



# **Turbines 1, 2, 3, and 4 NO<sub>x</sub>, O<sub>2</sub>, and CO Emissions Test Report**

*Prepared for:*

**CMS Generation Michigan Power L.L.C  
Livingston Generation Station**

Gaylord, Michigan

CMS Generation Michigan Power LLC  
Livingston Generation Station  
North Townline Road  
Gaylord, MI 49735

**RECEIVED**

**AUG 25 2017**

**AIR QUALITY DIVISION**

Project No. 17-5063.00  
August 22, 2017

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



**Executive Summary Table E-2  
Turbine 2 Summary of NOx and CO Emissions**

<b>Load</b>	<b>NOx pmm @ 15% O<sub>2</sub></b>	<b>CO lb/mmbtu</b>	<b>NOx lb/hr</b>
100%	75	0.37	137.3
95%	75	0.35	133.0
90%	71	0.39	104.7
85%	66	0.44	109.1
<b>Limit</b>	<b>75 ppm</b>	<b>0.48 lb/mmbtu</b>	<b>624.0lb/hr<sup>1</sup></b>

ppm: Part per million

15% O<sub>2</sub>: Concentration corrected to 15% Oxygen

Lb/mmBtu: Pound per million British thermal unit

Lb/hour: Pound per hour

1: Limit is for all four turbines combined (Turbines 1-4)

**Executive Summary Table E-3  
Turbine 3 Summary of NOx and CO Emissions**

<b>Load</b>	<b>NOx pmm @ 15% O<sub>2</sub></b>	<b>CO lb/mmbtu</b>	<b>NOx lb/hr</b>
100%	61	0.34	118.9
95%	61	0.32	113.3
90%	62	0.33	110.3
85%	60	0.37	104.6
<b>Limit</b>	<b>75 ppm</b>	<b>0.48 lb/mmbtu</b>	<b>624.0lb/hr<sup>1</sup></b>

ppm: Part per million

15% O<sub>2</sub>: Concentration corrected to 15% Oxygen

Lb/mmBtu: Pound per million British thermal unit

Lb/hour: Pound per hour

1: Limit is for all four turbines combined (Turbines 1-4)



**Executive Summary Table E-4  
Turbine 4 Summary of NOx and CO Emissions**

<b>Load</b>	<b>NOx pmm @ 15% O<sub>2</sub></b>	<b>CO lb/mmbtu</b>	<b>NOx lb/hr</b>
100%	69	0.33	122.0
95%	67	0.32	114.8
90%	67	0.32	108.2
85%	65	0.35	101.4
<b>Limit</b>	<b>75 ppm</b>	<b>0.48 lb/mmbtu</b>	<b>624.0lb/hr<sup>1</sup></b>

ppm: Part per million

15% O<sub>2</sub>: Concentration corrected to 15% Oxygen

Lb/mmBtu: Pound per million British thermal unit

Lb/hour: Pound per hour

1: Limit is for all four turbines combined (Turbines 1-4)





### 1.b Purpose of Testing

Turbine 1 is included in Michigan Renewable Operating Permit MI-ROP-N6526-2014a. The emission limits relevant to this emissions test program are summarized by Table 1.

**Table 1**  
**Operating Permit MI-ROP-N6526-2014a Emission Limits**  
**Turbines 2-4**

Pollutant	Limit
Nitrogen Oxides (NO <sub>x</sub> )	624.0 lb/hr <sup>1</sup>
	75 ppm @ 15%O <sub>2</sub>
Carbon Monoxide (CO)	0.48 lb/mmbtu

<sup>1</sup>: Limit is for all four turbines combined (Turbines 1-4)

### 1.c Source Description

The CMS-Gaylord facility located in Gaylord, Michigan operates four simple-cycle Turbines that fire natural gas (NG).

Each turbine is nominally rated at an output capacity of 39 Megawatts (MW). The turbines use natural gas as a primary fuel. The turbine generator consists of a compressor, combustion turbine, and generator. Energy is generated at the combustion turbine by drawing in ambient air by means of burning fuel and expanding the hot combustion gases in a three-stage turbine. A water injection system minimizes the emissions of nitrogen oxides from the turbines, while the emissions of CO and SO<sub>2</sub> are minimized by the efficient combustion of low sulfur bearing clean-burning fuels.

### 1.d Test Program Contact

Facility Contact:  
Mr. Steve Ellison  
CMS Generation Michigan Power LLC  
Livingston Generation Station  
North Townline Road  
Gaylord, MI 49735  
(989) 705-2552

Testing Team Contact:  
Mr. Todd Wessel  
Senior Project Manager  
BT Environmental Consulting, Inc.  
4949 Fernlee Ave  
Royal Oak, Michigan 48073  
Phone (616) 885-4013



## 1.e Testing Personnel

Names and affiliations for personnel who were present during the testing program are summarized by Table 2.

**Table 2**  
**Test Personnel**

<b>Name and Title</b>	<b>Affiliation</b>	<b>Telephone</b>
Mr. Steve Ellison	CMS Generation Michigan Power LLC Livingston Generation Station North Townline Road Gaylord, MI 49735	(989) 705-2552
Mr. Todd Wessel Senior Project Manager	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(616) 885-4013
Mr. Dave Trahan Environmental Technician	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(248) 548-8070
Mr. Dave Patterson		

## 2. Summary of Results

Sections 2.a through 2.d summarize the results of the emissions compliance test program.

### 2.a Operating Data

The following information was collected during the performance test:

1. Date, time, MW load
2. Natural gas flow
3. Water injection rate
4. Compressor temperature and pressure

### 2.b Applicable Permit

The applicable permit for this emissions test program is Michigan Renewable Operating Permit No. MI-ROP-N6526-2014a.

### 2.c Results



The overall results of the emissions compliance test program are summarized by Tables 3-6 (see Section 5.a). Detailed results for each engine can be found in Tables 7-10.

## **2.d Emission Regulation Comparison**

Emission limitations are summarized by Table 1.

## **3. Source Description**

Sections 3.a through 3.d provide a detailed description of the process.

### **3.a Process Description**

The CMS-Gaylord Generating Plant, located in Gaylord, Michigan, is owned and operated by CMS Generation Michigan Power LLC, Livingston Generation Station. The plant contains four Dresser-Rand combustion turbines that are utilized to generate electrical power. Each of the turbines (4) are rated at 39 Megawatts (MW) however, this rating is not achievable during the summer months. For this testing project the maximum achievable MW is approximately 33.0.

### **3.b Raw and Finished Materials**

The raw material supplied to the turbine includes natural gas. The finished material is electricity.

### **3.c Process Capacity**

Each turbine is nominally rated at an output capacity of approximately 39 Megawatts (MW).

### **3.d Process Instrumentation**

Process data monitored during the emissions test program is provided in Appendix E.

## **4. Sampling and Analytical Procedures**

Sections 4.a through 4.d provide a summary of the sampling and analytical procedures used to verify emission rates from the turbines.

### **4.a Sampling Train and Field Procedures**

Sampling and analysis procedures utilized the following test methods codified at Title 40, Part 60, Appendix A of the Code of Federal Regulations (40 CFR 60, Appendix A):

- Method 3A - "Determination of Molecular Weight of Dry Stack Gas"

- Method 7E - “Determination of Nitrogen Oxide Emissions from Stationary Sources”
- Method 10 - “Determination of Carbon Monoxide 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 10-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 D.

A detailed stratification traverse was conducted on the turbine during the first test run. The results of the traverse document that the turbine is not stratified. Therefore the sample gas was extracted at a four sampling points in each sampling port. Each test run sampled a different sampling port as illustrated in Figure 2. Twelve 24-minute test runs were conducted, three test runs at each load (4) on the turbine. A diagram of the reference monitoring system is illustrated in Figure 1.

The turbine NOx concentrations were measured in parts per million (ppm). The NOx concentration was converted to an emission rate and reported as Lb/MMBtu, using equation 19-1 of U.S. EPA Method 19 of Appendix A, 40 CFR 60. NOx concentrations were corrected to 15 percent oxygen using the equation below. Oxygen concentrations are reported in percent (%).

The calculation illustrated below utilizes dry bias corrected pollutant concentrations and the associated dry bias corrected O<sub>2</sub> concentrations.

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

where:

$C_{adj}$	=	Pollutant concentration corrected to 15 percent O <sub>2</sub> ppm.
$C_d$	=	Pollutant concentration measured, dry basis, ppm.
$\%O_2$	=	Measured O <sub>2</sub> concentration dry basis, percent.

In accordance with Method 7E, a 3-point (zero, mid, and high) bias check and calibration check was performed on the each analyzer prior to initiating the test program. Following each test run, a 2-point (zero and high) calibration drift check was performed. The NO<sub>x</sub> analyzer was operated at the 0-100 ppm range, the CO analyzer was operated in the 0-1000 ppm range and was calibrated in the 0-1000 range and in the 0-100 range, and the oxygen analyzer was operated in the 0-25% range. A USEPA Method 7E NO<sub>2</sub> to NO conversion efficiency test was performed and the results are included in Appendix E.

#### **4.b Recovery and Analytical Procedures**

Recovery and analytical procedures were described in Section 4.a.

#### **4.c Sampling Ports**

Figure 1 documents the exhaust stack dimensions and approximate sampling point locations.

#### **4.d Traverse Points**

Sixteen sampling points were tested for stratification in accordance with US EPA Method 7E, section 8.1.2. The mean concentration of the oxygen in the stack was approximately 16.77% with a maximum deviation of 0.08%. Therefore the turbine was deemed unstratified. The turbine exhaust stack is approximately 60 feet in height. The turbine exhaust gas flows through a rectangular exhaust duct with dimensions of 137.75 inches by 173.75 inches. Figure 1 documents the exhaust stack dimensions and approximate sampling point locations.

### **5. Test Results and Discussion**

Sections 5.a through 5.k provide a summary of the test results.

### 5.a Results Tabulation

The results of the emissions test program are summarized by Tables 3-5.

**Table 3  
Turbine 1 NOx and CO Summary**

<b>Load</b>	<b>NOx pmm @ 15% O<sub>2</sub></b>	<b>CO lb/mmBtu</b>	<b>NOx lb/hr</b>
100%	75	0.33	125.8
95%	77	0.31	126.9
95% *	71	0.36	116.0
90%	75	0.31	117.9
85%	75	0.30	103.1
<b>Limit</b>	<b>75 pmm</b>	<b>0.48 lb/mmBtu</b>	<b>624.0lb/hr<sup>1</sup></b>

ppm: Part per million

15% O<sub>2</sub>: Concentration corrected to 15% Oxygen

Lb/mmBtu: Pound per million British thermal unit

Lb/hour: Pound per hour

1: Limit is for all four turbines combined (Turbines 1-4)

\*The water injection ratio was changed and the 95% load was retested

**Table 4  
Turbine 2 NOx and CO Summary**

<b>Load</b>	<b>NOx pmm @ 15% O<sub>2</sub></b>	<b>CO lb/mmBtu</b>	<b>NOx lb/hr</b>
100%	75	0.37	137.3
95%	75	0.35	133.0
90%	71	0.39	104.7
85%	66	0.44	109.1
<b>Limit</b>	<b>75 pmm</b>	<b>0.48 lb/mmBtu</b>	<b>624.0lb/hr<sup>1</sup></b>

ppm: Part per million

15% O<sub>2</sub>: Concentration corrected to 15% Oxygen

Lb/mmBtu: Pound per million British thermal unit

Lb/hour: Pound per hour

1: Limit is for all four turbines combined (Turbines 1-4)

**Table 5  
Turbine 3 NOx and CO Summary**

<b>Load</b>	<b>NOx pmm @ 15% O<sub>2</sub></b>	<b>CO lb/mmBtu</b>	<b>NOx lb/hr</b>
100%	61	0.34	118.9
95%	61	0.32	113.3
90%	62	0.33	110.3
85%	60	0.37	104.6
<b>Limit</b>	<b>75 pmm</b>	<b>0.48 lb/mmBtu</b>	<b>624.0lb/hr<sup>1</sup></b>

ppm: Part per million  
 15% O<sub>2</sub>: Concentration corrected to 15% Oxygen  
 Lb/mmBtu: Pound per million British thermal unit  
 Lb/hour: Pound per hour  
 1: Limit is for all four turbines combined (Turbines 1-4)

**Table 6  
Turbine 4 NOx and CO Summary**

<b>Load</b>	<b>NOx pmm @ 15% O<sub>2</sub></b>	<b>CO lb/mmBtu</b>	<b>NOx lb/hr</b>
100%	69	0.33	122.0
95%	67	0.32	114.8
90%	67	0.32	108.2
85%	65	0.35	101.4
<b>Limit</b>	<b>75 pmm</b>	<b>0.48 lb/mmBtu</b>	<b>624.0lb/hr<sup>1</sup></b>

ppm: Part per million  
 15% O<sub>2</sub>: Concentration corrected to 15% Oxygen  
 Lb/mmBtu: Pound per million British thermal unit  
 Lb/hour: Pound per hour  
 1: Limit is for all four turbines combined (Turbines 1-4)

Detailed data for each test run can be found in Tables 7-10.

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**5.b Discussion of Results**

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Emission limitations for Michigan Renewable Operating Permit MI-ROP-N6526-2014a are summarized by Table 1 (see section 1.b) and Tables 3-5 (see section 5.c). The results of the emissions test program are summarized by Tables 3-5 (see section 5.a). Detailed data for each test run can be found in Tables 6-8.

**5.c Sampling Procedure Variations**

As discussed in section 4a, the the CO analyzer was operated in the 0-1000 ppm range and was calibrated in the 0-1000 range and in the 0-100 range. Linearity checks (calibration error) were conducted in each range to demonstrate the instruments accuracy across the ranges. Since the CO concentration in the stack was closer to the 88.65 calibration gas rather than the 480.1 calibration gas this gas was utilized throughout the testing study.

A detailed stratification traverse was conducted on the turbine during the first test run. The results of the traverse document that the turbine is not stratified. Therefore the sample gas was extracted at a four sampling points in each sampling port. Each test run sampled a different sampling port as illustrated in Figure 2. This was done due to the fact that the turbine operates in excess of 1000 degrees F and each port change takes a significant amount of time as well as the safety factors associated with testing hot sources.

All of the sampling variations were discussed and approved on site with the MDEQ representatives.

**5.d Process or Control Device Upsets**

While testing Turbine No. 1 it was noted that at the 95% load the turbine exceeded the permissible permit limit of 75 ppm NO<sub>x</sub> at 15% Oxygen. The water injection ratio was changed and that load level was retested with passing results.

**5.e Control Device Maintenance**

No control device maintenance was performed during the testing.

**5.f Audit Sample Analyses**

No audit samples were collected as part of the test program.

**5.g Calibration Sheets**

All relevant equipment calibration documents are provided as Appendix C.



#### **5.h Sample Calculations**

Sample calculations are provided in Appendix D.

#### **5.i Field Data Sheets**

Field documents relevant to the emissions test program are presented in Appendix B.

#### **5.j Laboratory Data**

No laboratory analysis was included in this test program.







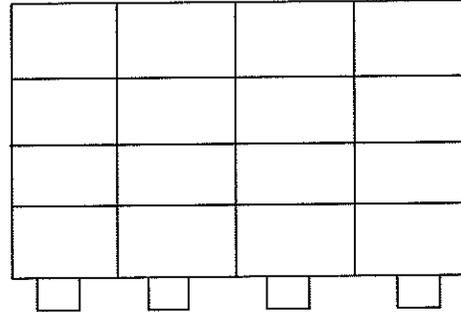
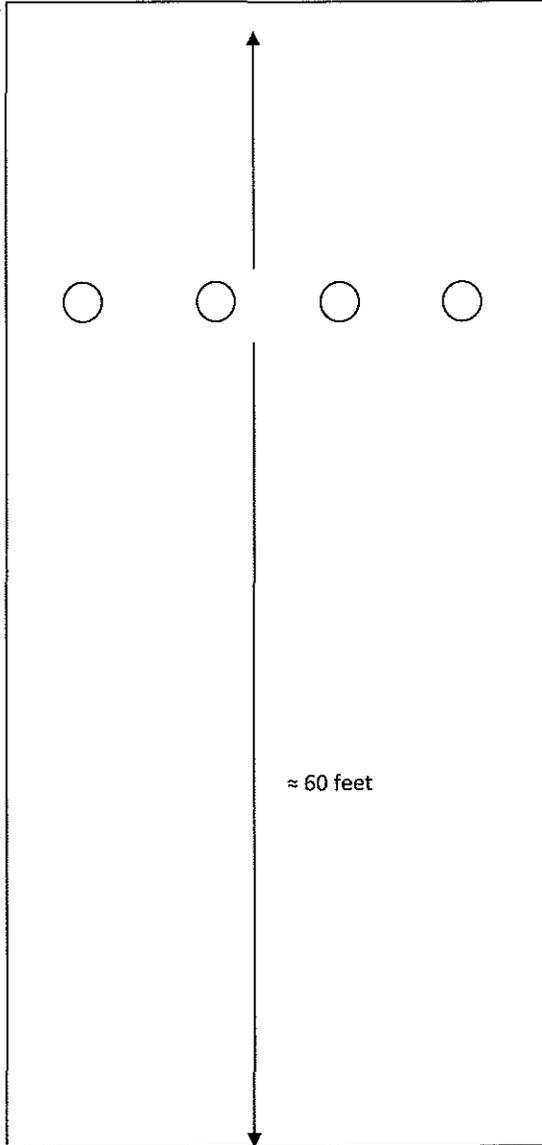




Stack Dimensions:

Depth: 137.75 inches

Width: 173.75 inches



Not to Scale

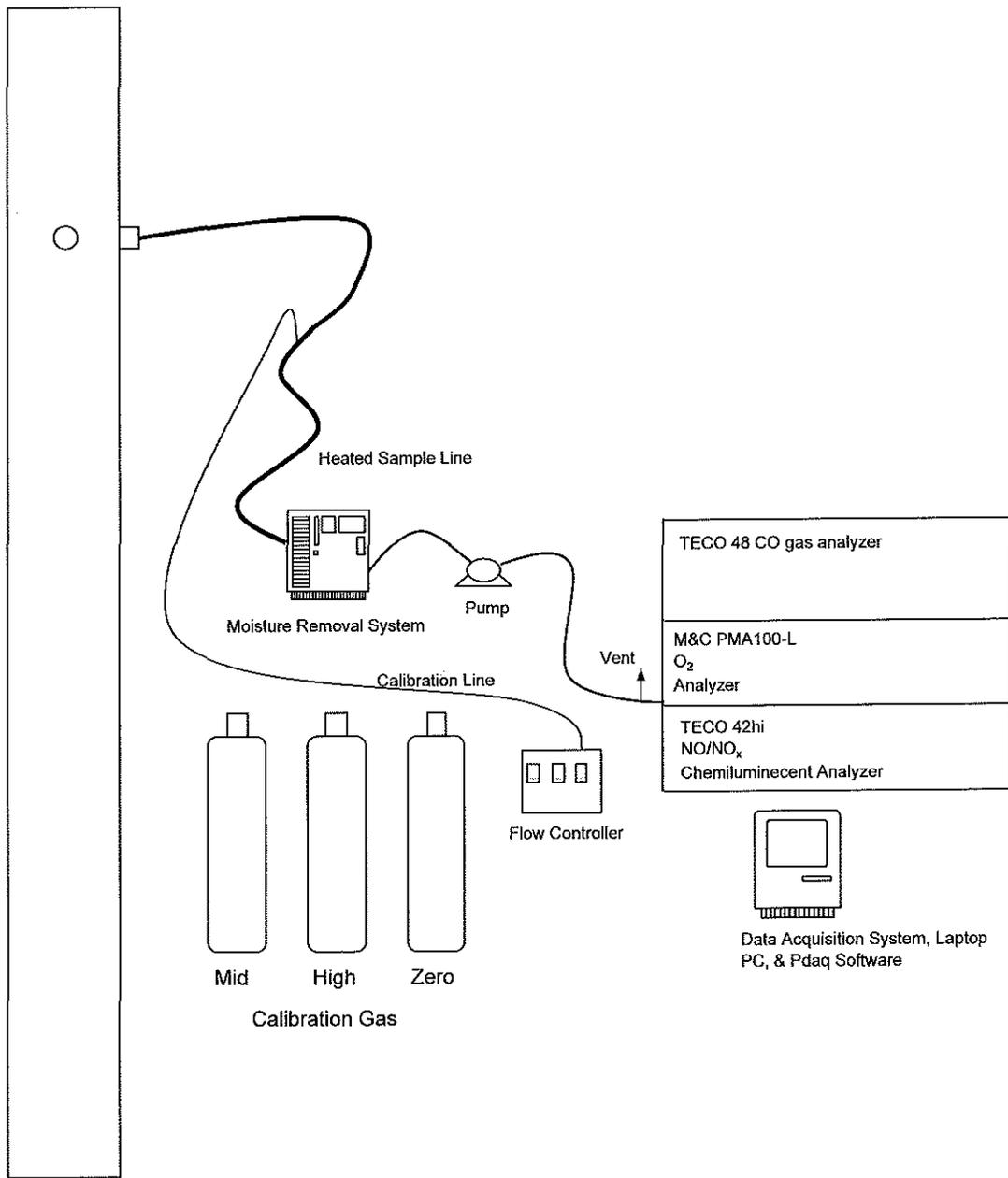
Points	Distance "
1	17.2
2	51.7
3	86.1
4	120.5

Figure No. 1

Site:  
Turbine 1-4  
CMS Energy  
Gaylord, Michigan

Sampling Date:  
June 27-30, 2017

BT Environmental Consulting,  
Inc.  
4949 Fernlee Avenue  
Royal Oak, Michigan 48073



**Figure No. 2**

<p><b>Site:</b> USEPA Method 3A, 7E, and 10 CMS Generation Michigan Power L.L.C. Gaylord, Michigan</p>	<p><b>Sampling Date:</b> June 27-30, 2017</p>	<p><b>BT Environmental Consulting Inc.</b> 4949 Fernlee Avenue Royal Oak, MI 48073</p>
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