



Gas Turbines NOx Emissions Test Report

Prepared for:

Wolverine Power Supply Cooperative, Inc.

Alpine Generation Plant
East of Flott Road on North side of M-32
Elmira, MI 48111

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AIR QUALITY DIVISION

Project No. 049AS-370903.02
August 24, 2018

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



EXECUTIVE SUMMARY

BT Environmental Consulting, Inc. (BTEC) was retained by Wolverine Power Supply Cooperative, Inc. (Wolverine Power) to evaluate nitrogen oxides (NO_x) and oxygen (O₂) concentrations at the Alpine Power Plant in Elmira, Michigan. The emissions test program was conducted from July 24th-July 25th, 2018.

Testing of each unit consisted of three 21-minute test runs for NO_x and O₂ at each of the four operating loads on each turbine (total of twelve 21-minute test runs per turbine). The emissions test program was required by MDEQ Air Quality Division Permit To Install (PTI) 206-14. The results of the emission test program are summarized by Table I.

**Table I
Overall Emission Summary
Test Date: July 24-25, 2018**

EU-CTG1

Load	Pollutant	Average Emission Rate	Emission Limit
142 MW	NO _x lb/MMBtu	0.0295	0.0327
	NO _x lb/hr	44.75	66.8
163 MW	NO _x lb/MMBtu	0.0289	0.0327
	NO _x lb/hr	48.11	66.8
183 MW	NO _x lb/MMBtu	0.0285	0.0327
	NO _x lb/hr	51.99	66.8
204 MW	NO _x lb/MMBtu	0.0319	0.0327
	NO _x lb/hr	64.50	66.8

EU-CTG2

Load	Pollutant	Average Emission Rate	Emission Limit
142 MW	NO _x lb/MMBtu	0.0295	0.0327
	NO _x lb/hr	44.67	66.8
163 MW	NO _x lb/MMBtu	0.0288	0.0327
	NO _x lb/hr	47.71	66.8
183 MW	NO _x lb/MMBtu	0.0269	0.0327
	NO _x lb/hr	48.78	66.8
204 MW	NO _x lb/MMBtu	0.0279	0.0327
	NO _x lb/hr	56.42	66.8



1. Introduction

BT Environmental Consulting, Inc. (BTEC) was retained by Wolverine Power Supply Cooperative, Inc. (Wolverine Power) to evaluate nitrogen oxides (NO_x) and oxygen (O₂) concentrations at the Alpine Power Plant in Elmira, Michigan. The emissions test program was conducted from July 24th-July 25th, 2018.

Testing of each unit consisted of three 21-minute test runs for NO_x and O₂ at each of the four operating loads on each turbine (total of twelve 21-minute test runs per turbine). The emissions test program was required by MDEQ Air Quality Division Permit To Install (PTI) 206-14.

1.a Identification, Location, and Dates of Test

Sampling and analysis for the emission test program was conducted on July 24th-July 25th, 2018 at the Alpine Power facility located in Elmira, Michigan. The test program included evaluation of NO_x and O₂ emissions from EU-CGT1 and EU-CGT2.

1.b Purpose of Testing

AQD issued PTI 206-14 to Wolverine Power. This permit limits emissions from each unit as summarized by Table 1.

Table 1
PTI 206-14 Emission Limitations

Emission Unit ID	NO_x Permit Limit
EU-CTG1 and EU-CTG2 each	3.27E-2 lb/MMBtu, Not including startup / shutdown
	66.8 lb/hr, Not including startup / shutdown

1.c Source Description

Wolverine Power operates two identical turbines designated as EU-CTG1 and EU-CTG2. Emission unit descriptions are as follows:

Two nominal 203 MW natural gas fired simple cycle combustion turbine generators, each with a peak heat input of 2,045 MMBtu/hr.



1.d Test Program Contacts

The contact for the source and test report is:

Laura Hoisington, P.E., CHMM
Environmental Specialist
Wolverine Power
10125 West Watergate Road
Cadillac, Michigan 49601
(231) 429-9783

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

Table 2
Test Personnel

Name and Title	Affiliation	Telephone
Mr. Todd Wessel Client Project Manager	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Shane Rabideau Field Technician	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Jeremy Howe	MDEQ Air Quality Division	(231) 775-4050

2. Summary of Results

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

2.a Operating Data

Basic operating parameters were recorded including load (megawatts), fuel flow (standard cubic feet per hour), and compressor temperature and pressure.

2.b Applicable Permit

The applicable permit for this emissions test program is PTI 206-14.



2.c Results

The overall results of the emission test program are summarized by Table 3 (see Section 5.a). Detailed results are summarized by Tables 4-5.

NO_x emissions from each unit were below the corresponding limit of 0.0327 lb/MMBtu.

3. Source Description

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

3.a Process Description

See section 1.c.

3.b Process Flow Diagram

Due to the simplicity of the natural gas compressor turbine, a process flow diagram is not necessary.

3.c Raw and Finished Materials

The raw material used by the process is natural gas.

3.d Process Capacity

Each turbine is rated at 203MW (nominal).

3.e Process Instrumentation

Each turbine is equipped with dry low oxides of nitrogen control.

4. Sampling and Analytical Procedures

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

4.a Sampling Train and Field Procedures

Turbine exhaust NO_x content was measured using a Teledyne Model T-200H NO_x gas analyzer, and the O₂ content was measured using a M&C Products PMA 100-L O₂ gas analyzer. A sample of the gas stream was drawn through an insulated 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 analyzer. Data was recorded at 4-second intervals on a PC equipped with data acquisition software.

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 Oxide Emissions from Stationary Sources*”, was used to measure the NO_x concentration of the exhaust gas.
- Method 19, “*Determination of Sulfur Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide, and Nitrogen Oxide Emission Rates*”, was used to calculate the exhaust gas flowrates.

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

A diagram of the stack showing sampling ports in relation to upstream and downstream disturbances is included as Figure 2.

4.d Traverse Points

A diagram of the stack indicating traverse point locations and stack dimensions is included as Figure 2.

5. Test Results and Discussion

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

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5.a Results Tabulation

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

**Table 3
Overall Emission Summary
Test Date: July 24-25, 2018**

EU-CTG1

Load	Pollutant	Average Emission Rate	Emission Limit
142 MW	NOx lb/MMBtu	0.0295	0.0327
	NOx lb/hr	44.75	66.8
163 MW	NOx lb/MMBtu	0.0289	0.0327
	NOx lb/hr	48.11	66.8
183 MW	NOx lb/MMBtu	0.0285	0.0327
	NOx lb/hr	51.99	66.8
204 MW	NOx lb/MMBtu	0.0319	0.0327
	NOx lb/hr	64.50	66.8

EU-CTG2

Load	Pollutant	Average Emission Rate	Emission Limit
142 MW	NOx lb/MMBtu	0.0295	0.0327
	NOx lb/hr	44.67	66.8
163 MW	NOx lb/MMBtu	0.0288	0.0327
	NOx lb/hr	47.71	66.8
183 MW	NOx lb/MMBtu	0.0269	0.0327
	NOx lb/hr	48.78	66.8
204 MW	NOx lb/MMBtu	0.0279	0.0327
	NOx lb/hr	56.42	66.8

5.b Discussion of Results

The overall results of the emission test program are summarized by Table 3 (see Section 5.a). Detailed results are summarized by Tables 4-5.

NOx emissions from each unit were below the corresponding limit of 0.0327 lb/MMBtu.

5.c Sampling Procedure Variations

There were no sampling variations used during the emission compliance test program.

5.d Process or Control Device Upsets

No upset conditions occurred during testing.

5.e Control Device Maintenance

There was no control equipment maintenance performed during the emissions test program.

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

There are no laboratory results for this test program. Raw CEM data is provided electronically in Appendix D.



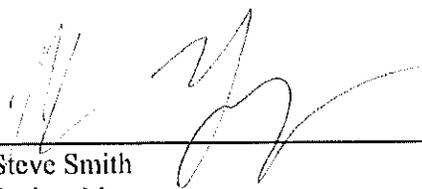
MEASUREMENT UNCERTAINTY STATEMENT

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

All testing performed was done in conformance to the ASTM D7036-04 standard. The information and opinions rendered in this report are exclusively for use by Wolverine Power. BTEC will not distribute or publish this report without Wolverine Power'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.

This report was prepared by:


Steve Smith
Project Manager

This report was reviewed by:

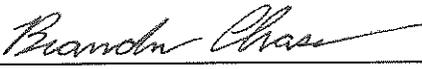

Brandon Chase
QA/QC Manager

Table 4
EU-CGT1 NOx Emission Rates
Wolverine Power Alpine
Elmira, MI
BTEC Project No. 049AS-370903.02
Sampling Dates: July 24, 2018

Parameter		Run 1	Run 2	Run 3	Average
142 MW	Test Run Date	7/24/2018	7/24/2018	7/24/2018	
	Test Run Time	7:31-8:15	8:26-9:12	9:26-10:09	
	Natural Gas Flow Rate (KSFH)	1,481.55	1,479.73	1,477.34	1,479.54
	HHV (Btu/scf)	1,025	1,025	1,025	1,025
	Oxygen Concentration (%)	13.23	13.19	13.17	13.20
	Oxygen Concentration (%), drift corrected as per USEPA 7E)	13.32	13.28	13.26	13.29
	Outlet Oxides of Nitrogen Concentration (ppmv)	10.34	10.47	10.58	10.46
	Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	10.27	10.31	10.43	10.34
	Outlet NOx Concentration (ppmv, corrected to 15% O ₂)	8.00	7.98	8.05	8.01
	NOx Emission Rate (lb/MMBtu)	0.0295	0.0294	0.0297	0.0295
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	44.75	44.58	44.93	44.75	
163 MW	Test Run Date	7/24/2018	7/24/2018	7/24/2018	
	Test Run Time	10:20-11:04	11:14-11:55	12:07-12:50	
	Natural Gas Flow Rate (KSFH)	1,625.95	1,623.40	1,626.70	1,625.35
	HHV (Btu/scf)	1,025	1,025	1,025	1,025
	Oxygen Concentration (%)	13.25	13.26	13.27	13.26
	Oxygen Concentration (%), drift corrected as per USEPA 7E)	13.34	13.35	13.36	13.35
	Outlet Oxides of Nitrogen Concentration (ppmv)	10.14	10.16	10.17	10.16
	Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	9.99	10.04	10.06	10.03
	Outlet NOx Concentration (ppmv, corrected to 15% O ₂)	7.80	7.85	7.87	7.84
	NOx Emission Rate (lb/MMBtu)	0.0287	0.0289	0.0290	0.0289
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	47.88	48.09	48.36	48.11	
183 MW	Test Run Date	7/24/2018	7/24/2018	7/24/2018	
	Test Run Time	13:01-13:44	13:55-14:38	14:48-15:30	
	Natural Gas Flow Rate (KSFH)	1,777.84	1,777.32	1,776.89	1,777.35
	HHV (Btu/scf)	1,025	1,025	1,025	1,025
	Oxygen Concentration (%)	13.37	13.40	13.42	13.40
	Oxygen Concentration (%), drift corrected as per USEPA 7E)	13.46	13.49	13.51	13.49
	Outlet Oxides of Nitrogen Concentration (ppmv)	9.82	9.86	9.84	9.84
	Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	9.67	9.75	9.77	9.73
	Outlet NOx Concentration (ppmv, corrected to 15% O ₂)	7.67	7.77	7.80	7.75
	NOx Emission Rate (lb/MMBtu)	0.0283	0.0286	0.0287	0.0285
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	51.48	52.15	52.34	51.99	
204 MW	Test Run Date	7/24/2018	7/24/2018	7/24/2018	
	Test Run Time	15:40-16:24	13:36-17:19	17:29-18:18	
	Natural Gas Flow Rate (KSFH)	1,975.89	1,973.29	1,975.20	1,974.79
	HHV (Btu/scf)	1,025	1,025	1,025	1,025
	Oxygen Concentration (%)	13.34	13.36	13.36	13.35
	Oxygen Concentration (%), drift corrected as per USEPA 7E)	13.42	13.44	13.44	13.43
	Outlet Oxides of Nitrogen Concentration (ppmv)	11.05	10.86	10.90	10.94
	Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	11.04	10.88	10.91	10.95
	Outlet NOx Concentration (ppmv, corrected to 15% O ₂)	8.71	8.60	8.63	8.65
	NOx Emission Rate (lb/MMBtu)	0.0321	0.0317	0.0318	0.0319
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	65.01	64.11	64.38	64.50	

ppmv = parts per million on a volume-to-volume basis
 lb/hr = pounds per hour
 Fd = 8,710 dscf/MMBtu

Equations
 lb/MMBtu = ppm * 1.194E-7 * Fd * 20.9 / (20.9 - O₂)
 lb/hr = lb/MMBtu * KSCFH * HHV * 1,000 scf/kscf * MMBtu/1,000,000 Btu

Table 5
EU-CGT2 NOx Emission Rates
Wolverine Power Alpine
Elmira, MI
BTEC Project No. 049AS-370903.02
Sampling Dates: July 25, 2018

	Parameter	Run 1	Run 2	Run 3	Average
142 MW	Test Run Date	7/25/2018	7/25/2018	7/25/2018	
	Test Run Time	7:08-7:49	8:01-8:43	8:54-9:35	
	Natural Gas Flow Rate (KSFH)	1,477.26	1,475.30	1,474.71	1,475.76
	HHV (Btu/scf)	1,025	1,025	1,025	1,025
	Oxygen Concentration (%)	13.24	13.24	13.27	13.25
	Oxygen Concentration (% , drift corrected as per USEPA 7E)	13.37	13.32	13.34	13.34
	Outlet Oxides of Nitrogen Concentration (ppmv)	10.14	10.25	10.35	10.25
	Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	10.17	10.25	10.38	10.27
	Outlet NOx Concentration (ppmv, corrected to 15% O ₂)	7.97	7.98	8.11	8.02
	NOx Emission Rate (lb/MMBtu)	0.0294	0.0294	0.0299	0.0295
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	44.45	44.43	45.14	44.67	
163 MW	Test Run Date	7/25/2018	7/25/2018	7/25/2018	
	Test Run Time	9:46-10:27	10:39-11:21	11:32-12:14	
	Natural Gas Flow Rate (KSFH)	1,621.26	1,619.86	1,616.13	1,619.08
	HHV (Btu/scf)	1,025	1,025	1,025	1,025
	Oxygen Concentration (%)	13.38	13.39	13.40	13.39
	Oxygen Concentration (% , drift corrected as per USEPA 7E)	13.45	13.46	13.47	13.46
	Outlet Oxides of Nitrogen Concentration (ppmv)	9.81	9.83	9.82	9.82
	Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	9.84	9.86	9.83	9.84
	Outlet NOx Concentration (ppmv, corrected to 15% O ₂)	7.79	7.82	7.80	7.80
	NOx Emission Rate (lb/MMBtu)	0.0287	0.0288	0.0287	0.0288
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	47.70	47.84	47.60	47.71	
183 MW	Test Run Date	7/25/2018	7/25/2018	7/25/2018	
	Test Run Time	12:33-13:15	13:28-14:10	14:20-15:02	
	Natural Gas Flow Rate (KSFH)	1,767.61	1,767.01	1,767.42	1,767.35
	HHV (Btu/scf)	1,025	1,025	1,025	1,025
	Oxygen Concentration (%)	13.52	13.53	13.54	13.53
	Oxygen Concentration (% , drift corrected as per USEPA 7E)	13.58	13.60	13.61	13.60
	Outlet Oxides of Nitrogen Concentration (ppmv)	9.09	9.03	8.99	9.04
	Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	9.10	9.04	9.00	9.05
	Outlet NOx Concentration (ppmv, corrected to 15% O ₂)	7.33	7.31	7.29	7.31
	NOx Emission Rate (lb/MMBtu)	0.0270	0.0269	0.0268	0.0269
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	48.95	48.75	48.62	48.78	
204 MW	Test Run Date	7/25/2018	7/25/2018	7/25/2018	
	Test Run Time	15:12-15:54	16:05-16:47	16:57-17:38	
	Natural Gas Flow Rate (KSFH)	1,982.12	1,974.28	1,971.21	1,975.87
	HHV (Btu/scf)	1,025	1,025	1,025	1,025
	Oxygen Concentration (%)	13.44	13.45	13.47	13.45
	Oxygen Concentration (% , drift corrected as per USEPA 7E)	13.51	13.52	13.55	13.53
	Outlet Oxides of Nitrogen Concentration (ppmv)	9.52	9.46	9.37	9.45
	Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	9.53	9.45	9.38	9.45
	Outlet NOx Concentration (ppmv, corrected to 15% O ₂)	7.61	7.55	7.52	7.56
	NOx Emission Rate (lb/MMBtu)	0.0280	0.0278	0.0277	0.0279
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	56.94	56.32	56.00	56.42	

ppmv = parts per million on a volume-to-volume basis
 lb/hr = pounds per hour
 Fd = 8,710 dscf/MMBtu

Equations

lb/MMBtu = ppm * 1.194E-7 * Fd * 20.9 / (20.9 - O₂)
 lb/hr = lb/MMBtu * KSCFH * HHV * 1,000 scf/kscf * MMBtu/1,000,000 Btu

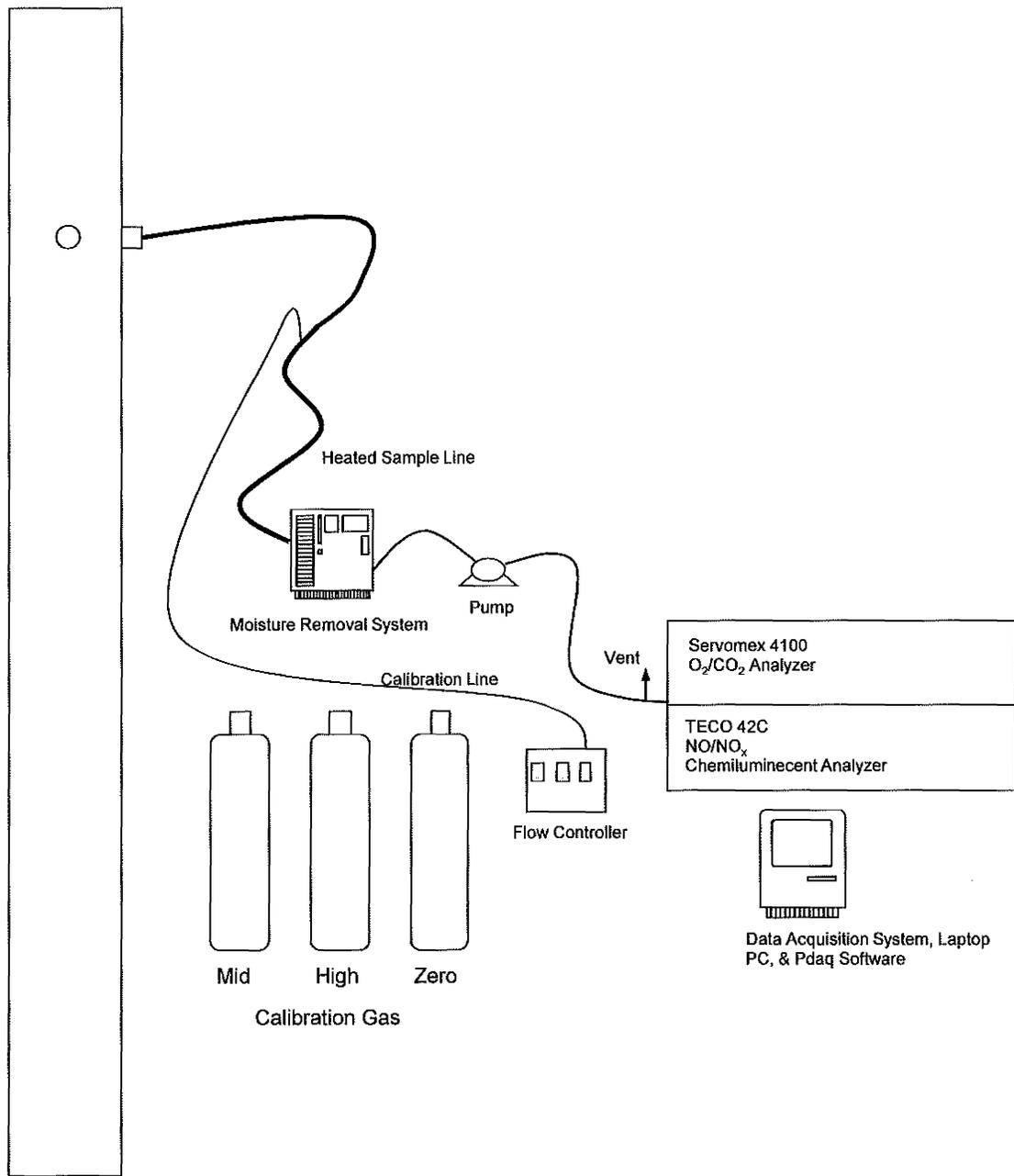
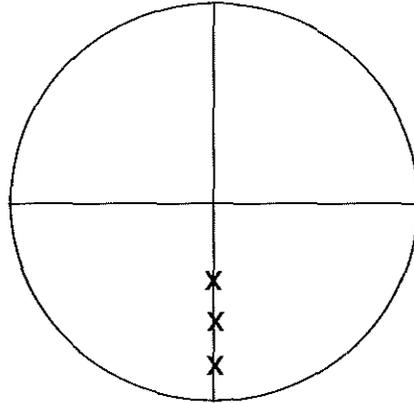
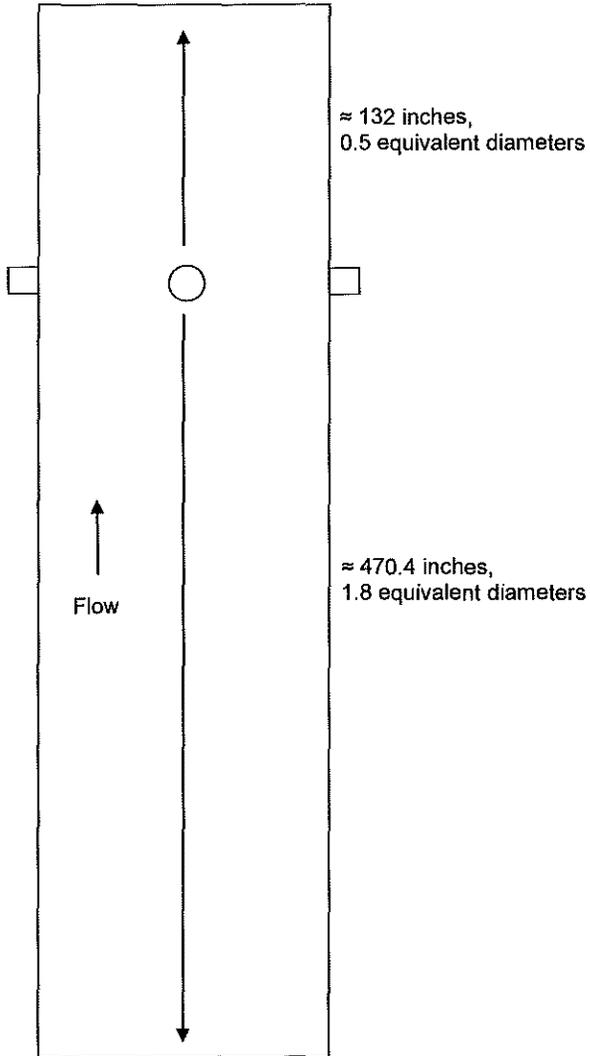


Figure No. 1

<p>Site: USEPA Method 3A,7E Wolverine Power Supply Cooperative, Inc. Elmira, Michigan</p>	<p>Sampling Date: July 24-25, 2018</p>	<p>BT Environmental Consulting Inc. 4949 Fernlee Avenue Royal Oak, MI 48073</p>
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diameter = 264 inches



Not to Scale

Points	Distance "
1	15.7
2	47.2
3	78.7

Figure No. 2

Site: EU-CTG1 and EU-CTG2
Wolverine Power Supply Cooperative, Inc.
Alpine, Michigan

Sampling Date:
July 24-25, 2018

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