REVIEW AND CERTIFICATION

All work, calculations, and other activities and tasks performed and presented in this document were carried out by me or under my direction and supervision. I hereby certify that, to the best of my knowledge, Montrose operated in conformance with the requirements of the Montrose Quality Management System and ASTM D7036-04 during this test project.

Signature: ______ Date: 3/10/2023

Name: John Nestor Title: District Manager

I have reviewed, technically and editorially, details, calculations, results, conclusions, and other appropriate written materials contained herein. I hereby certify that, to the best of my knowledge, the presented material is authentic, accurate, and conforms to the requirements of the Montrose Quality Management System and ASTM D7036-04.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 SUMMARY OF TEST PROGRAM

Poet Biorefining contracted Montrose Air Quality Services, LLC (Montrose) to perform a compliance emissions test program on the Hammermill Baghouse (FGFLOUR), Fermentation Scrubber (CE004), Thermal Oxidizer and associated Heat Recovery Boiler (CE010), and Regenerative Thermal Oxidizer (CE012) stack at the Poet Biorefining facility located in Caro, Michigan. The tests were conducted to satisfy the emissions testing requirements of the Renewable Operating Permit No. MI-ROP-N6996-2018a issued by the Michigan Department of Environment, Great Lakes, and Energy (EGLE).

The specific objectives were to:

- Measure the emissions of FPM as PM10/PM2.5 from the Hammermill Baghouses common stack
- Measure the emissions of total VOC and acetaldehyde from the Scrubber stack
- Measure the emissions of FPM, CPM, TPM as PM10/PM2.5, NOx, and total VOC from the TO&HRB
- Measure the emissions of FPM, CPM, TPM as PM10/PM2.5, NOx, and total VOC from the RTO stack during the three burner and two burner condition.
- Conduct the test program with a focus on safety

Montrose performed the tests to measure the emission parameters listed in Table 1-1.

TABLE 1-1
SUMMARY OF TEST PROGRAM

Test Date(s)	Unit ID/ Source Name	Activity/ Parameters	Test Methods	No. of Runs	Duration (Minutes)
1/10/2023	FGFLOUR	Velocity/Volumetric Flow Rate	EPA 1 & 2	3	60
1/10/2023	FGFLOUR	O_2, CO_2	EPA 3	3	60
1/10/2023	FGFLOUR	Moisture	EPA 4	3	60
1/10/2023	FGFLOUR	Total PM_{10}/$PM2_{.5}$	EPA 17	3	60
1/10/2023	CE012 STACK	Velocity/Volumetric Flow Rate	EPA 1 & 2	3	60
1/10/2023	CE004 STACK	Moisture	EPA 320	3	60
1/10/2023	CE004 STACK	VOC	EPA 320	3	60
1/10/2023	CE004 STACK	Acetaldehyde	EPA 320	3	60

1/11-1/12/2023	CE012 STACK	Velocity/Volumetric Flow Rate	EPA 1 & 2	3	60
1/11-1/12/2023	CE012 STACK	O_2, CO_2	EPA 3	3	60
1/11-1/12/2023	CE012 STACK	Moisture	EPA 4	3	60
1/11-1/12/2023	CE012 STACK	Total PM_{10}/$PM_{2.5}$	EPA 5/202	3	60
1/11-1/12/2023	CE012 STACK	Oxides of Nitrogen	EPA 7E	3	60
1/11-1/12/2023	CE012 STACK	VOC	EPA 320	3	60
1/11-1/12/2023	CE010 STACK	Velocity/Volumetric Flow Rate	EPA 1 & 2	3	60
1/11-1/12/2023	CE010 STACK	O_2, CO_2	EPA 3	3	60
1/11-1/12/2023	CE010 STACK	Moisture	EPA 4	3	60
1/11-1/12/2023	CE010 STACK	Total PM_{10}/$PM_{2.5}$	EPA 5/202	3	60
1/11-1/12/2023	CE010 STACK	Oxides of Nitrogen	EPA 7E	3	60
1/11-1/12/2023	CE010 STACK	VOC	EPA 320	3	60

To simplify this report, a list of Units and Abbreviations is included in Appendix D.1. Throughout this report, chemical nomenclature, acronyms, and reporting units are not defined. Please refer to the list for specific details.

This report presents the test results and supporting data, descriptions of the testing procedures, descriptions of the facility and sampling locations, and a summary of the quality assurance procedures used by Montrose. The average emission test results are summarized and compared to their respective permit limits in Table 1-2. Detailed results for individual test runs can be found in Section 4.0. All supporting data can be found in the appendices.

The testing was conducted by the Montrose personnel listed in Table 1-3. The tests were conducted according to the test plan (MW023AS-020558-PP-519) dated September 15, 2022 that was submitted to EGLE.

TABLE 1-2
SUMMARY OF AVERAGE COMPLIANCE RESULTS - FGFLOUR HAMMERMILL STACK
JANUARY 10, 2023

Parameter/Units	Average Results	Emission Limits
Total $PM_{2.5}$		
lb/hr*	0.082	0.93
Total PM_{10}		
lb/hr*	0.082	1.10
Total PM_1		
lb/1000 lb of gas	0.001	0.004

* The stack temperature was determined to be less than 85 °F. Particulate Matter less than 10 and less than 2.5 was determined by the gravimetric analysis of all filterable particulate matter captured by the USEPA Method 17 Train.

TABLE 1-3
SUMMARY OF AVERAGE COMPLIANCE RESULTS - CE004 SCRUBBER STACK
JANUARY 10, 2023

Parameter/Units	Average Results	Emission Limits
Total VOCs		
Lb/hr**	6.85	19.66
Acetaldehyde		
Lb/hr	0.9	1.5

** Total VOC by FTIR includes acetaldehyde, acetic acid, acrolein, ethanol, ethyl acetate, formaldehyde, formic acid, 2-furaldehyde, methanol.

TABLE 1-4
SUMMARY OF AVERAGE COMPLIANCE RESULTS - TO and HRB CE010 Stack
JANUARY 12, 2023

Parameter/Units	Average Results	Emission Limits
Total $PM_{10}/PM_{2.5}$		
lb/hr*	3.84	4.00
NOx		
lb/MMbtu	0.039	0.10
Total VOCs* **		
Lb/hr**	8.58	9.00
Total VOCs** **		
Lb/hr**	8.92	9.00

* Total Particulate Matter was determined by the summation of all filterable and condensable particulate matter captured by the USEPA Method 5/202 Train.

** Total VOC by FTIR includes acetaldehyde, acetic acid, acrolein, ethanol, ethyl acetate, formaldehyde, formic acid, 2-furaldehyde, methanol. Methane was detected, but was not included as it is an exempt VOC. The VOC limit is based on the combined emissions from the CE012 and CE010 stack.

*** Total VOC Emission limits are a combined limit from both the CE010 and CE012 stack. CE012 was fired under two conditions. The presented emissions results are for the two-burner condition.

**** Total VOC Emission limits are a combined limit from both the CE010 and CE012 stack. CE012 was fired under two conditions. The presented emissions results are for the three-burner condition.

TABLE 1-5
SUMMARY OF AVERAGE COMPLIANCE RESULTS - RTO CE012 Stack THREE-BURNER CONDITION
JANUARY 11, 2023

Parameter/Units	Average Results	Emission Limits
Total $PM_{10}/PM_{2.5}$		
lb/hr*	3.846	6.00
NOx		
lb/MMbtu	0.059	0.10
Total VOCs* **		
Lb/hr**	8.92	9.00

* Total Particulate Matter was determined by the summation of all filterable and condensable particulate matter captured by the USEPA Method 5/202 Train.

** Total VOC by FTIR includes acetaldehyde, acetic acid, acrolein, ethanol, ethyl acetate, formaldehyde, formic acid, 2-furaldehyde, methanol. Methane was detected, but was not included as it is an exempt VOC. The VOC limit is based on the combined emissions from the CE012 and CE010 stack.

*** Total VOC Emission limits are a combined limit from both the CE010 and CE012 stack. CE012 was fired under two conditions.

TABLE 1-6
SUMMARY OF AVERAGE COMPLIANCE RESULTS - RTO CE012 Stack TWO-BURNER CONDITION
JANUARY 12, 2023

Parameter/Units	Average Results	Emission Limits
Total $PM_{10}/PM_{2.5}$		
lb/hr*	3.74	6.00
NOx		
lb/MMbtu	0.06	0.10
Total VOCs* **		
Lb/hr**	8.58	9.00

* Total Particulate Matter was determined by the summation of all filterable and condensable particulate matter captured by the USEPA Method 5/202 Train.

** Total VOC by FTIR includes acetaldehyde, acetic acid, acrolein, ethanol, ethyl acetate, formaldehyde, formic acid, 2-furaldehyde, methanol. Methane was detected, but was not included as it is an exempt VOC.

*** Total VOC Emission limits are a combined limit from both the CE010 and CE012 stack. CE012 was fired under two conditions.

1.2 KEY PERSONNEL

A list of project participants is included below:

Facility Information

Source Location: POET Biorefinery
1551 Empire Drive
Caro, MI 48723
Contact: Coryn Houser
Role: EH&S Specialist
Company: POET Biorefinery
Email: Coryn.Houser@POET.com

Agency Information

Regulatory Agency: EGLE

Testing Company Information

Testing Firm: Montrose Air Quality Services, LLC

Contact: John Nestor
Title: District Manager
Telephone: 248-765-5032
Email: jonestor@montrose-env.com

Laboratory Information

Laboratory: Montrose Detroit
City, State: Royal Oak, Michigan
Method: EPA Method 17

Laboratory: Montrose Elk Grove
City, State: Elk Grove, Illinois
Method: EPA Method 202

Test personnel and observers are summarized in Table 1-3.

TABLE 1-3
TEST PERSONNEL AND OBSERVERS

Name	Affiliation	Role/Responsibility
John Nestor	Montrose	Field Project Manager, QI
Roy Zimmer	Montrose	Field Technician
Clayton Deronne	Montrose	Field Technician
Shane Rabideau	Montrose	Field Technician
Coryn Houser	Poet Biorefinery	Client Liaison
Tony Paul	Poet Biorefinery	Test Coordinator

2.0 PLANT AND SAMPLING LOCATION DESCRIPTIONS

2.1 PROCESS DESCRIPTION, OPERATION, AND CONTROL EQUIPMENT

POET Biorefinery operates a dry mill corn processing plant that produces ethanol from grain product. The final products from the facility are ethanol and distillers' grain with soluble that are used for fuel and livestock feed respectively. Compliance testing was conducted on the following sources with associated control devices.

- FGFLOUR, consisting of five hammermill baghouses (EUHAMMERMILL1 –EUHAMMERMILL5) exhausting to a common stack
- CE004, a packed-bed wet scrubber serving the fermentation and distillation processes (FGFERM&DIST)
- CE012, a regenerative thermal oxidizer (EURTO) serving the dried distiller's grains with solubles (DDGS) dryers and centrifugation
- CE010, a thermal oxidizer and heat recovery boiler (EUTO&HRB) serving the DDGS dryers and centrifugation

2.2 FLUE GAS SAMPLING LOCATION

Information regarding the sampling location is presented in Table 2-1.

TABLE 2-1
SAMPLING LOCATION

		Distance from Nearest Disturbance		
Sampling Location	**Stack Inside Dimensions (in.)**	**Downstream EPA "B" (in./dia.)**	**Upstream EPA "A" (in./dia.)**	**Number of Traverse Points**
FGFLOUR	54"	112 / 2.1	125 / 2.3	Isokinetic: 24 (12/port)
CE004	23.25"	72 / 3.1	14 / 0.6	Velocity: 16 (8/port)
CE010	79.25"	240 / 3.0	480 / 6.1	Isokinetic: 24 (12/port)
CE012	44"	404.3 / 8.9	960 / 10.5	Isokinetic: 16 (8/port)

Sample location(s) were verified in the field to conform to EPA Method 1. Acceptable cyclonic flow conditions were confirmed prior to testing using EPA Method 1, Section 11.4. See Appendices A.1 and A.2 for more information.

2.3 OPERATING CONDITIONS AND PROCESS DATA

Emission tests were performed while the source/units and air pollution control devices were operating at the conditions required by the permit. The unit were tested while operating at normal conditions.

Plant personnel were responsible for establishing the test conditions and collecting all applicable unit-operating data. The process data that was provided is presented in Appendix B.

3.0 SAMPLING AND ANALYTICAL PROCEDURES

3.1 TEST METHODS

The test methods for this test program were presented previously in Table 1-1. Additional information regarding specific applications or modifications to standard procedures is presented below.

3.1.1 EPA Method 1, Sample and Velocity Traverses for Stationary Sources

EPA Method 1 is used to assure that representative measurements of volumetric flow rate are obtained by dividing the cross-section of the stack or duct into equal areas, and then locating a traverse point within each of the equal areas. Acceptable sample locations must be located at least two stack or duct equivalent diameters downstream from a flow disturbance and one-half equivalent diameter upstream from a flow disturbance.

The sample port and traverse point locations are detailed in Appendix A.

3.1.2 EPA Method 2, Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

EPA Method 2 is used to measure the gas velocity using an S-type pitot tube connected to a pressure measurement device, and to measure the gas temperature using a calibrated thermocouple connected to a thermocouple indicator. Typically, Type S (Stausscheibe) pitot tubes conforming to the geometric specifications in the test method are used, along with an inclined manometer.

3.1.3 EPA Method 3, Gas Analysis for the Determination of Dry Molecular Weight

EPA Method 3 is used to calculate the dry molecular weight of the stack gas using one of three methods. The first choice is to measure the percent O_2 and CO_2 in the gas stream. A gas sample is extracted from a stack by one of the following methods: (1) single-point, grab sampling; (2) single-point, integrated sampling; or (3) multi-point, integrated sampling. The gas sample is analyzed for percent CO_2 and percent O_2 using either an Orsat or a Fyrite analyzer.

3.1.4 EPA Method 4, Determination of Moisture Content in Stack Gas

EPA Method 4 is a manual, non-isokinetic method used to measure the moisture content of gas streams. Gas is sampled at a constant sampling rate through a probe and impinger train. Moisture is removed using a series of pre-weighed impingers containing methodology-specific liquids and silica gel immersed in an ice water bath. The impingers are weighed after each run to determine the percent moisture.

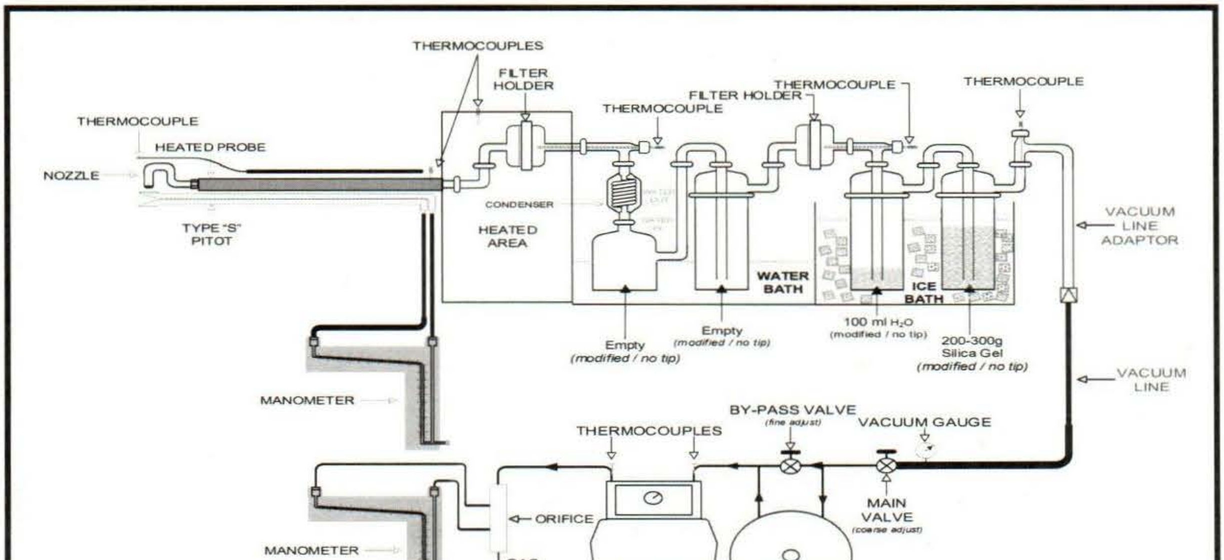
The typical sampling system is detailed in Figure 3-1.

3.1.5 EPA Method 5/202, Determination of Total Particulate Matter Emissions from Stationary Sources

EPA Method 5/202 is a manual, isokinetic test method used to measure emissions of FPM and Condensable particulate matter (CPM). CPM and FPM are then summed together to determine a total PM emission rate less than 10 microns and 2.5 microns. Particulate matter is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at 248 ±25 °F. The CPM is collected in dry impingers after filterable PM has been collected on a filter maintained as specified in either Method 5 of Appendix A-3 to 40 CFR 60, Method 17 of Appendix A-6 to 40 CFR 60, or Method 201A of Appendix M to 40 CFR 51. The organic and aqueous fractions of the impingers and an out-of-stack CPM filter are then taken to dryness and weighed. The total of the impinger fractions and the CPM filter represents the CPM. Compared to the version of Method 202 that was promulgated on December 17, 1991, this method eliminates the use of water as the collection media in impingers and includes the addition of a condenser followed by a water dropout impinger immediately after the final instack or heated filter. CPM is collected in the water dropout impinger, the modified Greenburg Smith impinger, and the CPM filter of the sampling train as described in this method. The impinger contents are purged with nitrogen immediately after sample collection to remove dissolved SO2 gases from the impinger The CPM filter is extracted with water and hexane. The impinger solution is then extracted with hexane. The organic and aqueous fractions are dried and the residues are weighed. The total of the aqueous and organic fractions represents the CPM. The potential artifacts from SO2 are reduced using a condenser and water dropout impinger to separate CPM from reactive gases. No water is added to the impingers prior to the start of sampling. To improve the collection efficiency of CPM, an additional filter (the "CPM filter") is placed between the second and third impingers.

The Typical Sampling System is detailed in Figure 3-1.

FIGURE 3-1
US EPA METHOD 5/202 SAMPLING TRAIN



3.1.6 EPA Methods 3A and 7E, Determination of Oxygen, Carbon Dioxide, and Nitrogen Oxides concentrations in Emissions from Stationary Source (Instrumental Analyzer Procedure)

Concentrations of O2, CO2, and NOx are measured simultaneously using EPA Methods 3A and 7E, which are instrumental test methods. Conditioned gas is sent to a series of analyzers to measure the gaseous emission concentrations. The performance requirements of the method must be met to validate the data.

Pertinent information regarding the performance of the method is presented below:

- Method Options:

o A dry extractive sampling system is used to report emissions on a dry basis

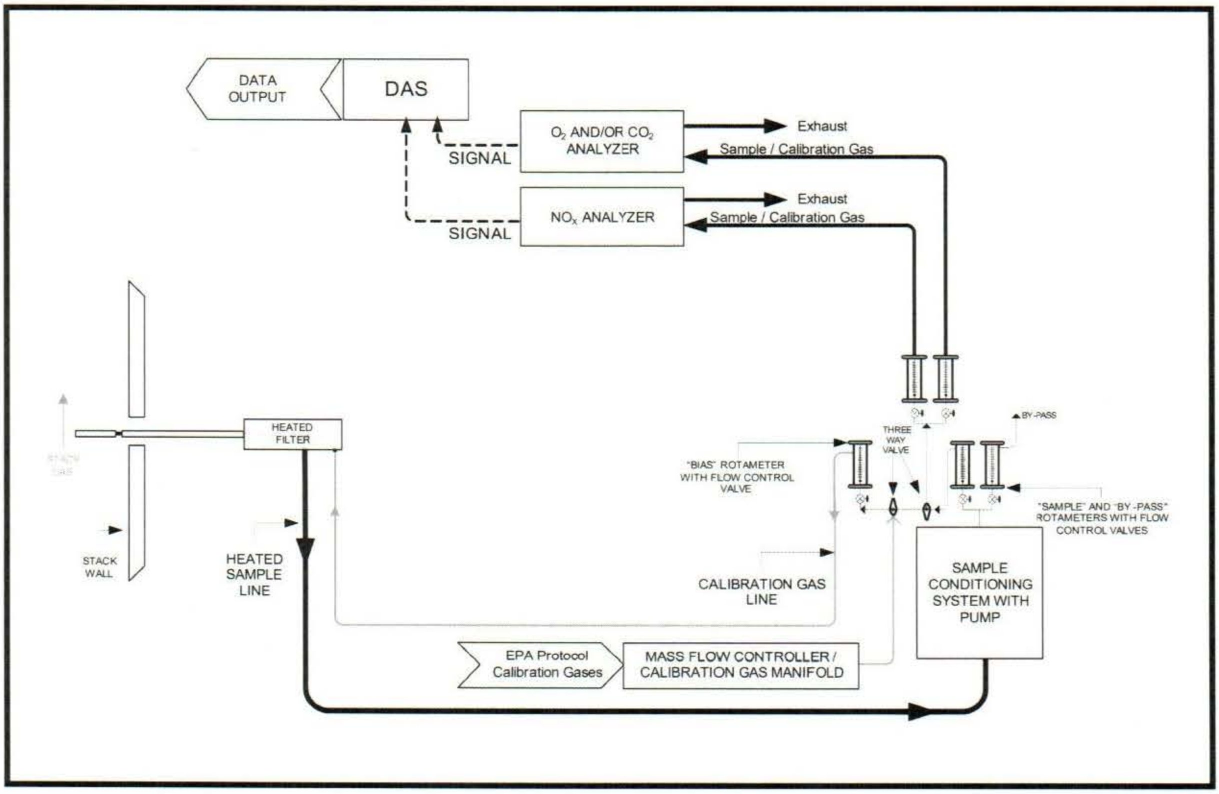
o A paramagnetic analyzer is used to measure O2

o A nondispersive infrared analyzer is used to measure CO2

o A chemiluminescent analyzer is used to measure NOx.

The sampling system is detailed in Figure 3-2.

FIGURE 3-2
EPA METHODS 3A (O_2 and CO2) and 7E SAMPLING TRAIN

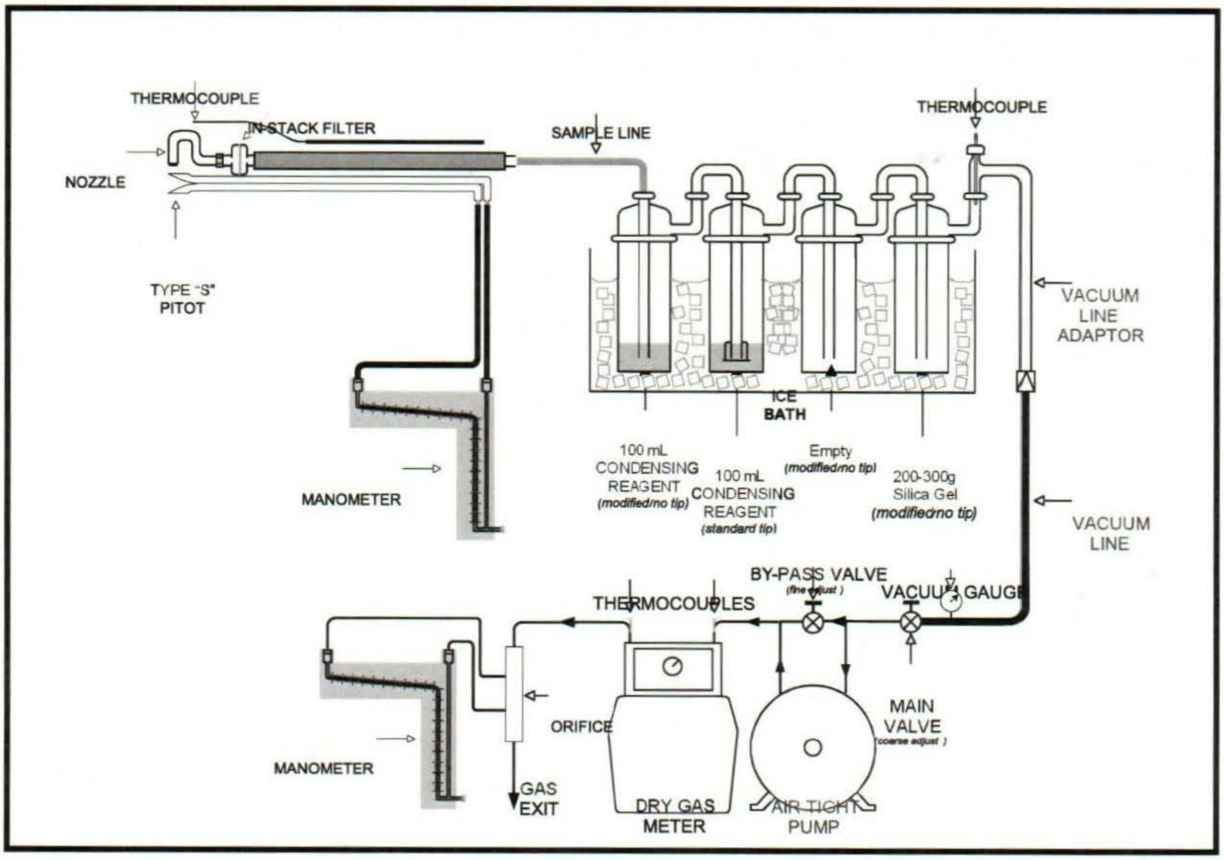


3.1.7 EPA Method 17, Determination of Particulate Matter Emissions from Stationary Sources

EPA Method 17 is a manual, isokinetic test method used to measure emissions of FPM. Particulate matter is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at stack temperature. The PM mass is determined gravimetrically after the removal of uncombined water.

The typical sampling system is detailed in Figure 3-1.

FIGURE 3-3
US EPA METHOD 17 SAMPLING TRAIN



3.1.8 EPA Method 320, VOC and HAP Determination using FTIR Spectroscopy

Speciated VOC and HAP sampling was conducted using FTIR instrumentation following the principles of USEPA Method 320 and ASTM Method D6348-12.

An MKS Model MultiGas 2030 FTIR analyzer was used to measure the specific VOC and HAP compounds. The analyzer is composed of a mks 2030 FTIR spectrometer, a high optical throughput sampling cell, analysis software, and a quantitative spectral library. The analyzer collects high resolution spectra in the mid infrared spectral region (400 to 4,000 cm^{-1}), which are analyzed using the quantitative spectral library. This provides an accurate, highly sensitive measurement of gases and vapors.

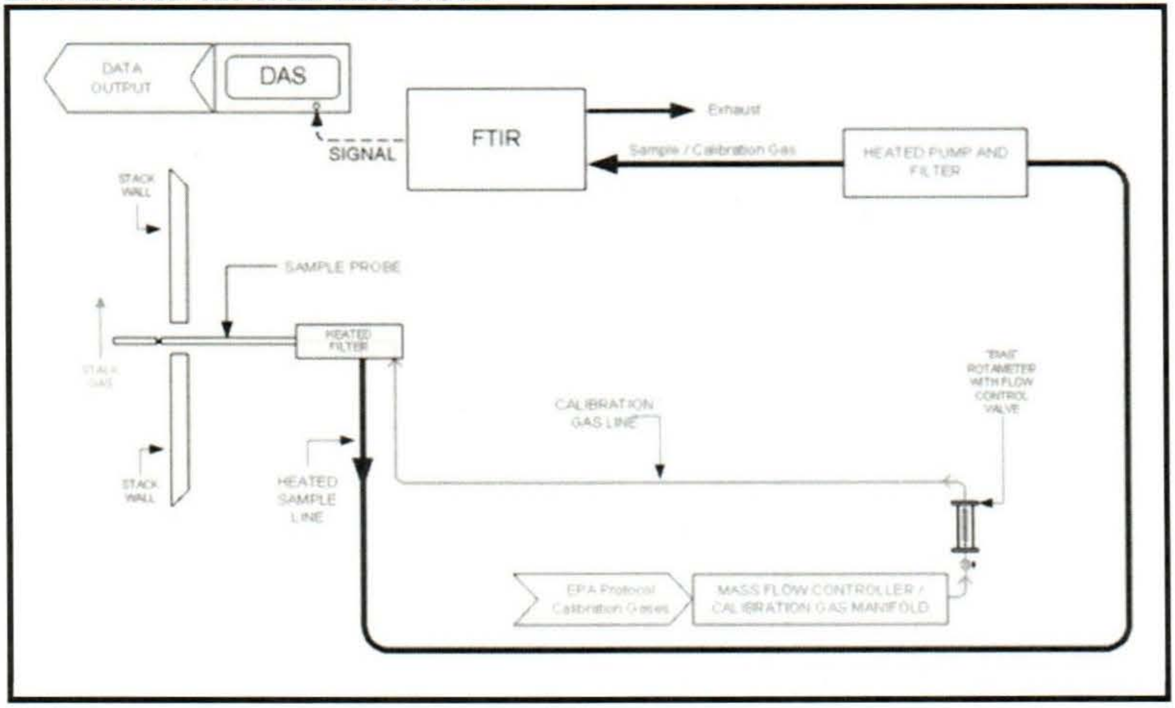
As shown in Figure 3-3, the sample delivery system consisted of a stainless steel sampling probe, calibration tee assembly, Teflon sampling line, fast loop bypass pump, and sample manifold. The gas sample was continuously extracted from each source at approximately 6 liters per minute.

Independent calculations of optical path length were not performed because the instrument has a fixed path of 5.11 meters. A signal to noise ratio test (S/N) was performed using MKS software to verify instrument performance.

Performance parameters measured included signal to noise tests, noise equivalent absorbance (NEA), detector linearity, background spectra, potential interferents, and cell and system leakage.

Quality assurance procedures included baseline measurement with ultra high purity nitrogen, measurement of a calibration transfer standard (~ 100 ppm methane), direct analyte calibration measurements, and measurements to determine baseline shift. SF_6 was used as a tracer gas in the calibration gases to verify the sample delivery system integrity.

Figure 3-4
EPA METHOD 320 SAMPLING TRAIN



The general FTIR field sampling procedure was as follows:

PRE-TEST

1) Background spectrum
   - Evaluate diagnostics of the instrumentation
2) Baseline (cylinder UHP-N_2 for zero check)
   - Determine the level of background noise
   - Observe spectrum for baseline tilt, i.e., indicates vibrations/perturbations affecting instrument
3) Calibration transfer standard (cylinder 100 ppm methane)

  - Determine level of response to evaluate the spectral response and stability of the instrument
  - Create a field reference spectrum
4) Baseline evaluation
   - Note baseline flush/clean out FTIR sample cell
   - Observe spectrum for baseline tilt
5) Collection of spectra stack gas
   - Determine stack gas analyte concentrations
6) Measurement of analyte calibration gas
7) Perform dynamic spiking recovery study (recovery must be $0.7 \le R \le 1.3$)

TEST (REPEAT EACH RUN)

1) Baseline Determination
2) Measurement of dynamic spike
3) Collect sequential spectra of stack gas
4) Baseline Determination
5) Measurement of Calibration Transfer Standard

POST-TEST

1) Baseline Determination
2) Measurement of Calibration Transfer Standard (i.e. span check)
3) Measurement of analyte calibration gas (optional)

A post test manual validation determined that ammonia and methane were present in the effluent. FTIR spectra were reprocessed to include ammonia and methane.

3.2 PROCESS TEST METHODS

The test plan did not require that process samples be collected during this test program; therefore, no process sample data are presented in this test report.

4.0 TEST DISCUSSION AND RESULTS

4.1 FIELD TEST DEVIATIONS AND EXCEPTIONS

No field deviations or exceptions from the test plan or test methods occurred during this test program.

4.2 PRESENTATION OF RESULTS

The average results are compared to the permit limits in Table 1-2. The results of individual compliance test runs performed are presented in Tables 4-1 through 4-3. Emissions are reported in units consistent with those in the applicable regulations or requirements. Additional information is included in the appendices as presented in the Table of Contents.

Concentration values in Table 4-1 denoted with a '<' were measured to be below the minimum detection limit (MDL) of the applicable analytical method. Emissions denoted with a '<' in Table 4-1 were calculated utilizing the applicable MDL concentration value instead of the "as measured" concentration value.

TABLE 4-1
TOTAL PM EMISSIONS RESULTS -
FGFLOUR HAMMERMILL STACK

Run Number	**1**	**2**	**3**	**Average**
Date	1/10/2023	1/10/2023	1/10/2023	--
Time	11:20-12:48	13:20-14:50	15:15-16:42	--
Flue Gas Parameters				
CO_2, % volume dry	0.0	0.0	0.0	0.0
O_2, % volume dry	20.9	20.9	20.9	20.9
flue gas temperature, °F	77.8	78.3	78.7	78.3
moisture content, % volume	1.08	2.13	2.23	1.81
Wet volumetric flow rate at actual conditions, acfm	26,153	25,831	25,418	25,801
Wet volumetric flow rate at standard conditions, scfm	25,714	25,378	24,953	25,348
Dry volumetric flow rate at standard conditions, dscfm	25,438	24,837	24,396	24,890
Total PM				
lb/hr	0.078	0.114	0.055	0.082
Total PM				
lb/1000 lb of gas	0.00068	0.00102	0.00050	0.00073

TABLE 4-2
VOC EMISSIONS RESULTS - CE004 SCRUBBER STACK

Date	1/10/2023	1/10/2023	1/10/2023	
Start Time				
End Time				
	Run 1	Run 2	Run 3	Average
Stack Conditions				
Average Gas Temperature °F	58	60	60	59
Effluent Moisture, percent by volume	1.5	1.5	1.5	1.5
Average Effluent Pressure in. hg	0.5	0.5	0.5	0.5
Effluent Volumetric Flow Rate, acfm	8,493	8,923	8,953	8,790
Effluent Volumetric Flow Rate, dscfm	8,572	8,962	9,002	8,845
Effluent Volumetric Flow Rate, scfm	8,669	9,094	9,136	8,966
Acetaldehyde				
ppmv wet	8.7	18.9	15.8	14.5
ppmv dry	8.8	19.2	16.0	14.7
lb/hr	0.52	1.18	0.99	0.90
Acetic Acid				
ppmv wet	< 10.8	< 10.9	< 9.8	10.5
ppmv dry	< 10.9	< 11.0	< 10.0	10.7
lb/hr	< 0.9	< 0.9	< 0.8	0.9
Acrolein				
ppmv wet	< 0.6	< 0.6	< 0.6	< 0.6
ppmv dry	< 0.6	< 0.6	< 0.6	< 0.6
lb/hr	< 0.0	< 0.0	< 0.0	< 0.0
Ethanol				
ppmv wet	18.4	21.4	25.9	21.9
ppmv dry	18.7	21.8	26.3	22.3
lb/hr	1.1	1.4	1.7	1.4
Ethyl Acetate				
ppmv wet	29.3	29.0	< 25.9	28.1
ppmv dry	29.7	29.5	< 26.3	28.5
lb/hr	3.5	3.6	< 3.3	3.5
Formaldehyde				
ppmv wet	0.4	0.4	0.4	0.4
ppmv dry	0.4	0.5	0.4	0.4
lb/hr	0.0	0.0	0.0	0.0
Formic Acid				
ppmv wet	< 0.3	< 0.3	< 0.3	< 0.3
ppmv dry	< 0.3	< 0.3	< 0.3	< 0.3
lb/hr	< 0.0	< 0.0	< 0.0	< 0.0
2-Furaldehyde				
ppmv wet	< 0.6	< 0.6	< 0.6	< 0.6
ppmv dry	< 0.6	< 0.6	< 0.6	< 0.6
lb/hr	< 0.1	< 0.1	< 0.1	< 0.1
Methanol				
ppmv wet	< 0.8	< 0.8	< 0.8	< 0.8
ppmv dry	< 0.8	< 0.8	< 0.8	< 0.8
lb/hr	< 0.0	< 0.0	< 0.0	< 0.0
Total VOCs				
lb/hr	< 6.21	< 7.34	< 6.99	< 6.85

TABLE 4-3
PARTICULATE AND GASEOUS EMISSIONS RESULTS - CE010 TO AND HRB STACK

Run Number	**1**	**2**	**3**	**Average**
Date	1/12/2023	1/12/2023	1/12/2023	--
Time	14:30-15:39	16:12-17:22	18:05-19:15	--
Flue Gas Parameters				
CO_2, % volume dry	8.7	9.6	9.7	9.33
O_2, % volume dry	6.0	4.5	4.5	4.93
flue gas temperature, °F	524.2	528.4	527.5	526.7
moisture content, % volume*	45.92	43.54	43.81	44.42
Wet volumetric flow rate at actual conditions, acfm	95,880	97,705	94,505	96,030
Wet volumetric flow rate at standard conditions, scfm	49,506	50,233	50,323	50,021
Dry volumetric flow rate at standard conditions, dscfm	26,774	28,361	28,274	27,803
Filterable PM				
lb/hr	3.376	3.067	2.958	3.133
Condensable PM				
lb/hr	0.811	0.657	0.640	0.703
Total PM				
lb/hr*	4.187	3.725	3.599	3.837
NO_X				
lb/mmBTU	0.044	0.037	0.035	0.039
VOC				
lb/hr**	< 5.92	< 5.66	< 5.38	< 5.66

* Total Particulate Matter was determined by the summation of all filterable and condensable particulate matter captured by the USEPA Method 5/202 Train.

** Total VOC by FTIR includes acetaldehyde, acetic acid, acrolein, ethanol, ethyl acetate, formaldehyde, formic acid, 2-furaldehyde, methanol. Methane was detected, but was not included as it is an exempt VOC.

TABLE 4-4
VOLATILE ORGANIC EMISSIONS RESULTS - CE010 TO AND HRB STACK

Date	1/12/2023	1/12/2023	1/12/2023	
Start Time	14:30	16:15	18:20	
End Time	15:33	17:18	19:23	
	Run 1	Run 2	Run 3	Average
	Flue Gas Parameters			
Average Gas Temperature °F	524	528	528	527
Effluent Moisture, percent by volume	0.0	0.0	0.0	0.0
Average Effluent Pressure in. hg	28.8	28.8	29.8	29.1
Effluent Volumetric Flow Rate, acfm	95,880	97,705	94,505	96,030
Effluent Volumetric Flow Rate, dscfm	26,774	28,361	28,274	27,803
Effluent Volumetric Flow Rate, scfm	49,506	50,233	50,323	50,021
	Acetaldehyde			
ppmv wet	< 0.5	0.5	0.6	0.5
ppmv dry	< 0.5	0.5	0.6	0.5
lb/hr	< 0.2	0.2	0.2	0.2
	Acetic Acid			
ppmv wet	0.9	1.0	0.7	0.8
ppmv dry	0.9	1.0	0.7	0.8
lb/hr	0.4	0.5	0.3	0.4
	Acrolein			
ppmv wet	1.9	2.6	2.9	2.5
ppmv dry	1.9	2.6	2.9	2.5
lb/hr	0.8	1.1	1.3	1.1
	Ethanol			
ppmv wet	7.5	6.0	6.1	6.5
ppmv dry	7.5	6.0	6.1	6.5
lb/hr	2.6	2.2	2.2	2.3
	Ethyl Acetate			
ppmv wet	0.7	0.7	0.5	0.6
ppmv dry	0.7	0.7	0.5	0.6
lb/hr	0.5	0.5	0.4	0.4
	Formaldehyde			
ppmv wet	1.7	0.4	< 0.4	0.9
ppmv dry	1.7	0.4	< 0.4	0.9
lb/hr	0.4	0.1	< 0.1	0.2
	Formic Acid			
ppmv wet	0.8	0.5	0.4	0.5
ppmv dry	0.8	0.5	0.4	0.5
lb/hr	0.3	0.2	0.2	0.2
	2-Furaldehyde			
ppmv wet	< 0.8	1.1	< 0.8	< 0.9
ppmv dry	< 0.8	1.1	< 0.8	< 0.9
lb/hr	< 0.6	0.8	< 0.6	< 0.7
	Methanol			
ppmv wet	0.7	< 0.5	< 0.5	< 0.6
ppmv dry	0.7	< 0.5	< 0.5	< 0.6
lb/hr	0.2	< 0.1	< 0.1	< 0.1
	Total VOCs			
lb/hr	< 5.92	< 5.66	< 5.38	< 5.66

TABLE 4-5
PARTICULATE AND GASEOUS EMISSIONS RESULTS - RTO CE012 STACK 3 BURNER CONDITION

Run Number	**1**	**2**	**3**	**Average**
Date	1/11/2023	1/11/2023	1/11/2023	--
Time	10:10-11:28	12:20-13:24	14:15-15:23	--
Flue Gas Parameters				
CO_2, % volume dry	5.70	5.80	5.90	5.80
O_2, % volume dry	11.10	11.10	11.10	11.10
flue gas temperature, °F	282.4	290.5	304.1	292.3
moisture content, % volume*	43.94	44.88	43.76	44.20
Wet volumetric flow rate at actual conditions, acfm	34,696	34,616	33,967	34,426
Wet volumetric flow rate at standard conditions, scfm	24,707	24,384	23,502	24,198
Dry volumetric flow rate at standard conditions, dscfm	13,850	13,440	13,217	13,502
Filterable PM				
lb/hr	0.593	0.089	0.096	0.259
Condensable PM				
lb/hr	2.579	3.958	4.222	3.586
Total PM				
lb/hr*	3.173	4.047	4.318	3.846
NO_X				
lb/mmBTU	0.059	0.059	0.059	0.059
VOC				
lb/hr**	< 3.45	< 3.16	< 3.18	< 3.26

* Total Particulate Matter was determined by the summation of all filterable and condensable particulate matter captured by the USEPA Method 5/202 Train.

** Total VOC by FTIR includes acetaldehyde, acetic acid, acrolein, ethanol, ethyl acetate, formaldehyde, formic acid, 2-furaldehyde, methanol. Methane was detected, but was not included as it is an exempt VOC.

TABLE 4-6
SPECIATED VOLATILE ORGANIC EMISSIONS RESULTS - RTO CE012 STACK 3 BURNER CONDITION

Date	1/11/2023	1/11/2023	1/11/2023	
Start Time	10:10	12:21	14:31	
End Time	11:17	13:26	15:36	
	Run 1	Run 2	Run 3	Average
	Stack Conditions			
Average Gas Temperature °F	282	290	304	292
Effluent Moisture, percent by volume	45.6	45.4	45.5	45.5
Average Effluent Pressure in. hg	29.96	29.96	29.96	29.96
Effluent Volumetric Flow Rate, acfm	34,696	34,616	33,967	34,426
Effluent Volumetric Flow Rate, dscfm	13,850	13,440	13,217	13,502
Effluent Volumetric Flow Rate, scfm	24,707	24,384	23,502	24,198
	Acetaldehyde			
ppmv wet	3.2	2.6	3.3	3.0
ppmv dry	5.9	4.7	6.0	5.5
lb/hr	0.54	0.43	0.53	0.50
	Acetic Acid			
ppmv wet	1.4	1.4	1.3	1.3
ppmv dry	2.5	2.5	2.4	2.5
lb/hr	0.32	0.32	0.28	0.31
	Acrolein			
ppmv wet	< 0.5	< 0.5	< 0.5	< 0.5
ppmv dry	< 0.9	< 0.9	< 0.9	< 0.9
lb/hr	< 0.11	< 0.11	< 0.10	< 0.11
	Ethanol			
ppmv wet	7.8	7.6	7.6	7.6
ppmv dry	14.3	13.9	13.9	14.0
lb/hr	1.38	1.33	1.28	1.33
	Ethyl Acetate			
ppmv wet	0.5	0.5	0.5	0.5
ppmv dry	0.8	0.8	0.9	0.8
lb/hr	0.15	0.15	0.15	0.15
	Formaldehyde			
ppmv wet	0.6	0.6	0.6	0.6
ppmv dry	1.1	1.1	1.0	1.1
lb/hr	0.07	0.07	0.06	0.07
	Formic Acid			
ppmv wet	0.5	0.5	0.4	0.5
ppmv dry	1.0	0.9	0.8	0.9
lb/hr	0.10	0.08	0.07	0.08
	2-Furaldehyde			
ppmv wet	2.0	1.7	1.9	1.9
ppmv dry	3.6	3.1	3.4	3.4
lb/hr	0.73	0.63	0.65	0.67
	Methanol			
ppmv wet	< 0.4	< 0.4	< 0.4	< 0.4
ppmv dry	< 0.7	< 0.7	< 0.7	< 0.7
lb/hr	< 0.05	< 0.05	< 0.05	< 0.05
	Total VOCs			
lb/hr	< 3.45	< 3.16	< 3.18	< 3.26

TABLE 4-7
PARTICULATE AND GASEOUS EMISSIONS RESULTS - RTO CE012 STACK 2 BURNER CONDITION

Run Number	**1**	**2**	**3**	**Average**
Date	1/11/2023	1/12/2023	1/12/2023	--
Time	16:20-17:24	8:25-9:29	10:05-11:12	--
Flue Gas Parameters				
CO_2, % volume dry	5.90	5.20	5.20	5.43
O_2, % volume dry	11.40	12.00	12.10	11.83
flue gas temperature, °F	291.6	292.8	266.8	283.7
moisture content, % volume*	42.42	43.96	43.03	43.14
Wet volumetric flow rate at actual conditions, acfm	33,728	32,942	31,887	32,853
Wet volumetric flow rate at standard conditions, scfm	23,678	23,003	23,066	23,249
Dry volumetric flow rate at standard conditions, dscfm	13,635	12,891	13,141	13,222
Filterable PM				
lb/hr	0.0870	0.082	0.031	0.067
Condensable PM				
lb/hr	4.265	3.235	3.519	3.673
Total PM				
lb/hr*	4.352	3.317	3.550	3.740
NO_X				
lb/mmBTU	0.061	0.060	0.061	0.061
VOC				
lb/hr**	< 2.88	< 3.22	< 2.67	< 2.93

* Total Particulate Matter was determined by the summation of all filterable and condensable particulate matter captured by the USEPA Method 5/202 Train.

** Total VOC by FTIR includes acetaldehyde, acetic acid, acrolein, ethanol, ethyl acetate, formaldehyde, formic acid, 2-furaldehyde, methanol. Methane was detected, but was not included as it is an exempt VOC.

TABLE 4-8
SPECIATED VOLATILE ORGANIC COMPOUND RESULTS - RTO CE012 STACK 2 BURNER CONDITION

Date	1/11/2023		1/12/2023		1/12/2023		
Start Time	16:20		8:51		10:38		
End Time	17:27		9:46		11:38		
	Run 1		Run 2		Run 3		Average
	Stack Conditions						
Average Gas Temperature °F	291		292		267		283
Effluent Moisture, percent by volume	45.4		45.7		45.5		45.5
Average Effluent Pressure in. hg	29.89		29.78		29.78		29.82
Effluent Volumetric Flow Rate, acfm	33,728		32,942		31,887		32,853
Effluent Volumetric Flow Rate, dscfm	13,635		12,891		13,141		13,222
Effluent Volumetric Flow Rate, scfm	23,678		23,003		23,066		23,249
	Acetaldehyde						
ppmv wet	2.8		1.4		2.4		2.2
ppmv dry	5.1		2.6		4.4		4.0
lb/hr	0.45		0.22		0.38		0.35
	Acetic Acid						
ppmv wet <	1.4	<	1.9	<	1.7		1.7
ppmv dry <	2.6	<	3.6	<	3.0		3.1
lb/hr <	0.31	<	0.42	<	0.36		0.36
	Acrolein						
ppmv wet <	0.5	<	0.5	<	0.5	<	0.5
ppmv dry <	0.9	<	0.9	<	0.9	<	0.9
lb/hr <	0.10	<	0.10	<	0.10	<	0.10
	Ethanol						
ppmv wet	6.7		8.2		7.1		7.3
ppmv dry	12.3		15.2		13.0		13.5
lb/hr	1.14		1.36		1.17		1.22
	Ethyl Acetate						
ppmv wet	0.4		1.0		0.5		0.6
ppmv dry	0.8		1.8		0.9		1.2
lb/hr	0.14		0.30		0.16		0.20
	Formaldehyde						
ppmv wet	0.6		0.5		0.5		0.6
ppmv dry	1.1		1.0		1.0		1.0
lb/hr	0.07		0.06		0.06		0.06
	Formic Acid						
ppmv wet	0.5		0.5		0.6		0.5
ppmv dry	1.0		0.8		1.1		1.0
lb/hr	0.09		0.08		0.10		0.09
	2-Furaldehyde						
ppmv wet	1.5		1.8		0.9		1.4
ppmv dry	2.8		3.4		1.6		2.6
lb/hr	0.54		0.64		0.31		0.49
	Methanol						
ppmv wet <	0.4	<	0.4	<	0.4	<	0.4
ppmv dry <	0.7	<	0.7	<	0.7	<	0.7
lb/hr <	0.05	<	0.05	<	0.05	<	0.05
	Total VOCs						
lb/hr <	2.88	<	3.22	<	2.67	<	2.93

5.0 INTERNAL QA/QC ACTIVITIES

5.1 QA/QC AUDITS

The meter box and sampling train(s) used during sampling performed within the requirements of their respective methods. All post-test leak checks, minimum metered volumes, minimum sample durations, and percent isokinetics met the applicable QA/QC criteria.

5.2 QA/QC DISCUSSION

All QA/QC criteria were met during this test program.

5.3 QUALITY STATEMENT

The meter box and sampling train used during sampling performed within the requirements of the test method. All post-test leak checks, minimum metered volumes, minimum sample durations, and percent isokinetics met the applicable QA/QC criteria.

EPA Methods 3A and 7E calibration audits were all within the measurement system performance specifications for the calibration drift checks, system calibration bias checks, and calibration error checks.

EPA Method 5 analytical QA/QC results are included in the laboratory report. The method QA/QC criteria were met. An EPA Method 5 reagent blank was analyzed. The maximum allowable amount that can be subtracted is 0.001% of the weight of the acetone used. The blank did not exceed the maximum residue allowed.

EPA Method 202 analytical QA/QC results are included in the laboratory report. The method QA/QC criteria were me. An EPA Method 202 Field Train Recovery Blank (FTRB) was collected. The maximum allowable amount that can be subtracted is 0.002 g (2.0 mg). For this project, the FTRB had a mass of 1.95 mg which was subtracted from each sample run CPM mass value.

The EPA Method 320 performance parameters measured included signal to noise tests, noise equivalent absorbance (NEA), detector linearity, background spectra, potential interferents, and cell and system leakage. Quality assurance procedures included baseline measurement with ultra-high purity nitrogen, measurement of a calibration transfer standard (~100 ppm ethylene), direct analyte calibration measurements, and measurements to determine baseline shift. SF6 was also used as a tracer gas in the calibration gases to verify the sample delivery system integrity. A dynamic matrix spike was performed using acetaldehyde, methanol, and SF6 as a tracer gas. The method QA/QC criteria were met.

Nitrogen Oxide Emission Rate, lb/MMBtu

$$E_{NOx} = \frac{(C_d)(MW)(F_c)(100)}{(385.3 \times 10^6)(CO_2)}$$

E_{NOx}	= 0	F_c	= 0
C_d	= 31	CO_2	= 8.6666
MW	= 46.01		

Where:

E_{NOx} = nitrogen oxides emission rate, (lb/MMBtu)
C_d = nitrogen oxides concentration, corrected for drift (ppmdv)
MW = molecular weight of nitrogen oxide (lb/lb-mole)
F_c = carbon based fuel factor (scf/MMBtu)
CO_2 = carbon dioxide content of the gas stream (%)
385.3 = volume occupied by one pound of gas at standard conditions (dscf/lbmole)
100 = conversion factor (%)
10^6 = conversion factor (ppm)

Nitrogen Oxide Emission Rate, lb/hr

$$E_{NOx} = \frac{(C_d)(MW)(60)(Q_{dstd})}{(385.3 \times 10^6)}$$

E_{NOx}	= #DIV/0!	MW	= 46.01
C_d	= 31	Q_{dstd}	= #DIV/0!

Where:

E_{NOx} = nitrogen oxides emission rate (lb/hr)
C_d = nitrogen oxides concentration, corrected for drift (ppmdv)
MW = molecular weight of nitrogen oxide (lb/lb-mole)
Q_{dstd} = volumetric flow rate of the dry gas stream at standard conditions (dscfm)
60 = conversion factor (min/hr)
385.3 = volume occupied by one pound of gas at standard conditions (dscf/lbmole)
10^6 = conversion factor (ppm)

Nitrogen Oxides Concentration Corrected for Oxygen

$$C_{7\%O_2} = C_d \frac{(20.9-7)}{(20.9-O_2)}$$

$C_{7\%O2}$ = 42.682
C_d = 31
O_2 = 5.96

Where:

$C_{7\%O2}$ = nitrogen oxides concentration corrected for oxygen (ppmdv@7%)
C_d = nitrogen oxides concentration, corrected for analyzer drift (ppmdv)
O_2 = oxygen content of the gas stream (%)
20.9 = oxygen content of ambient air (%)
0 = oxygen content for correction (%)

Nitrogen Oxide Emission Rate, lb/MMBtu

$$E_{NOx} = \frac{(C_d)(MW)(Fd)(20.9)}{\left(385.3\times10^6\right)(20.9-O_2)}$$

E_{NOx} = 0.0444 F_d = 8,710
C_d = 31 O_2 = 5.96
MW = 46.01

Where:

E_{NOx} = nitrogen oxides emission rate (lb/MMBtu)
C_d = nitrogen oxides concentration, corrected for drift (ppmdv)
MW = molecular weight of nitrogen oxide (lb/lb-mole)
F_d = oxygen based fuel factor (scf/MMBtu)
O_2 = oxygen content of the gas stream (%)
20.9 = oxygen content of ambient air (%)
385.3 = volume occupied by one pound of gas at standard conditions (dscf/lbmole)
10^6 = conversion factor (ppm)

Volumetric Flow of Gas Stream - Standard Conditions - Dry Basis

$$Q_{dstd} = Q_{std}\left(1 - \frac{B_{ws}}{100}\right)$$

Q_{dstd} = #DIV/0!
Q_{std} = #DIV/0!
B_{ws} = #DIV/0!

Where:

Q_{dstd} = volumetric flow rate of the dry gas stream at standard conditions (dscfm)
Q_{std} = volumetric flow rate of the gas stream at standard conditions (scfm)
B_{ws} = moisture content of the gas stream (%)
100 = conversion factor (%)

Nitrogen Oxides Concentration, Corrected for Analyzer Drift[4]

$$C_d = \left(C - \left(\frac{c_{0i} + c_{0f}}{2}\right)\right)\left(\frac{c_a}{\left(\frac{c_{si} + c_{sf}}{2}\right) - \left(\frac{c_{0i} + c_{0f}}{2}\right)}\right)$$

C_d = 31 C_a = 50.23
C = 31 C_{si} = -0.19821
C_{0i} = -0.0816 C_{sf} = 50
C_{0f} = 51

Where:

C_d = nitrogen oxides concentration, corrected for analyzer drift (ppmdv)
C = nitrogen oxides concentration (ppmdv)
C_{0i} = initial zero calibration value (ppm)
C_{0f} = final zero calibration value (ppm)
C_a = actual span gas value (ppm)
C_{si} = initial span calibration value (ppm)
C_{sf} = final span calibration value (ppm)

[4] Calculations for LIST OTHER COMPOUNDS are performed in a similar manner

Volumetric Flow of Gas Stream - Actual Conditions

$$Q_a = 60(V_s)(A_s)$$

Q_a = #DIV/0!
V_s = #DIV/0!
A_s = 0.00

Where:

Q_a = volumetric flow rate of the gas stream at actual conditions (acfm)
V_s = average velocity of the gas stream (ft/sec)
A_s = area of sample location (ft^2)
60 = conversion factor (sec/min)

Volumetric Flow of Gas Stream - Standard Conditions

$$Q_{std} = \frac{17.64(Q_a)(P_a)}{(T_s + 460)}$$

Q_{std}	= #DIV/0!	P_a	= 0.00
Q_a	= #DIV/0!	T_s	= #DIV/0!

Where:

Q_{std} = volumetric flow rate of the gas stream at standard conditions (scfm)
Q_a = volumetric flow rate of the gas stream at actual conditions (acfm)
P_a = average stack temperature (^{o}F)
T_s = stack pressure absolute (in. Hg)
17.64 = ratio of standard temperature over standard pressure (^{o}R/in. Hg)
460 = conversion (^{o}F to ^{o}R)

Molecular Weight of Wet Gas Stream

$$M_s = \left(M_d \times \left(1 - \frac{B_{ws}}{100} \right) \right) + \left(18 \times \frac{B_{ws}}{100} \right)$$

M_s = #DIV/0!
M_d = 29.62
B_{ws} = #DIV/0!

Where:

M_s = molecular weight of the wet gas stream (lb/lb-mole)
M_d = molecular weight of the dry gas stream (lb/lb-mole)
B_{ws} = moisture content of the gas stream (%)
18 = molecular weight of water (lb/lb-mole)
100 = conversion factor (%)

Velocity of Gas Stream

$$V_s = 85.49 \left(C_p \right) \left(\sqrt{\overline{\Delta P}} \right) \sqrt{\frac{\left(T_s + 460 \right)}{\left(M_s \right) \left(P_a \right)}}$$

V_s = #DIV/0! T_s = #DIV/0!
C_p = 0.00 M_s = #DIV/0!
$\sqrt{\Delta P}$ = #DIV/0! P_a = 0.00

Where:

V_s = average velocity of the gas stream (ft/sec)
C_p = pitot tube coefficient (dimensionless)
$\sqrt{\Delta P}$ = average square root of velocity pressures (in. H_2O)$^{1/2}$
T_s = average stack temperature (°F)
M_s = molecular weight of the wet gas stream (lb/lb-mole)
P_a = stack pressure absolute (in. Hg)
85.49 = pitot tube constant (ft/sec)([(lb/lb-mole)(in. Hg)]/[(°R)(in. H_2O)])$^{1/2}$
460 = conversion (°F to °R)

Percent Moisture[2]

$$B_{ws} = 100 \times \left[\frac{V_{w(std)}}{\left(V_{m(std)} + V_{w(std)}\right)} \right]$$

B_{ws} = #DIV/0!
$V_{w(std)}$ = 0.00
$V_{m(std)}$ = #DIV/0!

Where:
B_{ws} = moisture content of the gas stream (%)
$V_{w(std)}$ = volume of gas collected at standard conditions (scf)
$V_{m(std)}$ = volume of water vapor at standard conditions (scf)
100 = conversion factor (%)

Molecular Weight of Dry Gas Stream[3]

$$M_d = \left(44 \times \frac{CO_2}{100}\right) + \left(32 \times \frac{O_2}{100}\right) + \left(28 \times \frac{N_2}{100}\right)$$

M_d = 29.62 O_2 = 5.96
CO_2 = 8.6666 N_2 = 85.38

Where:
M_d = molecular weight of the dry gas stream (lb/lb-mole)
CO_2 = carbon dioxide content of the gas stream (%)
44 = molecular weight of carbon dioxide (lb/lb-mole)
O_2 = oxygen content of the gas stream (%)
32 = molecular weight of oxygen (%)
N_2 = nitrogen content of the gas stream (%)
28 = molecular weight of nitrogen (lb/lb-mole)

[2] The moisture saturation point was used if it was exceeded by the measured moisture content
[3] The remainder of the gas stream after subtractiong CO_2 and O_2 is assumed to be nitrogen

Volume of Dry Gas Collected Corrected to Standard Conditions

$$V_{m(std)} = \frac{17.64\left(V_m\right)\left(Y_d\right)\left(P_b + \frac{\Delta H}{13.6}\right)}{\left(T_m + 460\right)}$$

$V_{m(std)}$	= #DIV/0!	P_b	= 0.00
V_m	= 0.00	ΔH	= #DIV/0!
Y_d	= 0	T_m	= #DIV/0!

Where:

$V_{m(std)}$	= volume of gas collected at standard conditions (scf)
V_m	= volume of gas sampled at meter conditions (ft^3)
Y_d	= gas meter correction factor (dimensionless)
P_b	= barometric pressure (in. Hg)
ΔH	= average sample pressure (in. H_2O)
T_m	= average gas meter temperature (^oF)
13.6	= conversion factor (in. H_2O/in. Hg)
17.64	= ratio of standard temperature over standard pressure (^oR/in. Hg)
460	= conversion (^oF to ^oR)

Volume of Water Vapor Collected Corrected to Standard Conditions

$$V_{w(std)} = 0.04715 \times V_{wc} + 0.04715 \times V_{wsg}$$

$V_{w(std)}$	= 0.00
V_{wc}	= 0
V_{wsg}	= 0

Where:

$V_{w(std)}$	= volume of water vapor at standard conditions (scf)
V_{wc}	= weight of liquid collected (g)
V_{wsg}	= weight gain of silica gel (g)
0.04715	= volume occupied by one gram of water at standard conditions (ft^3/g)

Sample Calculations TO & HRB

Area of Sample Location

$$A_s = (\pi)\left(\frac{d_s}{2 \times 12}\right)^2$$

A_s = 0.00
d_s = 0

Where:

A_s = area of sample location (ft^2)
d_s = diameter of sample location (in)
12 = conversion factor (in/ft)
2 = conversion factor (diameter to radius)

Stack Pressure Absolute

$$P_a = P_b + \frac{P_s}{13.6}$$

P_a = 0.00
P_b = 0.00
P_s = 0

Where:

P_a = stack pressure absolute (in. Hg)
P_b = barometric pressure (in. Hg)
P_s = static pressure (in. H_2O)
13.6 = conversion factor (in. H_2O/in. Hg)

Isokinetic Calculations

Percent isokinetic of sampling rate (%)

$\%I = (P_{std} / T_{std}) * (T_{savg} / P_s) * [V_{mstd} / (v_s * M_{fd} * \theta) * (\pi * (D_n / 2)^2 / 144)] * (100 / 60)$

$\%I = (29.92 / 527.7) * (983.878 / 28.805) * (58.530 / (46.6500 * 0.541 * 60.0 * 3.141593 * (0.472 / 2) \wedge 2) / 144)$

$\%I =$ 102.7 %

Method 5 Calculations

Filterable PM total catch weight (mg)

$mg_{quan} =$ 55.80 mg

Filterable PM concentration (grains/dscf)

$C_{grcm} = 0.0154322 * mg_{quan} / V_{mstd}$

$C_{grcm} = 0.0154322 * 55.80 / 58.530$

$C_{grcm} =$ 0.0147 gr/ft^3

Filterable PM mass emission rate (lb/hr)

$EMR_{lbhr} = (mg_{quan} / V_{mstd}) * Q_{sd} * (60 / 453592)$

$EMR_{lbhr} = 55.80 / 58.530 * 26{,}774.1 * (60 / 453592)$

$EMR_{lbhr} =$ 3.376 lb/hr

Note: The results calculated on this page may differ slightly from the results presented in the final report. This differen attributed to "significant digit round-off errors" common when comparing computer spreadsheets results with those c using a calculator.

$v_s = 85.49 * Cp * (SQ\Delta P_{avg}) * (T_{savg} / (P_s * M_s))^{0.5}$

v_s = 85.49 * 0.84 * (0.5479) * (983.88 / (28.805 * 24.298)) ^ 0.5

v_s = 46.65 ft/sec

Wet volumetric flue gas flow rate at actual conditions (acfm)

$Q_{aw} = v_s * A * 60$ sec/min

$Q_{aw} = 46.650 * 34.255 * 60$

Q_{aw} = 95,880 ft^3/min

Wet volumetric flue gas flow rate at standard conditions (scfm)

$Q_{sdw} = v_s * A * (T_{std} / T_{savg}) * (P_s / P_{std}) * 60$ sec/min

$Q_{sdw} = 46.650 * 34.255 * (527.7 / 983.878) * (28.805 / 29.92) * 60$

Q_{sdw} = 49,506 ft^3/min

Dry volumetric flue gas flow rate at standard conditions (dscfm)

$Q_{sd} = M_{fd} * v_s * A * (T_{std} / T_{savg}) * (P_s / P_{std}) * 60$ sec/min

$Q_{sd} = 0.541 * 46.6500 * 34.2552 * (527.7 / 983.878) * (28.805 / 29.92) * 60$

Q_{sd} = 26,774 ft^3/min

Percent Excess Air

$\%EA = [\%O_2 - (0.5) * \%CO] / [0.264 * (100 - \%CO_2 - \%O_2) - (\%O_2 - 0.5 * \%CO)]$

$\%EA = ((6.00 - (0.5) * 0.00) / (0.264 * (100 - 8.70 - 6.00) - (6.00 - 0.5 * 0.00))) * 100$

%EA = 36.32 %

Volume of water vapor at standard conditions (68 °F, scf)

V_{wstd} = (0.04716 ft^3/g) * Vlc

V_{wstd} = (0.04716 * 1,053.7)

V_{wstd} = 49.7 ft^3

Percent moisture by volume as measured in flue gas

$\%H_2O$ (Measured) = 100 * [V_{wstd} / (V_{wstd} + V_{mstd})]

$\%H_2O$ (Measured) = 100 * (49.692 / (49.692 + 58.530))

$\%H_2O$ (Measured) = 45.92

$\%H_2O$ (Saturated) = (100 / P_{sam}) * 10 ^ (6.6911 - (3144 / (T_{savg} + 390.86 - 460)))

$\%H_2O$ (Saturated) = (100 / 28.804853) * 10 ^ (6.6911 - (3144 / (983.878333 + 390.86 - 460)))

$\%H_2O$ (Saturated) = 6232.84

$\%H_2O$ = 45.92

Absolute flue gas pressure

P_s = P_{sam} + (Pg / 13.6)

P_s = 28.76 + (0.61 / 13.6)

P_s = 28.80 in. Hg

Dry mole fraction of flue gas (dimensionless)

M_{fd} = 1 - ($\%H_2O$ / 100)

M_{fd} = 1 - (45.92 / 100)

M_{fd} = 0.541

Dry molecular weight of flue gas (lb/lb-mole)

M_d = [($\%CO_2$ / 100) * 44.0] + [($\%O_2$ / 100) * 32.0] + [((100 - $\%CO_2$ - $\%O_2$) / 100) * 28.0]

M_d = ((8.70 / 100) * 44.0) + ((6.00 / 100) * 32.0) + (((100 - 8.70 - 6.00) / 100) * 28.0)

M_d = 29.63 lb/lb-mole

M_d = 29.63

Wet molecular weight of flue gas (lb/lb-mole)

M_s = M_d * M_{fd} + (H_2OF_{wt} * ($\%H_2O$ / 100))

M_s = 29.632 * 0.541 + 18.02 * (45.92 / 100)

M_s = 24.30 lb/lb-mole

Average flue gas velocity (ft/sec)

USPEA Method 5/202 Nomenclature and Sample Calculations

Customer	POET Caro	**Project Number**	PROJ-020558
Computed By		**Calculation Date**	
Run Number	1		

Constants

CO_2F_{wt}= 44.0
O_2F_{wt}= 32.0
CON_2F_{wt}= 28.0
H_2OF_{wt}= 18.015
ArF_{wt}= 39.95

in wg= 0.073529
gr= 0.00014286
MMBtu= 1000000 Btu
CF_{wt}= 12.011
PF_{wt}= 44.0962

NO_2F_{wt}= 46.01
COF_{wt}= 28.01
$H_2SO_4F_{wt}$= 98.08
T_{std}= 527.67

$HClF_{wt}$= 36.46
SO_2F_{wt}= 64.06
Cl_2F_{wt}= 70.91
P_{std}= 29.92

Stack Variables

pitot tube coefficient (dimensionless)	0.84	Cp
barometric pressure, inHg	28.84	Pbar
elevation difference between ground level and meter box, ft	80	Ebox
elevation difference between ground level and sampling ports, ft	80	Esam
gamma, dry gas meter calibration factor (dimensionless)	0.9930	γ
net run time, minutes	60.0	θ
total mass of liquid collected in impingers, g	1053.7	Vlc
percent CO_2 by volume, dry basis, dimensionless, %	8.70	$\%CO_2$
percent O_2 by volume, dry basis, dimensionless, %	6.00	$\%O_2$
percent CO by volume, dry basis, dimensionless, %	0.00	%CO
percent N_2 by volume, dry basis, dimensionless, %	85.30	$\%N_2$
stack cross-sectional area, ft^2	34.2552	A
flue gas static pressure, inH_2O	0.61	Pg
average absolute flue gas temperature, 459.67°R+tsavg °F, R	983.88	Tsavg
average square root ΔP, inH_2O	0.55	SQDPavg
average pressure differential of orifice meter, in. wg	3.42	ΔH
dry gas meter temperature, 459.67°R+tsavg °F, R	516.96	Tm
volume of metered gas sample, dry actual cubic feet, ft^3	59.56	Vm
sampling nozzle diameter, in.	0.472	Dn

Calculated Stack Variables

Barometric pressure at sampling location

NOTE: Barometric pressure recorded at ground level

$$P_{sam} = P_{bar} - [(E_{sam} / 100 \text{ ft}) * 0.1 \text{ in. Hg}]$$

$$P_{sam} = 28.84 - ((80.0 / 100) * 0.1)$$

$$P_{sam} = 28.76 \text{ in. Hg}$$

Volume of dry gas sampled at standard conditions (dscf)

$$V_{mstd} = \gamma * Vm * [P_{bar} - ([(E_{box} / 100 \text{ ft}) * 0.1 \text{ in. Hg}] + (\Delta H / 13.6)) / P_{std}] * (T_{std} / T_m)$$

$$V_{mstd} = 0.9930 * 59.555 * ((28.84 - ((80.0 / 100) * 0.1) + (3.4167 / 13.6)) / 29.92) * (527.7 / 516.962$$

$$V_{mstd} = 58.530 \text{ ft}^3$$

Nitrogen Oxide Emission Rate, lb/MMBtu

$$E_{NOx} = \frac{(C_d)(MW)(F_c)(100)}{(385.3 \times 10^6)(CO_2)}$$

E_{NOx} = 0
C_d = 26
MW = 46.01
F_c = 0
CO_2 = 5.89843

Where:

E_{NOx} = nitrogen oxides emission rate, (lb/MMBtu)
C_d = nitrogen oxides concentration, corrected for drift (ppmdv)
MW = molecular weight of nitrogen oxide (lb/lb-mole)
F_c = carbon based fuel factor (scf/MMBtu)
CO_2 = carbon dioxide content of the gas stream (%)
385.3 = volume occupied by one pound of gas at standard conditions (dscf/lbmole)
100 = conversion factor (%)
10^6 = conversion factor (ppm)

Nitrogen Oxide Emission Rate, lb/hr

$$E_{NOx} = \frac{(C_d)(MW)(60)(Q_{dstd})}{(385.3 \times 10^6)}$$

E_{NOx} = #DIV/0!
C_d = 26
MW = 46.01
Q_{dstd} = #DIV/0!

Where:

E_{NOx} = nitrogen oxides emission rate (lb/hr)
C_d = nitrogen oxides concentration, corrected for drift (ppmdv)
MW = molecular weight of nitrogen oxide (lb/lb-mole)
Q_{dstd} = volumetric flow rate of the dry gas stream at standard conditions (dscfm)
60 = conversion factor (min/hr)
385.3 = volume occupied by one pound of gas at standard conditions (dscf/lbmole)
10^6 = conversion factor (ppm)

Nitrogen Oxides Concentration Corrected for Oxygen

$$C_{7\%O_2} = C_d \frac{(20.9-7)}{(20.9-O_2)}$$

$C_{7\%O2}$ = 58.283
C_d = 26
O_2 = 11.41

Where:
$C_{7\%O2}$ = nitrogen oxides concentration corrected for oxygen (ppmdv@7%)
C_d = nitrogen oxides concentration, corrected for analyzer drift (ppmdv)
O_2 = oxygen content of the gas stream (%)
20.9 = oxygen content of ambient air (%)
0 = oxygen content for correction (%)

Nitrogen Oxide Emission Rate, lb/MMBtu

$$E_{NOx} = \frac{(C_d)(MW)(Fd)(20.9)}{(385.3\times10^6)(20.9-O_2)}$$

E_{NOx} = 0.0606
C_d = 26
MW = 46.01
F_d = 8,710
O_2 = 11.41

Where:
E_{NOx} = nitrogen oxides emission rate (lb/MMBtu)
C_d = nitrogen oxides concentration, corrected for drift (ppmdv)
MW = molecular weight of nitrogen oxide (lb/lb-mole)
F_d = oxygen based fuel factor (scf/MMBtu)
O_2 = oxygen content of the gas stream (%)
20.9 = oxygen content of ambient air (%)
385.3 = volume occupied by one pound of gas at standard conditions (dscf/lbmole)
10^6 = conversion factor (ppm)

Volumetric Flow of Gas Stream - Standard Conditions - Dry Basis

$$Q_{dstd} = Q_{std}\left(1 - \frac{B_{ws}}{100}\right)$$

Q_{dstd} = #DIV/0!
Q_{std} = #DIV/0!
B_{ws} = #DIV/0!

Where:

Q_{dstd} = volumetric flow rate of the dry gas stream at standard conditions (dscfm)
Q_{std} = volumetric flow rate of the gas stream at standard conditions (scfm)
B_{ws} = moisture content of the gas stream (%)
100 = conversion factor (%)

Nitrogen Oxides Concentration, Corrected for Analyzer Drift[4]

$$C_d = \left(C - \left(\frac{c_{0i} + c_{0f}}{2}\right)\right)\left(\frac{c_a}{\left(\frac{c_{si} + c_{sf}}{2}\right) - \left(\frac{c_{0i} + c_{0f}}{2}\right)}\right)$$

C_d = 26
C = 27
C_{0i} = -0.3889
C_{0f} = 52
C_a = 50.23
C_{si} = -0.28042
C_{sf} = 52

Where:

C_d = nitrogen oxides concentration, corrected for analyzer drift (ppmdv)
C = nitrogen oxides concentration (ppmdv)
C_{0i} = initial zero calibration value (ppm)
C_{0f} = final zero calibration value (ppm)
C_a = actual span gas value (ppm)
C_{si} = initial span calibration value (ppm)
C_{sf} = final span calibration value (ppm)

[4] Calculations for LIST OTHER COMPOUNDS are performed in a similar manner

Volumetric Flow of Gas Stream - Actual Conditions

$$Q_a = 60(V_s)(A_s)$$

Q_a = #DIV/0!
V_s = #DIV/0!
A_s = 0.00

Where:

Q_a = volumetric flow rate of the gas stream at actual conditions (acfm)
V_s = average velocity of the gas stream (ft/sec)
A_s = area of sample location (ft^2)
60 = conversion factor (sec/min)

Volumetric Flow of Gas Stream - Standard Conditions

$$Q_{std} = \frac{17.64(Q_a)(P_a)}{(T_s + 460)}$$

Q_{std} = #DIV/0! P_a = 0.00
Q_a = #DIV/0! T_s = #DIV/0!

Where:

Q_{std} = volumetric flow rate of the gas stream at standard conditions (scfm)
Q_a = volumetric flow rate of the gas stream at actual conditions (acfm)
P_a = average stack temperature (^oF)
T_s = stack pressure absolute (in. Hg)
17.64 = ratio of standard temperature over standard pressure (^oR/in. Hg)
460 = conversion (^oF to ^oR)

Molecular Weight of Wet Gas Stream

$$M_s = \left(M_d \times \left(1 - \frac{B_{ws}}{100} \right) \right) + \left(18 \times \frac{B_{ws}}{100} \right)$$

M_s = #DIV/0!
M_d = 29.40
B_{ws} = #DIV/0!

Where:

M_s = molecular weight of the wet gas stream (lb/lb-mole)
M_d = molecular weight of the dry gas stream (lb/lb-mole)
B_{ws} = moisture content of the gas stream (%)
18 = molecular weight of water (lb/lb-mole)
100 = conversion factor (%)

Velocity of Gas Stream

$$V_s = 85.49 \left(C_p \right) \left(\sqrt{\Delta P} \right) \sqrt{\frac{(T_s + 460)}{(M_s)(P_a)}}$$

V_s = #DIV/0! T_s = #DIV/0!
C_p = 0.00 M_s = #DIV/0!
$\sqrt{\Delta P}$ = #DIV/0! P_a = 0.00

Where:

V_s = average velocity of the gas stream (ft/sec)
C_p = pitot tube coefficient (dimensionless)
$\sqrt{\Delta P}$ = average square root of velocity pressures (in. H_2O)$^{1/2}$
T_s = average stack temperature (^oF)
M_s = molecular weight of the wet gas stream (lb/lb-mole)
P_a = stack pressure absolute (in. Hg)
85.49 = pitot tube constant (ft/sec)([(lb/lb-mole)(in. Hg)]/[(^oR)(in. H_2O)])$^{1/2}$
460 = conversion (^oF to ^oR)

Percent Moisture[2]

$$B_{ws} = 100 \times \left[\frac{V_{w(std)}}{\left(V_{m(std)} + V_{w(std)}\right)} \right]$$

B_{ws} = #DIV/0!
$V_{w(std)}$ = 0.00
$V_{m(std)}$ = #DIV/0!

Where:

B_{ws} = moisture content of the gas stream (%)
$V_{w(std)}$ = volume of gas collected at standard conditions (scf)
$V_{m(std)}$ = volume of water vapor at standard conditions (scf)
100 = conversion factor (%)

Molecular Weight of Dry Gas Stream[3]

$$M_d = \left(44 \times \frac{CO_2}{100}\right) + \left(32 \times \frac{O_2}{100}\right) + \left(28 \times \frac{N_2}{100}\right)$$

M_d = 29.40
CO_2 = 5.8984
O_2 = 11.41
N_2 = 82.69

Where:

M_d = molecular weight of the dry gas stream (lb/lb-mole)
CO_2 = carbon dioxide content of the gas stream (%)
44 = molecular weight of carbon dioxide (lb/lb-mole)
O_2 = oxygen content of the gas stream (%)
32 = molecular weight of oxygen (%)
N_2 = nitrogen content of the gas stream (%)
28 = molecular weight of nitrogen (lb/lb-mole)

[2] The moisture saturation point was used if it was exceeded by the measured moisture content

[3] The remainder of the gas stream after subtractiong CO_2 and O_2 is assumed to be nitrogen

Volume of Dry Gas Collected Corrected to Standard Conditions

$$V_{m(std)} = \frac{17.64\,(V_m)(Y_d)\left(P_b + \frac{\Delta H}{13.6}\right)}{(T_m + 460)}$$

$V_{m(std)}$ = #DIV/0! P_b = 0.00
V_m = 0.00 ΔH = #DIV/0!
Y_d = 0 T_m = #DIV/0!

Where:
$V_{m(std)}$ = volume of gas collected at standard conditions (scf)
V_m = volume of gas sampled at meter conditions (ft^3)
Y_d = gas meter correction factor (dimensionless)
P_b = barometric pressure (in. Hg)
ΔH = average sample pressure (in. H_2O)
T_m = average gas meter temperature (^oF)
13.6 = conversion factor (in. H_2O/in. Hg)
17.64 = ratio of standard temperature over standard pressure (^oR/in. Hg)
460 = conversion (^oF to ^oR)

Volume of Water Vapor Collected Corrected to Standard Conditions

$$V_{w(std)} = 0.04715 \times V_{wc} + 0.04715 \times V_{wsg}$$

$V_{w(std)}$ = 0.00
V_{wc} = 0
V_{wsg} = 0

Where:
$V_{w(std)}$ = volume of water vapor at standard conditions (scf)
V_{wc} = weight of liquid collected (g)
V_{wsg} = weight gain of silica gel (g)
0.04715 = volume occupied by one gram of water at standard conditions (ft^3/g)

Sample Calculations

Area of Sample Location

$$\mathrm{A}_s = (\pi)\left(\frac{d_s}{2\times 12}\right)^2$$

A_s = 0.00
d_s = 0

Where:

A_s = area of sample location (ft^2)
d_s = diameter of sample location (in)
12 = conversion factor (in/ft)
2 = conversion factor (diameter to radius)

Stack Pressure Absolute

$$P_a = P_b + \frac{P_s}{13.6}$$

P_a = 0.00
P_b = 0.00
P_s = 0

Where:

P_a = stack pressure absolute (in. Hg)
P_b = barometric pressure (in. Hg)
P_s = static pressure (in. H_2O)
13.6 = conversion factor (in. H_2O/in. Hg)

Method Nomenclature and Sample Calculations

Isokinetic Calculations

Percent isokinetic of sampling rate (%)

$\%I = (P_{std} / T_{std}) * (T_{savg} / P_s) * [V_{mstd} / (v_s * M_{fd} * \theta) * (\pi * (D_n / 2)^2 / 144)] * (100 / 60)$

$\%I = (29.92 / 527.7) * (751.253 / 29.905) * (46.608 / (53.2369 * 0.576 * 60.0 * 3.141593 * (0.326 / 2) \wedge 2) / 144)$

$\%I =$ 103.8 %

Method 5 Calculations

Filterable PM total catch weight (mg)

$mg_{quan} =$ 2.25 mg

Filterable PM concentration (grains/dscf)

$C_{grcm} = 0.0154322 * mg_{quan} / V_{mstd}$

$C_{grcm} = 0.0154322 * 2.25 / 46.608$

$C_{grcm} =$ 0.0007 gr/ft^3

Filterable PM mass emission rate (lb/hr)

$EMR_{lbhr} = (mg_{quan} / V_{mstd}) * Q_{sd} * (60 / 453592)$

$EMR_{lbhr} = 2.25 / 46.608 * 13{,}634.7 * (60 / 453592)$

$EMR_{lbhr} =$ 0.087 lb/hr

Note: The results calculated on this page may differ slightly from the results presented in the final report. This differen attributed to "significant digit round-off errors" common when comparing computer spreadsheets results with those c using a calculator.

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$v_s = 85.49 * Cp * (SQ\Delta P_{avg}) * (T_{savg} / (P_s * M_s))^{0.5}$

$v_s = 85.49 * 0.84 * (0.7332) * (751.25 / (29.905 * 24.571)) \wedge 0.5$

$v_s =$ 53.24 ft/sec

Wet volumetric flue gas flow rate at actual conditions (acfm)

$Q_{aw} = v_s * A * 60$ sec/min

$Q_{aw} = 53.237 * 10.559 * 60$

$Q_{aw} =$ 33,728 ft^3/min

Wet volumetric flue gas flow rate at standard conditions (scfm)

$Q_{sdw} = v_s * A * (T_{std} / T_{savg}) * (P_s / P_{std}) * 60$ sec/min

$Q_{sdw} = 53.237 * 10.559 * (527.7 / 751.253) * (29.905 / 29.92) * 60$

$Q_{sdw} =$ 23,678 ft^3/min

Dry volumetric flue gas flow rate at standard conditions (dscfm)

$Q_{sd} = M_{fd} * v_s * A * (T_{std} / T_{savg}) * (P_s / P_{std}) * 60$ sec/min

$Q_{sd} = 0.576 * 53.2369 * 10.5592 * (527.7 / 751.253) * (29.905 / 29.92) * 60$

$Q_{sd} =$ 13,635 ft^3/min

Percent Excess Air

$\%EA = [\%O_2 - (0.5) * \%CO] / [0.264 * (100 - \%CO_2 - \%O_2) - (\%O_2 - 0.5 * \%CO)]$

$\%EA = ((11.40 - (0.5) * 0.00) / (0.264 * (100 - 5.90 - 11.40) - (11.40 - 0.5 * 0.00))) * 100$

$\%EA =$ 109.27 %

Volume of water vapor at standard conditions (68 °F, scf)

$V_{wstd} = (0.04716 \text{ ft}^3/\text{g}) * Vlc$

$V_{wstd} = (0.04716 * 728.0)$

$V_{wstd} = 34.3 \text{ ft}^3$

Percent moisture by volume as measured in flue gas

$\%H_2O \text{ (Measured)} = 100 * [V_{wstd} / (V_{wstd} + V_{mstd})]$

$\%H_2O \text{ (Measured)} = 100 * (34.332 / (34.332 + 46.608))$

$\%H_2O \text{ (Measured)} = 42.42$

$\%H_2O \text{ (Saturated)} = (100 / P_{sam}) * 10 \wedge (6.6911 - (3144 / (T_{savg} + 390.86 - 460)))$

$\%H_2O \text{ (Saturated)} = (100 / 29.904706) * 10 \wedge (6.6911 - (3144 / (751.253333 + 390.86 - 460)))$

$\%H_2O \text{ (Saturated)} = 403.88$

$\%H_2O = 42.42$

Absolute flue gas pressure

$P_s = P_{sam} + (Pg / 13.6)$

$P_s = 29.89 + (0.20 / 13.6)$

$P_s = 29.90 \text{ in. Hg}$

Dry mole fraction of flue gas (dimensionless)

$M_{fd} = 1 - (\%H_2O / 100)$

$M_{fd} = 1 - (42.42 / 100)$

$M_{fd} = 0.576$

Dry molecular weight of flue gas (lb/lb-mole)

$M_d = [(\%CO_2 / 100) * 44.0] + [(\%O_2 / 100) * 32.0] + [((100 - \%CO_2 - \%O_2) / 100) * 28.0]$

$M_d = ((5.90 / 100) * 44.0) + ((11.40 / 100) * 32.0) + (((100 - 5.90 - 11.40) / 100) * 28.0)$

$M_d = 29.40 \text{ lb/lb-mole}$

$M_d = 29.40$

Wet molecular weight of flue gas (lb/lb-mole)

$M_s = M_d * M_{fd} + (H_2OF_{wt} * (\%H_2O / 100))$

$M_s = 29.400 * 0.576 + 18.02 * (42.42 / 100)$

$M_s = 24.57 \text{ lb/lb-mole}$

Average flue gas velocity (ft/sec)

Method Nomenclature and Sample Calculations

Customer	POET Caro	**Project Number**	PROJ-020558
Computed By		**Calculation Date**	
Run Number	1		

Constants

CO_2F_{wt}= 44.0
O_2F_{wt}= 32.0
CON_2F_{wt}= 28.0
H_2OF_{wt}= 18.015
ArF_{wt}= 39.95

in wg= 0.073529
gr= 0.00014286
MMBtu= 1000000 Btu
CF_{wt}= 12.011
PF_{wt}= 44.0962

NO_2F_{wt}= 46.01
COF_{wt}= 28.01
$H_2SO_4F_{wt}$= 98.08
T_{std}= 527.67

$HClF_{wt}$= 36.46
SO_2F_{wt}= 64.06
Cl_2F_{wt}= 70.91
P_{std}= 29.92

Stack Variables

pitot tube coefficient (dimensionless)	0.84	Cp
barometric pressure, inHg	29.95	Pbar
elevation difference between ground level and meter box, ft	5	Ebox
elevation difference between ground level and sampling ports, ft	60	Esam
gamma, dry gas meter calibration factor (dimensionless)	0.9830	γ
net run time, minutes	60.0	θ
total mass of liquid collected in impingers, g	728.0	Vlc
percent CO_2 by volume, dry basis, dimensionless, %	5.90	$\%CO_2$
percent O_2 by volume, dry basis, dimensionless, %	11.40	$\%O_2$
percent CO by volume, dry basis, dimensionless, %	0.00	%CO
percent N_2 by volume, dry basis, dimensionless, %	82.70	$\%N_2$
stack cross-sectional area, ft^2	10.5592	A
flue gas static pressure, inH_2O	0.20	Pg
average absolute flue gas temperature, 459.67°R+tsavg °F, R	751.25	Tsavg
average square root ΔP, inH_2O	0.73	SQDPavg
average pressure differential of orifice meter, in. wg	1.88	ΔH
dry gas meter temperature, 459.67°R+tsavg °F, R	525.17	Tm
volume of metered gas sample, dry actual cubic feet, ft^3	46.93	Vm
sampling nozzle diameter, in.	0.326	Dn

Calculated Stack Variables

Barometric pressure at sampling location
NOTE: Barometric pressure recorded at ground level

$$P_{sam} = P_{bar} - [(E_{sam} / 100 \text{ ft}) * 0.1 \text{ in. Hg}]$$

$$P_{sam} = 29.95 - ((60.0 / 100) * 0.1)$$

$$P_{sam} = 29.89 \text{ in. Hg}$$

Volume of dry gas sampled at standard conditions (dscf)

$$V_{mstd} = \gamma * Vm * [P_{bar} - ([(E_{box} / 100 \text{ ft}) * 0.1 \text{ in. Hg}] + (\Delta H / 13.6)) / P_{std}] * (T_{std} / T_m)$$

$$V_{mstd} = 0.9830 * 46.933 * ((29.95 - ((5.0 / 100) * 0.1) + (1.8833 / 13.6)) / 29.92) * (527.7 / 525.170)$$

$$V_{mstd} = 46.608 \text{ ft}^3$$

Nitrogen Oxide Emission Rate, lb/MMBtu

$$E_{NOx} = \frac{(C_d)(MW)(F_c)(100)}{(385.3 \times 10^6)(CO_2)}$$

E_{NOx}	= 0	F_c	= 0
C_d	= 27	CO_2	= 5.74072
MW	= 46.01		

Where:

E_{NOx} = nitrogen oxides emission rate, (lb/MMBtu)
C_d = nitrogen oxides concentration, corrected for drift (ppmdv)
MW = molecular weight of nitrogen oxide (lb/lb-mole)
F_c = carbon based fuel factor (scf/MMBtu)
CO_2 = carbon dioxide content of the gas stream (%)
385.3 = volume occupied by one pound of gas at standard conditions (dscf/lbmole)
100 = conversion factor (%)
10^6 = conversion factor (ppm)

Nitrogen Oxide Emission Rate, lb/hr

$$E_{NOx} = \frac{(C_d)(MW)(60)(Q_{dstd})}{(385.3 \times 10^6)}$$

E_{NOx}	= #DIV/0!	MW	= 46.01
C_d	= 27	Q_{dstd}	= #DIV/0!

Where:

E_{NOx} = nitrogen oxides emission rate (lb/hr)
C_d = nitrogen oxides concentration, corrected for drift (ppmdv)
MW = molecular weight of nitrogen oxide (lb/lb-mole)
Q_{dstd} = volumetric flow rate of the dry gas stream at standard conditions (dscfm)
60 = conversion factor (min/hr)
385.3 = volume occupied by one pound of gas at standard conditions (dscf/lbmole)
10^6 = conversion factor (ppm)

Nitrogen Oxides Concentration Corrected for Oxygen

$$C_{7\%O_2} = C_d \frac{(20.9-7)}{(20.9-O_2)}$$

$C_{7\%O2}$ = 56.778
C_d = 27
O_2 = 11.11

Where:

$C_{7\%O2}$ = nitrogen oxides concentration corrected for oxygen (ppmdv@7%)
C_d = nitrogen oxides concentration, corrected for analyzer drift (ppmdv)
O_2 = oxygen content of the gas stream (%)
20.9 = oxygen content of ambient air (%)
0 = oxygen content for correction (%)

Nitrogen Oxide Emission Rate, lb/MMBtu

$$E_{NOx} = \frac{(C_d)(MW)(Fd)(20.9)}{(385.3\times10^6)(20.9-O_2)}$$

E_{NOx}	= 0.0591	F_d	= 8,710
C_d	= 27	O_2	= 11.11
MW	= 46.01		

Where:

E_{NOx} = nitrogen oxides emission rate (lb/MMBtu)
C_d = nitrogen oxides concentration, corrected for drift (ppmdv)
MW = molecular weight of nitrogen oxide (lb/lb-mole)
F_d = oxygen based fuel factor (scf/MMBtu)
O_2 = oxygen content of the gas stream (%)
20.9 = oxygen content of ambient air (%)
385.3 = volume occupied by one pound of gas at standard conditions (dscf/lbmole)
10^6 = conversion factor (ppm)

Volumetric Flow of Gas Stream - Standard Conditions - Dry Basis

$$Q_{dstd} = Q_{std}\left(1-\frac{B_{ws}}{100}\right)$$

Q_{dstd} = #DIV/0!
Q_{std} = #DIV/0!
B_{ws} = #DIV/0!

Where:
Q_{dstd} = volumetric flow rate of the dry gas stream at standard conditions (dscfm)
Q_{std} = volumetric flow rate of the gas stream at standard conditions (scfm)
B_{ws} = moisture content of the gas stream (%)
100 = conversion factor (%)

Nitrogen Oxides Concentration, Corrected for Analyzer Drift[4]

$$C_d = \left(C-\left(\frac{c_{0i}+c_{0f}}{2}\right)\right)\left(\frac{c_a}{\left(\frac{c_{si}+c_{sf}}{2}\right)-\left(\frac{c_{0i}+c_{0f}}{2}\right)}\right)$$

C_d = 27 C_a = 50.23
C = 27 C_{si} = 0.16049
C_{0i} = 0.0407 C_{sf} = 51
C_{0f} = 51

Where:
C_d = nitrogen oxides concentration, corrected for analyzer drift (ppmdv)
C = nitrogen oxides concentration (ppmdv)
C_{0i} = initial zero calibration value (ppm)
C_{0f} = final zero calibration value (ppm)
C_a = actual span gas value (ppm)
C_{si} = initial span calibration value (ppm)
C_{sf} = final span calibration value (ppm)

---

[4] Calculations for LIST OTHER COMPOUNDS are performed in a similar manner

Volumetric Flow of Gas Stream - Actual Conditions

$$Q_a = 60(V_s)(A_s)$$

Q_a = #DIV/0!
V_s = #DIV/0!
A_s = 0.00

Where:

Q_a = volumetric flow rate of the gas stream at actual conditions (acfm)
V_s = average velocity of the gas stream (ft/sec)
A_s = area of sample location (ft^2)
60 = conversion factor (sec/min)

Volumetric Flow of Gas Stream - Standard Conditions

$$Q_{std} = \frac{17.64(Q_a)(P_a)}{(T_s + 460)}$$

Q_{std} = #DIV/0! P_a = 0.00
Q_a = #DIV/0! T_s = #DIV/0!

Where:

Q_{std} = volumetric flow rate of the gas stream at standard conditions (scfm)
Q_a = volumetric flow rate of the gas stream at actual conditions (acfm)
P_a = average stack temperature (^{o}F)
T_s = stack pressure absolute (in. Hg)
17.64 = ratio of standard temperature over standard pressure (^{o}R/in. Hg)
460 = conversion (^{o}F to ^{o}R)

Molecular Weight of Wet Gas Stream

$$M_s = \left(M_d \times \left(1 - \frac{B_{ws}}{100}\right)\right) + \left(18 \times \frac{B_{ws}}{100}\right)$$

M_s = #DIV/0!
M_d = 29.36
B_{ws} = #DIV/0!

Where:
M_s = molecular weight of the wet gas stream (lb/lb-mole)
M_d = molecular weight of the dry gas stream (lb/lb-mole)
B_{ws} = moisture content of the gas stream (%)
18 = molecular weight of water (lb/lb-mole)
100 = conversion factor (%)

Velocity of Gas Stream

$$V_s = 85.49\left(C_p\right)\left(\sqrt{\Delta P}\right)\sqrt{\frac{\left(T_s + 460\right)}{\left(M_s\right)\left(P_a\right)}}$$

V_s = #DIV/0! T_s = #DIV/0!
C_p = 0.00 M_s = #DIV/0!
$\sqrt{\Delta P}$ = #DIV/0! P_a = 0.00

Where:
V_s = average velocity of the gas stream (ft/sec)
C_p = pitot tube coefficient (dimensionless)
$\sqrt{\Delta P}$ = average square root of velocity pressures (in. H_2O)$^{1/2}$
T_s = average stack temperature (^{o}F)
M_s = molecular weight of the wet gas stream (lb/lb-mole)
P_a = stack pressure absolute (in. Hg)
85.49 = pitot tube constant (ft/sec)([(lb/lb-mole)(in. Hg)]/[(^{o}R)(in. H_2O)])$^{1/2}$
460 = conversion (^{o}F to ^{o}R)

Percent Moisture[2]

$$B_{ws} = 100 \times \left[\frac{V_{w(std)}}{\left(V_{m(std)} + V_{w(std)}\right)} \right]$$

B_{ws} = #DIV/0!
$V_{w(std)}$ = 0.00
$V_{m(std)}$ = #DIV/0!

Where:

B_{ws} = moisture content of the gas stream (%)
$V_{w(std)}$ = volume of gas collected at standard conditions (scf)
$V_{m(std)}$ = volume of water vapor at standard conditions (scf)
100 = conversion factor (%)

Molecular Weight of Dry Gas Stream[3]

$$M_d = \left(44 \times \frac{CO_2}{100}\right) + \left(32 \times \frac{O_2}{100}\right) + \left(28 \times \frac{N_2}{100}\right)$$

M_d = 29.36 O_2 = 11.11
CO_2 = 5.7407 N_2 = 83.15

Where:

M_d = molecular weight of the dry gas stream (lb/lb-mole)
CO_2 = carbon dioxide content of the gas stream (%)
44 = molecular weight of carbon dioxide (lb/lb-mole)
O_2 = oxygen content of the gas stream (%)
32 = molecular weight of oxygen (%)
N_2 = nitrogen content of the gas stream (%)
28 = molecular weight of nitrogen (lb/lb-mole)

[2] The moisture saturation point was used if it was exceeded by the measured moisture content

[3] The remainder of the gas stream after subtractiong CO_2 and O_2 is assumed to be nitrogen

Volume of Dry Gas Collected Corrected to Standard Conditions

$$V_{m(std)} = \frac{17.64\left(V_m\right)\left(Y_d\right)\left(P_b + \frac{\Delta H}{13.6}\right)}{\left(T_m + 460\right)}$$

$V_{m(std)}$	= #DIV/0!	P_b	= 0.00
V_m	= 0.00	ΔH	= #DIV/0!
Y_d	= 0	T_m	= #DIV/0!

Where:

$V_{m(std)}$	= volume of gas collected at standard conditions (scf)
V_m	= volume of gas sampled at meter conditions (ft^3)
Y_d	= gas meter correction factor (dimensionless)
P_b	= barometric pressure (in. Hg)
ΔH	= average sample pressure (in. H_2O)
T_m	= average gas meter temperature (^oF)
13.6	= conversion factor (in. H_2O/in. Hg)
17.64	= ratio of standard temperature over standard pressure (^oR/in. Hg)
460	= conversion (^oF to ^oR)

Volume of Water Vapor Collected Corrected to Standard Conditions

$$V_{w(std)} = 0.04715 \times V_{wc} + 0.04715 \times V_{wsg}$$

$V_{w(std)}$	= 0.00
V_{wc}	= 0
V_{wsg}	= 0

Where:

$V_{w(std)}$	= volume of water vapor at standard conditions (scf)
V_{wc}	= weight of liquid collected (g)
V_{wsg}	= weight gain of silica gel (g)
0.04715	= volume occupied by one gram of water at standard conditions (ft^3/g)

Sample Calculations

Area of Sample Location

$$A_s = (\pi)\left(\frac{d_s}{2 \times 12}\right)^2$$

A_s = 0.00
d_s = 0

Where:

A_s = area of sample location (ft^2)
d_s = diameter of sample location (in)
12 = conversion factor (in/ft)
2 = conversion factor (diameter to radius)

Stack Pressure Absolute

$$P_a = P_b + \frac{P_s}{13.6}$$

P_a = 0.00
P_b = 0.00
P_s = 0

Where:

P_a = stack pressure absolute (in. Hg)
P_b = barometric pressure (in. Hg)
P_s = static pressure (in. H_2O)
13.6 = conversion factor (in. H_2O/in. Hg)

Isokinetic Calculations

Percent isokinetic of sampling rate (%)

$\%I = (P_{std} / T_{std}) * (T_{savg} / P_s) * [V_{mstd} / (v_s * M_{fd} * \theta) * (\pi * (D_n / 2)^2 / 144)] * (100 / 60)$

$\%I = (29.92 / 527.7) * (742.087 / 29.964) * (48.333 / (54.7638 * 0.561 * 60.0 * 3.141593 * (0.326 / 2) \wedge 2) / 144)$

$\%I =$ 106.0 %

Method 5 Calculations

Filterable PM total catch weight (mg)

$mg_{quan} =$ 15.65 mg

Filterable PM concentration (grains/dscf)

$C_{grcm} = 0.0154322 * mg_{quan} / V_{mstd}$

$C_{grcm} = 0.0154322 * 15.65 / 48.333$

$C_{grcm} =$ 0.0050 gr/ft^3

Filterable PM mass emission rate (lb/hr)

$EMR_{lbhr} = (mg_{quan} / V_{mstd}) * Q_{sd} * (60 / 453592)$

$EMR_{lbhr} = 15.65 / 48.333 * 13{,}849.9 * (60 / 453592)$

$EMR_{lbhr} =$ 0.593 lb/hr

Note: The results calculated on this page may differ slightly from the results presented in the final report. This differen attributed to "significant digit round-off errors" common when comparing computer spreadsheets results with those c using a calculator.

$v_s = 85.49 * Cp * (SQ\Delta P_{avg}) * (T_{savg} / (P_s * M_s))^{0.5}$

$v_s = 85.49 * 0.84 * (0.7565) * (742.09 / (29.964 * 24.372)) \text{^} 0.5$

$v_s =$ 54.76 ft/sec

Wet volumetric flue gas flow rate at actual conditions (acfm)

$Q_{aw} = v_s * A * 60$ sec/min

$Q_{aw} = 54.764 * 10.559 * 60$

$Q_{aw} =$ 34,696 ft^3/min

Wet volumetric flue gas flow rate at standard conditions (scfm)

$Q_{sdw} = v_s * A * (T_{std} / T_{savg}) * (P_s / P_{std}) * 60$ sec/min

$Q_{sdw} = 54.764 * 10.559 * (527.7 / 742.087) * (29.964 / 29.92) * 60$

$Q_{sdw} =$ 24,707 ft^3/min

Dry volumetric flue gas flow rate at standard conditions (dscfm)

$Q_{sd} = M_{fd} * v_s * A * (T_{std} / T_{savg}) * (P_s / P_{std}) * 60$ sec/min

$Q_{sd} = 0.561 * 54.7638 * 10.5592 * (527.7 / 742.087) * (29.964 / 29.92) * 60$

$Q_{sd} =$ 13,850 ft^3/min

Percent Excess Air

$\%EA = [\%O_2 - (0.5) * \%CO] / [0.264 * (100 - \%CO_2 - \%O_2) - (\%O_2 - 0.5 * \%CO)]$

$\%EA = ((11.10 - (0.5) * 0.00) / (0.264 * (100 - 5.70 - 11.10) - (11.10 - 0.5 * 0.00))) * 100$

$\%EA =$ 102.16 %

Volume of water vapor at standard conditions (68 °F, scf)

$V_{wstd} = (0.04716\ ft^3/g) * Vlc$

$V_{wstd} = (0.04716 * 803.4)$

$V_{wstd} = 37.9\ ft^3$

Percent moisture by volume as measured in flue gas

$\%H_2O\ (Measured) = 100 * [V_{wstd} / (V_{wstd} + V_{mstd})]$

$\%H_2O\ (Measured) = 100 * (37.888 / (37.888 + 48.333))$

$\%H_2O\ (Measured) = 43.94$

$\%H_2O\ (Saturated) = (100 / P_{sam}) * 10 \wedge (6.6911 - (3144 / (T_{savg} + 390.86 - 460)))$

$\%H_2O\ (Saturated) = (100 / 29.963529) * 10 \wedge (6.6911 - (3144 / (742.086667 + 390.86 - 460)))$

$\%H_2O\ (Saturated) = 348.83$

$\%H_2O = 43.94$

Absolute flue gas pressure

$P_s = P_{sam} + (Pg / 13.6)$

$P_s = 29.89 + (1.00 / 13.6)$

$P_s = 29.96$ in. Hg

Dry mole fraction of flue gas (dimensionless)

$M_{fd} = 1 - (\%H_2O / 100)$

$M_{fd} = 1 - (43.94 / 100)$

$M_{fd} = 0.561$

Dry molecular weight of flue gas (lb/lb-mole)

$M_d = [(\%CO_2 / 100) * 44.0] + [(\%O_2 / 100) * 32.0] + [((100 - \%CO_2 - \%O_2) / 100) * 28.0]$

$M_d = ((5.70 / 100) * 44.0) + ((11.10 / 100) * 32.0) + (((100 - 5.70 - 11.10) / 100) * 28.0)$

$M_d = 29.36$ lb/lb-mole

$M_d = 29.36$

Wet molecular weight of flue gas (lb/lb-mole)

$M_s = M_d * M_{fd} + (H_2OF_{wt} * (\%H_2O / 100))$

$M_s = 29.356 * 0.561 + 18.02 * (43.94 / 100)$

$M_s = 24.37$ lb/lb-mole

Average flue gas velocity (ft/sec)

USEPA Method 5 Nomenclature and Sample Calculations

Customer	POET Caro	**Project Number**	PROJ-020558
Computed By		**Calculation Date**	
Run Number	1		

Constants

CO_2F_{wt}= 44.0
O_2F_{wt}= 32.0
CON_2F_{wt}= 28.0
H_2OF_{wt}= 18.015
ArF_{wt}= 39.95

in wg= 0.073529
gr= 0.00014286
MMBtu= 1000000 Btu
CF_{wt}= 12.011
PF_{wt}= 44.0962

NO_2F_{wt}= 46.01
COF_{wt}= 28.01
$H_2SO_4F_{wt}$= 98.08
T_{std}= 527.67

$HClF_{wt}$= 36.46
SO_2F_{wt}= 64.06
Cl_2F_{wt}= 70.91
P_{std}= 29.92

Stack Variables

pitot tube coefficient (dimensionless)	0.84	Cp
barometric pressure, inHg	29.95	Pbar
elevation difference between ground level and meter box, ft	5	Ebox
elevation difference between ground level and sampling ports, ft	60	Esam
gamma, dry gas meter calibration factor (dimensionless)	0.9830	γ
net run time, minutes	60.0	θ
total mass of liquid collected in impingers, g	803.4	Vlc
percent CO_2 by volume, dry basis, dimensionless, %	5.70	$\%CO_2$
percent O_2 by volume, dry basis, dimensionless, %	11.10	$\%O_2$
percent CO by volume, dry basis, dimensionless, %	0.00	%CO
percent N_2 by volume, dry basis, dimensionless, %	83.20	$\%N_2$
stack cross-sectional area, ft^2	10.5592	A
flue gas static pressure, inH_2O	1.00	Pg
average absolute flue gas temperature, 459.67°R+tsavg °F, R	742.09	Tsavg
average square root ΔP, inH_2O	0.76	SQDPavg
average pressure differential of orifice meter, in. wg	2.02	ΔH
dry gas meter temperature, 459.67°R+tsavg °F, R	516.34	Tm
volume of metered gas sample, dry actual cubic feet, ft^3	47.84	Vm
sampling nozzle diameter, in.	0.326	Dn

Calculated Stack Variables

Barometric pressure at sampling location

NOTE: Barometric pressure recorded at ground level

$$P_{sam} = P_{bar} - [(E_{sam} / 100 \text{ ft}) * 0.1 \text{ in. Hg}]$$

$$P_{sam} = 29.95 - ((60.0 / 100) * 0.1)$$

$$P_{sam} = \quad 29.89 \text{ in. Hg}$$

Volume of dry gas sampled at standard conditions (dscf)

$$V_{mstd} = \gamma * Vm * [P_{bar} - ([(E_{box} / 100 \text{ ft}) * 0.1 \text{ in. Hg}] + (\Delta H / 13.6)) / P_{std}] * (T_{std} / T_m)$$

$$V_{mstd} = 0.9830 * 47.836 * ((29.95 - ((5.0 / 100) * 0.1) + (2.0167 / 13.6)) / 29.92) * (527.7 / 516.337)$$

$$V_{mstd} = \quad 48.333 \text{ ft}^3$$

Volumetric Flow of Gas Stream - Standard Conditions - Dry Basis

$$Q_{dstd} = Q_{std}\left(1 - \frac{B_{ws}}{100}\right)$$

Q_{dstd} = 8,572
Q_{std} = 8,699
B_{ws} = 1.5

Where:

Q_{dstd} = volumetric flow rate of the dry gas stream at standard conditions (dscfm)
Q_{std} = volumetric flow rate of the gas stream at standard conditions (scfm)
B_{ws} = moisture content of the gas stream (%)
100 = conversion factor (%)

Volumetric Flow of Gas Stream - Actual Conditions

$$Q_a = 60(V_s)(A_s)$$

Q_a = 8,493
V_s = 45.0554
A_s = 3.14

Where:
Q_a = volumetric flow rate of the gas stream at actual conditions (acfm)
V_s = average velocity of the gas stream (ft/sec)
A_s = area of sample location (ft^2)
60 = conversion factor (sec/min)

Volumetric Flow of Gas Stream - Standard Conditions

$$Q_{std} = \frac{17.64(Q_a)(P_a)}{(T_s + 460)}$$

Q_{std} = 8,699 P_a = 30.06
Q_a = 8,493 T_s = 58

Where:
Q_{std} = volumetric flow rate of the gas stream at standard conditions (scfm)
Q_a = volumetric flow rate of the gas stream at actual conditions (acfm)
P_a = average stack temperature (°F)
T_s = stack pressure absolute (in. Hg)
17.64 = ratio of standard temperature over standard pressure (°R/in. Hg)
460 = conversion (°F to °R)

Molecular Weight of Wet Gas Stream

$$M_s = \left(M_d \times \left(1 - \frac{B_{ws}}{100} \right) \right) + \left(18 \times \frac{B_{ws}}{100} \right)$$

M_s = 43.45
M_d = 43.84
B_{ws} = 1.5

Where:
M_s = molecular weight of the wet gas stream (lb/lb-mole)
M_d = molecular weight of the dry gas stream (lb/lb-mole)
B_{ws} = moisture content of the gas stream (%)
18 = molecular weight of water (lb/lb-mole)
100 = conversion factor (%)

Velocity of Gas Stream

$$V_s = 85.49 \left(C_p \right) \left(\sqrt{\Delta P} \right) \sqrt{\frac{(T_s + 460)}{(M_s)(P_a)}}$$

V_s = 45.0554 T_s = 58
C_p = 0.84 M_s = 43.45
$\sqrt{\Delta P}$ = 0.9966 P_a = 30.06

Where:
V_s = average velocity of the gas stream (ft/sec)
C_p = pitot tube coefficient (dimensionless)
$\sqrt{\Delta P}$ = average square root of velocity pressures (in. H_2O)$^{1/2}$
T_s = average stack temperature ($^{\circ}$F)
M_s = molecular weight of the wet gas stream (lb/lb-mole)
P_a = stack pressure absolute (in. Hg)
85.49 = pitot tube constant (ft/sec)([(lb/lb-mole)(in. Hg)]/[($^{\circ}$R)(in. H_2O)])$^{1/2}$
460 = conversion ($^{\circ}$F to $^{\circ}$R)

Percent Moisture[2]

$$B_{ws} = 100 \times \left[\frac{V_{w(std)}}{\left(V_{m(std)} + V_{w(std)} \right)} \right]$$

B_{ws} = 1.50
$V_{w(std)}$ = 0.00
$V_{m(std)}$ = #DIV/0!

Where:

B_{ws} = moisture content of the gas stream (%)
$V_{w(std)}$ = volume of gas collected at standard conditions (scf)
$V_{m(std)}$ = volume of water vapor at standard conditions (scf)
100 = conversion factor (%)

Molecular Weight of Dry Gas Stream[3]

$$M_d = \left(44 \times \frac{CO_2}{100} \right) + \left(32 \times \frac{O_2}{100} \right) + \left(28 \times \frac{N_2}{100} \right)$$

M_d = 43.84 O_2 = 0.00
CO_2 = 99 N_2 = 1.00

Where:

M_d = molecular weight of the dry gas stream (lb/lb-mole)
CO_2 = carbon dioxide content of the gas stream (%)
44 = molecular weight of carbon dioxide (lb/lb-mole)
O_2 = oxygen content of the gas stream (%)
32 = molecular weight of oxygen (%)
N_2 = nitrogen content of the gas stream (%)
28 = molecular weight of nitrogen (lb/lb-mole)

[2] The moisture saturation point was used if it is exceeded by the measured moisture content

[3] The remainder of the gas stream after removing CO_2 and O_2 is assumed to be nitrogen

Volume of Dry Gas Collected Corrected to Standard Conditions

$$V_{m(std)} = \frac{17.64\,(V_m)(Y_d)\left(P_b + \frac{\Delta H}{13.6}\right)}{(T_m + 460)}$$

$V_{m(std)}$	= #DIV/0!	P_b	= 30.02
V_m	= 0.00	ΔH	= #DIV/0!
Y_d	= 0.993	T_m	= #DIV/0!

Where:

$V_{m(std)}$ = volume of gas collected at standard conditions (scf)
V_m = volume of gas sampled at meter conditions (ft^3)
Y_d = gas meter correction factor (dimensionless)
P_b = barometric pressure (in. Hg)
ΔH = average sample pressure (in. H_2O)
T_m = average gas meter temperature (^oF)
13.6 = conversion factor (in. H_2O/in. Hg)
17.64 = ratio of standard temperature over standard pressure (^oR/in. Hg)
460 = conversion (^oF to ^oR)

Volume of Water Vapor Collected Corrected to Standard Conditions

$$V_{w(std)} = 0.04715 \times V_{wc} + 0.04715 \times V_{wsg}$$

$V_{w(std)}$ = 0.00
V_{wc} = 0
V_{wsg} = 0

Where:

$V_{w(std)}$ = volume of water vapor at standard conditions (scf)
V_{wc} = weight of liquid collected (g)
V_{wsg} = weight gain of silica gel (g)
0.04715 = volume occupied by one gram of water at standard conditions (ft^3/g)

Sample Calculations CO2 Scrubber Run 1

Area of Sample Location

$$\mathrm{A}_s = (\pi)\left(\frac{d_s}{2\times 12}\right)^2$$

A_s = 3.14
d_s = 24

Where:

A_s = area of sample location (ft^2)
d_s = diameter of sample location (in)
12 = conversion factor (in/ft)
2 = conversion factor (diameter to radius)

Stack Pressure Absolute

$$P_a = P_b + \frac{P_s}{13.6}$$

P_a = 30.06
P_b = 30.02
P_s = 0.5

Where:

P_a = stack pressure absolute (in. Hg)
P_b = barometric pressure (in. Hg)
P_s = static pressure (in. H_2O)
13.6 = conversion factor (in. H_2O/in. Hg)

USEPA Method Method 17 Nomenclature and Sample Calculations

Isokinetic Calculations

Percent isokinetic of sampling rate (%)

$\%I = (P_{std} / T_{std}) * (T_{savg} / P_s) * [V_{mstd} / (v_s * M_{fd} * \theta) * (\pi * (D_n / 2)^2 / 144)] * (100 / 60)$

$\%I = (29.92 / 527.7) * (537.503 / 29.966) * (69.410 / (27.4066 * 0.989 * 84.0 * 3.141593 * (0.308 / 2) \wedge 2) / 144)$

$\%I =$ 99.9 %

Method 5 Calculations

Filterable PM total catch weight (mg)

$mg_{quan} =$ 1.60 mg

Filterable PM concentration (grains/dscf)

$C_{grcm} = 0.0154322 * mg_{quan} / V_{mstd}$

$C_{grcm} = 0.0154322 * 1.60 / 69.410$

$C_{grcm} =$ 0.0004 gr/ft^3

Filterable PM mass emission rate (lb/hr)

$EMR_{lbhr} = (mg_{quan} / V_{mstd}) * Q_{sd} * (60 / 453592)$

$EMR_{lbhr} = 1.60 / 69.410 * 25{,}437.6 * (60 / 453592)$

$EMR_{lbhr} =$ 0.078 lb/hr

Note: The results calculated on this page may differ slightly from the results presented in the final report. This differen attributed to "significant digit round-off errors" common when comparing computer spreadsheets results with those c using a calculator.

001AS-

$v_s = 85.49 * Cp * (SQ\Delta P_{avg}) * (T_{savg} / (P_s * M_s))^{0.5}$

$v_s = 85.49 * 0.84 * (0.4829) * (537.50 / (29.966 * 28.720)) \wedge 0.5$

$v_s =$ 27.41 ft/sec

Wet volumetric flue gas flow rate at actual conditions (acfm)

$Q_{aw} = v_s * A * 60$ sec/min

$Q_{aw} = 27.407 * 15.904 * 60$

$Q_{aw} =$ 26,153 ft^3/min

Wet volumetric flue gas flow rate at standard conditions (scfm)

$Q_{sdw} = v_s * A * (T_{std} / T_{savg}) * (P_s / P_{std}) * 60$ sec/min

$Q_{sdw} = 27.407 * 15.904 * (527.7 / 537.503) * (29.966 / 29.92) * 60$

$Q_{sdw} =$ 25,714 ft^3/min

Dry volumetric flue gas flow rate at standard conditions (dscfm)

$Q_{sd} = M_{fd} * v_s * A * (T_{std} / T_{savg}) * (P_s / P_{std}) * 60$ sec/min

$Q_{sd} = 0.989 * 27.4066 * 15.9043 * (527.7 / 537.503) * (29.966 / 29.92) * 60$

$Q_{sd} =$ 25,438 ft^3/min

Percent Excess Air

$\%EA = [\%O_2 - (0.5) * \%CO] / [0.264 * (100 - \%CO_2 - \%O_2) - (\%O_2 - 0.5 * \%CO)]$

$\%EA = ((20.90 - (0.5) * 0.00) / (0.264 * (100 - 0.00 - 20.90) - (20.90 - 0.5 * 0.00))) * 100$

%EA = ######## %

Volume of water vapor at standard conditions (68 °F, scf)

V_{wstd} = (0.04716 ft^3/g) * Vlc

V_{wstd} = (0.04716 * 16.0)

V_{wstd} = 0.8 ft^3

Percent moisture by volume as measured in flue gas

$\%H_2O$ (Measured) = 100 * [V_{wstd} / (V_{wstd} + V_{mstd})]

$\%H_2O$ (Measured) = 100 * (0.755 / (0.755 + 69.410))

$\%H_2O$ (Measured) = 1.08

$\%H_2O$ (Saturated) = (100 / P_{sam}) * 10 ^ (6.6911 - (3144 / (T_{savg} + 390.86 - 460)))

$\%H_2O$ (Saturated) = (100 / 29.966176) * 10 ^ (6.6911 - (3144 / (537.503333 + 390.86 - 460)))

$\%H_2O$ (Saturated) = 3.18

$\%H_2O$ = 1.08

Absolute flue gas pressure

P_s = P_{sam} + (Pg / 13.6)

P_s = 29.98 + (-0.12 / 13.6)

P_s = 29.97 in. Hg

Dry mole fraction of flue gas (dimensionless)

M_{fd} = 1 - ($\%H_2O$ / 100)

M_{fd} = 1 - (1.08 / 100)

M_{fd} = 0.989

Dry molecular weight of flue gas (lb/lb-mole)

M_d = [($\%CO_2$ / 100) * 44.0] + [($\%O_2$ / 100) * 32.0] + [((100 - $\%CO_2$ - $\%O_2$) / 100) * 28.0]

M_d = ((0.00 / 100) * 44.0) + ((20.90 / 100) * 32.0) + (((100 - 0.00 - 20.90) / 100) * 28.0)

M_d = 28.84 lb/lb-mole

M_d = 28.84

Wet molecular weight of flue gas (lb/lb-mole)

M_s = M_d * M_{fd} + (H_2OF_{wt} * ($\%H_2O$ / 100))

M_s = 28.836 * 0.989 + 18.02 * (1.08 / 100)

M_s = 28.72 lb/lb-mole

Average flue gas velocity (ft/sec)

MONTROSE
ENVIRONMENTAL

USEPA Method Method 17 Nomenclature and Sample Calculations

Customer	Poet Caro	**Project Number**	PROJ-020558
Computed By	JSN	**Calculation Date**	2/12/2023
Run Number	1		

Constants

CO_2F_{wt}= 44.0	in wg= 0.073529	NO_2F_{wt}= 46.01	$HClF_{wt}$= 36.46
O_2F_{wt}= 32.0	gr= 0.00014286	COF_{wt}= 28.01	SO_2F_{wt}= 64.06
CON_2F_{wt}= 28.0	MMBtu= 1000000 Btu	$H_2SO_4F_{wt}$= 98.08	Cl_2F_{wt}= 70.91
H_2OF_{wt}= 18.015	CF_{wt}= 12.011	T_{std}= 527.67	P_{std}= 29.92
ArF_{wt}= 39.95	PF_{wt}= 44.0962		

Stack Variables

pitot tube coefficient (dimensionless)	0.84	Cp
barometric pressure, inHg	30.02	Pbar
elevation difference between ground level and meter box, ft	5	Ebox
elevation difference between ground level and sampling ports, ft	45	Esam
gamma, dry gas meter calibration factor (dimensionless)	0.9830	γ
net run time, minutes	84.0	θ
total mass of liquid collected in impingers, g	16.0	Vlc
percent CO_2 by volume, dry basis, dimensionless, %	0.00	$\%CO_2$
percent O_2 by volume, dry basis, dimensionless, %	20.90	$\%O_2$
percent CO by volume, dry basis, dimensionless, %	0.00	%CO
percent N_2 by volume, dry basis, dimensionless, %	79.10	$\%N_2$
stack cross-sectional area, ft^2	15.9043	A
flue gas static pressure, inH_2O	-0.12	Pg
average absolute flue gas temperature, 459.67°R+tsavg °F, R	537.50	Tsavg
average square root ΔP, inH_2O	0.48	SQDPavg
average pressure differential of orifice meter, in. wg	2.06	ΔH
dry gas meter temperature, 459.67°R+tsavg °F, R	519.21	Tm
volume of metered gas sample, dry actual cubic feet, ft^3	68.91	Vm
sampling nozzle diameter, in.	0.308	Dn

Calculated Stack Variables

Barometric pressure at sampling location

NOTE: Barometric pressure recorded at ground level

$$P_{sam} = P_{bar} - [(E_{sam} / 100 \text{ ft}) * 0.1 \text{ in. Hg}]$$

$$P_{sam} = 30.02 - ((45.0 / 100) * 0.1)$$

$$P_{sam} = 29.98 \text{ in. Hg}$$

Volume of dry gas sampled at standard conditions (dscf)

$$V_{mstd} = \gamma * Vm * [P_{bar} - ([(E_{box} / 100 \text{ ft}) * 0.1 \text{ in. Hg}] + (\Delta H / 13.6)) / P_{std}] * (T_{std} / T_m)$$

$$V_{mstd} = 0.9830 * 68.910 * ((30.02 - ((5.0 / 100) * 0.1) + (2.0625 / 13.6)) / 29.92) * (527.7 / 519.212)$$

$$V_{mstd} = 69.410 \text{ ft}^3$$