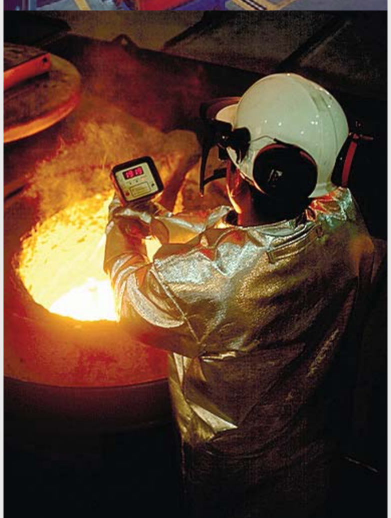
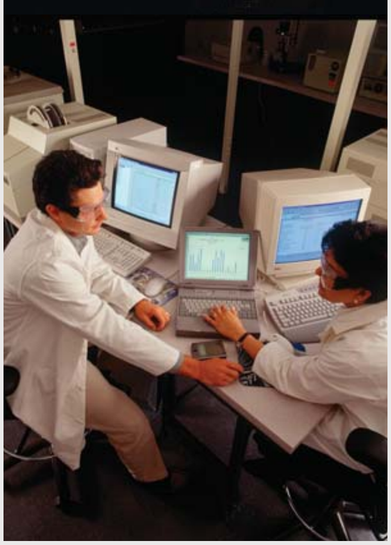
Casting Emission Reduction Program

www.cerp-us.org





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Pouring, Cooling, Shakeout Aluminum, Step Core, Cordis® Binder Comparison to HB

1412-114 HF

October 2006

(Revised for public distribution - November 2006)

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Pouring, Cooling, Shakeout Aluminum, Step Core, Cordis® Binder Comparison to HB

1412-114 HF

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

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

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

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TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

EXECUTIVE SUMMARY

This report contains the results of Test HF, an investigation and evaluation of the pouring, cooling, and shakeout airborne emissions in addition to quality of casting internal surface comparisons, from a low emission aluminum core binder system in greensand molds with no seacoal. Cores were made with a hot-air cured liquid inorganic sodium silicate/sodium polyphosphate foundry sand binder (Cordis® 4820BF, HA International, LLC), at 2.0% based on sand (BOS). All results of this test were compared to Test HB. Test HB was an updated core baseline test for greensand with no seacoal, which used a standard sodium silicate core binder (Solosil®131, Foseco Metallurgical Inc.) containing organic shakeout additive activated with CO_2, at 3.5% BOS.

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

The emissions results are reported in both pounds of analyte per pound of binder (lb/lb) and pounds of analyte per ton of metal poured (lb/ton). Emission Indicator results are presented in Table 1. Reductions in the pounds of emissions per ton of metal poured of 19%

Table 1 Average Emissions Indicators Summary Table

Analyte Name	Lb/Tn		Lb/Lb	
Emission Indicators	**Test HB**	**Test HF**	**Test HB**	**Test HF**
TGOC as Propane	0.1055	0.0854	0.0023	0.0034
HC as Hexane	0.0392	0.0345	0.0008	0.0014
Sum of Target Organic HAPs	0.0276	0.0073	0.0006	0.0003
Sum of Target POMs	0.0002	ND	<0.0001	ND

to 77% as compared to Test HB were calculated using this product. On a lb/lb of binder basis, emissions were approximately 50% higher for the two emission indicators which measure total organics. The Emission Indicator TGOC as Propane includes all exempted compounds including methane and the methane contribution has not been determined or removed.

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

A photographic record was made of the twelve coated core castings produced from the three molds poured during the sand conditioning runs. The surface quality for each of the conditioning run castings was assessed qualitatively relative to each other. Pictures of best, median and worst casting quality are shown in Appendix C. The castings were also compared to those from Test HB. The casting surface finish was acceptable, although not quite as good as that from the sodium silicate system.

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

1.0 INTRODUCTION

1.1. BACKGROUND

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

1.2. CERP/TECHNIKON OBJECTIVES

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

1.3. REPORT ORGANIZATION

This report has been written to document the methodology and results of a specific test plan that was used to evaluate the pouring, cooling and shakeout emissions from a hot-air cured liquid inorganic sodium silicate/sodium polyphosphate foundry sand binder (CORDIS®

4820BF, HA International, LLC) in a greensand mold with no seacoal and poured with aluminum. Emission results are then compared to Test HB, an aluminum core baseline which also tested emissions from greensand molds with no seacoal containing uncoated cores made with a CO_2 cured sodium silicate core binder (CARSIL® 700, Foseco Metallurgical Inc.).

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

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

1.4. SPECIFIC TEST PLAN AND OBJECTIVES

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

Table 1-1 Test Plan Summary

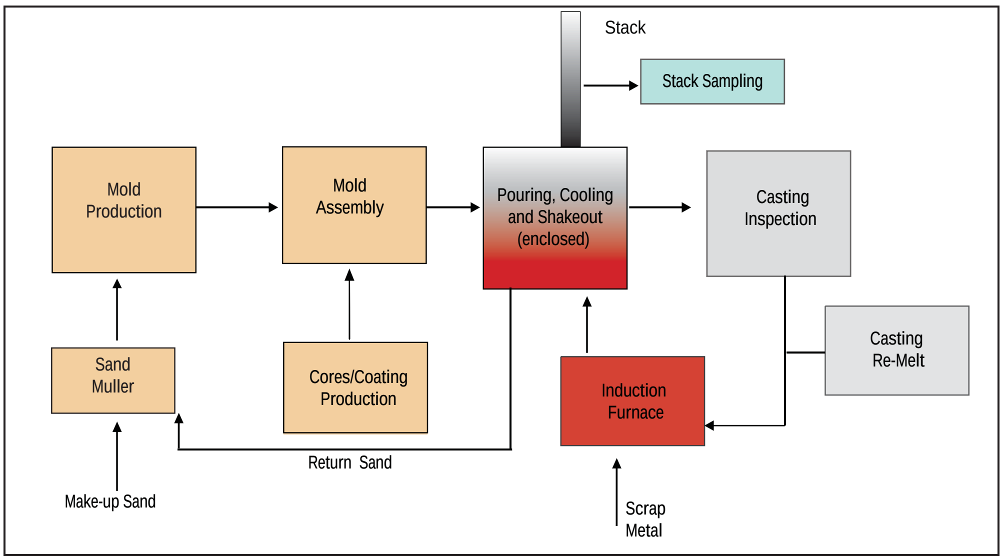
Test Plan Number	1412-123-HB	1412-114-HF
Type of Process Tested	Uncoated sodium silicate core in greensand without seacoal, PCS	Uncoated sodium silicate core in greensand without seacoal, PCS
Metal Poured	Aluminum	Aluminum
Casting Type	4-on step core	4-on step core
Greensand System	Wexford 450 sand, western and southern bentonite in a 5:2 ratio to yield 7.0 +/- 0.5 % MB clay, no seacoal	Wexford 450 sand, western and southern bentonite in a 5:2 ratio to yield 7.0 +/- 0.5 % MB clay, no seacoal
Core	3.5 % (BOS) Foseco Solosil®, CO2 activated, Wedron 530 silica sand	2.0% (BOS) HA International Cordis®, heat activated, Wedron 530 silica sand
Core Coating	Foseco Rheotec® XL + (SD50) for conditioning runs, none for emissions sampling runs	Pyrokote® 8855 for casting conditioning runs, none for emissions sampling runs
Number of Molds Poured	3 conditioning, 9 sampling	3 conditioning, 9 sampling
Test Dates	February 6, trough February 9, 2006	March 13 through March 16, 2006
Emissions Measured	55 target analytes and TGOC as propane, CO, CO2, NOx, SO2	55 target analytes and TGOC as propane, CO, CO2, NOx, SO2
Process Parameters Measured	Total casting, mold, and binder weights; metallurgical data, % LOI, sand temperature; stack temperature, moisture content, pressure, and volumetric flow rate	Total casting, mold, and binder weights; metallurgical data, % LOI, sand temperature; stack temperature, moisture content, pressure, and volumetric flow rate

2.0 TEST METHODOLOGY

2.1. DESCRIPTION OF PROCESS AND TESTING EQUIPMENT

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

Figure 2-1 Research Foundry Layout Diagram



2.2. DESCRIPTION OF TESTING PROGRAM

Both process and stack parameters were monitored and recorded. Process measurements included the weights of the casting and mold sand, loss on ignition (LOI) values for the mold prior to the test, and relevant metallurgical data. Measured stack gas parameters included stack temperature, pressure, volumetric flow rate, and moisture content. All parameters were maintained within prescribed ranges to ensure the reproducibility of the test runs.

Adsorption tube samples were collected and analyzed for fifty-six target organic compounds using procedures based on approved federal regulatory methods, including those of the US Environmental Protection Agency (EPA). Continuous on-line monitoring of Total Gaseous Organic concentration (TGOC), carbon dioxide (CO_2), carbon monoxide (CO), and nitrogen oxide (NOx) concentrations was conducted according to US EPA Methods 25A, 3A, 10, and 7E respectively.

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

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

Figure 2-2 Step Cores in Mold

Figure 2-3 Uncoated Step Cores

2.2.1. Test Plan Review and Approval

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

2.2.2. Mold, Core and Metal Preparation

In Technikon's Research foundry, castings were produced individually in discrete manually constructed mold packages, each of which consists of four cavities. The 4-on step core pattern was used. The molds and cores (Figure 2-2 and 2-3) were prepared to a standard composition by the Technikon production team. Relevant process data were collected and recorded. The total amount of metal melted was determined from the expected poured weight of the castings and the number of molds to be poured. The weight of metal poured into each mold was recorded on the process data summary sheet.

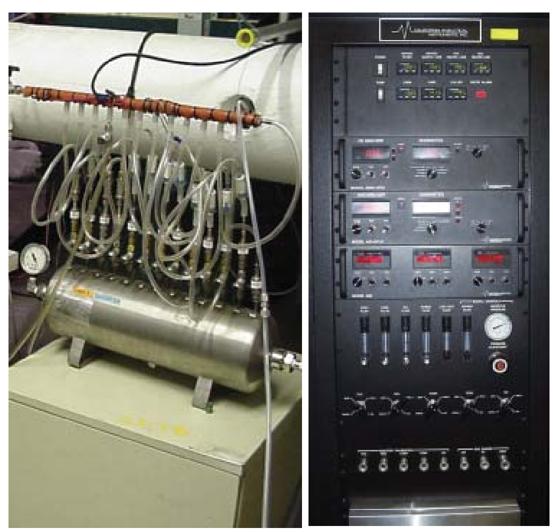
2.2.3. Individual Sampling Events

Replicate runs were performed on nine (9) mold packages. Three (3) conditioning cycles were run to condition the sand and to produce the coated castings used for surface quality comparisons. Prior to pouring for each run, each individual mold package was placed into a hooded enclosure containing a shaker table. The enclosed test stand was pre-heated to approximately 85°F. The flow rate of the emission capture air was nominally 300 scfm. Aluminum at approximately 1275°F was poured through an opening in the top of the emission enclosure, after which the opening was closed (Figure 2-4).

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

A heated sample probe is set into the exhaust stack of the hood to enable collection of total emissions from all phases of the casting process. Continuous air samples were collected during the forty-five minute pouring and cooling phase, during the five minute shakeout of the mold, and for an additional twenty five minute cooling period following shakeout. Figure 2-5 shows the sampling equipment used during collection of emissions. The total sampling time was seventy-five minutes.

Figure 2-5 Stack Sampling Equipment



2.2.4. Process Parameter Measurements

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

Table 2-1 Process Equipment and Methods

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

2.2.5. Air Emissions Analysis

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

Table 2-2 Emission Sampling and Analytical Methods

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

*These methods modified to meet specific CERP test objectives.

2.2.6. Data Reduction, Tabulation and Preliminary Report Preparation

The analytical results of the emissions tests provide the mass of each analyte in the sample. The total mass of the analyte emitted is calculated by multiplying the mass of analyte in the sample by the ratio of total stack gas volume to sample volume. The total stack gas volume is calculated from the measured stack gas velocity and duct diameter and corrected to dry standard conditions using the measured stack pressures, temperatures, gas molecular weight and moisture content. The total mass of analyte is then divided by the weight of the casting poured or weight of binder to provide emissions data in pounds of analyte per ton of metal or pounds of analyte per pound of binder.

Individual results for each analyte for all sampling events are included in Appendix B of this report. Average results for each event are given in Section 3.0, Table 3-1.

2.2.7. Report Preparation and Review

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

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

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

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

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

3.0 TEST RESULTS

The Cordis® binder used in Test HF for aluminum castings was a comparatively low emitting binder system. Reductions in the pounds of emissions per ton of metal poured for CERP's Emission Indicators of 19% to 77% as compared to Test HB were found using this product. Although, binder concentrations were higher for the baseline (3.5% BOS for Test HB vs. 2.0% for Test HF), statistically relevant reductions on a lb/lb binder basis were still noted for the sums of individual targeted organic analytes and HAPs on average at 53%. A detailed discussion of results can be found in Section 4.0 of this report.

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

The average emission results for individual target analytes and emission indicators for Test HF are presented in Tables 3-1a and 3-1b in lb/ton of metal and lb/lb of binder, respectively. Individual target compounds or isomer classes included in the tables are those that comprise at least 95% of the total targeted organic analytes measured, as well as the "Sum of Target Organic Analytes", the "Sum of Target Organic HAPs", and the "Sum of Target POMs". These three analyte sums are part of a group termed "Emission Indicators." Also included in this group and reported on the tables are "TGOC as Propane" and "HC as Hexane". In addition, the average values for selected criteria and greenhouse gases such as carbon monoxide, carbon dioxide, sulfur dioxide and nitrogen oxides are given. This table also includes the relative percent change in emissions from Test HB (the reference test) to Test HF. The relative percent change in this case is defined as the difference in concentrations between the current test and reference test, divided by the reference test concentration and expressed as a percentage.

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

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

Analyte Name	Reference Test HB	Test HF	Percent Change from Test HB
Emission Indicators	**Average**	**Average**	**%**
TGOC as Propane	0.1055	0.0854	**-19**
HC as Hexane	0.0392	0.0345	-12
Sum of Target Organic Analytes	0.0322	0.0074	**-77**
Sum of Target Organic HAPs	0.0276	0.0073	**-73**
Sum of Target POMs	0.0002	ND	NA
Selected Target Organic HAPs and POMs			
Acetaldehyde	0.0200	0.0038	**-81**
Propionaldehyde (Propanal)	0.0022	0.0004	**-83**
Toluene	0.0015	0.0004	**-72**
Xylenes	0.0013	0.0006	**-51**
Benzene	0.0011	0.0006	**-48**
Formaldehyde	0.0008	0.0011	35
Hexane	0.0005	0.0003	-34
Additional Selected Target Organic Analytes			
2-Butanone (MEK)	0.0021	ND	NA
Butyraldehyde/Methacrolein	0.0008	ND	NA
Trimethylbenzenes	0.0007	<0.0001	NA
Criteria Pollutants and Greenhouse Gases			
Carbon Dioxide	ND	0.1487	NA
Carbon Monoxide	0.0909	0.0173	NA
Nitrogen Oxides	ND	0.0004	NA
Sulfur Dioxide	ND	ND	NA

Selected Results constitute >95% of mass of all detected target VOCs for HF and/or HB
Names in italics are not included in top 95% of target organic analyte mass for Reference Test HB.
Bold numbers indicate those compounds whose calculated t-statistic is significant at alpha=0.05
NT = Not Tested
NA = Not Applicable
ND = Not Detected
<0.0001= less than reporting limit of 0.0001 lb/ton metal

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

Analyte Name	Reference Test HB	Test HF	Percent Change from Test HB
Emission Indicators	**Average**	**Average**	**%**
TGOC as Propane	0.0023	0.0034	**51**
HC as Hexane	0.0008	0.0014	**64**
Sum of Target Organic Analytes	0.0007	0.0003	**-56**
Sum of Target Organic HAPs	0.0006	0.0003	**-50**
Sum of Target POMs	<0.0001	ND	NA
Selected Target Organic HAPs and POMs			
Acetaldehyde	0.0004	0.0002	**-81**
Propionaldehyde (Propanal)	<0.0001	<0.0001	NA
Toluene	<0.0001	<0.0001	NA
Xylenes	<0.0001	<0.0001	NA
Benzene	<0.0001	<0.0001	NA
Formaldehyde	<0.0001	<0.0001	NA
Hexane	<0.0001	<0.0001	NA
Additional Selected Target Organic Analytes			
2-Butanone (MEK)	<0.0001	ND	NA
Butyraldehyde/Methacrolein	<0.0001	ND	NA
Trimethylbenzenes	<0.0001	<0.0001	NA
Criteria Pollutants and Greenhouse Gases			
Carbon Dioxide	ND	0.0062	NA
Carbon Monoxide	0.0019	0.0007	-63
Nitrogen Oxides	ND	<0.0001	NA
Sulfur Dioxide	ND	ND	NA

Selected Results constitute >95% of mass of all detected target VOCs for HF and/or HB
Names in italics are not included in top 95% of target organic analyte mass for Reference Test HB.
Bold numbers indicate those compounds whose calculated t-statistic is significant at alpha=0.05
NT= Not Tested
NA = Not Applicable
ND = Not Detected
<0.0001= less than reporting limit of 0.0001 lb/ton metal

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

Figures 3-1a to 3-3b graphically present the data from the tables for Test HF of the five emissions indicators as well as selected individual HAP, organic analyte, and criteria pollutant and greenhouse gas emissions data relative to Test HB as both lb/ton of metal and lb/lb of binder – Binder percentages influence emissions on a relative basis when calculated on a lb/lb binder basis. The lower binder concentration for Test HF (2.0% BOS) was recommended by the manufacturer, whereas the concentration used for Test HB (3.5% BOS) is common for sodium silicate binders.

Figure 3-1a Comparison of Emissions Indicators of HF to HB, Average Results – Lb/Tn Metal

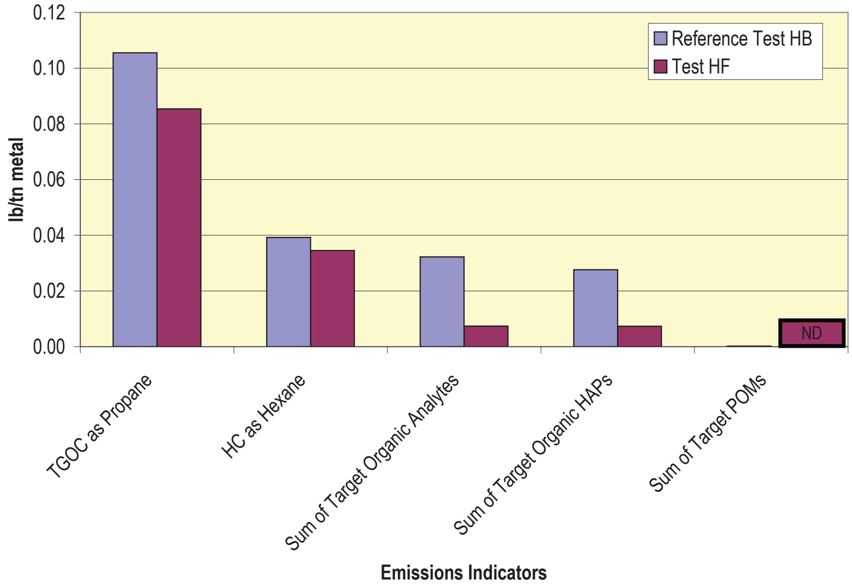


Figure 3-1b Comparison of Emissions Indicators of HF to HB, Average Results – Lb/Lb Binder

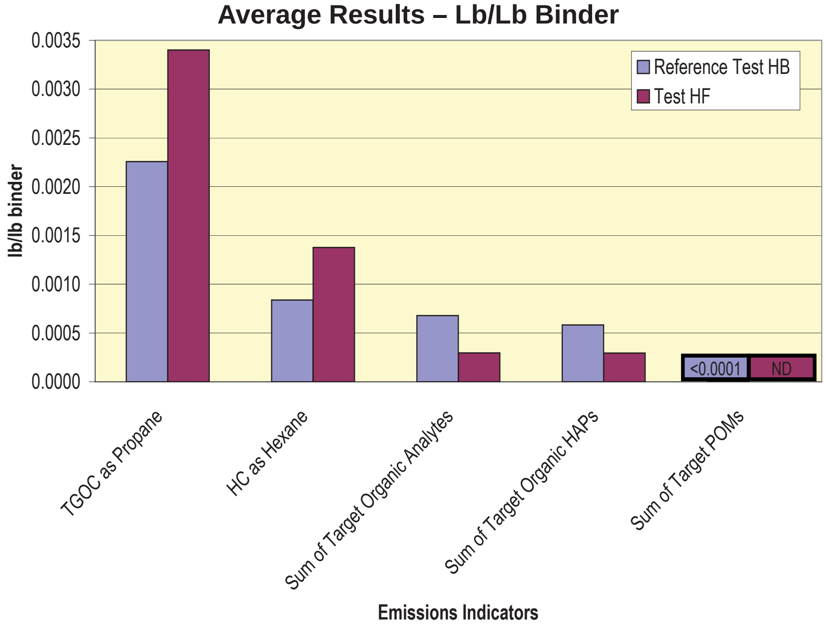


Figure 3-2a Comparison of Selected Organic HAP and POM Emissions of HF to HB, Average Results – Lb/Tn Metal

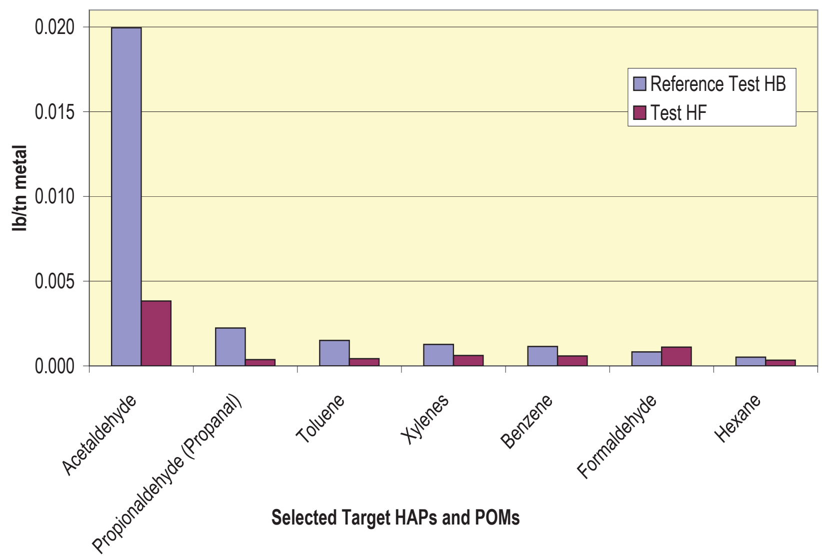


Figure 3-2b Comparison of Selected Organic HAP and POM Emissions of HF to HB, Average Results – Lb/Lb Binder

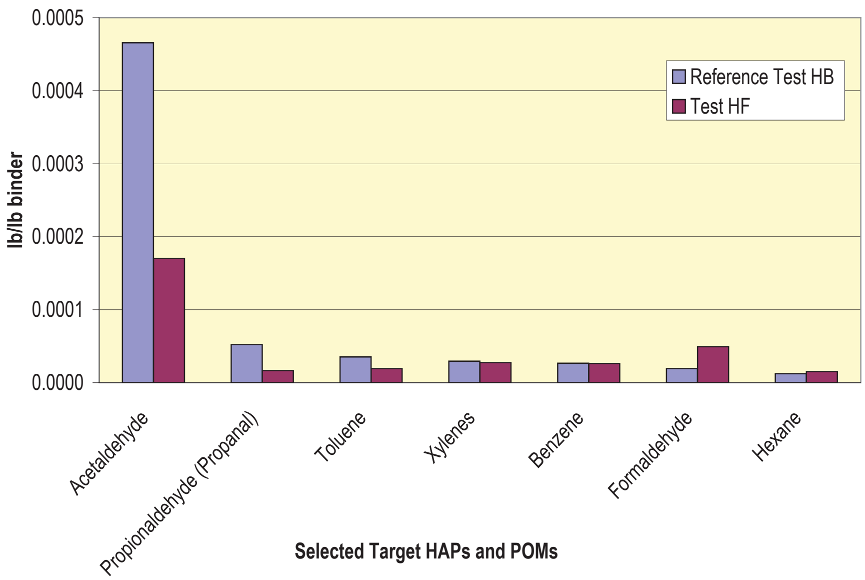


Figure 3-3a Comparison of Criteria Pollutants and Greenhouse Gases of HF to HB, Average Results – Lb/Tn Metal

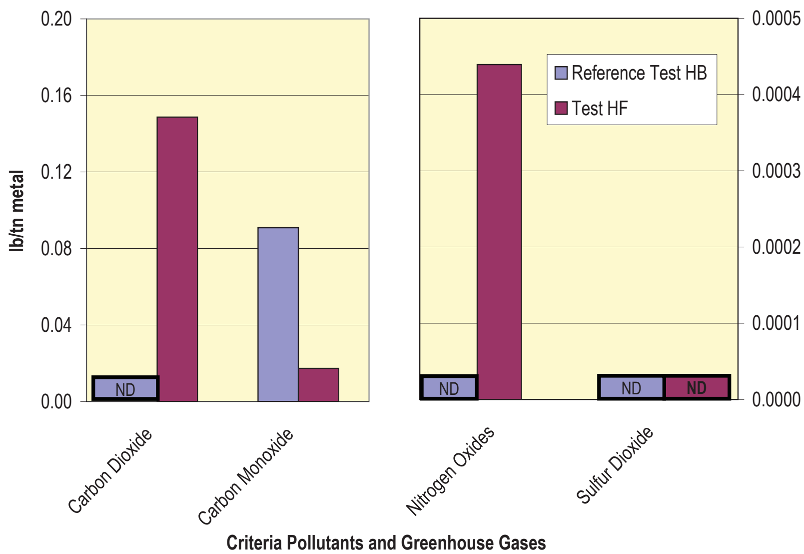
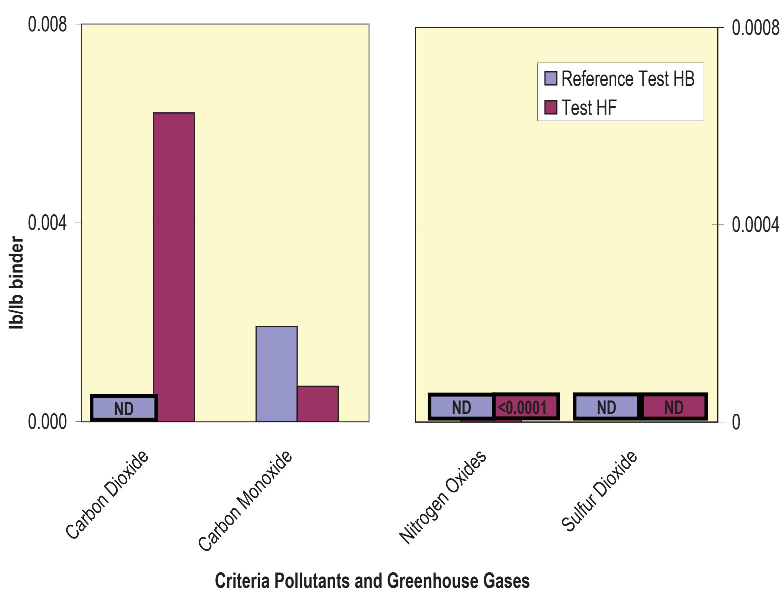


Figure 3-3b Comparison of Criteria Pollutants and Greenhouse Gases of HF to HB, Average Results – Lb/Lb Binder



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. EPA Method 25A represents the sum of detected volatile organics as propane and is weighted to the detection of the more volatile hydrocarbon species, beginning at methane, the single carbon alkane (C_1), with results calibrated against propane, which is the three-carbon alkane (C_3). The methane contribution from these results has not been determined or removed, as allowed by the method.

The HC as Hexane method represents the sum of all detected hydrocarbon compounds in the range between C_6 and C_{16}, with results calibrated against the six-carbon alkane, hexane (C_6). Results are determined by the summation of all chromatographic peak areas between the elution of hexane through the elution of hexadecane (C_{16}). The quantity of HC is determined by dividing the total summed area count by the area of hexane from the initial calibration curve derived from a five point calibration.

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

The average process parameters are reported in Table 3-2 and Appendix C.

A comparison was made between the surface quality of the coated core castings for Test HC and Test HB. The comparison consists initially of a visual examination of major and minor surface defects such as burn-in, gas holes or scabbing. Castings are first ranked according to those defects. To further differentiate surface quality among castings, the finish is tested by touch for smoothness. The smoothest casting with the fewest visual surface defects receives the highest ranking.

The comparative ranking of casting appearance for each casting made with coated cores used in the three conditioning runs for Test HF and Test HB is shown in Table 3-3. Each of the four castings from the molds of the three conditioning runs for the current test was assessed and compared relative to each other. Three benchmark visual casting quality rankings consisting of the best, the median, and the worst casting are assigned to three of the castings. The "best" designation means that a casting is the best appearing casting of the lot of twelve, and is given an in-series rank of "1". The "median" designation, given an in-series rank of "6", means that five castings are better in appearance and six are worse. The "worst" designation

Table 3-2 Summary of Test Plan Process Parameters

Greensand PCS with HA International Cordis Cores	Test HF	Test HB
Test Dates	**3/13/06-3/16/06**	**2/6/06-2/9/06**
Cast Weight, Lbs.	42.74	41.46
Pouring Time, sec.	16	17
Pouring Temp ,°F	1275	1278
Pour Hood Process Air Temp at Start of Pour, °F	87	87
Mixer Auto Dispensed Sand Weight, Lbs	50.07	50.00
Core Binder Weight, Lbs	1.00	1.74
% Core Binder (BOS)	2.01	3.49
% Core Binder	1.97	3.37
Total Core Weight in Mold, Lbs.	27.28	29.35
Total Binder Weight in Mold, Lbs.	0.536	0.990
Core LOI, %	0.14	0.62
Core Dogbone Tensile, psi	29	29
Core Age, hrs.	136	311
Muller Batch Weight, Lbs.	916	901
GS Mold Sand Weight, Lbs.	638	642
Mold Temperature, °F	69	69
Average Green Compression , psi	20.81	20.75
GS Compactability, %	44	42
GS Moisture Content, %	2.04	1.90
GS MB Clay Content, %	7.03	6.77
MB Clay Reagent, ml	37.3	34.1
1500°F LOI - Mold Sand, %	0.69	0.77
900°F Volatiles , %	0.32	0.28
Permeability Index	262	265
Sand Temperature, °F	77	71

Table 3-3 Casting Quality Rank Order

Rank Order of Appearance*	Mold number	Cavity Number	Test HB	Test HF
Rank1	HBCR1	3	Best	
Rank2	HFCR3	1		Best
Rank3	HFCR1	3		
Rank4	HFCR1	2		
Rank5	HBCR2	3	Median	
Rank6	HFCR3	2		
Rank7	HFCR2	1		
Rank8	HFCR2	4		Median
Rank9	HFCR3	4		
Rank10	HFCR1	2		
Rank11	HFCR2	2		
Rank12	HFCR2	3		
Rank 13	HBCR3	4	Worst	
Rank 14	HFCR3	3		
Rank 15	HFCR1	4		Worst

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

is assigned to that casting which is of the poorest quality, and is assigned an in-series rank of “12”. The remaining castings are then compared to these three benchmarks. The three-benchmark castings from Test HB then were compared and collated to the benchmark castings from Test HF. Castings from the conditioning runs are used for surface finish quality comparisons only. No emissions from these runs were sampled and are therefore not included in the emission results reported here.

The overall appearance of the Test HB castings was superior to the Test HF castings. There appeared to be considerably more veins and surface disruptions with the Test HF castings. The tensile strength of the Test HF cores was about double compared to the Test HB cores. It should be noted that the Test HB binder level was 3.5% BOS, while the Test HF binder was 2.0%, indicating that a lower binder concentration attains greater core strength levels using Cordis® binder.

The four appendices in this report contain detailed information regarding testing, sampling, data collection and results for each sampling event. Appendix A contains test plans, instructions and the sampling plan for Test HF. Appendix B contains detailed emissions data and average results for all targeted analytes. Target analyte practical quantitation reporting limits expressed in both lb/lb binder and lb/ton metal are also shown in Appendix B. These values are based on the practical quantitation limit which is related to the detection limitations of an analytical method and the capabilities of analytical instrumentation. Appendix C contains detailed process data and the pictorial casting record. Appendix D contains continuous monitor charts. The charts are presented to show TGOC, carbon monoxide, carbon dioxide, and oxides of nitrogen time-dependent emissions profiles for each pour. Appendix E contains acronyms and abbreviations.

4.0 DISCUSSION OF RESULTS

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

Examination of measured process parameters indicated that both tests were run within acceptable ranges and limits. A statistical determination of whether the means of emissions of the baseline test and the current test were different was made by calculating a T-test at a 95% significance level (α=0.05). Results at this significance level indicate that there is a 95% probability that the mean values for Test HF are not equivalent to those of Test HB. Therefore, it may be said that the differences in the average emission values are real differences, and not due to test, sampling, or analysis methodologies. This difference is indicated in Tables 3-1A and 3-1B in the column labeled “Percent Change from Test HB”. Values in this column presented in **bold font** indicate a greater than 95% probability that the two tests are statistically different.

In general, emissions for both Test HF and Test HB were low compared to traditional binder systems. Emission Indicator results expressed as lb/ton show reductions of 19% for TGOC as propane, 12% for HC as hexane, 77% in the Sum of Target Organic Analytes, and 73% in the Sum of Target Organic HAPs. No target POMs were detected for this binder system.

Binder percentages influence emissions on a relative basis when calculated on a lb/lb binder basis. The lower binder concentration for Test HF (2.0% BOS) was recommended by the manufacturer, whereas the concentration used for Test HB (3.5% BOS) is common for sodium silicate binders. When comparing emissions on a lb/lb binder basis for Emission Indicators, increases in TGOC as Propane and HC as Hexane of 51% and 64%, respectively were found. Decreases of approximately 50% were calculated for the Sums of Target Organic Analytes and HAPs as can be seen in Table 3-1B.

Seven organic analytes and isomer classes accounted for more than 95% of the concentration of all emitted targeted organic analytes detected from Test HF when calculated as lb/ton, as can be seen in Table 3-1A. Several aldehydes were top contributors, with acetaldehyde and formaldehyde portions being the highest at 52% and 15%, respectively. Benzene, toluene, and xylenes accounted for approximately 7% each, while propionaldehyde and hexane each contributed 5%.

There were statistical reductions from Test HB to Test HF for six of the seven analytes contributing to the top 95% of emissions on a lb/ton basis ranging from 34% to 81%. An increase of 35% in emissions was found for formaldehyde.

Results in a lb/lb binder basis for individual analytes were low relative to the stated reporting limit, so a relative percent difference between the two tests is not applicable except for acetaldehyde, which showed an 81% reduction from Test HB to Test HF.

APPENDIX A TEST & SAMPLE PLANS AND PROCESS INSTRUCTIONS

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TECHNIKON TEST PLAN

- **CONTRACT NUMBER:** 1412 **TASK NUMBER:** 1.2.3 **SERIES:** HB
- **SITE:** Research Foundry
- **TEST TYPE:** Pouring, cooling, shakeout: Baseline: Uncoated liquid sodium silicate foundry binder in Greensand. (conditioning run cores coated
- **METAL TYPE:** A356 Aluminum
- **MOLD TYPE:** 4-on step-cored greensand with no seacoal.
- **NUMBER OF MOLDS:** 3 engineering/conditioning/casting quality runs + 9 sampling runs.
- **CORE TYPE:** Step; Wedron 530 sand; 3.5% (BOS) Foseco Solosil® 131 binder, CO_2 activated.
- **CORE COATING:** Foseco Rheotec® XL (SD50) for the 3 engineering/ conditioning/ casting quality runs labeled HBCR1 to HBCR3, none for the emission sampling runs labeled HB001-HB009.
- **SAMPLE EVENTS:** 9
- **ANALYTE LIST:** List G, CO/CO_2, NOx, SO_2, TGOC
- **TEST DATE:** **START:** 6 Feb 2006
  FINISHED: 9 Feb 2006

TEST OBJECTIVES:

Measure selected PCS HAP & VOC emissions, CO, CO_2, NOx, and TGOC from Foseco Solosil® binder activated with CO_2 in greensand with no seacoal to update the core baseline database. This includes quality data for washed cores for casting internal surface comparisons.

VARIABLES:

The pattern will be the 4-on step core. The mold will be made with Wexford 450 sand, western and southern bentonite in a 5:2 ratio to yield 7.0 +/- 0.5% MB Clay, no seacoal, and tempered to 40-45% compactability, mechanically compacted. The molds will be maintained at 70-90°F prior to pouring. The sand heap will be maintained at 900 pounds. Molds will be poured with aluminum at 1270 +/- 10°F. Mold cooling will be 45 minutes followed by 15 minutes of shakeout, or until no more material remains to be shaken out, followed by 15 minutes additional sampling for a total of 75 minutes.

BRIEF OVERVIEW:

These greensand molds will be produced on mechanically assisted Osborne molding machines.

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

SPECIAL CONDITIONS:

The process will include rigorous maintenance of the size of sand heap and maintenance of the material and environmental testing temperatures to reduce seasonal and daily temperature dependent influence on the emissions. Initially a 1200 pound greensand heap will be created from a single muller batch. Nine hundred pounds will become the re-circulating heap. The balance will be used to makeup for attrition. Cores will be produced with Wedron 530 silica sand. The cores shall be bagged in plastic. Coated and dried cores will be bagged as soon as sufficiently cooled. The cores for the engineering/conditioning/casting quality runs HBCR1-3 will be dipped to provide 12 castings with an internal surface available for comparison to as best, average, and worst by other coated cores made with other core binders.

TECHNIKON TEST PLAN

- **CONTRACT NUMBER:** 1412 **TASK NUMBER:** 1.1.4 **SERIES:** HF
- **SITE:** Research Foundry
- **TEST TYPE:** Pouring, cooling, shakeout: uncoated Cordis® liquid inorganic core binder in greensand. (conditioning run cores coated)
- **METAL TYPE:** A356/357 Aluminum
- **MOLD TYPE:** 4-on step-cored greensand with no seacoal.
- **NUMBER OF MOLDS:** 3 engineering/conditioning + 9 Sampling
- **CORE TYPE:** Step; Wedron 530 sand; 2.0% Cordis® (BOS), hot air activated.
- **CORE COATING:** Customer choice for HFER1 to HFER3, none for production runs HF004-HF009
- **SAMPLE EVENTS:** 9
- **ANALYTE LIST:** List G, CO/CO_2, SO_2, NOx, TGOC
- **TEST DATE:** **Start:** 13 March 2006
  Finish: 16 March 2006

TEST OBJECTIVES:

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

VARIABLES:

The pattern will be the 4-on step core. The mold will be made with Wexford 450 sand, western and southern bentonite in a 5:2 ratio to yield 7.0 ± 0.5% MB Clay, no seacoal, and tempered to 40-45% compactability, mechanically compacted. The molds will be maintained at 70-90°F prior to pouring. The sand heap will be maintained at 900 pounds. Molds will be poured with aluminum at 1270 ± 10°F. Mold cooling will be 45 minutes followed by 15 minutes of shakeout, or until no more material remains to be shaken out, followed by 15 minutes additional sampling for a total of 75 minutes.

BRIEF OVERVIEW:

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

SPECIAL CONDITIONS:

The process will include rigorous maintenance of the size of sand heap and maintenance of the material and environmental testing temperatures to reduce seasonal and daily temperature dependent influence on the emissions. Initially a 1200 pound greensand heap will be created from a single muller batch. Nine hundred pounds will become the re-circulating heap. The balance will be used to makeup for attrition. Cores will be produced with Wedron 530 silica sand. The cores shall be bagged in plastic. Coated and dried cores will be bagged as soon as sufficiently cooled. The cores for the engineering runs HFER1-3 will be dipped to provide 12 castings with an internal surface available for comparison to as best, average, and worst by other coated cores made with other core binders.

RESEARCH FOUNDRY HB - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/6/2006											
CONDITIONING - 1											
THC, CO, CO_2 & NOx	HB CR-1	X									TOTAL

RESEARCH FOUNDRY HB - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/6/2006											
CONDITIONING - 2											
THC, CO, CO_2 & NOx	HB CR-2	X									TOTAL

RESEARCH FOUNDRY HB - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/6/2006											
CONDITIONING - 3											
THC, CO, CO_2 & NOx	HB CR-3	X									TOTAL

RESEARCH FOUNDRY HB - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/7/2006											
THC, CO, CO_2 & NOx	HB001	X									TOTAL
TO-17	HB00101		1						60	1	Carbopak charcoal
TO-17	HB00102				1				0		Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HB00103		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	HB00104				1				0		100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HB00105		1						1000	8	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	HB00106				1				0		100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HB00107		1						1000	10	DNPH Silica Gel (SKC 226-119)
TO11	HB00108				1				0		DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HB - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
2/7/2006											
THC, CO, CO_2 & NOx	HB002	X									TOTAL
TO-17	HB00201		1						60	1	Carbopak charcoal
TO-17	HB00202			1					60	2	Carbopak charcoal
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HB00203		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	HB00204			1					1000	7	100/50 mg Carbon Bead (SKC 226-80)
NIOSH 1500	HB00205		1						1000	8	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	HB00206			1					1000	9	100/50 mg Charcoal (SKC 226-01)
TO11	HB00207		1						1000	10	DNPH Silica Gel (SKC 226-119)
TO11	HB00208			1					1000	11	DNPH Silica Gel (SKC 226-119)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HB - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/7/2006											
THC, CO, CO_2 & NOx	HB003	X									TOTAL
TO-17	HB00301		1						60	1	Carbopak charcoal
TO-17 MS	HB00302		1						60	2	Carbopak charcoal
TO-17 MS	HB00303			1					60	3	Carbopak charcoal
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HB00304		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HB00305		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HB00306		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HB - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
2/8/2006											
THC, CO, CO_2 & NOx	HB004	X									TOTAL
TO-17	HB00401		1						60	1	Carbopak charcoal
TO-17	HB00402					1			60	1	Carbopak charcoal
TO-17	HB00406		1						25	2	Carbopak charcoal
	Excess								60	3	Blocked
TO-17	HB00407		1						200	4	Carbopak charcoal
TO-17	HB00408					1			200	4	Carbopak charcoal
OSHA ID200	HB00409		1						500	5	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	HB00403		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HB00404		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1500	9	Blocked
TO11	HB00405		1						1000	10	DNPH Silica Gel (SKC 226-119)
OSHA ID200	HB00410		1						1500	11	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	HB00411					1			1500	11	100/50 mg Carbon Bead (SKC 226-80)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HB - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/8/2006											
THC, CO, CO_2 & NOx	HB005	X									TOTAL
TO-17	HB00501		1						60	1	Carbopak charcoal
TO-17	HB00505		1						25	2	Carbopak charcoal
	Excess								60	3	Blocked
TO-17	HB00506		1						200	4	Carbopak charcoal
TO-17	HB00507					1			200	4	Carbopak charcoal
OSHA ID200	HB00508		1						500	5	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	HB00502		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HB00503		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1500	9	Blocked
TO11	HB00504		1						1000	10	DNPH Silica Gel (SKC 226-119)
OSHA ID200	HB00509		1						1500	11	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	HB00510					1			1500	11	100/50 mg Carbon Bead (SKC 226-80)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HB - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/8/2006											
THC, CO, CO_2 & NOx	HB006	X									TOTAL
TO-17	HB00601		1						60	1	Carbopak charcoal
	Excess								25	2	Blocked
	Excess								60	3	Blocked
NIOSH 1500	HB00605		1						200	4	100/50 mg Charcoal (SKC 226-01)
	Excess								500	5	Blocked
OSHA ID200	HB00602		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HB00603		1						1000	8	100/50 mg Charcoal (SKC 226-01)
TO11	HB00606		1						1500	9	DNPH Silica Gel (SKC 226-119)
TO11	HB00607					1			1500	9	DNPH Silica Gel (SKC 226-119)
TO11	HB00604		1						1000	10	DNPH Silica Gel (SKC 226-119)
NIOSH 1500	HB00608		1						1500	11	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	HB00609					1			1500	11	100/50 mg Charcoal (SKC 226-01)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HB - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/9/2006											
THC, CO, CO_2 & NOx	HB007	X									TOTAL
TO-17	HB00701		1						60	1	Carbopak charcoal
	Excess								25	2	Blocked
	Excess								60	3	Blocked
NIOSH 1500	HB00705		1						200	4	100/50 mg Charcoal (SKC 226-01)
	Excess								500	5	Blocked
OSHA ID200	HB00702		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HB00703		1						1000	8	100/50 mg Charcoal (SKC 226-01)
TO11	HB00706		1						1500	9	DNPH Silica Gel (SKC 226-119)
TO11	HB00707					1			1500	9	DNPH Silica Gel (SKC 226-119)
TO11	HB00704		1						1000	10	DNPH Silica Gel (SKC 226-119)
NIOSH 1500	HB00708		1						1500	11	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	HB00709					1			1500	11	100/50 mg Charcoal (SKC 226-01)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HB - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
2/9/2006											
THC, CO, CO_2 & NOx	HB008	X									TOTAL
TO-17	HB00801		1						60	1	Carbopak charcoal
	Excess								25	2	Blocked
	Excess								60	3	Blocked
	Excess								200	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HB00802		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HB00803		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1500	9	Blocked
TO11	HB00804		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1500	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HB - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
2/9/2006											
THC, CO, CO_2 & NOx	HB009	X									TOTAL
TO-17	HB00901		1						60	1	Carbopak charcoal
	Excess								25	2	Blocked
	Excess								60	3	Blocked
	Excess								200	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HB00902		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HB00903		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1500	9	Blocked
TO11	HB00904		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1500	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HF - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/14/2006											
CONDITIONING - 1											
THC, CO, CO_2 & NOx	HF CR-1	X									TOTAL

RESEARCH FOUNDRY HF - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/14/2006											
CONDITIONING - 2											
THC, CO, CO_2 & NOx	HF CR-2	X									TOTAL

RESEARCH FOUNDRY HF - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/14/2006											
CONDITIONING - 3											
THC, CO, CO_2 & NOx	HF CR-3	X									TOTAL

RESEARCH FOUNDRY HF - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/13/2006											
THC, CO, CO_2 & NOx	HF001	X									TOTAL
TO-17	HF00101		1						60	1	Carbopak charcoal
TO-17	HF00102				1				0		Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HF00103		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	HF00104				1				0		100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HF00105		1						1000	8	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	HF00106				1				0		100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HF00107		1						1000	10	DNPH Silica Gel (SKC 226-119)
TO11	HF00108				1				0		DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HF - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
3/13/2006											
THC, CO, CO_2 & NOx	HF002	X									TOTAL
TO-17	HF00201		1						60	1	Carbopak charcoal
TO-17	HF00202			1					60	2	Carbopak charcoal
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HF00203		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	HF00204			1					1000	7	100/50 mg Carbon Bead (SKC 226-80)
NIOSH 1500	HF00205		1						1000	8	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	HF00206			1					1000	9	100/50 mg Charcoal (SKC 226-01)
TO11	HF00207		1						1000	10	DNPH Silica Gel (SKC 226-119)
TO11	HF00208			1					1000	11	DNPH Silica Gel (SKC 226-119)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HF - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/13/2006											
THC, CO, CO_2 & NOx	HF003	X									TOTAL
TO-17	HF00301		1						60	1	Carbopak charcoal
TO-17 MS	HF00302		1						60	2	Carbopak charcoal
TO-17 MS	HF00303			1					60	3	Carbopak charcoal
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HF00304		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HF00305		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HF00306		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HF - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
3/15/2006											
THC, CO, CO_2 & NOx	HF004	X									TOTAL
TO-17	HF00401		1						60	1	Carbopak charcoal
TO-17	HF00402					1			60	1	Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HF00403		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HF00404		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HF00405		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HF - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/15/2006											
THC, CO, CO_2 & NOx	HF005	X									TOTAL
TO-17	HF00501		1						60	1	Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HF00502		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HF00503		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HF00504		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HF - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/15/2006											
THC, CO, CO_2 & NOx	HF006	X									TOTAL
TO-17	HF00601		1						60	1	Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HF00602		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HF00603		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HF00604		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HF - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/16/2006											
THC, CO, CO_2 & NOx	HF007	X									TOTAL
TO-17	HF00701		1						60	1	Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HF00702		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HF00703		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HF00704		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HF - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
3/16/2006											
THC, CO, CO_2 & NOx	HF008	X									TOTAL
TO-17	HF00801		1						60	1	Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HF00802		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HF00803		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HF00804		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

RESEARCH FOUNDRY HF - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments:
3/16/2006											
THC, CO, CO_2 & NOx	HF009	X									TOTAL
TO-17	HF00901		1						60	1	Carbopak charcoal
	Excess								60	2	Blocked
	Excess								60	3	Blocked
	Excess								500	4	Blocked
	Excess								500	5	Blocked
OSHA ID200	HF00902		1						1000	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								1000	7	Blocked
NIOSH 1500	HF00903		1						1000	8	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	9	Blocked
TO11	HF00904		1						1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Blocked
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

1412-1.2.3 Series HB

PCS Baseline: Greensand Uncoated Core with Foseco SOLOSIL® 131 Sodium Silicate Core Binder & Mechanized Molding

Process Instructions

A. Experiment:

1. Baseline emissions measurement from a greensand mold, with CO_2 cured Foseco SOLOSIL® 131 cores, made with all virgin Wexford W450 sand, bonded with Western & Southern Bentonite in the ratio of 5:2 to yield 7.0 +/- 0.5% MB Clay, & no seacoal. The molds shall be tempered with potable water to 40-45% compactability, poured at constant weight, temperature, surface area, & shape factor. This test will recycle the same mold material, replacing burned clay with new materials after each casting cycle and providing clay for the retained core sand.

B. Materials:

1. Mold sand:

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

2. Core:

a. Uncoated step core (for emission sampling runs HB001-HB009) made with virgin Wedron 530 silica sand and 3.5% (BOS) Foseco SOLOSIL® 131, CO_2 cured.

3. Core coating: Foseco Rheotec for engineering/conditioning/casting quality runs HBCR1-3 only; none for emission sampling runs HB001-HB009.

4. Metal:

a. 356 Aluminum poured at 1270 +/- 10°F.

5. Pattern release:

a. Black Diamond, hand wiped.

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

C. Briefing:

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

Caution

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

D. Silicate Cores:

1. Core sand mixing.

a. Clean the core sand mixer.
b. Add 50 pounds of virgin Wedron 530 to the running mixer.
c. Slowly pour 1.75 +/- 0.03 pounds of sodium silicate resin into the sand. Distribute the resin as it is poured. Avoid pouring the resin on the plows or walls of the mixer or in one location or resin balling will occur preventing proper mixing.
d. Mix for three minutes after the resin is all in.
e. One batch will make about 6 cores.

2. Making step cores.

a. Preheat the OSI Oven to 275°F
b. Place the core box on a flat surface large open side up.
c. Place about 2 inches of sand in the bottom of the step section. Firmly tamp the sand into the 1inch diameter bottom using a ½ inch diameter rod.
d. Place a few more inches of sand in the core box and compact it. Take care to avoid parting planes. Repeat until the box is full.
e. Scrape off the excess. Remove the unused sand away from the gassing area.
f. Place a gassing plate on the open end of the core box.
g. Hold the plate down and gas the core for 30 seconds on each of the two gas holes with 20 PSI CO_2 gas.

1) Core coating for runs HBCR-1 to HBCR-3. Go to step D.2.h for cores for emission sampling runs HB001-HB009

a) Store the client supplied core coating at 70-80°F for 24 hours prior to use.
b) Vigorously stir the client supplied core coating.
c) Test and record the Baumé scale reading.
d) Measure and record the coating temperature.
e) Dip the core in the tip-down position to within ½ inch of the blow end.

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

h. Immediately dry the cores in the OSI oven at 275°F.
i. Bag the cores in moisture proof bags for storage.
j. Identify each bag by batch number.
k. Record the date, batch number, the batch mix time, sand batch weight, resin weight, the gassing time, the gas pressure, individual dried core weight, good core count from each batch.

3. Dog Bone Manufacture

a. Hook up the CO_2 to the small Redford Carver Machine
b. Set the parameters per the AFS Procedure
c. If available, use the sand/sodium silicate mixture from core making; Proceed to step D.4.e

d. Use the KitchenAid® mixer
   1) Add 5 pounds of Wedron 530 to the running mixer.
   2) Slowly pour 80 +/- 2 grams of sodium silicate resin into the sand. Distribute the resin as it is poured. Avoid pouring the resin on the plows or walls of the mixer or in one location or resin balling will occur preventing proper mixing.
   3) Mix for three minutes after the resin is all in.

e. Fill the sand head with sand and place it under the blow head
f. Compress the sand head with the lever and hit the blow button
g. Gas the samples in the same manner until hardened
h. Bake the samples at 250°F for 2 hours
i. Immediately put the samples in a desiccator and take them to the green room and tensile test them.

E. Sand preparation
1. Start up batch: make 1, HBCR1.
a. Thoroughly clean the pre-production muller elevator and molding hoppers.
b. Weigh and add 1130 +/-10 pounds of new Wexford W450 lake sand, per the recipe, to the running pre-production muller to make a 1200 batch.
c. Add 5 pounds of potable water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
d. Add the clays slowly to the muller to allow them to be distributed throughout the sand mass in proportion to the sand weight per the recipe for this test.
e. Dry mull for about 3 minutes to allow distribution and some grinding of the clays to occur.
f. Temper the sand-clay mixture slowly, with potable water, to allow for distribution.
g. After about 16 pounds of water have been added allow 30 seconds of mixing then start taking compactability test samples.
h. Based on each test add water incrementally to adjust the temper. Allow 1 minute of mixing. Retest. Repeat until the compactability, as would be measured at the mold, is in the range 40-45%.
i. Discharge the sand into the mold station elevator.
j. Record the total sand mixed in the batch, the total of each type of clay added to the batch, the amount of water added, the total mix time, the final compactability and sand temperature at discharge into the mold. The sand will be characterized for Methylene Blue Clay, AFS clay, Moisture content, Compactability, Green Compression strength, Permeability 1500°F loss on ignition (LOI), and 900°F volatiles. Each volatile test requires a separate 50 gram sample from the collected sand. Each LOI test requires 3 separate 30 gram samples from the collected sand.
k. Empty the extra greensand from the mold hopper into a clean empty dump hopper whose tare weight is known. Set this sand aside to be used to maintain the recycled batch at 900+/-10 pounds

2. Re-mulling: HBCR2

a. Add to the sand recovered from poured mold **HBCR1** 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: HBCR3, HB001-HB009

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

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

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

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

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

F. Molding: Step core pattern.

1. Pattern preparation:

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

b. Repair any damaged pattern or gating parts.

2. Making the green sand mold.

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

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

Caution

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

c. Use the overhead crane to place the pre-weighed drag/cope flask on the mold machine table, parting line surface down.

d. Locate a 24 x 24 x 4 inch deep wood upset on top of the flask.

e. Make the green sand mold cope or drag on the Osborn Whisper Ram Jolt-Squeeze mold machine.

WARNING

Only properly trained personnel may operate this machine.

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

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

f. Open the air supply to the mold machine.

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

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

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

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

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

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

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

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

H. Shakeout.
1. After the 45 minute cooling time prescribed in the emission sample plan has elapsed turn on the shakeout unit and run for it the 15 minutes prescribed in the emission sample plan or until the sand has all fallen through the grating.

2. Turn off the shakeout.
3. Sample the emissions for 30 minutes after the start of shakeout, a total of 75 minutes.
    a. When the emission sampling is completed remove the flask, with casting, and recover the sand from the hopper and surrounding floor.

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

I. Melting:
1. Initial charge:
    a. Use the 75 KW Ajax induction furnace
    b. Charge the furnace with A-356/357 aluminum sows.
    c. No other alloys need to be added for emission testing purposes.
    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 A-356/357 aluminum sows under full power until all is melted and the temperature has reached 1250-1300°F.
    f. Slag the furnace and cover it.
    g. Hold the furnace at 1250-1300°F until near ready to tap.
    h. When ready to tap adjust the temperature to 1300-1325°F and slag the furnace.
    i. Record all metallic additions to the furnace, tap temperature, and pour temperature. Record all furnace activities with the associated time.

2. Back charging.
    a. Back charging may be necessary because of the pour weight of about 40 pounds. If additional aluminum is desired back charge with A-356/357 Aluminum sows or scrap aluminum of the same source.
    b. Follow the above steps beginning with F.1.e

3. Emptying the furnace.
    a. Pig the extra metal into steel sow molds away from the test hood.
    b. You need not wait for emission testing to be concluded to pig the metal.

J. Pouring:
1. Preheat the ladle.
2. Tap 180 pounds more or less of 1350°F metal into the cold ladle.
3. Casually pour the metal back to the furnace.
4. Cover the ladle.
5. Reheat the metal to 1320 +/- 20°F.

6. Tap 180 pounds, more or less, of Aluminum into the ladle.
7. Cover the ladle to conserve heat.
8. Move the ladle to the pour position, open the emission hood pour door and wait until the metal temperature reaches 1270 +/- 10°F.
9. Commence pouring keeping the sprue full.
10. Upon completion close the hood door, return the extra metal to the furnace, and cover the ladle.

K. Rank order evaluation.

1. The supervisor shall select a group of up to five persons to make a collective subjective judgment of the casting relative surface appearance.
2. The rank order evaluation for cored castings shall be done on castings from the Engineering/conditioning runs HBCR1-3, with coated cores, only.
3. Review the general appearance of the interior of the castings and select specific casting features to compare.
4. For each cavity 1-4:
   - **a.** Place each casting initially in sequential mold number order.
   - **b.** Beginning with the casting from mold HBCR1, compare it to castings from mold HBCR2.
   - **c.** Place the better appearing casting in the first position and the lesser appearing casting in the second position.
   - **d.** Repeat this procedure with HBCR1 to its nearest neighbors until all castings closer to the beginning of the line are better appearing than HBCR1 and the next casting farther down the line is inferior.
   - **e.** Repeat this comparison to next neighbors for each casting number.
   - **f.** When all casting numbers have been compared go to the beginning of the line and begin again comparing each casting to its nearest neighbor. Move the castings so that each casting is inferior to the next one closer to the beginning of the line and superior to the one next toward the tail of the line.
   - **g.** Repeat this comparison until all concur with the ranking order.

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

Thomas J Fennell Jr.
Process Engineer

1412-1.1.4-HF

PCS Product Test: Greensand Uncoated Core with Cordis® Core Binder & Mechanized Molding

Process Instructions

A. Experiment:

1. Product emissions measurement from a greensand mold, with CO_2 cured Cordis® cores, made with all virgin Wexford W450 sand, bonded with Western & Southern Bentonite in the ratio of 5:2 to yield 7.0 +/- 0.5 % MB Clay, & no seacoal. The molds shall be tempered with potable water to 40-45% compactability, poured at constant weight, temperature, surface area, & shape factor. This test will recycle the same mold material, 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:

a) Uncoated step core (for engineering runs HF001-HF009) made with virgin Wedron 530 silica sand and 2.0% (BOS) Cordis®, hot air cured.

3. Core coating:

a) Customer choice for engineering runs HFER1-3 only, none for engineering runs HF001-HF009.

4. Metal:

a) 356 Aluminum poured at 1270 +/- 10°F.

5. Pattern release:

a) Black Diamond, hand wiped.

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

C. Briefing:

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

2.

Caution

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

D. Laempe BeachBox® Cores:

1. Klein vibratory core sand mixer.

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

b) Calibrate the Klein mixer sand batch size.

i) Calibrate sand.

- Turn the AUTO/MAN switch to MANUAL on main control panel.
- Zero a container on the scale.
- Put the same container below the mixing bowl to catch the sand.
- Open a few bags of WEDRON 530 sand into the sand hopper and manually fill batch hopper using max. and min. proximity switches.
- Discharge the sand from the batch hopper using the single cycle push button. Catch the sand as it leaves the batch hopper and record the net weight and the dispensing time.
- Repeat 3 times to determine the weight variation. The sand should be 75-80°F.

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

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

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

f) 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 bowl when done.

Caution:

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

2. OSI core drying oven

a) Turn on the OSI core drying oven and give it a set point of 325°F.

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 warm box mode with gassing and working pressures and gas and purge time according to the core recipe sheet.

i) Core process setup

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

- ♦ Set the gas time to 0 seconds.
- ♦ Set the purge for 210 seconds(R/C).
- ♦ Total cycle time approximately 4 minutes.

d) Run the core machine for three (3) cycles and discard the cores. When the cores appear good begin test core manufacture. Five (5) good cores are required for each mold. Make five (5) additional 50 pound sand batches and run the sand out making core. A minimum of 75 cores are required.

e) After each core is made, place them on the belt of the OSI core drying oven for a complete cure.

f) After the cores have finished drying, weigh them and record their weight and time out of the oven.

g) 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.

4. Dog Bone Manufacture

a) Set the parameters per the AFS Procedure

b) Use the Kitchen Aid® mixer

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

ii) Slowly pour 45g of Cordis® resin into the sand. Distribute the resin as it is poured. Avoid pouring the resin on the plows or walls of the mixer or in one location or resin balling will occur preventing proper mixing.

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

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

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

e) Gas the samples in the same manner until hardened

f) Make 30 good dog bones.

g) Record the dog bone make times.

h) Immediately put the samples in a desiccator to cool.

i) Once cooled, weigh and test them, recording the weight and tensile strength.

E. Sand preparation

1. Start up batch: make 1, HFER1.

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

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

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

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

- **e)** Dry mull for about 3 minutes to allow distribution and some grinding of the clays to occur.
- **f)** Temper the sand-clay mixture slowly, with potable water, to allow for distribution.
- **g)** After about 16 pounds of water have been added allow 30 seconds of mixing then start taking compactability test samples.
- **h)** Based on each test add water incrementally to adjust the temper. Allow 1 minute of mixing. Retest. Repeat until the compactability, as would be measured at the mold, is in the range 40-45%.
- **i)** Discharge the sand into the mold station elevator.
- **j)** Record the total sand mixed in the batch, the total of each type of clay added to the batch, the amount of water added, the total mix time, the final compactability and sand temperature at discharge into the mold. The sand will be characterized for methylene blue clay, AFS clay, moisture content, compactability, green compression strength, permeability, 1500°F loss on ignition (LOI), and 900°F volatiles. Each volatile test requires a separate 50 gram sample from the collected sand. Each LOI test requires 3 separate 30 gram samples from the collected sand.
- **k)** Empty the extra greensand from the mold hopper into a clean empty dump hopper whose tare weight is known. Set this sand aside to be used to maintain the recycled batch at 900+/-10 pounds.

2. Re-mulling: HFER2

- **a)** Add to the sand recovered from poured mold HFER1 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: HFER3, HF001-HF012

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

F. Molding: Step core pattern.

1. Pattern preparation:

a) Inspect and tighten all loose pattern and gating pieces.
b) Repair any damaged pattern or gating parts.

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

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

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

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

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

   f) Open the air supply to the mold machine.

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

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

any pattern parts.

m) Manually spread one to two inches or so of sand over the pattern using a shovel. Source the sand from the overhead mold sand hopper by actuating the hopper gate valve with the lever located under the operators panel.

n) Fill the center potion of the flask.

o) Manually move sand from the center portion to the outboard areas and hand tuck the sand.

p) Finish filling the 24 x 24 x 10 inch flask and the upset with greensand from the overhead molding hopper.

q) Grab a sufficient sample of sand to fill a quart zip-lock bag. Label bag with the test series and sequence number, date, and time of day and deliver it immediately to the sand lab for analysis

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

s) The operator will grab a sand sample for the Lab. The sand technician will quickly measure the sand temperature and compactability and record the results.

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

u) Remove the upset and set it aside.

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

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

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

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

w) Screed the bottom of the drag mold flat to the bottom of the flask if required.

x) Press and release the LOWER DRAW/STOP push button to separate the flask and mold from the pattern.

y) Use the overhead crane to lift the mold half and remove it from the machine. If the mold half is a drag, roll it parting line side up, set it on the floor, blow it out.

z) Finally, press and release the DRAW DOWN pushbutton to cause the draw frame to return to the start position.

aa) Set four (4) step cores that have been weighed and logged into the drag. Verify that the cores are fully set and flush with the parting line and insert foam filter into its receiver.

bb) Close the cope over the drag being careful not to crush anything.

cc) Clamp the flask halves together.

dd) Weigh and record the weight of the closed un-poured mold, the pre-weighed flask, the uncoated cores, and the sand weight by difference.

ee) Measure and record the sand temperature.

ff) Deliver the mold to the previously cleaned shakeout to be poured.

gg) Cover the mold with the emission hood.

G. Emission hood:

1. Loading.

a) Hoist the mold onto the shakeout deck within the emission hood.

b) Close, seal, and lock the emission hood.

c) Adjust the ambient air heater control so that the measured temperature of the blended air within the hood is 85-90°F at the start of the test run.

H. Shakeout.

1. After the 45 minute cooling time prescribed in the emission sample plan has elapsed turn on the shakeout unit and run for it the 15 minutes prescribed in the emission sample plan or until the sand has all fallen through the grating.

2. Turn off the shakeout.

3. Sample the emissions for 30 minutes after the start of shakeout, a total of 75 minutes.

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

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

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

I. Melting:

1. Initial charge:

a) Use the 75 KW Ajax induction furnace

b) Charge the furnace with A-356/357 aluminum sows.

c) No other alloys need to be added for emission testing purposes.

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 A-356/357 aluminum sows under full power until all is melted and the temperature has reached 1250-1300°F.
- **f)** Slag the furnace and cover it.
- **g)** Hold the furnace at 1250-1300°F until near ready to tap.
- **h)** When ready to tap adjust the temperature to 1300-1325°F and slag the furnace.
- **i)** Record all metallic additions to the furnace, tap temperature, and pour temperature. Record all furnace activities with the associated time.

2. Back charging.

- **a)** Back charging may be necessary because of the pour weight of about 40 pounds. If additional aluminum is desired back charge with A-356/357 Aluminum sows or scrap aluminum of the same source.
- **b)** Follow the above steps beginning with F.1.e

3. Emptying the furnace.

- **a)** Pig the extra metal into steel sow molds away from the test hood.
- **b)** You need not wait for emission testing to be concluded to pig the metal.

J. Pouring:

1. Preheat the ladle.
2. Tap 180 pounds more or less of 1350°F metal into the cold ladle.
3. Casually pour the metal back to the furnace.
4. Cover the ladle.
5. Reheat the metal to 1320 +/- 20°F.
6. Tap 180 pounds, more or less, of Aluminum into the ladle.
7. Cover the ladle to conserve heat.
8. Move the ladle to the pour position, open the emission hood pour door and wait until the metal temperature reaches 1270 +/- 10°F.
9. Commence pouring keeping the sprue full.
10. Upon completion close the hood door, return the extra metal to the furnace, and cover the ladle.

K. Rank order evaluation.

1. The supervisor shall select a group of up to five persons to make a collective subjective judgment of the casting relative surface appearance.
2. The rank order evaluation for cored castings shall be done on castings from the Engineering/conditioning runs HFER1-3, with coated cores, only.
3. Review the general appearance of the interior of the castings and select specific casting features to compare.
4. For each cavity 1-4 :

- **a)** Place each casting initially in sequential mold number order.

b) Beginning with the casting from mold HFER1, compare it to castings from mold HFER2.
c) Place the better appearing casting in the first position and the lesser appearing casting in the second position.
d) Repeat this procedure with HFER1 to its nearest neighbors until all castings closer to the beginning of the line are better appearing than HFER1 and the next casting farther down the line is inferior.
e) Repeat this comparison to next neighbors for each casting number.
f) When all casting numbers have been compared go to the beginning of the line and begin again comparing each casting to its nearest neighbor. Move the castings so that each casting is inferior to the next one closer to the beginning of the line and superior to the one next toward the tail of the line.
g) Repeat this comparison until all concur with the ranking order.

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

Thomas J Fennell Jr.
Process Engineer

APPENDIX B DETAILED EMISSION RESULTS AND QUANTITATION LIMITS

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Test HB - Detailed Emission Results - Lb/Tn Metal

VOC	POM	HAP		HB001	HB002	HB003	HB004	HB005	HB006	HB007	HB008	HB009	Average	Standard Deviation
				7-Feb-06	7-Feb-06	7-Feb-06	8-Feb-06	8-Feb-06	8-Feb-06	9-Feb-06	9-Feb-06	09-Feb-06	—	—
			Emission Indicators											
			TGOC as Propane	9.88E-02	9.57E-02	1.12E-01	1.10E-01	1.06E-01	1.04E-01	9.31E-02	1.15E-01	1.14E-01	1.06E-01	8.17E-03
			HC as Hexane	4.00E-02	3.56E-02	3.74E-02	4.22E-02	4.60E-02	3.82E-02	I	4.44E-02	3.00E-02	3.92E-02	5.12E-03
			Sum of Target VOCs	2.47E-02	3.05E-02	2.90E-02	3.09E-02	3.64E-02	3.47E-02	3.22E-02	3.67E-02	3.43E-02	3.22E-02	3.87E-03
			Sum of Target HAPs	2.12E-02	2.60E-02	2.41E-02	2.71E-02	3.10E-02	2.94E-02	2.84E-02	3.15E-02	2.95E-02	2.76E-02	3.35E-03
			Sum of Target POMs	0.0000	0.0000	0.0000	0.0003	4.68E-04	0.00E+00	0.0005	0.0005	0.0000	2.01E-04	2.43E-04
			Selected Target HAPs and POMs											
V		H	**Acetaldehyde**	1.70E-02	1.94E-02	1.81E-02	1.78E-02	2.10E-02	2.13E-02	2.03E-02	2.29E-02	2.22E-02	2.00E-02	2.02E-03
V		H	**Propionaldehyde (Propanal)**	2.00E-03	2.24E-03	2.05E-03	1.85E-03	2.40E-03	2.47E-03	2.20E-03	2.57E-03	2.42E-03	2.24E-03	2.34E-04
V			**2-Butanone (MEK)**	1.90E-03	2.29E-03	1.95E-03	1.95E-03	2.20E-03	2.20E-03	2.09E-03	2.34E-03	2.14E-03	2.12E-03	1.59E-04
V		H	**Toluene**	7.02E-04	1.21E-03	1.07E-03	2.06E-03	2.07E-03	1.62E-03	1.56E-03	1.55E-03	1.25E-03	1.50E-03	4.92E-04
V		H	**Benzene**	5.25E-04	1.02E-03	8.24E-04	1.59E-03	1.66E-03	1.18E-03	1.07E-03	1.22E-03	1.21E-03	1.14E-03	3.50E-04
V		H	**Xylene, mp-**	3.67E-04	9.53E-04	9.30E-04	1.79E-03	1.44E-03	1.14E-03	9.15E-04	9.97E-04	8.48E-04	1.04E-03	4.19E-04
V		H	**Formaldehyde**	6.16E-04	6.95E-04	6.63E-04	6.89E-04	9.91E-04	9.91E-04	8.45E-04	8.78E-04	1.06E-03	8.25E-04	1.65E-04
V		H	**Hexane**	ND	4.74E-04	ND	5.57E-04	6.40E-04	6.40E-04	9.77E-04	8.51E-04	5.00E-04	5.15E-04	3.34E-04
V	P	H	**Methylnaphthalene, 2-**	ND	ND	ND	3.38E-04	4.68E-04	ND	4.85E-04	5.18E-04	ND	2.01E-04	2.45E-04
V		H	**Xylene, o-**	ND	ND	5.39E-04	4.26E-04	3.92E-04	ND	ND	ND	ND	1.51E-04	2.34E-04
V	P	H	**Acenaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 1,2-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 1,3-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 1,5-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 1,6-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 1,8-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 2,3-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 2,6-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 2,7-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Indene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Methylnaphthalene, 1-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Naphthalene**	ND	ND	ND	ND	ND	ND	ND	I	ND	ND	NA
V	P	H	**Trimethylnaphthalene, 2,3,5-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Acrolein**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Biphenyl**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Cresol, mp-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Cresol, o-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Ethylbenzene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Phenol**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Styrene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

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

Test HB - Detailed Emission Results - Lb/Tn Metal

VOC	POM	HAP		HB001	HB002	HB003	HB004	HB005	HB006	HB007	HB008	HB009	Average	Standard Deviation
				7-Feb-06	7-Feb-06	7-Feb-06	8-Feb-06	8-Feb-06	8-Feb-06	9-Feb-06	9-Feb-06	09-Feb-06	–	–
			Additional Selected Target VOCs											
V			Trimethylbenzene, 1,2,3-	ND	ND	ND	ND	3.32E-04	ND	ND	ND	ND	3.68E-05	1.46E-04
V			Pentanal (Valeraldehyde)	3.78E-04	I	4.97E-04	ND	3.70E-04	5.19E-04	3.58E-04	4.44E-04	3.68E-04	3.90E-04	1.49E-04
V			Trimethylbenzene, 1,2,4-	ND	7.20E-04	7.31E-04	6.93E-04	9.60E-04	7.61E-04	ND	7.71E-04	7.23E-04	5.95E-04	3.64E-04
V			Benzaldehyde	4.76E-04	7.10E-04	8.05E-04	3.67E-04	6.61E-04	6.61E-04	5.30E-04	6.60E-04	7.03E-04	6.24E-04	1.36E-04
V			Butyraldehyde/Methacrolein	7.14E-04	8.71E-04	8.34E-04	7.50E-04	8.68E-04	8.68E-04	8.17E-04	9.82E-04	9.05E-04	8.46E-04	7.99E-05
V			Crotonaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Diethylbenzene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Dimethylphenol, 2,4-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Dimethylphenol, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Dodecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Ethyltoluene, 2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Ethyltoluene, 3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Heptane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Hexaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Propylbenzene, n-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Trimethylbenzene, 1,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Undecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
			Criteria Pollutants and Greenhouse Gases											
			Carbon Dioxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
			Carbon Monoxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
			Nitrogen Oxides	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
			Sulfur Dioxide	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA

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

Test HB - Detailed Emission Results - Lb/Lb Binder

VOC	POM	HAP		HB001	HB002	HB003	HB004	HB005	HB006	HB007	HB008	HB009	Average	Standard Deviation
				7-Feb-06	7-Feb-06	7-Feb-06	8-Feb-06	8-Feb-06	8-Feb-06	9-Feb-06	9-Feb-06	09-Feb-06	—	—
			Emission Indicators											
			TGOC as Propane	2.17E-03	2.03E-03	1.91E-03	2.41E-03	2.35E-03	2.19E-03	2.12E-03	2.52E-03	2.61E-03	2.26E-03	2.32E-04
			HC as Hexane	8.55E-04	7.41E-04	6.07E-04	9.12E-04	9.97E-04	9.97E-04	I	9.42E-04	6.55E-04	8.38E-04	1.53E-04
			Sum of Target VOCs	5.28E-04	6.36E-04	4.70E-04	6.67E-04	7.90E-04	7.78E-04	7.07E-04	7.78E-04	7.49E-04	6.79E-04	1.15E-04
			Sum of Target HAPs	4.54E-04	5.40E-04	3.92E-04	5.86E-04	6.73E-04	6.61E-04	6.24E-04	6.68E-04	6.44E-04	5.82E-04	1.01E-04
			Sum of Target POMs	0.00E+00	0.00E+00	0.00E+00	7.30E-06	1.02E-05	1.02E-05	1.07E-05	1.10E-05	0.00E+00	5.47E-06	5.30E-06
			Selected Target HAPs and POMs											
V		H	**Acetaldehyde**	3.64E-04	4.03E-04	2.93E-04	3.85E-04	4.55E-04	4.55E-04	4.47E-04	4.86E-04	4.84E-04	4.19E-04	6.35E-05
V		H	**Propionaldehyde (Propanal)**	4.28E-05	4.67E-05	3.34E-05	4.00E-05	5.21E-05	5.21E-05	4.84E-05	5.46E-05	5.28E-05	4.70E-05	7.06E-06
V			**2-Butanone (MEK)**	4.06E-05	4.77E-05	3.17E-05	4.21E-05	4.78E-05	4.78E-05	4.58E-05	4.97E-05	4.66E-05	4.44E-05	5.60E-06
V		H	**Toluene**	1.50E-05	2.51E-05	1.73E-05	4.45E-05	4.49E-05	4.49E-05	3.43E-05	3.29E-05	2.73E-05	3.18E-05	1.15E-05
V		H	**Benzene**	1.12E-05	2.12E-05	1.34E-05	3.43E-05	3.60E-05	2.39E-05	2.35E-05	2.59E-05	2.65E-05	2.40E-05	8.24E-06
V		H	**Xylene, mp-**	7.85E-06	1.98E-05	1.51E-05	3.87E-05	3.13E-05	3.13E-05	2.01E-05	2.12E-05	1.85E-05	2.27E-05	9.46E-06
V		H	**Formaldehyde**	1.32E-05	1.45E-05	1.08E-05	1.49E-05	2.15E-05	2.15E-05	1.86E-05	1.86E-05	2.31E-05	1.74E-05	4.27E-06
V		H	**Hexane**	ND	9.86E-06	ND	1.20E-05	1.39E-05	1.39E-05	2.15E-05	1.81E-05	1.09E-05	1.11E-05	7.25E-06
V	P	H	**Methylnaphthalene, 2-**	ND	ND	ND	7.30E-06	1.02E-05	1.02E-05	1.07E-05	1.10E-05	ND	5.47E-06	5.30E-06
V		H	**Xylene, o-**	ND	ND	8.76E-06	9.19E-06	8.51E-06	8.51E-06	ND	ND	ND	3.89E-06	4.61E-06
V	P	H	**Acenaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 1,2-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 1,3-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 1,5-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 1,6-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 1,8-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 2,3-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 2,6-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Dimethylnaphthalene, 2,7-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Methylnaphthalene, 1-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	**Naphthalene**	ND	ND	ND	ND	ND	ND	ND	I	ND	ND	NA
V	P	H	**Trimethylnaphthalene, 2,3,5-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Acrolein**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Biphenyl**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Cresol, mp-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Cresol, o-**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Ethylbenzene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Phenol**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	**Styrene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

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Test HB - Detailed Emission Results - Lb/Lb Binder

VOC	POM	HAP		HB001	HB002	HB003	HB004	HB005	HB006	HB007	HB008	HB009	Average	Standard Deviation
				7-Feb-06	7-Feb-06	7-Feb-06	8-Feb-06	8-Feb-06	8-Feb-06	9-Feb-06	9-Feb-06	09-Feb-06	–	–
			Additional Selected Target VOCs											
V			Butyraldehyde/Methacrolein	1.53E-05	1.81E-05	1.36E-05	1.62E-05	1.88E-05	1.88E-05	1.80E-05	2.08E-05	1.97E-05	1.77E-05	2.30E-06
V			Benzaldehyde	1.02E-05	1.48E-05	1.31E-05	7.92E-06	1.44E-05	1.44E-05	1.16E-05	1.40E-05	1.53E-05	1.28E-05	2.47E-06
V			Trimethylbenzene, 1,2,4-	ND	1.50E-05	1.19E-05	1.50E-05	2.08E-05	2.08E-05	ND	1.64E-05	1.58E-05	1.28E-05	7.81E-06
V			Pentanal (Valeraldehyde)	8.09E-06	I	8.07E-06	ND	8.04E-06	8.04E-06	7.87E-06	9.43E-06	8.02E-06	7.19E-06	2.95E-06
V			Trimethylbenzene, 1,2,3-	ND	ND	ND	ND	7.19E-06	7.19E-06	ND	ND	ND	1.60E-06	3.17E-06
V			Crotonaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Diethylbenzene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Dimethylphenol, 2,4-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Dimethylphenol, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Dodecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Ethyltoluene, 2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Ethyltoluene, 3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Heptane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Hexaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Propylbenzene, n-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Trimethylbenzene, 1,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Undecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Indene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
			Criteria Pollutants and Greenhouse Gases											
			Carbon Dioxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
			Carbon Monoxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
			Nitrogen Oxides	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
			Sulfur Dioxide	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA

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Test HF - Detailed Emissions Data - Lb/Tn Metal

VOC	POM	HAP		HF001	HF002	HF003	HF004	HF005	HF006	HF007	HF008	HF009	Average	Standard Deviation
			Test Dates	13-Mar-06	13-Mar-06	13-Mar-06	15-Mar-06	15-Mar-06	15-Mar-06	16-Mar-06	16-Mar-06	16-Mar-06	—	—
Emission Indicators														
			TGOC as Propane	6.39E-02	1.01E-01	8.21E-02	6.85E-02	7.54E-02	7.40E-02	9.05E-02	1.30E-01	8.33E-02	8.54E-02	2.01E-02
			HC as Hexane	1.83E-02	2.47E-02	3.37E-02	2.89E-02	3.80E-02	3.43E-02	3.61E-02	4.99E-02	4.65E-02	3.45E-02	9.92E-03
			Sum of Target VOCs	2.58E-03	5.74E-03	4.81E-03	7.35E-03	8.40E-03	8.14E-03	8.71E-03	9.96E-03	9.59E-03	7.38E-03	2.43E-03
			Sum of Target HAPs	2.58E-03	5.74E-03	4.81E-03	7.35E-03	7.96E-03	8.14E-03	8.71E-03	9.96E-03	9.59E-03	7.33E-03	2.41E-03
			Sum of Target POMs	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
Selected Target Organic HAPs and POMs														
V		H	Acetaldehyde	2.58E-03	2.75E-03	2.91E-03	3.94E-03	4.17E-03	4.21E-03	4.27E-03	4.66E-03	4.96E-03	3.83E-03	8.67E-04
V		H	Formaldehyde	I	2.44E-03	9.64E-04	9.08E-04	8.85E-04	1.00E-03	8.08E-04	9.16E-04	9.58E-04	1.11E-03	5.42E-04
V		H	Xylene, mp-	ND	5.49E-04	3.58E-04	4.96E-04	7.25E-04	5.60E-04	7.45E-04	1.22E-03	8.96E-04	6.17E-04	3.44E-04
V		H	Benzene	ND	ND	5.73E-04	5.81E-04	6.87E-04	7.86E-04	9.09E-04	8.84E-04	8.84E-04	5.89E-04	3.57E-04
V		H	Toluene	ND	ND	ND	5.31E-04	5.53E-04	5.10E-04	7.65E-04	8.02E-04	6.91E-04	4.28E-04	3.36E-04
V		H	Propionaldehyde (Propanal)	ND	ND	ND	4.64E-04	5.00E-04	5.12E-04	5.74E-04	6.43E-04	6.38E-04	3.70E-04	2.84E-04
V		H	Hexane	ND	ND	ND	4.30E-04	4.32E-04	5.67E-04	6.41E-04	4.12E-04	5.59E-04	3.38E-04	2.64E-04
V		H	Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	4.20E-04	ND	4.66E-05	1.40E-04
V	P	H	Acenaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 1,2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 1,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 1,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 1,8-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 2,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 2,7-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Methylnaphthalene, 1-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Methylnaphthalene, 2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Trimethylnaphthalene, 2,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Cresol, mp-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Cresol, o-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Phenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Xylene, o-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

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Test HF - Detailed Emissions Data - Lb/Tn Metal

VOC	POM	HAP		HF001	HF002	HF003	HF004	HF005	HF006	HF007	HF008	HF009	Average	Standard Deviation
			Test Dates	13-Mar-06	13-Mar-06	13-Mar-06	15-Mar-06	15-Mar-06	15-Mar-06	16-Mar-06	16-Mar-06	16-Mar-06	–	–
Additional Selected Target Organic Analytes														
V			Trimethylbenzene, 1,2,4-	ND	ND	ND	ND	4.45E-04	ND	ND	ND	ND	4.95E-05	1.48E-04
V			Benzaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Butyraldehyde/Methacrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Crotonaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Diethylbenzene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Dimethylphenol, 2,4-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Dimethylphenol, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Dodecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Ethyltoluene, 2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Ethyltoluene, 3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Heptane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Hexaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Pentanal (Valeraldehyde)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Propylbenzene, n-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Trimethylbenzene, 1,2,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Trimethylbenzene, 1,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Undecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			2-Butanone (MEK)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Indene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
Criteria Pollutants and Greenhouse Gases														
			Carbon Dioxide	1.25E-01	ND	ND	2.84E-01	ND	ND	9.29E-01	ND	ND	1.49E-01	3.08E-01
			Carbon Monoxide	ND	4.29E-02	6.32E-04	ND	ND	ND	1.12E-01	ND	ND	1.73E-02	3.83E-02
			Nitrogen Oxides	3.14E-04	1.35E-03	1.40E-03	ND	ND	ND	3.87E-04	5.08E-04	ND	4.39E-04	5.63E-04
			Sulfur Dioxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

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Test HF - Detailed Emissions Data - Lb/Lb Binder

VOC	POM	HAP		HF001	HF002	HF003	HF004	HF005	HF006	HF007	HF008	HF009	Average	Standard Deviation
			Test Dates	13-Mar-06	13-Mar-06	13-Mar-06	15-Mar-06	15-Mar-06	15-Mar-06	16-Mar-06	16-Mar-06	16-Mar-06	—	—
Emission Indicators														
			TGOC as Propane	2.39E-03	3.97E-03	3.16E-03	2.95E-03	3.08E-03	2.91E-03	3.80E-03	5.12E-03	3.22E-03	3.40E-03	7.96E-04
			HC as Hexane	6.85E-04	9.73E-04	1.30E-03	1.24E-03	1.56E-03	1.35E-03	1.52E-03	1.97E-03	1.80E-03	1.38E-03	3.95E-04
			Sum of Target VOCs	9.66E-05	2.26E-04	1.85E-04	3.17E-04	3.44E-04	3.20E-04	3.65E-04	3.93E-04	3.71E-04	2.96E-04	9.99E-05
			Sum of Target HAPs	9.66E-05	2.26E-04	1.85E-04	3.17E-04	3.25E-04	3.20E-04	3.65E-04	3.93E-04	3.71E-04	2.94E-04	9.89E-05
			Sum of Target POMs	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
Selected Target Organic HAPs and POMs														
V		H	Acetaldehyde	9.66E-05	1.08E-04	1.12E-04	1.70E-04	1.71E-04	1.66E-04	1.79E-04	1.84E-04	1.92E-04	1.53E-04	3.67E-05
V		H	Formaldehyde	I	9.60E-05	3.72E-05	3.92E-05	3.62E-05	3.93E-05	3.39E-05	3.61E-05	3.70E-05	4.44E-05	2.09E-05
V		H	Xylene, mp-	ND	2.16E-05	1.38E-05	2.14E-05	2.96E-05	2.20E-05	3.13E-05	4.83E-05	3.46E-05	2.47E-05	1.36E-05
V		H	Benzene	ND	ND	2.21E-05	2.51E-05	2.81E-05	3.09E-05	3.82E-05	3.49E-05	3.42E-05	2.37E-05	1.43E-05
V		H	Toluene	ND	ND	ND	2.29E-05	2.26E-05	2.00E-05	3.21E-05	3.16E-05	2.67E-05	1.73E-05	1.36E-05
V		H	Propionaldehyde (Propanal)	ND	ND	ND	2.00E-05	2.04E-05	2.01E-05	2.41E-05	2.54E-05	2.47E-05	1.50E-05	1.14E-05
V		H	Hexane	ND	ND	ND	1.86E-05	1.77E-05	2.23E-05	2.69E-05	1.62E-05	2.16E-05	1.37E-05	1.07E-05
V		H	Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	1.66E-05	ND	1.84E-06	5.52E-06
V	P	H	Acenaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 1,2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 1,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 1,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 1,8-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 2,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Dimethylnaphthalene, 2,7-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Methylnaphthalene, 1-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Methylnaphthalene, 2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Trimethylnaphthalene, 2,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Cresol, mp-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Cresol, o-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Phenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V		H	Xylene, o-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

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Test HF - Detailed Emissions Data - Lb/Lb Binder

VOC	POM	HAP		HF001	HF002	HF003	HF004	HF005	HF006	HF007	HF008	HF009	Average	Standard Deviation
			Test Dates	13-Mar-06	13-Mar-06	13-Mar-06	15-Mar-06	15-Mar-06	15-Mar-06	16-Mar-06	16-Mar-06	16-Mar-06	–	–
Additional Selected Target Organic Analytes														0.00E+00
V			Trimethylbenzene, 1,2,4-	ND	ND	ND	ND	1.82E-05	ND	ND	ND	ND	2.02E-06	6.07E-06
V			Benzaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Butyraldehyde/Methacrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Crotonaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Diethylbenzene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Dimethylphenol, 2,4-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Dimethylphenol, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Dodecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Ethyltoluene, 2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Ethyltoluene, 3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Heptane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Hexaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Pentanal (Valeraldehyde)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Propylbenzene, n-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Trimethylbenzene, 1,2,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Trimethylbenzene, 1,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Undecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			2-Butanone (MEK)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V			Indene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
Criteria Pollutants and Greenhouse Gases														
			Carbon Dioxide	4.68E-03	ND	ND	1.22E-02	ND	ND	3.90E-02	ND	ND	6.21E-03	1.30E-02
			Carbon Monoxide	ND	1.69E-03	2.44E-05	ND	ND	ND	4.71E-03	ND	ND	7.14E-04	1.60E-03
			Nitrogen Oxides	1.17E-05	5.31E-05	5.38E-05	ND	ND	ND	1.62E-05	2.00E-05	ND	1.72E-05	2.19E-05
			Sulfur Dioxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

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

Practical Reporting Limits - Test HB

Analyte	Lb/Tn Metal	Analyte	Lb/Tn Metal	Analyte	Lb/Lb Binder	Analyte	Lb/Lb Binder
Carbon Monoxide	8.23E-02	Ethyltoluene, 2-	1.91E-04	Carbon Monoxide	1.64E-03	Ethyltoluene, 2-	7.25E-06
Carbon Dioxide	1.29E-01	Ethyltoluene, 3-	9.57E-04	Carbon Dioxide	2.58E-03	Ethyltoluene, 3-	3.62E-05
Nitrogen Oxides	8.82E-02	Formaldehyde	1.90E-04	Nitrogen Oxides	1.76E-03	Formaldehyde	7.18E-06
2-Butanone (MEK)	1.90E-04	Heptane	9.57E-04	2-Butanone (MEK)	7.18E-06	Heptane	3.62E-05
Acenaphthalene	9.57E-04	Hexaldehyde	1.90E-04	Acenaphthalene	3.62E-05	Hexaldehyde	7.18E-06
Acetaldehyde	1.90E-04	Hexane	1.91E-04	Acetaldehyde	7.18E-06	Hexane	7.25E-06
Acrolein	1.90E-04	Indan	9.57E-04	Acrolein	7.18E-06	Indan	3.62E-05
Benzaldehyde	1.90E-04	Indene	9.57E-04	Benzaldehyde	7.18E-06	Indene	3.62E-05
Benzene	1.91E-04	Methylnaphthalene, 1-	1.91E-04	Benzene	7.25E-06	Methylnaphthalene, 1-	7.25E-06
Biphenyl	9.57E-04	Methylnaphthalene, 2-	1.91E-04	Biphenyl	3.62E-05	Methylnaphthalene, 2-	7.25E-06
Butyraldehyde/Methacrolein	3.16E-04	Naphthalene	1.91E-04	Butyraldehyde/Methacrolein	1.20E-05	Naphthalene	7.25E-06
Cresol, mp-	9.57E-04	Nonane	9.57E-04	Cresol, mp-	3.62E-05	Nonane	3.62E-05
Cresol, o-	9.57E-04	o,m,p-Tolualdehyde	5.05E-04	Cresol, o-	3.62E-05	o,m,p-Tolualdehyde	1.91E-05
Crotonaldehyde	1.90E-04	Octane	9.57E-04	Crotonaldehyde	7.18E-06	Octane	3.62E-05
Cyclohexane	9.57E-04	Pentanal (Valeraldehyde)	1.90E-04	Cyclohexane	3.62E-05	Pentanal (Valeraldehyde)	7.18E-06
Decane	9.57E-04	Phenol	9.57E-04	Decane	3.62E-05	Phenol	3.62E-05
Diethylbenzene, 1,3-	9.57E-04	Propionaldehyde (Propanal)	1.90E-04	Diethylbenzene, 1,3-	3.62E-05	Propionaldehyde (Propanal)	7.18E-06
Dimethylnaphthalene, 1,2-	9.57E-04	Propylbenzene, n-	9.57E-04	Dimethylnaphthalene, 1,2-	3.62E-05	Propylbenzene, n-	3.62E-05
Dimethylnaphthalene, 1,3-	1.91E-04	Styrene	1.91E-04	Dimethylnaphthalene, 1,3-	7.25E-06	Styrene	7.25E-06
Dimethylnaphthalene, 1,5-	9.57E-04	Sulfur Dioxide	2.42E-03	Dimethylnaphthalene, 1,5-	3.62E-05	Sulfur Dioxide	9.16E-05
Dimethylnaphthalene, 1,6-	9.57E-04	Tetradecane	9.57E-04	Dimethylnaphthalene, 1,6-	3.62E-05	Tetradecane	3.62E-05
Dimethylnaphthalene, 1,8-	9.57E-04	HC as n-Hexane	5.81E-03	Dimethylnaphthalene, 1,8-	3.62E-05	HC as n-Hexane	2.20E-04
Dimethylnaphthalene, 2,3-	9.57E-04	Toluene	1.91E-04	Dimethylnaphthalene, 2,3-	3.62E-05	Toluene	7.25E-06
Dimethylnaphthalene, 2,6-	9.57E-04	Trimethylbenzene, 1,2,3-	1.91E-04	Dimethylnaphthalene, 2,6-	3.62E-05	Trimethylbenzene, 1,2,3-	7.25E-06
Dimethylnaphthalene, 2,7-	9.57E-04	Trimethylbenzene, 1,2,4-	1.91E-04	Dimethylnaphthalene, 2,7-	3.62E-05	Trimethylbenzene, 1,2,4-	7.25E-06
Dimethylphenol, 2,4-	9.57E-04	Trimethylbenzene, 1,3,5-	1.91E-04	Dimethylphenol, 2,4-	3.62E-05	Trimethylbenzene, 1,3,5-	7.25E-06
Dimethylphenol, 2,6-	9.57E-04	Trimethylnaphthalene, 2,3,5-	9.57E-04	Dimethylphenol, 2,6-	3.62E-05	Trimethylnaphthalene, 2,3,5-	3.62E-05
Dodecane	9.57E-04	Undecane	1.91E-04	Dodecane	3.62E-05	Undecane	7.25E-06
Ethylbenzene	1.91E-04	Xylene, mp-	1.91E-04	Ethylbenzene	7.25E-06	Xylene, mp-	7.25E-06
		Xylene, o-	1.91E-04			Xylene, o-	7.25E-06

Practical Reporting Limits - Test HF

Analyte	Lb/Tn Metal	Analyte	Lb/Tn Metal
Carbon Monoxide	7.87E-02	Ethyltoluene, 2-	3.31E-04
Carbon Dioxide	1.24E-01	Ethyltoluene, 3-	1.66E-03
Nitrogen Oxides	8.43E-02	Formaldehyde	3.18E-04
THC as Propane	1.24E-01	Heptane	1.66E-03
2-Butanone (MEK)	3.18E-04	Hexaldehyde	3.18E-04
Acenaphthalene	1.66E-03	Hexane	3.31E-04
Acetaldehyde	3.18E-04	Indan	1.66E-03
Acrolein	3.18E-04	Indene	1.66E-03
Benzaldehyde	3.18E-04	Methylnaphthalene, 1-	3.31E-04
Benzene	3.31E-04	Methylnaphthalene, 2-	3.31E-04
Biphenyl	1.66E-03	Naphthalene	3.31E-04
Butyraldehyde/Methacrolein	5.30E-04	Nonane	1.66E-03
Cresol, mp-	1.66E-03	o,m,p-Tolualdehyde	8.49E-04
Cresol, o-	1.66E-03	Octane	1.66E-03
Crotonaldehyde	3.18E-04	Pentanal (Valeraldehyde)	3.18E-04
Cyclohexane	1.66E-03	Phenol	1.66E-03
Decane	1.66E-03	Propionaldehyde (Propanal)	3.18E-04
Diethylbenzene, 1,3-	1.66E-03	Propylbenzene, n-	1.66E-03
Dimethylnaphthalene, 1,2-	1.66E-03	Styrene	3.31E-04
Dimethylnaphthalene, 1,3-	3.31E-04	Sulfur Dioxide	4.20E-03
Dimethylnaphthalene, 1,5-	1.66E-03	Tetradecane	1.66E-03
Dimethylnaphthalene, 1,6-	1.66E-03	HC as n-Hexane	1.01E-02
Dimethylnaphthalene, 1,8-	1.66E-03	Toluene	3.31E-04
Dimethylnaphthalene, 2,3-	1.66E-03	Trimethylbenzene, 1,2,3-	3.31E-04
Dimethylnaphthalene, 2,6-	1.66E-03	Trimethylbenzene, 1,2,4-	3.31E-04
Dimethylnaphthalene, 2,7-	1.66E-03	Trimethylbenzene, 1,3,5-	3.31E-04
Dimethylphenol, 2,4-	1.66E-03	Trimethylnaphthalene, 2,3,5-	1.66E-03
Dimethylphenol, 2,6-	1.66E-03	Undecane	3.31E-04
Dodecane	1.66E-03	Xylene, mp-	3.31E-04
Ethylbenzene	3.31E-04	Xylene, o-	3.31E-04

Analyte	Lb/Lb Binder	Analyte	Lb/Lb Binder
Carbon Monoxide	3.13E-03	Ethyltoluene, 2-	1.32E-05
Carbon Dioxide	4.92E-03	Ethyltoluene, 3-	6.60E-05
Nitrogen Oxides	3.36E-03	Formaldehyde	1.27E-05
THC as Propane	4.92E-03	Heptane	6.60E-05
2-Butanone (MEK)	1.27E-05	Hexaldehyde	1.27E-05
Acenaphthalene	6.60E-05	Hexane	1.32E-05
Acetaldehyde	1.27E-05	Indan	6.60E-05
Acrolein	1.27E-05	Indene	6.60E-05
Benzaldehyde	1.27E-05	Methylnaphthalene, 1-	1.32E-05
Benzene	1.32E-05	Methylnaphthalene, 2-	1.32E-05
Biphenyl	6.60E-05	Naphthalene	1.32E-05
Butyraldehyde/Methacrolein	2.11E-05	Nonane	6.60E-05
Cresol, mp-	6.60E-05	o,m,p-Tolualdehyde	3.38E-05
Cresol, o-	6.60E-05	Octane	6.60E-05
Crotonaldehyde	1.27E-05	Pentanal (Valeraldehyde)	1.27E-05
Cyclohexane	6.60E-05	Phenol	6.60E-05
Decane	6.60E-05	Propionaldehyde (Propanal)	1.27E-05
Diethylbenzene, 1,3-	6.60E-05	Propylbenzene, n-	6.60E-05
Dimethylnaphthalene, 1,2-	6.60E-05	Styrene	1.32E-05
Dimethylnaphthalene, 1,3-	1.32E-05	Sulfur Dioxide	1.67E-04
Dimethylnaphthalene, 1,5-	6.60E-05	Tetradecane	6.60E-05
Dimethylnaphthalene, 1,6-	6.60E-05	HC as n-Hexane	4.02E-04
Dimethylnaphthalene, 1,8-	6.60E-05	Toluene	1.32E-05
Dimethylnaphthalene, 2,3-	6.60E-05	Trimethylbenzene, 1,2,3-	1.32E-05
Dimethylnaphthalene, 2,6-	6.60E-05	Trimethylbenzene, 1,2,4-	1.32E-05
Dimethylnaphthalene, 2,7-	6.60E-05	Trimethylbenzene, 1,3,5-	1.32E-05
Dimethylphenol, 2,4-	6.60E-05	Trimethylnaphthalene, 2,3,5-	6.60E-05
Dimethylphenol, 2,6-	6.60E-05	Undecane	1.32E-05
Dodecane	6.60E-05	Xylene, mp-	1.32E-05
Ethylbenzene	1.32E-05	Xylene, o-	1.32E-05

APPENDIX C DETAILED PROCESS DATA AND CASTING QUALITY PHOTOS

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Test HB - Detailed Process Data

Greensand PCS													
Test Dates	**2/6/06**	**2/6/06**	**2/6/06**	**2/7/06**	**2/7/06**	**2/7/06**	**2/8/06**	**2/8/06**	**2/8/06**	**2/9/06**	**2/9/06**	**2/9/06**	**Averages**
Emissions Sample #	**HBER1**	**HBER2**	**HBER3**	**HB001**	**HB002**	**HB003**	**HB004**	**HB005**	**HB006**	**HB007**	**HB008**	**HB009**	
Production Sample #	**HB001**	**HB002**	**HB003**	**HB004**	**HB005**	**HB006**	**HB007**	**HB008**	**HB009**	**HB010**	**HB011**	**HB012**	
Cast Weight, Lbs.	40.85	40.70	42.10	42.75	40.80	32.50	43.20	43.40	40.40	43.95	42.45	43.65	**41.5**
Pouring Time, sec.	16	16	14	15	16	13	16	13	19	21	21	19	**17**
Pouring Temp ,°F	1277	1279	1278	1276	1274	1277	1277	1279	1279	1277	1280	1279	**1278**
Pour Hood Process Air Temp at Start of Pour, °F	85	87	85	86	86	86	87	88	90	86	88	88	**87**
Sand in Sodium Silicate Sand mix, lbs	50	50	50	50	50	50	50	50	50	50	50	50	**50**
Sodium Silicate in Sodium Silicate Core Sand Mix,lbs	1.74	1.75	1.75	1.75	1.72	1.72	1.75	1.76	1.74	1.75	1.77	1.74	**1.74**
Sodium Silicate Core CO2 Gassing Pressure, PSI	25	25	25	25	25	25	25	25	25	25	25	25	**25**
Sodium Silicate Core CO2 Gassing Time, sec	30	30	30	30	30	30	30	30	30	30	30	30	**30**
Sodium Silicate Content, % (BOS)	3.47	3.50	3.51	3.51	3.45	3.45	3.49	3.52	3.48	3.50	3.53	3.48	**3.49**
Sodium Silicate Content, % of Sand Mix	3.35	3.38	3.39	3.39	3.33	3.33	3.38	3.40	3.36	3.38	3.41	3.36	**3.37**
Total Weight of Baked Cores in Mold, Lbs.	29.11	28.74	29.15	29.41	29.51	29.30	29.81	29.44	29.26	29.27	29.12	29.03	**29.4**
Total Weight of Binder Cores in Mold, Lbs.	0.98	0.97	0.99	1.00	0.98	0.98	1.01	1.00	0.98	0.99	0.99	0.98	**1.0**
Baking Oven nominal temperature, °F	275	275	275	275	275	275	275	275	275	275	275	275	**275.0**
Average heated investment time, Minutes	60	60	60	60	60	60	60	60	60	60	60	60	**60.0**
Core LOI, %	NT	NT	NT	0.61	0.60	0.62	0.62	0.70	0.63	0.59	0.59	0.58	**0.6**
Core dogbone tensile, psi	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	**14.6**
Core age, hrs.	265	267	270	288	289	291	308	311	312	331	333	335	**311**
Muller Batch Weight, Lbs.	1204	910	890	900	900	900	900	900	900	900	900	910	**901**
GS Mold Sand Weight, Lbs.	638	642	632	649	643	641	642	636	644	637	643	639	**642**
Mold Temperature, °F	74	70	70	62	67	68	68	70	70	69	72	73	**69**
Average Green Compression , psi	22.00	20.44	21.97	20.62	19.50	20.71	21.30	21.77	20.25	20.15	20.68	21.75	**20.75**
GS Compactability, %	47	54	45	41	50	44	43	36	42	40	40	40	**42**
GS Moisture Content, %	1.52	2.44	2.20	1.90	2.12	2.16	1.70	1.72	1.70	1.92	2.04	1.82	**1.90**
GS MB Clay Content, %	7.34	6.74	6.35	7.14	6.74	6.55	6.74	6.94	7.14	6.35	6.94	6.35	**6.77**
MB Clay reagent, ml	37	34	32	36	34	33	34	35	36	32	35	32	**34**
1500°F LOI - Mold Sand, %	0.70	0.83	0.73	0.77	0.75	0.77	0.78	0.81	0.82	0.76	0.72	0.72	**0.77**
900°F Volatiles , %	0.34	0.34	0.40	0.40	0.28	0.30	0.30	0.32	0.26	0.24	0.24	0.22	**0.28**
Permeability index	261	261	271	250	281	271	251	256	260	270	271	271	**265**
Sand Temperature, °F	76	74	73	65	68	70	68	72	73	71	74	75	**71**

Appearance within group B:best, M:median, W: worst	4	5	8	Cavity 1
	3	9	10	Cavity 2
Overall appearance ranking: 1 = best, 6 = Median 12 =	1	6	11	Cavity 3
	2	7	12	Cavity 4

Notes:

No LOI tests were done on the cores for runs HB001-HB003 because the cores were coated and the coating would distort the LOI results.

Test HF - Detailed Process Data

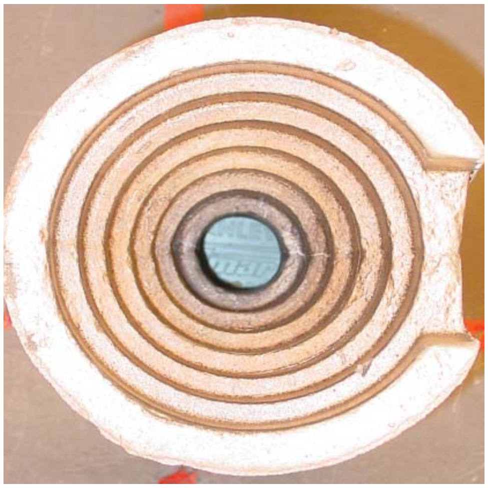
	Greensand PCS												
Test Dates	**3/13/2006**	**3/13/2006**	**3/13/2006**	**3/14/2006**	**3/14/2006**	**3/14/2006**	**3/15/2006**	**3/15/2006**	**3/15/2006**	**3/16/2006**	**3/16/2006**	**3/16/2006**	**Averages**
Emissions Sample #	**HF001**	**HF002**	**HF003**	**HFCR1**	**HFCR2**	**HFCR3**	**HF004**	**HF005**	**HF006**	**HF007**	**HF008**	**HF009**	
Production Sample #	**HF001**	**HF002**	**HF003**	**HF004**	**HF005**	**HF006**	**HF007**	**HF008**	**HF009**	**HF010**	**HF011**	**HF012**	
Cast Weight, Lbs.	40.25	42.45	41.40	42.75	39.60	39.65	46.15	44.00	41.75	45.15	42.20	41.35	**42.74**
Pouring Time, sec.	24	17	15	15	18	19	15	18	15	14	15	14	**16**
Pouring Temp ,°F	1273	1279	1269	1280	1273	1277	1278	1279	1276	1274	1275	1273	**1275**
Pour Hood Process Air Temp at Start of Pour, °F	87	86	88	85	86	85	88	86	87	87	87	87	**87**
Mixer auto dispensed sand weight, Lbs	50.07	50.07	50.07	50.07	50.07	50.07	50.07	50.07	50.07	50.07	50.07	50.07	**50.1**
Core binder weight, Lbs	1.00	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.0**
% core binder (BOS)	2.00	2.01	2.00	2.00	2.00	2.00	2.01	2.01	2.01	2.01	2.00	2.01	**2.01**
% core binder	1.96	1.97	1.96	1.96	1.97	1.97	1.97	1.97	1.97	1.97	1.96	1.97	**1.97**
Total core weight in mold, Lbs.	27.40	27.40	27.40	27.96	27.92	28.00	27.22	27.36	26.97	27.35	27.26	27.18	**27.3**
Total binder weight in mold, Lbs.	0.538	0.540	0.537	0.549	0.549	0.550	0.535	0.538	0.531	0.538	0.535	0.535	**0.5**
Core LOI, %	0.14	0.14	0.13	NT	NT	NT	0.15	0.14	0.16	0.12	0.12	0.12	**0.1**
Core dogbone tensile, psi	29	29	29	29	29	29	29	29	29	29	29	29	**28.6**
Core age, hrs.	96	98	101	118	120	121	139	143	145	164	166	168	**135.6**
Muller Batch Weight, Lbs.	1000	900	900	900	900	900	900	910	910	900	910	910	**915.6**
GS Mold Sand Weight, Lbs.	643	636	647	637	646	640	645	640	640	624	ND	627	**637.6**
Mold Temperature, °F	68	69	67	66	69	71	66	70	72	70	69	71	**69.2**
Average Green Compression , psi	21.03	19.86	19.67	19.76	21.32	20.01	21.65	20.57	19.68	21.11	22.24	21.47	**20.8**
GS Compactability, %	48	43	37	41	38	36	44	46	49	47	45	40	**44.3**
GS Moisture Content, %	1.97	2.26	2.06	1.84	1.86	1.82	1.87	1.96	1.88	1.90	1.72	2.76	**2.0**
GS MB Clay Content, %	7.26	7.36	6.42	7.17	7.55	7.17	6.79	7.36	6.79	7.36	6.98	6.98	**7.0**
MB Clay reagent, ml	38.5	39.0	34.0	38.0	40.0	38.0	36.0	39.0	36.0	39.0	37.0	37.0	**37.3**
1500°F LOI - Mold Sand, %	0.72	0.68	0.67	0.76	0.94	0.87	0.71	0.66	0.72	0.68	0.69	0.70	**0.7**
900°F Volatiles , %	0.52	0.28	0.24	0.20	0.32	0.26	0.26	0.24	0.40	0.26	0.30	0.38	**0.3**
Permeability index	260	261	263	250	254	261	255	256	249	273	274	269	**262.2**
Sand Temperature, °F	78	78	70	71	72	74	76	77	78	78	79	75	**76.6**
Casting Quality Appearance Rank			Cavity 1	8	5	1							
			Cavity 2	3	9	4							
			Cavity 3	2	10	11							
			Cavity 4	12	6	7							

Notes:

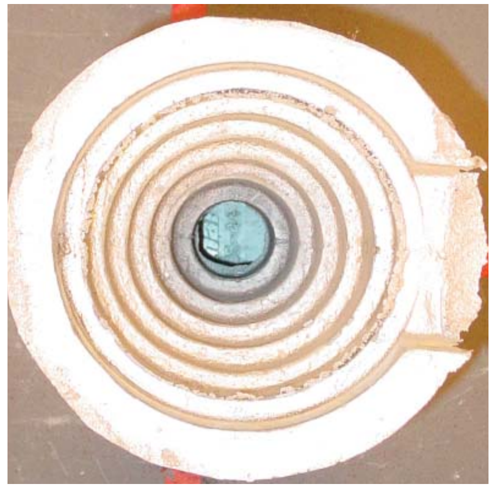
Overall appearance ranking: 1 = best, 6 = Median 12 = worst

Casting Surface Quality Comparison Photos

Best

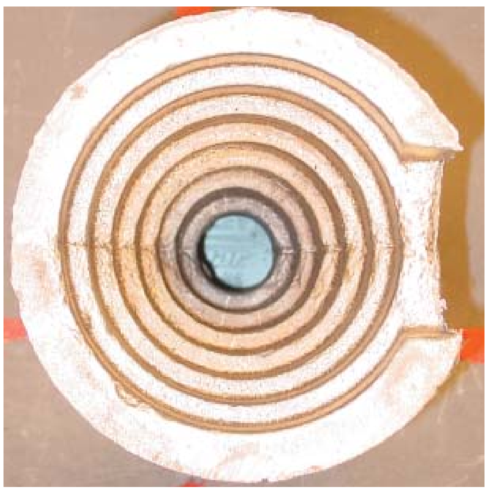


HB CR1 Cavity 3



HF CR3 Cavity 1

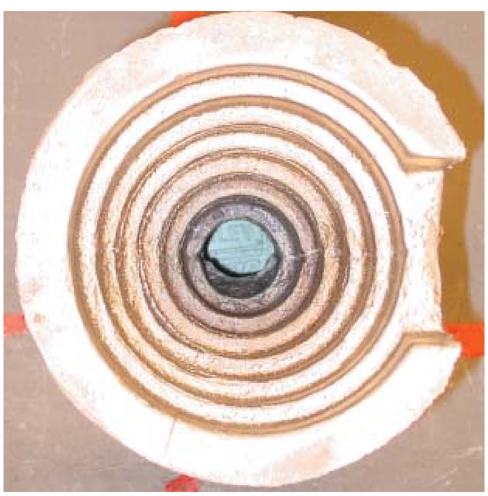
Median



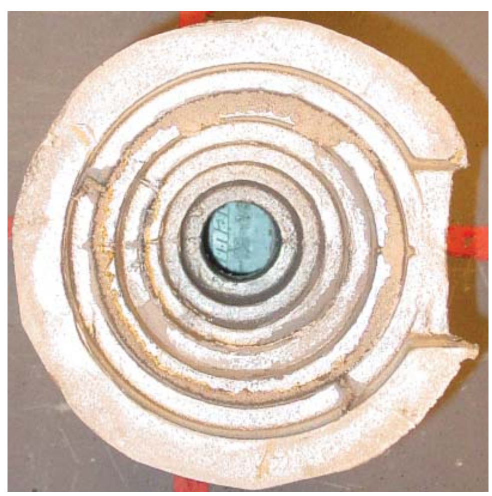
HB CR2 Cavity 3

HF CR2 Cavity 4

Worst



HB CR3 Cavity 4



HF CR1 Cavity 4

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APPENDIX D CONTINUOUS EMISSION MONITORING CHARTS

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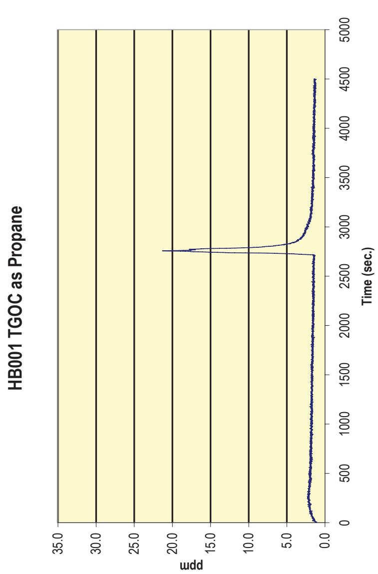
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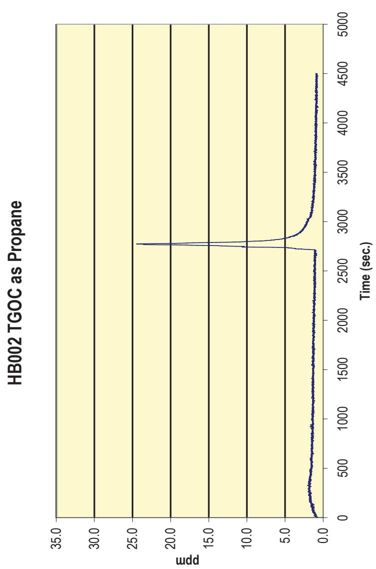
Time (sec.)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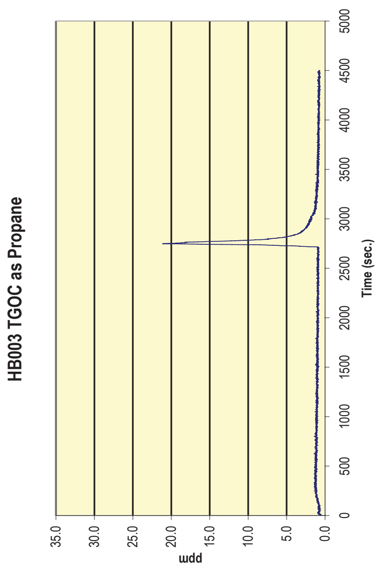
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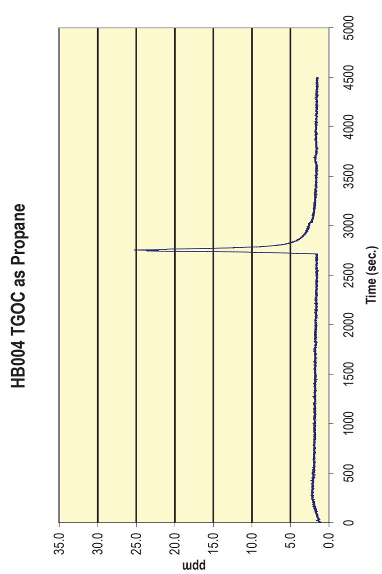
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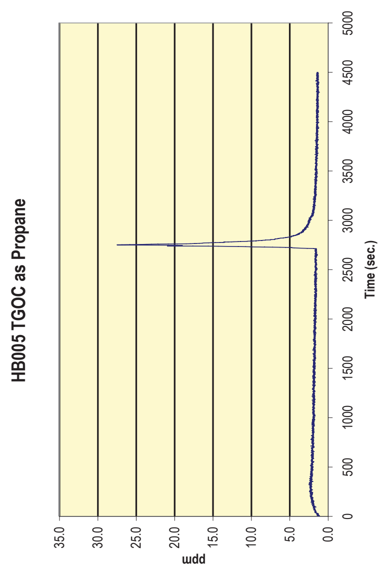
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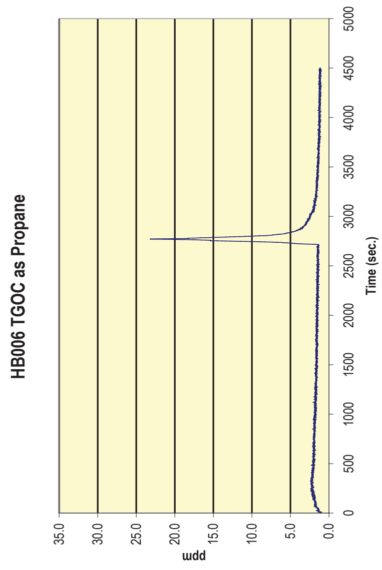
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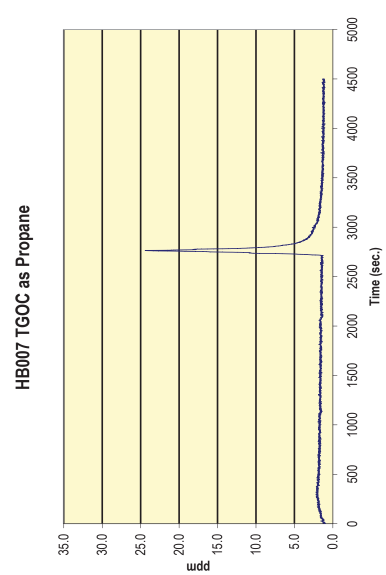
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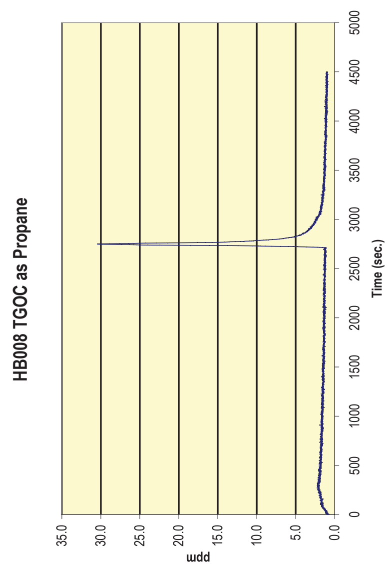
Time (sec.)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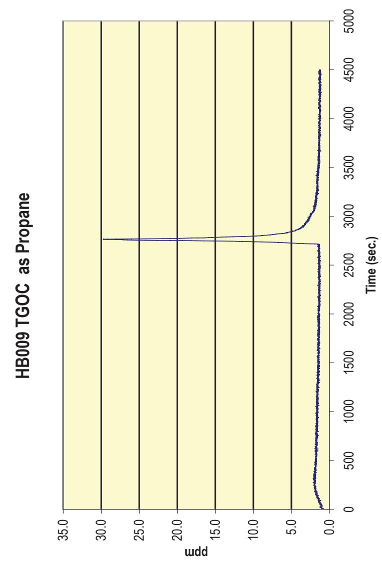
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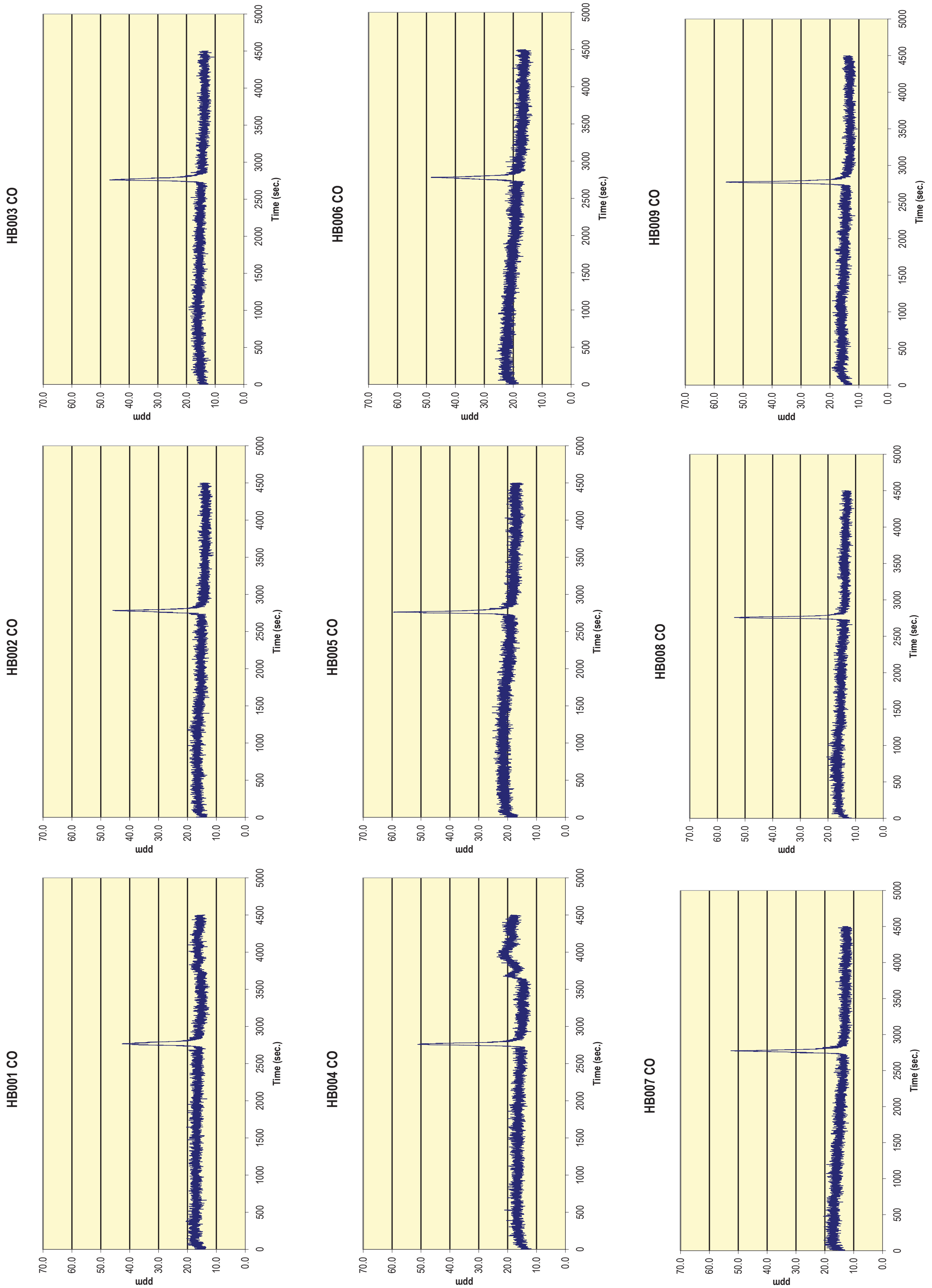
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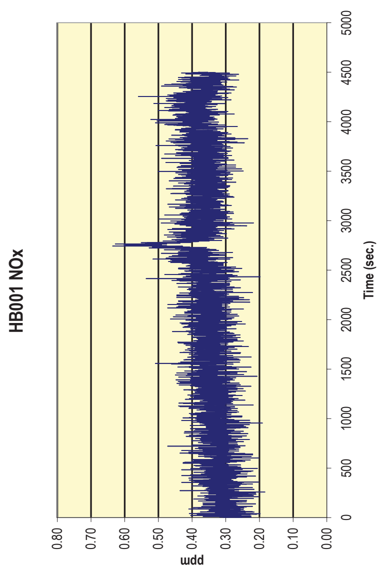
Time (sec.)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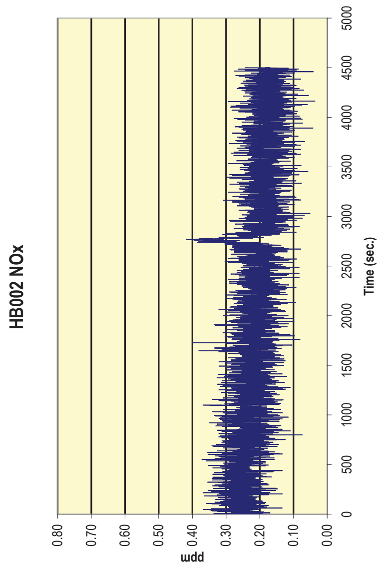
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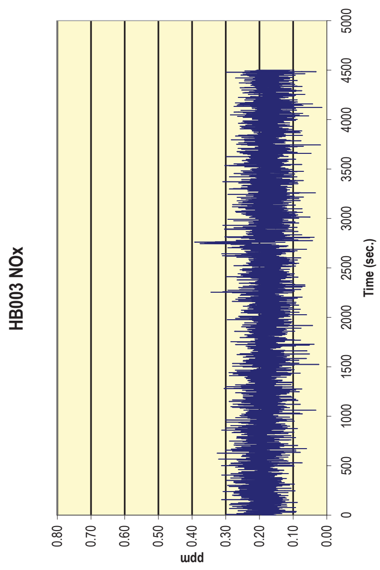
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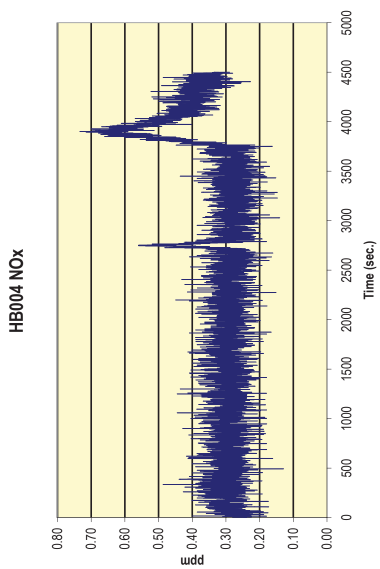
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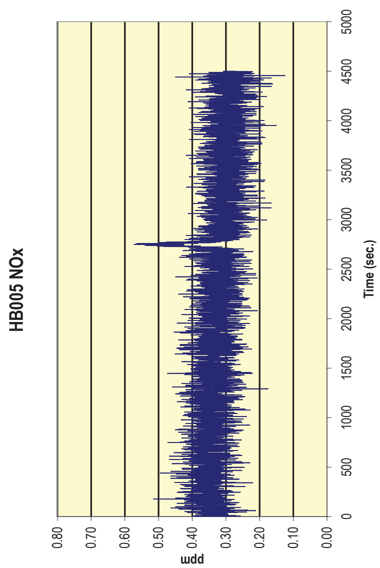
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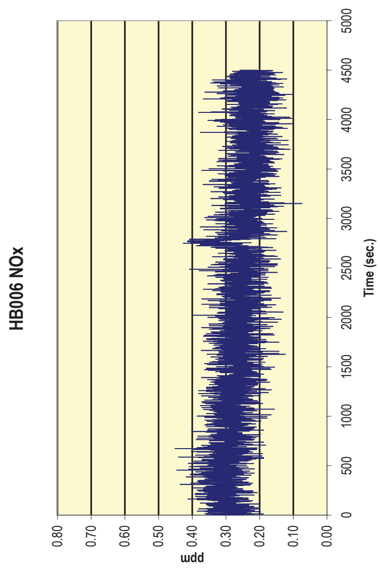
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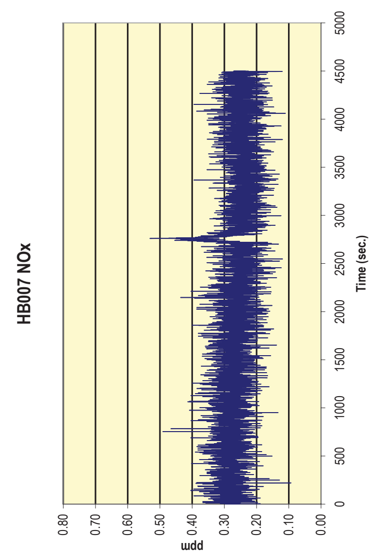
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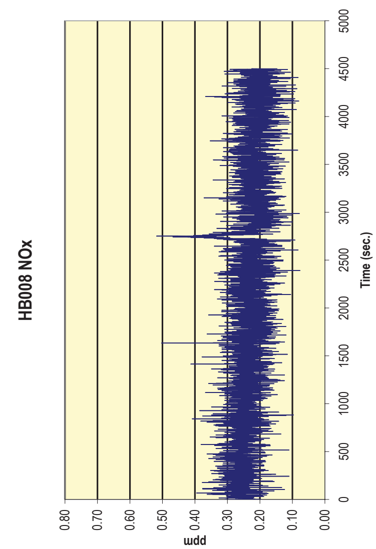
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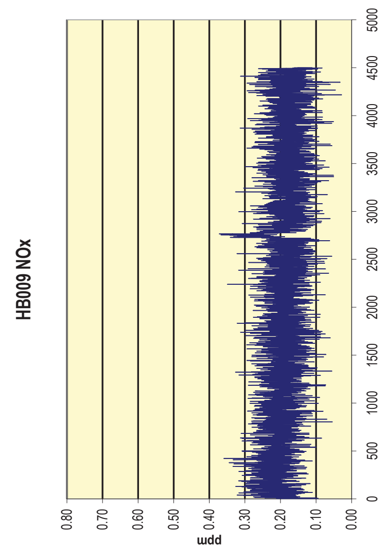
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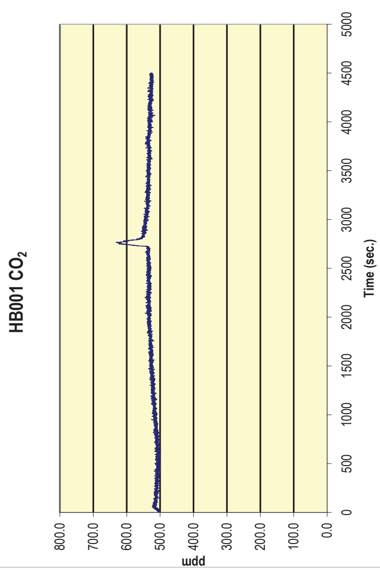
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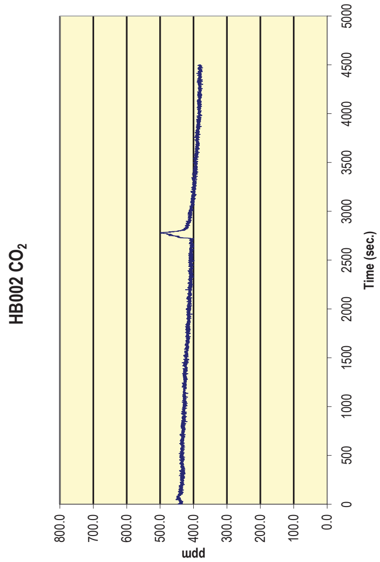
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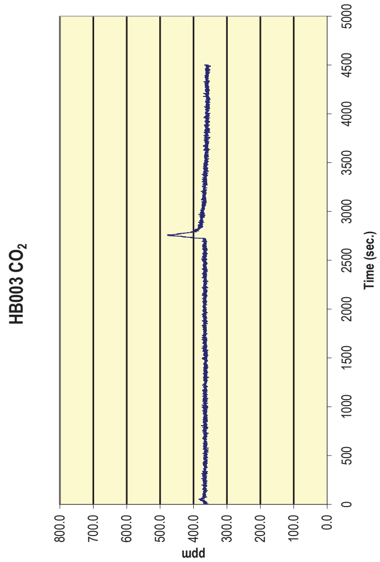
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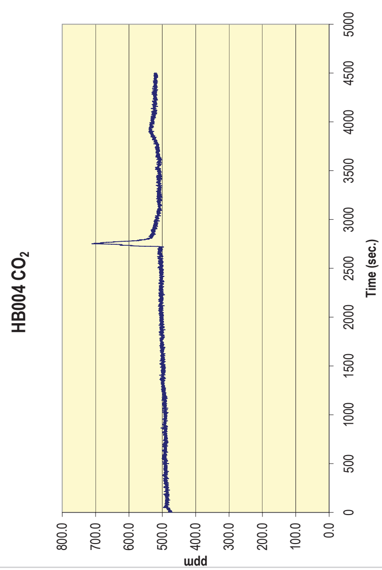
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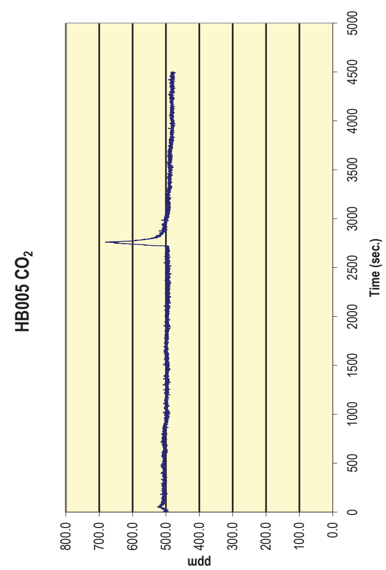
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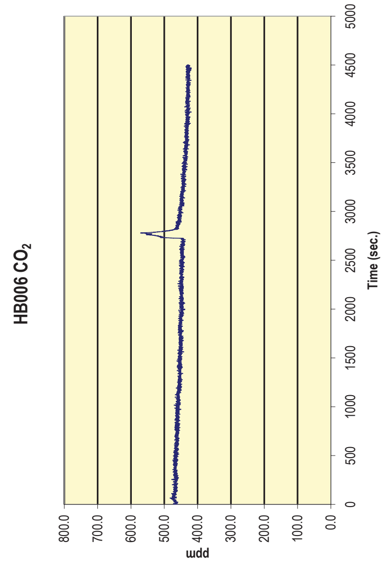
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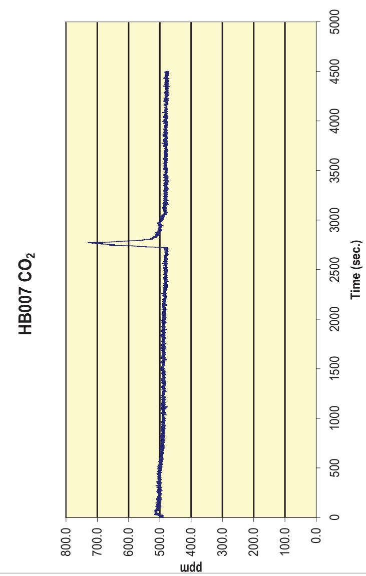
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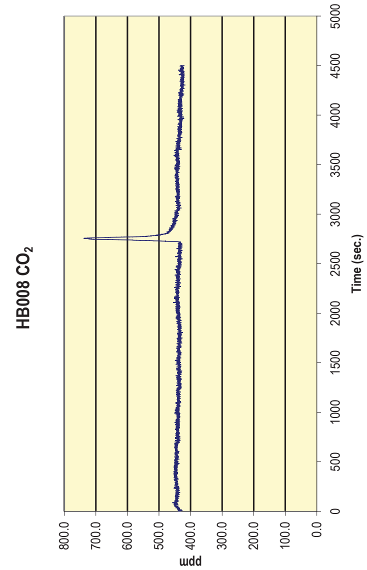
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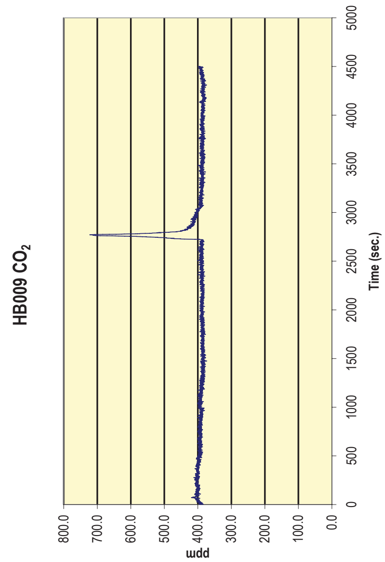
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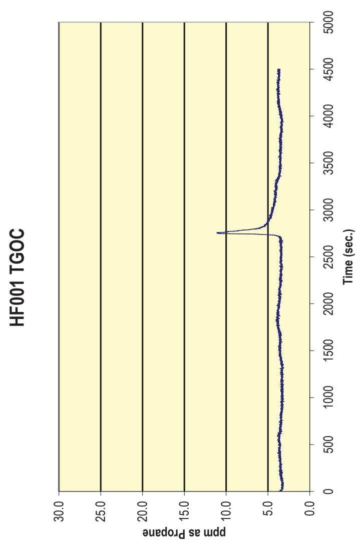
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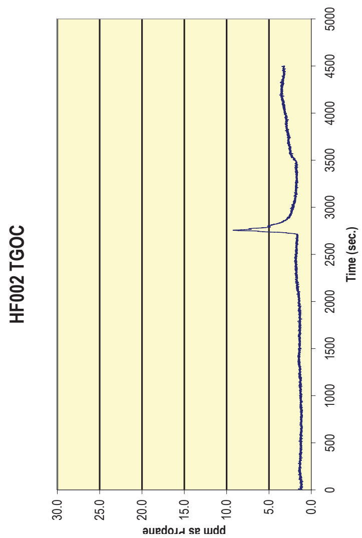
Time (sec.)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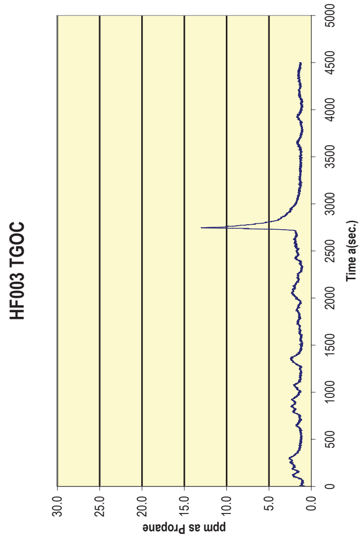
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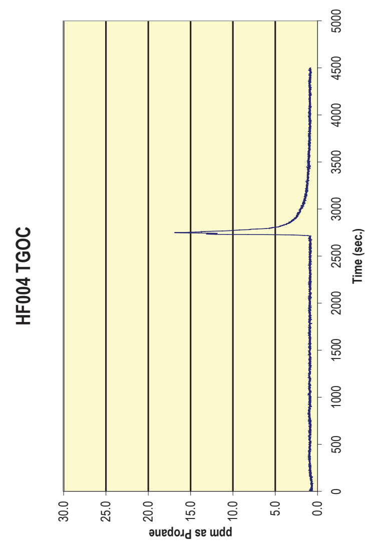
Time a(sec.)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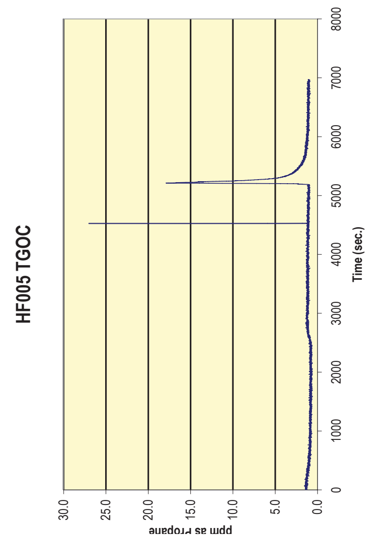
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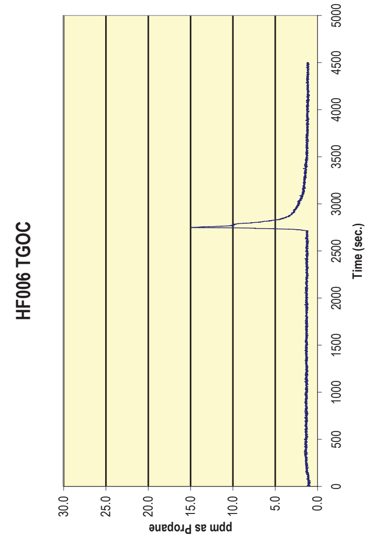
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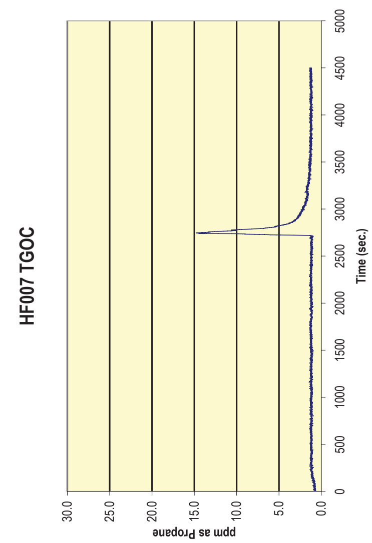
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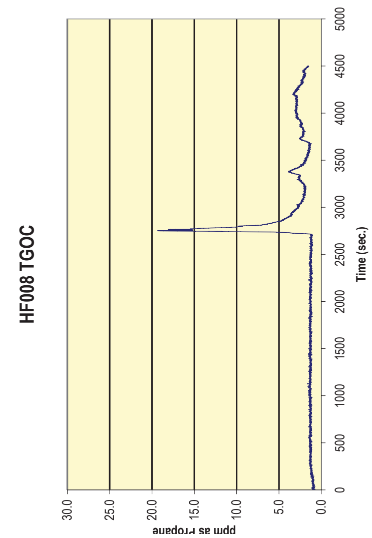
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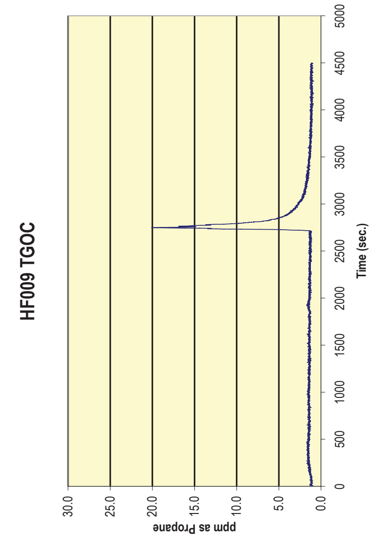
Time (sec.)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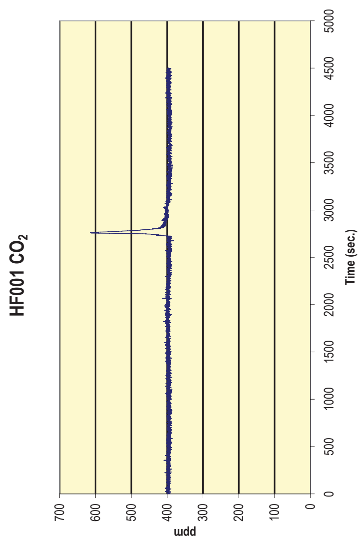
Time (sec.)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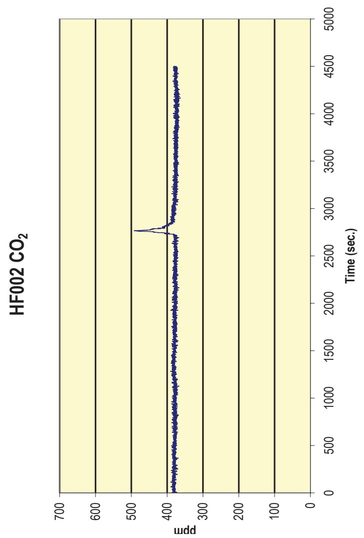
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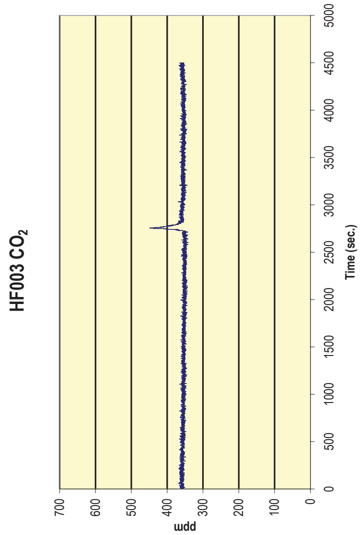
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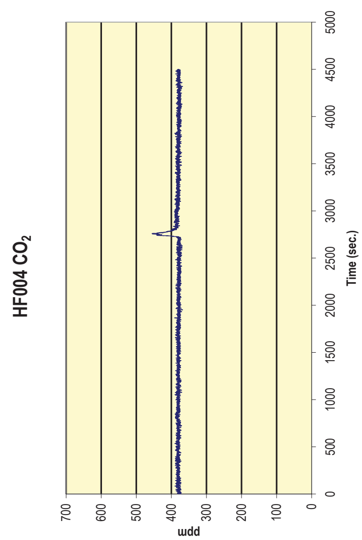
Time (sec.)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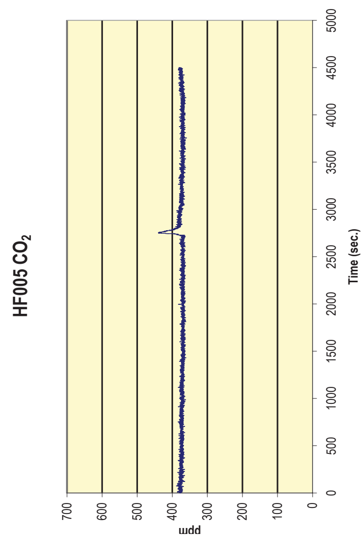
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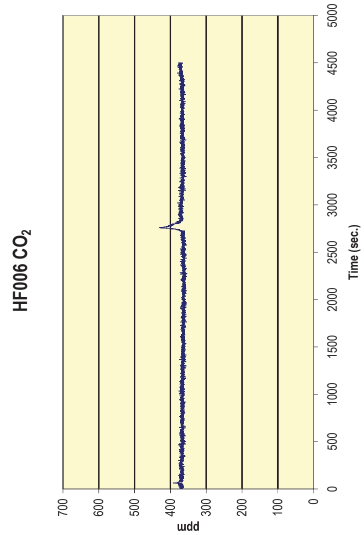
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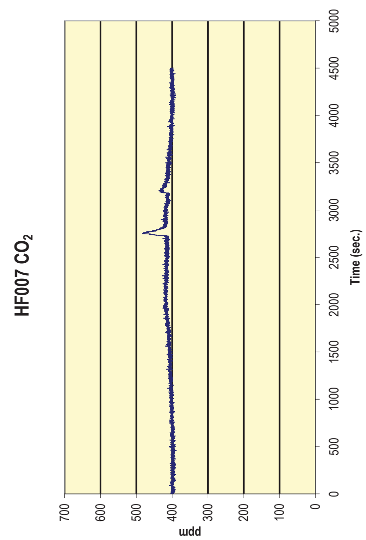
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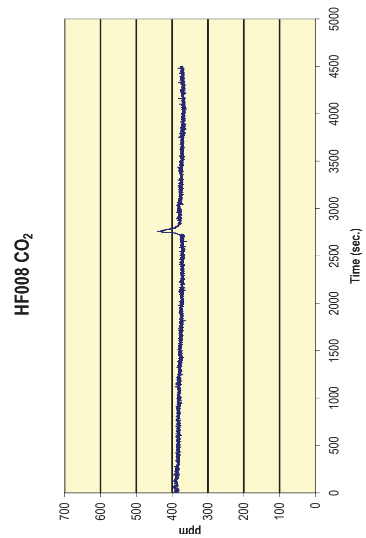
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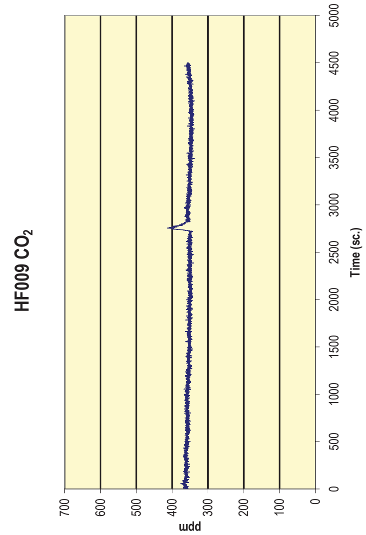
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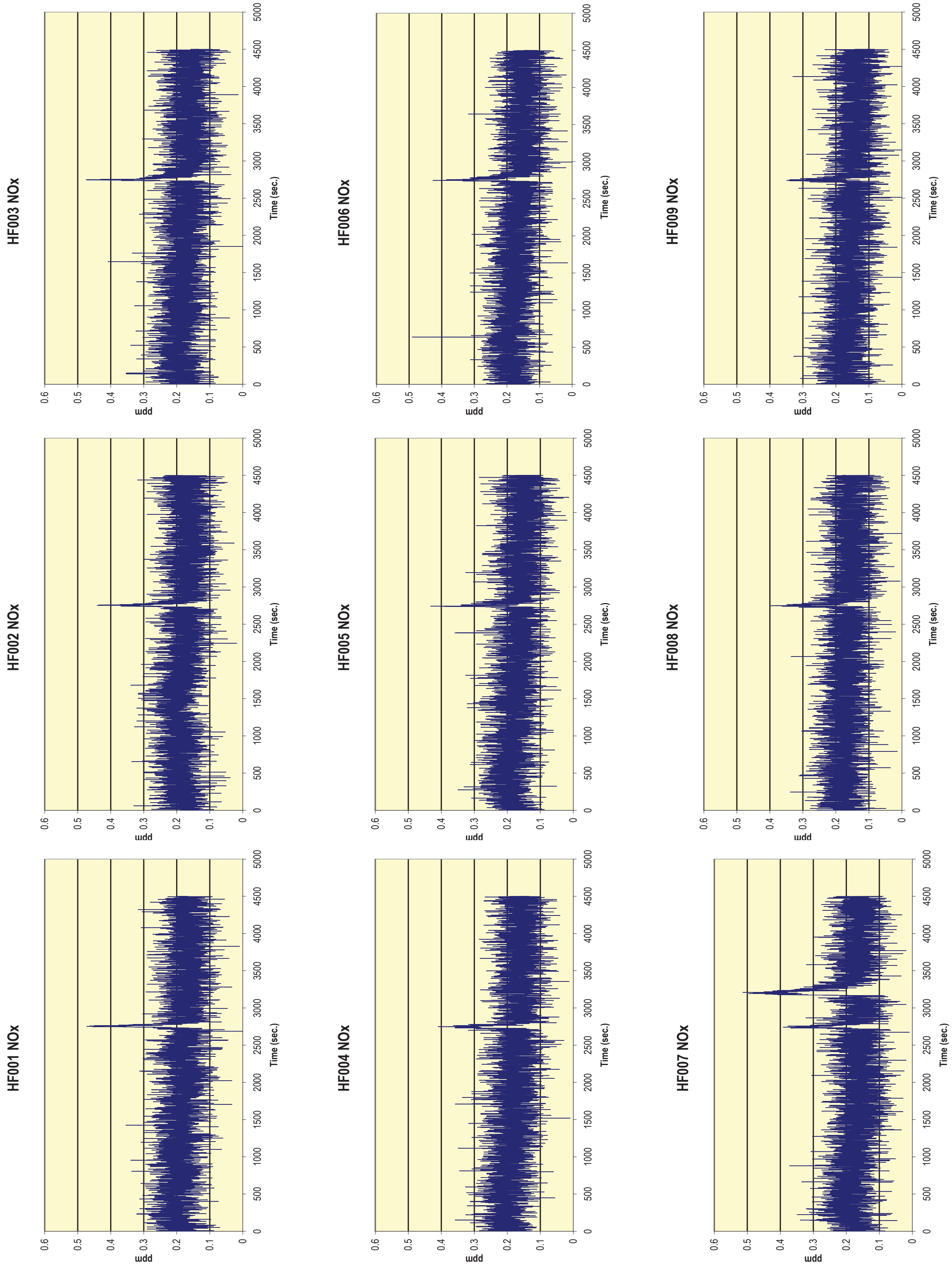
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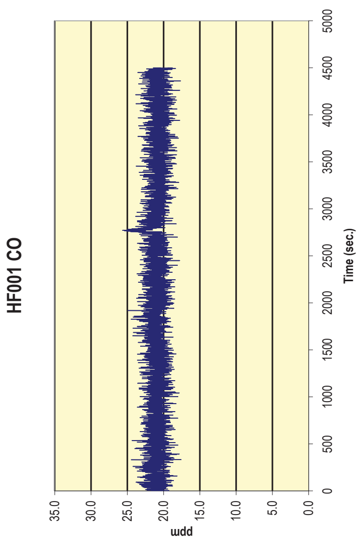
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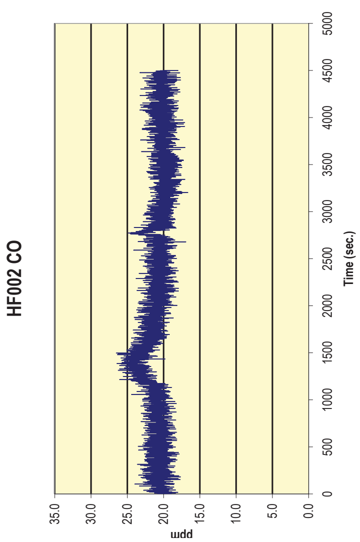
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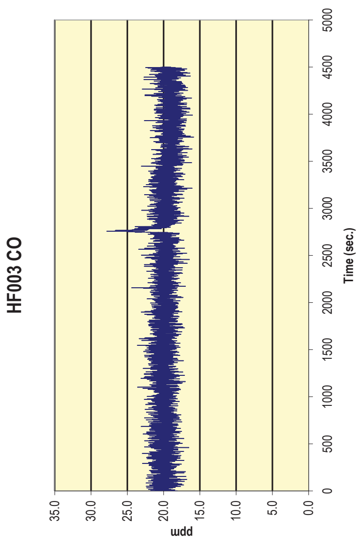
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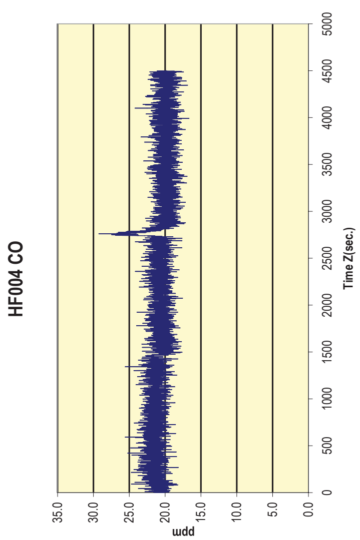
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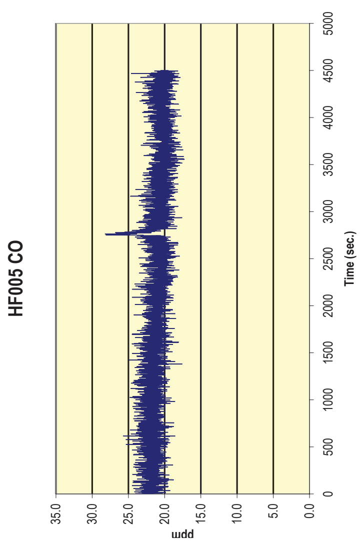
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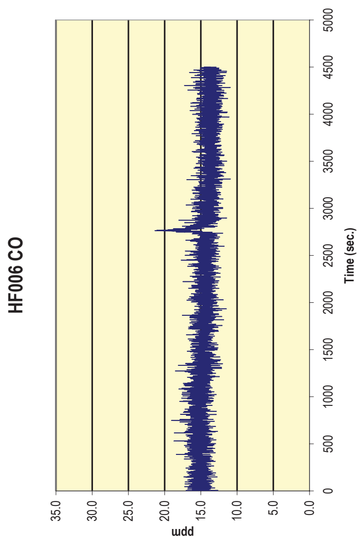
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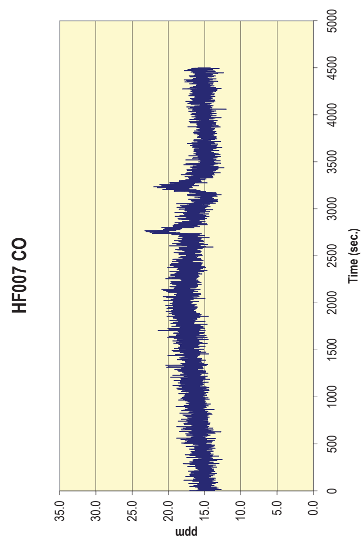
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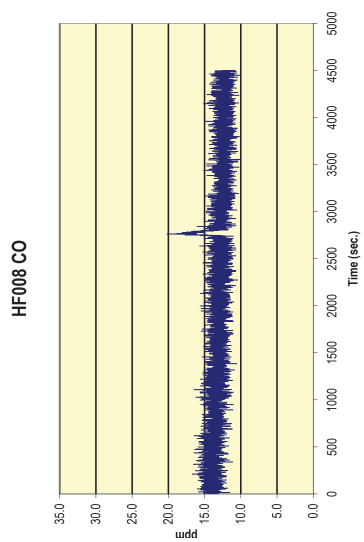
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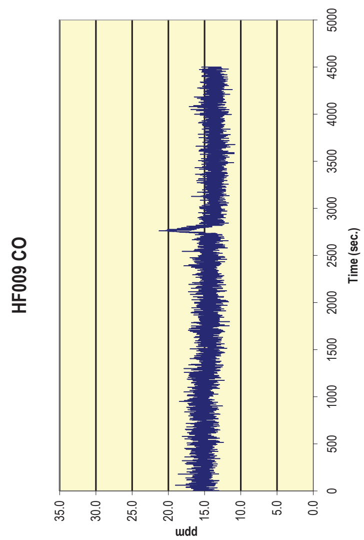
Time (sec.)


HF009 CO
ppm
Time (sec.)

APPENDIX E ACRONYMS AND ABBREVIATIONS

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ACRONYMS & ABBREVIATIONS

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

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