Casting Emission Reduction Program

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US Army Task N256

Greensand Prepared with Tap and Advanced Oxidant Enriched Water

Technikon # RE 2 000 100 DE

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United States Environmental Protection Agency

CISA

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Greensand Prepared with Tap and Advanced Oxidant Enriched Water

Technikon # RE 2 000 100 DE

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

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The data contained in this report were developed to assess the relative emissions profile of the product or process being evaluated 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 Production Foundry according to Production Test Plan DE. The testing was conducted as part of Casting Emission Reduction Program (CERP), a cooperative initiative between the Department of Defense (US Army Industrial Ecology Center) and the United States Council for Automotive Research (USCAR). CERP's purpose is to evaluate alternative casting materials and processes that are designed to reduce air emissions from foundries and/or improve the efficiency of casting processes. Other technical partners directly supporting the CERP 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).

The specific objective of Test Plan DE was to determine the emission reductions, if any, of organic Hazardous Air Pollutants (HAPs) and Volatile Organic Compounds (VOCs) for an **advanced oxidation (AO) water** tempered virgin greensand vented mold compared to the emissions from a similar mold prepared with tap water. No cores were used in the mold packages for Test Plan DE. Bentonite clays were added in the ratio of 5 western to 2 southern to maintain total clays at 8%. Organics, determined by LOI (1800°F), were maintained at 5% for the tap water tempered molds, and at 3% for the AO water tempered molds.

The Technikon Production Foundry is a basic greensand foundry similar to existing mechanized commercial foundries. It emulates an automotive foundry in the type and size of equipment, materials, and processes used. Coreless stars were used as the test mold pattern. The Production Foundry is used to evaluate materials, equipment, and processes in a continuous real-world production-like environment. It is instrumented to provide emission measurements, according to methods based on US EPA air testing protocols, of the sand system, and combined pouring, cooling, and shakeout processes. The Production Foundry is also instrumented so that process data on all activities of the metal casting process can be simultaneously and continuously collected in order to complete an economic impact evaluation of the prospective emission reducing strategy.

Impact Holding Machine

The testing performed in the Production Foundry involves the continuous collection of air samples over several sixty (60) minute periods at two (2) different sampling points. The sampling points are located in the sand system exhaust duct and the combined pouring/cooling/ shakeout exhaust duct. Process and stack parameters measured during the test include: the weight of the casting, mold, seacoal and clay additions; % Loss on Ignition (LOI) and % volatiles values for the mold sand; % clay content of the mold sand; % compactability of the mold sand; pouring temperatures; metallurgical data; and stack temperature, pressure, volumetric flow rate, and moisture content. The process parameters and the stack flow rates are maintained within prescribed ranges in order to ensure the repeatability of the tests.

Samples were collected and analyzed for a selected list of 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 castings processed each hour, this data is summarized in Table 1 on the next page. 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 dimethylbenzene and are reported as o,m,p-xylene though 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 Volatile Organic Compounds (VOCs) measured and includes the Hazardous Air Pollutants (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.

The results of the baseline, product, or process testing conducted in the Technikon foundries are not suitable for use as general emission factors. The specific materials used (gray iron from an electric melt furnace and greensand with seacoal); the specific casting produced (coreless stars); the specific production processes employed (an impact mold line); and the specific testing conditions (relatively low production rate, high capture efficiencies, and combined emissions from pouring, cooling and shakeout processes at the Production Foundry) produce emission results unique to the materials, castings, casting processes and measurement conditions used. The data produced are intended to demonstrate the relative emission reductions from the use of alternative materials, equipment and processes, and not the absolute emission levels that would be experienced in commercial foundries. A number of process parameters such as casting surface area, sand to metal ratios, pouring temperatures, stack flow rates, LOI levels, seacoal and resin contents, and the type of foundry (Cope & Drag versus Disa for example) can have a significant impact on actual emission levels.

Table 1 Summary of Test Results - Test Plan DE
Sand System and Combined Pouring, Cooling, Shakeout

Analyte	Tap Water (lbs/tn)	AO Water (Lbs/tn)	AO Water Difference from Tap Water (%)
TGOC (THC) as Propane	4.36	2.04	-53.2
HC as Hexane	1.88	0.949	-49.4
Sum of VOCs	0.519	0.187	-64.0
Sum of HAPs	0.519	0.187	-64.0
Sum of POMs	0.008	ND	-100
Benzene	0.159	0.069	-56.9
Toluene	0.161	0.071	-55.9
Ethylbenzene	0.032	ND	-100
o,m,p-Xylene	0.135	0.052	-61.5
Naphthalene	0.010	ND	-100
Phenol	ND	ND	N/A
Aniline	0.025	0.002	-91.9
Condensables	1.88	1.34	-28.7
Carbon Monoxide	ND	ND	N/A
Methane	ND	ND	N/A
Carbon Dioxide	115	116	0.87

ND: Non Detect; **NA**: Not Applicable

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1.0 Introduction

1.1 Background

The Casting Emission Reduction Program (CERP) is a cooperative initiative between the Department of Defense (US Army Industrial Ecology Center) 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 from foundries and/or improve the efficiency of 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 that has oversight for the testing conducted by CERP. Technikon, an applied research firm operates CERP under contract to the US Army.

Technikon facility Baghouses

1.2 CERP Objectives

The primary objective of CERP is to evaluate the impact of new materials, equipment, and processes on airborne emissions from the production of metal castings. To accomplish this objective, the Technikon facility has been created to evaluate alternate materials and production processes designed to achieve significant airborne emission reductions, especially for organic Hazardous Air Pollutants (HAPs). HAP emissions reduction from the alternative materials, equipment and production processes is expressed as a comparison to similar emissions from a baseline or reference test. 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 specifically designed to facilitate the collection and evaluation of airborne emissions, and associated process data. Candidate materials and/or processes are screened for emission reductions in the Pre-production Foundry and then further evaluated in the Production Foundry. The data collected during the various testing projects are evaluated to determine the impact of the alternate materials and/or processes on airborne emissions as well as on the quality and economics of casting and core manufacture. These alternate materials, equipment, and processes may need to be further adapted and defined so that they will integrate into current commercial green sand casting facilities smoothly and with minimal capital expenditure.

Pre-production testing is conducted in order to evaluate the impact on air emissions from a proposed alternative material, equipment or process. The Pre-Production Foundry is a simple, general-purpose manual foundry, which was adapted and instrumented to allow the collection of detailed emission measurements, using methods based on USEPA air testing protocols. Measurements are taken during pouring, casting cooling, and shakeout processes performed on discrete mold and core packages under tightly controlled conditions not feasible in a commercial foundry. The Pre-production foundry uses an eight-on, bottom-feed AFS step block as its test mold pattern. A report entitled Baseline Testing Emission Results – Pre-Production Foundry provides details of the baseline testing done in the Pre-Production Foundry. This report can be obtained from the Technikon web site at www.technikonllc.com.

Alternative materials, equipment and processes that, during their testing in the Pre-Production Foundry, demonstrate significant air emission reduction potential and preserve casting quality parameters are further evaluated in the Production Foundry. The Production Foundry's design as a basic green sand foundry was deliberately chosen so that whatever is tested in this facility could be easily converted for use in existing mechanized commercial foundries. The Production Foundry emulates an automotive foundry in the type and size of equipment, materials, and processes used. A single cavity automotive I-4 engine block mold is used to further evaluate materials, equipment, and processes in a continuous real-world production-like environment. The Production Foundry provides simultaneous, detailed, individual emission measurements, according to methods based on US EPA air testing protocols, of the melting, pouring, sand preparation, mold making, and core making processes. The Production Foundry is instrumented so that process data on all activities of the metal casting process can be simultaneously and continuously collected in order to complete an economic impact evaluation of the prospective emission reducing strategy. Castings are randomly selected to evaluate the impact of the alternate material, equipment, or process on the quality of the casting.

Test results for a particular process or product may not be the same from both foundries due to differences in the testing process. The Pre-production Foundry is designed to screen new products, processes, or equipment, whereas the Production Foundry is designed to test the effect of the product, process, or equipment in a continuous production-like environment.

The results of the testing conducted at both the Production and Pre-production Foundries are not suitable for use as general emission factors. The specific materials used (gray iron from an electric melt furnace, greensand with seacoal, and a cold box core with a relatively old resin binding system); the specific castings produced (an eight-on step block in the Pre-production Foundry and an I-4 automotive block in the Production Foundry); the specific production processes employed (a stationary hand-poured mold in the Pre-production Foundry and an impact mold line in the Production Foundry); and the specific testing conditions (relatively low stack velocity, long sampling times, high capture rates, and combined emissions from pouring, cooling and shakeout processes at the Production Foundry) produce emission results unique to the materials, castings, casting processes and measurement conditions used. The data produced are intended to demonstrate the relative emission reductions from the use of alternative materials, equipment and processes, and not the absolute emission levels that would be experienced in commercial foundries. A number of process parameters such as casting surface area, sand to metal ratios, pouring temperatures, stack flow rates, LOI levels, seacoal and resin contents, and the type of foundry (Cope & Drag versus Disa for example) can have a significant impact on actual emission levels.

1.3 Report Organization

This report has been designed to document the methodology used and results obtained during product testing in the Production Foundry. Section 1 presents a general overview of the testing, while Section 2 of this report includes a summary of the methodologies used for data collection and analysis, emission calculations, quality assurance, quality control (QA/QC) procedures, and data management and reduction methods. Process data and emissions measurement results are presented in Section 3 of this report, with detailed emissions data included in Appendix B. Section 4 of the report contains a discussion of the results of this test including conclusions drawn from the interpretation of the results.

The raw data, as well as the data validation and reduction steps used for the test presented in this report are included in the test series data binders, which are maintained at the Technikon facility. There are also several support documents, which provide details regarding the testing and analytical procedures used. Appendix F contains a listing of these documents.

1.4 Preliminary Testing

The testing presented in this report was performed according to the Technikon Production Testing Protocols. These protocols were established by Technikon, following the performance of a series of preliminary tests. It has been determined by Technikon that six to nine replicate tests will provide a statistically significant sample for the purpose of evaluating the emission reductions from alternative materials, equipment and processes. The results of the testing conducted in support of this conclusion are included in the document Technikon Production Testing Protocols.

1.5 Specific Test Plan and Objectives

This report contains the results of testing performed to assess HAP and VOC airborne emissions from Test Plan DE in the Technikon Production Foundry. Table 2 provides a summary of Test Plan DE. The approved test plans are included in Appendix A.

Table 2 Test Plan DE Summary

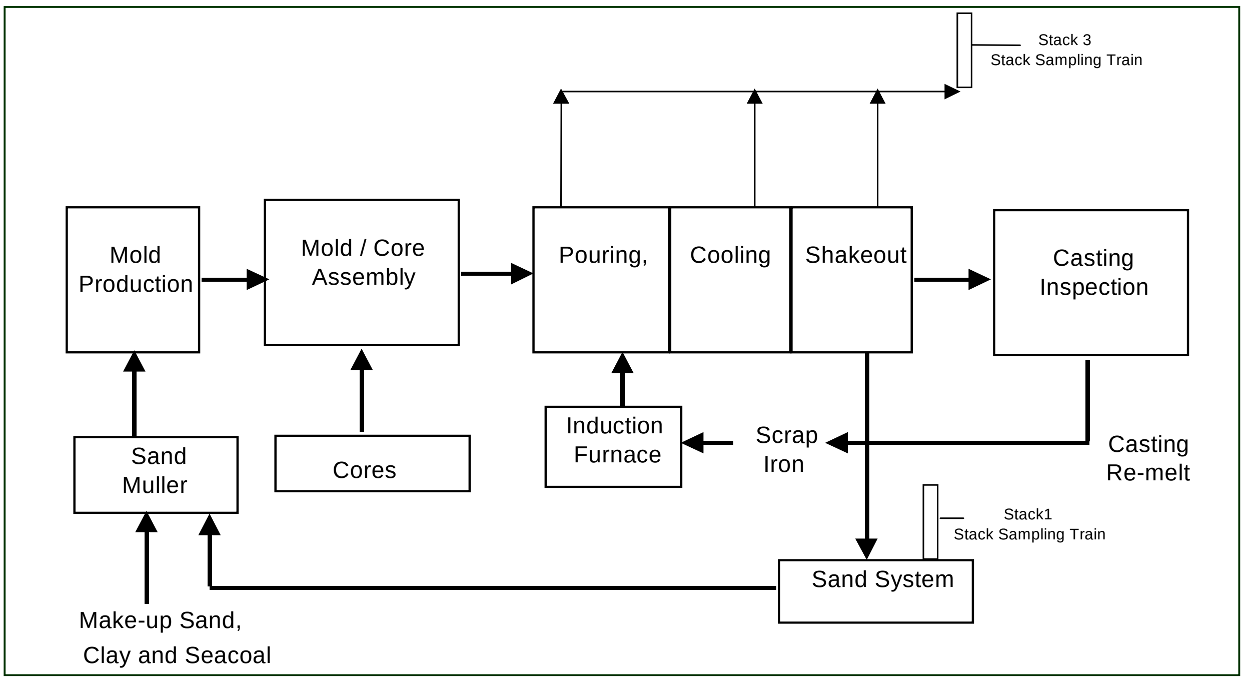
Test Series	DE
Test Dates	May 22, 2001; June 7, 2001
Number of Test Runs	Eight (8) one-hour tests
Sampling Points	Two (2) sampling points: sand system and combined pouring/cooling/shakeout.
Mold Type	Greensand with H&G Seacoal
Core Type	None
Casting Type	Coreless Stars
Emissions Measured	Selected Organic HAPs
Process and Stack Parameters Measured	Casting, Mold Weights, Molds processed, Metallurgical data, Mold Component Weights, % LOI (mold), % volatiles, % Clay, % Moisture, Stack Temperature, Stack Moisture Content, Stack Pressure, and Stack Volumetric Flow Rate

2.0 Test Methodology

2.1 Description of Process and Testing Equipment

Figure 1 is a flow diagram of the Production Foundry process.

Figure 1 Production Foundry Process Flowchart



2.2 Description of Testing Program

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

1. **Mold and Metal Preparation:** Molds were produced on an impact mold line. Iron was melted in two electric induction melt furnaces with a total capacity of 5 tons/hour. The amount of metal melted was determined from the poured weight of the casting and the number of molds to be poured. The metal composition was provided on a metal composition worksheet.

2. **Individual Sampling Events:** Sampling of each of the sampling points (sand system and combined pouring/cooling/shakeout) was conducted over eight (8) individual one-hour test runs. Each mold package was placed in a flask that was assigned a number and tracked by time and position throughout the process. The number of poured mold packages entering

each process step (sand system and combined pouring/cooling/shakeout) for each test hour was determined from the tracking data for each mold package. Air samples were collected continuously during each one-hour test run at each of the sampling points. The average casting weight and mold package counts were used to determine the total metal weight processed at each point during each test hour in order to correlate the emissions measurements with the metal weight processed.

Emission Sampling

Emissions samples were drawn from sampling ports located in conformance with US EPA Method 1 at each of the sampling points. The tip of the probe was located at the centroid of the duct in accordance with US EPA Method 18. The samples were collected at a constant rate in absorption tubes and the flow rate through each of the sample tubes was controlled using critical orifices.

3. **Process Parameter Measurements:** The finished castings were cleaned and quality checks of the castings were performed. Average mold weights were determined from weights of the various materials required to assemble the prescribed test mold configuration. The % LOI, % clays and % compactability of the mold were determined from periodic samples of the mold sand. Pouring temperatures were also recorded periodically during the testing to determine the average pour temperature. Table 3 lists the process parameters that were monitored during each test. The analytical equipment and methods used are also listed.

Table 3 Process Parameters Measured

Parameter	Analytical Equipment and Methods
Mold Weight	Standard Weight (Gravimetric)
Casting Weight	Standard Weight (Gravimetric)
Seacoal Weight	Simpson Technology (Calibrated Volumetric)
LOI% at mold	Denver Instruments XE-100 Analytical Scale (AFS procedure 5100-00-S)
Clay, % at mold	Dietert 535A MB Clay Tester (AFS Procedure 2210-00-S)
Metallurgical Parameters	
Pouring temperature	Electro-Nite DT 260 (T/C immersion pyrometer)
Carbon/Silica	Electro-Nite Datacast 2000 (Thermal Arrest) and Baird Foundry Mass Spectrometer
Alloy Weights	Ohaus DS10 (Gravimetric)
Mold Compactability	Dietert 319A Sand Squeezer (AFS procedure 2221-00-S)

4. **Air Emissions Analysis:** The specific sampling and analytical methods used in the Production Foundry tests were based on the US EPA reference methods shown in Table 4. The

details of the specific testing procedures and their variance from the reference methods are included in the Technikon Standard Operating Procedures.

Table 4 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, NIOSH 1500, 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.

5. **<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 pressure, temperature, gas molecular weight and moisture content. The total mass of analyte is then divided by the weight of metal determined from the average casting weight and the count of mold/core packages processed for the specific emission point and test hour. The results are calculated as pounds of analyte per ton of metal processed. The specific calculation formulas are included in the <u>Technikon Emissions Testing and Analytical Testing Operating Procedures.</u>

   The results of validated duplicate samples for individual sampling events (one-hour test runs) were averaged to provide the result for each analyte for each of the sampling events. The results for each analyte from the six sampling events were then averaged to provide the analyte’s average emission rate for the entire series. The averaged results of each of the sampling events and the corresponding series averages are included in Section 3 of this report.

6. **<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 Technikon 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

Table 1 presents a summary of the total emissions generated at the sand system and combined pouring, cooling, shakeout sampling points, for Test Plan DE.

Table 2 presents a summary of the test parameters for the test plan.

Table 3 presents the test equipment and methodologies used to measure the process parameters for Test Plan DE.

Table 4 presents a summary of the sampling and analytical methodologies utilized for Test Plan DE.

Table 5 presents Test Plan DE process data.

Table 6 presents the stack data and calculated flow rates for Test Plans DE.

A summary of the airborne emission results for Test Plan DE, in pounds of analyte per ton of metal poured, is presented in Table 7a and 7b, respectively. The data represents the individual and combined emissions from the sand system and pouring, cooling, and shakeout. The results include five emission factors, as well as the organic HAP compounds measured during the test.

Table 8 shows the Casting Quality Ranking Matrix.

Figures 2 and 3 present comparisons of the sand system emissions measured during Test DE for tap water and AO treated molds, based on results shown in Table 7a and 7b.

Transferring Molten Iron to Pouring Furnace

Figures 4 and 5 present similar charts of the combined pouring/cooling/shakeout results shown in Table 7a and 7b, and Figures 6 and 7 show the total results for both systems from Table 7a and 7b.

Figure 8 presents pictures of the “best,” “average,” and “worst” casting surface.

Appendix B contains tables presenting the results for all analytes measured during Test DE. The results presented in this report are not blank corrected.

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Table 5a Production Foundry Test DE Process Data – Stars / Tap Water

Average Casting Weight, lbs./mold	124.3
Average Mold Sand Weight lbs./mold	1322
Average Core Sand Weight, lbs./mold	N/A
Average Resin Weight, lbs./mold	N/A

Process Parameter	# of Samples	Minimum	Maximum		Average	Std Dev.
Compactability, %	29	38	48		42	2.344
LOI, % (at mold)	10	4.80	5.49		5.01	0.194
Clays, % (at mold)	10	7.06	8.33		7.86	0.406
Core LOI, %	N/D	N/D	N/D		N/D	N/D
Pouring Temperature, ^{o}F	9	2611	2690		2638	24.171

Mold Count							
Pour Date	5/22/2001	5/22/2001	5/22/2001	5/22/2001	5/22/2001		Averages
Test Number	DE001	DE002	DE003	DE004	DE005		
Number of Molds at Sand System	24	26	25	26	25		25
Test Number	DE021	DE022	DE023	DE024	DE025		
Number of Molds at Combined Pouring/Cooling/Shakeout	24	26	25	27	25		25

Table 5b Production Foundry Test DE Process Data – Stars / AO Water

Average Casting Weight, lbs./mold	124.3
Average Mold Sand Weight lbs./mold	1322
Average Core Sand Weight, lbs./mold	N/A
Average Resin Weight, lbs./mold	N/A

Process Parameter	# of Samples	Minimum	Maximum		Average	Std Dev.
Compactability, %	22	36	50		43	3.48
LOI, % (at mold)	8	3.51	3.66		3.53	0.076
Clays, % (at mold)	8	7.65	8.62		8.03	0.320
Core LOI, %	N/D	N/D	N/D		N/D	N/D
Pouring Temperature, ^{o}F	7	2610	2658		2639	16.14

Mold Count								
Pour Date	**6/7/2001**	**6/7/2001**	**6/7/2001**					**Averages**
Test Number	DE006	DE007	DE008					
Number of Molds at Sand System	24	24	25					24
Test Number	DE026	DE027	DE028					
Number of Molds at Combined Pouring/Cooling/Shakeout	26	25	26					26

Table 6a Production Foundry Test DE Stack Data and Calculated Flow Rates Stars / Tap Water

	Test Run Number	DE001	DE002	DE003	DE004	DE005	Average
Sand System	Average Stack Temperature, ºF	83	86	90	93	97	90
	Total Moisture Content, %	1.95	1.78	2.12	2.11	2.21	2.03
	Avg. Stack Pressure, in. Hg Abs.	29.50	29.52	29.54	29.55	29.55	29.53
	Average Stack Velocity, ft./sec.	44.5	44.6	44.8	44.3	43.1	44.3
	Stack Flow Rate, scfm	31,563	31,507	31,323	30,823	29,791	31,001
PCS Combined	**Test Run Number**	**DE021**	**DE022**	**DE023**	**DE024**	**DE025**	**Average**
	Average Stack Temperature, ºF	84	88	92	95	99	92
	Total Moisture Content, %	1.51	1.42	1.55	1.5	1.6	1.5
	Avg. Stack Pressure, in. Hg Abs.	29.46	29.43	29.46	29.48	29.47	29.46
	Average Stack Velocity, ft./sec.	68.4	68.3	68.5	68.7	68.1	68.40
	Stack Flow Rate, scfm	48,594	48,149	47,951	47,830	47,070	47,919

Table 6b Production Foundry Test DE Stack Data and Calculated Flow Rates Stars / AO Water

	Test Run Number	DE006	DE007	DE008			Average
Sand System	Average Stack Temperature, ºF	86	89	92			89
	Total Moisture Content, %	1.71	1.84	2.05			1.87
	Avg. Stack Pressure, in. Hg Abs.	29.66	29.66	29.65			29.66
	Average Stack Velocity, ft./sec.	40.6	41.2	41.1			41.0
	Stack Flow Rate, scfm	28,862	29,031	28,808			28,900
	Test Run Number	**DE026**	**DE027**	**DE028**			**Average**
PCS Combined	Average Stack Temperature, ºF	92	94	96			94.0
	Total Moisture Content, %	1.22	1.31	1.48			1.3
	Avg. Stack Pressure, in. Hg Abs.	29.52	29.52	29.51			29.52
	Average Stack Velocity, ft./sec.	67.2	67.4	67.5			67.37
	Stack Flow Rate, scfm	47,258	47,112	46,954			47,108

Table 7a Test Plan DE Average Test Results - Sand System and Combined Pouring/Cooling/Shakeout (Tap Water)

COMPOUND / SAMPLE NUMBER	SAND SYSTEM AVERAGE	COMBINED PCS AVERAGE	TOTAL
TGOC (THC) as Propane	0.655	3.70	4.36
HC as Hexane	0.776	1.10	1.88
Sum of VOCs	0.141	0.378	0.519
Sum of HAPs	0.141	0.378	0.519
Sum of POMs	0.008	ND	0.008
Individual Organic HAPs			
Benzene	0.035	0.124	0.159
Toluene	0.043	0.118	0.161
Ethylbenzene	0.008	0.024	0.032
o,m,p-Xylene	0.041	0.094	0.135
Naphthalene	0.010	ND	0.010
Phenol	ND	ND	N/A
Aniline	0.006	0.019	0.025
Other Analytes			
Condensable	0.712	1.17	1.88
Carbon Monoxide	ND	ND	N/A
Methane	ND	ND	N/A
Carbon Dioxide	43.0	72.4	115

All "**Other Analytes"** are not included in the sum of HAPs or VOCs.
NT: Not Tested; **N/A:** Not Applicable; **ND** Non-Detect

Table 7b Test Plan DE Average Test Results - Sand System and Combined Pouring/Cooling/Shakeout (AO Water)

COMPOUND / SAMPLE NUMBER	SAND SYSTEM AVERAGE	COMBINED PCS AVERAGE	TOTAL
TGOC (THC) as Propane	0.391	1.65	2.04
HC as Hexane	0.437	0.512	0.949
Sum of VOCs	0.058	0.129	0.187
Sum of HAPs	0.058	0.129	0.187
Sum of POMs	ND	ND	N/A
Individual Organic HAPs			
Benzene	0.019	0.050	0.069
Toluene	0.021	0.050	0.071
Ethylbenzene	ND	ND	N/A
o,m,p-Xylene	0.016	0.036	0.052
Naphthalene	ND	ND	N/A
Phenol	ND	ND	N/A
Aniline	0.002	ND	0.002
Other Analytes			
Condensable	0.436	0.904	1.34
Carbon Monoxide	ND	ND	N/A
Methane	ND	ND	N/A
Carbon Dioxide	46.2	70.3	116

All **"Other Analytes"** are not included in the sum of HAPs or VOCs.
NT: Not Tested**; N/A:** Not Applicable**; ND:** Non Detect

Table 8 Matrix for Ranking Castings Quality Surface

WORST			
40			
39			
38			
37			
36			
35			
34			
33			
32			
31			
30			
29			
28			
27			
26		Rank 14 Hour 3	Worst
25			
24 Worst	Rank 24 Hour 5	Rank 13 Hour 2	Average
23	Rank 23 Hour 1		
22	Rank 22 Hour 5		
21	Rank 21 Hour 3		
20	Rank 20 Hour 3	Rank 1 Hour 1	Best
19	Rank 19 Hour 4		
18	Rank 18 Hour 5		
17	Rank 17 Hour 5		
16	Rank 16 Hour 2		
15	Rank 15 Hour 3		
14	Rank 14 Hour 4		
13	Rank 13 Hour 4		
12 Average	Rank 12 Hour 3		
11	Rank 11 Hour 3		
10	Rank 10 Hour 4		
9	Rank 9 Hour 1		
8	Rank 8 Hour 2		
7	Rank 7 Hour 1		
6	Rank 6 Hour 2		
5	Rank 5 Hour 1		
4	Rank 4 Hour 5		
3	Rank 3 Hour 1		
2	Rank 2 Hour 2		
1 Best	Rank 1 Hour 1		
Ranking	DE-1 Tap water	DE-2 A/O water	
BEST			

Figure 2 Comparison of Emission Indicators for Production Test Plan DE – Sand System

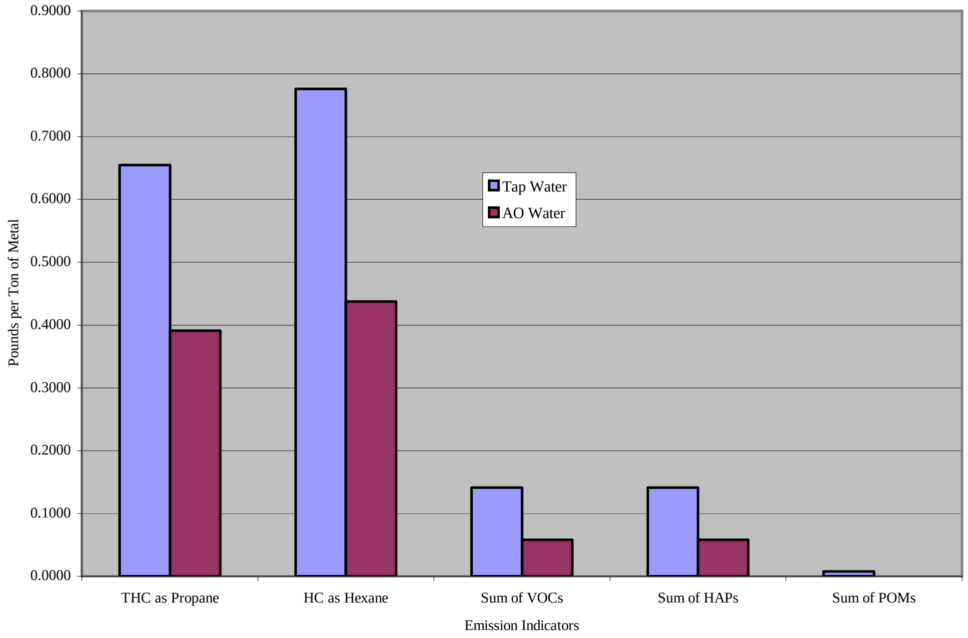


Figure 3 Comparison of Selected HAPs for Production Test Plan DE – Sand System

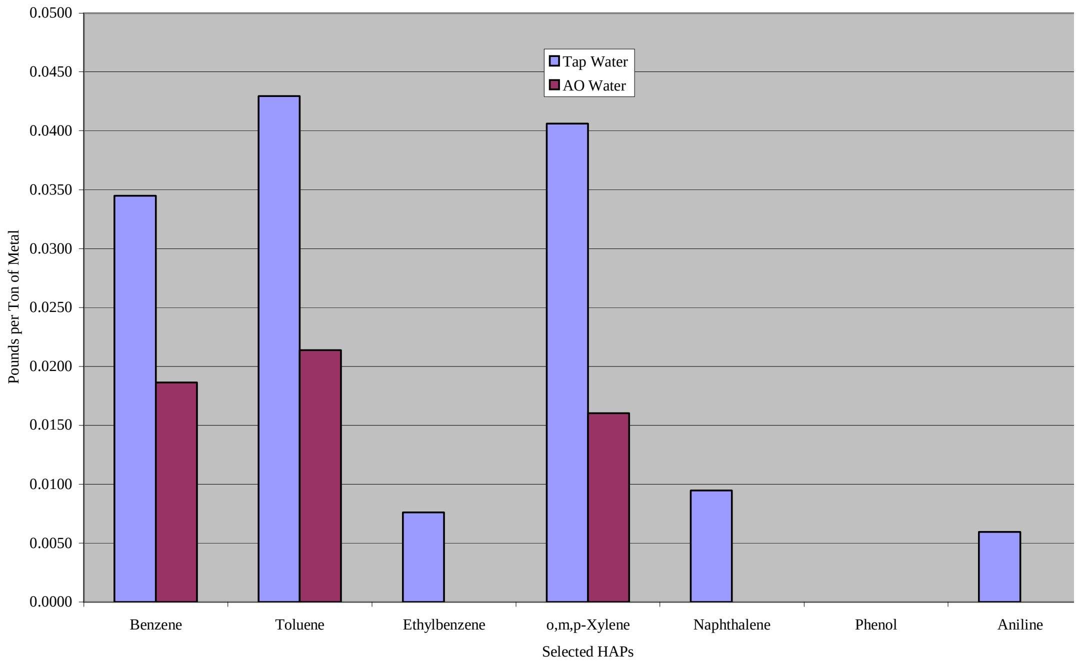


Figure 4 Comparison of Emission Indicators for Production Test Plan DE – Combined PCS

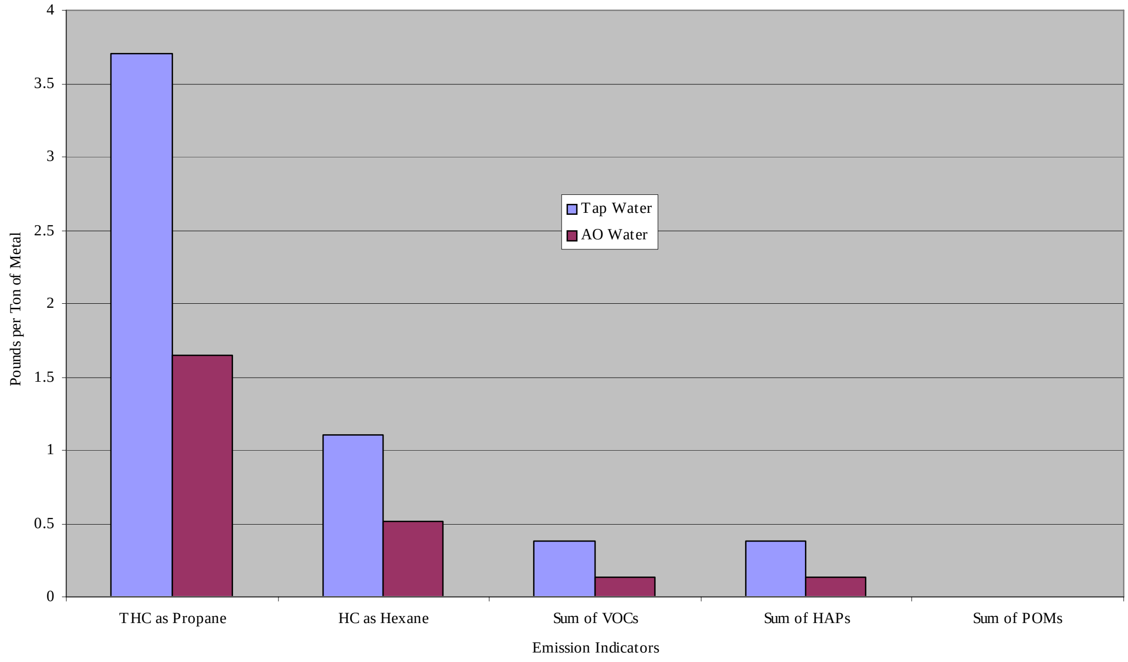


Figure 5 Comparison of Selected HAPs for Production Test Plan DE – Combined PCS

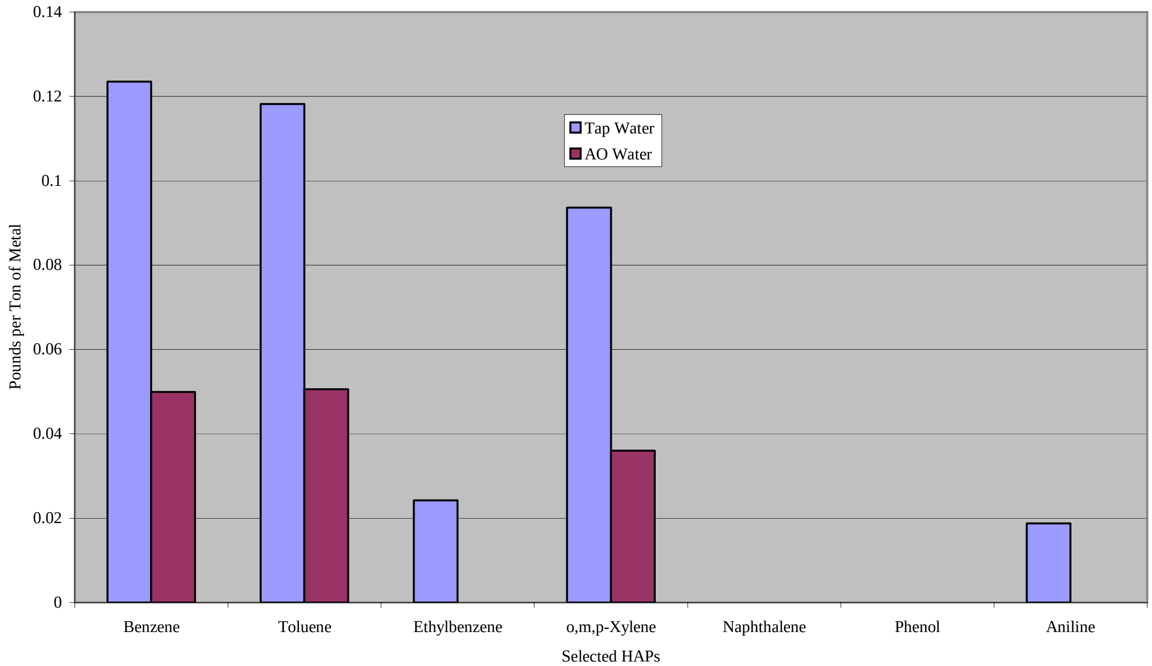


Figure 6 Comparison of Emission Indicators for Production Test Plan DE – Sand System and Combined PCS

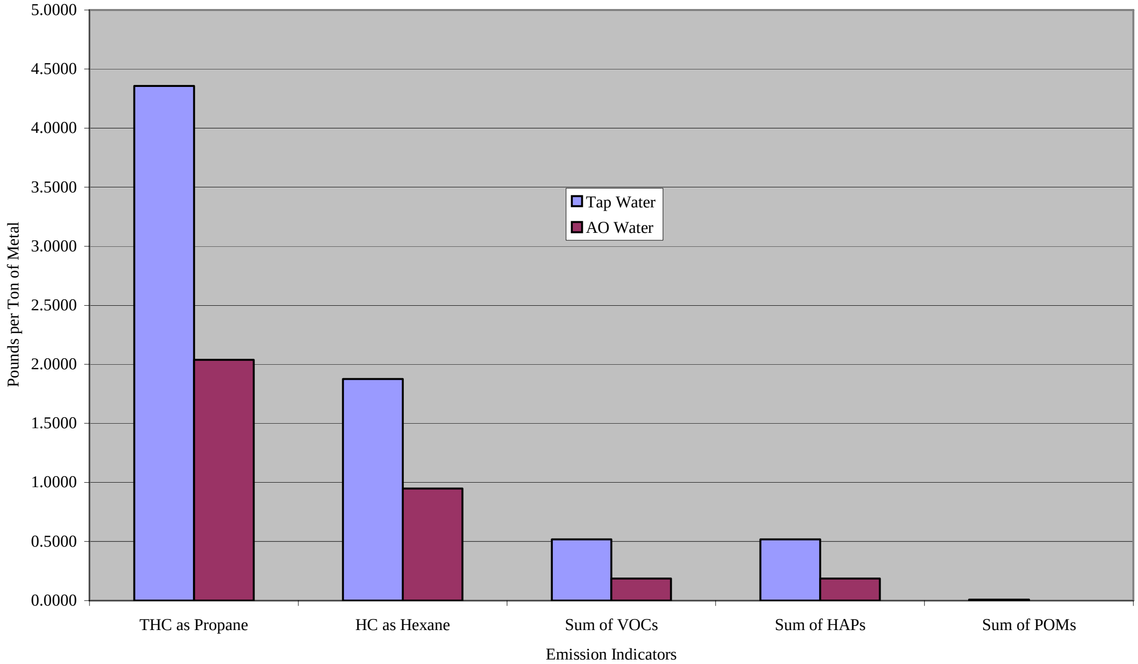


Figure 7 Comparison of Selected HAPs for Production Test Plan DE – Sand System and Combined PCS

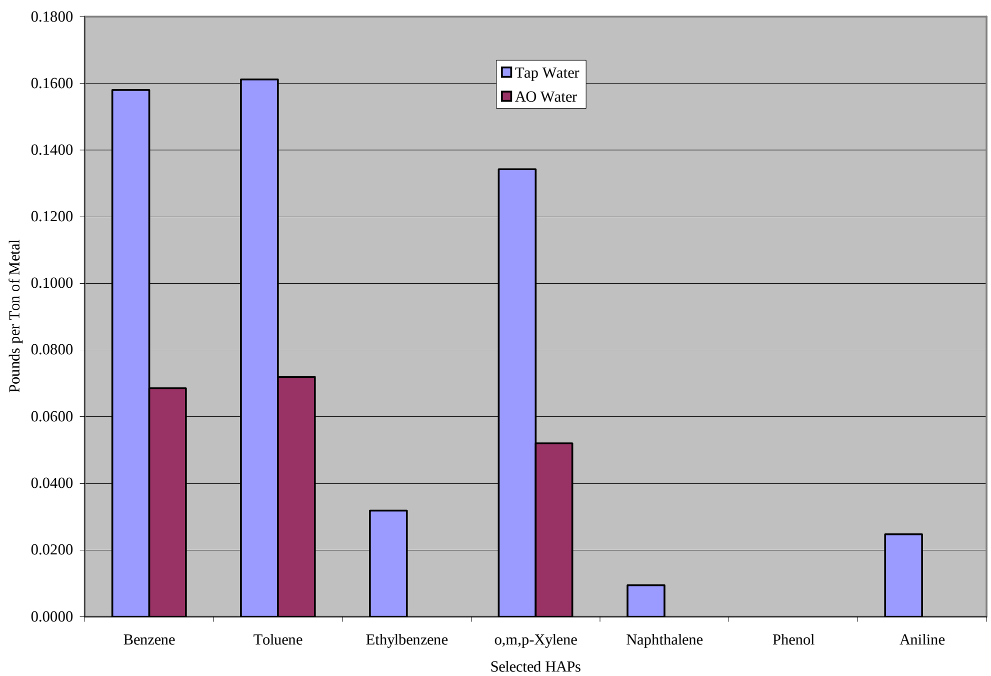
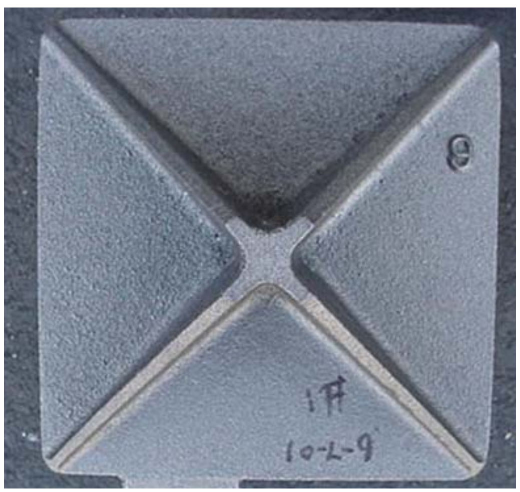


Figure 8 DE Tap AO Stars Surface Quality

Tap Water - Best - DE-1 - 1 of 24

Tap Water - Average - DE-1 - 13 of 24

Tap Water - Worst - DE-1 - 24 of 24



AO water - Best - DE-2 - 1 of 14

AO water - Average - DE-2 - 7 of 14

AO water - Worst - DE-2 - 14 of 14

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4.0 Discussion of Results

Protocols used for the greensand preparation, collection of process parameters, sampling, and analysis for test series DE were consistent with those used for previous Production Foundry testing.

A selected list of analytes was utilized in the analysis of stack emissions from Test Series DE. 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 selected list. In addition, samples were collected in Tedlar bags, and analyzed for carbon monoxide, carbon dioxide, methane, and volatile hydrocarbons in the range of C2 to C5. One sample was collected from the sand system and one from pouring/cooling/shakeout for each of the two test phases (tap water treated, and AO treated molds).

Emission indicators including TGOC (THC) as propane, HC as hexane, and the sums of measured VOCs (volatile organic compounds), HAPs (hazardous air pollutants), and POMs (polycyclic organic materials), are shown in Tables 7a and 7b. Two methods were employed to measure undifferentiated hydrocarbon emissions in Test DE, TGOC (THC) as Propane, performed in accordance with EPA Method 25A, and HC as Hexane by NIOSH Method 1500. Distinct differences in methodologies are present in each method that would be expected to produce dissimilar 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).

Results for Test DE show that total hydrocarbon emissions from the sand system and pouring/cooling/shakeout, measured as TGOC (THC) as Propane, were reduced by over 50% in the Advanced Oxidation (AO) treated greensand molds, when referenced against tap water treated molds. When measured as HC as Hexane, the same reduction of 50% is seen, although the overall rate of measured emissions is lower due to the weighting of the test procedure as discussed in the previous paragraph.

In terms of individual HAPs, the emission rate of toluene was slightly greater than any of the other HAP compounds, in both the tap water and AO treated molds. Total toluene emissions (sand system and PCS) were reduced by approximately 50% in the AO treated phase of Test DE, referenced against tap water treated molds. The majority of toluene emissions, as with all the HAP compounds detected in this test, occurred during the pouring, cooling, and shakeout phase of the casting process. In Test DE, HAP emissions during PCS exceeded those recovered from the sand system by approximately 70%, for all detected compounds.

One of the detected HAPs, aniline, was not expected to be present due to the absence of cores in the mold package. The presence of this compound in a coreless system can probably be attributed to the re-use of the mold sand from Test DD, the Production Foundry Casting Quality Baseline, which included a phenolic-urethane based resin core in the mold package.

Field tests have drawn an implication that a synergy exists between the sand grain size distribution, developed clay content, and the amount of organic materials necessary to produce a commercially satisfactory casting. In this test the tempering of the clay with tap water and AO enriched water was controlled to allow a demonstration of whether there is an enhanced development of the clay materials with the use of AO enriched tempering water and a possible reduction in the amount of organic material present without loss of casting quality.

The organic material was reduced from 5% with tap water to 3.5% with AO treated water (the test plan called for 3.0% LOI). Based on the CERP research paper PROCESS VARIABLE EVALUATION, a reduction of 1.5% in the Mold LOI would result in approximate 32% reduction in organic VOC emissions.

The clay re-bond rate necessary to maintain a Methlene Blue (MB) clay content of 7.86% with tap water was 0.18% of the batch weight compared to 0.36% for AO treated water with a MB clay content of 8.03%. Were the AO treated sand at 7.86% MB clay, the expected maintenance re-bond rate would have been 0.19%. With these nearly equivalent re-bond rates, the MB clay content of the tap water tempered sand was declining at a rate of 0.11% per turn of the sand system while the AO water treated sand MB clay content was increasing at a rate of 0.32% per turn. Had the test been conducted for a longer period of time, it is apparent by the rate of change in the MB clay content for both the tap water and the AO treated water that the AO treated water system would soon require less clay to support the same MB clay content.

Castings were sampled randomly from both the tap water and AO enriched water tempered runs for the purpose of assessing the greensand casting surface quality derived from the two processes. Most of the surfaces were similar but those from the AO enriched water tempered set did not achieve the quality of those from the tap water tempered set. Review) of the LOI (see the approved test plant in Appendix A), and the Volatiles data from both runs revealed that the agreed to burn down method, wherein no new coal is added, to reduce the LOI from the planned 5.0% to 3.0% (3.5% actually achieved) systematically depleted the mold of the beneficial lower temperature volatiles. This burn down method is also believed to be the reason that the LOI did not reach its target of 3.0%. Volatiles are still available but the continuous running of a single pattern with its constant mass and surface area moves the sand to equilibrium after which new volatilization essentially ceased. It would take a casting of larger section thickness to raise the mean sand temperature to realize more of the available volatiles. These physical/chemical equilibrium phenomenon are demonstrated in the CERP research paper PROCESS VARIABLE EVALUATION in the sections showing the emissions which come in part from the organic content of the mold sand from the independent influence of the casting mass and surface area. The AO casting surface appearance therefore appears to be an unintended consequence of the method of changing the LOI content. Further research with AO treated water, either in pre-production or the production foundry, building the sand from the bottom up with continuous addition of new coal might resolve this question and may yield results more consistent with commercial experience.

APPENDIX A APPROVED TEST PLAN FOR TEST SERIES DE

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TECHNIKON/CERP TEST PLAN

> **CONTRACT NUMBER**: 1256 **TASK NUMBER:** 130

> **CONTROL NUMBER**: RE 2 000100

> **SAMPLE FAMILY:** DE

> **SAMPLING EVENT:** 001 thru 008 Stack 1 (Total Sand System & Re-claimed Sand from Pits)

> **SAMPLING EVENT:** 021 thru 028 Stack 3 (Combined Pouring, Cooling, & Shakeout)

> **SITE: ____PRE-PRODUCTION (243)__X__ PRODUCTION(238)**

> **TEST TYPE:** Production Foundry Tap/AO water tempered coreless greensand study

> **MOLD TYPE**: Greensand from Foundry Casting Quality Baseline DD using the coreless star pattern.

> **NUMBER OF MOLDS POURED**: 2000-3000 as required to stabilize sand system

> **CORE TYPE**: None

> **TEST DATES:** **START:** 3 May 01
> **FINISH:** 7 Jun 01

TEST OBJECTIVES:

Primary:

a. Determine as a reference the amount of clay and seacoal necessary to maintain the clay at 8% and the LOI at 5% using tap water to temper the sand. Create a casting quality reference set.

b. Determine as a comparative the amount of clay and seacoal necessary to maintain the clay at 8% and the LOI at 3.0% using AO treated water to temper the sand. Compare casting quality to casting set from objective “a”.

Secondary:

a. Measure selected HAP & VOC emissions during 5% LOI with tap temper water and 3% LOI with AO temper water.

b. Monitor all segments of the test with the THC.

VARIABLES:

All molds will be made using system sand from test DD (Production Foundry Casting Quality Baseline) with H & G seacoal. Clay will be added in the ratio of 5 Western to 2 Southern bentonite to maintain an MB clay range of 8.0+/-0.5%. Compactability will be targeted at 40-45%. Organics will be maintained at an LOI (1800ºF) content of 5.0 +/- 0.3% for a tap water reference test then will be burned down and maintained at 3.0, +/-0.3% for all subsequent A/O water tests. Soda ash will be added at the rate of 0.0075 pounds per pound of clays and coals when A/O water is used. The muller will maintain a 2 minute door-to-door cycle time. Pouring temperature shall be nominally 2630ºF. The line will run at 44 molds per hour except during emission tests when it will run at 25 molds per hour consistent with previous production foundry emission tests. The test pattern will be the six on coreless star. Only H&G seacoal will be used as the organic mold additive

BRIEF OVERVIEW:

The emphasis of this test series is to evaluate the potential material consumption reduction from using advanced oxidation treatment of the temper water suggested by the pre-production tests. The experiences of selected foundries indicate that a reduction is possible without loss of casting quality even with short mulling cycles and reduced seacoal content.

In Part I the system will be stabilized at 8.0+/-0.5% MB clay and 5.0+/-0.3% LOI (1800^{o}F) using tap water with a 2 minute door-to-door mull cycle. Then four one-hour emission tests will be conducted. This configuration is typical of many foundries using high western bentonite-tap-water-tempered sand systems. A reference set of quality ranked castings will be created.

In Part I AO temper water and soda ash will be used. The LOIs will be burned down and stabilized at 3.0+/-0.3%. The sand will continue to be mulled with a 2 minute mull cycle. Casting will be sampled at a 10% rate during the transition period. Finally the sand will be tempered with AO water until it is stable at 8.0+/-0.5% MB clay and 2.8, +0.5, -0.1% LOI (1050^{o}F) after which four comparative one-hour emission tests will be conducted. A comparative set of quality ranked castings will be created. Following these emission tests the same sand will be re-conditioned with Isocure resin bonded core for more AO tests under test series EF with engine blocks.

SPECIAL CONDITIONS:

The muller cycle will be maintained at 2 minutes door-to-door. The AO generator will be coop-erated in continuous mode. A compactability of 40-45% is expected to yield a water clay ratio of 0.29-0.33. Higher water contents with this system sand leads to material handling problems and molds with inferior casting surface.

Manager Process Engineering (Technikon)	4/26/01 **Date**
V.P. Measurement Technologies (Technikon)	4-26-01 **Date**
V.P. Operations (Technikon)	4-26-01 **Date**
Emissions Team (USCAR)	5/31/01 **Date**
Process and Facilities Team (USCAR)	5/31/01 **Date**
Program Representative (CTC)	7/5/01 **Date**

Series DE

Process Instructions

for the Production Foundry Evaluation of Effect of Using Advanced Oxidant Treated Tempering Water

A. The Experiment:

1. The focus of test series DE is to demonstrate any difference in mold material consumption when using AO treated water vs. tap water as tempering water in a coreless greensand mold with seacoal at LOI contents typical of commercial foundries making commercial quality castings with the two sand preparation methods.
2. Emissions will be monitored during the entire sand system stabilization period.
3. Formal emissions tests will be conducted with the sand system stabilized using tap water as the tempering water and again after re-stabilization using AO treated water as the tempering water.
4. Test DE Part I: Tap water, 5% LOI.

   a. The test pattern shall be the six (6)–on coreless star.
   b. The sand pile used for test DD (Casting Quality Baseline) will be the feed material for this test. This sand was turned over 12 times during test DD.
   c. The MB clay content will be adjusted and stabilized during 12 turnovers of the sand system (4 casting sessions) to 8.0 +/- 0.5%. Clays will be added as necessary in a 5:2 western to southern bentonite ratio.
   d. The LOI (1800 F) will be adjusted and stabilized during this period to 5.0 +/- 0.3% using H&G bituminous seacoal.
   e. The sand will be tempered with tap water and mulled for only 2 minutes door-to-door.
   f. During the stabilization period emissions will be monitored by the THC.
   g. After stabilization is verified five (5) one-hour sequential emission tests, with a selected list of analytes, will be conducted at 25 molds per hour using a single cooling line. The first emission test will be conducted after the cooling line is full. Start of the second emission test will be delayed until molds with hot sand from the first casting cycle have filled the single cooling line.
   h. During the emission test cavities 2 & 5 of the star castings will be sampled each 10 molds and identified by emission test number (1-5), date and time. This set will form a tap water- 5% LOI reference casting set.
   i. Sand will be mulled, the prepared sand hopper kept supplied, and molds will continue to be produced until the 5th emission test is completed.

5. Test DE Part II: AO water, 3.0% LOI

   a. The test pattern shall be the six (6)–on coreless star.

b. The sand pile used for test DE Part I will be the feed material for this test. This sand will have been turned over 15 additional times during test DE Part I.

c. The MB clay content will be adjusted and stabilized during 12 turnovers of the sand system (4 casting sessions) to 8.0 +/- 0.5%. Clays will be added as necessary in a 5:2 western to southern bentonite ratio.

d. The LOI (1800^{o}F) will be adjusted and stabilized during this period to 3.0 +/- 0.3% using H&G bituminous seacoal.

e. The sand will be tempered with AO treated water and mulled for only 2 minutes door-to-door.

f. During the stabilization period emissions will be monitored by the THC.

g. During the conditioning cavity one (1) of the star castings will be sampled each 10 molds and identified by date & time. This set will form a tap water/AO water- (5%,3%) LOI transition casting set.

h. After stabilization is verified five (5) one-hour sequential emission tests, with a selected list of analytes, will be conducted at 25 molds per hour using a single cooling line. The first emission test will be conducted after the cooling line is full. Start of the second emission test will be delayed until molds with hot sand from the first casting cycle have filled the single cooling line.

i. During the emission test cavity one (1) of the star castings will be sampled each 10 molds and identified by emission test number (1-5), date and time. This set will form an AO water- 3% LOI comparative casting set.

j. Sand will be mulled, the prepared sand hopper kept supplied, and molds will continue to be produced until the 5th emission test is completed.

B. Equipment preparation.

Note: Start and operate the production foundry equipment only according to the Production Foundry Operating and Safety Manual.

1. Start the sand system baghouse and visually verify the air flow control dampers are in the standard position established in November 2000.

    a. Report the survey results.
    b. Correct any deviations.

2. Start the sand system equipment.
3. Start the mold line with at least 2 cooling lines operative.

C. Sand preparation during conditioning.

1. Use stored sand pile DD, Quality baseline.
2. Stop the cooler surge hopper discharge conveyor belt to prevent prepared and shakeout sand from returning to the originating sand storage hopper until the original contents are removed and counted.
3. Set the muller batch size to 5000 pounds. Actual batch size is about 4200 pounds.

a. Add western & southern bentonite and seacoal to the production muller according to a recipe to be supplied by the Process Engineer. The targets are:

(1) MB clay: 8.0 +/- 0.5% from a ratio of 5 western to 2 southern.
(2) LOI (1800^{o}F) 5.0+/- 0.3% for Part I emission test and 3.0 +/- 0.3 for Part II emission test.
(3) Compactability: 40-45%. The target moisture content range at 8% MB clay should be 2.8-3.6%. The minimum moisture requested is 2.6% at 7.5% MB clay to a maximum of 3.8% at 8.5% MB.

b. Use tap water to start and through the Part I emission test then change to AO treated water for the balance of the test series DE.
c. Add Soda Ash to the muller at the rate of 0.0075 # soda ash per pound of clay and seacoal when AO water is used.
d. For these tests only the muller door-to-door cycle time shall be 2 minutes instead of the standard 3 minutes.

4. Grab a bag of sand from one of the first 5 muller batches, seal it, and take it immediately to the sand lab for analysis. Record the date, time, and batch cycle number for the current day at each sampling. Sand sampling shall be every 10 batches.

a. The sand lab is to immediately, upon receipt, perform the following green property sand tests:

(1) Sand temperature.
(2) Moisture.
(3) Compactability.
(4) 2 by 2 sample weight.
(5) Green compression strength on a 2 by 2 standard test sample.

b. The following sand tests should be started upon completion of the above tests:
(1) MB clay.
(2) Mold LOI (1800^{o}F). Retain the burned sand in a sealed plastic bag properly identified.

c. The following sand tests should be performed on one sample per sand system turn after the test is completed

(1) AFS clay wash.
(2) GFN analysis.

5. Process all the original sand before returning any prepared or shakeout sand to the main storage hopper so that we can measure the size of the sand system as batch weight times batch count.

Note: When the sand storage hopper is exhausted turn on the cooler surge hopper discharge conveyor belt.

6. The process engineer will provide a re-bond recipe at startup based on the last sand sample from the test DD.
7. Sample the sand from the last muller cycle. Record the date, time, and batch cycle number for the current day each sampling.
8. From time to time the process engineer will change the re-bond recipe to reflect current values and maintain the system within the prescribed targets**.**

D. Mold making during conditioning

1. The mold line will operate at 44 molds per hour down two cooling lines, 1 and 2.

Note: Only one line can be used at 25 molds per hour if we run out of sand in the main storage hoppers before the sand returns from the molds.

2. Each conditioning day turn the sand system over 3 times making about 250 star molds.

E. Mold making during the Tap water reference emission test (Stars) and the AO comparative emission test (stars).

1. The mold line may operate at 44 molds per hour until the molds reach the pour furnace then the mold line must operate at 25 molds per hour down a single cooling line, either line 1 or 2.
2. Operate sufficient time to gather five 1-hour emission samples in a single day while the cooling line is full of molds of similar age.
3. The emission sampling team shall qualify each sample period based on acceptance criteria in the sample plan.

F. Melting

1. Two melt furnaces are required to support 44 molds per hour. Only one melt furnace is required for 25 molds per hour except to fill the pouring furnace.
2. Furnace charges shall conform to the generic Startup Charge (effectivity date 9 Mar 1999) and Back Charge (effectivity date 9 Apr 1999) recipes.
3. Pour the molds at 2630 +/- 30 ^{o}F.
4. The molds shall be poured full.
5. A record shall be kept for the melt furnace and pouring furnace operation. Where double tapping and charging are employed the record shall reflect the aggregate charge additions but separate tap events.
6. .Each melt heat shall have a Data Cast test and a spectrometer lug poured. Where double tapping and charging are employed only one test need be performed for the pair.
7. The pour furnace operator shall pour and submit a spectrometer lug after the initial filling and each hour thereafter until cessation of pouring.

8. It is imperative that the pouring be continuous during each of the 5-1 hr emission tests.
9. The emission testing shall not begin until hot castings continuously come out of the shake out. The second emission test of each day shall not begin until molds with hot sand from the first casting cycle fill the cooling line.
10. The Metallurgical lab will do spectrochemical analysis on all spectro lugs.

G. Casting sampling

1. Casting shall be sampled on a 10 % basis beginning at the start of the Part I emission test and continuing through the subsequent re-conditioning and Part II emission test. The castings shall be permanently marked, shot blast for 8 minutes and ranked by 5 persons in descending order of appearance base on a defined set of criteria including: casting general appearance, surface roughness on flat surfaces, and mechanical penetration in corners, swells, and expansion defects.

Steve Knight
Mgr. Process Engineering

DE Series Sample Plan - Tap Water - Conditioning (Stack 1)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/3/2001											THC on Stack 1 only
TEST 1											10:23am - 4:20 pm
THC	5/3/2001	X									M-25a
											at 3:20 line went from 44 to 54 mph

DE Series Sample Plan - Tap Water – Conditioning (Stack 3)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/15/2001											THC(JUM) on Stack 3
TEST 2											08:35am - 15:37pm
THC	5/15/2001	X									M-25a

DE Series Sample Plan - Tap water - Test (Stack 1 and 3)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/22/2001											THC(JUM) on Stack 1 and 3
TEST 3											30min. sample alternating stacks
											08:21:39 to14:26:38
THC (JUM)	5/22/2001	X									M-25a

DE Series Sample Plan - AO water - Conditioning (Stack 1 and 3)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/31/2001											Stack 1 and Stack 3
TEST 4											Method 25a
THC (JUM)	5/31/2001	X									Stack 1 (06:22:00 to 15:10)
THC (CAL)	5/31/2001	X									Stack 3 (06:22:00 to 15:10)

DE Series Sample Plan - AO water - Test (Stack 1 and 3)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
6/7/2001											Stack 1 and Stack 3
TEST 5											Method 25a
THC (JUM)	6/7/2001	X									Stack 1 (06:14:00 to 14:40
THC (CAL)	6/7/2001	X									Stack 3 (06:14:00 to 14:40

DE Series Sample Plan - Tap water / Coreless Greensand – Sand System (Stack 1)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/22/2001											SAMPLES TO: Scott Forbes
TEST 1											Train: CERP # 2
THC	DE00101	X									M-25a
Excess									60	1	Excess
Excess									60	2	Excess
Excess									100	3	Excess
Excess									100	4	Excess
Niosh 1500	DE00102		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE00103		1						500	6	SKC226-01
Niosh 1500	DE00104			1					500	7	SKC226-01, Duplicate
Niosh 1500	DE00105				1				0	7	QC Blank, SKC226-01
Niosh 1500	DE001PS		1						500	8	SKC226-01 to Penn St.
Niosh 1500	DE001PSB				1				0	8	QC Blank, SKC226-01 to Penn St.
Excess									1000	9	Excess
NIOSH 2002	DE00106		1						1000	10	SKC 226-15
NIOSH 2002	DE00107			1					1000	11	SKC226-15, Duplicate
NIOSH 2002	DE00108				1				0	11	QC Blank - SKC 226-15
Moisture									500	12	
Excess									5000	13	
PUF	DE001		1								

DE Series Sample Plan - Tap water / Coreless Greensand –Sand System (Stack 1)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/22/2001											SAMPLES TO: Scott Forbes
TEST 2											Train: CERP # 2
THC	DE00201	X									M-25a
Excess									60	1	Excess
Excess									60	2	Excess
Excess									100	3	Excess
Excess									100	4	Excess
Niosh 1500	DE00202		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE00203		1						500	6	SKC226-01
Niosh 1500	DE00204			1					500	7	SKC226-01, Duplicate
GAS,CO + CO2	DE00205		1						500	8	BAG Sample to Airtoxics Lab.
Excess									1000	9	Excess
NIOSH 2002	DE00206		1						1000	10	SKC 226-15
NIOSH 2002	DE00207			1					1000	11	SKC226-15, Duplicate
Moisture									500	12	
Excess									5000	13	
PUF	DE002		1								

DE Series Sample Plan - Tap water / Coreless Greensand – Sand System (Stack 1)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/22/2001											SAMPLES TO: Scott Forbes
TEST 3											Train: CERP # 2
THC	DE00301	X									M-25a
Excess									60	1	Excess
Excess									60	2	Excess
Excess									100	3	Excess
Excess									100	4	Excess
Niosh 1500	DE00302		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE00303		1						500	6	SKC226-01
Niosh 1500	DE00304			1					500	7	SKC226-01, Duplicate
Niosh 1500	DE003PS		1						500	8	SKC226-01 to Penn St.
Excess									1000	9	Excess
NIOSH 2002	DE00305		1						1000	10	SKC 226-15
NIOSH 2002	DE00306			1					1000	11	SKC226-15, Duplicate
Moisture									500	12	
Excess									5000	13	Excess
PUF	DE003		1								

DE Series Sample Plan - AO water / Coreless Greensand – Sand System (Stack 1)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/22/2001											SAMPLES TO: Scott Forbes
TEST 4											Train: CERP # 2
THC	DE00401	X									M-25a
Excess									60	1	Excess
Excess									60	2	Excess
Excess									100	3	Excess
Excess									100	4	Excess
Niosh 1500	DE00402		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE00403		1						500	6	SKC226-01
Niosh 1500	DE00404			1					500	7	SKC226-01, Duplicate
Niosh 1500	DE004PS		1						500	8	SKC226-01 to Penn St.
Excess									1000	9	Excess
NIOSH 2002	DE00405		1						1000	10	SKC 226-15
NIOSH 2002	DE00406			1					1000	11	SKC226-15, Duplicate
Moisture									500	12	
Excess									5000	13	Excess
PUF	DE004		1								

DE Series Sample Plan - AO water / Coreless Greensand – Sand System (Stack 1)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/22/2001											SAMPLES TO: Scott Forbes
TEST 5											Train: CERP # 2
THC	DE00501	X									M-25a
Excess									60	1	Excess
Excess									60	2	Excess
Excess									100	3	Excess
Excess									100	4	Excess
Niosh 1500	DE00502		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE00503		1						500	6	SKC226-01
Niosh 1500	DE00504			1					500	7	SKC226-01, Duplicate
Niosh 1500	DE00505				1				0	7	QC Blank, SKC226-01
Niosh 1500	DE005PS		1						500	8	SKC226-01 to Penn St.
Niosh 1500	DE005PSB				1				0	8	QC Blank, SKC226-01 to Penn St.
Excess									1000	9	Excess
NIOSH 2002	DE00506		1						1000	10	SKC 226-15
NIOSH 2002	DE00507			1					1000	11	SKC226-15, Duplicate
NIOSH 2002	DE00508				1				0	11	QC Blank - SKC 226-15
Moisture									500	12	
Excess									5000	13	
PUF	DE005		1								

DE Series Sample Plan - AO water / Coreless Greensand –Sand System (Stack 1)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
6/7/2001											SAMPLES TO: Scott Forbes
TEST 6											Train: CERP # 2
THC	DE00601	X									M-25a
Excess									60	1	Excess
Excess									60	2	Excess
Excess									100	3	Excess
Excess									100	4	Excess
Niosh 1500	DE00602		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE00603		1						500	6	SKC226-01
Niosh 1500	DE00604			1					500	7	SKC226-01, Duplicate
Niosh 1500	DE006PS		1						500	8	SKC226-01 to Penn St.
Niosh 1500	DE006PSB				1				0	8	QC Blank, SKC226-01 to Penn St.
Excess									1000	9	Excess
NIOSH 2002	DE00605		1						1000	10	SKC 226-15
NIOSH 2002	DE00606			1					1000	11	SKC226-15, Duplicate
Moisture									500	12	
Excess									5000	13	
PUF	DE006		1								

DE Series Sample Plan - AO water / Coreless Greensand –Sand System (Stack 1)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
6/7/2001											SAMPLES TO: Scott Forbes
TEST 7											Train: CERP # 2
THC	DE00701	X									M-25a
Excess									60	1	Excess
Excess									60	2	Excess
Excess									100	3	Excess
Excess									100	4	Excess
Niosh 1500	DE00702		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE00703		1						500	6	SKC226-01
Niosh 1500	DE00704			1					500	7	SKC226-01, Duplicate
GAS,CO + CO2	DE00705		1						500	8	BAG Sample to Airtoxics Lab.
Excess									1000	9	Excess
NIOSH 2002	DE00706		1						1000	10	SKC 226-15
NIOSH 2002	DE00707			1					1000	11	SKC226-15, Duplicate
Moisture									500	12	
Excess									5000	13	Excess
PUF	DE007		1								

DE Series Sample Plan - AO water / Coreless Greensand –Sand System (Stack 1)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
6/7/2001											SAMPLES TO: Scott Forbes
TEST 8											Train: CERP # 2
THC	DE00801	X									M-25a
Excess									60	1	Excess
Excess									60	2	Excess
Excess									100	3	Excess
Excess									100	4	Excess
Niosh 1500	DE00802		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE00803		1						500	6	SKC226-01
Niosh 1500	DE00804			1					500	7	SKC226-01, Duplicate
Niosh 1500	DE008PS		1						500	8	SKC226-01 to Penn St.
Niosh 1500	DE008PSB				1				0	8	QC Blank, SKC226-01 to Penn St.
Excess									1000	9	Excess
NIOSH 2002	DE00805		1						1000	10	SKC 226-15
NIOSH 2002	DE00806			1					1000	11	SKC226-15, Duplicate
Moisture									500	12	
Excess									5000	13	Excess
PUF	DE008		1								

DE Series Sample Plan - Tap Water / Coreless Greensand - P/C/S System (Stack 3)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/22/2001											SAMPLES TO: Scott Forbes
TEST 1											Train: CERP # 1
THC	DE02101	X									M-25a
Excess									20	1	Excess
Excess									25	2	Excess
Excess									25	3	Excess
Excess									200	4	Excess
Niosh 1500	DE02102		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE02103		1						500	6	SKC226-01
Niosh 1500	DE02104			1					500	7	SKC226-01, Duplicate
Niosh 1500	DE02105				1				0	7	QC Blank, SKC226-01
Niosh 1500	DE021PS		1						500	8	SKC226-01 to Penn St.
Niosh 1500	DE021PSB				1				0	8	QC Blank, SKC226-01 to Penn St.
Excess									1000	9	Excess
NIOSH 2002	DE02106		1						1000	10	SKC 226-15
NIOSH 2002	DE02107			1					1000	11	SKC226-15, Duplicate
NIOSH 2002	DE02108				1				0	11	QC Blank - SKC 226-15
Moisture									500	12	
Excess									5000	13	
PUF	DE021		1								

DE Series Sample Plan - Tap Water / Coreless Greensand - P/C/S System (Stack 3)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/22/2001											SAMPLES TO: Scott Forbes
TEST 2											Train: CERP # 1
THC	DE02201	X									M-25a
Excess									20	1	Excess
Excess									25	2	Excess
Excess									25	3	Excess
Excess									200	4	Excess
Niosh 1500	DE02202		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE02203		1						500	6	SKC226-01
Niosh 1500	DE02204		1						500	7	SKC226-01 Duplicate
GAS,CO + CO2	DE02205			1					500	8	BAG Sample to Airtoxics Lab.
Excess									1000	9	Excess
NIOSH 2002	DE02206		1						1000	10	SKC 226-15
NIOSH 2002	DE02207			1					1000	11	SKC226-15, Duplicate
Moisture									500	12	
Excess									5000	13	
PUF	DE022		1								

DE Series Sample Plan - Tap Water / Coreless Greensand - P/C/S System (Stack 3)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/22/2001											SAMPLES TO: Scott Forbes
TEST 3											Train: CERP # 1
THC	DE02301	X									M-25a
Excess									20	1	Excess
Excess									25	2	Excess
Excess									25	3	Excess
Excess									200	4	Excess
Niosh 1500	DE02302		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE02303		1						500	6	SKC226-01
Niosh 1500	DE02304			1					500	7	SKC226-01, Duplicate
Niosh 1500	DE023PS		1						500	8	SKC226-01 to Penn St.
Excess									1000	9	Excess
NIOSH 2002	DE02205		1						1000	10	SKC 226-15
NIOSH 2002	DE02206			1					1000	11	SKC226-15, Duplicate
Moisture									500	12	
Excess									5000	13	
PUF	DE023		1								

DE Series Sample Plan - AO Water / Coreless Greensand - P/C/S System (Stack 3)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/22/2001											SAMPLES TO: Scott Forbes
TEST 4											Train: CERP # 1
THC	DE02401	X									M-25a
Excess									20	1	Excess
Excess									25	2	Excess
Excess									25	3	Excess
Excess									200	4	Excess
Niosh 1500	DE02402		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE02403		1						500	6	SKC226-01
Niosh 1500	DE02404			1					500	7	SKC226-01, Duplicate
Niosh 1500	DE024PS		1						500	8	SKC226-01 to Penn St.
Excess									1000	9	Excess
NIOSH 2002	DE02405		1						1000	10	SKC 226-15
NIOSH 2002	DE02406			1					1000	11	SKC226-15, Duplicate
Moisture									500	12	
Excess									5000	13	
PUF	DE024		1								

DE Series Sample Plan - AO Water / Coreless Greensand - P/C/S System (Stack 3)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
5/22/2001											SAMPLES TO: Scott Forbes
TEST 5											Train: CERP # 1
THC	DE02501	X									M-25a
Excess									20	1	Excess
Excess									25	2	Excess
Excess									25	3	Excess
Excess									200	4	Excess
Niosh 1500	DE02502		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE02503		1						500	6	SKC226-01
Niosh 1500	DE02504			1					500	7	SKC226-01, Duplicate
Niosh 1500	DE02505				1				0	7	QC Blank, SKC226-01
Niosh 1500	DE025PS		1						500	8	SKC226-01 to Penn St.
Niosh 1500	DE025PSB				1				0	8	QC Blank, SKC226-01 to Penn St.
Excess									1000	9	Excess
NIOSH 2002	DE02506		1						1000	10	SKC 226-15
NIOSH 2002	DE02507			1					1000	11	SKC226-15, Duplicate
NIOSH 2002	DE02508				1				0	11	QC Blank - SKC 226-15
Moisture									500	12	
Excess									5000	13	
PUF	DE025		1								

DE Series Sample Plan - AO Water / Coreless Greensand - P/C/S System (Stack 3)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
6/7/2001											SAMPLES TO: Scott Forbes
TEST 6											Train: CERP # 1
THC	DE02601	X									M-25a
Excess									20	1	Excess
Excess									25	2	Excess
Excess									25	3	Excess
Excess									200	4	Excess
Niosh 1500	DE02602		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE02603		1						500	6	SKC226-01
Niosh 1500	DE02604		1						500	7	SKC226-01 Duplicate
Niosh 1500	DE026PS			1					500	8	SKC226-01 to Penn St.
Niosh 1500	DE026PSB				1				0	8	QC Blank, SKC226-01 to Penn St.
Excess									1000	9	Excess
NIOSH 2002	DE02605		1						1000	10	SKC 226-15
NIOSH 2002	DE02606			1					1000	11	SKC226-15, Duplicate
Moisture									500	12	
Excess									5000	13	
PUF	DE026		1								

DE Series Sample Plan - AO Water / Coreless Greensand - P/C/S System (Stack 3)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
6/7/2001											SAMPLES TO: Scott Forbes
TEST 7											Train: CERP # 1
THC	DE02701	X									M-25a
Excess									20	1	Excess
Excess									25	2	Excess
Excess									25	3	Excess
Excess									200	4	Excess
Niosh 1500	DE02702		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE02703		1						500	6	SKC226-01
Niosh 1500	DE02704			1					500	7	SKC226-01, Duplicate
GAS,CO + CO2	DE02705		1						500	8	BAG Sample to Airtoxics Lab.
Excess									1000	9	Excess
NIOSH 2002	DE02706		1						1000	10	SKC 226-15
NIOSH 2002	DE02707			1					1000	11	SKC226-15, Duplicate
Moisture									500	12	
Excess									5000	13	
PUF	DE027		1								

DE Series Sample Plan - AO Water / Coreless Greensand - P/C/S System (Stack 3)

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Amount	Flow (ml/min)	Train Channel	Comments
6/7/2001											SAMPLES TO: Scott Forbes
TEST 8											Train: CERP # 1
THC	DE02801	X									M-25a
Excess									20	1	Excess
Excess									25	2	Excess
Excess									25	3	Excess
Excess									200	4	Excess
Niosh 1500	DE02802		1						500	5	SKC226-01(Matrix Spike from Scott)
Niosh 1500	DE02803		1						500	6	SKC226-01
Niosh 1500	DE02804			1					500	7	SKC226-01, Duplicate
Niosh 1500	DE028PS		1						500	8	SKC226-01 to Penn St.
Niosh 1500	DE028PSB				1				0	8	QC Blank, SKC226-01 to Penn St.
Excess									1000	9	Excess
NIOSH 2002	DE02805		1						1000	10	SKC 226-15
NIOSH 2002	DE02806			1					1000	11	SKC226-15, Duplicate
Moisture									500	12	
Excess									5000	13	
PUF	DE028		1								

APPENDIX B TEST SERIES DE EMISSION TEST RESULTS

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Test DE Sand System Individual Test Results

POMs	HAPS	COMPOUND / SAMPLE NUMBER	DE001	DE002	DE003	DE004	DE005	Average Tap	STDEV Tap	DE006	DE007	DE008	Average AO	STDEV AO
		Pour Date	**05/22/2001**	**05/22/2001**	**05/22/2001**	**05/22/2001**	**05/222001**			**06/07/2001**	**06/07/2001**	**06/07/2001**		
		THC as Propane	5.74E-01	I	6.66E-01	6.76E-01	7.03E-01	6.55E-01	5.63E-02	3.81E-01	4.02E-01	3.90E-01	3.91E-01	1.03E-02
		HC as Hexane	1.06E+00	I	9.33E-01	5.78E-01	5.31E-01	7.76E-01	2.61E-01	4.93E-01	4.96E-01	3.23E-01	4.37E-01	9.89E-02
		Sum of VOCs	1.09E-01	I	1.96E-01	1.57E-01	1.03E-01	1.41E-01	4.36E-02	6.31E-02	5.66E-02	5.42E-02	5.80E-02	4.57E-03
		Sum of HAPs	1.09E-01	I	1.96E-01	1.57E-01	1.03E-01	1.41E-01	4.36E-02	6.31E-02	5.66E-02	5.42E-02	5.80E-02	4.57E-03
		Sum of POMs	ND	I	1.16E-02	1.07E-02	8.70E-03	1.03E-02	1.47E-03	ND	ND	ND	ND	ND
			Individual HAPs and VOCs											
	x	**Benzene**	3.21E-02	I	4.53E-02	3.52E-02	2.53E-02	3.45E-02	8.32E-03	2.00E-02	1.83E-02	1.77E-02	1.86E-02	1.21E-03
	x	**Toluene**	3.77E-02	I	5.60E-02	4.53E-02	3.29E-02	4.30E-02	1.01E-02	2.41E-02	2.14E-02	1.86E-02	2.14E-02	2.74E-03
	x	**Ethylbenzene**	5.73E-03	I	1.41E-02	1.06E-02	ND	1.01E-02	4.21E-03	ND	ND	ND	N/A	N/A
	x	**o,m,p-Xylene**	3.30E-02	I	6.02E-02	4.65E-02	2.28E-02	4.06E-02	1.63E-02	1.89E-02	1.70E-02	1.22E-02	1.60E-02	3.48E-03
z	x	**Naphthalene**	ND	I	1.41E-02	1.31E-02	1.06E-02	1.26E-02	1.80E-03	ND	ND	ND	N/A	N/A
	x	**Phenol**	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	x	**Aniline**	ND	I	6.02E-03	5.92E-03	1.19E-02	7.95E-03	3.43E-03	ND	ND	5.74E-03	5.74E-03	N/A
			Other Analytes											
		Condensables	4.64E-01	5.31E-01	I	3.83E-01	I	4.59E-01	7.41E-02	4.00E-01	4.73E-01	3.50E-01	4.08E-01	6.16E-02
		Carbon Monoxide	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Methane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Carbon Dioxide	NT	4.30E+01	NT	NT	NT	4.30E+01	N/A	NT	4.62E+01	NT	4.46E+01	2.22E+00
		Ethane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Propane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Isobutane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Butane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Neopentane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Isopentane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Pentane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	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**; ND:** Non-Detect

Test DE Sand System Individual Test Results

POMs	HAPS	COMPOUND / SAMPLE NUMBER	DE021	DE022	DE023	DE024	DE025	Tap	STDEV Tap	DE026	DE027	DE028	AO	STDEV AO
		Pour Date	**5/22/2001**	**5/22/2001**	**5/22/2001**	**5/22/2001**	**5/22/2001**			**6/7/2001**	**6/7/2001**	**6/7/2001**		
		THC as Propane	3.63E+00	I	3.86E+00	3.58E+00	3.75E+00	3.70E+00	1.23E-01	1.68E+00	1.64E+00	1.62E+00	1.65E+00	3.41E-02
		HC as Hexane	1.12E+00	I	1.04E+00	1.07E+00	1.17E+00	1.10E+00	6.05E-02	6.08E-01	3.19E-01	6.04E-01	5.11E-01	1.66E-01
		Sum of VOCs	3.90E-01	I	3.53E-01	3.64E-01	4.06E-01	3.78E-01	2.41E-02	1.57E-01	6.27E-02	1.66E-01	1.29E-01	5.73E-02
		Sum of HAPs	3.90E-01	I	3.53E-01	3.64E-01	4.06E-01	3.78E-01	2.41E-02	1.57E-01	6.27E-02	1.66E-01	1.29E-01	5.73E-02
		Sum of POMs	ND	I	ND	ND	ND	N/A	N/A	ND	ND	ND	#DIV/0!	#DIV/0!
			Individual HAPs and VOCs											
	x	**Benzene**	1.28E-01	I	1.08E-01	1.25E-01	1.33E-01	1.24E-01	1.10E-02	6.08E-02	3.23E-02	5.67E-02	4.99E-02	1.54E-02
	x	**Toluene**	1.26E-01	I	1.08E-01	1.14E-01	1.25E-01	1.18E-01	8.83E-03	6.08E-02	3.04E-02	6.04E-02	5.05E-02	1.75E-02
	x	**Ethylbenzene**	2.56E-02	I	2.31E-02	2.25E-02	2.58E-02	2.43E-02	1.70E-03	ND	ND	ND	N/A	N/A
	x	**o,m,p-Xylene**	9.89E-02	I	8.93E-02	8.73E-02	9.90E-02	9.36E-02	6.21E-03	3.57E-02	ND	3.63E-02	2.40E-02	2.08E-02
z	x	**Naphthalene**	ND	I	ND	ND	ND	N/A	N/A	ND	ND	ND	N/A	N/A
	x	**Phenol**	ND	I	ND	ND	ND	N/A	N/A	ND	ND	ND	N/A	N/A
	x	**Aniline**	1.21E-02	I	2.50E-02	1.53E-02	2.27E-02	1.88E-02	6.11E-03	ND	ND	1.25E-02	1.25E-02	N/A
			Other Analytes											
		Condensables	1.01E+00	9.64E-01	I	1.12E+00	9.31E-01	1.01E+00	8.45E-02	9.35E-01	9.42E-01	8.34E-01	9.04E-01	6.02E-02
		Carbon Monoxide	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Methane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Carbon Dioxide	NT	7.24E+01	NT	NT	NT	7.24E+01	N/A	NT	7.03E+01	NT	7.03E+01	N/A
		Ethane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Propane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Isobutane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Butane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Neopentane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Isopentane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	N/A	N/A
		Pentane	NT	ND	NT	NT	NT	N/A	N/A	NT	ND	NT	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; **ND**: Non-Detect

Test DE Tap & AO Test Results

POMs	HAPS	COMPOUND / SAMPLE NUMBER	DE001	DE002	DE003	DE004	DE005	DE006	DE007	DE008		STDEV
		Pour Date	**5/22/2001**	**5/22/2001**	**5/22/2001**	**5/22/2001**	**5/22/2001**	**6/7/2001**	**6/7/2001**	**6/7/2001**		
		THC as Propane	5.74E-01	I	6.66E-01	6.76E-01	7.03E-01	3.81E-01	4.02E-01	3.90E-01	5.42E-01	1.47E-01
		HC as Hexane	1.06E+00	I	9.33E-01	5.78E-01	5.31E-01	4.93E-01	4.96E-01	3.23E-01	6.31E-01	2.65E-01
		Sum of VOCs	1.09E-01	I	1.96E-01	1.57E-01	1.03E-01	6.31E-02	5.66E-02	5.42E-02	1.05E-01	5.41E-02
		Sum of HAPs	1.09E-01	I	1.96E-01	1.57E-01	1.03E-01	6.31E-02	5.66E-02	5.42E-02	1.05E-01	5.41E-02
		Sum of POMs	ND	I	1.16E-02	1.07E-02	8.70E-03	ND	ND	ND	4.43E-03	5.59E-03
			Individual HAPs and VOCs									
	x	**Benzene**	3.21E-02	I	4.53E-02	3.52E-02	2.53E-02	2.00E-02	1.83E-02	1.77E-02	2.77E-02	1.03E-02
	x	**Toluene**	3.77E-02	I	5.60E-02	4.53E-02	3.29E-02	2.41E-02	2.14E-02	1.86E-02	3.37E-02	1.36E-02
	x	**Ethylbenzene**	5.73E-03	I	1.41E-02	1.06E-02	ND	ND	ND	ND	4.35E-03	5.94E-03
	x	**o,m,p-Xylene**	3.30E-02	I	6.02E-02	4.65E-02	2.28E-02	1.89E-02	1.70E-02	1.22E-02	3.01E-02	1.76E-02
z	x	**Naphthalene**	ND	I	1.41E-02	1.31E-02	1.06E-02	ND	ND	ND	5.40E-03	6.82E-03
	x	**Phenol**	ND	I	ND	ND	ND	ND	ND	ND	N/A	N/A
	x	**Aniline**	ND	I	6.02E-03	5.92E-03	1.19E-02	ND	ND	5.74E-03	4.23E-03	4.49E-03
			Other Analytes									
		Condensables	0.4641	0.5310	I	0.3831	I	0.4004	0.4725	0.3500686	0.4335	0.0672
		Carbon Monoxide	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Methane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Carbon Dioxide	NT	4.30E+01	NT	NT	NT	NT	4.62E+01	NT	4.46E+01	2.22E+00
		Ethane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Propane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Isobutane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Butane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Neopentane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Isopentane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Pentane	NT	ND	NT	NT	NT	NT	ND	NT	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**; ND** Non-Detect

Test DE Tap & AO Test Results

POMs	HAPS	COMPOUND / SAMPLE NUMBER	DE021	DE022	DE023	DE024	DE025	DE026	DE027	DE028		STDEV
		Pour Date	**5/22/2001**	**5/22/2001**	**5/22/2001**	**5/22/2001**	**5/22/2001**	**6/7/2001**	**6/7/2001**	**6/7/2001**		
		THC as Propane	3.63E+00	I	3.86E+00	3.58E+00	3.75E+00	1.68E+00	1.64E+00	1.62E+00	2.82E+00	1.10E+00
		HC as Hexane	1.12E+00	I	1.04E+00	1.07E+00	1.17E+00	6.08E-01	3.19E-01	6.04E-01	8.48E-01	3.32E-01
		Sum of VOCs	3.90E-01	I	3.53E-01	3.64E-01	4.06E-01	1.57E-01	6.27E-02	1.66E-01	2.71E-01	1.39E-01
		Sum of HAPs	3.90E-01	I	3.53E-01	3.64E-01	4.06E-01	1.57E-01	6.27E-02	1.66E-01	2.71E-01	1.39E-01
		Sum of POMs	ND	I	ND	ND	ND	ND	ND	ND	N/A	N/A
			Individual HAPs and VOCs									
	x	**Benzene**	1.28E-01	I	1.08E-01	1.25E-01	1.33E-01	6.08E-02	3.23E-02	5.67E-02	9.20E-02	4.11E-02
	x	**Toluene**	1.26E-01	I	1.08E-01	1.14E-01	1.25E-01	6.08E-02	3.04E-02	6.04E-02	8.92E-02	3.81E-02
	x	**Ethylbenzene**	2.56E-02	I	2.31E-02	2.25E-02	2.58E-02	ND	ND	ND	1.39E-02	1.30E-02
	x	**o,m,p-Xylene**	9.89E-02	I	8.93E-02	8.73E-02	9.90E-02	3.57E-02	ND	3.63E-02	6.38E-02	3.94E-02
z	x	**Naphthalene**	ND	I	ND	ND	ND	ND	ND	ND	N/A	N/A
	x	**Phenol**	ND	I	ND	ND	ND	ND	ND	ND	N/A	N/A
	x	**Aniline**	1.21E-02	I	2.50E-02	1.53E-02	2.27E-02	ND	ND	1.25E-02	1.25E-02	9.85E-03
			Other Analytes									
		Condensables	1.01E+00	9.64E-01	I	1.12E+00	9.31E-01	9.35E-01	9.42E-01	8.34E-01	9.63E-01	8.90E-02
		Carbon Monoxide	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Methane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Carbon Dioxide	NT	7.24E+01	NT	NT	NT	NT	7.03E+01	NT	7.13E+01	1.46E+00
		Ethane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Propane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Isobutane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Butane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Neopentane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Isopentane	NT	ND	NT	NT	NT	NT	ND	NT	N/A	N/A
		Pentane	NT	ND	NT	NT	NT	NT	ND	NT	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 PRODUCTION PROCESS DATA

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DE Production Process Data
Stars / Tap Water

Compactability		Mold LOIs		Mold Clays		Core LOIs		Pour Temperatures	
42	5/22/2001	4.80	5/22/2001	8.10	5/22/2001	N/D	5/22/2001	2619	5/22/2001
42		5.13		7.87				2640	
41		5.49		8.22				2620	
41		4.87		8.10				2690	
42		4.90		8.33				2644	
41		5.00		7.41				2620	
48		4.90		7.87				2645	
46		5.08		7.06				2650	
45		4.99		8.10				2611	
46		4.98		7.52					
42									
40									
40									
40									
41									
41									
42									
42									
38									
39									
40									
42									
45									
45									
42									
42									
42									
40									
39									
2.34	41.93	0.194	5.01	0.406	7.86			24.17	2638
Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average

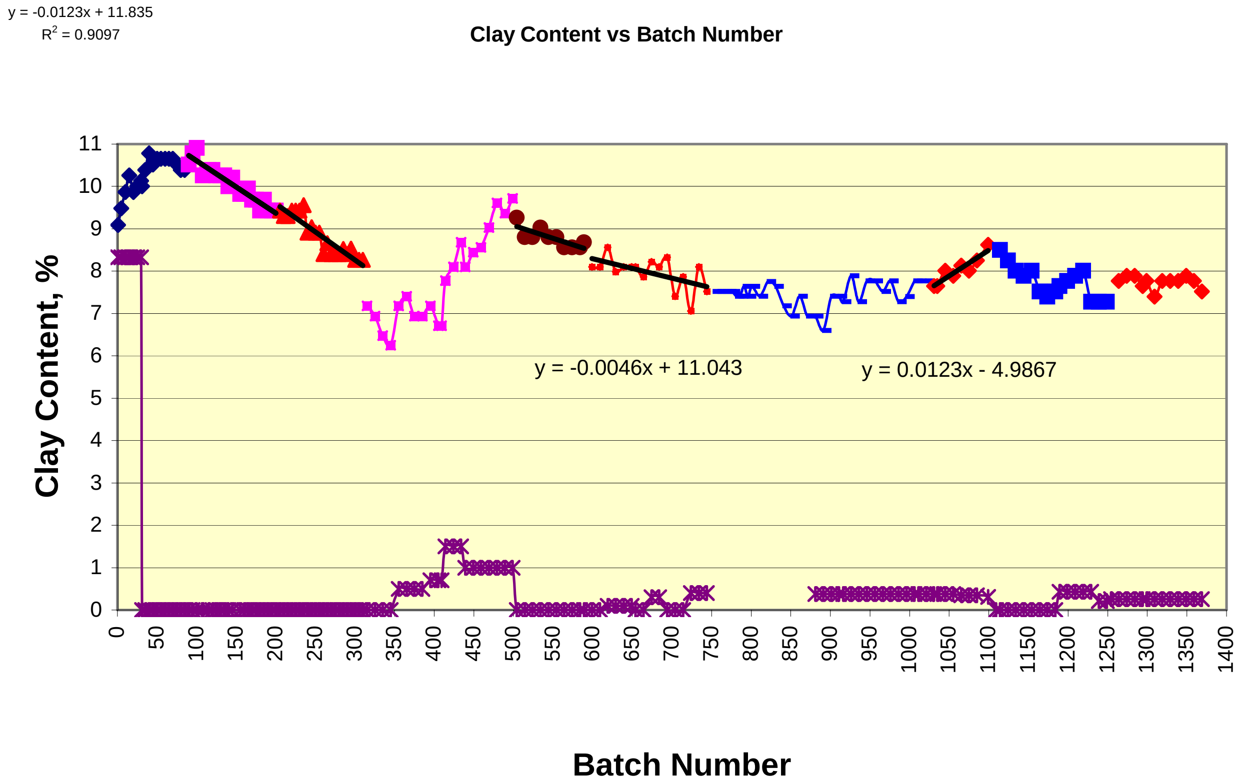
DE Production Process Data
Stars / Tap Water

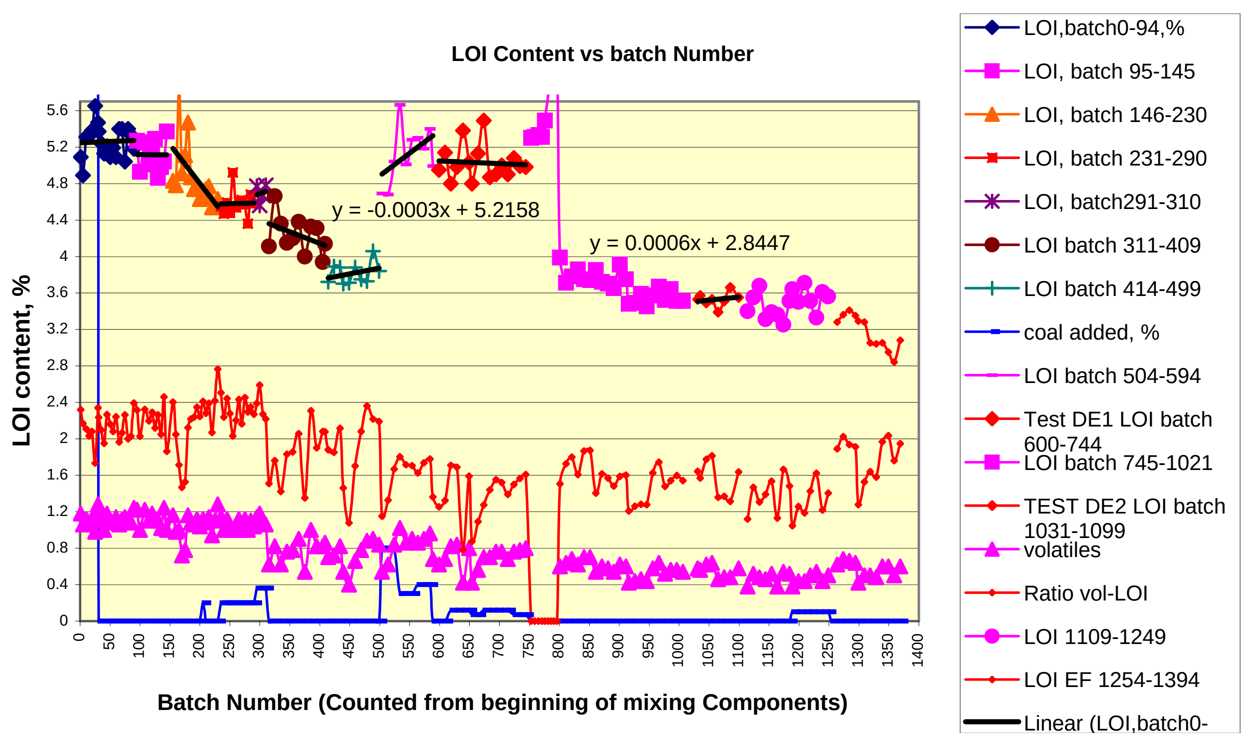
Compactability		Mold LOIs		Mold Clays		Core LOIs		Pour Temperatures	
45		3.53	6/7/2001	7.65	6/7/2001	N/D	6/7/2001	2658	6/7/2001
44		3.57		7.65				2642	
46		3.49		8.01				2634	
44		3.53		7.89				2650	
42		3.39		8.13				2631	
44		3.51		8.01				2610	
43		3.66		8.25				2651	
41		3.55		8.62					
42									
44									
43									
43									
36									
37									
41									
40									
43									
49									
50									
48									
40									
47									
3.48	43.27	0.076	3.53	0.320	8.03			16.14	2639
Std. Dev.	Average	Std. Dev	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average

Greensand Data

DATE	TIME	System size based on core sand accum	batches per turn	BATCH NO.	Accum batch no.	Turnover no. based on constant sand system size	Comments	Clay added per batch, % based on 5000# corrected 4200#	Coal added per batch, % based on 5000# corrected 4200#	CLAY,%	Clay Change %	Accum Clay Chg, %	LOI %	LOI Change %
22-May-01	640	48	24	5	654			0.00	0.07	8.10	0.00	-0.99	4.80	-0.23
Tap	712	48	24	15	664	*		0.00	0.07	7.87	-0.23	-1.22	5.13	0.33
Water	753	48	24	25	674	24		0.30	0.12	8.22	0.35	-0.87	5.49	0.36
Test DE-1	845	48	24	35	684	*		0.30	0.12	8.10	-0.12	-0.99	4.87	-0.62
	937	48	24	45	694	25		0.00	0.12	8.33	0.23	-0.76	4.90	0.03
	1045	48	24	55	704			0.00	0.12	7.41	-0.92	-1.68	5.00	0.10
	1140	48	24	65	714	*		0.00	0.12	7.87	0.46	-1.22	4.90	-0.10
	1235	48	24	75	724	26		0.40	0.07	7.06	-0.81	-2.03	5.08	0.18
	1336	48	24	85	734	*		0.40	0.07	8.10	1.04	-0.99	4.99	-0.09
	1430	48	24	95	744	27		0.40	0.07	7.52	-0.58	-1.57	4.98	-0.01
7-Jun-01	635	54.7	27.35	25	1031	37	1029	0.38	0.00	7.65			3.53	
AO water	717	54.3	27.15	29	1035	Change LOI		0.38	0.00	7.65			3.57	
Test DE-2	755	53.9	26.95	39	1045	door open space		0.38	0.00	8.01			3.49	
	835	53.5	26.75	49	1055	38	1057	0.38	0.00	7.89			3.53	
930	942	53.1	26.55	59	1065			0.35	0.00	8.13			3.39	
	1040	52.7	26.35	69	1075			0.35	0.00	8.01			3.51	
	1140	52.3	26.15	79	1085	39	1083	0.35	0.00	8.25			3.66	
	---	51.9	25.95	93	1099			0.31	0.00	8.62			3.55	

Greensand Clay and LOI Charts





APPENDIX D METHOD 25A CHARTS

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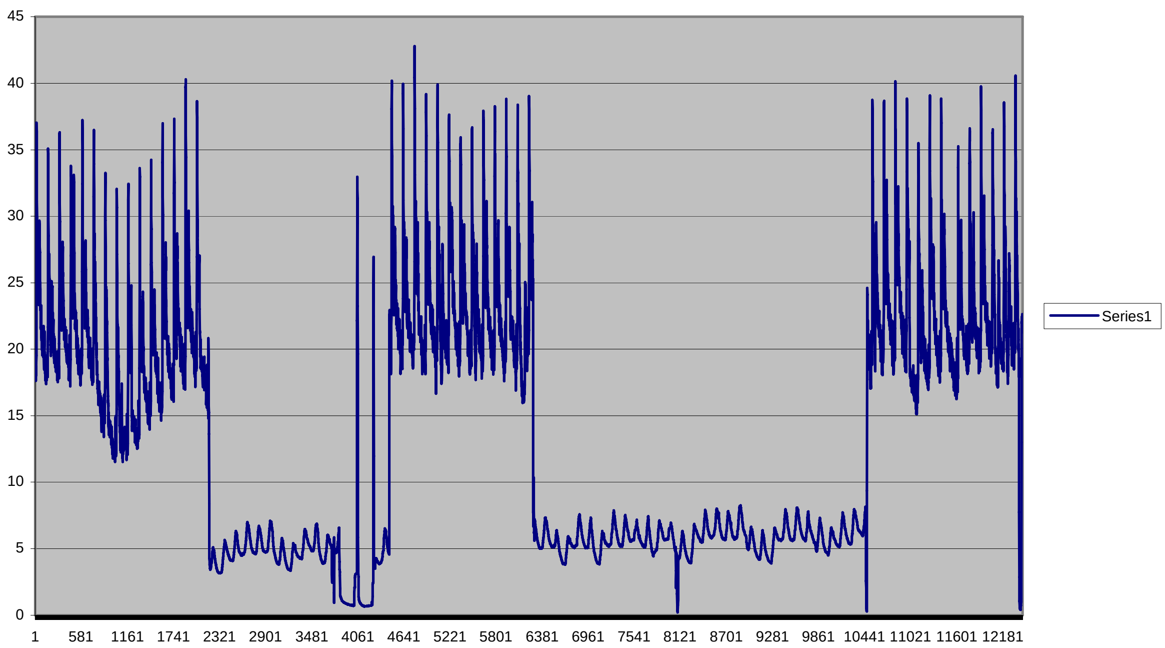
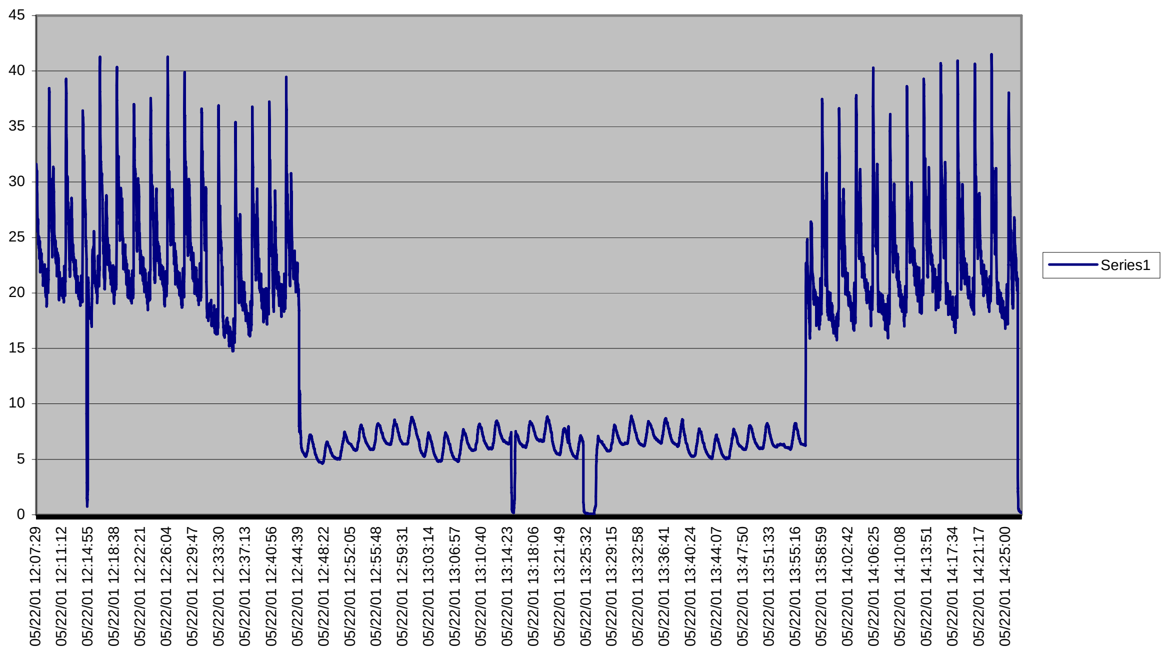
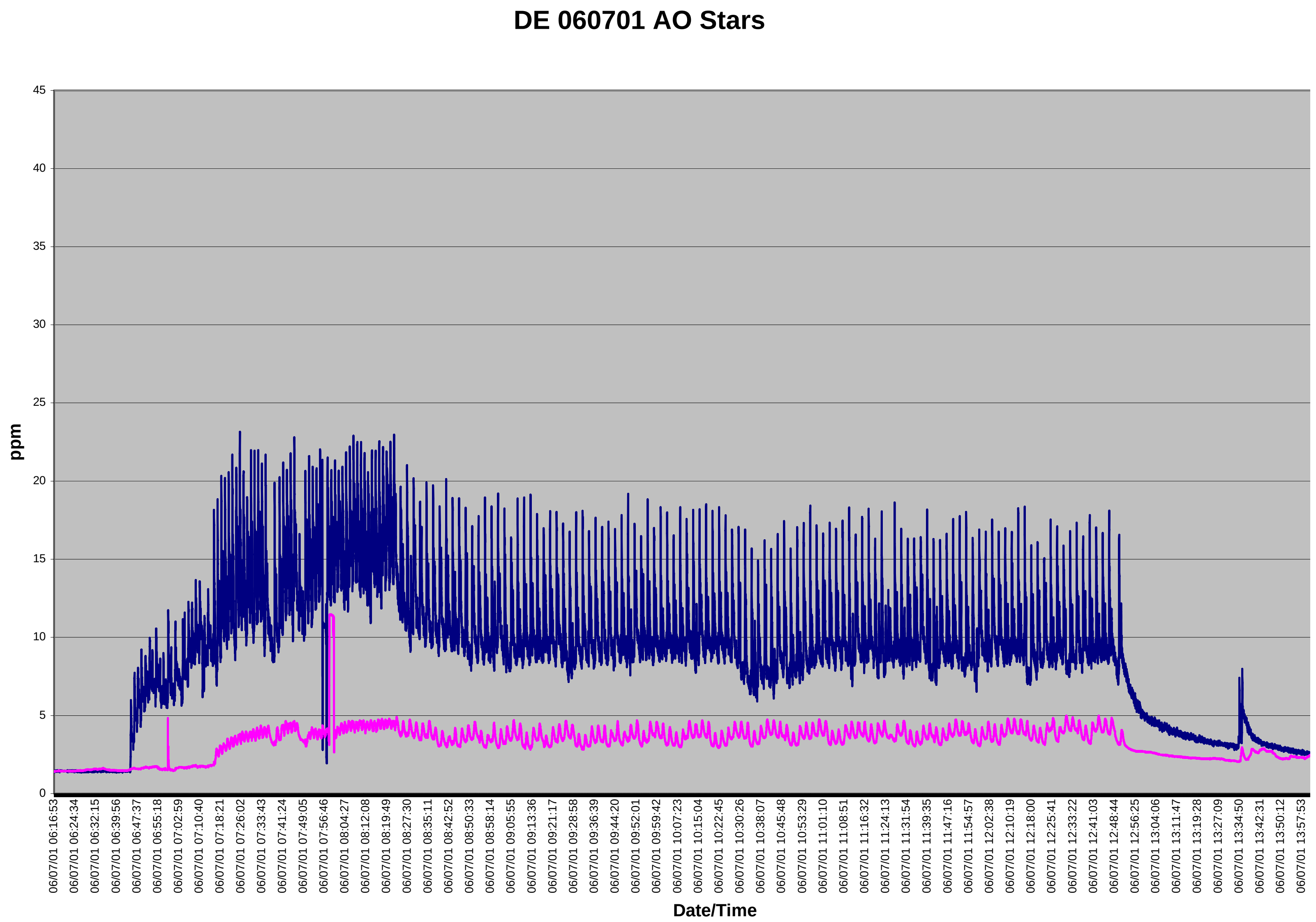
DE052201 Tap Stars






DE 060701 AO Stars
ppm
0
5
10
15
20
25
30
35
40
45
Date/Time

APPENDIX E LISTING OF SUPPORT DOCUMENTS

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Supporting Documents

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

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

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

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

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

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APPENDIX F GLOSSARY

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Glossary

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.