Casting Emission Reduction Program
www.cerp-us.org


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



*US Army Contract DAAE30-02-C-1095*
*FY2004 Tasks*
**WBS # 6.1.9**


# Quality Improvement: Star Mold and Step Core Emission Comparison

*Technikon # 1411-619 GU*

**December 2005**
*(Revised for public distribution.)*

United States Environmental Protection Agency

UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

*this page intentionally left blank*

# Quality Improvement: Star Mold and Step Core Emission Comparison

*Technikon # 1411-619 GU*

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

| | | |
|---|---|---|
| V.P. Measurement Technology | *// Original Signed //*<br>Clifford R. Glowacki, CIH | Date |
| V.P. Operations | *// Original Signed //*<br>George Crandell | Date |

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

*this page intentionally left blank*

# Table of Contents



# List of Figures and Tables

# Appendices

## Executive Summary

This report contains the results of emission measurements associated with Test GU. The objective of this test was to independently evaluate emissions from greensand using two baseline patterns. The two molds that were used for this test were:

1. 4-on Star Greensand Mold with Seacoal (reference)
2. 4-on Sodium Silicate Step Core in Greensand Mold with Seacoal

All testing was conducted by Technikon, LLC in its research foundry. The emissions results are reported in pounds of analyte per ton of metal poured.

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 and mold; Loss on Ignition (LOI) values for the mold; 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 runs. Samples were collected and analyzed for fifty-five (55) target. Continuous monitoring of the Total Gaseous Organic Concentration (TGOC) of the emissions was conducted according to US EPA Method 25A. CO, $CO_2$ and NOx were measured per their respective US EPA designated protocols. $SO_2$ was adsorbed on basic media and analyzed by OSHA Method ID200.

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

individual target HAPs measured and includes the selected POMs. The "Sum of POMs" is the sum of all of the polycyclic organic material measured.

Both patterns are made with the same sand so the results should represent the changes in pattern geometry as it affects the cast metal weight and the metal contact area. Those two parameters would predict that the step core pattern would yield 55% of the emissions of the baseline star pattern. All emission indicator results are very close to that prediction.

The Results for the emission indicators are shown in the following table reported as lb/tn of metal.

***Table A Test GU Emissions Indicators – Lb/Tn Metal***

| Emission Indicators | 4-on Star | Step Core | % Change |
|---|---|---|---|
| TGOC as Propane | 3.2798 | 1.6474 | -49.77 |
| HC as Hexane | 0.8024 | 0.4289 | -46.55 |
| Sum of Target VOCs | 0.4947 | 0.2327 | -52.96 |
| Sum of Target HAPs | 0.3898 | 0.1879 | -51.79 |
| Sum of Target POMs | 0.0207 | 0.0110 | -46.91 |

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

# 1.0 INTRODUCTION

## 1.1. Background

Technikon LLC is a privately held contract research organization located in McClellan, California, a suburb of Sacramento. Technikon offers emissions research services to industrial and government clients specializing in the metal casting and mobile emissions areas. Technikon operates the Casting Emission Reduction Program (CERP). CERP is a cooperative initiative between the Department of Defense (US Army) and the United States Council for Automotive Research (USCAR). The parties to the CERP Cooperative Research and Development Agreement (CRADA) include The Environmental Research Consortium (ERC), a Michigan partnership of DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation; the U.S. Army Research, Development, and Engineering Command (RDECOM-ARDEC); the American Foundry Society (AFS); and the Casting Industry Suppliers Association (CISA). The US Environmental Protection Agency (US EPA) and the California Air Resources Board (CARB) also have been participants in the CERP program and rely on CERP published reports for regulatory compliance data.

## 1.2. Objectives

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

## 1.3. Report Organization

This report has been designed to document the methodology and results of a specific test plan that was used to evaluate VOC emissions from a coreless greensand system compared to a sodium silicate cored greensand system. Section 2 of this report includes a summary of the methodologies used for data collection and analysis, emission calculations, QA/QC procedures, and data management and reduction methods. Specific data collected during this test are summarized in Section 3 of this report, with detailed data included in Appendix B of this report. Section 4 of this report contains a discussion of the results.

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

### 1.4. Specific Test Plan and Objectives

The objective of this test was to compare air emissions from two greensand patterns used by CERP for emissions testing. Historically the step core pattern had been used for emission comparison until 2002. For quality measurement reasons a decision was made to use the higher surface area star pattern for both emission and surface finish comparisons.

This has resulted in higher air emission results with the star pattern vs. the older step core pattern. This test was to document this difference and relate the emission change to the change in surface area between the two patterns.

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

***Table 1-1 Test Plan Summary***

| | 4-on Star Mold | Step Core Mold |
|---|---|---|
| Type of Process Tested | Greensand with 4-on Star | Greensand with Sodium Silicate Step Cores |
| Test Plan Number | 1411-619 GU | 1411-619 GU |
| Greensand System | Wexford W450, Western and Southern Bentonite, Seacoal | Wexford W450, Western and Southern Bentonite, Seacoal |
| Metal Poured | Class-30 Gray Iron Poured at 2680 F | Class-30 Gray Iron Poured at 2680 F |
| Core Coating | N/A | Uncoated |
| Core Type | N/A | Wedron 530 Silica Sand and 5% (BOS) JB DeVeene CleanKast #1 Sodium Silicate Binder. |
| Number of Molds Poured | 3 Star Conditioning, 6 Star | 4 Step Core |
| Test Dates | 12 July through 14 July 2005 | 18 July through 19 July 2005 |
| Emissions Measured | Selected HAPS and VOCs, CO, $CO_2$, NOx, $SO_2$, and TGOC | Selected HAPS and VOCs, CO, $CO_2$, NOx, $SO_2$, and TGOC |
| Process Parameters Measured | Total Casting, Mold, Binder Weights; Metallurgical data, % LOI; Stack Temperature, Moisture Content, Sand Temperature, Pressure, and Volumetric Flow Rate | Total Casting, Mold, Binder Weights; Metallurgical data, % LOI; Stack Temperature, Moisture Content, Sand Temperature, Pressure, and Volumetric Flow Rate |

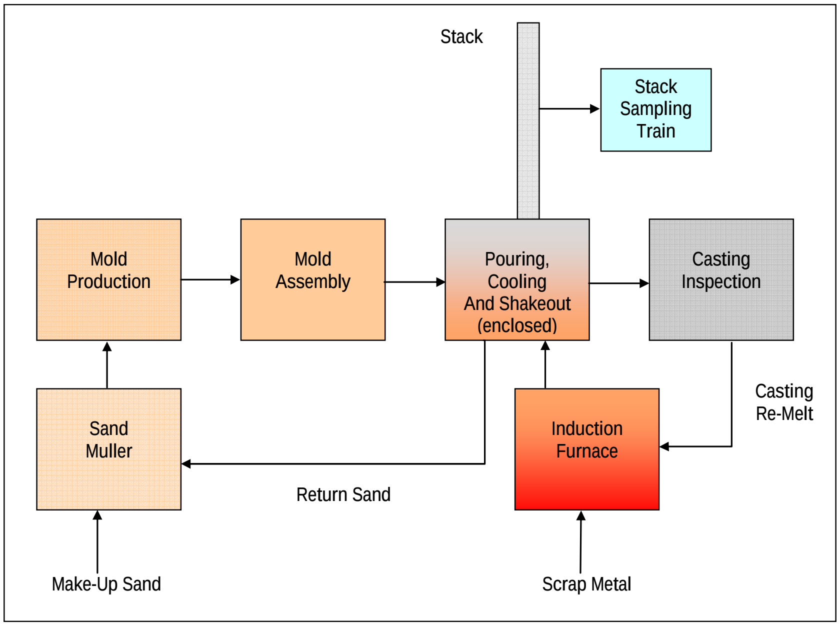
*this page intentionally left blank*

# 2.0 TEST METHODOLOGY

## 2.1.1. Description of Process and Testing Equipment

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

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




## 2.2. Description of Testing Program

***Figure 2-2 4-on Star Mold***

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

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

**<u>Mold and Metal Preparation:</u>** The 4-on star green-sand molds are prepared to a standard composition by the Technikon production team as shown in Figure 2-2.

The greensand molds with sodium silicate cores are prepared to the required composition as detailed in the test plan. A photographic view of the cores embedded in the mold is shown in Figure 2-3.

***Figure 2-3 Sodium Silicate Cores embedded in a Greensand Mold***

The mold is then placed on a shaker table which is enclosed in a hood as shown in Figure 2-4. This enclosure meets the criteria for a temporary total enclosure (TTE) as specified in US EPA Method 204.

***Figure 2-4 Temporary Total Enclosure at the Technikon Research Foundry***

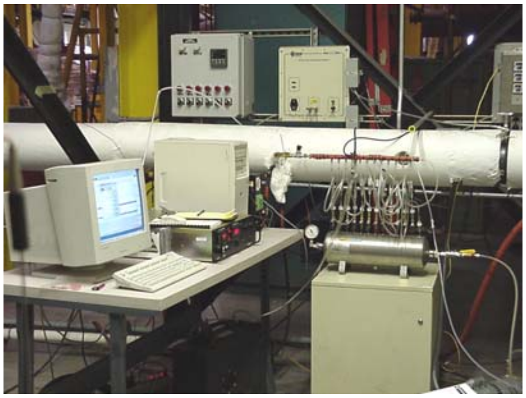
Iron is melted in a 1000 lb. Ajax induction furnace. The amount of metal melted is determined from the poured weight of the casting and the number of molds to be poured. The metal composition is prescribed by a metal composition worksheet. The metal is poured into the mold (Figure 2-5) through a cut-away section on top of the TTE. After the pouring operation is complete, the opening is closed. The weight of metal poured into each mold is recorded on the process data summary sheet.

***Figure 2-5 Metal pouring from ladle to mold in the TTE***

The emissions generated are collected and transported through a 6” duct (stack). Probes inserted at relevant locations on the stack provide for sampling of stack gas. One probe provides sampling for the train (Figure 2-6). The train is used to collect samples on media which are analyzed post test for various HAPs, POMs, and VOCs as detailed under the sampling plan in Appendix A.

Another probe in the stack is used to draw samples

*Figure 2-6 Sampling Train for Analyte Collection on Media*



and transport via a 63' heated sample line to an emissions bench (E-Bench Figure 2-7) in which is a battery of gas analyzers. This bench consists of a Total Hydrocarbon Analyzer, Infra-Red Analyzers (for CO and $CO_2$) and a Chemiluminescence Analyzer for NOx.

*Figure 2-7 E-Bench*

**Individual Sampling Events**: Replicate tests are performed on six (6) mold packages. The mold packages are placed into an enclosed test stand heated to approximately 85°F. Iron is poured through an opening in the top of the emission enclosure.

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.

**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 |
|---|---|
| Mold Weight | Cardinal 748E platform scale (Gravimetric) |
| Casting Weight | Cardinal 748E platform scale (Gravimetric) |
| Muller water weight | Cardinal 748E platform scale (Gravimetric) |
| Binder Weight | Mettler SB12001 Digital Scale (Gravimetric) |
| Volatiles | Mettler PB302 Scale (AFS Procedure 2213-00-S) |
| LOI % of Mold | Denver Instruments XE-100 Analytical Scale (AFS procedure 5100-00-S) |
| Metallurgical Parameters | |
| Pouring Temperature | Electro-Nite DT 260 (T/C Immersion Pyrometer) |
| Carbon/Silicon Fusion Temperature | Electro-Nite DataCast 2000 (Thermal Arrest) |
| Alloy Weights | Ohaus MP2 Scale |
| Mold Compactability | Dietert 319A Sand Squeezer (AFS Procedure 2221-00-S) |
| Carbon/Silicon | Electro-Nite DataCast 2000 (thermal arrest) |

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

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

| Measurement Parameter | Test Method |
|---|---|
| Port Location | EPA Method 1 |
| Number of Traverse Points | EPA Method 1 |
| Gas Velocity and Temperature | EPA Method 2 |
| Gas Density and Molecular Weight | EPA Method 3A |
| Gas Moisture | EPA Method 4, gravimetric |
| HAPs Concentration | EPA Method 18, TO11, NIOSH 1500 |
| VOCs Concentration | EPA Method 18, 25A, TO11, NIOSH 1500 |
| Carbon Monoxide | EPA Method 10 |
| Sulfur Dioxide | OSHA ID200 |
| Carbon Dioxide | EPA Method 3A |
| Nitrogen Oxides | EPA Method 7E |

These methods were specifically modified to meet the testing objectives of the CERP Program.

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

The results of each of the sampling events are included in Appendix B of this report. The results of each test are also averaged and are shown in Tables 3-1 and 3-2.

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

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

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

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

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

*this page intentionally left blank*

# 3.0 TEST RESULTS

The average emission results in pounds per ton of metal poured are presented in Table 3-1. This Table compares the emissions from the reference star mold and the Sodium Silicate core test. The table includes the individual target compounds that comprise at least 95% of the total VOCs measured, along with the corresponding Sum of VOCs, Sum of HAPs, and Sum of POMs. The table also includes TGOC as propane, HC as hexane, carbon monoxide (CO), carbon dioxide ($CO_2$), nitrogen oxides (NOx) and sulfur dioxide ($SO_2$).

Figures 3-1 to 3-3 present the five emissions indicators and selected individual HAP and VOC emissions data from Table 3-1 in graphical form

Appendix B contains the detailed data including the results for all analytes measured.

Table 3-2 includes the averages of the key process parameters. Detailed process data are presented in Appendix C.

***Table 3-1 Summary of Test Average Results – Lb/Tn Metal***

| Analytes | Reference Star Average | Step Core Average | % Change from Reference |
|---|---|---|---|
| Emission Indicators | | | |
| TGOC as Propane | 3.2798 | 1.6474 | -50 |
| HC as Hexane | 0.8024 | 0.4289 | -47 |
| Sum of Target VOCs | 0.4947 | 0.2327 | -53 |
| Sum of Target HAPs | 0.3898 | 0.1879 | -52 |
| Sum of Target POMs | 0.0207 | 0.0110 | -47 |
| Individual Target HAPs | | | |
| Benzene | 0.1642 | 0.0673 | -59 |
| Toluene | 0.0843 | 0.0423 | -50 |
| Xylenes | 0.0529 | 0.0284 | -46 |
| Hexane | 0.0156 | 0.0095 | -39 |
| Phenol | 0.0155 | 0.0073 | -53 |
| Naphthalene | 0.0126 | 0.0064 | -49 |
| Ethylbenzene | 0.0100 | 0.0056 | -44 |
| Cresols | 0.0094 | 0.0022 | -76 |
| Acetaldehyde | 0.0075 | 0.0084 | 13 |
| Methylnaphthalenes | 0.0070 | 0.0040 | -43 |
| Formaldehyde | 0.0051 | 0.0029 | -43 |
| Other Target VOCs | | | |
| Heptane | 0.0137 | 0.0083 | -39 |
| Octane | 0.0121 | 0.0078 | -35 |
| Trimethylbenzenes | 0.0109 | 0.0031 | -71 |
| Nonane | 0.0099 | 0.0059 | -40 |
| Ethyltoluenes | 0.0097 | 0.0040 | -58 |
| Decane | 0.0082 | 0.0048 | -41 |
| Undecane | 0.0075 | 0.0043 | -42 |
| *Dodecane* | 0.0058 | NA | NA |
| *Indene* | 0.0045 | NA | NA |
| *Cyclohexane* | 0.0044 | 0.0023 | -48 |
| Criteria Pollutants and Greenhouse Gases | | | |
| Carbon Monoxide | 5.5331 | 5.5992 | 1 |
| Carbon Dioxide | 13.7148 | 8.4009 | -39 |
| Nitrogen Oxides | 0.0056 | 0.0048 | -14 |
| Sulfur Dioxide | 0.0286 | 0.0115 | -60 |

Individual Results constitute >95% of mass of all detected target VOCs
Names in Italics are not included in top 95% of VOC mass for Step Cores.
Bold numbers indicate those compounds whose calculated t-statistic is significant at alpha=0.05

.

***Figure 3-1 Comparative Summary of Greensand Star to Step Cores, Average Results – Lb/Tn Metal***

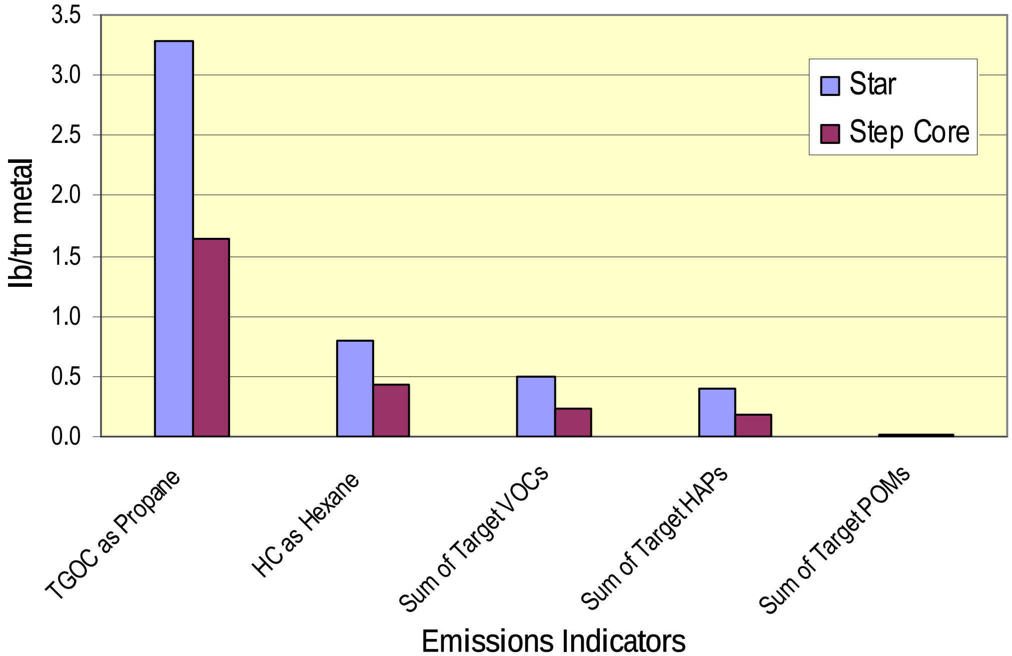



***Figure 3-2 Top 95 % Selected HAP & VOC Emissions Greensand Star to Step Cores, Average Results – Lb/Tn Metal***

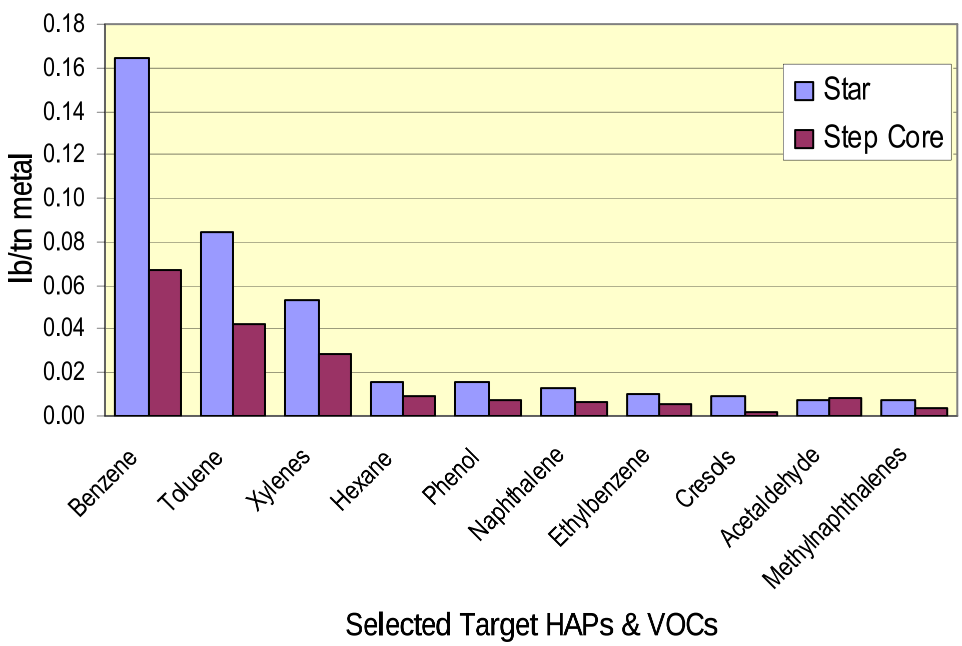


***Figure 3-3 Criteria Pollutants, Greenhouse Gases, and Other Analytes Greensand Star to Step Cores, Average Results – Lb/Tn Metal***

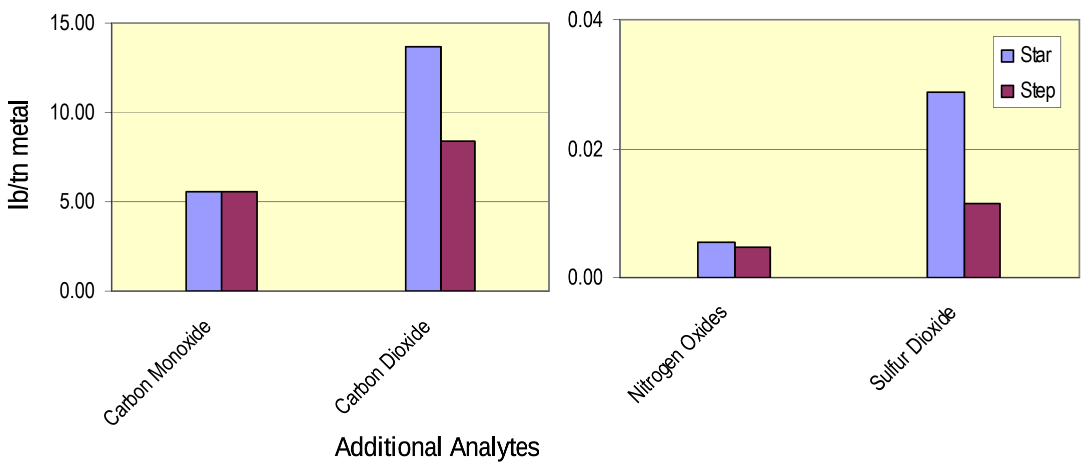



***Table 3-2 Summary of Test Average Process Parameters***

| Averages | 4-on Star | Step Core |
|---|---|---|
| Test Dates | 7/12/05-7/14/05 | 7/18/05-7/19/05 |
| Cast Weight (all metal inside mold), Lbs. | 95.8 | 113.2 |
| Pouring Time, sec. | 14.3 | 15.3 |
| Pouring Temp ,°F | 2682 | 2682 |
| Pour Hood Process Air Temp at Start of Pour, °F | 90 | 87 |
| Sand in Sodium Silicate Sand mix, lbs | No core mixing, blowing, or baking data, because no cores used in mold. | 50.00 |
| Sodium Silicate in Sodium Silicate Core Sand Mix, lbs | | 2.5 |
| Sodium Silicate Core CO2 Gassing Pressure, PSI | | 20.0 |
| Sodium Silicate Core CO2 Gassing Time, sec | | 28.3 |
| Sodium Silicate Content, % (BOS) | | 5.0 |
| Sodium Silicate Content, % of Sand Mix | | 4.77 |
| Total Weight of Baked Cores in Mold, Lbs. | | 30.0 |
| Baking Oven Nominal Temperature, °F | | 250 |
| Average Heated Investment Time, Minutes | | 120 |
| Greensand Muller Batch Weight, Lbs. | 902 | 902 |
| GS Mold Sand Weight, Lbs. | 640 | 646 |
| Greensand Muller Compactability, % | 55 | 55 |
| Greensand Mold Temperature, °F | 89 | 83 |
| Average Green Compression , psi | 17.92 | 22.86 |
| GS Mold Compactability, % | 43 | 41 |
| GS Moisture Content, % | 1.81 | 1.97 |
| Clay Addition, lbs | 2.45 | 3.20 |
| GS MB Clay Content, % | 5.36 | 5.59 |
| MB Clay Reagent, ml | 26.7 | 27.8 |
| Seacoal Addition, lbs | 1.8 | 2.5 |
| 1800°F LOI - Mold Sand, % | 5.05 | 5.17 |
| 900°F Volatiles , % | 1.09 | 0.99 |
| Permeability Index | 171 | 179 |

Method 25A charts for the tests are included in Appendix D of this report. The charts are presented to show the visual profile of emissions for each pour. They are presented in the 'overlay' mode, where analyzer signals (in ppm) for all the 4-on Star runs, are depicted on the same chart.

Method 10 charts for CO, Method 3A charts for $CO_2$ and Method 7E charts for NOx are also presented here. Charts for the Sodium Silicate core runs are presented similarly.

## 4.0 DISCUSSION OF RESULTS

In prior CERP tests the emission evaluation for greensand molds with and without organic cores was done with an 8-on step core mold. When a seacoal replacement was to be tested, the core cavity was set with a core made with a non-emitting sodium silicate binder. When casting surface quality evaluations were to be done, in addition to the emission determination, the cored surface was used to evaluate the core's impact and the greensand surface of the same casting was used to evaluate the impact of the greensand additives. This procedure didn't allow for comparison of the greensand surface quality, because the outside casting surface wasn't complex enough on the step core castings.

In 2002 the CERP Quality Committee received approval to use the 4-on star pattern for greensand surface and emission testing. These patterns became the new baseline patterns for product comparisons. Additionally, a 4-on step core pattern was built to evaluate only core emissions. In this test, GU, the patterns are run, after sand conditioning, in the same sand to determine emission differences. The star was run first followed by the step core. Make-up materials (clays and seacoal) were added for the respective thermal burnouts and to compensate for new core sand that contains no greensand bonding materials.

Previous CERP studies on the impact that process parameters have on the quantity and type of emissions measured from the pouring cooling and shakeout of greensand molds containing seacoal as the only organic material have been published. (See CERP website www.cerp-us.org.) These studies have demonstrated, with a high degree of reliability, that the emissions in iron are proportional to the metal weight poured, the metal contact surface with the sand, the quantity of organic material present in the sand and the exposure time. Each of these relationships is true but apparent only when all the other process parameters are not varied.

In each experiment, every attempt is made to keep the principal causes and secondary influences of the emissions fixed between the reference test and the comparative test so that for pouring, cooling, and shakeout, the emissions reflect only the difference in the materials being tested. In this experiment, GU, some of the process parameters were different by design so the emission difference between the reference star pattern and the comparative step core pattern, run in the same mold material, represents the net emissions resulting from the different patterns. The known uncompensated changes were due to the different patterns that changed the weight of metal poured, the metal contact surface, and the amount of sand to distribute the heat and supply organics to emit upon heating.

The average weight of metal in the molds was 95.8 pounds for the star pattern and 113.2 pounds for the step core pattern. This is an 18% increase for the step core pattern in poured metal weight. The relative metal contact areas were 1455 inches (star) and 682 inches (step core), accounting for a 53% reduction in area responsible for generating emissions. A combination of the two factors predicts a 55% ($1.18 \times 0.47 = 0.55$) lowering of net emissions for the step core system compared to baseline 4-on star pattern. As shown in Table 3-1, the five emission indicators closely reflect the predicted decrease in emissions. A check was performed of the top 8 analytes in the Target HAPs and Other Target VOCs and an average reduction of ~ 50% was observed. It can be concluded that the emissions are lower by 47% to 53%, in line with predictions stated above.

A unique behavior can be seen in the CO and $CO_2$ results. $CO_2$ is lower by 39% but there is no measurable difference in the CO values for the two systems studied here. The $SO_2$ reduction was around 60%, close to the predicted value. NOx differences are 14% but reported NOx values are close to or below instrument detection limits and meaningful inferences are not merited for this analyte.

## APPENDIX A APPROVED TEST PLAN, SAMPLE PLAN, AND PROCESS INSTRUCTIONS

*this page intentionally left blank*

# TECHNIKON TEST PLAN

- **Contract Number:** 1411 **TASK NUMBER** 619 **SERIES** GU
- **Site:** Research Foundry
- **Test Type:** Green Sand Baseline Comparison
- **Metal Type:** Class 30 Gray Iron poured at 2680 F
- **Mold Type:** Reference: 4-on Star with seacoal, Comparative: 4-on Sodium Silicate Step Core with seacoal.
- **Number of Molds:** 3 star conditioning, 6 star, 6 step core all same sand, total 15 molds
- **Core Type:** Step Core at 5% (BOS) JBDeVeene CleanKast #1 Sodium Silicate binder.
- **Core Coating:** Cores to be uncoated
- **Sample Events:** 6 star, 6 step mold, total 12 runs
- **Test Date(s):** **START:** 12 July 2005

  **FINISH:** 28 July 2005

**TEST OBJECTIVES:**

Measure selected PCS HAP & VOC emissions, CO, $CO_2$, $SO_2$, NOx, & TGOC.

Use Analyte list A

**VARIABLES:**

Two patterns will be the 4-on star and the 4-on step core. All molds will be made with Wexford W450 Lake Sand, western and southern bentonite in a 5:2 ratio to yield 7.0 +/- 0.5% MB Clay, 5% seacoal, and tempered to 40-50% compactability, mechanically compacted. The molds will be maintained at 80-90 deg. F prior to pouring. The sand heap will be maintained at 900 pounds. Molds will be poured with iron at 2680 +/- 10 deg. F. Mold cooling will be 45 minutes followed by 15 minutes of shakeout, or until no more material remains to be shaken out, followed by 15 minutes additional sampling for a total of 75 minutes. Cores will be made with Wedron 530 silica sand & 5% (BOS) JB DeVeene CleanKast #1 Sodium Silicate. No emission sampling will be done during core manufacture.

**BRIEF OVERVIEW:**

The green sand baseline test has previously been reevaluated to reflect improvements in analytic methods and foundry facilities and procedures. The first greensand baseline configuration was 6-on sodium silicate step cores in a 14 cubic foot greensand mold. The most recent was a 6.7 cubic foot 4-on coreless star greensand mold. Despite every effort to maintain the engineering ratios between the two mold configurations that drive emissions differences in the emissions measured did result. This test will attempt to resolve those differences.

The greensand molds will be produced on the mechanically assisted Osborne 716 molding machines and poured at a common pouring temperature of 2680 degrees F.

The measured emissions from the step core configuration will be compared to the those from the star as a reference.

**SPECIAL CONDITIONS:**

The step core configuration will be poured at 2680 degrees F to eliminate temperature as a factor. Historically the step core was poured at 2630 degrees F.

# Series 1411-6.1.9-GU

## *Comparison of Sodium Silicate Step Core to Coreless Star Configuration PCS Greensand Baseline Emissions Using Mechanized Molding*

## Process Instructions

**A.** Experiment:

**1.** Measure and compare a selected list of VOC emissions from a sodium silicate Step Core greensand mold to a coreless Star greensand mold. The greensand will contain seacoal. The same sand will be used sequentially to make the Star conditioning runs, Star reference test runs, and Step Core comparative test runs. The molds shall be tempered with potable water to 40-45% compactability and poured at constant temperature. This test will recycle the same mold material, replacing burned clay with new materials after each casting cycle and providing clay for the retained core sand.

**B.** Materials:

**1.** Mold sand: Virgin mix of Wexford W450 lake sand, western and southern bentonites in ratio of 5:2 to yield 7.0+/-0.5% Bentonite, H & G Seacoal to yield 5.0+/-0.3 % LOI, and potable water per recipe.

**2.** Core: Uncoated step core made with virgin Wedron 530 silica sand and 5.0% (BOS) JB DeVenne CleanKast #1 Sodium Silicate binder, CO2 activated.

**3.** Core coating: None

**4.** Metal: Class-30 gray cast iron poured at 2680 +/- 10°F.

**5.** Pattern release: Black Diamond, hand wiped.

**C.** Briefing:

**1.** The Process Engineer, Emissions Engineer, and the area Supervisor will brief the operating personnel on the requirements of the test at least one (1) day prior to the test.

**Caution**

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

**D.** Silicate Cores:

**1.** Core sand mixing.

**a.** Clean the core sand mixer.

**b.** Add 50 pounds of Wedron 530 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.

**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 30 seconds on each of the two gas holes with 20 psi $CO_2$ gas.
- **g.** Dry the cores for two hours at 250°F and allow cooling.
- **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.

**E.** Sand preparation

**1.** Start up batch: make 1, GUER1.

- **a.** Thoroughly clean the pre-production muller elevator and molding hoppers.
- **b.** Weigh and add 1230 +/-10 pounds of new Wexford W450 Lakesand, per the recipe, to the running pre-production muller to make a 1300 batch.
- **c.** Add 5 pounds of potable water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
- **d.** Add the clays and seacoal slowly to the muller to allow them to be distributed throughout the sand mass in proportion to the sand weight per the recipes for this test.
- **e.** Dry mull for about 3 minutes to allow distribution and some grinding of the clays to occur.
- **f.** Temper the sand-clay mixture slowly, with potable water, to allow for distribution.
- **g.** After about 2 gallons of water have been added allow 30 seconds of mixing then start taking compactability test samples.
- **h.** Based on each test add water incrementally to adjust the temper. Allow 1 minute of mixing. Retest. Repeat until the compactability is in the range 40-45%.
- **i.** Discharge the sand into the mold station elevator.
- **j.** Grab sufficient sample after the final compactability test to fill a quart zip-lock bag. Label the bag with the test series and sequence number, date, and time of day and deliver it immediately to the sand lab for analysis
- **k.** Record the total sand mixed in the batch, the total of each type of clay added to the batch, the total coal added, the amount of water added, the total mix time, the final compactability and sand temperature at discharge into the mold.
- **l.** The sand will be characterized for Methylene Blue Clay, AFS clay, Moisture content, Compactability, Green Compression strength, 1800°F loss on ignition (LOI), and 900 oF volatiles. Each volatile and LOI test requires a separate 50 gram sample from the collected sand.

**m.** Empty the extra greensand from the mold hopper into a clean empty dump hopper whose tare weight is known. Set this sand aside to be used to maintain the recycled batch at 900+/-10 pounds

**2.** Re-mulling: GUER2

**a.** Add to the sand recovered from poured mold GUER1 sufficient pre-blended sand so that the sand batch weight is 900 +/- 10 pounds. Record the sand weight.
**b.** Return the sand to the muller and dry blend for about one minute.
**c.** Add the clays, as directed by the process engineering staff, slowly to the muller to allow them to be distributed throughout the sand mass.
**d.** Add 5 pounds of water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
**e.** Follow the above procedure beginning at E.1.f.

**3.** Re-mulling: GUER3, GU001-GU0XX

**a.** Add to the sand recovered from the previous poured mold, mold machine spill sand, the residual mold hopper sand and sufficient pre-blended sand to total 900 +/- 10 pounds.
**b.** Return the sand to the muller and dry blend for about one minute.
**c.** Add the clays, as directed by the process engineering staff, slowly to the muller to allow them to be distributed throughout the sand mass. Note: The re-mull recipe will change after GU009.
**d.** Add 5 pounds of water to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
**e.** Follow the above procedure beginning at E.3.a.

**F.** Molding: Star and Step Core pattern.

**1.** Pattern preparation:

**a.** The Star pattern will be used for molds GUER1-GU009.
**b.** The Step Core pattern will be used for molds GU0010-GU015.
**c.** Inspect and tighten all loose pattern and gating pieces.
**d.** Repair any damaged pattern or gating parts.

**2.** Making the green sand mold.

**a.** For the Star pattern mount the Cope/Drag pattern on the North Osborne Whisper Ram molding machine.
**b.** For the Step Core pattern mount the drag pattern on one Osborne Whisper Ram molding machine and mount the cope pattern on the other Osborne machine.
**c.** Lightly apply parting release to the pattern and rub with an 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 of 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.**

**3.** Use the overhead crane to place the pre-weighed drag/cope flask on the mold machine table, parting line surface down.
**4.** Locate a 24 x 24 x4 inch deep wood upset on top of the flask.
**5.** Make the green sand mold cope or drag on the Osborn Whisper Ram Jolt-Squeeze mold machine.

**WARNING**
**Only properly trained personnel may operate this machine.**
**Proper personal protective equipment must be worn at all times while operating this equipment, including safety glasses with side shields and a properly fitting hard hat.**
**Industrial type boots are highly recommended.**

**WARNING**
**Stand clear of the mold machine table and swinging head during the following operation or serious injury or death could result.**

**a.** Open the air supply to the mold machine.

**WARNING**
**The squeeze head may suddenly swing to the outboard side or forward.**
**Do not stand in the outer corners of the molding enclosure.**

**b.** On the operator's panel turn the POWER switch to ON.
**c.** Turn the RAM-JOLT-SQUEEZE switch to ON.
**d.** Turn the DRAW UP switch to AUTO
**e.** Set the PRE-JOLT timer to 4-5 seconds.
**f.** Set the squeeze timer to 8 seconds.
**g.** For the Step Core pattern only set the crow-footed gagger on the support bar. Verify that it is at least ½ inch away from any pattern parts.
**h.** Manually riddle a half to one inch or so of sand on the pattern using a ¼ inch mesh riddle. Source the sand from the overhead mold sand hopper by actuating the CHATTER GATE valve located under the operators panel.
**i.** Fill the center portion of the flask.
**j.** Manually move sand from the center portion to the outboard areas and hand tuck the sand.
**k.** Finish filling the 24 x 24 x 10 inch flask and the upset with greensand from the over-head molding hopper.
**l.** Manually level the sand in the upset. By experience manually adjust the sand depth so that the resulting compacted mold is fractionally above the flask only height.
**m.** The operator will grab a sand sample for the Lab. The sand technician will quickly measure the sand temperature and compactability and record the results.
**n.** Initiate the settling of the sand in the flask by pressing the PRE-JOLT push button. Allow this cycle to stop before proceeding.
**o.** Remove the upset and set it aside.

**WARNING**
**Failure to stand clear of the molding table and flasks in the following operations could result in serious injury as this equipment is about to move up and down with great force.**

**WARNING**
**Stand clear of the entire mold machine during the following operations.**
**Several of the machine parts will be moving.**
**Failure to stand clear could result in severe injury even death.**

**p.** Using both hands initiate the automatic machine sequence by simultaneously pressing, holding for 2-3 seconds, and releasing the green push buttons on either side of the operators panel. The machine will squeeze and jolt the sand in the flask and then move the squeeze head to the side.

**WARNING**
**Do no re-approach the machine until the squeeze head has stopped at the side of the machine.**

**q.** Screed the bottom of the drag mold flat to the bottom of the flask if required.
**r.** Press and release the LOWER DRAW/STOP push button to separate the flask and mold from the pattern.
**s.** Use the overhead crane to lift the mold half and remove it from the machine. If the mold half is a drag, roll it parting line side up, set it on the floor, blow it out.
**t.** Finally, press and release the DRAW DOWN pushbutton to cause the draw frame to return to the start position.

**6.** Set four (4) step cores that have been weighed and logged into the drag. Verify that the cores are fully set and flush with the parting line.
**7.** Set the ceramic metal filter
**8.** Close the cope over the drag being careful not to crush anything.
**9.** Clamp the flask halves together.
**10.** Weigh and record the weight of the closed un-poured mold, the pre-weighed flask, the uncoated cores, and the sand weight by difference.
**11.** Measure and record the sand temperature.
**12.** Deliver the mold to the previously cleaned shakeout to be poured.
**13.** Cover the mold with the emission hood.

**G.** Pig molds
**1.** Each day make a 900 pound capacity pig mold for the following day's use.

**H.** Emission hood:
**1.** Loading.
**a.** Hoist the mold onto the shakeout deck within the emission hood.
**b.** Close, seal, and lock the emission hood
**c.** Adjust the ambient air heater control so that the measured temperature of the blended air within the hood is 85-90°F at the start of the test run.

**2.** Shakeout.
- **a.** After the 45 minute cooling time prescribed in the emission sample plan has elapsed turn on the shakeout unit and run for it the 15 minutes prescribed in the emission sample plan or until the sand has all fallen through the grating.
- **b.** Turn off the shakeout.
- **c.** Sample the emissions for 30 minutes after the start of shakeout, a total of 75 minutes.

**3.** When the emission sampling is completed remove the flask with casting, and recover the sand from the hopper and surrounding floor.
- **a.** Weigh and record the metal poured and the total sand weight recovered and rejoined with the left over mold sand from the molding hopper, spilled molding sand, and sand loosely adhered to the casting.
- **b.** Add sufficient unused premixed sand to the recycled sand to return the sand heap to 900 +/- 10 pounds.

**I.** Melting:

**1.** Initial iron 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 metallics 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 I.1.e

**3.** Emptying the furnace.
- **a.** Pig the extra metal at the side draft hood only to avoid contaminating the air sample.
- **b.** Cover the empty furnace with ceramic blanket to cool.

**J.** Pouring:

**1.** Preheat the ladle.

**a.** Tap 400 pounds more or less of 2700°F iron into the cold ladle.
**b.** Carefully pour the metal back to the furnace.
**c.** Cover the ladle.
**d.** Reheat the metal to 2780 +/- 20°F.
**e.** Tap 450 pounds of iron into the ladle while pouring inoculating alloys onto the metal stream near its base. Cover the ladle to conserve heat.
**f.** Move the ladle to the pour position and wait until the metal temperature reaches 2680 +/- 10°F.
**g.** Commence pouring keeping the sprue full.
**h.** Upon completion return the extra metal to the furnace, and cover the ladle.
**i.** Record the pour temperature and pour time on the heat log.

Steven M. Knight
Mgr. Process Engineering

### GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **7/12/2005** | | | | | | | | | | | |
| CONDITIONING - 1 | | | | | | | | | | | **Star Pattern** |
| THC, CO, CO2 & Nox | GU CR-1 | X | | | | | | | | | TOTAL |

### GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **7/12/2005** | | | | | | | | | | | |
| CONDITIONING - 2 | | | | | | | | | | | **Star Pattern** |
| THC, CO, CO2 & Nox | GU CR-2 | X | | | | | | | | | TOTAL |

### GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **7/12/2005** | | | | | | | | | | | |
| CONDITIONING - 3 | | | | | | | | | | | **Star Pattern** |
| THC, CO, CO2 & Nox | GU CR-3 | X | | | | | | | | | TOTAL |

### GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **7/13/2005** | | | | | | | | | | | |
| | | | | | | | | | | | **Star Pattern** |
| THC, CO, CO2 & Nox | GU001 | X | | | | | | | | | TOTAL |
| M-18 | GU00101 | | 1 | | | | | | 30 | 1 | Carbopak charcoal |
| M-18 | GU00102 | | | | 1 | | | | 0 | | Carbopak charcoal |
| | Excess | | | | | | | | 30 | 2 | Excess |
| | Excess | | | | | | | | 30 | 3 | Excess |
| | Excess | | | | | | | | 30 | 4 | Excess |
| OSHA ID200 | GU00103 | | 1 | | | | | | 1000 | 5 | 100/50 mg Carbon Bead (SKC 226-80) |
| OSHA ID200 | GU00104 | | | | 1 | | | | 0 | | 100/50 mg Carbon Bead (SKC 226-80) |
| | Excess | | | | | | | | 1000 | 6 | Excess |
| NIOSH 1500 | GU00105 | | 1 | | | | | | 1000 | 7 | 100/50 mg Charcoal (SKC 226-01) |
| NIOSH 1500 | GU00106 | | | | 1 | | | | 0 | | 100/50 mg Charcoal (SKC 226-01) |
| | Excess | | | | | | | | 1000 | 8 | Excess |
| TO11 | GU00107 | | 1 | | | | | | 1000 | 9 | DNPH Silica Gel (SKC 226-119) |
| TO11 | GU00108 | | | | 1 | | | | 0 | | DNPH Silica Gel (SKC 226-119) |
| | Excess | | | | | | | | 1000 | 10 | Excess |
| | Excess | | | | | | | | 1000 | 11 | Excess |
| | Moisture | | 1 | | | | | | 500 | 12 | TOTAL |
| | Excess | | | | | | | | 5000 | 13 | Excess |

## GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments: Channel 6 clogged during the run. Duplicate for OSHA ID200 to be done on GU003; do not send GU00204 for analysis. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **7/13/2005** | | | | | | | | | | | |
| | | | | | | | | | | | **Star Pattern** |
| THC, CO, CO2 & Nox | GU002 | X | | | | | | | | | TOTAL |
| M-18 | GU00201 | | 1 | | | | | | 30 | 1 | Carbopak charcoal |
| M-18 | GU00202 | | | 1 | | | | | 30 | 2 | Carbopak charcoal |
| | Excess | | | | | | | | 30 | 3 | Excess |
| | Excess | | | | | | | | 30 | 4 | Excess |
| OSHA ID200 | GU00203 | | 1 | | | | | | 1000 | 5 | 100/50 mg Carbon Bead (SKC 226-80) |
| OSHA ID200 | GU00204 | | | 1 | | | | | 1000 | 6 | 100/50 mg Carbon Bead (SKC 226-80) |
| NIOSH 1500 | GU00205 | | 1 | | | | | | 1000 | 7 | 100/50 mg Charcoal (SKC 226-01) |
| NIOSH 1500 | GU00206 | | | 1 | | | | | 1000 | 8 | 100/50 mg Charcoal (SKC 226-01) |
| TO11 | GU00207 | | 1 | | | | | | 1000 | 9 | DNPH Silica Gel (SKC 226-119) |
| TO11 | GU00208 | | | 1 | | | | | 1000 | 10 | DNPH Silica Gel (SKC 226-119) |
| | Excess | | | | | | | | 1000 | 11 | Excess |
| | Moisture | | 1 | | | | | | 500 | 12 | TOTAL |
| | Excess | | | | | | | | 5000 | 13 | Excess |

## GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **7/13/2005** | | | | | | | | | | | |
| | | | | | | | | | | | **Star Pattern** |
| THC, CO, CO2 & Nox | GU003 | X | | | | | | | | | TOTAL |
| M-18 | GU00301 | | 1 | | | | | | 30 | 1 | Carbopak charcoal |
| M-18 MS | GU00302 | | 1 | | | | | | 30 | 2 | Carbopak charcoal |
| M-18 MS | GU00303 | | | 1 | | | | | 30 | 3 | Carbopak charcoal |
| | Excess | | | | | | | | 30 | 4 | Excess |
| OSHA ID200 | GU00304 | | 1 | | | | | | 1000 | 5 | 100/50 mg Carbon Bead (SKC 226-80) |
| OSHA ID200 | GU00307 | | | 1 | | | | | 1000 | 6 | 100/50 mg Carbon Bead (SKC 226-80) |
| NIOSH 1500 | GU00305 | | 1 | | | | | | 1000 | 7 | 100/50 mg Charcoal (SKC 226-01) |
| | Excess | | | | | | | | 1000 | 8 | Excess |
| TO11 | GU00306 | | 1 | | | | | | 1000 | 9 | DNPH Silica Gel (SKC 226-119) |
| | Excess | | | | | | | | 1000 | 10 | Excess |
| | Excess | | | | | | | | 1000 | 11 | Excess |
| | Moisture | | 1 | | | | | | 500 | 12 | TOTAL |
| | Excess | | | | | | | | 5000 | 13 | Excess |

## GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments: Channel 1 plugged during the run. Breakthrough for M18 will be done on GU005; do not send samples GU00401 and GU00402 for analysis. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **7/14/2005** | | | | | | | | | | | |
| | | | | | | | | | | | **Star Pattern** |
| THC, CO, CO2 & Nox | GU004 | X | | | | | | | | | TOTAL |
| M-18 | GU00401 | | 1 | | | | | | 30 | 1 | Carbopak charcoal |
| M-18 | GU00402 | | | | | 1 | | | 30 | 1 | Carbopak charcoal |
| | Excess | | | | | | | | 30 | 2 | Excess |
| | Excess | | | | | | | | 30 | 3 | Excess |
| | Excess | | | | | | | | 30 | 4 | Excess |
| OSHA ID200 | GU00403 | | 1 | | | | | | 1000 | 5 | 100/50 mg Carbon Bead (SKC 226-80) |
| | Excess | | | | | | | | 1000 | 6 | Excess |
| NIOSH 1500 | GU00404 | | 1 | | | | | | 1000 | 7 | 100/50 mg Charcoal (SKC 226-01) |
| | Excess | | | | | | | | 1000 | 8 | Excess |
| TO11 | GU00405 | | 1 | | | | | | 1000 | 9 | DNPH Silica Gel (SKC 226-119) |
| | Excess | | | | | | | | 1000 | 10 | Excess |
| | Excess | | | | | | | | 1000 | 11 | Excess |
| | Moisture | | 1 | | | | | | 500 | 12 | TOTAL |
| | Excess | | | | | | | | 5000 | 13 | Excess |

## GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **7/14/2005** | | | | | | | | | | | |
| | | | | | | | | | | | **Star Pattern** |
| THC, CO, CO2 & Nox | GU005 | X | | | | | | | | | TOTAL |
| M-18 | GU00501 | | 1 | | | | | | 30 | 1 | Carbopak charcoal |
| M-18 | GU00505 | | | | | 1 | | | 30 | 1 | Carbopak charcoal |
| | Excess | | | | | | | | 30 | 2 | Excess |
| | Excess | | | | | | | | 30 | 3 | Excess |
| | Excess | | | | | | | | 30 | 4 | Excess |
| OSHA ID200 | GU00502 | | 1 | | | | | | 1000 | 5 | 100/50 mg Carbon Bead (SKC 226-80) |
| | Excess | | | | | | | | 1000 | 6 | Excess |
| NIOSH 1500 | GU00503 | | 1 | | | | | | 1000 | 7 | 100/50 mg Charcoal (SKC 226-01) |
| | Excess | | | | | | | | 1000 | 8 | Excess |
| TO11 | GU00504 | | 1 | | | | | | 1000 | 9 | DNPH Silica Gel (SKC 226-119) |
| | Excess | | | | | | | | 1000 | 10 | Excess |
| | Excess | | | | | | | | 1000 | 11 | Excess |
| | Moisture | | 1 | | | | | | 500 | 12 | TOTAL |
| | Excess | | | | | | | | 5000 | 13 | Excess |

## GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **7/14/2005** | | | | | | | | | | | |
| | | | | | | | | | | | **Star Pattern** |
| THC, CO, CO2 & Nox | GU006 | X | | | | | | | | | TOTAL |
| M-18 | GU00601 | | 1 | | | | | | 30 | 1 | Carbopak charcoal |
| | Excess | | | | | | | | 30 | 2 | Excess |
| | Excess | | | | | | | | 30 | 3 | Excess |
| | Excess | | | | | | | | 30 | 4 | Excess |
| OSHA ID200 | GU00602 | | 1 | | | | | | 1000 | 5 | 100/50 mg Carbon Bead (SKC 226-80) |
| | Excess | | | | | | | | 1000 | 6 | Excess |
| NIOSH 1500 | GU00603 | | 1 | | | | | | 1000 | 7 | 100/50 mg Charcoal (SKC 226-01) |
| | Excess | | | | | | | | 1000 | 8 | Excess |
| TO11 | GU00604 | | 1 | | | | | | 1000 | 9 | DNPH Silica Gel (SKC 226-119) |
| | Excess | | | | | | | | 1000 | 10 | Excess |
| | Excess | | | | | | | | 1000 | 11 | Excess |
| | Moisture | | 1 | | | | | | 500 | 12 | TOTAL |
| | Excess | | | | | | | | 5000 | 13 | Excess |

## GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| | | | | | | | | | | | **Sodium Silicate Cores** |
| THC, CO, CO2 & Nox | GU007 | X | | | | | | | | | TOTAL |
| M-18 | GU00701 | | 1 | | | | | | 30 | 1 | Carbopak charcoal |
| | Excess | | | | | | | | 30 | 2 | Excess |
| | Excess | | | | | | | | 30 | 3 | Excess |
| | Excess | | | | | | | | 30 | 4 | Excess |
| OSHA ID200 | GU00702 | | 1 | | | | | | 1000 | 5 | 100/50 mg Carbon Bead (SKC 226-80) |
| | Excess | | | | | | | | 1000 | 6 | Excess |
| NIOSH 1500 | GU00703 | | 1 | | | | | | 1000 | 7 | 100/50 mg Charcoal (SKC 226-01) |
| | Excess | | | | | | | | 1000 | 8 | Excess |
| TO11 | GU00704 | | 1 | | | | | | 1000 | 9 | DNPH Silica Gel (SKC 226-119) |
| | Excess | | | | | | | | 1000 | 10 | Excess |
| | Excess | | | | | | | | 1000 | 11 | Excess |
| | Moisture | | 1 | | | | | | 500 | 12 | TOTAL |
| | Excess | | | | | | | | 5000 | 13 | Excess |

## GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments: Channel 10 plugged during the run; duplicate for TO11 will be done on GU009. Do not send sample GU00808 for analysis. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| | | | | | | | | | | | **Sodium Silicate Cores** |
| THC, CO, CO2 & Nox | GU008 | X | | | | | | | | | TOTAL |
| M-18 | GU00801 | | 1 | | | | | | 30 | 1 | Carbopak charcoal |
| M-18 | GU00802 | | | 1 | | | | | 30 | 2 | Carbopak charcoal |
| | Excess | | | | | | | | 30 | 3 | Excess |
| | Excess | | | | | | | | 30 | 4 | Excess |
| OSHA ID200 | GU00803 | | 1 | | | | | | 1000 | 5 | 100/50 mg Carbon Bead (SKC 226-80) |
| OSHA ID200 | GU00804 | | | 1 | | | | | 1000 | 6 | 100/50 mg Carbon Bead (SKC 226-80) |
| NIOSH 1500 | GU00805 | | 1 | | | | | | 1000 | 7 | 100/50 mg Charcoal (SKC 226-01) |
| NIOSH 1500 | GU00806 | | | 1 | | | | | 1000 | 8 | 100/50 mg Charcoal (SKC 226-01) |
| TO11 | GU00807 | | 1 | | | | | | 1000 | 9 | DNPH Silica Gel (SKC 226-119) |
| TO11 | GU00808 | | | 1 | | | | | 1000 | 10 | DNPH Silica Gel (SKC 226-119) |
| | Excess | | | | | | | | 1000 | 11 | Excess |
| | Moisture | | 1 | | | | | | 500 | 12 | TOTAL |
| | Excess | | | | | | | | 5000 | 13 | Excess |

## GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments: Channel 1 plugged during the run; no M18 FID sample for this run. Do not send sample GU00901 for analysis. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| | | | | | | | | | | | **Sodium Silicate Cores** |
| THC, CO, CO2 & Nox | GU009 | X | | | | | | | | | TOTAL |
| M-18 | GU00901 | | 1 | | | | | | 30 | 1 | Carbopak charcoal |
| M-18 MS | GU00902 | | 1 | | | | | | 30 | 2 | Carbopak charcoal |
| M-18 MS | GU00903 | | | 1 | | | | | 30 | 3 | Carbopak charcoal |
| | Excess | | | | | | | | 30 | 4 | Excess |
| OSHA ID200 | GU00904 | | 1 | | | | | | 1000 | 5 | 100/50 mg Carbon Bead (SKC 226-80) |
| | Excess | | | | | | | | 1000 | 6 | Excess |
| NIOSH 1500 | GU00905 | | 1 | | | | | | 1000 | 7 | 100/50 mg Charcoal (SKC 226-01) |
| | Excess | | | | | | | | 1000 | 8 | Excess |
| TO11 | GU00906 | | 1 | | | | | | 1000 | 9 | DNPH Silica Gel (SKC 226-119) |
| TO11 | GU00907 | | | 1 | | | | | 1000 | 10 | DNPH Silica Gel (SKC 226-119) |
| | Excess | | | | | | | | 1000 | 11 | Excess |
| | Moisture | | 1 | | | | | | 500 | 12 | TOTAL |
| | Excess | | | | | | | | 5000 | 13 | Excess |

## GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| | | | | | | | | | | | **Sodium Silicate Cores** |
| THC, CO, CO2 & Nox | GU010 | X | | | | | | | | | TOTAL |
| M-18 | GU01001 | | 1 | | | | | | 30 | 1 | Carbopak charcoal |
| M-18 | GU01002 | | | | | 1 | | | 30 | 1 | Carbopak charcoal |
| | Excess | | | | | | | | 30 | 2 | Excess |
| | Excess | | | | | | | | 30 | 3 | Excess |
| | Excess | | | | | | | | 30 | 4 | Excess |
| OSHA ID200 | GU01003 | | 1 | | | | | | 1000 | 5 | 100/50 mg Carbon Bead (SKC 226-80) |
| | Excess | | | | | | | | 1000 | 6 | Excess |
| NIOSH 1500 | GU01004 | | 1 | | | | | | 1000 | 7 | 100/50 mg Charcoal (SKC 226-01) |
| | Excess | | | | | | | | 1000 | 8 | Excess |
| TO11 | GI01005 | | 1 | | | | | | 1000 | 9 | DNPH Silica Gel (SKC 226-119) |
| | Excess | | | | | | | | 1000 | 10 | Excess |
| | Excess | | | | | | | | 1000 | 11 | Excess |
| | Moisture | | 1 | | | | | | 500 | 12 | TOTAL |
| | Excess | | | | | | | | 5000 | 13 | Excess |

## GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| | | | | | | | | | | | **Sodium Silicate Cores** |
| THC, CO, CO2 & Nox | GU011 | X | | | | | | | | | TOTAL |
| M-18 | GU01101 | | 1 | | | | | | 30 | 1 | Carbopak charcoal |
| | Excess | | | | | | | | 30 | 2 | Excess |
| | Excess | | | | | | | | 30 | 3 | Excess |
| | Excess | | | | | | | | 30 | 4 | Excess |
| OSHA ID200 | GU01102 | | 1 | | | | | | 1000 | 5 | 100/50 mg Carbon Bead (SKC 226-80) |
| | Excess | | | | | | | | 1000 | 6 | Excess |
| NIOSH 1500 | GU01103 | | 1 | | | | | | 1000 | 7 | 100/50 mg Charcoal (SKC 226-01) |
| | Excess | | | | | | | | 1000 | 8 | Excess |
| TO11 | GU01104 | | 1 | | | | | | 1000 | 9 | DNPH Silica Gel (SKC 226-119) |
| | Excess | | | | | | | | 1000 | 10 | Excess |
| | Excess | | | | | | | | 1000 | 11 | Excess |
| | Moisture | | 1 | | | | | | 500 | 12 | TOTAL |
| | Excess | | | | | | | | 5000 | 13 | Excess |

## GU - SERIES SAMPLE PLAN

| Method | Sample # | Data | Sample | Duplicate | Blank | Breakthrough | Spike | Spike Duplicate | Flow (ml/min) | Train Channel | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| | | | | | | | | | | | **Sodium Silicate Cores** |
| THC, CO, CO2 & Nox | GU012 | X | | | | | | | | | TOTAL |
| M-18 | GU01201 | | 1 | | | | | | 30 | 1 | Carbopak charcoal |
| | Excess | | | | | | | | 30 | 2 | Excess |
| | Excess | | | | | | | | 30 | 3 | Excess |
| | Excess | | | | | | | | 30 | 4 | Excess |
| OSHA ID200 | GU01202 | | 1 | | | | | | 1000 | 5 | 100/50 mg Carbon Bead (SKC 226-80) |
| | Excess | | | | | | | | 1000 | 6 | Excess |
| NIOSH 1500 | GU01203 | | 1 | | | | | | 1000 | 7 | 100/50 mg Charcoal (SKC 226-01) |
| | Excess | | | | | | | | 1000 | 8 | Excess |
| TO11 | GU01204 | | 1 | | | | | | 1000 | 9 | DNPH Silica Gel (SKC 226-119) |
| | Excess | | | | | | | | 1000 | 10 | Excess |
| | Excess | | | | | | | | 1000 | 11 | Excess |
| | Moisture | | 1 | | | | | | 500 | 12 | TOTAL |
| | Excess | | | | | | | | 5000 | 13 | Excess |

# APPENDIX B DETAILED EMISSION RESULTS AND QUANTITATION LIMITS

*this page intentionally left blank*

## 4-on Star Detailed Emissions (Lb/Tn Metal)

| | GU001 | GU002 | GU003 | GU004 | GU005 | GU006 | Average | Standard Deviation |
|---|---|---|---|---|---|---|---|---|
| Test Dates | 13-Jul-05 | 13-Jul-05 | 13-Jul-05 | 14-Jul-05 | 14-Jul-05 | 14-Jul-05 | — | — |
| Emission Indicators | | | | | | | | |
| TGOC as Propane | 3.55E+00 | 3.47E+00 | 3.48E+00 | 3.09E+00 | 2.90E+00 | 3.18E+00 | 3.28E+00 | 2.62E-01 |
| HC as Hexane | 8.78E-01 | 9.35E-01 | 8.42E-01 | 7.38E-01 | 7.04E-01 | 7.19E-01 | 8.02E-01 | 9.57E-02 |
| Sum of Target VOCs | 5.00E-01 | 5.65E-01 | 4.99E-01 | 1.87E-02 | 4.53E-01 | 4.33E-01 | 4.95E-01 | 1.98E-01 |
| Sum of Target HAPs | 4.03E-01 | 4.50E-01 | 3.88E-01 | 1.60E-02 | 3.62E-01 | 3.42E-01 | 3.90E-01 | 1.57E-01 |
| Sum of Target POMs | 1.59E-02 | 2.18E-02 | 2.32E-02 | 0.00E+00 | 2.21E-02 | 2.06E-02 | 2.07E-02 | 8.84E-03 |
| Individual Target HAPs | | | | | | | | |
| Naphthalene | 9.86E-03 | 1.33E-02 | 1.40E-02 | I | 1.34E-02 | 1.24E-02 | 1.26E-02 | 1.64E-03 |
| Methylnaphthalene, 2- | 3.55E-03 | 4.68E-03 | 4.69E-03 | I | 4.62E-03 | 4.54E-03 | 4.41E-03 | 4.87E-04 |
| Methylnaphthalene, 1- | 1.76E-03 | 2.63E-03 | 3.15E-03 | I | 2.85E-03 | 2.51E-03 | 2.58E-03 | 5.20E-04 |
| Dimethylnaphthalene, 1,3- | 7.10E-04 | 1.18E-03 | 1.32E-03 | I | 1.26E-03 | 1.18E-03 | 1.13E-03 | 2.43E-04 |
| Acenaphthalene | ND | ND | ND | I | ND | ND | NA | NA |
| Dimethylnaphthalene, 1,2- | ND | ND | ND | I | ND | ND | NA | NA |
| Dimethylnaphthalene, 1,5- | ND | ND | ND | I | ND | ND | NA | NA |
| Dimethylnaphthalene, 1,6- | ND | ND | ND | I | ND | ND | NA | NA |
| Dimethylnaphthalene, 1,8- | ND | ND | ND | I | ND | ND | NA | NA |
| Dimethylnaphthalene, 2,3- | ND | ND | ND | I | ND | ND | NA | NA |
| Dimethylnaphthalene, 2,6- | ND | ND | ND | I | ND | ND | NA | NA |
| Dimethylnaphthalene, 2,7- | ND | ND | ND | I | ND | ND | NA | NA |
| Trimethylnaphthalene, 2,3,5- | ND | ND | ND | I | ND | ND | NA | NA |
| Xylene, mp- | 3.43E-02 | 3.88E-02 | 3.63E-02 | I | 3.15E-02 | 2.86E-02 | 3.39E-02 | 4.00E-03 |
| Xylene, o- | 1.95E-02 | 2.17E-02 | 2.05E-02 | I | 1.73E-02 | 1.62E-02 | 1.90E-02 | 2.27E-03 |
| Hexane | 1.65E-02 | 1.69E-02 | 1.56E-02 | I | 1.37E-02 | 1.54E-02 | 1.56E-02 | 1.26E-03 |
| Phenol | 1.41E-02 | 1.70E-02 | 1.72E-02 | I | 1.43E-02 | 1.46E-02 | 1.55E-02 | 1.54E-03 |
| Acetaldehyde | 7.74E-03 | 8.57E-03 | 8.44E-03 | 7.11E-03 | 6.65E-03 | 6.19E-03 | 7.45E-03 | 9.65E-04 |
| Cresol, o- | 5.08E-03 | 6.58E-03 | 6.47E-03 | I | 5.43E-03 | 5.50E-03 | 5.81E-03 | 6.74E-04 |
| Cresol, mp- | ND | 4.88E-03 | 5.04E-03 | I | 4.08E-03 | 4.12E-03 | 4.53E-03 | 5.01E-04 |
| 2-Butanone (MEK) | 2.30E-03 | 2.77E-03 | 2.83E-03 | 2.23E-03 | 2.40E-03 | 2.24E-03 | 2.46E-03 | 2.69E-04 |

Note: M18 GC/FID analysis was not conducted on run GU004 due to plugging of sample line.
NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

4-on Star Detailed Emissions (Lb/Tn Metal)

| | GU001 | GU002 | GU003 | GU004 | GU005 | GU006 | Average | Standard Deviation |
|---|---|---|---|---|---|---|---|---|
| Acrolein | ND | ND | ND | ND | ND | ND | NA | NA |
| Biphenyl | ND | ND | ND | I | ND | ND | NA | NA |
| Benzene | 1.83E-01 | 1.96E-01 | 1.47E-01 | I | 1.52E-01 | 1.44E-01 | 1.64E-01 | 2.35E-02 |
| Toluene | 8.81E-02 | 9.58E-02 | 8.88E-02 | I | 7.80E-02 | 7.07E-02 | 8.43E-02 | 9.89E-03 |
| Ethylbenzene | 1.03E-02 | 1.14E-02 | 1.08E-02 | I | 9.05E-03 | 8.55E-03 | 1.00E-02 | 1.19E-03 |
| Formaldehyde | 5.41E-03 | 5.92E-03 | 5.29E-03 | 5.53E-03 | 4.74E-03 | 3.74E-03 | 5.10E-03 | 7.72E-04 |
| Propionaldehyde (Propanal) | 1.29E-03 | 1.47E-03 | 1.43E-03 | 1.15E-03 | 1.18E-03 | 1.15E-03 | 1.28E-03 | 1.41E-04 |
| Other Target VOCs | | | | | | | | |
| Octane | 1.27E-02 | 1.30E-02 | 1.22E-02 | I | 1.07E-02 | 1.18E-02 | 1.21E-02 | 8.88E-04 |
| Trimethylbenzene, 1,2,4- | 1.00E-02 | 1.24E-02 | 1.21E-02 | I | 1.06E-02 | 9.38E-03 | 1.09E-02 | 1.31E-03 |
| Undecane | 7.16E-03 | 8.74E-03 | 8.61E-03 | I | 7.09E-03 | 5.90E-03 | 7.50E-03 | 1.18E-03 |
| Indene | 4.32E-03 | 5.46E-03 | 5.10E-03 | I | 3.94E-03 | 3.67E-03 | 4.50E-03 | 7.59E-04 |
| Cyclohexane | 4.64E-03 | 4.90E-03 | 4.17E-03 | I | 3.88E-03 | 4.16E-03 | 4.35E-03 | 4.11E-04 |
| Indan | 3.32E-03 | 4.08E-03 | 3.96E-03 | I | 3.29E-03 | 2.93E-03 | 3.52E-03 | 4.87E-04 |
| Styrene | 3.45E-03 | 3.90E-03 | 3.67E-03 | I | 2.71E-03 | 3.27E-03 | 3.40E-03 | 4.50E-04 |
| Butyraldehyde/Methacrolein | 7.32E-04 | 8.50E-04 | 7.98E-04 | 6.55E-04 | 7.34E-04 | 6.59E-04 | 7.38E-04 | 7.65E-05 |
| Trimethylbenzene, 1,3,5- | ND | ND | ND | I | ND | ND | NA | NA |
| Nonane | 1.04E-02 | 1.09E-02 | 1.02E-02 | I | 8.70E-03 | 9.32E-03 | 9.90E-03 | 8.83E-04 |
| Decane | 8.42E-03 | 9.29E-03 | 8.75E-03 | I | 7.49E-03 | 7.17E-03 | 8.22E-03 | 8.82E-04 |
| Propylbenzene, n- | ND | 2.11E-03 | 2.03E-03 | I | ND | ND | 2.07E-03 | 6.03E-05 |
| Crotonaldehyde | 3.60E-04 | ND | ND | ND | ND | ND | 3.60E-04 | NA |
| Diethylbenzene, 1,3- | ND | ND | ND | I | ND | ND | NA | NA |
| Heptane | 1.43E-02 | 1.52E-02 | 1.34E-02 | I | 1.26E-02 | 1.30E-02 | 1.37E-02 | 1.05E-03 |
| Ethyltoluene, 3- | 5.91E-03 | 7.02E-03 | 6.70E-03 | I | 5.76E-03 | 5.16E-03 | 6.11E-03 | 7.46E-04 |
| Dodecane | 5.12E-03 | 6.46E-03 | 6.53E-03 | I | 5.74E-03 | 4.97E-03 | 5.76E-03 | 7.27E-04 |
| Ethyltoluene, 2- | 3.36E-03 | 4.18E-03 | 4.04E-03 | I | 3.41E-03 | 3.04E-03 | 3.61E-03 | 4.83E-04 |
| Dimethylphenol, 2,4- | ND | ND | 3.36E-03 | I | ND | 2.80E-03 | 3.08E-03 | 3.97E-04 |
| Tetradecane | ND | 2.28E-03 | 2.68E-03 | I | 2.38E-03 | 2.04E-03 | 2.35E-03 | 2.66E-04 |
| o,m,p-Tolualdehyde | 9.30E-04 | 1.16E-03 | 1.10E-03 | 8.46E-04 | 9.49E-04 | 9.89E-04 | 9.95E-04 | 1.14E-04 |

Note: M18 GC/FID analysis was not conducted on run GU004 due to plugging of sample line.
NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

4-on Star Detailed Emissions (Lb/Tn Metal)

| | GU001 | GU002 | GU003 | GU004 | GU005 | GU006 | Average | Standard Deviation |
|---|---|---|---|---|---|---|---|---|
| Benzaldehyde | 7.00E-04 | 2.08E-03 | 5.20E-04 | 4.93E-04 | 3.98E-04 | 4.51E-04 | 7.73E-04 | 6.46E-04 |
| Pentanal (Valeraldehyde) | 4.55E-04 | 5.77E-04 | 5.72E-04 | 4.02E-04 | 4.44E-04 | 4.67E-04 | 4.86E-04 | 7.21E-05 |
| Hexaldehyde | 3.68E-04 | 4.52E-04 | 4.93E-04 | 3.27E-04 | 3.75E-04 | 4.02E-04 | 4.03E-04 | 6.04E-05 |
| Dimethylphenol, 2,6- | ND | ND | ND | I | ND | ND | NA | NA |
| Trimethylbenzene, 1,2,3- | ND | ND | ND | I | ND | ND | NA | NA |
| Criteria Pollutants, Greenhouse Gases and Other Analytes | | | | | | | | |
| Carbon Monoxide | 5.42E+00 | 5.56E+00 | 5.02E+00 | 5.17E+00 | 5.23E+00 | 6.80E+00 | 5.53E+00 | 6.49E-01 |
| Carbon Dioxide | 1.48E+01 | 1.59E+01 | 1.29E+01 | 1.39E+01 | 1.39E+01 | 1.10E+01 | 1.37E+01 | 1.70E+00 |
| Nitrogen Oxides | 6.04E-03 | 5.84E-03 | 5.19E-03 | 6.29E-03 | 4.91E-03 | 5.07E-03 | 5.56E-03 | 5.73E-04 |
| Sulfur Dioxide | 2.82E-02 | 3.05E-02 | 2.63E-02 | 2.82E-02 | 2.87E-02 | 3.00E-02 | 2.86E-02 | 1.47E-03 |

Note: M18 GC/FID analysis was not conducted on run GU004 due to plugging of sample line.
NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

| Step Core Detailed Emissions (Lb/Tn Metal) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | GU007 | GU008 | GU009 | GU010 | GU011 | GU012 | Average | Standard Deviation |
| Test Dates | 18-Jul-05 | 18-Jul-05 | 18-Jul-05 | 19-Jul-05 | 19-Jul-05 | 19-Jul-05 | — | — |
| Emission Indicators | | | | | | | | |
| TGOC as Propane | 1.80E+00 | 1.71E+00 | 1.58E+00 | 1.71E+00 | 1.59E+00 | 1.48E+00 | 1.65E+00 | 1.15E-01 |
| HC as Hexane | 5.07E-01 | 4.45E-01 | 4.56E-01 | 3.97E-01 | 3.96E-01 | 3.73E-01 | 4.29E-01 | 4.98E-02 |
| Sum of Target VOCs | 1.51E-02 | 2.58E-01 | 1.93E-02 | 2.30E-01 | 2.20E-01 | 2.21E-01 | 2.33E-01 | 1.12E-01 |
| Sum of Target HAPs | 1.30E-02 | 2.04E-01 | 1.66E-02 | 1.89E-01 | 1.80E-01 | 1.78E-01 | 1.88E-01 | 8.97E-02 |
| Sum of Target POMs | 0.00E+00 | 1.31E-02 | 0.00E+00 | 1.04E-02 | 1.01E-02 | 1.03E-02 | 1.10E-02 | 5.79E-03 |
| Individual Target HAPs | | | | | | | | |
| Benzene | I | 7.49E-02 | I | 6.89E-02 | 6.42E-02 | 6.12E-02 | 6.73E-02 | 6.00E-03 |
| Toluene | I | 4.55E-02 | I | 4.16E-02 | 4.19E-02 | 4.02E-02 | 4.23E-02 | 2.28E-03 |
| Xylene, mp- | I | 1.99E-02 | I | 1.76E-02 | 1.78E-02 | 1.78E-02 | 1.83E-02 | 1.09E-03 |
| Xylene, o- | I | 1.09E-02 | I | 1.00E-02 | 9.90E-03 | 9.65E-03 | 1.01E-02 | 5.25E-04 |
| Hexane | I | 1.01E-02 | I | 1.04E-02 | 9.44E-03 | 8.22E-03 | 9.54E-03 | 9.70E-04 |
| Acetaldehyde | 7.77E-03 | 7.49E-03 | 9.27E-03 | 9.19E-03 | 8.08E-03 | 8.74E-03 | 8.42E-03 | 7.51E-04 |
| Phenol | I | 7.92E-03 | I | 7.92E-03 | 6.17E-03 | 7.04E-03 | 7.26E-03 | 8.38E-04 |
| Naphthalene | I | 7.70E-03 | I | 5.93E-03 | 6.05E-03 | 5.84E-03 | 6.38E-03 | 8.82E-04 |
| Ethylbenzene | I | 6.00E-03 | I | 5.43E-03 | 5.56E-03 | 5.54E-03 | 5.63E-03 | 2.51E-04 |
| Formaldehyde | 2.45E-03 | 2.36E-03 | 3.94E-03 | 2.52E-03 | 2.44E-03 | 3.63E-03 | 2.89E-03 | 7.05E-04 |
| Methylnaphthalene, 2- | I | 2.92E-03 | I | 2.23E-03 | 2.12E-03 | 2.32E-03 | 2.40E-03 | 3.60E-04 |
| Cresol, o- | I | 2.72E-03 | I | 2.25E-03 | 1.73E-03 | 2.21E-03 | 2.23E-03 | 4.04E-04 |
| 2-Butanone (MEK) | 1.78E-03 | 1.65E-03 | 2.12E-03 | 1.74E-03 | 1.82E-03 | 1.93E-03 | 1.84E-03 | 1.67E-04 |
| Methylnaphthalene, 1- | I | 1.77E-03 | I | 1.65E-03 | 1.38E-03 | 1.52E-03 | 1.58E-03 | 1.65E-04 |
| Propionaldehyde (Propanal) | 1.01E-03 | 1.04E-03 | 1.31E-03 | 1.12E-03 | 1.09E-03 | 1.20E-03 | 1.13E-03 | 1.10E-04 |
| Dimethylnaphthalene, 1,3- | I | 7.53E-04 | I | 5.80E-04 | 5.70E-04 | 6.54E-04 | 6.39E-04 | 8.47E-05 |
| Acenaphthalene | I | ND | I | ND | ND | ND | NA | NA |
| Dimethylnaphthalene, 1,2- | I | ND | I | ND | ND | ND | NA | NA |
| Dimethylnaphthalene, 1,5- | I | ND | I | ND | ND | ND | NA | NA |
| Dimethylnaphthalene, 1,6- | I | ND | I | ND | ND | ND | NA | NA |

Note: M18 GC/FID analysis was not conducted on run GU004 due to plugging of sample line.
NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

| Step Core Detailed Emissions (Lb/Tn Metal) | GU007 | GU008 | GU009 | GU010 | GU011 | GU012 | Average | Standard Deviation |
|---|---|---|---|---|---|---|---|---|
| Dimethylnaphthalene, 1,8- | I | ND | I | ND | ND | ND | NA | NA |
| Dimethylnaphthalene, 2,3- | I | ND | I | ND | ND | ND | NA | NA |
| Dimethylnaphthalene, 2,6- | I | ND | I | ND | ND | ND | NA | NA |
| Dimethylnaphthalene, 2,7- | I | ND | I | ND | ND | ND | NA | NA |
| Trimethylnaphthalene, 2,3,5- | I | ND | I | ND | ND | ND | NA | NA |
| Acrolein | ND | ND | ND | ND | ND | ND | NA | NA |
| Biphenyl | I | ND | I | ND | ND | ND | NA | NA |
| Cresol, mp- | I | ND | I | ND | ND | ND | NA | NA |
| Other Target VOCs | | | | | | | | |
| Octane | I | 8.36E-03 | I | 8.30E-03 | 7.80E-03 | 6.86E-03 | 7.83E-03 | 6.94E-04 |
| Undecane | I | 5.13E-03 | I | 4.11E-03 | 4.05E-03 | 4.04E-03 | 4.33E-03 | 5.35E-04 |
| Trimethylbenzene, 1,2,4- | I | 6.56E-03 | I | ND | ND | 5.91E-03 | 3.12E-03 | 4.61E-04 |
| Cyclohexane | I | 2.70E-03 | I | 2.44E-03 | 2.15E-03 | 1.79E-03 | 2.27E-03 | 3.90E-04 |
| Styrene | I | 1.12E-03 | I | 1.19E-03 | 1.00E-03 | 1.08E-03 | 1.10E-03 | 7.96E-05 |
| Indan | I | 2.01E-03 | I | ND | ND | 1.68E-03 | 9.21E-04 | 2.31E-04 |
| Butyraldehyde/Methacrolein | 5.43E-04 | 5.64E-04 | 7.33E-04 | 5.97E-04 | 5.97E-04 | 6.68E-04 | 6.17E-04 | 7.10E-05 |
| Indene | I | ND | I | ND | ND | ND | NA | NA |
| Trimethylbenzene, 1,3,5- | I | ND | I | ND | ND | ND | NA | NA |
| Nonane | I | 6.32E-03 | I | 6.16E-03 | 5.92E-03 | 5.26E-03 | 5.92E-03 | 4.66E-04 |
| Decane | I | 5.37E-03 | I | 5.00E-03 | 4.68E-03 | 4.31E-03 | 4.84E-03 | 4.52E-04 |
| Crotonaldehyde | ND | ND | ND | ND | ND | ND | NA | NA |
| Diethylbenzene, 1,3- | I | ND | I | ND | ND | ND | NA | NA |
| Propylbenzene, n- | I | ND | I | ND | ND | ND | NA | NA |
| Heptane | I | 8.60E-03 | I | 8.70E-03 | 9.00E-03 | 6.94E-03 | 8.31E-03 | 9.29E-04 |
| Ethyltoluene, 3- | I | 3.84E-03 | I | 3.34E-03 | 3.34E-03 | 3.41E-03 | 3.48E-03 | 2.41E-04 |
| Ethyltoluene, 2- | I | 2.21E-03 | I | ND | ND | ND | 5.52E-04 | NA |
| o,m,p-Tolualdehyde | 7.30E-04 | 5.03E-04 | 6.74E-04 | ND | 4.79E-04 | 5.79E-04 | 4.94E-04 | 1.08E-04 |
| Pentanal (Valeraldehyde) | 3.14E-04 | 3.24E-04 | 4.55E-04 | 3.36E-04 | 3.50E-04 | 3.93E-04 | 3.62E-04 | 5.33E-05 |
| Benzaldehyde | 2.68E-04 | 2.85E-04 | 4.11E-04 | 3.27E-04 | 2.79E-04 | 2.92E-04 | 3.10E-04 | 5.33E-05 |

Note: M18 GC/FID analysis was not conducted on run GU004 due to plugging of sample line.
NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

| Step Core Detailed Emissions (Lb/Tn Metal) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | GU007 | GU008 | GU009 | GU010 | GU011 | GU012 | Average | Standard Deviation |
| Hexaldehyde | 2.74E-04 | 2.94E-04 | 3.70E-04 | 2.67E-04 | 2.72E-04 | 3.14E-04 | 2.99E-04 | 3.92E-05 |
| Tetradecane | I | ND | I | ND | ND | ND | NA | NA |
| Dimethylphenol, 2,4- | I | ND | I | ND | ND | ND | NA | NA |
| Dimethylphenol, 2,6- | I | ND | I | ND | ND | ND | NA | NA |
| Dodecane | I | ND | I | ND | ND | ND | NA | NA |
| Trimethylbenzene, 1,2,3- | I | ND | I | ND | ND | ND | NA | NA |
| Criteria Pollutants, Greenhouse Gases and Other Analytes | | | | | | | | |
| Carbon Monoxide | 5.76E+00 | 5.77E+00 | 4.72E+00 | 6.50E+00 | 6.07E+00 | 4.78E+00 | 5.60E+00 | 7.12E-01 |
| Carbon Dioxide | 7.02E+00 | 7.18E+00 | 1.06E+01 | 7.23E+00 | 8.00E+00 | 1.04E+01 | 8.40E+00 | 1.66E+00 |
| Nitrogen Oxides | 4.18E-03 | 4.95E-03 | 4.79E-03 | 5.01E-03 | 5.00E-03 | 4.80E-03 | 4.79E-03 | 3.13E-04 |
| Sulfur Dioxide | 1.14E-02 | 1.11E-02 | 1.10E-02 | 1.16E-02 | 1.19E-02 | 1.21E-02 | 1.15E-02 | 4.43E-04 |

Note: M18 GC/FID analysis was not conducted on run GU004 due to plugging of sample line.
NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

## Quantitation Limits – Star

| Analyte | Practical Reporting Limit lb/ton |
|---|---|
| | |
| Carbon Monoxide | 5.38E-02 |
| Carbon Dioxide | 5.38E-02 |
| Nitrogen Oxides | 5.38E-02 |
| 2-Butanone (MEK) | 2.03E-04 |
| Acenaphthalene | 2.70E-03 |
| Acetaldehyde | 2.03E-04 |
| Acrolein | 2.03E-04 |
| Benzaldehyde | 2.03E-04 |
| Benzene | 5.41E-04 |
| Biphenyl | 2.70E-03 |
| Butyraldehyde/Methacrolein | 3.38E-04 |
| Cresol, mp- | 2.70E-03 |
| Cresol, o- | 2.70E-03 |
| Crotonaldehyde | 2.03E-04 |
| Cyclohexane | 2.70E-03 |
| Decane | 2.70E-03 |
| Diethylbenzene, 1,3- | 2.70E-03 |
| Dimethylnaphthalene, 1,2- | 2.70E-03 |
| Dimethylnaphthalene, 1,3- | 5.41E-04 |
| Dimethylnaphthalene, 1,5- | 2.70E-03 |
| Dimethylnaphthalene, 1,6- | 2.70E-03 |
| Dimethylnaphthalene, 1,8- | 2.70E-03 |
| Dimethylnaphthalene, 2,3- | 2.70E-03 |
| Dimethylnaphthalene, 2,6- | 2.70E-03 |
| Dimethylnaphthalene, 2,7- | 2.70E-03 |
| Dimethylphenol, 2,4- | 2.70E-03 |
| Dimethylphenol, 2,6- | 2.70E-03 |
| Dodecane | 2.70E-03 |
| Ethylbenzene | 5.41E-04 |
| Ethyltoluene, 2- | 5.41E-04 |

| Analyte | Practical Reporting Limit lb/ton |
|---|---|
| | |
| Ethyltoluene, 3- | 2.70E-03 |
| Formaldehyde | 2.03E-04 |
| Heptane | 2.70E-03 |
| Hexaldehyde | 2.03E-04 |
| Hexane | 5.41E-04 |
| Indan | 2.70E-03 |
| Indene | 2.70E-03 |
| Methylnaphthalene, 1- | 5.41E-04 |
| Methylnaphthalene, 2- | 5.41E-04 |
| Naphthalene | 5.41E-04 |
| Nonane | 2.70E-03 |
| o,m,p-Tolualdehyde | 5.41E-04 |
| Octane | 2.70E-03 |
| Pentanal (Valeraldehyde) | 2.03E-04 |
| Phenol | 2.70E-03 |
| Propionaldehyde (Propanal) | 2.03E-04 |
| Propylbenzene, n- | 2.70E-03 |
| Styrene | 5.41E-04 |
| Sulfur Dioxide | 2.63E-03 |
| Tetradecane | 2.70E-03 |
| HC as Hexane | 6.68E-03 |
| Toluene | 5.41E-04 |
| Trimethylbenzene, 1,2,3- | 5.41E-04 |
| Trimethylbenzene, 1,2,4- | 5.41E-04 |
| Trimethylbenzene, 1,3,5- | 5.41E-04 |
| Trimethylnaphthalene, 2,3,5- | 2.70E-03 |
| Undecane | 5.41E-04 |
| Xylene, mp- | 5.41E-04 |
| Xylene, o- | 5.41E-04 |
| | |

## Quantitation Limits – Step Core

| Analyte | Practical Reporting Limit lb/ton |
|---|---|
| | |
| Carbon Monoxide | 4.57E-02 |
| Carbon Dioxide | 4.57E-02 |
| Nitrogen Oxides | 4.57E-02 |
| 2-Butanone (MEK) | 1.74E-04 |
| Acenaphthalene | 2.79E-03 |
| Acetaldehyde | 1.74E-04 |
| Acrolein | 1.74E-04 |
| Benzaldehyde | 1.74E-04 |
| Benzene | 5.58E-04 |
| Biphenyl | 2.79E-03 |
| Butyraldehyde/Methacrolein | 2.90E-04 |
| Cresol, mp- | 2.79E-03 |
| Cresol, o- | 2.79E-03 |
| Crotonaldehyde | 1.74E-04 |
| Cyclohexane | 2.79E-03 |
| Decane | 2.79E-03 |
| Diethylbenzene, 1,3- | 2.79E-03 |
| Dimethylnaphthalene, 1,2- | 2.79E-03 |
| Dimethylnaphthalene, 1,3- | 5.58E-04 |
| Dimethylnaphthalene, 1,5- | 2.79E-03 |
| Dimethylnaphthalene, 1,6- | 2.79E-03 |
| Dimethylnaphthalene, 1,8- | 2.79E-03 |
| Dimethylnaphthalene, 2,3- | 2.79E-03 |
| Dimethylnaphthalene, 2,6- | 2.79E-03 |
| Dimethylnaphthalene, 2,7- | 2.79E-03 |
| Dimethylphenol, 2,4- | 2.79E-03 |
| Dimethylphenol, 2,6- | 2.79E-03 |
| Dodecane | 2.79E-03 |
| Ethylbenzene | 5.58E-04 |
| Ethyltoluene, 2- | 5.58E-04 |

| Analyte | Practical Reporting Limit lb/ton |
|---|---|
| | |
| Ethyltoluene, 3- | 2.79E-03 |
| Formaldehyde | 1.74E-04 |
| HC as Hexane | 5.68E-03 |
| Heptane | 2.79E-03 |
| Hexaldehyde | 1.74E-04 |
| Hexane | 5.58E-04 |
| Indan | 2.79E-03 |
| Indene | 2.79E-03 |
| Methylnaphthalene, 1- | 5.58E-04 |
| Methylnaphthalene, 2- | 5.58E-04 |
| Naphthalene | 5.58E-04 |
| Nonane | 2.79E-03 |
| o,m,p-Tolualdehyde | 4.65E-04 |
| Octane | 2.79E-03 |
| Pentanal (Valeraldehyde) | 1.74E-04 |
| Phenol | 2.79E-03 |
| Propionaldehyde (Propanal) | 1.74E-04 |
| Propylbenzene, n- | 2.79E-03 |
| Styrene | 5.58E-04 |
| Sulfur Dioxide | 2.23E-03 |
| Tetradecane | 2.79E-03 |
| Toluene | 5.58E-04 |
| Trimethylbenzene, 1,2,3- | 5.58E-04 |
| Trimethylbenzene, 1,2,4- | 5.58E-04 |
| Trimethylbenzene, 1,3,5- | 5.58E-04 |
| Trimethylnaphthalene, 2,3,5- | 2.79E-03 |
| Undecane | 5.58E-04 |
| Xylene, mp- | 5.58E-04 |
| Xylene, o- | 5.58E-04 |
| | |

# APPENDIX C DETAILED PROCESS DATA

*this page intentionally left blank*

## Detailed Process Data

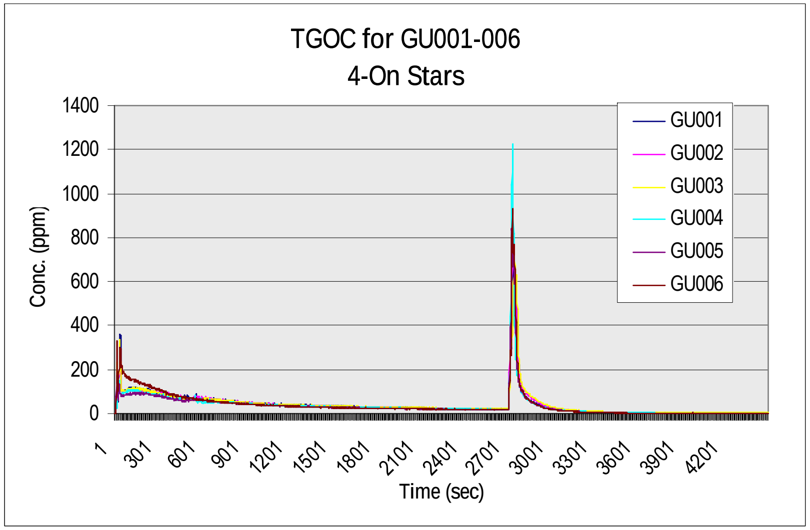
| Greensand PCS | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test Dates | Conditioning Runs | | | 4-on Star Pattern Runs | | | | | | Step Core Pattern Runs | | | | | | Non-conditioning Star Pattern Runs Average | Non-conditioning Star Pattern Runs St Dev | Non-conditioning Stepcore Pattern Runs Average | Non-conditioning Stepcore Pattern Runs St Dev |
| Emissions Sample # | GUER1 | GUER2 | GUER3 | GU001 | GU002 | GU003 | GU004 | GU005 | GU006 | GU007 | GU008 | GU009 | GU010 | GU011 | GU012 | | | | |
| Production Sample # | GU001 | GU002 | GU003 | GU004 | GU005 | GU006 | GU007 | GU008 | GU009 | GU0011 | GU0012 | GU0013 | GU0014 | GU0015 | GU0016 | | | | |
| Cast Weight (all metal inside mold), Lbs. | 92.5 | 96.0 | 94.5 | 93.0 | 93.5 | 96.0 | 97.5 | 97.0 | 98.0 | 113.5 | 113.0 | 112.0 | 112.5 | 113.0 | 115.0 | 95.8 | 2.11 | 113.2 | 1.03 |
| Pouring Time, sec. | 14 | 14 | 15 | 14 | 16 | 15 | 14 | 13 | 14 | 16 | 16 | 15 | 14 | 17 | 14 | 14 | 1.03 | 15 | 1.21 |
| Pouring Temp ,°F | 2678 | 2674 | 2669 | 2675 | 2686 | 2684 | 2682 | 2687 | 2678 | 2685 | 2682 | 2682 | 2682 | 2691 | 2672 | 2682 | 4.69 | 2682 | 6.15 |
| Pour Hood Process Air Temp at Start of Pour, °F | 85 | 86 | 94 | 89 | 88 | 92 | 87 | 92 | 94 | 85 | 87 | 91 | 86 | 88 | 88 | 90 | 2.80 | 87 | 2.07 |
| Sand in Sodium Silicate Sand mix, lbs | Star pattern was used. No cores are used when using the star pattern so there is no core mixing, blowing, or baking data | | | | | | | | | 50.00 | 50.00 | 50.00 | 50.00 | 50.00 | 50.00 | No core mixing, blowing, or baking data. | No core mixing, blowing, or baking data. | 50.00 | 0.00 |
| Sodium Silicate in Sodium Silicate Core Sand Mix,lbs | | | | | | | | | | 2.51 | 2.49 | 2.50 | 2.51 | 2.50 | 2.51 | | | 2.5 | 0.01 |
| Sodium Silicate Core CO2 Gassing Pressure, PSI | | | | | | | | | | 20 | 20 | 20 | 20 | 20 | 20 | | | 20 | 0.00 |
| Sodium Silicate Core CO2 Gassing Time, sec | | | | | | | | | | 20 | 30 | 30 | 30 | 30 | 30 | | | 28.33 | 4.08 |
| Sodium Silicate Content, % (BOS) | | | | | | | | | | 5.02 | 4.98 | 5.00 | 5.02 | 5.00 | 5.02 | | | 5.01 | 0.02 |
| Sodium Silicate Content, % of Sand Mix | | | | | | | | | | 4.78 | 4.74 | 4.76 | 4.78 | 4.76 | 4.78 | | | 4.77 | 0.01 |
| Total Weight of Baked Cores in Mold, Lbs. | | | | | | | | | | 30.00 | 30.18 | 30.10 | 29.92 | 29.74 | 30.00 | | | 29.99 | 0.15 |
| Baking Oven nominal temperature, °F | | | | | | | | | | 250 | 250 | 250 | 250 | 250 | 250 | | | 250 | 0.00 |
| Average heated investment time, Minutes | | | | | | | | | | 120 | 120 | 120 | 120 | 120 | 120 | | | 120 | 0.00 |
| Greensand Muller Batch Weight, Lbs. | 1361.7 | 900 | 900 | 900 | 910 | 900 | 900 | 900 | 900 | 900 | 900 | 910 | 900 | 900 | 900 | 902 | 4.08 | 902 | 4.08 |
| GS Mold Sand Weight, Lbs. | 670 | 657 | 648 | 648 | 639 | 633 | 640 | 640 | ND | 648 | 645 | 652 | 649 | 640 | 644 | 640 | 5.32 | 646 | 4.36 |
| Greensand Muller Compactability, % | 59 | 55 | 55 | ND | 55 | 55 | 53 | ND | 56 | 54 | 56 | 57 | 56 | 54 | 54 | 55 | 1.26 | 55 | 1.33 |
| Greensand Mold Temperature, °F | 90 | 90 | 95 | 91 | 86 | 92 | 87 | 87 | 90 | 82 | 83 | 91 | 76 | 81 | 86 | 89 | 2.43 | 83.2 | 5.01 |
| Average Green Compression , psi | 10.70 | 16.11 | 17.97 | 18.96 | 16.35 | 17.15 | 17.90 | 18.60 | 18.53 | 22.26 | 21.58 | 21.88 | 23.08 | 23.21 | 25.12 | 17.92 | 1.00 | 22.86 | 1.28 |
| GS Mold Compactability, % | 59 | 44 | 42 | 41 | 47 | 49 | 36 | 47 | 39 | 47 | 38 | 45 | 38 | 39 | 41 | 43 | 5.23 | 41 | 3.83 |
| GS Moisture Content, % | 2.26 | 1.70 | 1.96 | 1.64 | 1.96 | 1.86 | 1.58 | 1.94 | 1.88 | 1.92 | 1.98 | 2.06 | 2.10 | 1.90 | 1.86 | 1.81 | 0.16 | 1.97 | 0.09 |
| Clay Addition, lbs | 69.40 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 2.45 | 3.35 | 3.35 | 3.35 | 3.35 | 3.35 | 2.45 | 0.00 | 3.20 | 0.37 |
| GS MB Clay Content, % | 6.03 | 6.03 | 5.63 | 5.43 | 5.63 | 5.23 | 5.23 | 5.43 | 5.23 | 5.23 | 5.43 | 5.83 | 6.03 | 5.43 | 5.63 | 5.36 | 0.16 | 5.59 | 0.30 |
| MB Clay Reagent, ml | 30 | 30 | 28 | 27 | 28 | 26 | 26 | 27 | 26 | 26 | 27 | 29 | 30 | 27 | 28 | 26.7 | 0.82 | 27.8 | 1.47 |
| Seacoal Addition, lbs | 62.30 | 2.70 | 2.7 | 2.7 | 2.7 | 2.7 | 0 | 1.35 | 1.35 | 1.35 | 3.4 | 3.4 | 1.7 | 1.7 | 3.4 | 1.80 | 1.10 | 2.49 | 1.00 |
| 1800°F LOI - Mold Sand, % | 4.69 | 4.94 | 4.82 | 5.05 | 5.01 | 5.25 | 5.02 | 4.99 | 4.96 | 5.08 | 5.12 | 5.23 | 5.14 | 5.11 | 5.31 | 5.05 | 0.10 | 5.17 | 0.09 |
| 900°F Volatiles , % | 1.16 | 1.26 | 1.16 | 1.10 | 1.16 | 1.26 | 1.10 | 0.98 | 0.95 | 0.94 | 1.02 | 1.08 | 0.92 | 0.96 | 1.02 | 1.09 | 0.11 | 0.99 | 0.06 |
| Pemeability index | 171 | 179 | 180 | 186 | 175 | 179 | 189 | 189 | 195 | 185 | 198 | 192 | 190 | 210 | 193 | 186 | 7 | 195 | 9 |

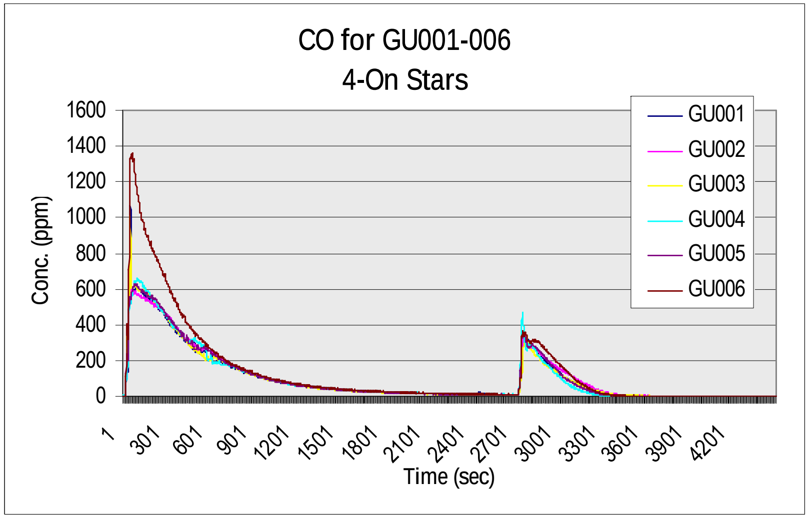
Notes: 1. Mold GU010 was partially poured into <5 sec, due to a crane error. The mold was immediately shaken out. The sand was remulled with no clay or seacol addition for mold GU011. The clay and seacoal additions entered under column GU011, were originally added to the muller for mold GU010.

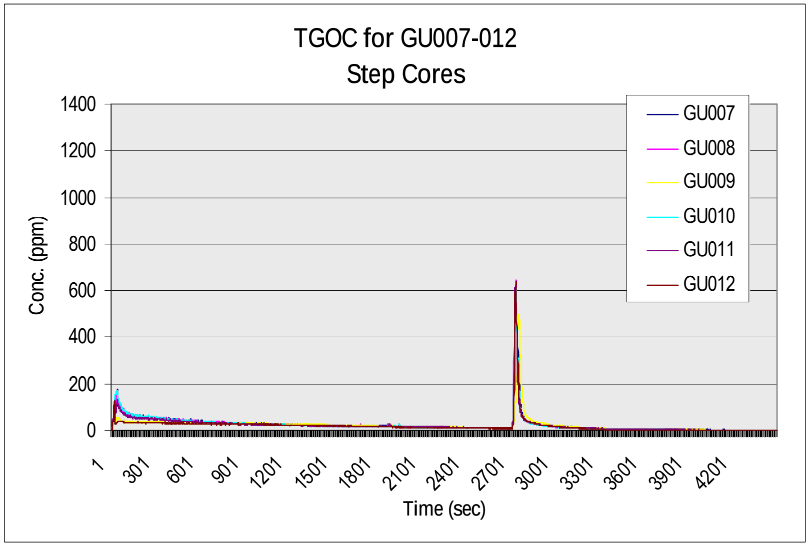
*this page intentionally left blank*

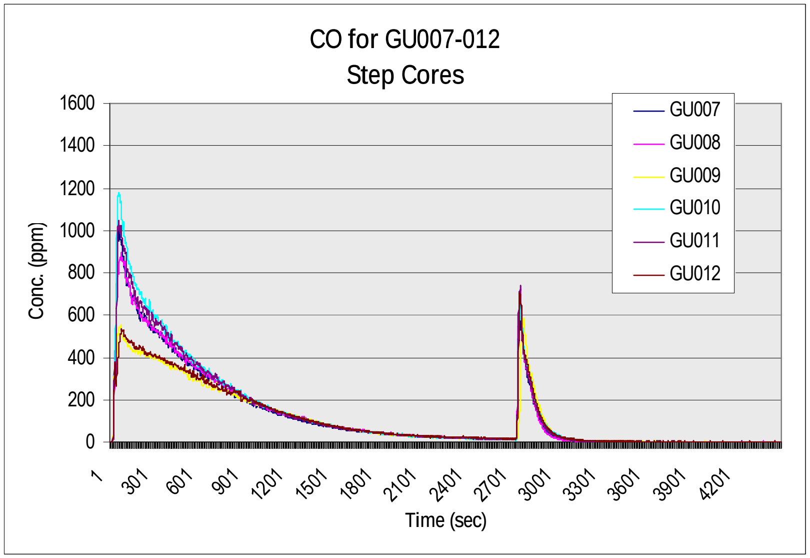
## APPENDIX D EMISSIONS PROFILE CHARTS

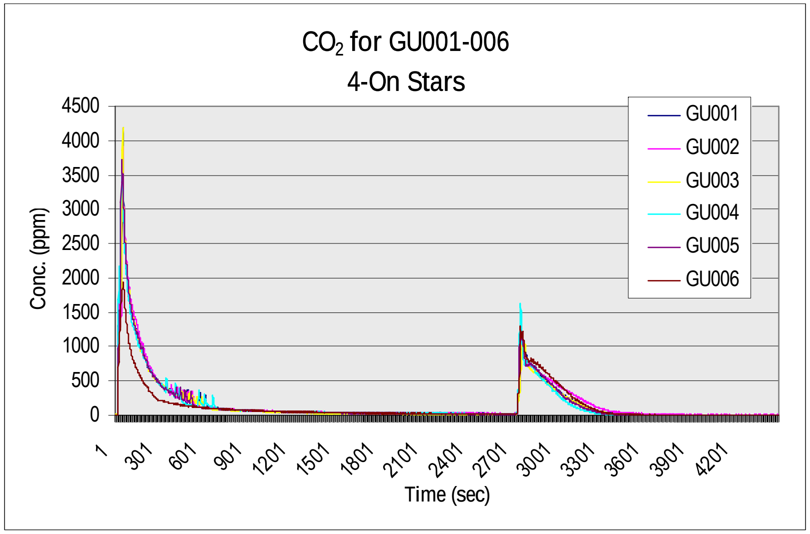
*this page intentionally left blank*

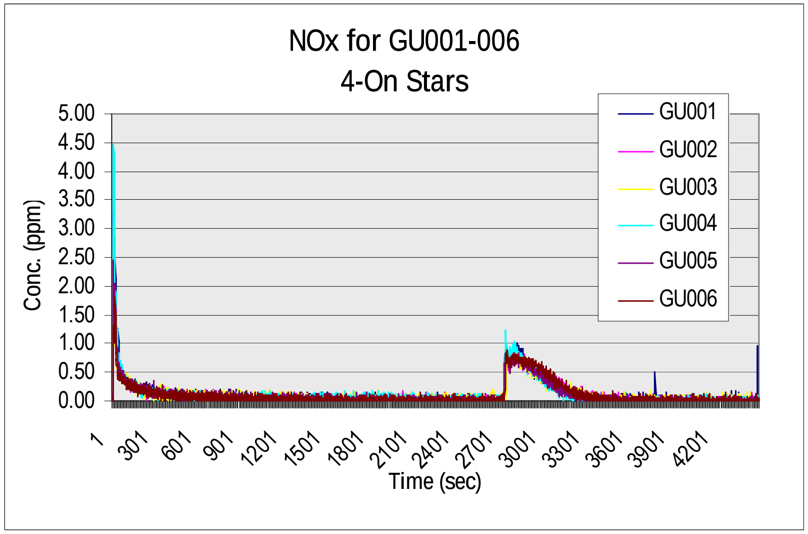

TGOC for GU001-006
4-On Stars
Conc. (ppm)
Time (sec)
GU001
GU002
GU003
GU004
GU005
GU006
0
200
400
600
800
1000
1200
1400
1
301
601
901
1201
1501
1801
2101
2401
2701
3001
3301
3601
3901
4201

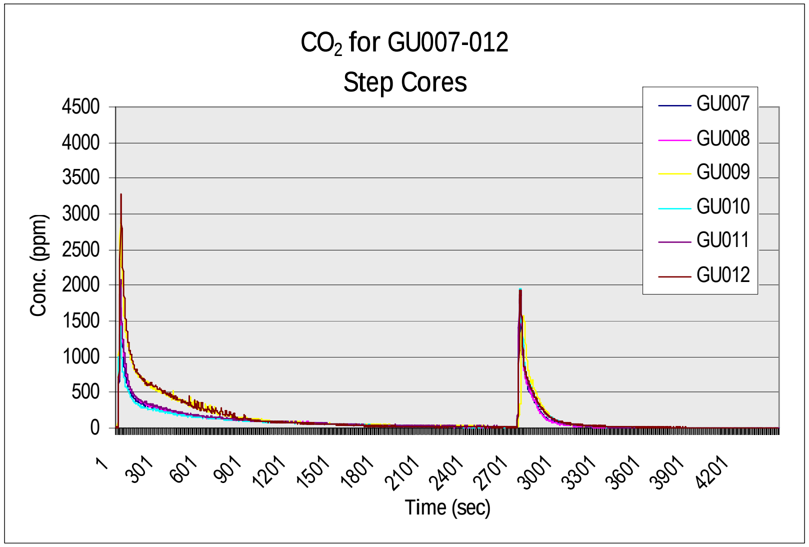

CO for GU001-006
4-On Stars
Conc. (ppm)
Time (sec)
GU001
GU002
GU003
GU004
GU005
GU006
0
200
400
600
800
1000
1200
1400
1600
1
301
601
901
1201
1501
1801
2101
2401
2701
3001
3301
3601
3901
4201

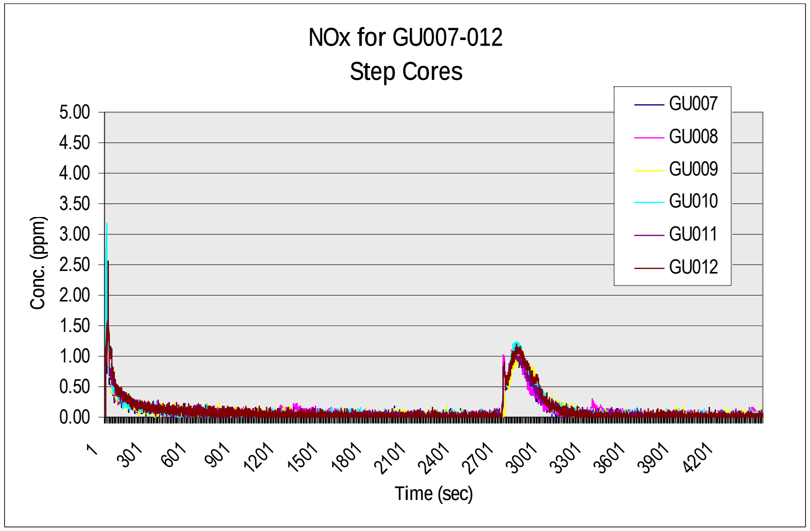

TGOC for GU007-012
Step Cores
Conc. (ppm)
Time (sec)
GU007
GU008
GU009
GU010
GU011
GU012
0
200
400
600
800
1000
1200
1400
1
301
601
901
1201
1501
1801
2101
2401
2701
3001
3301
3601
3901
4201


CO for GU007-012
Step Cores
Conc. (ppm)
Time (sec)
GU007
GU008
GU009
GU010
GU011
GU012
0
200
400
600
800
1000
1200
1400
1600
1
301
601
901
1201
1501
1801
2101
2401
2701
3001
3301
3601
3901
4201


CO2 for GU001-006
4-On Stars
Conc. (ppm)
Time (sec)
GU001
GU002
GU003
GU004
GU005
GU006


NOx for GU001-006
4-On Stars
Conc. (ppm)
Time (sec)
GU001
GU002
GU003
GU004
GU005
GU006


CO2 for GU007-012
Step Cores
Conc. (ppm)
Time (sec)
GU007
GU008
GU009
GU010
GU011
GU012


NOx for GU007-012
Step Cores
Conc. (ppm)
Time (sec)
GU007
GU008
GU009
GU010
GU011
GU012

# APPENDIX E ACRONYMS AND ABBREVIATIONS

*this page intentionally left blank*

# Acronyms and Abbreviations

| | |
|---|---|
| **BO** | Based on ( ). |
| **BOS** | Based on Sand. |
| **HAP** | Hazardous Air Pollutant defined by the 1990 Clean Air Act Amendment |
| **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. |
| **I** | Data rejected based on data validation considerations |
| **NA** | Not Applicable |
| **ND** | Non-Detect |
| **NOx** | Nitrogen Oxides |
| **NT** | Lab testing was not done |
| **POM** | Polycyclic Organic Matter (POM) including Naphthalene and other compounds that contain more than one benzene ring and have a boiling point greater than or equal to 100 degrees Celsius. |
| **TGOC as Propane** | Weighted to the detection of more volatile hydrocarbon species, beginning at C1 (methane), with results calibrated against a three-carbon alkane (propane). |
| **TTE** | Temporary Total Enclosure |
| **VOC** | Volatile Organic Compound |