



Boiler 9 and Turbines 7 and 8 Emissions Test Report

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Prepared for:

Western Michigan University

Kalamazoo, Michigan

Location: Western Michigan University
Robert M. Beam Power Plant
Kalamazoo, Michigan

Project No. 15-4732.00
January 13, 2016

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



EXECUTIVE SUMMARY

BT Environmental Consulting, Inc. (BTEC) was retained by Western Michigan University (WMU) to measure oxides of nitrogen (NO_x) emission rates from one boiler and NO_x and carbon monoxide (CO) emission rates from two turbines located at the WMU Robert M. Beam Power Plant in Kalamazoo, Michigan. Specifically, the emissions test program included measurement of NO_x and CO emission rates from the Turbines 7 and 8 cogeneration systems and measurement of NO_x emission rates from Boiler 9. On-site testing coordination was provided by NTH Consultants, Ltd. (NTH) on behalf of WMU. The facility operates under Michigan Department of Environmental Quality (MDEQ) Renewable Operating Permit (ROP) No. MI-ROP-K2131-2015a.

The emissions test program was conducted on November 17 and 18, 2015. The results of the emission test program are summarized by Table I.

Table I
Turbines 7 and 8 Cogeneration Systems and Boiler 9
Emissions Test Results Summary
Test Dates: November 17 and 18, 2015

Emission Unit	Pollutant	Emission Limitation	Emission Test Result
Boiler 9	NO _x	0.09 lbs/MMBtu	0.08 lbs/MMBtu
Turbine 7	NO _x	42 ppmvd @ 15% O ₂	24 ppmvd @ 15% O ₂
	NO _x	12.0 lbs/hr	8.9 lbs/hr
	CO	50 ppmvd @ 15% O ₂	4 ppmvd @ 15% O ₂
	CO	8.8 lbs/hr	1.0 lbs/hr
Turbine 8	NO _x	42 ppmvd @ 15% O ₂	18 ppmvd @ 15% O ₂
	NO _x	12.0 lbs/hr	6.9 lbs/hr
	CO	50 ppmvd @ 15% O ₂	4 ppmvd @ 15% O ₂
	CO	8.8 lbs/hr	0.9 lbs/hr

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1. Introduction

BT Environmental Consulting, Inc. (BTEC) was retained by Western Michigan University (WMU) to measure oxides of nitrogen (NO_x) emission rates from one boiler and NO_x and carbon monoxide (CO) emission rates from two turbines located at the WMU Robert M. Beam Power Plant in Kalamazoo, Michigan. Specifically, the emissions test program included measurement of NO_x and CO emission rates from the Turbines 7 and 8 cogeneration systems and measurement of NO_x emission rates from Boiler 9. On-site testing coordination was provided by NTH Consultants, Ltd. (NTH) on behalf of WMU. The facility operates under Michigan Department of Environmental Quality (MDEQ) Renewable Operating Permit (ROP) No. MI-ROP-K2131-2015a.

WMU recently received waivers from ROP performance testing at Boiler 6, Boiler 9 on fuel oil, and Heat Recovery Steam Generators (HRSGs) 7 and 8 in fresh air firing mode, due to very limited historic usage. Specifically, on May 11, 2015, MDEQ waived testing requirements for NO_x and CO at HRSGs 7 and 8 in fresh air fired mode, and on June 30, 2015, MDEQ waived testing requirements for NO_x and CO at Boiler 6 and NO_x at Boiler 9 while firing fuel oil. Copies of MDEQ's waiver letters are provided in Appendix A.

The emissions test program was conducted on November 17 and 18, 2015. The purpose of this report is to document the results of the test program.

AQD has published a guidance document entitled "Format for Submittal of Source Emission Test Plans and Reports" (December 2013). The following is a summary of the emissions test program and results in the format suggested by the aforementioned document.

1.a Identification, Location, and Dates of Test

Western Michigan University – Robert M. Beam Power Plant is located on Stadium Drive at WMU in Kalamazoo, Michigan. Sampling and analysis for the emission test program was conducted on November 17 and 18, 2015.

1.b Purpose of Testing

Emissions testing of the Turbines 7 and 8 cogeneration systems and Boiler 9 was required by Michigan ROP No. MI-ROP-K2131-2015a.

1.c Source Description

Boiler 9 is a natural gas-fired boiler rated for a maximum heat input capacity of 90 MMBtu/hr and 65,000 pounds per hour of steam. Boiler 9 also has fuel oil backup and is designed to fire oil at a maximum heat input of 88 MMBtu/hr. Turbines 7 and 8 are natural gas-fired turbines each rated at a maximum heat input rate of 60 MMBtu/hr.



Turbines 7 and 8 each exhaust to heat recovery steam generators (HRSG's 7 and 8) and each are equipped with duct burners.

1.d Test Program Contacts

The contact for the source and test report is:

Mr. George Jarvis
 Power Plant Director
 Western Michigan University
 1903 West Michigan Avenue
 Kalamazoo, Michigan 49008
 (269) 387-8548

Names and affiliations for personnel who were present during the testing program are summarized by Table 1.

**Table 1
 Test Personnel**

Name and Title	Affiliation	Telephone
Mr. George Jarvis Power Plant Director Western Michigan University	Western Michigan University 1903 West Michigan Avenue Kalamazoo, Michigan 49008	(269) 387-8548
Ms. Rhiana Dornbos Sr. Staff Engineer	NTH Consultants, Ltd. 608 S. Washington Ave. Lansing, Michigan 48823	(517) 702-2953
Mr. Barry Boulianne Senior Project Manager	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(248) 548-8072
Mr. Steve Smith Project Manager	BTEC 4949 Fernlee Avenue Royal Oak, MI 48073	(248) 548-8070
Mr. David Patterson Environmental Quality Analyst	MDEQ Air Quality Division	(517) 284-6782

2. Summary of Results

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

2.a Operating Data

Process data monitored during the emissions test program includes the information summarized in Appendix D.

2.b Applicable Permit

Emissions testing of the Turbines 7 and 8 cogeneration systems and Boiler 9 was required by Michigan ROP No. MI-ROP-K2131-2015a.

2.c Results

The overall results of the emission test program are summarized by Table 2 (see Section 5.a).

3. Source Description

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

3.a Process Description

Boiler 9 is a natural gas-fired boiler rated for a maximum heat input capacity of 90 MMBtu/hr and 65,000 pounds per hour of steam. Boiler 9 also has fuel oil backup and is designed to fire oil at a maximum heat input of 88 MMBtu/hr. Turbines 7 and 8 are natural gas-fired turbines each rated at a maximum heat input rate of 60 MMBtu/hr. Turbines 7 and 8 each exhaust to heat recovery steam generators (HRSG's 7 and 8) and each are equipped with duct burners. The maximum load level of Turbine 7 and 8 duct burner systems is 65,000 lbs steam/hr.

3.b Process Flow Diagram

Due to the simplicity of the processes, process flow diagrams are not necessary.

3.c Raw and Finished Materials

The raw material used by the process is natural gas.

3.d Process Capacity

Boiler 9 is a natural gas-fired boiler rated for a maximum heat input capacity of 90 MMBtu/hr and 65,000 pounds per hour of steam. Boiler 9 also has fuel oil backup and is designed to fire oil at a maximum heat input of 88 MMBtu/hr. Turbines 7 and 8 are natural gas-fired turbines each rated at a maximum heat input rate of 60 MMBtu/hr. Turbines 7 and 8 each exhaust to heat recovery steam generators (HRSG's 7 and 8) and each are equipped with duct burners. The maximum load level of Turbine 7 and 8 duct burner systems is 65,000 lbs steam/hr.

3.e Process Instrumentation

Process data monitored during the emissions test program includes the information summarized in Appendix D.

4. Sampling and Analytical Procedures

Sections 4.a through 4.d provide a summary of the sampling and analytical procedures used.

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4.a Sampling Train and Field Procedures

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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 Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources*”, was used to measure the O₂ concentration of the exhaust gas.
- Method 7E, “*Determination of Nitrogen Oxides Emissions from Stationary Sources*”, was used to measure the NO_x concentration of the exhaust gas.
- Method 10, “*Determination of Carbon Monoxide Emissions from Stationary Sources*”, was used to measure the CO concentration of the exhaust gas.
- Method 19, “*Determination of Sulfure Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide, and Nitrogen Dioxide Emission Rates*”, was used to calculate NO_x emission rates

Exhaust gas CO and O₂ content were measured using a Teledyne Model 300E CO/O₂ gas analyzer. Exhaust gas NO_x content was measured using a Thermo Electron 42C NO_x gas analyzer. A sample of the gas stream was drawn through a stainless-steel probe with an in-line glass fiber filter to remove any particulate, a heated Teflon[®] sample line, and through an electronic sample conditioner to remove the moisture from the sample before it enters the analyzers. Data was recorded at 10-second intervals on a PC equipped with data acquisition software. Triplicate 60-minute test runs were performed on the boiler, and triplicate 21-minute test runs were performed on each turbine.

In accordance with Method 7E, a 3-point (zero, mid, and high) calibration check was performed on the NO_x and CO/O₂ analyzers. Calibration drift checks were performed at the completion of each run.

An exhaust gas stratification test was performed at each sampling location. Since the exhaust gas at each location was not stratified, sampling was conducted at a single location.

4.b Recovery and Analytical Procedures

This test program did not include laboratory samples, consequently, sample recovery and analysis is not applicable to this test program.

4.c Sampling Ports

Sampling ports were located in the exhaust stacks downstream of the heat recovery steam generators for Turbines 7 and 8 and after Boiler 9.

4.d Traverse Points

An exhaust gas stratification test was performed at each sampling location. Since the exhaust gas at each location was not stratified, sampling was conducted at a single location.

5. Test Results and Discussion

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

5.a Results Tabulation

The overall results of the emissions test program are summarized by Table 2. Detailed results for the emissions test program are summarized by Tables 3, 4, and 5.

Table 2
Turbines 7 and 8 Cogeneration Systems and Boiler 9
Emissions Test Results Summary
Test Dates: November 17 and 18, 2015

Emission Unit	Pollutant	Emission Limitation	Emission Test Result
Boiler 9	NOx	0.09 lbs/MMBtu	0.08 lbs/MMBtu
Turbine 7	NOx	42 ppmvd @ 15% O ₂	24 ppmvd @ 15% O ₂
	NOx	12.0 lbs/hr	8.9 lbs/hr
	CO	50 ppmvd @ 15% O ₂	4 ppmvd @ 15% O ₂
	CO	8.8 lbs/hr	1.0 lbs/hr
Turbine 8	NOx	42 ppmvd @ 15% O ₂	18 ppmvd @ 15% O ₂
	NOx	12.0 lbs/hr	6.9 lbs/hr
	CO	50 ppmvd @ 15% O ₂	4 ppmvd @ 15% O ₂
	CO	8.8 lbs/hr	0.9 lbs/hr

5.b Discussion of Results

As summarized by Table 2, emissions from each unit are below the corresponding emission limitations.

5.c Sampling Procedure Variations

No sampling variations occurred during the testing.



5.d Process or Control Device Upsets

No upset conditions occurred during testing.

5.e Control Device Maintenance

The turbines and boiler are not equipped with add-on emissions control.

5.f Re-Test

The emissions test program was not a re-test.

5.g Audit Sample Analyses

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

5.h Calibration Sheets

Relevant equipment calibration documents are provided in Appendix B.

5.i Sample Calculations

Sample calculations are provided in Appendix C.

5.j Field Data Sheets

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

5.k Laboratory Data

Raw CEM data is provided electronically in Appendix D.

Table 3
Turbine 7 NOx and CO Emission Rates
Western Michigan University
Kalamazoo, MI
BTEC Project No. 15-4732.00
Sampling Date: 11/17/15

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	11/17/2015	11/17/2015	11/17/2015	
Test Run Time	10:44 - 11:05	11:26 - 11:47	12:04 - 12:25	
Oxygen Concentration (%)	11.0	10.8	10.5	10.8
Oxygen Concentration (%; drift corrected as per USEPA 7E)	10.7	10.6	10.3	10.6
Outlet Oxides of Nitrogen Concentration (ppmv)	41.8	42.1	42.7	42.2
Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	41.6	41.5	42.0	41.7
Outlet NOx Concentration (ppmv, corrected to 15% O ₂)	24.1	23.9	23.5	23.8
Outlet NOx Emission Rate (pph)	8.9	9.0	8.8	8.9
Outlet Carbon Monoxide Concentration (ppmv)	8.8	8.3	6.9	8.0
Outlet CO Concentration (ppmv, corrected as per USEPA 7E)	8.3	7.8	6.3	7.5
Outlet CO Concentration (ppmv, corrected to 15% O ₂)	4.8	4.5	3.5	4.3
Outlet CO Emission Rate pph	1.09	1.03	0.81	1.0
Fuel Flow Rate (scfm)	1632.0	1662.0	1657.0	1650.3
Cogeneration System Heat Input Rate (MMBtu/hr)	100.7	102.5	102.2	101.8

scfm = standard cubic feet per minute
ppmv = parts per million on a volume-to-volume basis
pph = pounds per hour

Co= Average of initial and final zero gases
Cma=Actual concentration of the calibration gas
Cm= Average of initial and final calibration gases

O ₂ Correction			
Co	0.30	0.31	0.32
Cma	9.9	9.9	9.9
Cm	10.13	10.06	10.10

NOx Correction			
Co	0.57	1.08	1.08
Cma	44.6	44.6	44.6
Cm	44.82	45.14	45.21

CO Correction			
Co	0.66	0.68	0.64
Cma	44.8	44.8	44.8
Cm	44.70	44.66	44.62

Table 4
Turbine 8 NOx and CO Emission Rates
Western Michigan University
Kalamazoo, MI
BTEC Project No. 15-4732.00
Sampling Date: 11/17/15

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	11/17/2015	11/17/2015	11/17/2015	
Test Run Time	8:36-8:57	9:11-9:32	9:47-10:08	
Oxygen Concentration (%)	11.1	11.1	11.2	11.1
Oxygen Concentration (%; drift corrected as per USEPA 7E)	10.9	10.9	11.0	11.0
Outlet Oxides of Nitrogen Concentration (ppmv)	30.9	30.6	29.9	30.5
Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	30.7	30.1	29.1	30.0
Outlet NOx Concentration (ppmv, corrected to 15% O ₂)	18.2	17.8	17.5	17.8
Outlet NOx Emission Rate (pph)	7.1	7.0	6.7	6.9
Outlet Carbon Monoxide Concentration (ppmv)	7.1	6.6	7.1	6.9
Outlet CO Concentration (ppmv, corrected as per USEPA 7E)	6.5	6.1	6.6	6.4
Outlet CO Concentration (ppmv, corrected to 15% O ₂)	3.9	3.6	3.9	3.8
Outlet CO Emission Rate pph	0.9	0.9	0.9	0.9
Fuel Flow Rate (scfm)	1726.0	1720.0	1686.0	1710.7
Cogeneration System Heat Input Rate (MMBtu/hr)	106.5	106.1	104.0	105.5

scfm = standard cubic feet per minute
 ppmv = parts per million on a volume-to-volume basis
 pph = pounds per hour

Co= Average of initial and final zero gases
 Cma=Actual concentration of the calibration gas
 Cm= Average of initial and final calibration gases

O ₂ Correction			
Co	0.29	0.29	0.29
Cma	9.9	9.9	9.9
Cm	10.08	10.06	10.09

NOx Correction			
Co	0.50	0.78	0.79
Cma	44.6	44.6	44.6
Cm	44.58	45.07	45.35

CO Correction			
Co	0.65	0.66	0.63
Cma	44.8	44.8	44.8
Cm	44.82	44.62	44.51

Table 5
Boiler 9 NOx Emission Rates
Western Michigan University
Kalamazoo, MI
BTEC Project No. 15-4732.00
Sampling Date: 11/18/15

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	11/18/2015	11/18/2015	11/18/2015	
Test Run Time	8:29-9:36	9:55-10:55	11:13-12:14	
Oxygen Concentration (%)	3.4	3.2	3.2	3.3
Oxygen Concentration (%; drift corrected as per USEPA 7E)	3.2	3.0	2.9	3.0
Outlet Oxides of Nitrogen Concentration (ppmv)	66.5	66.6	65.6	66.2
Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	66.8	66.6	65.6	66.3
Outlet NOx Emission Rate (lbs/MMBtu)	0.08	0.08	0.08	0.08

O ₂ Correction			
Co	0.26	0.27	0.26
Cma	9.9	9.9	9.9
Cm	10.09	10.06	10.05

NOx Correction			
Co	0.92	1.96	2.06
Cma	44.8	44.8	44.8
Cm	44.90	45.47	45.45

scfm = standard cubic feet per minute
 ppmv = parts per million on a volume-to-volume basis
 pph = pounds per hour

Co= Average of initial and final zero gases
 Cma=Actual concentration of the calibration gas
 Cm= Average of initial and final calibration gases

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