



**TEST REPORT
COMPLIANCE EMISSION TEST
GEORGIA-PACIFIC CHEMICALS LLC
TORVEX CATALYTIC OXIDIZER
GRAYLING, MICHIGAN**

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Prepared For:

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Test Dates: April 10 and 11, 2018



REPORT CERTIFICATION

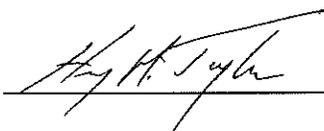
STATEMENT OF CONFORMANCE AND TEST REPORT CERTIFICATION

I certify, to the best of my knowledge, that this test program was conducted in a manner conforming to the criteria set forth in ASTM D7036-12: Standard Practice for Competence of Air Emission Testing Bodies, and that project management and supervision of all project related activities were performed by qualified individuals as defined by this practice.

I further certify that this test report and all attachments were prepared under my direction or supervision in accordance with the Montrose Air Quality Services, LLC quality management system designed to ensure that qualified personnel gathered and evaluated the test information submitted. Based on my inquiry of the person or persons who performed the sampling and analysis relating to this performance test, the information submitted in this test report is, to the best of my knowledge and belief, true, accurate, and complete.



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Vice President, Technical
Montrose Air Quality Services, LLC



Henry M. Taylor, QSTO
Quality Assurance Manager
Montrose Air Quality Services, LLC

1.0 INTRODUCTION AND SUMMARY

Montrose Air Quality Services, LLC (Montrose) was retained by Georgia-Pacific Chemicals LLC (Georgia-Pacific) to conduct a compliance emission test on the Torvex Catalytic Oxidizer which controls emissions from both the formaldehyde and resin production processes at their Beaver Creek facility in Grayling, Michigan.

The primary purpose of the test was to demonstrate compliance with the federal NSPS standard in the Code of Federal Regulations, Title 40, Part 60 (40 CFR 60), Subpart III and state permit emission limits summarized in Section 2.0, Table 2-1. Testing was conducted after the completion of several plant projects and enhancements which were communicated to the Michigan Department of Environmental Quality (MDEQ) Air Quality Division in a letter submitted in November 2017. The projects and enhancements included the replacement of the formaldehyde plant converter and heat transfer fluid tube bundle and loading of the formaldehyde converter with a catalyst that results in reduced methanol content of the final formaldehyde product. The final phase of the project was completed the week of March 12, 2018 which included the addition of an adiabatic catalyst bed to the converter and the replacement of the catalyst in the Torvex Catalytic Oxidizer to ensure that the oxidizer continues to perform according to design. Because 40 CFR 60.615(c)(2) requires the oxidizer temperatures during the most recent performance test at which compliance with §60.612(a) was determined to be used to determine compliance on a 3-hour average basis, and the test methodologies met the test methods and procedures in §60.614 of Subpart III, this compliance test at the high-load condition will establish new compliance temperatures for the catalytic oxidizer for periods when the RCI formaldehyde process is operating.

Testing was conducted at two separate operating scenarios (high-load and low-load) with the intent of validating or re-establishing the temperature limits for the control device to meet both the federal NSPS standard and the state permit limits.

Method 301 validation has already been completed and approved by the EPA for the NSPS formaldehyde process. For this reason, Fourier transform infrared (FTIR) procedures following Method 320 were used in lieu of Method 18. At all sampling locations, direct interface FTIR spectroscopy test procedures were used to determine the concentrations of specific known or suspected volatile organic compounds (VOC) and hazardous air pollutants (HAP). Method 320 was used to demonstrate compliance with the total organic compounds (TOC) destruction efficiency requirements.

In conjunction with the Method 320 compliance testing, Method 25A was also used to determine total VOC as an alternate method. Because dimethyl ether (DME) is the primary VOC in the aggregate vent stream, the VOC results are reported as DME and as propane.

The test summary for the emission source is outlined below:

Source	Parameters	Test Methods
Torvex Catalytic Oxidizer Inlet and Outlet	HAP: Formaldehyde, Methanol, Acetaldehyde, Phenol, Total HAP VOC: DME, TOC	1, 2, 3, 3A, 25A, 205, 320

Three 60-minute test runs were conducted at the high-load condition on April 10, 2018 to revalidate or re-establish the temperature limits at which the oxidizer must operate to comply with the NSPS emission standards and state permit limits. In addition, a second compliance test was conducted on April 11, 2018. The primary purpose of this test was to demonstrate compliance with the federal and state limits while operating at a low-low load condition which simulates an extended formaldehyde process start-up condition.

Testing was conducted in accordance with the sampling and analytical procedures presented in Test Plan No. 024AS-339543-PP-1 dated March 5, 2018. Specifically, testing was conducted pursuant to the following procedures:

- 40 CFR 60, Appendix A, USEPA Methods 1, 2, 3, 3A, and 25A
- 40 CFR 51, Appendix M, USEPA Method 205
- 40 CFR 63, Appendix A, USEPA Method 320
- Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III, Stationary Source Specific Methods
- ASTM Method D6348 – Determination of Gaseous Compounds by Extractive Direct Interface FTIR Spectroscopy

Messrs. Robert Morley and Randy Roden of Georgia-Pacific coordinated the test and monitored all pertinent process operations during the testing. Messrs. Don Chapman, Matthew Krueger, and William Witts of Montrose performed the test. Mr. Don Chapman was the onsite field test supervisor and qualified source testing individual for the test. Ms. Caryn Owens and Mr. Dave Patterson of the MDEQ witnessed the testing.

This report summarizes the test procedures and results of this test. Included as appendices is complete documentation of all calculation summaries, field data, FTIR data, reference method monitoring data, process data, test equipment calibration data, and test program qualifications.

During testing, Georgia-Pacific maintained manual and electronic data collections systems. Although the results of both are detailed in Appendix E, the continuous monitoring data is more reflective of the actual averages.

Summaries of the average test results for both the inlet and outlet of the catalytic oxidizer are presented in Tables 1-1 and 1-2 for the high-load and low-load respectively. Detailed summaries of the oxidizer's test results (inlet and outlet) for each test condition are included in Tables 5-1 through 5-4.

**TABLE 1-1
 CATALYTIC OXIDIZER (INLET AND OUTLET LOADING @ HIGH-LOAD)**

	AVERAGE (RUN NOS. 1 – 3)	
	Inlet	Outlet
GP Operating Parameters		
MeOH feed, gpm	20.5	
Catalyst temperature, °F	614.1	940.3
Differential temperature, °F	326.2	
Stack Gas Parameters		
Temperature, °F	71.0	645.6
Volumetric flow, acfm	7,037	13,356
Volumetric flow, scfm	6,798	6,141
Volumetric flow, dscfh	400,896	357,413
Total Non-Methane VOC (USEPA Method 25A as DME)		
ppmv wb	2,821.2	1.0
lb/hr	137.59	0.04
DRE, % by weight		99.97
Total Non-Methane VOC (USEPA Method 25A as Propane)		
ppmv wb	1,177.5	0.4
lb/hr	54.97	0.02
DRE, % by weight		99.97
Total VOC - by FTIR		
lb/hr	161.38	0.03
DRE, % by weight		99.98
Total HAP		
ppmv wb	723.9	0.6
ppmv @ 3% oxygen		0.7
lb/hr	26.50	0.02
DRE, % by weight		99.91
HAP - Acetaldehyde		
ppmv wb	89.91	< 0.1
lb/hr	4.19	< 0.003
DRE, % by weight		99.92
Dimethyl Ether		
ppmv wb	2,765.5	0.2
lb/hr	134.9	0.01
DRE, % by weight		99.99
HAP - Formaldehyde		
ppmv wb	228.5	0.1
lb/hr	7.26	0.002
DRE, % by weight		99.97
HAP - Methanol		
ppmv wb	385.9	0.3
lb/hr	13.09	0.01
DRE, % by weight		99.92
HAP - Phenol		
ppmv wb	19.6	< 0.1
lb/hr	1.95	< 0.01
DRE, % by weight		99.63

**TABLE 1-2
 CATALYTIC OXIDIZER (INLET AND OUTLET LOADING @ LOW-LOAD)**

	AVERAGE (RUN NOS. 4 – 6)	
	Inlet	Outlet
GP Operating Parameters		
MeOH feed, gpm	12.0	
Catalyst temperature, °F	614.6	822.2
Differential temperature, °F	207.6	
Stack Gas Parameters		
Temperature, °F	73.9	556.4
Volumetric flow, acfm	5,872	10,034
Volumetric flow, scfm	5,591	4,977
Volumetric flow, dscfh	329,993	289,946
Total Non-Methane VOC (USEPA Method 25A as DME)		
ppmv wb	1,862.0	3.4
lb/hr	74.70	0.12
DRE, % by weight		99.84
Total Non-Methane VOC (USEPA Method 25A as Propane)		
ppmv wb	814.2	1.5
lb/hr	31.27	0.05
DRE, % by weight		99.84
Total VOC - by FTIR		
lb/hr	94.13	0.02
DRE, % by weight		99.98
Total HAP		
ppmv wb	646.7	0.5
ppmv @ 3% oxygen		0.9
lb/hr	18.57	0.02
DRE, % by weight		99.90
HAP - Acetaldehyde		
ppmv wb	45.10	< 0.2
lb/hr	1.73	< 0.01
DRE, % by weight		99.58
Dimethyl Ether		
ppmv wb	1,883.2	< 0.1
lb/hr	75.55	< 0.003
DRE, % by weight		100.00
HAP - Formaldehyde		
ppmv wb	223.3	0.1
lb/hr	5.84	0.002
DRE, % by weight		99.96
HAP - Methanol		
ppmv wb	369.9	< 0.1
lb/hr	10.32	< 0.003
DRE, % by weight		99.97
HAP - Phenol		
ppmv wb	8.4	< 0.1
lb/hr	0.68	< 0.01
DRE, % by weight		99.14

2.0 PROCESS DESCRIPTION AND OPERATIONAL PARAMETERS

2.1 PROCESS DESCRIPTION

Formaldehyde Manufacturing

GP Beaver Creek operates an RCI process which manufactures formaldehyde solution and urea formaldehyde concentrate (UFC). The manufacturing process unit, constructed in 1990, is subject to 40 CFR 60, Subpart A – General Provisions, Subpart III – Standards of Performance for Volatile Organic Compound Emissions from a SOCOMI Air Oxidation Unit Process. Subpart III requires a reduction of TOC emissions (minus methane and ethane) of 98 weight-percent, or a TOC (minus methane and ethane) concentration of 20 ppmv on a dry basis corrected to three percent oxygen (O₂), whichever is less stringent. This compliance test was conducted to demonstrate compliance with the Subpart III federal standard and with the more stringent 99% TOC destruction efficiency requirement in the state air permit which is summarized in Table 2-1.

The primary equipment within the formaldehyde unit includes: Bulk methanol tank (independently controlled, and not vented to the catalytic oxidizer), methanol vaporizer and super heater, a catalytic converter to oxidize methanol to formaldehyde, heat transfer fluid system, an aftercooler, (three) absorbers, multiple formaldehyde and UFC storage tanks, formaldehyde/UFC load rack, and the catalytic oxidizer with a 2.5 MMBtu/hr natural gas burner. The catalytic oxidizer controls the emissions from the formaldehyde plant's absorber-3, the formaldehyde and urea-formaldehyde storage tanks, loading racks for formaldehyde and UFC, and all emissions from the equipment described in the Resin Manufacturing section below.

The formaldehyde manufacturing process starts when methanol is fed to the vaporizer. The methanol is injected into an air mixture consisting of recycled air from the formaldehyde plant's absorber and fresh air generated from two positive displacement blowers. This air mixture and methanol vapor pass through the vaporizer and into the super heater where they are heated by 150 psig steam. This superheated mixture passes into the converter, where it enters the catalyst tubes.

The reaction of air and methanol to produce formaldehyde gas is carried out with the aid of catalyst containing molybdenum and iron oxides. This exothermic reaction produces formaldehyde gas, water, and other byproducts which primarily include DME and carbon monoxide. As the vaporized mixture passes down the catalyst tubes, it is heated toward reaction temperature by a heat transfer fluid that surrounds the catalyst tubes in the converter. While the heat transfer fluid preheats the air-methanol mixture, it also removes the heat that comes from the reaction taking place in the lower part of the catalyst tube. The heat transfer fluid is operated at its boiling point, and the excess heat carried away in the vapors is condensed in the Heat Transfer Fluid Condenser. This condenser acts as a waste heat boiler which in turn produces steam for the plant. The air flow then takes the formaldehyde gas mixture through an aftercooler that creates more steam for the process as it removes heat from the formaldehyde gas mixture. Georgia-Pacific has also added an adiabatic bed to the process in order to improve the conversion of methanol to formaldehyde. The adiabatic bed is simply an additional layer of the catalyst suspended just below the converter tube sheet bundle. The adiabatic bed is intended to convert unreacted methanol passing through the converter tubes into formaldehyde, which will reduce the undesirable residual methanol in the product.

The air flow then takes the formaldehyde gas to the bottom of two absorbers which are in series. While the formaldehyde gas is flowing into the bottom of these absorbers, makeup and distillate water is being injected into the top of the absorbers. Absorber conditions are controlled to produce various concentrations of formaldehyde (typically 50%) which is pumped from the absorber basins to product storage tanks. A urea-formaldehyde concentrate product (UFC) is sometimes manufactured by replacing the water flow to the absorbers with a 50% urea solution.

The gas streams combine back together prior to passing through a third absorber, where essentially all the formaldehyde is absorbed into the feed water, and the temperature of the gas is cooled below 20 °C. A portion of the tail gas from the absorber is recycled back into the formaldehyde process while the excess is vented to the Torvex Catalytic Oxidizer.

Resin Manufacturing

The GP Beaver Creek facility also has a liquid resin manufacturing process that is regulated under the state air permit. Because the resin plant utilizes "batch reactors" and does not produce any of the chemicals listed in §60.617 or in § 60.707 as a product, co-product, by-product, or intermediate, it is not subject to NSPS Subpart III or Subpart RRR. Although the resin plant's batch reactors are not part of the Synthetic Organic Chemical Manufacturing Industry (SOCMI) process regulated under this subpart, Georgia-Pacific operated this process group in a manner which represented a normal high-load condition because this process group is interconnected to the catalytic oxidizer which was tested.

There are two "batch reactors" which are primarily used to manufacture Urea-Formaldehyde (UF) Resins and Phenol-Formaldehyde (PF) Resins. The reactors and the capacities are shown below. Each reactor is equipped with a condenser and vacuum pump with a seal water system, which is controlled by the catalytic oxidizer.

BATCH REACTORS

<u>Reactor</u>	<u>Capacity</u>	<u>Primary Resin Type</u>	<u>Secondary Resin Type</u>
K-1	20,000 gallons	Urea-Formaldehyde	
K-2	16,000 gallons	Phenol-Formaldehyde	Urea-Formaldehyde

With the exception of the methanol tank and ammonium hydroxide tank, the catalytic oxidizer controls emissions from the batch reactors, liquid raw material storage tanks, finished resin product storage tanks, and multiple tank and railcar loading racks. Although this equipment is not considered the primary emission source and was not the focus of the stack test, it was operated in a manner to represent normal high-load conditions during the compliance test at which new compliance temperatures were developed. This is discussed in detail in the operational parameters section.

2.2 OPERATIONAL TESTING PARAMETERS

As stated previously, the primary purpose of the test was to demonstrate compliance with the NSPS standard and the air permit's emission limits which are summarized in Table 2-1.

**TABLE 2-1
 EMISSION POINT SPECIFIC EMISSION LIMITATIONS AND STANDARDS**

Emission Point(s)	Pollutant/ Parameter	Permit Limit/Emission Standard	Actual Emissions (High-Load)	Actual Emissions (Low-Load)
	Formaldehyde (FTIR – Method 320)	0.04 lb/hr	0.002 lb/hr	0.002 lb/hr
	VOC (FTIR – Method 320)	1.8 lb/hr	0.03 lb/hr	0.02 lb/hr
RCI Process and Resin Plant (Catalytic Oxidizer)	DRE – TOC (FTIR – Method 320)	NSPS Subpart III: Reduce Total Organics by 98% by weight (minus methane and ethane) or 20 ppm by volume (dry basis)	99.98%	99.98%
	DRE – TOC (Method 25A; as DME and as Propane)	State Permit: Reduce Total Organics by 99% by weight (minus methane and ethane) or 20 ppm by volume (dry basis)	99.97%	99.84%

•Natural Gas was burned in the above combustion unit during the compliance test

2.2.1 Formaldehyde and Resin Manufacturing High-Load Condition

The RCI process at the Georgia-Pacific Beaver Creek facility was operated at or near maximum capacity and followed routine operating procedures during the compliance test. As previously described, the RCI process can manufacture either formaldehyde solution or UFC. When manufacturing UFC, formaldehyde gas is absorbed into the urea solution feed. Because the urea chemically reacts with a portion of the formaldehyde in the absorbers, emissions to the oxidizer are expected to be lower when manufacturing UFC. Therefore, formaldehyde solution of approximately 50% concentration was manufactured during the compliance test.

The maximum routine capacity is 21 gallons per minute feed rate of methanol to the process. The methanol flow rates are continuously monitored and recorded and are used to calculate the formaldehyde production rate. During the compliance test, the methanol feed rate was recorded every minute and averaged during each hourly test run. Three 60-minute test runs were conducted at the maximum routine capacity, along with both resin plant batch reactors in normal operation.

The catalytic oxidizer temperatures (before and after the catalyst bed) and the resulting differential temperature are continuously monitored and were recorded throughout the tests. These temperatures were recorded every minute and averaged during each hourly test run. These temperatures are used to establish the temperatures used to demonstrate continuous compliance as required by the Air Permit and the NSPS regulations. All monitoring data was averaged in accordance with NSPS monitoring and recordkeeping requirements. The monitoring parameters are summarized below:

<u>Sampling Location Control Equipment</u>	<u>Parameter(s) Monitored During Test</u>	<u>Method of Monitoring Parameter Setting</u>
Catalytic Oxidizer	Temperature before and after Catalyst Bed	DCS/PI

2.2.2 Formaldehyde and Resin Manufacturing Low-Load Condition

The RCI manufacturing process was operated at low-load conditions during the second compliance test while manufacturing formaldehyde solution. As previously described, the primary purpose of this test was to demonstrate compliance with federal and state limits while operating the formaldehyde plant at a low-low-load condition. The collected data is intended to support that during low formaldehyde production rates similar to those at plant startup, the facility is in compliance with the NSPS emission standard and state permit limits even though the delta T is below the three-hour block average temperature range described in 40 CFR 60.615(c)(2) which was established at high-load conditions.

During the low-load compliance test, the methanol feed rate was recorded every minute and averaged during each hourly test run. Three 60-minute test runs were conducted at the minimum routine capacity, along with both resin plant batch reactors in normal operation.

The catalytic oxidizer temperatures (before and after the catalyst bed) and the resulting differential temperature were recorded every minute and averaged during each hourly test run. These temperatures are used to establish the temperatures used to demonstrate continuous compliance as required by the Air Permit and the NSPS regulations. All monitoring data was averaged in accordance with NSPS monitoring and recordkeeping requirements. The monitoring parameters are summarized below:

<u>Sampling Location Control Equipment</u>	<u>Parameter(s) Monitored During Test</u>	<u>Method of Monitoring Parameter Setting</u>
Catalytic Oxidizer	Temperature before and after Catalyst Bed	DCS/PI

3.0 TESTING AND ANALYTICAL PROCEDURES

3.1 OVERVIEW

Montrose was retained by Georgia-Pacific to conduct a compliance emission test on the Torvex Catalytic Oxidizer inlet and outlet at their Beaver Creek facility in Grayling, Michigan.

Three 60-minute test runs were conducted at the high-load test condition on April 10, 2018, and three 60-minute test runs were conducted at the low-load test condition on April 11, 2018.

3.2 METHODOLOGY

Test procedures and sampling methodology followed 40 CFR 60, Appendix A, USEPA Methods 1-4 and 25A; 40 CFR 51, Appendix M, USEPA Method 205; 40 CFR 63, Appendix A, USEPA Method 320; ASTM Method D6348-03 (FTIR); and the Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III, Stationary Source Specific Methods.

3.2.1 Sampling Locations (USEPA Method 1)

The velocity sampling points at the sampling locations were determined following USEPA Method 1. The sampling locations and number of velocity sampling points were as follows:

Process	Sampling Location	Duct Inside Diameter/Dimensions (inches)	Upstream Distance from Flow Disturbance (inches)	Downstream Distance from Flow Disturbance (inches)	No. of Ports	Total Points
RCI Process & Resin Plant Process (combined)	Torvex Catalytic Oxidizer Inlet	17.5 x 20	20	70	4	16
	Torvex Catalytic Oxidizer Outlet	24	60	170	2	16

The catalytic oxidizer outlet and inlet sample port schematics are presented in Figures 3-1 and 3-2.

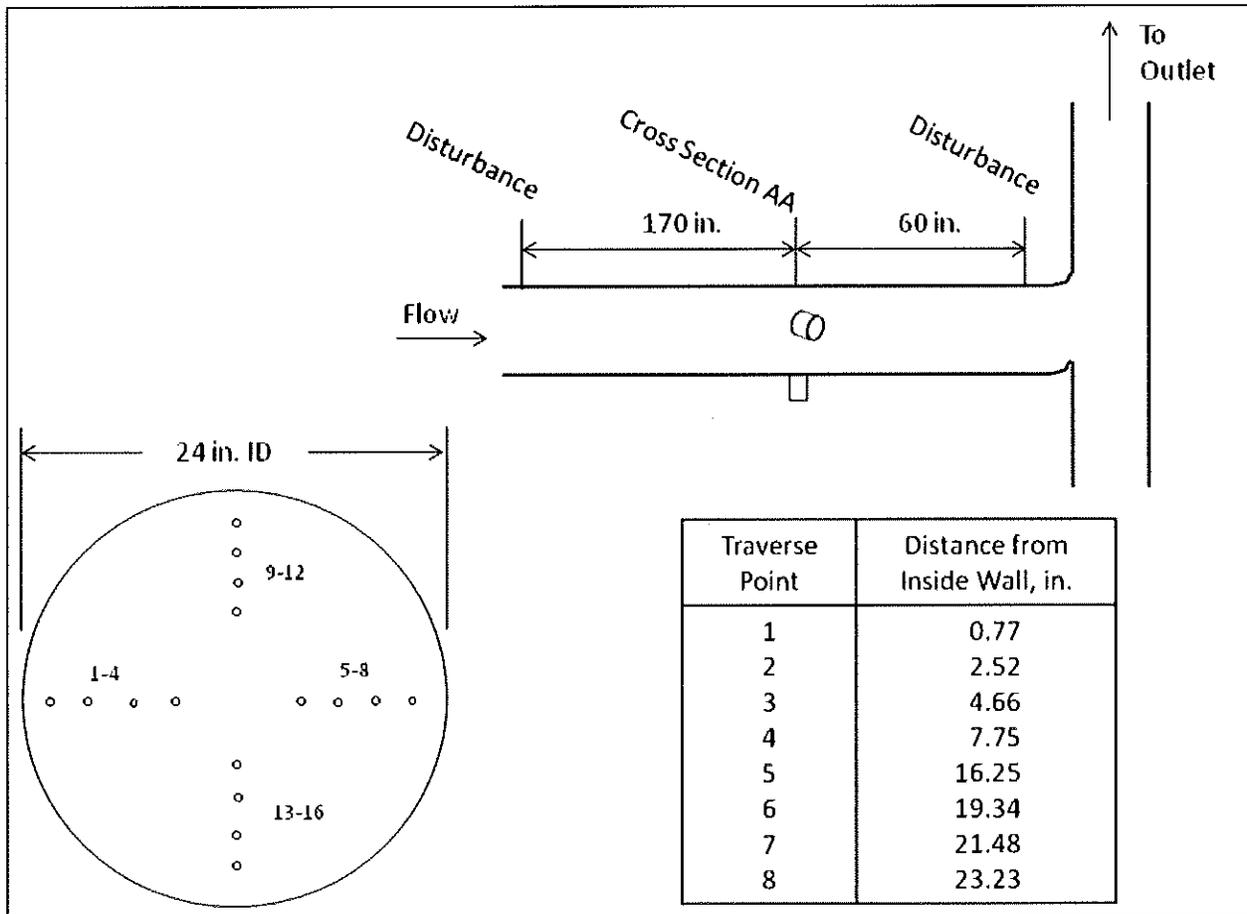
3.2.2 Gas Velocity and Volumetric Flow Rate Determination (USEPA Method 2)

Gas velocity and volumetric flow rate were determined following USEPA Method 2 procedures. Velocity traverses were performed using a Type-S pitot tube with the velocity head pressure measured on a Dwyer oil gauge inclined manometer to the nearest 0.01-in. H₂O. Temperature measurements were performed with a chromel-alumel thermocouple connected to a digital direct read-out potentiometer.

3.2.3 Stack Gas Molecular Weight (USEPA Methods 3 and 3A)

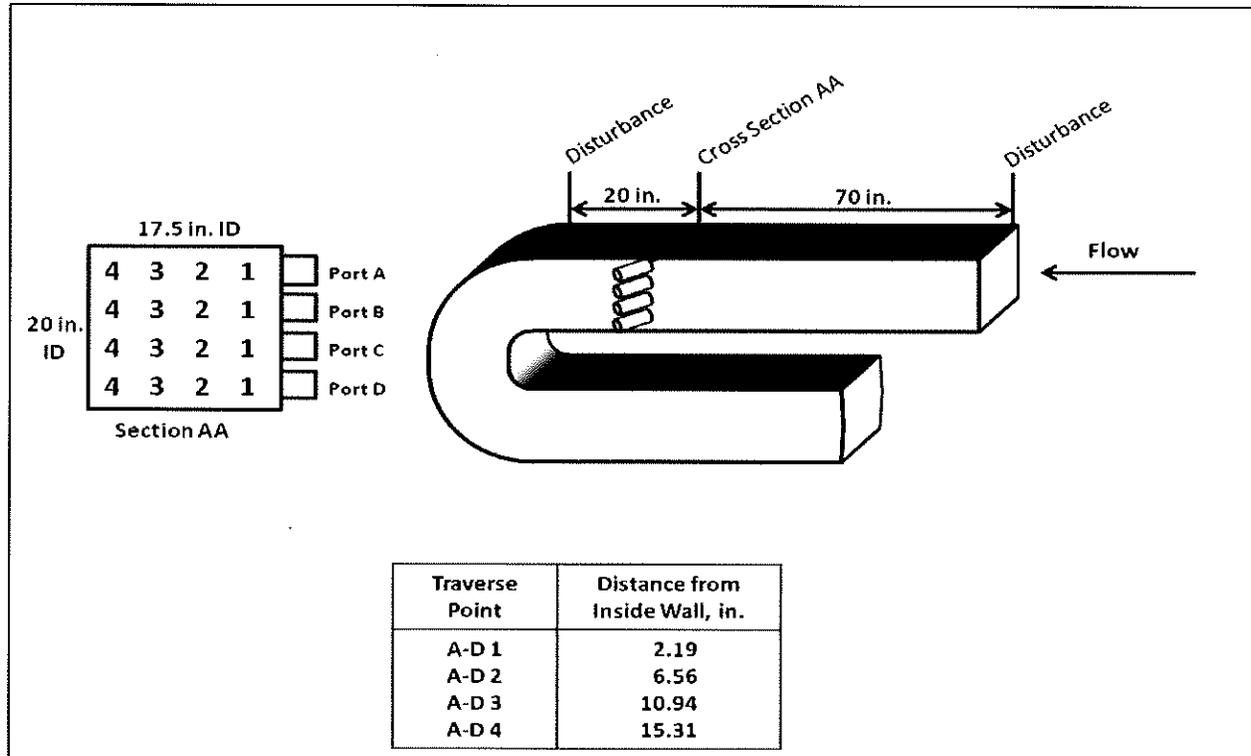
Stack gas molecular weight at the oxidizer inlet was determined following procedures described in USEPA Method 3. Integrated one-hour samples of the vent gas were collected in Tedlar bags, and an Orsat analyzer measured the O₂ and carbon dioxide (CO₂) contents. The nitrogen (N₂) content was calculated as the difference.

**FIGURE 3-1
 OUTLET SAMPLE PORT SCHEMATIC**



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**FIGURE 3-2
 INLET SAMPLE PORT SCHEMATIC**



At the oxidizer outlet, the O₂ and CO₂ concentrations were determined in accordance with USEPA Method 3A using a Servomex, Inc. Model 1440 paramagnetic O₂ and non-dispersive infrared CO₂ analyzer.

As shown in Figure 3-3, sample extraction to the O₂ and CO₂ analyzers was performed through a stainless steel probe with a calibration tee connected to a heated Teflon sample line. The Teflon sample line was connected to a Universal Analyzer Model No. 3082 electronic sample conditioner to remove moisture followed by a Teflon-lined pump. A sample manifold was connected to the exhaust side of the pump with the intake for the O₂ and CO₂ analyzers.

Calibration gases were injected directly into the calibration tee to determine the measurement system bias relative to direct monitor injection or calibration error. The system bias was determined before and after each 60-minute test run.

Calibration gases were diluted from USEPA Protocol 1 high concentration standards. Dilutions were performed using an Environics Model 4040 Gas Dilution System. The dilution system was verified on site following USEPA Method 205.

Results from the sample runs were continuously recorded by a data acquisition system consisting of an Omega OMB-DAQ-56 datalogger connected to a computer for digital data storage and reduction.

3.2.4 Stack Gas Moisture Determination

The stack gas moisture content was determined using FTIR measurements in accordance with USEPA Method 4, Section 16.3.

3.2.5 Total VOC Concentration (USEPA Method 25A)

Total VOC sampling was conducted in accordance with USEPA Method 25A using VIG Industries hydrocarbon analyzers equipped with a heated flame ionization detector (FID). Because DME is the primary VOC in the aggregate vent stream, the flame ionization analyzer was calibrated using DME, and the VOC results are reported as DME and converted to VOC as propane.

The sample delivery system consisted of a stainless steel probe, filter, and calibration tee (on the end of the probe) connected to a heated 250 °F Teflon sampling line. The sampling lines connected directly into the analyzers located in the Montrose monitoring trailer. The hydrocarbon analyzers are internally heated to keep the sample gas stream above its dew point (see Figure 3-4).

The hydrocarbon analyzers were calibrated with applicable zero, low, mid, and high-range propane and DME gases as specified in USEPA Method 25A. The calibration gases were generated from Protocol 1 calibration standards using an Environics Model 4040 Gas Dilution System. The dilution system was verified on site in accordance with USEPA Method 205.

FIGURE 3-3
REFERENCE METHOD O₂ AND CO₂ SAMPLING SYSTEM

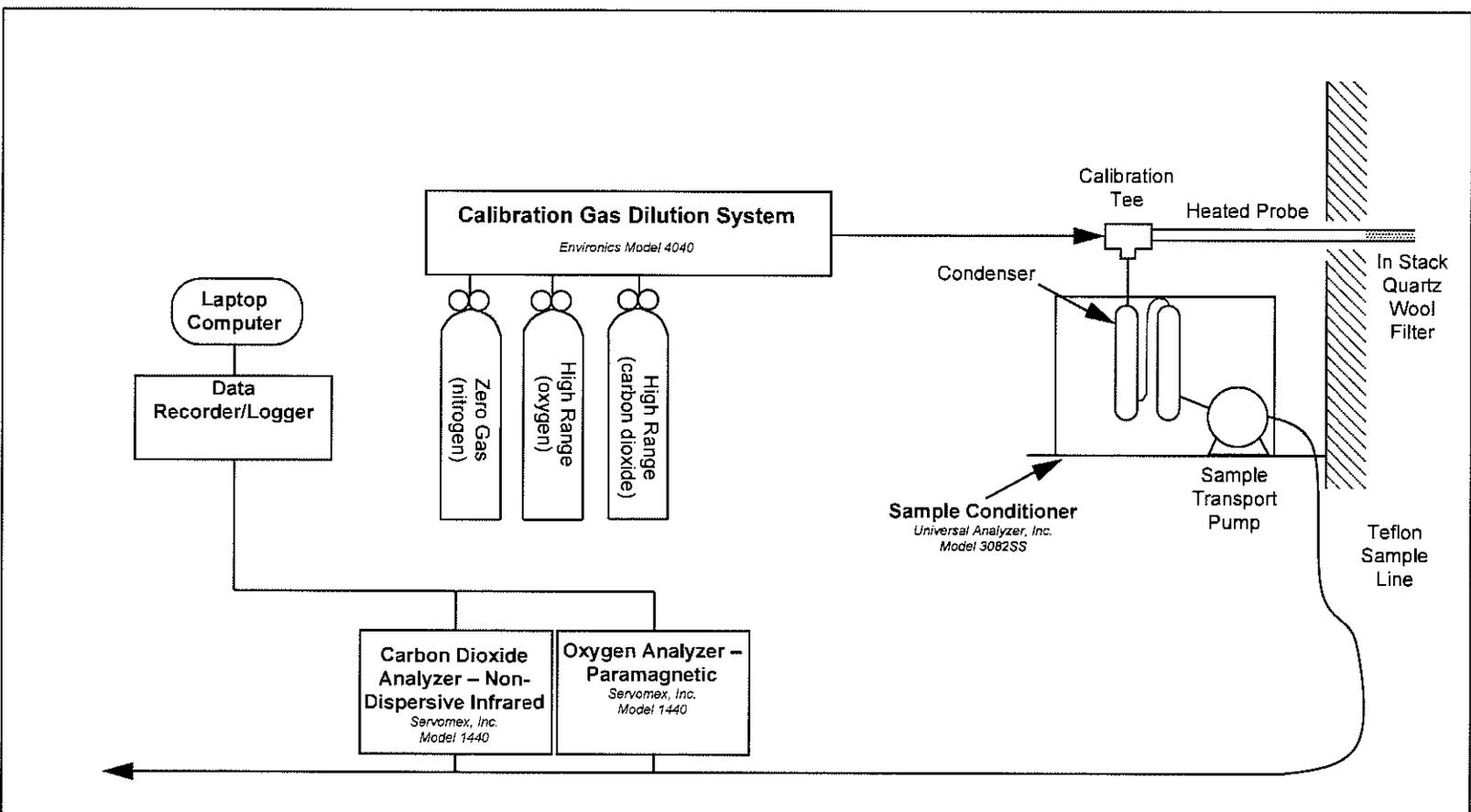
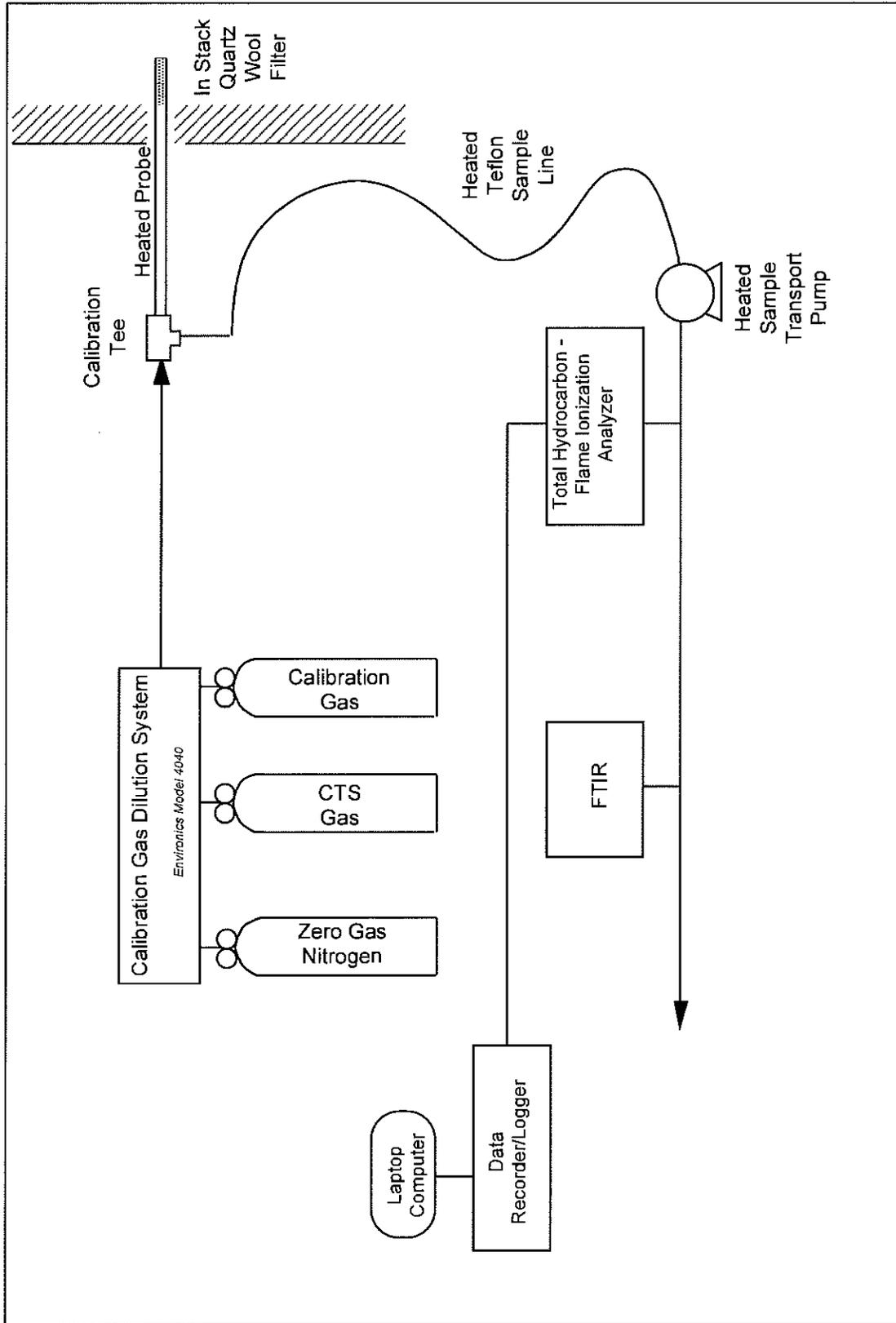


FIGURE 3-4
TOTAL VOC AND FTIR SAMPLING SYSTEM



A calibration error test was performed prior to testing, and a post-test calibration drift test was performed after each test repetition on each monitor.

The analyzer's data was collected at 15-second intervals by a data acquisition system consisting of an Omega OMB-DAQ-56 datalogger connected to a computer for digital data storage and reduction.

3.2.6 Gas Dilution System Verification (USEPA Method 205)

All applicable calibration gases were certified by USEPA Protocol 1 procedures. All diluted calibration standards were prepared using an Environics Model 4040 Gas Dilution System that was verified by a field evaluation following the requirements of USEPA Method 205.

The Servomex, Inc. Model 1440 O₂ analyzer was used for this procedure. It was initially calibrated following USEPA Method 3A procedures. After the calibration procedure was complete, two diluted standards and an EPA Protocol 1 standard were alternately introduced in triplicate, and an average instrument response was calculated for each standard. No single response differed by more than $\pm 2\%$ from the average response for each standard. The difference between the instrument average and the predicted concentration was less than $\pm 2\%$ for each diluted standard. The difference between the certified gas concentration and the average instrument response for the EPA Protocol 1 standard was less than $\pm 2\%$.

3.2.7 HAP and VOC Determination using FTIR Spectroscopy (USEPA Method 320)

HAP and VOC sampling was conducted using FTIR instrumentation following the principles of USEPA Method 320 and ASTM Method D6348-03. Please note that a USEPA Method 301 validation study was not performed because FTIR 301 validation has previously been completed and approved by the EPA for the NSPS formaldehyde process.

An MKS Model MultiGas 2030 FTIR was used to measure moisture and the specific compound concentrations. The MultiGas 2030 analyzer is composed of a 2102 process 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 3-4, the sample delivery system consisted of a stainless steel sampling probe, calibration tee, Teflon sampling line, fast loop bypass pump, dilution system, and sample manifold. The gas sample was continuously extracted from the source at approximately four liters per minute.

It should be noted that the main principles and calibration procedures of USEPA Method 320 were followed. USEPA Method 320 specifies a number of analytical uncertainty parameters that the analyst calculated to characterize the FTIR system performance. However, this did not provide analytical detection limits. To calculate the method detection limit (MDL) for the target compounds, the guidelines in Appendix B of 40 CFR 136 were followed. With this, the Student t-test is used to calculate the MDL for each analyte at a 99% confidence level. This follows

USEPA guidelines for reporting of zeroes or non-detects and also meets the NELAC requirements for determination of MDL values.

The MKS software calculates the analytical error of the FTIR measurement which includes the root mean standard deviation (RMSD). The concentration uncertainty reported by MKS is called the standard error of estimated concentration (SEC) and is also known as the marginal standard deviation. The uncertainties in the concentration are proportional to the square root of the sums of the squares of the residual. After the residual spectrum is obtained, which is called R, the error variance for the case of a single reference spectrum is calculated by the software.

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 interferences, 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 evaluate dilution ratios and verify the sample delivery system integrity. A dynamic matrix spike was performed using acetaldehyde and SF₆ as a tracer gas.

The general FTIR field sampling procedure was as follows:

PRE-TEST

- 1) Background spectrum
 - Evaluate diagnostics of the instrumentation
- 2) Baseline (cylinder UHP-N₂ 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 ethylene for span check)
 - 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 gases
- 7) Perform dynamic spiking recovery study (recovery must be $0.7 \leq R \leq 1.3$)

TEST (REPEAT EACH RUN)

- 1) Baseline determination
- 2) Measurement of calibration transfer standard
- 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)

4.0 QA/QC PROCEDURES

Quality assurance was ensured throughout the test program. QA/QC procedures specific to this compliance test program included the following:

4.1 EPA METHODS 3A, 25A, AND 320

1. Analyzers were checked to meet manufacturers' specifications at operating conditions.
2. Analyzers were pre-checked for span, zero drift, and linearity.
3. USEPA Protocol 1 and certified calibration gases were checked and introduced into the analyzers.
4. The sample line integrity was checked. All line heaters and grounding were checked.
5. The sampling and analysis system was set up and maintained at equilibrium for eight hours minimum on-site.
6. The flow meters, heaters, chillers, and pumps were pre-checked for proper operation.
7. Analyzer system performance was checked using gas standards for bias and calibration error per applicable USEPA Method.

Type and configuration of sampling equipment followed the 40 CFR 60, Appendix A protocols for USEPA Methods 1, 2, 3, 3A, 25A, and 320 and The USEPA Guidance Manual. Specifically, all sampling equipment was prepared and maintained to meet or exceed USEPA method requirements.

4.2 EPA METHOD 205

The Environics Model 4040 Gas Dilution System was verified on-site in accordance with USEPA Method 205 procedures. The verification was performed using a Protocol 1 calibration gas.

4.3 POST-TEST CALIBRATION OF EQUIPMENT

Post-test calibration of the sampling equipment that was pre-tested followed the post-test calibration requirement where such a requirement exists. Otherwise, post-test calibration was conducted following pre-test procedures. Standard procedures and data forms were used for post-test calibration of the equipment.

5.0 TEST RESULTS

The test results are presented in Tables 5-1 through 5-4¹.

The calculation summaries, field data, FTIR data, reference method monitoring data, process data, calibration data, and test program qualifications are included in the appendices.

¹MEASUREMENT UNCERTAINTY STATEMENT

Both qualitative and quantitative factors contribute to field measurement uncertainty and should be taken into consideration when interpreting the results contained within this report. Whenever possible, Montrose personnel reduce the impact of these uncertainty factors through the use of approved and validated test methods. In addition, Montrose personnel perform routine instrument and equipment calibrations and ensure that the calibration standards, instruments, and equipment used during test events meet, at a minimum, test method specifications as well as the specifications of the Montrose Quality Manual and ASTM D7036-04. The limitations of the various methods, instruments, equipment, and materials utilized during this test have been reasonably considered, but the ultimate impact of the cumulative uncertainty of this project is not fully identified within the results of this report.

**TABLE 5-1
 TORVEX CATALYTIC OXIDIZER (OUTLET EMISSIONS @ HIGH-LOAD)**

RUN NO.	1	2	3	Average
TEST DATE	4/10/2018	4/10/2018	4/10/2018	
TEST TIME	14:00-15:00	15:35-16:35	17:05-18:05	
GP Operating Parameters				
MeOH feed, gpm	20.5	20.5	20.5	20.5
Catalyst inlet temperature, °F	615.1	613.6	613.6	614.1
Catalyst outlet temperature, °F	939.1	941.1	940.8	940.3
Differential temperature, °F	324.0	327.5	327.2	326.2
Stack Gas Parameters				
Temperature, °F	643.0	646.9	646.9	645.6
Volumetric flow, acfm	13,507	13,384	13,178	13,356
Volumetric flow, scfm	6,225	6,146	6,053	6,141
Volumetric flow, dscfh	362,432	357,538	352,269	357,413
Total Non-Methane VOC (USEPA Method 25A as DME)				
ppmv wb	0.4	1.1	1.5	1.0
lb/hr	0.02	0.05	0.07	0.04
DRE, % by weight	99.99	99.96	99.95	99.97
Total Non-Methane VOC (USEPA Method 25A as Propane)				
ppmv wb	0.2	0.5	0.6	0.4
lb/hr	0.01	0.02	0.03	0.02
DRE, % by weight	99.99	99.96	99.95	99.97
Total VOC (Measured by FTIR)				
ppmv wb	0.8	0.8	0.9	0.8
ppmv db	0.8	0.8	0.9	0.8
lb/hr	0.03	0.03	0.04	0.03
DRE, % by weight	99.98	99.98	99.98	99.98
Total HAP				
ppmv wb	0.6	0.6	0.6	0.6
ppmv db	0.6	0.6	0.6	0.6
ppmv db @ 3% oxygen	0.7	0.7	0.7	0.7
lb/hr	0.02	0.02	0.02	0.02
DRE, % by weight	99.91	99.91	99.91	99.91
HAP - Acetaldehyde				
ppmv wb	< 0.1	< 0.1	< 0.1	< 0.1
lb/hr	< 0.003	< 0.003	< 0.003	< 0.003
DRE, % by weight	99.92	99.92	99.92	99.92
Dimethyl Ether				
ppmv wb	0.2	0.2	0.3	0.2
lb/hr	0.01	0.01	0.01	0.01
DRE, % by weight	99.99	99.99	99.99	99.99
HAP - Formaldehyde				
ppmv wb	0.1	0.1	0.1	0.1
lb/hr	0.002	0.002	0.002	0.002
DRE, % by weight	99.97	99.97	99.96	99.97
HAP - Methanol				
ppmv wb	0.3	0.3	0.3	0.3
lb/hr	0.01	0.01	0.01	0.01
DRE, % by weight	99.92	99.92	99.93	99.92
HAP - Phenol				
ppmv wb	< 0.1	< 0.1	< 0.1	< 0.1
lb/hr	< 0.01	< 0.01	< 0.01	< 0.01
DRE, % by weight	99.66	99.57	99.65	99.63

**TABLE 5-2
 TORVEX CATALYTIC OXIDIZER (INLET LOADING @ HIGH-LOAD)**

RUN NO.	:	1	2	3	
TEST DATE	:	4/10/2018	4/10/2018	4/10/2018	
TEST TIME	:	14:00-15:00	15:35-16:35	17:05-18:05	Average
GP Operating Parameters					
MeOH feed, gpm		20.5	20.5	20.5	20.5
Oxidizer inlet temperature, °F		615.1	613.6	613.6	614.1
Oxidizer outlet temperature, °F		939.1	941.1	940.8	940.3
Differential temperature, °F		324.0	327.5	327.2	326.2
Stack Gas Parameters					
Temperature, °F		70.4	71.0	71.5	71.0
Volumetric flow, acfm		7,102	7,033	6,977	7,037
Volumetric flow, scfm		6,866	6,795	6,733	6,798
Volumetric flow, dscfh		404,910	400,539	397,240	400,896
Total Non-Methane VOC (USEPA Method 25A as DME)					
ppmv wb		2,827.1	2,764.3	2,872.2	2,821.2
lb/hr		139.26	134.76	138.75	137.59
Total Non-Methane VOC (USEPA Method 25A as Propane)					
ppmv wb		1,179.9	1,153.7	1,198.8	1,177.5
lb/hr		55.64	53.84	55.43	54.97
Total VOC (Measured by FTIR)					
ppmv wb		3,467.5	3,525.8	3,474.9	3,489.4
ppmv db		3,542.8	3,615.2	3,559.4	3,572.5
lb/hr		162.18	162.56	159.39	161.38
Total HAP					
ppmv wb		714.1	742.0	715.5	723.9
ppmv db		729.6	760.9	732.9	741.1
lb/hr		26.55	26.86	26.09	26.50
HAP - Acetaldehyde					
ppmv wb		89.21	87.56	92.95	89.91
lb/hr		4.20	4.08	4.29	4.19
Dimethyl Ether					
ppmv wb		2,753.5	2,783.7	2,759.3	2,765.5
lb/hr		135.63	135.71	133.29	134.9
HAP - Formaldehyde					
ppmv wb		223.1	245.9	216.4	228.5
lb/hr		7.16	7.82	6.81	7.26
HAP - Methanol					
ppmv wb		380.4	391.7	385.6	385.9
lb/hr		13.03	13.28	12.95	13.09
HAP - Phenol					
ppmv wb		21.3	16.9	20.6	19.6
lb/hr		2.15	1.68	2.03	1.95

**TABLE 5-3
 TORVEX CATALYTIC OXIDIZER (OUTLET EMISSIONS @ LOW-LOAD)**

RUN NO.	4	5	6	Average
TEST DATE	4/11/2018	4/11/2018	4/11/2018	
TEST TIME	11:00-12:00	12:35-13:35	14:10-15:10	
GP Operating Parameters				
MeOH feed, gpm	12.0	12.0	12.0	12.0
Catalyst inlet temperature, °F	615.0	614.0	614.7	614.6
Catalyst outlet temperature, °F	822.3	821.4	822.9	822.2
Differential temperature, °F	207.2	207.4	208.2	207.6
Stack Gas Parameters				
Temperature, °F	556.6	556.1	556.6	556.4
Volumetric flow, acfm	10,037	10,021	10,044	10,034
Volumetric flow, scfm	4,978	4,972	4,981	4,977
Volumetric flow, dscfh	290,041	289,701	290,096	289,946
Total Non-Methane VOC (USEPA Method 25A as DME)				
ppmv wb	3.1	3.8	3.5	3.4
lb/hr	0.11	0.13	0.12	0.12
DRE, % by weight	99.85	99.82	99.83	99.84
Total Non-Methane VOC (USEPA Method 25A as Propane)				
ppmv wb	1.3	1.6	1.5	1.5
lb/hr	0.05	0.06	0.05	0.05
DRE, % by weight	99.85	99.82	99.83	99.84
Total VOC (Measured by FTIR)				
ppmv wb	0.4	0.6	0.7	0.6
ppmv db	0.5	0.6	0.8	0.6
lb/hr	0.02	0.02	0.03	0.02
DRE, % by weight	99.98	99.98	99.97	99.98
Total HAP				
ppmv wb	0.4	0.5	0.7	0.5
ppmv db	0.4	0.5	0.7	0.5
ppmv db @ 3% oxygen	0.6	0.8	1.1	0.9
lb/hr	0.01	0.02	0.02	0.02
DRE, % by weight	99.93	99.90	99.87	99.90
HAP - Acetaldehyde				
ppmv wb	< 0.1	0.2	0.4	< 0.2
lb/hr	< 0.003	0.01	0.01	< 0.01
DRE, % by weight	99.85	99.62	99.27	99.58
Dimethyl Ether				
ppmv wb	< 0.1	< 0.1	< 0.1	< 0.1
lb/hr	< 0.003	< 0.003	< 0.003	< 0.003
DRE, % by weight	100.00	100.00	100.00	100.00
HAP - Formaldehyde				
ppmv wb	0.1	0.1	0.1	0.1
lb/hr	0.002	0.003	0.003	0.002
DRE, % by weight	99.96	99.96	99.96	99.96
HAP - Methanol				
ppmv wb	< 0.1	< 0.1	< 0.1	< 0.1
lb/hr	< 0.003	< 0.003	< 0.003	< 0.003
DRE, % by weight	99.97	99.97	99.98	99.97
HAP - Phenol				
ppmv wb	< 0.1	< 0.1	< 0.1	< 0.1
lb/hr	< 0.01	< 0.01	< 0.01	< 0.01
DRE, % by weight	99.29	99.10	99.03	99.14

**TABLE 5-4
 TORVEX CATALYTIC OXIDIZER (INLET LOADING @ LOW-LOAD)**

RUN NO.	:	4	5	6	
TEST DATE	:	4/11/2018	4/11/2018	4/11/2018	
TEST TIME	:	11:00-12:00	12:35-13:35	14:10-15:10	Average
GP Operating Parameters					
MeOH feed, gpm		12.0	12.0	12.0	12.0
Oxidizer inlet temperature, °F		615.0	614.0	614.7	614.6
Oxidizer outlet temperature, °F		822.3	821.4	822.9	822.2
Differential temperature, °F		207.2	207.4	208.2	207.6
Stack Gas Parameters					
Temperature, °F		74.2	73.7	73.7	73.9
Volumetric flow, acfm		5,864	5,882	5,870	5,872
Volumetric flow, scfm		5,582	5,602	5,590	5,591
Volumetric flow, dscfh		329,566	330,738	329,676	329,993
Total Non-Methane VOC (USEPA Method 25A as DME)					
ppmv wb		1,850.2	1,894.2	1,841.5	1,862.0
lb/hr		74.10	76.14	73.85	74.70
Total Non-Methane VOC (USEPA Method 25A as Propane)					
ppmv wb		809.0	828.2	805.2	814.2
lb/hr		31.02	31.87	30.91	31.27
Total VOC (Measured by FTIR)					
ppmv wb		2,524.3	2,513.0	2,552.4	2,529.9
ppmv db		2,579.6	2,583.8	2,615.0	2,592.8
lb/hr		93.84	93.78	94.75	94.13
Total HAP					
ppmv wb		647.4	631.7	660.9	646.7
ppmv db		661.5	649.5	677.1	662.7
lb/hr		18.67	18.16	18.90	18.57
HAP - Acetaldehyde					
ppmv wb		46.30	43.78	45.24	45.10
lb/hr		1.77	1.68	1.73	1.73
Dimethyl Ether					
ppmv wb		1,877.0	1,881.3	1,891.4	1,883.2
lb/hr		75.18	75.62	75.86	75.55
HAP - Formaldehyde					
ppmv wb		220.9	218.8	230.1	223.3
lb/hr		5.77	5.73	6.02	5.84
HAP - Methanol					
ppmv wb		370.2	361.3	378.2	369.9
lb/hr		10.31	10.10	10.55	10.32
HAP - Phenol					
ppmv wb		9.9	7.8	7.3	8.4
lb/hr		0.81	0.64	0.60	0.68