Casting Emission Reduction Program
www.cerp-us.org

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Baseline: PCS from Coreless Greensand with Seacoal, Iron

Technikon # 1411-125 GQ

October 2005
(Revised for public distribution.)

United States Environmental Protection Agency

CISA

AFS

UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH
USCAR
DaimlerChrysler Ford Motor Company General Motors

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Baseline: PCS from Coreless Greensand with Seacoal, Iron

1411-125 GQ

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
VP 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 was not collected to assess casting quality, cost, or producibility.

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Executive Summary

This report contains the results of emission testing to evaluate the pouring, cooling, and shakeout SO_2 emissions from Test GQ, a coreless, 4-on greensand mold with seacoal. Test GQ results will be used to enhance baseline Test FK data with the addition of analyte SO_2 as a baseline against which other products and processes are to be compared. All testing was conducted by Technikon, LLC in its Research Foundry. The emissions results are reported in pounds of analyte per ton of metal poured.

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. Process and stack parameters were measured and include: the weights of the casting, mold and binder; Loss on Ignition (LOI) values for the mold prior to the test; metallurgical data; and stack temperature, pressure, volumetric flow rate, and moisture content. The process parameters were maintained within prescribed ranges in order to ensure the reproducibility of the tests runs. Samples were collected and analyzed for fifty-eight (58) target compounds using procedures based on regulatory methods including those of US EPA. Continuous monitoring of the Total Gaseous Organic Concentration (TGOC) and carbon dioxide (CO_2), carbon monoxide (CO), and nitrogen oxide (NOx) concentrations in the emissions were conducted according to US EPA Methods 25A, 3A, 10, and 7E respectively. Sulfur dioxide (SO_2) concentrations were determined using OSHA ID 200.

Mass emission rates for all analytes were calculated using continuous monitoring data, 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. These indicators include TGOC as propane, hydrocarbons (HC) as hexane, the sum of target analytes, 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 the Results section of this report.

Table 1 shows a summary of SO_2 concentrations in pounds per ton of metal (Lbs/Tn) collected by adsorption tube according to OSHA ID 200.

Table 1 Summary of SO_2 in Lbs/Tn of Metal

	Average	Standard Deviation
Sulfur Dioxide (Absorption Tube)	0.0296	0.0034

Results for the emission indicators are shown in Table 2, reported as lbs/tn of metal.

Table 2 Test Plan GQ Emissions Indicators – Lb/Tn Metal

	TGOC as Propane	HC as Hexane	Sum of Target Analytes	Sum of Target HAPs	Sum of Target POMs
Test GQ	3.2537	0.7012	0.4512	0.3818	0.0246

It must be noted that the 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 manufacturing 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.

1.2. 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 air emissions from a coreless greensand system. Section 2 of this report includes a summary of the methodologies used for data collection and analysis, 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 Appendix B of this report. Section 4 of this report contains a discussion of the results.

The raw data for this test series are included in a data binder that is maintained 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

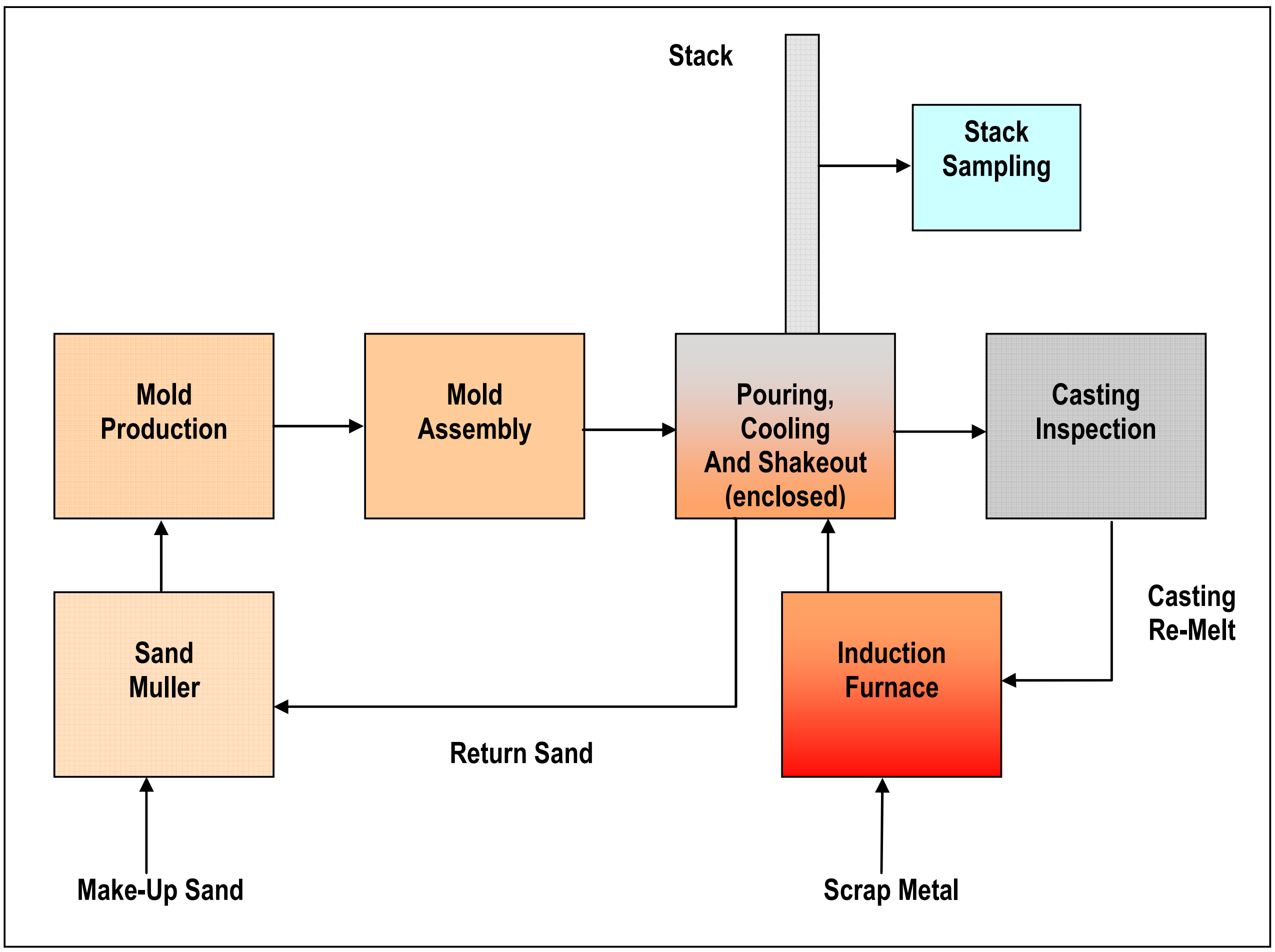
Type of Process Tested	Green Sand Baseline
Test Plan Number	1411-125 GQ
Greensand System	H & G Seacoal
Metal Poured	Iron
Casting Type	4-on Star
Number of Molds Poured	3 Conditioning plus 9 Sampling
Test Dates	5/2/05 through 5/6/05
Emissions Measured	• TGOC as Propane, CO_2, CO, NOx, • HC as Hexane, SO_2 • 58 Targeted Organic HAPs and VOCs
Process Parameters Measured	• Total Casting Weight • Mold Weights • Metallurgical Data • % LOI • Stack Temperature • Stack Moisture Content • Sand Temperature • Stack Pressure • Stack 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 process equipment.

Figure 2-1 Research Foundry Layout Diagram



2.2. Description of Testing Program

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

1. **Test Plan Review and Approval:** The proposed test plan was reviewed and approved by the Technikon staff.

2. **Mold and Metal Preparation:** The 4-on star greensand molds (Figure 2-2) are prepared to a standard composition by the Technikon production team. Iron is melted in a 1000 lb. Ajax induction furnace. The amount of metal melted is determined from the poured weight of the casting and the number of molds to be poured. The metal composition is prescribed by a metal composition worksheet. The weight of metal poured into each mold is recorded on the process data summary sheet.

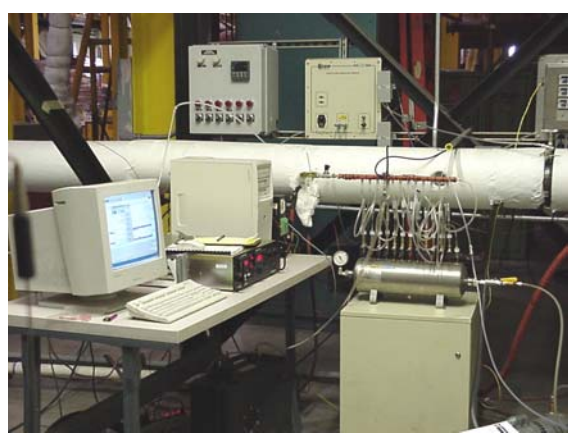
3. **Individual Sampling Events:** Replicate tests are performed on nine (9) mold packages after the conclusion of three (3) conditioning cycles. The mold packages are placed into an enclosed test stand (Figure 2-3) heated to approximately 85°F. Iron is poured through an opening in the top of the emission enclosure after which the opening is closed.

   Continuous air samples (Figure 2-4) are collected during the forty-five minute

Figure 2-2 4-on Star Greensand Mold

Figure 2-3 Total Enclosure Test Stand

Figure 2-4 Sampling Train



pouring and cooling process, during the fifteen minute shakeout of the mold, and for an additional fifteen minute period following shakeout. The total sampling time is seventy-five minutes.

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 Parameters Measured

Parameter	Analytical Equipment and Methods
Mold Weight	Cardinal 748E Platform Scale (Gravimetric)
Casting Weight	Cardinal 748E Platform Scale (Gravimetric)
Core Weight	Mettler SB12001 Digital Scale (Gravimetric)
Muller Water Weight	Cardinal 748E Platform Scale (Gravimetric)
Binder Weight	Ohaus MP-2 Digital Scale (Gravimetric)
Volatiles	Mettler PB302 Scale (AFS Procedure 2213-00-S)
LOI, % at Mold and Shakeout	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)

5. Air Emissions Analysis: Specific sampling and analytical methods used in the Research Foundry tests are based on the US EPA 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
Port Location	EPA Method 1
Number of Traverse Points	EPA Method 1
Gas Velocity and Temperature	EPA Method 2
Gas Density and Molecular Weight	EPA Method 3a
Gas Moisture	EPA Method 4, Gravimetric
HAPs Concentration	EPA Method 18, TO11
VOCs Concentration	EPA Method 18, 25A, TO11, NIOSH 1500
SO_2 Concentration	OSHA ID 20012

These methods were specifically modified to meet the testing objectives of the CERP Program.

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 times 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 to provide emissions data in pounds of analyte per ton of metal.

   The results of each of the sampling events are included in Appendix B of this report. The results of each test are also averaged and are shown in Table 3-1.

7. **Report Preparation and Review:** The Preliminary Draft Report is reviewed by the Process Team and Emissions Team 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 reviewed by the Vice President-Measurement Technologies, the Vice President-Operations, the Manager-Process Engineering, and the Technikon President. 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. 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 - Process Engineering and the Vice President - 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 VP-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 ton of metal poured are presented in Table 3-1. The table includes the individual target compounds that comprise at least 95% of the total VOCs measured, along with the corresponding Sum of Target Analytes, Sum of HAPs, and Sum of POMs. The table also includes TGOC as propane, HC as hexane, carbon monoxide, carbon dioxide, oxides of nitrogen, and sulfur dioxide averages.

Compounds that are structural isomers have been grouped together and are reported as a single quantity. 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 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 C_1 (methane), with results calibrated against the three-carbon alkane (propane). 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).

Other emissions indicators, in addition to TGOC as propane and HC as hexane, were calculated and are presented in these tables. The emissions indicator sum of target analytes is the sum of all the individual target analytes detected and includes targeted HAPs and POMs, as well as other targeted VOCs. 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.

Figures 3-1 to 3-3 present the five emissions indicators and selected individual HAP, VOC, criteria pollutants , and greenhouse gas emissions data from Table 3-1 in graphical form.

Appendix B contains the detailed data including the results for all analytes measured.

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

Appendix C contains detailed process data.

Method 25A charts for the tests are included in Appendix D of this report. The charts are presented to show the VOC, carbon monoxide, carbon dioxide, and oxides of nitrogen emission profiles for each pour.

Table 3-1 Summary of Test Plan GQ Average Results – Lb/Tn Metal

Analyte Name	lb/ton Average	lb/ton Standard Deviation
Emission Indicators		
TGOC as Propane	3.2537	0.3263
HC as Hexane	0.7012	0.0354
Sum of Target Analytes	0.4512	0.0377
Sum of HAPs	0.3818	0.0338
Sum of POMs	0.0246	0.0071
Individual Targeted HAP's & VOC's		
Benzene	0.1589	0.0192
Toluene	0.0795	0.0084
Xylenes	0.0454	0.0172
Hexane	0.0169	0.0020
Phenol	0.0131	0.0009
Naphthalene	0.0105	0.0014
Methylnaphthalenes	0.0105	0.0086
Ethylbenzene	0.0096	0.0008
Acetaldehyde	0.0070	0.0005
Cresols	0.0062	0.0027
Indene	0.0052	0.0004
Formaldehyde	0.0038	0.0007
Styrene	0.0029	0.0003
2-Butanone (MEK)	0.0025	0.0002
Propionaldehyde (Propanal)	0.0013	0.0001
Dimethylnaphthalenes	0.0004	0.0002
Other Individual Targeted VOC's		
Heptane	0.0160	0.0021
Octane	0.0119	0.0012
Nonane	0.0095	0.0006
Decane	0.0079	0.0004
Ethyltoluenes	0.0058	0.0023
Trimethylbenzenes	0.0044	0.0017
Criteria Pollutants & Green House Gasses		
Carbon Monoxide	5.4862	0.6436
Carbon Dioxide	12.9354	1.9988
Nitrogen Oxides	0.0057	0.0007
Sulfur Dioxide[1]	0.0296	0.0034

Individual results constitute >95% of mass of all detected target analytes
[1] Integrated sample taken using adsorbent tube

Table 3-2 Summary of Test Plan GQ Average Process Parameters

Test GQ - Greensand PCS	Average
Cast Weight - All Metal Inside Mold (lbs.)	90.7
Pouring Time (sec.)	14
Pouring Temp (°F)	2680
Pour Hood Process Air Temp At Start of Pour, F	87
Muller Batch Weight (lbs.)	900
GS Mold Sand Weight, (lbs.)	646
Mold Compactability, %	54
Mold Temperature (°F)	74
Average Green Compression (psi)	16.75
GS Compactability (%)	46
GS Moisture Content (%)	1.95
GS MBClay Content (%)	5.24
MB Clay Reagent, ml	26
1800°F LOI - Mold Sand (%)	5.37
900°F Volatiles (%)	1.18

Figure 3-1 Emission Indicators from Test Series GQ – Lb/Tn Metal

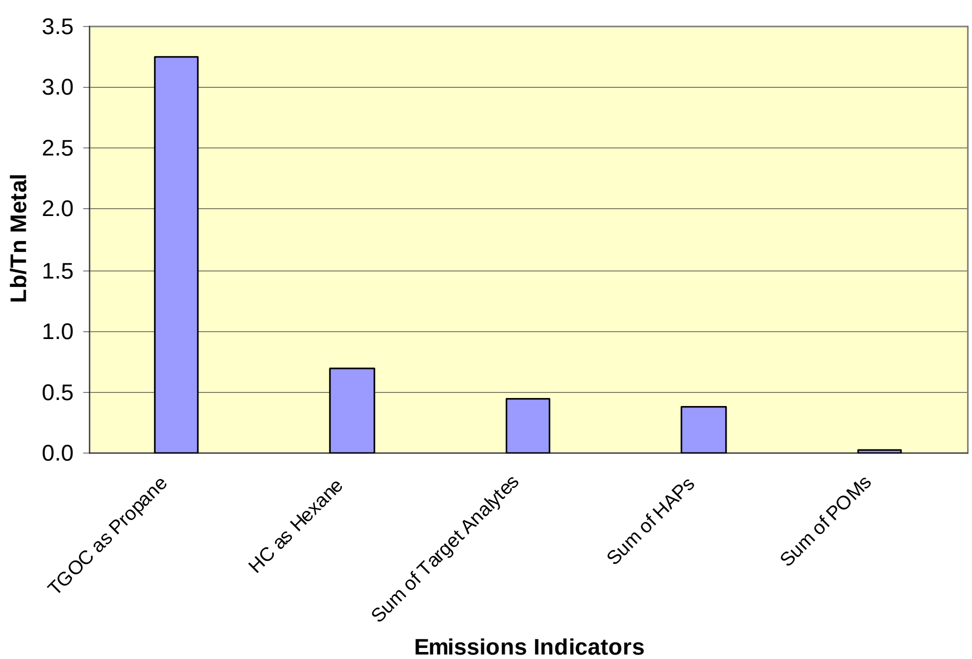


Figure 3-2 Targeted HAP Emissions from Test Series GQ – Lb/Tn Metal

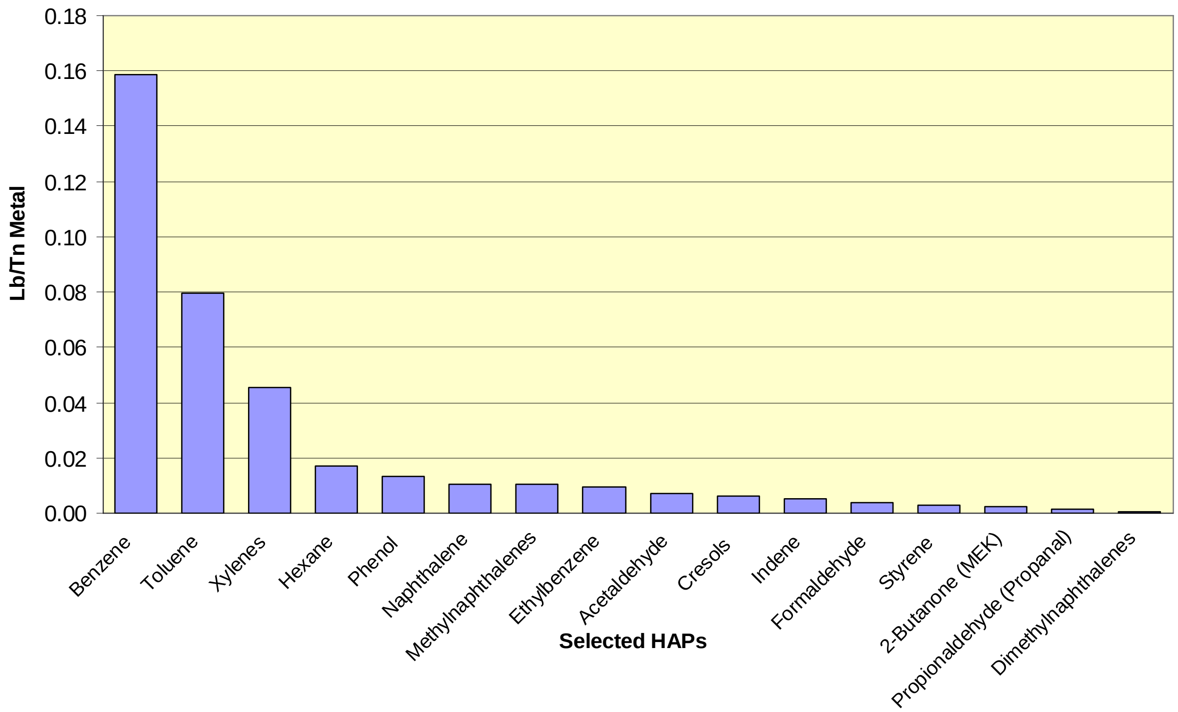
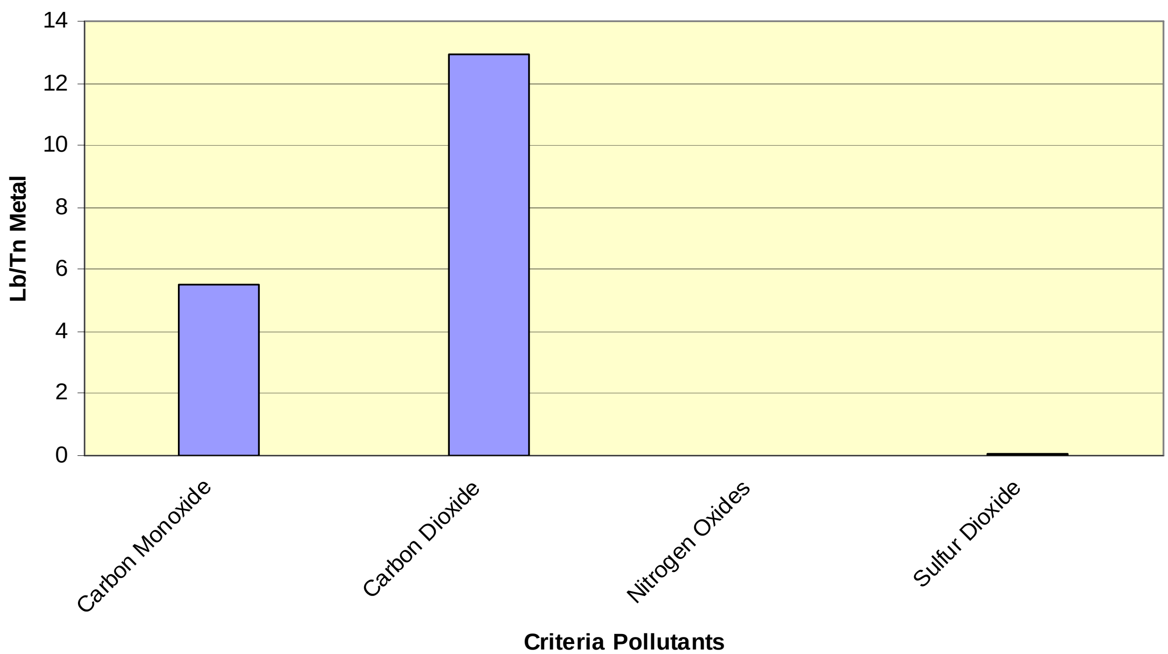


Figure 3-3 Selected Criteria Pollutants and Greenhouse Gasses from Test Series GQ – Lb/Tn Metal



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4.0 DISCUSSION OF RESULTS

Twenty-two (22) of the measured compounds comprised greater than 95% of the concentration as lb/ton of all VOCs emitted by the Greensand with seacoal baseline test series. Benzene alone accounted for approximately 35% of the total, while toluene and xylenes comprised 18%, and 10% respectively. The remaining nineteen (19) compounds in Table 3-1 comprised approximately 32% of the total VOCs.

No analyte analysis was done for run GQ002 due to equipment malfunction which resulted in no samples being taken. The associated compounds are therefore shown in Appendix B as not tested.

Observation of measured process parameters indicates that the tests were run within an acceptable range.

SO_2 was collected using adsorption tubes which provided integrated samples measured over the entire sampling period. Additionally, a CEMS analyzer from Western Research was used to continuously record SO_2 data. The data from the CEMS analyzer was invalidated because the instrument wasn't capable of accurate readings at the low concentration amounts of SO_2 measured (less than 1% of range).

No casting greensand surface analysis was performed because the objective of this test was only to add SO_2 to the emission analyte list for baseline test FK, which included a surface appearance analysis in the final report.

All target analyte concentrations and reporting limits expressed in pounds per ton of metal are shown in Appendix B.

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APPENDIX A APPROVED TEST PLAN AND SAMPLE PLAN FOR TEST SERIES GQ

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TECHNIKON TEST PLAN

- **CONTRACT NUMBER:** 1411 **TASK NUMBER:** 1.2.5 **Series:** GQ
- **SITE:** Research Foundry
- **TEST TYPE:** Baseline: Coreless Greensand, pouring, cooling, shakeout
- **METAL TYPE:** Class 30 gray iron
- **MOLD TYPE:** 4-on coreless star greensand with H&G seacoal
- **NUMBER OF MOLDS:** 3 conditioning + 9 Sampling
- **CORE TYPE:** None
- **SAMPLE EVENTS:** 9
- **ANALYTE LIST:** Same as that for 1410-FK with the addition of media for SO_2 measurement. A CEMS type SO_2 analyzer from Western Research will be sampling in parallel to the train**.**
- **TEST DATE:** **START:** 2 May 2005
  FINISHED: 6 May 2005

TEST OBJECTIVES:

Establish an Emission baseline (pouring, cooling, & shakeout) for the standard coreless mechanically produced clay, water, H&G seacoal greensand mold including the criteria gasses SO_2, NO_x, CO_2, & CO.

VARIABLES:

The pattern will be the 4-on star. The mold will be made with Wexford W450 sand, western and southern bentonite in a 5:2 ratio to yield 7.0 +/- 0.5% MB Clay, H & G seacoal to yield a 5.0 +/- 0.3% LOI, tempered to 40-45% compactability, mechanically compacted. The molds will be maintained at 80-90^{o}F prior to pouring. The sand heap will be maintained at 900 pounds. Molds will be poured with iron at 2680 +/- 10^{o}F. Mold cooling will be 45minutes follow by 15 minutes of shakeout, or until no more material remains to be shaken out.

BRIEF OVERVIEW:

This baseline will be similar to baseline FK in its preparation by mechanically assisted molding. The molds will be coreless because it is coreless molding is a simpler and less costly way to demonstrate consistent greensand emissions than molding with benign sodium silicate cores included. This new coreless standard mold, a 24 x 24 x 10/10 inch 4-on array of stars, will create a more inclusive greensand baseline against which future products can be compared in that it will include the above stated criteria gasses. Additionally it will demonstrate the transferability of historical greensand data.

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 1300-pound sand 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.

PRE-PRODUCTION GQ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
5/2/2005											**GQ CONDITIONING - RUN 1**
GQ CR-1											
THC, CO, CO2,Nox		x									

PRE-PRODUCTION GQ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
5/2/2005											**GQ CONDITIONING - RUN 2**
GQ CR-2											
THC, CO, CO2,Nox		x									

PRE-PRODUCTION GQ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
5/2/2005											**GQ CONDITIONING - RUN 3**
GQ CR-3											
THC, CO, CO2,Nox		x									

PRE-PRODUCTION GQ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
5/3/2005											
RUN 1											
THC, CO, CO2,Nox	GQ001	X									TOTAL
M-18	GQ00101		1						30	1	Carbopak
M-18	GQ00102				1				0		Carbopak
	Excess								30	2	Excess
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GQ00103		1						500	5	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GQ00104				1					0	100/50 mg Carbon Bead (SKC 226-80)
	Excess								500	6	Excess
NIOSH 1500	GQ00105		1						1000	7	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	GQ00106				1				0		100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GQ00107		1						1000	9	DNPH Silica Gel (SKC 226-119)
TO11	GQ00108				1				0		DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GQ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
5/3/2005											
RUN 2											
THC, CO, CO2,Nox	GQ002	X									TOTAL
M-18	GQ00201		1						30	1	Carbopak
	Excess								30	2	Excess
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GQ00202		1						500	5	100/50 mg Carbon Bead (SKC 226-80)
	Excess								500	6	Excess
NIOSH 1500	GQ00203		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GQ00204		1						1000	9	DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GQ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
5/3/2005											
RUN 3											
THC, CO, CO2,Nox	GQ003	X									TOTAL
M-18	GQ00301		1						30	1	Carbopak
M-18	GQ00302			1					30	2	Carbopak
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GQ00303		1						500	5	100/50 mg Carbon Bead (SKC 226-80)
	Excess								500	6	Excess
NIOSH 1500	GQ00304		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GQ00305		1						1000	9	DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GQ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
5/4/2005											
RUN 4											
THC, CO, CO2,Nox	GQ004	X									TOTAL
M-18	GQ00401		1						30	1	Carbopak
M-18 MS	GQ00402		1						30	2	Carbopak
M-18 MS	GQ00403			1					30	3	Carbopak
	Excess								60	4	Excess
OSHA ID200	GQ00404		1						500	5	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GQ00405			1					500	6	100/50 mg Carbon Bead (SKC 226-80)
NIOSH 1500	GQ00406		1						1000	7	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	GQ00407			1					1000	8	100/50 mg Charcoal (SKC 226-01)
TO11	GQ00408		1						1000	9	DNPH Silica Gel (SKC 226-119)
TO11	GQ00409			1					1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GQ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
5/4/2005											
RUN 5											
THC, CO, CO2,Nox	GQ005	X									TOTAL
M-18	GQ00501		1						30	1	Carbopak
M-18	GQ00502					1			30	1	Carbopak
	Excess								30	2	
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GQ00503		1						500	5	100/50 mg Carbon Bead (SKC 226-80)
	Excess								500	6	Excess
NIOSH 1500	GQ00504		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GQ00505		1						1000	9	DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GQ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
5/4/2005											
RUN 6											
THC, CO, CO2,Nox	GQ006	X									TOTAL
M-18	GQ00601		1						30	1	Carbopak
	Excess								30	2	Excess
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GQ00602		1						500	5	100/50 mg Carbon Bead (SKC 226-80)
	Excess								500	6	Excess
NIOSH 1500	GQ00603		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GQ00604		1						1000	9	DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GQ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
5/5/2005											
RUN 7											
THC, CO, CO2,Nox	GQ007	X									TOTAL
M-18	GQ00701		1						30	1	Carbopak
	Excess								30	2	Excess
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GQ00702		1						500	5	100/50 mg Carbon Bead (SKC 226-80)
	Excess								500	6	Excess
NIOSH 1500	GQ00703		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GQ00704		1						1000	9	DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GQ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
5/5/2005											
RUN 8											
THC, CO, CO2,Nox	GQ008	X									TOTAL
M-18	GQ00801		1						30	1	Carbopak
	Excess								30	2	Excess
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GQ00802		1						500	5	100/50 mg Carbon Bead (SKC 226-80)
	Excess								500	6	Excess
NIOSH 1500	GQ00803		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GQ00804		1						1000	9	DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GQ - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
5/5/2005											
RUN 9											
THC, CO, CO2,Nox	GQ009	X									TOTAL
M-18	GQ00901		1						30	1	Carbopak
	Excess								30	2	Excess
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GQ00902		1						500	5	100/50 mg Carbon Bead (SKC 226-80)
	Excess								500	6	Excess
NIOSH 1500	GQ00903		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GQ00904		1						1000	9	DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

Series GQ

PCS Greensand Baseline with H&G Seacoal & Mechanized Molding
Process Instructions

A. Experiment: Create Greensand baseline. Measure emissions from a greensand mold made with all virgin Wexford W450 sand, bonded with Western & Southern Bentonite in the ratio of 5:2 to yield 7.0 +/- 0.5% MB Clay, and H & G Seacoal to yield 5.0 +/- 0.3% LOI. 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.

B. Materials:

1. Mold Sand: Virgin mix of Wexford W450 lake sand, western and southern bentonites in ratio of 5:2, and potable water per recipe.
2. Core: None
3. Metal: Class 30-35 gray cast iron poured at 2680 +/- 10°F.
4. Pattern Spray: Black Diamond hand wiped.
5. 20 ppi 2 x 2 x 0.5 ceramic foam filter.

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

6. The following test shall be conducted:
- **a.** Sand Batch : Single sand batch to be used for all GQ molds.
- **b.** The recycled sand heap shall be maintained at 900+-10 pounds
- **c.** The first three (3) runs will be conditioning runs numbered GQER1-3 and will be monitored by THC only.
- **d.** Emission sampling will begin on the fourth turn. Nine (9) satisfactory sampling runs numbered GQ001-009 will be conducted monitored by both THC and sorption tubes. Should a run GQ00X need to be repeated the run will be numbered GQ00Xa, b, or c etc. The shop supervisor will monitor to assure the numbering consistency of the process data.
- **e.** The shop supervisor and the sampling team technician will coordinate the numbering between the two groups.
- **f.** GQER1: Virgin mix as described above, un-vented mold.
- **g.** GQER2, GQER3, GQ001-GQ0XX: Re-cycled, re-mulled, reconstituted greensand, potable water, un-vented molds.

C. Sand preparation

1. Start up batch: make one, GQER1.
- **a.** Thoroughly clean the pre-production muller elevator and molding hoppers.
- **b.** Weigh and add 1225 +/-10 pounds of new Wexford W450 Lakesand, per the recipe, to the running pre-production muller to make a 1300 batch.

- **c.** Add 5 pounds of potable 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. Re-test. Repeat until the compactability 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 charge and discharge.
- **l.** The sand will be immediately characterized for Methylene Blue Clay, Moisture content, Compactability, Green Compression strength, 1800°F loss on ignition (LOI), and 900°F volatiles. Each volatile and LOI test requires a separate 50-gram sample from the collected sand.
- **m.** 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: GQER2

- **a.** Add to the sand recovered from poured mold GQER1sufficient 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 B.1.f.

3. Re-mulling: GQER3, GQ001-GQ0XX

- **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 B.1.f.

D. Molding: 4-on star pattern.

1. Pattern preparation:
    - **a.** Inspect and tighten all loose pattern and gating pieces.
    - **b.** Repair any damaged pattern or gating parts.
    - **c.** Hand wipe liquid parting on the pattern once each run.

2. Mount the drag 4-on star pattern with gating into the mold machine bolster and bolt it down tightly.
3. Mount a cope follower board containing a pour cup pattern to the underside of the squeeze head plate.
4. Check the alignment of the pour cup by manually raising the table using the squeeze bypass valve at the bottom rear of the machine until the sprue pierces the pour cup pattern. Move the pour cup pattern as necessary.
5. Remove the sprue if making a mold drag half. Leave it attached if making a cope half.
6. Use the overhead crane to place the pre-weighed drag/cope flask on the mold machine table, parting line surface down.
7. Locate a 24 x 24 x 4 inch deep wood upset on top of the flask.
8. Make the green sand mold 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.** 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.
- **h.** Fill the 24 x 24 x 10 inch flask and the upset with greensand from the overhead molding hopper.

i. Manually level sand in the upset. By experience manually adjust the sand depth so that the resulting compacted mold is fractionally above the flask only height.

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.

j. Initiate the settling of the sand in the flask by pressing the PRE-JOLT push button. Allow this cycle to stop before proceeding.

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.

k. Using both hands initiate the automatic machine sequence by simultaneously pressing 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.

l. Remove the upset and set it aside.
m. Screed the bottom of the mold flat if required.
n. Press and release the LOWER DRAW/STOP push button to separate the flask and mold from the pattern.
o. Use the overhead crane to lift the mold half and remove it from the machine.
p. Finally, press and release the draw down pushbutton to cause the draw frame to return to the start position.

9. If the mold half is a drag, roll it parting line side up, set it on the floor, blow it out, insert foam filter, and cover it to keep it clean.
10. Close the cope over the drag being careful not to crush anything.
11. Clamp the flask halves together.
12. Weigh and record the weight of the closed un-poured mold, the pre-weighed flask, and the sand weight by difference
13. Deliver the mold to the previously cleaned shakeout to be poured.
14. Cover the mold with the emission hood.

E. Shakeout
1. After the cooling time prescribed in the test plan, turn on the shakeout unit and run it until the greensand has passed into the hopper below. Turn off the shakeout.
2. When the emission sampling is completed remove the flask with casting, and recover the sand from the hopper and surrounding floor.

3. **3.** Weigh and record the metal poured and the total sand weight recovered and rejoined with the left over mold sand from the molding hopper.
4. **4.** Add the un-used pre-mixed sand to the recycled sand to return the sand heap to 900 +/- 10 pounds.

F. Melting:

1. Initial 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 on top.
- **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 E.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.

G. Pouring:

1. Preheat the ladle.

- **a.** Tap 400 pounds more or less of 2700°F metal into the cold ladle.
- **b.** Casually pour the metal back to 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 2680 +/- 10°F.
- **h.** Commence pouring keeping the sprue full.

i. Upon completion return the extra metal to the furnace, and cover the ladle.

H. Rank order evaluation.

1. Ranking was not performed on these castings

Steven Knight
Mgr. Process Engineering

APPENDIX B TEST SERIES GQ DETAILED EMISSION RESULTS

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Test Plan GQ Individual Emission Test Results – Lb/Tn Metal

VOC	POM	HAP	Analyte Name	GQ001	GQ002	GQ003	GQ004	GQ005	GQ006	GQ007	GQ008	GQ009	Average	St. Dev.
			Test Dates	03-May-05	03-May-05	03-May-05	04-May-05	04-May-05	04-May-05	05-May-05	05-May-05	05-May-05	–	–
			Emission Indicators											
			TGOC as Propane	3.46E+00	3.77E+00	3.66E+00	3.18E+00	3.17E+00	2.97E+00	2.98E+00	3.30E+00	2.80E+00	3.25E+00	3.26E-01
	Y	Y	**HC as Hexane**	7.04E-01	NT	7.14E-01	7.66E-01	7.09E-01	7.09E-01	6.51E-01	6.98E-01	6.58E-01	7.01E-01	3.54E-02
			Sum of Target Analytes	4.89E-01	NT	4.63E-01	4.66E-01	4.68E-01	4.49E-01	3.89E-01	4.66E-01	3.78E-01	4.51E-01	3.77E-02
			Sum of HAPs	4.22E-01	NT	3.99E-01	4.02E-01	4.02E-01	3.83E-01	3.31E-01	3.92E-01	3.21E-01	3.82E-01	3.38E-02
			Sum of POMs	3.30E-02	NT	3.94E-02	2.03E-02	2.12E-02	2.12E-02	1.83E-02	2.24E-02	1.98E-02	2.46E-02	7.06E-03
			Individual Target Organic HAPs and POMs											
Y		Y	Benzene	1.84E-01	NT	1.64E-01	1.71E-01	1.74E-01	1.53E-01	1.35E-01	1.61E-01	1.28E-01	1.59E-01	1.92E-02
Y		Y	Toluene	8.60E-02	NT	8.04E-02	8.54E-02	8.51E-02	8.51E-02	6.74E-02	8.16E-02	6.51E-02	7.95E-02	8.42E-03
Y		Y	Xylene, mp-	3.32E-02	NT	3.04E-02	3.38E-02	3.32E-02	3.32E-02	3.04E-02	3.45E-02	3.00E-02	3.23E-02	1.77E-03
Y		Y	Xylene, o-	1.92E-02	NT	1.77E-02	1.94E-02	1.91E-02	1.91E-02	1.79E-02	2.03E-02	1.72E-02	1.87E-02	1.04E-03
Y		Y	Hexane	1.72E-02	NT	1.87E-02	1.69E-02	1.71E-02	1.71E-02	1.61E-02	1.92E-02	1.27E-02	1.69E-02	1.97E-03
Y		Y	Phenol	1.27E-02	NT	1.31E-02	1.42E-02	1.34E-02	1.34E-02	1.19E-02	1.46E-02	1.19E-02	1.31E-02	9.49E-04
Y	Y	Y	Naphthalene	8.64E-03	NT	8.55E-03	1.04E-02	1.12E-02	1.12E-02	1.06E-02	1.27E-02	1.09E-02	1.05E-02	1.38E-03
Y		Y	Ethylbenzene	1.03E-02	NT	9.49E-03	1.02E-02	1.01E-02	1.01E-02	8.32E-03	1.02E-02	8.43E-03	9.64E-03	8.21E-04
Y	Y	Y	Methylnaphthalene, 1-	1.83E-02	NT	2.61E-02	4.58E-03	4.10E-03	4.10E-03	3.08E-03	3.78E-03	3.64E-03	8.46E-03	8.74E-03
Y		Y	Acetaldehyde	7.34E-03	NT	6.41E-03	7.87E-03	6.78E-03	6.78E-03	7.33E-03	6.58E-03	6.77E-03	6.98E-03	4.88E-04
Y	Y	Y	Indene	5.57E-03	NT	4.72E-03	5.35E-03	5.46E-03	5.46E-03	4.57E-03	5.44E-03	4.84E-03	5.18E-03	3.97E-04
Y		Y	Cresol, o-	3.77E-03	NT	4.35E-03	4.60E-03	4.65E-03	5.26E-03	3.81E-03	5.12E-03	4.08E-03	4.45E-03	5.59E-04
Y		Y	Formaldehyde	3.85E-03	NT	2.59E-03	4.55E-03	4.12E-03	4.12E-03	4.37E-03	2.90E-03	3.85E-03	3.80E-03	6.94E-04
Y		Y	Methylnaphthalene, 2-	2.26E-03	NT	2.54E-03	3.29E-03	3.51E-03	3.51E-03	3.48E-03	4.51E-03	3.51E-03	3.33E-03	6.86E-04
Y		Y	Styrene	3.30E-03	NT	2.98E-03	3.11E-03	3.03E-03	3.03E-03	2.49E-03	2.74E-03	2.63E-03	2.91E-03	2.68E-04
Y		Y	Cresol, mp-	2.30E-03	NT	2.89E-03	2.96E-03	3.01E-03	3.71E-03	ND	2.56E-03	2.53E-03	2.85E-03	4.61E-04
Y		Y	2-Butanone (MEK)	2.25E-03	NT	2.15E-03	2.70E-03	2.52E-03	2.52E-03	2.53E-03	2.62E-03	2.65E-03	2.49E-03	1.94E-04
Y		Y	Propionaldehyde (Propanal)	1.36E-03	NT	1.21E-03	1.48E-03	1.30E-03	1.30E-03	1.32E-03	1.27E-03	1.24E-03	1.31E-03	8.36E-05
Y	Y	Y	Dimethylnaphthalene, 1,3-	4.72E-04	NT	ND	ND	4.37E-04	4.37E-04	ND	4.34E-04	4.45E-04	4.45E-04	1.58E-05
Y	Y	Y	Acenaphthalene	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	Dimethylnaphthalene, 1,2-	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	Dimethylnaphthalene, 1,5-	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	Dimethylnaphthalene, 1,6-	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	Dimethylnaphthalene, 1,8-	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	Dimethylnaphthalene, 2,3-	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	Dimethylnaphthalene, 2,6-	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	Dimethylnaphthalene, 2,7-	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	Trimethylnaphthalene, 2,3,5-	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y		Y	Acrolein	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y		Y	Biphenyl	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA

Test Plan GQ Individual Emission Test Results – Lb/Tn Metal

VOC	POM	HAP	Analyte Name	GQ001	GQ002	GQ003	GQ004	GQ005	GQ006	GQ007	GQ008	GQ009	Average	St. Dev.
			Individual Target VOCs, not including HAPs and POMs											
Y			Hexaldehyde	3.87E-04	NT	4.03E-04	4.32E-04	3.98E-04	3.98E-04	3.77E-04	4.23E-04	4.38E-04	4.07E-04	2.20E-05
Y			Pentanal (Valeraldehyde)	5.10E-04	NT	5.06E-04	5.37E-04	4.96E-04	4.96E-04	4.79E-04	4.92E-04	5.06E-04	5.03E-04	1.69E-05
Y			o,m,p-Tolualdehyde	ND	NT	5.20E-04	6.50E-04	5.78E-04	5.78E-04	5.80E-04	6.70E-04	6.96E-04	6.10E-04	6.28E-05
Y			Butyraldehyde/Methacrolein	8.32E-04	NT	7.60E-04	8.73E-04	7.98E-04	7.98E-04	8.05E-04	7.64E-04	7.97E-04	8.03E-04	3.61E-05
Y			Ethyltoluene, 2-	ND	NT	ND	7.77E-04	8.47E-04	8.47E-04	ND	ND	ND	8.24E-04	4.03E-05
Y			Benzaldehyde	1.66E-03	NT	1.53E-03	1.89E-03	1.86E-03	1.86E-03	1.94E-03	1.99E-03	2.11E-03	1.85E-03	1.83E-04
Y			Propylbenzene, n-	ND	NT	ND	ND	ND	ND	ND	2.11E-03	ND	2.11E-03	NA
Y			Diethylbenzene, 1,3-	2.38E-03	NT	ND	ND	ND	ND	ND	ND	ND	2.38E-03	NA
Y			Indan	3.47E-03	NT	2.99E-03	3.61E-03	3.54E-03	3.54E-03	3.23E-03	3.71E-03	3.12E-03	3.40E-03	2.56E-04
Y			Trimethylbenzene, 1,2,3-	5.21E-03	NT	4.28E-03	5.22E-03	5.09E-03	5.09E-03	4.75E-03	5.01E-03	4.60E-03	4.91E-03	3.35E-04
Y			Ethyltoluene, 3-	6.36E-03	NT	5.63E-03	6.57E-03	6.42E-03	6.42E-03	5.97E-03	6.82E-03	5.76E-03	6.24E-03	4.14E-04
Y			Decane	7.98E-03	NT	7.70E-03	8.04E-03	8.36E-03	8.36E-03	7.65E-03	8.14E-03	7.21E-03	7.93E-03	3.93E-04
Y			Nonane	9.79E-03	NT	9.77E-03	9.49E-03	9.60E-03	9.60E-03	9.05E-03	1.06E-02	8.37E-03	9.54E-03	6.42E-04
Y			Octane	1.22E-02	NT	1.30E-02	1.15E-02	1.17E-02	1.17E-02	1.03E-02	1.40E-02	1.05E-02	1.19E-02	1.22E-03
Y			Heptane	1.64E-02	NT	1.76E-02	1.50E-02	1.67E-02	1.67E-02	1.35E-02	1.92E-02	1.28E-02	1.60E-02	2.11E-03
Y			Crotonaldehyde	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y			Dimethylphenol, 2,4-	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y			Dimethylphenol, 2,6-	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y			Dodecane	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y			Tetradecane	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y			Trimethylbenzene, 1,2,4-	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y			Trimethylbenzene, 1,3,5-	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y			Undecane	ND	NT	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y			Cyclohexane	ND	NT	ND	ND	ND	ND	ND	ND	ND	ND	ND
			Criteria Pollutants and Greenhouse Gases											
			Carbon Monoxide	5.02E+00	6.06E+00	6.39E+00	4.76E+00	5.49E+00	4.88E+00	5.09E+00	6.41E+00	5.27E+00	5.49E+00	6.44E-01
			Carbon Dioxide	1.37E+01	9.22E+00	1.08E+01	1.35E+01	1.53E+01	1.36E+01	1.36E+01	1.16E+01	1.51E+01	1.29E+01	2.00E+00
			Nitrogen Oxides	4.29E-03	6.02E-03	6.48E-03	6.00E-03	5.62E-03	6.25E-03	6.04E-03	5.23E-03	5.26E-03	5.69E-03	6.73E-04
			Sulfur Dioxide[1]	2.61E-02	NT	3.00E-02	2.65E-02	3.21E-02	3.21E-02	2.57E-02	2.87E-02	3.52E-02	2.96E-02	3.43E-03

[1] Integrated sample taken using adsorbent tube
NT: Not Tested
ND: Not Detected
NA: Not Applicable

Test Plan GQ Quantitation Limits – Lb/Tn Metal

Analyte	Practical Reporting Limit lb/ton
Carbon Monoxide	5.62E-02
Carbon Dioxide	5.62E-02
Nitrogen Oxides	5.62E-02
Acenaphthalene	2.53E-03
Benzene	5.06E-04
Biphenyl	2.53E-03
Cresol, mp-	2.53E-03
Cresol, o-	2.53E-03
Cyclohexane	2.53E-03
Decane	2.53E-03
Diethylbenzene, 1,3-	2.53E-03
Dimethylnaphthalene, 1,2-	2.53E-03
Dimethylnaphthalene, 1,3-	5.06E-04
Dimethylnaphthalene, 1,5-	2.53E-03
Dimethylnaphthalene, 1,6-	2.53E-03
Dimethylnaphthalene, 1,8-	2.53E-03
Dimethylnaphthalene, 2,3-	2.53E-03
Dimethylnaphthalene, 2,6-	2.53E-03
Dimethylnaphthalene, 2,7-	2.53E-03
Dimethylphenol, 2,4-	2.53E-03

[1] Integrated sample with absorbent tube.

Analyte	Practical Reporting Limit lb/ton
Dimethylphenol, 2,6-	2.53E-03
Dodecane	2.53E-03
Ethylbenzene	5.06E-04
Ethyltoluene, 2-	5.06E-04
Ethyltoluene, 3-	2.53E-03
Heptane	2.53E-03
Hexane	5.06E-04
Indan	2.53E-03
Indene	2.53E-03
Methylnaphthalene, 1-	5.06E-04
Methylnaphthalene, 2-	5.06E-04
Naphthalene	5.06E-04
Nonane	2.53E-03
Octane	2.53E-03
Phenol	2.53E-03
Propylbenzene, n-	2.53E-03
Styrene	5.06E-04
Tetradecane	2.53E-03
THC as Undecane	2.53E-03
Toluene	5.06E-04
Trimethylbenzene, 1,2,3-	5.06E-04

Analyte	Practical Reporting Limit lb/ton
Trimethylbenzene, 1,2,4-	5.06E-04
Trimethylbenzene, 1,3,5-	5.06E-04
Trimethylnaphthalene, 2,3,5-	2.53E-03
Undecane	5.06E-04
Undecane	1.26E-03
Xylene, mp-	5.06E-04
Xylene, o-	5.06E-04
Sulfur Dioxide[1]	5.43E-03
THCs as n-Hexane	6.57E-03
2-Butanone (MEK)	1.94E-04
Acetaldehyde	1.94E-04
Acetone	1.94E-04
Acrolein	1.94E-04
Benzaldehyde	1.94E-04
Butyraldehyde/Methacrolein	3.23E-04
Crotonaldehyde	1.94E-04
Formaldehyde	1.94E-04
Hexaldehyde	1.94E-04
o,m,p-Tolualdehyde	5.17E-04
Pentanal (Valeraldehyde)	1.94E-04
Propionaldehyde (Propanal)	1.94E-04

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APPENDIX C TEST SERIES GQ DETAILED PROCESS DATA

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Test GQ Detailed Process Data

Greensand PCS							
Pour Date	**5/2/2005**	**5/2/2005**	**5/2/2005**	**5/3/2005**	**5/3/2005**	**5/3/2005**	**5/4/2005**
Emissions Sample #	**GQER1**	**GQER2**	**GQER3**	**GQ001**	**GQ002**	**GQ003**	**GQ004**
Production Sample #	**GQ001**	**GQ002**	**GQ003**	**GQ004**	**GQ005**	**GQ006**	**GQ007**
Cast Weight - All Metal Inside Mold (lbs.)	92.45	85.60	90.20	91.25	92.15	92.20	91.15
Pouring Time (sec.)	19	17	14	15	13	13	14
Pouring Temp (°F)	2673	2684	2674	2680	2668	2685	2679
Pour Hood Process Air Temp at Start of Pour (°F)	87.3	86.7	86.7	86.7	86.9	86.7	85.6
Muller Batch Weight (lbs.)	1362	900	900	900	900	900	900
GS Mold Sand Weight, (lbs.)	657	651	648	647	643	647	651
Mold Compactability, %	56	55	53	53	55	54	53
Mold Temperature (°F)	67.0	72.0	86.9	73.6	73.3	75.1	71.5
Average Green Compression (psi)	12.97	16.22	17.68	15.58	17.75	16.94	15.87
GS Compactability (%)	55	53	42	41	47	41	50
GS Moisture Content (%)	2.00	1.62	1.54	1.62	1.86	1.84	2.20
GS MBClay Content (%)	5.84	5.64	5.64	5.44	5.54	5.24	5.24
MB Clay Reagent, ml	29.0	28.0	28.0	27.0	27.5	26.0	26.0
1800°F LOI - Mold Sand (%)	4.80	4.76	4.82	4.99	5.08	5.14	5.39
900°F Volatiles (%)	1.24	1.18	1.16	1.24	1.20	1.16	1.20

Test GQ Detailed Process Data

Greensand PCS						
Pour Date	**5/4/2005**	**5/4/2005**	**5/5/2005**	**5/5/2005**	**5/5/2005**	**Average**
Emissions Sample #	**GQ005**	**GQ006**	**GQ007**	**GQ008**	**GQ009**	
Production Sample #	**GQ008**	**GQ009**	**GQ010**	**GQ011**	**GQ012**	
Cast Weight - All Metal Inside Mold (lbs.)	88.05	86.70	90.10	92.90	91.35	**90.65**
Pouring Time (sec.)	14	14	15	13	15	**14**
Pouring Temp (°F)	2672	2689	2673	2682	2688	**2680**
Pour Hood Process Air Temp at Start of Pour (°F)	88.7	86.7	86.9	85.8	86.7	**87**
Muller Batch Weight (lbs.)	900	900	900	900	900	**900**
GS Mold Sand Weight, (lbs.)	640	650	644	646	647	**646**
Mold Compactability, %	53	56	52	52	54	**54**
Mold Temperature (°F)	72.5	74.8	73.0	74.7	80.3	**74**
Average Green Compression (psi)	18.89	16.74	16.41	16.52	16.09	**16.75**
GS Compactability (%)	53	48	44	43	45	**46**
GS Moisture Content (%)	1.88	2.16	2.08	1.92	2.02	**1.95**
GS MBClay Content (%)	5.22	5.02	5.42	4.81	5.22	**5.24**
MB Clay Reagent, ml	26.0	25.0	27.0	24.0	26.0	**26.1**
1800°F LOI - Mold Sand (%)	5.43	5.50	5.62	5.56	5.66	**5.37**
900°F Volatiles (%)	1.24	1.18	1.06	1.20	1.14	**1.18**

APPENDIX D METHOD 25A CHARTS

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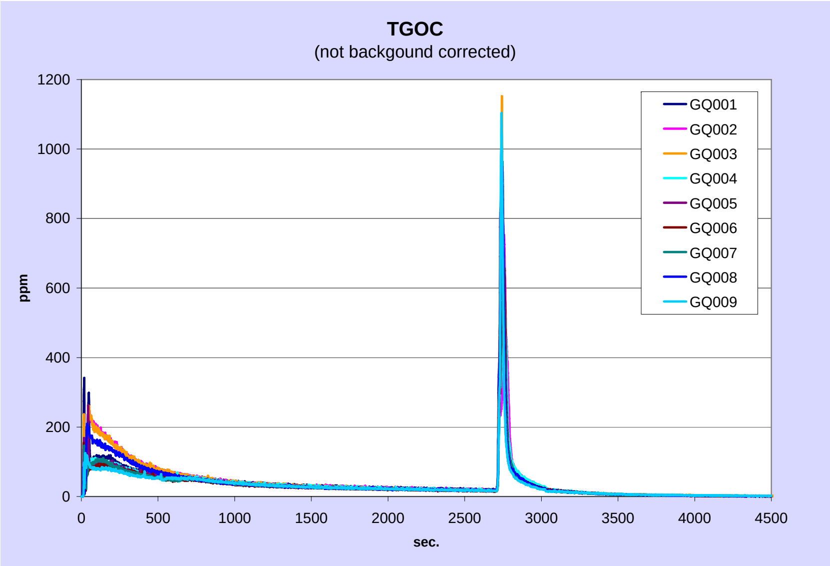
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GQ003
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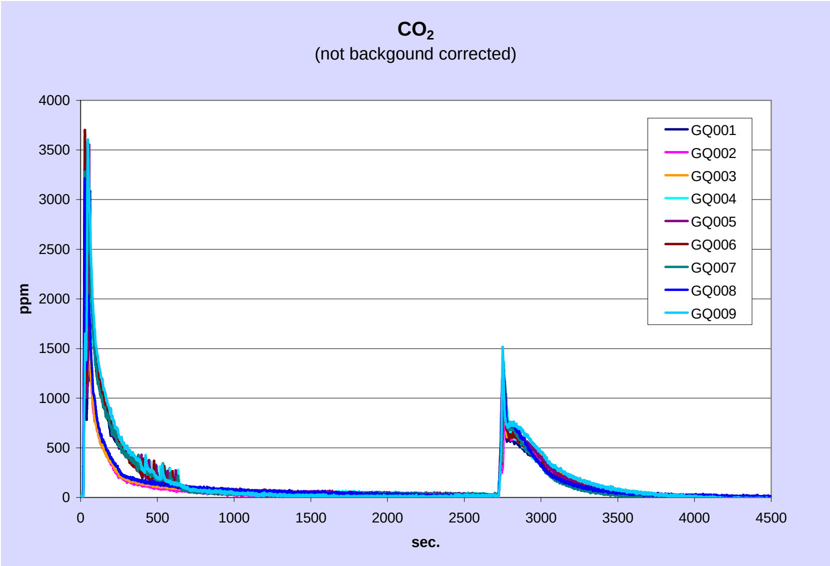
GQ006
GQ007
GQ008
GQ009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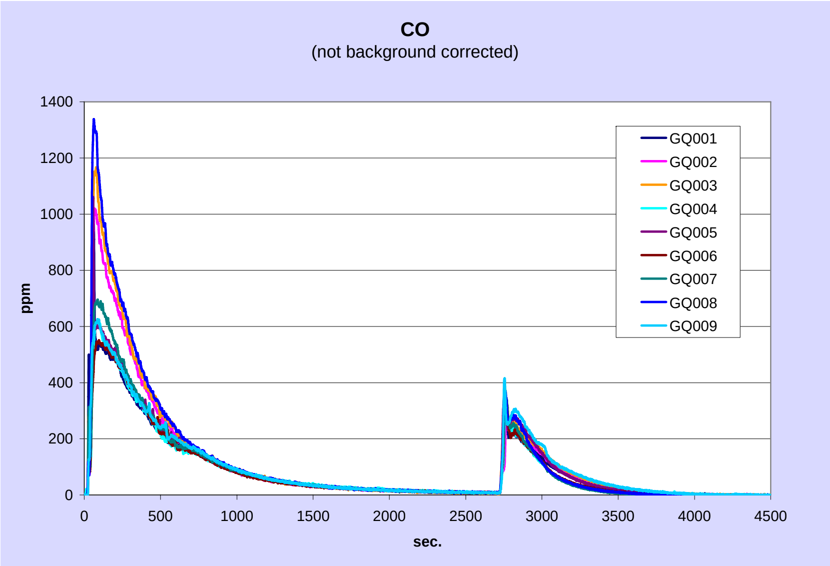
GQ009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GQ002
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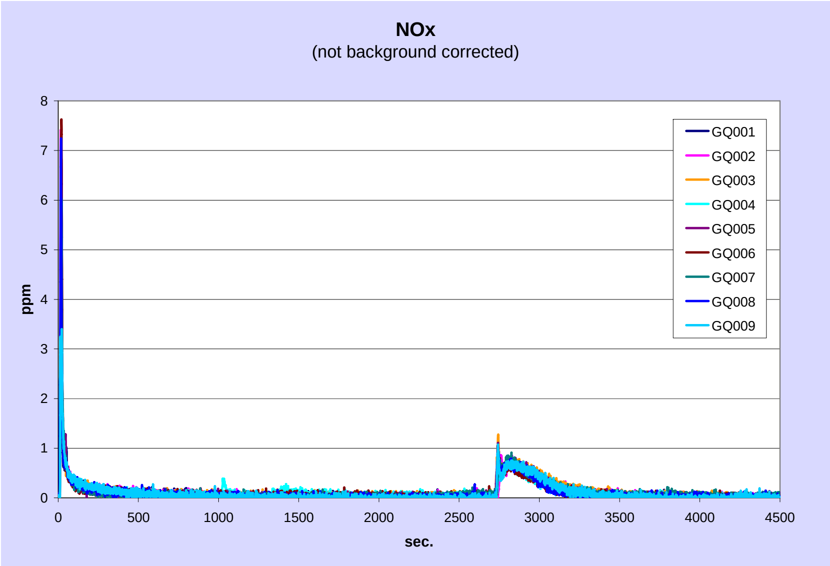
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(not background corrected)
ppm
sec.
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GQ002
GQ003
GQ004
GQ005
GQ006
GQ007
GQ008
GQ009

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APPENDIX E ACRONYMS AND ABBREVIATIONS

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Acronyms and Abbreviations

BO	Based on ( ).
BOS	Based on Sand.
HAP	Hazardous Air Pollutant defined by the 1990 Clean Air Act Amendment
HC as Hexane	Calculated by the summation of all area between elution of hexane through the elution of hexadecane. The quantity of HC is performed against a five-point calibration curve of hexane by dividing the total area count from C_6 through C_{16} to the area of hexane from the initial calibration curve.
I	Data rejected based on data validation considerations
NA	Not Applicable
ND	Non-Detect
NT	Lab testing was not done
POM	Polycyclic organic matter (POM) including naphthalene and other compounds that contain more than one benzene ring and have a boiling point greater than or equal to 100 degrees Celsius.
TGOC as Propane	Weighted to the detection of more volatile hydrocarbon species, beginning at C_1 (methane), with results calibrated against a three-carbon alkane (propane).
VOC	Volatile organic compound