Casting Emission Reduction Program
www.cerp-us.org

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Third Verification of Systems Integration and Validation Laboratory (SIVL) SO_2 Furan Molds

Technikon # 1411-237 GO

July 2005
Revised for public distribution.

EPA United States Environmental Protection Agency
CISA
AFS AMERICAN FOUNDRY SOCIETY, INC.
UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH
USCAR
DAIMLERCHRYSLER Ford Motor Company General Motors

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Third Verification of Systems Integration and Validation Laboratory (SIVL) SO_2 Furan Molds

Technikon # 1411-237 GO

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

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Executive Summary

This report contains the results of emissions testing to compare two different methodologies/technologies for quantifying the amount of SO_2, a criteria pollutant, emitted during the pouring, cooling and shakeout process in a foundry. The molds used for pouring/cooling/shakeout contained a furan made with a No-bake resin using sulphonic acid as a catalyst. The first method was EPA Method 6C using a UV photometric CEMS type analyzer. The other method was OSHA ID200, which used a solid adsorbent to absorb SO_2 that was subsequently analyzed by ion chromatography. The emission results are reported in pounds of analyte per pound of binder and pounds of analyte per ton of metal poured.

Continuous emission samples were collected over the entire process over a seventy-five minute period. It included the metal pouring/cooling/shakeout (PCS), and post shakeout phases. For this segment, process and stack parameters were measured. They included the weights of the casting, mold, and binder; 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.

Mass emission rates for SO_2 were calculated using continuous monitoring data, laboratory analytical results, measured source data and appropriate process data. Results are presented in detail in Appendix B. Table 1 summarizes the results from the tests conducted. The results indicate good agreement between the two methods studied for SO_2 quantification for developing emission factors at foundries.

Table 1 Test GO Pouring/Cooling/Shakeout SO_2 Emission Indicators

	SO_2 by EPA Method 6C		**SO_2 by OSHA ID 200 Method**	
Test GO	**Average**	**Standard Dev.**	**Average**	**Standard Dev.**
(Lb/Lb Binder)	0.0180	0.0007	0.0168	0.0006
(Lb/Tn Metal)	1.2652	0.0534	1.1768	0.0408

It must be noted that the emissions results from the testing performed are not suitable for use as emission factors or for purposes other than evaluating the relative emission changes 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. They 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; and the Casting Industry Suppliers Association. The US Environmental Protection Agency (US EPA) and the California Air Resources Board (CARB) also have been participants in the CERP program and rely on CERP published reports for regulatory compliance data.

1.2. TECHNIKON OBJECTIVES

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

The facility has two principal testing arenas: a Research 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.

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 results of a specific test plan that was used to compare two techniques/methods to quantify SO_2 emissions from a Furan No-Bake® binder 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. 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 folder 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. Details of the approved sampling plan are also included in this Appendix.

Table 1-1Test Plan Summary

Test Plan Number	**1411-237 GO**
Type of Process Tested	Furan No-Bake®, PCS Product Test
Binder System	HA International ENVIROSET 22®/TC-50
Metal Poured	Iron
Mold Type	4-on Gear
Sand Type	Wedron 530 sand
Number of Molds	6 PCS
Test Dates	Start: 9 May 2005 Finish: 12 May 2005
Emissions Measured	SO_2
Process Parameters Measured	♦ Total Casting Weight ♦ Mold Weight ♦ Binder Weights ♦ Metallurgical data ♦ % LOI ♦ Sand Temperature ♦ Stack Temperature ♦ Moisture Content ♦ Pressure ♦ Volumetric Flow Rate

The US EPA has designated SO_2 as a criteria pollutant. Industries such as coal-fired power plants are some of the largest generators of SO_2. Sulfur oxides evolved during cupola melting operations have been studied and quantified. However, SO_2 generated during PCS operations have not been monitored and reported in any Technikon study.

The sulfur sources for SO_2 evolution from foundry molds are seacoal (ground bituminous coal) and acid catalysts used in mold and core-making processes. These sources are transformed into sulfur oxide during contact with molten metal.

The work performed for this test sought to measure SO_2 generated during PCS operations in the Technikon Research Foundry. Two methods were used to measure SO_2 during the testing process. The first was using a commercially available UV photometric analyzer (Western Research series 900) that provided continuous monitoring of SO_2 evolution during the process. US EPA Method 6C protocol was adopted for this method. The second method used an impregnated activated beaded carbon media to absorb SO_2 that was analyzed off-line by Ion Chromatography to

provide an average SO_2 value for the process. OSHA ID200 protocol was used for this sampling and analysis.

The objective was to compare these two methods for SO_2 measurement from a stack source. The capital, installation and maintenance costs are moderately high (around $50 K for procurement and installation and $20K annually for consumables) for a UV analyzer. The costs involved with SO_2 analysis by ion chromatography are typically $50/sample. The results, if equivalent, could provide a basis for quantifying SO_2 from a foundry process by either technique. The second method could be adopted for exploratory purposes to estimate emission factors without the need for expensive stack testing.

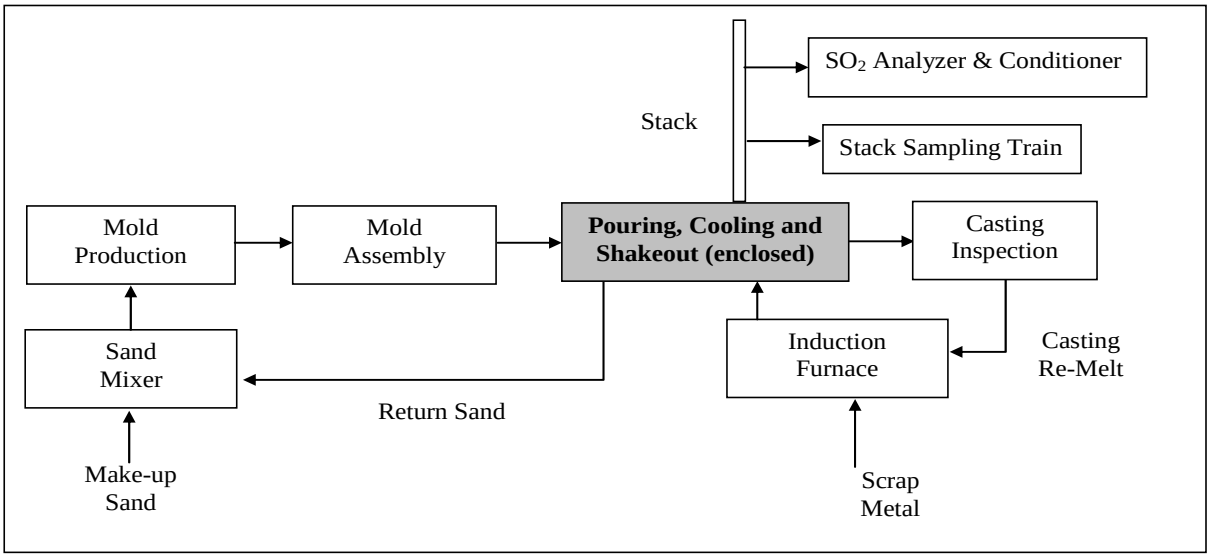
2.0 Test Methodology

2.1. DESCRIPTION OF PROCESS AND TESTING EQUIPMENT

A two part furan binder system was selected for this test. Sand mixing was performed using a Kloster paddle-type sand mixer and dispensed into a No-Bake® 4-on gear mold for the PCS process.

Figure 2-1 shows diagram of the Pre-Production Research Foundry process equipment.

Figure 2-1 Pre-Production Research Foundry Layout Diagram



The pouring, cooling and shakeout tests were conducted in a total enclosure test stand shown in Figure 2-2. The sampling train shown in Figure 2-3 included the calibrated orifices with adsorbent media to absorb SO_2. An additional probe was inserted into the stack (at the same location as the sampling train), the other end of which was connected to the SO_2 analyzer. A sample conditioner was included upstream of the SO_2 analyzer to remove moisture from the gas stream and deliver a dry sample to the analyzer. The details of the analyzer and the conditioning system are provided in Appendix E.

2.2. DESCRIPTION OF TESTING PROGRAM

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

Figure 2-2 Total Enclosure Test Stand

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

2. **Pouring, Cooling, and Shakeout:**

   a. **Mold and Metal Preparation:** The No-Bake® molds were prepared to a standard composition by the Technikon production team. Relevant process data was 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.

Figure 2-3 Sampling Train for SO_2 Collection

   b. **Individual Sampling Events:** Replicate tests were performed on six mold packages. The mold packages were placed into an enclosed test stand heated to approximately 85°F. Iron was poured into the mold through an opening in the top of the emission enclosure, after which the opening was closed.

   Continuous emission samples were collected during the forty-five minute pouring and cooling processes, during the fifteen-minute shakeout of the mold, and for an additional fifteen-minute period following shakeout. The total sampling time was seventy-five minutes.

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

Table 2-1Process Parameters Measured

Parameter	**Analytical Equipment and Methods**
Mold Weight	Cardinal 748E platform scale (Gravimetric)
Casting Weight	Cardinal 748E platform scale (Gravimetric)
Binder Weight	Mettler SB12001 Digital Scale (Gravimetric)
Loss on Ignition	Mettler PB302 Scale (AFS Procedure 2213-00-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

   a. **Foundry Emissions Analysis:** The specific sampling and analytical methods used in the Research Foundry tests are based on the US EPA and OSHA 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 2-2Sampling 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
Sulfur Dioxide*	OSHA ID200 and EPA Method 6C

* Criteria Pollutant

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

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

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

4. 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.

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3.0 Test Results

The average mass emission rates in pounds per pound of binder and pounds per ton of metal are presented in Table 3-1.

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

Method 6C charts for the tests are included in Appendix D of this report. The charts are presented to show the SO_2 emissions profile from the CEMS type analyzer for each emissions test.

Quantitation limits for SO_2 are presented in Appendix B.

Table 3-1Average Mass Emission Rates

	SO_2 (lb/ton of metal)			SO_2 (lb/lb of binder)		
	Method 6C	**OSHA ID 200**	**Difference**	**Method 6C**	**OSHA ID 200**	**Difference**
GO 001	1.2432	1.1729	0.0703	0.0179	0.0169	0.0010
GO 002	1.3448	1.2442	0.1006	0.0191	0.0177	0.0014
GO 003	I	I	I	I	I	I
GO 004	1.1987	1.1484	0.0503	0.0170	0.0163	0.0007
GO 005	1.2613	1.1408	0.1205	0.0181	0.0164	0.0017
GO 006	1.2779	1.1778	0.1001	0.0180	0.0166	0.0014
Average	1.2652	1.1768	0.0884	0.0180	0.0168	0.0012
SD	0.0534	0.0408	0.0278	0.0007	0.0006	0.0004
		t =	2.0136		t =	2.0303
		$t_{\frac{\alpha}{2}}$ =	2.365		$t_{\frac{\alpha}{2}}$ =	2.365

I = Invalidated

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

No-Bake Mix/Make/Cure	
Test Dates	**5/10/2005-5/12-2005**
	Average
Sand Dispensing Rate, lbs/15 sec	**30**
Binder Part1 + Part3 Dispensing Rate, gms/15 sec	**125.3**
Binder Part 2 Dispensing Rate, gms/15 sec	**53.7**
Calculated Standard % Binder	**1.28**
Calculated % Binder (BOS)	**1.30**
Mold Weight, lbs	**333.7**
Calculated Total Binder Weight, lbs	**4.28**
1800F LOI, %	**1.00**
Sand Temperature, deg F	**70**
Dogbone Core 2 hr. Tensile Strength, psi	**85**

No-Bake Pouring/Cooling/Shakeout	
Test Dates	**5/10/2005-5/12-2005**
	Average
Pouring Temp, deg F	**2633**
Pouring Time, sec.	**36**
Cast Weight (all metal inside mold), Lbs.	**122.08**
Process Air Temperature in Hood, deg F	**87**
Mold Temperature when placed in hood, deg F	**ND**
Ambient Temperature, deg F	**67**
Mold Age When Poured, hr	**22.7**
Test Length, min.	**75.0**

4.0 Discussion of Results

Table 3-1 provides a comparison of SO_2 in lb/ton of metal and lb/lb of binder for the two methods employed in this study. The values for SO_2 in lb/ton of metal using Method 6C indicate a % Relative Standard Deviation (RSD) of 4.22 % which is well within acceptable limits for such measurements. OSHA ID 200 method samples also yielded a % RSD of 3.47 % indicating that all tests conducted for this study were within acceptable process variations. Calculated values for lb/lb of binder, shown on the right half of Table 3.1 also have acceptable % RSD values.

A student "t" test statistic modified to include paired sample sets was adopted to derive statistical significance from the experimental data. The procedure included:

- Calculating differences between the individual pairs (each run constituted a pair)
- Rejection (or acceptance) of a hypothesis that the difference between the average of the differences is within a stated limit

The criteria used here is that the difference between the average of the differences is not larger (or smaller as the case may be) than 1 standard deviation (calculated from the differences). A 95% confidence level was used to provide for uncertainty issues.

From Table 3-1, for the lb/ton of metal data set, the "t" value for the difference between the averages of the difference is compared to $t_{\infty/2}$. Since $t < t_{\infty/2}$, we accept the hypothesis that the SO_2 emission factors measured by the two methods are equivalent within the bounds established by the statistical treatment used here. A similar conclusion can be drawn for the lb/lb of binder data. Detailed calculations for the statistics reported here are provided in Appendix F.

Note: OSHA ID 200 Method suggests the use of Teflon filters upstream of the adsorbent media to remove acid mist (from SO_3). This is to minimize collection of SO_3 which provides a positive bias. The Teflon filter was not used in this study. SO_3 is generated by the oxidation of SO_2 but non-catalytic conversion rates are so slow that most process conditions do not provide even small

amounts of SO_3 from process SO_2. Therefore the results are not expected to have been biased by any process SO_3 for these tests.

Method 6C utilizes a modified bubbler/impinger train assembly to measure SO_2 via wet chemistry collection and ion chromatography quantification. This is to evaluate the effects of any interfering species on the measurement from the continuous analyzer. Results are invalidated if the difference between the continuous analyzer and the wet chemistry method is greater than 7%. For this study, the train assembly test was not conducted. Oxides of nitrogen (NO, NO_2, etc.) typically cause interference with UV monitors. For this study, the use of a NOx analyzer indicated that NOx levels were too small to not be a source of interference for these tests.

SO_2 reporting limits expressed in lb/lb binder and lb/tn metal are shown in Appendix B.

The above results indicate that either method may provide a basis for quantifying SO2 emissions from a foundry process that is expected to have measurable emissions[*] of SO2. Adaptation of either method is one that a given foundry needs to address, dependent on costs and availability of trained personnel.

[*] Quantitation limits provided in this report will allow for calculation of measurable emission levels

APPENDIX A APPROVED TEST PLAN, SAMPLE PLANS AND PROCESS INSTRUCTIONS FOR GO

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TECHNIKON TEST PLAN

- **Contract Number:** 1411 **Task Number:** 2.3.7 **Series:** GO
- **Site:** Research Foundry
- **Test Type:** No-Bake Pour, cool, shakeout
- **Metal:** Class 30 gray iron
- **Mold Type:** 4-on variable tooth gear; No-Bake HA International Enviroset 22 ® Furan No-Bake resin @ 70 % of 1.3% total binder (BOS) and TC-50 mixed sulphonic acid catalyst @ 30 % of 1.3 % (BOS).
- **Sample Events:** 6
- **Analytes:** SO_2, CO, CO_2, NO_x, & TGOC.
- **Test Dates:** **Start:** 9 May 2005
  Finish: 9 May 2005

TEST OBJECTIVES:

1. The objective of this test is to validate the equivalency between media captured SO_2 and continuous measurement using an SO_2 analyzer, and to verify the operation of the continuous SO_2 analyzer.
2. Measure TGOC, CO_2, CO, NOx and SO_2 emissions from PCS of No-Bake molds.

VARIABLES:

No-bake PCS: The pattern shall be the 4-on gear. The mold shall be made with Wedron 530 sand. The binder shall be 1.30 +/-0.013% total (BOS) HA International Enviroset 22® resin (Part I) and TC-50 mixed sulphonic acids (Part II) combined in a ratio Part I I/Part II of 70/30. The sand will be mixed in the Kloster ribbon mixer and immediately dispensed. Molds will be made on the day before being poured and wrapped in plastic sheeting.

Molds will be poured with iron at 2630 +/- 10^{o}F. Mold cooling will be 45 minutes followed by 15 minutes of shakeout, or until no more material remains to be shaken out. The emission sampling shall include the pouring, cooling, shakeout, and 15 minutes of post shakeout for a total of 75 minutes.

A set of 12 dogbone tensile specimens shall be made from the material from each block pair and mold. The dogbones each will be weighed and tensile tested after two (2) hours of curing at 75^{o}F.

BRIEF OVERVIEW:

From a process viewpoint, this test is identical to 1411-113-GI. There will be 6 PCS molds.

SPECIAL CONDITIONS:

A Continuous Emission Measurement System (CEMS) type instrument will be used to measure SO_2 emissions in parallel to allow for comparison with 'sampling media' used in the train.

PRE-PRODUCTION GO - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
RUN 1											
THC, CO,CO2, SO2, NOX	GO001	X									TOTAL
	Excess								30	1	Excess
	Excess								30	2	Excess
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GO00101		1						200	5	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GO00102			1					200	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								800	7	Excess
	Excess								800	8	Excess
	Excess								800	9	Excess
OSHA ID200	GO00103		1						400	10	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GO00104					1			400	10	100/50 mg Carbon Bead (SKC 226-80)
	Excess								400	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GO - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
RUN 2											
THC, CO,CO2, SO2, NOX	GO002	X									TOTAL
	Excess								30	1	Excess
	Excess								30	2	Excess
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GO00201		1						200	5	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GO00202			1					200	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								800	7	Excess
	Excess								800	8	Excess
	Excess								800	9	Excess
OSHA ID200	GO00203		1						400	10	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GO00204					1			400	10	100/50 mg Carbon Bead (SKC 226-80)
	Excess								400	11	Excess
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GO - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
RUN 3											
THC, CO,CO2, SO2, NOX	GO003	X									TOTAL
	Excess								30	1	Excess
	Excess								30	2	Excess
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GO00301		1						200	5	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GO00302			1					200	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								800	7	Excess
	Excess								800	8	Excess
	Excess								800	9	Excess
OSHA ID200	GO00303		1						400	10	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GO00304			1					400	11	100/50 mg Carbon Bead (SKC 226-80)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GO - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
RUN 4											
THC, CO,CO2, SO2, NOX	GO004	X									TOTAL
	Excess								30	1	Carbopak
	Excess								30	2	Excess
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GO00401		1						200	5	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GO00402			1					200	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								800	7	Excess
	Excess								800	8	Excess
	Excess								800	9	Excess
OSHA ID200	GO00403		1						400	10	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GO00404				1				0		100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GO00405			1					400	11	100/50 mg Carbon Bead (SKC 226-80)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GO - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
RUN 5											
THC, CO,CO2, SO2, NOX	GO005	X									TOTAL
	Excess								30	1	Excess
	Excess								30	2	Excess
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GO00501		1						200	5	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GO00502			1					200	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								800	7	Excess
	Excess								800	8	Excess
	Excess								800	9	Excess
OSHA ID200	GO00503		1						400	10	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GO00504			1					400	11	100/50 mg Carbon Bead (SKC 226-80)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

PRE-PRODUCTION GO - SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
RUN 6											
THC, CO,CO2, SO2, NOX	GO006	X									TOTAL
	Excess								30	1	Excess
	Excess								30	2	Excess
	Excess								30	3	Excess
	Excess								60	4	Excess
OSHA ID200	GO00601		1						200	5	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GO00602			1					200	6	100/50 mg Carbon Bead (SKC 226-80)
	Excess								800	7	Excess
	Excess								800	8	Excess
	Excess								800	9	Excess
OSHA ID200	GO00603		1						400	10	100/50 mg Carbon Bead (SKC 226-80)
OSHA ID200	GO00604			1					400	11	100/50 mg Carbon Bead (SKC 226-80)
	Moisture		1						500	12	TOTAL
	Excess								5000	13	Excess

Series GO

Comparison of Media Sampled and Continuously Sampled SO_2 Emissions from Pouring Cooling & Shakeout of a Furan No-Bake Mold

Process Instructions

A. Experiment:
- **1.** Measure Selected criteria gaseous emissions from No-Bake molds during Pouring, Cooling, and Shakeout. Compare to test GI

B. Materials.
- **1.** No-Bake mold:
  - **a.** Part I: HA International Enviroset 22 ® Furan No-Bake binder.
  - **b.** Part II: HA International TC-50 sulphonic acid catalyst.
  - **c.** Wedron 530 Silica sand.
- **2.** Metal: Class 30 Grey Iron for Pouring, Cooling, Shakeout.

Caution: Observe all safety precautions attendant to these operations as delineated in the Preproduction operating and safety instruction manual as applicable to bldg. 238.

C. Furan No-Bake mold sand preparation.
- **1.** The furan No-Bake sand shall be 1.3 % total binder (BOS), Part I/Part II ratio 70/30.
- **2.** Calibrate the Kloster no-bake sand mixer to dispense 100 pounds/min more or less.
- **3.** Calibrate the binder pumps:
  - **a.** Part I: Based on the actual measured sand dispensing rate calibrate the Part I resin to be 70.00% of 1.3 % total binder BOS.
  - **b.** Part II: Based on the actual measured sand dispensing rate calibrate the Part II catalyst to be 30.00 % of 1.3 % total binder BOS.
  - **c.** All calibrations to have a tolerance of +/- 1% of the calculated value.

D. Mold requirements.
- **1.** Make six (6) gear molds according to standards determined in test series CW & CP capability studies.
  - **a.** Remove the front and top of the emission enclosure used for mix, make, cure, & store emission sampling.
  - **b.** Inspect the mold box for cracks and other damage. Repair before use.
  - **c.** Use 9/16 choke sleeve on sprue. Insert trunnion pin in mold box.
  - **d.** Prepare the mold box halves with a light coating of Ashland Zipslip® IP 78. Allow to fully dry.
  - **e.** Place the mold box drag half on the vibrating compaction table.
  - **f.** Begin filling the box.
  - **g.** When the box is about 3/4s full start the table vibration.

h. Manually spread the sand around the box as it is filling.
i. Slightly over fill the box.
j. Allow the vibrator to run an additional 5 seconds after the box is full.
k. Strike off the mold box so that the No-Bake drag mold is 5-1/2 inches thick, the cope mold is 5 inches thick.
l. Set the mold box with cope/drag half aside for 5 to 6 minutes or until it is hard to the touch.
m. Remove the two pivot-hole patterns from the mold box and mold.
n. Place a pallet on the roller conveyor.
o. Place a transport pallet on the floor. Place a sheet of polyethylene on the transport pallet large enough to wrap the finished mold.
p. Insert the carrier frame pivot pins into the cope/drag mold box pivot holes.
q. Using the crane and carrier frame invert the cope/drag box and suspend it about 1/8 inch or less above the pallet setting on the conveyor.
r. Remove the mold box cope/drag half from the mold by tapping lightly on the box with a soft hammer as you lift with the crane.
s. Set the cope/drag mold box aside.
t. Insert the pins of the carrier into the mold pivot holes.
u. Immediately raise, re-invert the drag mold parting line up, transport, and set the drag mold to the pallet on the floor.
v. Place the cope mold box on the vibrating compaction table.
w. Follow steps D.2.e-D.2.l.
x. Remove the box from the mold as was done with the drag half (2.D.o-2.D.s).
y. Immediately, close the unboxed cope mold over the drag mold, and wrap with 4-6 mil plastic. Store the mold for next day use at 80-90^{o}F.
z. The day the molds are to be used open the molds, rotate the cope mold to set it on edge.
aa. Drill cope vent holes per the template.
bb. Lift the drag mold and insert two steel straps under the mold. Return the drag mold to the pallet where it was.
cc. Blow out both mold halves.
dd. Apply a 1/4-3/8 inch glue bead of Foseco Core Fix 8 one inch (1) in from the outer edge of the drag mold.
ee. Immediately close cope onto drag. Visually check for closure.
ff. Connect the two (2) steel straps, one on either side of the pouring cup, with four (4) metal corner protectors each to hold the mold tightly closed.
gg. Weigh and record the weight of the sand only from the closed mold.
hh. Prior to pouring, glue a pouring basin over the sprue hole with Foseco CoreFix 8 or equivalent no emission water base refractory adhesive.

E. Tensile Dogbones: Use the last of the wasted sand to make 12 dogbone tensile test samples.(approx. 3 pounds)
1. Make 12 dogbones for each mold according to the protocol establish in capability study CW.
2. Place the assembled and clamped dogbone core box on the vibrating compaction table.
3. Start the Kloster mixer and waste a few pounds of sand.

4. Flood the core box with sand then stop the mixer.
5. Strike off the core box to ½ inch deep
6. Turn on the vibrating compaction table for 5 seconds.
7. Screed off most of the excess sand.
8. Screed the core box a second time moving in a back and forth manner to remove all excess sand.

Note: It is important to neither gouge the sand nor leave excess sand in center neck portion of the dogbone or the test results will be affected

9. Set aside for about 6-7 minutes or until hard to the touch.
10. Carefully remove the cores from the core box by separating the corebox components.
11. Store dogbones in a desiccating cabinet at 70-90^{o}F.
12. At one (1) hour break six (6) bones on the Thwing-Albert tensile tester and record the values on the Dogbone Tensile Log
13. At two (2) hours break six (6) bones on the Thwing-Albert tensile tester and record the values on the Dogbone Tensile log.
14. Bag three (3) dogbones, after tensile testing, from each mold for running 1800^{o}F core LOI. Report the average value for each mold.

F. Emission hood pouring ,cooling, shakeout:

1. Loading.
   - **a.** Hoist the mold onto the shakeout deck fixture within the emission hood with the pouring cup side toward the furnace.
   - **b.** Install ½ re-rod hanger in each riser vent and hang over shakeout supports.
   - **c.** Close and seal the emission hood and lock the ducts together.
   - **d.** Attach the heated ambient air duct to plenum
   - **e.** Wait to pour until the process air thermocouple is in the range 85-90^{o}F.
   - **f.** Record the ambient & process ambient air temperature.

2. Shakeout.
   - **a.** After 45 minutes of cooling time has elapsed turn on the shakeout unit and run for a full 15 minutes as prescribed in the emission test plan.
   - **b.** Turn off the shakeout. The emission sampling will continue for an additional 15 minutes or a total of 75 minutes
   - **c.** Wait for the emission team to signal that they are finished sampling.
   - **d.** Open the hood, remove the castings
   - **e.** Clean core sand out of the waste sand box, off the shakeout, and the floor.
   - **f.** Immediately load the next prepared mold and close the hood.
   - **g.** Weigh and record cast metal weight adjusted for the re-rod hanger weight.

G. Melting:

1. Initial charge:
   - **a.** Charge the furnace according to the Generic Start Up Charge for Pre-production heat recipe bearing effectivity date 6 Apr 2004.

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.
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 2700oF and slag the furnace.
j. Record all metallic and alloy additions to the furnace & tap temperature. Record all furnace activities with an associated time. Record Data Cast TPL, TPS, CE, C, & Si.

2. Back charging.
a. If additional iron is desired back charge according to the Generic Pre-production Last Melt heat recipe bearing effectivity date 18 Mar 1999.
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 G.1.e

3. Emptying the furnace.
a. Pig the extra metal after pouring the last test mold.

H. Pouring:
1. Preheat the ladle.
a. Tap 400 pounds more or less of 2700^{o}F metal into the cold ladle.
b. Casually pour the metal back to the furnace.
c. Cover the ladle.
d. Reheat the metal to 2780 +/- 20^{o}F.
e. Tap 450 pounds more or less 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, open the emission hood pour door and wait until the metal temperature reaches 2630 +/- 10^{o}F.
h. Commence pouring keeping the sprue full.
i. Upon completion close the hood door, return the extra metal to the furnace, and cover the ladle.
j. Record Pouring temperature and pour duration.

I. Casting cleaning
1. Spin blast set up.
a. Load the spin blast shot storage bin with 460 steel shot.
b. Turn on the spin blast bag house.
c. Turn on the spin blast machine.

d. Increase the magnetic feeder so that the motor amperage just turns to 12 amps from 11 amps.
e. Record the shot flow and the motor amperage for each wheel

2. Cleaning castings.
a. Place the four (4) castings from a single mold on one (1) casting basket.
b. Process each rotating basket for eight (8) minutes.
c. Remove and remark casting ID on each casting.

Steven Knight
Mgr. Process Engineering

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APPENDIX B TEST SERIES GO DETAILED EMISSION RESULTS

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Test Plan GO Individual PCS Emission Test Results – SO_2 Analyzer Data (US EPA Method 6C Table)

	GO 001	GO 002	GO 003	GO 004	GO 005	GO 006	Ave.	Stdev.	%RSD
Run Date	**5/10/05**	**5/10/05**	**5/11/05**	**5/11/05**	**5/11/05**	**5/12/05**			
scfm (ft3/min)	298.62	285.95	288.46	283.78	278.68	274.34			
Cast Wt. (lb)	124	121	122	121	122	122.5			
Test Time (min)	75	75	75	75	75	75			
Binder Wt. (lb)	38.1600	40.9400	38.4300	40.0400	42.9100	45.7700			
Raw Data in ppm									
SO2	21.0732	23.2290	I	20.8636	22.5400	23.2926	22.1997	1.1644	5.25%
Lb/Ton of Metal									
SO2	1.2432	1.3448	I	1.1987	1.2613	1.2779	1.2652	0.0534	4.22%
Lb/Lb Binder									
SO2	0.0179	0.0191	I	0.0170	0.0181	0.0180	0.0180	0.0007	4.08%

Test Plan GO Individual PCS Emission Test Results – Sampling Train Data
(OSHA ID200 Table)

Media Sample number	GO 101	GO 102	GO 103	GO 104	GO 201	GO 202	GO 203	GO 204	GO 301	GO 302	GO 303	GO 304	
Flow Rate (ml/min)	220.1	236.4	423.1	423.1	220.2	236.4	424.1	424.1	221.2	237.8	427.5	425.2	
scfm ft3/min	298.6	298.6	298.6	298.6	286.0	286.0	286.0	286.0	288.5	288.5	288.5	288.5	
Cast Wt. (lb)	124.00	124.00	124.00	124.00	121.00	121.00	121.00	121.00	122.00	122.00	122.00	122.00	
Test Time (min)	75	75	75	75	75	75	75	75	75	75	75	75	
Binder (lb)	4.307	4.307	4.307	4.307	4.259	4.259	4.259	4.259	4.280	4.280	4.280	4.280	
Lab Results (ug)	832.9	903.1	1649.2	84.4	919.7	1017.0	1590.1	178.7	745.0	811.0	1416.4	1376.7	

Media Sample number	GO 401	GO 402	GO 403	GO 404	GO 405	GO 501	GO 502	GO 503	GO 504	GO 601	GO 602	GO 603	GO 604
Flow Rate (ml/min)	221.8	238.2	428.3	0.0	425.8	222.1	238.3	428.8	426.4	221.8	237.9	428.9	426.0
scfm ft3/min	283.8	283.8	283.8	283.8	283.8	278.7	278.7	278.7	278.7	274.3	274.3	274.3	274.3
Cast Wt. (lb)	121	121	121	121	121	122	122	122	122	122.5	122.5	122.5	122.5
Test Time (min)	75	75	75	75	75	75	75	75	75	75	75	75	75
Binder (lb)	4.257	4.257	4.257	4.257	4.257	4.246	4.246	4.246	4.246	4.346	4.346	4.346	4.346
Lab Results (ug)	855.3	949.7	1492.4	4.0	1253.9	909.2	930.7	1642.1	1666.8	933.0	1003.3	1681.9	1618.7

Note: For test GO 003, the average SO2 in ppm was 18.84, lower than all the other tests.
The effect carried over to the tube results also where the SO2 values were also lower than other data points.
This could indicate some process effects that lowered overall SO2 evolution and therefore the SO2 values for the analyzer and also the tube data for GO 003 has been invalidated.

Test Plan GO Individual PCS Emission Test Results – Sampling Train Data
(OSHA ID200 Table)

					Test Results Lb/Lb of Binder							
GO 101	GO 102	GO 103	GO 104	GO 201	GO 202	GO 203	GO 204	GO 301	GO 302	GO 303	GO 304	
0.0164	0.0165	0.0169	0.0009	0.0175	0.0180	0.0157	0.0018	0.0142	0.0143	0.0139	0.0136	
GO 401	GO 402	GO 403	GO 404	GO 405	GO 501	GO 502	GO 503	GO 504	GO 601	GO 602	GO 603	GO 604
0.0160	0.0166	0.0145	Blank	0.0123	0.0168	0.0160	0.0157	0.0160	0.0166	0.0166	0.0155	0.0150

					Average Test Results Lb/Lb of Binder							
GO 101	GO 102	GO103+GO104	GO 201	GO 202	GO 203+GO 204	GO 301	GO 302	GO 303	GO 304			
0.0164	0.0165	0.0177	0.0175	0.0180	0.0175	0.0142	0.0143	0.0139	0.0136			
GO 401	GO 402	GO 403	GO 404	GO 405	GO 501	GO 502	GO 503	GO 504	GO 601	GO 602	GO 603	GO 604
0.0160	0.0166	0.0145	Blank	0.0123	0.0168	0.0160	0.0157	0.0160	0.0166	0.0166	0.0155	0.0150

					Average Test Results Lb/Lb of Binder							
GO 1 Ave	GO 2 Ave	GO 3 Ave	GO 004 Ave	GO 005 Ave	GO 006 Ave							
0.0169	0.0177	0.0143	0.0163	0.0164	0.0166							

					For Statistical Calculations Lb/Lb of Binder							
GO 1 Ave	GO 2 Ave	GO 3 Ave	GO 004 Ave	GO 005 Ave	GO 006 Ave	Ave	SD	RSD				
0.0169	0.0177	Invalid	0.0163	0.0164	0.0166	0.0168	0.0005	0.0327				

					Test Results Lb/Tn of Metal							
GO 101	GO 102	GO 103	GO 104	GO 201	GO 202	GO 203	GO 204	GO 301	GO 302	GO 303	GO 304	
1.1379	1.1487	1.1721	0.0600	1.2324	1.2694	1.1064	0.1243	0.9943	1.0069	0.9782	0.9559	
GO 401	GO 402	GO 403	GO 404	GO 405	GO 501	GO 502	GO 503	GO 504	GO 601	GO 602	GO 603	GO 604
1.1292	1.1675	1.0204	Blank	0.8624	1.1676	1.1140	1.0923	1.1150	1.1763	1.1793	1.0966	1.0625

					Average Test Results Lb/Tn of Metal							
GO 101	GO 102	GO103+GO104	GO 201	GO 202	GO 203+GO 204	GO 301	GO 302	GO 303	GO 304			
1.1379	1.1487	1.2321	1.2324	1.2694	1.2307	0.9943	1.0069	0.9782	0.9559			
GO 401	GO 402	GO 403	GO 404	GO 405	GO 501	GO 502	GO 503	GO 504	GO 601	GO 602	GO 603	GO 604
1.1292	1.1675	1.0204	Blank	0.8624	1.1676	1.1140	1.0923	1.1150	1.1763	1.1793	1.0966	1.0625

					Average Test Results Lb/Tn of Metal							
GO 1 Ave	GO 2 Ave	GO 3 Ave	GO 004 Ave	GO 005 Ave	GO 006 Ave							
1.1729	1.2442	1.0006	1.1484	1.1408	1.1778							

					For Statistical Calculations Lb/Tn of Metal							
GO 1 Ave	GO 2 Ave	GO 3 Ave	GO 004 Ave	GO 005 Ave	GO 006 Ave	Ave	SD	RSD				
1.1729	1.2442	I	1.1484	1.1408	1.1778	1.1768	0.0408	0.0347				

Test GO Quantitation Limits – Lb/Lb Binder

Analytes	Lb/Lb Binder
Sulfur Dioxide (Method OSHA ID 200)	2.57E-05
Sulfur Dioxide (Method 6C)	2.00E-04

Test GO Quantitation Limits – Lb/Tn Metal

Analytes	Lb/Tn Metal
Sulfur Dioxide (Method OSHA ID 200)	5.22E-02
Sulfur Dioxide (Method 6C)	1.47E-02

APPENDIX C TEST SERIES GO DETAILED PROCESS DATA

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GO Detailed Process Data

No-Bake Mix/Make/Cure							
Test Dates	5/10/2005	5/10/2005	5/10/2005	5/11/2005	5/11/2005	5/12/2005	
Emissions Sample # / Production Sample #	GO 001	GO 002	GO 003	GO 004	GO 005	GO 006	Average
Sand Dispensing Rate, lbs/15 sec	30	30	30	30	30	30	**30**
Binder Part1 + Part3 Dispensing Rate, gms/15 sec	125.3	125.3	125.3	125.3	125.3	125.3	**125.3**
Binder Part 2 Dispensing Rate, gms/15 sec	53.7	53.7	53.7	53.7	53.7	53.7	**53.7**
Calculated Standard % Binder	1.28	1.28	1.28	1.28	1.28	1.28	**1.28**
Calculated % Binder (BOS)	1.30	1.30	1.30	1.30	1.30	1.30	**1.30**
Mold Weight, lbs	335.6	331.8	333.5	331.7	330.8	338.6	**333.7**
Calculated Total Binder Weight, lbs	4.31	4.26	4.28	4.26	4.25	4.35	**4.28**
1800F LOI, %	1.04	0.98	0.98	1.01	0.99	0.98	**1.00**
Sand Temperature, deg F	ND	69	ND	70	72	69	**70**
Dogbone Core 2 hr. Tensile Strength, psi	62	62	113	136	33	105	**85**
No-Bake Pouring/Cooling/Shakeout							
Test Dates	5/10/2005	5/10/2005	5/10/2005	5/11/2005	5/11/2005	5/12/2005	
Emissions Sample # / Production Sample #	GO 001	GO 002	GO 003	GO 004	GO 005	GO 006	Average
Pouring Temp, deg F	2639	2628	2630	2634	2627	2638	**2633**
Pouring Time, sec.	45	41	26	36	33	37	**36**
Cast Weight (all metal inside mold), Lbs.	124.00	121.00	122.00	121.00	122.00	122.50	**122.08**
Process Air Temperature in Hood, deg F	87	86	86	88	87	87	**87**
Mold Temperature when placed in hood, deg F	ND	ND	ND	ND	ND	ND	**ND**
Ambient Temperature, deg F	62	66	66	69	71	68	**67**
Mold Age When Poured, hr	22.8	24.0	25.8	20.0	22.3	21.0	**22.7**
Test Length, Min	75.0	75.0	75.0	75.0	75.0	75.0	**75.0**

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APPENDIX D METHOD 6C CHARTS

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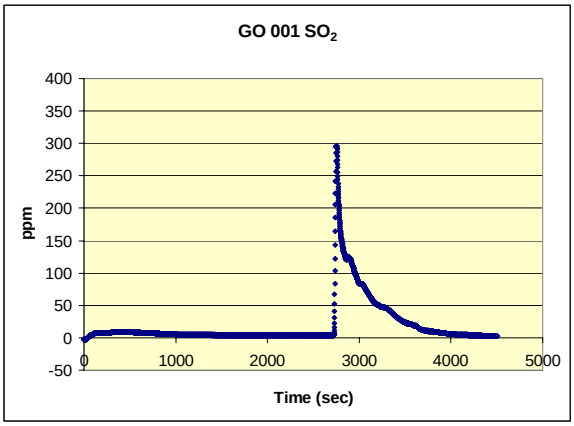
GO 001 SO2
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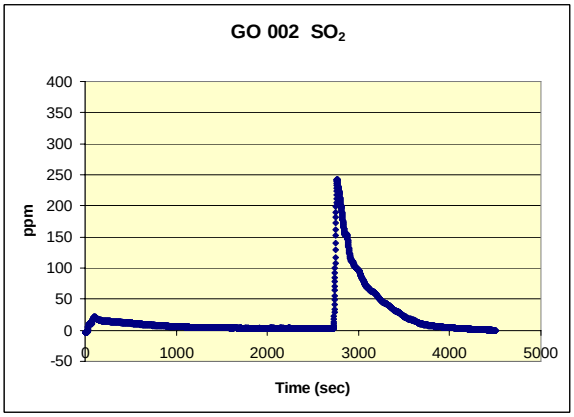
300
250
200
150
100
50
0
-50
0
1000
2000
3000
4000
5000
Time (sec)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ppm
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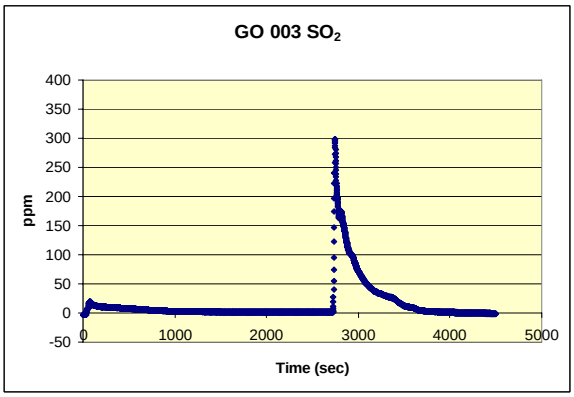
300
250
200
150
100
50
0
-50
0
1000
2000
3000
4000
5000
Time (sec)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ppm
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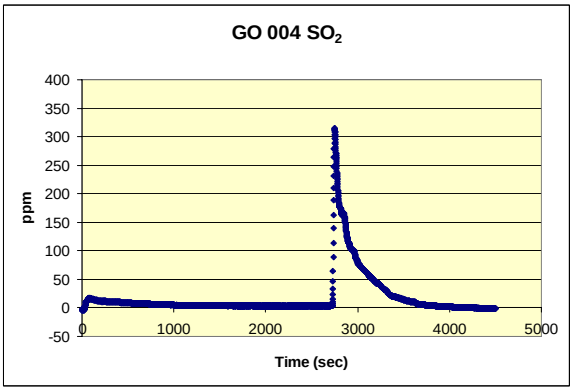
350
300
250
200
150
100
50
0
-50
0
1000
2000
3000
4000
5000
Time (sec)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ppm
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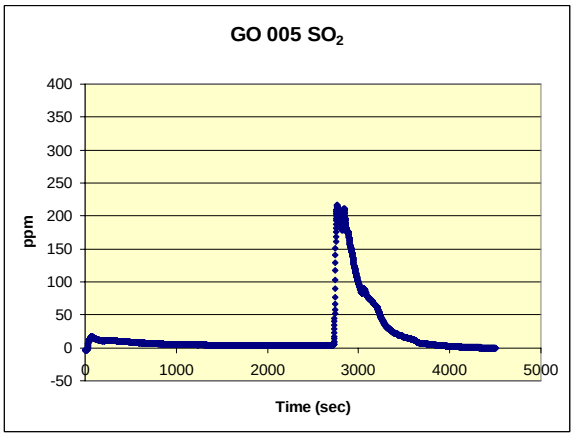
350
300
250
200
150
100
50
0
-50
0
1000
2000
3000
4000
5000
Time (sec)


GO 005 SO2
ppm
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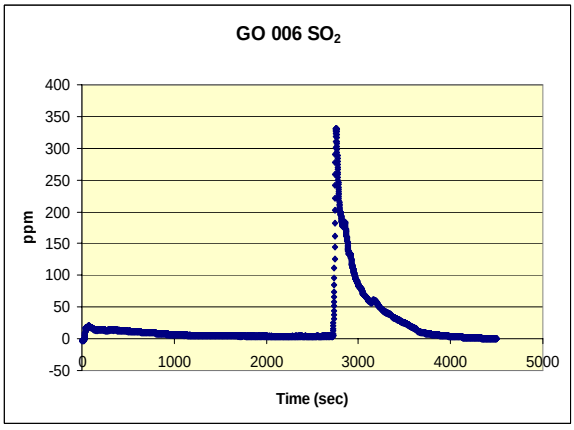
350
300
250
200
150
100
50
0
-50
0
1000
2000
3000
4000
5000
Time (sec)


GO 006 SO2
ppm
400
350
300
250
200
150
100
50
0
-50
0
1000
2000
3000
4000
5000
Time (sec)

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APPENDIX E SO_2 ANALYZER AND SAMPLE CONDITIONER

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SO_2 Analyzer

Model 900 series

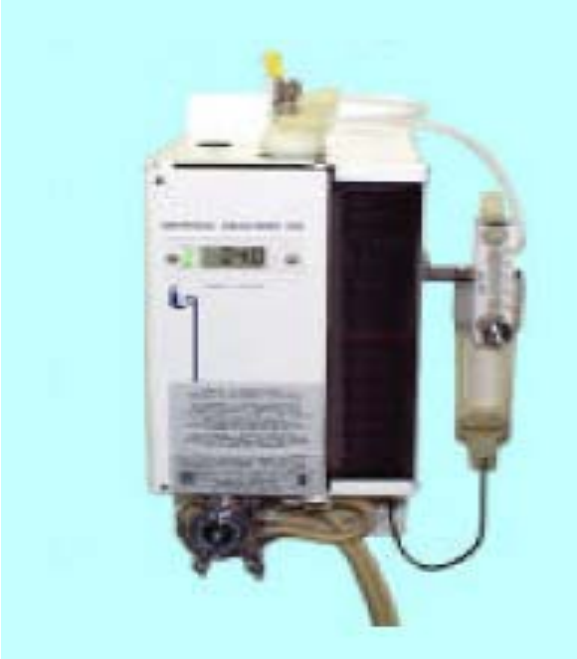
This analyzer is marketed by Ametek Instruments under the Western Research Brand name. It uses pulsed UV (dual beam, dual wavelength) lamps with a fixed optical configuration. The sources provide high intensity pulses at a fixed wavelength with low total power. This provide high resolution with excellent linearity over 4-5 orders of magnitude. It also provides for increased light throughput with reduced noise levels. The low total power of the lamps minimizes any sample photolysis. It can be configured to be used for measuring most gases that have UV absorbance. An optional configuration provides for longer sample cell for measuring lower concentrations.

Manufacturer	Western Research (now owned by AMETEK)
Measurement principle	Dual beam, dual wavelength UV light
Interference	None from H_2O and CO_2
Accuracy	Better than 0.25 ppm
Sample gas temperature	Ambient
Ambient conditions	5 to 50 ºC, 5 to 95 % RH, non-condensing
Zero drift	< 0.5 ppm in 24 h
Linearity	Better than ± 1% of F. S.
Reproducibility	Better than ± 1% of F. S.
Power	120 VAC ± 10%, 47 to 63 Hz or 220 VAC ± 10%, 47 to 63 Hz, 90W
Communications	Analog: 4x voltage outputs, any combination 0 to 100 mVDC, 0 to 1 VDC, 0 to 10VDC 4x 4-20mA self powered outputs Digital: 1 RS232 port for diagnostics 1 RS422 with Modbus (optional)
Dimensions	7 X 19 X 23.5 in
Weight	27 lbs (approx.)
Sample gas flow	1 to 2 l/min
Number of gases	Single
Response time	< 30 s to 90% of signal (without conditioning system)

Universal Sample Conditioner

Model 3080SS

This is a sample conditioner system which includes: a sample cooler, sample pump, water intrusion monitor with filter, rotometer w/needle valve, and cooler stand. It is designed to transfer sample gas to extractive analyzers. It uses a two-pass conditioner and utilizes the Peltier effect to deliver a dry gas stream to the analyzer.



Outlet sample dew point	5 ºC adjustable
Inlet sample temperature	Up to 260 ºC for S. S
Operating temperature	0 to 40 ºC
Maximum cooling power	252 BTUs/hr
Soluble gas removal	< 2% for SO_2
Dimensions	18 X 7.5 X 11 “
Weight	60 lbs (approximately)
Power requirements	95-125 VAC, 50/60 Hz, 700 W
Flow capacity	8 l/min maximum (at 15 % H_2O and 25 ºC ambient). For higher moisture and/or ambient temperatures, flow must be adjusted down.

APPENDIX F t-TEST APPLIED TO PAIRED SAMPLES

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A t-test applied to paired samples was used to analyze the data from a statistical significance viewpoint. Assumptions include independent sampling, normal distributions of the sample values, and unequal variances. The appropriate hypothesis is provided below:

The difference between the individual values was calculated. The average and standard deviation of these values (the differences) was calculated. The "t" value for was calculated from:[1]

$$t = \frac{\bar{y} - Do}{\sqrt{\frac{S_1^{\,2} + S_2^{\,2}}{n}}}$$

Where: $\bar{y}$ = average of the difference between individual paired values

Do = acceptable difference between individual paired values (user selected value)

$S_1^{\,2}$ = variance of sample set 1 (Method 6C values)

$S_2^{\,2}$ = variance of sample set 2 (OSHA ID 200 values)

n = number of paired sets (here 5)

The $t_{\frac{\alpha}{2}}$ value is read from a t statistic table with degrees of freedom (df) calculated from:

$$df = \frac{(n-1)^2}{(n-1)c^2 + (c-1)^2(n-1)}$$

Where: $$c = \frac{S_1^{\,2}/n}{\frac{S_1^{\,2} + S_2^{\,2}}{n}}$$

The rejection criterion is:

$$|t| > t_{\frac{\alpha}{2}} \text{ for a given } \alpha$$

The calculations are provided in the following table.

[1] An Introduction to Statistical Methods and Data Analysis, 3rd Ed., Lyman Ott, PWS-Kent Publishing, Boston, 1988.

	SO_2 (lb/ton of metal)			SO_2 (lb/lb of binder)		
	Method 6C	**OSHA ID 200**	**Difference**	**Method 6C**	**OSHA ID 200**	**Difference**
GO 001	1.2432	1.1729	0.0703	0.0179	0.0169	0.001
GO 002	1.3448	1.2442	0.1006	0.0191	0.0177	0.0014
GO 003	I	I	I	I	I	I
GO 004	1.1987	1.1484	0.0503	0.017	0.0163	0.0007
GO 005	1.2613	1.1408	0.1205	0.0181	0.0164	0.0017
GO 006	1.2779	1.1778	0.1001	0.018	0.0166	0.0014
Average	1.2652	1.1768	0.0884	0.0180	0.0168	0.0012
SD	0.0534	0.0408	0.0278	0.0007	0.0006	0.0004
		c =	0.6316		**c =**	0.6373
		df =	7.4820		**df =**	7.4391
		t =	2.0136		**t =**	2.0303

For the lb/ton data set:

$$t = 2.0136 \langle t_{\frac{\alpha}{2}} = 2.365$$

This value was calculated using:

n = 5
df = 7
confidence = 95%
$\bar{y} = 0.0884$
Do = 0.0278
$S_1^2 = (0.0534)^2$
$S_2^2 = (0.0408)^2$

For the lb/lb data set:

$$t = 2.0303 \langle t_{\frac{\alpha}{2}} = 2.365$$

This value was calculated using:

n = 5
df = 7
confidence = 95%
$\bar{y} = 0.0012$
Do = 0.0004
$S_1^2 = (0.0007)^2$
$S_2^2 = (0.0006)^2$

APPENDIX G ACRONYMS AND ABBREVIATIONS

BO	Based on ( )
BOS	Based on Sand
Emissions Indicators	Data summaries that provide an indication of a product's emissions
HAP	Hazardous Air Pollutant defined by the 1990 Clean Air Act Amendment
I	Data rejected based on data validation considerations
LOI	Loss On Ignition
NA	Not Applicable
NOx	Nitrogen Oxides
OSHA	Occupational Safety and Health Administration
PCS	Pouring/Cooling/Shakeout
RSD	Relative Standard Deviation
SD	Standard Deviation
SO_2	Sulfur Dioxide
SO_3	Sulfur Trioxide
US EPA	United States Environmental Protection Agency
CEMS	Continuous Emissions Monitoring System