Turbine 1 NOx and O_2 Emissions Test Report

Prepared for:

CMS Generation Michigan Power L.L.C
Kalamazoo Generation Station

Comstock, Michigan

CMS Generation
Kalamazoo River Generating Station
6900 E. Michigan Ave.
Comstock, MI 49048
(313) 617-3782

Project No. 049AS-466944
December 12, 2018

Montrose Air Quality Services, LLC
4949 Fernlee Avenue
Royal Oak, Michigan 48073
(248) 548-8070

STAC

ACCREDITED
TO ASTM D7036 ONLY
CERT #3971.01

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Executive Summary

Montrose Air Quality Services, LLC (MAQS) was retained by CMS Generation – Kalamazoo River Generation Station (CMS-Kalamazoo) to evaluate oxides of nitrogen (NOx) emission rates from one combustion turbine (EUCOMBTURB01) at the CMS-Kalamazoo facility located in Kalamazoo, Michigan. To determine NO_x lb/mmBtu and lb/hr emission rates and NO_x ppm concentrations corrected to 15% O_2, simultaneous NO_x and O_2 concentration measurements were obtained. The emission testing was conducted on November 1 and 2, 2018.

The emissions test program was conducted consistent with the MAQS Emissions Test Plan dated August 22, 2018 and submitted to Air Quality Division (AQD) of Michigan's Department of Environmental Quality (MDEQ) and MDEQ's approval letter dated August 30, 2018. The testing was performed to demonstrate compliance with Michigan Department of Environmental Quality Permit No. MI-ROP-N6731-2015a and Permit to Install (PTI) No. 8-18. The testing was also performed to demonstrate compliance with Title 40, Part 60, Subpart KKKK of the Code of Federal Regulations (40 CFR 60, Subpart KKKK) and 40 CFR 75, Appendix E. The turbine was tested at 4 different loads between 55 MW and 86 MW. Testing during each load consisted of triplicate 24-minute test runs while combusting natural gas.

In addition to demonstrating compliance with the NO_x ppm and lb/hr emission limits in PTI No. 8-18, NO_x emissions testing at KRGS was conducted to establish the 4-load correlation curve utilizing fuel flow data at each tested load according to the methodology of Section 2.1 of Appendix E to 40 CFR Part 75.

Triplicate test runs were completed at four operating loads on November 1, 2018. However, the test runs completed at the 55 MW and 65 MW operating loads were invalidated because on November 1, 2018, CMS-Kalamazoo discovered that the fuel supplier had started conducting unscheduled quality assurance/quality control and maintenance activities on the billing natural gas flow meter just prior to the start of stack testing. The QA/QC activities impacted natural gas flow data during the first five (5) runs at the two lower loads (55 and 65 MW) of the operating curve. Therefore, CMS-Kalamazoo elected to repeat the first six (6) test runs at the two lower loads on November 2, 2018 to obtain NO_x/fuel flow correlations for the 55 and 65 MW portion of the operating curve. The fuel flow during the two higher loads (75 and 85 MW) tested on November 1, 2018 was not affected; nor were the NO_x ppm or NO_x lb/hr results. The 4-load curve was developed using the emissions and fuel flow data obtained while operating at 75 and 85 MW on November 1, 2018 and at 55 MW and 65 MW on November 2, 2018.

Test data for the emissions test runs not used (55 and 65 MW runs on November 1, 2018) is included in this report but not reflected in the overall test results summary tables.

The results of the emissions test program are summarized in Executive Summary Table E-1.

Table E-1
Executive Summary of EUCOMBTURB01 NOx Emission Results

Load	Emission Rates			Permit Limits	
	NOx (ppm dry @ 15% O_2)	NOx (lb/MMBtu)	NOx (lb/hr)	NOX (ppm dry @ 15%O_2)	NOX (lb/hr)
55 MW	13.21	0.0486	36.0	15 ppm	72.9 lb/hr
65 MW	13.41	0.0494	39.8		
75 MW	13.50	0.0497	44.4		
85.4 MW	13.38	0.0493	49.0		

As shown in the above table, EUCOMBTURB01 was found to be in compliance with the emission limits established in Permit 8-18. A new correlation curve was established in accordance with 40 CFR Part 75, Appendix E and will be used for Acid Rain and Cross State Air Pollution Rule Compliance as well as the permit required Continuous Compliance Protocol.

1.0 Introduction

Montrose Air Quality Services, LLC (MAQS) was retained by CMS Generation – Kalamazoo River Generation Station (CMS-Kalamazoo) to evaluate oxides of nitrogen (NOx) emission rates from one combustion turbine (EUCOMBTURB01) at the CMS-Kalamazoo facility located in Kalamazoo, Michigan. To determine NO_x lb/mmBtu emission rates and lb/hr and NO_x ppm concentrations corrected to 15% O_2, simultaneous NO_x and O_2 concentration measurements were obtained. The emission testing was conducted on November 1 and 2, 2018.

The emissions test program was conducted consistent with the MAQS Emissions Test Plan dated August 22, 2018 and submitted to Air Quality Division (AQD) of Michigan's Department of Environmental Quality (MDEQ) and MDEQ's approval letter dated August 30, 2018. The testing was performed to demonstrate compliance with Michigan Department of Environmental Quality Permit No. MI-ROP-N6731-2015a and Permit to Install (PTI) No. 8-18. The testing was also performed to demonstrate compliance with Title 40, Part 60, Subpart KKKK of the Code of Federal Regulations (40 CFR 60, Subpart KKKK) and 40 CFR 75, Appendix E. The turbine was tested at 4 different loads between 55 MW and 86 MW. Testing during each load consisted of triplicate minimum 24-minute test runs while combusting natural gas.

In addition to demonstrating compliance with the NO_x ppm and lb/hr emission limits in PTI No. 8-18, NO_x emissions testing at KRGS was conducted to establish the 4-load correlation curve utilizing fuel flow data at each tested load according to the methodology of Section 2.1 of Appendix E to 40 CFR Part 75.

Triplicate test runs were completed at four operating loads on November 1, 2018. However, the test runs completed at the 55 MW and 65 MW operating loads were invalidated because on November 1, 2018, CMS-Kalamazoo discovered that the fuel supplier had started conducting unscheduled quality assurance/quality control and maintenance activities on the billing natural gas flow meter just prior to the start of stack testing. The QA/QC activities impacted natural gas flow data during the first five (5) runs at the two lower loads (55 and 65 MW) of the operating curve. Therefore, CMS-Kalamazoo elected to repeat the first six (6) test runs at the two lower loads on November 2, 2018 to obtain NO_x/fuel flow correlations for the 55 and 65 MW portion of the operating curve. The fuel flow during the two higher loads (75 and 85 MW) tested on November 1, 2018 was not affected; nor were the NO_x ppm or NO_x lb/hr results. The 4-load curve was developed using the emissions and fuel flow data obtained while operating at 75 and 85 MW on November 1, 2018 and at 55 MW and 65 MW on November 2, 2018.

Test data for the emissions test runs not used (55 and 65 MW runs on November 1, 2018) is included in this report but not reflected in the overall test results summary tables.

MAQS personnel Todd Wessel and Shane Rabideau performed the testing. Mr. Paul Snoes and Mr. Timothy Morrison of CMS assisted the study by coordinating process test times and gathering process data. Mr. David Patterson and Cody Yazzie of MDEQ were present to witness the testing.

2.0 Process Description

The CMS-Kalamazoo facility located in Comstock, Michigan operates one simple-cycle Turbine that fires natural gas (NG).

The turbine was previously rated at an output of approximately 74 Megawatts (MW). After recent modifications authorized under PTI 8-18, the turbine is now rated at an output capacity of approximately 86 MW. EUCOMBTURB01 is exclusively fired with natural gas. The turbine generator consists of a compressor, combustion turbine, and generator. Energy is generated at the combustion turbine by drawing in and compressing ambient air, burning fuel with the compressed air and expanding the hot combustion gases in a three stage turbine. The mechanical energy recovered in the turbine is used for both compression of the ambient air and electrical generation.

3.0 Sampling and Analytical Methodologies

Sampling and analytical methodologies are summarized in Sections 3.1 through 3.3. A Schematic drawing of MAQS's continuous emissions monitoring system is presented as Figure 1. Traverse point locations for the Turbine are illustrated in Figure 2.

3.1 Continuous Emissions Monitoring

Measurement of exhaust gas concentrations was conducted utilizing the following reference test methods codified at 40 CFR 60, Appendix A:

- Method 3A - "*Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources;*"
- Method 7E - "*Determination of Nitrogen Oxides Emissions from Stationary Sources;*"
- Method 19 - "*Determination of Sulfur Dioxide Removal and Particulate, Sulfur Dioxide and Nitrogen Oxides Rates*"

MAQS's extractive monitors require that the effluent gas sample be conditioned to eliminate any possible interference (i.e., water vapor and/or particulate matter) before being transported and injected into each analyzer. All components of the sampling system that contact the sample were constructed of Type 316 stainless steel, Pyrex glass or Teflon®. The output signal from each monitor was recorded at 4-second intervals on a PC equipped with Labview® II data acquisition software (DAS). The samples were extracted from the stack using a heated sample probe/filter assembly, heated sample line, stack gas conditioner with a Teflon diaphragm pump and routed through a distribution manifold for delivery to the analyzers. The configuration of the sampling system allowed for the injection of calibration gases directly to the analyzers or through the sampling system. All monitors in use were calibrated with U.S. EPA Protocol No. 1 calibration gases and operated to insure that zero drift, calibration gas drift, and calibration error met the specified method requirements. Copies of the Protocol gas certificates can be found in Appendix C, and all calibration gases were obtained from vendors participating in the EPA's Protocol Gas Verification Program as of the date that the calibration gases were certified.

The sample gas was extracted at three points in each of four ports for a total of twelve sample points per run as described by 40 CFR Part 75, Appendix E. The middle port was inaccessible and was not sampled and, consequently, the traverse points were a small deviation from the locations specified by Method 1; please see Figure 2. A diagram of the reference monitoring system is illustrated in Figure 1.

The turbine NO_x concentrations were measured in parts per million by volume, dry basis (ppmvd). The run average NO_x concentration was then corrected to 15 percent oxygen using the equation presented below. The lb/MMBtu emission rate was calculated using equation 19-1 of U.S. EPA Method 19 of Appendix A, 40 CFR 60. Oxygen concentrations are reported in percent by volume, dry basis (%). The gross heating value of the fuel (Btu/scf) was provided by CMS-Kalamazoo and was used to calculate the NO_x emissions on a lb/hr basis.

The MDEQ protocol approval letter stated to "Calculate the NOx emission rate in lb/mmBtu for each sampling point and determine the arithmetic average NOx emission rate of each test run." As this requirement is not practical and most likely residual language from when Method 20 was utilized for Appendix E testing, only the run averages were converted to the lb/mmBtu emission rate, vs. each point, as was done in previous test events and reporting.

The calculation illustrated below utilizes dry bias corrected pollutant concentrations and the associated dry bias corrected O_2 concentrations.

$$C_{adj} = C_d \frac{5.9}{20.9 - \%O_2}$$

where:

C_{adj}	=	Pollutant concentration corrected to 15 percent O_2 ppm.
C_d	=	Pollutant concentration measured, dry basis, ppm.
$\%O_2$	=	Measured O_2 concentration dry basis, percent.

3.2 Oxygen and Carbon Dioxide (USEPA Method 3A)

An M&C Products PMA 100-L analyzer was used to measure O_2 concentrations following the guidelines of U.S. EPA Method 3A, "Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from a Stationary Source (Instrumental Analyzer Procedure)". The analyzer calibration span was set equal to the concentration of the high level calibration gas and the analyzer was calibrated before the testing with a gas mixture not containing any O_2 (the high level NOx calibration gas) and high level USEPA Protocol 1 calibration gas. Following calibration, a mid range USEPA Protocol 1 gas (40 to 60% of calibration span) was introduced. The response error did not exceed 2% of the instrument span, as required by the method. Calibration error results are presented in Appendix A. Calibration drift checks were performed at the completion of each run.

3.3 Nitrogen Oxides (USEPA Method 7E)

A Thermo Environmental Model 42c analyzer was used to measure parts per million of nitrogen oxides in the dry sample gas following the guidelines of U.S. EPA Method 7E, "Determination of Nitrogen Oxides from Stationary Sources (Instrumental Analyzer Procedure)". The analyzer measures the concentration of NO_x by converting NO_x to NO and then measuring the light emitted by the reaction of NO with ozone. The NO_x analyzer calibration span was set equal to the high level calibration gas NO_x concentration. The NO_X sampling system was calibrated at three points: zero, mid-level (40-60% of the calibration span), and high level (equal to the calibration span) with USEPA Protocol 1 calibration gases. MAQS conducted several NO_2 to NO conversion efficiency tests, as specified in U.S. EPA Method 7E. The results of the NO_2 to NO conversion efficiency test can be found on the enclosed compact disk.

4.0 Test Results

The results of the emissions test program for NO_x ppm at 15% O_2 and lbs/hr rates are summarized by Table 1. The table also includes the NO_x emission rates expressed as lb/mmBtu; these emission rates were used in calculating the lbs/hr emission rates and development of the Appendix E correlation curve.

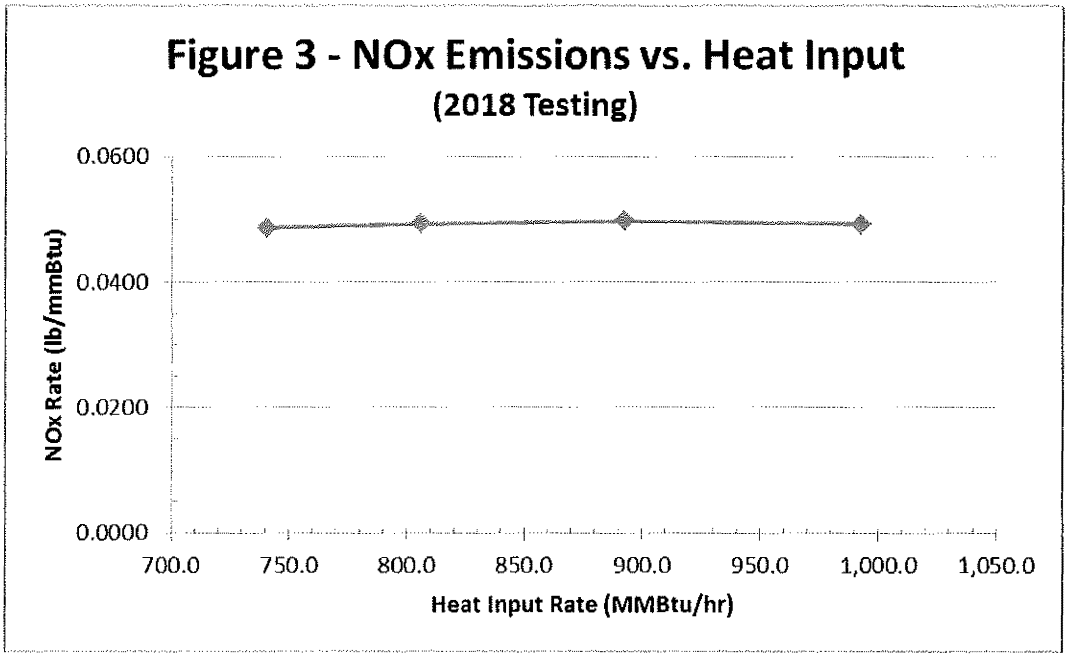
Table 1
Summary of EUCOMBTURB01 NOx Emission Results for Permit Compliance

Load	Emission Rates			Permit Limits	
	NOx (ppm dry @ 15% O_2)	NOx (lb/MMBtu)	NOx (lb/hr)	NOx (ppm dry @ 15%O_2)	NOx (lb/hr)
55 MW	13.21	0.0486	36.0	15 ppm	72.9 lb/hr
65 MW	13.41	0.0494	39.8		
75 MW	13.50	0.0497	44.4		
85.4 MW	13.38	0.0493	49.0		

This emissions test was also used to develop the correlation curve for estimation of NO_x emissions according to the methodology contained in 40 CFR Part 75, Appendix E. The average heat input (MMBtu/hr) and NO_x lb/MMBtu data at each of the four loads have been plotted along the x- and y-axis, respectively. The required Appendix E information is presented in the following table and figure.

Table 2
Summary of EUCOMBTURB01 Appendix E Emissions and Parametric Data

Heat Input (MMBtu/hr)	Nitrogen Oxides (lb/MMBtu)	Inlet Guide Vane [IGV] (Deg)	Compressor Discharge Temperature [CDT] (°F)	Compressor Discharge Pressure [CDP] (psi)	Exhaust Temperature [ET] (°F)
740.6	0.049	54.0	574.4	116.7	1,071.1
806.1	0.049	58.0	582.6	129.3	1,046.1
892.8	0.050	70.0	608.9	146.1	1,022.3
993.1	0.049	86.0	640.6	163.6	1,017.9
Vendor Ranges		42 - 86	520 - 725	90 - 220	950 – 1,125



The emissions test program was conducted following an approved emissions test protocol. The measurement uncertainty associated with this emissions test program includes the measurement uncertainty associated with the use of U.S. EPA Test Methods 3A, 7E, and 19 including:

- Uncertainty in Method 19 "F-factors" in terms of dscf/MMBtu, and
- Representative sampling locations for the reference method probe.

It would be virtually impossible to quantify the measurement uncertainty associated with the sampling location, however, this measurement uncertainty is mitigated for the reference method testing by moving the probe to three points across the stack in each of four ports during each emissions test run.

Because the emissions test program was conducted according to an approved emissions test plan, the measurement uncertainty for this emissions test program is considered adequate for the objectives of the emissions test program.

The results of all testing is presented in Tables 1 and 2. The following information is appended:

Appendix A – MAQS Calibration Error and Drift Correction Data
Appendix B – Field and Computer Generated Raw Data and Field Notes
Appendix C – Span Gas Certification Documentation
Appendix D – Example Calculations
Appendix E – Process Data
Appendix F – Test Program Correspondence
Appendix G – Compact Disk with all MAQS's CEMS data files

All testing performed was done in conformance to the ASTM D7036-04 standard. As required by 40 CFR 75, Appendix A, Section 6.1.2 (see certificate of accreditation in Appendix F), MAQS operated in conformance with the requirements of ASTM D7036-04 during this emissions test project and this emissions test report. The on-site emissions test program was supervised by Mr. Todd Wessel. Mr. Wessel's qualified individual certificate and information are also provided in Appendix F.

MEASUREMENT 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 Air Quality Services, LLC, (MAQS) personnel reduce the impact of these uncertainty factors through the use of approved and validated test methods. In addition, MAQS 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 our Quality Manual and ASTM D 7036-04. 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.

Limitations

The information and opinions rendered in this report are exclusively for use by CMS-Kalamazoo. MAQS will not distribute or publish this report without CMS-Kalamazoo's consent except as required by law or court order. MAQS accepts responsibility for the competent performance of its duties in executing the assignment and preparing reports in accordance with the normal standards of the profession, but disclaims any responsibility for consequential damages.

This report was prepared by: _____
Jacob Young
Staff Engineer

This report was reviewed by: _____
Randal J. Tysar, District Manager

Table 3
Detailed Summary of EUCOMBTURB01 NOx Emission Results
CMS Generation - Kalamazoo River Generation Station
November 1-2, 2018

Run	Date	Time	Power (MW)	NOx PPM DRY	O2 PPM	NOx PPM @ 15% O2	NOx lbs/mmBTU	NOx lbs/hr	Fuel Flow SCFH	BTU's BTU/scf
1	11/2/2018	0730-0800	55	13.66	14.86	13.34	0.0492	36.41	713650	1038
2	11/2/2018	0811-0841	55	13.39	14.87	13.10	0.0483	35.71	712710	1038
3	11/2/2018	0851-0921	55	13.44	14.88	13.17	0.0485	35.97	714120	1038
Average						13.21	0.0486	36.03		
4	11/2/2018	0936-1006	65	14.06	14.86	13.73	0.0506	40.77	776320	1038
5	11/2/2018	1017-1047	65	13.73	14.86	13.41	0.0494	39.80	776090	1038
6	11/2/2018	1059-1129	65	13.38	14.86	13.07	0.0481	38.86	777480	1038
Average						13.41	0.0494	39.81		
7	11/1/2018	1204-1239	75	13.6	14.92	13.42	0.0494	44.12	860620	1038
8	11/1/2018	1252-1322	75	13.57	14.9	13.34	0.0492	43.86	860340	1038
9	11/1/2018	1333-1403	75	13.94	14.91	13.73	0.0506	45.08	859390	1038
Average						13.50	0.0497	44.35		
10	11/1/2018	1422-1450	85.4	13.72	14.73	13.12	0.0483	47.91	955980	1038
11	11/1/2018	1503-1531	85.4	13.84	14.75	13.28	0.0489	48.48	955680	1038
12	11/1/2018	1543-1613	85.4	14.19	14.81	13.75	0.0506	50.35	958650	1038
Average						13.38	0.0493	48.91		

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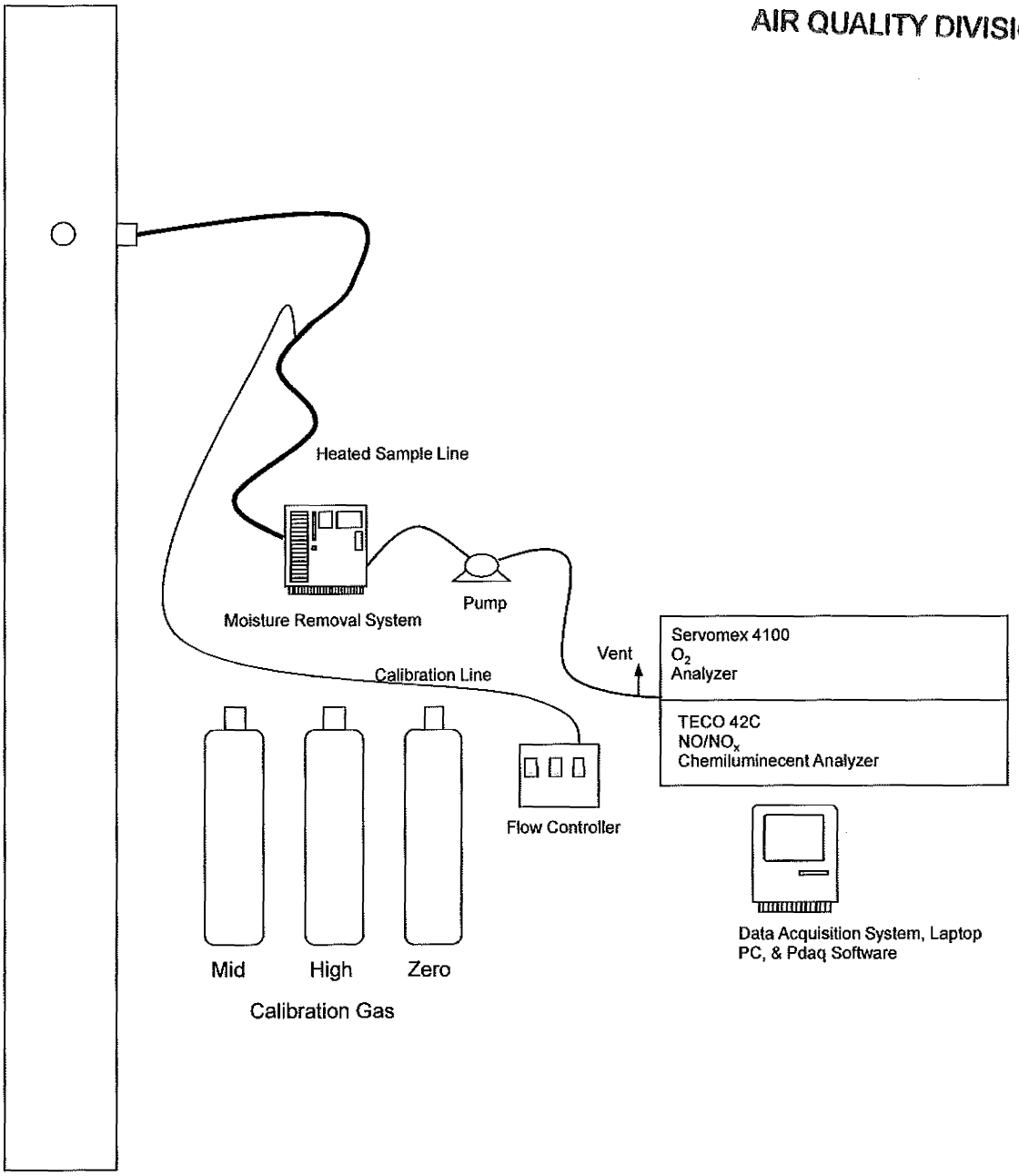

Figure No. 1

Site: **USEPA Method 3A and 7E** **CMS Energy** **Comstock TWP, Michigan**	**Sampling Date:** **November 1-2, 2018**	**Montrose Air Quality Services, LLC** **4949 Fernlee Avenue** **Royal Oak, Michigan 48073**

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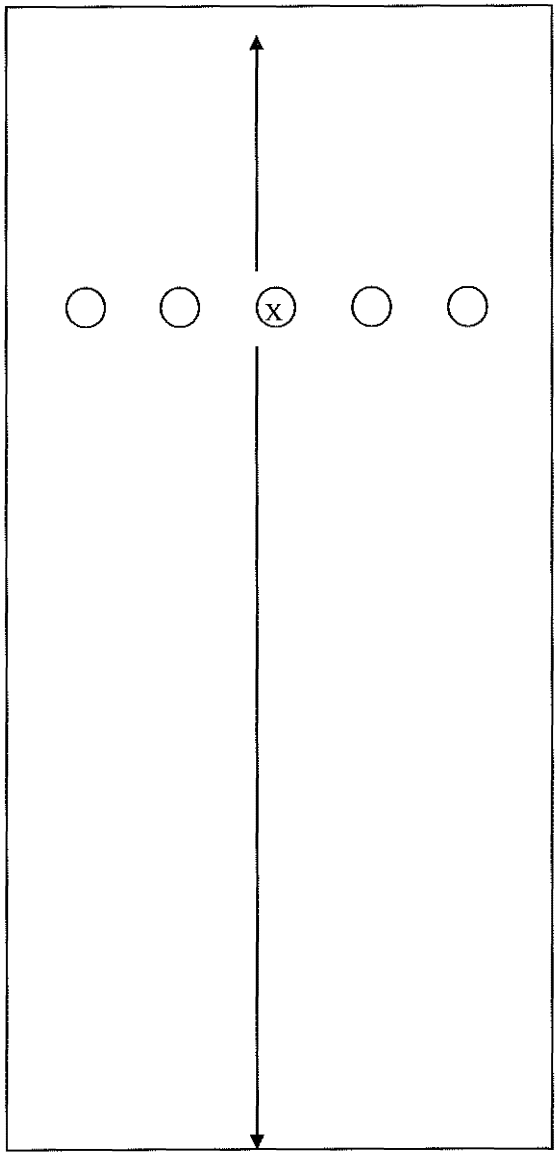
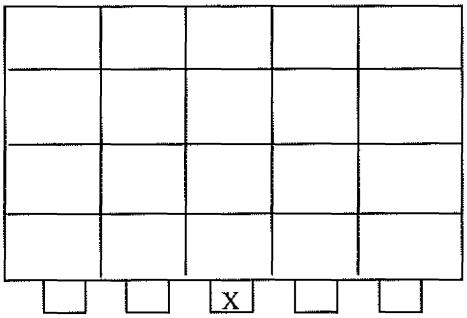
Stack Dimensions: 137.75" X 173.75"





Not to Scale

Note: The middle port was inaccessible and was not sampled

Figure No. 2

Site: **EUCOMTURB01 (Turbine 1)** **CMS Energy** **Comstock TWP, Michigan**	**Sampling Date:** **November 1-2, 2018**	**Montrose Air Quality Services, LLC** **4949 Fernlee Avenue** **Royal Oak, Michigan 48073**