Pre-Production Test (DQ)
Test Plan #RE100112DQ

WBS # 1.3.1.1

20/80 Western/Southern Bentonite Clay Ratios

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Casting Emission Reduction Program

Prepared by:
TECHNIKON LLC
5301 Price Avenue ? McClellan, CA, 95652 ? (916) 929-8001
www.technikonllc.com

US Army Task N256

Pre-Production Air Emission Test Report

20/80 Western/Southern Bentonite Clay Ratios

Technikon #RE100114 DQ

25 April 2001

United States Environmental Protection Agency

AMERICAN FOUNDRY SOCIETY, INC.

UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

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Pre-production Air Emission Tests

20/80 Western/Southern Bentonite Clay Ratios

CERP Test Plan #RE100112DQ

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

Written By:	Scott Forbes	4/25/01 Date
Process Engineering Manager:	Steven Knight	4/24/01 Date
VP Measurement Technologies:	Clifford Glowacki, CIH	4-25-01 Date
VP Operations:	George Crandell	4-25-01 Date
President:	William Walden	4/25/01 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 testing conducted at the Technikon/CERP Pre-Production Foundry to establish a tap water reference against which the effects of advanced oxidant (AO) enriched water on the emissions from vented cored greensand molds may be investigated. Casting surface quality was not evaluated during these tests. This report provides results from a total of nine test plans (tests), with the first three tests performed to condition virgin sand and mold materials. Results are presented for all nine tests, and separately for the six post-conditioning tests. The approved test plan for this test series may be found in Appendix A of this document. Points of comparison between this and related AO studies have been **bolded**.

This report contains the results of emission testing at the Casting Emission Reduction Program (CERP) Pre-Production Foundry operated by Technikon LLC. The specific objective of Test Plan DQ was to determine the emission reductions, if any, of organic Hazardous Air Pollutants (HAPs) and Volatile Organic Compounds (VOCs) for a vented **tap water** tempered virgin greensand mold utilizing a **20/80** Western to Southern bentonite clay ratio and Seacoal. The core package consisted of organic free sodium silicate cores so that the only known mold organic was Seacoal. The test results may be compared to Pre-Production Tests DR, and DT that also utilize a vented **tap water** tempered virgin greensand mold with Seacoal, and bentonite clay ratios of **50/50** and **80/20** Western to Southern respectively. In addition, test results may be compared to Pre-Production Tests DA, DS, and DU that are duplicates of DQ, DR, and DT, except that they utilize **advanced oxidation (AO) treated water** additions instead of tap water.

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 mold and core packages. The measurements are conducted under tightly controlled conditions not feasible in a commercial foundry. It is the initial step in the schema of evaluating a new product or process for the foundry industry. The results of testing in the Pre-production Foundry are evaluated to determine whether further testing in the Technikon Production Foundry is warranted.

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, core binder, and core; Loss on Ignition (LOI) values for the mold prior to the test and at shakeout; percent clays; 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 (9) individual sampling events were conducted for test plan DQ. Three tests were utilized to condition the sand to the tap water, based on historical data, and six tests were utilized for the actual test.

Samples were collected and analyzed for a limited list of twenty (20) 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 "condensables" 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. 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, for all nine-test runs, and for the six post-conditioning test runs, are shown in the following table. All results are measured as pounds emitted per ton of metal.

Number of Tests Included	**TGOC (THC) As Propane**	**HC as Hexane**	**Sum of VOCs**	**Sum of HAPs**	Sum of POMs
6	2.136	0.6072	0.2093	0.1881	ND
9	2.459	0.6435	0.2356	0.2127	ND

Due to the fact that the results expressed here are sums derived from a set of approximately 20 analytes, they are comparable only to test series utilizing an equivalent analyte list. All test series performed for the AO water/Tap water, clay ratio studies will utilize this analyte list, and are therefore comparable. But they cannot be compared to similarly titled results from test series in which an analytes list of greater than 70 compounds have been used to generate the data.

In addition, it must be noted that the reference and product testing performed is not suitable for use as general 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 and process research services to industrial and government clients specializing in the metal casting and mobile emissions areas. Technikon also 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). Each of these partners is represented on a Steering Committee (as voting or non-voting members) that has oversight for the CRADA testing conducted at the Technikon facility.

1.2 CERP Objectives

The primary objective of CERP program is to evaluate materials, equipment, and processes used in the production of metal castings. The Technikon facility was designed to evaluate alternate materials and production processes designed to achieve significant air emission reductions, especially for the 1990 Clean Air Act Amendment organic Hazardous Air Pollutants (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> mold and core packages under tightly controlled conditions not feasible in a commercial foundry. The Pre-production Foundry uses an eight-cavity, bottom feed AFS step block as its test mold pattern.

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 general 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.

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 in support of these tests 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 along with conclusions and recommendations.

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 and core 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.

Appendix A of this report contains the Test Plan for Test Series DQ.

Appendix B of this report contains detailed test results for Test Series DQ.

1.5 Specific Test Plan and Objectives

This report contains the results of testing performed to assess the emission reductions, if any, of organic Hazardous Air Pollutants (HAPs) and Volatile Organic Compounds (VOCs) for a tap water treated virgin greensand mold utilizing a 20/80 Western to Southern bentonite clay ratio and Seacoal. The core package consists of organic free sodium silicate cores so that the only known mold organic is Seacoal.

The results from test DQ will provide comparative data to Pre-production Tests DR and DT, which are also tap water tempered greensand molds with Seacoal, but with bentonite clay ratios of 50:50 and 80:20 Western to Southern, respectively. Test DQ will also provide a tap water reference for comparison to three additional Test Series, DA, DS, and DU, where advanced oxidation (AO) treated water additions were substituted for tap water in molds containing each of the three clay ratios listed above.

Table 1-1 provides a summary of the Test Plan. The detail of the approved test plan is included in Appendix A.

Table 1–1 Test Plan Summary

	Test Plan
Type of Process tested	20/80 Western to Southern Clays w/ Tap Water
Test Plan Number	RE 1 00112 DQ
Mold Type	Hand Rammed Greensand
Core Type	Organic Free Sodium Silicate
Casting Type	Eight-cavity bottom feed AFS step block
Baseline Comparison	Greensand
Number of molds poured	6 (9 including conditioning runs)
Test Dates	12/13/00, 12/14/00, 12/18/00
Emissions Measured	20 organic HAPs and VOCs
Process Parameters Measured	Total Casting, Mold and Core Weights, Metallurgical data, Mold and Core Component Weights, % LOI (mold and core), % Clay, Stack Temperature, Stack Moisture Content, Stack Pressure, and Stack Volumetric Flow Rate

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2.0 Test Methodology

2.1 Description of Process and Testing Equipment

The following figure is a diagram of the Pre-production Foundry process equipment.

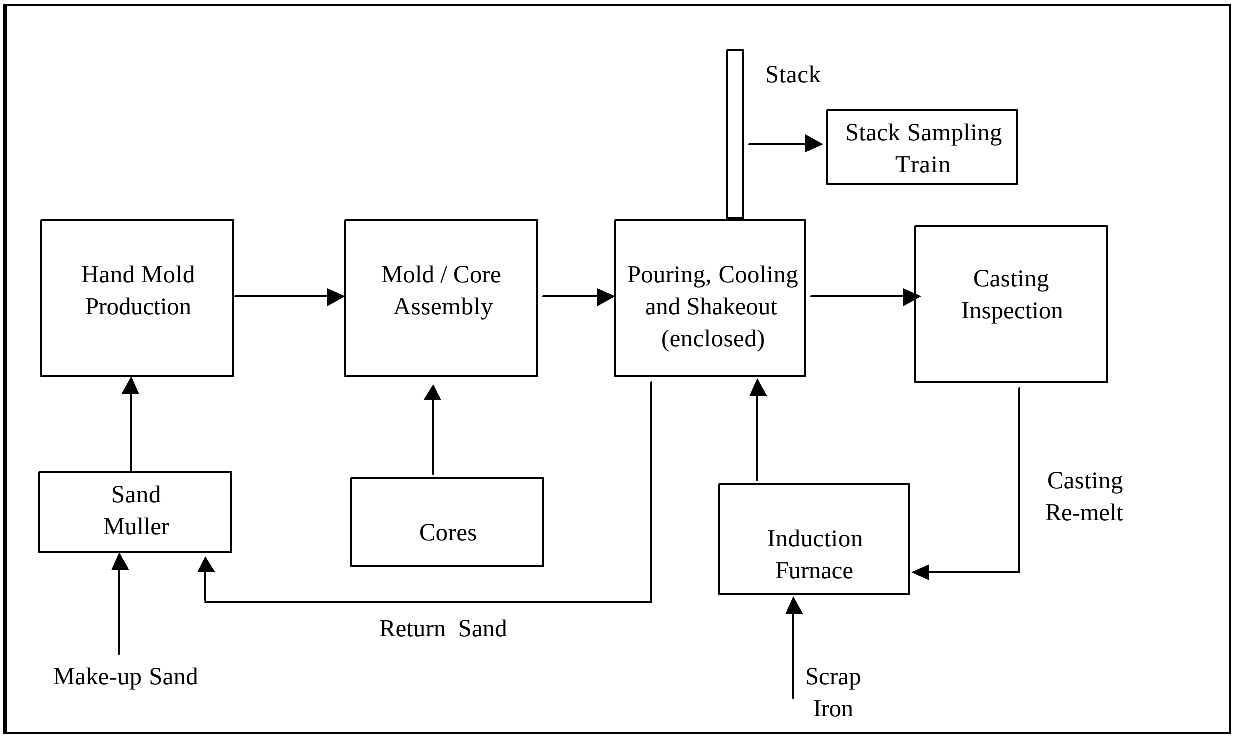

Figure 2-1 Pre-production Foundry Layout Diagram

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. Iron is melted in a 1000 lb. Ajax induction furnace (Model MFB-1000). 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. Iron 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

Pouring of 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.

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 MP@
Mold Compactability	Dietert 319A Sand Squeezer (AFS procedure 221-87-S)
Carbon/Silicon	Baird Foundry Mate Optical Emissions Spectrometer

5. **Emissions Measurement:** 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 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 developed 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. **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 for each sampling event are included in Appendix B of this report. The results for 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, and the Technikon President. Comments are incorporated into a Final Report that is circulated for signatures and then distributed.

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 CERP Standard Operating Procedures. In order to ensure the timely review of critical quality control parameters, the following procedures are followed:

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

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

3.0 Test Results

The average emission result, in pounds per ton of metal poured, is presented in Table 3-1 for tests reported in this document. This table includes all the individual organic HAP compounds that comprise the reduced analyte list for this test series, 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 3-1a through 3-1f present the five emissions indicators and individual HAP 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 log used during validation of the laboratory data is maintained in the Technikon offices.

Table 3-1 Test Series DQ Summary of Individual Test Results – Lbs/Ton of Metal

COMPOUND / SAMPLE NUMBER	Six Mold Average (Lb/tn)	Nine Mold Average (Lb/tn)
TGOC (THC) as Propane	2.136	2.459
HC as Hexane	0.6072	0.6435
Sum of VOCs	0.2093	0.2356
Sum of HAPs	0.1881	0.2127
Sum of POMs	ND	ND
Individual Organic HAPs		
Benzene	0.0891	0.1051
Toluene	0.0503	0.0547
Xylene (Total)	0.0371	0.0403
Ethylbenzene	0.0061	0.0068
Acetaldehyde	0.0055	0.0059
1-Methylnaphthalene	NA	NA
2-Methylnaphthalene	NA	NA
Naphthalene	NA	NA
Aniline	I	I
Phenol	I	I
Other VOCs		
Octane	0.0101	0.0117
1,2,4-Trimethylbenzene	0.0111	0.0113
Other Analytes		
Condensables	0.2147	0.2324
Carbon Monoxide	5.241	5.241
Methane	1.497	1.497
Carbon Dioxide	23.71	23.71

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

Figure 3-1a Test DQ – Emission Indicators – Average of 9 Molds

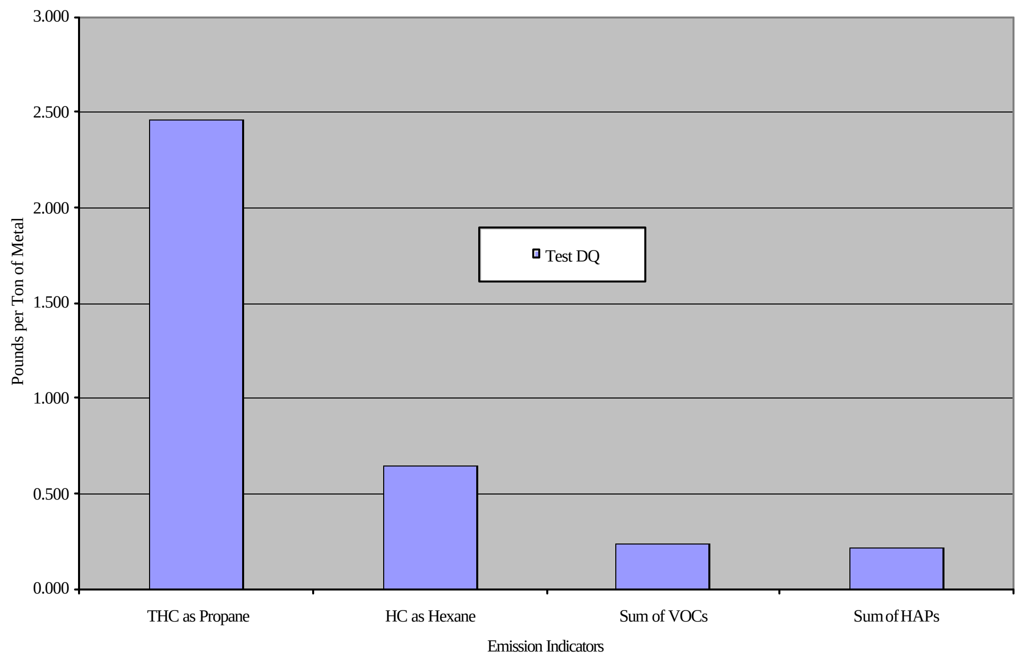

Figure 3-1b Test DQ – Emission Indicators – Average of 6 Molds

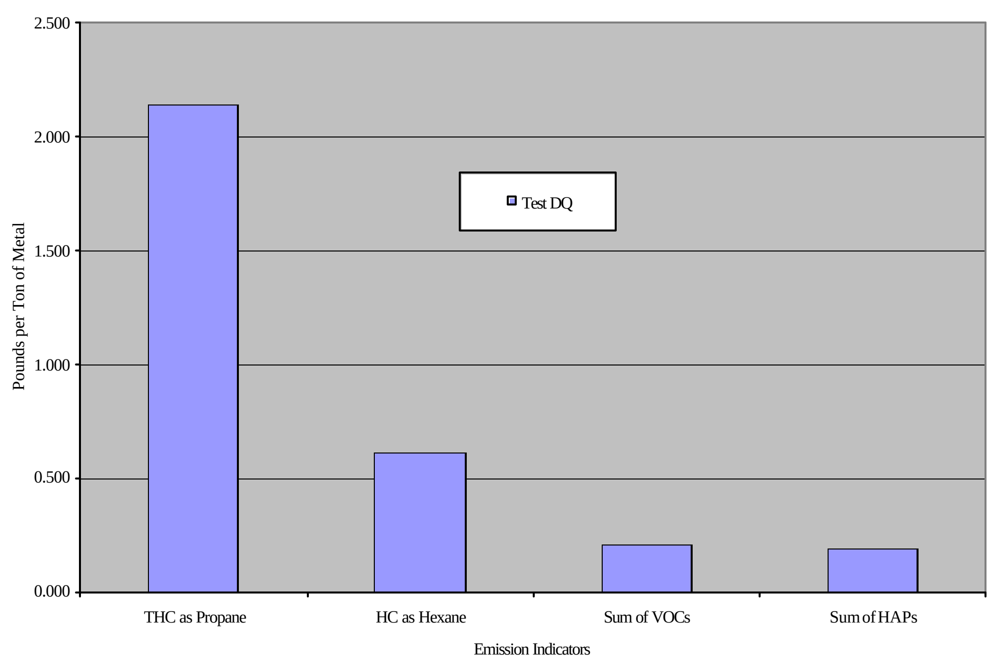

Figure 3-1c Test Series DQ – Comparison of Emission Indicators

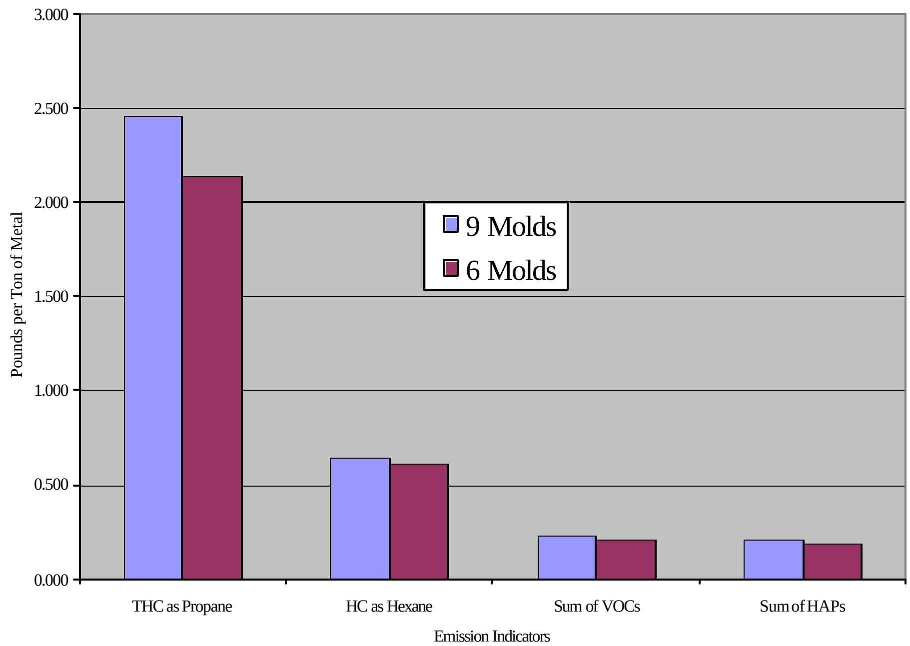

Figure 3-1d Test DQ – Selected HAPs – Average of 9 Molds

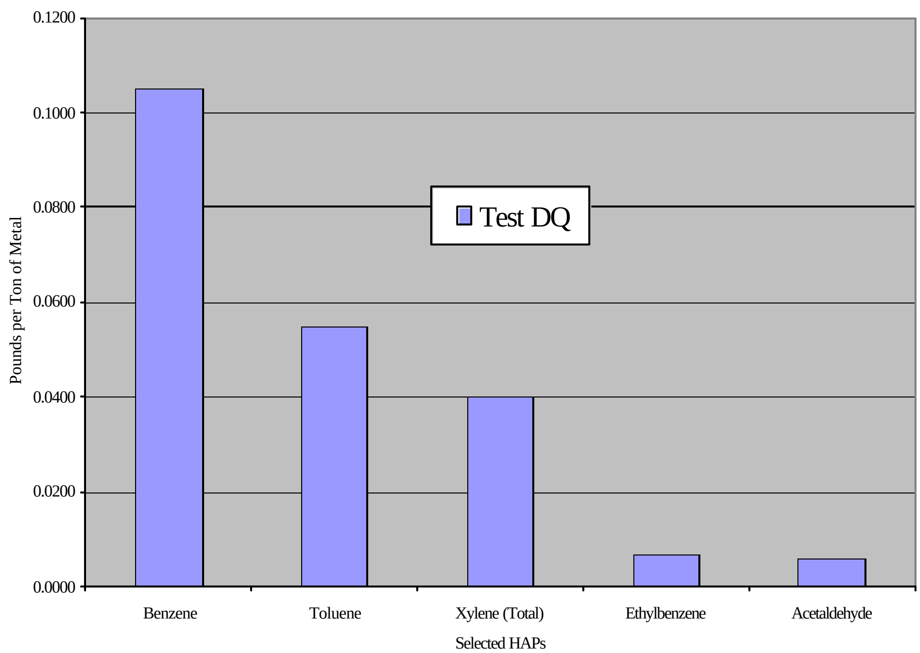

Figure 3-1e Test DQ – Selected HAPs – Average of 6 Molds

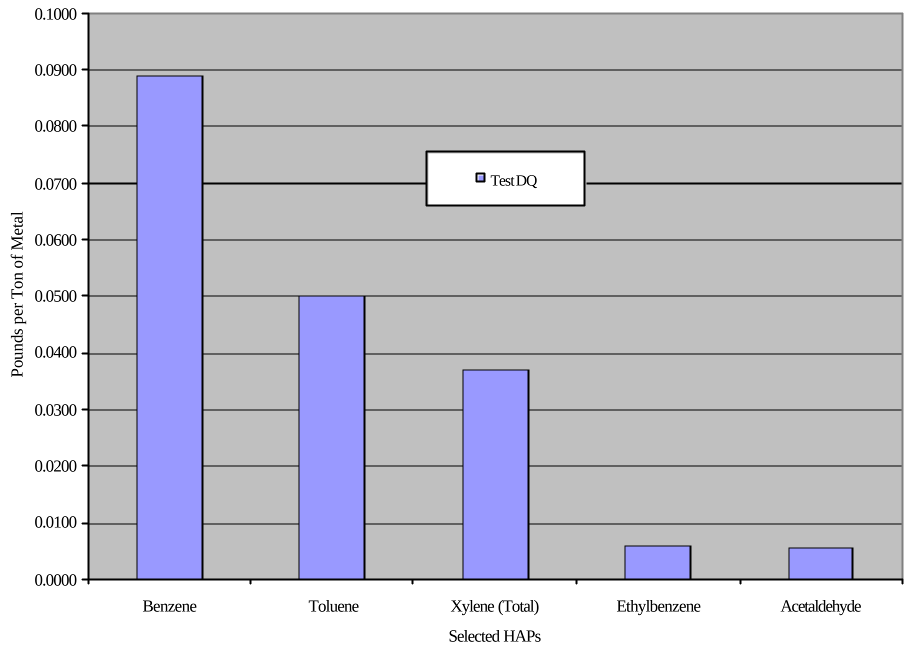

Figure 3-1f Test Series DQ – Comparison of Selected HAPs

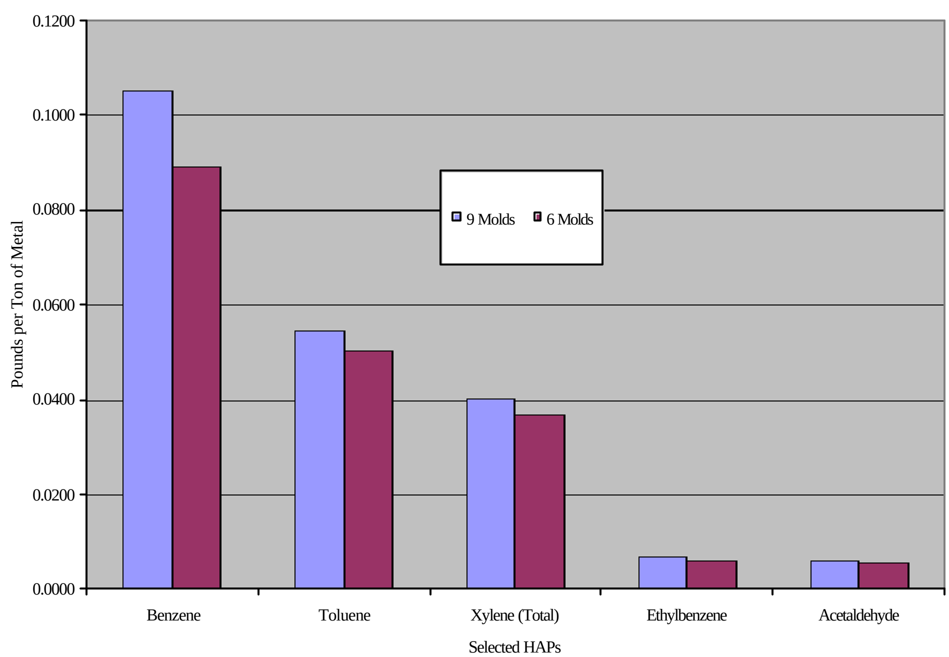

Table 3-2 Test Plan DQ - Average Process and Stack Parameters

Average Process and Stack Parameters	Average of DQ	Target Range
Casting Metal Weight, lbs.	252	240 - 250
Total Mold Weight, lbs.	1348	1350 - 1420
Total Core Weight, lbs.	59.71	58 - 60
Compactability, %	42	45 - 51
Total Binder Weight, lbs	2.84	2.8 - 3.1
Core Ratio Resin (part I) to co-reactant (part II)	N/A	N/A
Greensand mold LOI, % @ 1800°F	4.97	4.4 – 5.0
MB Clay, %	6.43	6.5 - 7.5
Core LOI, % @ 1400°F	0.62	0.2 - 0.8
Greensand Mold Volatiles, % @ 900° F	0.97	N/A
Pour Temperature, °F	2634	2620 - 2640
Mold green compressive strength, psi	13.79	8 – 15
Core Binder Content, %	4.76	4.9 - 5.1
Water Type used in Mold	Tap	Tap
Average Stack Temperature, °F	108	120 ± 20
Total Moisture Content, %	1.57	0-4
Average Stack Velocity, ft./sec.	15.89	17 ± 2
Avg. Stack Pressure, in. Hg	30.21	29.92 ± 1
Stack Flow Rate, scfm	692	700 ± 50

4.0 Discussion of Results

A selected analyte list was utilized in the analysis of stack emissions from Test Series DQ. The results for the sum of HAPs, VOCs, and POMs that are derived from this list can therefore only be compared to other test series that also utilize this reduced list. The sampling and analytical methodologies were the same for Tests DQ, DA, DR, DS, DT, and DU, so comparison of these six test series will allow the effects of advanced oxidation treatment to be evaluated against tap water for three different ratios of western/southern bentonite clays, 20/80, 50/50, and 80/20.

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 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).

TGOC results for the six post-conditioning molds exceeded HC as Hexane by a factor of approximately 3.5. When the three conditioning molds are added to the average results for these two analyses, TGOC exceeds HC as Hexane by a factor of almost 4. Average TGOC results decreased by 13% when only post-conditioning molds are considered, while HC as hexane results decreased by 5.5%.

Phenol and aniline were included in the selected analyte list, but results have not been incorporated due to sampling difficulties for the NIOSH 2002 method. Results for these analytes will be included in the comparative tests listed in the first paragraph.

Observation of measured process parameters indicates that the tests were run within an acceptable range.

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APPENDIX A APPROVED TEST PLAN FOR TEST SERIES DQ

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CERP TEST PLAN

- > **CONTRACT NUMBER:** 1256 **TASK NUMBER:** 130
- > **CONTROL NUMBER:** RE 1 00112
- > **SAMPLE FAMILY:** DQ
- > **SAMPLE EVENTS:** 001 thru 009
- > **SITE:** __X__ **PRE-PRODUCTION (243)____CERP FOUNDRY (238)**
- > **TEST TYPE:** Clay Ratio Study, using Tap Water Reference
- > **MOLD TYPE:** Greensand, 20/80: Western/Southern Bentonite ratio with Seacoal and using Tap Water
- > **NUMBER OF MOLDS:** 9
- > **CORE TYPE**: Sodium Silicate Step Block Cores
- > **TEST DATE:** **START:** 13 Dec 00

  FINISH: 18 Dec 00

TEST OBJECTIVES:

Primary: To determine the effects on HAP emissions from a tap water tempered southern bentonite rich sodium silicate cored greensand mold containing Seacoal as the only known organic source and compare those emissions to test series DR (tap water, silicate core, 50/50 western/southern bentonite), DT (tap water, silicate core, 80/20 western/southern bentonite), DA (A/O water, silicate core, 20/80 western/southern bentonite), DS (A/O water, silicate core, 50/50 western/southern bentonite), and DU (A/O water, silicate core, 80/20 western/southern bentonite). This group of tests is a follow up on test DA made with virgin materials run as a single batch turns test. Series DQ will be monitored by the total hydrocarbon analyzer, sample tubes, bags, and condensate trap.

VARIABLES: Sand composition shall be maintained at 7.0 +/- 0.5 % MB clay, 5.0 +/- 0.3 % LOI using Hill & Griffith supplied clay and Seacoal. The Western Bentonite /Southern Bentonite ratio shall be 20/80. Sodium silicate step cores will be made using Wedron 420 Silica sand and 5.0 % J.B. DeVeene Kleencast #1 binder, gassed with CO_2 and dried at 250° F for two hours. The statistical validity of the test will be based on nine sampling events (molds).

BRIEF OVERVIEW: This test along with companion tests DR, DT, DA, DS, & DU is intended to determine how silicate cored green sand with 80/20, 50/50 & 20/80 western/southern bentonite ratios respond to both tap water and A/O water treatment. The bentonite content and LOI will initially be adjusted to 7.0% +/- 0.5% and 5.0% +/- 0.3% respectively. Subsequent molds will be made on a single mold "turns" basis with the bond replacement rate based on current sand lab data to maintain the clay & LOI contents within the above ranges. DQ molds will be made only after the process lab determinations or projections are complete.

SPECIAL CONDITIONS: Only tap water shall be used. The total hydrocarbon analyzer, tube samples, & condensate trap shall be used to gather and conduct emission tests on the sand to form the (9) mold test. Process effects on sand physical and mechanical properties shall be tracked**.**

Process Engineering Manager (Technikon)	12/15/00 Date
V.P. Measurement Technology (Technikon)	12-15-00 Date
V.P. Operations (Technikon)	12-15-00 Date
Emissions Team (USCAR)	2/22/01 Date
Process and Facilities Team (USCAR)	2/22/01 Date
Project Manager (CTC)	4/25/01 Date

Series DQ

Pre-production process instructions

A. Experiment: A study to compare the impact of tap water on molds with the Western/Southern Bentonite ratio of 1:4. The mold will be made from virgin green sand mold materials consisting of Seacoal; bentonite in the ratio of 1:4; tempered with tap water; poured at constant weight, surface area, sodium silicate core weight, and shape factor, a single batch turns test. This test is to be compared to reference tests DR, & DT, and comparative tests DA, DS, & DU.

1. Mold sand: Virgin mix of Wexford W450 lake sand, Okie 90 silica sand, western and southern Bentonites in ratio of 1:4, Seacoal, and tap water per recipe.
2. Core: Step core made with Wedron 420 silica sand and 5% J.B. DeVeene Kleencast #1® sodium silicate core binder, gassed with CO_2.
3. Metal: Class 30-35 gray cast iron poured at 2630°F.

Caution

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

4. The following test shall be conducted:
   - **a)** Sand batch: Single sand batch to be used for all 9 DQ molds. All molds will be monitored in real time with the Airsense spectrometer and THC analyzer. Additionally sample tubes and condensables samples will be collected on each mold.
   - **b)** DQ001: Virgin mix as described above, vented mold, reference JB DeVeene Kleencast #1? cores, tap water.
   - **c)** DQ002-DQ009: The 20/80 western/southern bentonite comparative test; Re-mulled, reconstituted sand, tap water, vented mold, reference JB DeVeene Kleencast #1? cores.

B. Sodium silicate Core

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 resin into the sand. Distribute the resin as it is poured. Avoid pouring the resin on the plows or walls of the mixer or in one location or resin balling will occur preventing proper mixing.
   - **d)** Mix for three minutes after the resin is all in.
   - **e)** One batch will make about 6 cores.
   - **f)** Once per hour catch a clean 50-100 gm sample of the raw sand for the sand lab to perform a core LOI test. Place the sample in a clean bag and label with date and time.
2. Making step cores.
   - **a)** Place the 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 1inch 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 CO2 gas.
g) Dry the cores for two hours at 250^{o}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.
k) The sand lab will determine the core LOI and the Resin Content LOI associated with each mold.

C. Sand preparation

1. Start up batch: make 1, DQ001.

a) Thoroughly clean the pre-production muller.
b) Weigh and add 1600 +/- 50 pounds total new Wexford W450 lake sand and Oklahoma 90 silica sand, per the recipe, to the running pre-production muller.
c) Add 5 pounds of tap water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
d) Add the clays in proportion to the sand weight per the standardization mixture recipe for this test 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 tap 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. Grab sufficient sample at each compactability test to fill a quart zip-lock bag. Label each bag and retain it.
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 charge and discharge on each half batch, the time that the water was taken from its source, the time that each mold half was complete, the time the mold is delivered to the pour area, and the water type and temperature. Record the maximum muller current just prior to sand discharge.
l) The sand will be characterized for Methylene Blue Clay, Moisture content, Compactability, Green Compression strength, 1800^{o}F loss on ignition (LOI), and

900°F volatiles. Each volatile and LOI test requires a separate 50-gram sample from the collected sand.

NOTE: The sand lab data must be available and approved by the process engineer before the mold is committed to pouring.

2. Re-mulling: make 8, DQ002-DQ009.
   - **a)** Add all the sand from the previous mold to the muller including any sand previously mixed but not placed in the mold.
   - **b)** Add 5 pounds of tap water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
   - **c)** Add the clays and coals per the re-bond recipe slowly to the muller to allow them to be distributed throughout the sand mass. Follow the above procedure beginning at C.1.e.
   - **d)** 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 shall be taken from within the muller at three locations approximately 120 degrees apart. The sand will be tested for MB clay, compactability, and moisture content, green compression strength, 1800°F LOI, 900°F volatile. Each volatile and LOI test requires a separate 50-gram sample from the collected sand. Report results associated with the mold (test number, DQ0xx) from which it was taken.

NOTE: The sand lab data must be available from the blended shakeout sand and a recipe approved by the process engineer before the next mold is prepared. Additionally the sand lab data must be available and approved by the process engineer for the next mold's sand before the mold is committed to pouring.

NOTE: Once each day, at the time when the shakeout sand has been re-blended, the total sand shall be weighed and recorded. Extra sand shall be discarded to keep the batch weight at 1600 +/- 50 pounds.

D. 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 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. The step cores will be flush with the parting line. If a piece of the mold is missing contact your supervision for a decision on the acceptability of the mold.
g) Vent the cope when required according to the test list above 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 and record the closed unpoured mold, the core weigh, and the sand weight by difference.

E. 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 metal poured.
d) Place the recovered sand in its entirety back into the brushed out muller and blend for three (3) minutes. Take three (3) samples from the re-blended shakeout sand. The three (3) “SHAKEOUT” samples shall be taken from within the muller at three locations 120 degrees apart. The sand will be tested for MB clay, compactability, and moisture content, green compression, 1800^{o}F LOI, and 900^{o}F volatile. Each volatile and LOI test requires a separate 50-gram sample from the collected sand. Report results associated with the mold (test number, DA0xx) from which it was taken.

F. 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°F.
- **f)** Slag the furnace and add the balance of the alloys.
- **g)** Raise the temperature of the melt to 2700°F and take a DataCast 2000 sample. The temperature of the primary liquidus (TPL) must be in the range of 2200-2350°F.
- **h)** Hold the furnace at 2500-2550°F until near ready to tap.
- **i)** When ready to tap raise the temperature to 2700°F and slag the furnace.
- **j)** Record all metallic and alloy additions to the furnace, tap temperature, and pour temperature. Record all furnace activities with an associated time.

2. Back charging.

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

G. Pouring:

1. Preheat the ladle.

- **a)** Tap 400 pounds more or less of 2700°F metal into the cold ladle.
- **b)** Casually pour the metal back to the furnace.
- **c)** Cover the ladle.
- **d)** Reheat the metal to 2780 +/- 20°F.
- **e)** Tap 450 pounds of iron into the ladle while pouring inoculating alloys onto the metal stream near its base.
- **f)** Cover the ladle to conserve heat.
- **g)** Move the ladle to the pour position, open the emission hood pour door and wait until the metal temperature reaches 2630 +/- 10°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.

Steven Knight
Mgr. Process Engineering
12/12/00

PRE-PRODUCTION DQ SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/13/00											Samples to Clayton Lab.
EVENT 1											unless noted.
AIRSENSE	DQ00101										TOTAL
THC	DQ00102	X									TOTAL
NIOSH 1500 Mod.	DQ00103		1						200	1	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00104		1						200	2	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00105				1				0	2	QC-Manifold Blank
Excess									200	3	Excess
Excess									200	4	Excess
GAS, CO + CO2	DQ00106		1						60	5	BAG Sample to Airtoxics Lab.
TO11	DQ00107		1						500	6	Total
TO11	DQ00108				1				0	6	QC - Manifold Blank
Excess									500	7	Excess
NIOSH 2002	DQ00109		1						750	8	TOTAL (SKC 226-15)
NIOSH 2002	DQ00110				1				0	8	QC- Manifold Blank (SKC 226-15)
Excess									750	9	Excess
NIOSH 2011 Mod.	DQ00112		1						750	10	TOTAL (Orbo 53)
NIOSH 2011 Mod.	DQ00113				1				0	10	QC - Manifold Blanks (Orbo 53)
Excess									750	11	Excess
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DQ00114		1						15L		Sample using opposite port

PRE-PRODUCTION DQ SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/13/00											Samples to Clayton Lab.
EVENT 2											unless noted.
AIRSENSE	DQ00201										TOTAL
THC	DQ00202	X									TOTAL
NIOSH 1500 Mod.	DQ00203		1						200	1	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00204		1						200	2	TOTAL (Orbo 32 SM)
Excess									200	3	Excess
Excess									200	4	Excess
GAS,CO + CO2	DQ00205		1						60	5	BAG Sample to Airtoxics Lab.
TO11	DQ00206		1						500	6	TOTAL
TO11	DQ00207					1			500	6	TOTAL
Excess									500	7	Excess
NIOSH 2002	DQ00208		1						750	8	TOTAL (SKC 226-15)
Excess									750	9	Excess
NIOSH 2011 Mod.	DQ00209		1						750	10	TOTAL (Orbo 53)
Excess									750	11	Excess
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DQ00210		1						15L		Sample using opposite port

PRE-PRODUCTION DQ SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/13/00											Samples to Clayton Lab.
EVENT 3											unless noted.
AIRSENSE	DQ00301										TOTAL
THC	DQ00302	X									TOTAL
NIOSH 1500 Mod.	DQ00303		1						200	1	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00304			1					200	2	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00305		1						200	3	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00306			1					200	4	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00307				1						QC - (Orbo 32 SM)
GAS,CO + CO2	DQ00308		1						60	5	BAG Sample to Airtoxics Lab.
TO11	DQ00309		1						500	6	TOTAL
TO11	DQ00310			1					500	7	TOTAL
TO11	DQ00311				1						QC
NIOSH 2002	DQ00312		1						750	8	TOTAL (SKC 226-15)
NIOSH 2002	DQ00313			1					750	9	TOTAL (SKC 226-15)
NIOSH 2002	DQ00314				1						QC - (SKC 226-15)
NIOSH 2011 Mod.	DQ00315		1						750	10	TOTAL (Orbo 53)
NIOSH 2011 Mod.	DQ00316			1					750	11	TOTAL (Orbo 53)
NIOSH 2011 Mod.	DQ00317				1						QC - (Orbo 53)
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DQ00318		1						15L		Sample using opposite port

PRE-PRODUCTION DQ SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/14/00											Samples to Clayton Lab.
EVENT 4											unless noted.
AIRSENSE	DQ00401										TOTAL
THC	DQ00402	X									TOTAL
NIOSH 1500 Mod.	DQ00403		1						200	1	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00404		1						200	2	TOTAL (Orbo 32 SM)
Excess									200	3	Excess
Excess									200	4	Excess
GAS,CO + CO2	DQ00405		1						60	5	BAG Sample to Airtoxics Lab.
TO11	DQ00406		1						500	6	TOTAL
Excess									500	7	Excess
NIOSH 2002	DQ00407		1						750	8	TOTAL (SKC 226-15)
Excess									750	9	Excess
NIOSH 2011 Mod.	DQ00408		1						750	10	TOTAL (Orbo 53)
Excess									750	11	Excess
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DQ00409		1						15L		Sample using opposite port

PRE-PRODUCTION DQ SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/14/00											Samples to Clayton Lab.
EVENT 5											unless noted.
AIRSENSE	DQ00501										TOTAL
THC	DQ00502	X									TOTAL
NIOSH 1500 Mod.	DQ00503		1						200	1	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00504		1						200	2	TOTAL (Orbo 32 SM)
Excess									200	3	Excess
Excess									200	4	Excess
GAS,CO + CO2	DQ00505		1						60	5	BAG Sample to Airtoxics Lab.
TO11	DQ00506		1						500	6	TOTAL
Excess									500	7	Excess
NIOSH 2002	DQ00507		1						750	8	TOTAL (SKC 226-15)
Excess									750	9	Excess
NIOSH 2011 Mod.	DQ00508		1						750	10	TOTAL (Orbo 53)
Excess									750	11	Excess
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DQ00509		1						15L		Sample using opposite port

PRE-PRODUCTION DQ SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/14/00											Samples to Clayton Lab.
EVENT 6											unless noted.
AIRSENSE	DQ00601										TOTAL
THC	DQ00602	X									TOTAL
NIOSH 1500 Mod.	DQ00603		1						200	1	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00604		1						200	2	TOTAL (Orbo 32 SM)
Excess									200	3	Excess
Excess									200	4	Excess
GAS,CO + CO2	DQ00605		1						60	5	BAG Sample to Airtoxics Lab.
TO11	DQ00606		1						500	6	TOTAL
Excess									500	7	Excess
NIOSH 2002	DQ00607		1						750	8	TOTAL (SKC 226-15)
Excess									750	9	Excess
NIOSH 2011 Mod.	DQ00608		1						750	10	TOTAL (Orbo 53)
Excess									750	11	Excess
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DQ00609		1						15L		Sample using opposite port

PRE-PRODUCTION DQ SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/18/00											Samples to Clayton Lab.
EVENT 7											unless noted.
AIRSENSE	DQ00701										TOTAL
THC	DQ00702	X									TOTAL
NIOSH 1500 Mod.	DQ00703		1						200	1	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00704			1					200	2	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00705		1						200	3	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00706			1					200	4	TOTAL (Orbo 32 SM)
GAS,CO + CO2	DQ00707		1						60	5	BAG Sample to Airtoxics Lab.
TO11	DQ00708		1						500	6	TOTAL
TO11	DQ00709			1					500	7	TOTAL
NIOSH 2002	DQ00710		1						750	8	TOTAL (SKC 226-15)
NIOSH 2002	DQ00711			1					750	9	TOTAL (SKC 226-15)
NIOSH 2011 Mod.	DQ00712		1						750	10	TOTAL (Orbo 53)
NIOSH 2011 Mod.	DQ00713			1					750	11	TOTAL (Orbo 53)
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DQ00714		1						15L		Sample using opposite port

PRE-PRODUCTION DQ SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/18/00											Samples to Clayton Lab.
EVENT 8											unless noted.
AIRSENSE	DQ00801										TOTAL
THC	DQ00802	X									TOTAL
NIOSH 1500 Mod.	DQ00803		1						200	1	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00804		1						200	2	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00805				1						QC -Blank (Orbo 32 SM)
Excess									200	3	Excess
Excess									200	4	Excess
GAS,CO + CO2	DQ00806		1						60	5	BAG Sample to Airtoxics Lab.
TO11	DQ00807		1						500	6	TOTAL
TO11	DQ00808				1						QC - Blank
Excess									500	7	Excess
NIOSH 2002	DQ00809		1						750	8	TOTAL (SKC 226-15)
NIOSH 2002	DQ00810				1						QC -Blank(SKC 226-15)
Excess									750	9	Excess
NIOSH 2011 Mod.	DQ00811		1						750	10	TOTAL (Orbo 53)
NIOSH 2011 Mod.	DQ00812				1						QC - Blank (Orbo 53)
Excess									750	11	Excess
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DQ00813		1						15L		Sample using opposite port

PRE-PRODUCTION DQ SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/18/00											Samples to Clayton Lab.
EVENT 9											unless noted.
AIRSENSE	DQ00901										TOTAL
THC	DQ00902	X									TOTAL
NIOSH 1500 Mod.	DQ00903		1						200	1	TOTAL (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00904		1						200	2	TOTAL (Orbo 32 SM)
Excess									200	3	Excess
Excess									200	4	Excess
GAS,CO + CO2	DQ00905		1						60	5	BAG Sample to Airtoxics Lab.
TO11	DQ00906		1						500	6	TOTAL
Excess									500	7	Excess
NIOSH 2002	DQ00907		1						750	8	TOTAL (SKC 226-15)
Excess									750	9	Excess
NIOSH 2011 Mod.	DQ00908		1						750	10	TOTAL (Orbo 53)
Excess									750	11	Excess
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DQ00909		1						15L		Sample using opposite port

NIOSH 1500 Mod.	DQ00910						X		200		BOTTLE - Mix 1A (Orbo 32 SM)
NIOSH 1500 Mod.	DQ00911						X		200		BOTTLE - Mix 1A (Orbo 32 SM)

APPENDIX B TEST SERIES DQ - DETAILED RESULTS

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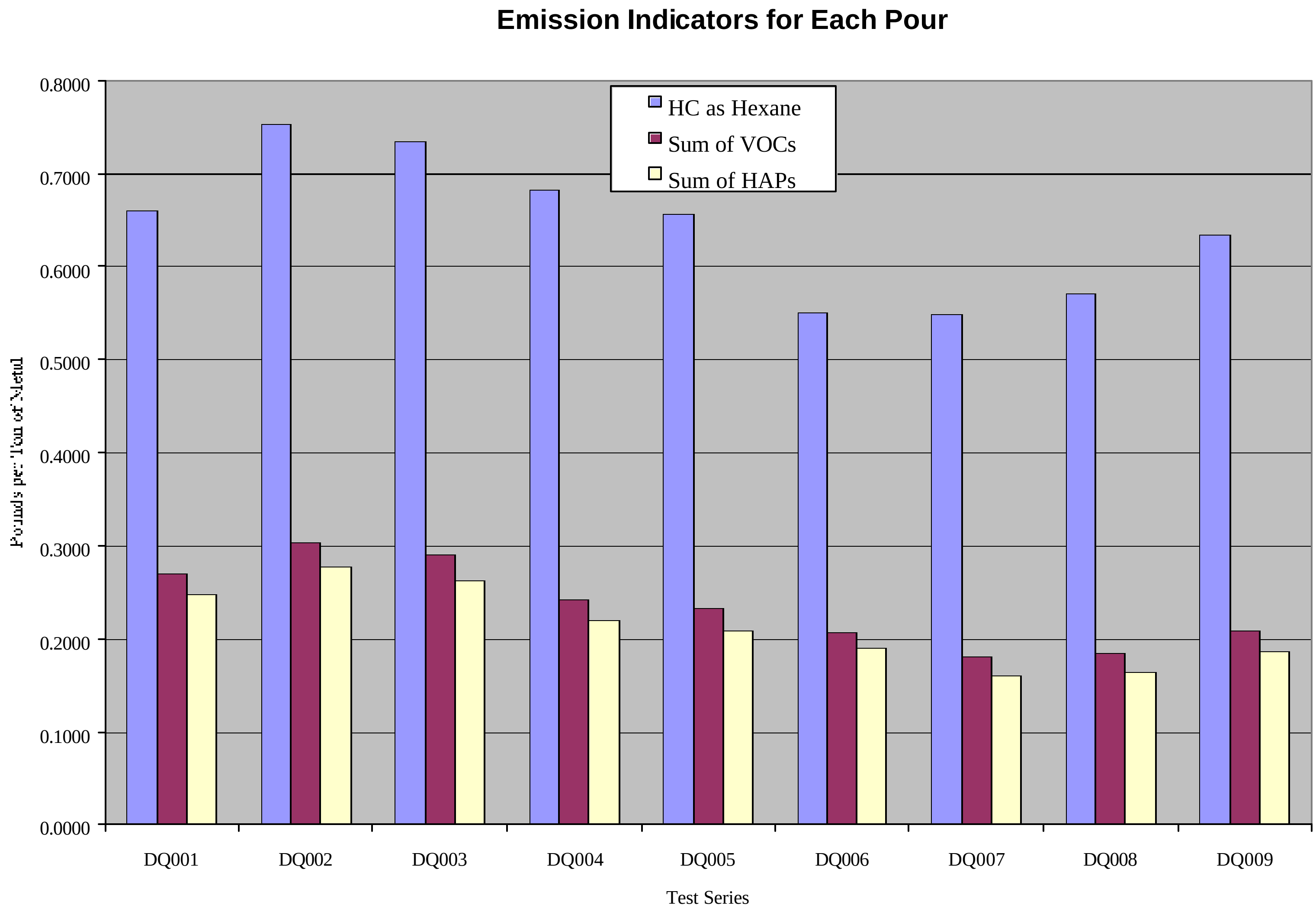
Emission Indicators for Each Pour
HC as Hexane
Sum of VOCs
Sum of HAPs
Pounds per Ton of Metal
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
DQ001
DQ002
DQ003
DQ004
DQ005
DQ006
DQ007
DQ008
DQ009
Test Series

Test Plan DQ Individual Test Results – Lbs/ton of Metal - Nine Runs

POMs	HAPS	COMPOUND / SAMPLE NUMBER	DQ001	DQ002	DQ003	DQ004	DQ005	DQ006	DQ007	DQ008	DQ009	AVERAGE	STDEV
		Pour Date	12/13/00	12/13/00	12/13/00	12/14/00	12/14/00	12/14/00	12/18/00	12/18/00	12/18/00		
		THC as Propane	3.22E+00	3.21E+00	2.88E+00	2.55E+00	2.30E+00	2.12E+00	1.95E+00	1.83E+00	2.07E+00	2.46E+00	5.34E-01
		HC as Hexane	6.61E-01	7.53E-01	7.35E-01	6.82E-01	6.56E-01	5.50E-01	5.50E-01	5.71E-01	6.34E-01	6.44E-01	7.50E-02
		Sum of VOCs	2.70E-01	3.04E-01	2.90E-01	2.42E-01	2.33E-01	2.08E-01	1.81E-01	1.84E-01	2.08E-01	2.36E-01	4.48E-02
		Sum of HAPs	2.47E-01	2.77E-01	2.62E-01	2.19E-01	2.09E-01	1.89E-01	1.61E-01	1.64E-01	1.86E-01	2.13E-01	4.19E-02
		Sum of POMs	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
			Individual HAPs and VOCs										
	z	Benzene	1.38E-01	1.43E-01	1.30E-01	1.09E-01	9.81E-02	9.52E-02	7.45E-02	7.38E-02	8.40E-02	1.05E-01	2.66E-02
	z	Toluene	5.56E-02	6.79E-02	6.70E-02	5.56E-02	5.61E-02	4.91E-02	4.42E-02	4.59E-02	5.08E-02	5.47E-02	8.40E-03
	z	Xylene (Total)	3.92E-02	5.04E-02	5.03E-02	4.13E-02	4.19E-02	3.52E-02	3.25E-02	3.43E-02	3.75E-02	4.03E-02	6.51E-03
		Octane	1.46E-02	1.59E-02	1.38E-02	1.20E-02	1.08E-02	8.71E-03	9.64E-03	9.07E-03	1.03E-02	1.17E-02	2.58E-03
		1,2,4-Trimethylbenzene	8.53E-03	1.16E-02	1.44E-02	1.07E-02	1.33E-02	9.93E-03	1.04E-02	1.10E-02	1.15E-02	1.13E-02	1.74E-03
	z	Ethylbenzene	7.09E-03	8.87E-03	8.71E-03	7.00E-03	7.17E-03	5.72E-03	5.07E-03	5.44E-03	6.08E-03	6.80E-03	1.36E-03
	z	Acetaldehyde	7.34E-03	6.69E-03	5.64E-03	5.93E-03	5.22E-03	4.10E-03	4.88E-03	5.00E-03	7.90E-03	5.85E-03	1.24E-03
x	z	1-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
x	z	2-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
x	z	Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	z	Aniline	I	I	I	I	I	I	I	I	I	N/A	N/A
	z	Phenol	I	I	I	I	I	I	I	I	I	N/A	N/A
			Other Analytes										
		Carbon Monoxide	5.40E+00	5.08E+00	NT	NT	NT	NT	NT	NT	NT	5.24E+00	2.30E-01
		Methane	1.56E+00	1.43E+00	NT	NT	NT	NT	NT	NT	NT	1.50E+00	9.14E-02
		Carbon Dioxide	3.00E+01	1.75E+01	NT	NT	NT	NT	NT	NT	NT	2.37E+01	8.85E+00
		Ethane	ND	ND	NT	NT	NT	NT	NT	NT	NT	N/A	N/A
		Propane	ND	ND	NT	NT	NT	NT	NT	NT	NT	N/A	N/A
		Isobutene	ND	ND	NT	NT	NT	NT	NT	NT	NT	N/A	N/A
		Butane	ND	ND	NT	NT	NT	NT	NT	NT	NT	N/A	N/A
		Neopentane	ND	ND	NT	NT	NT	NT	NT	NT	NT	N/A	N/A
		Isopentane	ND	ND	NT	NT	NT	NT	NT	NT	NT	N/A	N/A

Test Plan DQ Individual Test Results (continued)

POMs	HAPS	COMPOUND / SAMPLE NUMBER	DQ001	DQ002	DQ003	DQ004	DQ005	DQ006	DQ007	DQ008	DQ009	AVERAGE	STDEV
		Pentane	ND	ND	NT	NT	NT	NT	NT	NT	NT	N/A	N/A
		Condensables	3.16E-01	NA	2.55E-01	2.89E-01	2.39E-01	1.35E-01	2.04E-01	2.18E-01	2.03E-01	2.32E-01	5.63E-02

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

Test Plan DQ Individual Test Results – Lbs/ton of Metal – Six Runs

POMs	HAPS	COMPOUND / SAMPLE NUMBER	DQ004	DQ005	DQ006	DQ007	DQ008	DQ009	AVERAGE	STDEV
		Pour Date	12/14/00	12/14/00	12/14/00	12/18/00	12/18/00	12/18/00		
		THC as Propane	2.55E+00	2.30E+00	2.12E+00	1.95E+00	1.83E+00	2.07E+00	2.14E+00	2.56E-01
		HC as Hexane	6.82E-01	6.56E-01	5.50E-01	5.50E-01	5.71E-01	6.34E-01	6.07E-01	5.76E-02
		Sum of VOCs	2.42E-01	2.33E-01	2.08E-01	1.81E-01	1.84E-01	2.08E-01	2.09E-01	2.46E-02
		Sum of HAPs	2.19E-01	2.09E-01	1.89E-01	1.61E-01	1.64E-01	1.86E-01	1.88E-01	2.32E-02
		Sum of POMs	ND	ND	ND	ND	ND	ND	N/A	N/A
			Individual HAPs and VOCs							
	z	Benzene	1.09E-01	9.81E-02	9.52E-02	7.45E-02	7.38E-02	8.40E-02	8.91E-02	1.42E-02
	z	Ethylbenzene	7.00E-03	7.17E-03	5.72E-03	5.07E-03	5.44E-03	6.08E-03	6.08E-03	8.48E-04
	z	Toluene	5.56E-02	5.61E-02	4.91E-02	4.42E-02	4.59E-02	5.08E-02	5.03E-02	4.89E-03
	z	Xylene (Total)	4.13E-02	4.19E-02	3.52E-02	3.25E-02	3.43E-02	3.75E-02	3.71E-02	3.86E-03
		1,2,4-Trimethylbenzene	1.07E-02	1.33E-02	9.93E-03	1.04E-02	1.10E-02	1.15E-02	1.11E-02	1.17E-03
		Octane	1.20E-02	1.08E-02	8.71E-03	9.64E-03	9.07E-03	1.03E-02	1.01E-02	1.23E-03
	z	Acetaldehyde	5.93E-03	5.22E-03	4.10E-03	4.88E-03	5.00E-03	7.90E-03	5.50E-03	1.31E-03
x	z	1-Methylnaphthalene	ND	ND	ND	ND	ND	ND	N/A	N/A
x	z	2-Methylnaphthalene	ND	ND	ND	ND	ND	ND	N/A	N/A
x	z	Naphthalene	ND	ND	ND	ND	ND	ND	N/A	N/A
	z	Aniline	I	I	I	I	I	I	N/A	N/A
	z	Phenol	I	I	I	I	I	I	N/A	N/A
			Other Analytes							
		Condensables	2.89E-01	2.39E-01	1.35E-01	2.04E-01	2.18E-01	2.03E-01	2.15E-01	5.06E-02
			DQ001	**DQ002**	**AVERAGE**	**STDEV**				
		Pour Date	**12/13/00**	**12/13/00**						
		Carbon Monoxide	5.40E+00	5.08E+00	5.24E+00	2.30E-01				
		Methane	1.56E+00	1.43E+00	1.50E+00	9.14E-02				
		Carbon Dioxide	3.00E+01	1.75E+01	2.37E+01	8.85E+00				
		Ethane	ND	ND	N/A	N/A				
		Propane	ND	ND	N/A	N/A				
		Isobutene	ND	ND	N/A	N/A				
		Butane	ND	ND	N/A	N/A				
		Neopentane	ND	ND	N/A	N/A				
		Isopentane	ND	ND	N/A	N/A				
		Pentane	ND	ND	N/A	N/A				

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

APPENDIX C TEST SERIES DQ - DETAILED PROCESS AND SOURCE DATA

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Test Series DQ – Detailed Process and Source Data

Description	DQ001	DQ002	DQ003	DQ004	DQ005	DQ006	DQ007	DQ008	DQ009	Averages
	12/13/00	12/13/00	12/13/00	12/14/00	12/14/00	12/14/00	12/18/00	12/18/00	12/18/00	
Casting Metal Weight, lbs.	234	234	247	240	263	318	246	247	245	252
Total Mold Weight, lbs.	1362	1375	1362	1356	1363	1316	1351	1325	1322	1348
Total Core Weight, lbs.	59.60	59.55	60.35	59.26	59.06	58.97	60.55	60.11	59.94	59.71
Compactability, %	50	48	39	47	40	37	39	44	38	42
Total Binder Weight, lbs	2.84	2.83	2.87	2.82	2.81	2.81	2.88	2.86	2.85	2.84
No. Cavities Poured	8	8	8	8	8	8	8	8	8	8
LOI, % (at mold) 1800°F	5.88	5.20	4.89	4.95	4.85	4.82	4.57	4.59	4.99	4.97
LOI, % (at shakeout) 1800°F	5.26	5.25	4.55	4.81	4.63	4.53	4.17	4.00	4.56	4.64
Clays, % (at mold)	6.07	6.33	6.46	6.33	5.81	6.46	6.85	6.72	6.85	6.43
Clays, % (at shakeout)	5.68	5.17	5.17	4.65	5.30	5.56	5.43	5.68	5.56	5.36
LOI, % (Cores) 1400°F	0.59	0.67	0.60	0.64	0.57	0.63	0.60	0.61	0.64	0.62
Volatiles, % (at mold) avg. 900°F	1.26	1.00	1.02	1.06	1.04	0.92	0.82	0.74	0.88	0.97
Volatiles, % (at shakeout) avg. 900°F	1.16	1.04	0.94	1.06	0.90	0.78	0.82	0.72	0.70	0.90
Pouring Temperature, °F	2629	2633	2638	2640	2640	2623	2639	2629	2639	2634
Mold Strength, psi	10.92	11.11	11.73	12.75	13.58	14.75	15.01	17.32	16.98	13.79
Core Binder Content, %	4.76	4.76	4.76	4.76	4.76	4.76	4.76	4.76	4.76	4.76
Water Type used in Mold	Tap	Tap	Tap	Tap	Tap	Tap	Tap	Tap	Tap	N/A
Total Clays - added, lbs/mold	92.48	5.22	5.22	10.00	5.22	15.00	11.50	10.20	11.52	18.48
Seacoal - added, lbs/mold	87.04	0.00	0.00	1.00	2.00	2.00	3.00	3.00	12.00	12.23
Lignite - added, lbs/mold	-	-	-	-	-	-	-	-	-	-
Soda Ash - added, gms/mold	-	-	-	-	-	-	-	-	-	-
Mold Sand Acidity, pH	-	-	-	-	-	-	-	-	-	-
Average Stack Temperature, °F	104	104	111	104	109	118	104	107	111	108
Total Moisture Content, %	1.45	1.50	1.52	1.67	1.72	1.91	1.24	1.50	1.61	1.57

Test Series DQ – Detailed Process and Source Data

Description	DQ001	DQ002	DQ003	DQ004	DQ005	DQ006	DQ007	DQ008	DQ009	Averages
	12/13/00	12/13/00	12/13/00	12/14/00	12/14/00	12/14/00	12/18/00	12/18/00	12/18/00	
Average Stack Velocity, ft./sec.	15.9	15.9	16.0	15.8	15.9	16.0	15.8	15.8	15.9	15.89
Avg. Stack Pressure, in. Hg	30.09	30.03	30.03	30.18	30.24	30.24	30.40	30.38	30.34	30.21
Stack Flow Rate, scfm	694	693	688	694	691	684	699	695	691	692

Binder fraction = (binder (lbs)/(sand + binder (lbs)) Binder fraction x core weight used in mold = Total Binder Weight Example: (5.0 /(100 + 5.0)) = 0.0476 x 59.60 = 2.894 (lbs binder per mold).

NOTE:1 DQ006 has a high casting metal weight because of a larger than normal pour basin. Retain this test. THC data indicates the impact is less than 5% on the results and statistically, the confidence level in the conclusion is less without this test than with it.

APPENDIX D METHOD 25A CHARTS

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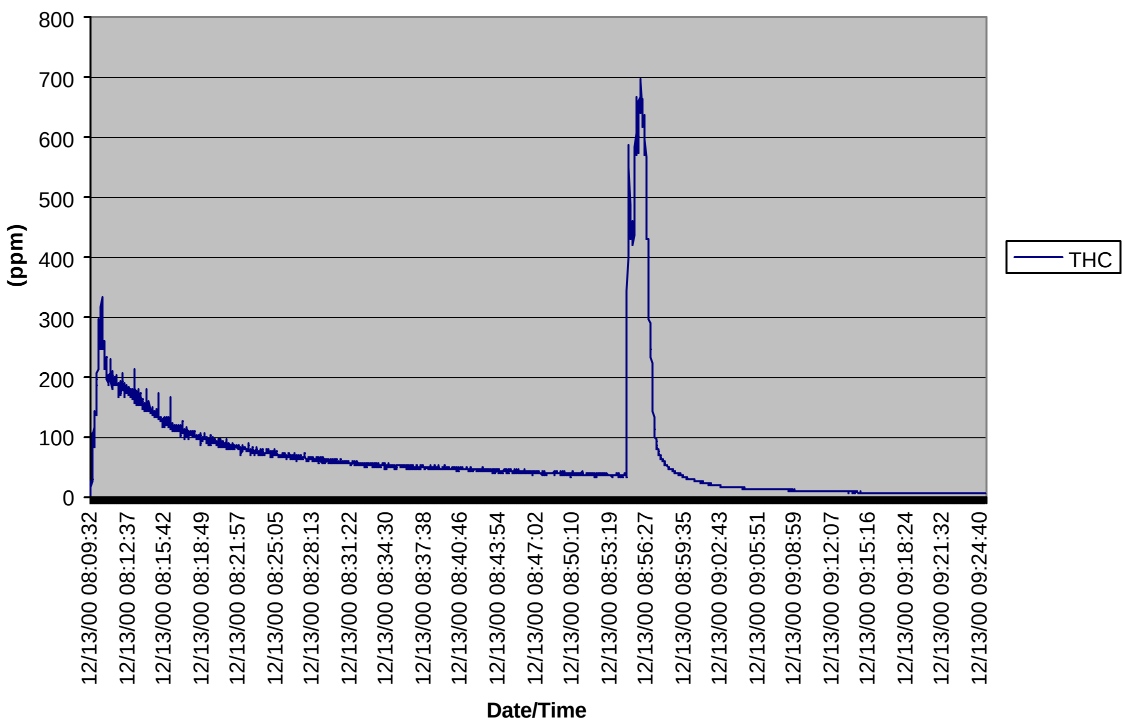
DQ001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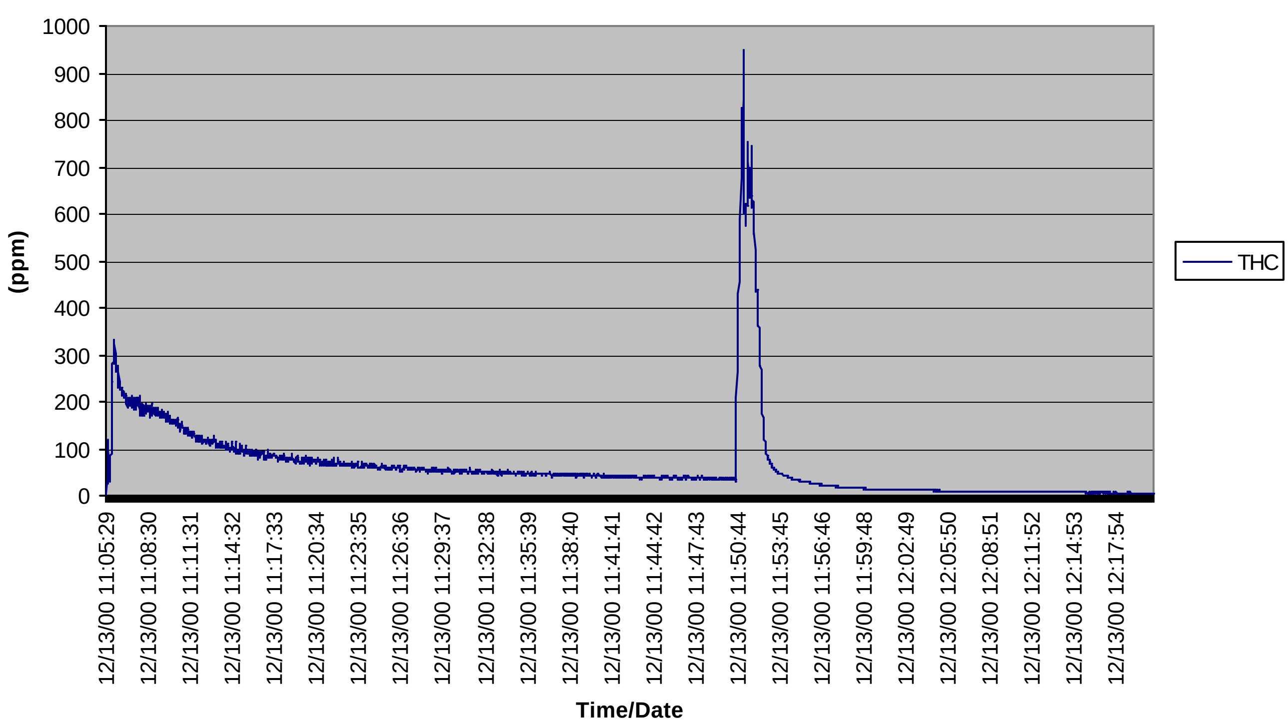
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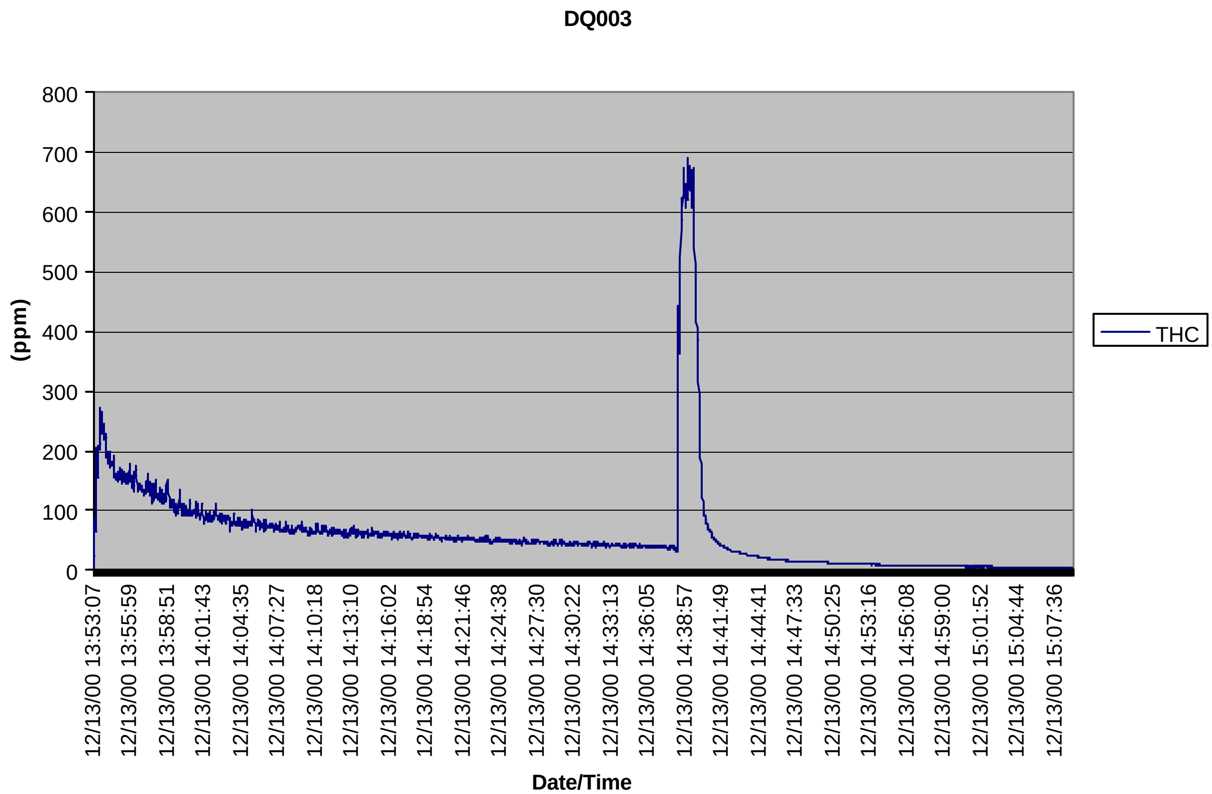
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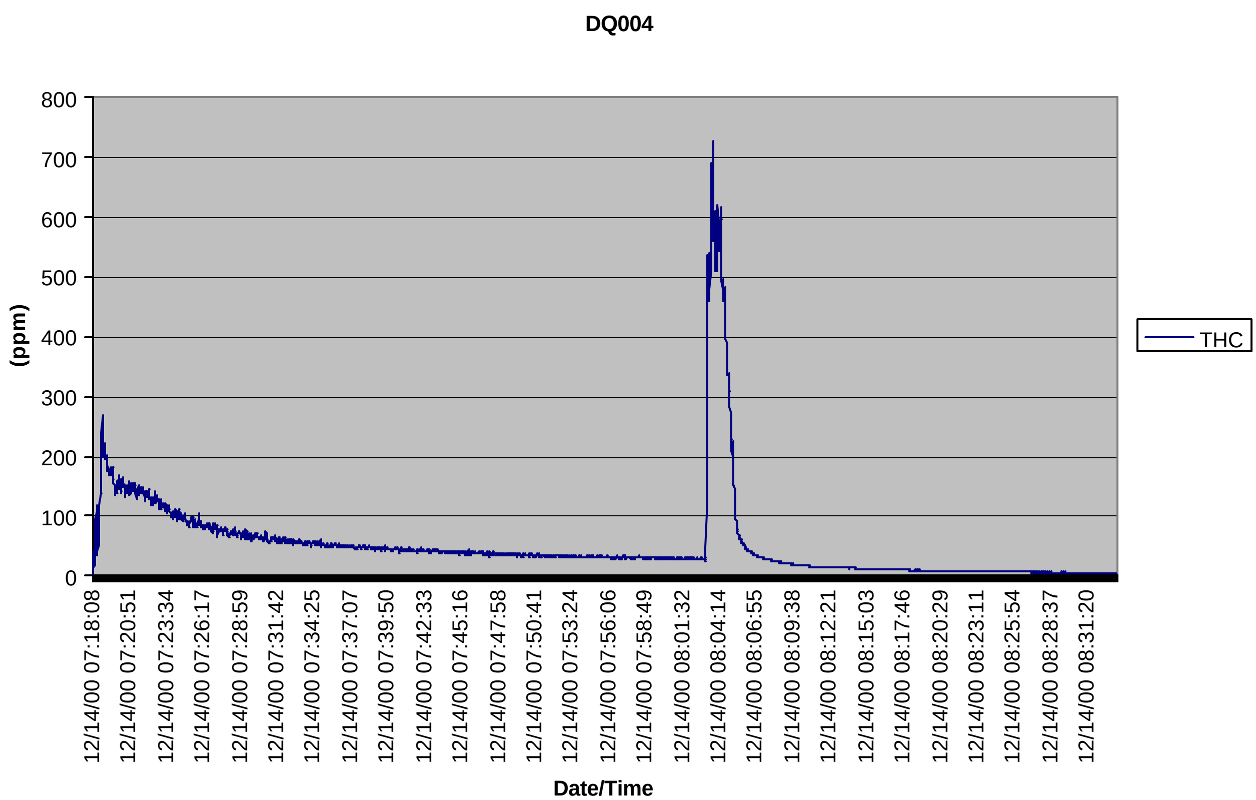
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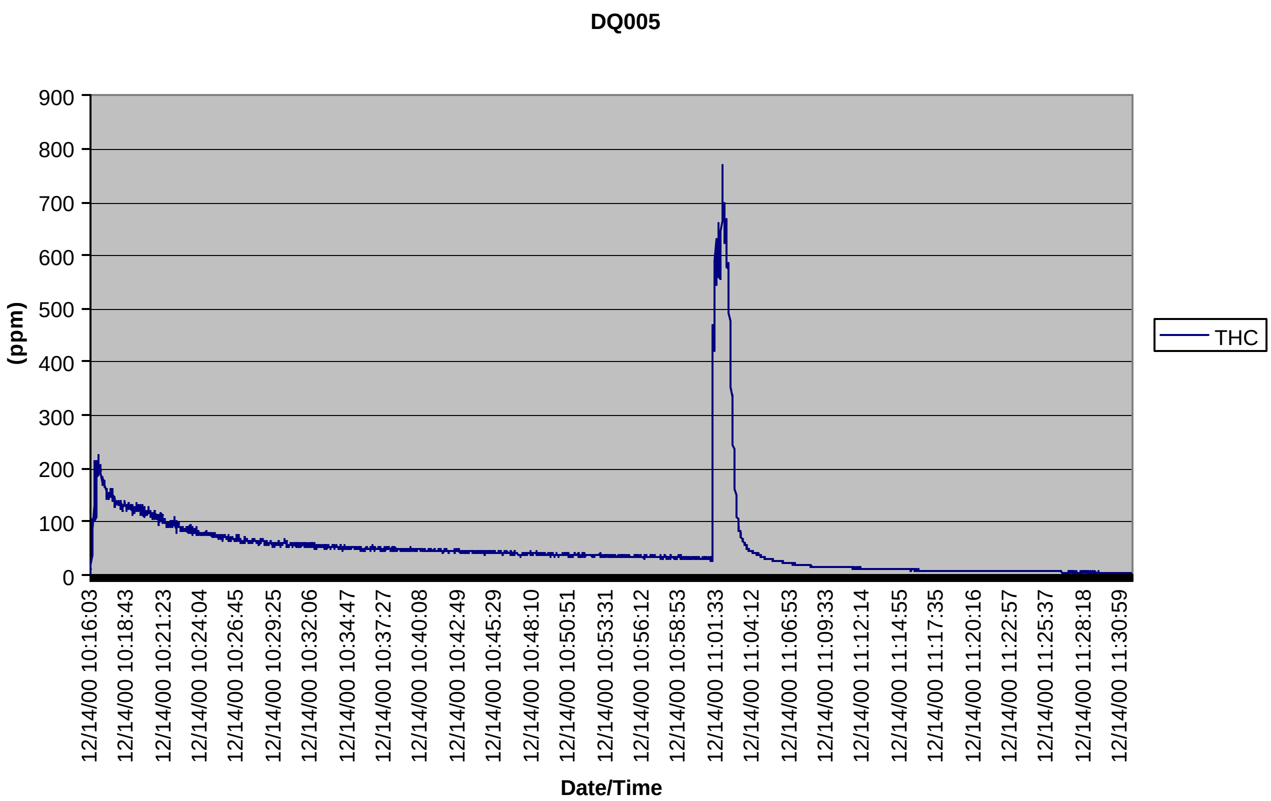
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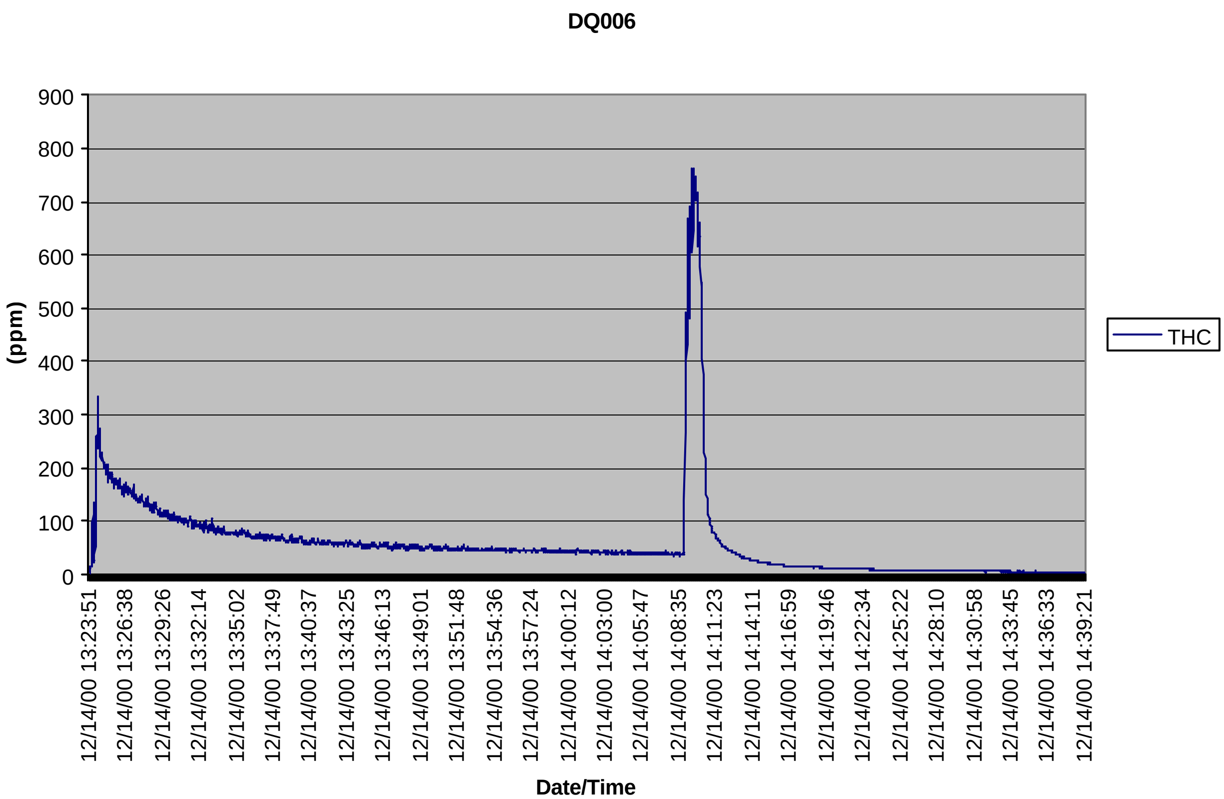
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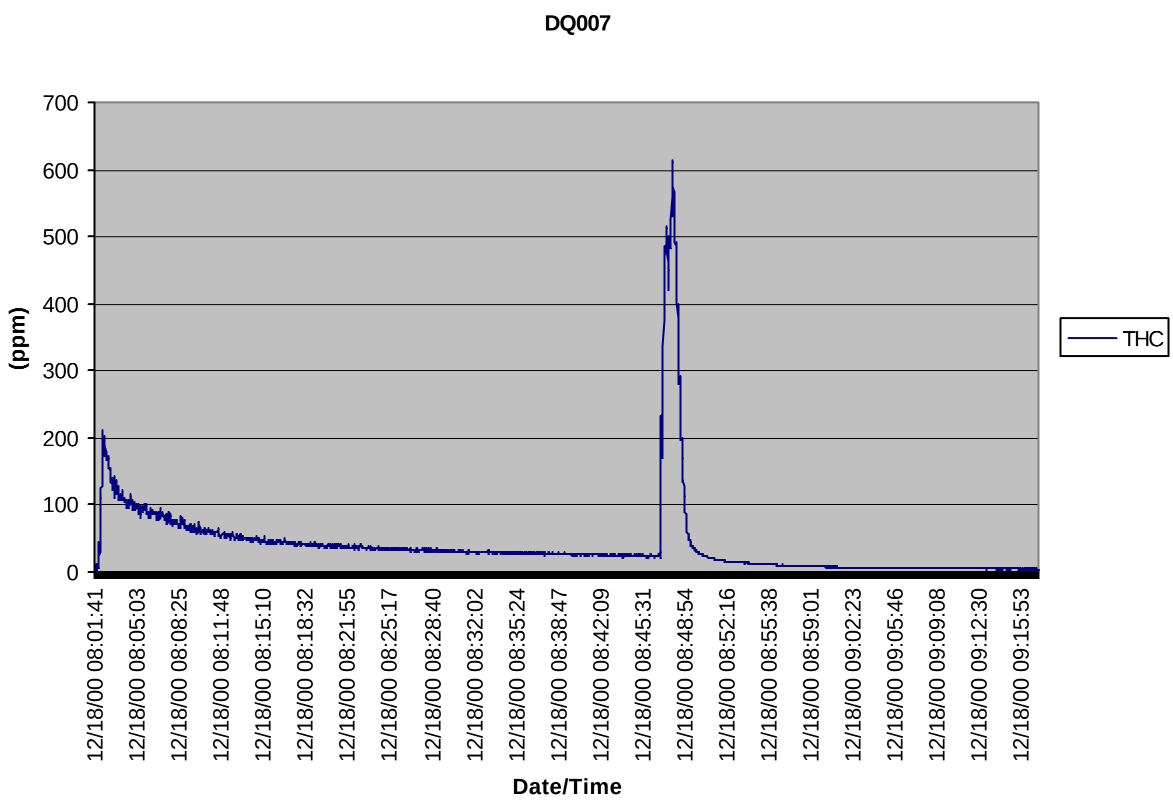
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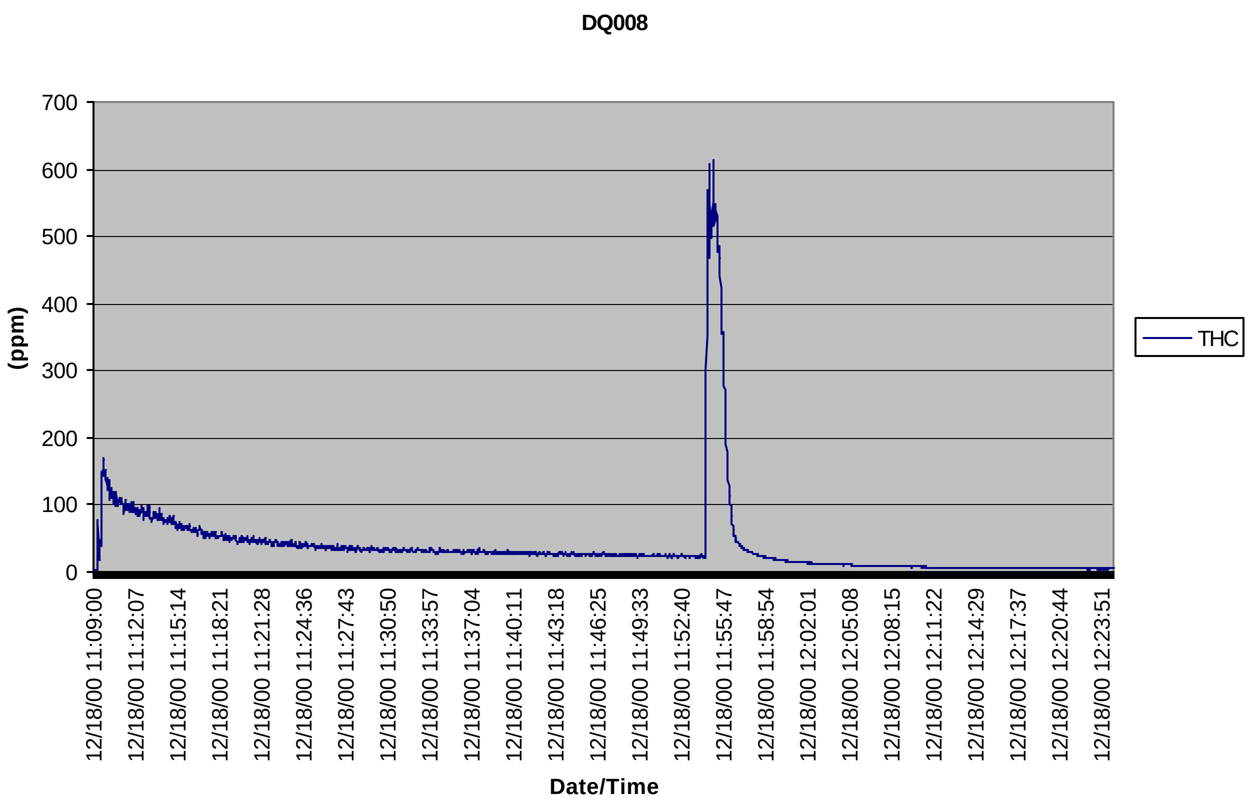
Date/Time


DQ008
700
600
500
400
300
200
100
0
(ppm)
THC
12/18/00 11:09:00
12/18/00 11:12:07
12/18/00 11:15:14
12/18/00 11:18:21
12/18/00 11:21:28
12/18/00 11:24:36
12/18/00 11:27:43
12/18/00 11:30:50
12/18/00 11:33:57
12/18/00 11:37:04
12/18/00 11:40:11
12/18/00 11:43:18
12/18/00 11:46:25
12/18/00 11:49:33
12/18/00 11:52:40
12/18/00 11:55:47
12/18/00 11:58:54
12/18/00 12:02:01
12/18/00 12:05:08
12/18/00 12:08:15
12/18/00 12:11:22
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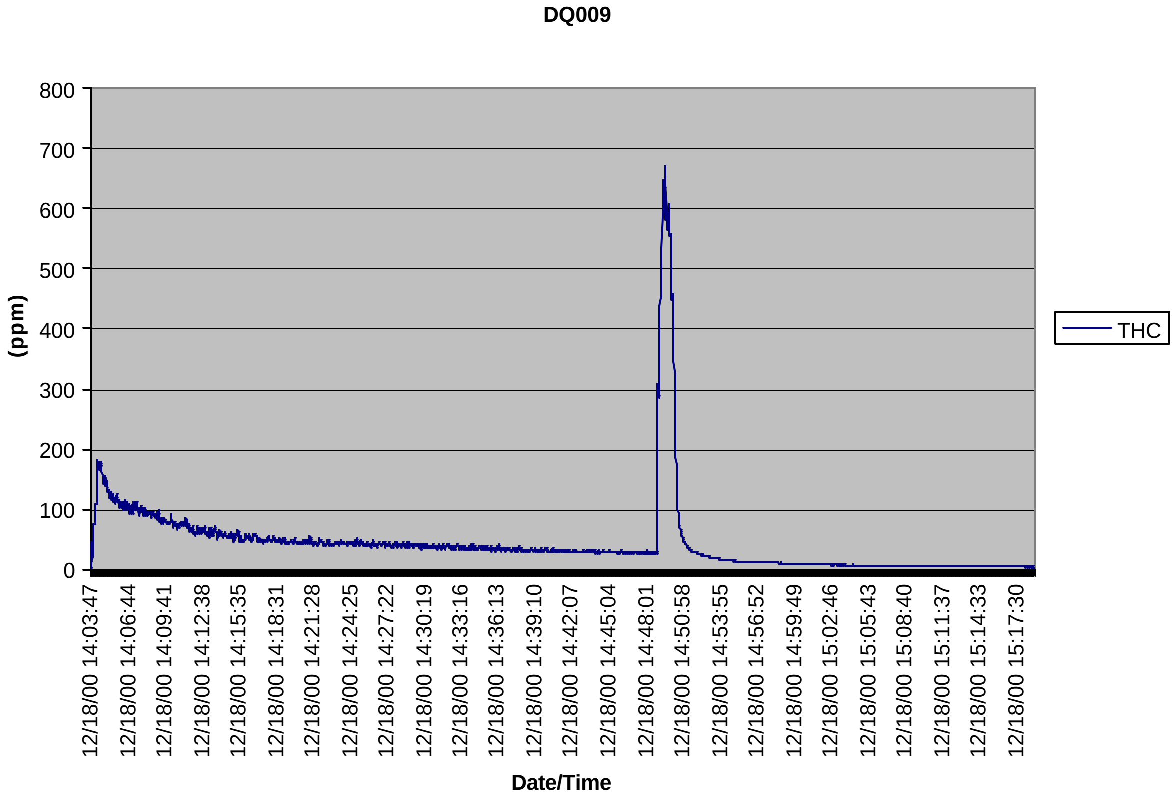
12/18/00 12:23:51
Date/Time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700
600
500
400
300
200
100
0
(ppm)
THC
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12/18/00 14:06:44
12/18/00 14:09:41
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12/18/00 14:15:35
12/18/00 14:18:31
12/18/00 14:21:28
12/18/00 14:24:25
12/18/00 14:27:22
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12/18/00 14:33:16
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12/18/00 14:42:07
12/18/00 14:45:04
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12/18/00 14:53:55
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Date/Time

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APPENDIX E 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. Emissions Testing and Analytical Testing Standard Operating Procedures.

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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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.
LOI	Loss On Ignition - the total weight change resulting from combustion in air at 1400^{o}F or 1800^{o}F.
ND	Non Detect, No Data
No Test	Lab testing was not done on this analyte.
HC as Undecane	Calculated by the summation of all area before elution of Hexane to after the elution of Anthracene. The quantity of THC is performed against a five-point calibration curve of Undecane by dividing the total area count from C6 to C14 to the area of Undecane curve from the initial calibration curve.