Casting Emission Reduction Program
www.cerp-us.org

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Baseline Test:
Pouring, Cooling, Shakeout of Uncoated Hot Box Core in Greensand without Seacoal, Iron

Technikon # 1411-122 GH

May 2005
Revised for public distribution

United States Environmental Protection Agency
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1411-122 GH

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

Process Engineering Manager	*// Original Signed //*	
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The data contained in this report were developed to provide a relative emissions baseline profile for future product or process evaluation. You may not obtain the same results in your facility. Data was not collected to assess cost or producibility.

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Executive Summary

This report contains the results of emission testing to evaluate the pouring, cooling, and shakeout emissions from Baseline GH, an uncoated HOTBOX core in a mold consisting of greensand without seacoal. Baseline GH will be used as a core baseline against which other HOTBOX products and processes are to be compared. Results are compared, for the convenience of the reader, to Reference Test FR that also used greensand molds without seacoal but with uncoated Phenolic Urethane step cores. All testing was conducted by Technikon, LLC in its Research Foundry. The emissions results are reported in both pounds of analyte per pound of binder and 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-six (56) target compounds using procedures based on US EPA Method 18. Continuous monitoring of the Total Gaseous Organic Concentration (TGOC) and the Carbon Dioxide, Carbon Monoxide, and Nitrogen Oxide concentrations in the emissions was conducted according to US EPA Methods 25A, 3A, 10, and 7E respectively.

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 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.

Results for the emission indicators are shown in the following table reported in both pounds per pound (lbs/lb) of binder and pounds per ton (lbs/ton) of metal. For the convenience of the reader, Reference Test FR Phenolic Urethane values are also shown.

Test Plans Reference FR & Baseline GH Emissions Indicators

	TGOC as Propane	HC as Hexane	Sum of Target Analytes	Sum of Target Haps	Sum of Target POMs
Baseline GH (Lb/Lb Binder)	0.0315	0.0082	0.0068	0.0064	0.0001
Baseline GH (Lb/ Ton Metal)	0.3024	0.0789	0.0655	0.0611	0.0005
Reference FR (Lb/Lb Binder)	0.1480	0.0482	0.0591	0.0554	0.0169
Reference FR (Lb/Ton Metal)	0.9259	0.3016	0.3705	0.3474	0.1059

A pictorial casting record was made of cavity #3 from each mold for reference to future castings made with vendor products. The pictures are shown in rank-order in Appendix C.

It must be noted that the baseline testing performed is not suitable for use as emission factors or for purposes other than evaluating the relative emission reductions associated with the use of alternative materials, equipment, or processes. The emissions measurements are unique to the specific castings produced, materials used, and testing methodology associated with these tests, and 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 mobile 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). Its purpose is to evaluate alternative casting materials and processes that are designed to reduce air emissions and/or produce more efficient casting processes. Other technical partners directly supporting the project include: 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 Technikon 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, especially for the 1990 Clean Air Act Amendment. The facility has two principal testing arenas: a Research Foundry designed to measure airborne emissions from individually poured molds, and a Production Foundry designed to measure air emissions in a continuous full scale production process. Each of these testing arenas has been specially designed to facilitate the collection and evaluation of airborne emissions and associated process data.

The Production Foundry provides simultaneous detailed individual emission measurements using methods based on US EPA protocols for the melting, pouring, sand preparation, mold making, and core making processes.

It must be noted that the baseline testing performed is not suitable for use as emission factors or for purposes other than evaluating the <u>relative emission</u> 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, and should not be used as the basis for estimating emissions from actual commercial foundry applications.

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 VOC emissions from a cored 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 the appendices 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

	Reference Test Plan FR	Baseline Test Plan GH
Type of Process Tested	Phenolic Urethane Core, Greensand without Seacoal, Iron PCS	Hot Box Core, Greensand without Seacoal, Iron PCS Baseline
Test Plan Number	1410 114 FR	1410 122 GH
Greensand System	Wexford W450 Lakesand, Western and Southern Bentonite, No Seacoal	Wexford W450 Lakesand, Western and Southern Bentonite, No Seacoal
Metal Poured	Iron	Iron
Casting Type	4-on Step Core	4-on Step Core
Core	1.4% Ashland ISOCURE® 305/904 Phenolic Urethane Binder System Amador A-70 Silica Sand	1.6% (BOS) HA International 747/89FR Hot Box Binder System, Wedron 530 Silica sand
Core Coating	None	None
Number of Molds Poured	3 Conditioning and 4 Sampling	3 Conditioning and 9 Sampling
Test Dates	1/12/04 through 1/30/04	11/8/04 through 11/12/04
Emissions Measured	TGOC as Propane, HC as Hexane, and 68 Targeted Organic HAPs and VOCs	TGOC as Propane, HC as Hexane, Carbon Monoxide, Carbon Dioxide, Nitrogen Oxides, Ammonia and 56 Targeted Organic HAPs and VOCs
Process Parameters Measured	Total Casting, Mold, Binder Weights; Metallurgical data, % LOI; Stack Temperature, Moisture Content, Sand Temperature, Pressure and Volumetric Flow Rate	Total Casting, Mold, Binder Weights; Metallurgical data, % LOI; Stack Temperature, Moisture Content, Sand Temperature, Pressure, and Volumetric Flow Rate

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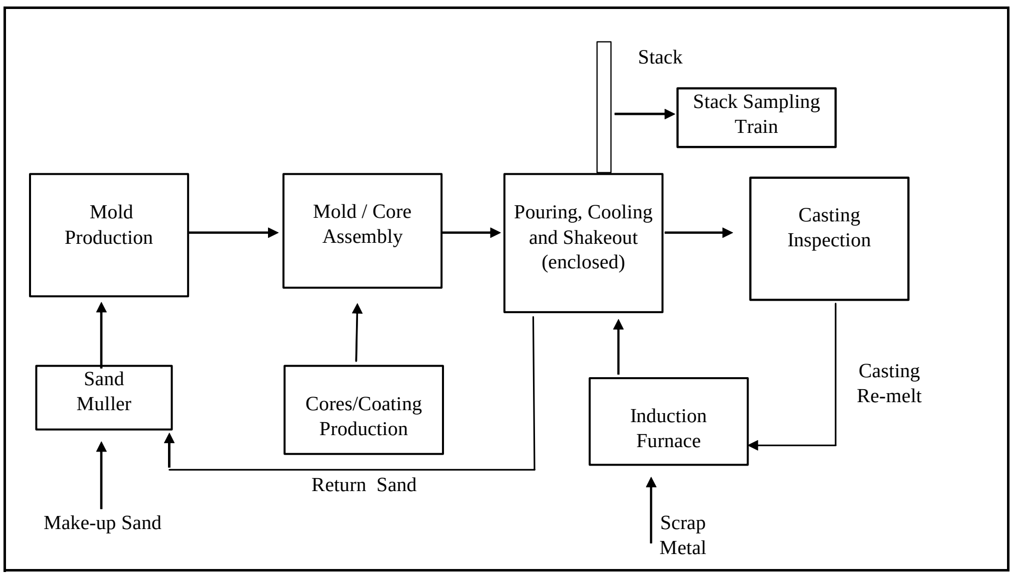
2.0 Test Methodology

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. **<u>Test Plan Review and Approval:</u>** The proposed test plan was reviewed and approved by the Technikon staff.

2. **<u>Mold, Core and Metal Preparation:</u>** The molds were prepared to a standard composition by the Technikon production team. The cores were supplied by the University of Northern Iowa to Technikon specification. Relevant process data was 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.

3. **<u>Individual Sampling Events:</u>** Replicate tests were performed on nine (9) mold packages after the conclusion of three (3) conditioning cycles. The mold packages were placed into an enclosed test stand heated to approximately 85°F. Iron was poured through an opening in the top of the emission enclosure, after which the opening was closed.

   Continuous air samples were collected during the forty-five minute 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 was seventy-five minutes.

Uncoated Step Cores in mold

Total Enclosure Test Stand

Continuous Monitoring Instrument

4. **<u>Process Parameter Measurements:</u>** 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)
Muller water weight	Cardinal 748E platform scale (Gravimetric)
Binder Weight, Core Weight	Mettler SB12001 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. **<u>Air Emissions Analysis:</u>** The 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 <u>Technikon Standard Operating Procedures.</u>

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, TO-17, NIOSH 1500, 2002
VOCs Concentration	EPA Method 18, 25A, TO11, TO-17, NIOSH 1500, 2002
Carbon Monoxide	EPA Method 10
Carbon Dioxide	EPA Method 3A
Nitrogen Oxides	EPA Method 7E

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

6. **<u>Data Reduction, Tabulation and Preliminary Report Preparation:</u>** 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 binder used or the weight of the

casting poured to provide emissions data in both pounds of analyte per pound of binder and pounds of analyte per ton of metal.

The results of each of the sampling events are included in the appendices of this report. The emissions results are also averaged and are shown in Tables 3-1 and 3-3.

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.

3.0 Test Results

The average emission results in pounds per pound (lbs/lb) of binder and pounds per ton (lbs/ton) of metal are presented comparatively to Reference Test FR in Tables 3-1 and 3-2 respectively. The tables include the individual target compounds that comprise at least 95% of the VOCs measured, along with the corresponding Sum of Target Analytes, Sum of Target HAPs, and Sum of Target POMs. The tables also include the TGOC as propane, HC as hexane, and selected criteria and greenhouse gases such as carbon monoxide, carbon dioxide, and nitrogen oxides.

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 o,m,p-xylene. Trimethylbenzenes and dimethylphenols are also 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 (volatile organic compounds). 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.

A determination of whether the means of the emissions from Reference Test FR and the current test, Baseline Test GH, were different was made by calculating a statistical T-test at a 95% significance level ($\alpha = 0.05$). Significance is indicated in Tables 3-1 and 3-2 by a bold format on the values in the "% Change from Baseline" column.

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

The ranking of casting appearance is in Table 3-4. Each casting from the third cavity of the mold from the Reference Test FR was compared to the other third cavity castings produced in this test. Three benchmark visual casting quality rankings consisting of the best, the median, and the worst casting were then assigned to three of the nine castings. The "best" designation means that a casting is the best appearing casting of the lot of nine, and is given a rank of "1". The "median" designation, given a rank of "5", means that four castings are better in appearance and four are worse. The "worst" designation is assigned to that casting which is of the poorest quality, and is assigned a rank of "9". The castings from Baseline Test GH underwent the same evaluative procedure. The three-benchmark castings from Test FR then were compared and collated to the benchmark castings from Test GH.

Figures 3-1 through 3-3 present the comparative five emissions indicators and selected individual HAP and VOC emissions data from Table 3-1 in graphical form. Similarly, Figures 3-3 and 3-4 present the comparative five emissions indicators and selected HAP and VOC emissions data in lb/ton of metal from Table 3-2 in graphical form.

Appendix B contains the detailed emissions data including the results for all analytes measured for both Baseline GH and Reference FR.

Detailed process data for both tests are presented in Appendix C.

All cavity 3 castings are photographically shown in Appendix C.

TGOC, criteria pollutants, and greenhouse gas charts for both tests are included in Appendix D of this report. The charts are presented to show time-dependent emissions profiles for each pour.

Table 3-1 Comparison Between Reference Test FR and Baseline Test GH - Average Lb/Lb Binder

Compound	Reference FR	Baseline GH	% Change from Reference
Emission Indicators			
TGOC as Propane	0.1480	0.0315	**-79**[1]
HC as Hexane	0.0482	0.0082	**-83**
Sum of Target Analytes	0.0591	0.0068	**-88**
Sum of Target HAPs	0.0554	0.0064	**-89**
Sum of Target POMs	0.0169	0.0001	**-100**
Individual Target HAPs and VOCs[2]			
Benzene	0.0174	0.0032	**-82**
Toluene	0.0026	0.0011	**-56**
Phenol	0.0113	0.0008	**-93**
o,m,p-Xylene	0.0010	0.0006	**-44**
o,m,p-Cresol	0.0030	0.0004	**-88**
Acetaldehyde	0.0005	0.0003	**-47**
Trimethylbenzenes	0.0013	0.0003	**-79**
Formaldehyde	0.0001	0.0002	**91**
Dimethylphenols	0.0003	<0.0001[3]	NA
Hexane	0.0001	<0.0001	NA
Ethylbenzene	0.0001	<0.0001	NA
Naphthalene	0.0062	<0.0001	NA
Pentanal	ND[4]	<0.0001	NA
Butyraldehyde/Methacrolein	0.0001	<0.0001	NA
Benzaldehyde	<0.0001	<0.0001	NA
2-Butanone	<0.0001	<0.0001	NA
Hexaldehyde	ND	<0.0001	NA
Methylnaphthalenes	0.0085	ND	NA
Biphenyl	0.0001	ND	NA
Dimethylnaphthalenes	0.0022	ND	NA
Styrene	0.0003	ND	NA
Propionaldehyde	<0.0001	ND	NA
1,3-Diethylbenzene	0.0002	ND	NA
Dodecane	0.0004	ND	NA
Ethyltoluenes	0.0005	ND	NA
Heptane	<0.0001	ND	NA
Indene	0.0004	ND	NA
Propylbenzene	0.0002	ND	NA
Tetradecane	0.0001	ND	NA
Undecane	0.0002	ND	NA
Additional Target Analytes, Criteria Pollutants and Greenhouse Gases			
Ammonia	0.0057	0.0017	NA
Carbon Dioxide	2.9959[5]	0.5481	**-82**
Carbon Monoxide	NT	0.2021	NA
Nitrogen Oxides	NT	0.0017	NA

[1] Bold numbers indicate those compounds whose calculated t-statistic is significant at alpha=0.05.
[2] Individual results constitute > 95% of mass of all detected target analytes.
[3] Values reported as <0.0001 were measured as being above the detection limit but were below the reporting limit of 0.0001.
[4] ND: Non Detect; NA: Not Applicable; NT: Not Tested.
[5] The carbon dioxide and carbon monoxide results were generated via the collection of bag samples. These results do not have the accuracy of the continuous monitoring results.

Table 3-2 Comparison Between Reference Test FR and Baseline Test GH - Average Lb/Ton Metal

Compound	Reference FR	Baseline GH	% Change from Reference
Emission Indicators			
TGOC as Propane	0.9259	0.3024	**-67**[1]
HC as Hexane	0.3016	0.0789	**-74**
Sum of Target Analytes	0.3705	0.0655	**-82**
Sum of Target HAPs	0.3474	0.0611	**-82**
Sum of Target POMs	0.1059	0.0005	**-100**
Individual Target HAPs and VOCs [2]			
Benzene	0.1088	0.0303	**-72**
Toluene	0.0161	0.0109	-32
Phenol	0.0707	0.0075	**-89**
o,m,p-Xylene	0.0064	0.0061	-5
o,m,p-Cresol	0.0187	0.0028	**-85**
Acetaldehyde	0.0034	0.0028	-19
Trimethylbenzenes	0.0079	0.0026	**-67**
Formaldehyde	0.0008	0.0023	194
Dimethylphenols	0.0017	0.0008	**-51**
Hexane	0.0006	0.0008	38
Ethylbenzene	0.0007	0.0006	-23
Naphthalene	0.0389	0.0005	**-99**
Pentanal	ND[3]	0.0004	NA
Butyraldehyde/Methacrolein	0.0004	0.0003	-27
Benzaldehyde	0.0002	0.0002	3
2-Butanone	0.0002	0.0002	-9
Hexaldehyde	ND	0.0001	NA
Dimethylnaphthalenes	0.0082	ND	NA
Methylnaphthalenes	0.0533	ND	NA
Biphenyl	0.0007	ND	NA
Styrene	0.0017	ND	NA
Propionaldehyde	0.0002	ND	NA
1,3-Diethylbenzene	0.0015	ND	NA
Ethyltoluenes	0.0028	ND	NA
Dodecane	0.0023	ND	NA
Indene	0.0027	ND	NA
n-Propylbenzene	0.0010	ND	NA
Tetradecane	0.0009	ND	NA
Undecane	0.0014	ND	NA
Criteria Pollutants and Greenhouse Gases			
Ammonia	NT	0.0543	NA
Carbon Monoxide	NT[4]	1.9407	NA
Carbon Dioxide	18.5334	5.2651	**-72**
Nitrogen Oxides	NT	0.0159	NA

[1] Bold numbers indicate those compounds whose calculated t-statistic is significant at alpha=0.05.
[2] Individual results constitute > 95% of mass of all detected target analytes.
[3] ND: Non Detect; NA: Not Applicable; NT: Not Tested.
[4] The carbon dioxide and carbon monoxide results were generated via the collection of bag samples. These results do not have the accuracy of the continuous monitoring results.

Table 3-3 Summary of Test Plan GH Average Process Parameters

Greensand PCS	Phenolic Urethane	Hot Box
	Reference Test FR	Baseline Test GH
Test Dates	1/12/04-1/30/04	11/8/04-11/12/04
Cast Weight (all metal inside mold), Lbs.	111.06	112.46
Pouring Time, sec.	28	18
Pouring Temp ,°F	2632	2630
Pour Hood Process Air Temp at Start of Pour, ^{o}F	87	87
Total Uncoated Core Weight in Mold, Lbs.	25.25	29.08
Core Reported Resin Content w/o catalyst, %BOS	1.39	1.60
Core Binder Calculated Resin Content w/o Catalyst , %	1.38	1.57
Core Binder Resin Weight w/o Catalyst, %	0.35	0.46
Core Binder Catalyst Reported Content, % BOR	Amine gas	18.0
Total Binder Weight in Mold, Lbs.	0.35	0.54
Core LOI, %	1.26	1.22
Approximate core age, hrs (note 1)	61	400
Core box temperature, F	NA	425
Average heated investment time, Seconds	NA	55
Muller Batch Weight, Lbs.	900	900
GS Mold Sand Weight, Lbs.	620	631
Mold Compactability, %	56	56
Mold Temperature, ^{o}F	70	81
Average Green Compression , psi	11	23.2
GS Compactability, %	53	43
GS Moisture Content, %	2.27	1.91
GS MB Clay Content, %	6.02	8.37
MB Clay Reagent, ml	26	32
1800°F LOI - Mold Sand, %	0.71	0.94
900°F Volatiles , %	0.24	0.25

NA= Not Applicable
Note 1=Cores were bagged in plastic after manufacture

Figure 3-1 Comparative Emission Indicators from Test Series GH and Reference FR – Lb/Lb Binder

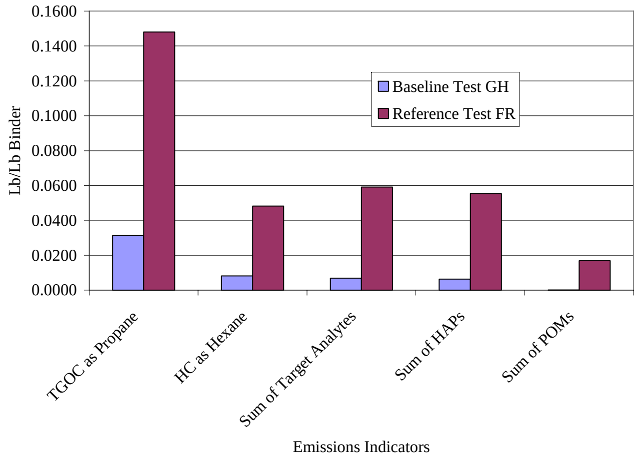


Figure 3-2 Comparative Selected HAP Emissions from Test Series GH and Reference FR – Lb/Lb Binder

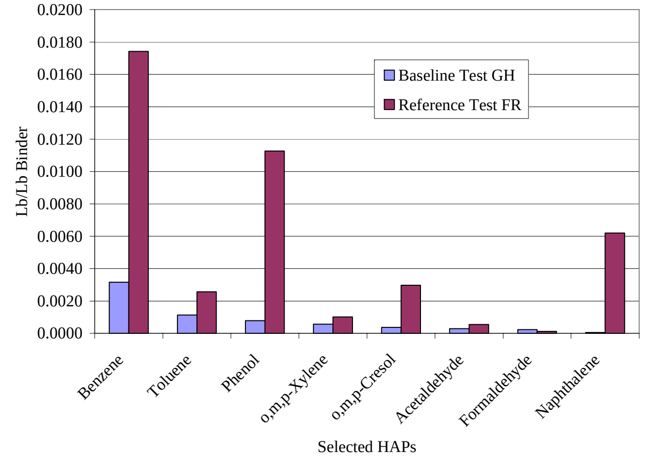


Figure 3-3 Comparative Selected VOC Emissions from Test Series GH and Reference FR – Lb/Lb Binder

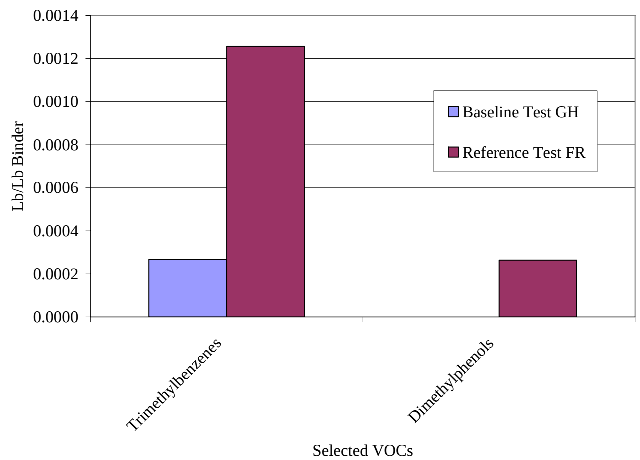


Figure 3-4 Comparative Emissions Indicators from Test Series GH and Reference FR– Lb/Tn Metal

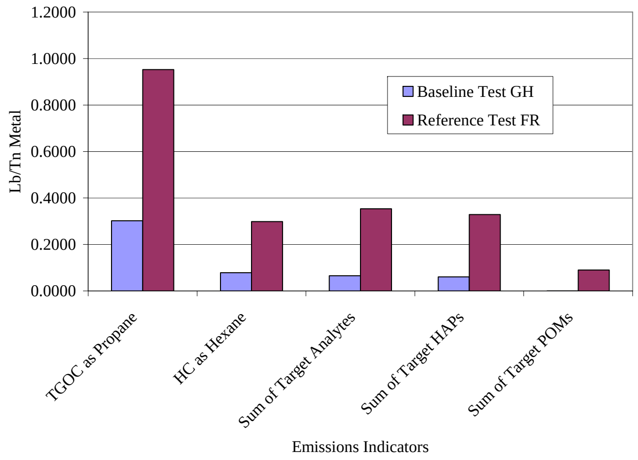


Figure 3-5 Comparative Selected HAPs from Test Series GH and Reference FR – Lb/Tn Metal

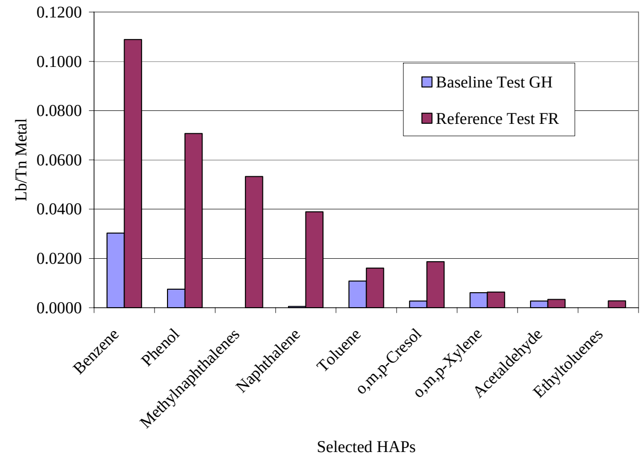


Figure 3-6 Comparative Selected VOCs from Test Series GH and Reference FR – Lb/Tn Metal

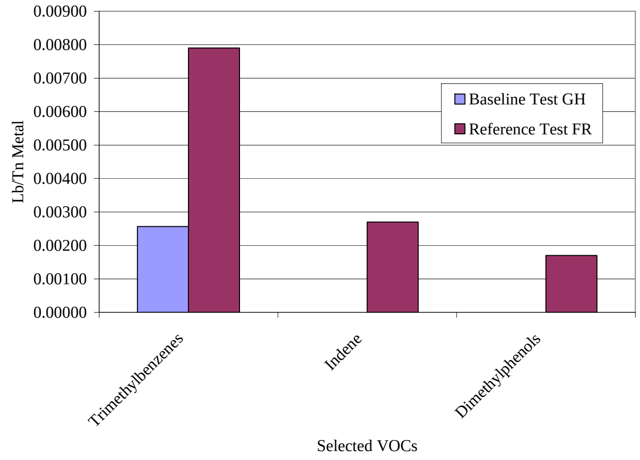


Table 3-4 Rank Order of Casting Surface Quality

Rank Order of Appearance	Mold Cavity 3 Test ID	Benchmark within Test	
Overall Best Casting to Overall Worst Casting	*Production Number*	*Test FR*	*Baseline GH*
Rank1	FR003	1-Best	
Rank2	FR002		
Rank3	FR001	3-Median	
Rank4	GH008		1-Best
Rank5	GH007		
Rank6	GH005		
Rank7	GH004		
Rank8	GH006		5-Median
Rank9	GH009		
Rank10	GH012		
Rank11	GH011		
Rank12	GH010		9-Worst
Rank 13	FR004	4 Worst	

4.0 Discussion of Results

The sampling and analytical methodologies were the same for Test Plans FR and GH except for the determination of carbon monoxide, carbon dioxide, and nitrogen oxides. Carbon monoxide and carbon dioxide were collected in a Tedlar bag for offsite analysis on Test FR and were determined on-line with NIST traceable monitors for Test GH. The on-line monitors provide significantly more accurate data than the bag samples. Similarly, the nitrogen oxides were not tested for under Test FR, but were determined on-line for Test GH. All of the on-line monitoring results are corrected for ambient background. See Appendix B for the detailed results.

The results in Table 3.2 show a **67%** reduction in TGOC (THC) as propane, a **74%** reduction in HC as hexane, an **82%** reduction in Sum of Target Analytes, an **82%** reduction in Sum of HAPs, and a **100%** reduction in Sum of POMs for Test GH compared to Test FR, respectively.

Eight (8) of the measured compounds comprised greater than 94% of the mass of all VOCs detected from Test GH. Benzene, toluene, & phenol contributed 42, 16, & 11 % respectively to the total VOCs and HAPs. The remaining VOCs listed in Table 3-2 individually contributed 1-9% of the total VOCs and HAPs.

The emission indicators in Tables 3-1 and 3-2 show that the Hotbox core binder used in Baseline Test GH resulted in an overall reduction in emissions of 67-99% compared to the phenolic urethane binder used in Test FR. The results also show that each of the target VOCs and HAPs are lower in GH than in FR except for formaldehyde which increased by a factor of approximately three (3)

Casting quality comparisons indicate that hot box cores, Test GH, gave us a lower quality surface finish as compared to the Test FR (ColdBox® with anti-vein additives) castings. The addition of anti-veining additive on core coating would be recommended to foundries using this resin system.

Measured process parameters indicated that all tests were run within acceptable established limits, and replicate tests were conducted following similar procedures. Although the binder used in Test GH was applied at a higher concentration (1.57%) compared to the binder used in Test FR (1.38%), core LOIs at pouring/cooling/shakeout were virtually identical.

A determination of whether the results of the reference test and the test GH were different was made using the "Student" T-test at a 95% significance level ($\alpha = 0.05$). Results of the T-test indicate that there is a 95% probability that the mean emission values for GH are nonequivalent to those of FR. Therefore, it may be said that the differences in the average emission values are not due to test variability, but are real differences. Detailed results of the T-Statistics calculation are found in Appendix B.

Two methods were employed to measure undifferentiated hydrocarbon emissions, TGOC as propane, performed in accordance with EPA Method 25A, and HC as hexane. EPA Method 25A, TGOC (as propane), is weighted to the detection of more volatile hydrocarbon species, beginning at C1 (methane), with results calibrated against a three-carbon alkane (propane). HC as hexane is weighted to the detection of relatively less volatile compounds. This method detects hydrocarbon compounds in the alkane range between C6 and C16, with results calibrated against a six-carbon alkane (hexane).

Target analyte reporting limits expressed in both pounds per pound of binder and pounds per ton of metal are shown in Appendix B.

APPENDIX A APPROVED TEST PLANS, INSTRUCTIONS, AND SAMPLE PLANS FOR REFERENCE FR & TEST SERIES GH

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Technikon Test Plan

- > **CONTRACT NUMBER:** 1410 **TASK NUMBER:** 1.1.4 **SERIES**: FR
- > **SITE:** Pre-production
- > **TEST TYPE:** Product Test: Pouring, cooling, & shakeout of uncoated Phenolic urethane step cores with anti-veining compounds.
- > **METAL TYPE:** Class 30 gray iron
- > **MOLD TYPE:** Virgin, no seacoal, greensand with 4-on PU step-cores recycled after each pour.
- > **NUMBER OF MOLDS:** Three engineering & conditioning runs + 4 sampling runs each from reference cores w/o anti-veining additive and two (2) anti-veining compounds. Twenty-one (21) runs total.
- > **CORE TYPE:** Step: 1.4% Ashland ISOCURE ® Phenolic Urethane LF305 part I (55%), 904GR Part II (45%), amine cured. 50-120 hrs old. Reference cores shall not contain anti-veining material. Test cores shall contain 1% (BOS) Ashland 070359 red iron oxide fine or 2% (BOS) Chesapeake Specialty Products SpherOX® black iron oxide fine.
- > **CORE COATING:** Cores shall be uncoated**.**
- > **SAMPLE EVENTS:** 4 runs each for reference cores and two core sets containing different anti-veining materials, total twelve sample runs (12).
- > **TEST DATE:** **START:** 12 Jan 2004
  FINISHED: 30 Jan 2004

TEST OBJECTIVES:

Measure the airborne pouring, cooling, & shakeout emissions for organic step cores containing anti-veining compounds in a mechanically-produced clay, water, and coal-less greensand mold.

VARIABLES:

The pattern will be the 4-on step core. The mold will be made with Wexford W450 Lakesand, 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 80-90 ^{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. Cores will be made with Amador-70 silica sand heated to 85-90^{o}F and made in an 80-90°F heated enclosed core machine. No emission sampling will be done during core manufacture.

BRIEF OVERVIEW:

This is the first test to include materials contained in the core in addition to the binder. The purpose of the included core additives is to reduce the veining defect common to silica sand cores poured with iron. This test and test FT, using different anti-veining materials, are intended to determine if the anti-veining compounds impact the emissions from the base binder in an uncoated core poured with iron.

The greensand molds will be produced on the mechanically assisted Osborne 716 molding machines.

The emission results will be compared to an internal baseline of uncoated step cores of the same binder content. In addition to a suite of selected emission analytes TGOC, CO, & CO_2 content of the runs will be monitored using instruments specific to those gasses.

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 for each subtest a 1300 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 Amador A-70 silica sand at 85-90°F. The core shall be maintained at 80-90°F awaiting insertion in the mold. The cores shall be stabilized for 50-120 hours when tested.

Series FR

*PCS Core Product Test in Greensand with Ashland 305/904 Core Binder, anti-veining compound, & Mechanized Moldin*g

Process Instructions

A. Experiment:

1. Measure pouring, cooling, & shakeout emissions from uncoated organic cores, containing an anti-veining compound, in 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, & 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. Emissions will be compared to those from the same mold configuration containing cores with no anti-veining compound

B. Materials:

1. Mold sand: Virgin mix of **Wexford W450** lake sand, western and southern bentonites in the ratio of 5:2, and potable water per recipe.
2. Core: Step cores made with virgin **Amador A-70** sand and 1.4% Ashland ISOCURE® **LF305/52-904GR** regular phenolic urethane binder in a 55/45 ratio, TEA catalyzed. Reference cores shall be made without any anti-veining compound and the test cores shall include an anti-veining compound.
3. Anti Vein Compounds: To the test core sand mixes shall be added:
    1) 1% (BOS) Ashland (070359) **Red Iron Oxide Fine** (Fe_2O_3) or
    2) 2% (BOS) of Chesapeake Specialty Products SpherOX® Black Iron Oxide Fine (Fe_3O_4).
4. Metal: Class-30 gray cast iron poured at 2630 +/- 10^{o}F.
5. Pattern Spray: **Black Diamond**, <u>hand wiped</u>.

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 Preproduction operating and safety instruction manual.

D. ISOCURE® regular Step Cores:

1. Premix anti-veining compound in blue R/C mixer.
    a. Make 2 batches of sand. The first containing 1% (BOS) Ashland red iron oxide fine anti-veining compound, and the other 2% (BOS) Chesapeake Specialty Products' black iron oxide fine anti-veining compound.
    b. For each batch add 400 pounds of dry A-70 sand to the R/C mixer.

- **c.** Distribute 4.00 pounds of Ashland red iron oxide to one batch and 8.00 pounds of black iron oxide to the remaining batch. Clean the mixer with 50 pounds of clean sand between batches.
- **d.** Mix each batch for 10 minutes.
- **e.** Place the respective batches in clean containers to be heated to 85-90°F degrees prior to mixing with the core binder.

2. Klein vibratory core sand mixer.
- **a.** Attach the day tanks with the intended part I and part II binder components via respective binder shut-off valves so that they gravity feed to the respective pumps. The binder components should be 80-85°F.
- **b.** On the main control panel turn the AUTO/MAN switch to MANUAL, turn on main disconnects and MASTER START push button.
- **c.** Fill the Part I and Part II pumps and de-air the lines.
- **d.** Calibrate the Klein mixer.
  - **1)** Remove the mixing bowl skirt to gain access to the binder injection tubes and the bottom side of the batch hopper outlet gate.
  - **2)** Calibrate sand. Recalibrate for each sand mixture used.
    - **a)** Turn the AUTO/MAN switch to MANUAL on main control panel.
    - **b)** Place one bucket of preheated sand, raw, or containing one of the iron oxides, of at least fifty-two (52) pounds net weight, into the sand hopper and manually fill batch hopper using max and min. proximity switches.
    - **c)** Discharge the sand from the batch hopper using the single cycle push button. Catch the sand as it leaves the batch hopper and record the net weight and the dispensing time.
    - **d)** Repeat 3 times to determine the weight variation. The sand should be 80-85°F.

  - **3)** Calibrate the binder pumps.
    - **a)** Adjust the part I dispensing rate by adjusting the part I pump stroke to be 55% of 1.4% (0.77% BOS) of the average sand batch weight dispensed in D.2.e.2).
    - **b)** Adjust the machine's inlet air pressure to dispense the binder in about the same time as the sand is dispensed, about 10-15 seconds.
    - **c)** Record the pressure and dispensing time, and net weight.
    - **d)** Repeat 3 times to determine the variation in dispensing rate.
    - **e)** Adjust the part II dispensing rate by adjusting the part II pump stroke to be 45% of 1.4% (.63% BOS) of the average sand rate dispensed in D.2.e.2).
    - **f)** Repeat D.2.d.3).c), & d) for Part II pump.

  - **4)** Turn off the mixer and replace the mixing bowl skirt.

- **e.** Turn on the mixer and turn the AUTO/MAN switch to AUTO.
- **f.** Press the SINGLE CYCLE push button on the operator's station to make a batch of sand. Make three (3) batches to start the Redford Carver core machine.
- **g.** Make a batch of sand for every 7 core machine cycles when using the step core. About two (2) batches will be retained in the core machine sand magazine.
- **h.** Clean the mixer after each material.

- **i.** Approximately 7 batches will be needed for each core material type.
- **j.** Mix the sand without anti-veining compound first, then the material containing the 1% red iron oxide, and finally the material containing the 2% black iron oxide.

Caution: Do not make more sand than sand magazine will hold plus one (1) batch. If too much sand is made the sand will be exposed to captured TEA and significantly shorten the sand bench life.

3. Redford/Carver core machine.
- **a.** Mount the Step-Core core box on the Carver/Redford core machine.
- **b.** Start the core machine auxiliary equipment per the Production Foundry OSI for that equipment.
- **c.** Set up the core machine in the cold box mode with gassing and working pressures and gas and purge time according to the core recipe sheet.
- **d.** Core process setup
  - **1)** Set the TEA to a nominal 5 grams per blow (gas time 0.75 sec (R/C), flow .019 lbs/sec(Luber).
  - **2)** Set the blow pressure to 30+/-2 psi for 3 seconds (R/C).
  - **3)** Set the max purge pressure to 45 psi on the Luber gas generator.
  - **4)** Purge for 20 seconds (R/C) with a 10 second rise time (Luber).
  - **5)** Total cycle time approximately 1 minute.

- **e.** Run the core machine for three (3) cycles and discard the cores. When the cores appear good begin test core manufacture. Five (5) good cores are required for each mold. Make five (5) additional 50 pound sand batches and run the sand out making core. A minimum of 35 cores are required.
- **f.** One half hour to 1 hour after manufacture randomly perform a scratch hardness test on the outer edge of the blow surface on 10% of the cores and record the results on the Core Production Log. Values less than 25 shall be marked with a HOLD TAG until they can be 100% scratch hardness tested to re-qualify. Contact the Process Engineer for disposition on all cores with values less than 15 after 1 hour. Weigh each core and log the results.
- **g.** The sand lab will sample, at the time of manufacture, one (1) core from each row of each shelf (1 of 11) on each core rack. Those cores will be tested for LOI using the standard 1800^{o}F core LOI test method and reported out associated with the core rack shelf it represents. Qualified cores receiving the green Quality Checked tag must have LOI values between 1.25-1.50%. Individual rows that qualify may have the Quality Checked tag affixed. Only cores with the green Quality Tag bearing the current test series and dates and signature of the lab technician and core rack/shelf/position on shelf may be taken to the mold assembly area.

Note: The core rack position from the Quality Checked tag shall be transferred to the mold assembly check list with the core weights.

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

E. Sand preparation

1) Start up batch: make 3, FRCD1, FRCD4, & FRCD7. One batch is for each type of core material.

- **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. Retest. 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 ziplock 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.
- **l)** The sand will be 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: FRCD2, FRCD5, & FRCD8

- **a.** Add to the sand recovered from poured mold FRCD1, FRCD4, or FRCD 7 sufficient pre-blended sand so that the sand batch weight is 900 +/- 10 pounds. Record the sand weight.
- **b.** Return the sand to the muller and dry blend for about one minute.
- **c.** Add the clays, as directed by the process engineering staff, slowly to the muller to allow them to be distributed throughout the sand mass.
- **d.** Add 5 pounds of water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
- **e.** Follow the above procedure beginning at E.1.f.

3. Re-mulling: FRCD3, FRCD6, FRCD9 & FR001-FR0XX
   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 of 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 x4 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.** Initiate the settling of the sand in the flask by pressing the PRE-JOLT push button. Allow this cycle to stop before proceeding.
- **n.** 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.

- **o.** 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.

- **p.** Screed the bottom of the drag mold flat to the bottom of the flask if required.
- **q.** Press and release the LOWER DRAW/STOP push button to separate the flask and mold from the pattern.
- **r.** 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.
- **s.** 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.
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 coated 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^{o}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 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^{o}F.
   - **f.** Slag the furnace and add the balance of the alloys.
   - **g.** Raise the temperature of the melt to 2700^{o}F and take a DataCast 2000 sample. The temperature of the primary liquidus (TPL) must be in the range of 2200-2350^{o}F.
   - **h.** Hold the furnace at 2500-2550^{o}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 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 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 five persons to make a collective subjective judgment of the casting relative surface appearance.
2. Review the general appearance of the castings and select specific casting features to compare.
3. For cavity 3 only:
a. Place each casting initially in sequential mold number order.
b. Beginnings with the casting from mold FR001 compare it to casting from mold FR002.
c. Place the better appearing casting in the first position and the lesser appearing casting in the second position.
d. Repeat this procedure with FR001 to its nearest neighbors until all castings closer to the beginning of the line are better appearing than FR001 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.

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

Steven M. Knight
Mgr. Process Engineering

PRE-PRODUCTION FR - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/15/2004											
RUN 1											
THC	FR001	X									TOTAL
M-18	FR00101		1						60	1	Carbopak charcoal
M-18 MS	FR00102		1						60	2	Carbopak charcoal
M-18 MS	FR00103			1					60	3	Carbopak charcoal
Gas, CO, CO2	FR00104		1						60	4	Tedlar Bag
Gas, CO, CO2	FR00105				1				0		Tedlar Bag
NIOSH 1500	FR00106		1						1000	5	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	FR00107				1				0		100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	FR00108		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
NIOSH 2002	FR00109				1				0		100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	FR00110		1						1000	9	DNPH Silica Gel (SKC 226-119)
TO11	FR00111				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 FR - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/15/2004											
RUN 2											
THC	FR002	X									TOTAL
M-18	FR00201		1						60	1	Carbopak charcoal
M-18	FR00202			1					60	2	Carbopak charcoal
M-18	FR00203				1				0		Carbopak charcoal
	Excess								60	3	Excess
Gas, CO, CO2	FR00204		1						60	4	Tedlar Bag
NIOSH 1500	FR00205		1						1000	5	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	FR00206			1					1000	6	100/50 mg Charcoal (SKC 226-01)
NIOSH 2002	FR00207		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
NIOSH 2002	FR00208			1					1000	8	100/50 mg Silica Gel (SKC 226-10)
TO11	FR00209		1						1000	9	DNPH Silica Gel (SKC 226-119)
TO11	FR00210			1					1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION FR - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/16/2004											
RUN 3											
THC	FR003	X									TOTAL
M-18	FR00301		1						60	1	Carbopak charcoal
M-18	FR00302					1			60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
Gas, CO, CO2	FR00303		1						60	4	Tedlar Bag
NIOSH 1500	FR00304		1						1000	5	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	FR00305		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	FR00306		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 FR - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/16/2004											
RUN 4											
THC	FR004	X									TOTAL
M-18	FR00401		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
Gas, CO, CO2	FR00402		1						60	4	Tedlar Bag
NIOSH 1500	FR00403		1						1000	5	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	FR00404		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	FR00405		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

Technikon Test Plan

> **CONTRACT NUMBER**:	1411 **TASK NUMBER**: 1.2.2 **SERIES**: GH
> **SITE:**	Pre-production
> **TEST TYPE:**	Baseline: Uncoated Hotbox Core in Greensand: pouring, cooling, shakeout
> **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: 1.6% (BOS) HA International 747 Hot box resin and 18% (BOR) 89FR Hotbox catalyst.
> **CORE COATING:**	None
> **SAMPLE EVENTS:**	9
> **ANALYTE LIST**:	List E
> **TEST DATE:**	START: 8 Nov 2004
	FINISHED: 12 Nov 2004

TEST OBJECTIVES:

Establish an emission reference baseline (pouring, cooling, & shakeout) for a typical uncoated hotbox core set in a mechanically-produced clay, water, and coal-less greensand mold. The baseline will become a reference against which future hotbox vendor test materials can be compared.

VARIABLES:

The pattern will be the 4-on step core. 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, 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 AFS standard drag only step core castings to make a new baseline against which future hotbox core products can be compared. The cores will be manufactured under the direction of the of the University of Northern Iowa Metals Casting Center

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 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 as soon as sufficiently cooled. The cores will be approximately 3 weeks old when tested.

Series GH

PCS Greensand Uncoated Core Baseline with HA International 747/89FR Hotbox core binder & Mechanized Molding

Process Instructions

A. Experiment

1. Create an organic Hotbox core-in-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, & 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: Virgin mix of Wexford W450 lake sand, western and southern bentonites in ratio of 5:2, and potable water per recipe.
2. Core: Uncoated step core made with virgin Wedron 530 silica sand and 1.6% (BOS) HA International 747/89FR Phenol-Formaldehyde hotbox binder in a 100/18 ratio heat activated.
3. Core coating: None
4. Metal: Class-30 gray cast iron poured at 2630 +/- 10^{o}F.
5. Pattern Spray: Black Diamond, hand wiped.

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 Preproduction operating and safety instruction manual.

D. Hotbox two-piece Step Cores:

1. Cores will be manufactured under the direction of the University of Northern Iowa Metal Castings Center.
   - **a.** After manufacture and cooling the cores will be sealed in polyethylene bags and packed in a compartmentalized wooden crate for shipping.
   - **b.** The sand lab will sample one (1) core from the shipping box for each mold produced just prior to the emission test to represent the four (4) cores placed in that mold. Those cores will be tested for LOI using the standard 1800^{o}F core LOI test method and reported out associated with the test mold it is to represent.

E. Sand preparation

1. Start up batch: make 1, GHER1.
  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. Retest. 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 discharge into the mold.
  l. The sand will be characterized for Methylene Blue Clay, AFS clay, Moisture content, Compactability, Green Compression strength, 1800^{o}F loss on ignition (LOI), and 900 oF 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: GHER2
  a. Add to the sand recovered from poured mold GHER1 sufficient pre-blended sand so that the sand batch weight is 900 +/- 10 pounds. Record the sand weight.
  b. Return the sand to the muller and dry blend for about one minute.
  c. Add the clays, as directed by the process engineering staff, slowly to the muller to allow them to be distributed throughout the sand mass.
  d. Add 5 pounds of water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
  e. Follow the above procedure beginning at E.1.f.

3. Re-mulling: GHER3, GH001-GH0XX
  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 of 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 x4 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 over-head 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 no 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.
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^{o}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 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^{o}F.
      - **f.** Slag the furnace and add the balance of the alloys.
      - **g.** Raise the temperature of the melt to 2700^{o}F and take a DataCast 2000 sample. The temperature of the primary liquidus (TPL) must be in the range of 2200-2350^{o}F.
      - **h.** Hold the furnace at 2500-2550^{o}F until near ready to tap.
      - **i.** When ready to tap raise the temperature to 2700^{o}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^{o}F iron into the cold ladle.
   b. Carefully pour the metal back to the furnace.
   c. Cover the ladle.
   d. Reheat the metal to 2780 +/- 20^{o}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^{o}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 five persons to make a collective subjective judgment of the casting relative surface appearance.
2. Review the general appearance of the castings and select specific casting features to compare.
3. For each cavity :
   a. Place each casting initially in sequential mold number order.
   b. Beginning with casting from mold GH001 compares it to castings from mold GH002.
   c. Place the better appearing casting in the first position and the lesser appearing casting in the second position.
   d. Repeat this procedure with GH001 to its nearest neighbors until all castings closer to the beginning of the line are better appearing than GH001 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.

4. Record mold number by rank-order series for this cavity.
5. Compare GH rankings to those in test FR cavity 3

Steven M. Knight
Mgr. Process Engineering

PRE-PRODUCTION GH - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/9/2004											
RUN 1											
THC, CO, CO2, NOX	GH001	X									TOTAL
M-18	GH00101		1						60	1	Carbopak charcoal
M-18	GH00102				1				0		Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 2002	GH00103		1						1000	5	100/50 mg Silica Gel (SKC 226-10)
NIOSH 2002	GH00104				1				0		100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	6	Excess
NIOSH 1500	GH00105		1						1000	7	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	GH00106				1				0		100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GH00107		1						1000	9	DNPH Silica Gel (SKC 226-119)
TO11	GH00108				1				0		DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GH00109		1						1000	10	Acid Silica Gel (SKC 226-10-06)
NIOSH 6016	GH00110				1				0		Acid Silica Gel (SKC 226-10-06)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GH - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/9/2004											
RUN 2											
THC, CO, CO2, NOX	GH002	X									TOTAL
M-18	GH00201		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 2002	GH00202		1						1000	5	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	6	Excess
NIOSH 1500	GH00203		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GH00204		1						1000	9	DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
NIOSH 6016	GH00205								1000	11	Acid Silica Gel (SKC 226-10-06)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GH - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/9/2004											
RUN 3											
THC, CO, CO2, NOX	GH003	X									TOTAL
M-18	GH00301		1						60	1	Carbopak charcoal
M-18	GH00302			1					60	2	Carbopak charcoal
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 2002	GH00303		1						1000	5	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	6	Excess
NIOSH 1500	GH00304		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GH00305		1						1000	9	DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
NIOSH 6016	GH00306								1000	11	Acid Silica Gel (SKC 226-10-06)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GH - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/10/2004											
RUN 4											
THC, CO, CO2, NOX	GH004	X									TOTAL
M-18	GH00401		1						60	1	Carbopak charcoal
M-18 MS	GH00402		1						60	2	Carbopak charcoal
M-18 MS	GH00403			1					60	3	Carbopak charcoal
	Excess								60	4	Excess
NIOSH 2002	GH00404		1						1000	5	100/50 mg Silica Gel (SKC 226-10)
NIOSH 2002	GH00405			1					1000	6	100/50 mg Silica Gel (SKC 226-10)
NIOSH 1500	GH00406		1						1000	7	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	GH00407			1					1000	8	100/50 mg Charcoal (SKC 226-01)
TO11	GH00408		1						1000	9	DNPH Silica Gel (SKC 226-119)
TO11	GH00409			1					1000	10	DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GH00410		1						1000	11	Acid Silica Gel (SKC 226-10-06)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GH - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/10/2004											
RUN 5											
THC, CO, CO2, NOX	GH005	X									TOTAL
M-18	GH00501		1						60	1	Carbopak charcoal
M-18	GH00502					1			60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								40	3	Excess
	Excess								60	4	Excess
NIOSH 2002	GH00503		1						1000	5	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	6	Excess
NIOSH 1500	GH00504		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GH00505		1						1000	9	DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GH00506		1						1000	10	Acid Silica Gel (SKC 226-10-06)
NIOSH 6016	GH00507			1					1000	11	Acid Silica Gel (SKC 226-10-06)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GH - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/10/2004											
RUN 6											
THC, CO, CO2, NOX	GH006	X									TOTAL
M-18	GH00601		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 2002	GH00602		1						1000	5	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	6	Excess
NIOSH 1500	GH00603		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GH00604		1						1000	9	DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
NIOSH 6016	GH00605		1						1000	11	Acid Silica Gel (SKC 226-10-06)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GH - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/11/2004											
RUN 7											
THC, CO, CO2, NOX	GH007	X									TOTAL
M-18	GH00701		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 2002	GH00702		1						1000	5	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	6	Excess
NIOSH 1500	GH00703		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GH00704		1						1000	9	DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
NIOSH 6016	GH00705		1						1000	11	Acid Silica Gel (SKC 226-10-06)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GH - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/11/2004											
RUN 8											
THC, CO, CO2, NOX	GH008	X									TOTAL
M-18	GH00801		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 2002	GH00802		1						1000	5	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	6	Excess
NIOSH 1500	GH00803		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GH00804		1						1000	9	DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
NIOSH 6016	GH00805		1						1000	11	Acid Silica Gel (SKC 226-10-06)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GH - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/11/2004											
RUN 9											
THC, CO, CO2, NOX	GH009	X									TOTAL
M-18	GH00901		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 2002	GH00902		1						1000	5	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	6	Excess
NIOSH 1500	GH00903		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GH00904		1						1000	9	DNPH Silica Gel (SKC 226-119)
	Excess								1000	10	Excess
NIOSH 6016	GH00905		1						1000	11	Acid Silica Gel (SKC 226-10-06)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

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APPENDIX B DETAILED EMISSION RESULTS FOR REFERENCE FR AND TEST SERIES GH

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Test Plan FR Individual Emission Test Results – Lb/Lb

HAPs	POMs	Compound/Sample Number	FR001	FR002	FR003	FR004	Average	STDEV
		Test Dates	**1/15/04**	**1/15/04**	**1/16/04**	**1/16/04**		
		TGOC as Propane	1.55E-01	1.41E-01	1.57E-01	1.39E-01	1.48E-01	9.38E-03
		HC as Hexane	4.88E-02	5.06E-02	5.04E-02	4.30E-02	4.82E-02	3.54E-03
		Sum of VOCs	5.77E-02	5.84E-02	6.13E-02	I	5.91E-02	1.92E-03
		Sum of HAPs	5.37E-02	5.44E-02	5.82E-02	I	5.54E-02	2.44E-03
		Sum of POMs	1.47E-02	1.71E-02	1.88E-02	I	1.69E-02	2.06E-03
		Individual Organic HAPs						
x		**Benzene**	1.93E-02	1.45E-02	1.85E-02	I	1.74E-02	2.60E-03
x		**Phenol**	1.02E-02	1.25E-02	1.11E-02	I	1.13E-02	1.18E-03
x	z	**Naphthalene**	5.89E-03	6.21E-03	6.50E-03	I	6.20E-03	3.04E-04
x	z	**2-Methylnaphthalene**	4.72E-03	5.70E-03	6.26E-03	I	5.56E-03	7.77E-04
x	z	**1-Methylnaphthalene**	2.48E-03	3.02E-03	3.30E-03	I	2.94E-03	4.17E-04
x		**Toluene**	2.75E-03	2.29E-03	2.66E-03	I	2.57E-03	2.48E-04
x		**o-Cresol**	2.18E-03	2.67E-03	2.56E-03	I	2.47E-03	2.52E-04
x		**Aniline**	1.80E-03	2.26E-03	1.88E-03	2.34E-03	2.07E-03	2.73E-04
x	z	**1,3-Dimethylnaphthalene**	7.16E-04	9.11E-04	1.02E-03	I	8.84E-04	1.56E-04
x		**m,p-Xylene**	8.81E-04	7.83E-04	8.23E-04	I	8.29E-04	4.93E-05
x		**Acetaldehyde**	4.97E-04	5.86E-04	5.20E-04	5.81E-04	5.46E-04	4.43E-05
x		**m,p-Cresol**	4.20E-04	5.58E-04	5.33E-04	I	5.04E-04	7.35E-05
x	z	**1,6-Dimethylnaphthalene**	2.88E-04	3.65E-04	4.14E-04	I	3.55E-04	6.35E-05
x	z	**2,6-Dimethylnaphthalene**	2.56E-04	3.27E-04	3.72E-04	I	3.18E-04	5.86E-05
x	z	**2,7-Dimethylnaphthalene**	2.56E-04	3.27E-04	3.72E-04	I	3.18E-04	5.86E-05
x		**Styrene**	1.64E-04	4.94E-04	1.56E-04	I	2.71E-04	1.93E-04
x		**o-Xylene**	1.97E-04	1.83E-04	1.81E-04	I	1.87E-04	8.82E-06
x	z	**1,2-Dimethylnaphthalene**	1.24E-04	1.65E-04	1.84E-04	I	1.58E-04	3.04E-05
x		**Formaldehyde**	1.61E-04	1.12E-04	1.15E-04	1.10E-04	1.24E-04	2.46E-05
x	z	**2,3-Dimethylnaphthalene**	ND	5.29E-05	3.15E-04	I	1.23E-04	1.69E-04
x		**Biphenyl**	9.52E-05	1.20E-04	1.43E-04	I	1.19E-04	2.39E-05
x		**Ethylbenzene**	1.11E-04	1.27E-04	1.08E-04	I	1.15E-04	9.96E-06
x		**Hexane**	8.21E-05	9.70E-05	9.69E-05	I	9.20E-05	8.58E-06
x		**Propionaldehyde**	3.85E-05	3.63E-05	3.51E-05	3.85E-05	3.71E-05	1.73E-06
x		**2-Butanone**	3.94E-05	4.46E-05	3.45E-05	2.61E-05	3.61E-05	7.85E-06
x	z	**1,5-Dimethylnaphthalene**	ND	ND	9.79E-05	I	3.26E-05	5.65E-05
x	z	**Acenaphthalene**	ND	ND	ND	I	ND	NA
x	z	**1,8-Dimethylnaphthalene**	ND	ND	ND	I	ND	NA
x	z	**2,3,5-Trimethylnaphthalene**	ND	ND	ND	I	ND	NA
x		**Dimethylaniline**	ND	ND	ND	ND	ND	NA
x		**Acrolein**	ND	ND	ND	ND	ND	NA
		Other VOCs						
		1,2,4-Trimethylbenzene	1.04E-03	8.72E-04	7.74E-04	I	8.94E-04	1.33E-04
		Indene	4.72E-04	4.18E-04	4.23E-04	I	4.38E-04	2.95E-05
		Dodecane	4.12E-04	4.40E-04	2.68E-04	I	3.73E-04	9.24E-05
		1,2,3-Trimethylbenzene	4.16E-04	3.56E-04	3.17E-04	I	3.63E-04	5.03E-05
		2,4-Dimethylphenol	2.19E-04	2.95E-04	2.76E-04	I	2.64E-04	3.94E-05
		3-Ethyltoluene	2.86E-04	2.58E-04	2.22E-04	I	2.55E-04	3.22E-05

Test Plan FR Individual Emission Test Results – Lb/Lb cont.

HAPs	POMs	Compound/Sample Number	FR001	FR002	FR003	FR004	Average	STDEV
		Test Dates	**1/15/04**	**1/15/04**	**1/16/04**	**1/16/04**		
		Other VOCs						
		1,3-Diethylbenzene	3.95E-04	3.25E-04	ND	I	2.40E-04	2.11E-04
		Undecane	1.89E-04	2.54E-04	2.08E-04	I	2.17E-04	3.34E-05
		2-Ethyltoluene	1.99E-04	1.98E-04	1.97E-04	I	1.98E-04	1.13E-06
		Propylbenzene	1.44E-04	1.85E-04	1.42E-04	I	1.57E-04	2.40E-05
		Tetradecane	1.19E-04	1.47E-04	1.74E-04	I	1.47E-04	2.79E-05
		Butyraldehyde/Methacrolein	9.17E-05	6.72E-05	5.53E-05	6.35E-05	6.94E-05	1.56E-05
		Benzaldehyde	4.86E-05	4.04E-05	3.04E-05	3.34E-05	3.82E-05	8.13E-06
		Heptane	ND	1.06E-04	ND	I	3.54E-05	6.14E-05
		Cyclohexane	ND	ND	ND	I	ND	NA
		Decane	ND	ND	ND	I	ND	NA
		2,6-Dimethylphenol	ND	ND	ND	I	ND	NA
		Indan	ND	ND	ND	I	ND	NA
		Nonane	ND	ND	ND	I	ND	NA
		Octane	ND	ND	ND	I	ND	NA
		1,3,5-Trimethylbenzene	ND	ND	ND	I	ND	NA
		Crotonaldehyde	ND	ND	ND	ND	ND	NA
		Hexaldehyde	ND	ND	ND	ND	ND	NA
		o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	NA
		Pentanal	ND	ND	ND	ND	ND	NA
		Other Analytes						
		Carbon Dioxide	2.97E+00	NA	3.13E+00	2.89E+00	3.00E+00	1.22E-01
		Methane	3.52E-03	NA	6.18E-03	5.62E-03	5.11E-03	1.40E-03
		Carbon Monoxide	ND	NA	ND	ND	ND	NA
		Ethane	ND	NA	ND	ND	ND	NA
		Propane	ND	NA	ND	ND	ND	NA
		Isobutane	ND	NA	ND	ND	ND	NA
		Butane	ND	NA	ND	ND	ND	NA
		Neopentane	ND	NA	ND	ND	ND	NA
		Isopentane	ND	NA	ND	ND	ND	NA
		Pentane	ND	NA	ND	ND	ND	NA

I: Data rejected based on data validation considerations.

ND: Non Detect; NA: Not Applicable

All "Other Analytes" are not included in the Sum of VOCs or HAPs.

Test Plan FR Individual Emission Test Results – Lb/Ton Metal

HAPs	POMs	COMPOUND / SAMPLE NUMBER	FR001	FR002	FR003	FR004	Average	STDEV
		Test Dates	**1/15/04**	**1/15/04**	**1/16/04**	**1/16/04**		
		TGOC as Propane	9.52E-01	9.14E-01	9.71E-01	8.66E-01	9.26E-01	4.67E-02
		HC as Hexane	2.99E-01	3.28E-01	3.12E-01	2.68E-01	3.02E-01	2.53E-02
		Sum of VOCs	3.54E-01	3.78E-01	3.80E-01	I	3.71E-01	1.47E-02
		Sum of HAPs	3.29E-01	3.52E-01	3.61E-01	I	3.47E-01	1.65E-02
		Sum of POMs	9.03E-02	1.11E-01	1.17E-01	I	1.06E-01	1.38E-02
		Individual Organic HAPs						
x		**Benzene**	1.18E-01	9.36E-02	1.14E-01	I	1.09E-01	1.33E-02
x		**Phenol**	6.24E-02	8.11E-02	6.86E-02	I	7.07E-02	9.53E-03
x	z	**Naphthalene**	3.61E-02	4.02E-02	4.03E-02	I	3.89E-02	2.39E-03
x	z	**2-Methylnaphthalene**	2.90E-02	3.69E-02	3.88E-02	I	3.49E-02	5.22E-03
x	z	**1-Methylnaphthalene**	1.52E-02	1.95E-02	2.05E-02	I	1.84E-02	2.80E-03
x		**Toluene**	1.69E-02	1.48E-02	1.65E-02	I	1.61E-02	1.10E-03
x		**o-Cresol**	1.34E-02	1.73E-02	1.58E-02	I	1.55E-02	1.96E-03
x		**Aniline**	1.10E-02	1.47E-02	1.16E-02	1.46E-02	1.30E-02	1.93E-03
x	z	**1,3-Dimethylnaphthalene**	4.39E-03	5.90E-03	6.35E-03	I	5.55E-03	1.03E-03
x		**m,p-Xylene**	5.40E-03	5.07E-03	5.10E-03	I	5.19E-03	1.82E-04
x		**Acetaldehyde**	3.04E-03	3.79E-03	3.22E-03	3.62E-03	3.42E-03	3.46E-04
x		**m,p-Cresol**	2.58E-03	3.62E-03	3.30E-03	I	3.16E-03	5.34E-04
x	z	**1,6-Dimethylnaphthalene**	1.76E-03	2.36E-03	2.56E-03	I	2.23E-03	4.16E-04
x	z	**2,6-Dimethylnaphthalene**	1.57E-03	2.12E-03	2.30E-03	I	2.00E-03	3.83E-04
x	z	**2,7-Dimethylnaphthalene**	1.57E-03	2.12E-03	2.30E-03	I	2.00E-03	3.83E-04
x		**Styrene**	1.01E-03	3.20E-03	9.67E-04	I	1.72E-03	1.28E-03
x		**o-Xylene**	1.21E-03	1.18E-03	1.12E-03	I	1.17E-03	4.46E-05
x	z	**1,2-Dimethylnaphthalene**	7.61E-04	1.07E-03	1.14E-03	I	9.89E-04	2.01E-04
x		**Formaldehyde**	9.87E-04	7.23E-04	7.13E-04	6.84E-04	7.77E-04	1.41E-04
x	z	**2,3-Dimethylnaphthalene**	ND	3.43E-04	1.95E-03	I	7.64E-04	1.04E-03
x		**Biphenyl**	5.84E-04	7.78E-04	8.87E-04	I	7.50E-04	1.53E-04
x		**Ethylbenzene**	6.81E-04	8.20E-04	6.69E-04	I	7.23E-04	8.39E-05
x		**Hexane**	5.03E-04	6.28E-04	6.01E-04	I	5.77E-04	6.57E-05
x		**Propionaldehyde**	2.36E-04	2.35E-04	2.17E-04	2.40E-04	2.32E-04	1.01E-05
x		**2-Butanone**	2.41E-04	2.89E-04	2.13E-04	1.63E-04	2.27E-04	5.27E-05
x	z	**1,5-Dimethylnaphthalene**	ND	ND	6.06E-04	I	2.02E-04	3.50E-04
x	z	**1,8-Dimethylnaphthalene**	ND	ND	ND	I	ND	NA
x	z	**2,3,5-Trimethylnaphthalene**	ND	ND	ND	I	ND	NA
x	z	**Acenaphthalene**	ND	ND	ND	I	ND	NA
x		**Acrolein**	ND	ND	ND	ND	ND	NA
x		**N,N-Dimethylaniline**	ND	ND	ND	ND	ND	NA
		Other VOCs						
		1,2,4-Trimethylbenzene	6.35E-03	5.65E-03	4.79E-03	I	5.60E-03	7.81E-04
		Indene	2.89E-03	2.71E-03	2.62E-03	I	2.74E-03	1.38E-04
		Dodecane	2.52E-03	2.85E-03	1.66E-03	I	2.34E-03	6.16E-04
		1,2,3-Trimethylbenzene	2.55E-03	2.31E-03	1.96E-03	I	2.27E-03	2.97E-04
		2,4-Dimethylphenol	1.34E-03	1.91E-03	1.71E-03	I	1.66E-03	2.87E-04
		3-Ethyltoluene	1.75E-03	1.67E-03	1.37E-03	I	1.60E-03	1.99E-04

Test Plan FR Individual Emission Test Results – Lb/Ton Metal cont.

HAPs	POMs	COMPOUND / SAMPLE NUMBER	FR001	FR002	FR003	FR004	Average	STDEV
		Test Dates	**1/15/04**	**1/15/04**	**1/16/04**	**1/16/04**		
		Other VOCs						
		1,3-Diethylbenzene	2.42E-03	2.11E-03	ND	I	1.51E-03	1.32E-03
		Undecane	1.16E-03	1.64E-03	1.29E-03	I	1.36E-03	2.52E-04
		2-Ethyltoluene	1.22E-03	1.28E-03	1.22E-03	I	1.24E-03	3.66E-05
		n-Propylbenzene	8.81E-04	1.20E-03	8.81E-04	I	9.86E-04	1.81E-04
		Tetradecane	7.27E-04	9.50E-04	1.08E-03	I	9.19E-04	1.79E-04
		Butyraldehyde/Methacrolein	5.61E-04	4.35E-04	3.43E-04	3.95E-04	4.34E-04	9.31E-05
		Benzaldehyde	2.98E-04	2.62E-04	1.88E-04	2.08E-04	2.39E-04	5.01E-05
		Heptane	ND	6.89E-04	ND	I	2.30E-04	3.98E-04
		1,3,5-Trimethylbenzene	ND	ND	ND	I	ND	NA
		2,6-Dimethylphenol	ND	ND	ND	I	ND	NA
		Cyclohexane	ND	ND	ND	I	ND	NA
		Decane	ND	ND	ND	I	ND	NA
		Indan	ND	ND	ND	I	ND	NA
		Nonane	ND	ND	ND	I	ND	NA
		Octane	ND	ND	ND	I	ND	NA
		Crotonaldehyde	ND	ND	ND	ND	ND	NA
		Hexaldehyde	ND	ND	ND	ND	ND	NA
		Pentanal	ND	ND	ND	ND	ND	NA
		o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	NA
		Other Analytes						
		Carbon Dioxide	1.82E+01	NA	1.94E+01	1.80E+01	1.85E+01	7.38E-01
		Methane	2.16E-02	NA	3.83E-02	3.50E-02	3.16E-02	8.87E-03
		Carbon Monoxide	ND	NA	ND	ND	ND	NA
		Ethane	ND	NA	ND	ND	ND	NA
		Propane	ND	NA	ND	ND	ND	NA
		Isobutane	ND	NA	ND	ND	ND	NA
		Butane	ND	NA	ND	ND	ND	NA
		Neopentane	ND	NA	ND	ND	ND	NA
		Isopentane	ND	NA	ND	ND	ND	NA
		Pentane	ND	NA	ND	ND	ND	NA

I: Data rejected based on data validation considerations.

ND: Non Detect; NA: Not Applicable

All "Other Analytes" are not included in the Sum of VOCs or HAPs.

Test FR Quantitation Limits – Lb/Lb Binder

Analytes	Lb/Lb Binder
1,2,3-Trimethylbenzene	1.87E-05
1,2,4-Trimethylbenzene	1.87E-05
1,3,5-Trimethylbenzene	1.87E-05
1,3-Dimethylnaphthalene	1.87E-05
1-Methylnaphthalene	1.87E-05
2-Ethyltoluene	1.87E-05
2-Methylnaphthalene	1.87E-05
Benzene	1.87E-05
Ethylbenzene	1.87E-05
Hexane	1.87E-05
m,p-Xylene	1.87E-05
Naphthalene	1.87E-05
o-Xylene	1.87E-05
Styrene	1.87E-05
Toluene	1.87E-05
Undecane	1.87E-05
1,2-Dimethylnaphthalene	9.33E-05
1,3-Diethylbenzene	9.33E-05
1,5-Dimethylnaphthalene	9.33E-05
1,6-Dimethylnaphthalene	9.33E-05
1,8-Dimethylnaphthalene	9.33E-05
2,3,5-Trimethylnaphthalene	9.33E-05
2,3-Dimethylnaphthalene	9.33E-05
2,4-Dimethylphenol	9.33E-05

Analytes	Lb/Lb Binder
2,6-Dimethylnaphthalene	9.33E-05
2,6-Dimethylphenol	9.33E-05
2,7- Dimethylnaphthalene	9.33E-05
3-Ethyltoluene	9.33E-05
Acenaphthalene	9.33E-05
Biphenyl	9.33E-05
Cyclohexane	9.33E-05
Decane	9.33E-05
Dodecane	9.33E-05
Heptane	9.33E-05
Indan	9.33E-05
Indene	9.33E-05
m,p-Cresol	9.33E-05
Nonane	9.33E-05
o-Cresol	9.33E-05
Octane	9.33E-05
Phenol	9.33E-05
Propylbenzene	9.33E-05
Tetradecane	9.33E-05
HC as Hexane	5.65E-04
2-Butanone (MEK)	1.67E-05
Acetaldehyde	1.67E-05
Acrolein	1.67E-05

Analytes	Lb/Lb Binder
Benzaldehyde	1.67E-05
Butyraldehyde	1.67E-05
Crotonaldehyde	1.67E-05
Formaldehyde	1.67E-05
Hexaldehyde	1.67E-05
Butyraldehyde/Methacrolein	2.78E-05
o,m,p-Tolualdehyde	4.45E-05
Pentanal (Valeraldehyde)	1.67E-05
Propionaldehyde (Propanal)	1.67E-05
Aniline	1.12E-04
Dimethylaniline	1.12E-04
Carbon Monoxide	4.40E-02
Methane	2.51E-03
Carbon Dioxide	6.91E-02
Ethane	4.71E-02
Propane	6.91E-02
Isobutane	9.11E-02
Butane	9.11E-02
Neopentane	1.13E-01
Isopentane	1.13E-01
Pentane	1.13E-01

Test FR Quantitation Limits – Lb/Tn Metal

Analytes	Lb/Tn Metal
1,2,3-Trimethylbenzene	1.17E-04
1,2,4-Trimethylbenzene	1.17E-04
1,3,5-Trimethylbenzene	1.17E-04
1,3-Dimethylnaphthalene	1.17E-04
1-Methylnaphthalene	1.17E-04
2-Ethyltoluene	1.17E-04
2-Methylnaphthalene	1.17E-04
Benzene	1.17E-04
Ethylbenzene	1.17E-04
Hexane	1.17E-04
m,p-Xylene	1.17E-04
Naphthalene	1.17E-04
o-Xylene	1.17E-04
Styrene	1.17E-04
Toluene	1.17E-04
Undecane	1.17E-04
1,2-Dimethylnaphthalene	5.85E-04
1,3-Diethylbenzene	5.85E-04
1,5-Dimethylnaphthalene	5.85E-04
1,6-Dimethylnaphthalene	5.85E-04
1,8-Dimethylnaphthalene	5.85E-04
2,3,5-Trimethylnaphthalene	5.85E-04
2,3-Dimethylnaphthalene	5.85E-04
2,4-Dimethylphenol	5.85E-04

Analytes	Lb/Tn Metal
2,6-Dimethylnaphthalene	5.85E-04
2,6-Dimethylphenol	5.85E-04
2,7- Dimethylnaphthalene	5.85E-04
3-Ethyltoluene	5.85E-04
Acenaphthalene	5.85E-04
Biphenyl	5.85E-04
Cyclohexane	5.85E-04
Decane	5.85E-04
Dodecane	5.85E-04
Heptane	5.85E-04
Indan	5.85E-04
Indene	5.85E-04
m,p-Cresol	5.85E-04
Nonane	5.85E-04
o-Cresol	5.85E-04
Octane	5.85E-04
Phenol	5.85E-04
Propylbenzene	5.85E-04
Tetradecane	5.85E-04
HC as Hexane	3.54E-03
2-Butanone (MEK)	1.05E-04
Acetaldehyde	1.05E-04
Acrolein	1.05E-04

Analytes	Lb/Tn Metal
Benzaldehyde	1.05E-04
Butyraldehyde	1.05E-04
Crotonaldehyde	1.05E-04
Formaldehyde	1.05E-04
Hexaldehyde	1.05E-04
Butyraldehyde/Methacrolein	1.74E-04
o,m,p-Tolualdehyde	2.79E-04
Pentanal (Valeraldehyde)	1.05E-04
Propionaldehyde (Propanal)	1.05E-04
Aniline	7.04E-04
Dimethylaniline	7.04E-04
Carbon Monoxide	2.76E-01
Methane	1.58E-02
Carbon Dioxide	4.33E-01
Ethane	4.18E-02
Propane	4.33E-01
Isobutane	5.71E-01
Butane	5.71E-01
Neopentane	7.09E-01
Isopentane	7.09E-01
Pentane	7.09E-01

Test Plan GH Individual Emission Test Results – Lb/Lb Binder

HAPs	POMs	Compound/Sample Number	GH001	GH002	GH003	GH004	GH005	GH006	GH007	GH008	GH009	Average	STDEV
		Test Dates	**11/9/04**	**11/9/04**	**11/9/04**	**11/10/04**	**11/10/04**	**11/10/04**	**11/11/04**	**11/11/04**	**11/11/04**		
		TGOC as Propane	3.34E-02	3.06E-02	3.45E-02	3.07E-02	2.74E-02	3.22E-02	3.27E-02	2.90E-02	3.31E-02	3.15E-02	2.29E-03
		HC as Hexane	9.02E-03	8.30E-03	9.01E-03	7.99E-03	7.45E-03	7.45E-03	8.15E-03	7.88E-03	8.69E-03	8.22E-03	5.96E-04
		Sum of Target Analytes	7.27E-03	7.52E-03	7.84E-03	I	6.56E-03	3.88E-03	7.50E-03	7.12E-03	6.90E-03	6.82E-03	1.25E-03
		Sum of HAPs	6.71E-03	7.05E-03	7.25E-03	I	6.22E-03	3.53E-03	7.03E-03	6.72E-03	6.44E-03	6.37E-03	1.19E-03
		Sum of POMs	7.22E-05	5.61E-05	6.81E-05	5.28E-05	5.24E-05	4.67E-05	5.03E-05	4.46E-05	4.31E-05	5.40E-05	1.01E-05
			Individual Organic HAPs										
x		**Benzene**	3.00E-03	3.06E-03	3.22E-03	2.90E-03	3.16E-03	I	3.33E-03	3.33E-03	3.28E-03	3.16E-03	1.59E-04
x		**Toluene**	1.09E-03	1.10E-03	1.15E-03	I	1.08E-03	1.18E-03	1.13E-03	1.13E-03	1.18E-03	1.13E-03	3.95E-05
x		**Phenol**	9.99E-04	9.87E-04	9.55E-04	6.72E-04	5.48E-04	7.16E-04	9.17E-04	6.39E-04	6.40E-04	7.86E-04	1.76E-04
x		**m,p-Xylene**	5.33E-04	5.57E-04	5.61E-04	I	5.18E-04	5.36E-04	5.34E-04	5.30E-04	5.59E-04	5.41E-04	1.59E-05
x		**Acetaldehyde**	I	3.07E-04	3.03E-04	2.80E-04	2.77E-04	2.81E-04	2.90E-04	2.90E-04	2.86E-04	2.89E-04	1.07E-05
x		**Formaldehyde**	2.26E-04	2.76E-04	2.21E-04	2.10E-04	2.40E-04	2.18E-04	2.84E-04	2.52E-04	2.09E-04	2.37E-04	2.79E-05
x		**o-Cresol**	3.82E-04	3.49E-04	3.87E-04	2.05E-04	1.10E-04	2.35E-04	1.83E-04	1.62E-04	6.10E-05	2.31E-04	1.18E-04
x		**Hexane**	1.07E-04	8.46E-05	8.11E-05	7.95E-05	7.29E-05	8.07E-05	7.69E-05	7.88E-05	I	8.27E-05	1.05E-05
x		**o-Xylene***	9.13E-05	8.89E-05	9.07E-05	8.62E-05	8.70E-05	9.22E-05	9.05E-05	9.24E-05	9.58E-05	9.05E-05	2.93E-06
x		**m,p-Cresol**	1.15E-04	1.13E-04	1.21E-04	9.05E-05	ND	7.40E-05	9.05E-05	8.12E-05	ND	7.60E-05	4.59E-05
x		**Ethylbenzene***	6.23E-05	5.66E-05	5.92E-05	5.47E-05	5.50E-05	5.83E-05	5.66E-05	5.80E-05	6.28E-05	5.82E-05	2.89E-06
x	z	**Naphthalene**	7.22E-05	5.61E-05	6.81E-05	5.28E-05	5.24E-05	4.67E-05	5.03E-05	4.46E-05	4.31E-05	5.40E-05	1.01E-05
x		**2-Butanone**	2.28E-05	1.68E-05	2.13E-05	1.87E-05	2.13E-05	1.98E-05	I	2.68E-05	2.45E-05	2.15E-05	3.21E-06
x	z	**2-Methylnaphthalene**	I	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**Acenaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x		**Biphenyl**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1,2-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1,3-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1,5-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1,6-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1,8-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

Test Plan GH Individual Emission Test Results – Lb/Lb Binder (continued)

HAPs	POMs	Compound/Sample Number	GH001	GH002	GH003	GH004	GH005	GH006	GH007	GH008	GH009	Average	STDEV
		Test Dates	**11/9/04**	**11/9/04**	**11/9/04**	**11/10/04**	**11/10/04**	**11/10/04**	**11/11/04**	**11/11/04**	**11/11/04**		
x	z	**2,3-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**2,6-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**2,7-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1-Methylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x		**Styrene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**2,3,5-Trimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x		**Acrolein**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x		**Propionaldehyde**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
			Other VOCs										
		1,3,5-Trimethylbenzene	1.97E-04	2.12E-04	2.29E-04	2.10E-04	2.32E-04	2.04E-04	2.26E-04	2.16E-04	2.18E-04	2.16E-04	1.16E-05
		2,4-Dimethylphenol	1.99E-04	1.43E-04	1.76E-04	1.05E-04	ND	6.07E-05	ND	7.75E-05	ND	8.45E-05	7.69E-05
		1,2,4-Trimethylbenzene	1.36E-04	ND	7.32E-05	ND	ND	ND	1.28E-04	ND	1.27E-04	5.15E-05	6.35E-05
		Pentanal	I	3.72E-05	4.01E-05	3.62E-05	3.45E-05	3.83E-05	3.84E-05	3.94E-05	3.96E-05	3.80E-05	1.89E-06
		Butyraldehyde/Methacrolein	I	3.38E-05	3.50E-05	3.16E-05	3.28E-05	3.22E-05	3.46E-05	3.24E-05	3.36E-05	3.32E-05	1.20E-06
		Benzaldehyde	3.06E-05	2.25E-05	2.54E-05	2.48E-05	2.43E-05	I	2.88E-05	2.35E-05	2.52E-05	2.56E-05	2.71E-06
		Hexaldehyde	I	1.58E-05	1.50E-05	1.50E-05	1.42E-05	1.24E-05	1.69E-05	1.49E-05	1.47E-05	1.49E-05	1.28E-06
		Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		1,3-Diethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		2,6-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Dodecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		2-Ethyltoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		3-Ethyltoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Heptane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Indene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

Test Plan GH Individual Emission Test Results – Lb/Lb Binder (continued)

HAPs	POMs	Compound/Sample Number	GH001	GH002	GH003	GH004	GH005	GH006	GH007	GH008	GH009	Average	STDEV
		Test Dates	**11/9/04**	**11/9/04**	**11/9/04**	**11/10/04**	**11/10/04**	**11/10/04**	**11/11/04**	**11/11/04**	**11/11/04**		
		Propylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		1,2,3-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Undecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Crotonaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
			Other Analytes										
		Carbon Dioxide	5.72E-01	5.21E-01	5.80E-01	5.51E-01	4.92E-01	6.13E-01	5.45E-01	5.36E-01	5.23E-01	5.48E-01	3.61E-02
		Carbon Monoxide	1.92E-01	1.98E-01	2.06E-01	1.84E-01	1.80E-01	2.18E-01	2.16E-01	2.08E-01	2.17E-01	2.02E-01	1.43E-02
		Ammonia	2.64E-03	4.10E-03	4.80E-03	4.82E-03	5.91E-03	6.25E-03	7.52E-03	7.50E-03	7.39E-03	5.66E-03	1.70E-03
		Nitrogen Oxides	1.73E-03	1.53E-03	1.74E-03	1.61E-03	1.67E-03	1.63E-03	1.73E-03	1.57E-03	1.71E-03	1.66E-03	7.45E-05
		Acetone	1.33E-04	1.19E-04	1.21E-04	1.37E-04	1.85E-04	1.69E-04	2.10E-04	2.23E-04	2.31E-04	1.70E-04	4.46E-05

I: Data rejected based on data validation considerations.

ND: Non Detect; NA; Not Applicable

All "Other Analytes" are not included in the Sum of Target Analytes, HAPs.

*** : Results reported as a minimum due to apparent breakthrough.**

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

HAPs	POMs	COMPOUND / SAMPLE NUMBER	GH001	GH002	GH003	GH004	GH005	GH006	GH007	GH008	GH009	Average	STDEV
		Test Dates	**11/9/04**	**11/9/04**	**11/9/04**	**11/10/04**	**11/10/04**	**11/10/04**	**11/11/04**	**11/11/04**	**11/11/04**		
		TGOC as Propane	3.28E-01	2.97E-01	3.21E-01	2.95E-01	2.62E-01	3.12E-01	3.09E-01	2.83E-01	3.15E-01	3.02E-01	2.06E-02
		HC as Hexane	8.85E-02	8.06E-02	8.38E-02	7.67E-02	7.13E-02	7.23E-02	7.70E-02	7.70E-02	8.28E-02	7.89E-02	5.57E-03
		Sum of Target Analytes	7.14E-02	7.30E-02	7.29E-02	I	6.28E-02	3.77E-02	7.09E-02	6.96E-02	6.58E-02	6.55E-02	1.18E-02
		Sum of HAPs	6.58E-02	6.85E-02	6.74E-02	I	5.95E-02	3.43E-02	6.64E-02	6.57E-02	6.14E-02	6.11E-02	1.13E-02
		Sum of POMs	7.09E-04	5.45E-04	6.33E-04	5.07E-04	5.02E-04	4.52E-04	4.76E-04	4.36E-04	4.11E-04	5.19E-04	9.68E-05
			Individual Organic HAPs										
x		**Benzene**	2.95E-02	2.98E-02	3.00E-02	2.78E-02	3.02E-02	I	3.15E-02	3.25E-02	3.12E-02	3.03E-02	1.44E-03
x		**Toluene**	1.07E-02	1.07E-02	1.07E-02	I	1.03E-02	1.14E-02	1.07E-02	1.11E-02	1.13E-02	1.09E-02	3.68E-04
x		**Phenol**	9.81E-03	9.58E-03	8.89E-03	6.45E-03	5.25E-03	6.94E-03	8.67E-03	6.24E-03	6.10E-03	7.55E-03	1.69E-03
x		**m,p-Xylene**	5.23E-03	5.41E-03	5.22E-03	I	4.96E-03	5.20E-03	5.05E-03	5.18E-03	5.33E-03	5.20E-03	1.43E-04
x		**Acetaldehyde**	I	2.98E-03	2.82E-03	2.68E-03	2.65E-03	2.72E-03	2.74E-03	2.84E-03	2.73E-03	2.77E-03	1.04E-04
x		**Formaldehyde**	2.22E-03	2.68E-03	2.06E-03	2.01E-03	2.29E-03	2.11E-03	2.69E-03	2.46E-03	1.99E-03	2.28E-03	2.73E-04
x		**o-Cresol**	3.75E-03	3.39E-03	3.60E-03	1.96E-03	1.06E-03	2.28E-03	1.73E-03	1.59E-03	5.82E-04	2.22E-03	1.14E-03
x		**o-Xylene***	8.96E-04	8.63E-04	8.44E-04	8.27E-04	8.32E-04	8.94E-04	8.55E-04	9.03E-04	9.13E-04	8.70E-04	3.24E-05
x		**Hexane**	1.05E-03	8.21E-04	7.54E-04	7.63E-04	6.98E-04	7.83E-04	7.26E-04	7.70E-04	I	7.96E-04	1.10E-04
x		**m,p-Cresol**	1.13E-03	1.10E-03	1.12E-03	8.68E-04	ND	7.18E-04	8.55E-04	7.94E-04	ND	7.31E-04	4.40E-04
x		**Ethylbenzene***	6.12E-04	5.49E-04	5.51E-04	5.25E-04	5.26E-04	5.65E-04	5.35E-04	5.67E-04	5.99E-04	5.59E-04	3.04E-05
x	z	**Naphthalene**	7.09E-04	5.45E-04	6.33E-04	5.07E-04	5.02E-04	4.52E-04	4.76E-04	4.36E-04	4.11E-04	5.19E-04	9.68E-05
x		**2-Butanone**	2.24E-04	1.63E-04	1.99E-04	1.79E-04	2.04E-04	1.92E-04	I	2.62E-04	2.34E-04	2.07E-04	3.18E-05
x	z	**1,2-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1,3-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1,5-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1,6-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1,8-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1-Methylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

Test Plan GH Individual Emission Test Results – Lb/Tn Metal (continued)

HAPs	POMs	COMPOUND / SAMPLE NUMBER	GH001	GH002	GH003	GH004	GH005	GH006	GH007	GH008	GH009	Average	STDEV
		Test Dates	11/9/04	11/9/04	11/9/04	11/10/04	11/10/04	11/10/04	11/11/04	11/11/04	11/11/04		
x	z	**2,3,5-Trimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**2,3-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**2,6-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**2,7-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**2-Methylnaphthalene**	I	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**Acenaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x		**Biphenyl**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x		**Styrene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x		**Acrolein**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
x		**Propionaldehyde**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
			Other VOCs										
		1,3,5-Trimethylbenzene	1.93E-03	2.06E-03	2.13E-03	2.02E-03	2.22E-03	1.98E-03	2.13E-03	2.11E-03	2.08E-03	2.07E-03	8.75E-05
		2,4-Dimethylphenol	1.95E-03	1.39E-03	1.64E-03	1.00E-03	ND	5.88E-04	ND	7.58E-04	ND	8.14E-04	7.40E-04
		1,2,4-Trimethylbenzene	1.33E-03	ND	6.81E-04	ND	ND	ND	1.21E-03	ND	1.21E-03	4.92E-04	6.10E-04
		Pentanal	I	3.62E-04	3.73E-04	3.48E-04	3.30E-04	3.71E-04	3.63E-04	3.85E-04	3.78E-04	3.64E-04	1.77E-05
		Butyraldehyde/Methacrolien	I	3.28E-04	3.26E-04	3.03E-04	3.14E-04	3.12E-04	3.27E-04	3.16E-04	3.20E-04	3.18E-04	8.61E-06
		Benzaldehyde	3.00E-04	2.18E-04	2.36E-04	2.38E-04	2.33E-04	I	2.72E-04	2.30E-04	2.40E-04	2.46E-04	2.67E-05
		Hexaldehyde	I	1.53E-04	1.40E-04	1.44E-04	1.36E-04	1.21E-04	1.60E-04	1.45E-04	1.41E-04	1.43E-04	1.18E-05
		1,2,3-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		1,3-Diethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		2,6-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		2-Ethyltoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		3-Ethyltoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Dodecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Heptane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Indene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

Test Plan GH Individual Emission Test Results – Lb/Tn Metal(continued)

HAPs	POMs	COMPOUND / SAMPLE NUMBER	GH001	GH002	GH003	GH004	GH005	GH006	GH007	GH008	GH009	Average	STDEV
		Test Dates	**11/9/04**	**11/9/04**	**11/9/04**	**11/10/04**	**11/10/04**	**11/10/04**	**11/11/04**	**11/11/04**	**11/11/04**		
		Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		n-Propylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Undecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Crotonaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
			Other Analytes										
		Acetone	1.31E-03	1.15E-03	1.12E-03	1.32E-03	1.77E-03	1.64E-03	1.98E-03	2.18E-03	2.20E-03	1.63E-03	4.29E-04
		Ammonia	2.60E-02	3.98E-02	4.47E-02	4.62E-02	5.65E-02	6.06E-02	7.10E-02	7.33E-02	7.05E-02	5.43E-02	1.63E-02
		Carbon Monoxide	1.88E+00	1.93E+00	1.92E+00	1.77E+00	1.72E+00	2.11E+00	2.04E+00	2.03E+00	2.07E+00	1.94E+00	1.35E-01
		Carbon Dioxide	5.62E+00	5.06E+00	5.39E+00	5.29E+00	4.71E+00	5.94E+00	5.15E+00	5.24E+00	4.98E+00	5.27E+00	3.61E-01
		Nitrogen Oxides	1.69E-02	1.49E-02	1.62E-02	1.55E-02	1.59E-02	1.59E-02	1.64E-02	1.54E-02	1.63E-02	1.59E-02	6.11E-04

I: Data rejected based on data validation considerations.

ND: Non Detect; NA; Not Applicable

All "Other Analytes" are not included in the Sum of Target Analytes, HAPs.

*** : Results reported as a minimum due to apparent breakthrough.**

Baseline GH Quantitation Limits – Lb/Lb Binder

Analytes	Lb/Lb Binder
1,2,3-Trimethylbenzene	1.23E-05
1,2,4-Trimethylbenzene	1.23E-05
1,3,5-Trimethylbenzene	1.23E-05
1,3-Dimethylnaphthalene	1.23E-05
1-Methylnaphthalene	1.23E-05
2-Ethyltoluene	1.23E-05
2-Methylnaphthalene	1.23E-05
Benzene	1.23E-05
Ethylbenzene	1.23E-05
Hexane	1.23E-05
m,p-Xylene	1.23E-05
Naphthalene	1.23E-05
o-Xylene	1.23E-05
Styrene	1.23E-05
Toluene	1.23E-05
Undecane	1.23E-05
1,2-Dimethylnaphthalene	6.13E-05
1,3-Diethylbenzene	6.13E-05
1,5-Dimethylnaphthalene	6.13E-05
1,6-Dimethylnaphthalene	6.13E-05
1,8-Dimethylnaphthalene	6.13E-05

Analytes	Lb/Lb Binder
2,3,5-Trimethylnaphthalene	6.13E-05
2,3-Dimethylnaphthalene	6.13E-05
2,4-Dimethylphenol	6.13E-05
2,6-Dimethylnaphthalene	6.13E-05
2,6-Dimethylphenol	6.13E-05
2,7- Dimethylnaphthalene	6.13E-05
3-Ethyltoluene	6.13E-05
Acenaphthalene	6.13E-05
Biphenyl	6.13E-05
Cyclohexane	6.13E-05
Decane	6.13E-05
Dodecane	6.13E-05
Heptane	6.13E-05
Indan	6.13E-05
Indene	6.13E-05
m,p-Cresol	6.13E-05
Nonane	6.13E-05
o-Cresol	6.13E-05
Octane	6.13E-05
Phenol	6.13E-05
Propylbenzene	6.13E-05

Analytes	Lb/Lb Binder
Tetradecane	6.13E-05
HC as Hexane	3.71E-04
2-Butanone (MEK)	1.22E-05
Acetaldehyde	1.22E-05
Acrolein	1.22E-05
Benzaldehyde	1.22E-05
Butyraldehyde	1.22E-05
Crotonaldehyde	1.22E-05
Formaldehyde	1.22E-05
Hexaldehyde	1.22E-05
Butyraldehyde/Methacrolein	2.03E-05
o,m,p-Tolualdehyde	3.25E-05
Pentanal (Valeraldehyde)	1.22E-05
Propionaldehyde (Propanal)	1.22E-05
Aniline	7.52E-05
Dimethylaniline	1.50E-04
Ammonia	7.43E-04
Carbon Monoxide	2.91E-03
Carbon Dioxide	4.57E-03
Nitrogen Oxides	3.12E-03

Baseline GH Quantitation Limits – Lb/Tn Metal

Analytes	Lb/Tn Metal
1,2,3-Trimethylbenzene	1.18E-04
1,2,4-Trimethylbenzene	1.18E-04
1,3,5-Trimethylbenzene	1.18E-04
1,3-Dimethylnaphthalene	1.18E-04
1-Methylnaphthalene	1.18E-04
2-Ethyltoluene	1.18E-04
2-Methylnaphthalene	1.18E-04
Benzene	1.18E-04
Ethylbenzene	1.18E-04
Hexane	1.18E-04
m,p-Xylene	1.18E-04
Naphthalene	1.18E-04
o-Xylene	1.18E-04
Styrene	1.18E-04
Toluene	1.18E-04
Undecane	1.18E-04
1,2-Dimethylnaphthalene	5.89E-04
1,3-Diethylbenzene	5.89E-04
1,5-Dimethylnaphthalene	5.89E-04
1,6-Dimethylnaphthalene	5.89E-04
1,8-Dimethylnaphthalene	5.89E-04

Analytes	Lb/Tn Metal
2,3,5-Trimethylnaphthalene	5.89E-04
2,3-Dimethylnaphthalene	5.89E-04
2,4-Dimethylphenol	5.89E-04
2,6-Dimethylnaphthalene	5.89E-04
2,6-Dimethylphenol	5.89E-04
2,7- Dimethylnaphthalene	5.89E-04
3-Ethyltoluene	5.89E-04
Acenaphthalene	5.89E-04
Biphenyl	5.89E-04
Cyclohexane	5.89E-04
Decane	5.89E-04
Dodecane	5.89E-04
Heptane	5.89E-04
Indan	5.89E-04
Indene	5.89E-04
m,p-Cresol	5.89E-04
Nonane	5.89E-04
o-Cresol	5.89E-04
Octane	5.89E-04
Phenol	5.89E-04
Propylbenzene	5.89E-04

Analytes	Lb/Tn Metal
Tetradecane	5.89E-04
HC as Hexane	5.89E-02
2-Butanone (MEK)	1.77E-03
Acetaldehyde	1.77E-03
Acrolein	1.77E-03
Benzaldehyde	1.77E-03
Butyraldehyde	1.77E-03
Crotonaldehyde	1.77E-03
Formaldehyde	1.77E-03
Hexaldehyde	1.77E-03
Butyraldehyde/Methacrolein	2.94E-03
o,m,p-Tolualdehyde	4.71E-03
Pentanal (Valeraldehyde)	1.77E-03
Propionaldehyde (Propanal)	1.77E-03
Aniline	1.18E-02
Dimethylaniline	2.36E-02
Ammonia	1.18E-01
Carbon Monoxide	2.79E-02
Carbon Dioxide	4.39E-02
Nitrogen Oxides	3.12E-03

APPENDIX C TEST SERIES FR & GH DETAILED PROCESS DATA

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Test FR Detailed Process Data

Greensand PCS					
Test Dates	1/15/2004	1/15/2004	1/16/2004	1/16/2004	Averages
Emissions Sample # / Production Sample #	FR 01	FR 02	FR 03	FR 04	
Core Additive	Reference w/o Additive				
Cast Weight (all metal inside mold), Lbs.	110.95	108.35	112.35	112.60	**111.1**
Pouring Time, sec.	36	26	24	24	**28**
Pouring Temp ,°F	2636	2632	2630	2631	**2632**
Pour Hood Process Air Temp at Start of Pour, °F	88	89	85	87	**87**
Mixer auto dispensed batch weight, Lbs	45.35	45.35	45.35	45.35	**45.35**
Calibrated auto dispensed binder weight, Lbs	0.633	0.633	0.633	0.633	**0.633**
Core binder calibrated weight, %BOS	1.39	1.39	1.39	1.39	**1.39**
Core binder calibrated weight, %	1.38	1.38	1.38	1.38	**1.38**
Total uncoated core weight in mold, Lbs.	24.70	25.50	25.30	25.50	**25.25**
Total binder weight in mold, Lbs.	0.340	0.351	0.348	0.351	**0.347**
Core LOI, %	1.19	1.25	1.37	1.23	**1.26**
Core dogbone tensile, psi	39.5	39.5	39.5	39.5	**39.5**
Core age, hrs.	41	55	73	76	**61**
Muller Batch Weight, Lbs.	900	900	900	900	**900**
GS Mold Sand Weight, Lbs.	613	622	619	626	**620**
Mold compactability, %	55	54	57	57	**56**
Mold Temperature, °F	72	70	67	69	**70**
Average Green Compression , psi	11.30	12.16	10.44	10.08	**11.00**
GS Compactability, %	53	47	55	55	**53**
GS Moisture Content, %	1.86	2.28	2.36	2.56	**2.27**
GS MB Clay Content, %	5.58	6.20	6.20	6.08	**6.02**
MB Clay reagent, ml	25.0	26.5	26.5	26.0	**26.0**
1800°F LOI - Mold Sand, %	0.71	0.68	0.74	0.72	**0.71**
900°F Volatiles , %	0.20	0.24	0.30	0.20	0.24
Appearance within group B:best, M:median, W: worst	M		B	W	
Overall appearance ranking: 1 = best, 9 = worst	6		4	9	

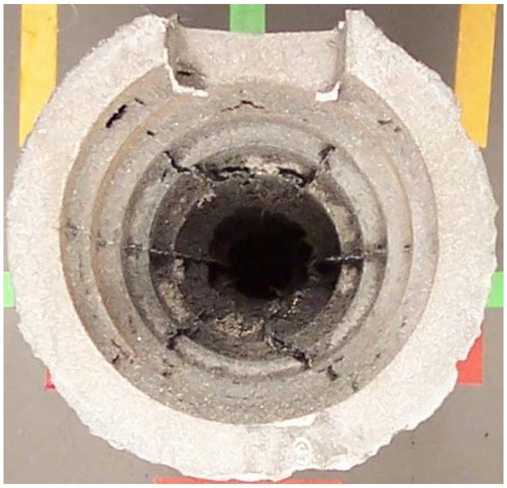
Baseline GH Detailed Process Data

Greensand PCS													
Test Dates	**11/8/04**	**11/8/04**	**11/8/04**	**11/9/04**	**11/9/04**	**11/9/04**	**11/10/04**	**11/10/04**	**11/10/04**	**11/11/04**	**11/11/04**	**11/11/04**	
Emissions Sample #		**GHER2**	**GHER3**	**GH001**	**GH002**	**GH003**	**GH004**	**GH005**	**GH006**	**GH007**	**GH008**	**GH009**	**Averages**
Production Sample #	**GH001**	**GH002**	**GH003**	**GH004**	**GH005**	**GH006**	**GH007**	**GH008**	**GH009**	**GH010**	**GH011**	**GH012**	
Cast Weight (all metal inside mold), Lbs.	138.10	99.65	114.88	110.00	111.20	116.10	112.55	112.85	111.35	114.29	110.50	113.30	**112.46**
Pouring Time, sec.	24	17	18	19	19	15	17	19	15	20	18	19	**17.89**
Pouring Temp ,°F	2630	2628	2632	2631	2625	2618	2634	2630	2623	2638	2636	2635	**2630.00**
Pour Hood Process Air Temp at Start of Pour, °F	86	88	86	88	86	87	87	86	87	86	88	86	**86.78**
Total Uncoated Core Weight in Mold, Lbs.	27.82	28.98	29.00	29.03	29.14	29.08	29.08	29.11	29.06	29.09	29.05	29.03	**29.08**
Core Reported Resin Content w/o Catalyst, %BOS	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	**1.60**
Core Binder Calculated Resin Content w/o Catalyst, %	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	**1.57**
Core Binder Resin Weight w/o Calatyst, Lbs	0.44	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	**0.46**
Core Binder Catalyst Reported Content, %BOR	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	**18.0**
Total Binder Weight in Mold, Lbs.	0.52	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	**0.54**
Core LOI, % Note 2	1.20	1.17	1.23	1.27	1.19	1.27	1.19	1.18	1.15	1.25	1.20	1.25	**1.22**
Approximate Core Age, hrs.	400	400	400	400	400	400	400	400	400	400	400	400	**400**
Core box temperature, F	425	425	425	425	425	425	425	425	425	425	425	425	**425**
Average heated investment time, Seconds	55	55	55	55	55	55	55	55	55	55	55	55	**55**
Muller Batch Weight, Lbs.	1300	900	900	900	900	900	900	900	900	900	900	900	**900**
GS Mold Sand Weight, Lbs.	639	643	648	631	633	634	639	632	625	628	635	620	**631**
Muller Compactability, %	58	54	57	57	55	54	56	55	57	57	54	60	**56**
Mold Temperature, °F	73	80	83	80	82	83	77	82	83	76	81	84	**81**
Average Green Compression , psi	18.8	14.8	20.4	22.7	21.2	22.2	24.4	22.5	22.3	25.1	24.0	24.2	**23.2**
GS Compactability, %	53	49	44	46	39	41	44	41	40	46	38	49	**42.7**
GS Moisture Content, %	2.62	2.14	1.98	1.80	1.80	1.66	1.76	1.60	1.58	1.94	2.08	3.00	**1.91**
GS MB Clay Content, %	8.17	8.04	8.17	8.43	8.56	8.43	8.30	8.3	8.17	8.3	8.43	8.43	**8.4**
MB Clay Reagent, ml	31.5	31.0	31.5	32.5	33.0	32.5	32.0	32.0	31.5	32.0	32.5	32.5	**32.3**
1800°F LOI - Mold Sand, %	0.88	0.86	0.88	0.99	0.90	0.92	0.93	1.05	0.92	0.90	0.91	0.97	**0.94**
900°F Volatiles , %	0.24	0.22	0.34	0.52	0.40	0.42	0.16	0.20	0.08	0.18	0.18	0.08	**0.25**
	GHER1	**GHER2**	**GHER3**	**GH001**	**GH002**	**GH003**	**GH004**	**GH005**	**GH006**	**GH007**	**GH008**	**GH009**	
	GH001	**GH002**	**GH003**	**GH004**	**GH005**	**GH006**	**GH007**	**GH008**	**GH009**	**GH010**	**GH011**	**GH012**	
Core Surface Appearance Ranking 1 = Best, 9 = Worst													
Core Surface Cavity 1	ND	2a	4a	3	4	7	2	1	8	9	6	5	
Core Surface Cavity 2	ND	3a	0a	2	3	5	4	1	9	8	7	6	
Core Surface Cavity 3 (reference cavity)	ND	1b	1a	4	3	5	2	1	6	9	8	7	
Core Surface Cavity 4	ND	0a	0b	4	3	5	1	2	7	9	6	8	

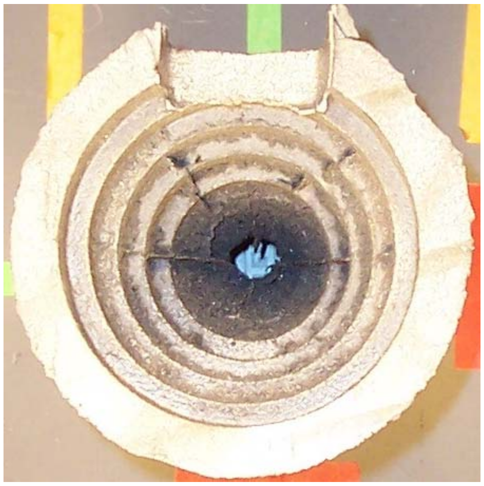
Note 1: Mold 1 was scrapped, no casting

Best Appearing Casting from Mold FR003 & GH008


Median Appearing Casting from Mold FR001 & GH006

Worst Appearing Casting from Mold FR004 & GH010

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APPENDIX D TGOC, CRITERIA POLLUTANTS, AND GREENHOUSE GAS

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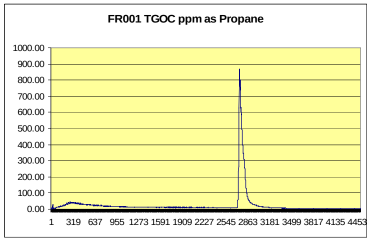
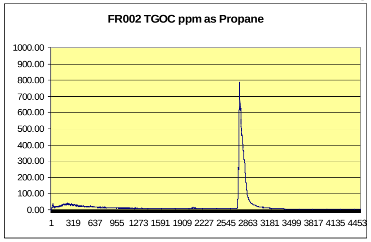
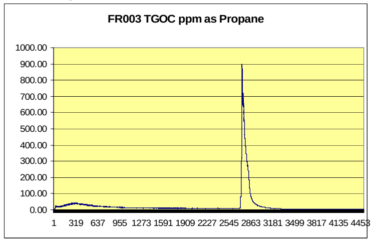
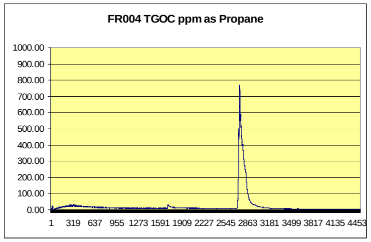
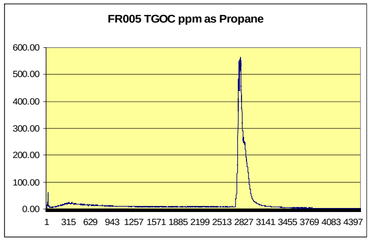
Test FR Pouring/Cooling/Shakeout

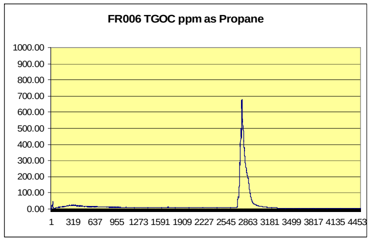


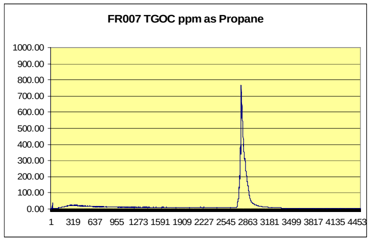


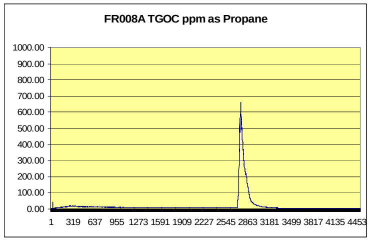


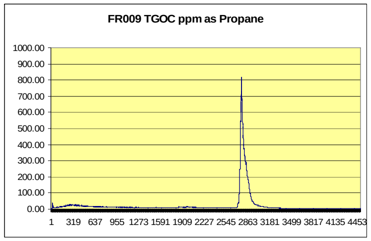




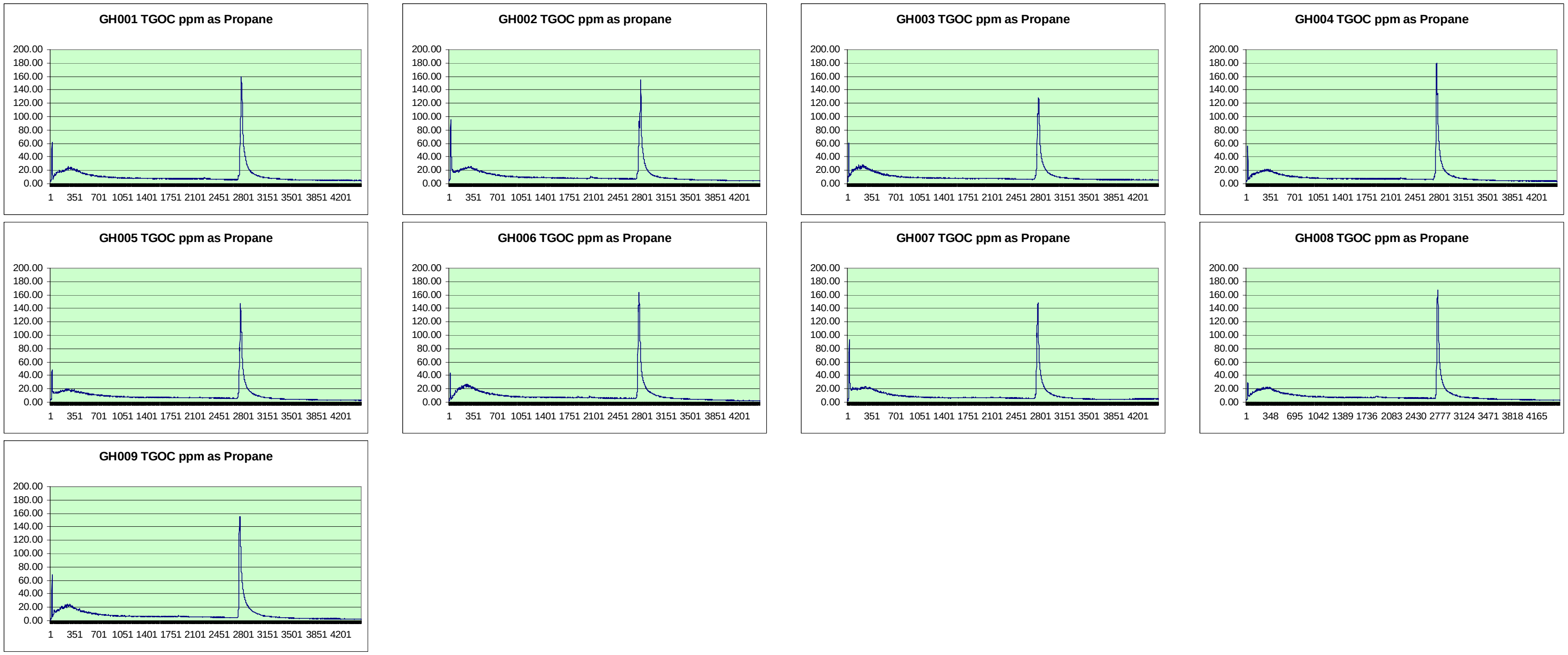




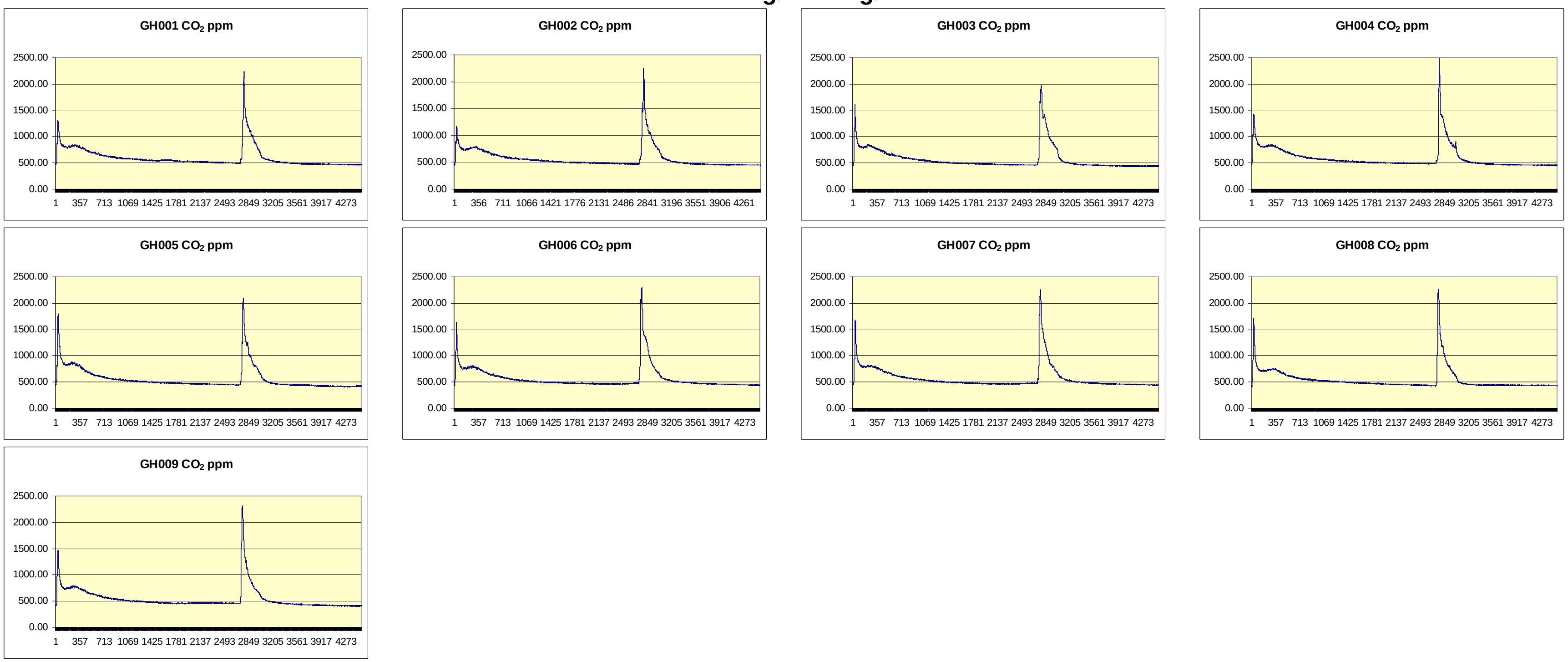




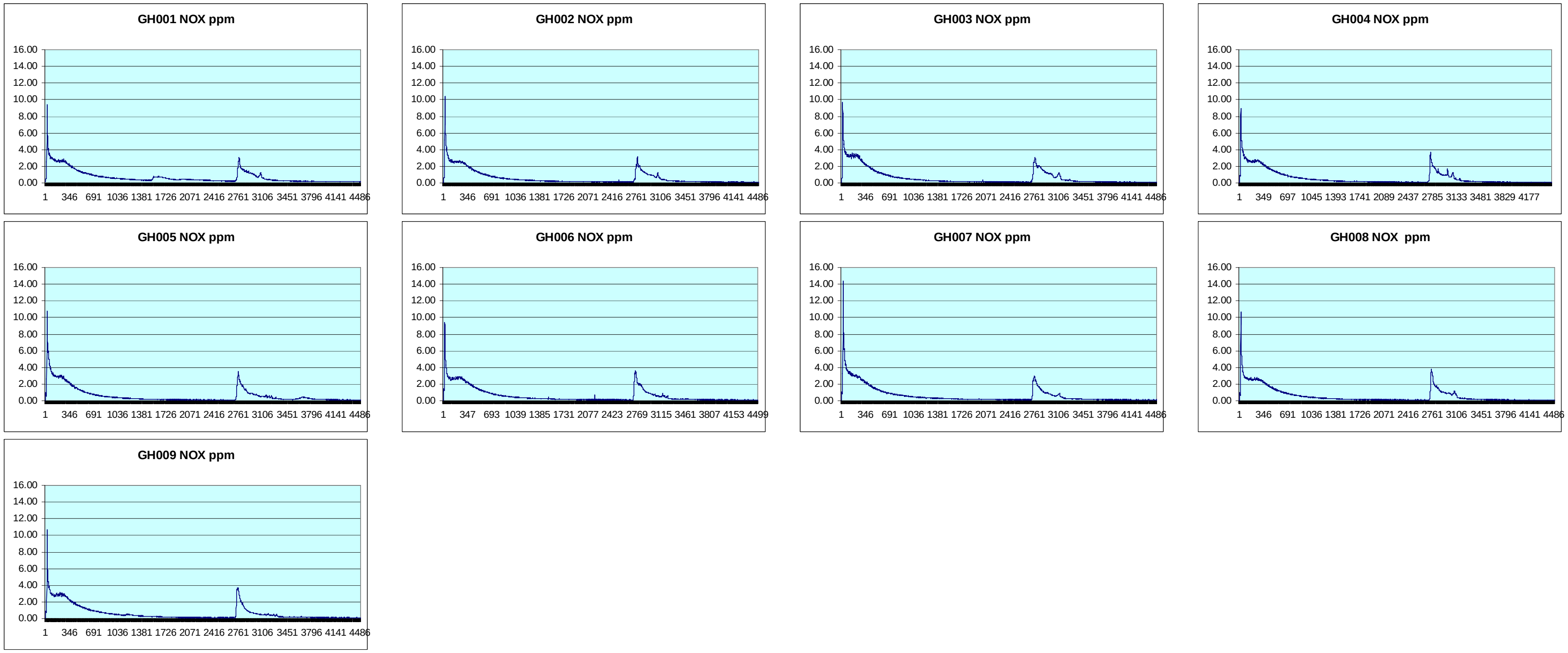
Test GH Pouring/Cooling/Shakeout



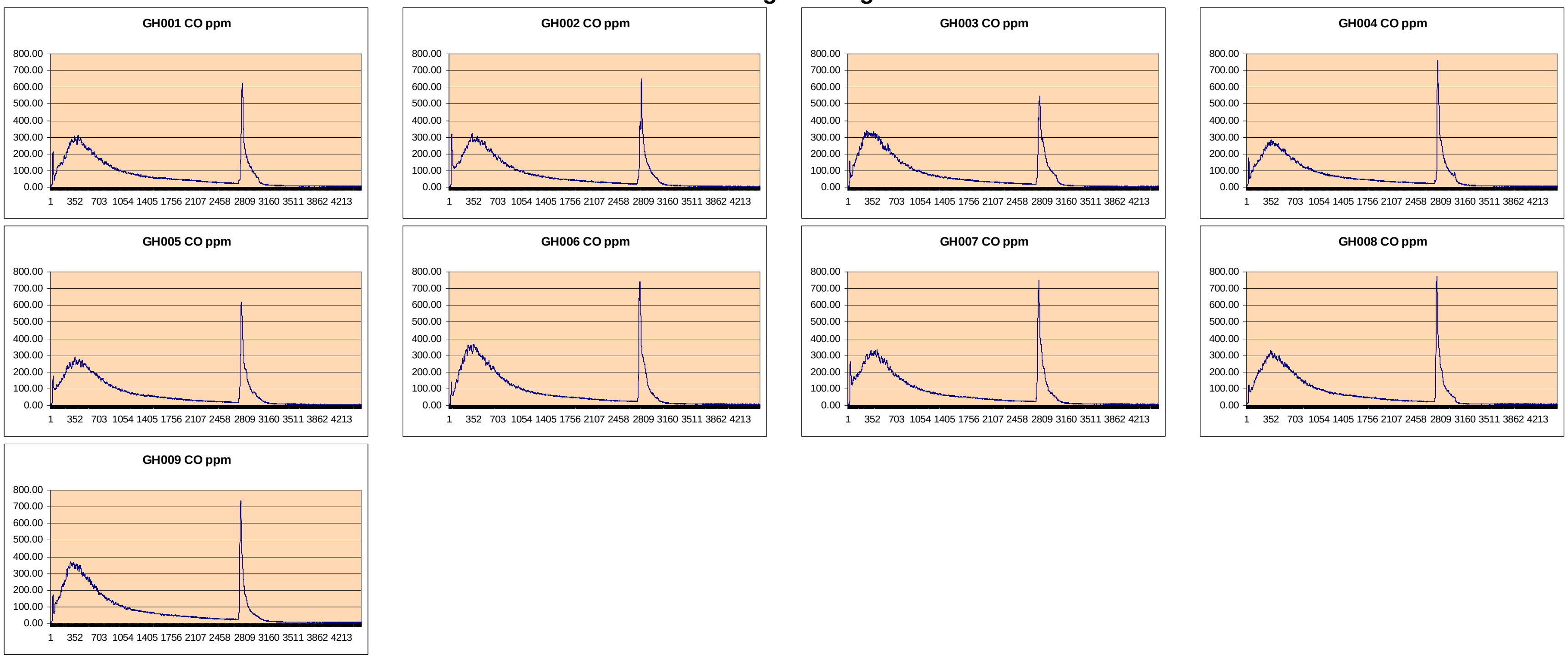
Test GH Pouring/Cooling/Shakeout



Test GH Pouring/Cooling/Shakeout



Test GH Pouring/Cooling/Shakeout



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APPENDIX E GLOSSARY

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 C6 through C16 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 C1 (methane), with results calibrated against a three-carbon alkane (propane).
VOC	Volatile Organic Compound