	0.0039
Sum of Target POMs	0.0017	0.0003
Selected Target HAPs and POMs		
Acetaldehyde	0.0104	0.0008
Benzene	0.0081	0.0011
Toluene	0.0036	0.0004
Xylenes	0.0027	0.0004
Phenol	0.0014	0.0004
Formaldehyde	0.0013	0.0001
Propionaldehyde (Propanal)	0.0013	0.0002
2-Butanone (MEK)	0.0010	0.0002
Methylnaphthalenes	0.0009	0.0001
Naphthalene	0.0007	0.0001
Hexane	0.0007	0.0002
Styrene	0.0004	0.0001
Additional Selected Target VOCs		
Heptane	6.35E-04	3.70E-04
Benzaldehyde	4.80E-04	5.48E-05
Trimethylbenzenes	1.26E-03	3.88E-04
Criteria Pollutants and Greenhouse Gases		
Carbon Dioxide	4.0596	0.3929
Carbon Monoxide	1.3975	0.1114
Nitrogen Oxides	0.0016	0.0006
Sulfur Dioxide	0.0060	0.0008

NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data
Selected results constitute >95% mass of all detected target analytes.
<0.0001= less than reporting limit of 0.0001 lb/ton metal
Numbers are calculated with full precision to avoid rounding errors.

Table 3-1b Summary of Top 95% of Emission Averages – Lb/Lb Binder

Analyte Name	Average	Standard Deviation
Emission Indicators		
TGOC as Propane	0.0078	0.0009
HC as Hexane	0.0017	0.0005
Sum of Target VOCs	0.0015	0.0002
Sum of Target HAPs	0.0014	0.0001
Sum of Target POMs	0.0001	<0.0001
Selected Target HAPs and POMs		
Acetaldehyde	0.0004	<0.0001
Benzene	0.0003	<0.0001
Toluene	0.0001	<0.0001
Xylenes	0.0001	<0.0001
Phenol	0.0001	<0.0001
Formaldehyde	0.0001	<0.0001
Propionaldehyde (Propanal)	0.0001	<0.0001
2-Butanone (MEK)	<0.0001	<0.0001
Methylnaphthalenes	<0.0001	<0.0001
Hexane	<0.0001	<0.0001
Naphthalene	<0.0001	<0.0001
Styrene	<0.0001	<0.0001
Additional Selected Target VOCs		
Heptane	<0.0001	<0.0001
Benzaldehyde	<0.0001	<0.0001
Trimethylbenzenes	0.0001	<0.0001
Criteria Pollutants and Greenhouse Gases		
Carbon Dioxide	0.1713	0.0177
Carbon Monoxide	0.0589	0.0045
Nitrogen Oxides	0.0001	<0.0001
Sulfur Dioxide	0.0003	0.0001

NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data
Selected results constitute >95% of the mass of all detected target analytes.
<0.0001= less than reporting limit of 0.0001 lb/lb binder
Numbers are calculated with full precision to avoid rounding errors.

Figure 3-1a Emissions Indicators for Test GZ, Average Results – Lb/Tn Metal

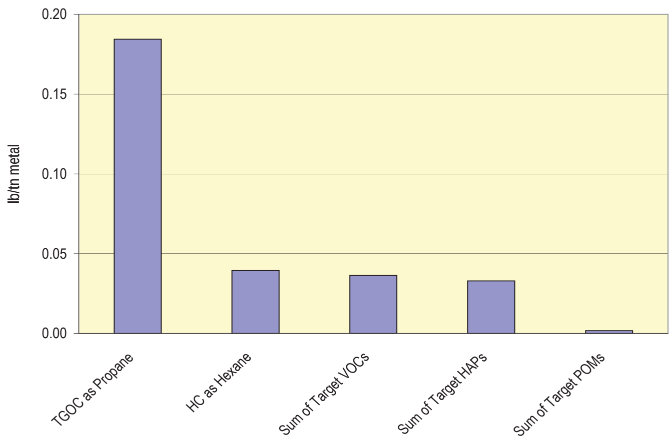


Figure 3-1b Emissions Indicators for Test GZ, Average Results – Lb/Lb Binder

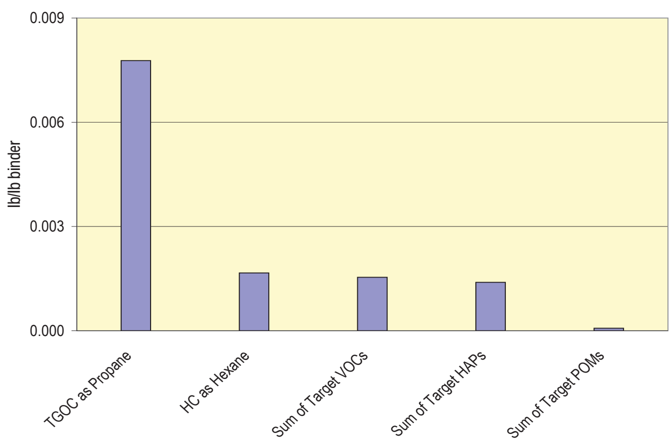
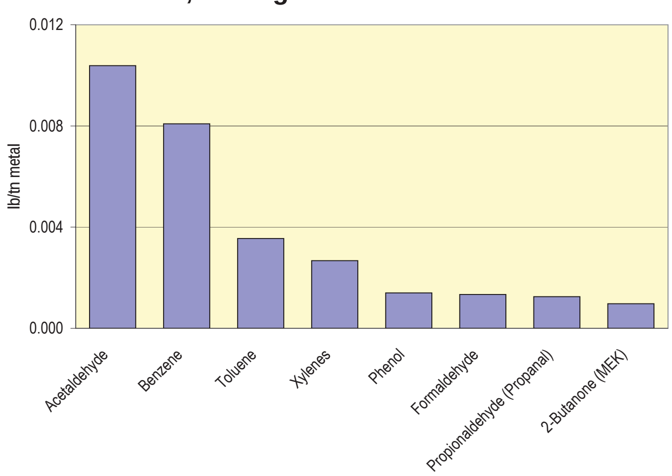


Figure 3-2a Selected HAP and VOC Emissions for Test GZ, Average Results – Lb/Tn Metal



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 are treated and reported in a similar manner.

Figures 3-1 to 3-3 present a graphical depiction of the five emissions indicators as well as selected individual HAP, VOC, and criteria pollutant and greenhouse gas emissions data from Test GZ given in Tables 3-1a and 3-1b.

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, performed in accordance with Wisconsin Cast Metals Association – Maximum Potential to Emit (WCMA – MPTE) Method revised 07-26-01. EPA Method 25A is weighted to the detection of the more volatile hydrocarbon species, beginning at methane, the single carbon alkane (C_1), with results calibrated against propane, which is the three-carbon alkane (C_3). The HC as hexane method detects hydrocarbon compounds in the alkane range between C_6 and C_{16}, with results calibrated against the six-carbon alkane, hexane (C_6).

The emissions indicator called the "Sum of Target VOCs" is the sum of all individual target VOCs detected and 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 the 188 listed 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 HAPs", while the "Sum of Target POMs" only sums those HAPs that are also defined as POMs.

Figure 3-2b Selected HAP and VOC Emissions for Test GZ, Average Results – Lb/Lb Binder

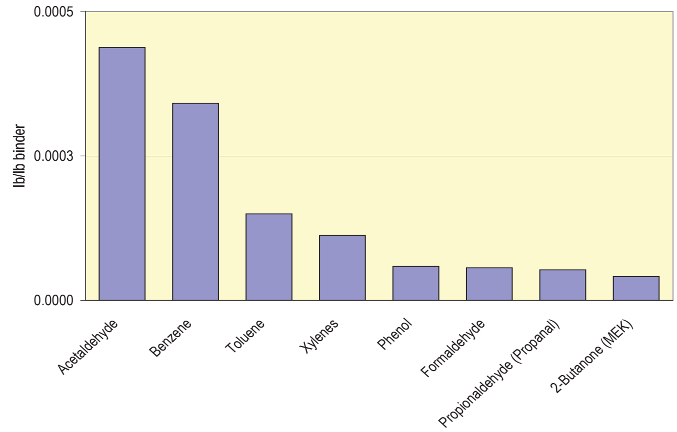


Figure 3-3a Criteria Pollutants and Greenhouse Gases for Test GZ, Average Results – Lb/Tn Metal

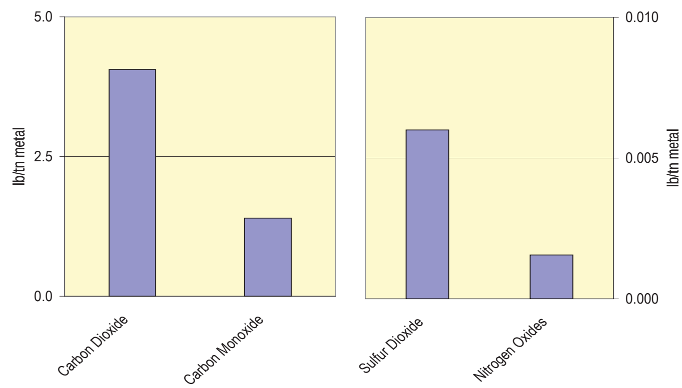


Figure 3-3b Criteria Pollutants and Greenhouse Gases for Test GZ, Average Results – Lb/Lb Binder

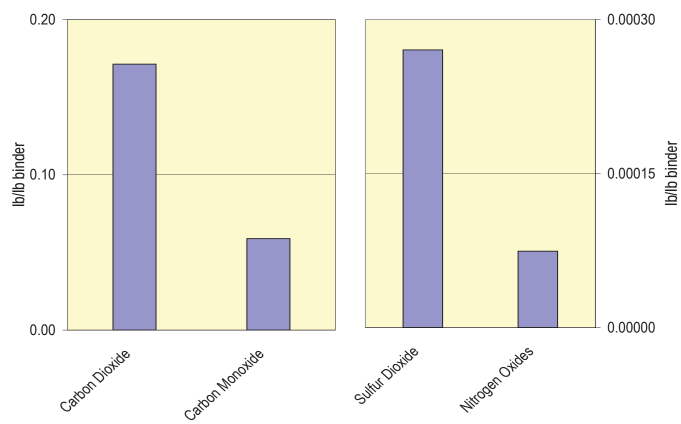


Table 3-2 Summary of Test Plan Process Parameters

Greensand PCS with Sodium Silicate Cores	
Test Dates	12/12/05-12/21/05
Cast Weight, Lbs.	118.91
Pouring Time, sec.	12.67
Pouring Temp ,°F	2632
Pour Hood Process Air Temp at Start of Pour, °F	87
Sand in Sodium Silicate Sand mix, lbs	50
Sodium Silicate in Sodium Silicate Core Sand Mix,lbs	2.51
Sodium Silicate Core CO2 Gassing Pressure, PSI	20
Sodium Silicate Core CO2 Gassing Time, sec	30
Sodium Silicate Content, % (BOS)	5.01
Sodium Silicate Content, % of Sand Mix	4.77
Total Weight of Baked Cores in Mold, Lbs.	29.52
Binder Weight in Mold, Lbs	1.41
Baking Oven nominal temperature, °F	250
Core LOI, %	0.85
Core dogbone tensile, psi	27.3
Core age, hrs.	195
Muller Batch Weight, Lbs.	901
GS Mold Sand Weight, Lbs.	645
Mold Temperature, °F	73
Average Green Compression , psi	22.71
GS Compactability, %	39
GS Moisture Content, %	2.11
GS MB Clay Content, %	7.17
MB Clay reagent, ml	36.56
1800°F LOI - Mold Sand, %	0.86
900°F Volatiles , %	0.28
Permeability index	239
Sand Temperature, °F	78

On December 19, 2005 the EPA amended the list of HAPs by removing methyl ethyl ketone (also known as MEK or 2-Butanone). Although this compound was removed from the federal list of hazardous air pollutants, it may still be regulated as such by individual states. It therefore is still reported as a HAP in the tables and appendices of this report as both a single analyte and as a contributor to the "Sum of HAPs" emission indicator.

Table 3-2 includes the averages of the key process parameters.

The comparative ranking of casting appearance for each casting made with coated cores poured after the three conditioning runs and the emission test runs for GZ is shown in Table 3-3. Each of the four castings from the molds of the three runs was assessed and compared relative to each other. 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 a casting is the best appearing casting 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

Table 3-3 Casting Quality Rank Order

Rank Order	Mold Number	Cavity Number	Test GZ
1	GZ013	4	Best
2	GZ013	3	
3	GZ015	3	
4	GZ015	4	
5	GZ015	1	
6	GZ013	1	Median
7	GZ014	3	
8	GZ014	1	
9	GZ013	2	
10	GZ014	4	
11	GZ015	2	
12	GZ014	2	Worst

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 benchmark castings. The runs GZ013 to GZ015 are used for surface finish quality comparisons only. Emissions from these runs and the three initial conditioning runs were not sampled and are therefore not included in the emission results reported here.

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 GW. Appendix B contains detailed emissions data and average results for all targeted analytes. Target analyte reporting limits expressed in both pounds per pound of binder and pounds per ton of metal are also shown in Appendix B. These values are based on the practical quantitation limit which is related to the detection limitations of an analytical method and the capabilities of analytical instrumentation. 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 emission time-dependent emissions profiles for each pour. Appendix E contains acronyms and abbreviations.

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4.0 DISCUSSION OF RESULTS

Fifteen (15) targeted analytes and isomer classes accounted for more than 95% of the concentration in both lb/ton metal and lb/lb binder of all targeted VOCs detected from Test GZ as can be seen in Tables 3-1a and 3-1b. The highest contributors to total measured emissions were from acetaldehyde, benzene, and toluene at 29, 22, and 10 percent, respectively. The remaining twelve analytes contributed 7% and less to the top 95% of emitters.

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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 Sodium Silicate Cold Box Core in Greensand.
- **METAL TYPE:** Class 30, gray iron.
- **MOLD TYPE**: 4-on step-cored 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 GZER1 to GZER3, Foseco Isomol for GZ013 to GZ015, none for production runs GZ004-GZ012 (emission runs GZ001-GZ009.)
- **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.

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

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

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 CO2 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, & 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 12 dog bones made for a 2 hour 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.

- **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.

M. Shot Blasting

1. All castings from emission runs GZER1-GZER3 and production runs GZ013-GZ015 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 GZ001-GZ009 will be shot blasted for 8 minutes at 12 amps, weighed and the weight recorded, and recycled.

N. 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 production runs GZ013-015, 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 GZ013, compare it to castings from mold GZ014.
   - **c.** Place the better appearing casting in the first position and the lesser appearing casting in the second position.
   - **d.** Repeat this procedure with GZ013 to its nearest neighbors until all castings closer to the beginning of the line are better appearing than GZ014 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.

Thomas J Fennell Jr.
Process Engineer

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APPENDIX B DETAILED EMISSION RESULTS AND QUANTITATION LIMITS

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Detailed Emission Results for GZ

VOC	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	2.65E-02	2.72E-02	3.23E-02	3.10E-02	3.53E-02	3.55E-02	3.74E-02	3.54E-02	3.48E-02	3.29E-02	3.87E-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 HAPs and POMs											
V		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
V		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
V		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
V		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
V		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
V		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
V		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
V		H	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
V	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
V		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
V		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
V	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
V		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
V		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
V	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
V	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
V	P	H	Acenaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,8-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,7-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Indene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Trimethylnaphthalene, 2,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V		H	Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V		H	Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V		H	Cresol, mp-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V		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

Detailed Emission Results for GZ

VOC	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 VOCs											
V			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
V			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
V			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
V			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
V			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
V			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
V			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
V			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
V			o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	3.50E-04	ND	ND	3.89E-05	1.17E-04
V			Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Diethylbenzene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Dimethylphenol, 2,4-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Dimethylphenol, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Dodecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Ethyltoluene, 2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Hexaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Propylbenzene, n-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Trimethylbenzene, 1,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Undecane	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

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

GZ Detailed Emission Results - Lb/Lb Binder

VOC	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	1.18E-03	1.16E-03	1.37E-03	1.36E-03	1.47E-03	1.48E-03	1.55E-03	1.46E-03	1.49E-03	1.39E-03	1.39E-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 HAPs and POMs											
V		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
V		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
V		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
V		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
V		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
V		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
V		H	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
V		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
V	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
V		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
V	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
V		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
V		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
V		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
V	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
V	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
V	P	H	Acenaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,8-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,7-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Trimethylnaphthalene, 2,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V		H	Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V		H	Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V		H	Cresol, mp-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V		H	Cresol, o-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA

NT= Not Tested
ND= Not Detected
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GZ Detailed Emission Results - Lb/Lb Binder

VOC	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 VOCs											
V			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
V			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
V			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
V			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
V			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
V			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
V			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
V			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
V			Indene	ND	ND	2.41E-05	ND	ND	ND	ND	ND	ND	2.68E-06	8.05E-06
V			o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	1.45E-05	ND	ND	1.61E-06	4.84E-06
V			Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Diethylbenzene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Dimethylphenol, 2,4-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Dimethylphenol, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Dodecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Ethyltoluene, 2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Hexaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Propylbenzene, n-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Trimethylbenzene, 1,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V			Undecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
			Criteria Pollutants and Greenhouse Gases											
			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
			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
			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
			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

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

Quantation Limits - Lb/Tn Metal

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

Quantatiion Limits - Lb/Lb Binder

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

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APPENDIX C DETAILED PROCESS DATA AND CASTING QUALITY PHOTOS

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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			
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
													Cavity 1	6	8	5
													Cavity 2	9	12	11
													Cavity 3	2	7	3
													Cavity 4	1	10	4

Note 1: 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 appllied correctly. More cores were made, and coated correctly. The rankings shown are with the second coating. No data was taken in regards to the mold other than compactability.

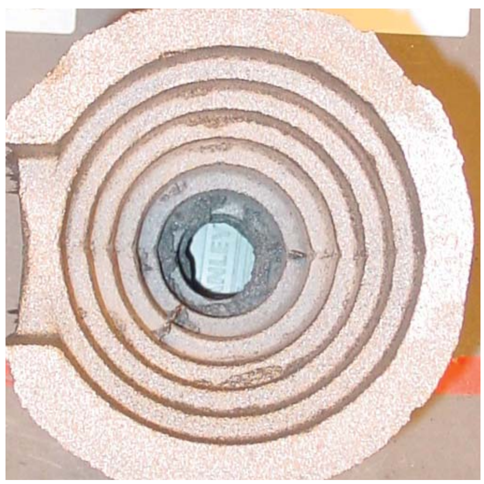
Note 2: There is no data for the reported for the mixing of the cores for batch GZ012, because no data was recorded

Note 3: 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

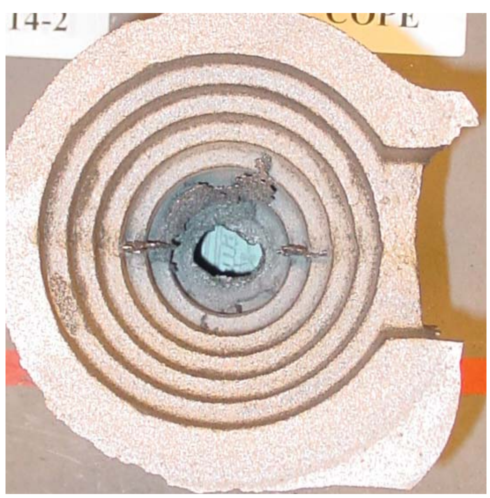
Casting Surface Quality Comparison Photos

Best
GZ013 Cavity 4

Median
GZ013 Cavity 1



Worst
GZ014 Cavity 2



APPENDIX D CONTINUOUS EMISSION MONITORING CHARTS

All continuous emissions charts have been background corrected.

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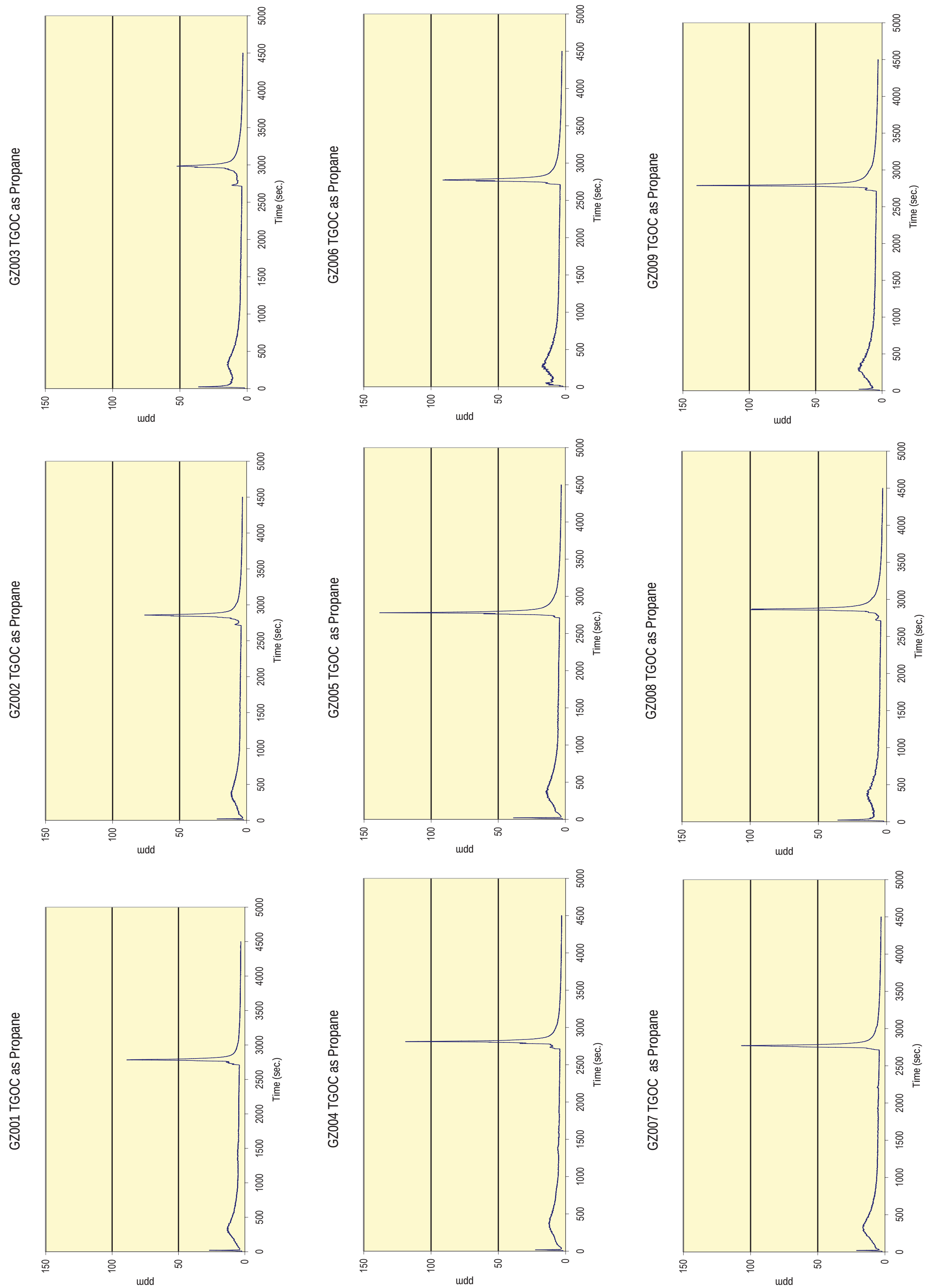
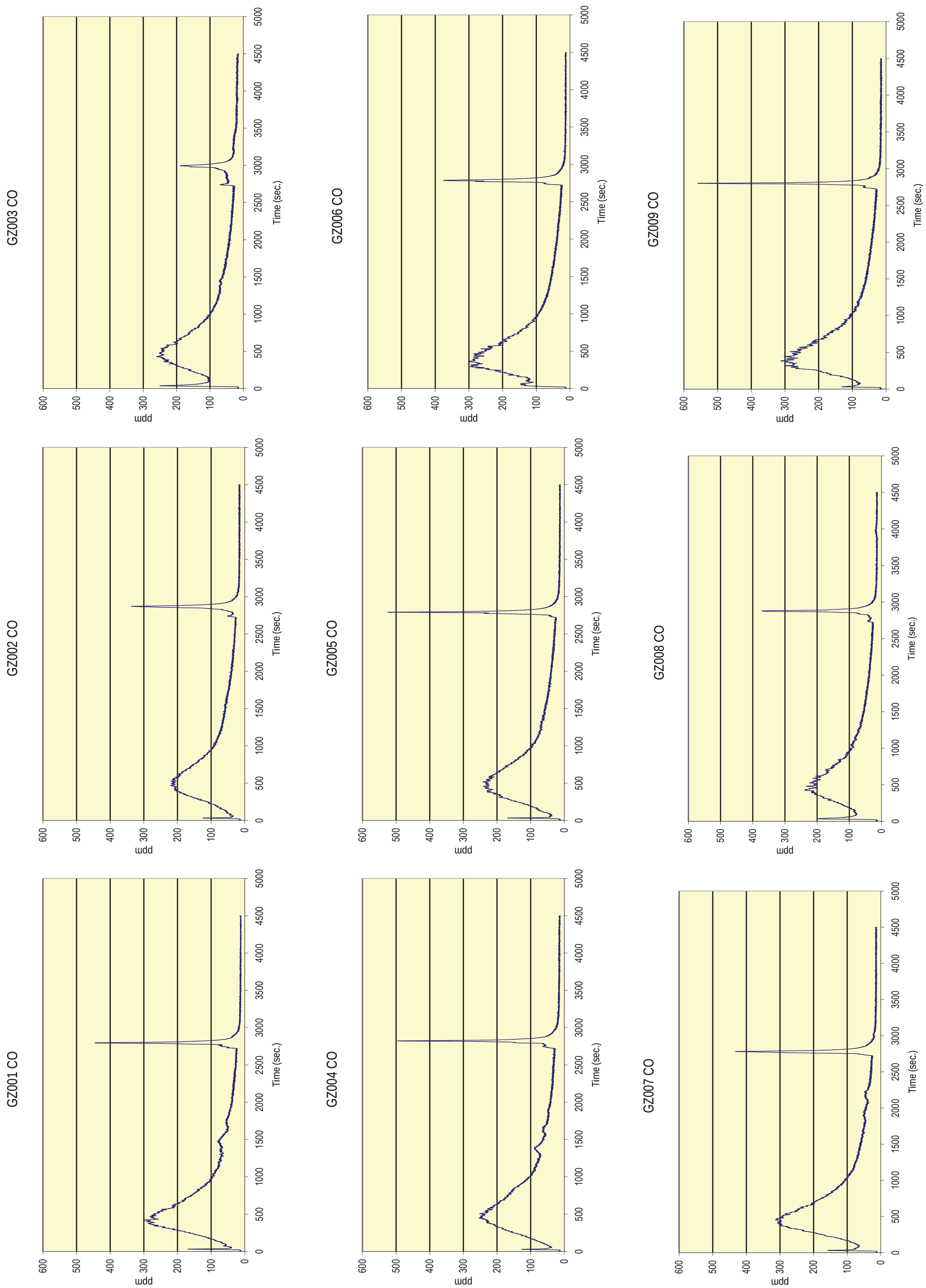
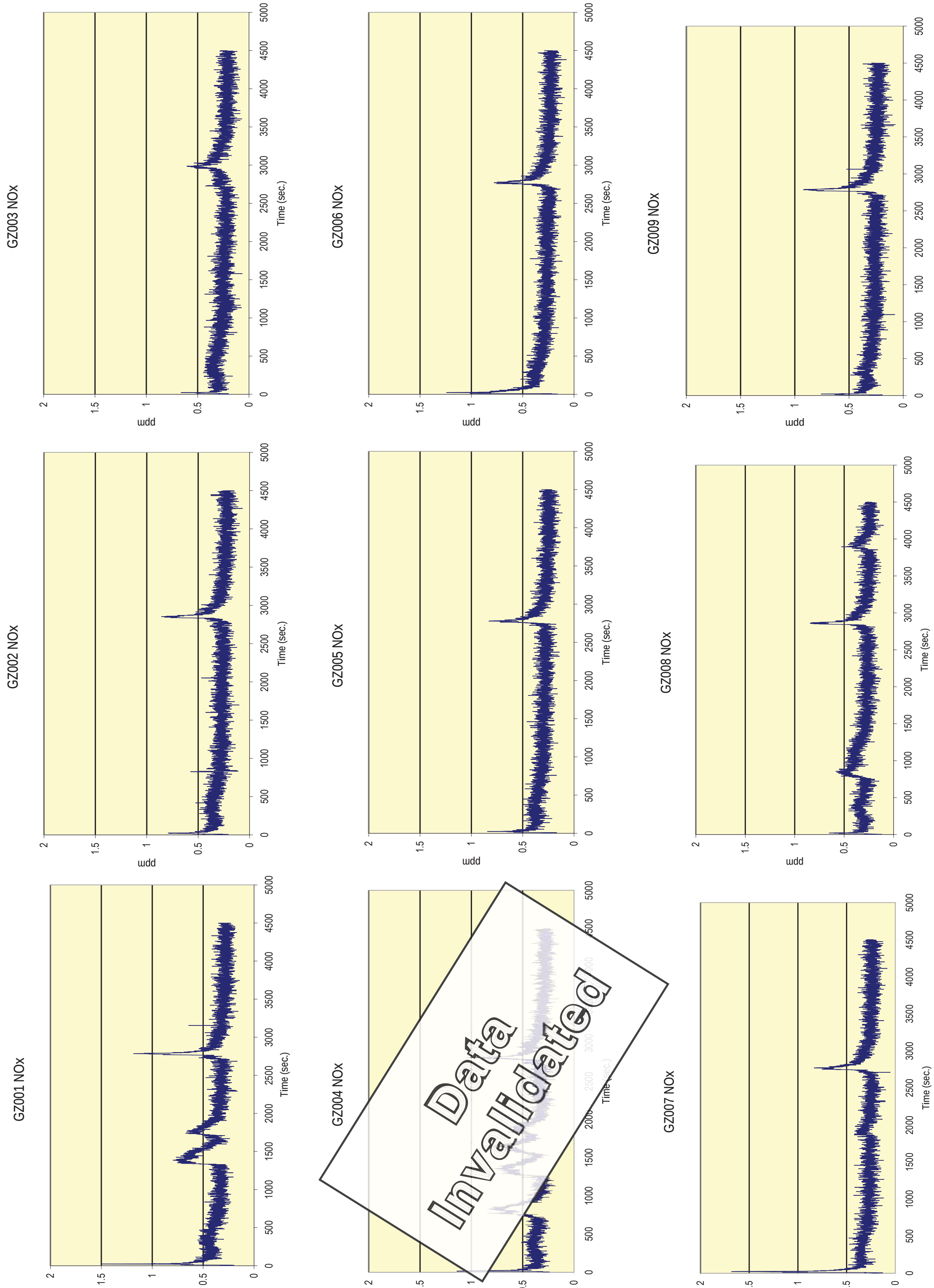

GZ001 TGOC as Propane
GZ002 TGOC as Propane
GZ003 TGOC as Propane
GZ004 TGOC as Propane
GZ005 TGOC as Propane
GZ006 TGOC as Propane
GZ007 TGOC as Propane
GZ008 TGOC as Propane
GZ009 TGOC as Propane
ppm
Time (sec.)
0
50
100
150
500
1000
1500
2000
2500
3000
3500
4000
4500
5000


GZ001 CO
GZ002 CO
GZ003 CO
GZ004 CO
GZ005 CO
GZ006 CO
GZ007 CO
GZ008 CO
GZ009 CO
ppm
Time (sec.)
0
100
200
300
400
500
600
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000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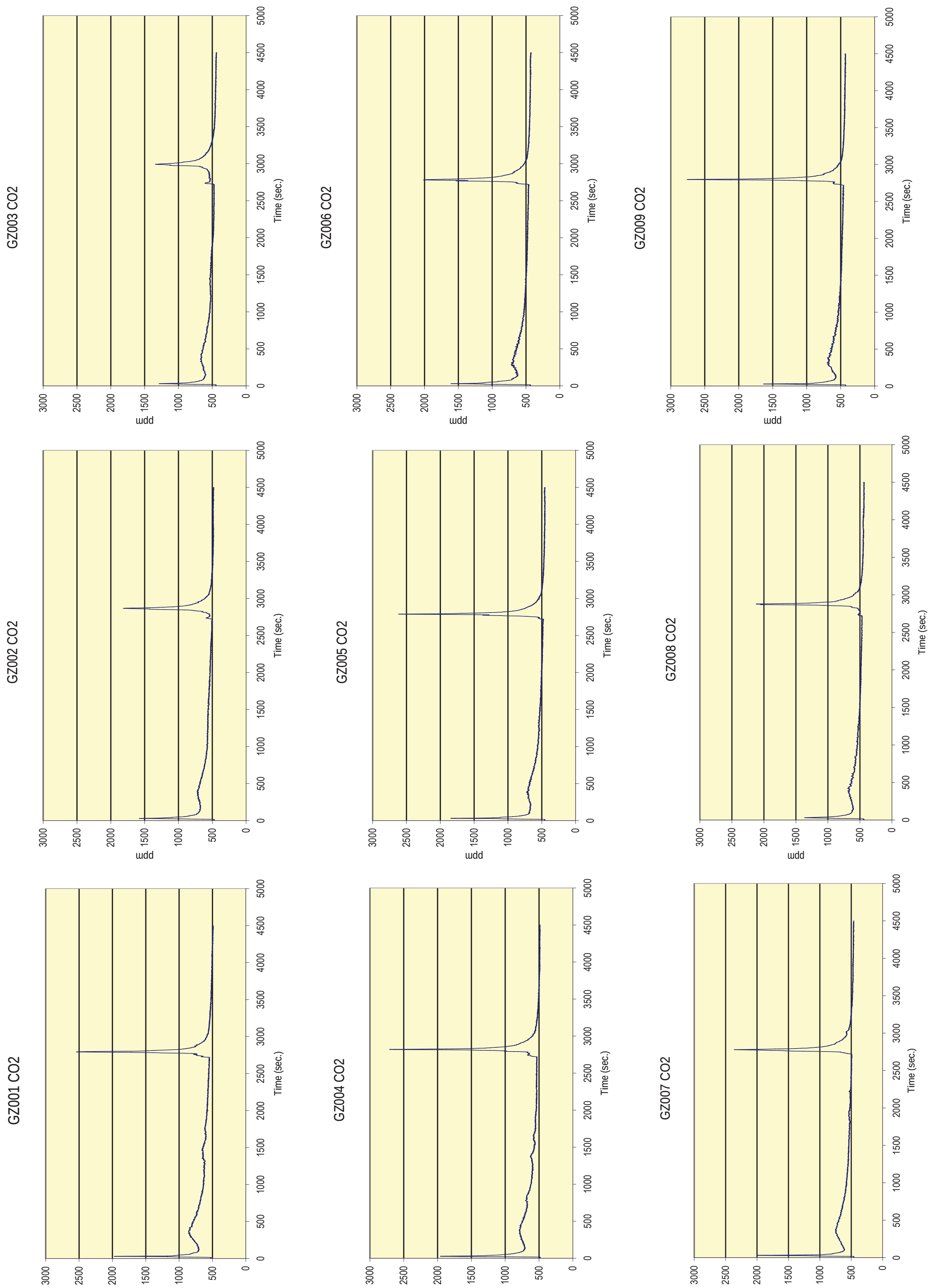
GZ002 NOx
GZ003 NOx
GZ004 NOx
Data Invalidated
GZ005 NOx
GZ006 NOx
GZ007 NOx
GZ008 NOx
GZ009 NOx
ppm
Time (sec.)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GZ006 CO2
GZ009 CO2
GZ002 CO2
GZ005 CO2
GZ008 CO2
GZ001 CO2
GZ004 CO2
GZ007 CO2
ppm
Time (sec.)

APPENDIX E ACRONYMS AND ABBREVIATIONS

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ACRONYMS & ABBREVIATIONS

AFS	American Foundry Society
ARDEC	(US) Army Armament Research, Development and Engineering Center
ATCAP	Armament Titanium Casting Advancement Program
BO	Based on ( ).
BOS	Based on Sand.
CAAA	Clean Air Act Amendments of 1990
CARB	California Air Resources Board
CEMS	Continuous Emissions Monitoring Systems
CERP	Casting Emission Reduction Program
CISA	Casting Industry Suppliers Association
CO	Carbon Monoxide
CRADA	Cooperative Research and Development Agreement
DOD	Department of Defense
DOE	Department of Energy
EEF	Established Emission Factors
EPA	Environmental Protection Agency
ERC	Environmental Research Consortium
FID	Flame Ionization Detector
GC	Gas Chromatography
GS	Greensand
HAP	Hazardous Air Pollutant defined by the 1990 Clean Air Act Amendment
HC as Hexane	The quantity of undifferentiated hydrocarbons determined by Wisconsin Cast Metals Association – maximum potential to emit method, revised 07/26/01.
I	Invalidated Data
Lb/Lb	Pound per pound of binder used
Lb/Tn	Pound per ton of metal poured
LOI	Loss on ignition
MACT	Maximum Achievable Control Technology
NA	Not Applicable; Not Available
ND	Non-Detect; Not Detected

NT	Not Tested - Lab testing was not done
PCS	Pouring, Cooling, Shakeout
POM	Polycyclic Organic Matter
PTE	Potential to Emit
QA/QC	Quality Assurance/Quality Control
TEA	Triethylamine
TGOC	Total Gaseous Organic Concentration
TGOC as Propane	Quantity of undifferentiated hydrocarbons including methane determined by EPA Method 25A.
THC	Total Hydrocarbon Concentration
TTE	Temporary Total Enclosure
US EPA	United States Environmental Protection Agency
USCAR	United States Council for Automotive Research
VOC	Volatile Organic Compound
WBS	Work Breakdown Structure