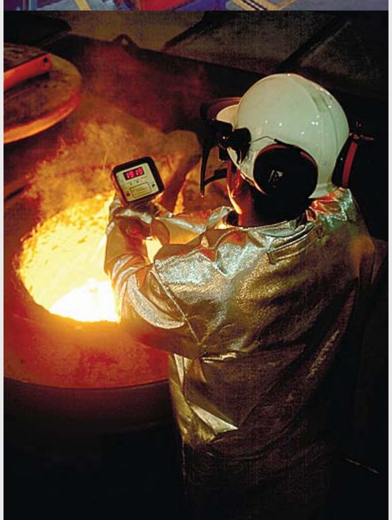
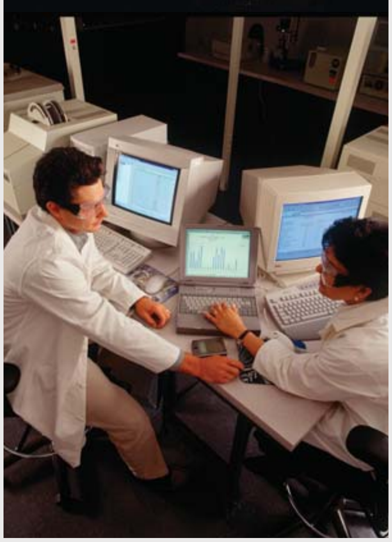
CERP

Casting Emission Reduction Program

www.cerp-us.org





Operated by

TECHNIKON

5301 Price Avenue

McClellan, CA 95652

916-929-8001

www.technikonllc.com

US Army Contract W15QKN-05-D-0030

FY2005 Tasks

WBS # 1.2.1

Baseline Test – Greensand with Phenolic Urethane Cores - Pouring, Cooling and Shakeout

1412-121 GY

April 2006

(Revised for public distribution - May 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

this page intentionally left blank

Baseline Test – Greensand with Phenolic Urethane Cores - Pouring, Cooling and Shakeout

1412-121 GY

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
Vice President, 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 casting, cost, or producability.

this page intentionally left blank

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

EXECUTIVE SUMMARY

This report contains the results of emission testing to evaluate the pouring, cooling, and shakeout emissions from Test GY, an uncoated phenolic urethane ColdBox® core in a green-sand mold without seacoal. The testing performed involved the collection of continuous air samples over a seventy-five minute period, including the mold pouring, cooling, shake-out, and post shakeout periods for nine molds using a 4-on-step core pattern. This is a baseline test which will be used as a core baseline against which other ColdBox® products and processes may be compared. All testing was conducted by Technikon, LLC in its Research Foundry. The emissions results are reported in both pounds of analyte per ton of metal and pounds of analyte per pound of binder. Table 1 shows a summary of the average emissions indicators.

Both process and stack parameters were measured. These 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 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.

Table 1 Average Emissions Indicators Summary

Analyte Name	Lb/Ton Metal	Lb/Lb Binder
TGOC as Propane	1.0321	0.1537
HC as Hexane	0.5135	0.0765
Sum of Target VOCs	0.4969	0.0662
Sum of Target HAPs	0.4473	0.0596
Sum of Target POMs	0.1567	0.0207

Adsorption tube samples were collected and analyzed for fifty-eight (58) 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. Results are presented in detail 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). Detailed descriptions of these indicators can be found in Section 3.0 of this report.

A photographic casting record was made of the twelve coated castings produced from the first three molds used as conditioning runs. These molds were poured prior to those molds poured for generation of sampling emissions. The surface quality for each of the conditioning run castings was assessed relative to the others and will be used as a comparative reference to future castings made with vendor products. The pictures are shown in rank-order in Appendix C.

It must be noted that the results from the baseline 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. CERP Background and Objectives

The Casting Emission Reduction Program (CERP) is a co-operative initiative between the Department of Defense (US Army) and the United States Council for Automotive Research (USCAR), a partnership of DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation. The signers of the CERP Cooperative Research and Development Agreement (CRADA) include: the USCAR Environmental Leadership Council; 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.

CERP's primary purpose is to evaluate materials, equipment, and processes 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 test foundry is designed to facilitate the repeatable collection and evaluation of airborne emissions and associated process data.

1.2. Test Objectives

The objective of this test was to evaluate emissions and establish a baseline from the pouring, cooling and shakeout of an uncoated phenolic urethane ColdBox® core in a greensand mold without seacoal. This test also incorporated the new quality measurement procedures approved by the CERP Steering Committee for step core casting evaluation.

1.3. Test Plan summary

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 for GY

Type of Process Tested	Uncoated phenolic urethane Coldbox® core in greensand without seacoal, iron, PCS
Test Plan Number	1412-121 GY
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	1.4 % (BOS) Ashland Isocure ® LF305/52-904GR binder system in a 55/45 ratio, TEA activated, Wedron 530 sand
Core Coating	Ashland VelvaPlast®CGW 9022 SL for conditioning runs, none for sampling runs
Number of Molds Poured	3 conditioning and 9 sampling
Test Dates	October 5, 2005 through October 7, 2005
Emissions Measured	58 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

1.4. Report Organization

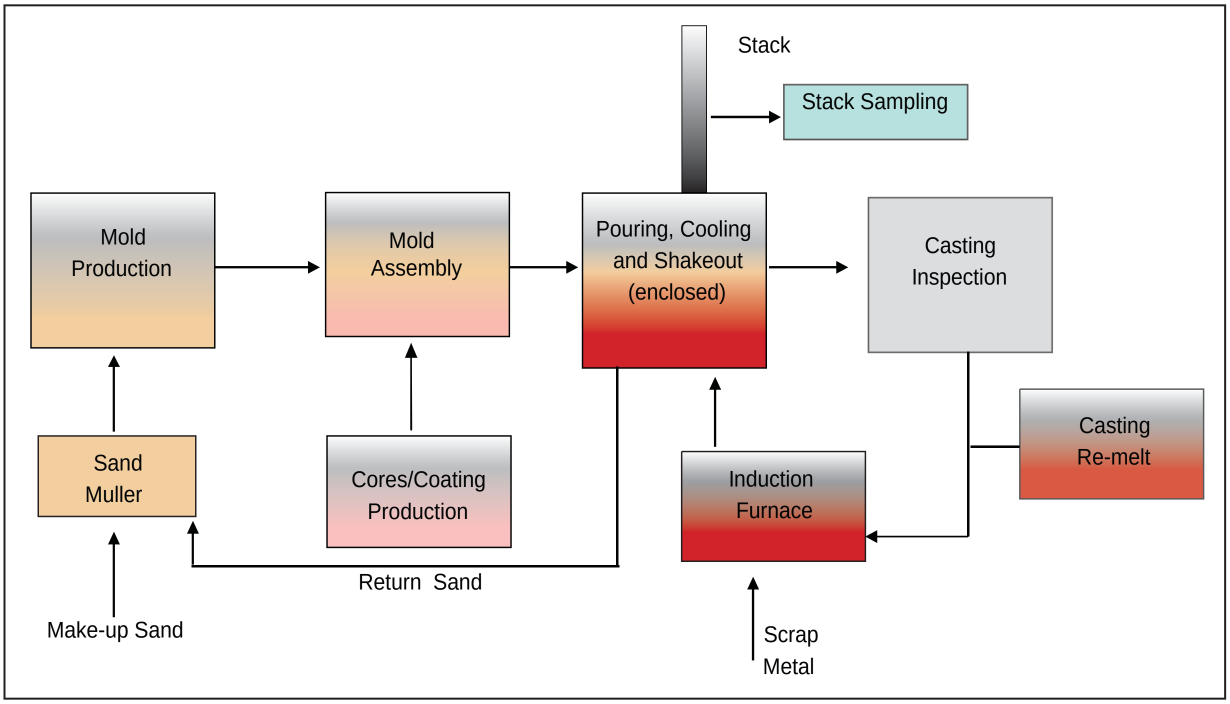
This report has been designed to document the methodology and results of a specific test plan that was used to evaluate the pouring, cooling and shakeout emissions from a phenolic urethane ColdBox® cored greensand system without the addition of seacoal. Section 2 of this report includes a summary of 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.

2.0 TESTING METHODOLOGY

2.1. Description of Process and Testing Equipment

Figure 2-1 graphically shows the research foundry test process.

Figure 2-1 Foundry Layout Diagram



2.2. Description of Testing Program

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

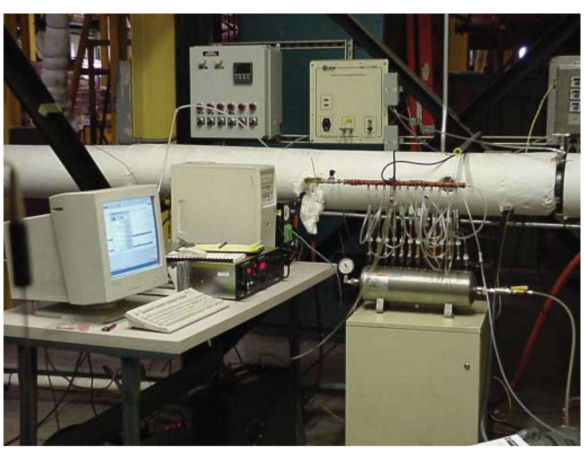
2.2.1. Test Plan Review and Approval

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

Figure 2-2 Uncoated Step Cores in Mold

Figure 2-3 Total Enclosure Test Stand

Figure 2-4 Sampling Equipment



2.2.2. Mold and Metal Preparation

The molds and cores were prepared (Figure 2-2) to a standard composition by the Technikon production team. 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.

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 2-3).

Continuous emission samples were collected during the forty-five minute pouring and cooling process, during the five minute shakeout of the mold, and for an additional period following shakeout (Figure 2-4). The total sampling time was seventy-five minutes.

2.2.4. Process Parameter Measurements:

Table 2-1 lists the process parameters that were 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	Mettler SB12001 Digital Scale (Gravimetric)
Core Weight	MyWeigh i2600
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 the 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 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 and pounds of analyte per pound of binder, respectively.

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 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.

this page intentionally left blank

3.0 TEST RESULTS

The average emission results in pounds per pound (lb/lb) of binder and pounds per ton (lb/ton) of metal are presented for Test GY 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 VOCs measured, as well as the "Sum of Target VOCs", the "Sum of Target HAPs", and the "Sum of Target POMs". These three sums are part of a group termed "Emission Indicators". Also included in this group are average emission results for 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. CO_2 results are reported as NA since individual results were all invalidated due to problems with the instrument.

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.

Two methods were employed to measure undifferentiated hydrocarbon emissions as emission indicators: TGOC as propane, performed in accordance with EPA Method

Table 3-1a Summary Emission Averages - Lb/Tn Metal

Analyte Name	Average	Standard Deviation
Emission Indicators		
TGOC as Propane	1.0321	0.0478
HC as Hexane	0.5135	0.0148
Sum of Target VOCs	0.4969	0.1544
Sum of Target HAPs	0.4473	0.1391
Sum of Target POMs	0.1567	0.0128
Selected Target HAPs		
Phenol	0.1038	0.0085
Benzene	0.0886	0.0069
Methylnaphthalenes	0.0838	0.0076
Naphthalene	0.0477	0.0023
Cresols	0.0363	0.0030
Aniline	0.0302	0.0024
Dimethylnaphthalenes	0.0248	0.0033
Toluene	0.0154	0.0010
Xylenes	0.0063	0.0003
Acetaldehyde	0.0054	0.0007
Other Target VOCs		
Trimethylbenzenes	0.0130	0.0031
Dimethylphenols	0.0109	0.0010
Octane	0.0074	0.0016
Criteria Pollutants, Greenhouse Gases and Other Analytes		
Carbon Monoxide	1.8376	0.1461
Nitrogen Oxides	0.0087	0.0012
Sulfur Dioxide	0.0084	0.0011
Carbon Dioxide	NA	NA

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

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 the single carbon alkane, methane (C_1), with results calibrated against propane (C_3), which is the three-carbon alkane. 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).

Table 3-1b Summary Emission Averages - Lb/Lb Binder

Analyte Name	Average	Standard Deviation
Emission Indicators		
TGOC as Propane	0.1537	0.0078
HC as Hexane	0.0765	0.0025
Sum of Target VOCs	0.0662	0.0230
Sum of Target HAPs	0.0596	0.0208
Sum of Target POMs	0.0207	0.0021
Selected Target HAPs		
Phenol	0.0137	0.0053
Methylnaphthalenes	0.0124	0.0013
Benzene	0.0117	0.0045
Naphthalene	0.0063	0.0024
Cresols	0.0054	0.0005
Aniline	0.0045	0.0004
Dimethylnaphthalenes	0.0037	0.0005
Toluene	0.0020	0.0008
Other Target VOCs		
Trimethylbenzenes	0.0019	0.0004
Dimethylphenols	0.0016	0.0001
Criteria Pollutants, Greenhouse Gases and Other Analytes		
Carbon Monoxide	0.2739	0.0260
Nitrogen Oxides	0.0013	0.0002
Sulfur Dioxide	0.0013	0.0002
Carbon Dioxide	NA	NA

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

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.

On December 19, 2005 the EPA amended the list of HAPs by removing methyl ethyl ketone (MEK) (2-Butanone). Although this compound was removed on the federal list of hazardous air pollutants, it may still be regulated 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 Summary of Test Plan Process Parameter

GY - Greensand PCS with Phenolic Urethane Cores	
Test Dates	10/04/05-10/07/05
Cast weight, lbs.	116.31
Pouring time, sec.	11.33
Pouring temp ,°F	2633
Pour hood process air temp at start of pour, °F	87
Mixer auto dispensed sand weight, lbs	50.15
Core binder part I weight, g	175.40
Core binder part II weight, g	143.16
Total core binder weight, g	318.56
% core binder (BOS)	1.400
% core binder	1.381
Total core weight in mold, lbs.	28.26
Total binder weight in mold, lbs.	0.390
Core LOI, %	1.12
Core dogbone tensile, psi	262
Core age, hrs.	69
Muller batch weight, lbs.	903
GS mold sand weight, lbs.	642
Mold compactability, %	56
Mold temperature, °F	85
Average green compression , psi	22.64
GS compactability, %	42
GS moisture content, %	2.01
GS MB clay content, %	7.21
MB clay reagent, ml	37.39
1800°F LOI - mold sand, %	0.80
900°F volatiles , %	0.41
Permeability index	229
Sand temperature, °F	86

The ranking of casting appearance for the coated cores used in the three conditioning runs is given in Table 3-3. Each of the four castings from the molds of the three conditioning runs, labeled as conditioning runs (CR), 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 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 and are presented in Table 3-3 in order of decreasing quality. The conditioning runs are used for surface quality comparisons only, their emissions are not included in the emission results.

Table 3-3 Rank Order of Casting Surface Quality

Rank Order	Mold No.	Cavity No.
1 - Best	GYCR2	2
2	GYCR2	1
3	GYCR1	3
4	GYCR3	1
5	GYCR1	2
6 - Median	GYCR2	4
7	GYCR1	1
8	GYCR3	3
9	GYCR2	3
10	GYCR3	4
11	GYCR1	4
12 - Worst	GYCR3	2

Figures 3-1 through 3-4 present a graphical depiction of the five emissions indicators and selected individual HAP, VOC, and criteria pollutant and greenhouse gas emissions data from Tables 3-1a and 3-1b.

Figure 3-1a Emission Indicators - Lb/Tn Metal

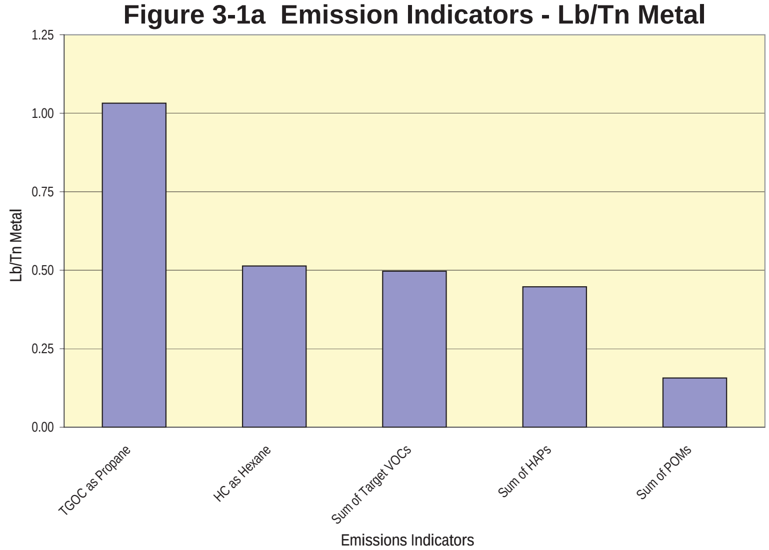


Figure 3-1b Emission Indicators - Lb/Lb Binder

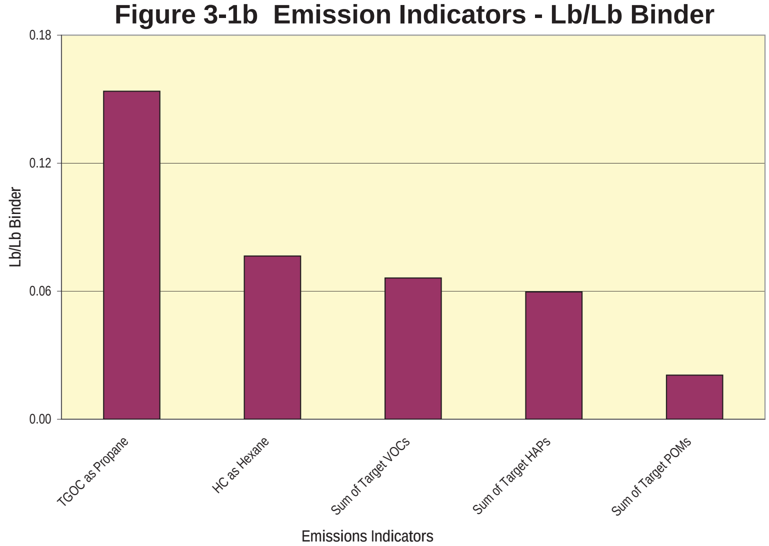


Figure 3-2a Selected Target HAPs and POMs - Lb/Tn Metal

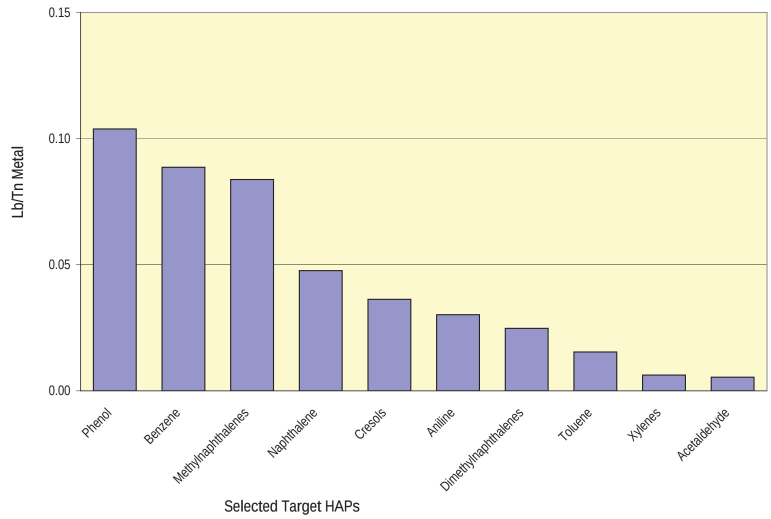


Figure 3-2b Selected Target HAPs and POMs - Lb/Lb Binder

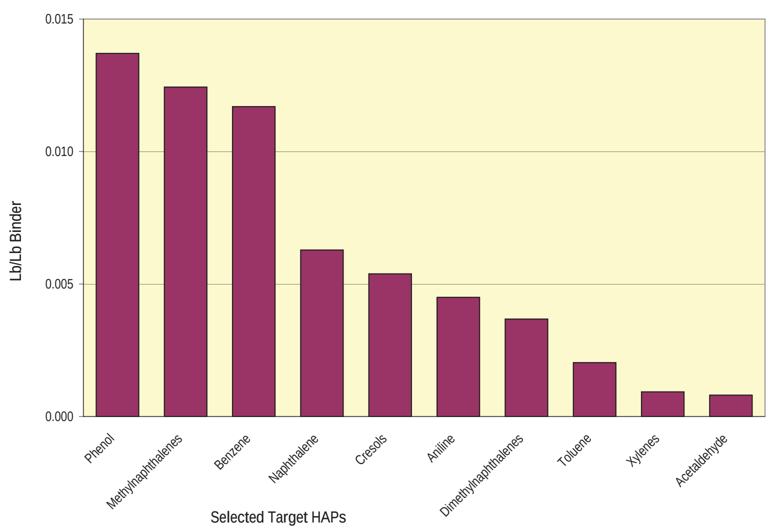


Figure 3-3a Selected Target VOCs - Lb/Tn Metal

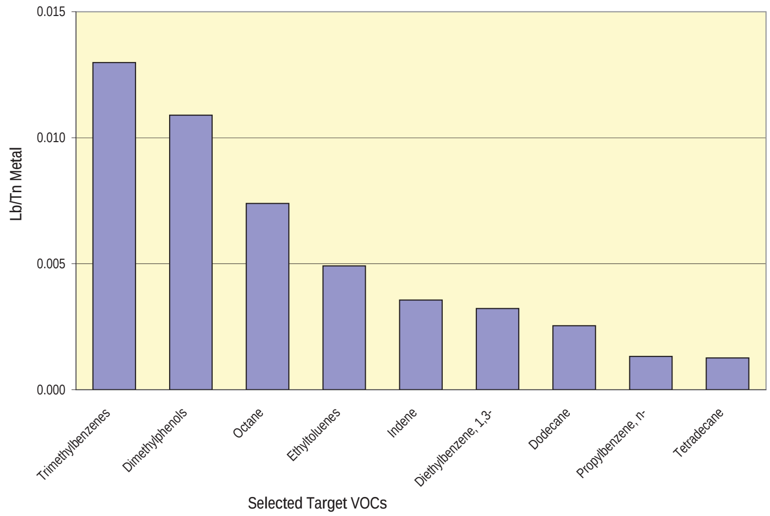
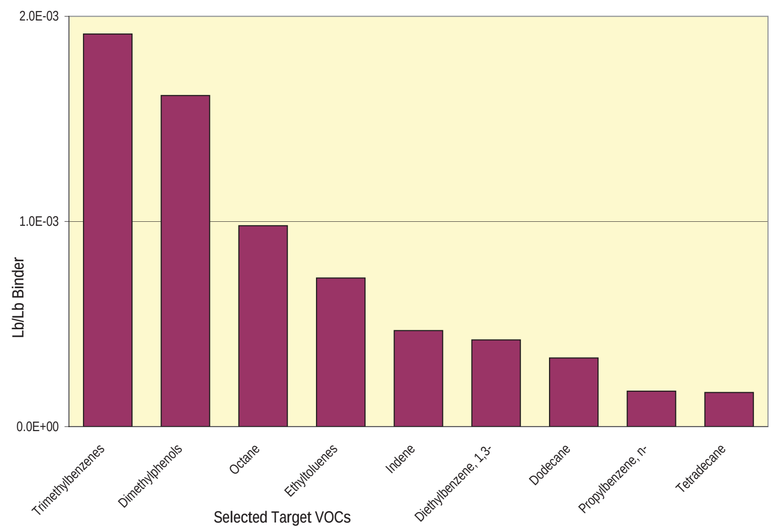


Figure 3-3b Selected Target VOCs - Lb/Lb Binder



The four appendices in this report contain detailed information regarding testing and sampling, and data and results for each sampling event. Appendix A contains test plans, instructions and the sampling plan for test GY. 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, including pictures of the castings and Appendix D contains Method 25A charts. The charts are presented to show time-dependent emissions profiles of TGOC, carbon monoxide, carbon dioxide, and oxides of nitrogen for each pour.

Figure 3-4a Criteria Pollutants, Greenhouse Gases and Other Analytes - Lb/Tn Metal

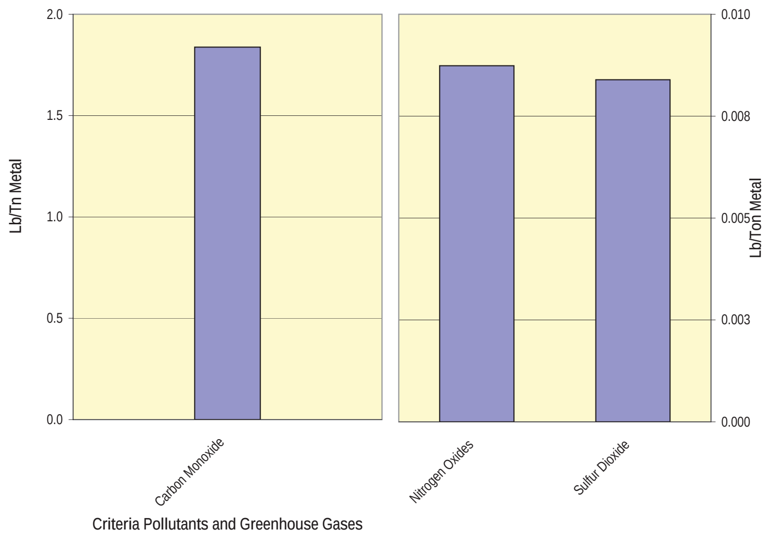
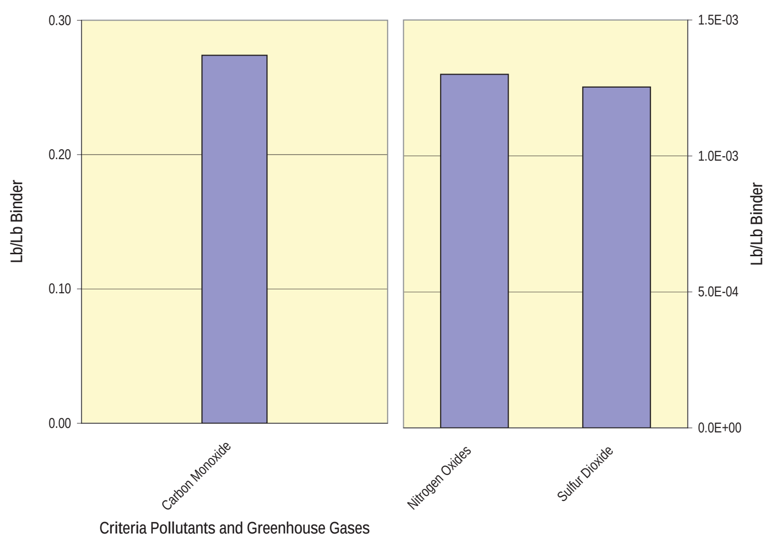


Figure 3-4b Criteria Pollutants, Greenhouse Gases and Other Analytes - Lb/Lb Binder



this page intentionally left blank

4.0 CONCLUSIONS

Thirteen (13) targeted analytes and isomer classes accounted for the top 95% of the mass as lb/ton of metal of all targeted VOCs detected from Test GY as can be seen in Table 3-1a. Ten (10) of the measured HAP compounds and isomer classes comprised almost 90%. Phenol, benzene, methylnaphthalenes and naphthalene contributed the highest percentages at 21, 18, 17, and 10% respectively. Ten (10) individual compounds and isomer classes accounted for over 95% of the emissions as lb/lb binder as shown in Table 3-1b with similar contributions for the above analytes.

Measured parameters indicated that all pours were conducted within acceptable pre-established limits and all runs followed similar procedures, assuring that all pours were run in a reproducible and replicate manner.

this page intentionally left blank

Appendix A Test and Sample Plans and Process Instructions

this page intentionally left blank

TECHNIKON TEST PLAN

- **CONTRACT NUMBER:** 1412 **TASK NUMBER:** 1.2.1 **SERIES:** GY
- **SITE:** Research Foundry
- **TEST TYPE:** Pouring, cooling, shakeout:
  Baseline: Uncoated Phenolic Urethane ColdBox® 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.
- **CORE TYPE:** Step; Wedron 530 sand; 1.4% (BOS) Ashland Isocure® LF305/52-904GR binder in a 55/45 ratio, TEA activated.
- **CORE COATING:** Ashland VelvaPlast® CGW 9022 SL for GYCR1 to GYCR3, none for production runs GY001-GY009.
- **SAMPLE EVENTS:** 9
- **ANALYTE LIST:** List A Modified , CO/CO_2, SO_2, NOx, TGOC
- **TEST DATE:** **Start:** 3 Oct 2005
  Finished: 10 Oct 2005

TEST OBJECTIVES:

Measure selected PCS HAP & VOC emissions, CO, CO_2, NO_x, and TGOC from Ashland ISOCURE® LF305/52-904GR core binder activated with TEA 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 will be approximately 2-4 days old when tested. The cores for the engineering runs GYCR1-3 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 GY - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
10/6/2005											
THC, CO, CO2 & Nox	GY004	X									TOTAL
M-18	GY00401		1						60	1	Carbopak charcoal
M-18	GY00402					1			60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
NIOSH 2002	GY00403		1						500	4	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	5	Excess
OSHA ID200	GY00404		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GY00405		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GY00406		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GY - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
10/6/2005											
THC, CO, CO2 & Nox	GY005	X									TOTAL
M-18	GY00501		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
NIOSH 2002	GY00502		1						500	4	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	5	Excess
OSHA ID200	GY00503		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GY00504		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GY00505		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GY - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
10/6/2005											
THC, CO, CO2 & Nox	GY006	X									TOTAL
M-18	GY00601		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
NIOSH 2002	GY00602		1						500	4	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	5	Excess
OSHA ID200	GY00603		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess

RESEARCH FOUNDRY GY - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
10/5/2005											
THC, CO, CO2 & Nox	GY002	X									TOTAL
M-18	GY00201		1						60	1	Carbopak charcoal
M-18	GY00202			1					60	2	Carbopak charcoal
	Excess								60	3	Excess
NIOSH 2002	GY00203		1						500	4	150/75 mg Silica Gel (SKC 226-10)
NIOSH 2002	GY00204			1					500	5	150/75 mg Silica Gel (SKC 226-10)
OSHA ID200	GY00205		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GY00206			1					1000	7	100/50 mg Carbon Bead (SKC 226-80)
NIOSH 1500	GY00207		1						1000	8	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	GY00208			1					1000	9	100/50 mg Charcoal (SKC 226-01)
TO11	GY00209		1						1000	10	DNPH Silica Gel (SKC 226-119)
TO11	GY00210			1					1000	11	DNPH Silica Gel (SKC 226-119)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GY - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
10/5/2005											
THC, CO, CO2 & Nox	GY003	X									TOTAL
M-18	GY00301		1						60	1	Carbopak charcoal
M-18 MS	GY00602		1						60	2	Carbopak charcoal
M-18 MS	GY00603			1					60	3	Carbopak charcoal
NIOSH 2002	GY00604		1						500	4	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	5	Excess
OSHA ID200	GY00605		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GY00606		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GY00607		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GY - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
10/6/2005											
THC, CO, CO2 & Nox	GY004	X									TOTAL
M-18	GY00401		1						60	1	Carbopak charcoal
M-18	GY00402					1			60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
NIOSH 2002	GY00403		1						500	4	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	5	Excess
OSHA ID200	GY00404		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GY00405		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GY00406		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GY - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
10/6/2005											
THC, CO, CO2 & Nox	GY005	X									TOTAL
M-18	GY00501		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
NIOSH 2002	GY00502		1						500	4	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	5	Excess
OSHA ID200	GY00503		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GY00504		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GY00505		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GY - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
10/6/2005											
THC, CO, CO2 & Nox	GY006	X									TOTAL
M-18	GY00601		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
NIOSH 2002	GY00602		1						500	4	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	5	Excess
OSHA ID200	GY00603		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GY00604		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GY00605		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GY - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
10/7/2005											
THC, CO, CO2 & Nox	GY007	X									TOTAL
M-18	GY00701		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
NIOSH 2002	GY00702		1						500	4	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	5	Excess
OSHA ID200	GY00703		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GY00704		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GY00705		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GY - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments: Sample GY00801 was blocked by sealing cap from shipping tube; sample no good because no flow went through the media.
10/7/2005											
THC, CO, CO2 & Nox	GY008	X									TOTAL
M-18	GY00801		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
NIOSH 2002	GY00802		1						500	4	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	5	Excess
OSHA ID200	GY00803		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GY00804		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GY00805		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY GY - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
10/7/2005											
THC, CO, CO2 & Nox	GY009	X									TOTAL
M-18	GY00901		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
NIOSH 2002	GY00902		1						500	4	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	5	Excess
OSHA ID200	GY00903		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Excess
NIOSH 1500	GY00904		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Excess
TO11	GY00905		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

Series GY

PCS Baseline: Greensand Uncoated Core with Ashland ISOCURE® LF305/52-904GR Cold Box Core Binder & Mechanized Molding

Process Instructions

A Experiment:

1 Baseline emissions measurement from a greensand mold, with TEA cured Ashland ISOCURE® LF305/52-904GR 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 made with virgin Wedron 530 silica sand and 1.4% (BOS) Ashland ISOCURE® LF305/52-904GR binder in a 55/45 ratio, TEA cured.

3 Core coating:

a) Engineering/conditioning runs GYCR1-3 only, none for runs GY001 through GY009. Ashland Velvaplast® CGW 9022 SL.

4 Metal:

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

5 Pattern release:

a) Black Diamond, hand wiped.

b) 20 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 Cold box one-piece Step Cores:

1 Cores were manufactured at Technikon LLC .

a) After manufacture the cores were sealed in polyethylene bags, numbered and dated to relate to manufacturing process parameters recorded at that, time.

b) The sand lab will sample one (1) core from each mold produced just prior to the emission test to represent the four (4) cores placed in that mold. Those cores sampled 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.

2 Core coating for runs GYCR-1 to GYCR-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) Sample at least 100 cc of coating in a graduated cylinder to determine the bulk density and record (or use a specific gravity hydrometer).

d) Measure and record the coating temperature.

e) Dip the core in the tip-down position to within ½ inch of the blow end.

i) The tip of an un-dipped core can be used as a substitute for the LOI test sample for the engineering runs.

f) Allow the coating to stop running and begin dripping, then shake the core a couple of times and set it aside tip up.

g) Dry the coated core at 230°F for 2 hours. Measure and record un-dipped and dried dipped weight.

Note:
Do not put un-dipped cores for production runs GY001 through GY009 in the drying oven as un-captured emissions will result.

h) Re-bag the cores.

E Sand preparation

1 Start up batch: make 1, GYCR1.

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 2 gallons 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: GYCR2

- **a)** Add to the sand recovered from poured mold GYCR1 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.

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

3 Re-mulling: GYCR3, GY001-GY009

- **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: Step core pattern.

1 Pattern preparation:

a) Inspect and tighten all loose pattern and gating pieces.
b) 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.

3 Use the overhead crane to place the pre-weighed drag/cope flask on the mold machine table, parting line surface down.
4 Locate a 24 x 24 x 4 inch deep wood upset on top of the flask.
5 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.

a) 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.

b) On the operator's panel turn the POWER switch to ON.
c) Turn the RAM-JOLT-SQUEEZE switch to ON.
d) Turn the DRAW UP switch to AUTO.
e) Set the PRE-JOLT timer to 4-5 seconds.
f) Set the squeeze timer to 8 seconds.
g) Set the crow-footed gagger on the support bar. Verify that it is at least ½ inch away from

any pattern parts.

h) Manually riddle a half to one inch or so of sand on the pattern using a ¼ inch mesh riddle. Source the sand from the overhead mold sand hopper by actuating the CHATTER GATE valve located under the operators panel.
i) Fill the center potion of the flask.
j) Manually move sand from the center portion to the outboard areas and hand tuck the sand.
k) Finish filling the 24 x 24 x 10 inch flask and the upset with greensand from the overhead molding hopper.
l) 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.
m) 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.
n) Initiate the settling of the sand in the flask by pressing the PRE-JOLT push button. Allow this cycle to stop before proceeding.
o) 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.

p) 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.

q) Screed the bottom of the drag mold flat to the bottom of the flask if required.
r) Press and release the LOWER DRAW/STOP push button to separate the flask and mold from the pattern.
s) 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.
t) Finally, press and release the DRAW DOWN pushbutton to cause the draw frame to return to the start position.

6 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.
7 Close the cope over the drag being careful not to crush anything.
8 Clamp the flask halves together.
9 Weigh and record the weight of the closed un-poured mold, the pre-weighed flask, the uncoated cores, and the sand weight by difference.
10 Measure and record the sand temperature.
11 Deliver the mold to the previously cleaned shakeout to be poured.
12 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.

2 Shakeout.
a) 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.
b) Turn off the shakeout.
c) Sample the emissions for 30 minutes after the start of shakeout, a total of 75 minutes.

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

3 Emptying the furnace.

- **a)** Pig the extra metal only after the last emission measurement is complete to avoid contaminating the air sample.
- **b)** Cover the empty furnace with ceramic blanket to cool.

J 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.

K 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 GYCR1-3, 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 GYCR1, compare it to casting from mold GYCR2.
- **c)** Place the better appearing casting in the first position and the lesser appearing casting in the second position.
- **d)** Repeat this procedure with GYCR1 to its nearest neighbors until all castings closer to the beginning of the line are better appearing than GYCR1 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.

L Record mold number by rank-order series for this cavity.

Steve Knight
Mgr. Process Engineering

APPENDIX B DETAILED EMISSION RESULTS AND QUANTITATION LIMITS

this page intentionally left blank

Detailed Emissions Lb/Tn Metal

VOC	POM	HAP		GY001	GY002	GY003	GY004	GY005	GY006	GY007	GY008	GY009	Average	Standard Deviation
			Test Dates	5-Oct-05	5-Oct-05	5-Oct-05	6-Oct-05	6-Oct-05	6-Oct-05	7-Oct-05	7-Oct-05	07-Oct-05		
			Emission Indicators											
			TGOC as Propane	9.31E-01	1.02E+00	1.09E+00	1.00E+00	1.04E+00	1.07E+00	1.04E+00	1.03E+00	1.08E+00	1.03E+00	4.78E-02
			HC as Hexane	5.01E-01	5.06E-01	5.35E-01	5.06E-01	5.33E-01	5.13E-01	5.00E-01	4.98E-01	5.28E-01	5.13E-01	1.48E-02
			Sum of Target VOCs	4.52E-01	4.65E-01	5.23E-01	4.85E-01	4.97E-01	5.05E-01	5.15E-01	4.03E-02	5.32E-01	4.97E-01	1.54E-01
			Sum of Target HAPs	4.00E-01	4.12E-01	4.65E-01	4.38E-01	4.45E-01	4.58E-01	4.71E-01	3.83E-02	4.89E-01	4.47E-01	1.39E-01
			Sum of Target POMs	1.37E-01	1.42E-01	1.65E-01	1.46E-01	1.62E-01	1.63E-01	1.67E-01	I	1.71E-01	1.57E-01	1.28E-02
			Individual Target HAPs											
V		H	Phenol	9.29E-02	9.53E-02	1.05E-01	1.01E-01	9.89E-02	1.09E-01	1.09E-01	I	1.19E-01	1.04E-01	8.50E-03
V		H	Benzene	8.03E-02	8.27E-02	9.53E-02	9.80E-02	8.62E-02	8.17E-02	9.47E-02	I	9.00E-02	8.86E-02	6.86E-03
V	P	H	Methylnaphthalene, 2-	4.74E-02	4.91E-02	5.81E-02	5.14E-02	5.69E-02	5.76E-02	5.88E-02	I	6.13E-02	5.51E-02	5.06E-03
V	P	H	Naphthalene	4.45E-02	4.54E-02	5.14E-02	4.57E-02	4.87E-02	4.82E-02	4.80E-02	I	4.94E-02	4.77E-02	2.33E-03
V		H	Aniline	2.83E-02	3.02E-02	3.14E-02	2.60E-02	2.92E-02	3.26E-02	3.07E-02	2.94E-02	3.41E-02	3.02E-02	2.39E-03
V		H	Cresol, o-	2.68E-02	2.69E-02	3.03E-02	2.70E-02	3.02E-02	3.04E-02	3.04E-02	I	3.41E-02	2.95E-02	2.50E-03
V	P	H	Methylnaphthalene, 1-	2.49E-02	2.57E-02	2.99E-02	2.67E-02	2.97E-02	2.99E-02	3.14E-02	I	3.16E-02	2.87E-02	2.59E-03
V		H	Toluene	1.37E-02	1.41E-02	1.57E-02	1.66E-02	1.53E-02	1.65E-02	1.57E-02	I	1.56E-02	1.54E-02	1.02E-03
V	P	H	Dimethylnaphthalene, 1,3-	8.57E-03	8.84E-03	1.06E-02	9.29E-03	1.10E-02	1.11E-02	1.15E-02	I	1.17E-02	1.03E-02	1.23E-03
V	P	H	Dimethylnaphthalene, 2,6-	6.11E-03	6.26E-03	7.68E-03	6.69E-03	7.84E-03	7.94E-03	8.24E-03	I	8.46E-03	7.40E-03	9.14E-04
V		H	Cresol, mp-	6.47E-03	6.22E-03	6.75E-03	6.01E-03	6.75E-03	7.19E-03	6.89E-03	I	7.75E-03	6.76E-03	5.52E-04
V		H	Acetaldehyde	4.64E-03	4.95E-03	5.01E-03	4.92E-03	5.39E-03	5.62E-03	5.50E-03	6.90E-03	5.73E-03	5.41E-03	6.68E-04
V		H	Xylene, mp-	4.75E-03	4.86E-03	5.42E-03	5.40E-03	5.35E-03	5.45E-03	5.25E-03	I	5.33E-03	5.23E-03	2.70E-04
V	P	H	Dimethylnaphthalene, 1,6-	3.48E-03	3.56E-03	4.32E-03	3.74E-03	4.41E-03	4.45E-03	4.61E-03	I	4.67E-03	4.16E-03	4.84E-04
V	P	H	Dimethylnaphthalene, 1,2-	ND	1.98E-03	2.04E-03	1.78E-03	2.13E-03	2.14E-03	2.24E-03	I	2.22E-03	1.82E-03	7.48E-04
V		H	Biphenyl	1.06E-03	1.07E-03	1.27E-03	1.18E-03	1.40E-03	1.40E-03	1.49E-03	I	1.53E-03	1.30E-03	1.83E-04
V	P	H	Dimethylnaphthalene, 2,3-	8.81E-04	9.14E-04	1.11E-03	9.91E-04	1.16E-03	1.16E-03	1.17E-03	I	1.25E-03	1.08E-03	1.33E-04
V		H	Xylene, o-	9.23E-04	9.34E-04	1.06E-03	1.11E-03	1.16E-03	1.04E-03	1.01E-03	I	1.07E-03	1.04E-03	8.08E-05
V		H	Formaldehyde	8.16E-04	8.81E-04	8.55E-04	1.01E-03	8.68E-04	8.85E-04	9.15E-04	1.27E-03	9.72E-04	9.42E-04	1.37E-04
V		H	Styrene	7.13E-04	7.38E-04	8.17E-04	8.10E-04	8.56E-04	8.00E-04	8.07E-04	I	8.19E-04	7.95E-04	4.64E-05
V		H	Ethylbenzene	4.88E-04	4.90E-04	5.45E-04	6.46E-04	5.96E-04	5.81E-04	5.77E-04	I	6.07E-04	5.66E-04	5.57E-05
V		H	Hexane	6.05E-04	4.01E-04	4.45E-04	6.40E-04	5.16E-04	4.90E-04	5.50E-04	I	5.48E-04	5.24E-04	7.92E-05
V		H	Propionaldehyde (Propanal)	2.48E-04	2.69E-04	2.90E-04	2.68E-04	2.97E-04	2.88E-04	2.97E-04	3.90E-04	2.95E-04	2.94E-04	4.00E-05
V	P	H	Trimethylnaphthalene, 2,3,5-	ND	ND	ND	ND	ND	6.16E-04	6.56E-04	I	6.40E-04	2.39E-04	3.30E-04
V	P	H	Acenaphthalene	1.56E-03	ND	ND	ND	ND	ND	ND	I	ND	1.95E-04	5.51E-04
V		H	2-Butanone (MEK)	ND	ND	2.59E-04	2.13E-04	ND	2.24E-04	2.42E-04	3.17E-04	2.49E-04	1.67E-04	1.29E-04
V	P	H	Dimethylnaphthalene, 1,5-	ND	ND	ND	ND	ND	ND	ND	I	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,8-	ND	ND	ND	ND	ND	ND	ND	I	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,7-	ND	ND	ND	ND	ND	ND	ND	I	ND	NA	NA
V		H	Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
V		H	Dimethylaniline	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA

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

Detailed Emisions - Lb/Lb Binder

VOC	POM	HAP		GY001	GY002	GY003	GY004	GY005	GY006	GY007	GY008	GY009	Average	Standard Deviation
			Test Dates	5-Oct-05	5-Oct-05	5-Oct-05	6-Oct-05	6-Oct-05	6-Oct-05	7-Oct-05	7-Oct-05	07-Oct-05		
			Emission Indicators											
			TGOC as Propane	1.39E-01	1.47E-01	1.52E-01	1.55E-01	1.50E-01	1.58E-01	1.59E-01	1.58E-01	1.66E-01	1.54E-01	7.83E-03
			HC as Hexane	7.47E-02	7.28E-02	7.45E-02	7.85E-02	7.75E-02	7.57E-02	7.65E-02	7.69E-02	8.13E-02	7.65E-02	2.51E-03
			Sum of Target VOCs	6.73E-02	6.68E-02	7.28E-02	7.52E-02	7.21E-02	7.46E-02	7.88E-02	6.21E-03	8.19E-02	6.62E-02	2.30E-02
			Sum of Target HAPs	5.97E-02	5.93E-02	6.48E-02	6.78E-02	6.46E-02	6.75E-02	7.21E-02	5.91E-03	7.52E-02	5.96E-02	2.08E-02
			Sum of Target POMs	2.05E-02	2.04E-02	2.30E-02	2.27E-02	2.35E-02	2.41E-02	2.55E-02	I	2.63E-02	2.07E-02	2.12E-03
			Individual Target HAPs											
V		H	Phenol	1.39E-02	1.37E-02	1.46E-02	1.57E-02	1.44E-02	1.61E-02	1.67E-02	I	1.83E-02	1.37E-02	5.35E-03
V		H	Benzene	1.20E-02	1.19E-02	1.33E-02	1.52E-02	1.25E-02	1.21E-02	1.45E-02	I	1.39E-02	1.17E-02	4.54E-03
V	P	H	Methylnaphthalene, 2-	7.07E-03	7.07E-03	8.08E-03	7.96E-03	8.27E-03	8.49E-03	9.00E-03	I	9.43E-03	7.26E-03	2.83E-03
V	P	H	Naphthalene	6.63E-03	6.54E-03	7.16E-03	7.08E-03	7.07E-03	7.12E-03	7.34E-03	I	7.60E-03	6.28E-03	2.38E-03
V		H	Aniline	4.22E-03	4.34E-03	4.37E-03	4.02E-03	4.24E-03	4.81E-03	4.70E-03	4.54E-03	5.24E-03	4.50E-03	3.72E-04
V		H	Cresol, o-	3.99E-03	3.88E-03	4.21E-03	4.19E-03	4.39E-03	4.49E-03	4.66E-03	I	5.24E-03	3.89E-03	1.51E-03
V	P	H	Methylnaphthalene, 1-	3.71E-03	3.70E-03	4.16E-03	4.14E-03	4.31E-03	4.41E-03	4.80E-03	I	4.87E-03	3.79E-03	1.48E-03
V		H	Toluene	2.05E-03	2.03E-03	2.19E-03	2.57E-03	2.22E-03	2.43E-03	2.41E-03	I	2.40E-03	2.03E-03	7.84E-04
V	P	H	Dimethylnaphthalene, 1,3-	1.28E-03	1.27E-03	1.48E-03	1.44E-03	1.59E-03	1.63E-03	1.77E-03	I	1.79E-03	1.36E-03	5.44E-04
V	P	H	Dimethylnaphthalene, 2,6-	9.11E-04	9.01E-04	1.07E-03	1.04E-03	1.14E-03	1.17E-03	1.26E-03	I	1.30E-03	9.77E-04	3.92E-04
V		H	Cresol, mp-	9.65E-04	8.95E-04	9.39E-04	9.31E-04	9.81E-04	1.06E-03	1.05E-03	I	1.19E-03	8.91E-04	3.46E-04
V		H	Acetaldehyde	6.92E-04	7.12E-04	6.98E-04	7.63E-04	7.83E-04	8.30E-04	8.41E-04	1.06E-03	8.83E-04	8.07E-04	1.18E-04
V		H	Xylene, mp-	7.08E-04	6.99E-04	7.55E-04	8.37E-04	7.78E-04	8.04E-04	8.03E-04	I	8.20E-04	6.89E-04	2.63E-04
V	P	H	Dimethylnaphthalene, 1,6-	5.18E-04	5.12E-04	6.02E-04	5.80E-04	6.40E-04	6.57E-04	7.06E-04	I	7.19E-04	5.48E-04	2.18E-04
V	P	H	Dimethylnaphthalene, 1,2-	ND	2.85E-04	2.84E-04	2.76E-04	3.09E-04	3.15E-04	3.42E-04	I	3.42E-04	2.39E-04	1.38E-04
V		H	Biphenyl	1.58E-04	1.54E-04	1.77E-04	1.83E-04	2.04E-04	2.07E-04	2.27E-04	I	2.36E-04	1.72E-04	7.04E-05
V	P	H	Dimethylnaphthalene, 2,3-	1.31E-04	1.32E-04	1.55E-04	1.54E-04	1.68E-04	1.71E-04	1.78E-04	I	1.92E-04	1.42E-04	5.70E-05
V		H	Formaldehyde	1.22E-04	1.27E-04	1.19E-04	1.57E-04	1.26E-04	1.31E-04	1.40E-04	1.96E-04	1.50E-04	1.41E-04	2.44E-05
V		H	Xylene, o-	1.38E-04	1.34E-04	1.48E-04	1.72E-04	1.68E-04	1.53E-04	1.55E-04	ND	1.64E-04	1.37E-04	5.30E-05
V		H	Styrene	1.06E-04	1.06E-04	1.14E-04	1.26E-04	1.24E-04	1.18E-04	1.23E-04	I	1.26E-04	1.05E-04	4.01E-05
V		H	Ethylbenzene	7.27E-05	7.04E-05	7.58E-05	1.00E-04	8.66E-05	8.58E-05	8.83E-05	I	9.35E-05	7.48E-05	2.97E-05
V		H	Hexane	9.03E-05	5.77E-05	6.19E-05	9.92E-05	7.49E-05	7.24E-05	8.41E-05	I	8.43E-05	6.94E-05	2.92E-05
V		H	Propionaldehyde (Propanal)	3.70E-05	3.87E-05	4.04E-05	4.15E-05	4.31E-05	4.25E-05	4.55E-05	6.03E-05	4.54E-05	4.38E-05	6.78E-06
V	P	H	Trimethylnaphthalene, 2,3,5-	ND	ND	ND	ND	ND	9.09E-05	1.00E-04	I	9.85E-05	3.22E-05	4.83E-05
V	P	H	Acenaphthalene	2.32E-04	ND	ND	ND	ND	ND	ND	I	ND	2.58E-05	7.74E-05
V		H	2-Butanone (MEK)	ND	ND	3.61E-05	3.30E-05	ND	3.31E-05	3.70E-05	4.89E-05	3.83E-05	2.51E-05	1.94E-05
V	P	H	Dimethylnaphthalene, 1,5-	ND	ND	ND	ND	ND	ND	ND	I	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,8-	ND	ND	ND	ND	ND	ND	ND	I	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,7-	ND	ND	ND	ND	ND	ND	ND	I	ND	NA	NA
V		H	Acrolein	ND	ND	ND	ND	ND	ND	ND	I	ND	NA	NA
V		H	Dimethylaniline	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA

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

Practical Report Limits by Analyte - Lb/Tn Metal

Analyte	Practical Reporting Limit lb/ton Metal	Analyte	Practical Reporting Limit lb/ton Metal
Carbon Monoxide	2.78E-02	Ethyltoluene, 2-	1.80E-04
Carbon Dioxide	4.37E-02	Ethyltoluene, 3-	9.02E-04
Nitrogen Oxides	2.98E-02	Formaldehyde	1.76E-04
2-Butanone (MEK)	1.76E-04	Heptane	9.02E-04
Acenaphthalene	9.02E-04	Hexaldehyde	1.76E-04
Acetaldehyde	1.76E-04	Hexane	1.80E-04
Acetone	1.76E-04	Indan	9.02E-04
Acrolein	1.76E-04	Indene	9.02E-04
Aniline	2.04E-03	Methylnaphthalene, 1-	1.80E-04
Benzaldehyde	1.76E-04	Methylnaphthalene, 2-	1.80E-04
Benzene	1.80E-04	Naphthalene	1.80E-04
Biphenyl	9.02E-04	Nonane	9.02E-04
Butyraldehyde/Methacrolein	2.93E-04	o,m,p-Tolualdehyde	4.68E-04
Cresol, mp-	9.02E-04	Octane	9.02E-04
Cresol, o-	9.02E-04	Pentanal (Valeraldehyde)	1.76E-04
Crotonaldehyde	1.76E-04	Phenol	9.02E-04
Cyclohexane	9.02E-04	Propionaldehyde (Propanal)	1.76E-04
Decane	9.02E-04	Propylbenzene, n-	9.02E-04
Diethylbenzene, 1,3-	9.02E-04	Styrene	1.80E-04
Dimethylaniline	4.09E-03	Sulfur Dioxide	4.24E-03
Dimethylnaphthalene, 1,2-	9.02E-04	Tetradecane	9.02E-04
Dimethylnaphthalene, 1,3-	1.80E-04	THC as Undecane	9.02E-04
Dimethylnaphthalene, 1,5-	9.02E-04	THCs as n-Hexane	5.36E-03
Dimethylnaphthalene, 1,6-	9.02E-04	Toluene	1.80E-04
Dimethylnaphthalene, 1,8-	9.02E-04	Trimethylbenzene, 1,2,3-	1.80E-04
Dimethylnaphthalene, 2,3-	9.02E-04	Trimethylbenzene, 1,2,4-	1.80E-04
Dimethylnaphthalene, 2,6-	9.02E-04	Trimethylbenzene, 1,3,5-	1.80E-04
Dimethylnaphthalene, 2,7-	9.02E-04	Trimethylnaphthalene, 2,3,5-	9.02E-04
Dimethylphenol, 2,4-	9.02E-04	Undecane	1.80E-04
Dimethylphenol, 2,6-	9.02E-04	Xylene, mp-	1.80E-04
Dodecane	9.02E-04	Xylene, o-	1.80E-04
Ethylbenzene	1.80E-04		

Practical Report Limits by Analyte - Lb/Lb Binder

Analyte	Practical Reporting Limit lb/lb Binder
Carbon Monoxide	4.15E-03
Carbon Dioxide	6.52E-03
Nitrogen Oxides	4.44E-03
Acenaphthalene	8.66E-05
Benzene	1.73E-05
Biphenyl	8.66E-05
Cresol, mp-	8.66E-05
Cresol, o-	8.66E-05
Cyclohexane	8.66E-05
Decane	8.66E-05
Diethylbenzene, 1,3-	8.66E-05
Dimethylnaphthalene, 1,2-	8.66E-05
Dimethylnaphthalene, 1,3-	1.73E-05
Dimethylnaphthalene, 1,5-	8.66E-05
Dimethylnaphthalene, 1,6-	8.66E-05
Dimethylnaphthalene, 1,8-	8.66E-05
Dimethylnaphthalene, 2,3-	8.66E-05
Dimethylnaphthalene, 2,6-	8.66E-05
Dimethylnaphthalene, 2,7-	8.66E-05
Dimethylphenol, 2,4-	8.66E-05
Dimethylphenol, 2,6-	8.66E-05
Dodecane	8.66E-05
Ethylbenzene	1.73E-05
Ethyltoluene, 2-	1.73E-05
Ethyltoluene, 3-	8.66E-05
Heptane	8.66E-05
Hexane	1.73E-05
Indan	8.66E-05
Indene	8.66E-05
Methylnaphthalene, 1-	1.73E-05
Methylnaphthalene, 2-	1.73E-05
Naphthalene	1.73E-05

Analyte	Practical Reporting Limit lb/lb Binder
Nonane	8.66E-05
Octane	8.66E-05
Phenol	8.66E-05
Propylbenzene, n-	8.66E-05
Styrene	1.73E-05
Tetradecane	8.66E-05
THC as Undecane	8.66E-05
Toluene	1.73E-05
Trimethylbenzene, 1,2,3-	1.73E-05
Trimethylbenzene, 1,2,4-	1.73E-05
Trimethylbenzene, 1,3,5-	1.73E-05
Trimethylnaphthalene, 2,3,5-	8.66E-05
Undecane	1.73E-05
Xylene, mp-	1.73E-05
Xylene, o-	1.73E-05
Aniline	1.97E-04
Dimethylaniline	3.93E-04
Sulfur Dioxide	4.08E-04
THCs as n-Hexane	5.15E-04
2-Butanone (MEK)	1.69E-05
Acetaldehyde	1.69E-05
Acetone	1.69E-05
Acrolein	1.69E-05
Benzaldehyde	1.69E-05
Butyraldehyde/Methacrolein	2.81E-05
Crotonaldehyde	1.69E-05
Formaldehyde	1.69E-05
Hexaldehyde	1.69E-05
o,m,p-Tolualdehyde	4.50E-05
Pentanal (Valeraldehyde)	1.69E-05
Propionaldehyde (Propanal)	1.69E-05

APPENDIX C DETAILED PROCESS DATA AND CASTING QUALITY PHOTOS

this page intentionally left blank

Detailed Process Data

Greensand PCS

Test Dates	10/4/2005	10/4/2005	10/4/2005	10/5/2005	10/5/2005	10/5/2005	10/6/2005	10/6/2005	10/6/2005	10/7/2005	10/7/2005	10/7/2005	Averages
Emissions Sample #	GYCR1	GYCR2	GYCR3	GY001	GY002	GY003	GY004	GY005	GY006	GY007	GY008	GY009	
Production Sample #	GYCR1	GYCR2	GYCR3	GY001	GY002	GY003	GY004	GY005	GY006	GY007	GY008	GY009	
Cast weight, lbs.	112.65	114.20	112.10	116.00	112.20	109.15	120.90	112.70	115.10	119.95	120.40	120.35	116.3
Pouring time, sec.	11	10	10	11	12	16	10	9	9	11	12	12	11
Pouring temp ,°F	2638	2640	2627	2634	2634	2637	2635	2622	2630	2625	2637	2641	2633
Pour hood process air temp at start of pour, °F	86	91	90	85	89	87	88	86	89	88	87	88	87
Mixer auto dispensed sand weight, lbs	50.15	50.15	50.15	50.15	50.15	50.15	50.15	50.15	50.15	50.15	50.15	50.15	50.2
Core binder part I weight, g	174.4	175.5	174.4	175.9	176.6	175.9	174.0	174.7	175.5	176.5	175.0	174.5	175.4
Core binder part II weight, g	143.3	142.8	144.7	143.1	142.6	144.1	143.7	142.6	143.3	142.5	143.1	143.4	143.2
Total core binder weight, g	317.7	318.3	319.1	319.0	319.2	320.0	317.7	317.3	318.8	319.0	318.1	317.9	318.6
% core binder (BOS)	1.40	1.40	1.40	1.40	1.40	1.41	1.40	1.39	1.40	1.40	1.40	1.40	1.40
% core binder	1.38	1.38	1.38	1.38	1.38	1.39	1.38	1.38	1.38	1.38	1.38	1.38	1.38
Total core weight in mold, lbs.	28.41	28.61	28.32	28.10	28.18	28.29	28.32	28.22	28.23	28.33	28.30	28.40	28.3
Total binder weight in mold, lbs.	0.391	0.395	0.392	0.389	0.390	0.392	0.390	0.388	0.390	0.392	0.390	0.391	0.4
Core LOI, %	1.18	1.17	1.14	1.12	1.10	1.13	1.14	1.14	1.14	1.12	1.11	1.11	1.1
Core dogbone tensile, psi	262	262	262	262	262	262	262	262	262	262	262	262	262
Core age, hrs.	19	22	24	43	45	48	66	69	71	90	93	95	69
Muller batch weight, lbs.	1204	900	900	900	900	910	900	900	910	910	900	900	903
GS mold sand weight, lbs.	650	643	657	642	652	639	645	644	650	632	639	638	642
Mold compactability, %	58	56	55	57	55	57	56	55	57	57	56	58	56
Mold temperature, °F	78	80	87	84	86	86	81	86	83	83	84	87	85
Average green compression , psi	18.58	18.17	18.57	20.66	21.17	22.13	21.61	23.02	21.71	25.49	24.18	23.81	22.64
GS compactability, %	47	45	40	41	43	44	39	42	40	41	43	47	42
GS moisture content, %	2.06	2.33	1.95	1.85	2.02	2.22	1.82	2.05	1.93	1.95	2.11	2.13	2.01
GS MB clay content, %	7.33	6.95	7.23	7.52	7.14	6.75	7.43	7.33	6.85	7.52	6.75	7.62	7.21
MB clay reagent, ml	38.0	36.0	37.5	39.0	37.0	35.0	38.5	38.0	35.5	39.0	35.0	39.5	37.4
1800°F LOI - mold sand, %	0.90	1.01	1.02	0.87	0.84	0.72	0.73	0.72	0.74	0.81	0.95	0.86	0.80
900°F volatiles , %	0.40	0.54	0.48	0.34	0.46	0.40	0.44	0.42	0.32	0.40	0.46	0.44	0.41
Permeability index	236	230	225	229	235	234	232	231	225	227	230	221	229
Sand temperature, °F	82	85	80	85	88	83	85	92	ND	ND	82	89	86
Appearance within group:	7	2	4	Cavity 1									
B:best, M:median, W: worst	5	1	12	Cavity 2									
Overall appearance ranking:	3	9	8	Cavity 3									
1 = best, 6 = Median 12 = worst	11	6	10	Cavity 4									

Notes:
Cores in molds 1-3 were coated. The coated core weight is given.
The core weight for 1 core in molds GYCR1, and GY009 was estimated based on the weight of the core, when it was made.
All core weights were measured at the time they were placed in the molds.

GYCR1-1

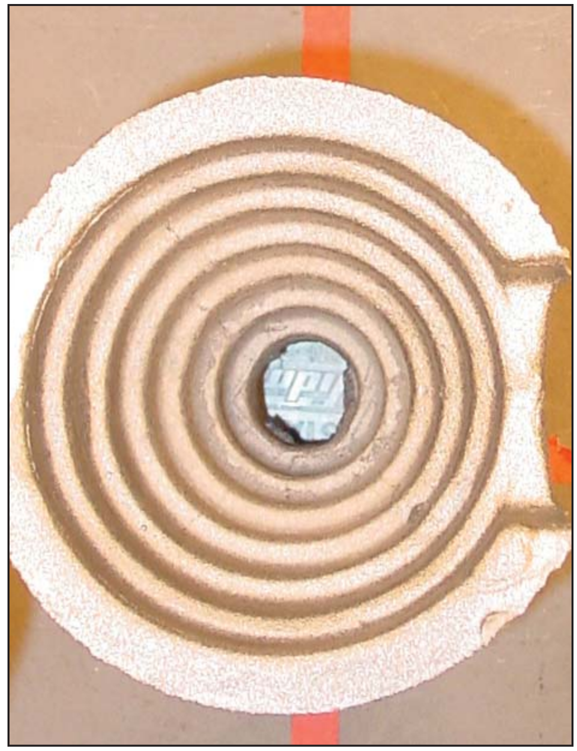
GYCR1-2

GYCR1-3

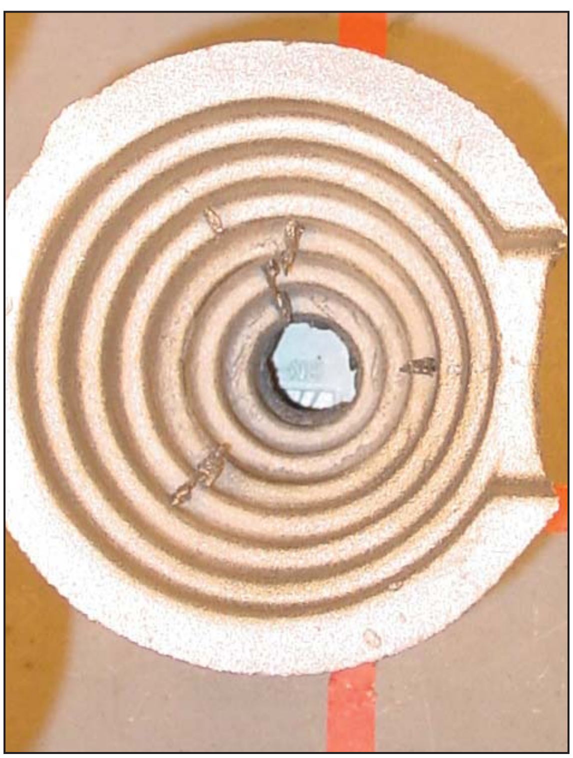
GYCR1-4

GYCR2-1

GYCR2-2 - Best



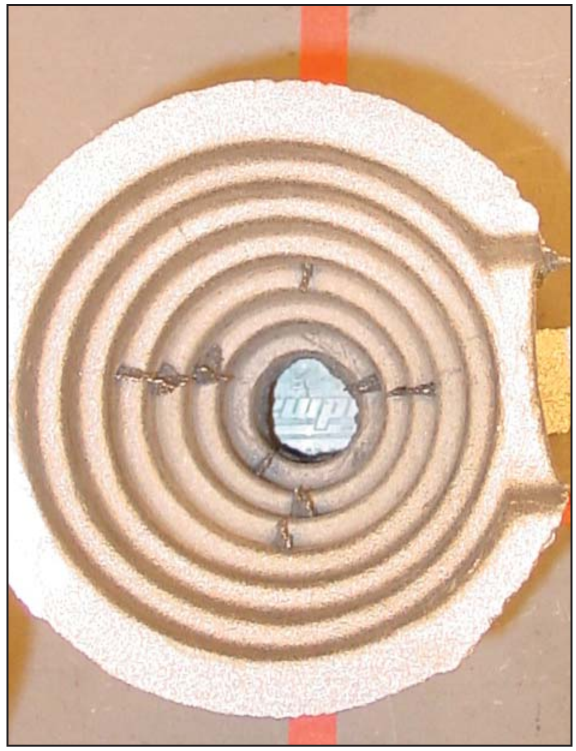
GYCR2-3



GYCR2-4 - Median

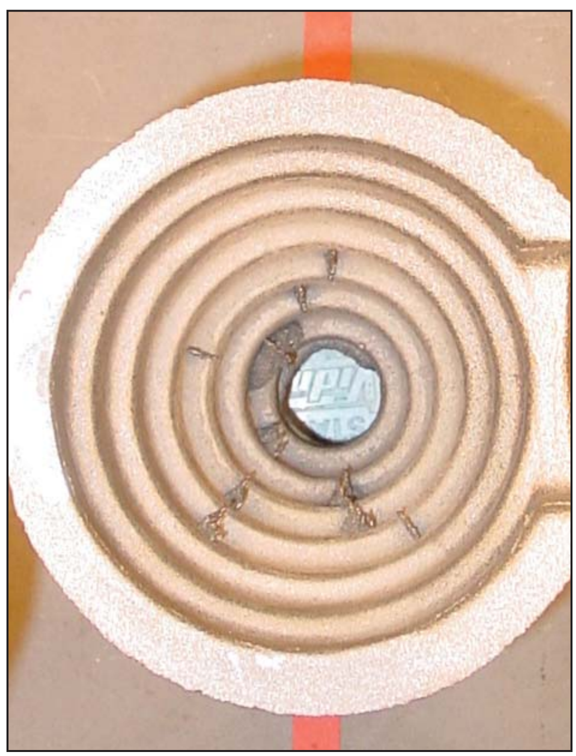
GYCR3-1

GYCR3-2 - Worst



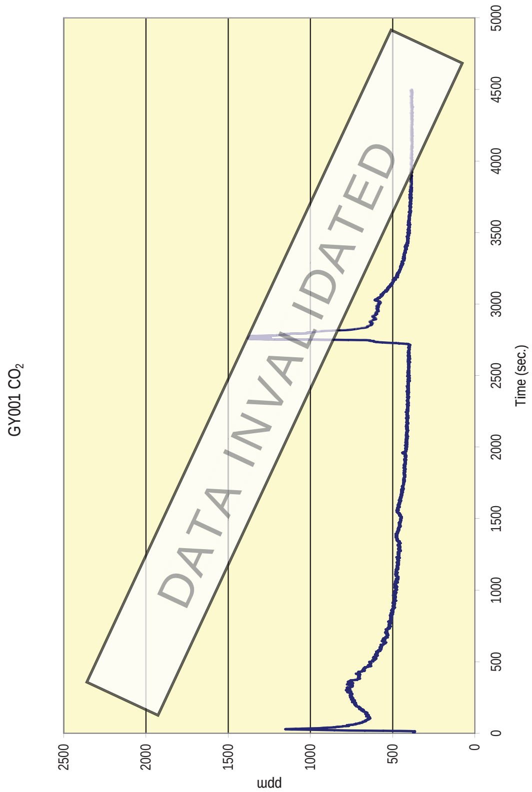
GYCR3-3

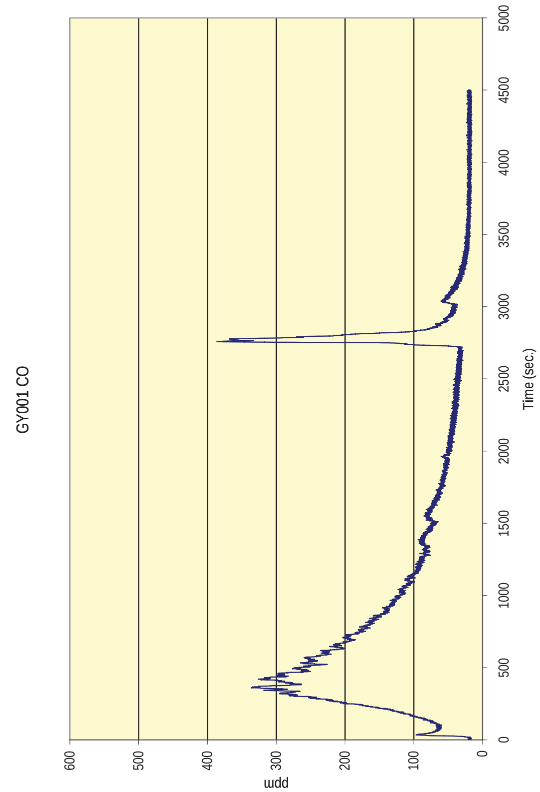
GYCR3-4

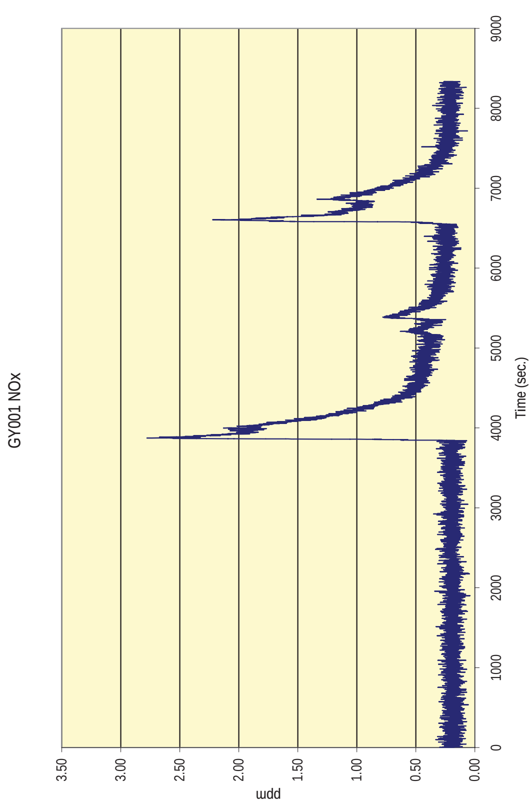


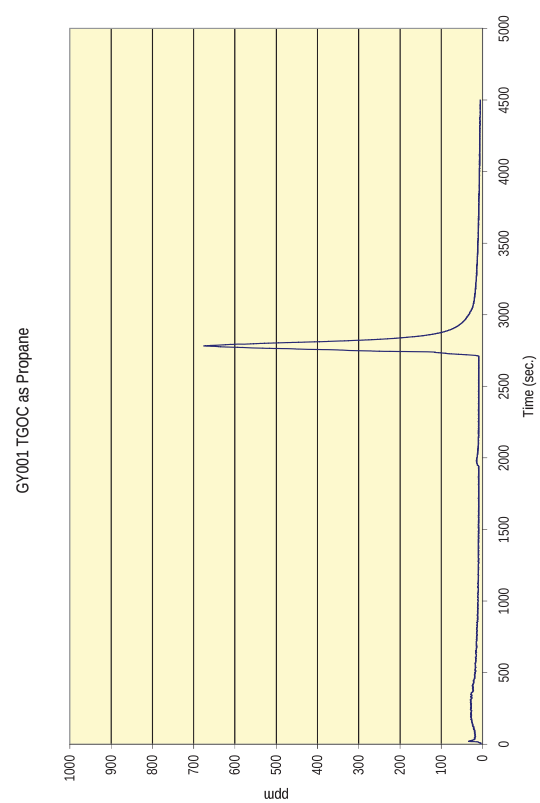
APPENDIX D CONTINUOUS EMISSION CHARTS

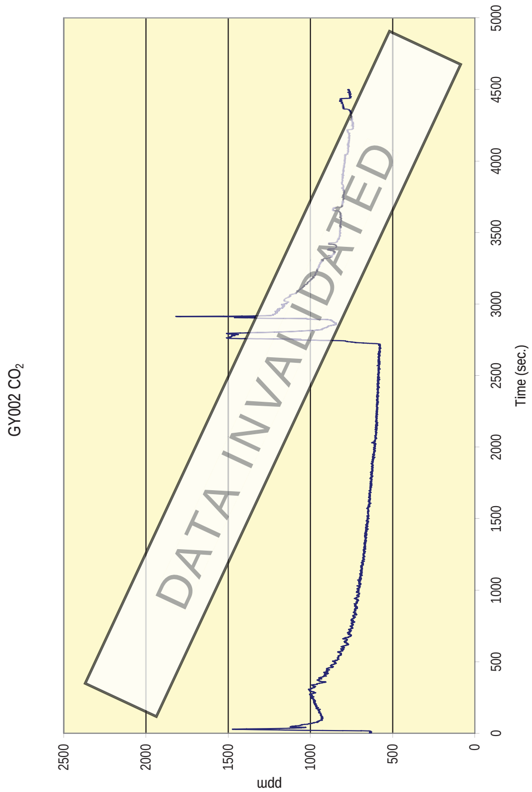
this page intentionally left blank

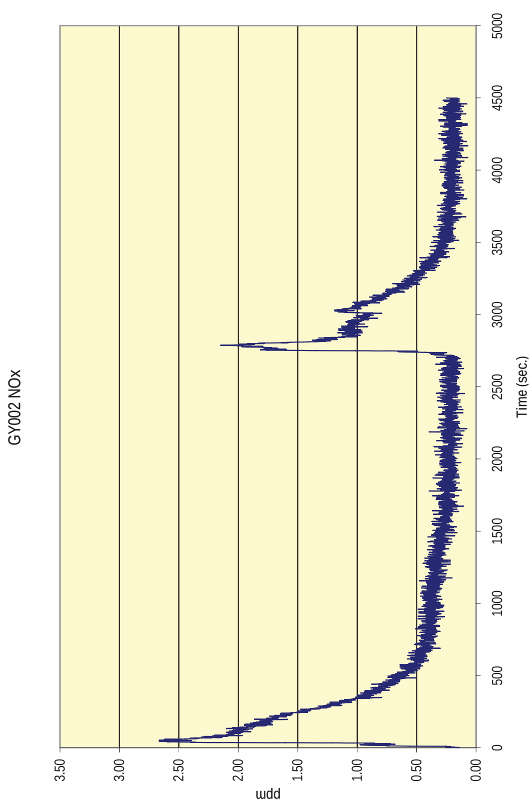

GY001 CO_2
DATA INVALIDATED
ppm
Time (sec.)

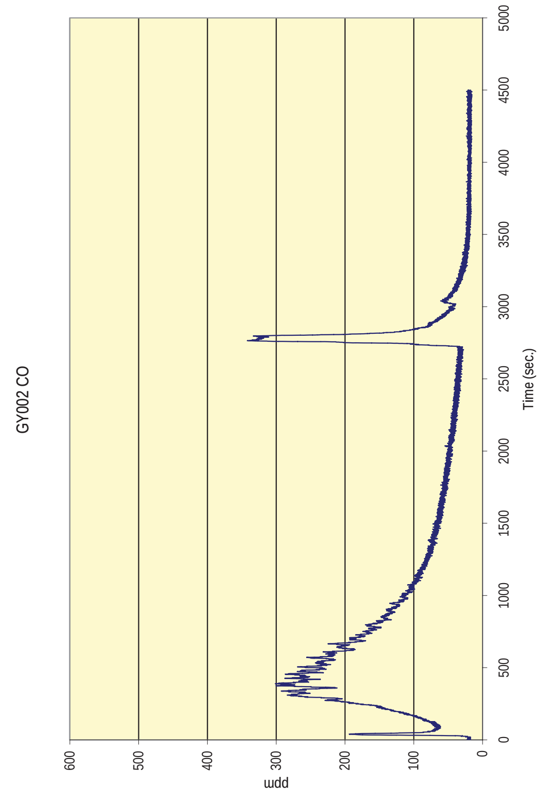

GY001 CO
ppm
Time (sec.)

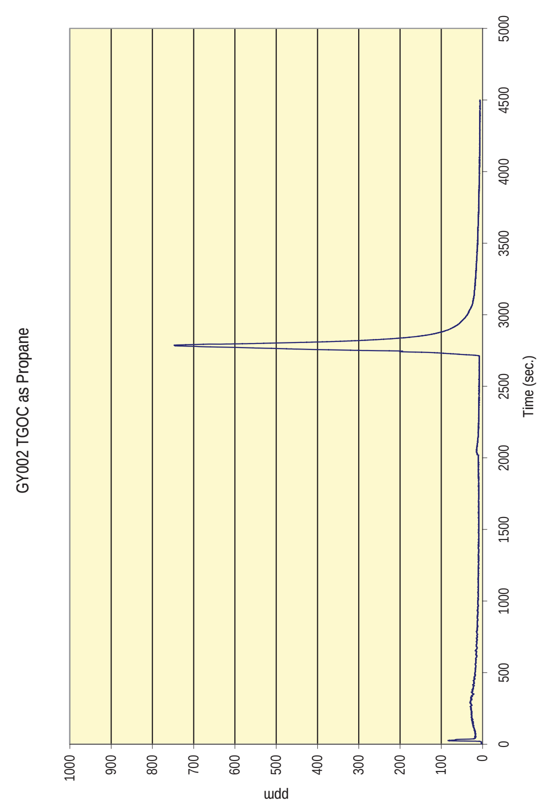

GY001 NOx
ppm
Time (sec.)

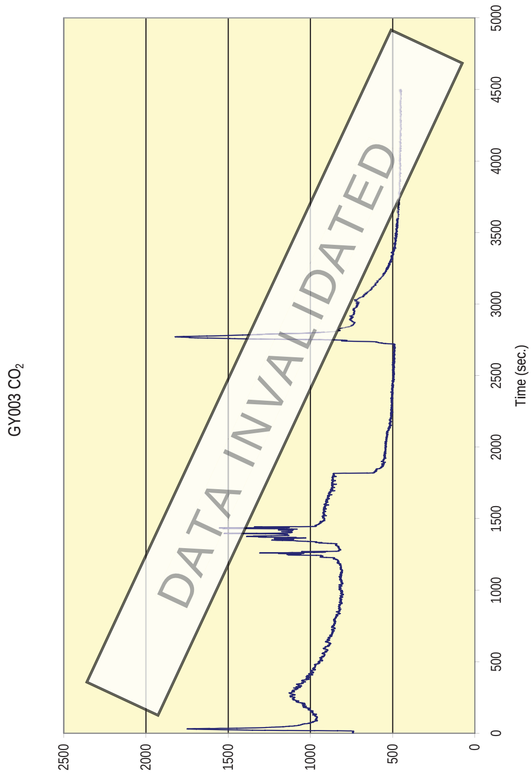

GY001 TGOC as Propane
ppm
Time (sec.)

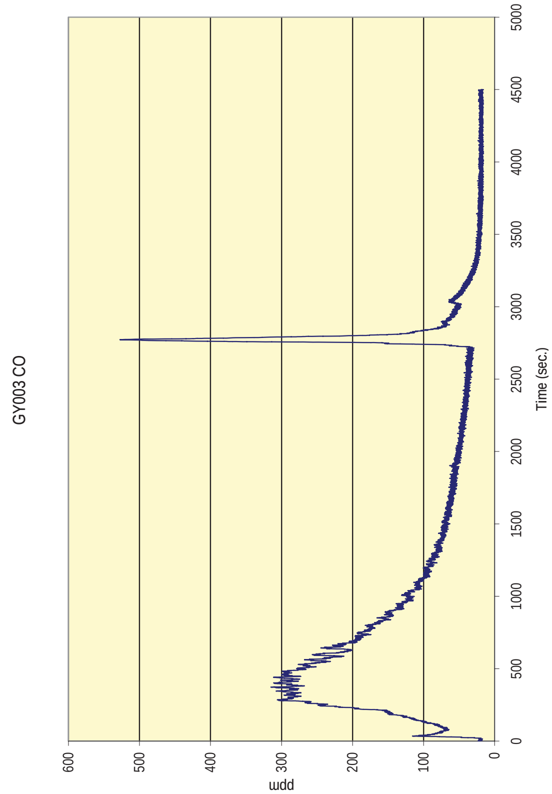

GY002 CO2
DATA INVALIDATED
ppm
Time (sec.)

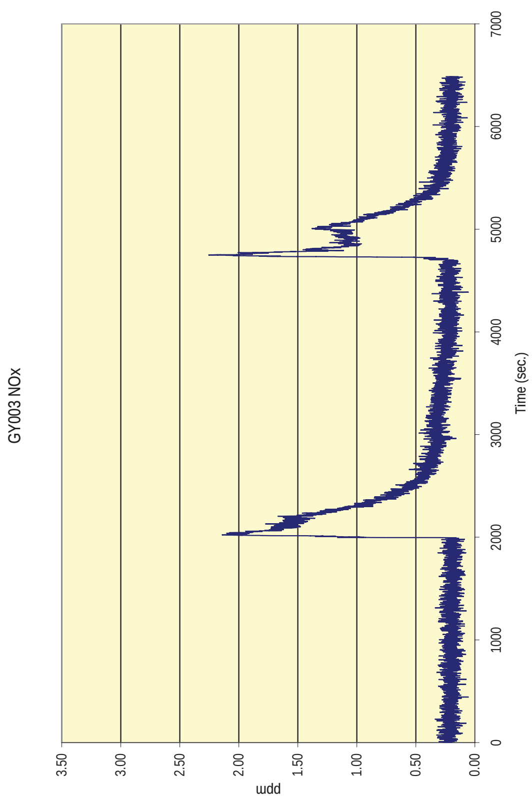

GY002 NOx
ppm
Time (sec.)

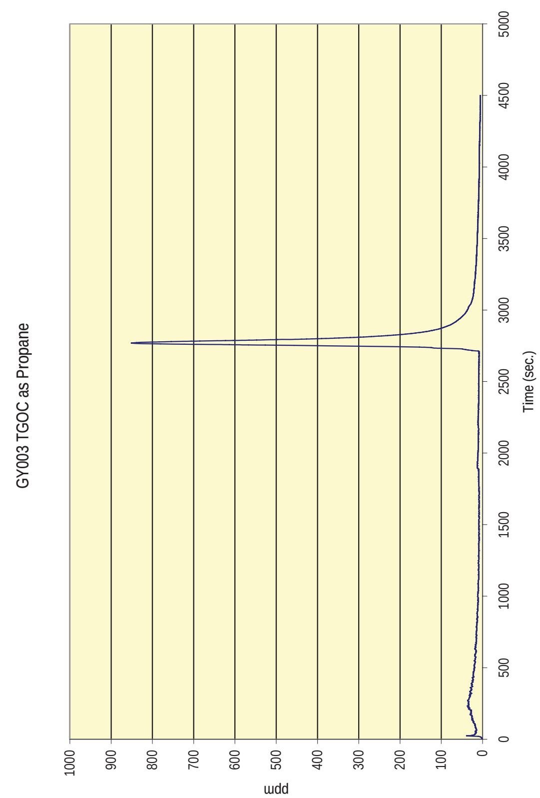

GY002 CO
ppm
Time (sec.)

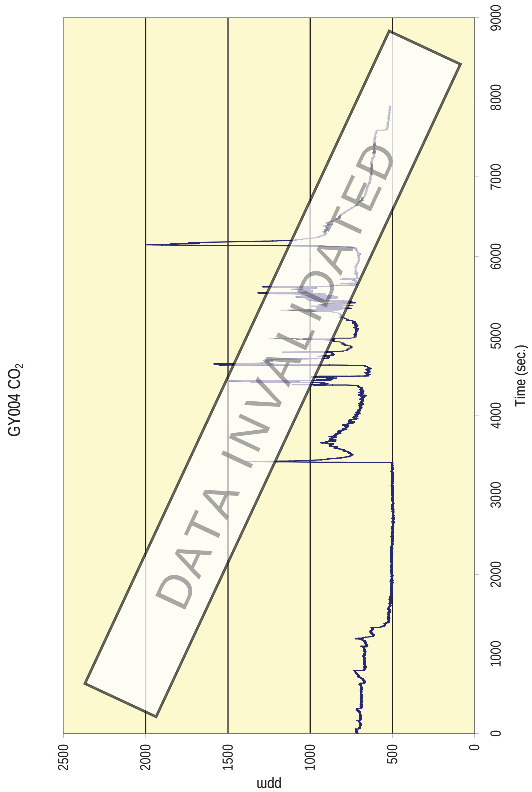

GY002 TGOC as Propane
ppm
Time (sec.)

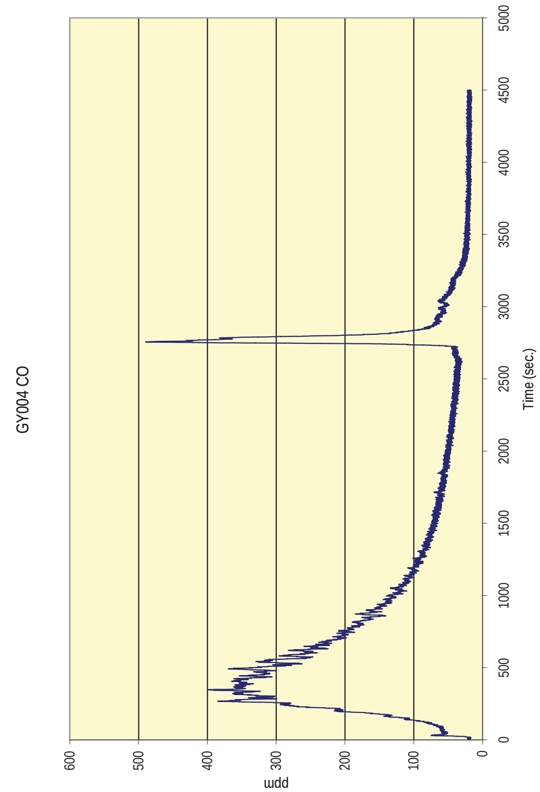

GY003 CO_2
ppm
Time (sec.)
DATA INVALIDATED

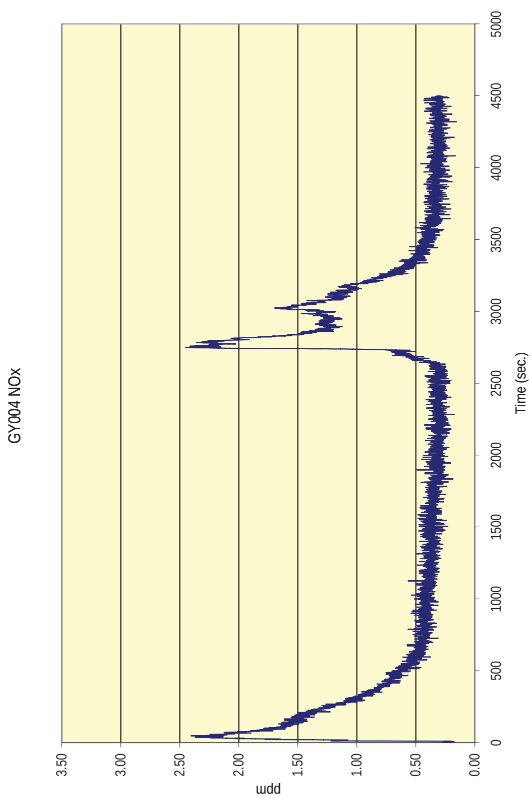

GY003 CO
ppm
Time (sec.)

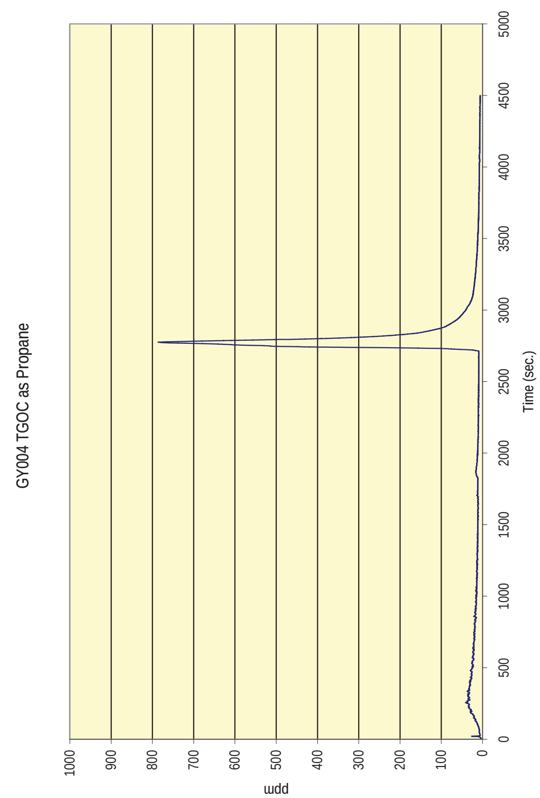

GY003 NOx
ppm
Time (sec.)

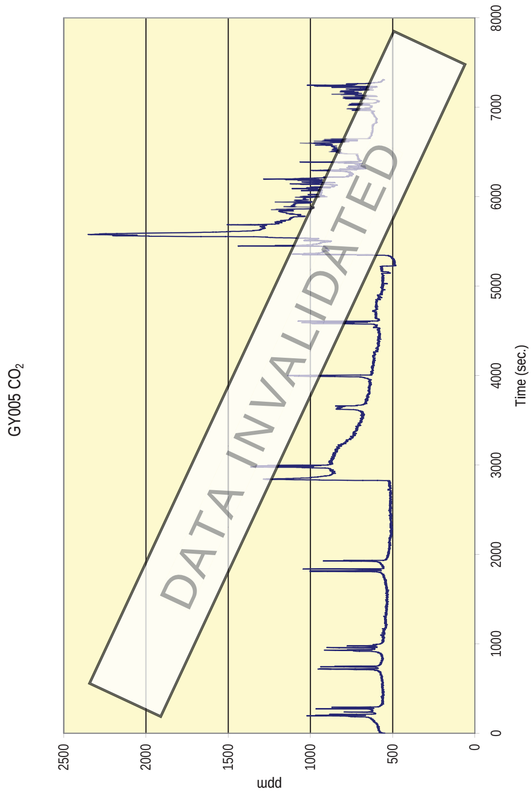

GY003 TGOC as Propane
ppm
Time (sec.)

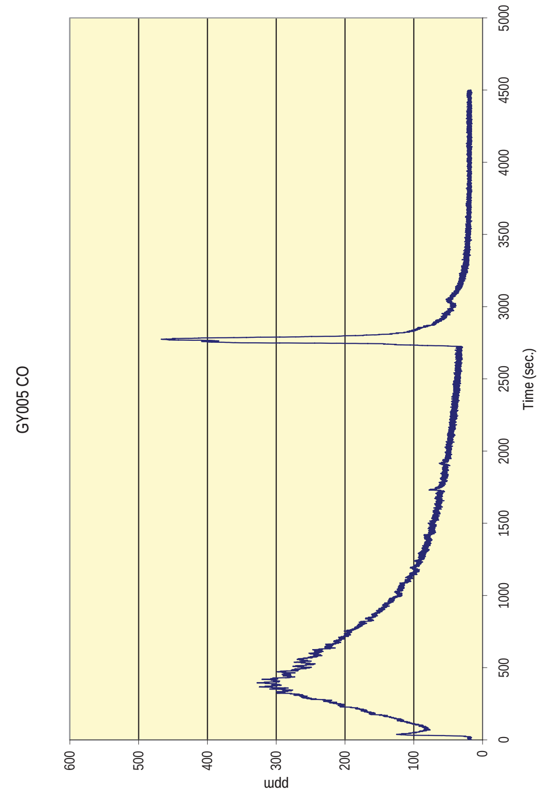

GY004 CO$_2$
DATA INVALIDATED
ppm
Time (sec.)

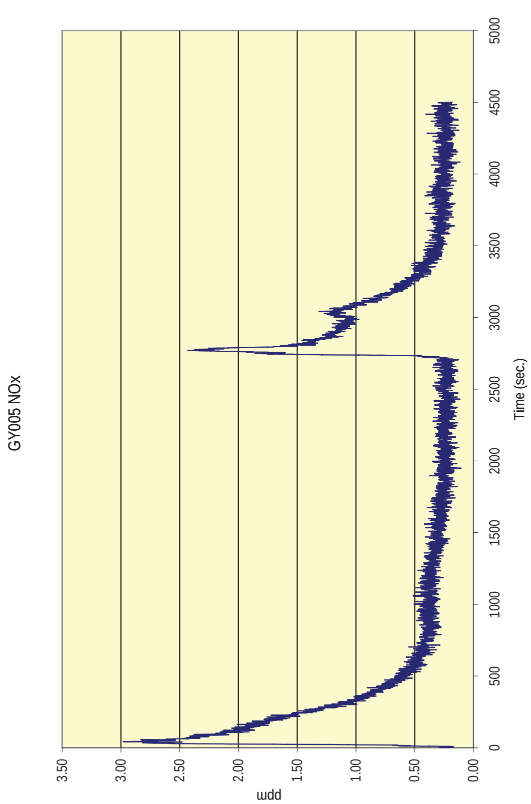

GY004 CO
ppm
Time (sec.)

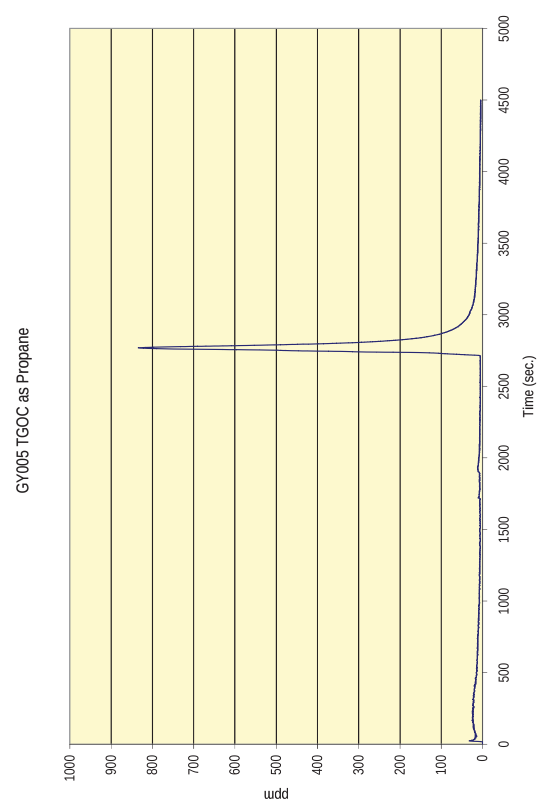

GY004 NOx
ppm
Time (sec.)

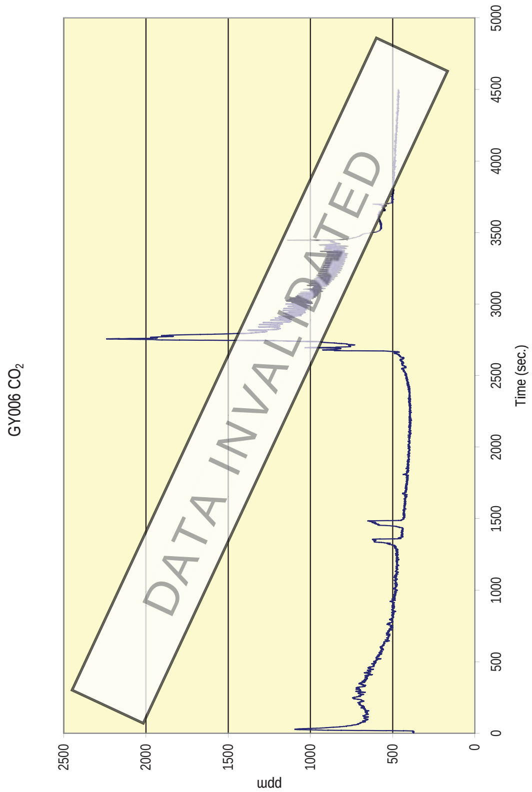

GY004 TGOC as Propane
ppm
Time (sec.)

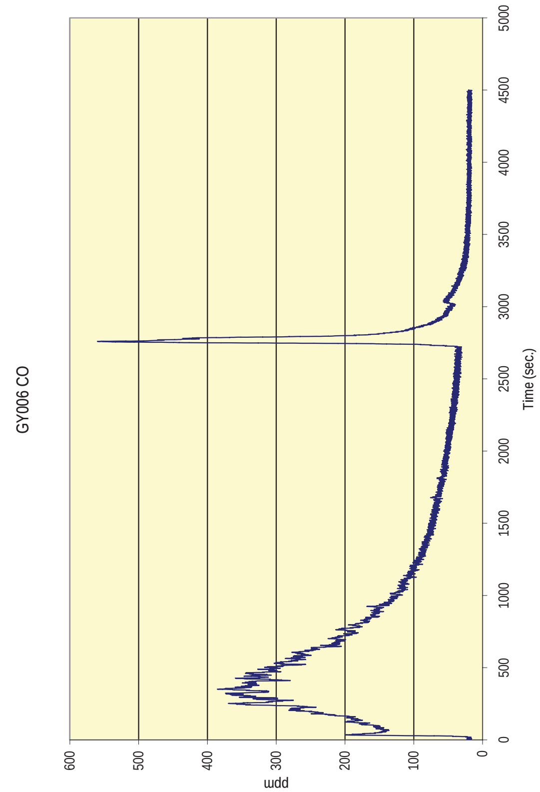

GY005 CO2
DATA INVALIDATED
ppm
Time (sec.)

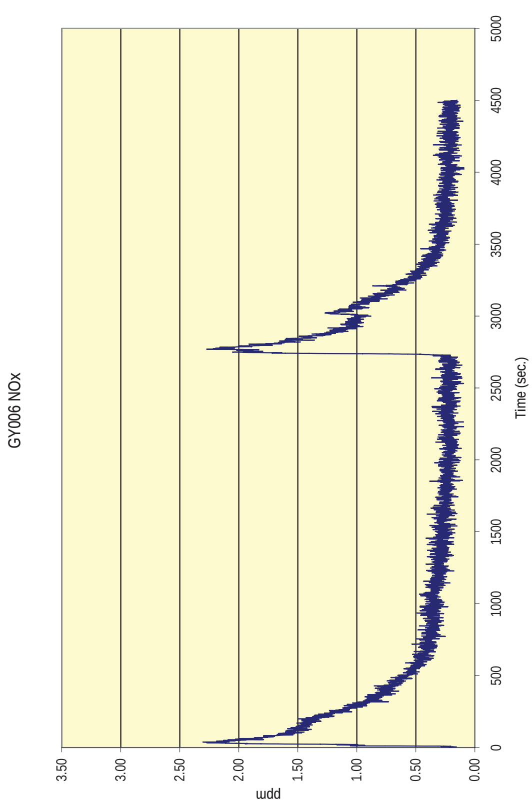

GY005 CO
ppm
Time (sec.)

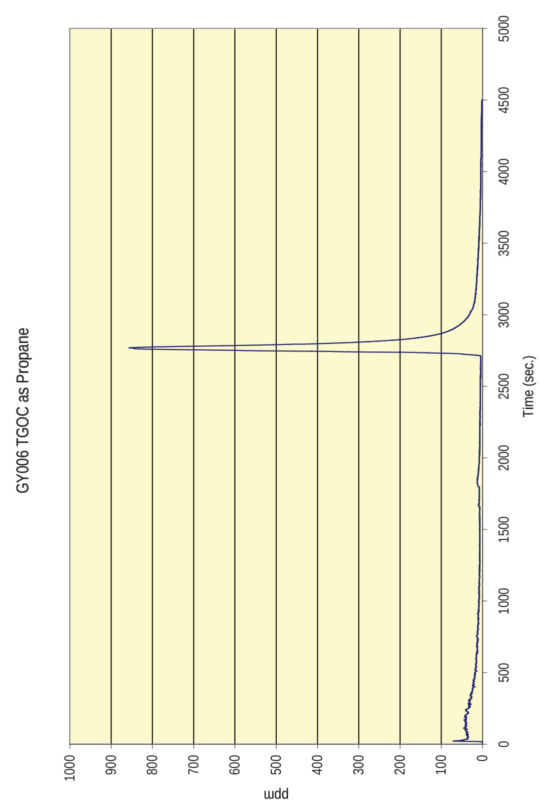

GY005 NOx
ppm
Time (sec.)

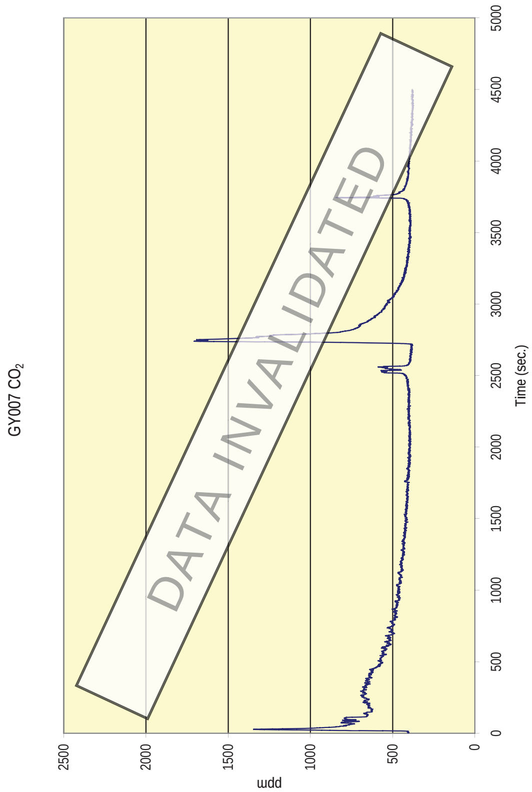

GY005 TGOC as Propane
ppm
Time (sec.)

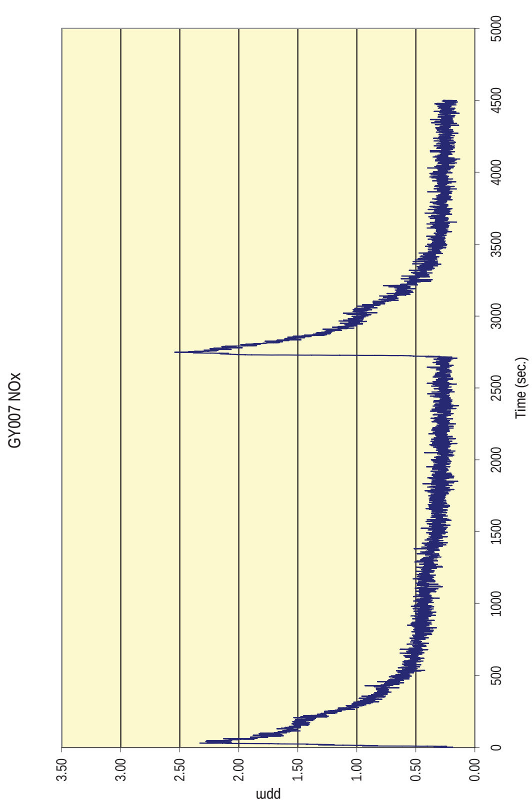

GY006 CO_2
DATA INVALIDATED
ppm
Time (sec.)

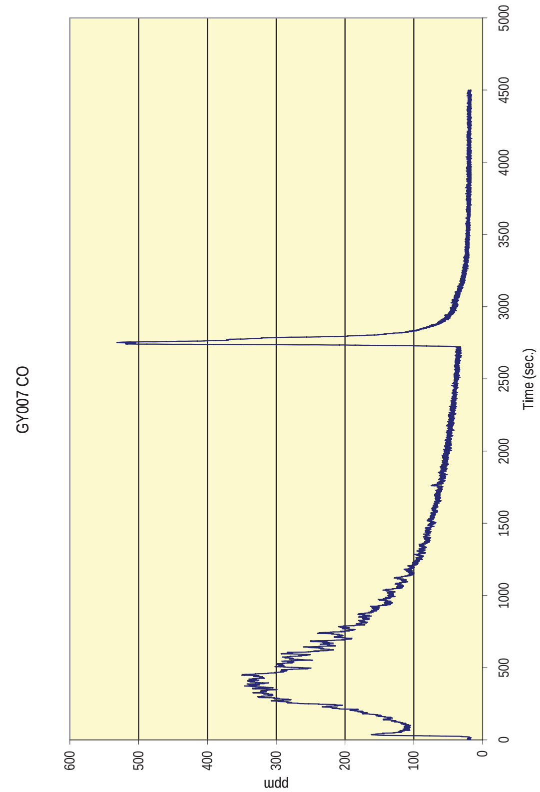

GY006 CO
ppm
Time (sec.)

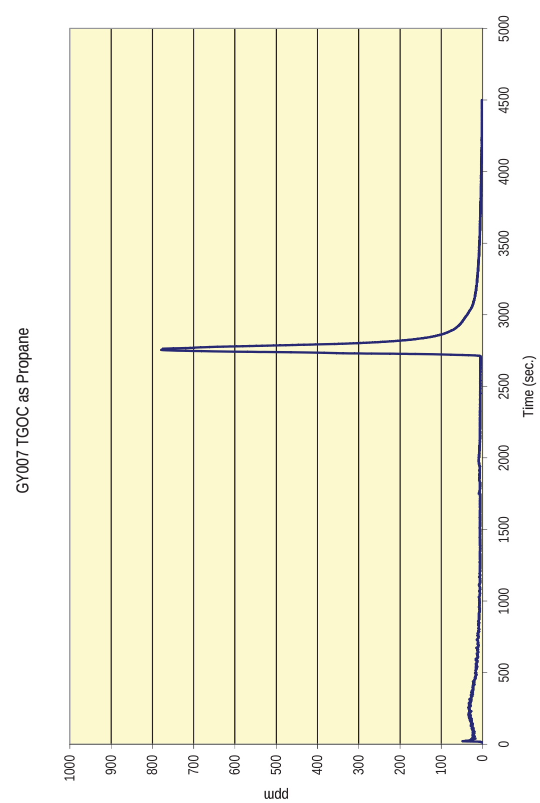

GY006 NOx
ppm
Time (sec.)

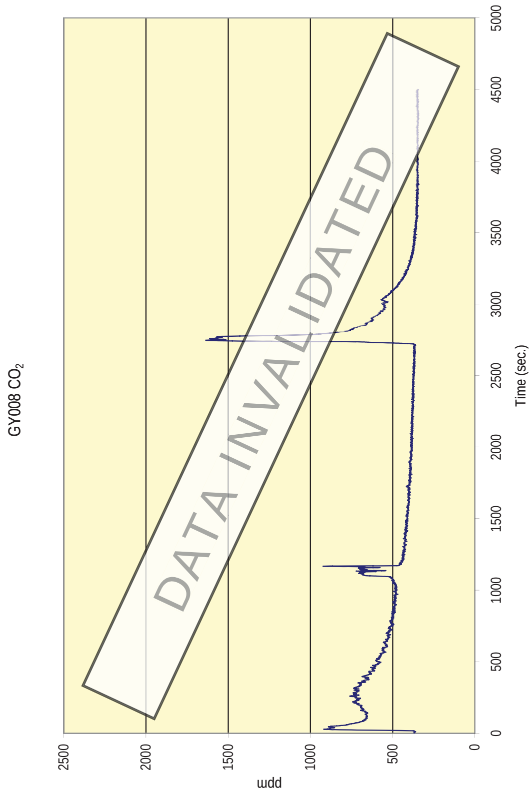

GY006 TGOC as Propane
ppm
Time (sec.)

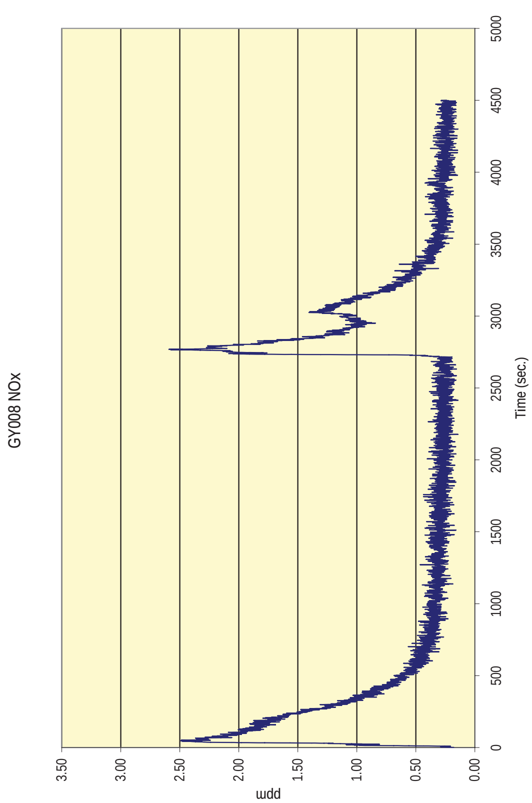

GY007 CO_2
DATA INVALIDATED
ppm
Time (sec.)

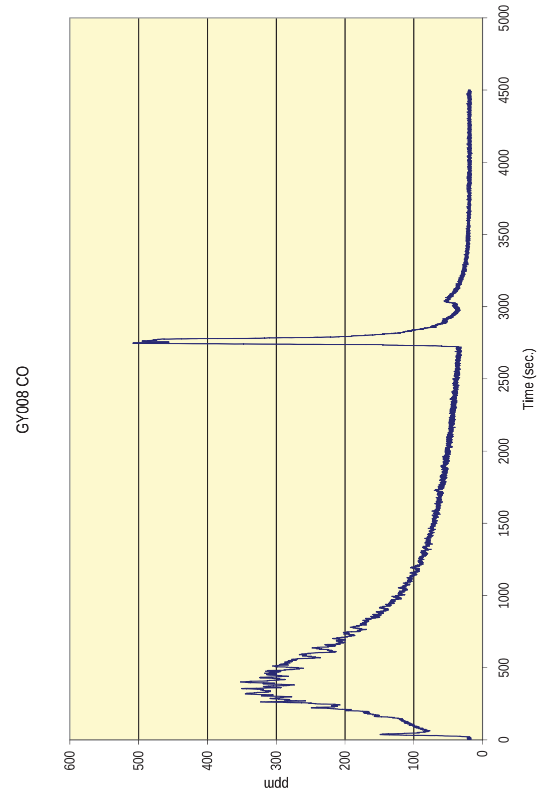

GY007 NOx
ppm
Time (sec.)

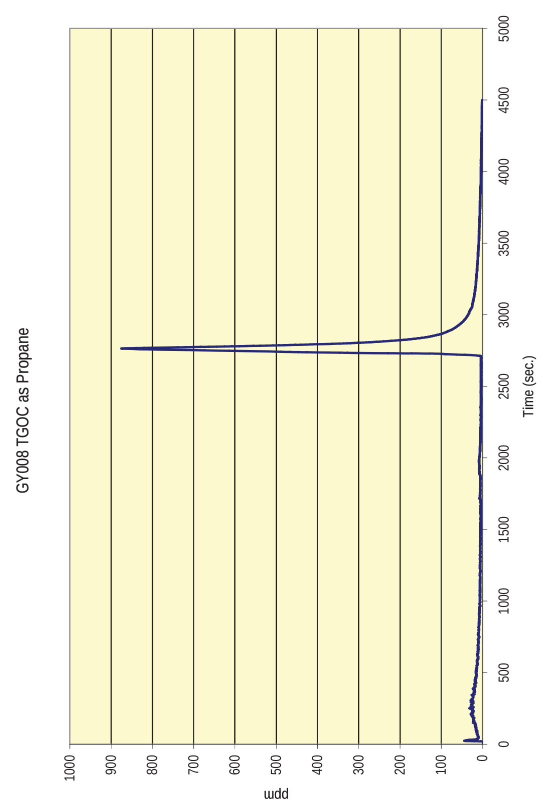

GY007 CO
ppm
Time (sec.)

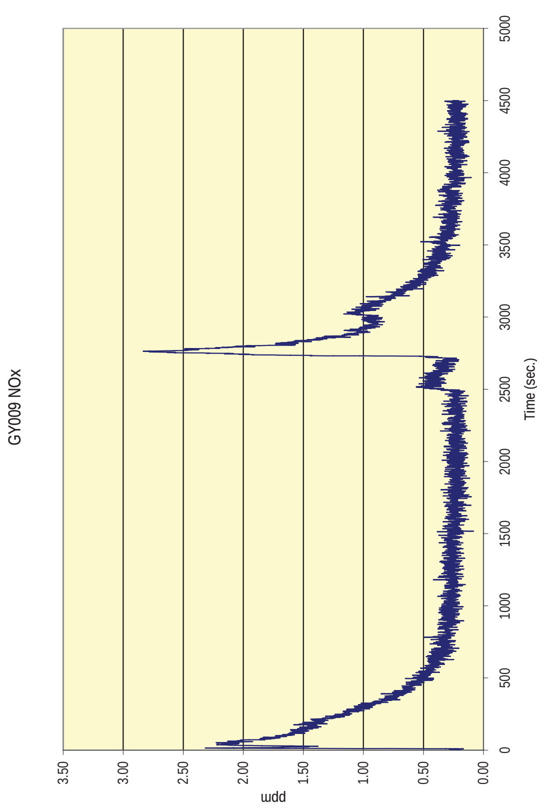

GY007 TGOC as Propane
ppm
Time (sec.)

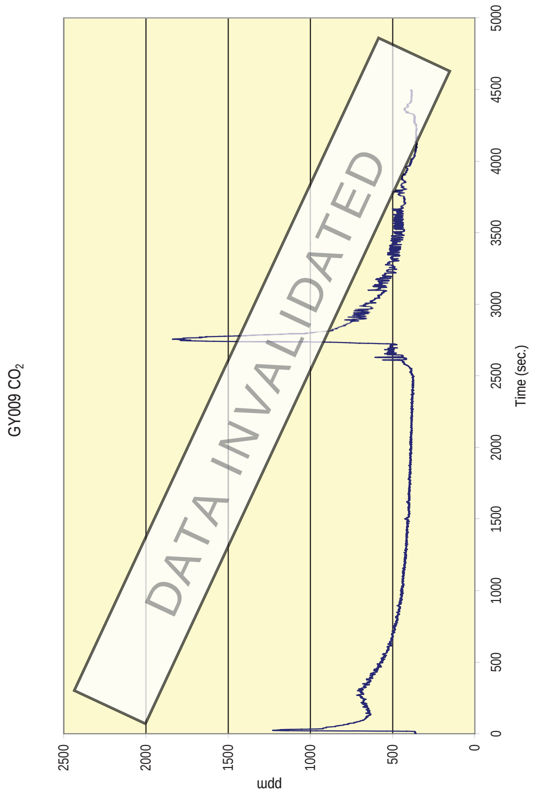

GY008 CO_2
DATA INVALIDATED
ppm
Time (sec.)

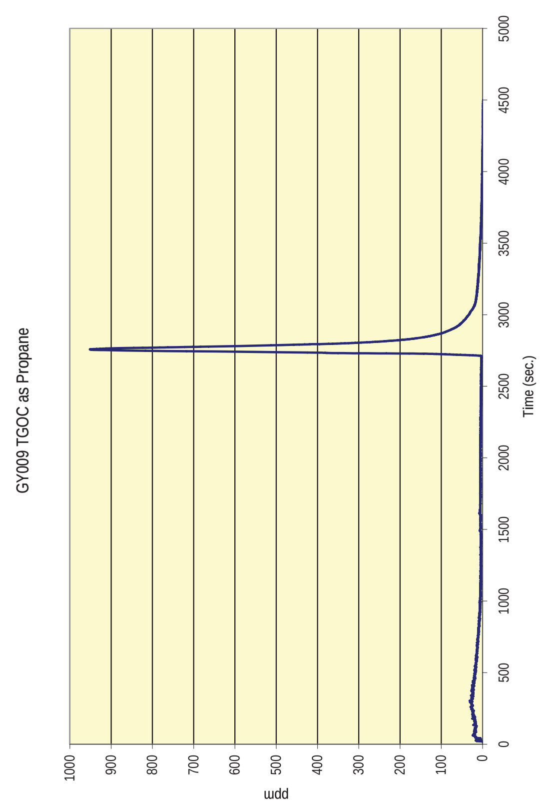

GY008 NOx
ppm
Time (sec.)

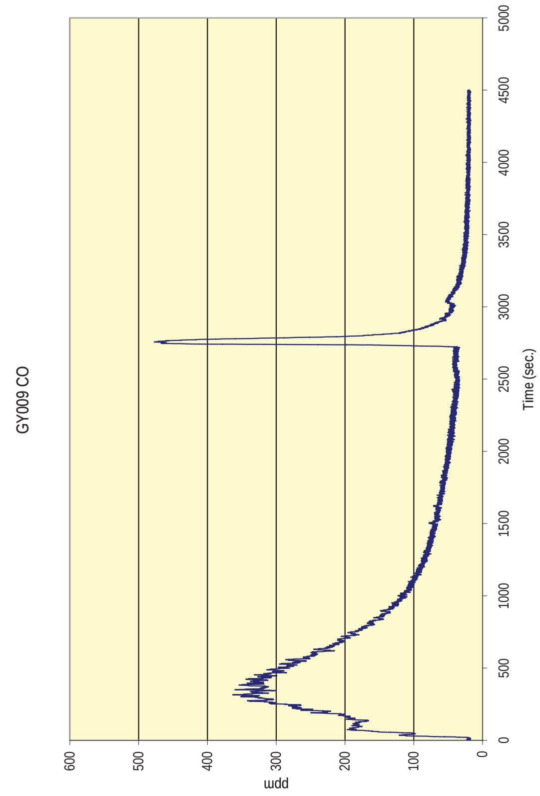

GY008 CO
ppm
Time (sec.)


GY008 TGOC as Propane
ppm
Time (sec.)


GY009 NOx
ppm
Time (sec.)


GY009 CO2
ppm
Time (sec.)
DATA INVALIDATED


GY009 TGOC as Propane
ppm
Time (sec.)


GY009 CO
ppm
Time (sec.)

this page intentionally left blank

APPENDIX E ACRONYMS AND ABBREVIATIONS

this page intentionally left blank

Acronyms & Abbreviations

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
EPA	Environmental Protection Agency
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
MSDS	Material Safety Data Sheets
NA	Not Applicable; Not Available
ND	Non-Detect
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NIST	National Institute of Standards and Technology
NT	Not Tested - Lab testing was not done
PCS	Pouring, Cooling, Shakeout
PM	Particulate Matter

POM	Polycyclic Organic Matter
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