CERP

Casting Emission Reduction Program

www.cerp-us.org

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WBS # 1.1.4

Product Test: Hill & Griffith's Seacoal Replacement Mix and Graphite Parting Agent

Technikon # 1411-114 GL

August 2005

(revised for public distribution)

United States Environmental Protection Agency

CISA

AMERICAN FOUNDRY SOCIETY, INC.

UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

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

Senior Scientist	// Original Signed // Sue Anne Sheya, PhD	Date
V.P. Operations	// Original Signed // George Crandell	Date

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

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Executive Summary

This report contains the results of emission testing to evaluate the pouring, cooling, and shakeout emissions from Test GL, a coreless greensand system using a seacoal replacement product and a graphite base liquid parting agent from Hill & Griffith. These data are compared to results from Test FK, a baseline using a standard greensand seacoal system. 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 prior to the test; metallurgical data; and stack temperature, pressure, volumetric flow rate, and moisture content. The mold sand was preconditioned with three (3) casting cycles before the test commenced. The test was conducted in the same manner as baseline test FK. The process parameters were maintained within prescribed ranges in order to ensure the reproducibility of the tests runs. Samples were collected and analyzed for seventy (70) target compounds using procedures based on US EPA Method 18. Continuous monitoring of Total Gaseous Organic Concentration (TGOC), CO, CO_2, and NOx in the emissions was conducted according to US EPA Methods 25A, 10, 3A, and 7E, respectively.

Compounds that are structural isomers have been grouped together and are reported as a single quantity. For example: ortho-, meta-, and para-xylene are the three structural isomers of dimethyl benzene and their sum is reported as xylenes. Trimethylbenzenes and dimethylphenols are also treated and reported in a similar manner.

Two methods were employed to measure undifferentiated hydrocarbon emissions as emission indicators: TGOC as propane, performed in accordance with EPA Method 25A, and HC as hexane, performed in accordance with Wisconsin Cast Metals Association – Maximum Potential to Emit (WCMA – MPTE) Method revised 07-26-01. EPA Method 25A is weighted to the detection of the more volatile hydrocarbon species, beginning at C1 (methane), with results calibrated against the three-carbon alkane (propane). The HC as hexane method detects hydrocarbon compounds in the alkane range between C6 and C16, with results calibrated against the six-carbon alkane (hexane).

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

Table 1 Test Plans FK and GL Emissions Indicators – Lb/Tn Metal

Analytes	TGOC as Propane	HC as Hexane	Sum of Target VOCs	Sum of Target HAPs	Sum of Target POMs
Test FK (Lb/Tn)	3.350	0.4015	0.4294	0.3437	0.0197
Test GL (Lb/Tn)	0.705	0.1700	0.0948	0.0877	0.0024

A pictorial casting record was made of cavity 3 from the best, median, and worst molds from both Tests FK and GL. The pictures are shown in rank-order in Section 3 of this document.

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

1.0 INTRODUCTION

1.1. Background

Technikon LLC is a privately held contract research organization located in McClellan, California, a suburb of Sacramento. Technikon offers emissions research services to industrial and government clients specializing in metal casting. 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), a laboratory of the United States Army; 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. Technikon Objectives

The primary objective of Technikon 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 has been specially designed to facilitate 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 emissions from a coreless 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 Appendices B and C 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

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

Table 1-1 Test Plan Summary

	Test FK	Test GL
Type of Process Tested	standard greensand baseline with seacoal	greensand replacement products
Test Plan Number	1410 122 FK	1411 114 GL
Greensand System	Wexford W450 Lakesand, 7% bentonite 5% H & G seacoal	Wexford W450 Lakesand, 7% bentonite, 5% H & G seacoal replacement mix and H & G Aqua Part II® graphite liquid parting agent
Metal Poured	iron	iron
Casting Type	4-on star	4-on star
Number of Molds Poured	9	9
Test Dates	8/12/03 - 8/21/03	1/12/05 - 1/16/05
Emissions Measured	TGOC as propane, HC as hexane, 66 target compounds	TGOC as propane, HC as hexane, 70 target compounds, CO, CO_2 & NOx
Process Parameters Measured	total casting weight , mold weights; metallurgical data, % LOI; stack temperature, moisture content, sand temperature, pressure, and volumetric flow rate	total casting weight, mold weights; metallurgical data, % LOI; stack temperature, moisture content, sand temperature, pressure, and volumetric flow rate

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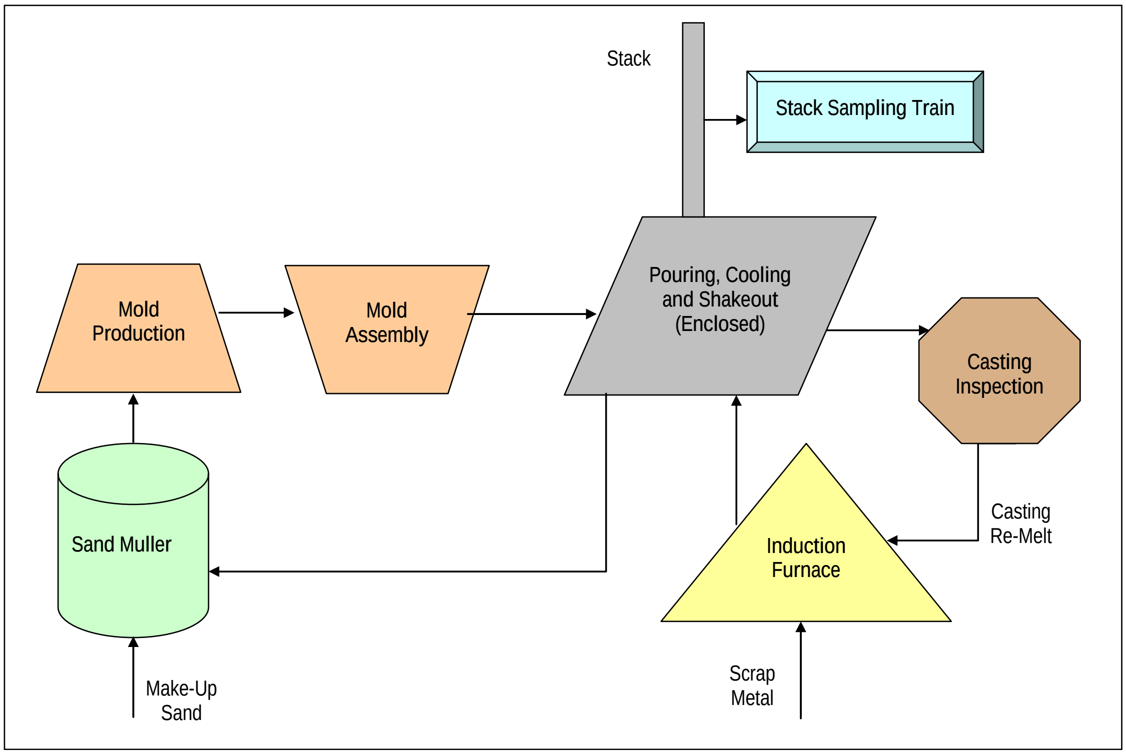
2.0 TEST METHODOLOGY

2.1. Description of Process and Testing Equipment

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

Figure 2-1 Research Foundry Layout Diagram

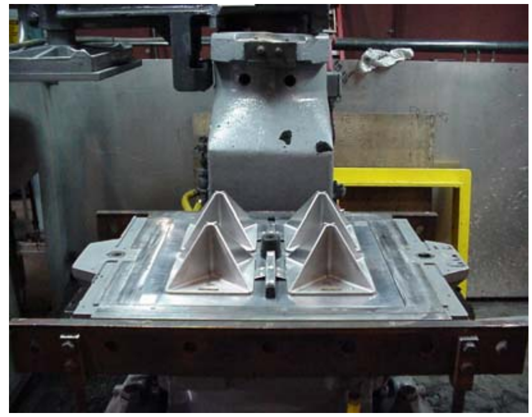


2.2. Description of Testing Program

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

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

Figure 2-2 4-On Star Pattern



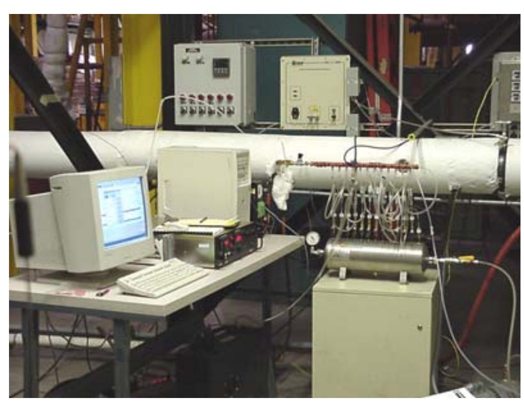
2. **Mold and Metal Preparation:** The 4-on star greensand molds are prepared to a standard composition by the Technikon production team. Iron is melted in a 1000 lb. Ajax induction furnace. The amount of metal melted is determined from the poured weight of the casting and the number of molds to be poured. The metal composition is prescribed by a metal composition worksheet. The weight of metal poured into each mold is recorded on the process data summary sheet.

Figure 2-3 Total Enclosure Test Stand

3. **Individual Sampling Runs:** After preconditioning the molding sand for three (3) casting cycles, replicate tests are performed on nine (9) mold packages. The mold packages are placed into an enclosed test stand heated to approximately 85°F. Iron at 2680°F 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.

Figure 2-4 Method 25A (TGOC) and Method 18 Sampling Train



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

Table 2-1 Process Parameters Measured

Parameter	Analytical Equipment and Methods
Mold Weight	Cardinal 748E Platform Scale (Gravimetric)
Casting Weight	Ohaus MP2 Platform Scale (Gravimetric)
Volatiles	Denver Instruments XE-100 Analytical Scale (AFS procedure 5100-00-S)
LOI, % at Mold and Shakeout	Denver Instruments XE-100 Analytical Scale (AFS procedure 5100-00-S)
Core and Sand Temperatures	J & K Type Digital Thermometer
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)

5. **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 Process Parameters Measured

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, TO17
VOCs Concentration	EPA Method 18, 25A, TO11, TO17, NIOSH 1500
Carbon Monoxide	EPA Method 10
Carbon Dioxide	EPA Method 3A
Nitrogen Oxides	EPA Method 7E

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

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

   The results of each of the sampling runs are included in the appendices of this report. The emissions results of each test are also averaged and are shown in Table 3-1.

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

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

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

- Immediately following the individual sampling events performed for each test, specific process parameters are reviewed by the Manager - Process Engineering to ensure that the parameters are maintained within the prescribed control ranges. Where data are not within the prescribed ranges, the Manager - Process Engineering and the Vice President -

Operations determine whether the individual test samples should be invalidated or flagged for further analysis following review of the laboratory data.

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

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3.0 TEST RESULTS

The average mass emission rates in pounds per ton of metal for individual target analytes and emission indicators are presented in Table 3-1 for Tests FK and GL. The mass emission rate of each target compound was calculated using continuous data or the laboratory analytical results as appropriate, the measured stack and sampling parameters, and the weight of each casting.

Compounds that are structural isomers have been grouped together and are reported as a single quantity. For example, ortho-, meta-, and para-xylene are the three structural isomers of dimethyl benzene, and their sum is reported as xylenes. Trimethylbenzenes, dimethylphenols, and several other compound classes are also treated and reported in a similar manner. The separate individual isomer results are available in Appendix B of this report. Individual target compounds included in these tables are those that comprise at least 95% of the total target analytes detected as well as carbon monoxide, carbon dioxide, nitrogen oxides, HC as hexane and TGOC as propane.

Two methods were employed to measure undifferentiated hydrocarbon emissions as emission indicators: TGOC as propane, performed in accordance with EPA Method 25A, and HC as hexane, performed in accordance with NIOSH Method 1500. EPA Method 25A is weighted to the detection of the more volatile hydrocarbon species, beginning at C_1 (methane), with results calibrated against the three-carbon alkane (propane). The HC as hexane method detects hydrocarbon compounds in the alkane range between C_6 and C_{16}, with results calibrated against the six-carbon alkane (hexane).

Other “Emissions Indicators”, in addition to TGOC as propane and HC as hexane, were calculated. The emissions indicator “Sum of Target VOCs” (volatile organic compounds) is the sum of all the individual target analytes detected and includes targeted HAPs and POMs, as well as other targeted VOCs. By definition, HAPs are specific compounds listed in the Clean Air Act Amendments of 1990. The term POM defines not one compound, but a broad class of compounds based on chemical structure and boiling point. POMs as a class are a listed HAP. A subset of the 188 listed EPA HAPs was targeted for collection and analysis. These individual target HAPs (which may also be POMs by nature of their chemical properties) detected in the samples are summed together and defined as the “Sum of Target HAPs,” while the “Sum of Target POMs” only sums those HAPs that are also defined as POMs.

Figures 3-1 to 3-3 present the five emissions indicators and target HAP and VOC emissions data from Table 3-1 in graphical form. The percentage change in emissions for Test GL compared to the baseline Test FK is shown in Table 3-1.

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.

The comparative ranking of casting appearance is presented in Table 3-3. Each casting from the third cavity of the mold from the baseline test FK was compared to the other third cavity castings produced in this test. Three benchmark visual casting quality rankings consisting of the best, the median, and the worst casting were then assigned to three of the nine castings. The “best” designation means that a casting is the best appearing casting of the lot of nine, and is given a rank of “1”. The “median” designation, given a rank of “5”, means that four castings are better in appearance and four are worse. The “worst” designation is assigned to that casting which is of the poorest quality, and is assigned a rank of “9”. The castings from Test GL underwent the same evaluative procedure. The three-benchmark castings from Test FK then were compared and collated to the benchmark castings from Test GL.

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

Table 3-1 Summary of Tests FK and GL Average Emissions – Lb/Tn Metal

	Baseline Average Test FK	Average[1] Test GL	% Change from Baseline FK[2, 3]
Emission Indicators			
TGOC as Propane	3.3541	0.7048	-79
HC as Hexane	0.4015	0.1700	-58
Sum of Target VOCs	0.4294	0.0948	-78
Sum of Target HAPs	0.3437	0.0877	-74
Sum of Target POMs	0.0197	0.0024	-88
Target Organic VOCs Including HAPs and POMs			
Benzene	0.1450	0.0292	-80
Acetaldehyde	0.0035	0.0207	485
Toluene	0.0744	0.0121	-84
Xylenes	0.0506	0.0091	-82
Formaldehyde	0.0028	0.0036	28
Phenol	0.0072	0.0024	-67
Hexane	0.0128	0.0021	-84
Heptane	0.0122	0.0020	-83
Naphthalene	0.0127	0.0019	-85
Ethylbenzene	0.0084	0.0015	-81
Criteria Pollutants and Greenhouse Gases			
Carbon Monoxide	NT[4]	2.7522	NA
Carbon Dioxide	NT	5.8533	NA
Nitrogen Oxides	NT	0.0022	NA

[1] Individual results constitute > 95% of mass of all detected target analytes for GL.
[2] Bold numbers indicate those compounds whose calculated t-statistic is significant at alpha=0.05.
[3] Any discrepancies apparent in percent difference calculations are due to rounding. Calculations were performed on number prior to rounding to four decimal places.
[4] ND: Non Detect; NA: Not Applicable; NT: Not Tested.

Table 3-2 Summary of Test Plans FK and GL Average Process Parameters

Greensand PCS	Test FK	Test GL
Test Dates	8/12/03 - 8/21/03	1/10/05 - 1/14/05
Cast Weight - All Metal Inside Mold (lbs.)	100.5	96.6
Pouring Time (sec.)	19	16
Pouring Temp (°F)	2681	2681
Pour Hood Process Air Temp at start of Pour, F	87	87
Muller Batch Weight (lbs.)	895	900
GS Mold Sand Weight, (lbs.)	648	643
Mold Compactability, %	46	55
Mold Temperature (°F)	84	71
Average Green Compression (psi)	12.47	23.85
GS Compactability (%)	40	40
GS Moisture Content (%)	2.04	2.03
GS MB Clay Content (%)	6.88	7.39
MB Clay Reagent, ml	27	35
1800°F LOI - Mold Sand (%)	5.19	1.13
900°F Volatiles (%)	1.01	0.56
Liquid Parting Spray (grams)	0.00	40

Table 3-3 Rank Order of Casting Surface Quality of Cope Cavity 3 for Tests FK and GL

Test FK	Ranking	Test GL
FK001	**1**	GL006
FK002	**2**	GL004
FK003	**3**	GL001
FK006	**4**	GL007
FK008	**5**	GL003
FK005	**6**	GL005
FK009	**7**	GL010
FK007	**8**	GL011
FK004	**9**	GL002
	10	GL012
	11	GL008
	12	GL009

Scale: 1 = Best, 12 = Worst

Figure 3-1 Emission Indicators from Test Series FK and GL – Lb/Tn Metal

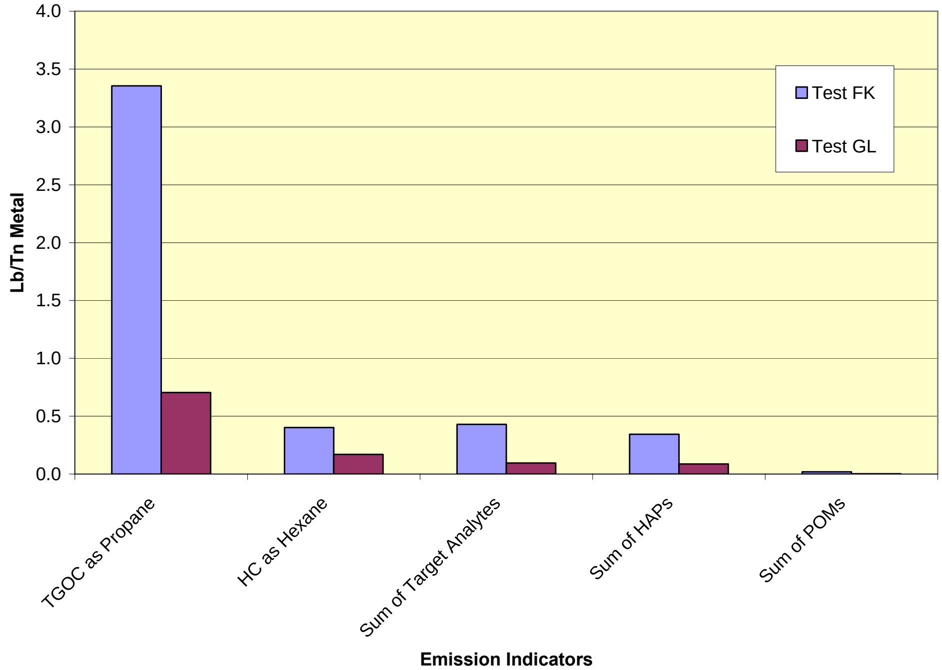

Figure 3-2 Target Organic VOCs Including HAPs and POMs Emissions from Test Series FK and GL – Lb/Tn Metal

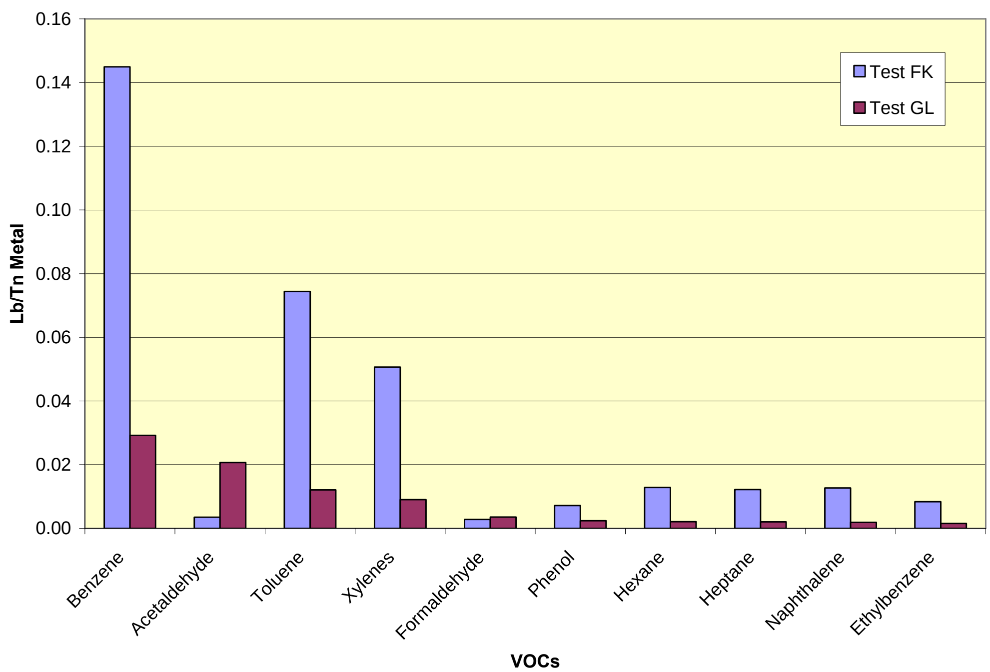

Figure 3-3 Criteria Pollutants and Greenhouse Gasses Emissions from Test Series FK and GL – Lb/Tn Metal

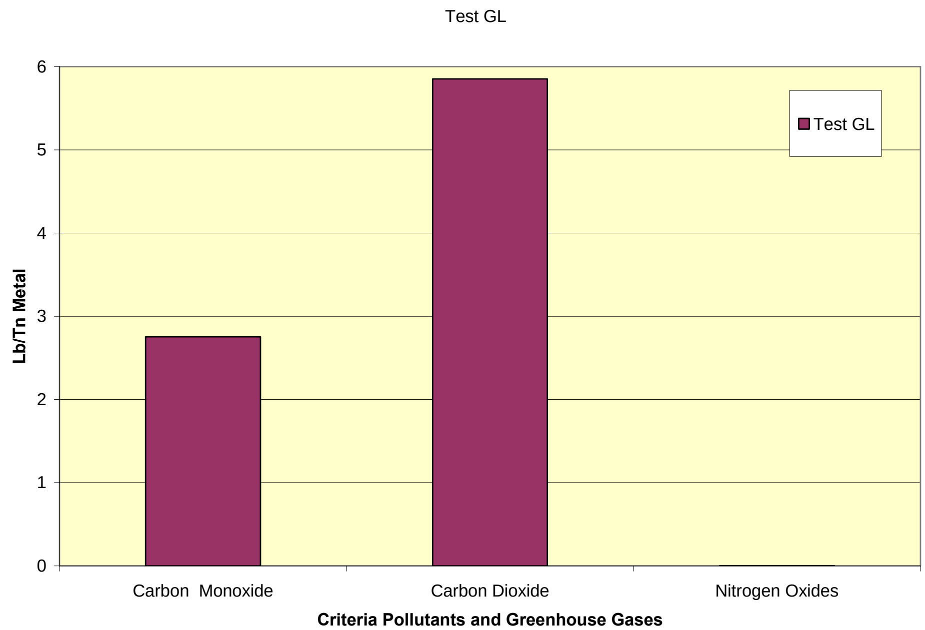

Figure 3-4 Best Appearing Casting from Mold FK001

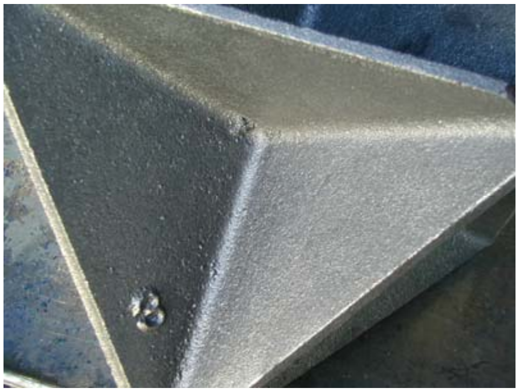

Figure 3-5 Median Appearing Casting from Mold FK008

Figure 3-6 Worst Appearing Casting from Mold FK004

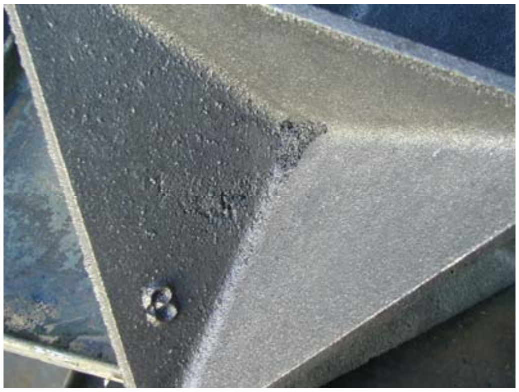

Figure 3-7 Best Appearing Casting from Mold GL006

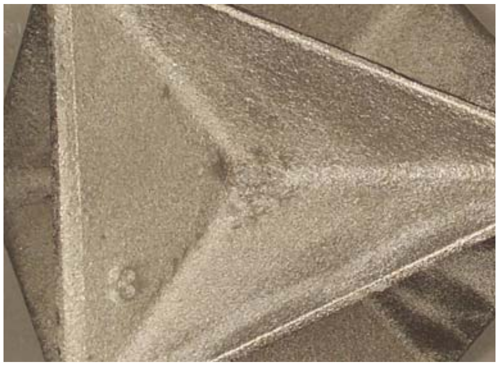

Figure 3-8 Median Appearing Casting from Mold GL005

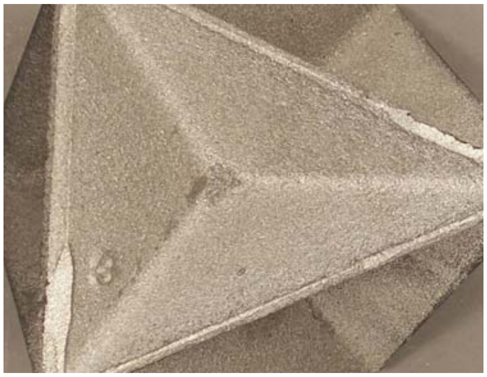

Figure 3-9 Worst Appearing Casting from Mold GL009

4.0 DISCUSSION OF RESULTS

The sampling and analytical methodologies were the same for Tests FK and GL.

Observation of measured process parameters indicates that the tests were run within an acceptable range. In Table 3-1, the "% Change from Test FK" emissions values presented in **bold** letters indicate a greater than 95% probability that the differences in the average values were not the result of variability in the test protocol as determined from T-statistic calculations. Tables showing the T-statistics calculated are found in Appendix B.

The results of the tests performed for the comparison of Test FK to test GL show a 79% reduction in TGOC as propane, a 58**%** reduction in HC as hexane, a 78**%** reduction in Sum of Target VOCs, a 74**%** reduction in Sum of Target HAPs, and an 88**%** reduction in Sum of Target POMs when expressed in pounds per ton of metal. Benzene was found to be the largest contributor to the total HAPs and VOCs for both Tests FK and GL, but an 80**%** decrease in benzene was found for Test GL compared to the baseline Test FK.

Subsequent to Test FK the carbon dioxide, carbon monoxide and methane distribution results reported were found to be inaccurate. The inaccuracy is thought to be due to contamination of the Tedlar bag samples between the time of collection and the time they were analyzed. Therefore, these data are not shown in this report for Test FK.

Two methods were employed to measure undifferentiated hydrocarbon emissions as emission indicators: TGOC as propane, performed in accordance with EPA Method 25A, and HC as hexane, performed in accordance with Wisconsin Cast Metals Association – Maximum Potential to Emit (WCMA – MPTE) Method revised 07-26-01. EPA Method 25A is weighted to the detection of the more volatile hydrocarbon species, beginning at C1 (methane), with results calibrated against the three-carbon alkane (propane). The HC as hexane method detects hydrocarbon compounds in the alkane range between C6 and C16, with results calibrated against the six-carbon alkane (hexane).

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

The casting surface appearance was recorded for each mold. The castings' surface quality were ranked in order of best to worst by experienced foundry personnel based on a strict set of surface defects most likely caused by mold sand characteristics. Other surface defects originating from slag inclusions, broken molds or the loose sand that result from disruption of the mold were ignored. The criteria chosen were penetration, both burn-in and burn-on, expansion defects, and general surface texture both visual and as a tactile sensation. Only cavity 3 was evaluated. The mold GL006 casting was judged to have the best casting surface based on the criteria. Mold GL005 was judged to be a median casting, and mold GL009 was judged to have the worst casting surface.

APPENDIX A APPROVED TEST PLANS AND SAMPLE PLANS FOR TEST SERIES FK AND GL

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TECHNIKON TEST PLAN

- **CONTRACT NUMBER:** 1410 **TASK NUMBER:** 1.2.2 **SERIES:** FK
- **SITE:** Pre-production
- **TEST TYPE:** Baseline: Coreless Greensand, pouring, cooling, shakeout
- **METAL TYPE:** Class 30 gray iron
- **MOLD TYPE:** 4-on coreless star greensand with H&G seacoal
- **NUMBER OF MOLDS:** 3 conditioning + 9 Sampling
- **CORE TYPE:** None
- **SAMPLE EVENTS:** 9
- **TEST DATE START:** 11 Aug 2003

  FINISHED: 9 Sept 2003

TEST OBJECTIVES:

Establish an Emission baseline (pouring, cooling, & shakeout) for the standard coreless mechanically produced clay, water, H&G seacoal greensand mold.

VARIABLES:

The pattern will be the 4-on star. The mold will be made with Wexford W450 sand, western and southern bentonite, in a 5:2 ratio to yield 7.0 +/- 0.5% MB Clay, H&G seacoal to yield a 5.0 +/- 0.3% LOI, tempered to 40-45% compactability, mechanically compacted. The molds will be maintained at 80-90^{o}F prior to pouring. The sand heap will be maintained at 900 pounds. Molds will be poured with iron at 2680 +/- 10^{o}F. Mold cooling will be 45 minutes follow by 15 minutes of shakeout, or until no more material remains to be shaken out.

BRIEF OVERVIEW:

Mechanically assisted molding has demonstrated its superior consistency over hand rammed molds (CERP test FH). Coreless molding is a simpler and less costly way to demonstrate consistent greensand emissions than molding with benign sodium silicate cores included. The new coreless standard mold, a 24 x 24 x 10/10 inch 4-on array of stars, requires a new baseline against which future products can be compared. Additionally it will demonstrate the transferability of historical greensand data.

SPECIAL CONDITIONS:

The process will include rigorous maintenance of the size of sand heap and maintenance of the material and environmental testing temperatures to reduce seasonal and daily temperature dependent influence on the emissions. Initially a 1300 pound sand heap will be created from a single muller batch. Nine hundred pounds will become the re-circulating heap. The balance will be used to makeup for attrition.

Series FK

PCS Greensand Baseline with H&G Seacoal & Mechanized Molding
Process Instructions

Experiment: Create Greensand baseline. Measure emissions from a greensand mold made with all virgin Wexford W450 sand, bonded with Western & Southern Bentonite in the ratio of 5:2 to yield 7.0 +/- 0.5% MB Clay, & H&G Seacoal to yield 5.0 +/- 0.3% LOI. The molds shall be tempered with potable water to 40-45% compactability, poured at constant weight, temperature, surface area, & shape factor. This test will recycle the same mold material, replacing burned clay with new materials after each casting cycle.

A. Materials:
1. Mold sand: Virgin mix of Wexford W450 lake sand, western and southern bentonites in ratio of 5:2, and potable water per recipe.
2. Core: None
3. Metal: Class 30-35 gray cast iron poured at 2680 +/- 10^{o}F.
4. Pattern Spray: Black Diamond hand wiped.

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

B. The following test shall be conducted:

1. Sand batch: Single sand batch to be used for all FK molds.
2. The recycled sand heap shall be maintained at 900+-10 pounds
3. The first three (3) runs will be conditioning runs numbered FKCD1-3 and will be monitored by THC only.
4. Emission sampling will begin on the 4th turn. Nine (9) satisfactory sampling runs numbered FK001-009 will be conducted monitored by both THC and sorption tubes. Should a run FK00X need to be repeated the run will be numbered FK00Xa, b, or c etc. The shop supervisor will monitor to assure the numbering consistency of the process data.
5. The shop supervisor and the sampling team technician will coordinate the numbering between the two groups.
6. FKCD1: Virgin mix as described above, un-vented mold.
7. FKCD2, FKCD3, FK001-FK0XX: Re-cycled, re-mulled, reconstituted greensand, potable water, un-vented molds.

C. Sand preparation

1. Start up batch: make 1, FKCD1.

   a. Thoroughly clean the pre-production muller elevator and molding hoppers.
   b. Weigh and add 1225 +/-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 to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
- **d.** Add the clays slowly to the muller to allow them to be distributed throughout the sand mass in proportion to the sand weight per the recipe 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 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 amount of water added, the total mix time, the final compactability and sand temperature at charge and discharge.
- **l.** The sand will be immediately characterized for Methylene Blue Clay, Moisture content, Compactability, Green Compression strength, 1800 oF 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: FKCD2

- **a.** Add to the sand recovered from poured mold FKCD1 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 C.1.f.

3. Re-mulling: FKCD3, FK001-FK0XX

- **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.

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 C.1.f.

D. Molding: 4- on star pattern.

1. Pattern preparation:

a. Inspect and tighten all loose pattern and gating pieces.
b. Repair any damaged pattern or gating parts.
c. Hand wipe liquid parting on the pattern once each run.

2. Mount the drag 4-on star pattern with gating into the mold machine bolster and bolt it down tightly.
3. Mount a cope follower board containing a pour cup pattern to the underside of the squeeze head plate.
4. Check the alignment of the pour cup by manually raising the table using the squeeze by-pass valve at the bottom rear of the machine until the sprue pierces the pour cup pattern. Move the pour cup pattern as necessary.
5. Remove the sprue if making a mold drag half. Leave it attached if making a cope half.
6. Use the overhead crane to place the pre-weighed drag/cope flask on the mold machine table, parting line surface down.
7. Locate a 24 x 24 x4 inch deep wood upset on top of the flask.
8. Make the green sand mold 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. 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.

h. Fill the 24 x 24 x 10 inch flask and the upset with greensand from the overhead molding hopper.
i. Manually level sand in the upset. By experience manually adjust the sand depth so that the resulting compacted mold is fractionally above the flask only height.

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.

j. Initiate the settling of the sand in the flask by pressing the PRE-JOLT push button. Allow this cycle to stop before proceeding.

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.

k. Using both hands initiate the automatic machine sequence by simultaneously pressing 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.

l. Remove the upset and set it aside.
m. Screed the bottom of the mold flat if required.
n. Press and release the LOWER DRAW/STOP push button to separate the flask and mold from the pattern.
o. Use the overhead crane to lift the mold half and remove it from the machine.
p. Finally, press and release the draw down pushbutton to cause the draw frame to return to the start position.

9. If the mold half is a drag, roll it parting line side up, set it on the floor, blow it out, and cover it to keep it clean.
10. Close the cope over the drag being careful not to crush anything.
11. Clamp the flask halves together.
12. Weigh and record the weight of the closed un-poured mold, the pre-weighed flask, and the sand weight by difference
13. Deliver the mold to the previously cleaned shakeout to be poured.
14. Cover the mold with the emission hood.

E. Shakeout.

1. After the cooling time prescribed in the test plan turn on the shakeout unit and run it until the greensand has passed into the hopper below. Turn off the shakeout.
2. When the emission sampling is completed remove the flask with casting, and recover the sand from the hopper and surrounding floor.

3. Weigh and record the metal poured and the total sand weight recovered and rejoined with the left over mold sand from the molding hopper.
4. Add the un-used pre-mixed sand to the recycled sand to return the sand heap to 900 +/- 10 pounds.

F. Melting:

1. Initial charge:

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

2. Back charging.

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

G. Emptying the furnace.

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

H. Pouring:

1. Preheat the ladle.

   a. Tap 400 pounds more or less of 2700^{o}F metal into the cold ladle.
   b. Casually pour the metal back to the furnace.
   c. Cover the ladle.
   d. Reheat the metal to 2780 +/- 20 oF.

e. Tap 450 pounds of iron into the ladle while pouring inoculating alloys onto the metal stream near its base.
f. Cover the ladle to conserve heat.
g. Move the ladle to the pour position, and wait until the metal temperature reaches 2680 +/- 10 oF.
h. Commence pouring keeping the sprue full.
i. Upon completion return the extra metal to the furnace, and cover the ladle.

Steven Knight
Mgr. Process Engineering

PRE-PRODUCTION FK - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
8/11/2003											FK CONDITIONING - RUN 1
FK CR-1											
THC		x									

PRE-PRODUCTION FK - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
8/11/2003											FK CONDITIONING - RUN 2
FK CR-2											
THC		x									

PRE-PRODUCTION FK - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
8/11/2003											FK CONDITIONING - RUN 3
FK CR-3											
THC		x									

PRE-PRODUCTION FK - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
8/12/2003											
RUN 1											
THC	FK001	X									TOTAL
M-18	FK00101		1						20	1	Carbopak charcoal
M-18 MS	FK00102		1						20	2	Carbopak charcoal
M-18 MS	FK00103			1					20	3	Carbopak charcoal
Gas, CO, CO2	FK00104		1						60	4	Tedlar Bag
Gas, CO, CO2	FK00105				1				0		Tedlar Bag
	Excess								500	5	Excess
	Excess								500	6	Excess
NIOSH 1500	FK00106		1						1000	7	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	FK00107				1				0		100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	FK00108		1						1000	9	DNPH Silica Gel (SKC 226-119)
TO11	FK00109				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

PRE-PRODUCTION FK - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
8/12/2003											
RUN 2											
THC	FK002	X									TOTAL
M-18	FK00201		1						20	1	Carbopak charcoal
M-18	FK00202			1					20	2	Carbopak charcoal
M-18	FK00203				1				0		Carbopak charcoal
	Excess								20	3	
Gas, CO, CO2	FK00204		1						60	4	Tedlar Bag
	Excess								500	5	Excess
	Excess								500	6	Excess
NIOSH 1500	FK00205		1						1000	7	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	FK00206			1					1000	8	100/50 mg Charcoal (SKC 226-01)
TO11	FK00207		1						1000	9	DNPH Silica Gel (SKC 226-119)
TO11	FK00208			1					1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION FK - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
8/12/2003											
RUN 3											
THC	FK003	X									TOTAL
M-18	FK00301		1						30	1	Carbopak charcoal
M-18	FK00302					1			30	1	Carbopak charcoal
	Excess								30	2	Excess
	Excess								30	3	Excess
Gas, CO, CO2	FK00303		1						60	4	Tedlar Bag
	Excess		1						500	5	Excess
	Excess								500	6	Excess
NIOSH 1500	FK00304		1						500	7	100/50 mg Charcoal (SKC 226-01)
	Excess								500	8	Excess
TO11	FK00305		1						500	9	DNPH Silica Gel (SKC 226-119)
	Excess								500	10	Excess
	Excess								500	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION FK - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
8/19/2003											
RUN 4											
THC	FK004	X									TOTAL
M-18	FK00401		1						30	1	Carbopak charcoal
	Excess								30	2	Excess
	Excess								30	3	Excess
Gas, CO, CO2	FK00402		1						60	4	Tedlar Bag
	Excess		1						500	5	Excess
	Excess								500	6	Excess
NIOSH 1500	FK00403		1						500	7	100/50 mg Charcoal (SKC 226-01)
	Excess								500	8	Excess
TO11	FK00404		1						500	9	DNPH Silica Gel (SKC 226-119)
	Excess								500	10	Excess
	Excess								500	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION FK - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
8/19/2003											
RUN 5											
THC	FK005	X									TOTAL
M-18	FK00501		1						30	1	Carbopak charcoal
M-18	FK00502			1					30	2	Carbopak charcoal
	Excess								30	3	Excess
Gas, CO, CO2	FK00503		1						60	4	Tedlar Bag
	Excess		1						500	5	Excess
	Excess								500	6	Excess
NIOSH 1500	FK00504		1						500	7	100/50 mg Charcoal (SKC 226-01)
	Excess								500	8	Excess
TO11	FK00505		1						500	9	DNPH Silica Gel (SKC 226-119)
	Excess								500	10	Excess
	Excess								500	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION FK - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
8/20/2003											
RUN 6											
THC	FK006	X									TOTAL
M-18	FK00601		1						30	1	Carbopak charcoal
M-18 MS	FK00602		1						30	2	Carbopak charcoal
M-18 MS	FK00603			1					30	3	Carbopak charcoal
Gas, CO, CO2	FK00604		1						60	4	Tedlar Bag
	Excess		1						500	5	Excess
	Excess								500	6	Excess
NIOSH 1500	FK00605		1						500	7	100/50 mg Charcoal (SKC 226-01)
	Excess								500	8	Excess
TO11	FK00606		1						500	9	DNPH Silica Gel (SKC 226-119)
	Excess								500	10	Excess
	Excess								500	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION FK - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
8/20/2003											
RUN 7											
THC	FK007	X									TOTAL
M-18	FK00701		1						30	1	Carbopak charcoal
	Excess								30	2	Excess
	Excess								30	3	Excess
Gas, CO, CO2	FK00702		1						60	4	Tedlar Bag
	Excess		1						500	5	Excess
	Excess								500	6	Excess
NIOSH 1500	FK00703		1						500	7	100/50 mg Charcoal (SKC 226-01)
	Excess								500	8	Excess
TO11	FK00704		1						500	9	DNPH Silica Gel (SKC 226-119)
	Excess								500	10	Excess
	Excess								500	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION FK - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
8/20/2003											
RUN 8											
THC	FK008	X									TOTAL
M-18	FK00801		1						30	1	Carbopak charcoal
	Excess								30	2	Excess
	Excess								30	3	Excess
Gas, CO, CO2	FK00802		1						60	4	Tedlar Bag
	Excess		1						500	5	Excess
	Excess								500	6	Excess
NIOSH 1500	FK00803		1						500	7	100/50 mg Charcoal (SKC 226-01)
	Excess								500	8	Excess
TO11	FK00804		1						500	9	DNPH Silica Gel (SKC 226-119)
	Excess								500	10	Excess
	Excess								500	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION FK - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
8/21/2003											
RUN 9											
THC	FK009	X									TOTAL
M-18	FK00901		1						30	1	Carbopak charcoal
	Excess								30	2	Excess
	Excess								30	3	Excess
Gas, CO, CO2	FK00902		1						60	4	Tedlar Bag
	Excess		1						500	5	Excess
	Excess								500	6	Excess
NIOSH 1500	FK00903		1						500	7	100/50 mg Charcoal (SKC 226-01)
	Excess								500	8	Excess
TO11	FK00904		1						500	9	DNPH Silica Gel (SKC 226-119)
	Excess								500	10	Excess
	Excess								500	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

TECHNIKON TEST PLAN

- **CONTRACT NUMBER:** 1411 **TASK NUMBER:** 1.1.4 **SERIES:** GL
- **SAMPLE EVENTS:** 9
- **SITE:** Pre-Production
- **TEST TYPE:** Vendor Seacoal replacement premix and with graphite pattern release; PCS
- **METAL TYPE:** Class 30 gray iron
- **MOLD TYPE:** 4-on coreless star greensand with H&G premix and graphite-containing liquid pattern release agent.
- **NUMBER OF MOLDS:** 9 + 3 pattern spray conditioning.
- **CORE TYPE:** None
- **TEST DATE START:** 12 Jan 2005

FINISHED: 16 Jan 2005

TEST OBJECTIVES:

Measure the Pouring, Cooling, & Shakeout air emissions from molds made from greensand containing an H&G premix without seacoal and with the pattern coated with a release agent containing graphite. Results shall be reported as pounds of emission /ton of metal poured. The results of this test series will be compared to the Greensand baseline with seacoal FK.

VARIABLES:

The pattern will be the 4-on star. The mold will be made with virgin Wexford W450 sand and H&G premix to yield 7% western and southern bentonite in a 5:2 ratio, no seacoal, tempered to 40-45% compactability, and mechanically compacted. A water based liquid parting H&G Aqua-Part II® will be used to coat the pattern surfaces at a rate of 20 grams per half pattern. The molds will be maintained at 80-90^{o}F prior to pouring. The sand heap will be maintained at 900 pounds. Molds will be poured with iron at 2680 +/- 10^{o}F. Mold cooling will be 45minutes follow by 15 minutes of shakeout, or until no more material remains to be shaken out. The initial process air temperature will be maintained at 85-90^{o}F. Emission testing will be a total of 75 minutes.

BRIEF OVERVIEW:

The molds will be compacted on an Osborn Jolt squeeze mold. The sand from each run will be collected and sand from the original sand mixture will be added as necessary to maintain the sand heap size. Burned out pre-mix will be replaced to maintain the clay content.

SPECIAL CONDITIONS:

The process will include rigorous maintenance of the size of sand heap and maintenance of the material and testing environmental temperatures to reduce seasonal and daily temperature dependent influence on the emissions

Series-GL

PCS product test: Virgin Greensand with H&G Premix ®, AQUA PART II- Graphite Pattern release, & Mechanized Molding

Process Instructions

A. Experiment:

1. Measure pouring, cooling, & shakeout emissions from a coreless greensand mold made with all virgin Wexford W450 sand, bonded with H & G premix to yield 7.0 +/- 0.5% MB Clay. The molds shall be tempered with potable water to 45-50% compactability in the mold, poured at constant weight, temperature, surface area, & shape factor. This test will recycle the same mold material, replacing burned clay with new Premix materials after each casting cycle. Emissions & surface appearance will be compared to the greensand baseline with seacoal FK and the greensand baseline without seacoal but with pattern release agent FI.

B. Materials:

1. Mold sand: Virgin mix of Wexford W450 lake sand & H&G Premix® containing Western Bentonite, Cellulose, starch, Soda ash, and H&G Kwik Mull® polymeric additive.
2. Metal: Class-30 gray cast iron poured at 2680 +/- 10^{o}F.
3. Pattern release: H&G AQUA PART II-Graphite brushed on at a rate of 20 gm/mold half.

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. Sand preparation

1. Start up batch: make 1, GLER1

- **a.** Thoroughly clean the pre-production muller, elevator, and molding hoppers.
- **b.** Weigh and add 1203 +/-10 pounds of new Wexford W450 Lakesand, per the recipe, to the pre-production muller to make a 1300 batch.
- **c.** Add 5 pounds of potable to the muller to suppress dust distributing it across the sand. Allow to mix for 1 minute.
- **d.** Add 97 pounds of H&G Premix, slowly, to the muller to allow it to be distributed throughout the sand mass in proportion to the sand weight per the recipe 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 12-14 pounds 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 45-50%.
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 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 premix added to the batch, the amount of water added, the total mix time, the final compactability and sand temperature at discharge.
l. The sand will be characterized for Methylene Blue Clay, Moisture content, Compactability, Green Compression strength, 1800^{o}F loss on ignition (LOI), and 900^{o}F volatiles, and permeability. 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: GLER2, GLER3, & GL004-GL009

a. Add to the sand recovered from poured mold GLER1 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 Premix, 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.

E. Molding: Star pattern.
1. Pattern preparation:
a. Inspect and tighten all loose pattern and gating pieces.
b. Repair any damaged pattern or gating parts.

2. Making the green sand mold.
a. Mount the cope pattern on one Osborne Whisper Ram molding machine and. This pattern will serve for both the cope and drag by removing the sprue when making the drag.
b. Paint on H&G AQUA-PART II – Graphite pattern release on the pattern particularly in the corners and recesses totaling 40+/- 2 gms per mold.
1) Weigh the brush & container before and after application to determine the amount applied. Record the pre and post weight and amount dispensed.

Caution: Do not pour gross amounts of parting oil on the pattern to be blown off with air. This practice will leave insufficient 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. Shovel the sand from the overhead mold sand hopper by actuating the CHATTER GATE valve located under the operators panel.
h. Fill the center potion of the flask.
i. Manually move sand from the center portion to the outboard areas and hand tuck the sand.
j. Finish filling the 24 x 24 x 10 inch flask and the upset with greensand from the overhead molding hopper.
k. 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.
l. Initiate the settling of the sand in the flask by pressing the PRE-JOLT push button. Allow this cycle to stop before proceeding.
m. 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.

n. 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 not re-approach the machine until the squeeze head has stopped at the side of the machine.

o. Screed the bottom of the drag mold flat to the bottom of the flask if required.
p. q. Press and release the LOWER DRAW/STOP push button to separate the flask and mold from the pattern.
q. 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.
r. Finally, press and release the DRAW DOWN pushbutton to cause the draw frame to return to the start position.

6. Close the cope over the drag being careful not to crush anything.
7. Clamp the flask halves together.
8. Weigh and record the weight of the closed un-poured mold, the pre-weighed flask, the coated cores, and the sand weight by difference.
9. Measure and record the sand temperature.
10. Deliver the mold to the previously cleaned shakeout to be poured.
11. Cover the mold with the emission hood.

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

G. 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 oF 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.

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

2. Back charging.

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

3. Emptying the furnace.

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

I. Pouring:

1. Preheat the ladle.

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

J. Rank order evaluation.

1. The supervisor shall select a group of five persons to make a collective subjective judgment of the casting relative surface appearance.

2. Review the general appearance of the castings and select specific casting features to compare.

3. For cavity 3 only:

- **a.** Place each casting initially in sequential mold number order.
- **b.** Beginning with casting from mold GL001, compare it to castings from mold GL002.
- **c.** Place the better appearing casting in the first position and the lesser appearing casting in the second position.
- **d.** Repeat this procedure with GL001 to its nearest neighbors until all castings closer to the beginning of the line are better appearing than GL001 and the next casting farther down the line is inferior.
- **e.** Repeat this comparison to next neighbors for each casting number.
- **f.** When all casting numbers have been compared go to the beginning of the line and begin again comparing each casting to its nearest neighbor. Move the castings so that each casting is inferior to the next one closer to the beginning of the line and superior to the one next toward the tail of the line.
- **g.** Repeat this comparison until all concur with the ranking order.

4. Record mold number by rank-order series for this cavity.

Steven M. Knight
Mgr. Process Engineering

PRE-PRODUCTION GL - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/10/2005											**GL CONDITIONING - RUN 1**
GL CR-1											
THC, CO,CO2, NOX		x									

PRE-PRODUCTION GL - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/11/2005											**GL CONDITIONING - RUN 2**
GL CR-2											
THC, CO,CO2, NOX		x									

PRE-PRODUCTION GL - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/11/2005											**GL CONDITIONING - RUN 3**
GL CR-3											
THC, CO,CO2, NOX		x									

PRE-PRODUCTION GL - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/11/2005											
RUN 1											
THC, CO,CO2, NOX	GL001	X									TOTAL
M-18	GL00101		1						60	1	Carbopak charcoal
M-18	GL00102				1				0		Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
	Excess								1000	5	Excess
	Excess								1000	6	Excess
NIOSH 1500	GL00103		1						1000	7	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	GL00104				1				0		100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GL00105		1						1000	9	DNPH Silica Gel (SKC 226-119)
TO11	GL00106				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

PRE-PRODUCTION GL - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/12/2005											
RUN 2											
THC, CO,CO2, NOX	GL002	X									TOTAL
M-18	GL00201		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
	Excess								1000	5	Excess
	Excess								1000	6	Excess
NIOSH 1500	GL00202		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GL00203		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

PRE-PRODUCTION GL - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/12/2005											
RUN 3											
THC, CO,CO2, NOX	GL003	X									TOTAL
M-18	GL00301		1						60	1	Carbopak charcoal
M-18	GL00302			1					60	2	Carbopak charcoal
	Excess								60	3	Excess
	Excess								60	4	Excess
	Excess								1000	5	Excess
	Excess								1000	6	Excess
NIOSH 1500	GL00303		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GL00304		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

PRE-PRODUCTION GL - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/12/2005											
RUN 4											
THC, CO,CO2, NOX	GL004	X									TOTAL
M-18	GL00401		1						60	1	Carbopak charcoal
M-18 MS	GL00402		1						60	2	Carbopak charcoal
M-18 MS	GL00403			1					60	3	Carbopak charcoal
	Excess								60	4	Excess
	Excess								1000	5	Excess
	Excess								1000	6	Excess
NIOSH 1500	GL00404		1						1000	7	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	GL00405			1					1000	8	100/50 mg Charcoal (SKC 226-01)
TO11	GL00406		1						1000	9	DNPH Silica Gel (SKC 226-119)
TO11	GL00407			1					1000	10	DNPH Silica Gel (SKC 226-119)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GL - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/13/2005											
RUN 5											
THC, CO,CO2, NOX	GL005	X									TOTAL
M-18	GL00501		1						60	1	Carbopak charcoal
M-18	GL00502					1			60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								40	3	Excess
	Excess								60	4	Excess
	Excess								1000	5	Excess
	Excess								1000	6	Excess
NIOSH 1500	GL00503		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GL00504		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

PRE-PRODUCTION GL - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/13/2005											
RUN 6											
THC, CO,CO2, NOX	GL006	X									TOTAL
M-18	GL00601		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
	Excess								1000	5	Excess
	Excess								1000	6	Excess
NIOSH 1500	GL00602		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GL00603		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

PRE-PRODUCTION GL - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/13/2005											
RUN 7											
THC, CO,CO2, NOX	GL007	X									TOTAL
M-18	GL00701		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
	Excess								1000	5	Excess
	Excess								1000	6	Excess
NIOSH 1500	GL00702		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GL00703		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

PRE-PRODUCTION GL - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/14/2005											
RUN 8											
THC, CO,CO2, NOX	GL008	X									TOTAL
M-18	GL00801		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
	Excess								1000	5	Excess
	Excess								1000	6	Excess
NIOSH 1500	GL00802		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GL00803		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

PRE-PRODUCTION GL - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/14/2005											
RUN 9											
THC, CO,CO2, NOX	GL009	X									TOTAL
M-18	GL00901		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
	Excess								1000	5	Excess
	Excess								1000	6	Excess
NIOSH 1500	GL00902		1						1000	7	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	8	Excess
TO11	GL00903		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 TEST SERIES FK AND GL DETAILED EMISSION RESULTS

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Test Plan FK Individual Test Results – Lb/Tn Metal

HAPs	POMs	COMPOUND / SAMPLE NUMBER	FK001	FK002	FK003	FK004	FK005	FK006	FK007	FK008	FK009	Average	STDEV
		Test Dates	**8/12/03**	**8/12/03**	**8/12/03**	**8/19/03**	**8/19/03**	**8/20/03**	**8/20/03**	**8/20/03**	**8/21/03**		
		TGOC as Propane	3.41E+00	3.36E+00	3.66E+00	3.44E+00	3.05E+00	3.03E+00	3.39E+00	3.54E+00	3.30E+00	3.35E+00	2.05E-01
		HC as Hexane	4.66E-01	4.38E-01	3.85E-01	3.76E-01	3.53E-01	3.60E-01	4.20E-01	4.11E-01	4.05E-01	4.02E-01	3.68E-02
		Sum of Target VOCs	4.39E-01	I	4.77E-01	4.02E-01	4.46E-01	4.26E-01	4.19E-01	4.07E-01	4.20E-01	4.29E-01	2.42E-02
		Sum of Target HAPs	3.58E-01	I	3.82E-01	3.28E-01	3.54E-01	3.38E-01	3.36E-01	3.19E-01	3.34E-01	3.44E-01	2.01E-02
		Sum of Target POMs	1.05E-02	I	2.08E-02	1.02E-02	2.66E-02	2.83E-02	1.58E-02	1.80E-02	2.73E-02	1.97E-02	7.29E-03
		Individual Organic HAPs											
x		**Benzene**	1.67E-01	I	1.68E-01	1.51E-01	1.39E-01	1.34E-01	1.41E-01	1.34E-01	1.26E-01	1.45E-01	1.54E-02
x		**Toluene**	8.02E-02	I	7.86E-02	7.32E-02	7.44E-02	7.13E-02	7.52E-02	6.91E-02	7.32E-02	7.44E-02	3.63E-03
x		**m,p-Xylene**	3.26E-02	I	3.46E-02	3.09E-02	3.40E-02	3.22E-02	3.32E-02	3.03E-02	3.45E-02	3.28E-02	1.59E-03
x		**o-Xylene**	1.82E-02	I	1.86E-02	1.69E-02	1.84E-02	1.69E-02	1.82E-02	1.69E-02	1.86E-02	1.78E-02	7.72E-04
x		**Hexane**	1.47E-02	I	1.41E-02	1.32E-02	1.22E-02	1.19E-02	1.22E-02	1.30E-02	1.12E-02	1.28E-02	1.18E-03
x	z	**Naphthalene**	7.85E-03	I	1.41E-02	7.04E-03	1.65E-02	1.69E-02	1.05E-02	1.17E-02	1.70E-02	1.27E-02	4.04E-03
x		**o-Cresol**	4.02E-03	I	1.15E-02	5.46E-03	1.27E-02	9.48E-03	8.18E-03	8.83E-03	1.02E-02	8.79E-03	2.91E-03
x		**Ethylbenzene**	8.45E-03	I	9.11E-03	7.90E-03	8.51E-03	7.73E-03	8.69E-03	7.96E-03	8.49E-03	8.35E-03	4.61E-04
x		**Phenol**	5.76E-03	I	9.04E-03	4.68E-03	9.11E-03	8.50E-03	6.44E-03	5.81E-03	8.21E-03	7.20E-03	1.72E-03
x		**m,p-Cresol**	2.96E-03	I	6.46E-03	2.55E-03	7.06E-03	6.42E-03	4.58E-03	4.60E-03	5.64E-03	5.03E-03	1.66E-03
x		**Styrene**	3.89E-03	I	4.07E-03	3.46E-03	3.92E-03	3.39E-03	3.71E-03	3.41E-03	3.96E-03	3.73E-03	2.73E-04
x	z	**2-Methylnaphthalene**	1.56E-03	I	3.42E-03	1.66E-03	5.17E-03	5.69E-03	2.64E-03	3.12E-03	5.18E-03	3.55E-03	1.62E-03
x		**Acetaldehyde**	3.97E-03	4.25E-03	3.59E-03	3.47E-03	3.32E-03	3.41E-03	3.52E-03	3.44E-03	2.85E-03	3.53E-03	3.95E-04
x		**Formaldehyde**	3.90E-03	3.12E-03	2.46E-03	3.40E-03	2.88E-03	3.07E-03	2.77E-03	1.59E-03	1.77E-03	2.77E-03	7.40E-04
x	z	**1-Methylnaphthalene**	1.11E-03	I	2.35E-03	1.13E-03	3.39E-03	3.87E-03	1.87E-03	2.28E-03	3.61E-03	2.45E-03	1.08E-03
x		**2-Butanone**	1.38E-03	1.45E-03	1.33E-03	1.13E-03	1.21E-03	1.23E-03	1.54E-03	1.59E-03	1.43E-03	1.37E-03	1.56E-04
x	z	**1,3-Dimethylnaphthalene**	ND	I	9.26E-04	4.06E-04	1.49E-03	1.78E-03	7.78E-04	8.98E-04	1.49E-03	9.71E-04	5.98E-04
x		**Propionaldehyde**	7.18E-04	7.89E-04	6.58E-04	6.35E-04	6.36E-04	6.10E-04	6.84E-04	6.50E-04	5.66E-04	6.61E-04	6.45E-05
x	z	**1,2-Dimethylnaphthalene**	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1,5-Dimethylnaphthalene**	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1,6-Dimethylnaphthalene**	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**1,8-Dimethylnaphthalene**	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**2,3,5-Trimethylnaphthalene**	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**2,3-Dimethylnaphthalene**	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**2,6-Dimethylnaphthalene**	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**2,7-Dimethylnaphthalene**	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA
x	z	**Acenaphthalene**	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA
x		**Biphenyl**	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA
x		**Acrolein**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

Test Plan FK Individual Test Results – Lb/Tn Metal (cont")

HAPs	POMs	COMPOUND / SAMPLE NUMBER	FK001	FK002	FK003	FK004	FK005	FK006	FK007	FK008	FK009	Average	STDEV
		Test Dates	8/12/03	8/12/03	8/12/03	8/19/03	8/19/03	8/20/03	8/20/03	8/20/03	8/21/03		
		Other VOCs											
		Heptane	1.40E-02	I	1.37E-02	1.24E-02	1.15E-02	1.14E-02	1.20E-02	1.19E-02	1.04E-02	1.22E-02	1.18E-03
		Octane	1.24E-02	I	1.23E-02	1.11E-02	1.09E-02	1.02E-02	1.09E-02	1.13E-02	1.04E-02	1.12E-02	7.97E-04
		1,2,4-Trimethylbenzene	9.43E-03	I	1.12E-02	8.72E-03	1.23E-02	1.24E-02	1.07E-02	1.08E-02	1.33E-02	1.11E-02	1.53E-03
		Nonane	8.29E-03	I	8.59E-03	7.64E-03	8.01E-03	7.60E-03	7.72E-03	7.70E-03	7.74E-03	7.91E-03	3.57E-04
		Decane	5.16E-03	I	7.06E-03	5.05E-03	7.14E-03	7.10E-03	5.68E-03	6.26E-03	7.15E-03	6.33E-03	9.16E-04
		Indene	5.52E-03	I	7.28E-03	4.74E-03	7.25E-03	5.64E-03	6.11E-03	5.85E-03	7.05E-03	6.18E-03	9.29E-04
		Undecane	3.29E-03	I	5.17E-03	3.99E-03	5.89E-03	5.97E-03	5.03E-03	5.37E-03	5.79E-03	5.06E-03	9.59E-04
		Acetone	5.06E-03	4.95E-03	5.01E-03	4.51E-03	4.67E-03	4.82E-03	5.69E-03	I	5.53E-03	5.03E-03	4.03E-04
		3-Ethyltoluene	3.23E-03	I	5.24E-03	2.51E-03	5.74E-03	6.11E-03	5.31E-03	5.01E-03	4.62E-03	4.72E-03	1.24E-03
		1,2,3-Trimethylbenzene	3.67E-03	I	4.46E-03	3.48E-03	4.85E-03	5.03E-03	4.29E-03	4.15E-03	5.15E-03	4.38E-03	6.11E-04
		Cyclohexane	4.54E-03	I	4.40E-03	4.21E-03	3.92E-03	3.96E-03	3.71E-03	3.79E-03	3.38E-03	3.99E-03	3.82E-04
		1,3,5-Trimethylbenzene	3.07E-03	I	3.26E-03	2.83E-03	3.36E-03	I	3.27E-03	3.09E-03	4.49E-03	3.34E-03	5.38E-04
		Indan	2.94E-03	I	2.69E-03	2.25E-03	3.12E-03	2.72E-03	2.52E-03	2.54E-03	3.08E-03	2.73E-03	3.01E-04
		2-Ethyltoluene	3.04E-03	I	ND	2.75E-03	1.82E-03	ND	3.17E-03	3.03E-03	ND	1.73E-03	1.49E-03
		2,4-Dimethylphenol	ND	I	2.95E-03	ND	3.15E-03	2.35E-03	ND	2.13E-03	ND	1.32E-03	1.45E-03
		Benzaldehyde	1.02E-03	1.12E-03	1.02E-03	8.36E-04	9.25E-04	9.37E-04	1.14E-03	1.03E-03	9.29E-04	9.95E-04	9.80E-05
		Dodecane	ND	I	3.15E-03	ND	ND	2.87E-03	ND	1.90E-03	ND	9.90E-04	1.41E-03
		Tetradecane	ND	I	ND	ND	1.29E-03	2.08E-03	ND	ND	1.92E-03	6.61E-04	9.39E-04
		o,m,p-Tolualdehyde	I	7.07E-04	6.70E-04	7.25E-04	5.13E-04	5.62E-04	5.85E-04	6.88E-04	5.86E-04	6.29E-04	7.76E-05
		Butyraldehyde/Methacrolien	4.67E-04	5.26E-04	4.49E-04	4.00E-04	4.39E-04	4.30E-04	4.99E-04	3.85E-04	I	4.49E-04	4.75E-05
		Hexaldehyde	3.08E-04	3.20E-04	2.91E-04	2.29E-04	2.39E-04	2.10E-04	2.67E-04	1.89E-04	I	2.56E-04	4.74E-05
		Pentanal	2.48E-04	2.93E-04	2.61E-04	ND	1.97E-04	1.92E-04	2.49E-04	2.46E-04	ND	1.87E-04	1.10E-04
		Crotonaldehyde	2.17E-04	2.01E-04	ND	ND	ND	ND	ND	ND	ND	4.65E-05	9.23E-05
		1,3-Diethylbenzene	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA
		2,6-Dimethylphenol	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA
		n-Propylbenzene	ND	I	ND	ND	ND	ND	ND	ND	ND	ND	NA

Test Plan FK Individual Test Results – Lb/Tn Metal (cont')

HAPs	POMs	COMPOUND / SAMPLE NUMBER	FK001	FK002	FK003	FK004	FK005	FK006	FK007	FK008	FK009	Average	STDEV
		Test Dates	8/12/03	8/12/03	8/12/03	8/19/03	8/19/03	8/20/03	8/20/03	8/20/03	8/21/03		
		Other Analytes											
		Carbon Dioxide	I	I	I	I	I	I	I	I	I	I	NA
		Methane	I	I	I	I	I	I	I	I	I	I	NA
		Carbon Monoxide	I	I	I	I	I	I	I	I	I	I	NA
		Ethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Propane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Isobutane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Butane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Neopentane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Isopentane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
		Pentane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA

I: Data rejected based on data validation considerations.

ND: Non Detect; NA: Not Applicable

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

Test Plan FK Quantitation Limits – Lb/Tn Metal

Analytes	Lb/Tn Metal
1,2,3-Trimethylbenzene	3.86E-04
1,2,4-Trimethylbenzene	3.86E-04
1,3,5-Trimethylbenzene	3.86E-04
1,3-Dimethylnaphthalene	3.86E-04
1-Methylnaphthalene	3.86E-04
2-Ethyltoluene	3.86E-04
2-Methylnaphthalene	3.86E-04
Benzene	3.86E-04
Ethylbenzene	3.86E-04
Hexane	3.86E-04
m,p-Xylene	3.86E-04
Naphthalene	3.86E-04
o-Xylene	3.86E-04
Styrene	3.86E-04
Toluene	3.86E-04
Undecane	3.86E-04
1,2-Dimethylnaphthalene	1.93E-03
1,3-Diethylbenzene	1.93E-03
1,5-Dimethylnaphthalene	1.93E-03
1,6-Dimethylnaphthalene	1.93E-03
1,8-Dimethylnaphthalene	1.93E-03
2,3,5-Trimethylnaphthalene	1.93E-03
2,3-Dimethylnaphthalene	1.93E-03
2,4-Dimethylphenol	1.93E-03
2,6-Dimethylnaphthalene	1.93E-03
2,6-Dimethylphenol	1.93E-03
2,7- Dimethylnaphthalene	1.93E-03
3-Ethyltoluene	1.93E-03
Acenaphthalene	1.93E-03

Analytes	Lb/Tn Metal
Biphenyl	1.93E-03
Cyclohexane	1.93E-03
Decane	1.93E-03
Dodecane	1.93E-03
Heptane	1.93E-03
Indan	1.93E-03
Indene	1.93E-03
m,p-Cresol	1.93E-03
Nonane	1.93E-03
o-Cresol	1.93E-03
Octane	1.93E-03
Phenol	1.93E-03
Propylbenzene	1.93E-03
Tetradecane	1.93E-03
2-Butanone (MEK)	1.96E-04
Acetaldehyde	1.96E-04
Acetone	1.96E-04
Acrolein	1.96E-04
Benzaldehyde	1.96E-04
Butyraldehyde	1.96E-04
Crotonaldehyde	1.96E-04
Formaldehyde	1.96E-04
Hexaldehyde	1.96E-04
Butyraldehyde/Methacrolein	3.26E-04
o,m,p-Tolualdehyde	5.22E-04
Pentanal (Valeraldehyde)	1.96E-04
Propionaldehyde (Propanal)	1.96E-04
HC as Hexane	6.29E-03

Analytes	Lb/Tn Metal
Carbon Monoxide	5.30E-01
Methane	3.03E-02
Carbon Dioxide	8.33E-01
Ethane	5.68E-01
Propane	8.33E-01
Isobutane	1.10E+00
Butane	1.10E+00
Neopentane	1.36E+00
Isopentane	1.36E+00
Pentane	1.36E+00

Test Plan GL Individual Test Results – Lb/Tn Metal

POM	VOC	HAP	Analyte Name	GL001	GL002	GL003	GL004	GL005	GL006	GL007	GL008	GL009	Average	St. Dev.
			Test Dates	11-Jan-05	12-Jan-05	12-Jan-05	12-Jan-05	13-Jan-05	13-Jan-05	13-Jan-05	14-Jan-05	14-Jan-05	–	–
			Emission Indicators											
			TGOC as Propane	7.42E-01	7.81E-01	7.85E-01	6.84E-01	7.73E-01	6.47E-01	6.80E-01	6.98E-01	5.54E-01	7.05E-01	7.53E-02
			HC as Hexane	1.74E-01	1.71E-01	1.75E-01	1.86E-01	1.80E-01	1.64E-01	1.86E-01	1.64E-01	1.30E-01	1.70E-01	1.71E-02
			Sum of Target VOCs	9.89E-02	9.64E-02	1.01E-01	9.73E-02	9.95E-02	9.61E-02	9.60E-02	9.14E-02	7.73E-02	9.48E-02	7.11E-03
			Sum of Target HAPs	9.18E-02	8.95E-02	9.31E-02	8.94E-02	9.13E-02	8.85E-02	8.85E-02	8.43E-02	7.34E-02	8.77E-02	5.94E-03
			Sum of Target POMs	2.81E-03	2.18E-03	2.78E-03	2.43E-03	2.32E-03	2.18E-03	2.65E-03	2.26E-03	1.61E-03	2.36E-03	3.70E-04
			Individual Target Organic HAPs and POMs											
	Y	Y	Benzene	2.97E-02	2.92E-02	3.17E-02	2.88E-02	2.94E-02	3.00E-02	2.96E-02	2.81E-02	2.64E-02	2.92E-02	1.44E-03
	Y	Y	Acetaldehyde	1.97E-02	1.99E-02	2.06E-02	2.14E-02	2.16E-02	2.07E-02	2.13E-02	2.13E-02	1.97E-02	2.07E-02	7.76E-04
	Y	Y	Toluene	1.29E-02	1.27E-02	1.28E-02	1.23E-02	1.28E-02	1.23E-02	1.19E-02	1.11E-02	1.00E-02	1.21E-02	9.64E-04
	Y	Y	m,p-Xylene	8.07E-03	7.85E-03	7.27E-03	7.03E-03	7.06E-03	6.52E-03	6.18E-03	5.60E-03	4.41E-03	6.67E-03	1.15E-03
	Y	Y	Formaldehyde	4.06E-03	3.61E-03	3.63E-03	3.47E-03	3.59E-03	3.25E-03	3.35E-03	3.33E-03	3.65E-03	3.55E-03	2.41E-04
	Y	Y	Propionaldehyde	2.67E-03	2.67E-03	2.68E-03	2.82E-03	2.82E-03	2.71E-03	2.89E-03	2.73E-03	2.47E-03	2.72E-03	1.21E-04
	Y	Y	o-Xylene	2.88E-03	2.81E-03	2.78E-03	2.77E-03	2.76E-03	2.58E-03	2.53E-03	2.37E-03	I	2.68E-03	1.73E-04
	Y	Y	Phenol	2.93E-03	2.74E-03	2.74E-03	2.47E-03	2.70E-03	2.28E-03	2.28E-03	1.92E-03	1.46E-03	2.39E-03	4.67E-04
	Y	Y	Hexane	2.27E-03	2.12E-03	2.22E-03	2.01E-03	2.30E-03	2.22E-03	2.01E-03	2.06E-03	1.75E-03	2.11E-03	1.73E-04
Y	Y	Y	Naphthalene	2.14E-03	1.75E-03	2.21E-03	1.98E-03	1.86E-03	1.79E-03	2.18E-03	1.84E-03	1.32E-03	1.90E-03	2.77E-04
	Y	Y	Ethylbenzene	1.52E-03	1.54E-03	1.60E-03	1.59E-03	1.64E-03	1.57E-03	1.49E-03	1.44E-03	I	1.55E-03	6.45E-05
	Y	Y	2-Butanone	1.27E-03	1.24E-03	1.21E-03	1.29E-03	1.30E-03	1.22E-03	1.29E-03	1.19E-03	1.08E-03	1.23E-03	6.84E-05
	Y	Y	Styrene	1.15E-03	9.41E-04	1.10E-03	1.01E-03	9.67E-04	1.03E-03	1.06E-03	9.84E-04	8.60E-04	1.01E-03	8.64E-05
Y	Y	Y	2-Methylnaphthalene	6.66E-04	4.27E-04	5.62E-04	4.55E-04	4.60E-04	3.92E-04	4.71E-04	4.19E-04	2.92E-04	4.61E-04	1.05E-04
Y	Y	Y	Acenaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	1,2-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	1,3-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	1,5-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	1,6-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	1,8-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	2,3-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	2,6-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	2,7-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	1-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
Y	Y	Y	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y	Y	Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y	Y	m,p-Cresol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y	Y	o-Cresol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y	Y	Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y	Y	p-Cymene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y	Y	Cumene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA

Test Plan GL Individual Test Results – Lb/Tn Metal (con't)

POM	VOC	HAP	Analyte Name	GL001	GL002	GL003	GL004	GL005	GL006	GL007	GL008	GL009	Average	St. Dev.
			Individual Target VOCs, not including HAPs and POMs											
	Y		Heptane	1.56E-03	1.51E-03	1.97E-03	2.17E-03	2.45E-03	2.57E-03	2.12E-03	2.30E-03	1.68E-03	2.04E-03	3.84E-04
	Y		3-Ethyltoluene	1.20E-03	1.29E-03	1.35E-03	1.37E-03	1.43E-03	1.30E-03	1.24E-03	1.14E-03	I	1.29E-03	9.37E-05
	Y		Indene	1.14E-03	1.03E-03	1.21E-03	1.01E-03	9.60E-04	9.28E-04	1.19E-03	8.97E-04	I	1.05E-03	1.22E-04
	Y		1,2,3-Trimethylbenzene	8.68E-04	9.55E-04	9.75E-04	8.96E-04	9.03E-04	7.75E-04	9.16E-04	7.60E-04	5.64E-04	8.46E-04	1.28E-04
	Y		Butyraldehyde/Methacrolein	7.62E-04	7.65E-04	7.89E-04	8.26E-04	8.85E-04	8.13E-04	8.42E-04	8.09E-04	7.26E-04	8.02E-04	4.77E-05
	Y		Hexaldehyde	8.44E-04	7.33E-04	4.94E-04	7.93E-04	7.17E-04	4.11E-04	4.10E-04	3.86E-04	3.56E-04	5.72E-04	1.97E-04
	Y		Pentanal	4.67E-04	4.52E-04	4.15E-04	4.56E-04	4.65E-04	4.02E-04	3.94E-04	4.03E-04	3.45E-04	4.22E-04	4.10E-05
	Y		Benzaldehyde	2.34E-04	2.23E-04	2.15E-04	2.32E-04	2.33E-04	2.17E-04	2.08E-04	2.17E-04	1.97E-04	2.20E-04	1.22E-05
	Y		2-Ethyltoluene	ND	ND	1.71E-04	1.61E-04	1.66E-04	1.95E-04	1.83E-04	1.92E-04	ND	1.78E-04	1.40E-05
	Y		Cyclohexane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		Decane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		1,3-Diethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		2,6-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		Dodecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		Indan	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		Nonane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		Octane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		n-Propylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		1,2,4-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		1,3,5-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		Undecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		Crotonaldehyde	I	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		o,m,p-Tolualdehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		a-Methylstyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		sec-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		tert-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		1,2-Diethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		1,4-Diethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		2,3-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		2,5-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		3,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		3,5-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		4-Ethyltoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		Isobutylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		Tridecane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		2,3,5-Trimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Y		2,4,6-Trimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
			Criteria Pollutants and Greenhouse Gases											
			Carbon Monoxide	2.86E+00	2.82E+00	2.82E+00	2.83E+00	2.74E+00	2.66E+00	2.67E+00	2.71E+00	2.66E+00	2.75E+00	8.09E-02
			Carbon Dioxide	6.14E+00	6.82E+00	5.56E+00	6.13E+00	5.39E+00	5.72E+00	5.63E+00	4.73E+00	6.57E+00	5.85E+00	6.37E-01
			Nitrogen Oxides	I	5.01E-03	1.73E-03	3.49E-03	2.12E-03	3.51E-03	I	3.30E-03	3.48E-04	2.17E-03	1.80E-03

Test Series GL Quantitation Limits – Lb/Tn Metal

Analytes	Lb/Tn Metal
1,2,3-Trimethylbenzene	1.40E-04
1,2,4-Trimethylbenzene	1.40E-04
1,3,5-Trimethylbenzene	1.40E-04
1,3-Dimethylnaphthalene	1.40E-04
1-Methylnaphthalene	1.40E-04
2-Ethyltoluene	1.40E-04
2-Methylnaphthalene	1.40E-04
Benzene	1.40E-04
Ethylbenzene	1.40E-04
Hexane	1.40E-04
m,p-Xylene	1.40E-04
Naphthalene	1.40E-04
o-Xylene	1.40E-04
Styrene	1.40E-04
Toluene	1.40E-04
Undecane	1.40E-04
1,2-Dimethylnaphthalene	7.00E-04
1,3-Diethylbenzene	7.00E-04
1,5-Dimethylnaphthalene	7.00E-04
1,6-Dimethylnaphthalene	7.00E-04
1,8-Dimethylnaphthalene	7.00E-04

Analytes	Lb/Tn Metal
2,3,5-Trimethylnaphthalene	7.00E-04
2,3-Dimethylnaphthalene	7.00E-04
2,4-Dimethylphenol	7.00E-04
2,6-Dimethylnaphthalene	7.00E-04
2,6-Dimethylphenol	7.00E-04
2,7- Dimethylnaphthalene	7.00E-04
3-Ethyltoluene	7.00E-04
Acenaphthalene	7.00E-04
Biphenyl	7.00E-04
Cyclohexane	7.00E-04
Decane	7.00E-04
Dodecane	7.00E-04
Heptane	7.00E-04
Indan	7.00E-04
Indene	7.00E-04
m,p-Cresol	7.00E-04
Nonane	7.00E-04
o-Cresol	7.00E-04
Octane	7.00E-04
Phenol	7.00E-04
Propylbenzene	7.00E-04

Analytes	Lb/Tn Metal
Tetradecane	7.00E-04
HC as Hexane	4.28E-03
2-Butanone (MEK)	1.33E-04
Acetaldehyde	1.33E-04
Acetone	1.33E-04
Acrolein	1.33E-04
Benzaldehyde	1.33E-04
Butyraldehyde	1.33E-04
Crotonaldehyde	1.33E-04
Formaldehyde	1.33E-04
Hexaldehyde	1.33E-04
Butyraldehyde/Methacrolein	2.21E-04
o,m,p-Tolualdehyde	3.54E-04
Pentanal (Valeraldehyde)	1.33E-04
Propionaldehyde (Propanal)	1.33E-04
Carbon Monoxide	3.30E-02
Carbon Dioxide	5.19E-02
Nitrogen Oxides	3.54E-02
TGOC as Propane	7.05E-01

Test Series FK and GL Emissions Comparison – T-Statistics

	Average Test FK	Standard Deviation	Average Test GL	% Change from Baseline FK
Emission Indicators				
TGOC as Propane	3.3541	0.2052	0.7048	-79
HC as Hexane	0.4015	0.0368	0.1700	-58
Sum of Target Analytes	0.4294	0.0242	0.0948	-78
Sum of HAPs	0.3437	0.0201	0.0877	-74
Sum of POMs	0.0197	0.0073	0.0024	-88
Target Organic VOCs Including HAPs and POMs				
Diethylbenzenes	NA	NA	NA	NA
2,3,5-Trimethylnaphthalene	NA	NA	NA	NA
2-Butanone	0.0014	0.0002	0.0012	-10
Acenaphthalene	NA	NA	NA	NA
Acetaldehyde	0.0035	0.0004	0.0207	485
Acrolein	NA	NA	NA	NA
Benzaldehyde	0.0010	0.0001	0.0002	-78
Benzene	0.1450	0.0154	0.0292	-80
Biphenyl	NA	NA	NA	NA
Butylbenzene	NT	NT	NA	NA
Butyraldehyde/Methacrolein	0.0004	0.0000	0.0008	78
Cresols	0.0138	0.0045	NA	NA
Crotonaldehyde	0.0000	0.0001	NA	NA
Cyclohexane	0.0040	0.0004	NA	NA
Decane	0.0063	0.0009	NA	NA
Dimethylnaphthalenes	0.0010	0.0006	NA	NA
Dimethylphenols	0.0013	0.0014	NA	NA
Dodecane	0.0010	0.0014	NA	NA
Ethylbenzene	0.0084	0.0005	0.0015	-81
Ethyltoluenes	0.0064	0.0014	0.0013	-80
Formaldehyde	0.0028	0.0007	0.0036	28
Heptane	0.0122	0.0012	0.0020	-83
Hexaldehyde	0.0003	0.0000	0.0006	123
Hexane	0.0128	0.0012	0.0021	-84
Indan	0.0027	0.0003	NA	NA
Indene	0.0062	0.0009	0.0010	-83
Methylnaphthalenes	0.0060	0.0027	0.0005	-92
Naphthalene	0.0127	0.0040	0.0019	-85
Nonane	0.0079	0.0004	NA	NA
n-Propylbenzene	NA	NA	NA	NA
o,m,p-Tolualdehyde	0.0006	0.0001	NA	NA
Octane	0.0112	0.0008	NA	NA
Pentanal	0.0002	0.0001	0.0004	125
Phenol	0.0072	0.0017	0.0024	-67
Propionaldehyde	0.0007	0.0001	0.0027	311
Styrene	0.0037	0.0003	0.0010	-73
Toluene	0.0744	0.0036	0.0121	-84
Trimethylbenzenes	0.0184	0.0025	0.0008	-95
Undecane	0.0051	0.0010	NA	NA
Xylenes	0.0506	0.0023	0.0091	-82
Criteria Pollutants and Greenhouse Gases				
Carbon Monoxide	NT	NT	2.7522	NA
Carbon Dioxide	32.2452	1.9070	5.8533	-82
Nitrogen Oxides	NT	NT	0.0022	NA

Bold numbers indicate those compounds whose calculated t-statistic is significant at alpha=0.05
ND: Non Detect; NA: Not Applicable; NT: Not Tested

APPENDIX C TEST SERIES FK AND GL DETAILED PROCESS DATA

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Test FK Detailed Process Data

Greensand PCS										
Test Dates	**8/12/2003**	**8/12/2003**	**8/12/2003**	**8/19/2003**	**8/19/2003**	**8/20/2003**	**8/20/2003**	**8/20/2003**	**8/21/2003**	**Average**
Emissions Sample # / Production Sample #	**FK 001**	**FK 002**	**FK 003**	**FK 004**	**FK 005**	**FK 006**	**FK 007**	**FK 008**	**FK 009**	
Cast Weight (all metal inside mold), Lbs.	97.5	103.0	96.0	96.5	107.5	104.0	96.5	103.0	100.5	**100.5**
Pouring Time, sec.	22	19	24	19	17	23	16	15	15	**19**
Pouring Temp ,°F	2673	2682	2688	2684	2689	2671	2684	2680	2682	**2681**
Pour Hood Process Air Temp at Start of Pour,	85	88	89	88	88	86	88	88	87	**87**
Muller Batch Weight, Lbs.	895.07	895.10	894.60	1294.88 [1]	894.99	894.88	894.88	894.88	894.88	**894.91** [2]
GS Mold Sand Weight, Lbs.	650	646	650	646	640	656	650	646	650	**648**
Mold compactability, %	45	43	48	46	45	45	50	50	45	**46**
Mold Temperature, °F	80	86	90	75	85	79	90	90	81	**84**
Average Green Compression , psi	12.16	11.42	10.48	13.65	13.62	12.61	12.24	11.89	14.15	**12.47**
GS Compactability, %	35	42	28	42	40	41	47	44	45	**40**
GS Moisture Content, %	1.89	1.92	1.98	1.98	2.02	2.00	2.20	2.16	2.18	**2.04**
GS Clay Content, %	7.00	6.74	6.74	7.00	7.26	7.00	6.74	6.74	6.74	**6.88**
MB Clay reagent, ml	27.0	26.0	26.0	27.0	28.0	27.0	26.0	26.0	26.0	**26.6**
1800°F LOI - Mold Sand, %	4.86	4.95	4.86	5.10	5.18	5.31	5.35	5.48	5.64	**5.19**
900°F Volatiles , %	0.98	1.16	0.96	1.02	0.96	0.94	1.02	1.24	0.80	**1.01**

Note 1: The procedure for accumulating return sand components had not been strictly adhered to, so all sand materials were gathered together and reblended to maintain constitutional integrity.
Note 2: Average of all muller batch weights except FK004. See Note 1.

Test GL Detailed Process Data

Greensand PCS													
Pour Date	**1/10/2005**	**1/11/2005**	**1/11/2005**	**1/11/2005**	**1/12/2005**	**1/12/2005**	**1/12/2005**	**1/13/2005**	**1/13/2005**	**1/13/2005**	**1/14/2005**	**1/14/2005**	**Average**
Emissions Sample #	**GLCR1**	**GLCR2**	**GLCR3**	**GL001**	**GL002**	**GL003**	**GL004**	**GL005**	**GL006**	**GL007**	**GL008**	**GL009**	
Production Sample #	**GL001**	**GL002**	**GL003**	**GL004**	**GL005**	**GL006**	**GL007**	**GL008**	**GL009**	**GL010**	**GL011**	**GL012**	
Cast Weight - All Metal Inside Mold (lbs.)	94.6	95.7	97.5	96.0	97.0	98.3	96.6	97.3	97.9	96.3	93.5	96.7	**96.6**
Pouring Time (sec.)	21	20	23	21	18	17	15	17	13	14	14	19	**16**
Pouring Temp (°F)	2668	2686	2670	2680	2689	2672	2685	2683	2674	2677	2686	2685	**2681**
Pour Hood Process Air Temp at Start of Pour (°F)	86	90	86	86	87	87	86	89	91	87	86	86	**87**
Muller Batch Weight (lbs.)	1297	900	900	900	900	900	900	900	900	900	900	900	**900**
GS Mold Sand Weight, (lbs.)	668	658	657	647	643	644	641	647	642	642	645	638	**643**
Mold Compactability, %	56	57	52	58	55	54	54	53	55	56	56	58	**55**
Mold Temperature (°F)	70	64	67	78	79	69	74	65	74	73	62	67	**71**
Average Green Compression (psi)	14.75	17.66	19.32	22.23	19.81	23.86	25.02	27.36	27.06	23.35	21.54	24.42	**23.85**
GS Compactability (%)	56	61	44	46	35	32	34	42	40	44	46	45	**40**
GS Moisture Content (%)	2.66	2.78	2.14	2.14	2.36	1.84	1.86	1.74	1.84	2.16	2.38	1.94	**2.03**
GS MBClay Content (%)	7.13	7.34	7.55	7.55	7.76	7.34	6.92	6.92	7.76	7.66	7.66	6.92	**7.39**
MB Clay reagent, ml	34.0	35.0	36.0	36.0	37.0	35.0	33.0	33.0	37.0	36.5	36.5	33.0	**35.2**
1800°F LOI - Mold Sand (%)	1.18	1.15	1.20	1.11	1.19	1.13	1.17	1.15	1.18	1.06	1.11	1.09	**1.13**
900°F Volatiles (%)	0.66	0.60	0.60	0.52	0.50	0.50	0.62	0.68	0.62	0.50	0.56	0.58	**0.56**
Liquid Parting Spray (grams)	39.7	39.9	40	40	40	40.3	39.9	40.3	40.1	39.9	40	40	**40.1**
Rank order 1=best, 5 = median, 9 = worst	2a	6a	3a	2	4	1	3	8	9	5	6	7	

APPENDIX D METHOD CHARTS

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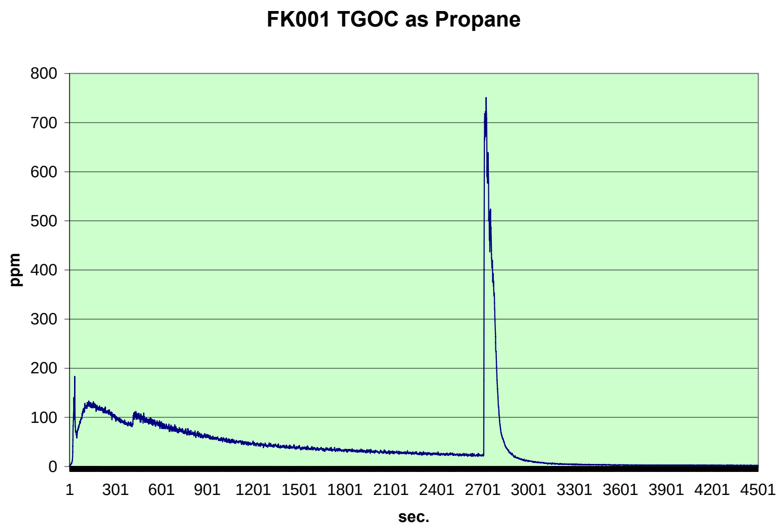
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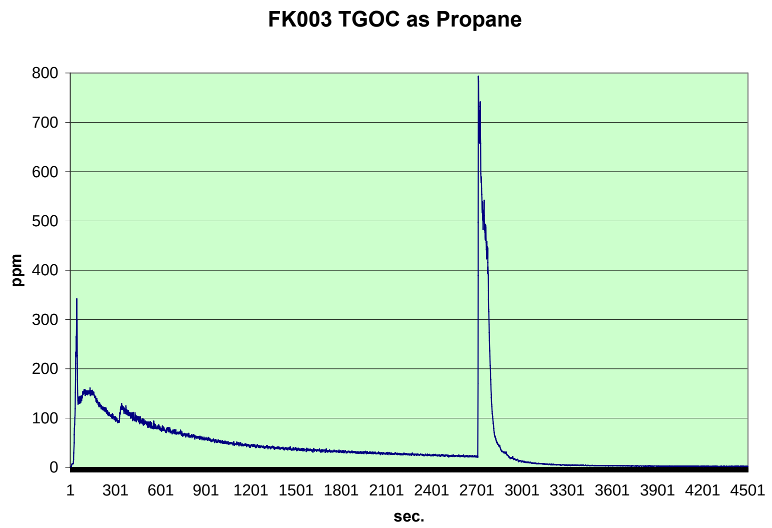
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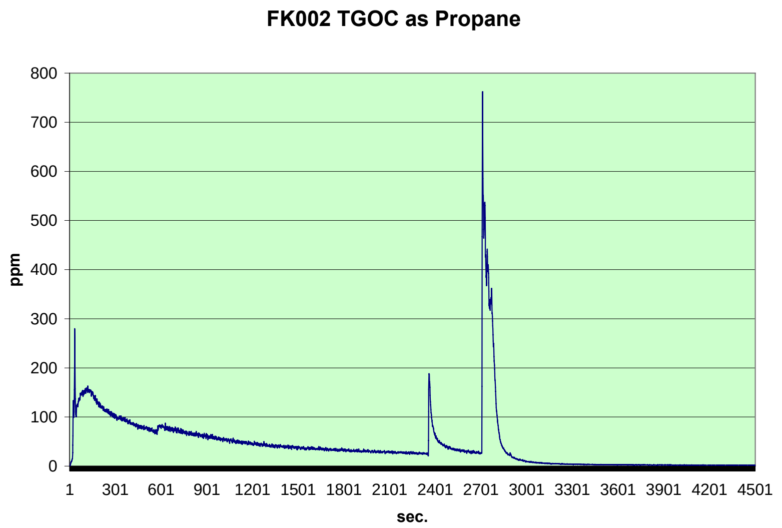
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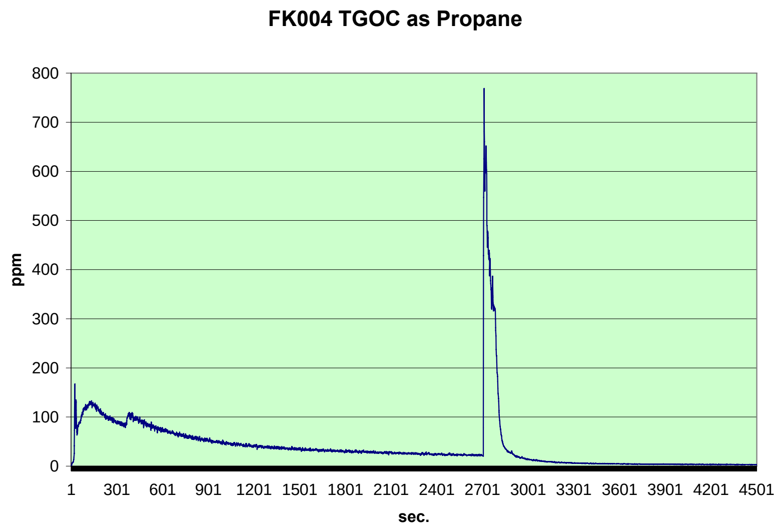
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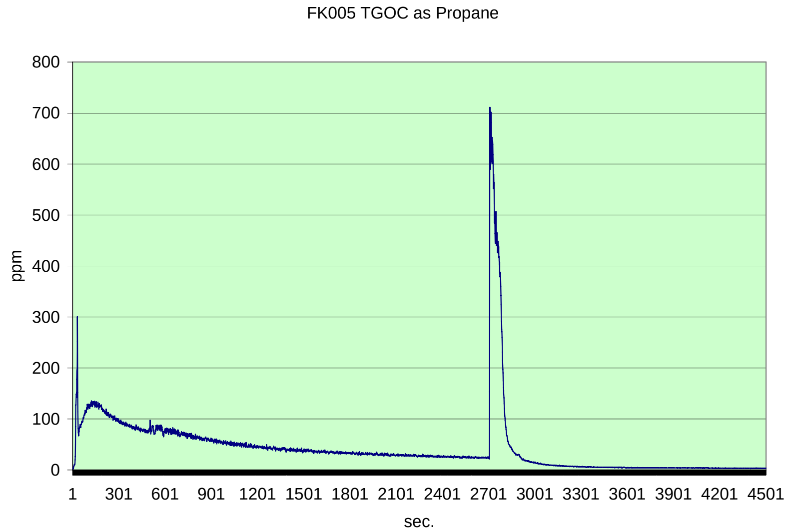
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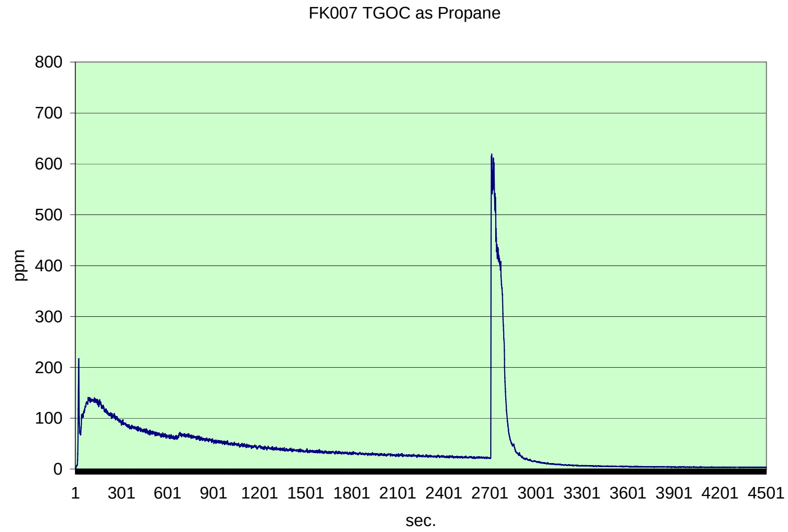
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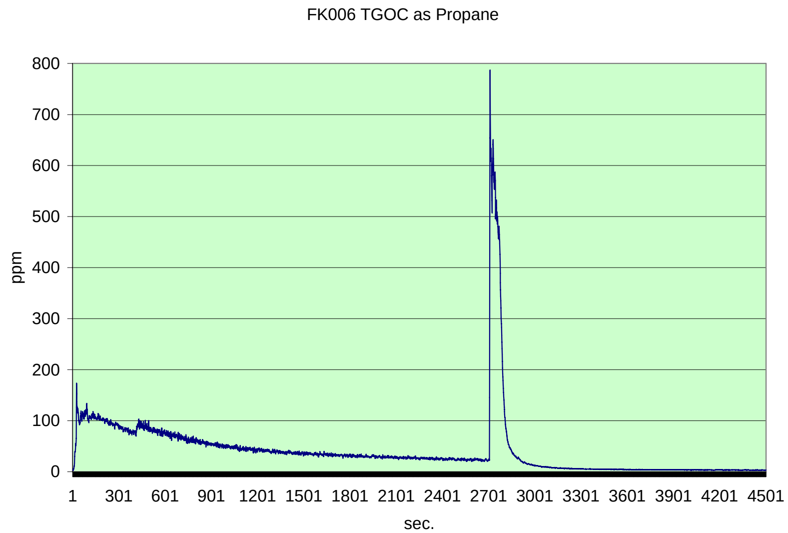
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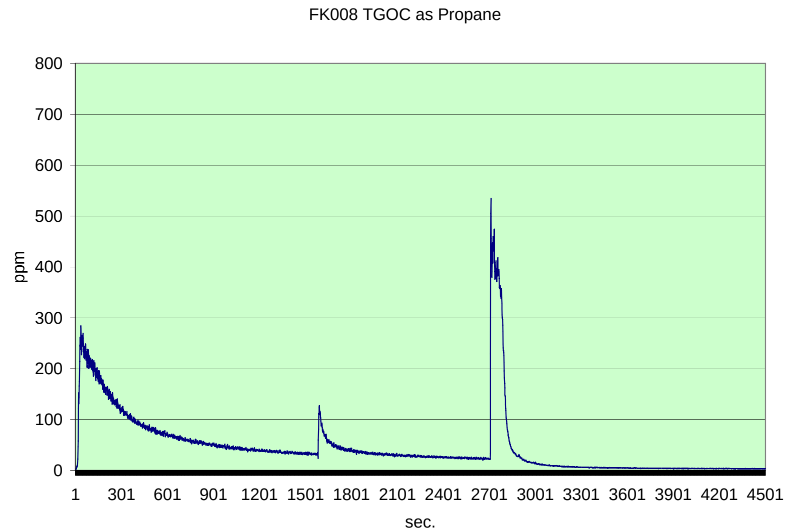
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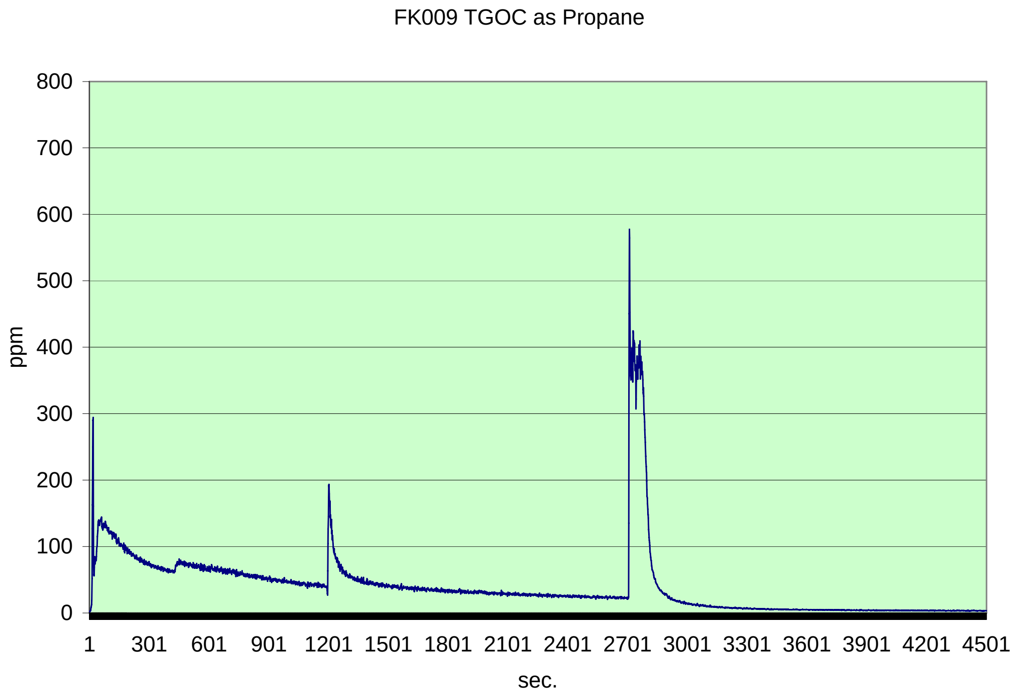
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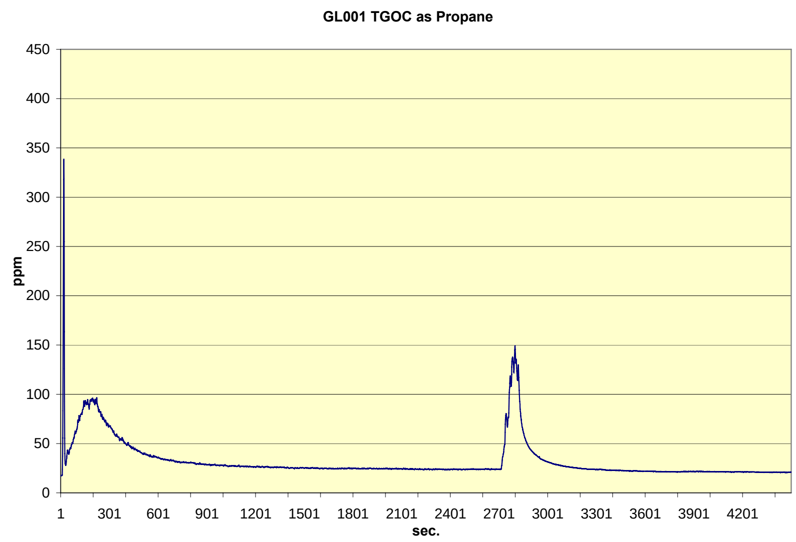
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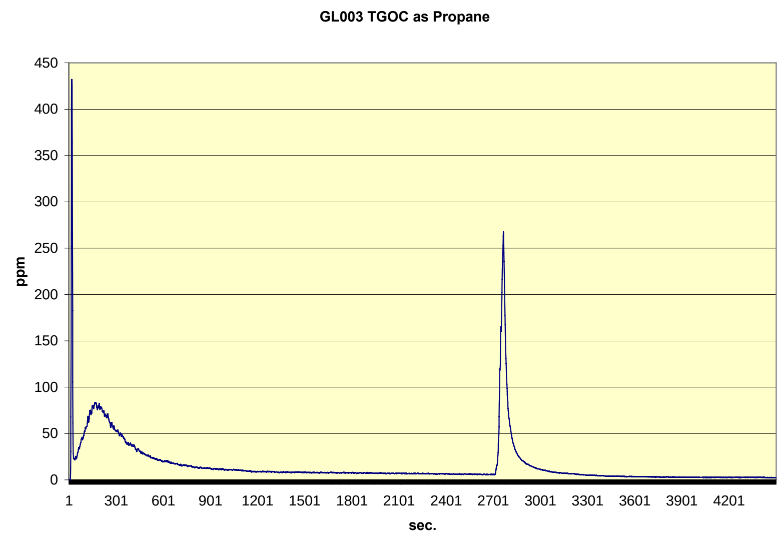
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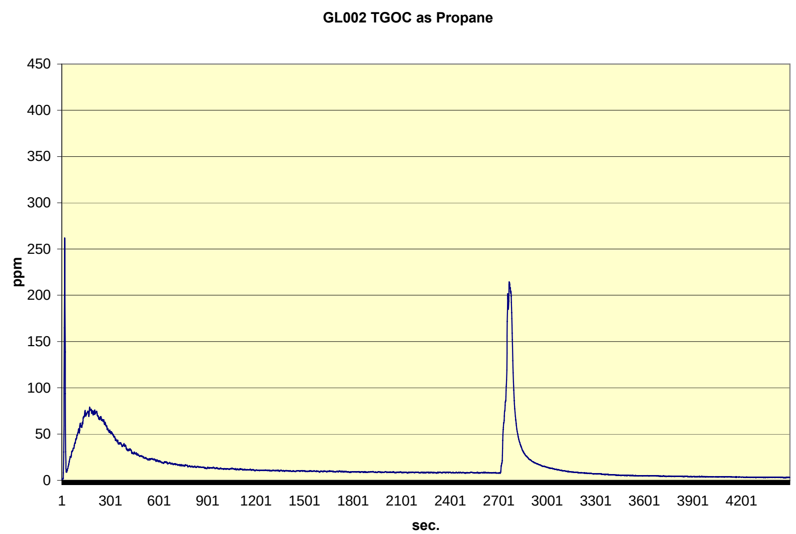
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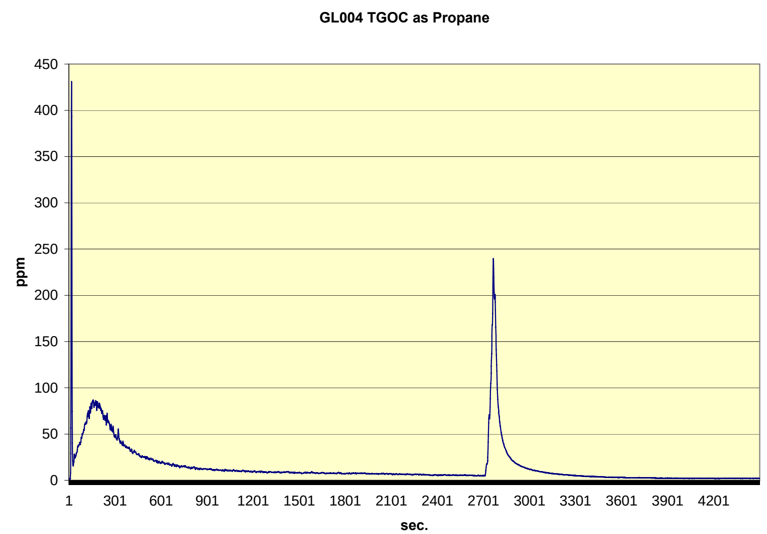
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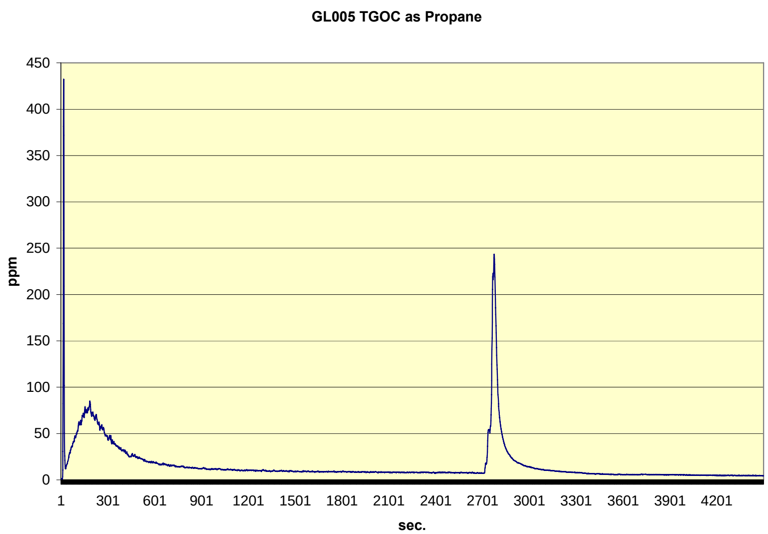
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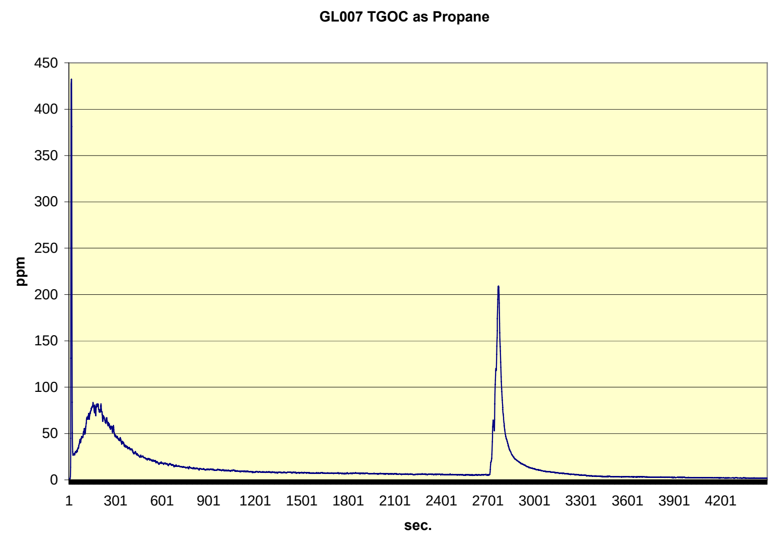
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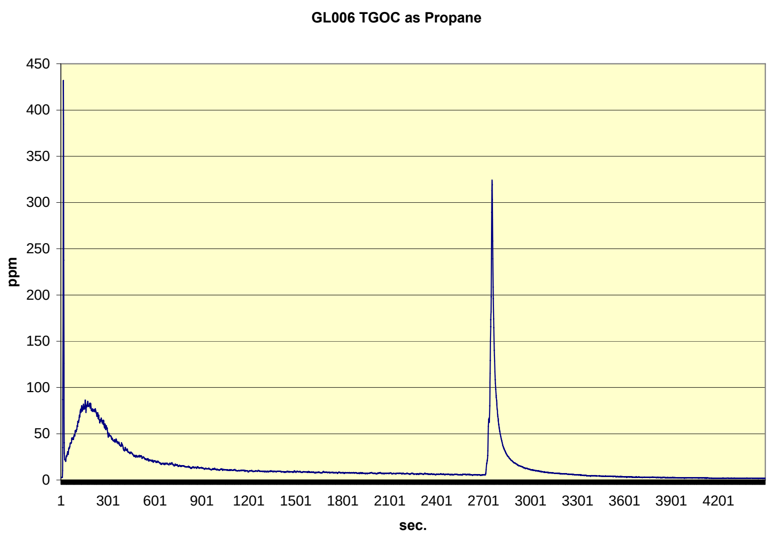
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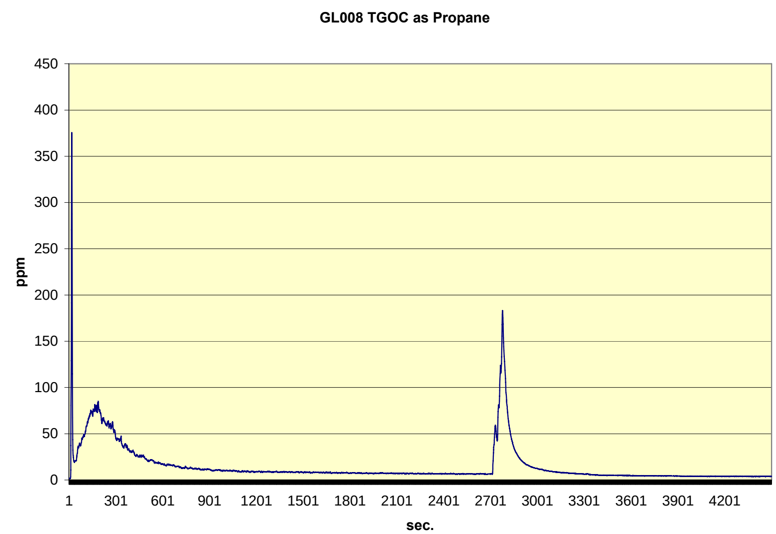
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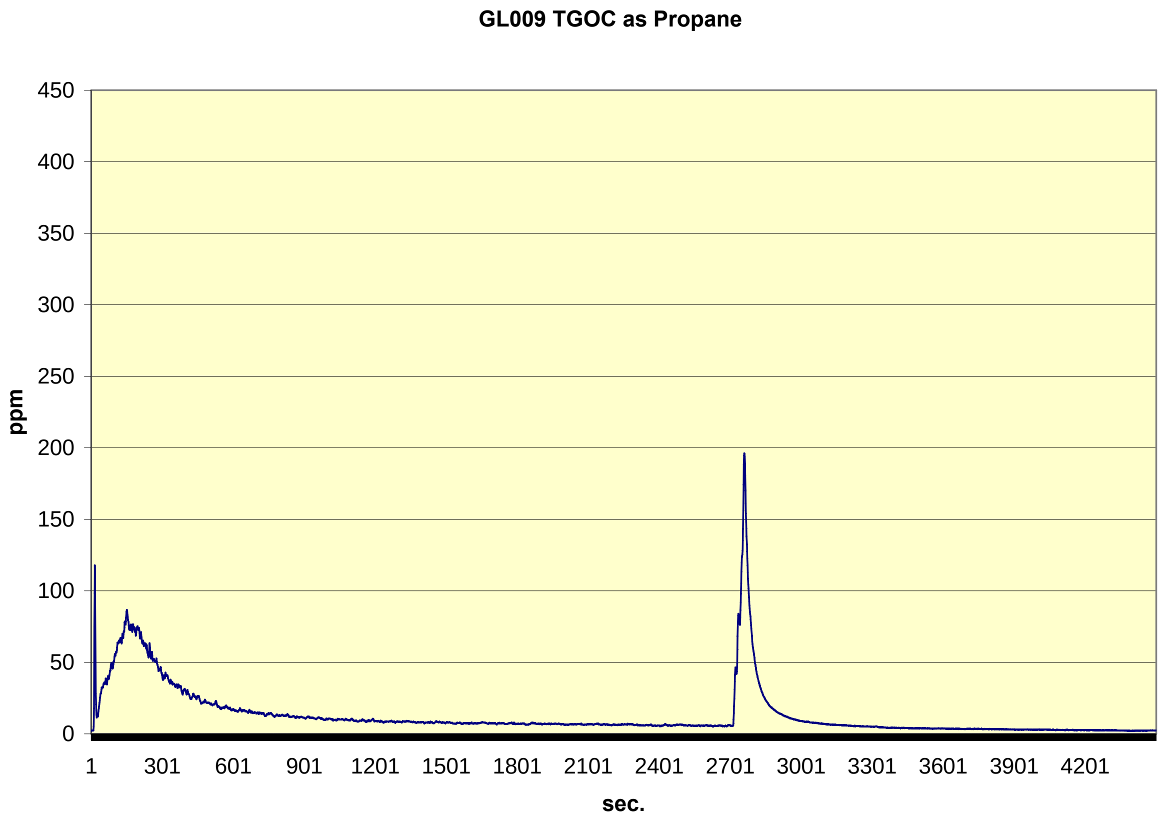
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sec.

APPENDIX E ACRONYMS & ABBREVIATIONS

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Acronyms & 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
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).
VOC	Volatile Organic Compound