CERP

Casting Emission Reduction Program

Prepared by:

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FY 2003

Baseline

Pouring, Cooling, Shakeout of Coreless Greensand with Seacoal Poured with Iron

Technikon #1410-122 FK

10 November 2003

(This document revised for public distribution)

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Pouring, Cooling, Shakeout of Coreless Baseline Greensand with Seacoal, Iron and PCS

1410-122 FK

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

Research Chemist	*// Original Signed //* Carmen Hornsby	Date
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The data contained in this report were developed to assess the relative emissions profile of the product or process being evaluated. You may not obtain the same results in your facility. Data was not collected to assess casting quality, cost, or producibility.

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Executive Summary

This report contains the results of emission testing to evaluate the pouring, cooling, and shakeout emissions from Test FK a coreless, greensand system with seacoal. Test FK will be used as a baseline against which other products and processes are to be compared. All testing was conducted by Technikon, LLC in its Pre-Production 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 process parameters were maintained within prescribed ranges in order to ensure the reproducibility of the tests runs. Samples were collected and analyzed for sixty-six (66) target compounds using procedures based on US EPA Method 18. Continuous monitoring of the Total Gaseous Organic Concentration (TGOC) of the emissions was conducted according to US EPA Method 25A.

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

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

Test Plan FK Emissions Indicators – Lb/Tn Metal

	TGOC as Propane	HC as Hexane	Sum of VOCs	Sum of HAPs	Sum of POMs
Test FK	3.354	0.4015	0.4294	0.3437	0.0197

A pictorial casting record was made of cavity 3 from each mold for reference for future castings made with vendor products. The pictures are shown in rank-order in Appendix C

It must be noted that the results from the reference and product testing performed are not suitable for use as emission factors or for other purposes other than evaluating the <u>relative emission reductions</u> associated with the use of alternative materials, equipment, or manufacturing processes.

The emissions measurements are unique to the specific castings produced, materials used, and testing methodology associated with these tests. These measurements should not be used as the basis for estimating emissions from actual commercial foundry applications.

1.0 Introduction

1.1 Background

Technikon LLC is a privately held contract research organization located in McClellan, California, a suburb of Sacramento. Technikon offers emissions research services to industrial and government clients specializing in the metal casting and mobile emissions areas. Technikon operates the Casting Emission Reduction Program (CERP). CERP is a cooperative initiative between the Department of Defense (US Army) and the United States Council for Automotive Research (USCAR). Its purpose is to evaluate alternative casting materials and processes that are designed to reduce air emissions and/or produce more efficient casting processes. Other technical partners directly supporting the project include: the American Foundry Society (AFS); the Casting Industry Suppliers Association (CISA); the US Environmental Protection Agency (US EPA); and the California Air Resources Board (CARB).

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, especially for the 1990 Clean Air Act Amendment. The facility has two principal testing arenas: a Pre-Production Foundry designed to measure airborne emissions from individually poured molds, and a Production Foundry designed to measure air emissions in a continuous full scale production process. Each of these testing arenas has been specially designed to facilitate the collection and evaluation of airborne emissions and associated process data.

The Production Foundry provides simultaneous detailed individual emission measurements using methods based on US EPA protocols for the melting, pouring, sand preparation, mold making, and core making processes.

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.

1.3 Report Organization

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

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

1.4 Specific Test Plan and Objectives

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

Table 1-1 Test Plan Summary

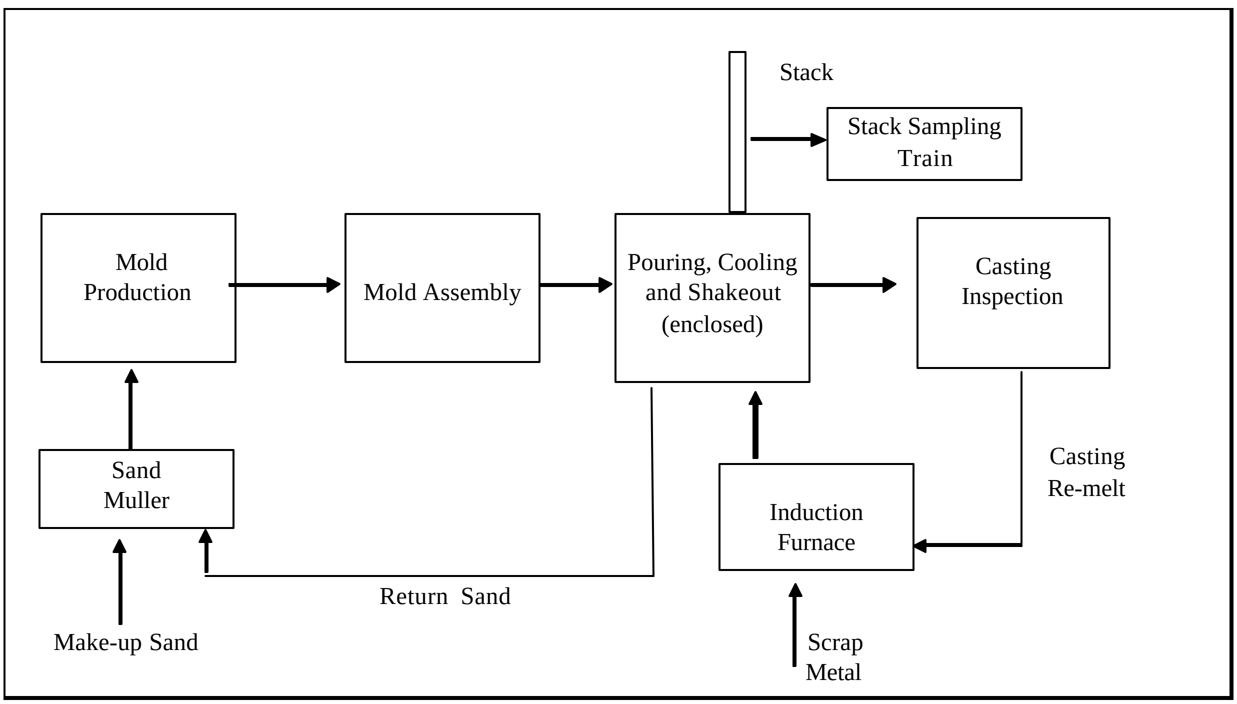
	Test Plan
Type of Process tested	Coreless Greensand Iron PCS Baseline
Test Plan Number	1410 122 FK
Greensand System	Virgin Lakesand, Bentonite Clay and H & G Seacoal
Metal Poured	Iron
Casting Type	4-on Star
Number of molds poured	3 Conditioning + 9 Sampling
Test Dates	8/12/03 > 8/21/03
Emissions Measured	TGOC as Propane, HC as Hexane, 66 Organic HAPs and VOCs
Process Parameters Measured	Total Casting, Mold Weights; Metallurgical data, % LOI; Stack Temperature, Moisture Content, Sand Temperature, Pressure, and Volumetric Flow Rate

2.0 Test Methodology

2.1 Description of Process and Testing Equipment

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

Figure 2-1 Pre-Production Foundry Layout Diagram



2.2 Description of Testing Program

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

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

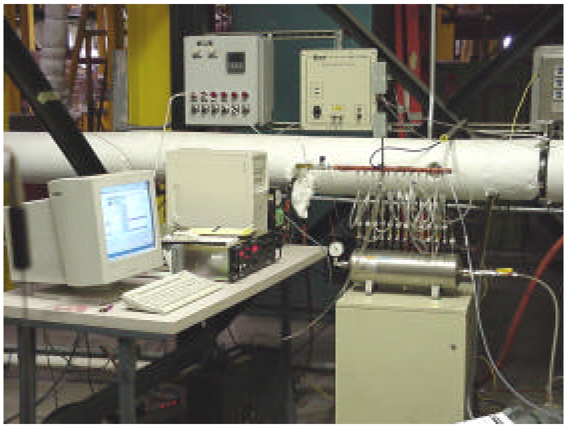
2. **Mold and Metal Preparation:** The 4-on star greensand molds are prepared to a standard composition by the Technikon production team. Iron is melted in a 1000 lb. Ajax induction furnace. The amount of metal melted is determined from the poured weight of the casting and the number of molds to be poured.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


4-on Star Greensand Mold

3. **Individual Sampling Events:** 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 is poured through an opening in the top of the emission enclosure.


Total Enclosure Test Stand

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.


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	Acme 4260 Crane Scale (Gravimetric)
Casting Weight	Ohaus MP2 Scale
Muller water weight	Cardinal 748E platform scale (Gravimetric)
Binder Weight	Mettler PJ8000 Digital Scale (Gravimetric)
Volatiles	Mettler PB302 Scale (AFS Procedure 2213-00-S)
LOI, % at Mold and Shakeout	Denver Instruments XE-100 Analytical Scale (AFS procedure 5100-00-S)
Metallurgical Parameters	
Pouring Temperature	Electro-Nite DT 260 (T/C Immersion Pyrometer)
Carbon/Silicon Fusion Temperature	Electro-Nite DataCast 2000 (Thermal Arrest)
Alloy Weights	Ohaus MP2 Scale
Mold Compactability	Dietert 319A Sand Squeezer (AFS Procedure 2221-00-S)
Carbon/Silicon	Electro-Nite DataCast 2000 (thermal arrest)

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

Table 2-2 Sampling and Analytical Methods

Measurement Parameter	Test Method
Port Location	EPA Method 1
Number of Traverse Points	EPA Method 1
Gas Velocity and Temperature	EPA Method 2
Gas Density and Molecular Weight	EPA Method 3a
Gas Moisture	EPA Method 4, gravimetric
HAPs Concentration	EPA Method 18, TO11
VOCs Concentration	EPA Method 18, 25A, TO11

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

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

The total mass of analyte is then divided by the weight of the casting poured to provide emissions data in pounds of analyte per ton of metal.

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

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

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

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

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

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

3.0 Test Results

The average emission results in pounds per ton of metal poured are presented in Table 3-1. The tables include the individual target compounds that comprise at least 95% of the total VOCs measured, along with the corresponding Sum of VOCs, Sum of HAPs, and Sum of POMs. The table also includes the TGOC as propane, HC as hexane, methane, and carbon dioxide.

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

Appendix B contains the detailed data including the results for all analytes measured. Table 3-2 includes the averages of the key process parameters. Detailed process data are presented in Appendix C.

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

The best, median, and worst appearing Cavity-3 castings are shown in Figures 3-4, 3-5, and 3-6 respectively.

All Cavity-3 castings are shown in Appendix C.

The ranking of casting appearance is in Table 3-3.

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

Analytes	Test FK (Lb/Tn Metal)	STDEV
TGOC as Propane	3.354	0.2052
HC as Hexane	0.4015	0.0368
Sum of VOCs	0.4294	0.0242
Sum of HAPs	0.3437	0.0201
Sum of POMs	0.0197	0.0073
Individual Organic HAPs		
Benzene	0.1450	0.0154
Toluene	0.0744	0.0036
o,m,p-Xylene	0.0506	0.0023
o,m,p-Cresol	0.0138	0.0045
Hexane	0.0128	0.0012
Naphthalene	0.0127	0.0040
Ethylbenzene	0.0084	0.0005
Phenol	0.0072	0.0017
Methylnaphthalenes	0.0060	0.0027
Other VOCs		
Trimethylbenzenes	0.0184	0.0025
Heptane	0.0122	0.0012
Octane	0.0112	0.0008
Nonane	0.0079	0.0004
Ethyltoluenes	0.0064	0.0014
Decane	0.0063	0.0009
Indene	0.0062	0.0009
Undecane	0.0051	0.0010
Cyclohexane	0.0040	0.0004
Other Analytes		
Carbon Dioxide	32.25	1.907
Methane	0.0561	0.0059

Individual results constitute >95% of mass of all detected VOCs.

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

Background Methane and Carbon Dioxide were found at 0.0545 and 33.36 Lb/Tn Metal respectively.

Table 3-2 Summary of Test Plan FK Average Process Parameters

Greensand PCS	
Test Dates	8/12/03 – 8/21/03
Cast Weight (all metal inside mold), Lbs.	100.5
Pouring Time, sec.	19
Pouring Temp ,°F	2681
Pour Hood Process Air Temp at Start of Pour, °F	87
Muller Batch Weight, Lbs.	894.91
GS Mold Sand Weight, Lbs.	648
Mold compactability, %	46
Mold Temperature, °F	84
Average Green Compression , psi	12.47
GS Compactability, %	40
GS Moisture Content, %	2.04
GS Clay Content, %	6.88
MB Clay Reagent, ml.	26.6
1800°F LOI – Mold Sand, %	5.19
900°F Volatiles , %	1.01

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

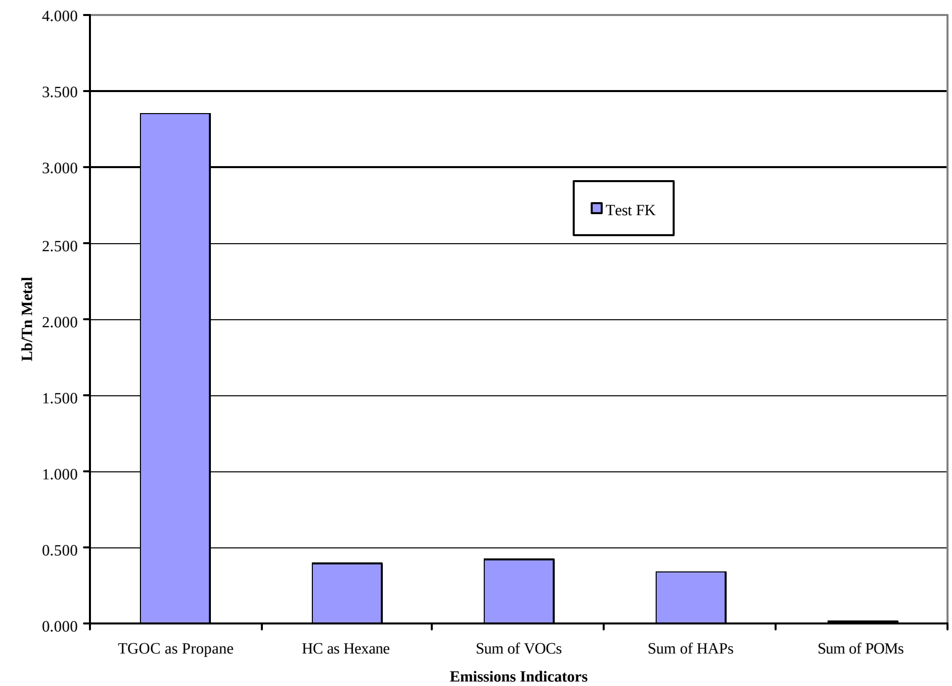


Figure 3-2 Selected HAP Emissions from Test Series FK – Lb/Tn Metal

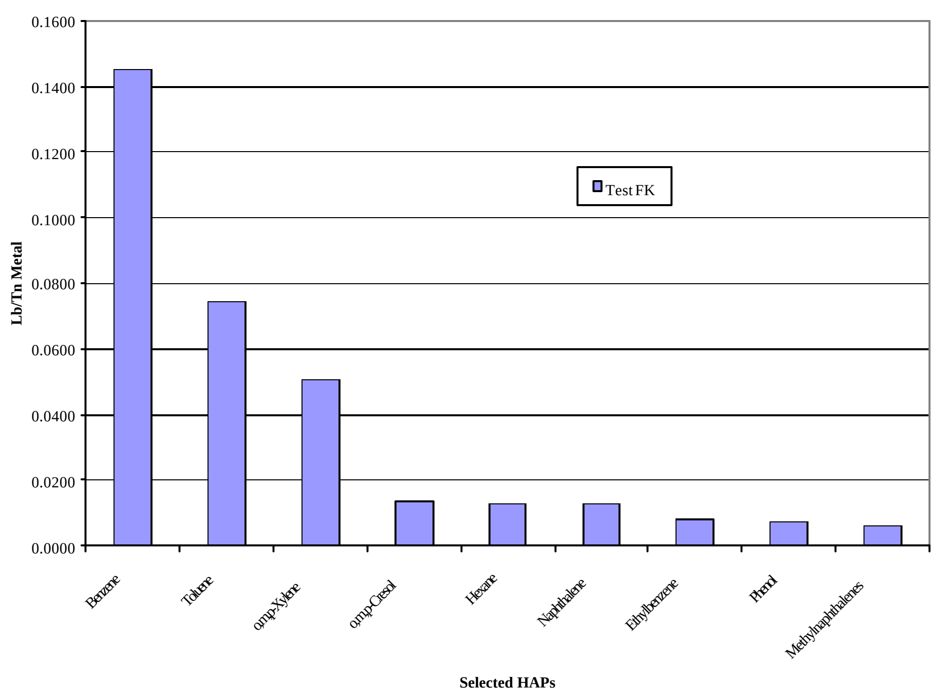


Figure 3-3 Selected VOC Emissions from Test Series FK – Lb/Tn Metal

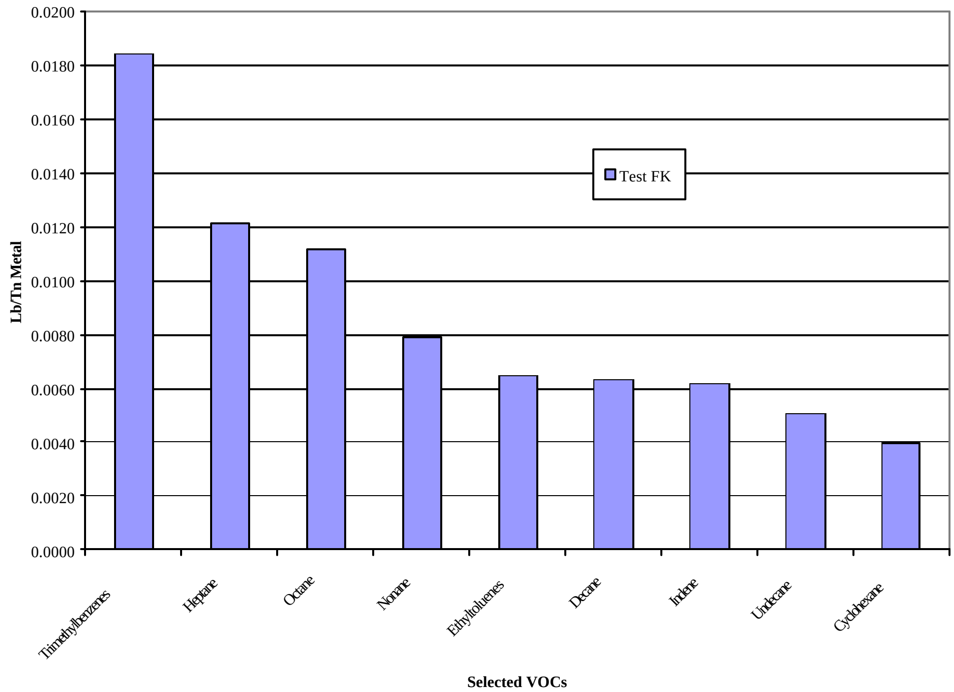


Table 3-3 Rank Order of Casting Surface Quality

FK CASTING RANK-ORDER

COPE CAVITY #	BEST				MED				WORST
1									
2									
3	FK 01	FK 02	FK 03	FK 06	FK 08	FK 05	FK 09	FK 07	FK 04
4									
RANK	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
	Photos				Photos				Photos

Numbers in the body of the table are the run number

Figure 3-4 Best Appearing Casting from Mold FN001

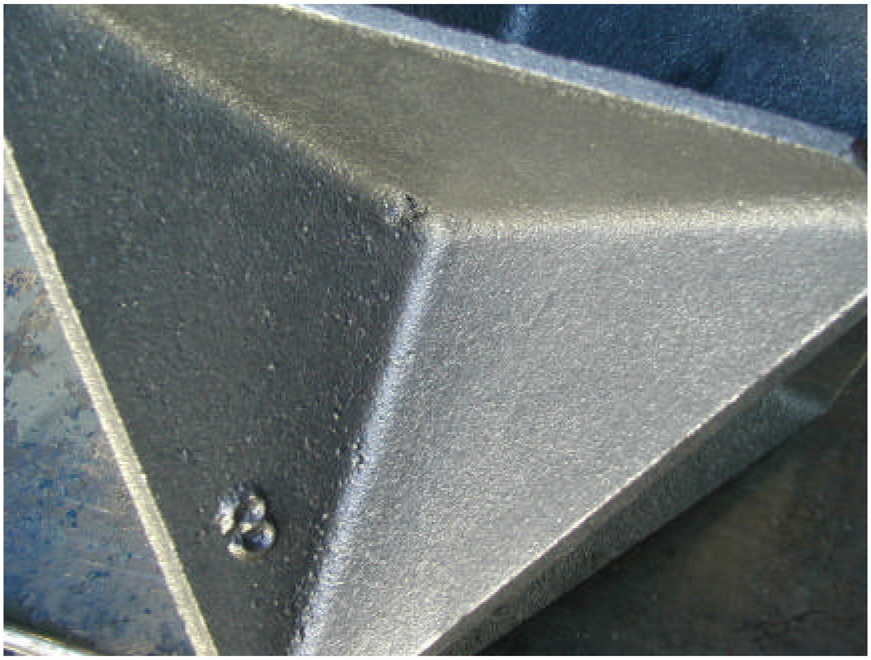


Figure 3-5 Picture of Median Appearance from Mold FN008

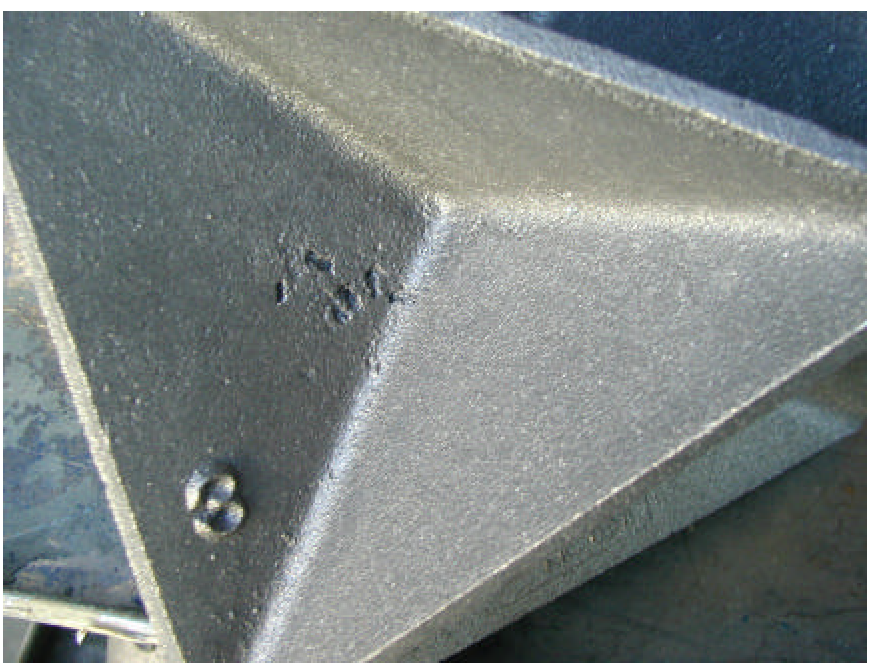
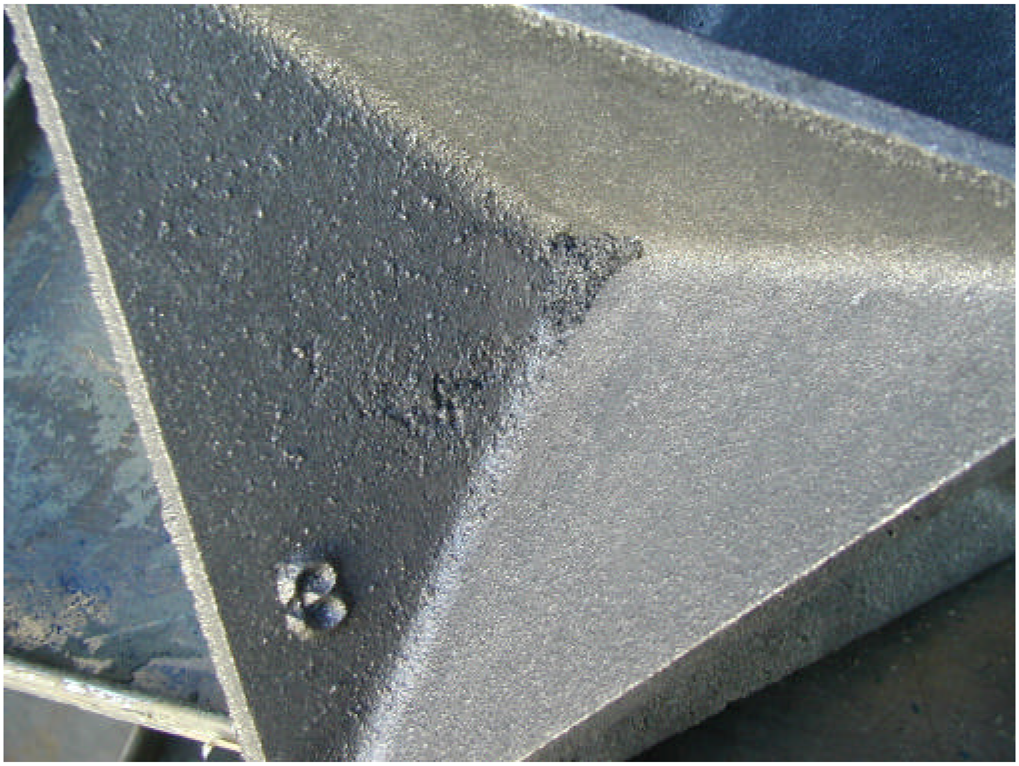


Figure 3-6 Worst Appearing Casting from Mold FN004



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4.0 Discussion of Results

Eighteen (18) of the measured compounds comprised greater than 95% of the mass of all VOCs emitted by the Greensand with seacoal baseline test series. Benzene comprised approximately 42%, toluene 22%, and o,m,p-xylene 15% of the total HAPs. Trimethylbenzenes, ethyltoluenes, and other lighter hydrocarbons together comprised approximately 18% of the total VOCs.

Carbon dioxide and methane were detected in the ambient sample for Test FK. See Table 3-1.

Two methods were employed to measure undifferentiated hydrocarbon emissions, TGOC (THC) as propane, performed in accordance with EPA Method 25A, and HC as hexane. EPA Method 25A, TGOC (as propane), is weighted to the detection of more volatile hydrocarbon species, beginning at C1 (methane), with results calibrated against a three-carbon alkane (propane). HC as hexane is weighted to the detection of relatively less volatile compounds. This method detects hydrocarbon compounds in the alkane range between C6 and C16, with results calibrated against a six-carbon alkane (hexane).

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

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

The casting surface appearance was recorded for each mold. The castings' surface quality were ranked in order of best to worst by 4 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 to be consistent with test FH wherein all cavities were rank-ordered within cavity and then the cavities were compared. In test FH cavity 3 most consistently exhibited the superior surface at each level of the rank-order. The mold FK001 cavity 3 casting was judged to have the best casting surface based on the criteria, mold FK008 cavity 3 was judged to be a median casting, and mold FK004 cavity 3 was judged to have the worst casting surface.

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APPENDIX A APPROVED TEST PLAN AND SAMPLE PLAN FOR TEST SERIES FK

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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 45minutes followed 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.

Process Engineering Manager (Technikon)	Date
V.P. Measurement Technology (Technikon)	Date
V.P. Operations (Technikon)	Date
Test Design Committee Representative	Date
Emission Committee Representative	Date

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.

5. The following test shall be conducted:

   a. Sand batch: Single sand batch to be used for all FK molds.
   b. The recycled sand heap shall be maintained at 900+-10 pounds
   c. The first three (3) runs will be conditioning runs numbered FKCD1-3 and will be monitored by THC only.
   d. Emission sampling will begin on the 4th tern. 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.
   e. The shop supervisor and the sampling team technician will coordinate the numbering between the two groups.
   f. FKCD1: Virgin mix as described above, un-vented mold.
   g. FKCD2, FKCD3, FK001-FK0XX: Re-cycled, re-mulled, reconstituted greensand**,** potable water, un-vented molds.

B. 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^{o}F loss on ignition (LOI), and 900^{o}F 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 B.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 B.1.f.

C. 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 bypass 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 operator's 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.
q. 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.
r. Close the cope over the drag being careful not to crush anything.

- **s.** Clamp the flask halves together.
- **t.** Weigh and record the weight of the closed un-poured mold, the pre-weighed flask, and the sand weight by difference
- **u.** Deliver the mold to the previously cleaned shakeout to be poured.
- **v.** Cover the mold with the emission hood.

D. 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 competed 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.

E. 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.

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.

F. Pouring:

1. Preheat the ladle.

- **a.** Tap 400 pounds more or less of 2700°F metal into the cold ladle.
- **b.** Casually pour the metal back to the furnace.
- **c.** Cover the ladle.
- **d.** Reheat the metal to 2780 +/- 20°F.
- **e.** Tap 450 pounds of iron into the ladle while pouring inoculating alloys onto the metal stream near its base.
- **f.** Cover the ladle to conserve heat.
- **g.** Move the ladle to the pour position, and wait until the metal temperature reaches 2680 +/- 10°F.
- **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											**FJ 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											**FJ 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											**FJ 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

APPENDIX B TEST SERIES FK DETAILED EMISSION RESULTS

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Test Plan FK Individual Emission 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 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 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 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 Emission 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		
		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 Emission 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**		
		Other Analytes											
		Carbon Dioxide	3.47E+01	3.26E+01	3.25E+01	3.35E+01	2.86E+01	3.09E+01	3.40E+01	3.06E+01	3.27E+01	3.22E+01	1.91E+00
		Methane	4.41E-02	5.64E-02	5.92E-02	5.77E-02	5.74E-02	4.90E-02	6.03E-02	5.86E-02	6.26E-02	5.61E-02	5.86E-03
		Carbon Monoxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	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

APPENDIX C TEST SERIES FK DETAILED PROCESS DATA

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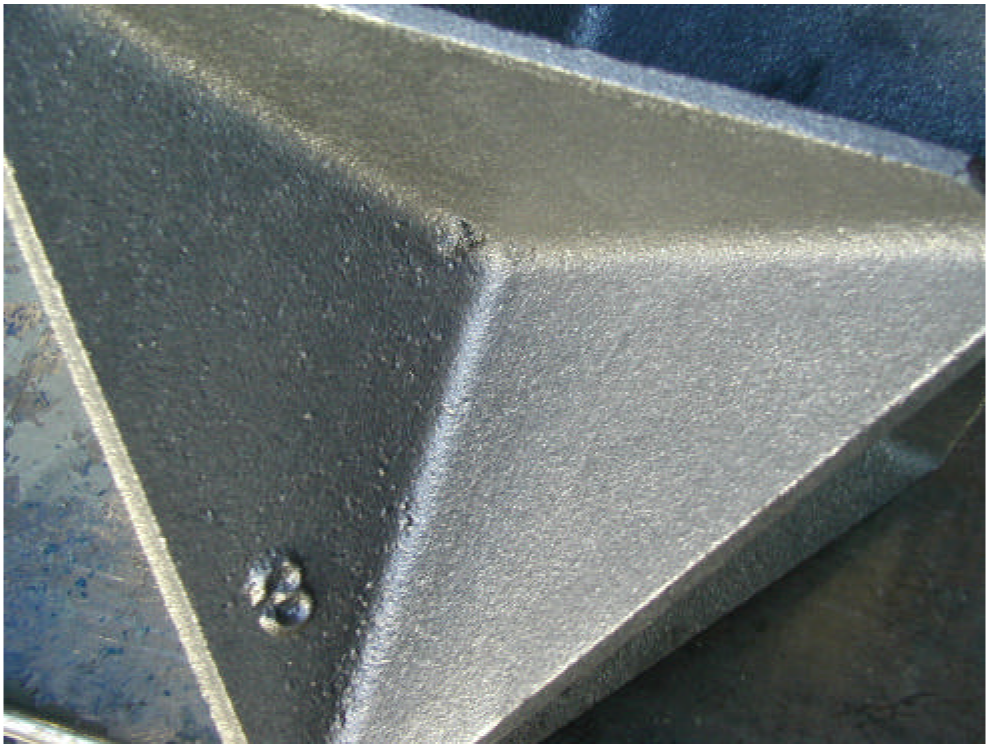
Test FK Detailed Process Data

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**

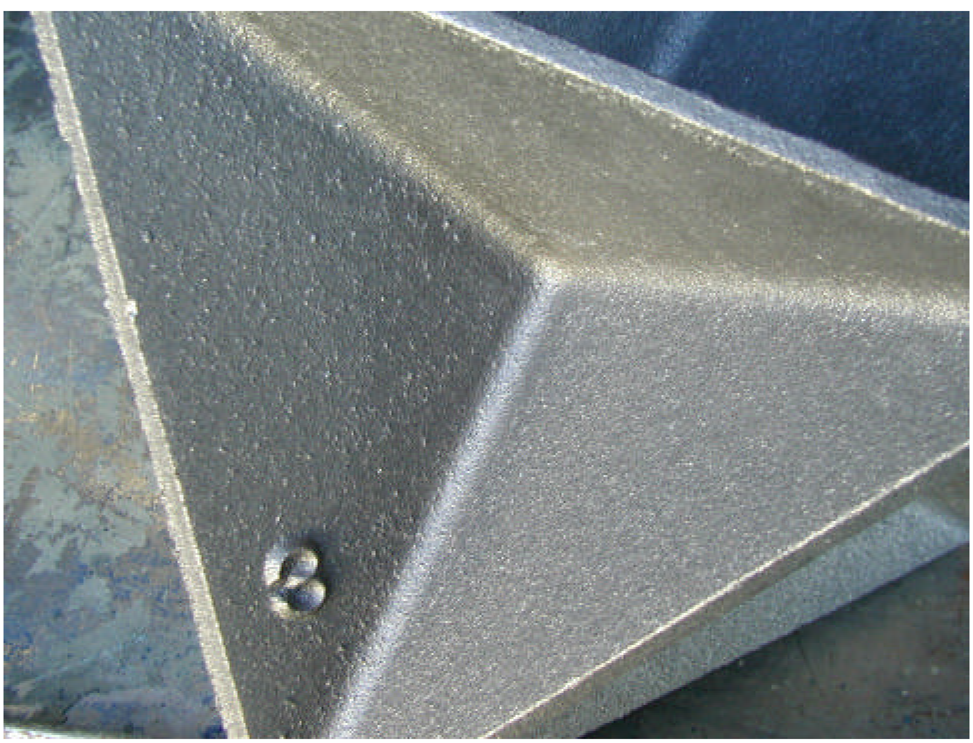
Note 1: The procedure for accumulating return sand components had not been strictly adhered to, so all sand materials were gathered together and reblended to maintain constitutional integrity.

Note 2: Average of all muller batch weights except FK004. See Note 1.

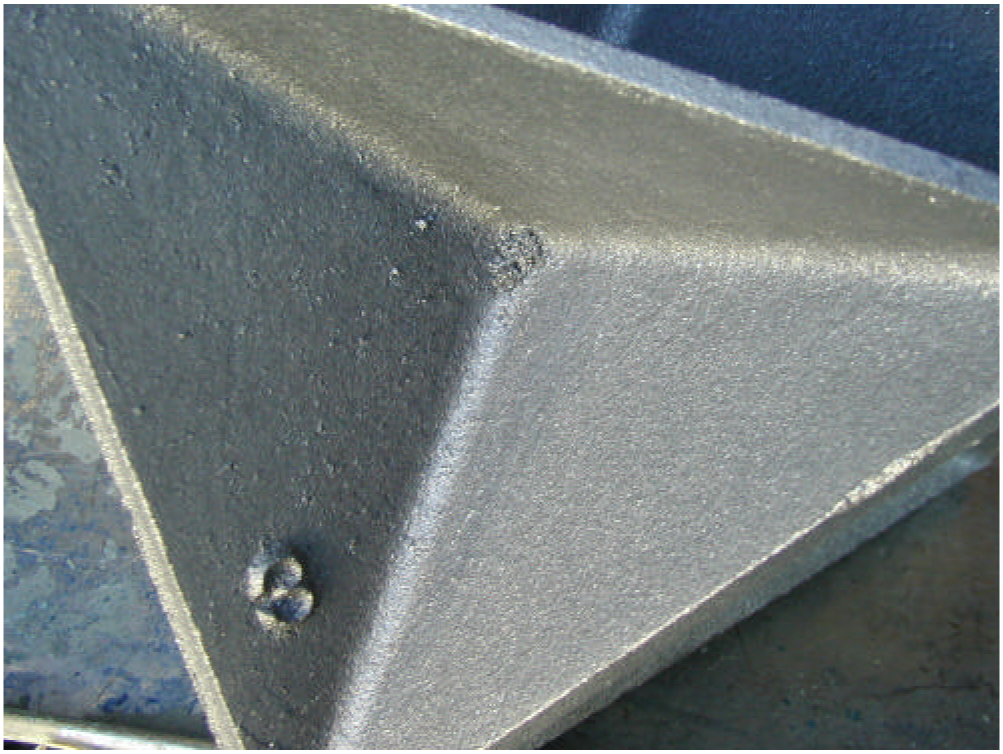
Picture C1 Mold FN001 cavity 3 casting ranked 1 of 9.



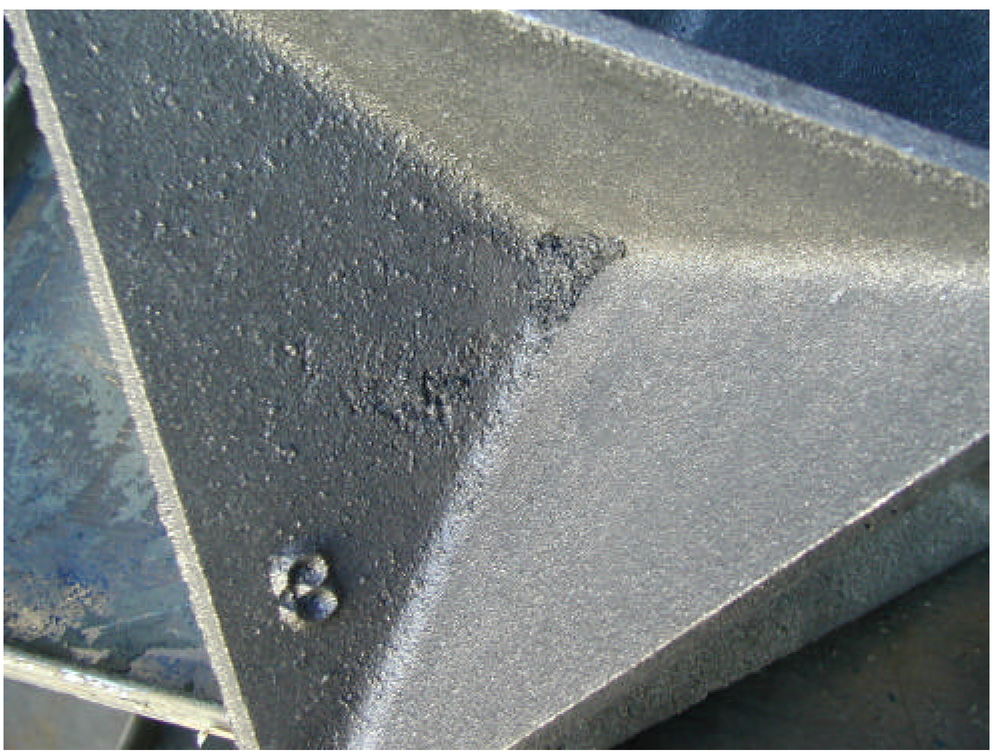
Picture C2 Mold FN002 cavity 3 casting ranked 2 0f 9.



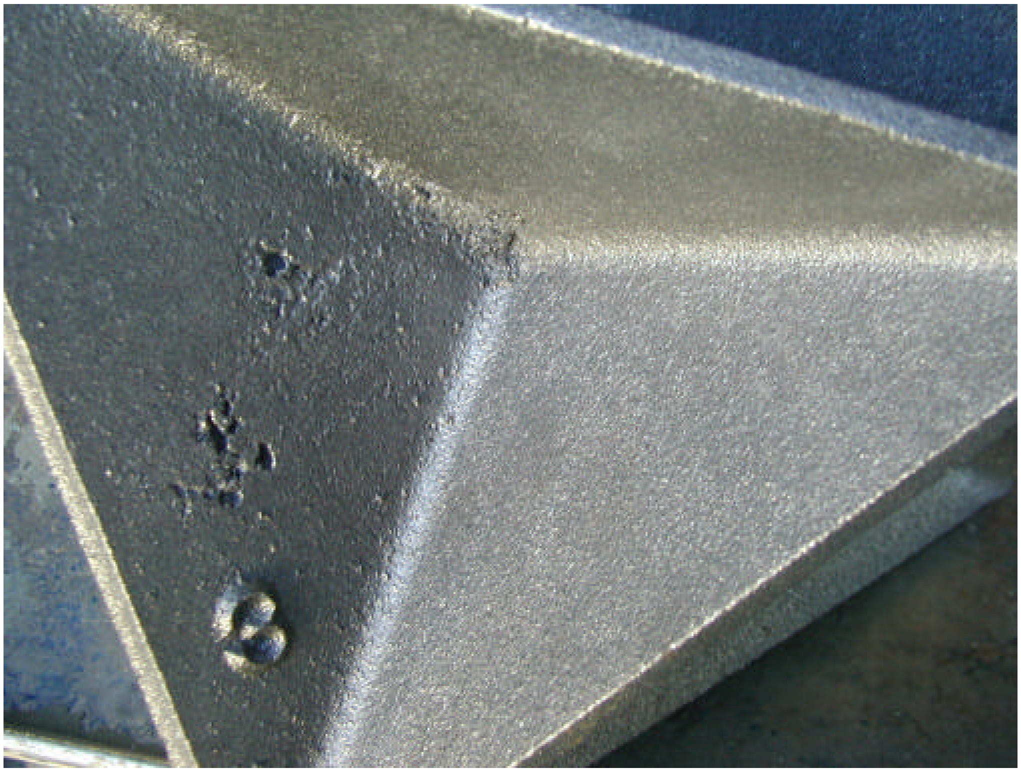
Picture C3 Mold FN003 cavity 3 casting ranked 3 of 9



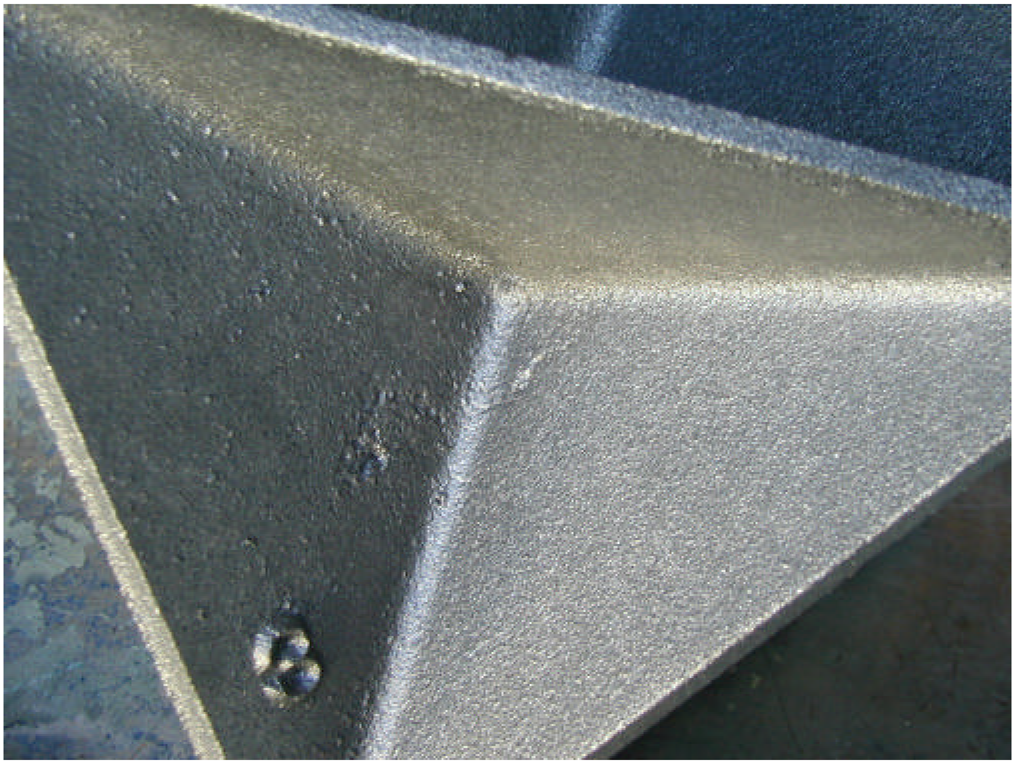
Picture C4 Mold FN004 cavity 3 casting ranked 9 of 9



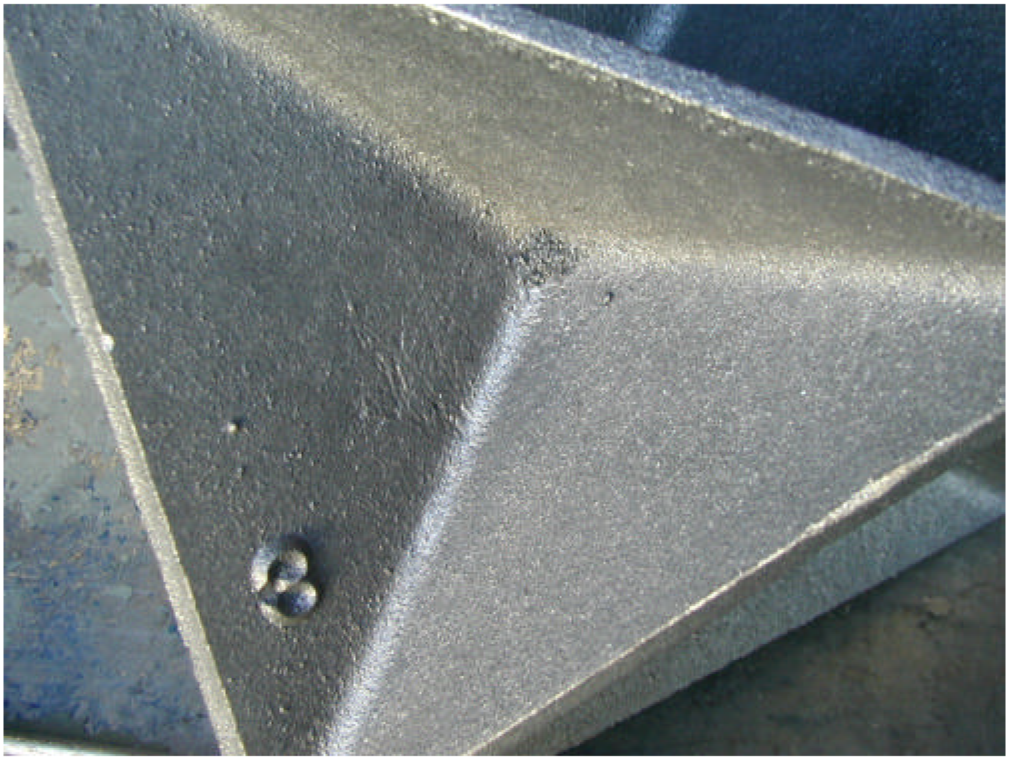
Picture C5 Mold FN005 cavity 3 casting ranked 6 of 9



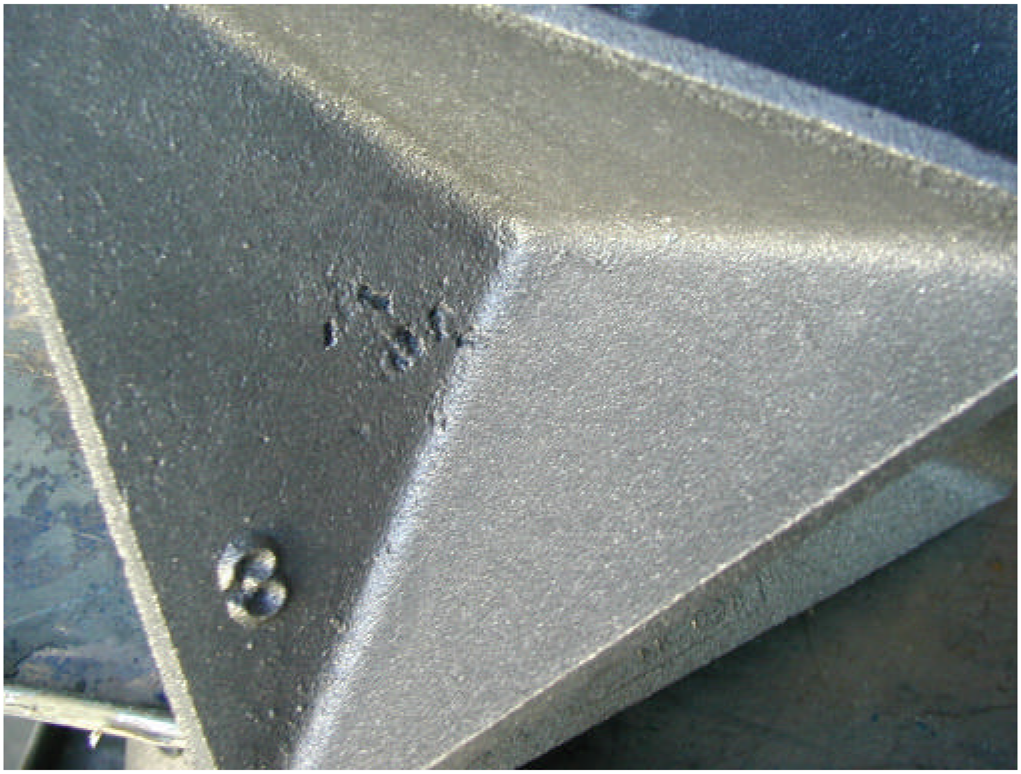
Picture C6 Mold FN006 cavity 3 casting ranked 4 of 9



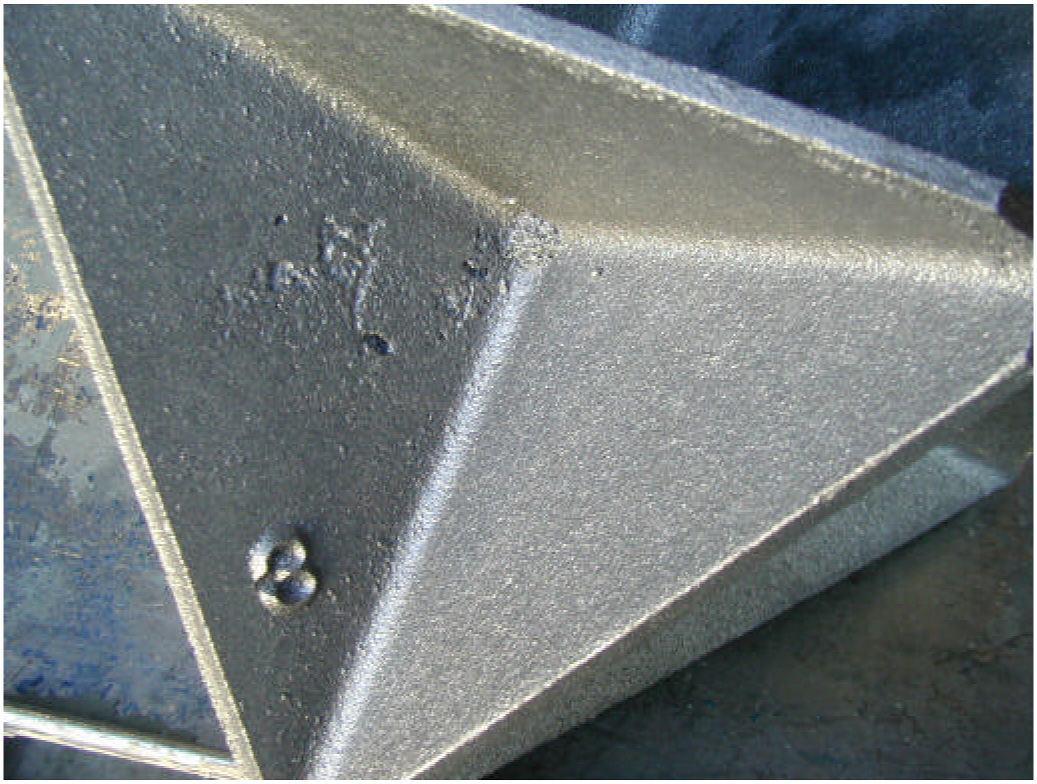
Picture C7 Mold FN007 cavity 3 casting ranked 8 of 9



Picture C8 Mold FN008 cavity 3 casting ranked 5 0f 9



Picture C9 Mold FN009 cavity 3 casting ranked 7 of 9



APPENDIX D METHOD 25A CHARTS

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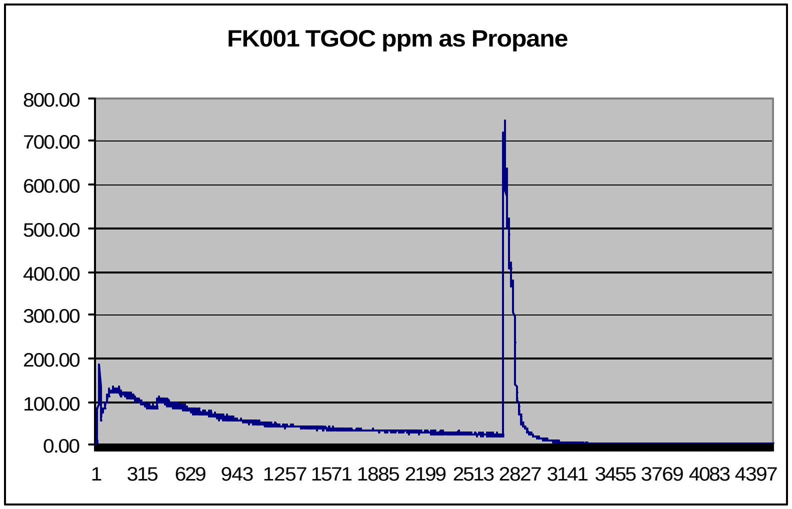
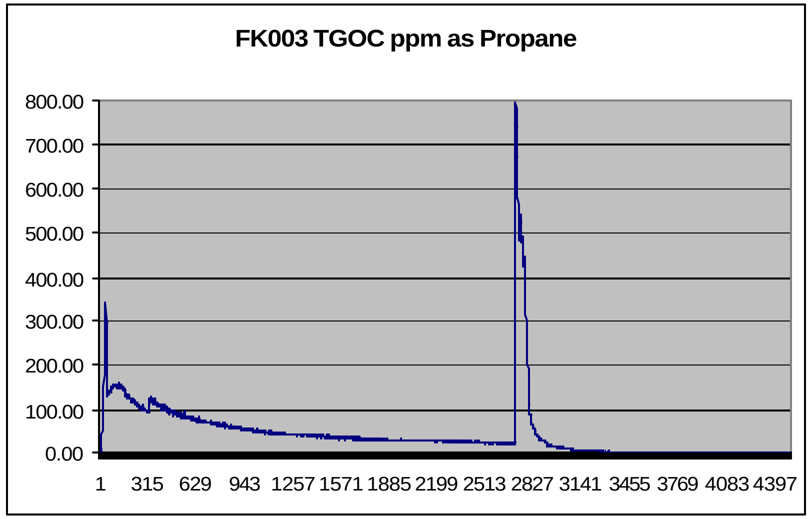
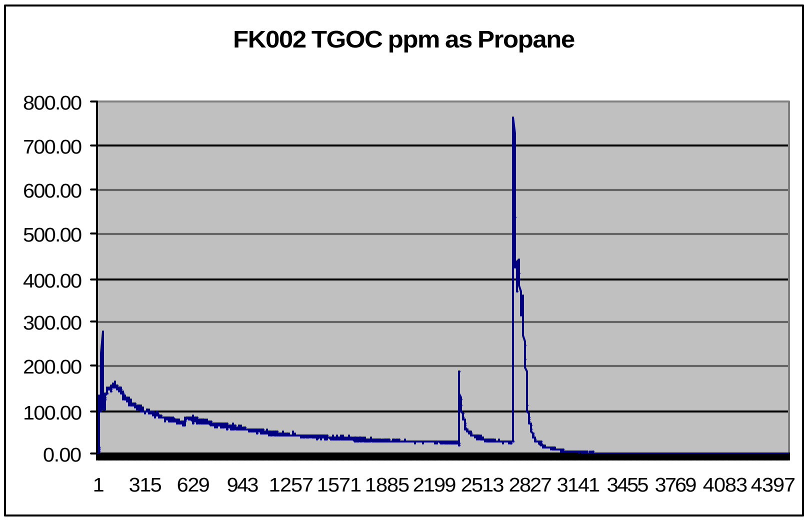
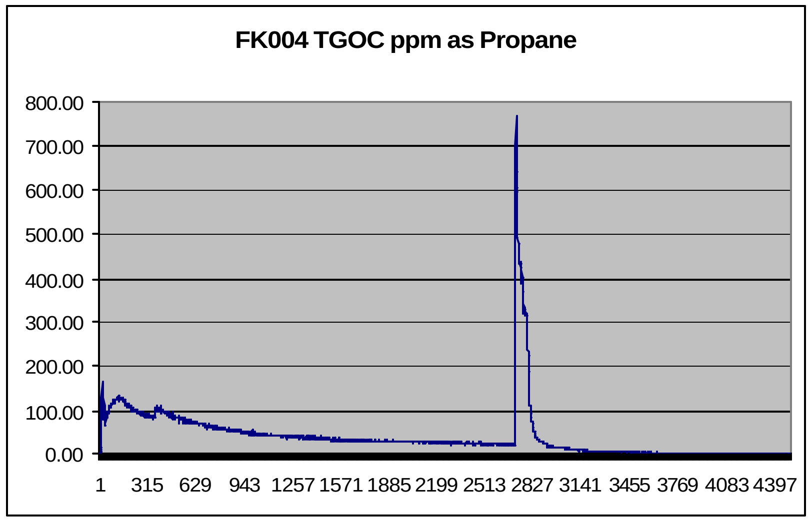
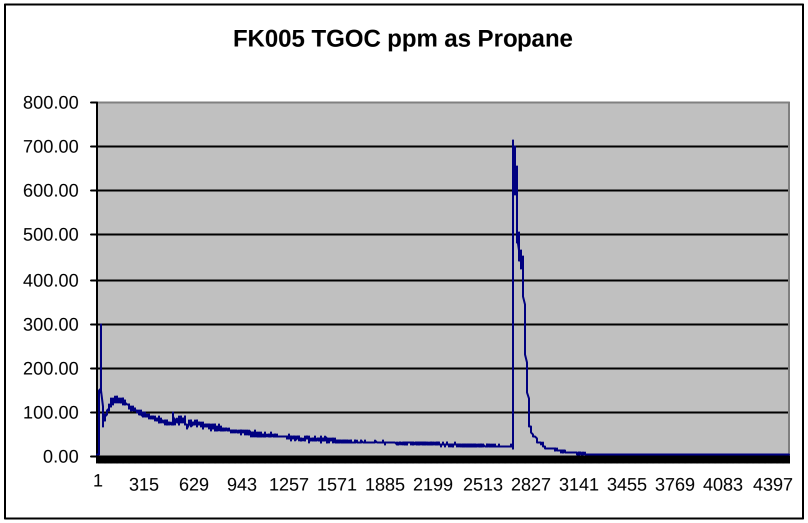
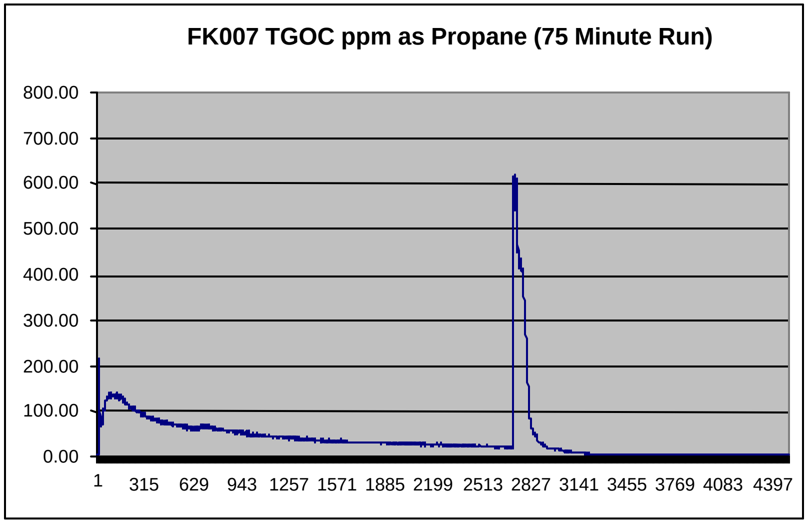

FK001 TGOC ppm as Propane
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
1 315 629 943 1257 1571 1885 2199 2513 2827 3141 3455 3769 4083 4397

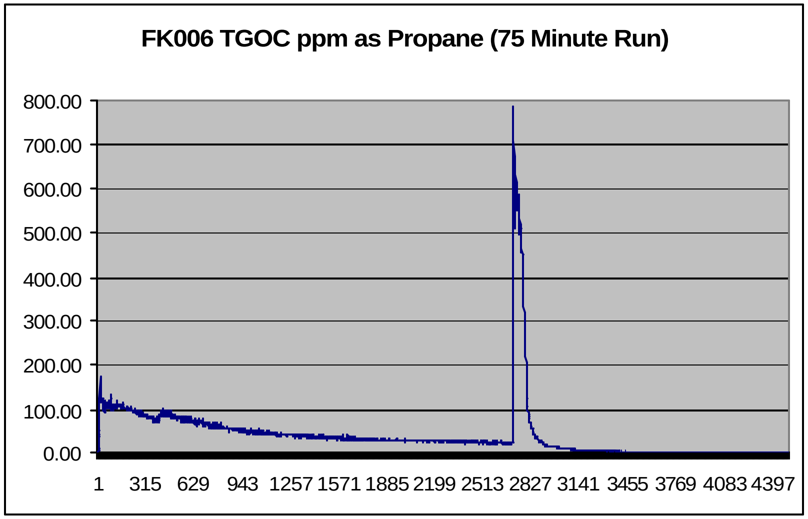

FK003 TGOC ppm as Propane
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
1 315 629 943 1257 1571 1885 2199 2513 2827 3141 3455 3769 4083 4397

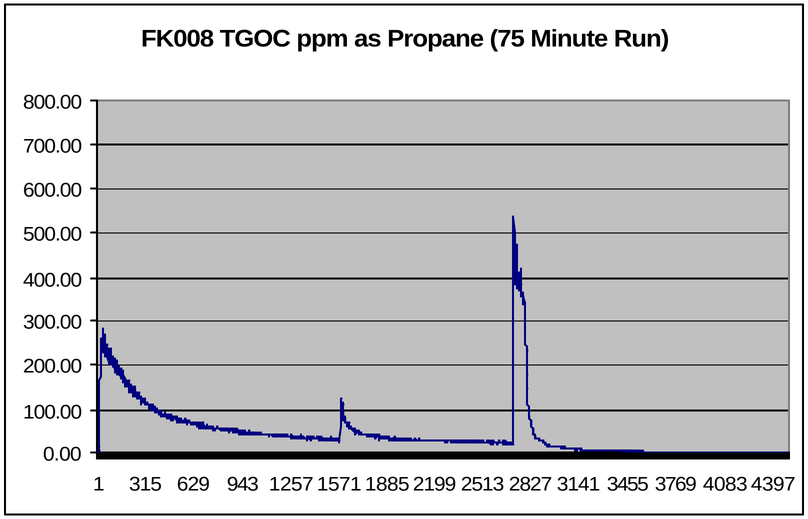

FK002 TGOC ppm as Propane
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
1 315 629 943 1257 1571 1885 2199 2513 2827 3141 3455 3769 4083 4397

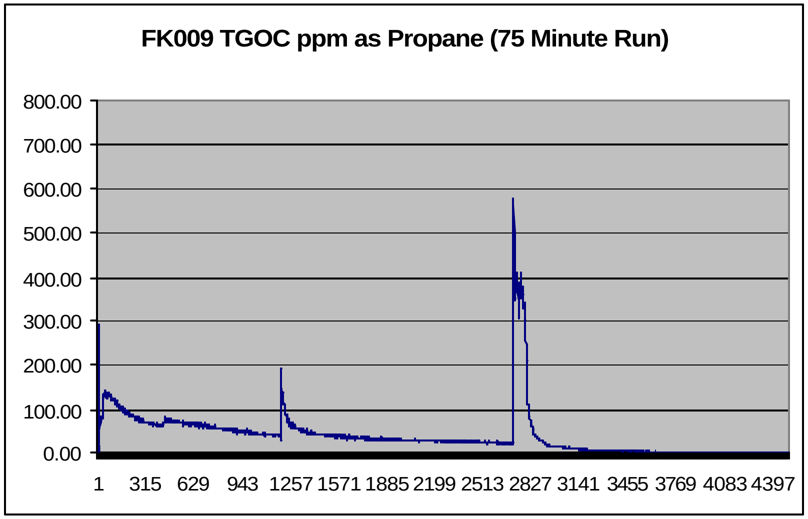

FK004 TGOC ppm as Propane
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
1 315 629 943 1257 1571 1885 2199 2513 2827 3141 3455 3769 4083 4397


FK005 TGOC ppm as Propane
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
1 315 629 943 1257 1571 1885 2199 2513 2827 3141 3455 3769 4083 4397


FK007 TGOC ppm as Propane (75 Minute Run)
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
1 315 629 943 1257 1571 1885 2199 2513 2827 3141 3455 3769 4083 4397


FK006 TGOC ppm as Propane (75 Minute Run)
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
1 315 629 943 1257 1571 1885 2199 2513 2827 3141 3455 3769 4083 4397


FK008 TGOC ppm as Propane (75 Minute Run)
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
1 315 629 943 1257 1571 1885 2199 2513 2827 3141 3455 3769 4083 4397


FK009 TGOC ppm as Propane (75 Minute Run)
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
1
315
629
943
1257
1571
1885
2199
2513
2827
3141
3455
3769
4083
4397

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APPENDIX E GLOSSARY

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Glossary

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