Casting Emission Reduction Program
www.cerp-us.org

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

US Army Contract DAAE30-02-C-1095
FY2004 Tasks
WBS # 1.1.5

Vendor Product Test: HA and OSCO Shell Mold - Pouring, Cooling and Shakeout

Technikon # 1411-115 GN

November 2005
(Revisd for public distribution.)

United States Environmental Protection Agency

CISA

AFS American Foundry Society, Inc.

UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH
USCAR
DaimlerChrysler Ford Motor Company General Motors

this page intentionally left blank

Vendor Product Test: HA and OSCO Shell Mold - Pouring, Cooling and Shakeout

Technikon # 1411-115 GN

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 R. 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 reference process profile. You may not obtain the same results in your facility. Data were not collected to assess casting quality, cost, or producibility.

this page intentionally left blank

Table of Contents

Figures and Tables

Appendices

Executive Summary

This report contains the results of emission testing to evaluate the pouring, cooling, and shakeout emissions from Test GN, a coreless 6-cavity shell sand mold. Test GN compares an OSCO Industries low emission shell sand resin formulation to HA International Super F2-E/J19P12689W shell sand formulation using the same pattern. All molds were made by OSCO Industries. 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 sand; 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 fifty-six (56) target compounds for both HA and OSCO tests using procedures based on regulatory methods, including those of US EPA. Continuous monitoring of the Total Gaseous Organic Concentration (TGOC), carbon dioxide (CO_2), carbon monoxide (CO), and nitrogen oxide (NOx) concentrations in the emissions were conducted according to US EPA Methods 25A, 3A, 10, and 7E respectively.

Mass emission rates for all analytes were calculated using continuous monitoring data, laboratory analytical results, measured source data and appropriate process data. Results are presented in detail in Appendix B. Individual analyte emissions were calculated in addition to five emission indicators. These indicators include TGOC as propane, hydrocarbons (HC) as hexane, the sum of target volatile organic compounds (VOCs), the sum of target hazardous air pollutants (HAPs), and the sum of target polycyclic organic matter (POM). Detailed descriptions of these indicators can be found in the Results section of this report.

.

Results comparing emission indicators for both HA and OSCO tests are shown in Table 1 reported as lbs/tn of metal.

Table 1 GN Average Emissions Indicators Summary Table - Lb/Tn Metal

Analyte Name	HA Binder	OSCO Binder	Percent Difference
TGOC as Propane	1.6320	1.4045	-14%
HC as Hexane	0.5607	0.4718	-16%
Sum of Target VOCs	0.5730	0.7705	34%
Sum of Target HAPs	0.5126	0.4378	-15%
Sum of Target POMs	0.0191	0.0252	32%

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

1.0 INTRODUCTION

1.1. Background

Technikon LLC is a privately held contract research organization located in McClellan, California, a suburb of Sacramento. Technikon offers emissions research services to industrial and government clients specializing in the metal casting and mobile emissions areas. Technikon operates the Casting Emission Reduction Program (CERP). CERP is a cooperative initiative between the Department of Defense (US Army) and the United States Council for Automotive Research (USCAR). The parties to the CERP Cooperative Research and Development Agreement (CRADA) include The Environmental Research Consortium (ERC), a Michigan partnership of DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation; the U.S. Army Research, Development, and Engineering Command (RDECOM-ARDEC), 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. All published reports are available on the CERP web site at www.cerp-us.org.

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 the pouring, cooling and shakeout emissions from 2 (two) different shell sand formulations. 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 the appendices 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.

1.3.1. 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

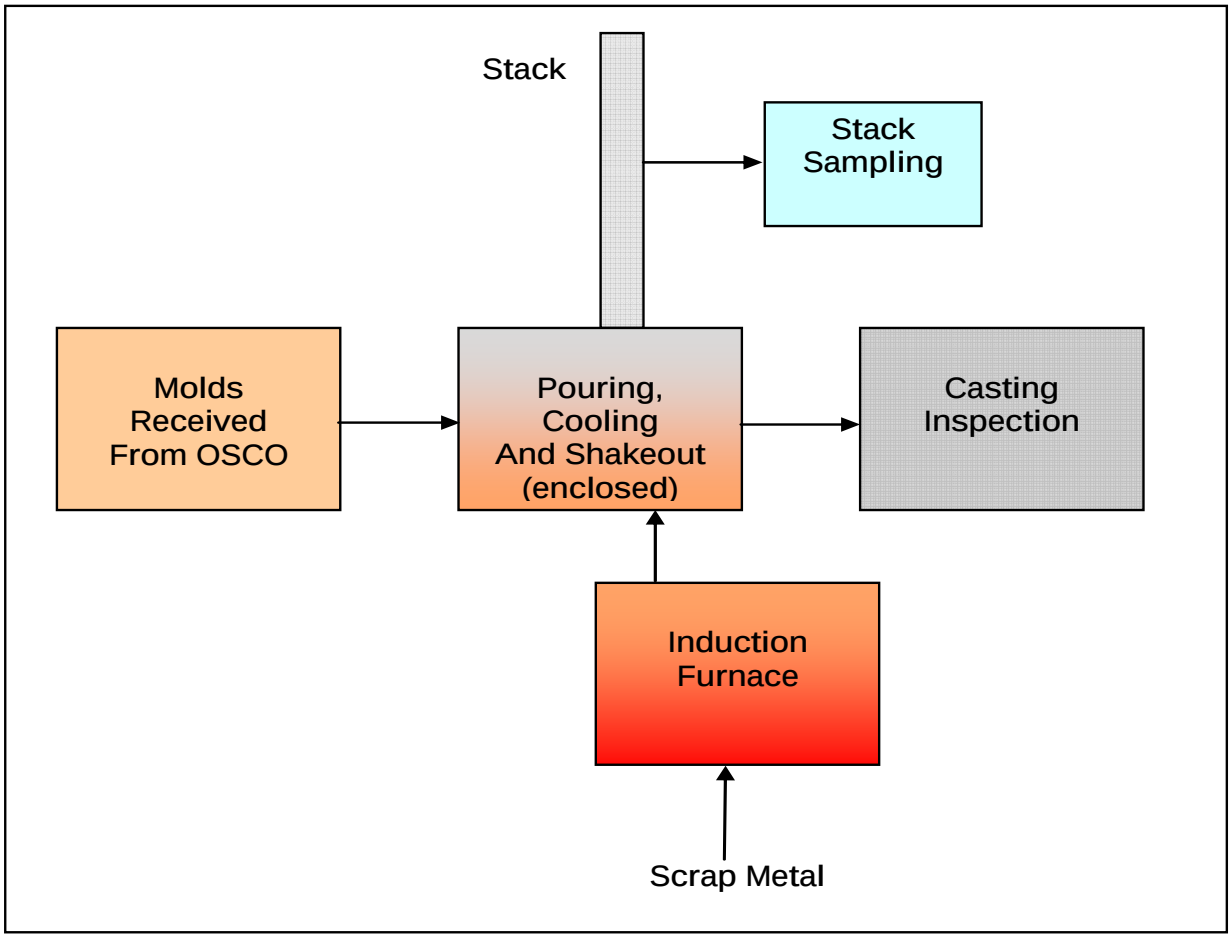
	Baseline Test Plan GN
Type of Process tested	Shell Mold, Iron, PCS
Test Plan Number	1411 115 GN
Metal Poured	Iron
Casting Type	6-Cavity Shell mold
Mold	HA Super F2 E/J19P12689W Pre-Coated Shell Sand & OSCO "Low Emission" Shell Sand.
Core Coating	None
Number of Molds Poured	Sample 6 Mold HA, 5 Molds OSCO, Total of 11 Molds.
Test Dates	3/28/05 through 3/31/05
Emissions Measured	56 Analytes and TGOC as Propane, CO,CO_2,NO_x
Process Parameters Measured	Total Casting, Mold Weights; Metallurgical data, % LOI; Stack Temperature, Moisture Content, Air Volumetric Flow Rate, Temperature, and Pressure

2.0 TEST METHODOLOGY

2.1. Description of Process and Testing Equipment

Figure 2-1 is a flow chart of this test process.

Figure 2-1 Foundry Layout Diagram



2.2. Description of Testing Program

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

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

2. **Mold and Metal Preparation:** Shell molds of the same geometry prepared from the two test materials were provided by an outside foundry. Each mold was placed on a bed of new silica sand in a tray for pouring (Figure 2-2). Relevant process data were collected and recorded. Iron was melted in a 1000 lb. Ajax induction furnace. The amount of metal melted was determined from the poured weight of the casting and the number of molds to be poured. The metal composition was Class-30 Gray Iron as prescribed by a metal composition worksheet. The weight of metal poured into each mold was recorded on the process data summary sheet.

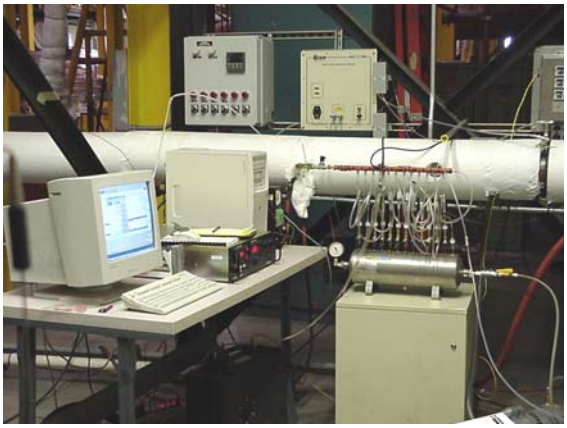
3. **Individual Sampling Events**: Replicate tests were performed on six (6) mold packages made using HA resin, and five mold packages made using OSCO resin. Prior to pouring, the mold packages were placed into an enclosed test stand heated to approximately 85°F. The flow rate of the emission capture air was nominally 300 scfm. Iron was poured through an opening in the top of the emission enclosure, after which the opening was closed (Figure 2-3).

   Emissions were monitored during the 60 minute pouring and cooling process, during the five minute shakeout of the mold, and for an additional ten minute period following shakeout. The total sampling time was seventy-five minutes (Figure 2-4).

Figure 2-2 Six-Cavity Shell Mold in Emission Hood

Figure 2-3 Total Enclosure Test Stand

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
Shell Mold Weight	Ohaus MP2 Scale
Casting weight	Ohaus MP2 Scale
LOI, % Shell Mold before pour	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
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	US EPA Method 1
Number of Traverse Points	US EPA Method 1
Gas Velocity and Temperature	US EPA Method 2
Gas Density and Molecular Weight	US EPA Method 3a
Gas Moisture	US EPA Method 4, Gravimetric
Target VOCs and HAPs	US EPA TO17, TO11, NIOSH 1500, 2002
Ammonia	NIOSH 6016
TGOC	US EPA Method 25A
CO	US EPA Method 10
CO_2	US EPA Method 3A
NO_x	US EPA Method 7E

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 or weight of binder 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 through 3-3.

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" publication. 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 of Process Engineering and the Vice President of 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 Vice President of 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 Tables 3-1 through 3-3. These tables include for both sample sets the individual target compounds that comprise at least 95% of the total VOCs measured, along with the corresponding Sum of Target VOCs, Sum of Target HAPs, and Sum of Target POMs. Also included are TGOC as propane, HC as hexane, and averages for carbon monoxide, carbon dioxide, and oxides of nitrogen.

CO, CO_2 NOx and TGOC as propane are all averaged over the 75 minute testing period. The average value is than background corrected and reported in the tables. Real time continuous monitoring charts are not background corrected.

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. All other isomers are 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 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 and are presented in these tables. The emissions indicator called the Sum of Target VOCs is the sum of all the individual target VOCs detected and includes targeted HAPs and POMs. 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 3-4 present a graphical comparison between the two binder systems using the five emissions indicators and selected individual HAP, VOC, criteria pollutant and greenhouse gas emissions data from Tables 3-1 and 3-2 .

Table 3-4 includes the summary of the key process parameters.

Appendix B contains detailed emissions data for all targeted analytes for both HA and OSCO binder tests.

Appendix C contains detailed process data.

Method 25A charts for the tests are included in Appendix D of this report. The charts presented show TGOC, carbon monoxide, carbon dioxide, and oxides of nitrogen emission time profiles for each pour.

Table 3-1 Summary of Test GN Average Results, Lb/Tn Metal - Osco Binder

Analyte Name	Average	Standard Deviation
Emission Indicators		
TGOC as Propane	1.4045	0.2765
HC as Hexane	0.4718	0.0411
Sum of Target VOCs	0.4957	0.1950
Sum of Target HAPs	0.4378	0.1784
Sum of Target POMs	0.0252	0.0107
Individual Target HAPs		
Phenol	0.1412	0.0300
Benzene	0.1179	0.0192
Cresols	0.0484	0.0328
Toluene	0.0366	0.0088
Formaldehyde	0.0233	0.0016
Xylenes	0.0188	0.0041
Naphthalene	0.0101	0.0022
Acetaldehyde	0.0097	0.0010
Hexane	0.0062	0.0009
Other Target VOCs		
Dimethylphenols	0.0216	0.0076
Hexaldehyde	0.0073	0.0005
Indene	0.0061	0.0012
Heptane	0.0057	0.0008
Dimethylnaphthalenes	0.0049	0.0031
Octane	0.0048	0.0006
Pentanal (Valeraldehyde)	0.0046	0.0004
Butyraldehyde/Methacrolein	0.0037	0.0003
Criteria Pollutants, Greenhouse Gases and Other Analytes		
Ammonia	0.2748	0.0562
Carbon Dioxide	68.7912	3.4479
Carbon Monoxide	9.3828	0.1367
Nitrogen Oxides	0.1624	0.0063

Individual results constitute >95% of mass of all detected target analytes.
NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

Table 3-2 Summary of Test GN Average Results, Lb/Tn Metal – HA Binder

Analyte Name	Average	Standard Deviation
Emission Indicators		
TGOC as Propane	1.63202	0.18764
HC as Hexane	0.56068	0.05327
Sum of Target VOCs	0.57302	0.14281
Sum of Target HAPs	0.51261	0.13201
Sum of Target POMs	0.01915	0.00504
Individual Target HAPs		
Phenol	0.20669	0.05525
Benzene	0.11135	0.03428
Cresols	0.06342	0.01745
Toluene	0.03903	0.01176
Xylenes	0.02080	0.00636
Formaldehyde	0.01999	0.00205
Acetaldehyde	0.01211	0.00158
Naphthalene	0.00905	0.00255
Hexane	0.00669	0.00184
Other Target VOCs		
Indene	0.00624	0.00159
Heptane	0.00617	0.00166
Hexaldehyde	0.00612	0.00046
Octane	0.00519	0.00130
Butyraldehyde/Methacrolein	0.00458	0.00040
Pentanal (Valeraldehyde)	0.00427	0.00041
Benzaldehyde	0.00360	0.00028
Dimethylphenols	0.01723	0.00563
Criteria Pollutants, Greenhouse Gases and Other Analytes		
Carbon Monoxide	12.2216	1.0872
Carbon Dioxide	71.4744	2.1085
Nitrogen Oxides	0.1847	0.0094
Ammonia	0.2654	0.0482

Individual results constitute >95% of mass of all detected target analytes.
NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

Table 3-3 Comparison of Lb/Tn Values for Osco Binder to HA Binder

Analyte Name	HA Binder	OSCO Binder	Percent Difference
Emission Indicators			
TGOC as Propane	1.6320	1.4045	-14%
HC as Hexane	0.5607	0.4718	-16%
Sum of Target VOCs	0.5730	0.4957	-13%
Sum of Target HAPs	0.5126	0.4378	-15%
Sum of Target POMs	0.0191	0.0252	32%
Individual Target HAPs			
Phenol	0.2067	0.1412	-32%
Benzene	0.1113	0.1179	6%
Cresols	0.0634	0.0484	-24%
Toluene	0.0390	0.0366	-6%
Formaldehyde	0.0200	0.0233	16%
Xylenes	0.0208	0.0188	-10%
Naphthalene	0.0090	0.0101	11%
Acetaldehyde	0.0121	0.0097	-20%
Hexane	0.0067	0.0062	-8%
Dimethylnaphthalenes	—	0.0049	NA
Other Target VOCs			
Indene	0.0062	0.0061	-3%
Dimethylphenols	0.0172	0.0216	25%
Heptane	0.0062	0.0057	-7%
Hexaldehyde	0.0061	0.0073	20%
Octane	0.0052	0.0048	-7%
Butyraldehyde/Methacrolein	0.0046	0.0037	-19%
Pentanal (Valeraldehyde)	0.0043	0.0046	8%
Benzaldehyde	0.0036	—	NA
Criteria Pollutants, Greenhouse Gases and Other Analytes			
Ammonia	0.2654	0.27478	4%
Carbon Dioxide	71.4744	68.7912	-4%
Carbon Monoxide	12.2216	9.3828	-23%
Nitrogen Oxides	0.1847	0.1624	-12%

Individual results constitute >95% of mass of all detected target analytes.
NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

Table 3-4 GN Summary of Process Parameters

Greensand PCS	HA Super F2	Osco Reclaimed
Test Dates	3/28-30/05	3/30-31/05
Emissions Sample #	GN001-006	GN020-024
Production Sample #	GN001-006	GN007-011
Cast Weight (all metal inside mold), Lbs.	43.72	44
Pouring Time, sec.	18	17
Pouring Temp ,°F	2632	2635.00
Pour Hood Process Air Temp at Start of Pour, °F	86	88
Total Shell Mold Weight, Lbs.	30.57	31.51
Reported Core Binder Content, %BOS	4.75	3.85
Core Binder Calculated Resin Content , %	4.53	3.71
Total Binder Weight in Mold, Lbs.	1.39	1.17
Weight of Mold Remaining as Core Butts, Lbs	8.7	5.0
Shell Mold LOI, %	5.12	4.98
Approximate Shell Mold Age, Days	11	13

Figure 3-1 Comparison of Emission Indicators from Binders Used in Test GN – Lb/Tn Metal

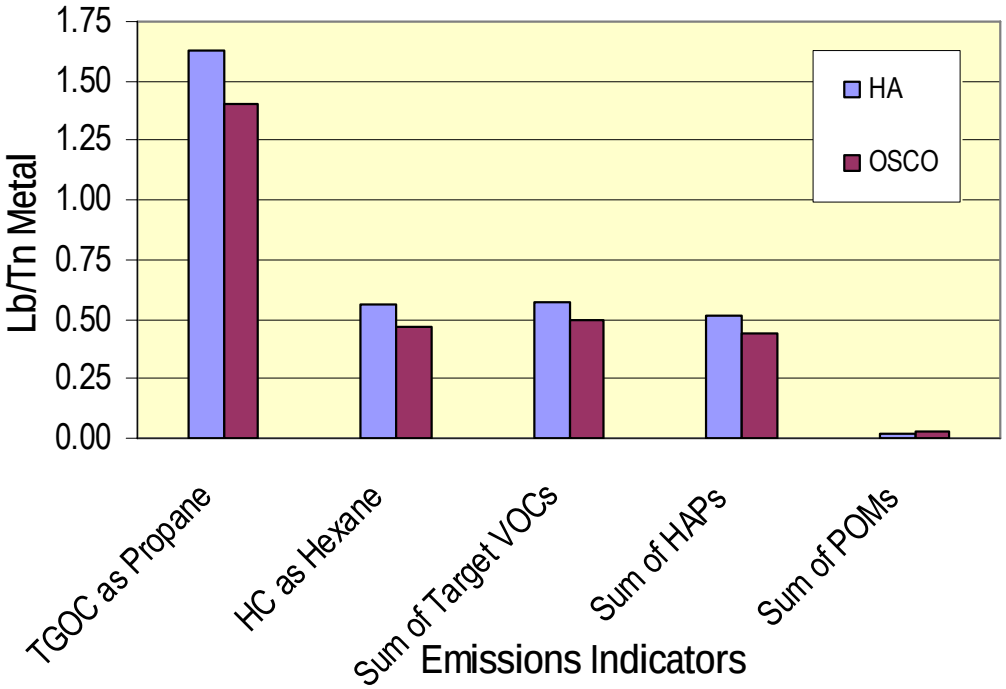


Figure 3-2 Comparison of Target HAPs from Binders Used in Test GN – Lb/Tn Metal

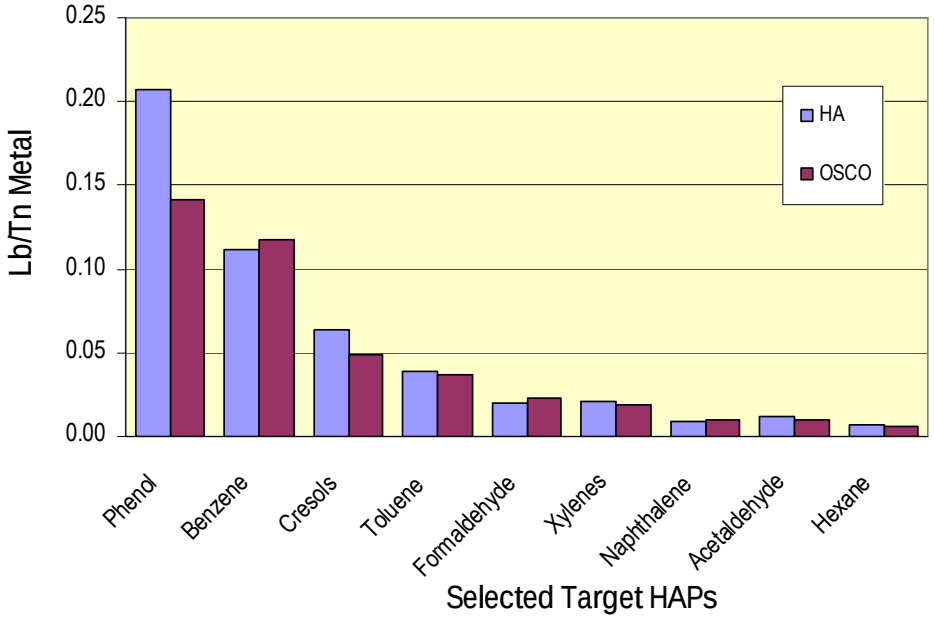


Figure 3-3 Comparison of VOCs from Binders Used in Test GN – Lb/Tn Metal

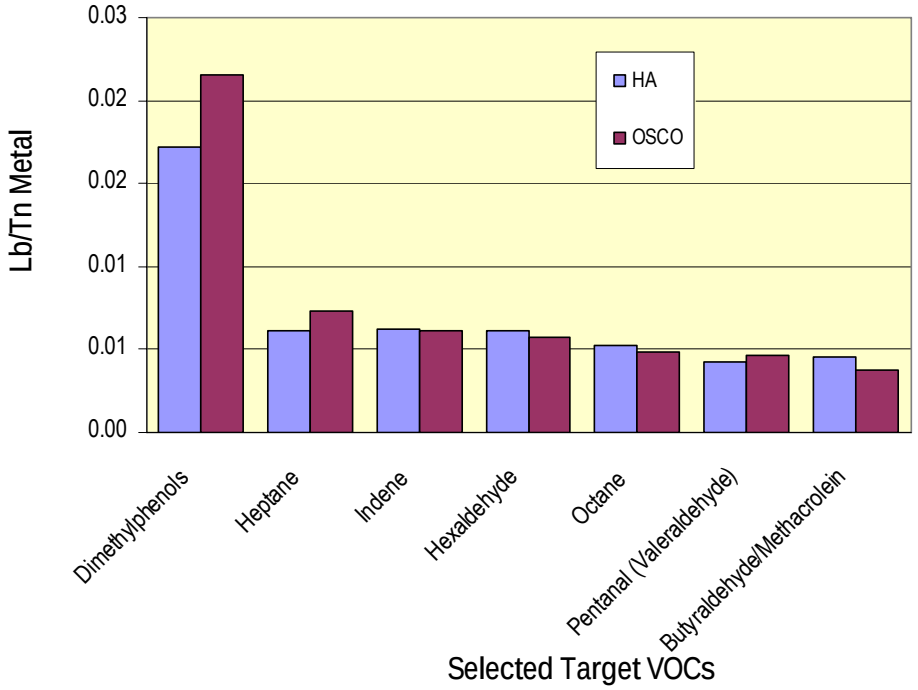
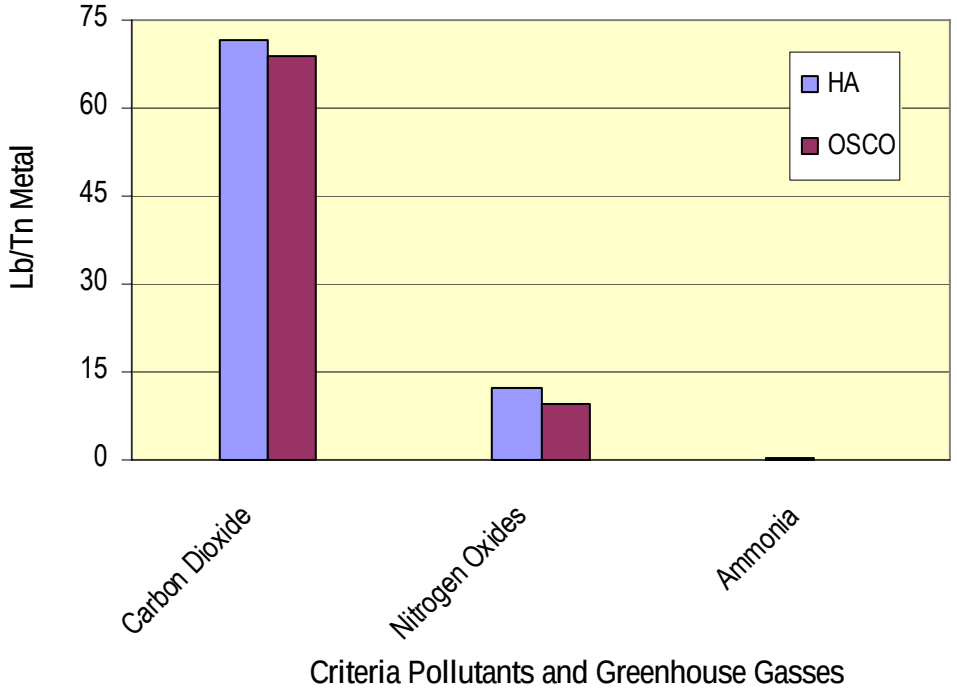


Figure 3-4 Comparison of Criteria Pollutants and Greenhouse Gasses from Binders Used in Test GN – Lb/Tn Metal



4.0 DISCUSSION OF RESULTS

The difference in emissions between the binders as denoted by the Emission Indicators in Tables 3-1 and 3-2, shows a decrease of approximately 15% for the major emission indicators (sum of target HAPs, sum of target VOCs, TGOC and HC as hexane). The Sum of POMs for the OSCO resin showed a 30% increase.

Of the fifty six (56) individual targeted compounds, seventeen (17) VOCs were responsible for approximately 95% of the concentration emitted as lb/ton by the shell mold with both the OSCO resin and HA resins, as can be seen in Tables 3-1 and 3-2. The highest contributors from both binders were phenol, benzene, cresol and toluene. These four analytes were responsible for approximately 70% of the lb/ton emissions for both resin systems. Phenol accounted for 36% of the total for the reference HA resin 28% for the OSCO resin. Although ammonia is neither a VOC nor HAP, it was responsible for the highest emitted concentration for both resin systems.

Table 3-3 shows a 32% decrease in phenol emissions for the OSCO resin as compared to the reference HA resin. Cresol and toluene emissions decreased 24% and 6%, respectively while benzene emissions increased 6%. There was a decrease in emissions in seven of eleven of the individual targeted HAPs.

No surface analysis of castings was performed because all molds were provided by outside sources.

Measured process parameters indicated that all pours were conducted within acceptable established limits and all runs followed similar procedures, assuring that tests for both resins were run in a reproducible and replicate manner.

this page intentionally left blank

APPENDIX A APPROVED TEST PLANS, INSTRUCTIONS, AND SAMPLE PLANS

this page intentionally left blank

Technikon Test Plan

- **CONTRACT NUMBER: 1411 TASK NUMBER: 1.1.5 SERIES: GN**
- **SITE: Pre-production**
- **TEST TYPE: Product Test : Pouring, cooling, & shakeout of uncoated shell molds.**
- **METAL TYPE: Class 30 gray iron**
- **MOLD TYPE: Shell molds of client pattern 15”x20”x 5”/5”**
- **NUMBER OF MOLDS: 6 molds each of 2 shell resin compositions, (12) runs total, or 9 molds of the HA international and 3 OSCO Industries molds TBD based on emission variability**
- **CORE TYPE: None**
- **CORE COATING: None**
- **SAMPLE EVENTS: 12 total runs.**
- **TEST DATE: START: 21 March 2005**
  FINISHED: 8 April 2005

TEST OBJECTIVES:

Measure and compare the airborne pouring, cooling, & shakeout emissions from a single geometry shell mold made from a reference commercial HA International shell resin and a “low emission” comparative resin made by OSCO Industries on reclaimed shell sand.

VARIABLES:

The OSCO Industries supplied shell molds will be from a 6-on housing pattern. The molds will be made from new sand and resin supplied by HA International or with recycled shell sand with an OSCO Industries developed “low emissions” resin. Molds will be poured with iron at 2630 +/- 10°F. Mold cooling will be 60 minutes followed by 5 minutes of shakeout 10 minutes additional sampling for a total of 75 minutes.

BRIEF OVERVIEW:

This is the first shell mold test done by Technikon LLC although similar shell core materials have been tested. The emission results from the uncoated OSCO Industries “low emission” shell sands will be compared to an internal baseline of the uncoated HA International shell sands manufactured by OSCO Industries on the same mold pattern. In addition to a suite of selected emission analytes TGOC, CO, CO_2 & NOx content of the runs will be monitored using instru-

ments specific to those gasses. The molds contain about 30 pounds shell sand containing about 3-4% resin.

SPECIAL CONDITIONS:

A mold holding frame specific to these molds will be built for pouring of the molds in the emission hood. The Molds will be about 2 week old when tested and were not sealed since manufacture.

Series 1411-1.1.5-GN

PCS Shell Molds with HA International & OSCO Industries "Low Emission" Shell Sand Binders
Process Instructions

A. Experiment:

1. Measure pouring, cooling, & shakeout emissions from shell sand molds made by OSCO Industries from new sand and HA International shell sand resin or from reclaimed OSCO shell sand and an OSCO Industries developed " low emission" shell sand resin.
2. A minimum of six (6), maximum of nine (9), HA molds will be tested. The number will be based on achieving a +/- 10% variability about the mean TGOC emission value at 90% confidence.
3. A minimum of three (3), maximum of six (6), OSCO sand molds will be tested to fill out a schedule of twelve (12) total molds.
4. If any problems develop while on the first of each mold type said run will be then considered an "Engineering" run. This run will be replaced by the next numbered mold as a "test run". Data shall be retained and recorded for all runs.

B. Materials:

1. HA International supplied new material shell sand as a baseline mold.
2. OSCO Industries supplied reclaimed sand with an OSCO Industries developed "low emission" shell sand binder as a comparative mold.
3. Metal: Class-30 gray cast iron poured at 2630 +/- 10°F.
4. Pattern: Six on housing. All molds made by OSCO Industries.

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. Shell sand molds:

1. Shell molds will be manufactured for us by OSCO Industries, Jackson, Ohio.
2. Weigh and record the weight of all molds received.
3. Nine (9) molds of the HA international resin sand most nearly alike in color and weight will be selected from the 15 molds supplied for the test.
4. Six (6) molds of the OSCO Industries "low emission" binder most nearly alike in color and weight will be selected form the 25 molds supplied for the test.

5. The sand lab will sample from the corner of each of the 15 molds to be used. Those molds will be tested for LOI using the standard 1800°F core LOI test method.

Caution
Do not breach the mold cavities when obtaining the lab samples.

E. Emission hood:

1. Loading.

a. Place a mold pouring tray containing 1-2 inches of clean dry Nevada 70 sand on the shakeout assembly within the emission hood.

b. Place a shell mold with the pour basin near the pouring deck side onto the mold pouring tray within the emission hood.

CAUTION
Keep the parting line of the shell mold below the top of the pouring tray.

c. Close, seal, and lock the emission hood

d. 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 60 minute cooling time prescribed in the emission sample plan has elapsed turn on the shakeout unit and run for it the 5 minutes prescribed in the emission sample plan.

b. Turn off the shakeout.

c. Sample the emissions for 15 minutes after the start of shakeout, a total of 75 minutes.

3. When the emission sampling is completed remove the mold pouring pan, castings and sand.

a. Weigh and record the metal poured and un-decomposed core butts.

b. Clean any spilled sand from the hood, shakeout , and floor.

F. Melting:

1. Initial iron charge:

a. Charge the furnace according to the heat recipe.

b. Place part of the steel scrap on the bottom, followed by carbon alloys, and the balance of the steel.

c. Place a pig on top on top.

d. Bring the furnace contents to the point of beginning to melt over a period of 1 hour at reduced power.

e. Add the balance of the metallics under full power until all is melted and the temperature has reached 2600 to 2700°F.

f. Slag the furnace and add the balance of the alloys.

g. Raise the temperature of the melt to 2700°F and take a DataCast 2000 sample. The temperature of the primary liquidus (TPL) must be in the range of 2200-2350°F.

h. Hold the furnace at 2500-2550°F until near ready to tap.
i. When ready to tap raise the temperature to 2700°F and slag the furnace.
j. Record all metallic and alloy additions to the furnace, tap temperature, and pour temperature. Record all furnace activities with an associated time.

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

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

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

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

Steven M. Knight
Mgr. Process Engineering

PRE-PRODUCTION GN - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/28/2005											**HA MOLD TEST**
RUN 1											
THC	GN001	X									TOTAL
CO, CO2	GN001	X									TOTAL
M-18	GN00101		1						60	1	Carbopak charcoal
M-18	GN00102				1				0		Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 1500	GN00103		1						1000	5	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	GN00104				1				0		100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	GN00105		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
NIOSH 2002	GN00106				1				0		100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	GN00107		1						1000	9	DNPH Silica Gel (SKC 226-119)
TO11	GN00108				1				0		DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GN00109		1						1000	10	Acid Silica Gel (SKC 226-10-06)
NIOSH 6016	GN00110				1				0		Acid Silica Gel (SKC 226-10-06)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GN - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/28/2005											**HA MOLD TEST**
RUN 2											
THC	GN002	X									TOTAL
CO, CO2	GN002	X									TOTAL
M-18	GN00201		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 1500	GN00202		1						1000	5	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	GN00203		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	GN00204		1						1000	9	DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GN00205		1						1000	10	Acid Silica Gel (SKC 226-10-06)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GN - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/29/2005											**HA MOLD TEST**
RUN 3											
THC	GN003	X									TOTAL
CO, CO2	GN003	X									TOTAL
M-18	GN00301		1						60	1	Carbopak charcoal
M-18 MS	GN00302		1						60	2	Carbopak charcoal
M-18 MS	GN00303			1					60	3	Carbopak charcoal
	Excess								60	4	Excess
NIOSH 1500	GN00304		1						1000	5	100/50 mg Charcoal (SKC 226-01)
NIOSH 1500	GN00305			1					1000	6	100/50 mg Charcoal (SKC 226-01)
NIOSH 2002	GN00306		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
NIOSH 2002	GN00307			1					1000	8	100/50 mg Silica Gel (SKC 226-10)
TO11	GN00308		1						1000	9	DNPH Silica Gel (SKC 226-119)
TO11	GN00309			1					1000	10	DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GN00310		1						1000	11	Acid Silica Gel (SKC 226-10-06)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GN - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/29/2005											**HA MOLD TEST**
RUN 4											
THC	GN004	X									TOTAL
CO, CO2	GN004	X									TOTAL
M-18	GN00401		1						60	1	Carbopak charcoal
M-18	GN00402			1					60	2	Carbopak charcoal
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 1500	GN00403		1						1000	5	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	GN00404		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	GN00405		1						1000	9	DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GN00406		1						1000	10	Acid Silica Gel (SKC 226-10-06)
NIOSH 6016	GN00407			1					1000	11	Acid Silica Gel (SKC 226-10-06)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GN - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/29/2005											**HA MOLD TEST**
RUN 5											
THC	GN005	X									TOTAL
CO, CO2	GN005	X									TOTAL
M-18	GN00501		1						60	1	Carbopak charcoal
M-18	GN00502					1			60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 1500	GN00503		1						1000	5	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	GN00504		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	GN00505		1						1000	9	DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GN00506		1						1000	10	Acid Silica Gel (SKC 226-10-06)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GN - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/30/2005											**HA MOLD TEST**
RUN 6											
THC	GN006	X									TOTAL
CO, CO2	GN006	X									TOTAL
M-18	GN00601		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 1500	GN00602		1						1000	5	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	GN00603		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	GN00604		1						1000	9	DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GN00605		1						1000	10	Acid Silica Gel (SKC 226-10-06)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GN - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/30/2005											**OSCO MOLD TEST**
RUN 1											
THC	GN020	X									TOTAL
CO, CO2	GN020	X									TOTAL
M-18	GN02001		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 1500	GN02002		1						1000	5	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	GN02003		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	GN02004		1						1000	9	DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GN02005		1						1000	10	Acid Silica Gel (SKC 226-10-06)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GN - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/30/2005											**OSCO MOLD TEST**
RUN 2											
THC	GN021	X									TOTAL
CO, CO2	GN021	X									TOTAL
M-18	GN02101		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 1500	GN02102		1						1000	5	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	GN02103		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	GN02104		1						1000	9	DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GN02105		1						1000	10	Acid Silica Gel (SKC 226-10-06)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GN - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/31/2005											**OSCO MOLD TEST**
RUN 3											
THC	GN022	X									TOTAL
CO, CO2	GN022	X									TOTAL
M-18	GN02201		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 1500	GN02202		1						1000	5	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	GN02203		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	GN02204		1						1000	9	DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GN02205		1						1000	10	Acid Silica Gel (SKC 226-10-06)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GN - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/31/2005											**OSCO MOLD TEST**
RUN 4											
THC	GN023	X									TOTAL
CO, CO2	GN023	X									TOTAL
M-18	GN02301		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 1500	GN02302		1						1000	5	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	GN02303		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	GN02304		1						1000	9	DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GN02305		1						1000	10	Acid Silica Gel (SKC 226-10-06)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GN - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
3/31/2005											**OSCO MOLD TEST**
RUN 5											
THC	GN024	X									TOTAL
CO, CO2	GN024	X									TOTAL
M-18	GN02401		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 1500	GN02402		1						1000	5	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	GN02403		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	GN02404		1						1000	9	DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GN02405		1						1000	10	Acid Silica Gel (SKC 226-10-06)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GN - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
Test not run.											**OSCO MOLD TEST**
RUN 6											
THC	GN025	X									TOTAL
CO, CO2	GN025	X									TOTAL
M-18	GN02501		1						60	1	Carbopak charcoal
	Excess								60	2	Excess
	Excess								60	3	Excess
	Excess								60	4	Excess
NIOSH 1500	GN02502		1						1000	5	100/50 mg Charcoal (SKC 226-01)
	Excess								1000	6	Excess
NIOSH 2002	GN02503		1						1000	7	100/50 mg Silica Gel (SKC 226-10)
	Excess								1000	8	Excess
TO11	GN02504		1						1000	9	DNPH Silica Gel (SKC 226-119)
NIOSH 6016	GN02505		1						1000	10	Acid Silica Gel (SKC 226-10-06)
	Excess								1000	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

this page intentionally left blank

APPENDIX B DETAILED EMISSION RESULTS AND QUANTITATION LIMITS

this page intentionally left blank

Test GN Individual Emission Test Results, Lb/Tn Metal - HA Binder

VOC	POM	HAP		GN001	GN002	GN003	GN004	GN005	GN006	Average	Standard Deviation
			Test Dates	28-Mar-05	28-Mar-05	29-Mar-05	29-Mar-05	29-Mar-05	30-Mar-05	—	—
			Emission Indicators								
			TGOC as Propane	1.81E+00	1.45E+00	1.45E+00	1.61E+00	1.84E+00	I	1.63E+00	1.88E-01
			HC as Hexane	5.62E-01	5.20E-01	5.05E-01	6.55E-01	5.78E-01	5.45E-01	5.61E-01	5.33E-02
			Sum of Target VOCs	6.66E-01	6.02E-01	3.17E-01	7.10E-01	6.36E-01	5.07E-01	5.73E-01	1.43E-01
			Sum of Target HAPs	5.97E-01	5.34E-01	2.72E-01	6.29E-01	5.59E-01	4.47E-01	5.06E-01	1.31E-01
			Sum of Target POMs	1.54E-02	1.61E-02	6.21E-03	1.56E-02	1.32E-02	1.10E-02	1.29E-02	3.78E-03
			Individual Target HAPs								
V		H	2-Butanone (MEK)	ND	3.49E-04	3.58E-04	3.28E-04	ND	4.59E-04	2.49E-04	1.98E-04
V	P	H	Acenaphthalene	ND	1.92E-03	ND	ND	ND	ND	3.19E-04	7.82E-04
V		H	Biphenyl	2.76E-03	3.13E-03	ND	ND	ND	ND	9.82E-04	1.53E-03
V	P	H	Methylnaphthalene, 2-	1.34E-03	1.31E-03	6.08E-04	1.49E-03	1.43E-03	1.04E-03	1.20E-03	3.30E-04
V	P	H	Methylnaphthalene, 1-	3.29E-03	2.96E-03	1.17E-03	2.47E-03	2.18E-03	1.97E-03	2.34E-03	7.54E-04
V		H	Acrolein	1.90E-03	3.01E-03	2.09E-03	2.97E-03	3.11E-03	2.45E-03	2.59E-03	5.17E-04
V		H	Ethylbenzene	3.36E-03	3.21E-03	1.48E-03	3.62E-03	3.67E-03	2.71E-03	3.01E-03	8.24E-04
V		H	Styrene	3.44E-03	3.62E-03	1.48E-03	4.03E-03	3.95E-03	2.78E-03	3.21E-03	9.60E-04
V		H	Propionaldehyde (Propanal)	2.65E-03	3.40E-03	3.20E-03	3.55E-03	4.24E-03	3.05E-03	3.35E-03	5.38E-04
V		H	Xylene, o-	4.88E-03	4.58E-03	2.10E-03	5.20E-03	5.25E-03	3.84E-03	4.31E-03	1.20E-03
V		H	Hexane	6.45E-03	7.37E-03	3.35E-03	7.91E-03	8.62E-03	6.44E-03	6.69E-03	1.84E-03
V	P	H	Naphthalene	1.07E-02	9.88E-03	4.43E-03	1.16E-02	9.59E-03	8.04E-03	9.05E-03	2.55E-03
V		H	Acetaldehyde	9.92E-03	1.22E-02	1.16E-02	1.37E-02	1.41E-02	1.11E-02	1.21E-02	1.58E-03
V		H	Xylene, mp-	2.26E-02	1.70E-02	7.68E-03	1.98E-02	1.82E-02	1.37E-02	1.65E-02	5.24E-03
V			Dimethylphenol, 2,6-	2.07E-02	1.73E-02	8.10E-03	2.25E-02	1.91E-02	1.39E-02	1.70E-02	5.25E-03
V		H	Formaldehyde	1.72E-02	1.94E-02	2.12E-02	2.32E-02	1.99E-02	1.90E-02	2.00E-02	2.05E-03
V		H	Toluene	5.25E-02	3.88E-02	1.90E-02	4.81E-02	4.14E-02	3.44E-02	3.90E-02	1.18E-02
V		H	Cresol, mp-	6.98E-02	6.76E-02	3.23E-02	7.97E-02	7.61E-02	5.50E-02	6.34E-02	1.75E-02
V		H	Benzene	1.50E-01	1.16E-01	5.32E-02	1.38E-01	1.15E-01	9.55E-02	1.11E-01	3.43E-02

NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

Test GN Individual Emission Test Results, Lb/Tn Metal - HA Binder

VOC	POM	HAP		GN001	GN002	GN003	GN004	GN005	GN006	Average	Standard Deviation
V		H	Phenol	2.34E-01	2.18E-01	1.06E-01	2.64E-01	2.32E-01	1.86E-01	2.07E-01	5.53E-02
V	P	H	Dimethylnaphthalene, 1,2-	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,3-	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,5-	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,6-	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,8-	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,3-	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,6-	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,7-	ND	ND	ND	ND	ND	ND	NA	NA
V	P	H	Trimethylnaphthalene, 2,3,5-	ND	ND	ND	ND	ND	ND	NA	NA
V		H	Cresol, o-	ND	ND	ND	ND	ND	ND	NA	NA
			Other Individual Target VOCs								
V			Cyclohexane	ND	ND	ND	ND	ND	ND	NA	NA
V			Dimethylphenol, 2,4-	ND	ND	ND	ND	ND	ND	NA	NA
V			Dodecane	ND	ND	ND	ND	ND	ND	NA	NA
V			Ethyltoluene, 2-	ND	ND	ND	ND	ND	ND	NA	NA
V			Indan	ND	ND	ND	ND	ND	ND	NA	NA
V			Trimethylbenzene, 1,3,5-	ND	ND	ND	ND	ND	ND	NA	NA
V			Indene	5.81E-03	6.28E-03	3.42E-03	8.14E-03	6.67E-03	7.11E-03	6.24E-03	1.59E-03
V			Heptane	6.18E-03	6.75E-03	3.14E-03	7.17E-03	7.94E-03	5.86E-03	6.17E-03	1.66E-03
V			Hexaldehyde	5.82E-03	6.11E-03	6.52E-03	6.28E-03	6.60E-03	5.39E-03	6.12E-03	4.57E-04
V			Octane	5.25E-03	5.63E-03	2.85E-03	6.12E-03	6.50E-03	4.78E-03	5.19E-03	1.30E-03
V			Butyraldehyde/Methacrolein	4.20E-03	4.40E-03	4.74E-03	4.84E-03	5.15E-03	4.14E-03	4.58E-03	3.99E-04
V			Pentanal (Valeraldehyde)	3.87E-03	4.27E-03	4.28E-03	4.43E-03	4.93E-03	3.81E-03	4.27E-03	4.07E-04
V			Benzaldehyde	3.39E-03	3.63E-03	3.68E-03	3.99E-03	3.72E-03	3.20E-03	3.60E-03	2.76E-04
V			Nonane	3.44E-03	3.40E-03	1.55E-03	3.76E-03	3.82E-03	2.89E-03	3.14E-03	8.47E-04
V			Decane	2.92E-03	2.87E-03	1.32E-03	3.27E-03	3.07E-03	ND	2.24E-03	1.30E-03
V			Trimethylbenzene, 1,2,3-	1.49E-03	1.39E-03	9.10E-04	2.17E-03	1.69E-03	1.73E-03	1.56E-03	4.18E-04

NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

Test GN Individual Emission Test Results, Lb/Tn Metal - HA Binder

VOC	POM	HAP		GN001	GN002	GN003	GN004	GN005	GN006	Average	Standard Deviation
V			Propylbenzene, n-	1.99E-03	1.70E-03	1.11E-03	2.28E-03	2.10E-03	ND	1.53E-03	8.53E-04
V			o,m,p-Tolualdehyde	1.32E-03	1.37E-03	1.40E-03	1.41E-03	1.33E-03	1.21E-03	1.34E-03	7.19E-05
V			Ethyltoluene, 3-	ND	ND	8.85E-04	1.70E-03	2.16E-03	1.73E-03	1.08E-03	9.32E-04
V			Undecane	ND	ND	8.69E-04	ND	1.94E-03	1.51E-03	7.20E-04	8.59E-04
V			Tetradecane	1.88E-03	2.18E-03	ND	ND	ND	ND	6.77E-04	1.05E-03
V			Crotonaldehyde	5.22E-04	5.83E-04	5.94E-04	6.06E-04	6.54E-04	5.73E-04	5.89E-04	4.33E-05
V			Trimethylbenzene, 1,2,4-	ND	ND	ND	ND	ND	2.26E-03	3.77E-04	9.23E-04
V			Diethylbenzene, 1,3-	ND	ND	ND	1.65E-03	ND	ND	2.75E-04	6.73E-04
			Criteria Pollutants, Greenhouse Gases and Other Analytes								
			Carbon Monoxide	1.02E+01	1.26E+01	1.22E+01	1.32E+01	1.30E+01	1.20E+01	1.22E+01	1.09E+00
			Carbon Dioxide	I	6.96E+01	7.10E+01	6.99E+01	7.49E+01	7.19E+01	7.15E+01	2.11E+00
			Nitrogen Oxides	1.79E-01	1.72E-01	1.95E-01	1.78E-01	1.93E-01	1.91E-01	1.85E-01	9.36E-03
			Ammonia	1.88E-01	2.79E-01	2.86E-01	3.34E-01	2.58E-01	2.48E-01	2.65E-01	4.82E-02

NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

Test GN Individual Emission Test Results, Lb/Tn Metal - Osco Binder

VOC	POM	HAP		GN020	GN021	GN022	GN023	GN024	Average	Standard Deviation
			Test Dates	30-Mar-05	30-Mar-05	31-Mar-05	31-Mar-05	31-Mar-05	—	—
			Emission Indicators							
			TGOC as Propane	1.02E+00	1.44E+00	1.59E+00	1.25E+00	1.72E+00	1.40E+00	2.77E-01
			HC as Hexane	4.35E-01	4.31E-01	5.14E-01	4.65E-01	5.15E-01	4.72E-01	4.11E-02
			Sum of Target VOCs	3.40E-01	4.99E-01	6.49E-02	5.43E-01	5.95E-01	4.96E-01	1.95E-01
			Sum of Target HAPs	2.92E-01	4.38E-01	4.30E-02	4.73E-01	5.20E-01	4.32E-01	1.76E-01
			Sum of Target POMs	1.75E-02	1.72E-02	ND	1.84E-02	2.35E-02	1.92E-02	2.56E-03
			Individual Target HAPs							
V		H	Phenol	1.01E-01	1.37E-01	NT	1.56E-01	1.70E-01	1.41E-01	3.00E-02
V		H	Benzene	9.04E-02	1.25E-01	NT	1.21E-01	1.35E-01	1.18E-01	1.92E-02
V		H	Cresol, mp-	ND	5.61E-02	NT	6.71E-02	7.04E-02	4.84E-02	3.28E-02
V		H	Toluene	2.52E-02	3.50E-02	NT	3.98E-02	4.62E-02	3.66E-02	8.83E-03
V		H	Formaldehyde	2.19E-02	2.15E-02	2.50E-02	2.37E-02	2.44E-02	2.33E-02	1.56E-03
V		H	Xylene, mp-	1.03E-02	1.44E-02	NT	1.70E-02	1.81E-02	1.50E-02	3.47E-03
V	P	H	Naphthalene	7.29E-03	9.68E-03	NT	1.08E-02	1.25E-02	1.01E-02	2.19E-03
V		H	Acetaldehyde	8.56E-03	9.45E-03	1.11E-02	9.21E-03	9.92E-03	9.66E-03	9.60E-04
V		H	Hexane	4.92E-03	6.64E-03	NT	6.24E-03	6.85E-03	6.16E-03	8.67E-04
V	P	H	Dimethylnaphthalene, 1,8-	7.60E-03	4.43E-03	NT	4.69E-03	7.64E-03	6.09E-03	1.77E-03
V		H	Xylene, o-	2.94E-03	3.87E-03	NT	4.11E-03	4.48E-03	3.85E-03	6.53E-04
V		H	Propionaldehyde (Propanal)	2.85E-03	3.18E-03	3.69E-03	2.96E-03	3.24E-03	3.18E-03	3.25E-04
V		H	Acrolein	2.23E-03	2.93E-03	2.88E-03	1.99E-03	2.52E-03	2.51E-03	4.10E-04
V		H	Ethylbenzene	1.83E-03	2.37E-03	NT	2.76E-03	2.79E-03	2.44E-03	4.51E-04
V		H	Styrene	1.83E-03	2.11E-03	NT	2.00E-03	2.41E-03	2.09E-03	2.43E-04
V	P	H	Methylnaphthalene, 1-	1.76E-03	1.65E-03	NT	1.59E-03	2.07E-03	1.77E-03	2.13E-04
V	P	H	Methylnaphthalene, 2-	8.85E-04	1.42E-03	NT	1.32E-03	1.32E-03	1.23E-03	2.38E-04
V		H	2-Butanone (MEK)	4.35E-04	5.77E-04	3.24E-04	4.15E-04	ND	3.50E-04	2.16E-04
V	P	H	Acenaphthalene	ND	ND	NT	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,2-	ND	ND	NT	ND	ND	NA	NA

NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

Test GN Individual Emission Test Results, Lb/Tn Metal - Osco Binder

VOC	POM	HAP		GN020	GN021	GN022	GN023	GN024	Average	Standard Deviation
V	P	H	Dimethylnaphthalene, 1,3-	ND	ND	NT	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,5-	ND	ND	NT	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 1,6-	ND	ND	NT	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,3-	ND	ND	NT	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,6-	ND	ND	NT	ND	ND	NA	NA
V	P	H	Dimethylnaphthalene, 2,7-	ND	ND	NT	ND	ND	NA	NA
V	P	H	Trimethylnaphthalene, 2,3,5-	ND	ND	NT	ND	ND	NA	NA
V		H	Biphenyl	ND	ND	NT	ND	ND	NA	NA
V		H	Cresol, o-	ND	ND	NT	ND	ND	NA	NA
			Other Individual Target VOCs							
V			Dimethylphenol, 2,6-	1.19E-02	1.92E-02	NT	2.63E-02	2.89E-02	2.16E-02	7.64E-03
			Hexaldehyde	6.69E-03	7.22E-03	7.97E-03	7.19E-03	7.60E-03	7.33E-03	4.80E-04
V			Indene	4.42E-03	6.25E-03	NT	6.42E-03	7.23E-03	6.08E-03	1.19E-03
V			Heptane	4.59E-03	6.01E-03	NT	5.90E-03	6.46E-03	5.74E-03	8.05E-04
V			Octane	4.01E-03	5.01E-03	NT	4.96E-03	5.36E-03	4.83E-03	5.77E-04
V			Pentanal (Valeraldehyde)	4.02E-03	4.49E-03	5.14E-03	4.57E-03	4.90E-03	4.62E-03	4.28E-04
V			Butyraldehyde/Methacrolein	3.47E-03	3.46E-03	4.09E-03	3.69E-03	3.94E-03	3.73E-03	2.79E-04
V			Benzaldehyde	2.84E-03	2.57E-03	2.99E-03	2.66E-03	2.82E-03	2.78E-03	1.62E-04
V			Nonane	1.96E-03	2.66E-03	NT	2.78E-03	2.94E-03	2.58E-03	4.32E-04
V			Decane	1.62E-03	2.22E-03	NT	2.41E-03	2.47E-03	2.18E-03	3.90E-04
V			o,m,p-Tolualdehyde	1.14E-03	1.00E-03	1.09E-03	1.07E-03	1.10E-03	1.08E-03	5.25E-05
V			Trimethylbenzene, 1,2,3-	1.03E-03	8.75E-04	NT	9.26E-04	9.51E-04	9.45E-04	6.33E-05
V			Crotonaldehyde	6.17E-04	5.59E-04	5.99E-04	5.01E-04	5.42E-04	5.64E-04	4.63E-05
V			Cyclohexane	ND	ND	NT	ND	ND	NA	NA
V			Diethylbenzene, 1,3-	ND	ND	NT	ND	ND	NA	NA
V			Dimethylphenol, 2,4-	ND	ND	NT	ND	ND	NA	NA
V			Dodecane	ND	ND	NT	ND	ND	NA	NA
V			Ethyltoluene, 2-	ND	ND	NT	ND	ND	NA	NA
V			Ethyltoluene, 3-	ND	ND	NT	ND	ND	NA	NA

NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

Test GN Individual Emission Test Results, Lb/Tn Metal - Osco Binder

VOC	POM	HAP		GN020	GN021	GN022	GN023	GN024	Average	Standard Deviation
V			Indan	ND	ND	NT	ND	ND	NA	NA
V			Propylbenzene, n-	ND	ND	NT	ND	ND	NA	NA
V			Tetradecane	ND	ND	NT	ND	ND	NA	NA
V			Trimethylbenzene, 1,2,4-	ND	ND	NT	ND	ND	NA	NA
V			Trimethylbenzene, 1,3,5-	ND	ND	NT	ND	ND	NA	NA
V			Undecane	ND	ND	NT	ND	ND	NA	NA
			Criteria Pollutants, Greenhouse Gases and Other Analytes							
			Carbon Monoxide	9.37E+00	9.36E+00	9.62E+00	9.27E+00	9.29E+00	9.38E+00	1.37E-01
			Carbon Dioxide	7.38E+01	6.92E+01	6.91E+01	6.75E+01	6.43E+01	6.88E+01	3.45E+00
			Nitrogen Oxides	1.70E-01	1.63E-01	1.63E-01	1.64E-01	1.52E-01	1.62E-01	6.30E-03
			Ammonia	1.99E-01	2.36E-01	3.34E-01	2.89E-01	3.16E-01	2.75E-01	5.62E-02

NT= Not Tested
ND= Not Detected
NA= Not Applicable
I=Invalidated Data

Quantitation Limits - HA Binder

Analyte	Practical Reporting Limit lb/ton	Analyte	Practical Reporting Limit lb/ton
Carbon Monoxide	7.59E-02	Ethyltoluene, 2-	1.99E-04
Carbon Dioxide	7.59E-02	Ethyltoluene, 3-	9.94E-04
Nitrogen Oxides	7.59E-02	Formaldehyde	2.96E-04
2-Butanone (MEK)	2.96E-04	Heptane	9.94E-04
Acenaphthalene	9.94E-04	Hexaldehyde	2.96E-04
Acetaldehyde	2.96E-04	Hexane	1.99E-04
Acrolein	2.96E-04	Indan	9.94E-04
Ammonia	1.98E-03	Indene	9.94E-04
Benzaldehyde	2.96E-04	Methylnaphthalene, 1-	1.99E-04
Benzene	1.99E-04	Methylnaphthalene, 2-	1.99E-04
Biphenyl	9.94E-04	Naphthalene	1.99E-04
Butyraldehyde/Methacrolein	4.93E-04	Nonane	9.94E-04
Cresol, mp-	9.94E-04	o,m,p-Tolualdehyde	7.89E-04
Cresol, o-	9.94E-04	Octane	9.94E-04
Crotonaldehyde	2.96E-04	Pentanal (Valeraldehyde)	2.96E-04
Cyclohexane	9.94E-04	Phenol	9.94E-04
Decane	9.94E-04	Propionaldehyde (Propanal)	2.96E-04
Diethylbenzene, 1,3-	9.94E-04	Propylbenzene, n-	9.94E-04
Dimethylnaphthalene, 1,2-	9.94E-04	Styrene	1.99E-04
Dimethylnaphthalene, 1,3-	1.99E-04	Tetradecane	9.94E-04
Dimethylnaphthalene, 1,5-	9.94E-04	THCs as n-Hexane	1.05E-02
Dimethylnaphthalene, 1,6-	9.94E-04	Toluene	1.99E-04
Dimethylnaphthalene, 1,8-	9.94E-04	Trimethylbenzene, 1,2,3-	1.99E-04
Dimethylnaphthalene, 2,3-	9.94E-04	Trimethylbenzene, 1,2,4-	1.99E-04
Dimethylnaphthalene, 2,6-	9.94E-04	Trimethylbenzene, 1,3,5-	1.99E-04
Dimethylnaphthalene, 2,7-	9.94E-04	Trimethylnaphthalene, 2,3,5-	9.94E-04
Dimethylphenol, 2,4-	9.94E-04	Undecane	1.99E-04
Dimethylphenol, 2,6-	9.94E-04	Xylene, mp-	1.99E-04
Dodecane	9.94E-04	Xylene, o-	1.99E-04
Ethylbenzene	1.99E-04		

Quanititation Limits - OSCO Binder

Analyte	Practical Reporting Limit Lb/Tn	Analyte	Practical Reporting Limit Lb/Tn
Carbon Monoxide	7.69E-02	Ethyltoluene, 2-	1.89E-04
Carbon Dioxide	7.69E-02	Ethyltoluene, 3-	9.44E-04
Nitrogen Oxides	7.69E-02	Formaldehyde	3.07E-04
2-Butanone (MEK)	3.07E-04	Heptane	9.44E-04
Acenaphthalene	9.44E-04	Hexaldehyde	3.07E-04
Acetaldehyde	3.07E-04	Hexane	1.89E-04
Acrolein	3.07E-04	Indan	9.44E-04
Ammonia	1.99E-03	Indene	9.44E-04
Benzaldehyde	3.07E-04	Methylnaphthalene, 1-	1.89E-04
Benzene	1.89E-04	Methylnaphthalene, 2-	1.89E-04
Biphenyl	9.44E-04	Naphthalene	1.89E-04
Butyraldehyde/Methacrolein	5.11E-04	Nonane	9.44E-04
Cresol, mp-	9.44E-04	o,m,p-Tolualdehyde	8.18E-04
Cresol, o-	9.44E-04	Octane	9.44E-04
Crotonaldehyde	3.07E-04	Pentanal (Valeraldehyde)	3.07E-04
Cyclohexane	9.44E-04	Phenol	9.44E-04
Decane	9.44E-04	Propionaldehyde (Propanal)	3.07E-04
Diethylbenzene, 1,3-	9.44E-04	Propylbenzene, n-	9.44E-04
Dimethylnaphthalene, 1,2-	9.44E-04	Styrene	1.89E-04
Dimethylnaphthalene, 1,3-	1.89E-04	Tetradecane	9.44E-04
Dimethylnaphthalene, 1,5-	9.44E-04	THCs as n-Hexane	9.96E-03
Dimethylnaphthalene, 1,6-	9.44E-04	Toluene	1.89E-04
Dimethylnaphthalene, 1,8-	9.44E-04	Trimethylbenzene, 1,2,3-	1.89E-04
Dimethylnaphthalene, 2,3-	9.44E-04	Trimethylbenzene, 1,2,4-	1.89E-04
Dimethylnaphthalene, 2,6-	9.44E-04	Trimethylbenzene, 1,3,5-	1.89E-04
Dimethylnaphthalene, 2,7-	9.44E-04	Trimethylnaphthalene, 2,3,5-	9.44E-04
Dimethylphenol, 2,4-	9.44E-04	Undecane	1.89E-04
Dimethylphenol, 2,6-	9.44E-04	Xylene, mp-	1.89E-04
Dodecane	9.44E-04	Xylene, o-	1.89E-04
Ethylbenzene	1.89E-04		

this page intentionally left blank

APPENDIX C DETAILED PROCESS DATA

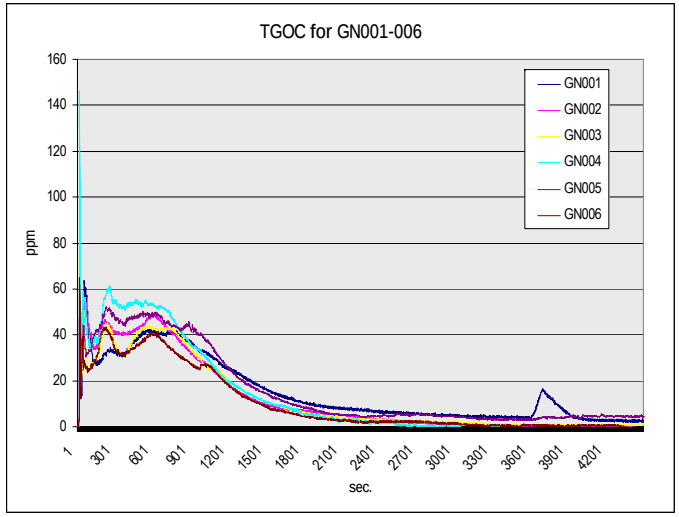
this page intentionally left blank

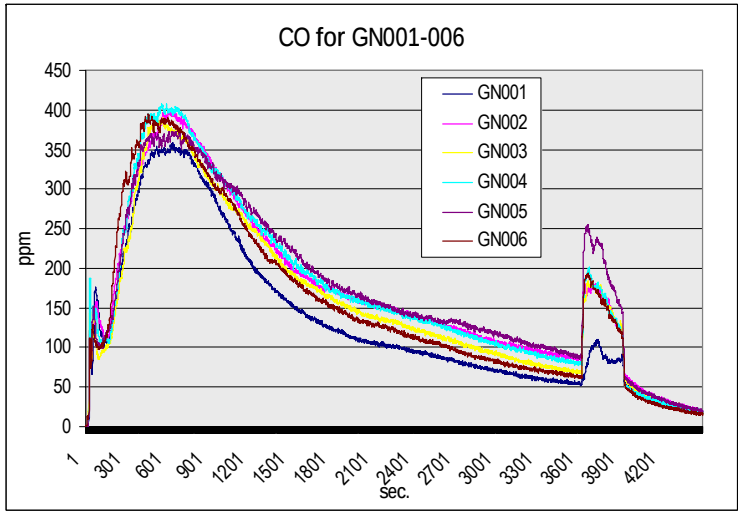
Shell Mold Type	HA Super F2							Osco Reclaimed						
Test Dates	3/28/05	3/28/05	3/29/05	3/29/05	3/29/05	3/30/05	Averages	3/30/05	3/30/05	3/31/05	3/31/05	3/31/05	NT	Averages
Emissions Sample #	GN001	GN002	GN003	GN004	GN005	GN006		GN020	GN021	GN022	GN023	GN024		
Production Sample #	GN001	GN002	GN003	GN004	GN005	GN006		GN007	GN008	GN009	GN010	GN011	GN012	
Cast Weight (all metal inside mold), Lbs.	43.85	44.00	43.25	42.90	44.25	44.05	43.72	43.95	44.10	43.80	43.80	43.50	NT	43.83
Pouring Time, sec.	21	17	22	17	17	16	18	17	16	16	16	21	NT	17.20
Pouring Temp ,°F	2639	2630	2623	2624	2639	2637	2632	2639	2633	2640	2630	2633	NT	2635
Pour Hood Process Air Temp at Start of Pour, °F	85.6	86.5	85.6	86	87	86	86	88	85	88	88	90	NT	88
Total Shell mold Weight, Lbs.	30.25	30.35	30.85	31.05	30.95	29.95	30.57	30.90	31.25	32.50	31.45	31.45	NT	31.51
Core Reported Binder Content, %BOS	4.75	4.75	4.75	4.75	4.75	4.75	4.75	3.85	3.85	3.85	3.85	3.85	NT	3.85
Core Binder Calculated Resin Content , %	4.53	4.53	4.53	4.53	4.53	4.53	4.53	3.71	3.71	3.71	3.71	3.71	NT	3.71
Total Binder Weight in Mold, Lbs.	1.37	1.38	1.40	1.41	1.40	1.36	1.39	1.15	1.16	1.20	1.17	1.17	NT	1.17
Weight of mold remaining as core butts, Lbs	7.45	9.70	10.10	8.05	8.25	8.55	8.68	3.00	4.20	6.20	6.30	5.05	NT	4.95
Shell mold LOI, %	5.22	5.05	5.04	5.17	5.19	5.05	5.12	5.07	5.30	5.03	4.75	4.75	NT	4.98
Approximate Shell mold Age, days	10	10	11	11	11	12	11	12	12	13	13	13	NT	13

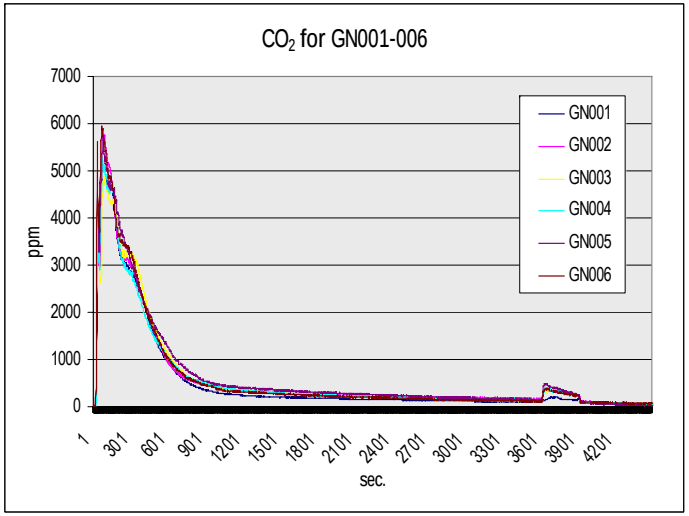
this page intentionally left blank

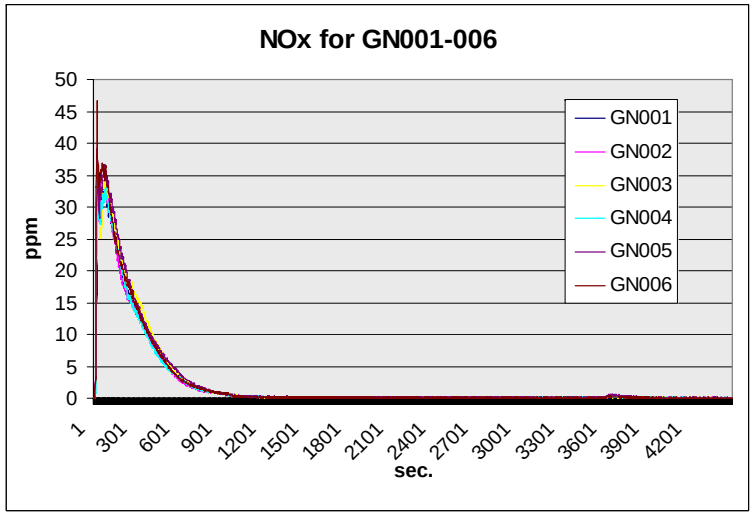
APPENDIX D METHODS 3A, 7E, 10, 25A, & OTHER CHARTS

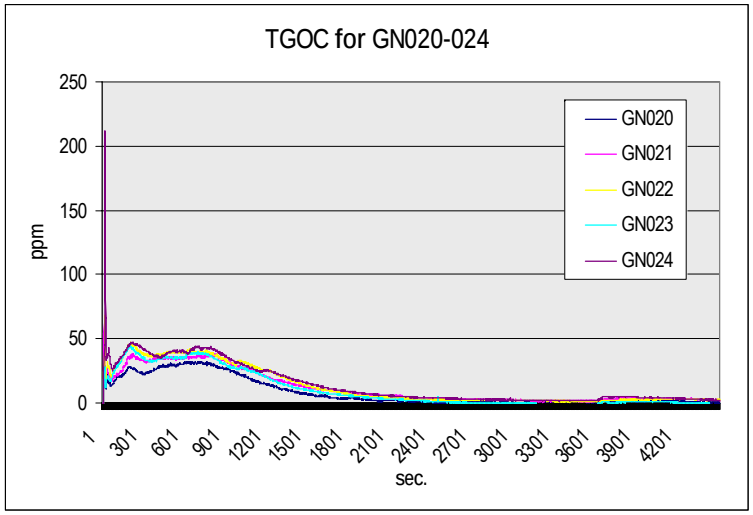
this page intentionally left blank

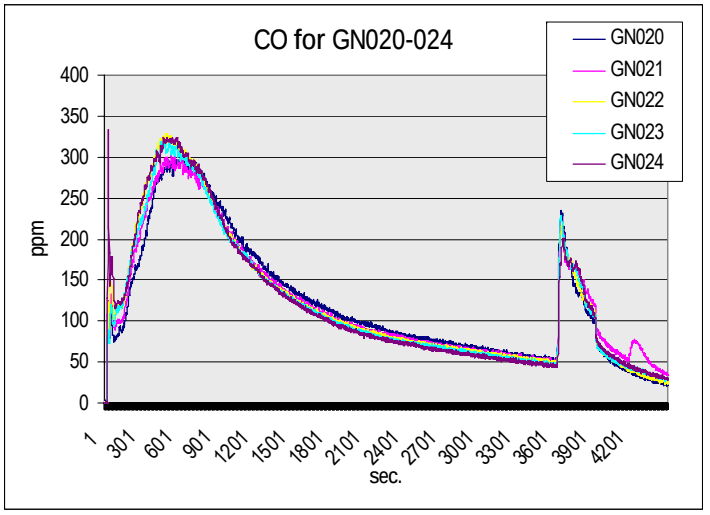

TGOC for GN001-006
ppm
sec.
GN001
GN002
GN003
GN004
GN005
GN006

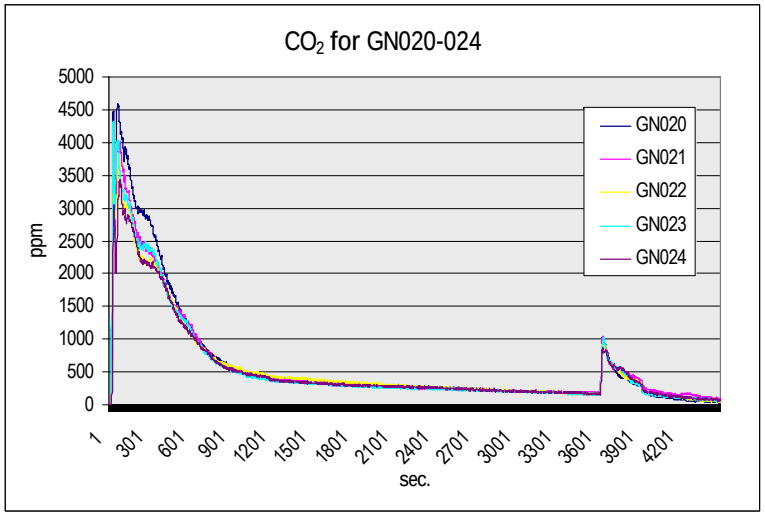

CO for GN001-006
ppm
sec.
GN001
GN002
GN003
GN004
GN005
GN006

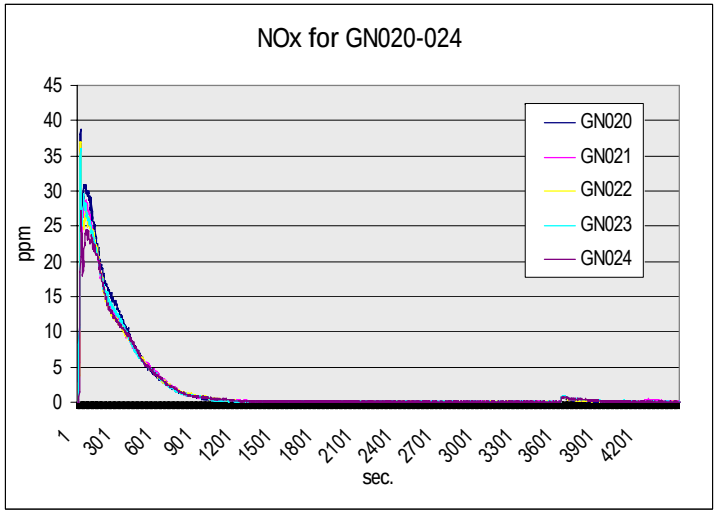

CO2 for GN001-006
ppm
sec.
GN001
GN002
GN003
GN004
GN005
GN006


NOx for GN001-006
ppm
sec.
GN001
GN002
GN003
GN004
GN005
GN006


TGOC for GN020-024
ppm
sec.
GN020
GN021
GN022
GN023
GN024


CO for GN020-024
ppm
sec.
GN020
GN021
GN022
GN023
GN024


CO2 for GN020-024
ppm
sec.
GN020
GN021
GN022
GN023
GN024


NOx for GN020-024
ppm
sec.
GN020
GN021
GN022
GN023
GN024

APPENDIX E ACRONYMS & ABBREVIATIONS

this page intentionally left blank

Acronyms and Abbreviations

BO	Based on ( ).
BOS	Based on Sand.
HAP	Hazardous Air Pollutant defined by the 1990 Clean Air Act Amendment
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	Total Gaseous Organic Compounds which are 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
scfm	Standard Cubic Feet Per Minute
PCS	Pouring, Cooling and Shakeout