CERP

Casting Emission Reduction Program

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FY 2002 Tasks

Pre-Production Foundry Greensand Baseline Emission Test

Technikon # 1409-121 EM

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EPA United States Environmental Protection Agency

CISA

AFS

UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

USCAR

DaimlerChrysler Ford Motor Company General Motors

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Pre-Production Foundry

Greensand Baseline Emission Test

1409-121 EM

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

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

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Executive Summary

This report contains the results of emission testing to develop an improved Greensand (with Seacoal) Sodium Silicate/Iron emissions baseline. A series of enhancements were incorporated into the testing process from gained knowledge in emission measurement, process stability, and emission collection technology that were not included in previous baseline test (AY). All testing was conducted in the Pre-Production foundry, operated by Technikon, LLC.

The emissions results are reported in pounds of emissions per ton of metal poured. Results were not expressed in pounds per pound of binder because the inorganic binder system used for this test did not contribute to the overall organic emissions.

The Pre-Production Foundry is a simple general purpose manual foundry that was adapted and instrumented to make detailed organic emission measurements, using methods based on EPA protocols for pouring, casting cooling, and shakeout processes on discrete molds. The measurements are conducted under tightly controlled conditions not feasible in a commercial foundry. Evaluating a new product or process in the Technikon Pre-Production Foundry reduces the risk of new material or product introduction for the foundry industry.

The specific objective of the baseline test was to establish air emission data against which the air emissions from new materials, equipment and processes, designed to reduce organic Hazardous Air Pollutants (HAPs) and Volatile Organic Compounds (VOCs), could be compared.

The testing performed involved the collection of continuous air samples over a seventy-five minute period, including the mold pouring, cooling, shakeout, and post shakeout periods. Process and stack parameters were measured and include: the weights of the casting, mold, binder; Loss on Ignition (LOI) values for the mold prior to the test; metallurgical data; and stack temperature, pressure, volumetric flow rate and moisture content. The process parameters were maintained within prescribed ranges in order to ensure the reproducibility of the tests. Twelve (12) molds were poured for this test. The first three molds poured were used as preconditioning cycles before the beginning of the test. Samples were collected and analyzed for over seventy (70) target compounds using procedures based on US EPA Method 18. Continuous monitoring of the Total Gaseous Organic Concentration (TGOC) of the emissions was conducted according to US EPA Method 25A. Finally, the "condensable" organic material in the emissions was determined using a Technikon developed procedure. The "condensable" represent the "back half" catch from US EPA Method 5.

The mass emission rate of each parameter or target compound was calculated, in pounds per ton of metal, using the Method 25A data or the laboratory analytical results, the measured source data, and the weight of each casting. Results for structural isomers have been grouped and reported as a single entity. For example, ortho-, meta-, and para-xylene are the three (3) structural isomers of dimethyl benzene. The separate isomer results are available in Appendix B of this report. Several "emissions indicators," in addition to the TGOC as Propane, were also calculated. The HC as Hexane results represent the sum of all organic compounds detected and expressed as Hexane. All of the following sums are sub-groups of this measure. The "Sum of VOCs" is based on the sum of the individual target VOCs measured and includes the selected HAPs and selected Polycyclic Organic Material (POMs) listed in the Clean Air Act Amendments of 1990. The "Sum of HAPs" is the sum of the individual target HAPs measured and includes the selected POMs. Finally, the "Sum of POMs" is the sum of all of the polycyclic organic material measured.

Results for the emission indicators are shown in the following table. All results are measured as pounds emitted per ton of metal.

TGOC as Propane	HC as Hexane	Sum of VOCs	Sum of HAPs	Sum of POMs
2.00	0.421	0.342	0.264	0.011

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

1.0 Introduction

1.1 Introduction

Technikon LLC is a privately held contract research organization located in McClellan, California, a suburb of Sacramento. Technikon offers emissions research services to industrial and government clients specializing in the metal casting and mobile emissions areas. Technikon operates the Casting Emission Reduction Program (CERP). CERP is a cooperative initiative between the Department of Defense (US Army) and the United States Council for Automotive Research (USCAR). Its purpose is to evaluate alternative casting materials and processes that are designed to reduce air emissions and/or produce more efficient casting processes. Other technical partners directly supporting the project include: the American Foundry Society (AFS); the Casting Industry Suppliers Association (CISA); the US Environmental Protection Agency (USEPA); and the California Air Resources Board (CARB).

1.2 CERP 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, especially for the Clean Air Act Amendment. The facility has two principal testing arenas: a Pre-Production Foundry designed to measure airborne emissions from individually poured molds, and a Production Foundry designed to measure air emissions in a continuous full scale production process. Each of these testing arenas has been specially designed to facilitate the collection and evaluation of airborne emissions and associated process data. The data collected during the various testing projects are evaluated to determine both the airborne emissions impact of the materials and/or process changes, and their stability and impact upon the quality and economics of casting and core manufacture. The materials, equipment, and processes may need to be further adapted and defined so that they will integrate into current casting facilities smoothly and with minimum capital expenditure.

Normally, Pre-Production testing is conducted first in order to evaluate the air emissions impact of a proposed alternative material, equipment, or process in the most cost effective manner. The Pre-Production Foundry is a simple general purpose manual foundry that was adapted and instrumented to make detailed emission measurements using methods based on EPA protocols for pouring, casting cooling, and shakeout processes on discrete molds under tightly controlled conditions not feasible in a commercial foundry.

The Production Foundry's design as a basic greensand foundry was deliberately chosen so that whatever is tested in this facility will also be convertible to existing mechanized commercial foundries. The type and size of equipment, materials, and processes used emulate an automotive foundry. This facility is used to evaluate materials, equipment, and processes in a continuous process that is allowed to vary to the limits of commercial experience in a controlled manner.

The Production Foundry provides simultaneous detailed individual emission measurements using methods based on USEPA protocols of the melting, pouring, sand preparation, mold making, and core making processes. It is instrumented so that the data on all activities of the metal casting process can be simultaneously and continuously collected, in order to completely evaluate the economic impact of the prospective emission reducing strategy. The Production Foundry's test casting is a single cavity Ford Motor Company I-4 engine block. Castings are randomly selected to evaluate the impact of the material, equipment, or process on casting quality. Alternative materials, equipment, and processes that demonstrate significant air emission reduction potential, preserve casting quality parameters, and that are economically viable based on the Pre-Production testing, may be further evaluated in the Production Foundry.

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

1.3 Report Organization

This report has been designed to document the methodology and results of a specific test plan that was used to evaluate the performance of an alternative material, equipment, or process in the Pre-Production Foundry. Section 2 of this report includes a summary of the methodologies used for data collection and analysis, emission calculations, QA/QC procedures, and data management and reduction methods. Specific data collected during this test are summarized in Section 3 of this report, with detailed data included in Appendices B and C of this report. Section 4 of this report contains a discussion of the results and recommendations for additional testing, if any.

The raw data for this test series are included in a data binder that is maintained at the Technikon facility.

1.4 Preliminary Testing

The foundations for the specific test protocols and airborne emission measurements have been determined from testing performed to:

- Establish the required number of samples needed to statistically support the evaluation of emission reduction potentials of the alternative materials, equipment, and processes that may be evaluated;

- Provide a series of standardized emissions from standard mold packages.

It has been determined that nine replicate tests will provide a statistically significant sample for the purposes of evaluating the emission reductions from alternative materials, equipment, and processes. The results of the testing conducted in support of this conclusion is included in a report entitled Evaluation of the Required Number of Replicate Tests to Provide Statistically Significant Air Emission Reduction Comparisons for the CERP Pre-Production Foundry Test Program.

1.5 Specific Test Plan and Objectives

This report contains the results of testing performed to provide reference or baseline data on the VOC and HAP emissions from a Greensand with Seacoal system. 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
Type of Process tested	Greensand* (Seacoal) Baseline
Test Plan Number	EM
Core Binder System	Sodium Silicate Cores
Metal Poured	Iron
Casting Type	Step Cores
Number of molds poured	12
Test Dates	7/3/02 > 7/19/02
Emissions Measured	TGOC as Propane, HC as Hexane, 70 Organic HAPs and VOCs
Process Parameters Measured	Total Casting, Mold, and Binder Weights; Metallurgical data, % LOI; Stack Temperature, Moisture Content, Sand Temperature, Pressure, and Volumetric Flow Rate

* Greensand is a mixture of a refractory aggregate (e.g. quartz sand) and a clay binder activated by water.

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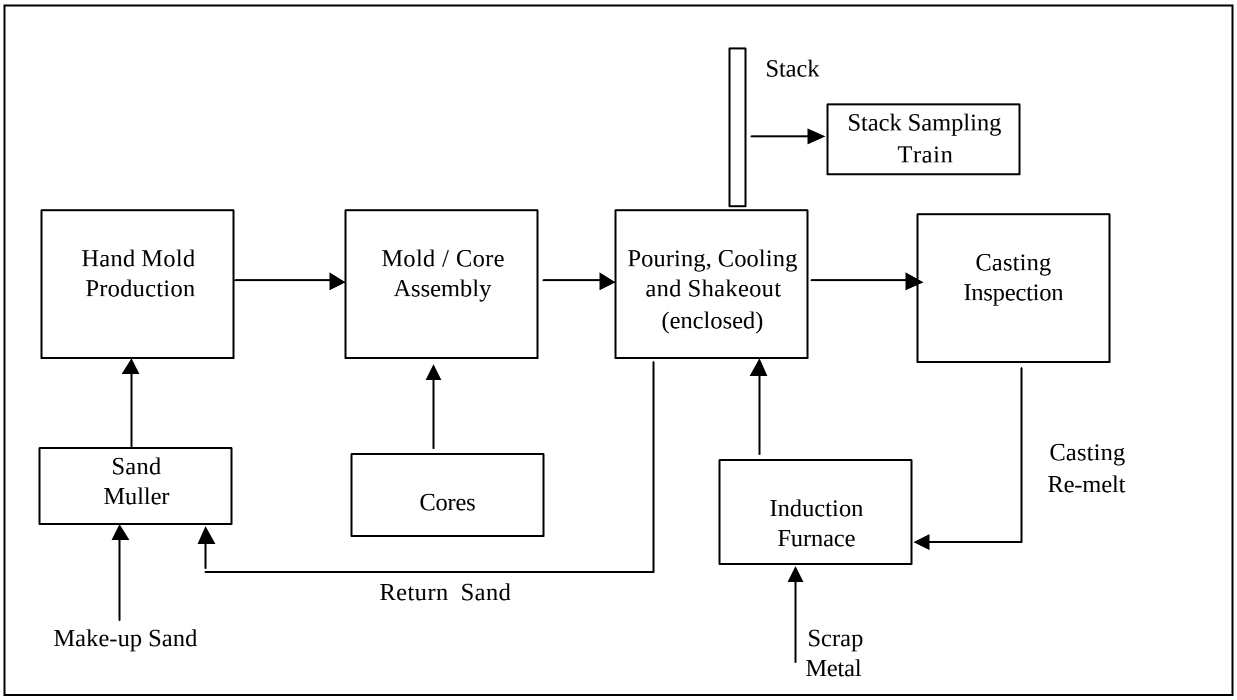
2.0 Test Methodology

2.1 Description of Process and Testing Equipment

Figure 2-1 is a diagram of the Pre-Production Foundry process equipment.

Figure 2-1 Pre-Production Foundry Layout Diagram



2.2 Description of Testing Program

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

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

2. **<u>Mold, Core and Metal Preparation:</u>** The molds and cores are prepared to a standard composition by the Technikon production team. The cores are made either by hand (if sodium silicate) or blown by a Redford core blower, and relevant process data are collected. If new core processes are being tested, the cores are placed in new lake sand/clay/water molds without other organic material such as coal. If new mold binder systems or processes are being evaluated, organic free sodium silicate step cores are placed into the molds. Virgin materials are used and are preconditioned for three (3) casting cycles before the beginning of the test. Iron is melted in a 1000 lb. Ajax induction furnace. The amount of metal melted is determined from the poured weight of the casting and the number of molds to be poured. The

metal composition is prescribed by a metal composition worksheet. The weight of metal poured into each mold is recorded on the process data summary sheet.

3. **Individual Sampling Events:** Replicate tests are performed on nine (9) mold/core packages. The mold/core packages are placed into an enclosed test stand. Iron is poured through an opening in the top of the emission enclosure. The opening is closed as soon as pouring is completed. Continuous air samples are collected during the forty-five minute pouring and cooling process, during the fifteen minute shakeout of the mold, and for an additional fifteen minute period following shakeout. The total sampling time is seventy-five minutes.

Setting of Step Cores in Mold

Pouring Step Core Molds Through Opening in Collection Hood

The finished castings are cleaned and quality checks of the castings are performed. Additional tests may be required for new mold materials with the molding sand being recycled into new molds to evaluate the long-term effects on molding sand properties.

The weights of the molds, cores, seacoal additions, and binder are recorded for each mold on the Process Data Summary Sheet. In addition, the pouring temperature, number of cavities poured, the %LOI and the % clays of the mold before pouring and at shakeout, and the % LOI of the core are recorded on the Process Data Summary Sheet.

Castings on the Shakeout Deck

The unheated emission hood is ventilated at approximately 700 SCFM through a 12-inch diameter heated duct. Emissions samples are drawn from a sampling port located to ensure conformance with EPA Method 1. The tip of the probe is located in the centroid of the duct. The samples are collected at a constant rate in adsorption tubes (test sample and duplicate sample).

4. **Process Parameter Measurements:** Table 2-1 lists the process parameters that are monitored during each test. The analytical equipment and methods used are also listed.

Table 2-1 Process Parameters Measured

Parameter	Analytical Equipment and Methods
Core Weight	Mettler PJ8000 Digital Scale (Gravimetric)
Mold Weight	Acme 4260 Crane Scale (Gravimetric)
Casting Weight	Westweigh PP2847 Platform Scale (Gravimetric)
Seacoal Weight	Toledo PAC-DPC-606050 balance (Gravimetric)
Binder Weight	Mettler PJ8000 Digital Scale (Gravimetric)
Volatiles	Mettler PB302 Scale (AFS procedure 2213-00-S)
LOI, % at mold and shakeout	Denver Instruments XE-100 Analytical Scale (AFS procedure 5100-00-S)
Core LOI, %	Denver Instruments XE-100 Analytical Scale (AFS procedure 5100-00-S)
Clay, % at mold and shakeout	Dietert 535A MB Clay Tester (AFS Procedure 2210-00-S)
Metallurgical Parameters	
Pouring Temperature	Electro-Nite DT 260 (T/C immersion pyrometer)
Carbon/Silicon Fusion Temperature	Electro-Nite Datacast 2000 (Thermal Arrest)
Alloy Weights	Ohaus MP2
Mold Compactability	Dietert 319A Sand Squeezer (AFS procedure 2221-00-S)
Carbon/Silicon	Baird Foundry Mate Optical Emissions Spectrometer

5. **Air Emissions Analysis:** The specific sampling and analytical methods used in the Pre-Production Foundry tests are based on the USEPA reference methods shown in Table 2-2. The details of the specific testing procedures and their variance from the reference methods are included in the Technikon Standard Operating Procedures.

Table 2-2 Sampling and Analytical Methods

Measurement Parameter	Test Method
Port location	EPA Method 1
Number of traverse points	EPA Method 1
Gas velocity and temperature	EPA Method 2
Gas density and molecular weight	EPA Method 3a
Gas moisture	EPA Method 4, gravimetric
HAPs concentration	EPA Method 18, TO11, NIOSH 2002*
VOCs concentration	EPA Method 18, 25A, TO11, NIOSH 2002*
Condensable	Technikon method **

*These methods were specifically modified to meet the testing objectives of the CERP Program.
**The Technikon condensable method is intended to provide a measure of the EPA Method 5 "back-half" determination.

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

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

7. **Report Preparation and Review:** The Preliminary Draft Report is reviewed by the Process Team and Emissions Team to ensure its completeness, consistency with the test plan, and adherence to the prescribed QA/QC procedures. Appropriate observations, conclusions and recommendations are added to the report to produce a Draft Report. The Draft Report is reviewed by the Vice President-Measurement Technologies, the Vice President-Operations, the Manager-Process Engineering, and the Technikon President. Comments are incorporated into a draft Final Report prior to final signature approval and distribution to the CERP Steering Committee for approval to post on the Technikon public access site.

2.3 Quality Assurance and Quality Control (QA/QC) Procedures

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

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

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

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3.0 Test Results

The average emission results, in pounds per ton of metal poured, is presented in Table 3-1. This table includes the individual target compounds that comprise at least 95% of the total VOCs measured, along with the corresponding sum of VOCs, sum of HAPs, and sum of POMs. The table also includes the TGOC as Propane, HC as Hexane, methane and carbon monoxide, if any, and carbon dioxide (both emitted and ambient). Figures 3-1, 3-2, and 3-3 present the five emissions indicators and selected individual HAP and VOC emissions data from Table 3-1 in graphical form. Appendix B contains the detailed data including the results for all analytes measured. Table 3-2 includes the averages of the key process and source parameters and the data target ranges. Detailed process and source data are presented in Appendix C.

Method 25A charts for the tests are included in Appendix D of this report. The charts are presented to show the VOC profile of emissions for each pour.

Table 3-1 Summary of Test Plan EM Average Results

Analyte	Average	STDEV
TGOC as Propane	2.00	0.301
HC as Hexane	0.421	0.075
Sum of VOCs	0.342	0.073
Sum of HAPs	0.264	0.056
Sum of POMs	0.011	0.003
Individual Organic HAPs		
Benzene	0.100	0.020
Toluene	0.059	0.010
o,m,p-Xylene	0.043	0.008
Hexane	0.013	0.002
o,m,p-Cresol	0.010	0.009
Phenol	0.009	0.004
Naphthalene	0.007	0.002
Ethylbenzene	0.007	0.001
Acetaldehyde	0.006	0.002
Methylnaphthalenes	0.004	0.001
Other VOCs		
Trimethylbenzenes	0.016	0.004
Heptane	0.013	0.002
Octane	0.011	0.002
Ethyltoluenes	0.009	0.003
Nonane	0.008	0.001
Decane	0.006	0.002
Undecane	0.004	0.001
Other Analytes		
Condensibles	0.455	0.137
Acetone	0.006	0.001
Carbon Dioxide	22.7	1.88
Methane	0.036	0.003
Carbon Dioxide (Blank)	22.1	NA
Methane (Blank)	0.034	NA

Individual results constitute >95% of mass of all detected VOCs.*

ND: Non Detect; NA: Not Applicable

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

Table 3-2 Summary of Test Plan EM Process and Stack Parameters

Description	Report Average	Process Data Target Ranges
Casting Metal Weight, lbs.	207	205-215
Total Mold Weight, lbs.	1307	1320-1380
Total Core Weight, lbs.	58.9	58-62
Compactability, %	52	45-51
Sand Temperature. *F	103	95-105
Total Binder Weight, lbs	1.437	1.41-1.45
No. Cavities Poured	8	8
LOI, % (at mold)	5.07	4.50-5.50
LOI, % (at shakeout)	4.91	4.30-5.30
Clays, % (at mold)	7.28	6.70-7.30
Clays, % (at shakeout)	6.58	6.30-6.90
Volatiles, % (at mold) avg.	1.10	N/A
Volatiles, % (at shakeout) avg.	1.00	N/A
Pouring time, sec.	18	16-22
Pouring Temperature, °F	2641	2620-2640
Ambient Temperature, °F	73	N/A
Average Stack Temperature, °F	109	N/A
Total Moisture Content, %	2.31	N/A
Average Stack Velocity, ft./sec.	16.7	N/A
Avg. Stack Pressure, in. Hg	29.86	N/A
Stack Flow Rate, scfm	714	650-750

Figure 3-1 Emission Indicators from Test Series EM

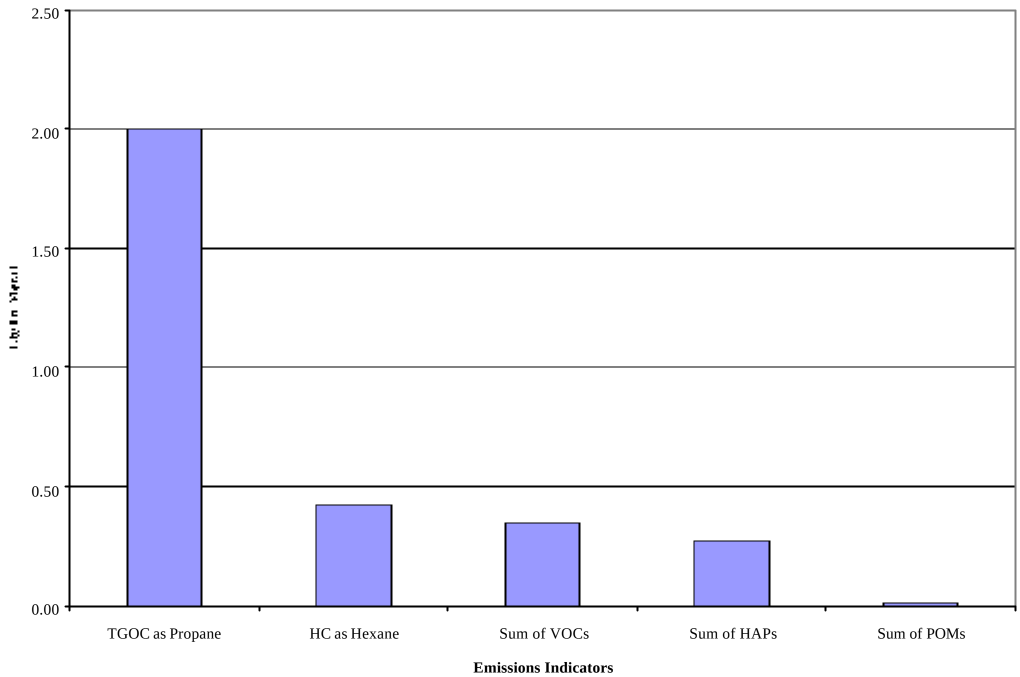


Figure 3-2 Selected HAP Emissions from Test Series EM

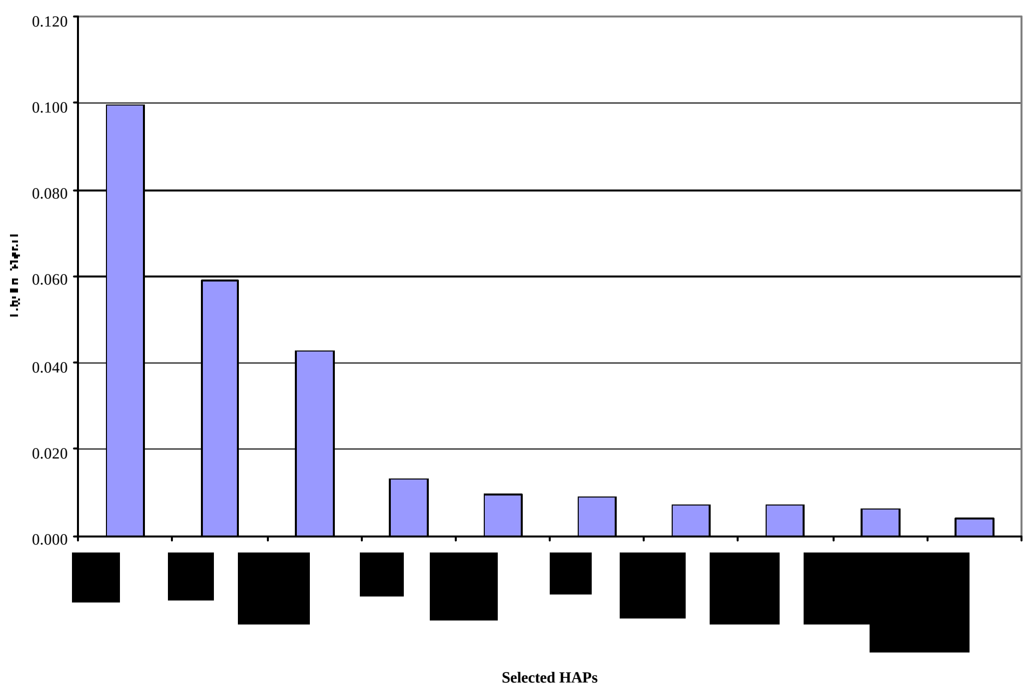
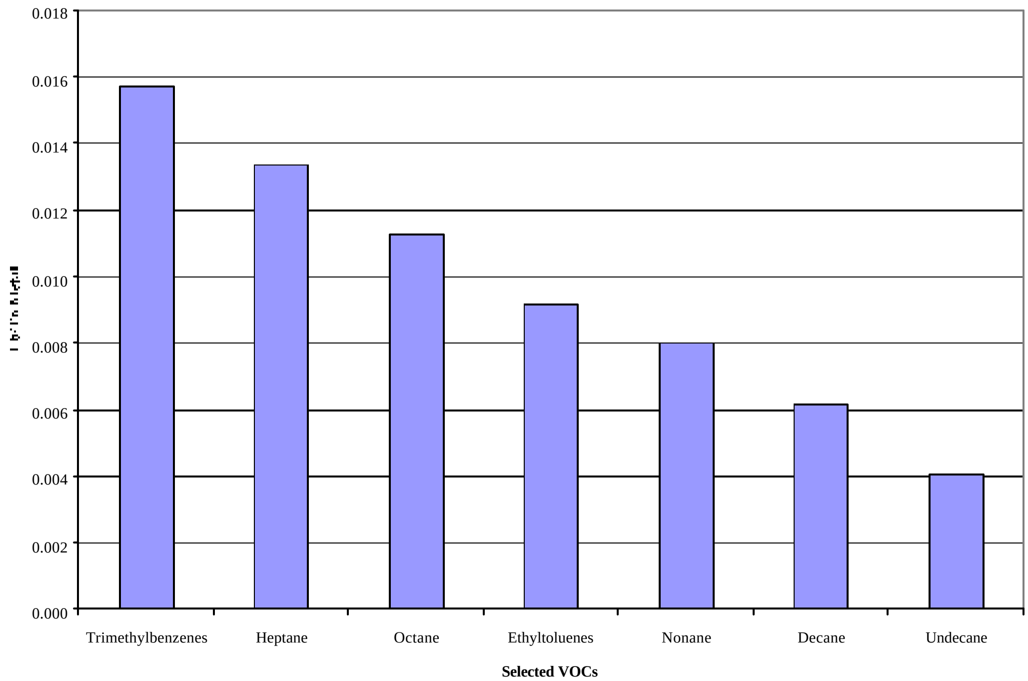


Figure 3-3 Selected VOC Emissions from Test Series EM



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4.0 Discussion of Results

Seventeen (17) of the measured compounds comprised greater than 95% of the mass of all VOCs measured in the Greensand (with seacoal) baseline test series. Benzene comprised approximately 38%, toluene 22%, and o,m,p-xylene 16% of the total HAPs. Trimethylbenzenes, ethyltoluenes, and lighter hydrocarbons comprised approximately 20% of the total VOCs.

The results are reported in pounds of emissions per ton of metal poured. Results were not expressed in pounds per pound of binder because the binder system used for this test series did not contribute to the overall organic emissions.

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

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

Observation of measured process parameters indicates that the test was run within an acceptable range.

This updated Greensand Baseline will be used as the comparison for future greensand studies.

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APPENDIX A APPROVED TEST AND SAMPLE PLAN FOR EM

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TEST PLAN

> **CONTRACT NUMBER:** 1409 **TASK NUMBER**: 1.2.1

> **WORK ORDER NUMBER** 0208

> **SAMPLE EVENTS**: 001 thru 012

> **SITE**: _X_ **PRE-PRODUCTION(243**) ____ **CERP FOUNDRY(238)**

> **TEST TYPE:** Green Sand Emission Baseline 2002

> **MOLD TYPE:** Green sand made from virgin Wexford W450 lakesand, western and southern bentonite, H & G Seacoal, & water

> **NUMBER OF MOLDS:** 12

> **CORE TYPE:** Sodium Silicate Step Block Core

> **TEST DATE:** **START:** 1 Jul 2002

FINISH: 11 Jul 2002

TEST OBJECTIVES:

This test is an upgrade of the same base line determined in test AY. It will incorporate our gained knowledge to date in emission measurement, process stability, and emission collection technology. This baseline upgrade will include the following items not in previous baselines:

1. All materials will be virgin from a known source for repeatability.
2. Process materials will be normalized to 95-105 degrees Fahrenheit at the start of the test.
3. The ambient air passing through the collection hood will be controlled to 80-90 Degrees Fahrenheit.
4. The virgin materials will be preconditioned for three (3) casting cycles before the beginning of the test.
5. Emissions will be captured via a heated manifold multi-channel vacuum source with precision orifices to control flow rate.
6. The sum of condensables & sum of POMs will be measured in addition to sum of VOCs and sum of HAPs.
7. HC as Hexane will be measured separately.
8. TGOC (THC) as propane will be measured separately in real time.

PARAMETERS:

~ The mold sand will be greensand made from all virgin Wexford W450 lake sand, 7% western and southern bentonite in a 4.25:1 ratio and H&G Seacoal to produce a 5% LOI. The measured MB clay content will be controlled to 7.0+/-0.3% and the LOI from Coal and core binder condensates will be controlled to 5.0 +/- 0.5%

~ Cores will be made from Wexford W450 lake sand and 5% (BOS) JB DeVeene CleanKast #1® binder, CO_2 activated.

~ The mold temperature at the start of the test will be in the range 95-105^{o}F

- ~ The ambient air through the collection hood will be controlled in the range 80-90°F.
- ~ The virgin mold will be preconditioned three (3) times through the molding /pouring/cooling/shakeout sequence prior to start of the test to establish a distribution of organic condensates.
- ~ The metal will be class 35 cast iron poured at 2630 +/- 10°F.
- ~ Pour time will be 25-40 seconds, cooling 45 minutes from start of pour, shakeout 15 minutes. Post shakeout emission sampling will continue for another 15 minutes for a total test time of 75 minutes.
- ~ The emission hood shall be closed throughout the test except that the pour door shall necessarily be open during the pour.
- ~ The entire sampling period will be monitored in real time with the THC analyzer.

BRIEF OVERVIEW:

The green sand baseline excludes the emitters from the core but includes those from the mold (seacoal). This test is the 3rd upgrade of the greensand baseline. The first was formulated without the benefit of any prior on-site emission experience and while as good as any in the industry could clearly be improved. The second built on on-site experience demonstrated the learned repeatability of the process and limits of the emission collection protocols. The second base line became the first published baseline against which things were measured. The second baseline measured the process with greater accuracy and permitted incremental improvements in the stability of the process which, of course, exposed limits in the emission measurement. This synergism between process variation and emission detection has improved both the process consistency and detection capability to the point that it is appropriate to roll our current how-to-do knowledge into an update of the baseline.

SPECIAL CONDITIONS:

None

__*Original signed*________________________ ____________________________________
Manager Process Engineering Date

__*Original signed*________________________ ____________________________________
VP Measurement Technology Date

___*Original signed*______________________ ____________________________________
VP Operations Date

Series EM

Greensand Emission Baseline 2002
Process Instructions

A. Experiment: Green Sand Emission Baseline 2002

1. Mold sand: Virgin Wexford W450 Lake sand, 5.67% Western Bentonite, 1.33% Southern Bentonite, 5.44% H&G D-4 Seacoal.
2. Core: Step core made with Virgin Wexford W450 sand and 5 % J B DeVeene CleanKast #1 sodium silicate binder, CO_2 activated.
3. Metal: Class-30 Gray cast iron.

B. 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.

C. Step Cores.

1. Core sand mixing.

   a. Clean the core sand mixer.
   b. Add 50 pounds of Wedron 420 silica sand to the running mixer.
   c. Slowly pour 2.5 +/- .03 pounds of sodium silicate binder into the sand. Distribute the resin as it is poured. Avoid pouring the resin on the plows or walls of the mixer or in only 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. Place the closed step-core core box on a flat surface large open side up.
   b. 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.
   c. 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.
   d. Scrape off the excess. Remove the unused sand away from the gassing area.
   e. Place a gassing plate on the open end of the core box.
   f. Hold the plate down and gas the core for 20 seconds on each of the two gas holes with 20 psi CO_2 gas.
   g. Dry the cores for two hours at 250°F and allow to cool.
   h. Bag the cores in moisture proof bags for storage.

i. Identify each bag by batch number.
j. 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.

D. Sand preparation

1. Start up batches: make 1: 0208-001

a. The day before molding is to commence pre heat 1600 pounds of sand to 115-125^{o}F.
b. Thoroughly clean the pre-production muller.
c. Add a pre-weighed quantity of the heated Lake sand (50 GFN) per the new mixture recipe, approximately 1500 pounds total to the running pre-production muller.
d. Add 5 pounds of potable water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
e. Add the clays and coal per the new mixture recipe slowly to the muller to allow them to be distributed throughout the sand mass.
f. Dry mull for about 3 minutes to allow distribution and some grinding of the clays to occur.
g. Split the batch into approximately equal sized portions.
h. To each half-batch temper the sand-clay-coal mixture slowly with water to allow for distribution.
i. After about 2 gallons of water have been added allow 30 seconds of mixing then start taking compactability test samples.
j. Based on each test add water incrementally to adjust the temper. Allow 1 minute of mixing. Retest. Repeat until the compactability is in the range 45-51%.
k. Measure the sand temperature. If it is 95-105^{o}F discharge the sand into the mold half.
l. Record the total sand mixed in the combined batch, the total of each type of clay and coal added to the combined batch, the amount of water added to each half batch, the total mix time on each half batch, the final compactability and sand temperature at discharge on each half batch.

2. Re-mulling: make 11; 0208-002 to 0208-012.

a. Add all the sand from the previous mold to the muller.
b. Add 5 pounds of potable water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
c. Add the clays per the re-bond recipe slowly to the muller to allow them to be distributed throughout the sand mass.
d. Follow the above procedure beginning at D.1.f.

3. The sand lab will sample the mold sand from each mold as it is being made and from the shaken out sand after it has been re-blended but before the additions are made. The three (3) "MOLD" samples will be taken from the initial muller discharge into the drag, from the last sand into the drag, and the last sand into the cope. The three (3) "SHAKEOUT" samples will taken from within the muller at three locations approximately 120 degrees apart. The prepared sand and shakeout sand will be tested for 1800°F LOI, 900°F Volatiles, MB clay, compactability, and moisture content and reported associated with the mold (test number, 0208-0xx) from which it was taken. Additionally the prepared sand will be tested for Green compressive strength.

E. Molding: Step block 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. 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**.**

b. Riddle 4 inches of loose sand on the pattern and ram all pockets and the perimeter tightly using only vertical strokes.

Note: Non- vertical ramming strokes will move blocks of compacted sand leaving voids which may cause the mold to fail. Do not ram all the sand to form a parting plane surface or the mold can fail. Add sand in increments of 4-6 inches of loose sand ramming tightly around the pattern.

c. When the rammed sand covers the pattern by 3 or more inches the sand can be rammed less tightly but still avoid lamination planes.
d. Level off the cope and drag mold surfaces opposite the pattern to minimize metal splatter and allow the mold to be fully supported.
e. Cut the pour basin smoothly to reduce the amount of sand prone to get washed down the sprue.
f. Remove the pattern, inspect and blow out the mold, and set the cores in the drag. Verify that the cores are fully set in their prints. If a piece of the mold is missing contact your supervision for a decision on the acceptability of the mold.
g. Vent the cope with ¼ vents according to the template.
h. Close the mold straight being careful not to crush anything.
i. Bolt the flask halves together and deliver the mold to the pouring area.
j. Weigh the assembled un-poured flask, mold, and cores. Record the weight on the melt log**.**

Note: When weighing the flask assembly, tare (zero) the scale with the bail hanging freely from the scale. Lift the flask a few inches off the floor so that it is not touching anything. Allow the scale and load to settle until the scale reads a constant value. The net mold sand plus core weight should not vary by more than 30 pounds.

F. 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. Measure the ambient air temperature. Adjust the ambient air heater control so that the measured temperature entering the hood is 80-90^{o}F.

2. Shakeout.

a. After the 45 minute cooling time prescribed in the emission test plan has elapsed turn on the shakeout unit and run for it the 30 minutes prescribed in the emission test plan or until the sand has all fallen into the pit.
b. Sample the emissions for 30 minutes after the start of shakeout.
c. Turn off the shakeout, open the hood, remove the flask with casting, and recover the sand from the pit.
d. Weigh and record the cast metal weight and the sand weight by difference on the melt log.
e. Gather the shake out sand and re-blend it for two (2) minutes in the muller with about 5 pounds of water to suppress dust and retard segregation. Sample this sand from various parts of the batch, at least three (3), places from within the muller. Seal the sand sample and deliver to the sand lab. The Laboratory will analyze the sand sample and report MB clay and LOI as SHAKEOUT 0208-0xx sand.

G. Melting:

1. Initial charge:

a. Charge the furnace according to the heat recipe.
b. Place part of the steel scrap on the bottom, followed by carbon alloys, and the balance of the steel.
c. Place a pig on top on top.
d. Bring the furnace contents to the point of beginning to melt over a period of 1 hour at reduced power.
e. Add the balance of the metallic under full power until all is melted and the temperature has reached 2600 to 2700^{o}F.
f. Slag the furnace and add the balance of the alloys.
g. Raise the temperature of the melt to 2700^{o}F and take a DataCast 2000 sample. The temperature of the primary liquidus (TPL) must be in the range of 2200-2350^{o}F.
h. Hold the furnace at 2500-2550^{o}F until near ready to tap.
i. When ready to tap raise the temperature to 2700^{o}F and slag the furnace.

j. Record all metallic and alloy additions to the furnace, tap temperature, and pour temperature. Record all furnace activities with an associated time.

2. Back charging.

a. Back charge the furnace according to the heat recipe,
b. Charge a few pieces of steel first to make a splash barrier, followed by the carbon alloys.
c. Follow the above steps beginning with G.1.e

3. Emptying the furnace.

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

H. Pouring:

1. Preheat the ladle.

a. Tap 400 pounds more or less of 2700^{o}F iron into the cold ladle.
b. Carefully pour the metal back to the furnace.
c. Cover the ladle.
d. Reheat the metal to 2780 +/- 20^{o}F.
e. Tap 450 pounds of iron into the ladle while pouring inoculating alloys onto the metal stream near its base.
f. Cover the ladle to conserve heat.
g. Move the ladle to the pour position, open the emission hood pour door and wait until the metal temperature reaches 2630 +/- 10^{o}F.
h. Commence pouring keeping the sprue full.
i. Upon completion close the hood door, return the extra metal to the furnace, and cover the ladle.
j. Record the pour temperature and pour time on the heat log

Steven M. Knight
Manager, Process Engineer

PRE-PRODUCTION EM - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
7/3/02											
CONDITIONING - 1											
THC	EM-00101	X									TOTAL

PRE-PRODUCTION EM - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
7/8/02											
CONDITIONING - 2											
THC	EM-00201	X									TOTAL

PRE-PRODUCTION EM - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
7/9/02											
CONDITIONING - 3											
THC	EM-00301	X									TOTAL

PRE-PRODUCTION EM - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
7/9/02											
EVENT 4											
THC	EM-00401	X									TOTAL
M-18	EM-00402		1						20	1	Carbopak charcoal
M-18	EM-00403				1				0		Carbopak charcoal
M-18 MS	EM-00404		1						20	2	Carbopak charcoal
M-18 MS	EM-00405			1					20	3	Carbopak charcoal
Gas, CO, CO2	EM-00406		1						60	4	Tedlar Bag
Gas, CO, CO2	EM-00407				1				0		Tedlar Bag
NIOSH 2002	EM-00408		1						500	5	150/75 mg Silica Gel (SKC 226-10)
NIOSH 2002	EM-00409				1				0		150/75 mg Silica Gel (SKC 226-10)
	Excess								500	6	Excess
NIOSH 1500	EM-00410		1						800	7	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	EM-00411				1				0		100/50 mg Charcoal (SKC 226-01)
	Excess								800	8	Excess
TO11	EM-00412		1						1000	9	(DPNH cartridge sep-pak)
TO11	EM-00413				1				0		(DPNH cartridge sep-pak)
NIOSH 2016	EM-00414		1						1000	10	DNPH SKC 226-119
NIOSH 2016	EM-00415			1					1000	11	DNPH SKC 226-119
NIOSH 2016	EM-00416				1				0		DNPH SKC 226-119
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess
Condensibles	EM-00417		1						16000		Sample at Opposite Port
Condensibles	EM-00418				1				0		Sample at Opposite Port

PRE-PRODUCTION EM - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
7/10/02											
EVENT 5											
THC	EM-00501	X									TOTAL
M-18	EM-00502		1						20	1	Carbopak charcoal
M-18	EM-00503			1					20	2	Carbopak charcoal
	Excess								20	3	Excess
Gas, CO, CO2	EM-00504		1						60	4	Tedlar Bag
NIOSH 2002	EM-00505		1						500	5	150/75 mg Silica Gel (SKC 226-10)
NIOSH 2002	EM-00506			1					500	6	150/75 mg Silica Gel (SKC 226-10)
NIOSH 1500	EM-00507		1						800	7	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	EM-00508			1					800	8	100/50 mg Charcoal (SKC 226-01)
TO11	EM-00509		1						1000	9	(DPNH cartridge sep-pak)
TO11	EM-00510			1					1000	10	(DPNH cartridge sep-pak)
NIOSH 2016	EM-00511		1						1000	11	DNPH SKC 226-119
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess
Condensibles	EM-00512		1						16000		Sample at Opposite Port

PRE-PRODUCTION EM - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
7/10/02											
EVENT 6											
THC	EM-00601	X									TOTAL
M-18	EM-00602		1						20	1	Carbopak charcoal
M-18	EM-00603					1			20	1	Carbopak charcoal
	Excess								20	2	Excess
	Excess								20	3	Excess
Gas, CO, CO2	EM-00604		1						60	4	Tedlar Bag
NIOSH 2002	EM-00605		1						500	5	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	6	Excess
NIOSH 1500	EM-00606		1						800	7	100/50 mg Charcoal (SKC 226-01)
	Excess								800	8	Excess
TO11	EM-00607		1						1000	9	(DPNH cartridge sep-pak)
TO11	EM-00608					1			1000	9	(DPNH cartridge sep-pak)
NIOSH 2016	EM-00609		1						1000	10	DNPH SKC 226-119
	Excess								1000	11	
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess
Condensibles	EM-00610		1						16000		Sample at Opposite Port
Condensibles	EM-00611					1			16000		Sample at Opposite Port

PRE-PRODUCTION EM - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
7/11/02											
EVENT 7											
THC	EM-00701	X									TOTAL
M-18	EM-00702		1						20	1	Carbopak charcoal
	Excess								20	2	Excess
	Excess								20	3	Excess
Gas, CO, CO2	EM-00703		1						60	4	Tedlar Bag
NIOSH 2002	EM-00704		1						500	5	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	6	Excess
NIOSH 1500	EM-00705		1						800	7	100/50 mg Charcoal (SKC 226-01)
	Excess								800	8	Excess
TO11	EM-00706		1						1000	9	(DPNH cartridge sep-pak)
NIOSH 2016	EM-00707		1						1000	10	DNPH SKC 226-119
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess
Condensibles	EM-00708		1						16000		Sample at Opposite Port

PRE-PRODUCTION EM - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
7/16/02											
EVENT 8											
THC	EM-00801	X									TOTAL
M-18	EM-00802		1						20	1	Carbopak charcoal
	Excess								20	2	Excess
	Excess								20	3	Excess
Gas, CO, CO2	EM-00803		1						60	4	Tedlar Bag
NIOSH 2002	EM-00804		1						500	5	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	6	Excess
NIOSH 1500	EM-00805		1						800	7	100/50 mg Charcoal (SKC 226-01)
	Excess								800	8	Excess
TO11	EM-00806		1						1000	9	(DPNH cartridge sep-pak)
NIOSH 2016	EM-00807		1						1000	10	DNPH SKC 226-119
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess
Condensibles	EM-00808		1						16000		Sample at Opposite Port

PRE-PRODUCTION EM - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
7/16/02											
EVENT 9											
THC	EM-00901	X									TOTAL
M-18	EM-00902		1						20	1	Carbopak charcoal
	Excess								20	2	Excess
	Excess								20	3	Excess
Gas, CO, CO2	EM-00903		1						60	4	Tedlar Bag
NIOSH 2002	EM-00904		1						500	5	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	6	Excess
NIOSH 1500	EM-00905		1						800	7	100/50 mg Charcoal (SKC 226-01)
	Excess								800	8	Excess
TO11	EM-00906		1						1000	9	(DPNH cartridge sep-pak)
NIOSH 2016	EM-00907		1						1000	10	DNPH SKC 226-119
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess
Condensibles	EM-00908		1						16000		Sample at Opposite Port

PRE-PRODUCTION EM - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
7/17/02											
EVENT 10											
THC	EM-01001	X									TOTAL
M-18	EM-01002		1						20	1	Carbopak charcoal
	Excess								20	2	Excess
	Excess								20	3	Excess
Gas, CO, CO2	EM-01003		1						60	4	Tedlar Bag
NIOSH 2002	EM-01004		1						500	5	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	6	Excess
NIOSH 1500	EM-01005		1						800	7	100/50 mg Charcoal (SKC 226-01)
	Excess								800	8	Excess
TO11	EM-01006		1						1000	9	(DPNH cartridge sep-pak)
NIOSH 2016	EM-01007		1						1000	10	DNPH SKC 226-119
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess
Condensibles	EM-01008		1						16000		Sample at Opposite Port

PRE-PRODUCTION EM - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
7/18/02											
EVENT 11											
THC	EM-01101	X									TOTAL
M-18	EM-01102		1						20	1	Carbopak charcoal
	Excess								20	2	Excess
	Excess								20	3	Excess
Gas, CO, CO2	EM-01103		1						60	4	Tedlar Bag
NIOSH 2002	EM-01104		1						500	5	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	6	Excess
NIOSH 1500	EM-01105		1						800	7	100/50 mg Charcoal (SKC 226-01)
	Excess								800	8	Excess
TO11	EM-01106		1						1000	9	(DPNH cartridge sep-pak)
NIOSH 2016	EM-01107		1						1000	10	DNPH SKC 226-119
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess
Condensibles	EM-01108		1						16000		Sample at Opposite Port

PRE-PRODUCTION EM - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
7/19/02											
EVENT 12											
THC	EM-01201	X									TOTAL
M-18	EM-01202		1						20	1	Carbopak charcoal
	Excess								20	2	Excess
	Excess								20	3	Excess
Gas, CO, CO2	EM-01203		1						60	4	Tedlar Bag
NIOSH 2002	EM-01204		1						500	5	150/75 mg Silica Gel (SKC 226-10)
	Excess								500	6	Excess
NIOSH 1500	EM-01205		1						800	7	100/50 mg Charcoal (SKC 226-01)
	Excess								800	8	Excess
TO11	EM-01206		1						1000	9	(DPNH cartridge sep-pak)
NIOSH 2016	EM-01207		1						1000	10	DNPH SKC 226-119
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess
Condensibles	EM-01208		1						16000		Sample at Opposite Port

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APPENDIX B TEST SERIES EM DETAILED RESULTS

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Test EM Individual Test Results – Lb/Tn Metal

HAPs	POMs	COMPOUND / SAMPLE NUMBER	EM004	EM005	EM006	EM007	EM008	EM009	EM010	EM011	EM012	Average	STDEV
		Pour Dates	**7/9/02**	**7/10/02**	**7/10/02**	**7/11/02**	**7/16/02**	**7/16/02**	**7/17/02**	**7/18/02**	**7/19/02**		
		THC as Propane	2.03E+00	2.26E+00	2.41E+00	2.06E+00	1.67E+00	2.22E+00	1.81E+00	I	1.55E+00	2.00E+00	3.01E-01
		HC as Hexane	4.56E-01	5.16E-01	5.39E-01	4.48E-01	3.75E-01	4.19E-01	3.66E-01	3.40E-01	3.28E-01	4.21E-01	7.53E-02
		Sum of VOCs	3.79E-01	4.01E-01	4.60E-01	3.95E-01	2.90E-01	3.46E-01	2.95E-01	2.55E-01	2.53E-01	3.42E-01	7.26E-02
		Sum of HAPs	2.90E-01	3.14E-01	3.55E-01	3.06E-01	2.22E-01	2.68E-01	2.26E-01	2.01E-01	1.97E-01	2.64E-01	5.57E-02
		Sum of POMs	4.09E-03	1.03E-02	1.44E-02	1.55E-02	1.29E-02	9.42E-03	1.13E-02	8.26E-03	9.53E-03	1.06E-02	3.44E-03
			Individual Organic HAPs										
x		**Benzene**	1.05E-01	1.27E-01	1.28E-01	1.10E-01	8.54E-02	1.04E-01	8.39E-02	7.87E-02	7.37E-02	9.95E-02	2.01E-02
x		**Toluene**	6.27E-02	6.80E-02	7.41E-02	6.61E-02	5.25E-02	6.08E-02	5.37E-02	4.84E-02	4.52E-02	5.90E-02	9.67E-03
x		**m,p-Xylene**	3.18E-02	3.02E-02	3.52E-02	3.10E-02	2.47E-02	2.68E-02	2.47E-02	2.12E-02	2.01E-02	2.73E-02	5.08E-03
x		**o-Xylene**	1.72E-02	1.76E-02	2.03E-02	1.78E-02	1.37E-02	1.52E-02	1.38E-02	1.19E-02	1.19E-02	1.55E-02	2.91E-03
x		**Hexane**	1.06E-02	1.54E-02	1.63E-02	1.47E-02	1.15E-02	1.40E-02	1.29E-02	1.14E-02	1.17E-02	1.32E-02	2.03E-03
x		**Phenol**	1.42E-02	1.02E-02	1.61E-02	1.10E-02	2.56E-03	7.80E-03	6.14E-03	5.72E-03	6.61E-03	8.93E-03	4.35E-03
x	z	**Naphthalene**	I	6.63E-03	9.10E-03	9.66E-03	7.98E-03	6.18E-03	6.97E-03	5.23E-03	5.86E-03	7.20E-03	1.58E-03
x		**Ethylbenzene**	8.17E-03	8.13E-03	9.37E-03	8.12E-03	6.44E-03	7.02E-03	6.49E-03	5.49E-03	5.37E-03	7.18E-03	1.36E-03
x		**Acetaldehyde**	6.18E-03	6.40E-03	1.05E-02	7.01E-03	5.52E-03	5.66E-03	5.31E-03	4.89E-03	4.81E-03	6.26E-03	1.76E-03
x		**o-Cresol**	1.34E-02	1.02E-02	1.42E-02	1.12E-02	ND	7.30E-03	ND	ND	ND	6.25E-03	6.23E-03
x		**m,p-Cresol**	7.05E-03	3.65E-03	7.45E-03	5.98E-03	ND	3.06E-03	2.03E-03	ND	2.54E-03	3.53E-03	2.79E-03
x		**Styrene**	3.81E-03	3.09E-03	3.74E-03	3.37E-03	2.58E-03	2.48E-03	2.21E-03	1.88E-03	1.91E-03	2.79E-03	7.47E-04
x	z	**2-Methylnaphthalene**	4.09E-03	2.15E-03	3.14E-03	3.46E-03	2.88E-03	1.90E-03	2.51E-03	1.71E-03	2.11E-03	2.66E-03	7.93E-04
x		**2-Butanone**	1.70E-03	1.72E-03	2.37E-03	1.73E-03	1.64E-03	1.95E-03	1.77E-03	1.62E-03	1.48E-03	1.77E-03	2.56E-04
x	z	**1-Methylnaphthalene**	I	1.48E-03	2.17E-03	2.37E-03	2.00E-03	1.34E-03	1.78E-03	1.32E-03	1.56E-03	1.75E-03	3.93E-04
x		**Formaldehyde**	2.78E-03	1.81E-03	2.17E-03	1.24E-03	1.89E-03	1.40E-03	1.43E-03	1.18E-03	1.31E-03	1.69E-03	5.27E-04
x		**Propionaldehyde**	7.71E-04	8.60E-04	1.09E-03	6.69E-04	8.00E-04	8.23E-04	6.61E-04	6.24E-04	5.89E-04	7.65E-04	1.55E-04
x	z	**1,2-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
x	z	**1,3-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
x	z	**1,5-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
x	z	**1,6-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
x	z	**1,8-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
x	z	**2,3,5-Trimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
x	z	**2,3-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA

Test EM Individual Test Results – Lb/Tn Metal

HAPS	POMS	COMPOUND / SAMPLE NUMBER	EM004	EM005	EM006	EM007	EM008	EM009	EM010	EM011	EM012	Average	STDEV
			Individual Organic HAPs continued										
x	z	**2,6-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
x	z	**2,7-Dimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
x	z	**Acenaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
x		**Biphenyl**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
x		**Cumene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
x		**Aniline**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
x		**N,N-Dimethylaniline**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
x		**Acrolein**	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
			Other VOCS										
		Heptane	1.10E-02	1.61E-02	1.60E-02	1.50E-02	1.18E-02	1.45E-02	1.30E-02	1.14E-02	1.12E-02	1.33E-02	2.10E-03
		Octane	9.85E-03	1.34E-02	1.44E-02	1.29E-02	9.24E-03	1.21E-02	1.08E-02	8.78E-03	1.01E-02	1.13E-02	1.99E-03
		1,2,4-Trimethylbenzene	1.22E-02	9.10E-03	1.19E-02	1.06E-02	8.33E-03	8.10E-03	8.29E-03	6.28E-03	6.66E-03	9.05E-03	2.12E-03
		Nonane	7.43E-03	9.29E-03	1.04E-02	9.17E-03	6.94E-03	8.32E-03	7.36E-03	6.37E-03	6.77E-03	8.00E-03	1.36E-03
		Decane	6.81E-03	7.22E-03	8.54E-03	7.70E-03	4.90E-03	6.16E-03	5.55E-03	4.13E-03	4.39E-03	6.16E-03	1.53E-03
		3-Ethyltoluene	5.91E-03	5.03E-03	6.25E-03	5.24E-03	4.42E-03	4.26E-03	4.12E-03	3.25E-03	3.32E-03	4.64E-03	1.05E-03
		1,2,3-Trimethylbenzene	5.61E-03	4.25E-03	5.38E-03	4.71E-03	3.69E-03	3.64E-03	3.59E-03	2.82E-03	3.16E-03	4.09E-03	9.67E-04
		Undecane	5.55E-03	4.01E-03	5.92E-03	5.20E-03	3.38E-03	3.54E-03	3.63E-03	2.45E-03	2.89E-03	4.06E-03	1.22E-03
		Cyclohexane	3.93E-03	5.11E-03	5.32E-03	4.55E-03	3.60E-03	4.20E-03	3.55E-03	2.65E-03	2.65E-03	3.95E-03	9.57E-04
		2-Ethyltoluene	3.66E-03	2.59E-03	3.87E-03	3.24E-03	2.26E-03	2.16E-03	2.25E-03	1.82E-03	1.91E-03	2.64E-03	7.61E-04
		Indene	5.69E-03	3.35E-03	5.05E-03	4.22E-03	2.67E-03	2.60E-03	ND	ND	ND	2.62E-03	2.21E-03
		1,3,5-Trimethylbenzene	3.30E-03	2.73E-03	3.33E-03	2.92E-03	2.43E-03	2.30E-03	2.29E-03	1.87E-03	2.04E-03	2.58E-03	5.25E-04
		4-Ethyltoluene	2.82E-03	2.32E-03	2.98E-03	2.54E-03	2.21E-03	2.08E-03	2.03E-03	ND	ND	1.89E-03	1.12E-03
		Dodecane	2.48E-03	ND	2.32E-03	ND	ND	2.30E-03	ND	ND	ND	7.88E-04	1.18E-03
		Benzaldehyde	4.64E-04	5.44E-04	5.40E-04	3.99E-04	3.85E-04	1.16E-03	1.09E-03	1.01E-03	9.31E-04	7.25E-04	3.16E-04
		Butyraldehyde/Methacrolein	6.45E-04	6.84E-04	7.92E-04	5.00E-04	5.26E-04	3.20E-04	3.52E-04	3.16E-04	ND	4.59E-04	2.41E-04
		o,m,p-Tolualdehyde	5.64E-04	5.15E-04	7.13E-04	4.54E-04	4.68E-04	4.37E-04	ND	ND	ND	3.50E-04	2.75E-04
		Pentanal	3.19E-04	3.28E-04	4.15E-04	2.72E-04	2.69E-04	2.62E-04	2.46E-04	2.08E-04	1.90E-04	2.79E-04	6.81E-05
		Crotonaldehyde	3.45E-04	3.36E-04	4.28E-04	ND	2.83E-04	ND	ND	ND	ND	1.55E-04	1.87E-04
		Hexaldehyde	1.77E-04	2.02E-04	2.76E-04	1.84E-04	1.73E-04	1.51E-04	1.46E-04	ND	ND	1.45E-04	9.06E-05
		1,2-Diethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA

Test EM Individual Test Results – Lb/Tn Metal

HAPS	POMS	COMPOUND / SAMPLE NUMBER	EM004	EM005	EM006	EM007	EM008	EM009	EM010	EM011	EM012	Average	STDEV
			Other VOCS continued										
		1,3-Diethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		1,3-Diisopropylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		1,4-Diethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		2,3,5-Trimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		2,3-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		2,4,6-Trimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		2,5-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		2,6-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		3,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		3,5-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		a-Methylstyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		Anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		Isobutylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		n-Propylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		p-cymene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		sec-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		tert-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		Tridecane	I	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA

Test EM Individual Test Results – Lb/Tn Metal

HAPS	POMS	COMPOUND / SAMPLE NUMBER	EM004	EM005	EM006	EM007	EM008	EM009	EM010	EM011	EM012	Average	STDEV
			Other Analytes										
		Condensibles*	6.37E-01	5.63E-01	4.58E-01	3.83E-01	6.43E-01	2.63E-01	4.55E-01	3.91E-01	3.00E-01	4.55E-01	1.37E-01
		Acetone	6.36E-03	6.58E-03	8.57E-03	5.68E-03	5.52E-03	6.09E-03	5.45E-03	5.05E-03	4.40E-03	5.97E-03	1.18E-03
		Carbon Monoxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		Carbon Dioxide	2.05E+01	2.58E+01	2.18E+01	2.48E+01	2.28E+01	2.04E+01	2.13E+01	2.31E+01	2.39E+01	2.27E+01	1.88E+00
		Methane	3.25E-02	3.70E-02	3.97E-02	3.61E-02	3.49E-02	2.81E-02	3.67E-02	3.66E-02	3.79E-02	3.55E-02	3.41E-03
		Ethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		Propane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		Isobutane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		Butane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		Neopentane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		Isopentane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
		Pentane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA

I: Data rejected based on data validation considerations; ND: Non Detect; NA: Not Applicable

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

***Condensibles Method Blank results: 8.3 mg.; Solvent Blank results: 1.2 mg. Condensibles are also reported as a minimum due to apparent breakthrough.**

Test EM Reporting Limits – Lb/Tn Metal

Miscellaneous	
aniline	3.60E-03
dimethylaniline	6.29E-03
HC as hexane	5.74E-03
butyraldehyde/methacrolein	2.44E-04
o,m,p-tolualdehyde	3.90E-04

4.25E-04	2.12E-03			1.46E-04
hexane	cyclohexane	phenol	t-butylbenzene	2-butanone
benzene	heptane	o-cresol	s-butylbenzene	acetaldehyde
toluene	octane	m,p-cresol	indan	acetone
ethylbenzene	nonane	2,6-dimethylphenol	indene	acrolein
m,p-xylene	isopropylbenzene	2,4-dimethylphenol	butylbenzene	benzaldehyde
styrene	3-ethyltoluene	2,5-dimethylphenol	dodecane	crotonaldehyde
o-xylene	4-ethyltoluene	3,5-dimethylphenol	tridecane	formaldehyde
1,3,5-trimethylbenzene	a-methylstyrene	2,3-dimethylphenol	biphenyl	hexaldehyde
2-ethyltoluene	decane	3,4-dimethylphenol	tetradecane	pentanal
1,2,4-trimethylbenzene	isobutylbenzene	2,4,6-trimethylphenol	2,6-dimethylnaphthalene	propionaldehyde
1,2,3-trimethylbenzene	p-cymene	2,3,5-trimethylphenol	1,6-dimethylnaphthalene	
undecane	1,3-diethylbenzene	2,7-dimethylnaphthalene	acenaphthalene	
naphthalene	1,4-diethylbenzene	2,3-dimethylnaphthalene	1,2-dimethylnaphthalene	
2-methylnaphthalene	1,2-diethylbenzene	1,5-dimethylnaphthalene		
1-methylnaphthalene	1,3-diisopropylbenzene	2,3,5-trimethylnaphthalene		
1,3-dimethylnaphthalene	anthracene	1,8-dimethylnaphthalene		

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APPENDIX C TEST SERIES EM DETAILED PROCESS AND SOURCE DATA

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Test EM Detailed Process Data

Description	Conditioning			Test series EM										
	EM001	EM002	EM003	EM004	EM005	EM006	EM007	EM008	EM009	EM010	EM011	EM012	Ave. All	**Report Ave**
Date	7/3/02	7/8/02	7/9/02	7/9/02	7/10/02	7/10/02	7/11/02	7/16/02	7/16/02	7/17/02	7/18/02	7/19/02		
Casting Metal Weight, lbs.	177	213	219	223	201	208	195	203	215	213	209	195	206	**207**
Total Mold Weight, lbs.	1383	1376	1334	1361	1279	1317	1292	1317	1268	1318	1301	1310	1321	**1307**
Total Core Weight, lbs.	62.1	59.0	60.8	59.3	60.0	60.0	60.5	58.4	58.7	58.7	57.3	57.6	59.4	**58.9**
Compactability, %	53	48	52	54	53	52	54	---	50	---	51	52	52	**52**
Sand Temperature, *F	82	81	110	104	104	100	100	106	100	115	100	95	100	**103**
Total Binder Weight, lbs: Note 1,2	1.513	1.439	1.483	1.446	1.463	1.463	1.474	1.424	1.430	1.432	1.398	1.404	1.448	**1.437**
No. Cavities Poured	6	8	8	8	8	8	8	8	8	8	8	8	8	**8**
LOI, % (at mold)	4.85	5.16	4.72	4.71	5.38	5.30	5.04	4.84	5.01	5.00	4.97	5.36	5.03	**5.07**
LOI, % (at shakeout)	4.75	5.21	4.62	4.10	5.08	4.89	4.94	5.01	5.36	4.85	4.63	5.36	4.90	**4.91**
Clays, % (at mold) Note 5	7.50	7.90	7.25	7.12	7.90	8.03	7.00	7.38	7.00	7.25	7.12	6.74	7.35	**7.28**
Clays, % (at shakeout) Note 5	7.50	7.51	6.62	5.73	6.60	7.12	6.62	6.87	6.62	7.12	6.48	6.08	6.74	**6.58**
Volatiles, % (at mold) avg.	1.42	1.16	1.18	1.06	1.24	1.28	0.98	1.12	1.14	1.04	0.92	1.08	1.13	**1.10**
Volatiles, % (at shakeout) avg.	1.28	1.04	1.18	0.94	1.00	1.08	1.12	0.94	0.96	1.02	0.80	1.14	1.04	**1.00**
Pouring time, sec.	31	22	23	22	17	27	16	21	13	15	14	16	20	**18**
Pouring Temperature, °F	2626	2641	2645	2628	2645	2649	2638	2636	2642	2646	2645	2636	2640	**2641**
Ambient Temperature, F	Not Measured	Not Measured	75	82	74	88	74	64	77	68	68	66	74	**73**
Average Stack Temperature, °F	Not Measured	Not Measured	Not Measured	123	110	122	106	101	111	105	101	102		**109**
Total Moisture Content, %	Not Measured	Not Measured	Not Measured	2.40	2.47	2.77	2.17	2.31	2.08	2.16	2.12	2.29		**2.31**
Average Stack Velocity, ft./sec.	Not Measured	Not Measured	Not Measured	16.8	16.8	17.2	16.8	16.7	16.6	16.5	16.9	16.4		**16.7**
Avg. Stack Pressure, in. Hg	Not Measured	Not Measured	Not Measured	29.84	29.83	29.78	29.81	29.90	29.84	29.93	29.96	29.88		**29.86**
Stack Flow Rate, scfm	Not Measured	Not Measured	Not Measured	696	715	710	719	722	705	710	735	710		**714**

Note 1: Core binder is J.B. DeVeene Kleencast # 1 organic free sodium silicate Note 6

Note 2: Binder weight = core weight x .025/1.025

Note 3: The sand for molds 3,5,7,8,10,&11 was heated at 110 degrees F overnight in an oven to emulate the sand temerature of sand used a second time in the same day.

Note 4: Mold EM012 was made on 7/18/02 as the second pour of the day but was not poured until 7/19/03

Note 5: The 1800 degree F LOI test includes decomposition of $CaCO_3$ that has been found to vary from 0.1-0.5 % from supposedly identical samples o f sand.
The typical burnout is 0.3 % per cycle. Apparent increases in LOI from mold to shakeout or decreases from shakeout to the next mold may have variable carbonates as the reason.

Note 6: This run had a short sprue, only 3 inchs vs 12 with pour cup, Test castings and runner were complete

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APPENDIX D METHOD 25A CHARTS

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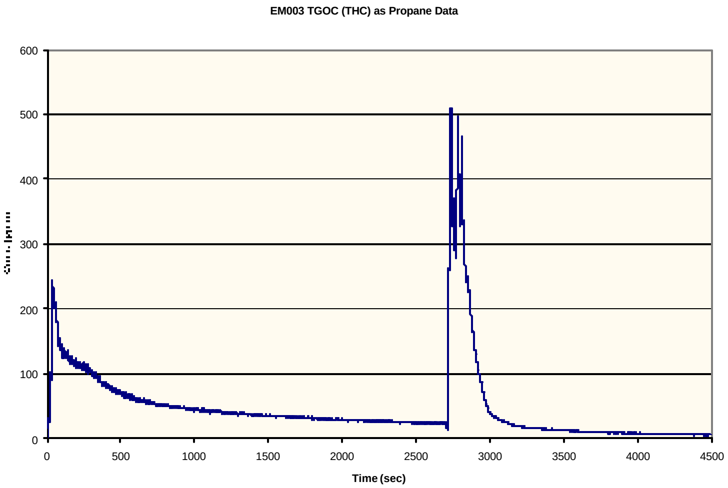
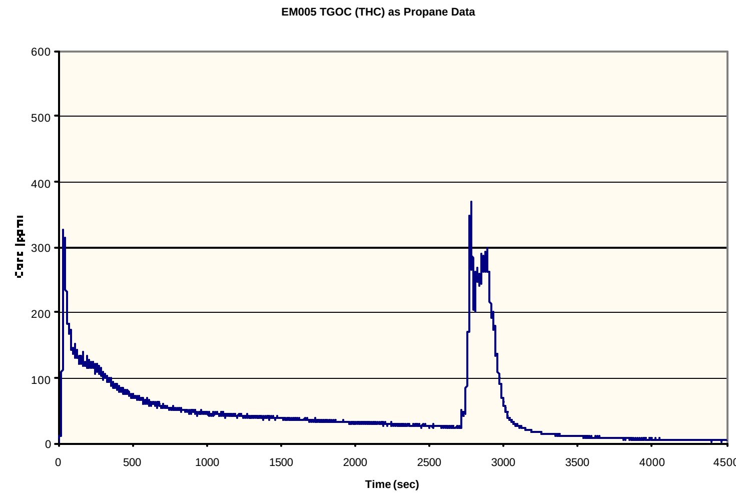

EM003 TGOC (THC) as Propane Data
0
100
200
300
400
500
600
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Time (sec)


EM005 TGOC (THC) as Propane Data
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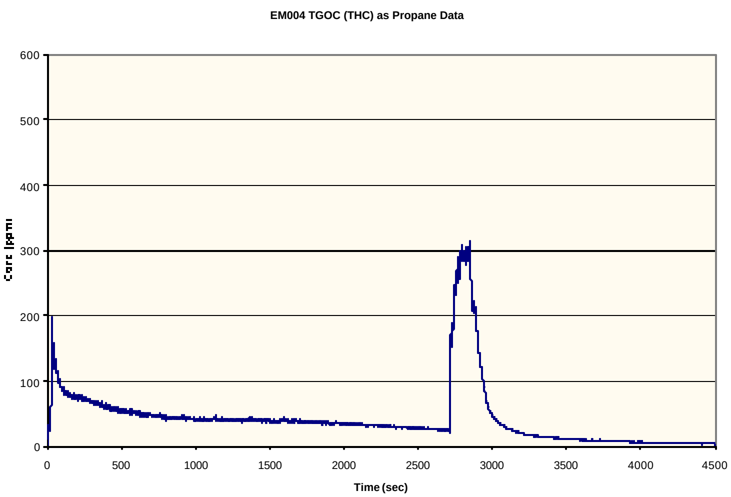
100
200
300
400
500
600
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Time (sec)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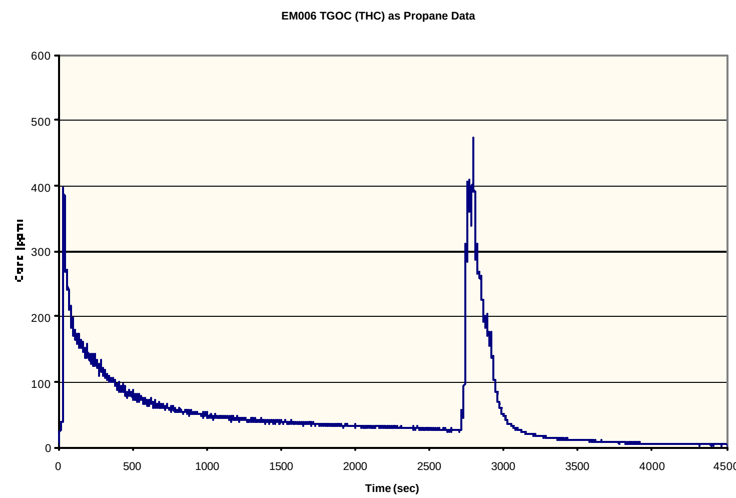
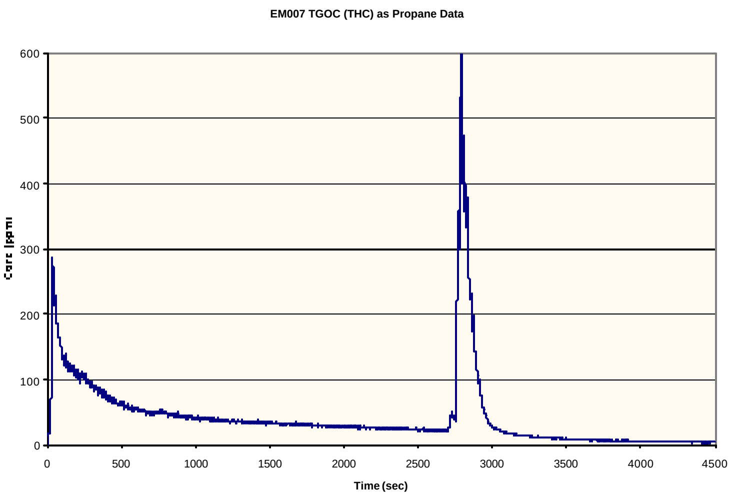
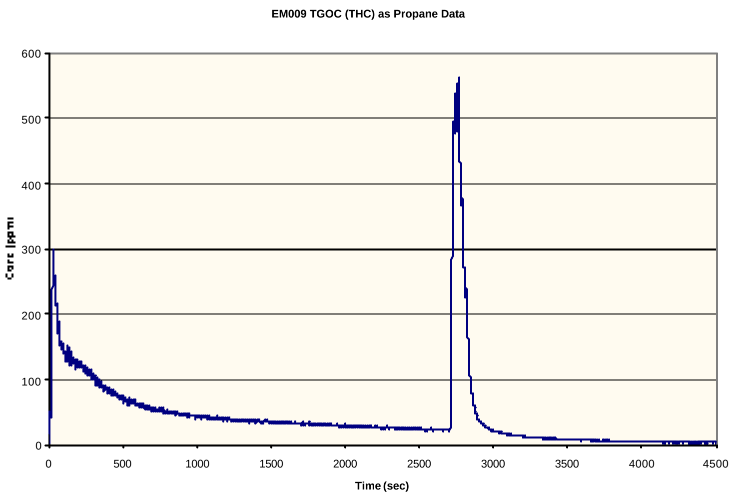
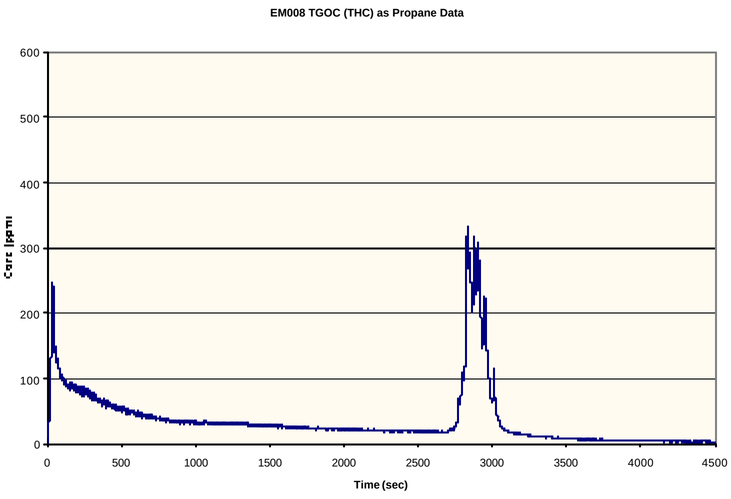
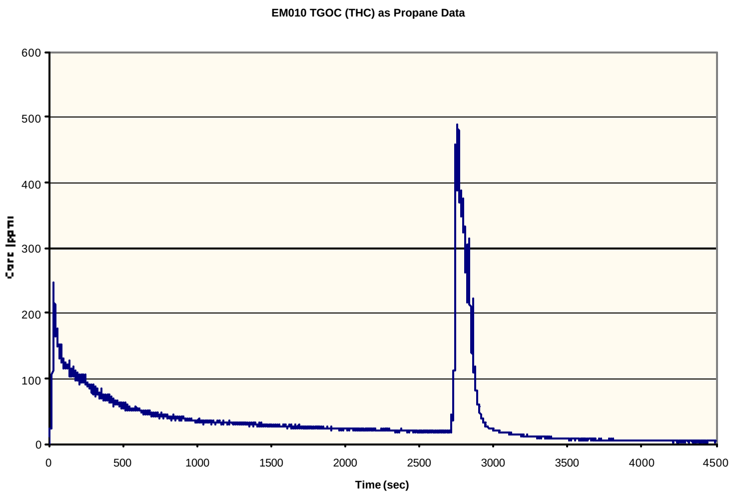
0
100
200
300
400
500
600
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Time (sec)

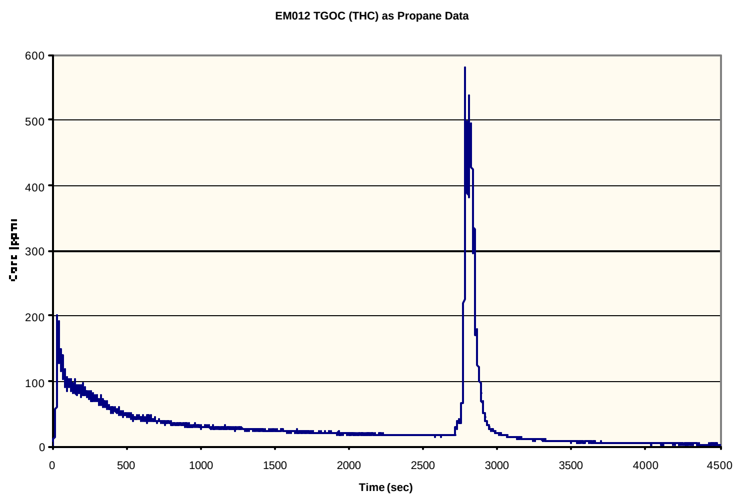

EM006 TGOC (THC) as Propane Data
0
100
200
300
400
500
600
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Time (sec)


EM007 TGOC (THC) as Propane Data
Conc (ppm)
Time (sec)


EM009 TGOC (THC) as Propane Data
Conc (ppm)
Time (sec)


EM008 TGOC (THC) as Propane Data
Conc (ppm)
Time (sec)


EM010 TGOC (THC) as Propane Data
Conc (ppm)
Time (sec)


EM012 TGOC (THC) as Propane Data
Conc (ppm)
600
500
400
300
200
100
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Time (sec)

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APPENDIX E LISTING OF SUPPORT DOCUMENTS

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Listing of Supporting Documents

The following documents contain specific test results, procedures, and documentation used in support of this Test Plan

1. Casting Emission Reduction Program – Foundry Product Testing Guide: Reducing Emissions by Comparative Testing, May 4, 1998.

2. CERP Testing, Quality Assurance/Quality Control Procedures Manual.

3. Emission Baseline Test Results for the CERP Pre-Production Foundry Processes.

4. Evaluation of the Required Number of Replicate Tests to Provide Statistically Significant Air Emission Reduction Comparisons for the CERP Pre-Production Foundry Test Program.

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APPENDIX F GLOSSARY

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Glossary

ND Non Detect, No Data

NA Not Applicable

HC as Hexane Calculated by the summation of all area between elution of Hexane through the elution of Hexadecane. The quantity of HC is performed against a five-point calibration curve of Hexane by dividing the total area count from C6 through C16 to the area of Hexane from the initial calibration curve.

POM Polycyclic Organic Matter (POM) including Naphthalene and other compounds that contain more than one benzene ring and have a boiling point greater than or equal to 100 degrees Celsius.

BO Based on ( ).

BOS Based on Sand.

LOI Loss of Ignition. LOI represents the change in weight of a sample expressed as % of the original dry weight as a consequence of combustion in air at the test temperature of 1400°F