



Casting Emission Reduction Program

[www.cerp-us.org](http://www.cerp-us.org)



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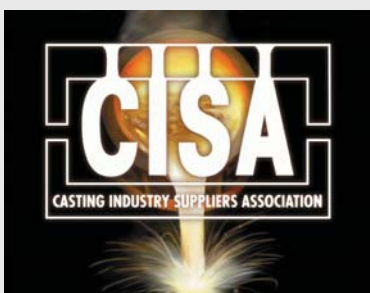
*US Army Contract W15QKN-05-D-0030  
FY2005 Tasks  
WBS # 1.2.3*

*PCS Al CO<sub>2</sub> Cured, 4-on  
Step Core, Sodium Silicate*

1412-123 HB

June 2006

*(Revised for public distribution - November 2006)*



UNITED STATES COUNCIL  
FOR AUTOMOTIVE RESEARCH

DAIMLERCHRYSLER



General Motors

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## 1412-123 HB

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 producibility.

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**EXECUTIVE SUMMARY**

This report contains the results of Test HB, an emissions test to evaluate the pouring, cooling, and shakeout emissions from a sodium silicate binder activated with CO<sub>2</sub> in greensand with no seacoal and poured with A356 aluminum. Results from this test update and add to the core baseline database. This report includes quality data for casting internal surface comparisons. The emissions results are reported in both pounds of analyte per pound of binder (lb/lb) and pounds of analyte per ton of metal poured (lb/ton).

The testing performed involved the collection of continuous air samples over a seventy-five minute period, including the mold pouring, cooling, shakeout, and post shakeout periods for nine molds using a 4-on step core pattern. Emission indicator results are summarized in Table 1. It must be noted that the reported TGOC results include the exempted compound methane. At present, the methane contribution to these results has not been determined or removed.

**Table 1 HB Average Emissions Indicators  
Summary Table**

Analyte Name	Lb/Tn Metal	Lb/Lb Binder
TGOC as Propane	0.1055	0.0023
HC as Hexane	0.0392	0.0008
Sum of Target VOCs	0.0322	0.0007
Sum of Target HAPs	0.0297	0.0006
Sum of Target POMs	0.0002	<0.0001

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

In addition, results from the testing performed 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.

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## **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 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](http://www.cerp-us.org).

### **1.2. CERP/TECHNIKON OBJECTIVES**

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

### **1.3. REPORT ORGANIZATION**

This report has been designed to document the methodology and results of a specific test plan that was used to evaluate the pouring, cooling and shakeout emissions from an un-

coated CO<sub>2</sub> cured sodium silicate core, in a greensand mold with no seacoal and poured with aluminum. Section 2 of this report includes a summary of the methodologies used for data collection and analysis, procedures for emission calculations, QA/QC procedures, and data management and reduction methods. Specific data collected during this test are summarized in Section 3 of this report, with detailed data included in the appendices of this report. Section 4 of this report contains a discussion of the results.

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

#### 1.4. SPECIFIC TEST PLAN AND OBJECTIVES

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

**Table 1-1 Test Plan Summary**

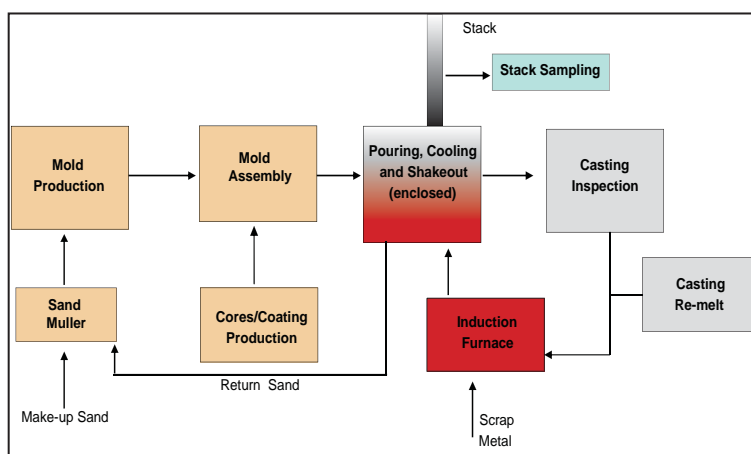
Type of Process Tested	Uncoated sodium silicate core in greensand without seacoal, aluminum, PCS
Test Plan Number	1412-123-HB
Metal Poured	Aluminum
Casting Type	4-on step core
Greensand System	Wexford 450 sand, western and southern bentonite in a 5:2 ratio to yield 7.0 +/- 0.5 % MB clay, no seacoal
Core	3.5 % (BOS) Foseco Solosil®, CO <sub>2</sub> activated, Wedron 530 sand
Core Coating	Foseco Rheotec® XL for conditioning runs, none for emissions sampling runs
Number of Molds Poured	3 conditioning, 9 sampling
Test Dates	February 6, 2006 through February 9, 2006
Emissions Measured	57 target analytes and TGOC as propane, CO, CO <sub>2</sub> , NO <sub>x</sub> , SO <sub>2</sub>
Process Parameters Measured	Total casting, mold, and binder weights; metallurgical data, % LOI, sand temperature; stack temperature, moisture content, pressure, and volumetric flow rate

## 2.0 TEST METHODOLOGY

### 2.1. DESCRIPTION OF PROCESS AND TESTING EQUIPMENT

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

**Figure 2-1 Research Foundry Layout Diagram**



### 2.2. DESCRIPTION OF TESTING PROGRAM

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-eight (58) target compounds using procedures based on approved state and/or federal regulatory methods, including those of the US Environmental Protection Agency (EPA). Continuous on-line monitoring of Total Gaseous Organic Concentration (TGOC), carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO), and nitrogen oxide (NO<sub>x</sub>) concentrations was conducted according to US EPA Methods 25A, 3A, 10, and 7E respectively.

Mass emission rates for all analytes were calculated using continuous monitoring or laboratory analytical results, measured source data and appropriate process data. Detailed emission results are presented in Appendix B. Individual analyte emissions were calculated in addition to five “Emission Indicators” which include TGOC as propane, hydrocarbons (HC) as hexane, the sum of target VOCs, the sum of target hazardous air pollutants (HAPs), and the sum of target polycyclic organic matter (POM). Full descriptions of these indicators can be found in Section 3.0 of this report.

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

**Figure 2-2 Mold and Step Cores**



#### *2.2.1. Test Plan Review and Approval*

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

**Figure 2-3 Coated Step Cores**



#### *2.2.2. Mold, Core and Metal Preparation*

The molds and cores (Figure 2-2 and 2-3) were prepared to a standard composition by the Technikon production team. The core sand was mixed using a single plow mixer. The cores were hand rammed and gassed with CO<sub>2</sub> until cured and then coated with the vendor supplied core coating and dried in an OSI core drying oven (Figure 2-3). Relevant process data were collected and recorded. Aluminum was melted in a 75 kW furnace (Figure 2-4). The amount of metal melted was determined from the poured weight of the casting and the number of molds to be poured. The weight of metal poured into each mold was recorded on the process data summary sheet.

**Figure 2-4 Metal Melting in Furnace**



### 2.2.3. Individual Sampling Events

Replicate runs were performed on nine (9) mold packages after the conclusion of three (3) conditioning cycles. Prior to pouring for each run, each mold package was placed into an enclosed test stand heated to approximately 85°F. The flow rate of the emission capture air was nominally 300 scfm. Aluminum was poured through an opening in the top of the emission enclosure, after which the opening was closed (Figure 2-5).

**Figure 2-5 Pouring Metal into Mold in Total Enclosure Hood**



Continuous air samples were collected during the forty-five minute pouring and cooling process, during the five minute shakeout of the mold, and for an additional twenty five minute cooling period following shakeout. Figure 2-6 shows the sampling equipment used during collection of emissions. The total sampling time was seventy-five minutes.

**Figure 2-6 Method 25A (TGOC) and Method 18 Sampling Train**



### 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)
<b>Metallurgical Parameters</b>	
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 regulatory reference methods shown in Table 2-2. The details of the specific testing procedures and their variance from the reference methods are included in the Technikon Standard Operating Procedures.

**Table 2-2 Emission Sampling and Analytical Methods**

Measurement Parameter	Test Method(s)
Port Location	US EPA Method 1
Number of Traverse Points	US EPA Method 1
Gas Velocity and Temperature	US EPA Method 2
Gas Density and Molecular Weight	US EPA Method 3a
Gas Moisture	US EPA Method 4 (Gravimetric)
Target VOCs and HAPs	US EPA Methods TO17, TO11; NIOSH Methods 1500, 2002
TGOC	US EPA Method 25A
CO	US EPA Method 10
CO <sub>2</sub>	US EPA Method 3A
NO <sub>x</sub>	US EPA Method 7E
SO <sub>2</sub>	OSHA ID 200

Some methods modified to meet specific CERP test objectives.

### 2.2.6. *Data Reduction, Tabulation and Preliminary Report Preparation*

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

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

### *2.2.7. Report Preparation and Review*

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

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

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

- Immediately following the individual sampling events performed for each test, specific process parameters are reviewed by the Manager - Process Engineering to ensure that the parameters are maintained within the prescribed control ranges. Where data are not within the prescribed ranges, the Manager of Process Engineering and the Vice President of Operations determine whether the individual test samples should be invalidated or flagged for further analysis following review of the laboratory data.
- The source (stack) and sampling parameters, analytical results and corresponding laboratory QA/QC data are reviewed by the Emissions Measurement Team to confirm the validity of the data. The 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.

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### 3.0 TEST RESULTS

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

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

Analyte Name	Average	Standard Deviation
<b>Emission Indicators</b>		
TGO as Propane	0.1055	0.0082
HC as Hexane	0.0392	0.0051
Sum of Target VOCs	0.0322	0.0039
Sum of Target HAPs	0.0297	0.0035
Sum of Target POMs	0.0002	0.0001
<b>Selected Target HAPs and POMs</b>		
Acetaldehyde	0.0200	0.0020
Propionaldehyde (Propanal)	0.0022	0.0002
2-Butanone (MEK)	0.0021	0.0002
Toluene	0.0015	0.0005
Xylenes	0.0013	0.0006
Benzene	0.0011	0.0003
Formaldehyde	0.0008	0.0002
<b>Additional Selected Target VOCs</b>		
Butyraldehyde/Methacrolein	0.0008	0.0001
Trimethylbenzenes	0.0007	0.0004
<b>Criteria Pollutants and Greenhouse Gases</b>		
Carbon Dioxide	ND	NA
Carbon Monoxide	0.0909	0.0631
Nitrogen Oxides	ND	NA
Sulfur Dioxide	ND	NA

NT= Not Tested

ND= Not Detected

NA= Not Applicable

I=Invalidated Data

Selected results constitute >95% of the mass of all detected target analytes.

<0.0001= less than reporting limit of 0.0001 lb/ton metal

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

Analyte Name	Average	Standard Deviation
<b>Emission Indicators</b>		
TGO as Propane	0.0023	0.0002
HC as Hexane	0.0008	0.0002
Sum of Target VOCs	0.0007	0.0001
Sum of Target HAPs	0.0006	0.0001
Sum of Target POMs	<0.0001	<0.0001
<b>Selected Target HAPs and POMs</b>		
Acetaldehyde	0.0004	0.0001
Propionaldehyde (Propanal)	<0.0001	<0.0001
2-Butanone (MEK)	<0.0001	<0.0001
Toluene	<0.0001	<0.0001
Xylenes	<0.0001	<0.0001
Benzene	<0.0001	<0.0001
Formaldehyde	<0.0001	<0.0001
<b>Additional Selected Target VOCs</b>		
Butyraldehyde/Methacrolein	<0.0001	<0.0001
Trimethylbenzenes	<0.0001	<0.0001
<b>Criteria Pollutants and Greenhouse Gases</b>		
Carbon Dioxide	ND	NA
Carbon Monoxide	0.0019	0.0014
Nitrogen Oxides	ND	NA
Sulfur Dioxide	ND	NA

NT= Not Tested

ND= Not Detected

NA= Not Applicable

I=Invalidated Data

Selected results constitute >95% of the mass of all detected target analytes.

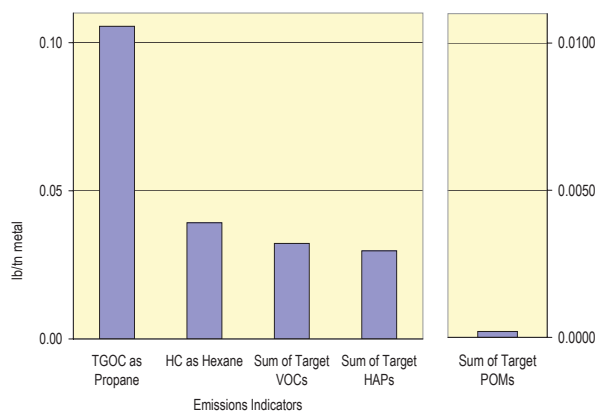
<0.0001= less than reporting limit of 0.0001 lb/lb binder

analytes measured continuously on-line in real time at Technikon during the test have been background corrected. These include CO, CO<sub>2</sub>, NO<sub>x</sub> and THC as propane.

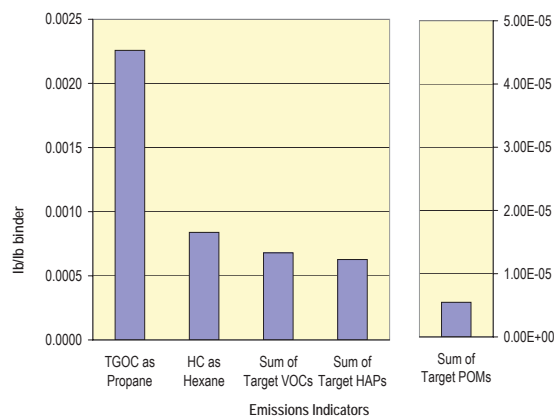
Compounds that are structural isomers have been grouped together and are reported as a single isomer class. For example: ortho-, meta-, and para-xylene are the three structural isomers of dimethyl benzene and their sum is reported as xylenes. All other isomers are treated and reported in a similar manner.

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

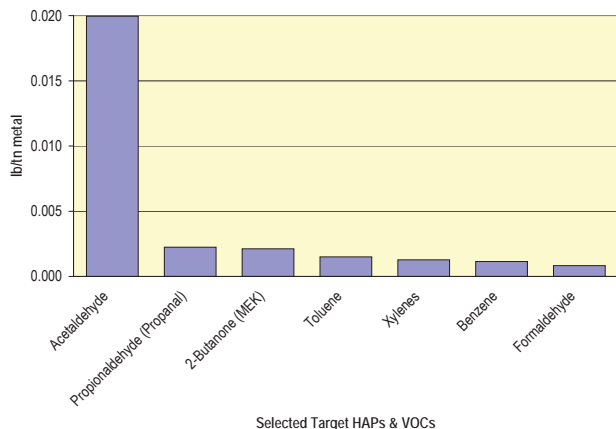
**Figure 3-1a Emissions Indicators for Test HB, Average Results – Lb/Tn Metal**



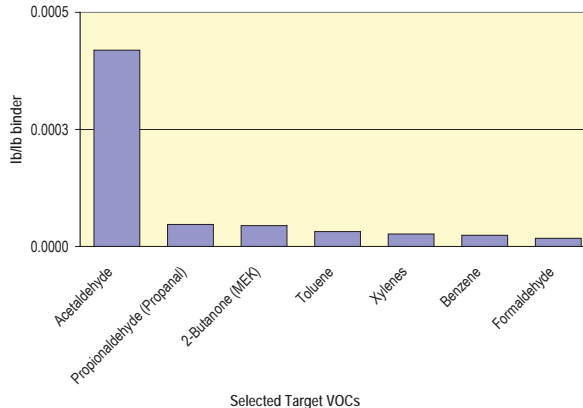
**Figure 3-1b Emissions Indicators for Test HB, Average Results – Lb/Lb Binder**



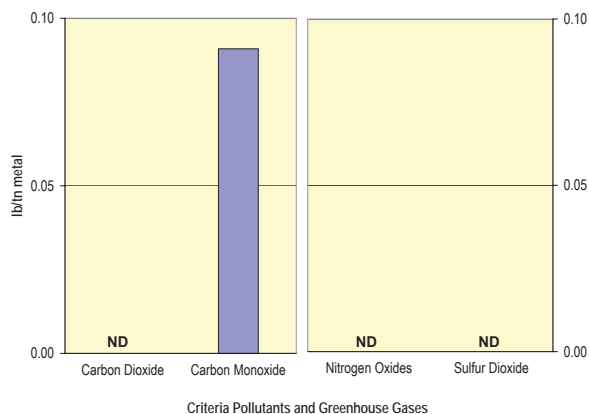
**Figure 3-2a Selected HAP and VOC Emissions for Test HB, Average Results – Lb/Tn Metal**



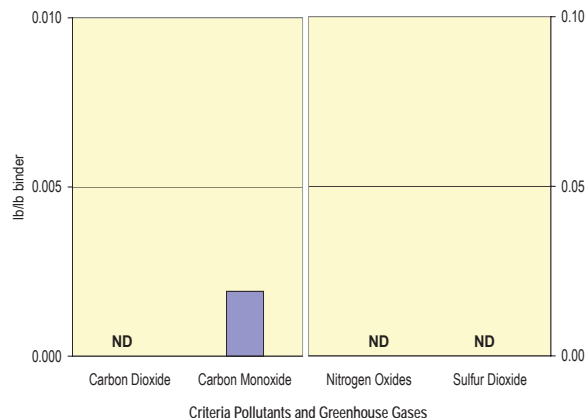
**Figure 3-2b Selected HAP and VOC Emissions for Test HB, Average Results – Lb/Lb Binder**



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



**Figure 3-3b Criteria Pollutants and Greenhouse Gases for Test 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, performed in accordance with Wisconsin Cast Metals Association – Maximum Potential to Emit (WCMA – MPTE) Method revised 07-26-01. EPA Method 25A is weighted to the detection of the more volatile hydrocarbon species, beginning at methane, the single carbon alkane ( $C_1$ ), with results calibrated against propane, which is the three-carbon alkane ( $C_3$ ). The HC as hexane method detects hydrocarbon compounds in the alkane range between  $C_6$  and  $C_{16}$ , with results calibrated against the six-carbon alkane, hexane ( $C_6$ ).

The emissions indicator called the “Sum of Target VOCs” is the sum of all individual target VOCs detected and includes compounds which may also be defined as HAPs and POMs. The term VOC has a precise regulatory definition codified by the US EPA in the Code of Federal Regulations (CFR). Target VOCs are those compounds which are chosen for analysis based on the chemistry of the binder system and operation parameters. By definition, HAPs are specific compounds listed in the Clean Air Act Amendments of 1990. The term POM defines not one compound, but a broad class of compounds based on chemical structure and boiling point. POMs as a class are a listed HAP. A subset of the original 188 listed EPA HAPs was targeted for collection and analysis. These individual target HAPs (which may also be POMs by nature of their chemical properties) detected in the samples are summed together and defined as the “Sum of Target HAPs”, while the “Sum of Target

**Table 3-2 Summary of Test Plan Process Parameters**

Greensand PCS with Sodium Silicate Cores	
Test Dates	2/6-2/9/06
Cast Weight, Lbs.	41.46
Pouring Time, sec.	17
Pouring Temp, °F	1278
Pour Hood Process Air Temp at Start of Pour, °F	87
Sand in Sodium Silicate Sand mix, lbs	50.00
Sodium Silicate in Sodium Silicate Core Sand Mix, lbs	1.74
Sodium Silicate Core CO2 Gassing Pressure, PSI	25
Sodium Silicate Core CO2 Gassing Time, sec	30
Sodium Silicate Content, % (BOS)	3.49
Sodium Silicate Content, % of Sand Mix	3.37
Total Weight of Baked Cores in Mold, Lbs.	29.35
Total Weight of Binder Cores in Mold, Lbs.	0.99
Baking Oven nominal temperature, °F	275
Core LOI, %	0.62
Core dogbone tensile, psi	29.0
Core age, hrs.	311
Muller Batch Weight, Lbs.	901
GS Mold Sand Weight, Lbs.	642
Mold Temperature, °F	69
Average Green Compression, psi	20.75
GS Compactability, %	42
GS Moisture Content, %	1.90
GS MB Clay Content, %	6.77
MB Clay reagent, ml	34.11
1500°F LOI - Mold Sand, %	0.77
900°F Volatiles, %	0.28
Permeability index	265
Sand Temperature, °F	71

results from this test are reported along with other process parameters in Table 3-2 and Appendix C.

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

POMs” only sums those HAPs that are also defined as POMs.

A dogbone tensile test was performed on the core sand for this test. The dogbone tensile test sand was mixed in a Hobart (KitchenAid) lab mixer. The dogbone tensile test specimens were blown on a Redford Carver core blowing machine. Test specimens were made in a manner consistent with AFS 3315-00-S. The gas time and pressure were changed from the reference procedure due to a 3-on core box instead of a 1-on core box. The tensile specimens were stored in a desiccator for 5 minutes after coming out of the core box, weighed, and then tested. The specimens were tested on a Thwing-Albert QC-3A. The

**Table 3-3 Casting Quality Rank Order**

Rank Order	Mold No.	Cavity No.	Test HB
1	HBCR1	3	Best
2	HBCR1	4	
3	HBCR1	2	
4	HBCR1	1	
5	HBCR2	1	
6	HBCR2	3	Median
7	HBCR2	4	
8	HBCR3	1	
9	HBCR2	2	
10	HBCR3	2	
11	HBCR3	3	
12	HBCR3	4	Worst

relative to each other. Three benchmark visual casting quality rankings consisting of the best, the median, and the worst casting are assigned to three of the castings. The “best” designation means that a casting is the best appearing casting of the lot of twelve, and is given an in-series rank of “1”. The “median” designation, given an in-series rank of “6”, means that five castings are better in appearance and six are worse. The “worst” designation is assigned to that casting which is of the poorest quality, and is assigned an in-series rank of “12”. The remaining castings are then compared to these three benchmark castings. The three conditioning runs are used for surface finish quality comparisons only. Emissions from these runs were not sampled and are therefore not included in the emission results reported here. These castings will be used as baselines for inorganic binders poured in the planned aluminum tests.

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 HB. Appendix B contains detailed emissions data and average results for all targeted analytes. Target analyte practical quantitation reporting limits expressed in both pounds per pound of binder and pounds per ton of metal are also shown in Appendix B. These values are based on the practical quantitation limit which is related to the detection limitations of an analytical method and the capabilities of analytical instrumentation. Appendix C contains detailed process data and the pictorial casting record. Appendix D contains continuous monitor charts. The charts are presented to show TGO, carbon monoxide, carbon dioxide, and oxides of nitrogen time-dependent emissions profiles for each pour. Appendix E contains acronyms and abbreviations.

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## **4.0 DISCUSSION OF RESULTS**

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Of the fifty-eight targeted analytes collected and analyzed using adsorption tube methods, only sixteen (16) individual compounds were measurable above the practical quantitation limit as determined by the analytical laboratory. Only nine (9) of these analytes accounted for 95% of emissions in both lb/ton metal and lb/lb binder concentration as can be seen in Tables 3-1a and 3-1b. The highest contributor to total measured emissions was acetaldehyde at 62%, followed by propionaldehyde (propanal) and 2-butanone (MEK) at 7% each, toluene at 4%, and the xylene isomers and benzene at 4% each. The remaining three analytes contributed 3% and less to the top 95% of targeted emitters. All other analytes targeted were determined to be non-detect. On-line real-time continuous gaseous emissions of CO<sub>2</sub>, CO, and NO<sub>x</sub> were also determined to be at a level of non-detect when averaged over the entire 75 minute testing period. In data validation and verification of results from this test, an analyte is defined as non-detect if its concentration is below the practical quantitation limit.

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<b>APPENDIX A</b>	<b>TEST &amp; SAMPLE PLANS AND PROCESS INSTRUCTIONS</b>
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## TECHNIKON TEST PLAN

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◆ <b>CONTRACT NUMBER:</b>	1412	<b>TASK NUMBER:</b>	1.2.3	<b>SERIES:</b>	HB
◆ <b>SITE:</b>	Research Foundry				
◆ <b>TEST TYPE:</b>	Pouring, cooling, shakeout: Baseline: Uncoated liquid sodium silicate foundry binder in Greensand. (conditioning run cores coated				
◆ <b>METAL TYPE:</b>	A356 Aluminum				
◆ <b>MOLD TYPE:</b>	4-on step-cored greensand with no seacoal.				
◆ <b>NUMBER OF MOLDS:</b>	3 engineering/conditioning/casting quality runs + 9 sampling runs.				
◆ <b>CORE TYPE:</b>	Step; Wedron 530 sand; 3.5% (BOS) Foseco Solosil® 131 binder, CO <sub>2</sub> activated.				
◆ <b>CORE COATING:</b>	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.				
◆ <b>SAMPLE EVENTS:</b>	9				
◆ <b>ANALYTE LIST:</b>	List G, CO/CO <sub>2</sub> , NO <sub>x</sub> , SO <sub>2</sub> , TGOC				
◆ <b>TEST DATE:</b>	<b>START:</b>	6 Feb 2006			
	<b>FINISHED:</b>	9 Feb 2006			

### TEST OBJECTIVES:

Measure selected PCS HAP & VOC emissions, CO, CO<sub>2</sub>, NO<sub>x</sub>, and TGOC from Foseco Solosil® binder activated with CO<sub>2</sub> 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.

JUNE 2006

**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 <sub>2</sub> & 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 <sub>2</sub> & 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 <sub>2</sub> & 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 <sub>2</sub> & 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 <sub>2</sub> & NO <sub>x</sub>	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 <sub>2</sub> & NO <sub>x</sub>	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

JUNE 2006

## 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 <sub>2</sub> & NO <sub>x</sub>	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 <sub>2</sub> & NO <sub>x</sub>	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

JUNE 2006

**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 <sub>2</sub> & NO <sub>x</sub>	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 <sub>2</sub> & NO <sub>x</sub>	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 <sub>2</sub> & 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 <sub>2</sub> & 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

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## 1412-1.2.3 Series HB

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### ***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<sub>2</sub> 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<sub>2</sub> 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.**

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**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 1 inch 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<sub>2</sub> 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<sub>2</sub> 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 1/2 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 portion 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

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<b>APPENDIX B</b>	<b>DETAILED EMISSION RESULTS AND QUANTITATION LIMITS</b>
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Test HB - Detailed Emission Results - Lb/Tn Metal

VOC	POM	HAP	Test Dates	HB001 7-Feb-06	HB002 7-Feb-06	HB003 7-Feb-06	HB004 8-Feb-06	HB005 8-Feb-06	HB006 8-Feb-06	HB007 9-Feb-06	HB008 9-Feb-06	HB009 09-Feb-06	Average	Standard Deviation
			Emission Indicators										—	—
			TGOC as Propane	9.88E-02	9.57E-02	1.12E-01	1.10E-01	1.08E-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	2.31E-02	2.82E-02	2.61E-02	2.91E-02	3.32E-02	3.19E-02	3.05E-02	3.38E-02	3.16E-02	2.97E-02	3.48E-03
			Sum of Target POMs	ND	ND	ND	0.0003	4.68E-04	ND	0.0005	0.0005	ND	2.01E-04	7.92E-05
			Selected Target HAPs and POMs											
V	H	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	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	H	H	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	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	H	Benzene	5.25E-04	1.02E-03	8.24E-04	1.59E-03	1.68E-03	1.18E-03	1.07E-03	1.22E-03	1.21E-03	1.14E-03	3.50E-04
V	H	H	Xylene, mp-	3.67E-04	9.53E-04	1.79E-03	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	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	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	H	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	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	H	H	Acenaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Dimethylnaphthalene, 1,2-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Dimethylnaphthalene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Dimethylnaphthalene, 1,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Dimethylnaphthalene, 1,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Dimethylnaphthalene, 1,8-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Dimethylnaphthalene, 2,3-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Dimethylnaphthalene, 2,6-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Dimethylnaphthalene, 2,7-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Indene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Methylnaphthalene, 1-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Naphthalene	ND	ND	ND	ND	ND	ND	ND	I	ND	ND	NA
V	H	H	Trimethylnaphthalene, 2,3,5-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Cresol, mp-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Cresol, o-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Phenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H	H	Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

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[illegible]

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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	—	—
			Emission Indicators										
				2.17E-03	2.03E-03	1.91E-03	2.41E-03	2.35E-03	2.19E-03	2.12E-03	2.61E-03	2.26E-03	2.32E-04
				8.55E-04	7.41E-04	6.07E-04	9.12E-04	9.97E-04	9.97E-04	I	6.55E-04	8.38E-04	1.53E-04
				5.28E-04	6.36E-04	4.70E-04	6.67E-04	7.90E-04	7.78E-04	7.07E-04	7.49E-04	6.79E-04	1.15E-04
				4.94E-04	5.88E-04	4.24E-04	6.28E-04	7.21E-04	7.09E-04	6.69E-04	6.90E-04	6.27E-04	1.06E-04
				ND	ND	ND	7.30E-06	1.02E-05	1.07E-05	1.07E-05	ND	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	4.19E-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	5.28E-05	4.70E-05	7.06E-06
V	H		2-Butanone (MEK)	4.06E-05	4.77E-05	3.17E-05	4.21E-05	4.78E-05	4.78E-05	4.58E-05	4.68E-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	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	2.65E-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	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	2.31E-05	1.74E-05	4.27E-06
V	H		Hexane	9.86E-06	ND	ND	1.20E-05	1.39E-05	1.39E-05	2.15E-05	1.81E-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	ND	5.47E-06	5.30E-06
V	H		Xylene, o-	ND	ND	ND	9.19E-06	8.51E-06	8.51E-06	ND	ND	3.89E-06	4.61E-06
V	P	H	Acenaphthalene	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	NA
V	P	H	Dimethylnaphthalene, 1,3-	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	NA
V	P	H	Dimethylnaphthalene, 1,6-	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	NA
V	P	H	Dimethylnaphthalene, 2,3-	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	NA
V	P	H	Dimethylnaphthalene, 2,7-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Methylnaphthalene, 1-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	P	H	Naphthalene	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	NA
V	H		Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H		Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H		Cresol, mp-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H		Cresol, o-	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H		Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H		Phenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
V	H		Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

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

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<b>APPENDIX C</b>	<b>DETAILED PROCESS DATA AND CASTING QUALITY PHOTOS</b>
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## Test HB - Detailed Process Data

Test Dates		Greensand PCS																Averages	
Emissions Sample #		2/6/06	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	2/8/06	2/8/06	2/8/06	2/8/06	2/8/06	2/9/06	2/9/06	2/9/06
Production Sample #		HB001	HB002	HB003	HB004	HB005	HB006	HB007	HB008	HB009	HB010	HB011	HB012	HB013	HB014	HB015	HB016	HB017	HB018
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	1.72	1.75	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	3.45	3.49	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	3.33	3.38	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	0.98	1.01	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	0.62	0.70	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					
Casing Quality Appearance Ranking		4	5	8	Cavity 1														
		3	9	10	Cavity 2														
		1	6	11	Cavity 3														
		2	7	12	Cavity 4														

## Notes:

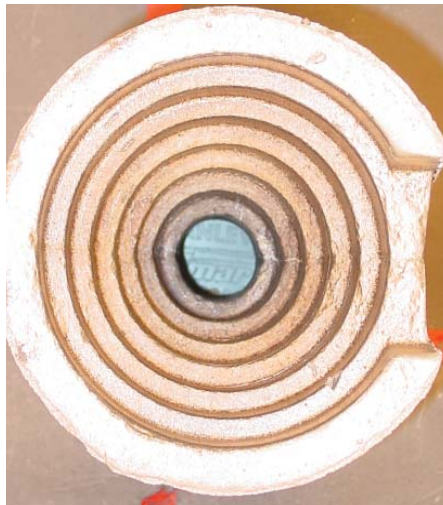
No LOI tests were done on the cores for runs HB001-HB003 because the cores were coated and the coating would distort the LOI results.

NT: Not Tested

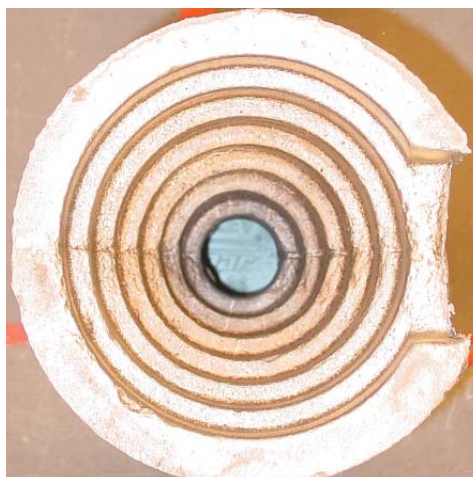
Overall appearance ranking: 1 = best, 6 = Median 12 = worst

**Casting Surface Quality Comparison Photos**

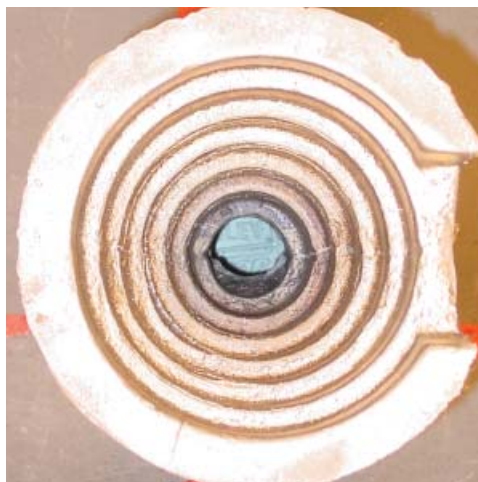
**Best**  
***HBCR1 Cavity 3***



**Median**  
***HBCR2 Cavity 3***



**Worst**  
***HBCR3 Cavity 4***

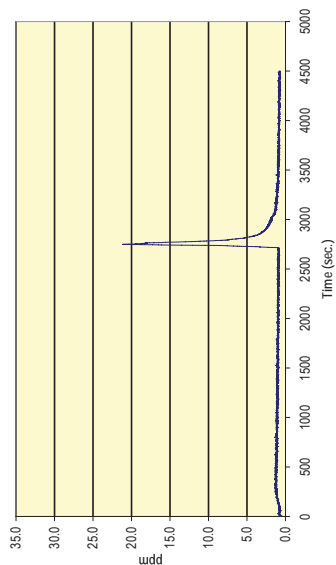


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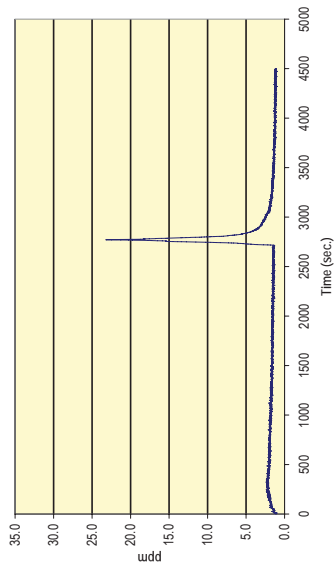
<b>APPENDIX D</b>	<b>CONTINUOUS EMISSION MONITORING CHARTS</b>
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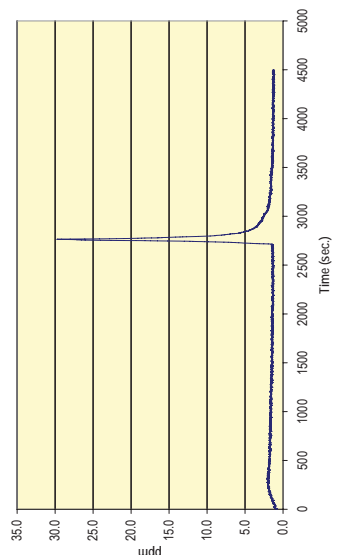
HB003 TGOC as Propane



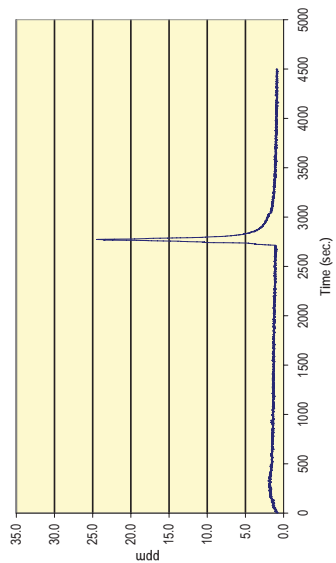
HB006 TGOC as Propane



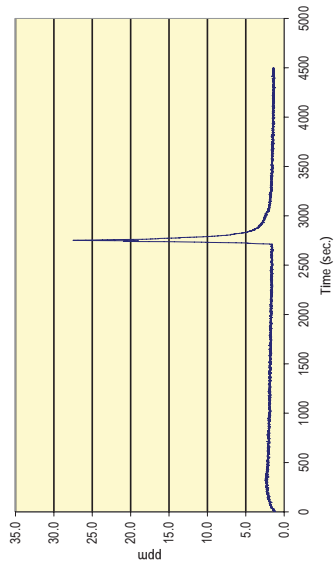
HB009 TGOC as Propane



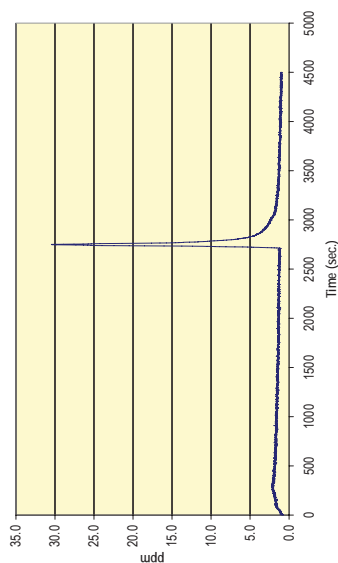
HB002 TGOC as Propane



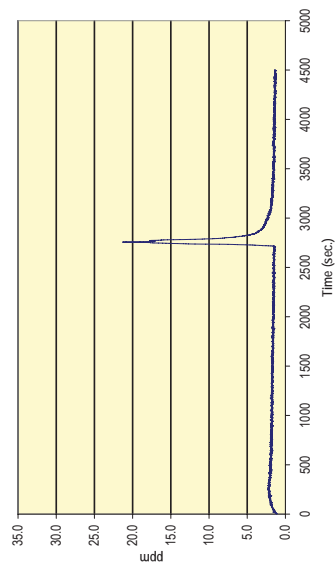
HB005 TGOC as Propane



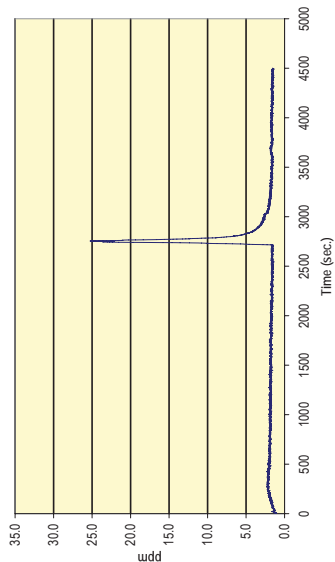
HB008 TGOC as Propane



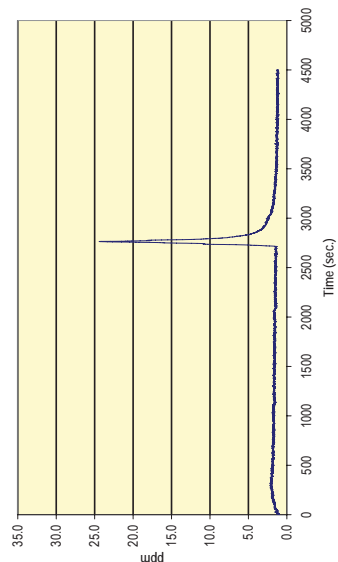
HB001 TGOC as Propane

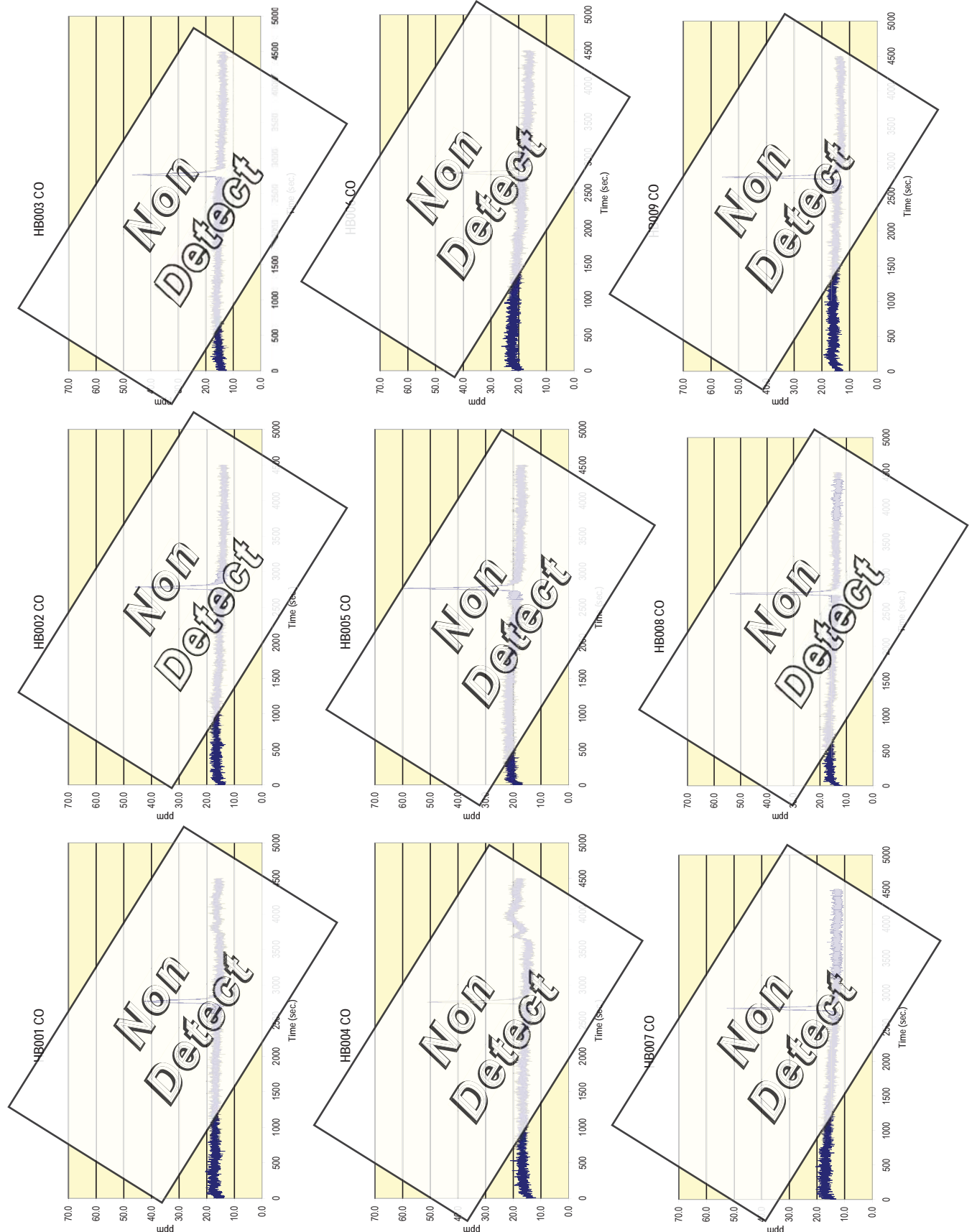


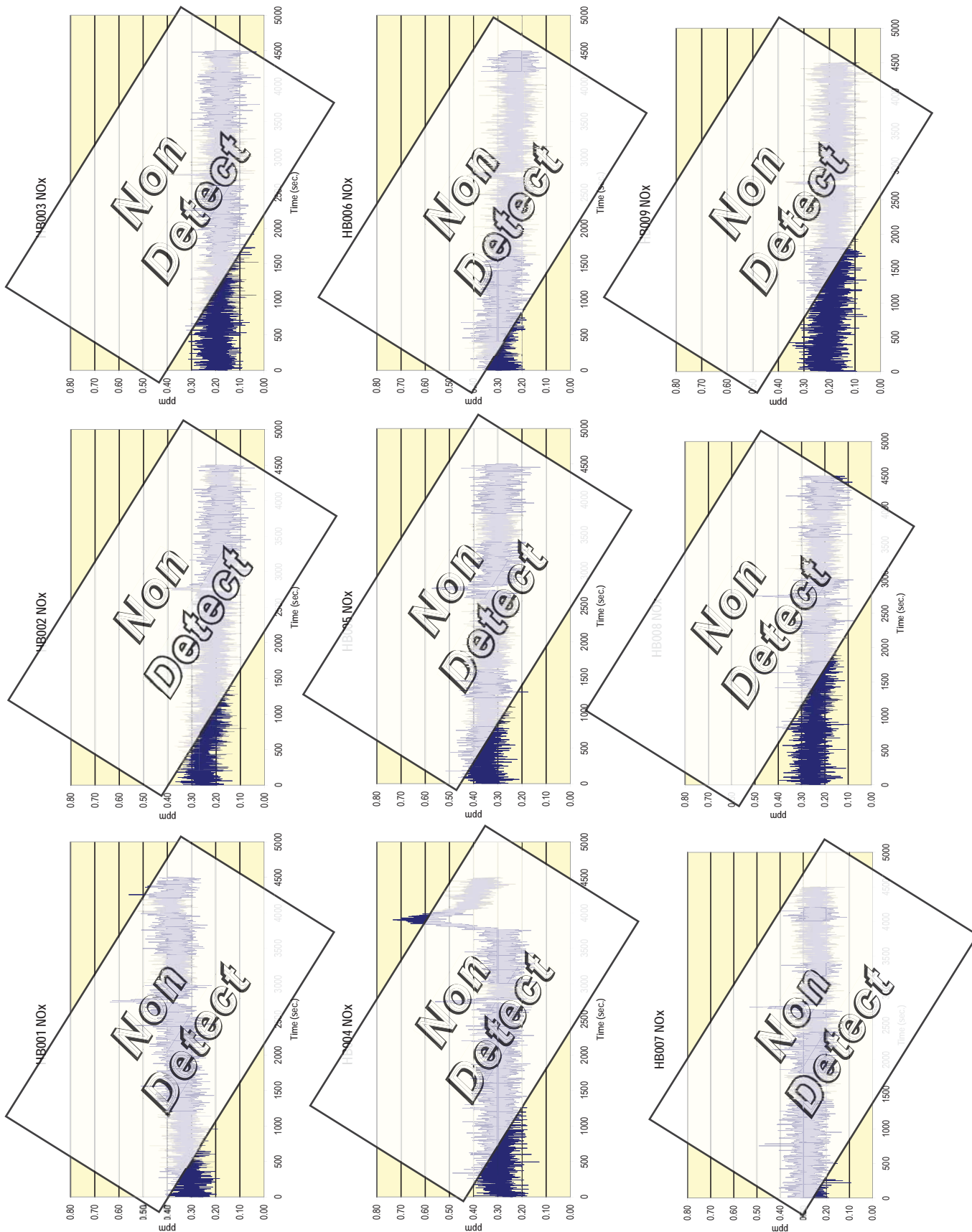
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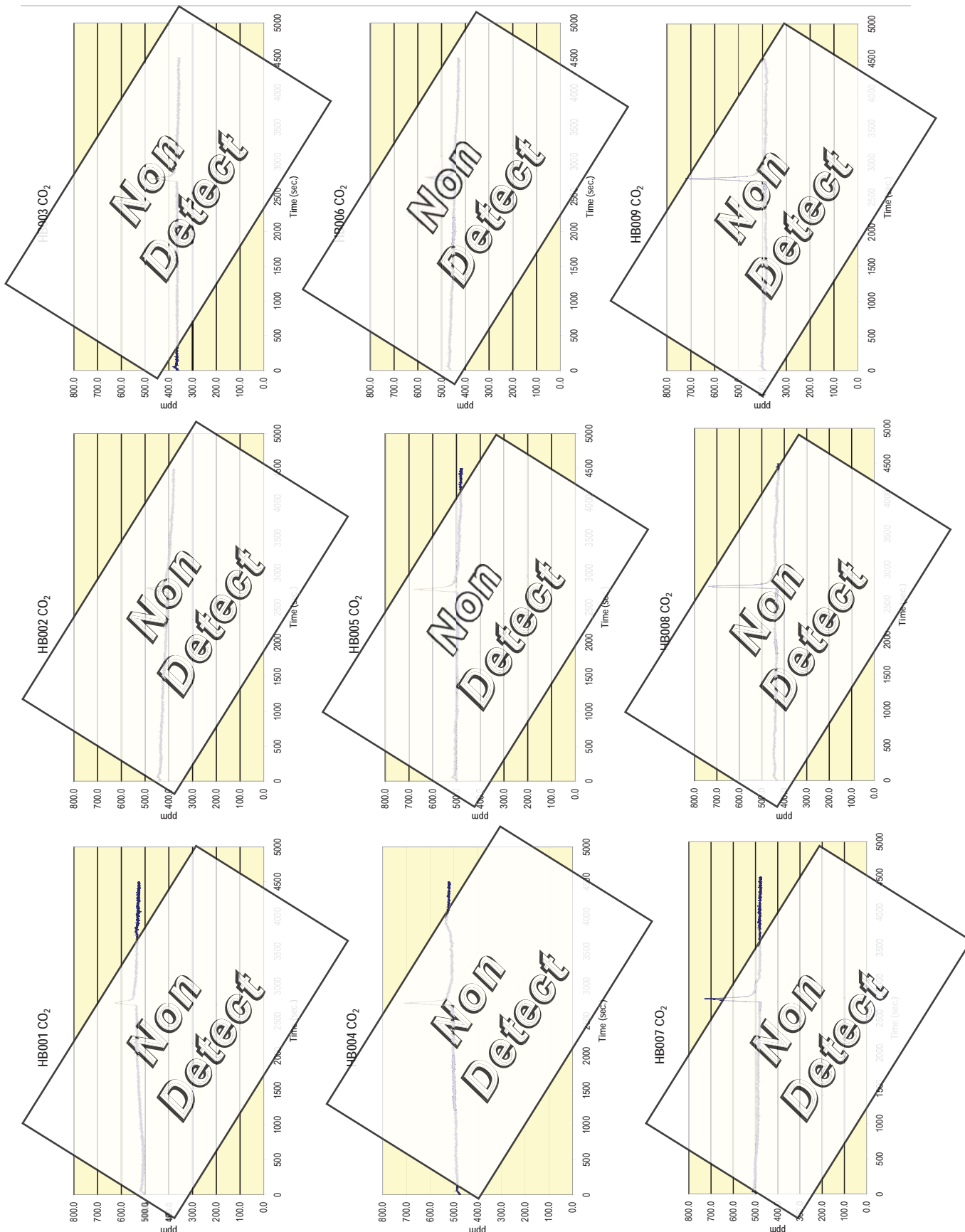


HB007 TGOC as Propane









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<b>APPENDIX E</b>	<b>ACRONYMS AND ABBREVIATIONS</b>
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## ACRONYMS & ABBREVIATIONS

<b>AFS</b>	American Foundry Society
<b>ARDEC</b>	(US) Army Armament Research, Development and Engineering Center
<b>BO</b>	Based on ( ).
<b>BOS</b>	Based on Sand.
<b>CAAA</b>	Clean Air Act Amendments of 1990
<b>CARB</b>	California Air Resources Board
<b>CERP</b>	Casting Emission Reduction Program
<b>CFR</b>	Code of Federal Regulations
<b>CISA</b>	Casting Industry Suppliers Association
<b>CO</b>	Carbon Monoxide
<b>CRADA</b>	Cooperative Research and Development Agreement
<b>DOD</b>	Department of Defense
<b>DOE</b>	Department of Energy
<b>EEF</b>	Established Emission Factors
<b>EPA</b>	Environmental Protection Agency
<b>ERC</b>	Environmental Research Consortium
<b>FID</b>	Flame Ionization Detector
<b>GS</b>	Greensand
<b>HAP</b>	Hazardous Air Pollutant defined by the 1990 Clean Air Act Amendment
<b>HC as Hexane</b>	The quantity of undifferentiated hydrocarbons determined by Wisconsin Cast Metals Association – maximum potential to emit method, revised 07/26/01.
<b>I</b>	Invalidated Data
<b>kW</b>	Kilowatt - A unit of power equal to 1,000 watts
<b>Lb/Lb</b>	Pound per pound of binder used
<b>Lb/Tn</b>	Pound per ton of metal poured
<b>LOI</b>	Loss on ignition
<b>NA</b>	Not Applicable; Not Available
<b>ND</b>	Non-Detect; Not detected below the practical quantitation limit
<b>NT</b>	Not Tested - Lab testing was not done
<b>PCS</b>	Pouring, Cooling, Shakeout
<b>POM</b>	Polycyclic Organic Matter
<b>QA/QC</b>	Quality Assurance/Quality Control

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<b>SO<sub>2</sub></b>	Sulfur Dioxide
<b>TGOC</b>	Total Gaseous Organic Concentration
<b>TGOC as Propane</b>	Quantity of undifferentiated hydrocarbons including methane determined by EPA Method 25A.
<b>THC</b>	Total Hydrocarbon Concentration
<b>US EPA</b>	United States Environmental Protection Agency
<b>USCAR</b>	United States Council for Automotive Research
<b>UV</b>	Ultraviolet
<b>VOC</b>	Volatile Organic Compound
<b>W</b>	Watt - an International System unit of power equal to one joule per second
<b>WBS</b>	Work Breakdown Structure