BTEC Inc.

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
(313) 617-3782

Project No. 14-4494.00
April 25, 2014

BT Environmental Consulting, Inc.
4949 Fernlee Avenue
Royal Oak, Michigan 48073
(248) 548-8070

BTEC Inc.

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Executive Summary

BT Environmental Consulting, Inc. (BTEC) was retained by CMS Generation – Kalamazoo River Generation Station (CMS-Kalamazoo) to evaluate oxides of nitrogen (NOx) emission rates from 1 combustion turbine at the CMS-Kalamazoo facility located in Kalamazoo, Michigan. To permit the determination of NO_x lb/mmBtu emission rates and NO_x concentrations corrected to 15% O_2, simultaneous NO_x and O_2 concentration measurements were obtained. The emission testing was conducted on March 14th, 2014.

The emissions test program was conducted consistent with the BTEC Emissions Test Plan dated January 24th, 2014 and submitted to Air Quality Division (AQD) of Michigan's Department of Environmental Quality (see Appendix F for test plan approval letter). The testing was performed to demonstrate compliance with Michigan Department of Environmental Quality (MDEQ) Permit No. MI-ROP-N6731-2011 and in accordance with Appendix E, 40 CFR, Part 75, and U.S. EPA Reference Methods 3A, 7E, and 19 found in 40 CFR, Part 60, Appendix A. The turbine was tested at 4 different loads between 66 MW and 72 MW. Testing during each load consisted of triplicate 24-minute test runs while combusting natural gas.

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

Table E-1
Executive Summary of EUCOMTURB01 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)
72 MW	12.34	0.045	40.8	15 ppm	48.3 lb/hr
70 MW	11.92	0.044	38.6	15 ppm	48.3 lb/hr
68 MW	11.28	0.042	35.7	15 ppm	48.3 lb/hr
66 MW	11.78	0.043	36.3	15 ppm	48.3 lb/hr

1.0 Introduction

BT Environmental Consulting, Inc. (BTEC) was retained by CMS Generation – Kalamazoo River Generation Station (CMS-Kalamazoo) to evaluate oxides of nitrogen (NOx) emission rates from 1 combustion turbine at the CMS-Kalamazoo facility located in Kalamazoo, Michigan. To permit the determination of NO_x lb/mmBtu emission rates and NO_x concentrations corrected to 15% O_2, simultaneous NO_x and O_2 concentration measurements were obtained.

The emissions test program was conducted consistent with the BTEC Emissions Test Plan dated January 24th, 2014 and submitted to Air Quality Division (AQD) of Michigan's Department of Environmental Quality (see Appendix F for test plan approval letter). The testing was performed to demonstrate compliance with Michigan Department of Environmental Quality (MDEQ) Permit No. MI-ROP-N6731-2011 and in accordance with Appendix E, 40 CFR, Part 75, and U.S. EPA Reference Methods 3A, 7E, and 19 found in 40 CFR, Part 60, Appendix A. The turbine was tested at 4 different loads between 66 MW and 72 MW. Testing during each load consisted of triplicate 24-minute test runs while combusting natural gas.

The emission testing was conducted on March 14th, 2014. BTEC personnel Matt Young and Paul Molenda performed the testing. Mr. Nathan Hude from the MDEQ was onsite to witness the test program. Mr. Thomas Andreski and Mr. Timothy Morrison of CMS assisted the study by coordinating process test times and gathering process data.

2.0 Process Description

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

The turbine has a maximum output capacity of approximately 73 Megawatts (MW) and 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 BTEC'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- Determinations of Oxygen and Carbon Dioxide Concentrations in Emissions From Stationary Sources;
- Method 7E - Determination of Nitrogen Oxides Emissions From Stationary Sources;

BTEC'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.

There is a one hour time difference between BTEC's DAS and CMS's DAS (BTEC time 8:50 = CMS time 7:50).

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; 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) used was provided by CMS-Kalamazoo and was used to calculate the NO_x emissions on a lb/hr basis.

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)

A M&C PMA 100L non-dispersive infra-red (NDIR) 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 42i-HL Chemiluminescence 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. BTEC 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 are summarized by Table 1.

Table 1
Summary of EUCOMTURB01 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)
72 MW	12.34	0.045	40.8	15ppm	48.3 lb/hr
70 MW	11.92	0.044	38.6	15ppm	48.3 lb/hr
68 MW	11.28	0.042	35.7	15ppm	48.3 lb/hr
66 MW	11.78	0.043	36.3	15ppm	48.3 lb/hr

The emissions test program was conducted following an approved emissions test protocol (see Appendix F for a copy of the test plan approval letter). 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:

- Inaccuracy 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 duct 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 – BTEC 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 – Compact Disk with all BTEC's CEMS data files
Appendix F – Test Plan Approval Letter

Limitations

The information and opinions rendered in this report are exclusively for use by CMS-Kalamazoo. BTEC will not distribute or publish this report without CMS-Kalamazoo's consent except as required by law or court order. BTEC 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.

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REPORT SIGNATURES

BTEC operated in conformance with the requirements of ASTM D7036-04 during this emissions test project and this emissions test report. All testing was conducted/supervised at all times by a Qualified Individual (QI) as defined in 40 CFR Part 72.2.:

This report was prepared by: Brandon Chase

Brandon V. Chase
Quality Manager

This report was reviewed by: Randal J. Tyser

Randal J. Tyser
Technical Manager

Table 1
Summary of EUCOMTURB01 NOx Emission Results

Load	Emission Rates			Permit Limits	
	NOx (ppm @15% O_2)	NOx (Lb/MMBtu)	NOx lb/hr	NOX (ppm @ 15%O_2)	NOX (lb/hr)
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Table 2
Detailed Summary of EUCOMTURB01 NOx Emission Results
CMS Generation - KalamazooRiver Generation Station
March 14th, 2014

Load Set Point	Load				Summary of Per Run Averages for DAHS Data									Drift Corrected as per Method 7E		Emission Results			Load Set Point
MW	(% Load Based on Rating of 73.5 MW)	Run No.	Start Date/Time	EndDate/Time	No. of Values	Comp Dis (psia)	Exh Temp (oF)	Gas Flow (HSCFH)	Gas GCV (Btu/scf)	Gross Heat Input (mmBtu/hr)	Inlet Temp (°F)	Load (MW)	Pitch (Degrees)	NOx Conc. (ppmvd)	O2 Conc. (Vol-%)	NOx Conc. (ppmvd @15% O2)	NOx Rate (lb/mmBtu)	NOx Mass Emissions (lbs/hr)	
72	98.0%	1	3/14/2014 7:50	3/14/2014 8:25	36	142.6	1,013.60	8,846.10	1,014.00	897.0	593.2	72.1	70.7	12.57	14.97	12.51	0.046	41.3	
72	98.0%	2	3/14/2014 8:30	3/14/2014 9:05	36	142.9	1,015.30	8,857.10	1,014.00	898.1	596.2	72.1	71.5	12.47	15.10	12.69	0.047	42.0	72MW
72	98.0%	3	3/14/2014 9:25	3/14/2014 10:00	36	143.3	1,018.70	8,872.90	1,014.00	899.7	602.3	72.1	72.6	11.56	15.13	11.82	0.044	39.2	
70	95.2%	1	3/14/2014 10:20	3/14/2014 10:55	36	139.7	1,019.50	8,677.20	1,014.00	879.9	600.4	70.1	70.3	12.05	14.96	11.97	0.044	38.8	
70	95.2%	2	3/14/2014 11:00	3/14/2014 11:35	36	139.9	1,021.70	8,679.80	1,014.00	880.1	601.9	70.1	70.8	12.8	14.77	12.32	0.045	39.9	70MW
70	95.2%	3	3/14/2014 11:40	3/14/2014 12:12	33	140.1	1,023.80	8,664.40	1,014.00	878.6	605.3	70.1	71.2	11.7	14.89	11.49	0.042	37.2	
68	92.5%	1	3/14/2014 12:30	3/14/2014 13:00	31	136.3	1,024.10	8,462.50	1,014.00	858.1	601.1	68.1	68.5	11.29	15.06	11.41	0.042	36.1	
68	92.5%	2	3/14/2014 13:10	3/14/2014 13:42	33	136.6	1,024.60	8,468.70	1,014.00	858.7	604.3	68.1	69	10.96	15.09	11.13	0.041	35.2	68MW
68	92.5%	3	3/14/2014 13:45	3/14/2014 14:15	31	136.5	1,024.20	8,464.30	1,014.00	858.3	601.9	68.1	68.9	11.21	15.05	11.31	0.042	35.7	
66	89.8%	1	3/14/2014 14:35	3/14/2014 15:06	32	132.8	1,029.20	8,248.70	1,014.00	836.4	596.9	66	66.1	11.37	15.04	11.45	0.042	35.3	
66	89.8%	2	3/14/2014 15:10	3/14/2014 15:40	31	132.9	1,029.30	8,252.60	1,014.00	836.8	597.4	66.1	66.3	11.36	15.08	11.52	0.042	35.5	66MW
66	89.8%	3	3/14/2014 15:40	3/14/2014 16:11	32	132.9	1,029.00	8,267.30	1,014.00	838.3	595.2	66.1	66.1	12.22	15.08	12.39	0.046	38.3	

		No. of Values	Comp Dis (psia)	Exh Temp (oF)	Gas Flow (HSCFH)	Gas GCV (Btu/scf)	Gross Heat Input (mmBtu/hr)	Inlet Temp (°F)	Load (MW)	Pitch (Degrees)	NOx Conc. (ppmvd)	O2 Conc. (Vol-%)	NOx Conc. (ppmvd @15% O2)	NOx Rate (lb/mmBtu)	NOx Mass Emissions (lbs/hr)	Load Set Point
98.0%	3-run Averages	36	142.9	1015.87	8858.70	1014.00	898.27	597.23	72.10	71.60	12.20	15.07	12.34	0.045	40.8	72MW
95.2%	3-run Averages	35	139.9	1021.67	8673.80	1014.00	879.52	602.53	70.10	70.77	12.18	14.87	11.92	0.044	38.6	70MW
92.5%	3-run Averages	32	136.5	1024.30	8465.17	1014.00	858.37	602.43	68.10	68.80	11.15	15.07	11.28	0.042	35.7	68MW
89.8%	3-run Averages	32	132.9	1029.17	8256.20	1014.00	837.18	596.50	66.07	66.17	11.65	15.07	11.78	0.043	36.3	66MW

Figures

BTEC Inc.

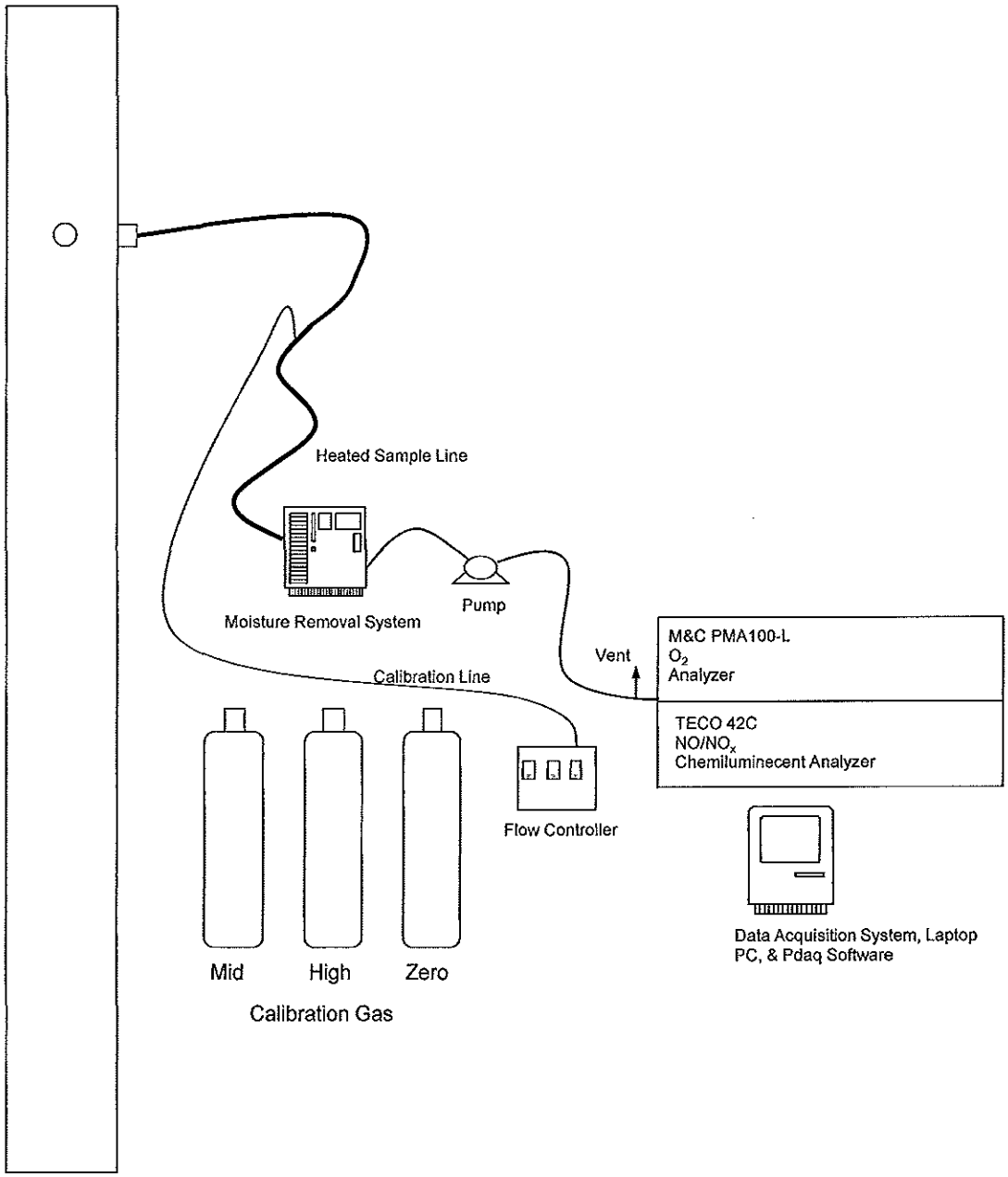

Figure No. 1

Site:	Sampling Date:	
USEPA Method 3A and 7E CMS Energy Comstock TWP, Michigan	March 14, 2014	BT Environmental Consulting Inc. 4949 Fernlee Avenue Royal Oak, Michigan 48073

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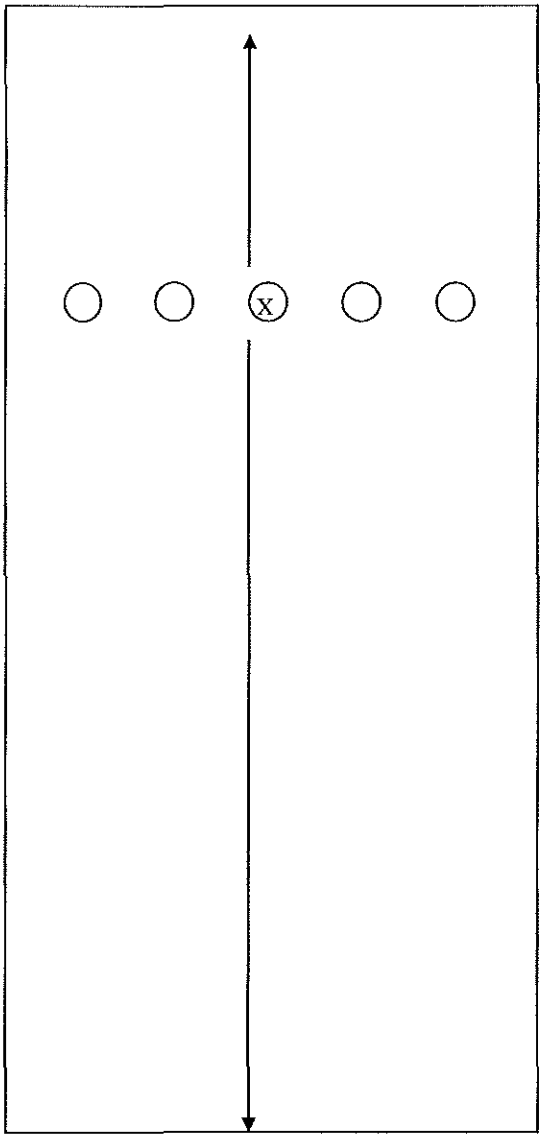
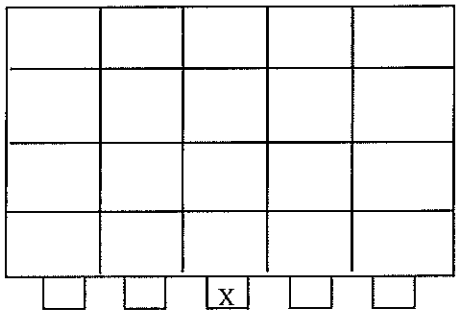
Stack Dimensions: 137.75" X 173.75"





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:** **March 14, 2014**	**BT Environmental Consulting Inc.** **4949 Fernlee Avenue** **Royal Oak, Michigan 48073**