BTEC Inc.

Gas Turbines NOx and CO Emissions Test Report

Prepared for:

Wolverine Power Supply Cooperative, Inc.

Sumpter Generation Plant
8509 Rawsonville Rd
Belleville, MI 48111

Project No. 049AS-370903.01
August 6, 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 (NOx) and oxygen (O_2) Relative Accuracy Test Audits (RATA) on four natural gas-fired simple cycle combustion turbines (Units 1-4) at the Wolverine Power facility located in Belleville, Michigan. A verification test on Unit 1 was conducted for carbon monoxide (CO) emission rates (in lb/hr and lb/MMBtu). The emissions test program was conducted from June 12th-June 15th, 2018.

Testing of each unit consisted of twelve 21-minute test runs for NOx and O_2. Verification of CO emission rates from Unit 1 consisted of triplicate 21-minute test runs. The emissions test program was required by MDEQ Air Quality Division Renewable Operating Permit (ROP) No. MI-ROP-M4854-2014c. The results of the emission test program are summarized by Table I.

Table I
Overall Emission Summary
Test Date: June 12-15, 2018

Unit 1

Pollutant	Average Emission Rate	Emission Limit
NOx RATA	4.8%	20%
NOx lb/hr	24.01	-
NOx ppm @ 15% O_2	7.52	75
NOx lb/MMBtu	0.028	-
CO lb/MMBtu	0.016	0.057
CO lb/hr	13.93	-

Unit 2

Pollutant	Average Emission Rate	Emission Limit
NOx RATA	3.7%	20%
NOx lb/hr	25.43	-
NOx ppm @ 15% O_2	7.77	75
NOx lb/MMBtu	0.029	-

Unit 3

Pollutant	Average Emission Rate	Emission Limit
NOx RATA	0.9%	20%
NOx lb/hr	33.18	-
NOx ppm @ 15% O_2	10.17	75
NOx lb/MMBtu	0.037	-

Unit 4

Pollutant	Average Emission Rate	Emission Limit
NOx RATA	5.0%	20%
NOx lb/hr	28.20	-
NOx ppm @ 15% O_2	8.83	75
NOx lb/MMBtu	0.033	-

1. Introduction

BT Environmental Consulting, Inc. (BTEC) was retained by Wolverine Power Supply Cooperative, Inc. (Wolverine Power) to evaluate nitrogen oxides (NOx) and oxygen (O_2) Relative Accuracy Test Audits (RATA) on four natural gas-fired simple cycle combustion turbines (Units 1-4) at the Wolverine Power facility located in Belleville, Michigan. A verification test on Unit 1 was conducted for carbon monoxide (CO) emission rates (in lb/hr and lb/MMBtu). The emissions test program was conducted from June 12th-June 15th, 2018.

Testing of each unit consisted of twelve 21-minute test runs for NOx and O_2. Verification of CO emission rates from Unit 1 consisted of triplicate 21-minute test runs. The emissions test program was required by MDEQ Air Quality Division Renewable Operating Permit (ROP) No. MI-ROP-M4854-2014c.

1.a Identification, Location, and Dates of Test

Sampling and analysis for the emission test program was conducted on June 12th-June 15th, 2018 at the Wolverine Power facility located in Belleville, Michigan. The test program included evaluation of NOx, O_2, and CO emissions from Units 1-4.

1.b Purpose of Testing

AQD issued Renewable Operating Permit MI-ROP-M4854-2014c to Wolverine Power. This permit limits emissions from each unit as summarized by Table 1.

Table 1
CO and NOx Emission Limitations
Wolverine Power Belleville, MI

Units	Permit No.	NOx Emission Limit	CO Emission Limits
1-4	MI- ROP-M4854-2014c	75 ppm corrected to 15% O_2*	0.057 lb/MMBtu*

*except during startups and shut downs.

1.c Source Description

Wolverine Power operates four identical turbines designated as EU-UNIT1, EU-UNIT2, EU-UNIT3, and EU-UNIT4. Nominal 83 MW electrical output General Electric PG7121 (EA) simple cycle combustion turbine, fueled by pipeline quality natural gas, equipped with dry low oxides of nitrogen control.

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
Ms. Stephanie Jarrett, P.E. Senior Environmental Engineer	Fishbeck, Thompson, Carr, & Huber Inc. 39500 Mackenzie Drive, Suite 100 Novi, Michigan 48377	(248) 417-9425
Mr. Mason Sakshaug Field Technician	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Josh Boulianne Field Technician	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Ms. Regina Hines	MDEQ Air Quality Division	(313) 418-0895

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 Renewable Operating Permit (ROP) No. MI-ROP-M4854-2014c.

2.c Results

The overall results of the emission test program are summarized by Table 3 (see Section 5.a). NOx lb/MMBtu RATA results are summarized by Tables 4-7. NOx ppm @15%, NOx lb/hr, and CO lb/hr results for each run are included on the drift calculation spread sheets in Appendix B.

NOx emissions from each unit were below the corresponding limit of 75 ppmv, corrected to 15% O_2. CO emissions were also below the limit of 0.057 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 83MW.

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 NOx content was measured using a Teledyne Model T-200H NOx gas analyzer, the CO content was measured using a Teledyne Model 300EM CO gas analyzer,

and the O_2 content was measured using a M&C Products PMA 100-L O_2 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 O_2 concentration of the exhaust gas.
- Method 7E, *"Determination of Nitrogen Oxide Emissions from Stationary Sources"*, was used to measure the NOx 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 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.

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 4-7. NOx ppm @15%, NOx lb/hr, and CO lb/hr results for each run are included on the drift calculation spread sheets in Appendix B.

Table 3
Overall Emission Summary
Test Date: June 12-15, 2018

Unit 1

Pollutant	Average Emission Rate	Emission Limit
NOx RATA	4.8%	20%
NOx lb/hr	24.01	-
NOx ppm @ 15% O_2	7.52	75
NOx lb/MMBtu	0.028	-
CO lb/MMBtu	0.016	0.057
CO lb/hr	13.93	-

Unit 2

Pollutant	Average Emission Rate	Emission Limit
NOx RATA	3.7%	20%
NOx lb/hr	25.43	-
NOx ppm @ 15% O_2	7.77	75
NOx lb/MMBtu	0.029	-

Unit 3

Pollutant	Average Emission Rate	Emission Limit
NOx RATA	0.9%	20%
NOx lb/hr	33.18	-
NOx ppm @ 15% O_2	10.17	75
NOx lb/MMBtu	0.037	-

Unit 4

Pollutant	Average Emission Rate	Emission Limit
NOx RATA	5.0%	20%
NOx lb/hr	28.20	-
NOx ppm @ 15% O_2	8.83	75
NOx lb/MMBtu	0.033	-

5.b Discussion of Results

The overall results of the emission test program are summarized by Table 3 (see Section 5.a). NOx lb/MMBtu RATA results are summarized by Tables 4-7. NOx ppm @15%, NOx lb/hr, and CO lb/hr results for each run are included on the drift calculation spread sheets in Appendix B.

NOx emissions from each unit were below the corresponding limit of 75 ppmv, corrected to 15% O_2. CO emissions were also below the limit of 0.057 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 C.

5.i Sample Calculations

Sample calculations are provided in Appendix D.

5.j Field Data Sheets

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

5.k Laboratory Data

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

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: _____
For Steve Smith
Project Manager

This report was reviewed by: _____
Brandon Chase
QA/QC Manager

Table 4
Summary of NOx lb/MMBtu RATA Results
Wolverine Power
June 12, 2018

Unit 1

NO_X lb/MMBtu Relative Accuracy

	Relative Accuracy:		4.8		
Run #	**Time**	**RM lb/MMBtu**	**PEM lb/MMBtu**	**Diff**	**%Diff**
1	**8:04-8:24**	**0.028**	**0.030**	**-0.002**	**-0.08**
2	8:50-9:10	0.029	0.029	0.000	-0.01
3	9:23-9:43	0.028	0.029	-0.001	-0.05
4	9:59-10:19	0.028	0.029	-0.001	-0.03
5	10:30-10:50	0.028	0.029	-0.001	-0.04
6	11:01-11:21	0.028	0.029	-0.001	-0.03
7	**11:32-12:02**	**0.027**	**0.029**	**-0.002**	**-0.06**
8	12:03-12:23	0.027	0.029	-0.002	-0.06
9	12:33-12:53	0.028	0.029	-0.001	-0.05
10	**13:03-13:23**	**0.027**	**0.029**	**-0.002**	**-0.07**
11	13:34-13:54	0.027	0.028	-0.001	-0.02
12	14:03-14:23	0.027	0.028	-0.001	-0.04
		0.028	0.029	-0.001	-0.036
	Sdev		0.0004		
	CC		0.0003		
	RA (based on Ref. Meth.)		**4.8%**		
	Bias Test Pass/Fail		**Pass**		
	Bias Adjustment Factor		**1.000**		

Confidence Coefficient =
n=9
t = 2.306

$$CC = t_{0.975}\frac{S_d}{\sqrt{n}}$$

P.S. 2 Equation 2-5

Standard Deviation =

$$S_d = \left[\frac{\sum_{i=1}^{n} d_i^2 - \frac{\left(\sum_{i=1}^{n} d_i\right)^2}{n}}{n-1}\right]^{1/2}$$

P.S. 2 Equation 2-4

Relative Accuracy =
RM=Reference Monitor

$$RA = \frac{|\bar{d}| + |cc|}{\overline{RM}} x100$$

P.S. 2 Equation 2-6

RA calculated as specified in Performance Specification 2, Appendix B, 40 CFR 60 - Equation 2-4

As specified in P.S. 2, subsection 8.4.4, three sets of test runs may be rejected, these rejected test runs are high-lighted in the table

Used Method 19 Eq. 19-1

Table 5
Summary of NOx lb/MMBtu RATA Results
Wolverine Power
June 13, 2018

Unit 2

NO_X lb/MMBtu Relative Accuracy

Relative Accuracy: **3.7**

Run #	Time	RM lb/MMBtu	PEM lb/MMBtu	Diff	%Diff
1	**6:38-6:58**	**0.030**	**0.032**	**-0.002**	**-0.06**
2	7:09-7:29	0.030	0.031	-0.001	-0.04
3	7:39-7:59	0.029	0.030	-0.001	-0.03
4	8:09-8:29	0.029	0.030	-0.001	-0.04
5	**8:39-8:59**	**0.028**	**0.030**	**-0.002**	**-0.06**
6	9:09-9:29	0.028	0.029	-0.001	-0.03
7	9:39-9:59	0.028	0.029	-0.001	-0.03
8	10:09-10:29	0.028	0.029	-0.001	-0.02
9	**10:39-10:59**	**0.028**	**0.029**	**-0.001**	**-0.05**
10	11:09-11:29	0.029	0.029	0.000	-0.02
11	11:39-11:59	0.028	0.029	-0.001	-0.04
12	12:09-12:29	0.028	0.029	-0.001	-0.03
		0.029	0.029	-0.001	-0.030

Sdev	0.0003
CC	0.0002
RA (based on Ref. Meth.)	**3.7%**
Bias Test Pass/Fail	**Pass**
Bias Adjustment Factor	**1.000**

Confidence Coefficient = P.S. 2 Equation 2-5

n=9

t = 2.306

$$CC = t_{0.975}\frac{S_d}{\sqrt{n}}$$

Standard Deviation = P.S. 2 Equation 2-4

$$S_d = \left[\frac{\sum_{i=1}^{n} d_i^2 - \frac{\left(\sum_{i=1}^{n} d_i\right)^2}{n}}{n-1}\right]^{1/2}$$

Relative Accuracy = P.S. 2 Equation 2-6

RM=Reference Monitor

$$RA = \frac{|\bar{d}| + |cc|}{\overline{RM}} x100$$

RA calculated as specified in Performance Specification 2, Appendix B, 40 CFR 60 - Equation 2-4

As specified in P.S. 2, subsection 8.4.4, three sets of test runs may be rejected, these rejected test runs are high-lighted in the table

Used Method 19 Eq. 19-1

BTEC Inc.

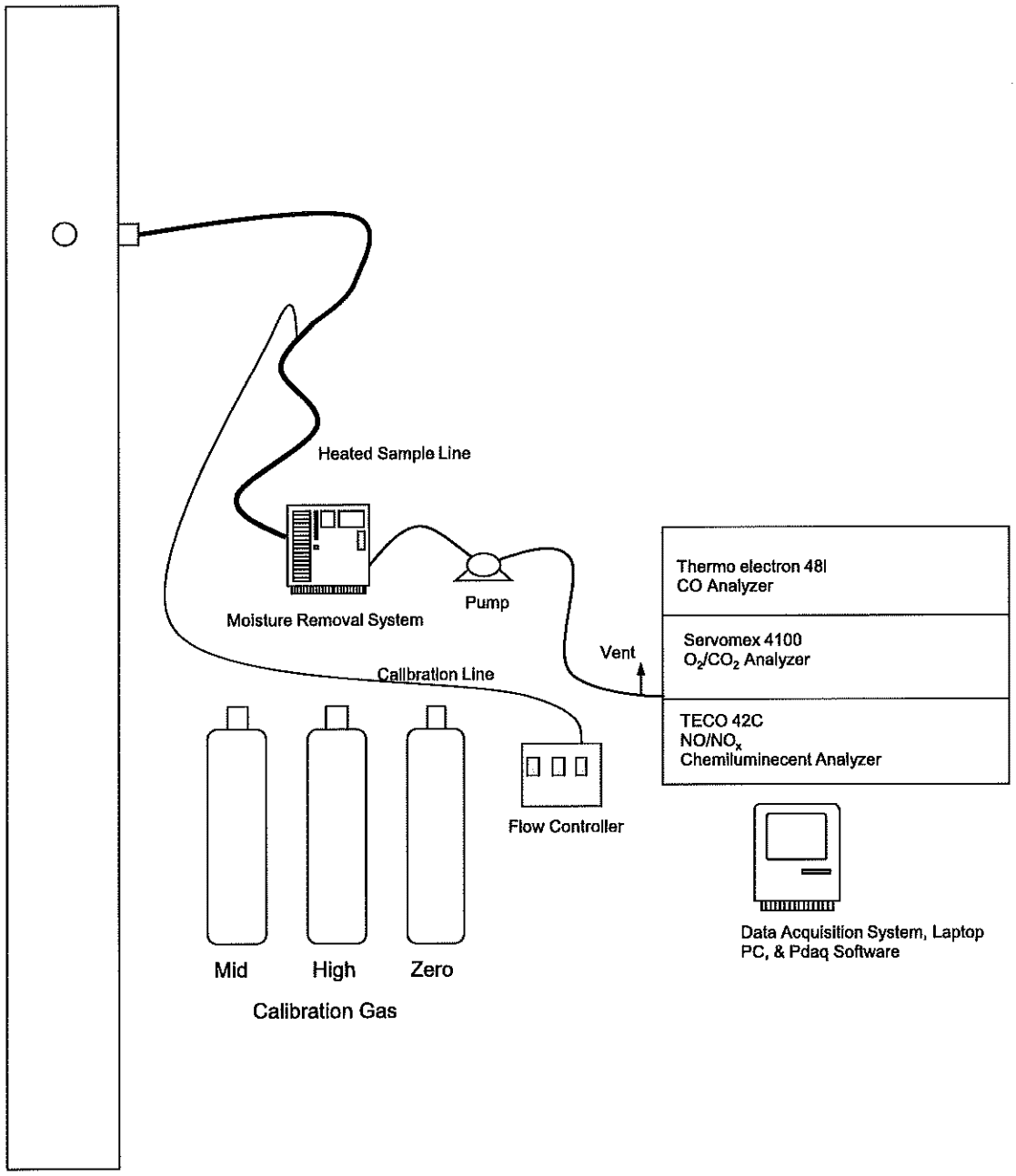


Figure No. 1

Site: **USEPA Method 3A,7E,10** **Wolverine Power Supply Cooperative, Inc.** **Belleville, Michigan**	**Sampling Date:** **June 12-15, 2018**
BT Environmental Consulting Inc. **4949 Fernlee Avenue** **Royal Oak, MI 48073**	

Table 6
Summary of NOx lb/MMBtu RATA Results
Wolverine Power
June 14, 2018

Unit 3

NO_X lb/MMBtu Relative Accuracy

	Relative Accuracy:		**0.9**		
Run #	**Time**	**RM lb/MMBtu**	**PEM lb/MMBtu**	**Diff**	**%Diff**
1	**6:41-7:01**	**0.040**	**0.039**	**0.001**	**0.02**
2	7:11-7:31	0.038	0.038	0.000	0.00
3	7:41-8:01	0.038	0.038	0.000	-0.01
4	8:11-8:31	0.038	0.038	0.000	0.00
5	8:41-9:01	0.038	0.038	0.000	-0.01
6	9:11-9:31	0.038	0.038	0.000	-0.01
7	**9:41-10:01**	**0.037**	**0.038**	**-0.001**	**-0.03**
8	10:11-10:31	0.037	0.037	0.000	0.00
9	10:41-11:01	0.037	0.037	0.000	-0.01
10	11:11-11:31	0.037	0.037	0.000	0.00
11	11:41-12:01	0.037	0.037	0.000	-0.01
12	**12:11-12:31**	**0.036**	**0.037**	**-0.001**	**-0.01**
		0.037	0.038	0.000	-0.005
	Sdev		0.0002		
	CC		0.0001		
	RA (based on Ref. Meth.)		**0.9%**		
	Bias Test Pass/Fail		**Pass**		
	Bias Adjustment Factor		**1.000**		

Confidence Coefficient =
n=9
t = 2.306

$$CC = t_{0.975}\frac{S_d}{\sqrt{n}}$$

P.S. 2 Equation 2-5

Standard Deviation =

$$S_d = \left[\frac{\sum_{i=1}^{n} d_i^2 - \frac{\left(\sum_{i=1}^{n} d_i\right)^2}{n}}{n-1}\right]^{1/2}$$

P.S. 2 Equation 2-4

Relative Accuracy =
RM=Reference Monitor

$$RA = \frac{|\bar{d}| + |cc|}{\bar{RM}} x100$$

P.S. 2 Equation 2-6

RA calculated as specified in Performance Specification 2, Appendix B, 40 CFR 60 - Equation 2-4

As specified in P.S. 2, subsection 8.4.4, three sets of test runs may be rejected, these rejected test runs are high-lighted in the table

Used Method 19 Eq. 19-1

Table 7
Summary of NOx lb/mmbtu RATA Results
Wolverine Power
June 15, 2018

Unit 4

NO_X lb/MMBtu Relative Accuracy

	Relative Accuracy:		**5.0**		
Run #	**Time**	**RM lb/MMBtu**	**PEM lb/MMBtu**	**Diff**	**%Diff**
1	**6:28-6:58**	**0.033**	**0.035**	**-0.002**	**-0.06**
2	**7:10-7:30**	**0.032**	**0.034**	**-0.002**	**-0.06**
3	7:40-8:00	0.033	0.034	-0.001	-0.03
4	8:10-8:30	0.033	0.034	-0.001	-0.03
5	8:40-9:00	0.033	0.034	-0.001	-0.04
6	9:10-9:30	0.033	0.034	-0.001	-0.04
7	9:40-10:00	0.033	0.034	-0.001	-0.04
8	10:10-10:30	0.032	0.034	-0.002	-0.05
9	10:40-11:00	0.032	0.034	-0.002	-0.05
10	11:10-11:30	0.032	0.034	-0.002	-0.06
11	**11:40-12:00**	**0.032**	**0.034**	**-0.002**	**-0.06**
12	12:10-12:30	0.032	0.034	-0.002	-0.06
		0.033	0.034	-0.001	-0.044
	Sdev		0.0003		
	CC		0.0002		
	RA (based on Ref. Meth.)		**5.0%**		
	Bias Test Pass/Fail		**Pass**		
	Bias Adjustment Factor		**1.000**		

Confidence Coefficient =
n=9
t = 2.306

$$CC = t_{0.975}\frac{S_d}{\sqrt{n}}$$

P.S. 2 Equation 2-5

Standard Deviation =

$$S_d = \left[\frac{\sum_{i=1}^{n} d_i^2 - \frac{\left(\sum_{i=1}^{n} d_i\right)^2}{n}}{n-1}\right]^{1/2}$$

P.S. 2 Equation 2-4

Relative Accuracy =
RM=Reference Monitor

$$RA = \frac{|\bar{d}| + |cc|}{\bar{RM}} x100$$

P.S. 2 Equation 2-6

RA calculated as specified in Performance Specification 2, Appendix B, 40 CFR 60 - Equation 2-4

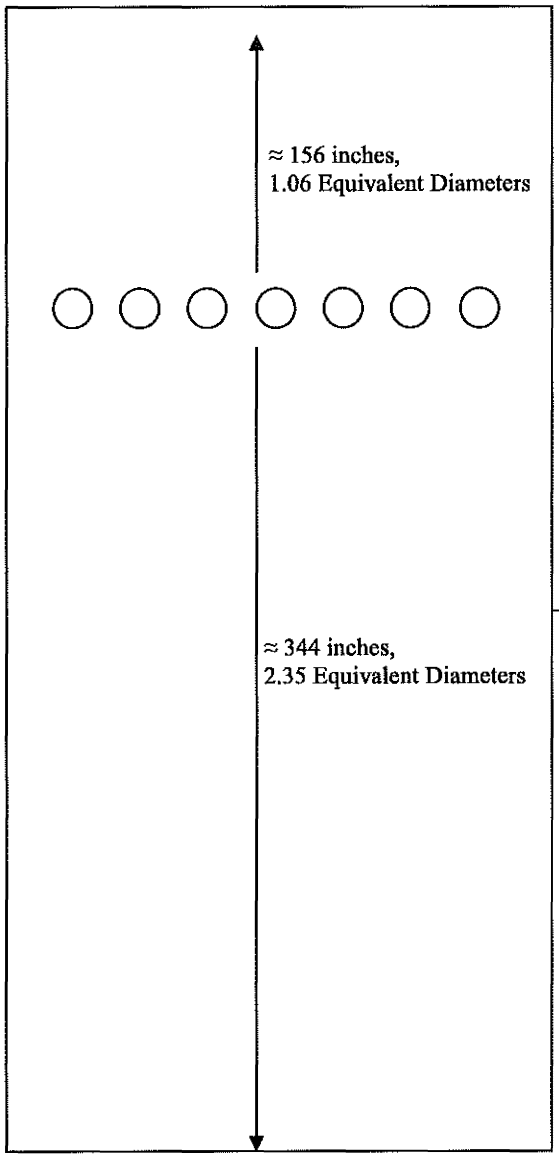
As specified in P.S. 2, subsection 8.4.4, three sets of test runs may be rejected, these rejected test runs are high-lighted in the table

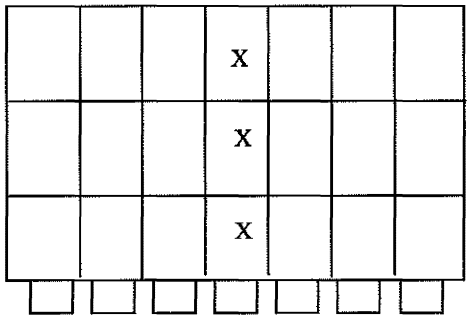
Used Method 19 Eq. 19-1

BTEC Inc.

Stack Dimensions:

Depth:	108	inches
Width:	228	inches
Equivalent Diameter:	146.6	inches





X = sample point

Not to Scale

Points	Distance "
1	18.0
2	54.0
3	90.0

EU-UNIT1, EU-UNIT2, EU-UNIT3, and EU-UNIT4 Exhaust stacks are all identical dimensions

Figure No. 2

Site: **Units 1-4** **Wolverine Power Supply Cooperative, Inc.** **Belleville, Michigan**	**Sampling Date:** **June 12-15, 2018**
BT Environmental Consulting, Inc. **4949 Fernlee Avenue** **Royal Oak, Michigan 48073**	