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Sulfuric Acid Mist Test Method Evaluation on the Trimer Control System

B1877

at Guardian Industries Corp.
14600 Romine Rd
Carleton, MI 48117

Test Dates: February 17 & 18, 2016

Project 16-214

Prepared by:
Empire Stack Testing, LLC. (AETB)
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General Manager
March 18, 2016

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1. TEST RESULTS SUMMARY (TRS)

Table 1-1: Results Summary

			Stack Parameters					
			O_2	CO_2	Moisture	Temperature	Flow Rate	
Site	**Date**	**Run**	**(%)**	**(%)**	**(%)**	**(F)**	**(ACFM)**	**(DSCFM)**
CTM 13B Inlet	**2/17/2016**	**1 (2)**	8.0	6.0	7.70	1026	140950	45323
	2/18/2016	**2 (5)**	9.0	7.0	9.9	1022	137753	43891
	2/18/2016	**3 (8)**	10.0	7.0	11.6	1013	139374	43983
		Average	9.0	6.7	9.73	1020	139359	44399
CTM 13B Outlet	**2/17/2016**	**1 (3)**	13.0	5.5	11.6	635	147978	61942
	2/18/2016	**2 (6)**	12.5	5.5	8.9	631	153826	67400
	2/18/2016	**3 (9)**	12.0	6.5	8.7	629	148099	65365
		Average	12.5	5.8	9.73	632	149968	64902

			Emissions					
			H2SO4			SO2		
Site	**Date**	**Run**	**(lbs/ton glass)**	**(lbs/hr)**	**(ppmvd)**	**(lbs/ton glass)**	**(lbs/hr)**	**(ppmvd)**
CTM 13B Inlet	**2/17/2016**	**1 (2)**	0.135	2.39	3.45	3.227	57.28	126.77
	2/18/2016	**2 (5)**	0.421	7.47	11.15	3.851	68.36	156.23
	2/18/2016	**3 (8)**	0.216	3.83	5.70	4.457	79.12	180.46
		Average	**0.257**	**4.56**	**6.77**	**3.845**	**68.25**	**154.49**
CTM 13B Outlet	**2/17/2016**	**1 (3)**	0.118	2.08	2.20	0.325	5.73	9.28
	2/18/2016	**2 (6)**	0.058	1.03	1.00	0.204	3.60	5.36
	2/18/2016	**3 (9)**	0.054	0.96	0.96	0.250	4.40	6.75
		Average	**0.0770**	**1.36**	**1.39**	**0.2597**	**4.58**	**7.13**
Control Efficiency (%) lbs/hr			**70.3%**			**93.3%**		
CTM 013 Outlet	**2/17/2016**	**1 (1)**	0.070	1.23	1.30	0.402	7.09	11.48
	2/18/2016	**2 (4)**	0.040	0.71	0.69	0.236	4.16	6.19
	2/18/2016	**3 (7)**	0.044	0.78	0.78	0.307	5.41	8.29
		Average	**0.051**	**0.91**	**0.92**	**0.315**	**5.55**	**8.65**
Permit Limit			**n/a**	**1.6**	**n/a**	**1.2**	**n/a**	**n/a**

Table 1-2: Production Data Summary

Production Data Summary				
		Production Rate		**Pressure Drop**
Date	**Run**	**Tons/Day**	**Tons/hr**	**in. WC**
2/17/2016	**1**	426	17.75	13.2
2/18/2016	**2**	423	17.625	13.2
2/18/2016	**3**	423	17.625	13.2

Table 1-3: Summary of Analytical QA/QC Results

Test Method	Parameter	QA/QC Criteria	Ground Site QA/QC Status	Outlet Site QA/QC Status	Inlet Site QA/QC Status	Within QC Criteria?
RM 2	Pitot Leak Check	Δ 0.0" H_2O / 15 seconds	▨	0.0 @ 5.0" (max)	0.0 @ 4.4" (max)	Yes
CTM013	Sample Train Leak Check (post test)	<0.02 cfm	0.002 cfm @ 7.0" H_2O (max)	▨	▨	Yes
	Probe Temperature	> 350 °F	375°F (avg.)	▨	▨	Yes
	Thimble Temperature	> 500 °F	526°F (avg.)	▨	▨	Yes
CTM13B	Sample Train Leak Check (post test)	<0.02 cfm	▨	0.017 cfm @ 17.0" H_2O (max)	0.013 cfm @ 13.0" H_2O (max)	Yes
	Probe Temperature	> 400 °F	▨	473°F (avg.)	467°F (avg.)	Yes
	Thimble Temperature	> 500 °F	▨	501°F (avg.)	502°F (avg.)	Yes
	Isokinetics	90 – 110 %	▨	91 – 105 %	93 – 100 %	Yes

2. FACILITY INFORMATION & STATEMENT OF CERTIFICATION

Facility Information

Name of Source Operator: Guardian Industries Corp.

Name of Source Owner: Guardian Industries Corp.

Address of Owner: 14600 Romine Road, Carleton, MI 4811 7

Source Identification: Glass Manufacturing

Location of Source: 14600 Romine Road, Carleton, MI 4811 7

Owners Representative: Michael Smolenski

STATEMENT OF CERTIFICATION

I certify that "to the best of my knowledge" the state and federal regulations, operating permits, or plan approvals applicable to this source and/or control device to be tested have been reviewed and that all testing requirements therein have been incorporated into the test plan.

Signature	**Signature**
EHS MANAGER	Project Manager
Title	**Title**
3/17/2016	3-18-16
Date	**Date**
Source owner/operator	On-site supervisor for the test team

3. INTRODUCTION

3.1 Introduction

Guardian Industries Corp. (Guardian) has contracted Empire Stack Testing, LLC. (Empire) to perform Sulfuric Acid (H_2SO_4) testing services on their glass furnace in Carleton, Michigan. Testing used CTM-13B at both the inlet and outlet of the Trimer control system, with simultaneous testing via CTM-13 at the outlet. The impinger solutions were also analyzed for SO_2.

Section 5 of this report contains the sampling and analytical procedures used to perform the test program. Section 6 details the quality assurance/quality control (QA/QC) procedures for the test program.

3.2 Test Program Objective

The objective of this test program was to quantify the H_2SO_4 emissions of the parameters listed in Table 3-1 from the inlet and outlet of the Trimer control system. All testing followed applicable methodologies of the Environmental Protection Agency (EPA), and as defined in Table 3-1.

3.3 Test Personnel

Coordinating the test program were:

Michael Smolenski
Guardian Industries Corp.
(734)-654-4283

Michael T. Karter, QSTI
Empire Stack Testing, LLC.
(716)-481-6749

Mike Challis, CET, B.Sc., C. Chem
Maxxam Analytics International
(905)- 817-5790, ext. 5790

3.4 Test Plan

Testing for all parameters was completed in triplicate following Reference Methods (RMs). The test program incorporates reference methods outlined in the United States Environmental Protection Agency (USEPA) Code of Federal Regulations Title 40, Part 60 (40CFR60), Appendix A. See Table 3-1 below.

Table 3-1: Summary of Test Plan

PARAMETER	METHOD	ANALYSIS	SAMPLE DURATION (MINUTES)	TEST LOCATION(S)
Flow Rate	RM 1 & 2	S-Type Pitot Tube / Manometer	various	Inlet & Outlet
Dry Molecular Weight	RM 3	O_2 and CO_2 Fyrites	various	Inlet & Outlet
Moisture	RM 4	Gravimetric	72	Inlet & Outlet
H_2SO_4 & SO_2	CTM 013	Ion Chromatography	72(2)	Outlet
H_2SO_4 & SO_2	CTM 013B	Ion Chromatography	72	Inlet(1) & Outlet(3)

NOTES:

(1)	The inlet site has a single test port, therefore a non-isokinetic sample was collected at a single traverse point. Emission rates were calculated using the flow rate measured at the outlet site.
(2)	*NOTE: The sample time and rate have been changed from 30 minutes at 10 lpm to allow direct comparison to the CTM 013B samples.*
(3)	Due to limited access through ports at the outlet stack, CTM 013 for the outlet was sampled through a port in the horizontal ductwork directly upstream of the base of the stack.
CTM:	Conditional Test Method
H_2SO_4:	Sulfuric Acid
RM:	United States Environmental Protection Agency Reference Method

3.5 Test Schedule

Day 1 (February 16, 2016): Mobilize to Guardian
Day 2 (February 17, 2016): Complete setup & complete 1 test run
Day 3 (February 17 & 18, 2016): Complete 2 test runs
Day 4 (February 19, 2016): Demobilize from site

3.6 Process Description

Flat glass manufacturing Line #2 consisting of a raw material melting Furnace, glass forming and finishing, and glass cutting. Line #2 produces flat glass using the float method. Materials are weighed and mixed with water in the batch-house before entering the natural gas fired Furnace. Glass then enters the tin bath to be formed and drawn. Next, it enters a lehr to reduce its temperature. The emission unit is controlled by a new (Trimer ECS) Control Device consisting of a Dry Scrubber, Particulate Filter, and Selective Catalytic Reduction (SCR).

3.7 Plant data

The plant's SCADA system continuously records the operating data to be included in the test report. The plant provided plant operation and summarized pertinent operating data to represent plant operation. These data and summaries were provided electronically (MS Excel).

4. PRESENTATION OF RESULTS / EXECUTIVE SUMMARY

This Executive Summary discusses, in detail, the test results and any anomalies, their resolution, and any effect on the results quality or usability.

4.1 Discussion of Results

Testing was completed on February 17-18, 2016 for H_2SO_4 and SO_2. During this test program, the facility operated at a production rate of 426 tpd (17.75 tph) for run 1 and 423 tpd (17.625 tph) for runs 2 and 3.

The test results illustrate the furnace's SO_2 and H_2SO_4 emissions were less than (compliant with) the established permit limits. All field and lab data are included in the appendices of this report.

4.1.1 Isokinetics

Each CTM 13B sample run for H_2SO_4 met the isokinetic limit of 100 % ± 10%. These and other QAQC criteria are summarized in Table 1-3.

4.1.2 H_2SO_4 Test Result (CTM 13B)

The average emission rate of sulfuric acid was 1.36 lbs/hr and 0.0770 lbs/ton of glass. The unit demonstrated compliance with the emission limit of 1.6 lbs/hr. The sulfuric acid control equipment yielded a control efficiency (CE) of 70.3%. See Table 1-1.

4.1.3 SO_2 Test Results (CTM 13B)

The sulfur dioxide emission rate was quantified as 4.58 lbs/hr and/or 0.2597 lbs/ton of glass. The unit demonstrated compliance with the emission limit of 1.2 lbs/ton. The sulfur dioxide control equipment yielded a control efficiency (CE) of 93.3%. See Table 1-1.

4.1.4 H_2SO_4 Test Result (CTM 13)

The average emission rate of sulfuric acid was 0.91 lbs/hr and 0.051 lbs/ton of glass. The unit demonstrated compliance with the emission limit of 1.6 lbs/hr. See Table 1-1.

4.1.5 SO_2 Test Results (CTM 13)

The sulfur dioxide emission rate was quantified as 5.55 lbs/hr and/or 0.315 lbs/ton of glass. The unit demonstrated compliance with the emission limit of 1.2 lbs/ton. See Table 1-1.

4.2 Anomalies

A 15-minute purge was not performed at the CTM 13 outlet ground site after the first run on 2/17/2016.

No other anomalies were recorded during testing nor report production.

5. SAMPLING AND ANALYTICAL PROCEDURES

This section provides a brief overview of the specific test methods that were used to determine the Sulfuric Acid emissions from each the glass furnace. All test method procedures were performed in accordance with the USEPA Reference Methods given in 40CFR60, Appendix A. The details of each method are given in the following sections.

5.1 Reference Method Test Location

The emission point exhausts the gases from the furnace that produces float glass. Emissions are discharged to atmosphere after passing through the Trimer control system. The inlet test location is horizontal duct with an internal diameter (ID) of 6'-3". The vertical exhaust stack has an ID of 6'-6.5".

The inlet duct is fixed with a single 6-inch diameter port. The test ports are located approximately 5 equivalent diameters downstream of a disturbance and 1 equivalent diameters upstream of another disturbance. See Figure 5-1.

The exhaust stack is fixed with two 10-inch diameter ports. The test ports are located approximately 13 equivalent diameters downstream of a disturbance and 2.3 equivalent diameters upstream of another disturbance. See Figure 5-2.

The ground site of the exhaust stack is fixed with two 6-inch diameter ports. The test ports are located approximately 8 equivalent diameters downstream of a disturbance and 1 equivalent diameter upstream of another disturbance. See Figure 5-3.

5.2 Sampling Point Location

5.2.1 Volumetric Flow

Representative measurement of pollutant emissions and total volumetric flow rate from a stationary source requires a measurement site where the effluent stream is flowing in a known direction and cyclonic flow is not present. See section 3.3.1, below.

According to Reference Method 1, the cross section of the stack is divided into equal areas and a traverse point is then located within each of these areas. The number of duct diameters upstream and downstream from the test location to a flow disturbance determines the number of traverse points in a cross section.

As these stacks have diameters >24 inches the outermost traverse points were at least 1 inch from the stack walls.

Sampling was performed at 12 traverse points per traverse for a total of 24 sampling points, as set forth by RM 1. See Figures 5-4, 5-5, and 5-6.

5.3 Stack Gas Velocity and Volumetric Flow Rate

According to Reference Method 2, the gas velocity in a stack was determined from the average velocity head with a type S Pitot tube, gas density, stack temperature, and stack pressure.

The average velocity head was determined by using an inclined manometer and a type S Pitot tube with a known coefficient of 0.84 that is determined geometrically by standards set forth in Reference Method 2. Stack temperature was taken at each traverse point using a type K thermocouple. Static pressure was determined by using a straight tap and an inclined manometer.

5.3.1 Cyclonic Flow Check

The initial velocity traverse and cyclonic flow check were performed prior to beginning the first test run. These data were used to determine the appropriateness of the sample site and determine sampling rates and dwell times. These data were included in the test report. Source modification, alternative sampling procedures or selection of a more suitable location is required when cyclonic flow patterns exist with an average rotation angle (α) greater than 20°. Four possible alternatives available for conducting isokinetic particulate emission testing or flow determinations when cyclonic or nonparallel flow patterns exist are:

- Find another more suitable location.
- Modify the source to permit standard sampling procedures to be used. This can be done by installing flow-straightening vanes or longer stack extensions tangential to the stack axis upstream of the sampling location.
- Apply the modified sampling procedures of alignment approach or time-weighted alignment method to obtain accurate results. (See 40CFR60, Appendix A, RM 1, Section 11.5)
- Use standard or alternative methodology that gives results biased high (in the agency's favor).

5.4 Oxygen & Carbon Dioxide Concentration (RM 3)

The Oxygen and Carbon Dioxide concentrations used in the calculation of the stack gases molecular weight were measured according to RM-3 with grab samples and Fyrite gas analyzers.

5.5 Moisture Determination (RM 4)

The determination of effluent moisture was performed as part of the wet-chemistry sampling, as detailed below in CTM013 and CTM013B.

5.6 Sulfuric Acid (CTM-013)

5.6.1 Background

This method was developed as an alternative to EPA Method 8 for determining sulfuric acid emissions from Kraft recovery furnaces. When testing recovery furnaces, EPA Method 8 is subject to significant interference from sulfates, which are present in the particulate matter, and sulfur dioxide. The alternative method uses a quartz in-line filter to remove particulate matter from the gas stream prior to capturing sulfuric acid. The use of a controlled condensation technique eliminates the potential for interference from sulfur dioxide.

A gas sample is extracted from the sampling point in the recovery furnace stack. The sulfuric acid vapor or mist (including sulfur trioxide) and the sulfur dioxide are separated, and both fractions are measured separately by either the barium-thorin titration method or Ion Chromatography (IC).

5.6.2 Sampling

The sampling train consists of a glass nozzle and heated glass probe, which were maintained at the temperature of >177°C (350°F). The probe was then connected to the filter holder housed in an oven box that was also maintained at the temperature of >500 °F. The filter holder was constructed of quartz with a quartz thimble filter.

Sampling was performed for a minimum of 72 minutes at a constant rate (±10%) of ~5.0 lpm (~2 cfm). *NOTE: The sample time and rate have been changed from 30 minutes at 10 lpm to allow direct comparison to the CTM 013B samples.*

A condenser connects the thimble to the train. The condenser was filled with water and its temperature was maintained between 75 and 85°C (167 to 185°F). The condenser was followed by two Greenburg-Smith impingers and then a modified Greenburg-Smith impinger. The first two impingers contained 100 ml of 3% hydrogen peroxide (H_2O_2). The third impinger contained 100 ml of distilled deionized water (RODI). The fourth impinger contained approximately 500 g of silica gel desiccant.

A vacuum line connects the outlet of the last impinger to the control module. The control module consists of a vacuum gauge, rotary pump, by-pass and main valve, dry gas meter, orifice, and an inclined manometer. The sample train is illustrated in Figure 5-7.

Coinciding with the sampling were velocity, moisture, and dry molecular weight determinations.

5.6.3 Sample Purge

At the completion of the test run, the probe was separated from the thimble, and a 15-minute purge with clean air was performed as required by the method at the same rate at the test run.

5.6.4 Sample Recovery

Recovery was performed onsite in Empire's mobile laboratory at the completion of each test run.

Container 1

Rinse separately the probe, quartz thimble holder and the H_2SO_4 condenser with deionized water using multiple rinse. After completing the rinses, the lid on the sample container was tightened and the height of the fluid level marked. The filter was discarded.

Container 2:

The liquid from the first two impingers was quantitatively transferred into a clean sample bottle (glass or plastic).

Container 3

The water from the third impinger was weighed in the field, and then discarded.

Blank H_2O_2

Take ~100 ml of H_2O_2 and place it in a recovery bottle. The liquid level on the bottle was marked.

5.6.5 Analysis

The samples were shipped to Maxxam Analytics International of Mississauga, Ontario, Canada for analysis for either IC or titration. The impinger solutions will also be analyzed for SO_2.

5.7 Sulfuric Acid (CTM-013B)

5.7.1 Background

Sulfuric acid emissions from combustion sources have traditionally been measured using EPA Method 8. EPA Method 8 adopts the principle of selective solvent absorption (SSA) and captures sulfur trioxide/sulfuric acid (SO_3/H_2SO_4) in 80% isopropyl alcohol (IPA) and SO2 in 3% hydrogen peroxide. However, this method was originally promulgated for determining SO_3/H_2SO_4 emissions from stationary sources in the absence of other particulate matter. The drawback of this method is the absence of a filter to effectively remove particulates before the capture of SO_3/H_2SO_4 in IPA. For instance, particulate matter in flue gases from combination boilers, recovery furnaces, and thermal oxidizers would be captured in the IPA along with SO_3/H_2SO_4, contribute SO_4 2- ions, and cause positive biases in the sulfate measurements. NCASI Method 8A was developed as an alternative to EPA Method 8 and uses a heated quartz filter for capturing particulates, thereby eliminating the potential for interference from particulate sulfate. The quartz filter is maintained at temperatures > 500°F, thereby allowing the gaseous SO3/H2SO4 to pass through and be selectively condensed in a temperature controlled condenser. The condenser cools the flue gases below the dew point of SO_3/H2SO_4 but above the dew point of water, thereby eliminating the potential for interference from SO_2. This method was tested extensively on Kraft recovery furnaces and was approved by the EPA for use on recovery furnaces in December 1996 (NCASI 1997).

The measurement method described here was developed and validated as an alternative for determining sulfuric acid emissions from combination boilers and recovery furnaces equipped with dry particulate control devices. The method combines the heated quartz probe/filter portion of NCASI Method 8A along with the impinger train used in EPA Method 8. This allows for the efficient separation of particulates while obviating the need for controlled condensation (CC) which is cumbersome and difficult to implement in the field. Sulfuric acid is not retained on the filter as the filter temperatures are well above the dew point of sulfuric acid. The isokinetic version of the method, summarized in the following sections, can be used to sample combustion sources in pulp mills equipped with wet control devices. Possible interfering agents of this method are fluorides, free ammonia, and dimethyl aniline.

A gas sample is extracted isokinetically from the sampling point on the stack. The particulates are captured on the quartz filter. SO_3/H2SO_4 and SO_2 pass through the filter and are captured by the isopropyl alcohol (IPA) and 3% hydrogen peroxide, respectively. The two sulfate fractions are quantified separately using either suppressed Ion Chromatography (IC) or the barium-thorin titration method.

5.7.2 **Sampling**

The sampling train consisted of a glass nozzle and heated glass probe, which were maintained at the temperature of >400°F. The probe was then connected to the filter holder housed in an oven box that was also maintained at the temperature of >500 °F. The filter holder was constructed of quartz with a quartz thimble filter. This allows sulfur trioxide (SO_3) and sulfuric acid vapor to pass through the filter without being captured.

An isokinetic sample was collected at a rate of approximately 0.7 cubic feet per minute (cfm) for 72 minutes. Five Greenburg-Smith impingers similar to those used in EPA Method 8 are used. The first two impingers hold 100 ml each of 100% Isopropyl Alcohol (IPA). The third and fourth impingers hold 100 ml each of 3% hydrogen peroxide (H_2O_2). The fifth impinger holds silica-gel. The first and third impingers must have standard tips. The second and fourth impingers must be modified by replacing the insert with an approximately 13-mm (½-in.) ID glass tube, having an unconstricted tip located 13 mm (½ in.) from the bottom of the impinger. The unheated filter/filter holder (Borosilicate glass with glass frit filter support and a silicone rubber gasket) is placed between the second and third impingers (between IPA and peroxide).

A vacuum line connected the outlet of the last impinger to the control module. The control module consisted of a vacuum gauge, rotary pump, by-pass and main valve, dry gas meter, orifice, and an inclined manometer. The sample train is illustrated in Figure 5-8.

Coinciding with the sampling were velocity, moisture, and dry molecular weight determinations.

5.7.3 Sample Purge

At the completion of the test run, the probe was separated from the thimble, and a 15-minute purge with clean air was performed as required by the method at a rate of approximately 0.75 cfm.

5.7.4 Sample Recovery

Recovery was performed onsite in Empire's mobile laboratory at the completion of each test run.

Container 1

The contents of the first and second impingers were measured for water gain and transferred to a leak-free glass storage bottle. The IPA rinse (~100 mL divided amongst three rinses) of the impingers, connecting glassware, and front-half of the filter holder was added to the container such that the final volume was ~350 ml. The unheated filter was added into this container.

Container 2

The contents of the third and fourth impingers were measured for water gain and transferred to a leak-free glass storage bottle. The RODI rinse (~100 mL divided amongst three rinses) of the impingers and connecting glassware was added to the container. *NOTE: This step deviates from CTM013B for the purpose of analyzing these impingers' contents for* SO_2.

Blank-IPA

100 ml of the IPA absorbing solution was placed in a leak-free glass storage bottle.

5.7.5 Analysis

The samples were shipped to Maxxam Analytics International of Mississauga, Ontario, Canada for analysis for either IC or titration. The impinger solutions will also be analyzed for SO_2.

Figure 5-1: Test Port Location (Inlet)

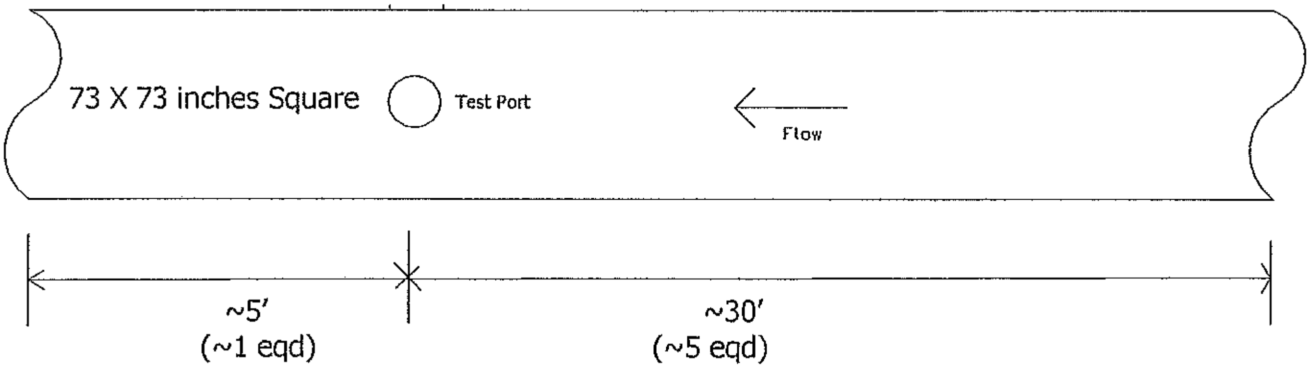


Figure 5-2: Test Port Location (Outlet)

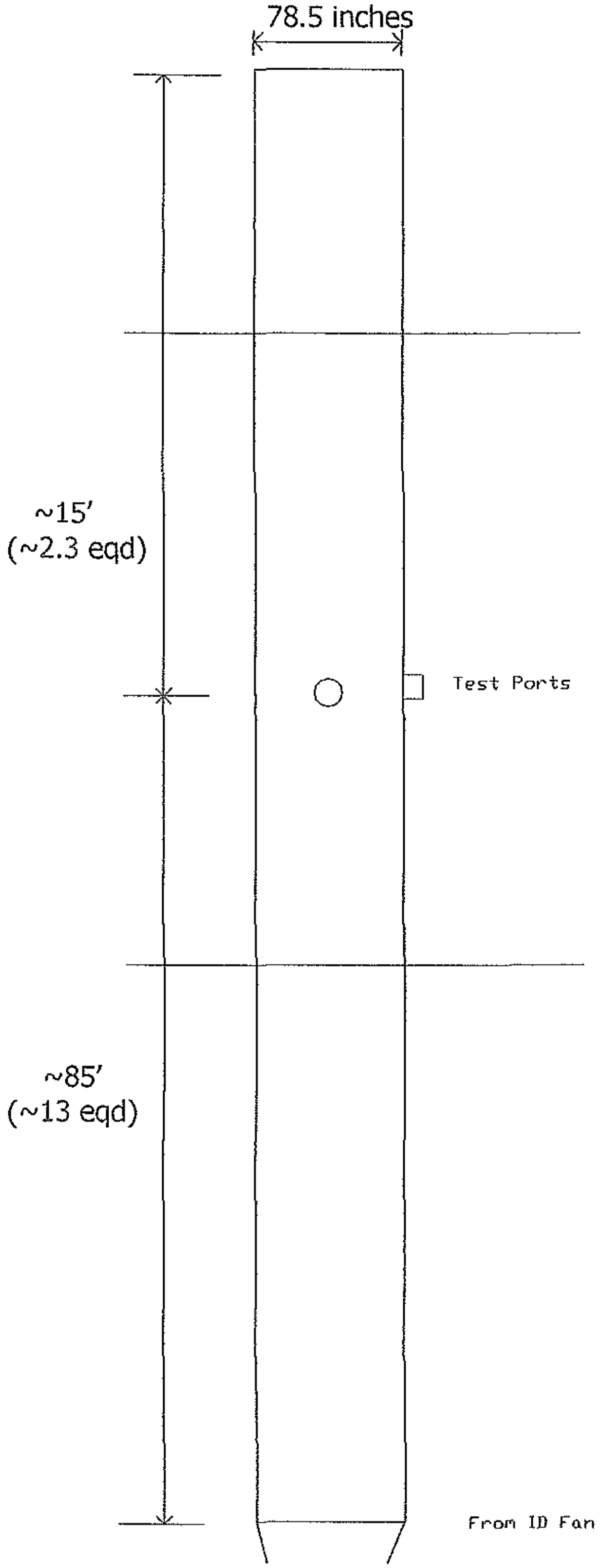


Figure 5-3: Test Port Location (Outlet Ground Site)

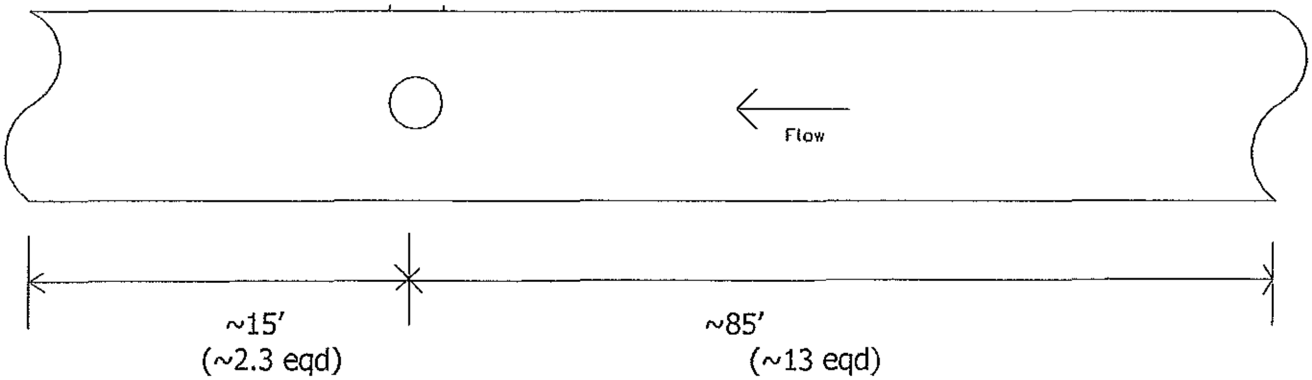
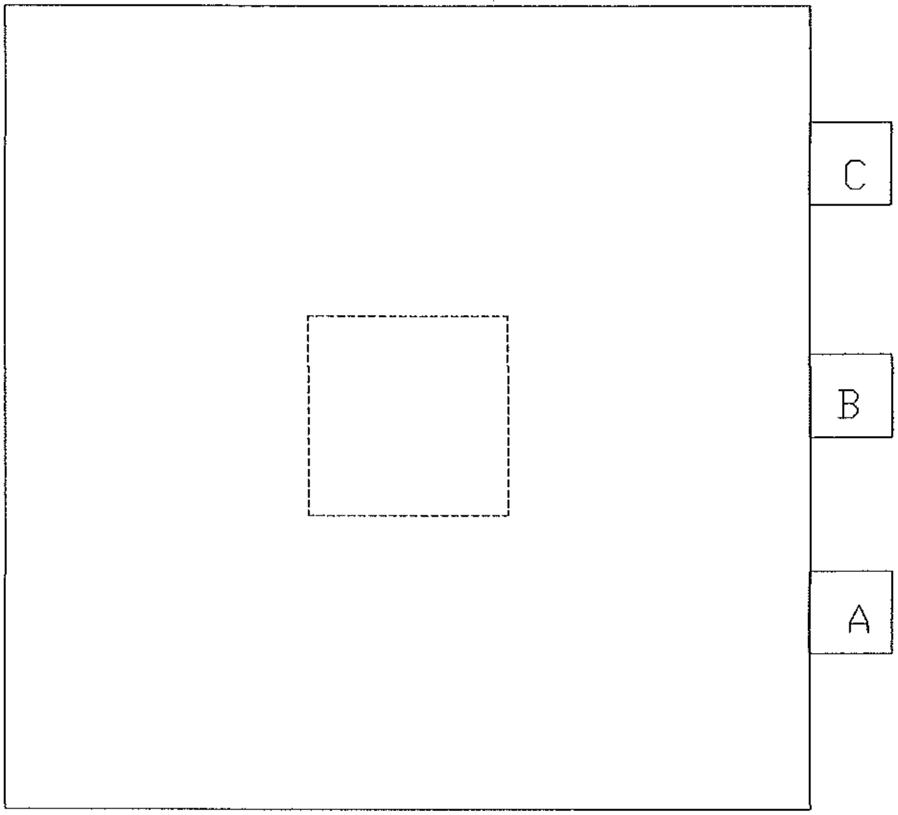


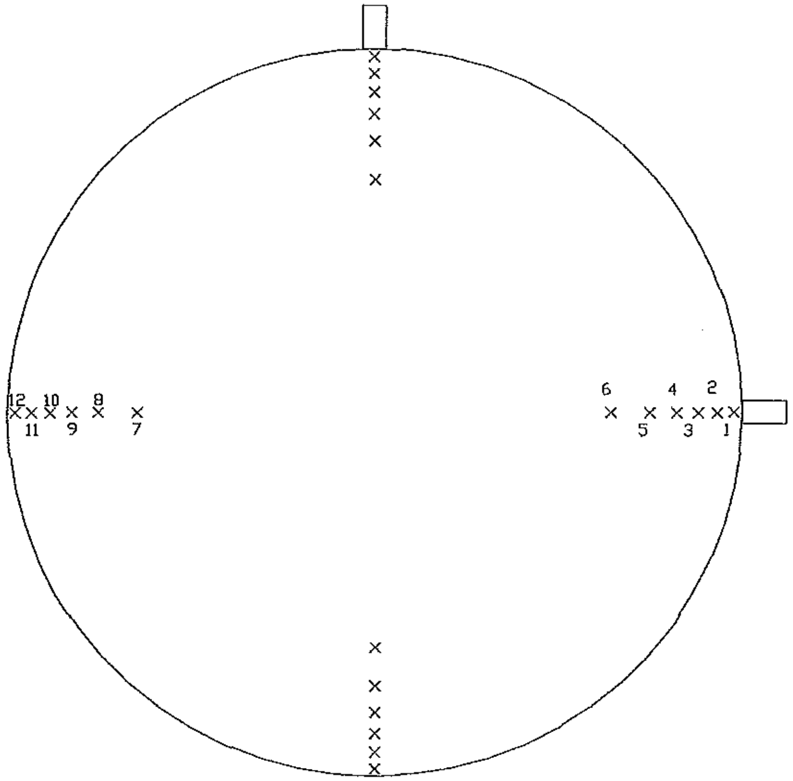
Figure 5-4: Sampling Point Locations (Inlet)



Note: Only a single port is present

Traverse Point Number	Distance from Port Edge (inches)
Centroid:	27.4 – 45.6"
Internal Dimensions:	73 X 73"
Port Length:	7"

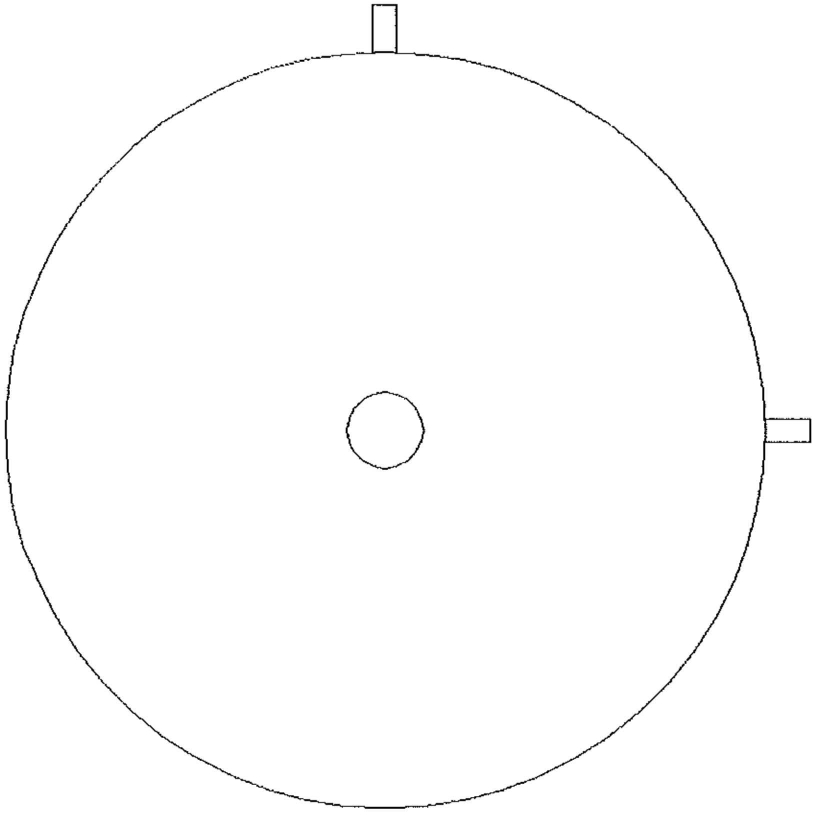
Figure 5-5: Sampling Point Locations (Outlet)



Traverse Point Number (inches)	Distance from Inner Wall (%)	Distance from Port Edge
1	2.1	11.6
2	6.7	15.3
3	11.8	19.3
4	17.7	23.9
5	25.0	29.6
6	35.6	37.9
7	64.4	60.6
8	75.0	68.9
9	82.3	74.6
10	88.2	79.2
11	93.3	83.2
12	97.9	86.9

Diameter: 78.5″
Nipple: 10″

Figure 5-6: Sampling Point Locations (Outlet Ground Site)



Note: Only a single port is present

Traverse Point Number	Distance from Port Edge (inches)
Centroid:	26.8 – 51.7″
Internal Dimensions:	78.5″
Port Length:	6″

Figure 5-7: CTM 013 Sampling Train

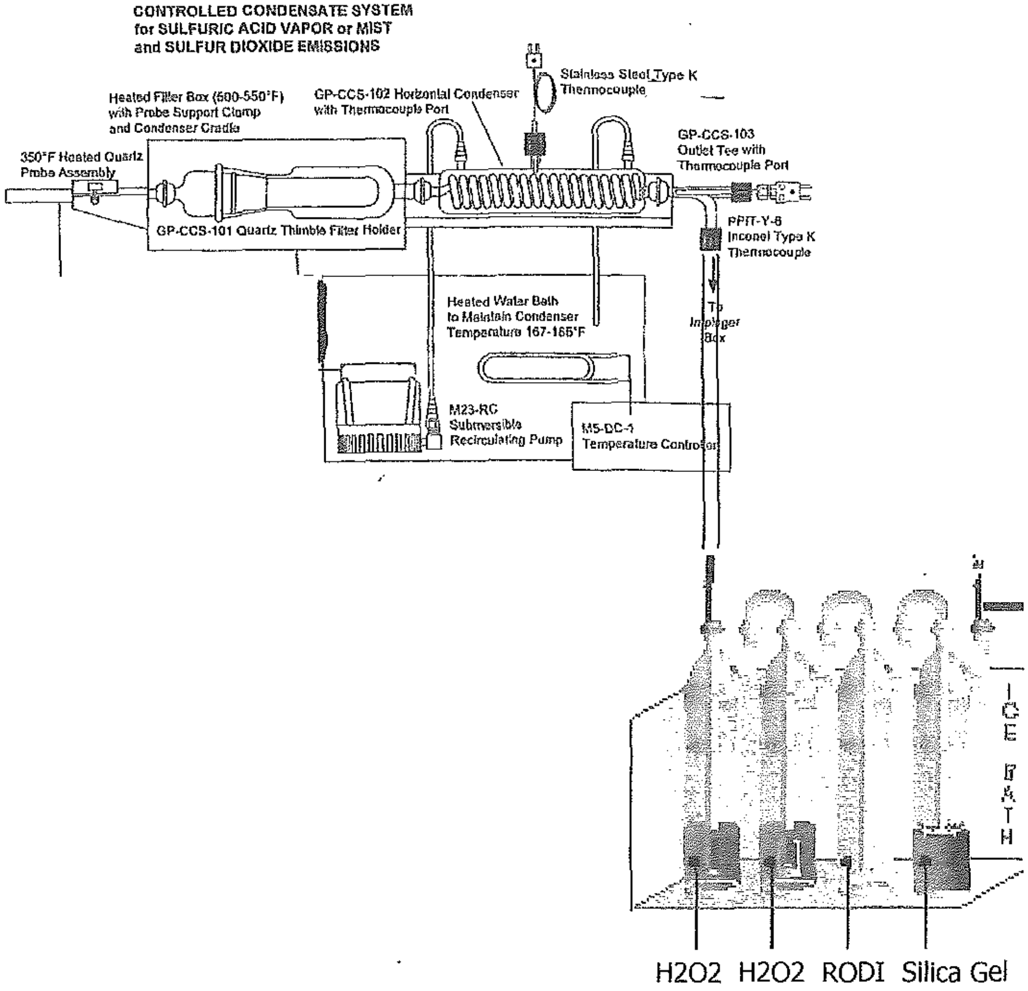
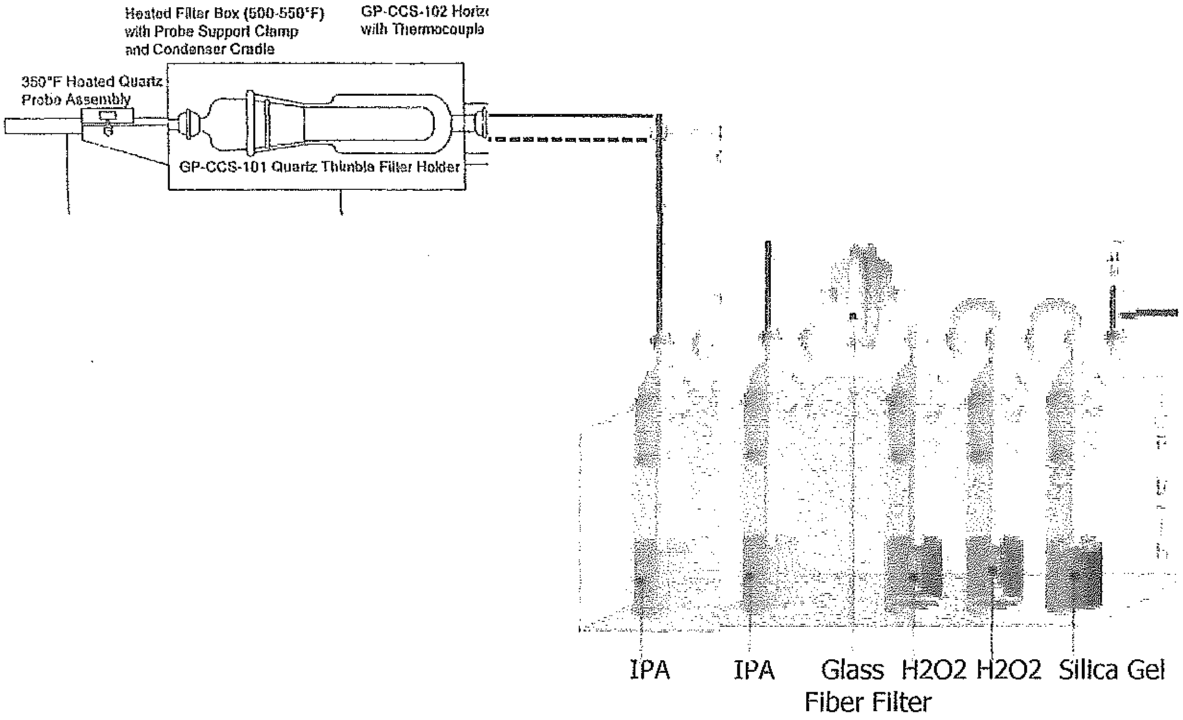


Figure 5-8: CTM 013B Sampling Train



6. QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

Quality control procedures for all aspects of field sampling, sample preservation and holding time, reagent quality, analytical methods, analyst training and safety, instrument cleaning, calibration, and safety were followed. These procedures were consistent with EPA Guidelines documented in:

EPA 600/9-76-005, Quality assurance Handbook for Air Pollution Measurement Systems, Volume I
EPA 454/R-98-004, Quality assurance Handbook for Air Pollution Measurement Systems, Volume II
EPA 600/R-94-038c, Quality assurance Handbook for Air Pollution Measurement Systems, Volume III

6.1 Chain of Custody

Documentation of the Chain-of-Custody of samples and data obtained during the test program is essential for insuring the validity of the test program results. Chain-of-Custody procedures were followed during sampling, sample and data transport, sample preparation and analysis, storage of data, as well as with archived samples and reported results. Empire follows the protocol listed in SW 846, Section 1.3 during field sampling and in-house laboratory analysis.

6.2 Equipment and Sampling Preparation

Sampling equipment was cleaned, checked, and calibrated prior to use in the field. Each parameter's sampling method requires specific cleaning methods of the glassware, train components, and recovery containers. These materials were then sealed prior to shipment to the field.

6.3 Calibrations

6.3.1 Pitot Calibration

Pitot tubes were calibrated according to Reference Method 2, Section 10.1. Pitot tubes were given a baseline coefficient of 0.84 when they meet certain geometrically measured angles and dimensions as set forth in the method.

6.3.2 Thermocouple Display Calibration

Following Method 2, Section 10.3, an NIST Traceable Electronic Thermocouple Calibrator/Simulator (ALTEK) for post-test calibrations is used. If the display being calibrated and the ALTEK were within +/-1°F and/or +/-2% of the reference temperature, the calibration is acceptable, else the display is re-calibrated.

6.3.3 Thermocouple Calibration

According to EMTIC GD-28, a single point (at ambient temperature) check of the thermocouple was made prior to and following each test program. If the thermocouple being calibrated and the certified thermometer were within +/- 2.0 °F of each other, the calibration is acceptable. The thermocouple must also respond appropriately to a change in temperature. Thermocouples that fail either of these criteria were repaired or discarded.

6.3.4 Barometer Calibration

Empire's barometer is compared prior to and following testing with the barometer from the National Weather Service (NWS) located at the Buffalo International Airport. If the barometer disagrees from the Airport's absolute station pressure reading by more than +/- 2.3 millimeters (mm) (0.1 inch) of Hg, the barometer is adjusted. Elevation corrections were performed if the barometer and NWS elevations differ by more than 10 feet (elevation) of each other.

If necessary, readings taken in the field were corrected based on the degree of error between the Empire barometer and the NWS.

Alternatively, during testing, the barometric station pressure can be obtained online from the nearest NOAA or FAA weather station.

6.4 Leak Checks

6.4.1 Sample Trains (CTM013)

A leak-check prior to the sample run is optional; however, a leak-check after the sampling run is mandatory. The leak-check procedure is as follows:

Temporarily attach a suitable (e.g., 0- to 40-cc/min) rotameter (or Gilibrator) to the outlet of the DGM, and place a vacuum gauge at or near the probe inlet. Plug the probe inlet, pull a vacuum of at least 250 mm (10 in.) Hg, and note the flow rate as indicated by the rotameter. A leakage rate not in excess of 2 percent of the average sampling rate is acceptable.

6.4.2 Sample Trains (CTM013B)

Both pre- and post-run leak checks were conducted. A pre-test leak check was performed to verify integrity of the vacuum system. A leak check is mandatory at the conclusion of each isokinetic sampling run. The leak check was conducted in accordance with the procedures outlined in Reference Method 5, Section 8.5.9, except that it was conducted at a vacuum equal to or greater than the maximum value reached during the sampling run. If the leakage rate is found to be no greater than

0.02 cfm, the results were acceptable and no correction was applied to the total volume of dry gas metered.

6.4.3 Pitot Leak Check

The pitot tubes used during the test program were leak checked prior to the test series and following each traverse set, as prescribed in RM 2, Section 8.1. The leak check was performed by pressurizing the positive side of the pitot to at least 3 inches of water. No loss of pressure for 15 seconds indicates a successful leak check. This procedure was repeated with a vacuum applied to the negative side of the Pitot tube as well.

6.5 Sample Recovery

All sample volumes and reagent volumes were measured and recorded on Empire's recovery data sheets and included in the report. All recovery procedures were intended to meet the requirements of the methods.

6.6 Data Reduction

The QA/QC procedures for data reduction include using computer programs to generate tables of results. Results for at least one test run were double-checked and re-calculated by hand. These pages were included in the report.

The data were logged directly to a laptop hard drive, where calculations were performed using MS-Excel spreadsheets. These data were archived nightly to flash media or compact disks (CDs). Copies of these data were available in the field electronically or in print form, upon request.

6.7 Sample Recovery

All sample volumes and reagent volumes were measured and recorded on Empire's recovery data sheets and included in the report. All recovery procedures were intended to meet the requirements of the methods.

6.8 Data Reduction

The QA/QC procedures for data reduction include using computer programs to generate tables of results. Results for at least one test run were double-checked and re-calculated by hand. These pages are included in the report.

The wet-chemistry data were logged directly to a separate laptop hard drive, where calculations were performed using MS-Excel spreadsheets. These data were archived nightly to flash media. Copies of these data were available in the field electronically or in print form, upon request. Paper datasheets will only be used in an emergency.

6.9 Safety

These methods involve hazardous materials, operations, and equipment. Empire established appropriate safety and health practices and determined the applicability of regulatory limitations before performing this test program.

The test site shall meet the criteria of RM 1. Test ports (loosened and cleaned), safe access, and suitable power to be provided by the client. The above items need to be ready upon arrival of the test crew.

Delay or Lost Time (delays) of the field crew due to causes beyond the control of Empire Stack Testing, LLC. (Empire) may include (but were not limited to weather, cyclonic flow conditions, process upsets or failure, or the facility's inability to maintain the desired test conditions). Inclement weather includes (but is not limited to) lightning, strong rains, blizzards, high winds (≥30 mph), high humidity, and/or working temperatures below 20 °F or above 90 °F. Empire's field leader retains the right of final refusal to stop testing for any unsafe condition.

A. CTM DATA & CALCULATIONS (CTM 13B-Inlet)

Empire Stack Testing, LLC.

GENERAL TEST INFORMATION

Client:	Guardian	**Stack Dia. or D_e., (in.):**	73.0	**Area of Duct (ft^2):**	37.0065
Project No.:	16-214	**No. of Ports:**	2	**Port Location from**	
Site:	Trimer Outlet	**Points/Port:**	12	**Upstream Disturbance (D_b):**	5.00
Address:	14600 Romine Rd			**Port Location from**	
City/State:	Carleton, MI	**Runs/Test:**	3	**Dnstream Disturbance (D_a):**	1.00
Test of:	H2SO4	**Specif. Compds.:**	n/a	Particulate Matter	
Test Method:	CTM-013B		H2SO4	Gas 1	
			SO2	Gas 2	
			n/a	Gas 3	

Source Type:	Glass Furnace	t_{std} (°F) :	68	**Rectangular Ducts**	
Control Equip.:	Trimer	T_{std} (°R) :	528	**Length (in.):**	73.0
Test Location:	Inlet			**Width (in.):**	73.0

SUMMARY OF STACK PARAMETERS

Test Date	2/17/2016	2/18/2016	2/18/2016	
Run No.	2	5	8	**Avg.**
t_s - Stack Temperature, °F	1026	1022	1013	**1020**
P_s - Stack Absolute Pressure, in. Hg.	29.34	29.69	29.79	**29.61**
V_s - Stack Velocity, ft/sec.	63.48	62.04	62.77	**62.76**
Q_a - Volumetric Flow Rate/Actual Conditions, ACFM	140950	137753	139374	**139359**
Q_s - Volumetric Flow Rate/Dry Standard Conditions, DSCFM	45323	43891	43983	**44399**
CO_2 , %	6.0	7.0	7.0	**6.7**
O_2 , %	8.0	9.0	10.0	**9.0**
CO, %	0.0	0.0	0.0	**0.0**
N_2 , %	86.0	84.0 ✓	83.0	**84.3**
M_d - Dry Molecular Weight, lb/lb-mole	29.28	29.48 ✓	29.52	**29.43**
M_s - Wet Molecular Weight, lb/lb-mole	28.41	28.34	28.18	**28.31**
$V_{m(std)}$ - Sample Volume - Dry Standard Conditions, DSCF	62.686	64.442	65.342	**64.157**
Stack Moisture Content, %	7.7	9.9	11.6	**9.73**
Isokinetic, %	93.2	98.9	100.1	**97.4**

EMISSIONS SUMMARY FOR: H2SO4

C_w - Conc., w/v, Back Half, mg/M^3	14.08	45.48	23.24	**27.60**
C_v - Conc., v/v, Back Half, ppmvd	3.45	11.15	5.70	**6.77**
C_{vO2} - Conc., v/v, Back Half Corrected to 7% O_2, ppmvd	3.72	13.02	7.27	**8.00**
P_{mrb} - Pollutant Mass Rate, Back Half, lbs/hr.	2.39	7.47	3.83	**4.56**

EMISSIONS SUMMARY FOR: SO2

C_w - Conc., w/v, Back Half, mg/M^3	337.65	416.12	480.65	**411.47**
C_v - Conc., v/v, Back Half, ppmvd	126.77	156.23	180.46	**154.49**
C_{vO2} - Conc., v/v, Back Half Corrected to 7% O_2, ppmvd	136.60	182.49	230.13	**183.07**
P_{mrb} - Pollutant Mass Rate, Back Half, lbs/hr.	57.28	68.36	79.12	**68.25**

Empire Stack Testing, LLC.

SPECIFIC RUN INFORMATION

Project: 16-214
Run: 2
Test Date: 2/17/2016

Location: Inlet
Test Of: H2SO4
Runs/Test: 3

Operator: MK,RM,JS,TH,JK

Isokinetic Sampling - Data Summary

		Filter I.D. No.:	n/a	**Meter Box I.D. No.:**	N2	**$\%CO_2$:**	6.0
Pbar. (in. Hg.):	29.45	**Thimble I.D. No.:**	n/a	**Meter Y:**	1.0004	**$\%O_2$:**	8.0
Pstatic (in. H_2O):	-1.5	**Pitot I.D. No.:**	3P2	**ΔH @:**	1.995	**%CO :**	0.0
Dn :	0.3740	**T-Couple I.D. No.:**	3T2	**Time/Point:**	0:03:00	**$\%N_2$:**	86.0
Cp :	0.84	**Nozzle I.D. No.:**	GF-3	**Total Time (Θ):**	72		

Leak Checks	**Meter Pre:**	0.013	**cfm**	**@**	15.0	**in. Hg.**	**Pitot(-):**	ok	**@**	3.3	**in. H_2O**
	Meter Post:	0.013	**cfm**	**@**	13.0	**in. Hg.**	**Pitot(+):**	ok	**@**	4.3	**in. H_2O**

Trvs.	Time	ΔP	ΔH	Meter	Temperatures (°F)						Vac.
Pt. No.	(24Hr.)	(in. H_2O)	(in. H_2O)	Vm(cf)	Stack	Meter In	Meter Out	Filter	Probe	Exit	(in. Hg.)
1	18:30:00	0.45	3.04	942.900	1063	68	67	501	455	39	4.0
2	18:33:00	0.45	3.01	945.5	1076	69	67	500	453	35	5.0
3	18:36:00	0.45	3.00	948.0	1087	71	67	505	471	36	5.0
4	18:39:00	0.45	3.39	949.9	911	73	67	500	470	36	9.0
5	18:42:00	0.44	3.16	952.7	983	76	68	504	470	37	10.0
6	18:45:00	0.44	3.13	955.4	999	79	68	503	471	40	10.0
7	18:48:00	0.44	3.12	958.2	1010	81	69	503	469	43	10.0
8	18:51:00	0.44	3.11	962.0	1018	83	69	503	469	48	10.0
9	18:54:00	0.44	3.08	964.0	1035	85	70	502	469	57	10.0
10	18:57:00	0.44	3.11	966.0	1025	86	71	501	451	58	10.0
11	19:00:00	0.44	3.16	968.9	1006	88	72	504	451	58	10.0
12	19:03:00	0.44	3.10	971.8	1038	90	73	501	465	58	9.0
	19:06:00			974.625							
1	19:48:00	0.44	3.01	974.625	1055	73	72	505	459	31	11.0
2	19:51:00	0.44	3.00	977.6	1066	76	72	503	476	40	9.0
3	19:54:00	0.44	2.97	980.2	1085	79	72	501	477	45	10.0
4	19:57:00	0.44	2.97	983.0	1088	82	72	501	473	51	11.0
5	20:00:00	0.40	2.93	985.4	971	84	73	500	476	55	11.0
6	20:03:00	0.40	2.90	988.1	992	87	73	499	466	58	10.0
7	20:06:00	0.44	3.21	990.8	988	89	74	501	464	58	10.0
8	20:09:00	0.44	3.14	993.7	1022	91	75	500	468	60	10.0
9	20:12:00	0.44	3.14	996.3	1023	92	75	501	473	61	10.0
10	20:15:00	0.44	3.13	999.1	1033	94	76	499	471	62	10.0
11	20:18:00	0.44	3.13	1001.8	1034	94	77	500	474	62	10.0
12	20:21:00	0.44	3.16	1004.4	1021	95	78	502	476	63	11.0
	20:24:00			1007.162							
		Avg.	Avg.	Sum	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.
		0.44	3.09	64.262	1026.2	82.7	71.5	501.6	467.4	49.6	9.4
		Avg. Sqrt.					Avg. Tm				Max.
		0.662		Purge 2035-2050			77.1				11.0

SPECIFIC RUN INFORMATION (contd.)

Project: 16-214
Run: 2

Test Of: H2SO4
Location: Inlet

Analytical Information

Moisture Determination - Data Summary

		Imp. 1	Imp. 2	Imp. 3	Imp. 4	Silica Gel	
Final	(ml)	631.2	664.1	709.6	778.1	(g)	966.2
Initial	(ml)	669.9	681.7	631.6	734.5	(g)	920.2
Gain	(ml)	**-38.7**	**-17.6**	**78.0**	**43.6**	(g)	**46.0**
						ts	1026
						SVP	29.9200

Blank Corrections

Particulate
Front Half

Reagent		Acetone	Water
Blank Volume	(ml)		
Gross Wt.	(g)		
Tare Wt.	(g)		
Blank Wt. Gain	(g)		
Blank Conc.	(g/ml)		

Gaseous Pollutants
Back Half

Reagent			IPA	H2O2	Total Blank Conc. per Analyte
Blank Volume		(ml)	147.0	211.0	
Analyte Blank Mass	H2SO4	(mg)	0.00	0.00	
	SO2	(mg)	0.00	0.25	
	n/a	(mg)	0.00	0.00	
Analyte Blank Conc.	H2SO4	(mg/ml)	0.00E+00	0.00E+00	**0.00E+00**
	SO2	(mg/ml)	0.00E+00	1.18E-03	**1.18E-03**
	n/a	(mg/ml)	0.00E+00	0.00E+00	**0.00E+00**

Blank Concentration = Blank Mass / Blank Volume

Particulate Weight - Data Summary
Front Half

		Filter	Thimble	Acetone	Water	Total Gain
	I.D.	n/a	n/a	0	0	
Beaker Vol.		n/a	n/a	0.0	0.0	
Gross Wt.	(g)					
Tare Wt.	(g)					
Blank Corr.	(g)					
Gain	(g)					

Gaseous Pollutants - Data Summary
Back Half

Analyte		IPA	H2O2	n/a
Volume	(ml)	266.0	475.0	0.0
Analyte	mg Collect. (C)	Molec. Weight M_w	Blank Corr.	mg Correct. (C_{corr})
H2SO4	25.00	98.08	0.00	**25.00**
SO2	600.00	64.07	0.56	**599.44**
n/a	0.00	0.00	0.00	**0.00**

Blank Correction = Analyte Volume x Total Blank Conc.

SPECIFIC RUN INFORMATION (contd.)

Project: 16-214
Run: 2
Test Of: H2SO4
Location: Inlet

Reference Method No. 2 Calculations

Average Stack Velocity				
	$V_s = K_p\ C_p\ \mathrm{SQRT}\ \Delta P_{avg}\ \mathrm{SQRT}\ (T_s / (P_s\ M_s))$	$V_s =$	63.48	ft/sec.
Average Stack Volumetric Flow Rate				
	$Q_a = 60\ V_s\ A_s$	$Q_a =$	140950.4	ACFM
Average Stack Volumetric Flow Rate				
	$Q_s = 60\ V_s\ A_s\ (1\text{-}B_{ws})\ ((T_{std}\ P_{s)} / (P_{std}\ T_s))$	$Q_s =$	45323.0	DSCFM

Reference Method No. 3 Calculations

Molecular Weight, Dry				
	$M_d = 0.44\ \%CO_2 + 0.32\ \%O_2 + 0.28\ (\%CO + N_2)$	$M_d =$	29.28	lb/lb-mole
Molecular Weight, Wet				
	$M_s = M_d\ (1\text{-}B_{ws}) + 18\ B_{ws}$	$M_s =$	28.41	lb/lb-mole

Reference Method No. 4 Calculations

Sample Volume, Standard Conditions				
	$V_{m(std)} = V_m\ Y\ ((T_{std}\ P_m) / (T_m\ P_{std}))$	$V_{m(std)} =$	62.686	DSCF
Water Vapor Volume Collected				
	$V_{wc(std)} = .04706\ (V_f - V_i)$	$V_{wc(std)} =$	3.073	ft^3
Water Vapor Volume Collected				
	$V_{wsg(std)} = .04715\ (W_f - W_i)$	$V_{wsg(std)} =$	2.169	ft^3
Moisture Volume Fraction of Stack Gas				
	$B_{ws} = (V_{wc(std)} + V_{wsg(std)})/(V_{wc(std)} + V_{wsg(std)} + V_{m(std)})$	$B_{ws} =$	0.077	
Vapor Pressure of Stack H_2O				
	$VP = SVP - .000367\ (P_s)\ (1 + (ts - 32/1571))$	$VP =$	29.902	
Bws VP				
	$B_{ws}VP = VP / P_s$	$B_{ws}VP =$	1.019	
Min B_{ws} or B_{ws} VP				
	If $B_{ws} > B_{ws}VP$, then $B_{ws}VP$	MIN B_{ws} or $B_{ws}VP =$	0.077	

Gas No. 1
Calculations for: H2SO4 **Reference Method:** CTM-013B

Stack Concentration, w/v - Back Half				
	$C_w = (C_{cor}\ 35.31) / V_{m(std)}$	$C_w =$	14.08	mg / M^3
Stack Concentration, v/v - Back Half				
	$C_v = C_w\ (24.055 / M_W)$	$C_v =$	3.45	ppmv
Stack Concentration, v/v - Back Half Corrected to 7% O_2				
	$C_{vO2} = C_v\ ((20.9\text{-}7) / (20.9\text{-}\%O_2))$	$C_{vO2} =$	3.72	ppmv @7%O_2
Mass Emissions Rate - Back Half				
	$P_{mrb} = (C_{cor}\ DSCFM\ 60)/(Vm_{(std)}\ 454000)$	$P_{mrb} =$	2.39	lbs/hr.

Gas No. 2
Calculations for: SO2 **Reference Method:** CTM-013B

Stack Concentration, w/v - Back Half				
	$C_w = (C_{cor}\ 35.31) / V_{m(std)}$	$C_w =$	337.65	mg / M^3
Stack Concentration, v/v - Back Half				
	$C_v = C_w\ (24.055 / M_W)$	$C_v =$	126.77	ppmv
Stack Concentration, v/v - Back Half Corrected to 7% O_2				
	$C_{vO2} = C_v\ ((20.9\text{-}7) / (20.9\text{-}\%O_2))$	$C_{vO2} =$	136.60	ppmv @7%O_2
Mass Emissions Rate - Back Half				
	$P_{mrb} = (C_{cor}\ DSCFM\ 60)/(Vm_{(std)}\ 454000)$	$P_{mrb} =$	57.28	lbs/hr.

Empire Stack Testing, LLC.

SPECIFIC RUN INFORMATION

Project: 16-214
Run: 6
Test Date: 2/18/2016

Location: Inlet
Test Of: H2SO4
Runs/Test: 3

Operator: MK,RM,JS,TH,JK

Isokinetic Sampling - Data Summary

Pbar. (in. Hg.):	29.80	Filter I.D. No.:	n/a	Meter Box I.D. No.:	N2	$\%CO_2$:	7.0
Pstatic (in. H_2O):	-1.5	Thimble I.D. No.:	n/a	Meter Y:	1.0004	$\%O_2$:	9.0
Dn :	0.3740	Pitot I.D. No.:	3P2	ΔH @:	1.995	%CO :	0.0
Cp :	0.84	T-Couple I.D. No.:	3T2	Time/Point:	0:03:00	$\%N_2$:	84.0
		Nozzle I.D. No.:	GF-3	Total Time (Θ):	72		

Leak	Meter Pre:	0.003	cfm @	15.0	in. Hg.	Pitot(-):	ok	@	3.3	in. H_2O
Checks	Meter Post:	0.002	cfm @	13.0	in. Hg.	Pitot(+):	ok	@	4.3	in. H_2O

Trvs.	Time	ΔP	ΔH	Meter	Temperatures (°F)						Vac.
Pt. No.	(24Hr.)	(in. H_2O)	(in. H_2O)	Vm(cf)	Stack	Meter In	Meter Out	Filter	Probe	Exit	(in. Hg.)
1	9:05:00	0.40	2.76	8.033	1026	66	65	502	467	27	7.0
2	9:08:00	0.43	2.91	10.5	1057	67	65	502	476	30	10.0
3	9:11:00	0.43	2.89	13.1	1071	70	65	502	477	32	12.0
4	9:14:00	0.43	2.88	15.8	1080	74	66	500	478	35	12.0
5	9:17:00	0.43	2.87	18.5	1090	76	66	501	475	39	13.0
6	9:20:00	0.43	3.15	21.0	957	79	67	501	476	46	13.0
7	9:23:00	0.43	3.12	23.9	978	82	68	502	475	60	12.0
8	9:26:00	0.43	3.09	26.6	994	84	68	500	475	60	11.0
9	9:29:00	0.43	3.08	29.8	1004	86	69	501	477	61	10.0
10	9:32:00	0.43	3.05	32.2	1019	87	70	501	475	58	10.0
11	9:35:00	0.43	3.05	35.0	1025	89	71	502	471	58	10.0
12	9:38:00	0.43	3.01	37.6	1043	90	71	504	474	60	10.0
	9:41:00			40.525							
1	10:30:00	0.44	3.00	40.525	1065	74	72	501	477	42	13.0
2	10:33:00	0.44	2.97	43.5	1081	75	71	503	466	40	12.0
3	10:36:00	0.44	2.95	46.0	1091	78	71	506	469	44	12.0
4	10:39:00	0.44	3.49	48.7	858	81	72	505	477	48	12.0
5	10:42:00	0.44	3.19	51.3	987	84	72	502	479	49	12.0
6	10:45:00	0.44	3.18	54.0	994	86	72	507	478	51	12.0
7	10:48:00	0.40	2.87	56.9	1008	89	73	502	482	53	12.0
8	10:51:00	0.40	2.87	59.5	1012	90	74	505	481	53	12.0
9	10:54:00	0.40	2.86	62.2	1021	92	74	501	479	53	12.0
10	10:57:00	0.40	2.85	65.0	1029	93	75	503	481	53	12.0
11	11:00:00	0.40	2.91	67.6	999	94	76	501	481	54	12.0
12	11:03:00	0.40	2.86	70.3	1029	95	77	501	482	55	12.0
	11:06:00			73.269							
		Avg.	Avg.	Sum	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.
		0.42	2.99	65.236	1021.6	82.5	70.4	502.3	476.2	48.4	11.5
		Avg. Sqrt.					Avg. Tm				Max.
		0.651	Purge 1125-1140 @ 0.75 cfm				76.5				13.0

000032

Empire Stack Testing, LLC.

SPECIFIC RUN INFORMATION (contd.)

Project: 16-214
Run: 5

Test Of: H2SO4
Location: Inlet

Analytical Information
Moisture Determination - Data Summary

		Imp. 1	Imp. 2	Imp. 3	Imp. 4	Silica Gel	
Final	(ml)	700.6	693.9	772.1	755.1	(g)	930.8
Initial	(ml)	699.1	697.1	702.4	716.1	(g)	888.2
Gain	(ml)	1.5	-3.2	69.7	39.0	(g)	42.6

ts	1022
SVP	29.9200

Blank Corrections
Particulate
Front Half

Reagent		Acetone	Water
Blank Volume	(ml)		
Gross Wt.	(g)		
Tare Wt.	(g)		
Blank Wt. Gain	(g)		
Blank Conc.	(g/ml)		

Gaseous Pollutants
Back Half

Reagent			IPA	H2O2	Total Blank Conc. per Analyte
Blank Volume		(ml)	147.0	211.0	
Analyte Blank Mass	H2SO4	(mg)	0.00	0.00	
	SO2	(mg)	0.00	0.25	
	n/a	(mg)	0.00	0.00	
Analyte Blank Conc.	H2SO4	(mg/ml)	0.00E+00	0.00E+00	0.00E+00
	SO2	(mg/ml)	0.00E+00	1.18E-03	1.18E-03
	n/a	(mg/ml)	0.00E+00	0.00E+00	0.00E+00

Blank Concentration = Blank Mass / Blank Volume

Particulate Weight - Data Summary
Front Half

		Filter	Thimble	Acetone	Water	Total Gain
	I.D.	n/a	n/a	0	0	
Beaker Vol.		n/a	n/a	0.0	0.0	
Gross Wt.	(g)					
Tare Wt.	(g)					
Blank Corr.	(g)					
Gain	(g)					

Gaseous Pollutants - Data Summary
Back Half

Analyte		IPA	H2O2	n/a
Volume	(ml)	340.0	477.0	0.0

Analyte	mg Collect. (C)	Molec. Weight M_w	Blank Corr.	mg Correct. (C_{corr})
H2SO4	83.00	98.08	0.00	83.00
SO2	760.00	64.07	0.56	759.44
n/a	0.00	0.00	0.00	0.00

Blank Correction = Analyte Volume x Total Blank Conc.

Empire Stack Testing, LLC.

SPECIFIC RUN INFORMATION (contd.)

Project: 16-214
Run: 5

Test Of: H2SO4
Location: Inlet

Reference Method No. 2 Calculations

Average Stack Velocity	$V_s = K_p\ C_p\ \text{SQRT}\ \Delta P_{avg}\ \text{SQRT}\ (T_s / (P_s\ M_s))$	V_s= ✓ 62.04	ft/sec.
Average Stack Volumetric Flow Rate	$Q_a = 60\ V_s\ A_s$	Q_a= ✓ 137753.0	ACFM
Average Stack Volumetric Flow Rate	$Q_s = 60\ V_s\ A_s\ (1-B_{ws})\ ((T_{std}\ P_s) / (P_{std}\ T_s))$	Q_s= ✓ 43890.8	DSCFM

Reference Method No. 3 Calculations

Molecular Weight, Dry	$M_d = 0.44\ \%CO_2 + 0.32\ \%O_2 + 0.28\ (\%CO + N_2)$	M_d= ✓ 29.48	lb/lb-mole
Molecular Weight, Wet	$M_s = M_d\ (1-B_{ws}) + 18\ B_{ws}$	M_s= 28.34 ✓	lb/lb-mole

Reference Method No. 4 Calculations

Sample Volume, Standard Conditions	$V_{m(std)} = V_m\ Y\ ((T_{std}\ P_m) / (T_m\ P_{std}))$	$V_{m(std)}$ = ✓ 64.442	DSCF
Water Vapor Volume Collected	$V_{wc(std)} = .04706\ (V_f - V_i)$	$V_{wc(std)}$ = ✓ 5.035	ft^3
Water Vapor Volume Collected	$V_{wsg(std)} = .04715\ (W_f - W_i)$	$V_{wsg(std)}$= ✓ 2.009	ft^3
Moisture Volume Fraction of Stack Gas	$B_{ws} = (V_{wc(std)} + V_{wsg(std)})/(V_{wc(std)} + V_{wsg(std)} + V_{m(std)})$	B_{ws}= 0.099 ✓	
Vapor Pressure of Stack H_2O	$VP = SVP - .000367\ (P_s)\ (1+(ts-32/1571))$	VP= 29.902	
Bws VP	$B_{ws}VP = VP / P_s$	$B_{ws}VP$= 1.007	
Min B_{ws} or B_{ws} VP	If $B_{ws} > B_{ws}VP$, then $B_{ws}VP$	MIN B_{ws} or $B_{ws}VP$= 0.099 ✓	

Gas No. 1

Calculations for: H2SO4 **Reference Method:** CTM-013B

Stack Concentration, w/v - Back Half	$C_w = (C_{cor}\ 35.31) / V_{m(std)}$	C_w= ✓ 45.48	mg / M^3
Stack Concentration, v/v - Back Half	$C_v = C_w\ (24.055 / M_W)$	C_v= ✓ 11.15	ppmv
Stack Concentration, v/v - Back Half Corrected to 7% O_2	$C_{vO2} = C_v\ ((20.9-7) / (20.9-\%O_2))$	C_{vO2}= 13.02	ppmv @7%O_2
Mass Emissions Rate - Back Half	$P_{mrb} = (C_{cor}\ DSCFM\ 60)/(Vm_{(std)}\ 454000)$	P_{mrb}= 7.47	lbs/hr.

Gas No. 2

Calculations for: SO2 **Reference Method:** CTM-013B

Stack Concentration, w/v - Back Half	$C_w = (C_{cor}\ 35.31) / V_{m(std)}$	C_w= ✓ 416.12	mg / M^3
Stack Concentration, v/v - Back Half	$C_v = C_w\ (24.055 / M_W)$	C_v= ✓ 156.23	ppmv
Stack Concentration, v/v - Back Half Corrected to 7% O_2	$C_{vO2} = C_v\ ((20.9-7) / (20.9-\%O_2))$	C_{vO2}= 182.49	ppmv @7%O_2
Mass Emissions Rate - Back Half	$P_{mrb} = (C_{cor}\ DSCFM\ 60)/(Vm_{(std)}\ 454000)$	P_{mrb}= ✓ 68.36	lbs/hr.

Empire Stack Testing, LLC.

SPECIFIC RUN INFORMATION

Project: 16-214
Run: 8
Test Date: 2/18/2016

Location: Inlet
Test Of: H2SO4
Runs/Test: 3

Operator: MK,RM,JS,TH,JK

Isokinetic Sampling - Data Summary

		Filter I.D. No.:	n/a	**Meter Box I.D. No.:**	N2	**$\%CO_2$:**	7.0
Pbar. (in. Hg.):	29.90	**Thimble I.D. No.:**	n/a	**Meter Y:**	1.0004	**$\%O_2$:**	10.0
Pstatic (in. H_2O):	-1.5	**Pitot I.D. No.:**	3P2	**ΔH @:**	1.995	**%CO :**	0.0
Dn :	0.3740	**T-Couple I.D. No.:**	3T2	**Time/Point:**	0:03:00	**$\%N_2$:**	83.0
Cp :	0.84	**Nozzle I.D. No.:**	GF-3	**Total Time (Θ):**	72		

Leak Checks	**Meter Pre:**	0.004	**cfm @**	15.0	**in. Hg.**	**Pitot(-):**	ok	**@**	4.4	**in. H_2O**
	Meter Post:	0.002	**cfm @**	17.0	**in. Hg.**	**Pitot(+):**	ok	**@**	4.1	**in. H_2O**

Trvs. Pt. No.	Time (24Hr.)	ΔP (in. H_2O)	ΔH (in. H_2O)	Meter Vm(cf)	Temperatures (°F) Stack	Meter In	Meter Out	Filter	Probe	Exit	Vac. (in. Hg.)
1	**13:00:00**	0.42	**2.94**	**87.276**	1028	75	74	503	470	45	10.0
2	13:03:00	0.43	**3.01**	89.5	1032	77	74	500	479	44	13.0
3	13:06:00	0.43	**2.99**	92.2	1046	80	75	500	478	45	14.0
4	13:09:00	0.43	**2.98**	94.7	1055	82	75	500	475	45	15.0
5	13:12:00	0.43	**2.96**	97.6	1068	84	75	505	469	47	15.0
6	13:15:00	0.43	**2.93**	100.6	1084	86	75	503	480	53	15.0
7	13:18:00	0.43	**3.49**	103.1	840	87	76	500	476	59	15.0
8	13:21:00	0.44	**3.25**	106.0	970	89	76	500	468	60	15.0
9	13:24:00	0.44	**3.22**	108.8	990	91	77	503	477	62	15.0
10	13:27:00	0.44	**3.20**	111.8	998	92	77	501	478	63	15.0
11	13:30:00	0.43	**3.12**	114.4	1007	93	78	502	468	63	15.0
12	13:33:00	0.44	**3.19**	117.3	1006	94	78	506	479	61	15.0
	13:36:00			**120.301**							
1	**14:16:00**	0.44	**3.16**	**120.301**	1002	79	77	504	477	44	15.0
2	14:19:00	0.44	**3.38**	122.8	902	79	76	503	480	43	16.0
3	14:22:00	0.44	**3.12**	125.8	1021	81	77	508	480	47	16.0
4	14:25:00	0.44	**3.08**	128.8	1045	84	77	506	476	55	16.0
5	14:28:00	0.44	**3.07**	131.3	1050	86	77	501	478	58	16.0
6	14:31:00	0.44	**3.04**	134.4	1068	88	77	502	475	59	17.0
7	14:34:00	0.44	**3.04**	137.3	1072	89	78	500	472	59	17.0
8	14:37:00	0.44	**3.02**	139.8	1086	90	78	500	473	58	17.0
9	14:40:00	0.44	**3.29**	142.5	960	91	79	505	475	56	17.0
10	14:43:00	0.44	**3.24**	145.4	982	92	79	504	475	55	17.0
11	14:46:00	0.44	**3.24**	148.0	982	92	79	502	475	54	17.0
12	14:49:00	0.44	**3.19**	150.9	1009	93	80	501	473	53	17.0
	14:52:00			**153.807**							
		Avg.	Avg.	Sum	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.
		0.44	3.13	66.531	1012.6	86.4	76.8	502.5	475.3	53.7	15.4
		Avg. Sqrt.					Avg. Tm				Max.
		0.660	Purge 1511-1526 @ 0.75 cfm				81.6				17.0

SPECIFIC RUN INFORMATION (contd.)

Project: 16-214
Run: 8

Test Of: H2SO4
Location: Inlet

Analytical Information

Moisture Determination - Data Summary

		Imp. 1	Imp. 2	Imp. 3	Imp. 4	Silica Gel	
Final	(ml)	691.7	682.4	698.6	778.5	(g)	964.5
Initial	(ml)	668.5	679.6	628.1	741.0	(g)	916.4
Gain	(ml)	**23.2**	**2.8**	**70.5**	**37.5**	(g)	**48.1**

fs	1013
SVP	29.9200

Blank Corrections

Particulate
Front Half

Reagent		Acetone	Water
Blank Volume	(ml)		
Gross Wt.	(g)		
Tare Wt.	(g)		
Blank Wt. Gain	(g)		
Blank Conc.	(g/ml)		

Gaseous Pollutants
Back Half

Reagent			IPA	H2O2	Total Blank Conc. per Analyte
Blank Volume		(ml)	147.0	211.0	
Analyte Blank Mass	H2SO4	(mg)	0.00	0.00	
	SO2	(mg)	0.00	0.25	
	n/a	(mg)	0.00	0.00	
Analyte Blank Conc.	H2SO4	(mg/ml)	0.00E+00	0.00E+00	**0.00E+00**
	SO2	(mg/ml)	0.00E+00	1.18E-03	**1.18E-03**
	n/a	(mg/ml)	0.00E+00	0.00E+00	**0.00E+00**

Blank Concentration = Blank Mass / Blank Volume

Particulate Weight - Data Summary
Front Half

		Filter	Thimble	Beaker 1	Beaker 2	Total Gain
	I.D.	n/a	n/a	Acetone	Water	
Beaker Vol.		n/a	n/a	0.0	0.0	
Gross Wt.	(g)					
Tare Wt.	(g)					
Blank Corr.	(g)					
Gain	(g)					

Gaseous Pollutants - Data Summary
Back Half

Analyte		IPA	H2O2	n/a
Volume	(ml)	342.0	465.0	0.0
Analyte	**mg Collect. (C)**	**Molec. Weight M_w**	**Blank Corr.**	**mg Correct. (C_{corr})**
H2SO4	43.00	98.08	0.00	**43.00**
SO2	890.00	64.07	0.55	**889.45**
n/a	0.00	0.00	0.00	**0.00**

Blank Correction = Analyte Volume x Total Blank Conc.

SPECIFIC RUN INFORMATION (contd.)

Project: 16-214
Run: 8
Test Of: H2SO4
Location: Inlet

Reference Method No. 2 Calculations

Average Stack Velocity	$V_s = K_p\ C_p\ \text{SQRT}\ \Delta P_{avg}\ \text{SQRT}\ (T_s / (P_s\ M_s))$	V_s=	62.77	ft/sec.
Average Stack Volumetric Flow Rate	$Q_a = 60\ V_s\ A_s$	Q_a=	139373.9	ACFM
Average Stack Volumetric Flow Rate	$Q_s = 60\ V_s\ A_s\ (1\text{-}B_{ws})\ ((T_{std}\ P_s) / (P_{std}\ T_s))$	Q_s=	43983.3	DSCFM

Reference Method No. 3 Calculations

Molecular Weight, Dry	$M_d = 0.44\ \%CO_2 + 0.32\ \%O_2 + 0.28\ (\%CO + N_2)$	M_d=	29.52	lb/lb-mole
Molecular Weight, Wet	$M_s = M_d\ (1\text{-}B_{ws}) + 18\ B_{ws}$	M_s=	28.18	lb/lb-mole

Reference Method No. 4 Calculations

Sample Volume, Standard Conditions	$V_{m(std)} = V_m\ Y\ ((T_{std}\ P_m) / (T_m\ P_{std}))$	$V_{m(std)}$ =	65.342	DSCF
Water Vapor Volume Collected	$V_{wc(std)} = .04706\ (V_f - V_i)$	$V_{wc(std)}$ =	6.306	ft^3
Water Vapor Volume Collected	$V_{wsg(std)} = .04715\ (W_f - W_i)$	$V_{wsg(std)}$=	2.268	ft^3
Moisture Volume Fraction of Stack Gas	$B_{ws} = (V_{wc(std)} + V_{wsg(std)})/(V_{wc(std)} + V_{wsg(std)} + V_{m(std)})$	B_{ws}=	0.116	
Vapor Pressure of Stack H_2O	$VP = SVP\text{-}.000367\ (P_s)\ (1+(ts\text{-}32/1571))$	VP=	29.902	
Bws VP	$B_{ws}VP = VP / P_s$	$B_{ws}VP$=	1.004	
Min B_{ws} or B_{ws} VP	If $B_{ws} > B_{ws}VP$, then $B_{ws}VP$	MIN B_{ws} or $B_{ws}VP$=	0.116	

Gas No. 1
Calculations for: H2SO4 **Reference Method:** CTM-013B

Stack Concentration, w/v - Back Half	$C_w = (C_{cor}\ 35.31) / V_{m(std)}$	C_w=	23.24	mg / M^3
Stack Concentration, v/v - Back Half	$C_v = C_w\ (24.055 / M_W)$	C_v=	5.70	ppmv
Stack Concentration, v/v - Back Half Corrected to 7% O_2	$C_{vO2} = C_v\ ((20.9\text{-}7) / (20.9\text{-}\%O_2))$	C_{vO2}=	7.27	ppmv @7%O_2
Mass Emissions Rate - Back Half	$P_{mrb} = (C_{cor}\ DSCFM\ 60)/(Vm_{(std)}\ 454000)$	P_{mrb}=	3.83	lbs/hr.

Gas No. 2
Calculations for: SO2 **Reference Method:** CTM-013B

Stack Concentration, w/v - Back Half	$C_w = (C_{cor}\ 35.31) / V_{m(std)}$	C_w=	480.65	mg / M^3
Stack Concentration, v/v - Back Half	$C_v = C_w\ (24.055 / M_W)$	C_v=	180.46	ppmv
Stack Concentration, v/v - Back Half Corrected to 7% O_2	$C_{vO2} = C_v\ ((20.9\text{-}7) / (20.9\text{-}\%O_2))$	C_{vO2}=	230.13	ppmv @7%O_2
Mass Emissions Rate - Back Half	$P_{mrb} = (C_{cor}\ DSCFM\ 60)/(Vm_{(std)}\ 454000)$	P_{mrb}=	79.12	lbs/hr.

Empire Stack Testing, LLC.

Sample Recovery Data

Client: Guardian Carleton
Project No.: 16-214
Site: Carleton, MI
Date: 2/17
Recovery by: TH-

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Notes:

Run: 2 013B - INLET

	Imp. 1	Imp.2	Imp.3	Imp.4	Imp.5	Imp. 6	Imp. 7	Imp.8		Silica gel
Contents	IPA	IPA	H_2O_2	H_2O_2						SG
Final (g)	631.2	664.1	709.6	778.1						966.2
Initial (g)	669.9	681.7	631.6	734.5						920.2
Gain (g)										
Rinse ( )										

Particulate Weight Information *observed white film inside glassware prior to impingers

SG Color: 75% PINK

	Front 1/2					Back 1/2				
	Filter	Thimble	Beaker1	Beaker2	Total Gain	Filter	Beaker1	Beaker2	Beaker3	Total Gain
I.D.										
Gross (g)										
Tare (g)										
Blank (g)										
Gain (g)										

Sample Containers	ID:	C1	C2	3	4	5	5A	5B	5C
	Volume (ml):	266	475						

Run: 5 013B- INLET

	Imp. 1	Imp.2	Imp.3	Imp.4	Imp.5	Imp. 6	Imp. 7	Imp.8		Silica gel
Contents	IPA	IPA	H_2O_2	H_2O_2						SG
Final (g)	700.6	693.9	772.1	755.1						930.8
Initial (g)	699.1	697.1	702.4	716.1						~~837.8~~ tlh
Gain (g)										888.2
Rinse ( )										

Particulate Weight Information *observed white film inside glassware prior to impingers.

SG Color: 95% Pink

	Front 1/2					Back 1/2				
	Filter	Thimble	Beaker1	Beaker2	Total Gain	Filter	Beaker1	Beaker2	Beaker3	Total Gain
I.D.										
Gross (g)										
Tare (g)										
Blank (g)										
Gain (g)										

Sample Containers	ID:	C1	C2	3	4	5	5A	5B	5C
	Volume (ml):	340	477						

Run: 8 013B- INLET

	Imp. 1	Imp.2	Imp.3	Imp.4	Imp.5	Imp. 6	Imp. 7	Imp.8		Silica gel
Contents	IPA	IPA	H_2O_2	H_2O_2						SG
Final (g)	691.7	682.4	698.6	778.5						964.5
Initial (g)	668.5	679.6	628.1	741.0						916.4
Gain (g)										
Rinse ( )										

Particulate Weight Information

SG Color:

	Front 1/2					Back 1/2				
	Filter	Thimble	Beaker1	Beaker2	Total Gain	Filter	Beaker1	Beaker2	Beaker3	Total Gain
I.D.										
Gross (g)										
Tare (g)										
Blank (g)										
Gain (g)										

Sample Containers	ID:	C1	C2	3	4	5	5A	5B	5C
	Volume (ml):	342	465						