Casting Emission Reduction Program

Prepared by:

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US Army Task N256

Phenolic Urethane / Aluminum Greensand Baseline Test Without Seacoal Baseline Emissions Test

Technikon #RV100109DN

25 June 2001

This document was revised for unlimited public distribution

United States Environmental Protection Agency

CISA

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UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

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Pre-Production Air Emission Test Report

Greensand Without Seacoal

Phenolic Urethane / Aluminum

Baseline Emissions Test

RV100109DN

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

Written By:	Scott Forbes	6-28-01 Date
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~~President~~:	William Walden	6-26-01 Date

The data contained in this report were developed to assess the relative emissions profile of the product or process being evaluated against a standardized baseline process profile. 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 a Greensand (without Seacoal) Phenolic Urethane / Aluminum emissions baseline. All testing was conducted in the CERP Pre-Production foundry, operated by Technikon, LLC.

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. This report documents the following baseline test series: A background baseline test for an Aluminum Greensand (without Seacoal) mold system utilizing phenolic urethane resin.

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. Nine molds were poured for this 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), formerly Total Hydrocarbon Content (THC), 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: although separate results are available in Appendix B of this report. Several "emissions indicators," in addition to the TGOC (THC) 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 HAPs and 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 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 (THC) As Propane	HC as Hexane	Sum of VOCs	Sum of HAPs	Sum of POMs
1.61	1.53	0.230	0.154	0.027

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 Background

Technikon LLC is a privately held contract research organization located in McClellan, California, a suburb of Sacramento. Technikon offers emissions research services to industrial and government clients specializing in the metal casting and mobile emissions areas. Technikon operates the Casting Emission Reduction Program (CERP). CERP is a cooperative initiative between the Department of Defense (US Army) and the United States Council for Automotive Research (USCAR). Its purpose is to evaluate alternative casting materials and processes that are designed to reduce air emissions and/or produce more efficient casting processes. Other technical partners directly supporting the project include: the American Foundry Society (AFS); 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 HAP. 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 <u>discrete</u> molds under tightly controlled conditions not feasible in a commercial foundry. The Pre-Production Foundry uses a four-cavity, AFS irregular gear mold as its test pattern for No-Bake testing. All No-Bake testing occurs in the Pre-Production 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 <u>continuous</u> 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 <u>relative emission reductions</u> 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 <u>should not</u> 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. There are several support documents that provide details regarding the testing and analytical procedures used. Appendix F contains a listing of these support documents.

1.4 Preliminary Testing

The foundation 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 Phenolic Urethane No-Bake binder 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 (No Seacoal) Phenolic Urethane
Test Plan Number	RV100109DN
Binder System	Delta HA Coldbox 24-912/23-907/TEA
Metal Poured	Aluminum
Casting Type	Step Cores
Number of molds poured	9
Test Dates	02-26-01 > 02-28-01
Emissions Measured	70 organic HAPs and VOCs
Process Parameters Measured	Total Casting, Mold, and Binder Weights; Metallurgical data, % LOI; Stack Temperature, Moisture Content, Pressure, and Volumetric Flow Rate

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2.0 Test Methodology

2.1 Description of Process and Testing Equipment

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

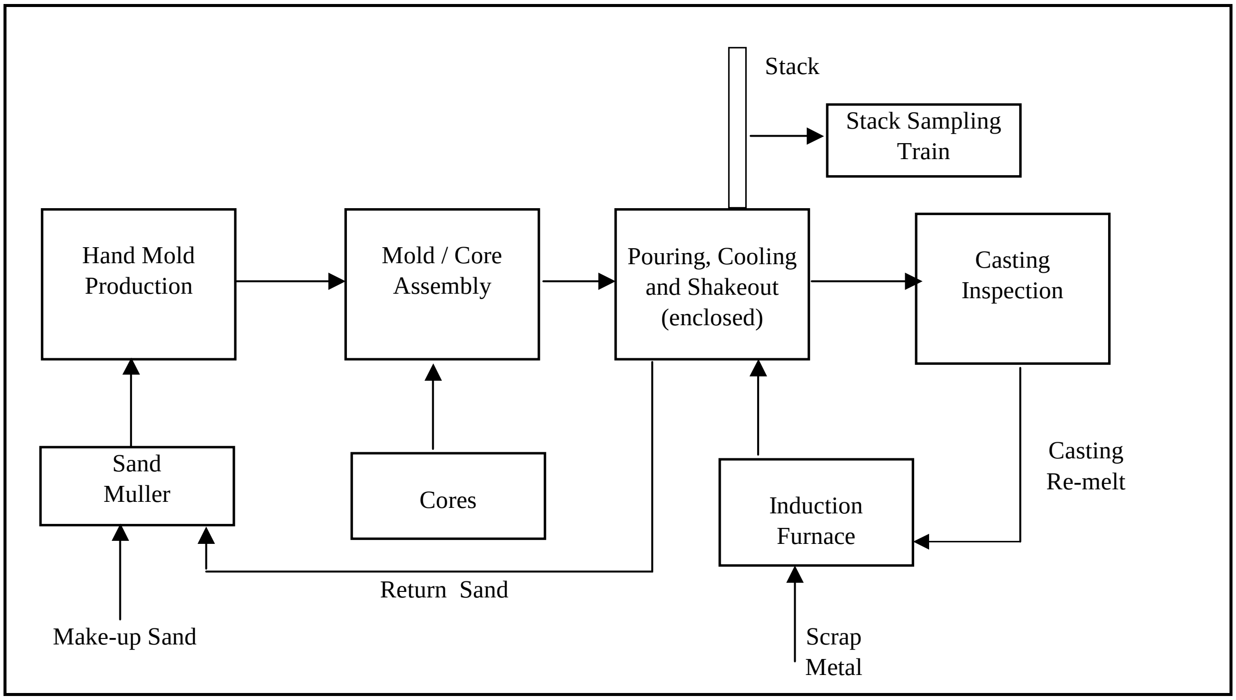


Figure 2-1 Pre-Production Foundry Layout Diagram

2.2 Description of Testing Program

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

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

2. **Mold, Core and Metal Preparation:** The molds and cores are prepared to a standard composition by the CERP 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. If new mold binder systems or processes are being evaluated, organic free sodium silicate step cores are placed into the molds. Aluminum is melted in a 250 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 mold/core packages. The mold/core packages are placed into an enclosed test stand. Aluminum is poured through an opening in the top of the 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

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.

Pouring of Step Core Molds Through Opening in Collection Hood

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).

Castings on the Shake Out Deck

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 212-87-S)
LOI, % at mold and shakeout	Denver Instruments XE-100 Analytical Scale (AFS procedure 212-87-S)
Core LOI, %	Denver Instruments XE-100 Analytical Scale (AFS procedure 321-87-S)
Clay, % at mold and shakeout	Dietert 535A MB Clay Tester (AFS Procedure 210-89-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 221-87-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 Emissions Testing and Analytical Testing 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 analysis	EPA Method 18, 25A, TO11, NIOSH 2002*
Condensables	Technikon method **

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

6. **<u>Data Reduction, Tabulation and Preliminary Report Preparation</u>:** The analytical results of the emissions tests provide the mass of each analyte in the sample. The total mass of the analyte emitted is calculated by multiplying the mass of analyte in the sample times the ratio of total stack gas volume to sample volume. The total stack gas volume is calculated from the measured stack gas velocity and duct diameter, and corrected to dry standard conditions using the measured stack pressures, temperatures, gas molecular weight and moisture content. The total mass of analyte is then divided by the weight of 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. **<u>Report Preparation and Review</u>:** 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, and the Technikon President. Comments are incorporated into a draft Final Report prior to final signature approval and distribution.

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

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

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

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

3.0 Test Results

The average emission result, in pounds per ton of metal poured, is presented in Table 3-1 for tests reported in this document. This table includes the individual organic HAP compounds that comprise at least 95% of the total HAPs measured, along with the corresponding sum of VOCs, sum of HAPs, and sum of POMs. The table also includes the TGOC (THC) as Propane and HC as Hexane. Figures 3-1, 3-2, and 3-3 present the five emissions indicators, and selected individual HAP and VOC emissions data from Tables 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. All emission results are presented without blank or background correction. 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.

The Validation Log included in Appendix E of this report presents the results of the data validation process.

Table 3-1 Summary of Test Plan DN Average Results

ANALYTES	Test DN Lbs/Tn
TGOC (THC) as Propane	1.61
HC as Hexane	1.53
Sum of VOCs	0.230
Sum of HAPs	0.154
Sum of POMs	0.027
Individual Organic HAPs	
Phenol	0.062
Naphthalene	0.026
Aniline	0.019
o,m,p-Cresol	0.018
Acetaldehyde	0.009
Benzene	0.006
Toluene	0.005
o,m,p-Xylene	0.004
Other VOCs	
Trimethylbenzenes	0.044
Ethyltoluenes	0.018
Undecane	0.006
Diethylbenzenes	0.003
Other Analytes	
Condensables	0.560
Carbon Monoxide	ND
Methane	ND
Carbon Dioxide	59.2
Acetone	0.005

I: Data was rejected based on data validation considerations.
All "Other Analytes" are not included in the sum of HAPs or VOCs.
N/A: Not Applicable; NT: Not Tested

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

Average Process and Stack Parameters	Average of DN	Target Range
Casting Metal Weight, lbs.	88	86 - 90
Total Mold Weight, lbs.	1411	1350 - 1420
Total Core Weight, lbs.	58.58	58 - 60
Compactability, %	49	45 - 51
Total Binder Weight, lbs	0.694	0.68 - 0.73
Core Ratio Resin (part I) to co-reactant (part II)	50 / 50	50 / 50
Greensand mold LOI, % @ 1800°F	0.88	0.2 - 1.2
MB Clay, %	6.78	6.5 - 7.5
Core LOI, % @ 1400°F	1.24	1.3 - 1.9
Greensand Mold Volatiles, % @ 900°F	0.28	N/A
Pour Temperature, °F	1273	1260 - 1280
Mold green compressive strength, psi	9.17	8 - 12
Core Binder Content, % (True)	1.2	1.18 - 1.22
Water Type used in Mold	Tap	Tap
Average Stack Temperature, °F	81	80 ± 10
Total Moisture Content, %	0.95	N/A
Average Stack Velocity, ft./sec.	15.8	15 ± 2
Avg. Stack Pressure, in. Hg	29.93	N/A
Stack Flow Rate, scfm	720	700 ± 50

Figure 3-1 Emission Indicators from Test Series DN

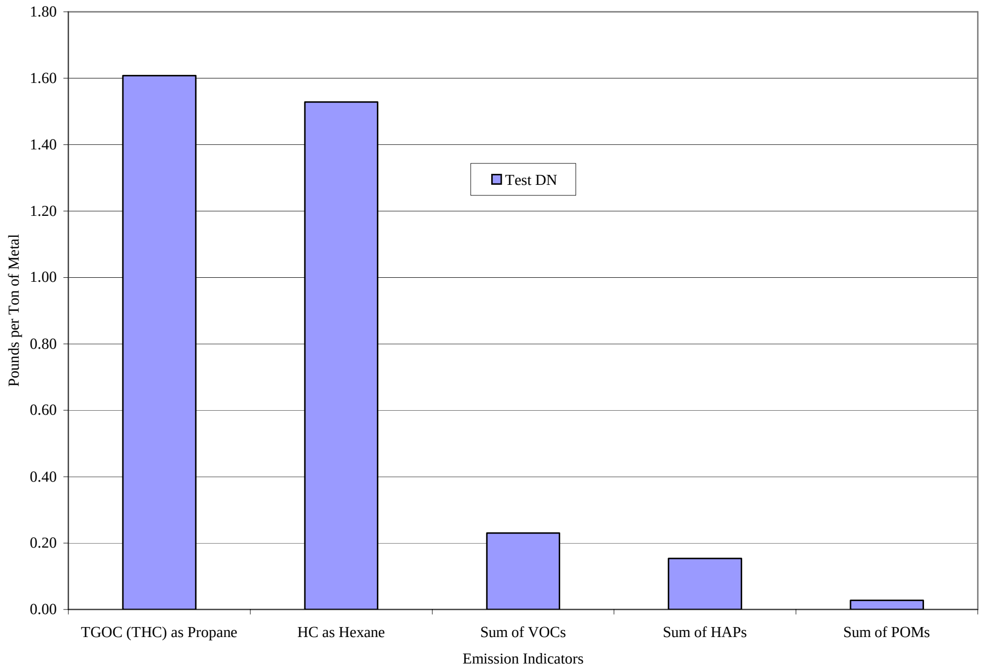


Figure 3-2 Selected HAP Emissions from Test Series DN

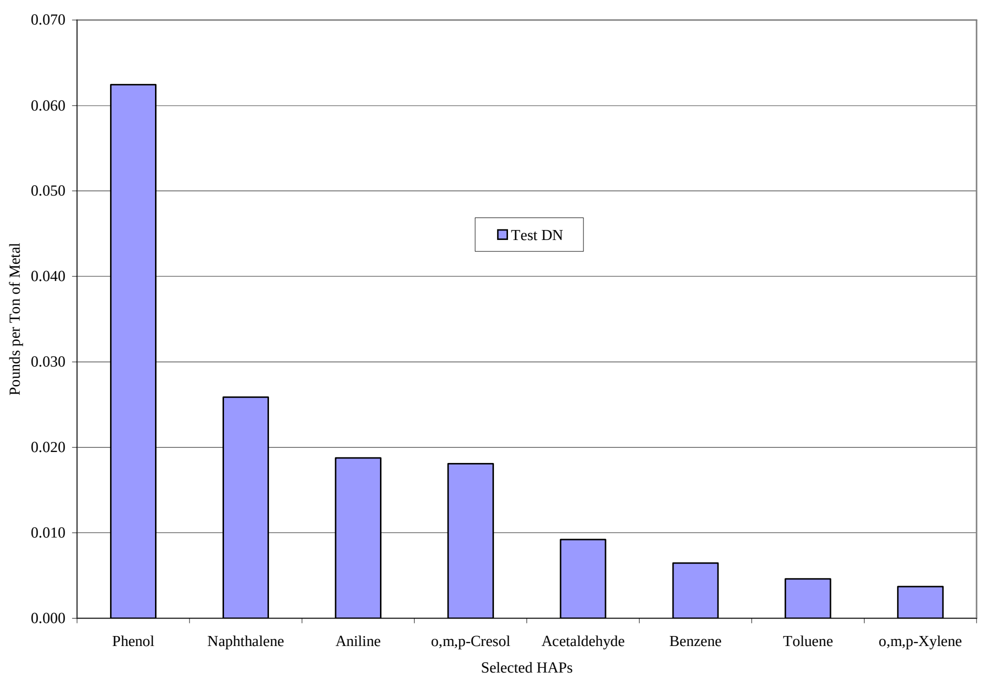
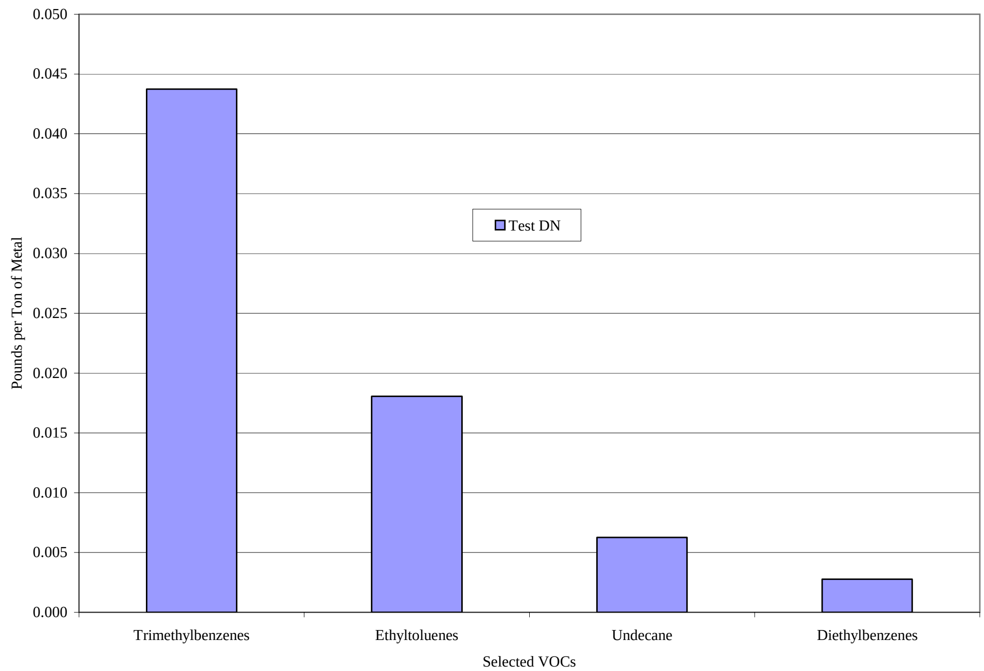


Figure 3-3 Selected VOC Emissions from Test Series DN



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4.0 Discussion of Results

Twelve (12) of the measured compounds comprise greater than 95% of the mass of all VOCs measured in the Greensand (Without Seacoal) Phenolic Urethane Aluminum baseline test series. Of these VOCs, eight (8) of the compounds, phenol, naphthalene, aniline, o,m,p-cresol, acetaldehyde, benzene, toluene, and o,m,p-xylene are HAPs, and one of them, naphthalene, is also a POM. Phenolic compounds and aromatic hydrocarbon compounds predominate the speciated emissions profile, both as VOCs and HAPs

Two methods were employed to measure undifferentiated hydrocarbon emissions, TGOC (THC) as propane, performed in accordance with EPA Method 25A, and HC as hexane. Both methods yielded similar values, expressed as pounds per ton of metal poured. This is true even though distinct differences in methodologies are present that would not necessarily be expected to produce equivalent results. 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 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.

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APPENDIX A APPROVED TEST PLAN FOR TEST SERIES DN

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TECHNIKON TEST PLAN

> **CONTRACT NUMBER**: 1256 **TASK NUMBER:** 120

> **CONTROL NUMBER: RV 1 00109**

> **SAMPLE FAMILY: DN**

> **SAMPLE EVENTS**: 001 Thru 010

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

> **TEST TYPE:** Delta HA Phenolic Urethane Coldbox Core (24-912 Part I, 23-907 Part II, TEA Activator) – Aluminum Core Baseline

> **MOLD TYPE:** Greensand without Seacoal

> **NUMBER OF MOLDS:** 10

> **CORE TYPE:** __Delta HA Phenolic Urethane Coldbox Step Cores

> **TEST DATE:** **START:** 26 Feb 2001
> **FINISH:** 28 FEB 2001

TEST OBJECTIVES:

PRIMARY: To measure emissions from an organic core in a greensand mold without Seacoal poured with aluminum in order to create a greensand core baseline for aluminum.

VARIABLES: The greensand will be made from virgin Wexdford W450 Lakesand, western and southern bentonite in the amount of 7.0 +/- 0.5 % in the ratio of 4:1, and water. No Seacoal is to be used. The step pattern will be used and the mold will be poured with A-356/357 aluminum at 1250 +/-10 degrees Fahrenheit.
Cores will be made from virgin Wexford W450 Lakesand and 1.2 % (BOS) Delta 24-912 part I and 23-907 Part II resin, TEA catalyzed.

BRIEF OVERVIEW: This test will become a greensand core baseline for aluminum.

SPECIAL CONDITIONS: The test will be monitored by the THC analyzer , tube and bag samples are to be taken, and condensable PUFs shall be employed.

Original Signed	2/20/01
Senior Process Engineer (Technikon)	**Date**
Original Signed	2/22/01
Research Manager (Technikon)	**Date**
Original Signed	2/21/01
Operations Manager (Technikon)	**Date**
Original Signed	2/22/01
Emissions Team (USCAR)	**Date**
Original Signed	2/22/01
Process and Facilities Team (USCAR)	**Date**
Original Signed	4/25/01
Project Manager	**Date**

Series DN

Pre-Production Process Instructions
Aluminum Core Greensand Baseline

A. Experiment: Experiment: Create a core baseline for organic core in greensand without Seacoal poured with aluminum.

B. Materials:

1. Mold sand: Virgin Wexford W450 Lake sand, Western and Southern Bentonite clay totaling 7 +/- 0.5 % in the ratio of 4:1, and water. No Seacoal is to be used.
2. Core: Eight step cores made from Wexford W450 bonded with 1.2 % (BOS) Delta Phenolic Urethane cold box resin 24-912 Part I and 23-907 part II in a 55/45 ratio.
3. Metal: A-356/357 Aluminum

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

C. Cores:

1. Mount CERP Step Core corebox on the Carver/Redford core machine.
2. Start the core machine auxiliary equipment per the Pilot foundry OSI for that equipment.
3. Set up the core machine in the cold box mode with gassing and working pressures and gas and purge time according to the core recipe sheet.
4. Run the machine for three (3) cycles and discard the cores. On the first good appearing core following the first three (3) perform a scratch hardness test in five (5) locations evenly spaced around the largest ring. Record the results on the Core Production Log. If the average of the five readings is greater than 50 begin test core manufacture.
5. Place eleven (11) step cores on each row of each shelf on each rack. Thirty-three (33) cores per shelf.
6. The sand lab will sample one (1) core from each shelf and row on each core rack and perform a scratch hardness and core LOI tests. If the scratch hardness falls below 50 the cores are not to be sent to pre-production or used in tests without the subsequent approval of the Process Engineer. The results will be reported with the associated date, sample time, rack, shelf, and row number. The sand lab will sample one (1) core from the core rack for each mold produced just prior to the emission test to represent the eight cores placed in that mold. Those cores will be tested for LOI at the 1050 degree Fahrenheit core LOI test method and reported out associated with the test mold it is to represent as **RESIN CONTENT LOI**. Qualified cores receiving the green **Quality Checked** tag must have **RESIN CONTENT LOI** values between **1.05-1.25%.** If any of the cores fall out of spec then each row out of spec must be rejected. Individual rows that qualify may have the Quality Checked tag affixed. Only cores with the green Quality Tag bearing the current test series and dates and signature of the lab technician may be taken to the mold assembly area.

D. Sand preparation

1. Start up batches: make 2: DN001, DNT002.
   - **a.** Thoroughly clean the pre-production muller.

b. Add a pre-weighed quantity of Lake sand (50 GFN) and Okie #1 sand (90 GFN) per the **new mixture recipe**, approximately 1600 pounds total to the running pre-production muller.

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 per the **new mixture recipe** slowly to the muller to allow them to be distributed throughout the sand mass.

e. Dry mull for about 3 minutes to allow distribution and some grinding of the clays to occur.

f. Split the batch into approximately equal sized portions.

g. To each half-batch temper the sand-clay mixture slowly with water to allow for distribution.

h. After about 2 gallons of water have been added allow 30 seconds of mixing then start taking compactability test samples.

i. 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%.

j. Discharge the sand into the mold half.

k. Record the total sand mixed in the combined batch, the total of each type of clay 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 7: DN003-DN010.

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 C.1.e.

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 be taken from within the muller at three locations approximately 120 degrees apart. The sand will be tested for 1500^{o}F LOI, 900^{o}F Volatiles, MB clay, compactability, moisture content, and green compressive strength and be reported associated with the mold (test number, DN00x) from which it was taken.

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

Caution: 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 be washed down the sprue.
- **f.** Remove the pattern, inspect and blow out the mold, and set the cores in the drag.
- **g.** Verify that the cores are fully set in their prints. The step cores will be flush with the parting line. If a piece of the mold is missing contact your supervisor for a decision on the acceptability of the mold.
- **h.** Vent the cope with ¼ vents according to the template.
- **i.** Close the mold straight being careful not to crush anything.
- **j.** Bolt the flask halves together and deliver the mold to the pouring area.

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
- **2.** Shakeout.
  - **a.** After the cooling time prescribed in the emission test, plan turn on the shakeout unit and run for the time prescribed in the emission test plan.
  - **b.** Turn off the shakeout, open the hood, remove the flask with casting, and recover the sand from the pit.
  - **c.** Weigh and record the closed unpoured mold weight, the core weight, cast metal weight, and the sand weight by difference.

G. Melting:
- **1.** Initial charge:
  - **a.** Use the 250 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^{o}F.
   - **f.** Slag the furnace and cover it.
   - **g.** Hold the furnace at 1250-1300^{o}F until near ready to tap.
   - **h.** When ready to tap, adjust the temperature to 1300-1325^{o}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 90 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.

H. Pouring:

1. Preheat the ladle.
2. Tap 180 pounds more or less of 1350^{o}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^{o}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 1250 +/- 10^{o}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.

Steven Knight
Sr. Process Engineer

PRE-PRODUCTION DN SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/26/01											Short pour, manifold blanks
EVENT 1											transferred to test DN002
AIRSENSE											
THC	DN00101	X									TOTAL
M-18 MS (quant)	DN00102		1						20	1	TOTAL M-18 MS
M-18 MS (quant)	DN00103				1				0	1	Manifold Blank now DN00211
Excess									20	2	Excess
M-18	DN00104		1						40	3	TOTAL M-18 FID
M-18	DN00105				1				0	3	Manifold Blank now DN00212
Excess	---								40	4	Excess
Gas, CO+CO2	DN00106		1						60	5	Tedlar Bag
NIOSH 1500 (short list)	DN00107		1						500	6	TOTAL (Orbo 32s)
NIOSH 1500 (short list)	DN00108				1				0	6	Manifold Blank now DN00213
Excess	---								500	7	Excess
NIOSH 2002	DN00109		1						1000	8	TOTAL (SKC 226-15)
NIOSH 2002	DN00110				1				0	8	Manifold Blank now DN00214
Excess	---								1000	9	Excess
TO11	DN00111		1						1000	10	TOTAL (DNPH)
TO11	DN00112				1				0	10	Manifold Blank now DN00215
Excess	---								1000	11	Excess
Moisture	---		1						500	12	TOTAL
Excess	---								2500	13	Excess
PUF	DN001		1						16L		

PRE-PRODUCTION DN SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/26/01											
EVENT 2											
AIRSENSE											
THC	DN00201	X									TOTAL
M-18 MS (quant)	DN00202		1						20	1	TOTAL M-18 MS
M-18 MS (quant)	DN00203					1			20	1	Breakthrough M-18 MS
Excess	---								20	2	Excess
M-18	DN00204		1						40	3	TOTAL M-18 FID
M-18	DN00205					1			40	3	Breakthrough M-18 FID
Excess	---								40	4	Excess
Gas, CO+CO2	DN00206		1						60	5	Tedlar Bag
NIOSH 1500 (short list)	DN00207		1						500	6	TOTAL (Orbo 32s)
Excess	---								500	7	Excess
NIOSH 2002	DN00208		1						1000	8	TOTAL (SKC 226-15)
Excess	---								1000	9	Excess
TO11	DN00209		1						1000	10	TOTAL (DNPH)
TO11	DN00210					1			1000	10	Breakthrough (DNPH)
Excess	---								1000	11	Excess
Moisture	---		1						500	12	TOTAL
Excess	---								2500	13	Excess
PUF	DN002		1						16L		

M-18 MS (quant)	DN00211				1				0	1	Manifold Blank was DN00103
M-18	DN00212				1				0	3	Manifold Blank was DN00105
NIOSH 1500 (short list)	DN00213				1				0	6	Manifold Blank was DN00108
NIOSH 2002	DN00214				1				0	8	Manifold Blank was DN00110
TO11	DN00215				1				0	10	Manifold Blank was DN00112

PRE-PRODUCTION DN SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/26/01											
EVENT 3											
AIRSENSE											
THC	DN00301	X									TOTAL
M-18 MS (quant)	DN00302		1						20	1	TOTAL M-18 MS
M-18 MS (quant)	DN00303			1					20	2	DUP M-18 MS
M-18	DN00304		1						40	3	TOTAL M-18 FID
M-18	DN00305			1					40	4	DUP M-18 FID
Gas, CO+CO2	DN00306		1						60	5	Tedlar Bag
NIOSH 1500 (short list)	DN00307		1						500	6	TOTAL (Orbo 32s)
NIOSH 1500 (short list)	DN00308			1					500	7	DUP (Orbo 32s)
NIOSH 2002	DN00309		1						1000	8	TOTAL (SKC 226-15)
NIOSH 2002	DN00310			1					1000	9	DUP (SKC 226-15)
TO11	DN00311		1						1000	10	TOTAL (DNPH)
TO11	DN00312			1					1000	11	DUP (DNPH)
Moisture	---		1						500	12	TOTAL
Excess	---								2500	13	Excess
PUF	DN003		1						16L		

PRE-PRODUCTION DN SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/27/01											
EVENT 4											
AIRSENSE											
THC	DN00401	X									TOTAL
M-18 MS (quant)	DN00402		1						20	1	TOTAL M-18 MS
M-18 MS (quant)	DN00403				1				0	1	QC Blank
Excess	---								20	2	Excess
M-18	DN00404		1						40	3	TOTAL M-18 FID
M-18	DN00405				1				0	3	QC Blank
Excess	---								40	4	Excess
Gas, CO+CO2	DN00406		1						60	5	Tedlar Bag
NIOSH 1500 (short list)	DN00407		1						500	6	TOTAL (Orbo 32s)
NIOSH 1500 (short list)	DN00408				1				0	6	QC Blank
Excess	---								500	7	Excess
NIOSH 2002	DN00409		1						1000	8	TOTAL (SKC 226-15)
NIOSH 2002	DN00410				1				0	8	QC Blank
Excess	---								1000	9	Excess
TO11	DN00411		1						1000	10	TOTAL (DNPH)
TO11	DN00412				1				0	10	QC Blank
Excess	---								1000	11	Excess
Moisture	---		1						500	12	TOTAL
Excess	---								2500	13	Excess
PUF	DN004		1						16L		

PRE-PRODUCTION DN SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/27/01											
EVENT 5											
AIRSENSE											
THC	DN00501	X									TOTAL
M-18 MS (quant)	DN00502		1						20	1	TOTAL M-18 MS
Excess	---								20	2	Excess
M-18	DN00503		1						40	3	TOTAL M-18 FID
Excess	---								40	4	Excess
Gas, CO+CO2	DN00504		1						60	5	Tedlar Bag
NIOSH 1500 (short list)	DN00505		1						500	6	TOTAL (Orbo 32s)
Excess	---								500	7	Excess
NIOSH 2002	DN00506		1						1000	8	TOTAL (SKC 226-15)
Excess	---								1000	9	Excess
TO11	DN00507		1						1000	10	TOTAL (DNPH)
Excess	---								1000	11	Excess
Moisture	---		1						500	12	TOTAL
Excess	---								2500	13	Excess
PUF	DN005		1						16L		

PRE-PRODUCTION DN SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/27/01											
EVENT 6											
AIRSENSE											
THC	DN00601	X									TOTAL
M-18 MS (quant)	DN00602		1						20	1	TOTAL M-18 MS
Excess	---								20	2	Excess
M-18	DN00603		1						40	3	TOTAL M-18 FID
Excess	---								40	4	Excess
Gas, CO+CO2	DN00604		1						60	5	Tedlar Bag
NIOSH 1500 (short list)	DN00605		1						500	6	TOTAL (Orbo 32s)
Excess	---								500	7	Excess
NIOSH 2002	DN00606		1						1000	8	TOTAL (SKC 226-15)
Excess	---								1000	9	Excess
TO11	DN00607		1						1000	10	TOTAL (DNPH)
Excess	---								1000	11	Excess
Moisture	---		1						500	12	TOTAL
Excess	---								2500	13	Excess
PUF	DN006		1						16L		

PRE-PRODUCTION DN SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/28/01											
EVENT 7											
AIRSENSE											
THC	DN00701	X									TOTAL
M-18 MS (quant)	DN00702		1						20	1	TOTAL M-18 MS
M-18 MS (quant)	DN00703			1					20	2	DUP M-18 MS
M-18	DN00704		1						40	3	TOTAL M-18 FID
M-18	DN00705			1					40	4	DUP M-18 FID
Gas, CO+CO2	DN00706		1						60	5	Tedlar Bag
NIOSH 1500 (short list)	DN00707		1						500	6	TOTAL (Orbo 32s)
NIOSH 1500 (short list)	DN00708			1					500	7	DUP (Orbo 32s)
NIOSH 2002	DN00709		1						1000	8	TOTAL (SKC 226-15)
NIOSH 2002	DN00710			1					1000	9	DUP (SKC 226-15)
TO11	DN00711		1						1000	10	TOTAL (DNPH)
TO11	DN00712			1					1000	11	DUP (DNPH)
Moisture	---		1						500	12	TOTAL
Excess	---								2500	13	Excess
PUF	DN007		1						16L		

PRE-PRODUCTION DN SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/28/01											
EVENT 8											
AIRSENSE											
THC	DN00801	X									TOTAL
M-18 MS (quant)	DN00802		1						20	1	TOTAL M-18 MS
Excess	---								20	2	Excess
M-18	DN00803		1						40	3	TOTAL M-18 FID
Excess	---								40	4	Excess
Gas, CO+CO2	DN00804		1						60	5	Tedlar Bag
NIOSH 1500 (short list)	DN00805		1						500	6	TOTAL (Orbo 32s)
Excess	---								500	7	Excess
NIOSH 2002	DN00806		1						1000	8	TOTAL (SKC 226-15)
Excess	---								1000	9	Excess
TO11	DN00807		1						1000	10	TOTAL (DNPH)
Excess	---								1000	11	Excess
Moisture	---		1						500	12	TOTAL
Excess	---								2500	13	Excess
PUF	DN008		1						16L		

PRE-PRODUCTION DN SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/28/01											
EVENT 9											
AIRSENSE											
THC	DN00901	X									TOTAL
M-18 MS (quant)	DN00902		1						20	1	TOTAL M-18 MS
Excess	---								20	2	Excess
M-18	DN00903		1						40	3	TOTAL M-18 FID
Excess	---								40	4	Excess
Gas, CO+CO2	DN00904		1						60	5	Tedlar Bag
NIOSH 1500 (short list)	DN00905		1						500	6	TOTAL (Orbo 32s)
Excess	---								500	7	Excess
NIOSH 2002	DN00906		1						1000	8	TOTAL (SKC 226-15)
Excess	---								1000	9	Excess
TO11	DN00907		1						1000	10	TOTAL (DNPH)
Excess	---								1000	11	Excess
Moisture	---		1						500	12	TOTAL
Excess	---								2500	13	Excess
PUF	DN009		1						16L		

PRE-PRODUCTION DN SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
2/28/01											
EVENT 10											
AIRSENSE											
THC	DN01001	X									TOTAL
M-18 MS (quant)	DN01002		1						20	1	TOTAL M-18 MS
Excess	---								20	2	Excess
M-18	DN01003		1						40	3	TOTAL M-18 FID
Excess	---								40	4	Excess
Gas, CO+CO2	DN01004		1						60	5	Tedlar Bag
NIOSH 1500 (short list)	DN01005		1						500	6	TOTAL (Orbo 32s)
Excess	---								500	7	Excess
NIOSH 2002	DN01006		1						1000	8	TOTAL (SKC 226-15)
Excess	---								1000	9	Excess
TO11	DN01007		1						1000	10	TOTAL (DNPH)
Excess	---								1000	11	Excess
Moisture	---		1						500	12	TOTAL
Excess	---								2500	13	Excess
PUF	DN010		1						16L		
M-18	DN01008						X		40		BOTTLE - Mix 1A
M-18	DN01009						X		40		BOTTLE - Mix 1A
TO11	DN01010						X		1000		BOTTLE - Mix 2
TO11	DN01011						X		1000		BOTTLE - Mix 2

APPENDIX B TEST SERIES DN DETAILED RESULTS

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Test Plan DN Individual Test Results – Lb/Tn Metal													
POMs	HAPs	COMPOUND / SAMPLE NUMBER	DN002	DN003	DN004	DN005	DN006	DN007	DN008	DN009	DN010	Average	STDEV
		Pour Date	**2/26/01**	**2/26/01**	**2/27/01**	**2/27/01**	**2/27/01**	**2/28/01**	**2/28/01**	**2/28/01**	**2/28/01**		
		TGOC (THC) as Propane	1.50E+00	1.87E+00	1.61E+00	1.57E+00	1.56E+00	1.82E+00	1.48E+00	1.44E+00	1.63E+00	1.61E+00	1.49E-01
		HC as Hexane	1.82E+00	1.97E+00	1.61E+00	1.47E+00	1.39E+00	1.69E+00	1.31E+00	1.09E+00	1.41E+00	1.53E+00	2.73E-01
		Sum of VOCs	1.87E-01	2.50E-01	2.32E-01	2.29E-01	2.29E-01	3.07E-01	2.03E-01	2.25E-01	2.11E-01	2.30E-01	3.40E-02
		Sum of HAPs	1.13E-01	1.69E-01	1.55E-01	1.49E-01	1.54E-01	2.13E-01	1.38E-01	1.52E-01	1.43E-01	1.54E-01	2.70E-02
		Sum of POMs	2.73E-02	3.63E-02	3.33E-02	2.55E-02	2.43E-02	3.73E-02	2.04E-02	2.28E-02	1.92E-02	2.74E-02	6.72E-03
			Individual HAPs and VOCs										
	z	**Phenol**	4.12E-02	6.07E-02	6.12E-02	6.09E-02	6.54E-02	9.16E-02	5.54E-02	6.80E-02	5.75E-02	6.24E-02	1.33E-02
		Trimethylbenzenes	4.49E-02	4.61E-02	4.56E-02	4.59E-02	4.34E-02	4.90E-02	3.85E-02	4.06E-02	3.97E-02	4.37E-02	3.47E-03
x	z	**Naphthalene**	2.73E-02	3.20E-02	2.87E-02	2.55E-02	2.43E-02	3.26E-02	2.04E-02	2.28E-02	1.92E-02	2.59E-02	4.73E-03
	z	**Aniline**	7.77E-03	2.65E-02	1.77E-02	1.62E-02	1.79E-02	2.80E-02	1.77E-02	1.49E-02	2.22E-02	1.88E-02	6.16E-03
	z	**o,m,p-Cresol**	1.08E-02	2.02E-02	1.68E-02	1.93E-02	1.76E-02	2.56E-02	1.72E-02	1.76E-02	1.76E-02	1.81E-02	3.85E-03
		Ethyltoluenes	1.53E-02	1.84E-02	1.83E-02	1.83E-02	1.84E-02	2.30E-02	1.62E-02	1.80E-02	1.65E-02	1.81E-02	2.20E-03
	z	**Acetaldehyde**	9.02E-03	8.89E-03	9.02E-03	9.21E-03	9.53E-03	9.94E-03	8.59E-03	9.35E-03	9.31E-03	9.21E-03	3.90E-04
	z	**Benzene**	6.14E-03	5.30E-03	5.56E-03	6.66E-03	6.50E-03	7.03E-03	7.12E-03	7.61E-03	6.28E-03	6.47E-03	7.44E-04
		Undecane	5.69E-03	6.54E-03	6.38E-03	6.36E-03	6.19E-03	8.55E-03	5.29E-03	5.86E-03	5.52E-03	6.26E-03	9.55E-04
	z	**Toluene**	4.25E-03	3.73E-03	4.67E-03	4.70E-03	4.57E-03	5.05E-03	5.12E-03	5.20E-03	4.21E-03	4.61E-03	4.84E-04
	z	**o,m,p-Xylene**	3.12E-03	2.86E-03	3.79E-03	3.72E-03	4.09E-03	4.59E-03	3.92E-03	3.94E-03	3.36E-03	3.71E-03	5.25E-04
		Diethylbenzenes	3.34E-03	3.64E-03	3.04E-03	2.99E-03	3.22E-03	3.36E-03	ND	2.77E-03	2.51E-03	2.76E-03	1.09E-03
		Butyraldehyde/Methacrolien	1.74E-03	2.27E-03	2.37E-03	2.17E-03	2.61E-03	3.32E-03	2.19E-03	2.57E-03	2.74E-03	2.44E-03	4.44E-04
	z	**2-Butanone**	1.30E-03	1.95E-03	1.55E-03	1.61E-03	1.96E-03	2.65E-03	1.59E-03	1.74E-03	2.16E-03	1.83E-03	3.98E-04
		Dodecane	2.89E-03	1.74E-03	ND	2.85E-03	ND	1.65E-03	2.42E-03	2.41E-03	ND	1.55E-03	1.24E-03
x	z	**Methylnaphthalenes**	ND	4.31E-03	4.51E-03	ND	ND	4.66E-03	ND	ND	ND	1.50E-03	2.25E-03
	z	**Formaldehyde**	1.88E-03	1.69E-03	1.31E-03	1.18E-03	1.23E-03	1.25E-03	8.11E-04	8.46E-04	8.36E-04	1.23E-03	3.75E-04
		Pentanal	I	7.23E-04	7.55E-04	7.98E-04	8.71E-04	1.13E-03	6.83E-04	6.94E-04	7.85E-04	8.05E-04	1.44E-04
		Tridecane	ND	1.22E-03	ND	ND	ND	2.69E-03	ND	ND	ND	4.34E-04	9.37E-04
		Benzaldehyde	ND	4.69E-04	4.55E-04	3.64E-04	4.90E-04	6.52E-04	ND	ND	4.78E-04	3.23E-04	2.53E-04
	z	**Propionaldehyde**	ND	2.22E-04	ND	3.70E-04	4.45E-04	2.05E-04	ND	ND	ND	1.38E-04	1.78E-04
	z	**Acrolein**	ND	5.13E-04	ND	ND	ND	ND	ND	ND	ND	5.70E-05	1.71E-04
x	z	**Dimethylnaphthalenes**	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
x	z	**2,3,5-Trimethylnaphthalene**	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A

Test Plan DN Individual Test Results – Lb/Tn Metal

POMs	HAPs	COMPOUND / SAMPLE NUMBER	DN002	DN003	DN004	DN005	DN006	DN007	DN008	DN009	DN010	Average	STDEV
		Pour Date	2/26/01	2/26/01	2/27/01	2/27/01	2/27/01	2/28/01	2/28/01	2/28/01	2/28/01		
	z	Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	z	Cumene	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	z	Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	z	Hexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	z	N,N-Dimethylaniline	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	z	Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		1,3-Diisopropylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Trimethylphenols	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Dimethylphenols	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
x		Acenaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		a-Methylstyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Butylbenzenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Crotonaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Heptane	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Hexaldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Indene	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		n-Propylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		p-Cymene	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Tetradecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
			Other Analytes										
		Condensables	6.04E-01	5.95E-01	5.60E-01	6.54E-01	5.94E-01	5.57E-01	5.30E-01	4.99E-01	4.49E-01	5.60E-01	6.14E-02
		Carbon Monoxide	ND	ND	ND	ND	N/A	ND	ND	ND	ND	N/A	N/A
		Methane	ND	ND	ND	ND	N/A	ND	ND	ND	ND	N/A	N/A

Test Plan DN Individual Test Results – Lb/Tn Metal													
POMs	**HAPs**	**COMPOUND / SAMPLE NUMBER**	**DN002**	**DN003**	**DN004**	**DN005**	**DN006**	**DN007**	**DN008**	**DN009**	**DN010**	**Average**	**STDEV**
		Pour Date	**2/26/01**	**2/26/01**	**2/27/01**	**2/27/01**	**2/27/01**	**2/28/01**	**2/28/01**	**2/28/01**	**2/28/01**		
		Carbon Dioxide	6.02E+01	5.86E+01	6.37E+01	6.08E+01	N/A	5.85E+01	5.67E+01	5.60E+01	I	5.92E+01	2.63E+00
		Ethane	ND	ND	ND	ND	N/A	ND	ND	ND	ND	N/A	N/A
		Propane	ND	ND	ND	ND	N/A	ND	ND	ND	ND	N/A	N/A
		Isobutane	ND	ND	ND	ND	N/A	ND	ND	ND	ND	N/A	N/A
		Butane	ND	ND	ND	ND	N/A	ND	ND	ND	ND	N/A	N/A
		Neopentane	ND	ND	ND	ND	N/A	ND	ND	ND	ND	N/A	N/A
		Isopentane	ND	ND	ND	ND	N/A	ND	ND	ND	ND	N/A	N/A
		Pentane	ND	ND	ND	ND	N/A	ND	ND	ND	ND	N/A	N/A
		Acetone	5.31E-03	1.09E-02	4.37E-03	4.39E-03	4.14E-03	4.73E-03	4.04E-03	3.98E-03	4.43E-03	5.14E-03	2.20E-03

I: Data was rejected based on data validation considerations.
All "Other Analytes" are not included in the sum of HAPs or VOCs.
N/A: Not Applicable; NT: Not Tested; ND: Non-Detect

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APPENDIX C TEST SERIES DN DETAILED PROCESS AND SOURCE DATA

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Test DN Process and Source Data												
Description	**DN001**	**DN002**	**DN003**	**DN004**	**DN005**	**DN006**	**DN007**	**DN008**	**DN009**	**DN010**	**Averages**	**Averages**
	2/26/01	**2/26/01**	**2/26/01**	**2/27/01**	**2/27/01**	**2/27/01**	**2/27/01**	**2/28/01**	**2/28/01**	**2/28/01**	**all**	**DN002-010**
Casting Metal Weight, lbs.	80	**87**	**88**	**86**	**88**	**89**	**87**	**89**	**89**	**87**	87	**88**
Total Mold Weight, lbs.	1396	**1403**	**1456**	**1403**	**1387**	**1424**	**1416**	**1413**	**1396**	**1403**	1410	**1411**
Total Core Weight, lbs.	58.77	**58.84**	**58.85**	**58.56**	**58.36**	**58.38**	**58.51**	**58.63**	**58.57**	**58.56**	58.60	**58.58**
Compactability, %	52	**50**	**51**	**48**	**49**	**49**	**49**	**49**	**48**	**48**	49	**49**
Total Binder Weight, lbs	0.697	**0.697**	**0.697**	**0.694**	**0.692**	**0.692**	**0.693**	**0.695**	**0.694**	**0.694**	0.694	**0.694**
No. Cavities Poured	7	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	8	**8**
LOI, % (at mold) 1800°F	-	**0.87**	**0.87**	**0.86**	**0.87**	**0.9**	**0.92**	**0.9**	**0.91**	**0.86**	0.88	**0.88**
Clays, % (at mold)	6.51	**6.90**	**6.64**	**7.03**	**6.77**	**7.03**	**6.90**	**6.64**	**6.51**	**6.64**	6.76	**6.78**
Clays, % (at shakeout)	6.90	**6.77**	**6.64**	**6.12**	**5.60**	**4.69**	**6.77**	**6.64**	**5.86**	**6.38**	6.24	**6.16**
LOI, % (Cores) 1400°F	-	**1.18**	**1.23**	**1.23**	**1.26**	**1.33**	**1.14**	**1.27**	**1.30**	**1.21**	1.24	**1.24**
Volatiles, % (at mold) avg. 900°F	0.22	**0.20**	**0.30**	**0.26**	**0.26**	**0.26**	**0.30**	**0.30**	**0.30**	**0.32**	0.27	**0.28**
Volatiles, % (at shakeout) avg. 900°F	0.28	**0.24**	**0.28**	**0.24**	**0.26**	**0.26**	**0.30**	**0.30**	**0.26**	**0.36**	0.28	**0.28**
Pouring Temperature, °F	1253	**1271**	**1279**	**1278**	**1260**	**1279**	**1269**	**1281**	**1269**	**1270**	1271	**1273**
Mold Strength, psi	7.74	**8.54**	**6.45**	**6.45**	**10.02**	**9.97**	**10.16**	**10.22**	**10.16**	**10.58**	9.03	**9.17**
Core Binder, true %	1.18	**1.18**	**1.18**	**1.18**	**1.18**	**1.18**	**1.18**	**1.18**	**1.18**	**1.18**	1.18	**1.18**
Water Type used in Mold	Tap	**Tap**	**Tap**	**Tap**	**Tap**	**Tap**	**Tap**	**Tap**	**Tap**	**Tap**	Tap	**Tap**
Total Clays - added, lbs/mold	88.00	**87.60**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	17.56	9.73
Seacoal - added, lbs/mold	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.00	0.00
Average Stack Temperature, °F	79	**82**	**82**	**78**	**81**	**83**	**83**	**78**	**81**	**83**	81	**81**
Total Moisture Content, %	1.14	**1.17**	**1.38**	**1.07**	**0.99**	**0.97**	**0.98**	**0.66**	**0.68**	**0.66**	0.97	**0.95**
Average Stack Velocity, ft./sec.	15.8	**15.6**	**16.1**	**15.8**	**15.8**	**15.8**	**15.9**	**15.5**	**15.8**	**15.8**	15.8	**15.8**
Avg. Stack Pressure, in. Hg	29.93	**29.90**	**29.90**	**30.01**	**29.98**	**29.95**	**29.88**	**29.91**	**29.90**	**29.90**	29.93	**29.93**
Stack Flow Rate, scfm	721	**707**	**729**	**723**	**722**	**720**	**719**	**713**	**722**	**721**	720	**720**

BO = Based on ( )
Binder = Resin + Co-reactant
Binder fraction = (binder (lbs)/(sand + binder (lbs)) Binder fraction x core weight used in mold = Total Binder Weight
Example: (2.40 /(200 + 2.40)) = 0.01185 x 58.77 = 0.6969 (lbs binder per mold). % Resin cores.
Note 1: Type of metal poured is Aluminum.
Note 2: DN001 was a short pour. Only seven out of eight cavities were poured. This test will not be used in the average for report.
Note 3: Average for clay additions; No additions were required after initial set-up. DN001 and DN002 "average all" is average of DN001-010. Average 002-010 is average for tests 2-10 only.

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APPENDIX D METHOD 25A CHARTS

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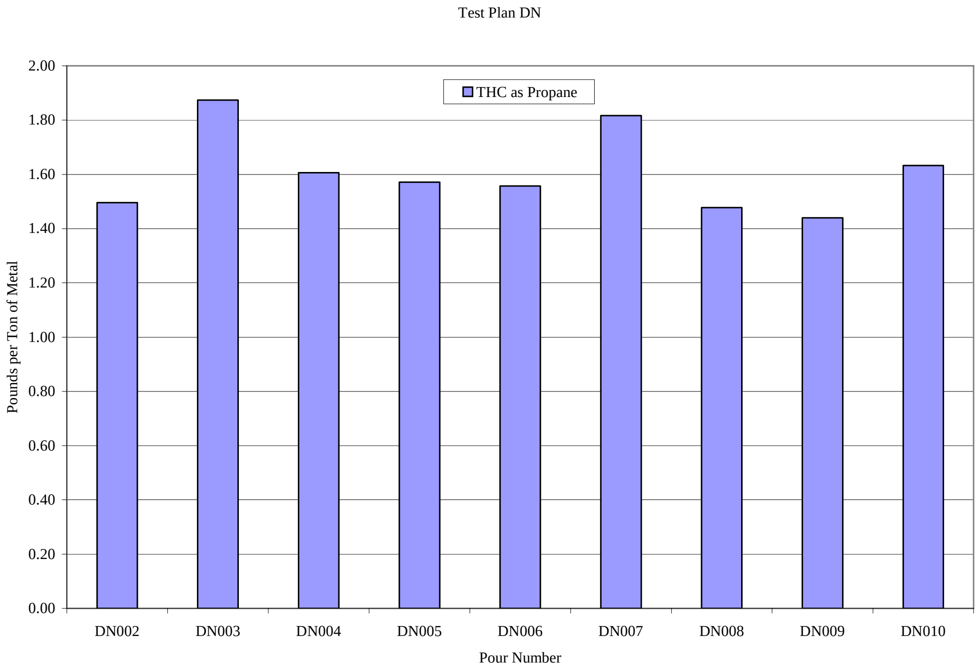
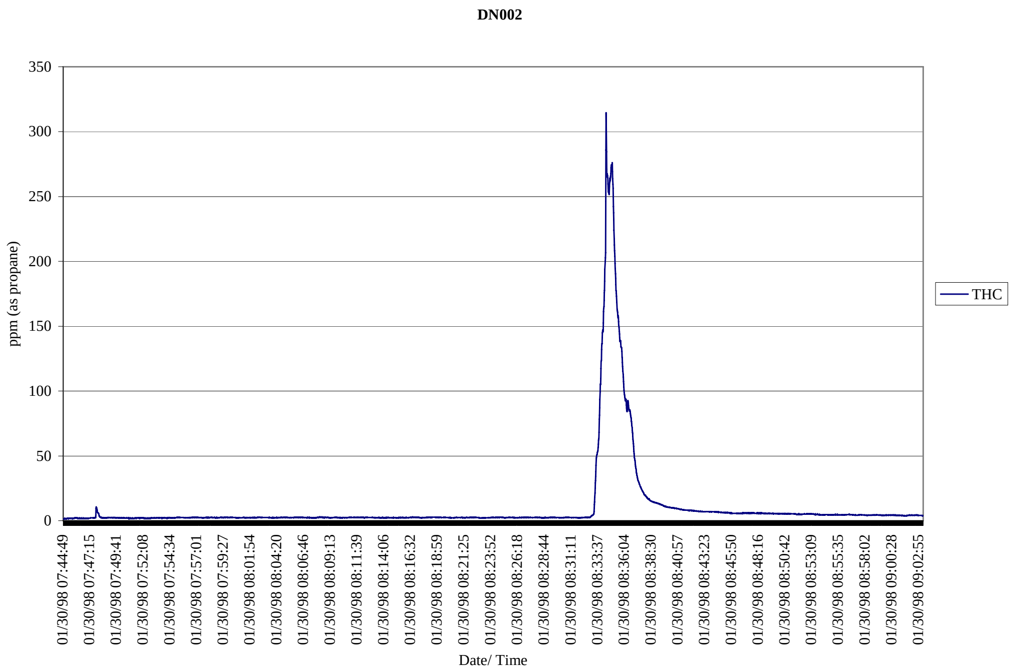
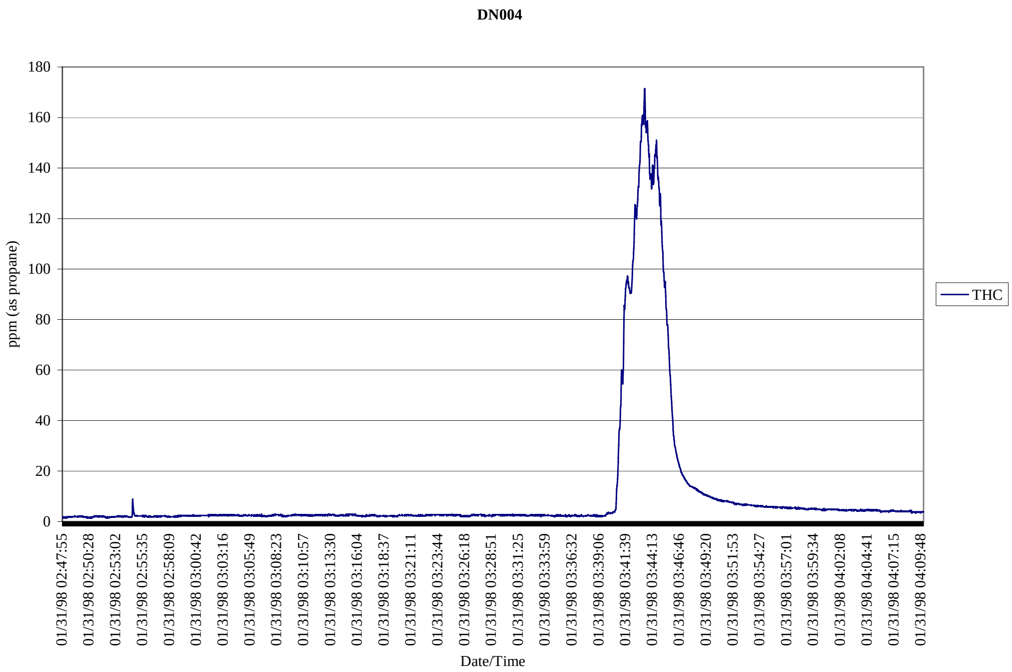
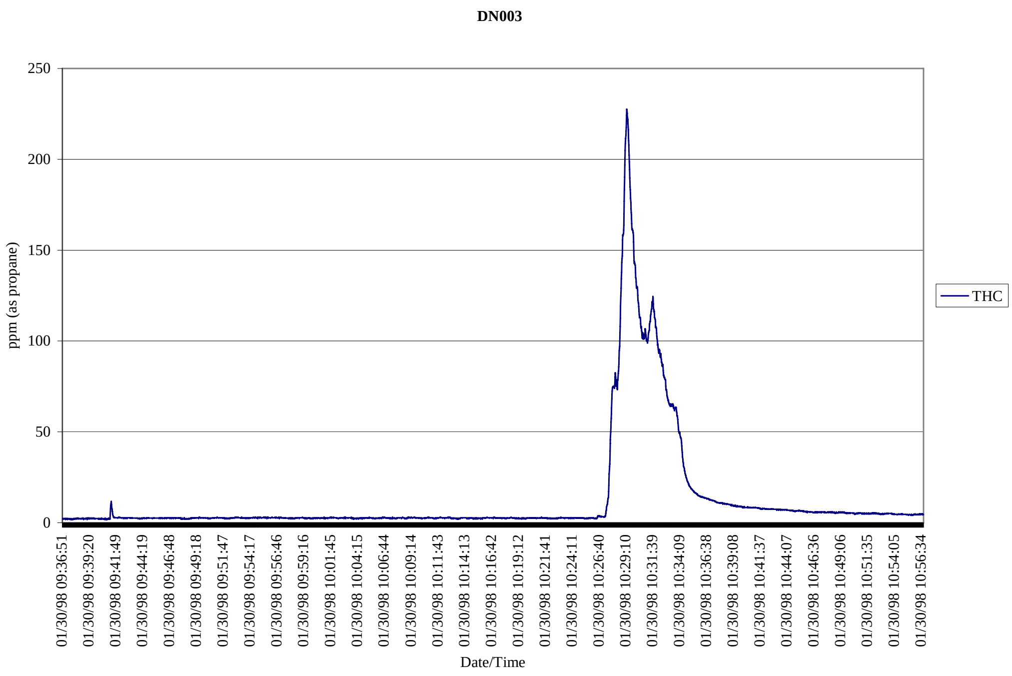
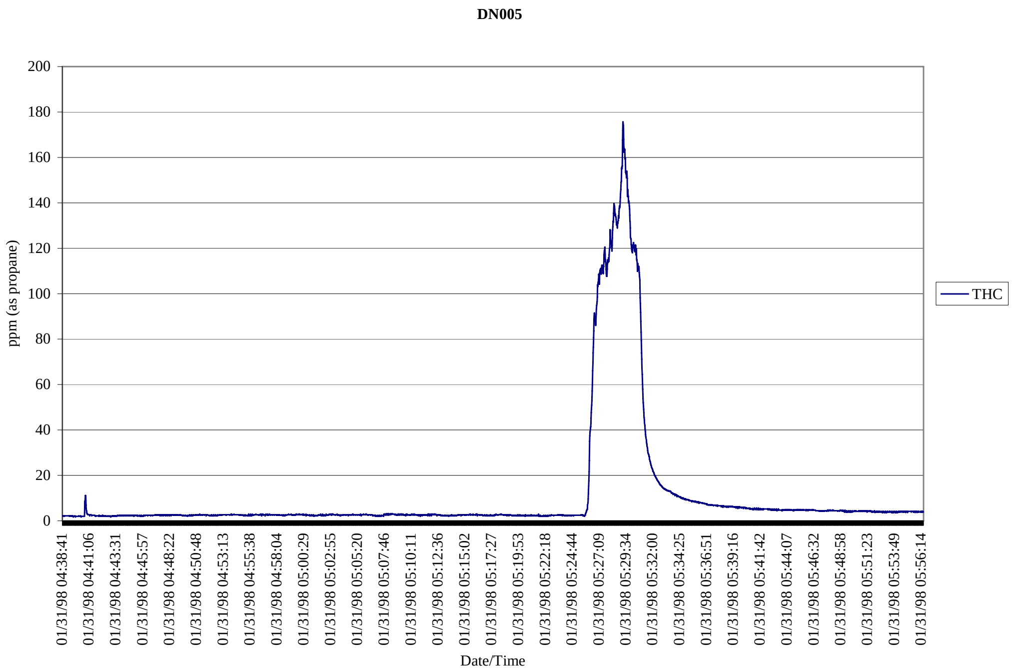
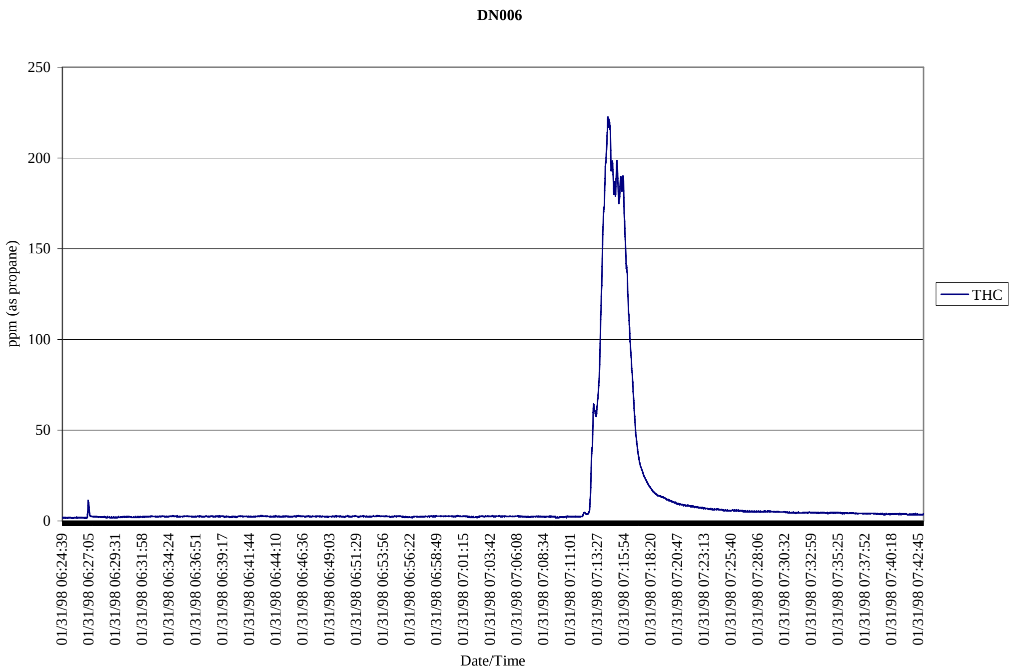

Test Plan DN
THC as Propane
Pounds per Ton of Metal
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
DN002
DN003
DN004
DN005
DN006
DN007
DN008
DN009
DN010
Pour Number

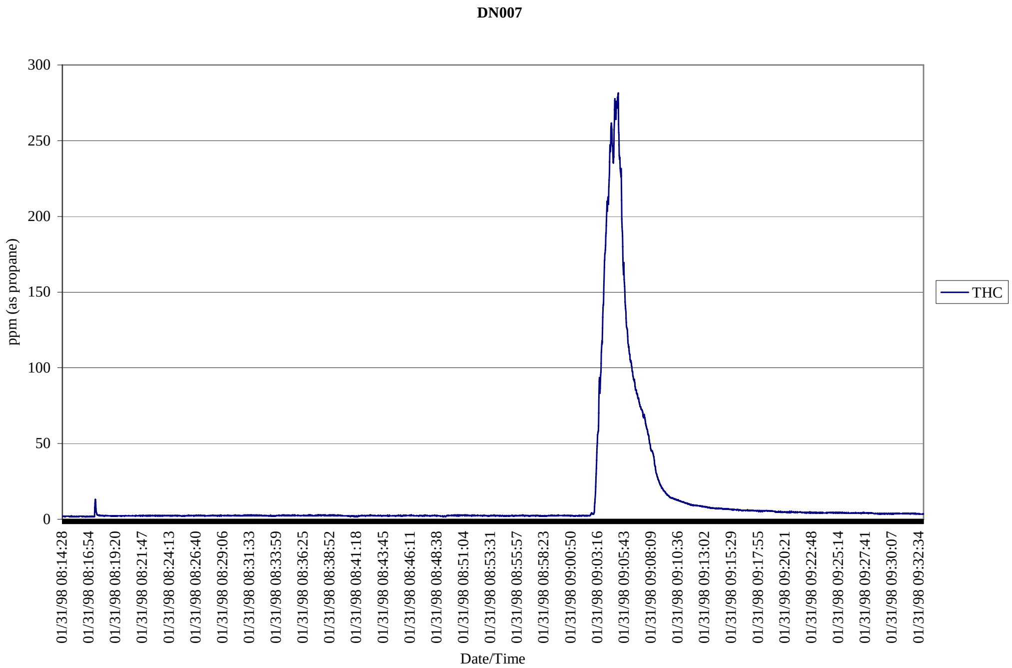

DN002
ppm (as propane)
0
50
100
150
200
250
300
350
THC
01/30/98 07:44:49
01/30/98 07:47:15
01/30/98 07:49:41
01/30/98 07:52:08
01/30/98 07:54:34
01/30/98 07:57:01
01/30/98 07:59:27
01/30/98 08:01:54
01/30/98 08:04:20
01/30/98 08:06:46
01/30/98 08:09:13
01/30/98 08:11:39
01/30/98 08:14:06
01/30/98 08:16:32
01/30/98 08:18:59
01/30/98 08:21:25
01/30/98 08:23:52
01/30/98 08:26:18
01/30/98 08:28:44
01/30/98 08:31:11
01/30/98 08:33:37
01/30/98 08:36:04
01/30/98 08:38:30
01/30/98 08:40:57
01/30/98 08:43:23
01/30/98 08:45:50
01/30/98 08:48:16
01/30/98 08:50:42
01/30/98 08:53:09
01/30/98 08:55:35
01/30/98 08:58:02
01/30/98 09:00:28
01/30/98 09:02:55
Date/ Time


DN004
ppm (as propane)
THC
Date/Time
180
160
140
120
100
80
60
40
20
0
01/31/98 02:47:55
01/31/98 02:50:28
01/31/98 02:53:02
01/31/98 02:55:35
01/31/98 02:58:09
01/31/98 03:00:42
01/31/98 03:03:16
01/31/98 03:05:49
01/31/98 03:08:23
01/31/98 03:10:57
01/31/98 03:13:30
01/31/98 03:16:04
01/31/98 03:18:37
01/31/98 03:21:11
01/31/98 03:23:44
01/31/98 03:26:18
01/31/98 03:28:51
01/31/98 03:31:25
01/31/98 03:33:59
01/31/98 03:36:32
01/31/98 03:39:06
01/31/98 03:41:39
01/31/98 03:44:13
01/31/98 03:46:46
01/31/98 03:49:20
01/31/98 03:51:53
01/31/98 03:54:27
01/31/98 03:57:01
01/31/98 03:59:34
01/31/98 04:02:08
01/31/98 04:04:41
01/31/98 04:07:15
01/31/98 04:09:48


DN003
ppm (as propane)
THC
Date/Time
250
200
150
100
50
0
01/30/98 09:36:51
01/30/98 09:39:20
01/30/98 09:41:49
01/30/98 09:44:19
01/30/98 09:46:48
01/30/98 09:49:18
01/30/98 09:51:47
01/30/98 09:54:17
01/30/98 09:56:46
01/30/98 09:59:16
01/30/98 10:01:45
01/30/98 10:04:15
01/30/98 10:06:44
01/30/98 10:09:14
01/30/98 10:11:43
01/30/98 10:14:13
01/30/98 10:16:42
01/30/98 10:19:12
01/30/98 10:21:41
01/30/98 10:24:11
01/30/98 10:26:40
01/30/98 10:29:10
01/30/98 10:31:39
01/30/98 10:34:09
01/30/98 10:36:38
01/30/98 10:39:08
01/30/98 10:41:37
01/30/98 10:44:07
01/30/98 10:46:36
01/30/98 10:49:06
01/30/98 10:51:35
01/30/98 10:54:05
01/30/98 10:56:34


DN005
ppm (as propane)
Date/Time
THC
0
20
40
60
80
100
120
140
160
180
200
01/31/98 04:38:41
01/31/98 04:41:06
01/31/98 04:43:31
01/31/98 04:45:57
01/31/98 04:48:22
01/31/98 04:50:48
01/31/98 04:53:13
01/31/98 04:55:38
01/31/98 04:58:04
01/31/98 05:00:29
01/31/98 05:02:55
01/31/98 05:05:20
01/31/98 05:07:46
01/31/98 05:10:11
01/31/98 05:12:36
01/31/98 05:15:02
01/31/98 05:17:27
01/31/98 05:19:53
01/31/98 05:22:18
01/31/98 05:24:44
01/31/98 05:27:09
01/31/98 05:29:34
01/31/98 05:32:00
01/31/98 05:34:25
01/31/98 05:36:51
01/31/98 05:39:16
01/31/98 05:41:42
01/31/98 05:44:07
01/31/98 05:46:32
01/31/98 05:48:58
01/31/98 05:51:23
01/31/98 05:53:49
01/31/98 05:56:14


DN006
ppm (as propane)
Date/Time
THC
0
50
100
150
200
250
01/31/98 06:24:39
01/31/98 06:27:05
01/31/98 06:29:31
01/31/98 06:31:58
01/31/98 06:34:24
01/31/98 06:36:51
01/31/98 06:39:17
01/31/98 06:41:44
01/31/98 06:44:10
01/31/98 06:46:36
01/31/98 06:49:03
01/31/98 06:51:29
01/31/98 06:53:56
01/31/98 06:56:22
01/31/98 06:58:49
01/31/98 07:01:15
01/31/98 07:03:42
01/31/98 07:06:08
01/31/98 07:08:34
01/31/98 07:11:01
01/31/98 07:13:27
01/31/98 07:15:54
01/31/98 07:18:20
01/31/98 07:20:47
01/31/98 07:23:13
01/31/98 07:25:40
01/31/98 07:28:06
01/31/98 07:30:32
01/31/98 07:32:59
01/31/98 07:35:25
01/31/98 07:37:52
01/31/98 07:40:18
01/31/98 07:42:45


DN007
ppm (as propane)
300
250
200
150
100
50
0
Date/Time
THC
01/31/98 08:14:28
01/31/98 08:16:54
01/31/98 08:19:20
01/31/98 08:21:47
01/31/98 08:24:13
01/31/98 08:26:40
01/31/98 08:29:06
01/31/98 08:31:33
01/31/98 08:33:59
01/31/98 08:36:25
01/31/98 08:38:52
01/31/98 08:41:18
01/31/98 08:43:45
01/31/98 08:46:11
01/31/98 08:48:38
01/31/98 08:51:04
01/31/98 08:53:31
01/31/98 08:55:57
01/31/98 08:58:23
01/31/98 09:00:50
01/31/98 09:03:16
01/31/98 09:05:43
01/31/98 09:08:09
01/31/98 09:10:36
01/31/98 09:13:02
01/31/98 09:15:29
01/31/98 09:17:55
01/31/98 09:20:21
01/31/98 09:22:48
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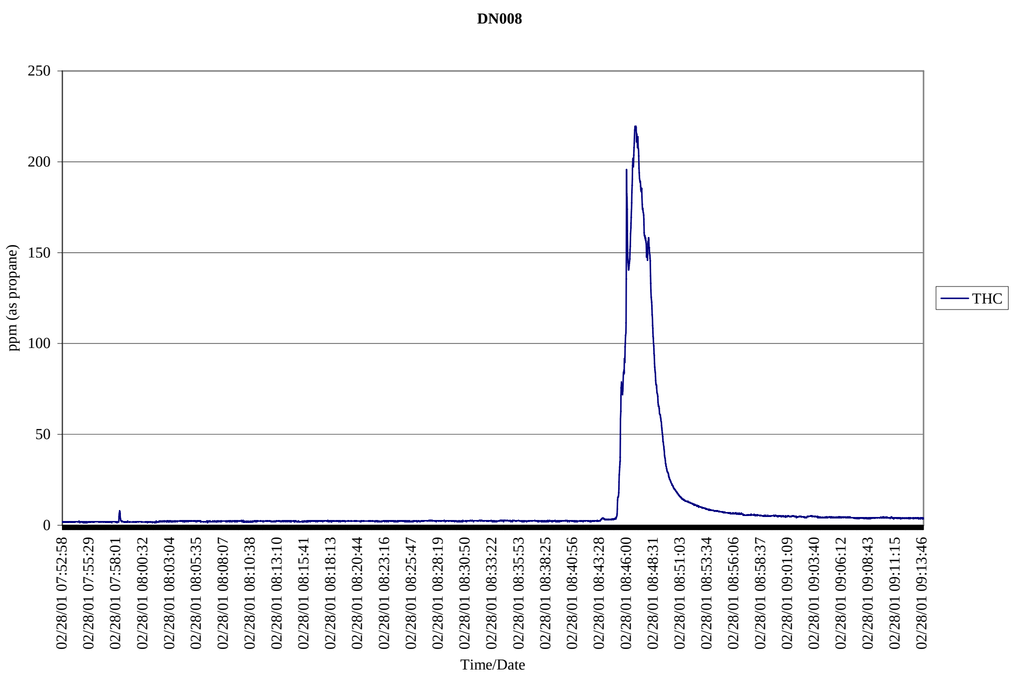
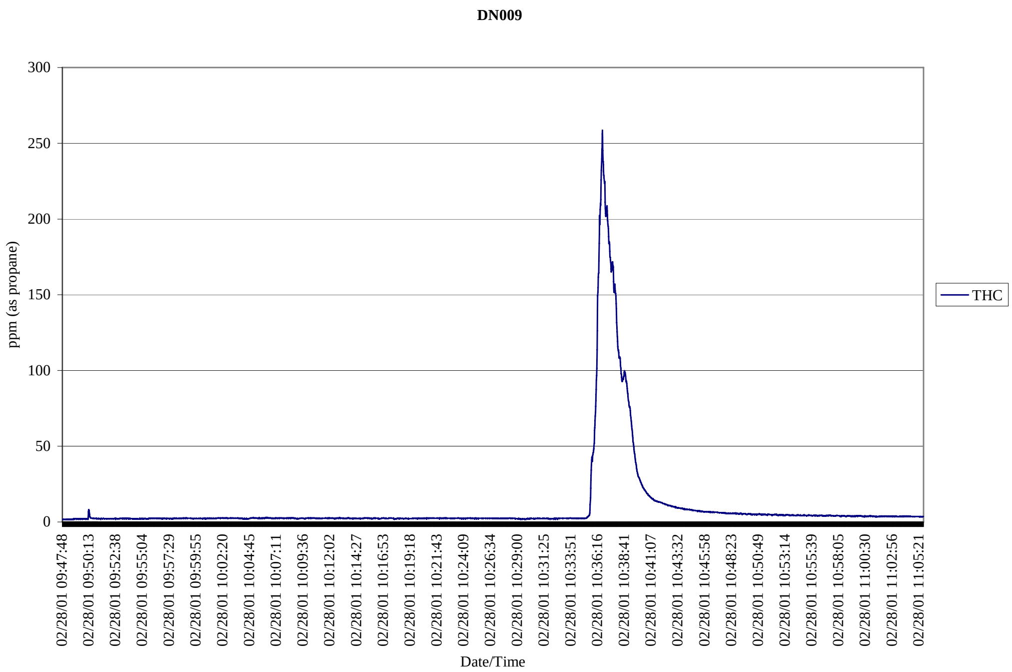
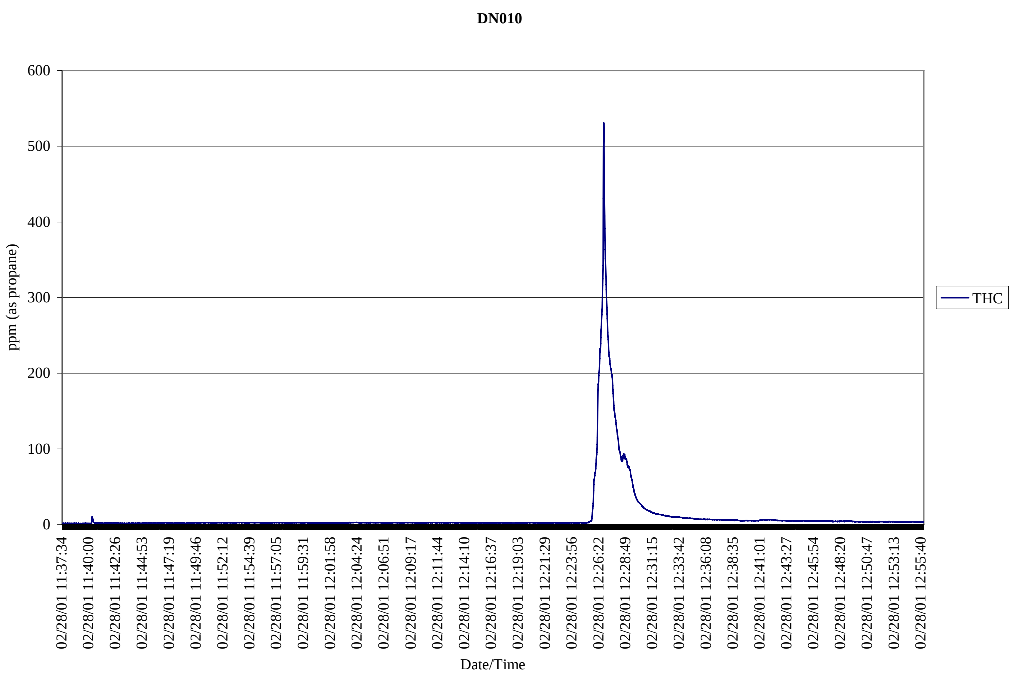
01/31/98 09:30:07
01/31/98 09:32:34


DN008
ppm (as propane)
250
200
150
100
50
0
Time/Date
THC
02/28/01 07:52:58
02/28/01 07:55:29
02/28/01 07:58:01
02/28/01 08:00:32
02/28/01 08:03:04
02/28/01 08:05:35
02/28/01 08:08:07
02/28/01 08:10:38
02/28/01 08:13:10
02/28/01 08:15:41
02/28/01 08:18:13
02/28/01 08:20:44
02/28/01 08:23:16
02/28/01 08:25:47
02/28/01 08:28:19
02/28/01 08:30:50
02/28/01 08:33:22
02/28/01 08:35:53
02/28/01 08:38:25
02/28/01 08:40:56
02/28/01 08:43:28
02/28/01 08:46:00
02/28/01 08:48:31
02/28/01 08:51:03
02/28/01 08:53:34
02/28/01 08:56:06
02/28/01 08:58:37
02/28/01 09:01:09
02/28/01 09:03:40
02/28/01 09:06:12
02/28/01 09:08:43
02/28/01 09:11:15
02/28/01 09:13:46


DN009
ppm (as propane)
300
250
200
150
100
50
0
THC
Date/Time


DN010
ppm (as propane)
600
500
400
300
200
100
0
THC
Date/Time

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APPENDIX E VALIDATION LOG (AVAILABLE IN HARD COPY ONLY)

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APPENDIX F LISTING OF SUPPORT DOCUMENTS

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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 G GLOSSARY

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t-Test	The calculated T statistic, Ts, is compared against a table value. The table value is a function of the sample size and on the level of confidence desired. For tests with nine sample values each, the T value associated with a confidence level of 95% is 2.12. Calculated values of Ts greater than or equal to this value would indicate that there is 95% or better probability that the differences between the two test series were not the result of test variability.
ND	Non Detect, No Data
No Test	Lab testing was not done on this analyte.
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.
BO	Based on ( ).
BOS	Based on Sand.
Binder	= Part 1 + Part 2 + Part 3.
Resin	= Part 1.
Co-Reactant	= Part 2.
Catalyst	= Part 3.