



**The University of Michigan
North Campus Research
Complex Powerhouse
Gas Turbine Emissions Test
Report**

Prepared for:

The North Campus Research Complex

Ann Arbor, Michigan

RECEIVED

APR 17 2018

AIR QUALITY DIVISION

NCRC Powerhouse
2800 Plymouth Road
Ann Arbor, Michigan

Project No. 049AS-239750
April 12, 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 The University of Michigan (U of M) North Campus Research Complex (NCRC) power plant to conduct an emissions test program for nitrogen oxides emission rates from a single gas turbine (EU-Turbine) at the U of M facility located in Ann Arbor, Michigan. The emissions test program was conducted on February 16, 2018.

Testing of the turbine consisted of triplicate 21-minute test runs while firing natural gas and triplicate 21-minute test runs while firing fuel oil. The emissions test program was required by MDEQ Air Quality Division Permit No. MI-ROP-M0675-2014a. The results of the emission test program are summarized by Table I. As summarized by Table I, the testing indicated that the turbine is in compliance with corresponding emission limitations and was performed in accordance with the emissions test plan and the MDEQ test plan approval letter.

Table I
Overall Emission Summary
Test Date: February 16, 2018

Fuel	NOx Emission Average (lb/hr)	Emission Limit (lb/hr)
Natural Gas	17.8	36.1
Fuel Oil	23.9	36.1



1. Introduction

BT Environmental Consulting, Inc. (BTEC) was retained by The University of Michigan (U of M) North Campus Research Complex (NCRC) powerhouse to conduct an emissions test program for nitrogen oxides emission rates from a single gas turbine (EU-Turbine) at the U of M facility located in Ann Arbor, Michigan. The emissions test program was conducted on February 16, 2018.

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

Sampling and analysis for the emission test program was conducted on February 16, 2018 at the U of M facility located in Ann Arbor, Michigan. The test program included evaluation of NOx emissions from one turbine.

1.b Purpose of Testing

AQD issued Permit No. MI-ROP-M0675-2014a to U of M. The permit limits emissions from the oxidizers as summarized by Table 1.

Table 1
NOx Emission Limitations
The University of Michigan – NCRC

Fuel	Emission Limit (lb/hr)
Natural Gas	36.1
Fuel Oil	36.1

1.c Source Description

The emission unit is a single gas turbine with a capacity of 40.1 MMBTU/hr, used to produce electricity, fueled with natural gas, and/or No. 2 fuel oil. Exhaust from the turbine can either be sent through the waste heat boiler (EU-DUCTBURNER) for heat recovery and steam generation or exhausted through a by-pass stack (SV-BYPASS).

EU-DUCTBURNER provides supplemental heat to Boiler No. 4. This burner only fires natural gas and is rated at 32 MMBTU/hr heat input. The duct burner heat combines with



the exhaust heat from EU-TURBINE to generate additional steam. The emission test program was conducted with EU-DUCTBURNER off.

1.d Test Program Contacts

The contact for the source and test report is:

Mr. Stephen O’Rielly
Manager
The University of Michigan
Environmental, Health, & Safety
Environmental Protection & Permitting Program
Campus Safety Services Building
1239 Kipke Drive
Ann Arbor, Michigan 48109
(734) 763-4642

RECEIVED

APR 17 2018

AIR QUALITY DIVISION

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. Randal Tysar Senior Environmental Engineer	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Steve Smith Field Project Manager	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Mason Sakshaug Environmental Technician	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Jake Zott Environmental Technician	BTEC 4949 Fernlee Royal Oak, MI 48073	(517) 284-6782
Ms. Brandi Campbell Environmental Specialist	University of Michigan Environmental, Health, & Safety Department	(734) 647-9017
Ms. Diane Kavanaugh Vetort Environmental Quality Analyst	MDEQ	(517) 416-3537



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 is discussed in Section 5.k.

2.b Applicable Permit

The applicable permit for this emissions test program is Permit No. MI-ROP-M0675-2014a.

2.c Results

The tests for NO_x under both conditions (gas and oil) were below the limit of 36.1 lb/hr.

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 turbine, a flow diagram is not necessary.

3.c Raw and Finished Materials

The raw material is natural gas or distillate fuel oil.

3.d Process Capacity

The turbine is rated for a maximum heat input capacity of 40.1 MMBtu/hr and the duct burner is rated for a maximum heat capacity of 32 MMBtu/hr.

3.e Process Instrumentation

The turbine is regulated by electric power load (KW) and the duct burner for the waste heat boiler is regulated based on steam header pressure.

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

Measurement of exhaust gas velocity, molecular weight, and moisture content were conducted using the following reference test methods codified at 40 CFR 60, Appendix A:

- Method 1 -“Sample and Velocity Traverses for Stationary Sources”
- Method 2 -“Determination of Stack Gas Velocity and Volumetric Flow rate”
- Method 3A -“Determination of Molecular Weight of Dry Stack Gas”
- Method 4 - “Determination of Moisture Content in Stack Gases”
- Method 7E -“Determination of Nitrogen Oxides Emissions from Stationary Sources”

Stack gas velocity traverses were conducted in accordance with the procedures outlined in Methods 1 and 2. An S-type pitot tube with a thermocouple assembly, calibrated in accordance with Method 2 was used to measure exhaust gas velocity pressures (using a manometer) and temperatures during testing. The S-type pitot tube dimensions were within specified limits, therefore, a baseline pitot tube coefficient of 0.84 (dimensionless) was assigned.

A cyclonic flow check was performed at the sampling location. The existence of cyclonic flow is determined by measuring the flow angle at each sample point. The flow angle is the angle between the direction of flow and the axis of the stack. If the average of the absolute values of the flow angles is greater than 20 degrees, cyclonic flow exists. The null angle was determined to be less than 20 degrees at each sampling point.

The Molecular Weight of the gas stream was evaluated according to procedures outlined in Title 40, Part 60, Appendix A, Method 3A. The O₂ /CO₂ content of the gas stream was measured using an O₂ /CO₂ analyzer.

Exhaust gas moisture content was evaluated using Method 4. Exhaust gas was extracted as part of the moisture sampling and passed through (i) two impingers, each with 100 ml water, (ii) an empty impinger, and (iii) an impinger filled with silica gel. Exhaust gas moisture content is then determined gravimetrically.

Oxygen (USEPA Method 3A)

The O₂ content of the gas stream was measured using a Servomex O₂ gas analyzer. The gas stream was drawn through a stainless-steel probe with a heated in-line filter to remove any particulate, a heated Teflon[®] sample line, through a refrigerated Teflon[®] sample conditioner to remove the moisture from the sample before it entered the O₂ analyzer. Data was recorded on a PC equipped with data acquisition software. Recorded O₂

concentrations were averaged and reported for the duration of each test (as drift corrected per Method 7E). Drawings of the sampling train used for the testing program are presented as Figures 1 and 2.

In accordance with Method 3A, a 3-point (zero, mid, and high) bias check and calibration check was performed on the O₂ analyzer prior to initiating the test program. Following each test run, a 2-point (zero and high) calibration drift check was performed. The O₂ analyzer was operated at the 0-25 ppm range.

Nitrogen Oxide Concentrations (USEPA Method 7E)

The NO_x content of the gas stream was measured using a Thermo Model 42i NO_x gas analyzer. The gas stream was drawn through a stainless-steel probe with a heated in-line filter to remove any particulate, a heated Teflon[®] sample line, through a refrigerated Teflon[®] sample conditioner to remove the moisture from the sample before it entered the NO_x analyzer. Data was recorded on a PC equipped with data acquisition software. Recorded NO_x concentrations were averaged and reported for the duration of each 21-minute test (as drift corrected per Method 7E). A drawing of the sampling train used for the testing program is presented as Figure 1.

In accordance with Method 7E, a 3-point (zero, mid, and high) bias check and calibration check was performed on the NO_x analyzer prior to initiating the test program. Following each test run, a 2-point (zero and high) calibration drift check was performed. The NO_x analyzer was operated at the 0-200 ppm range.

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 3.

4.d Traverse Points

A diagram of the stack indicating traverse point locations and stack dimensions is included as Figure 3.

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 and 5.

Table 3
Overall Emission Summary
Test Date: February 16, 2018

Fuel	NOx Emission Average (lb/hr)	Emission Limit (lb/hr)
Natural Gas	17.8	36.1
Fuel Oil	23.9	36.1

5.b Discussion of Results

The tests for NOx under both conditions (gas and oil) were below the limit of 36.1 lb/hr.

5.c Sampling Procedure Variations

There were no procedure variations. In addition, the test program did not include any aborted test runs or test runs that included failed quality assurance results.

5.d Process or Control Device Upsets

There were no upsets.

5.e Control Device Maintenance

Normal routine maintenance activities were performed within the last three months.

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.

Table 4
Gas NOx Emission Rates
U of M - NCRC
Ann Arbor, Michigan
BTEC Project No. 049AS-239750
Sampling Date: 2/16/2018

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	2/16/2018	2/16/2018	2/16/2018	
Test Run Time	7:44-8:04	8:32-8:52	9:09-9:29	
Outlet Flowrate (dscfm)	29,214	29,141	29,748	29,368
Outlet NOx Concentration (ppmv, corrected as per USEPA 7E)	84.7	83.9	84.5	84.4
NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	17.7	17.5	18.0	17.8

dscfm = dry standard cubic feet per minute

ppmv = parts per million on a volume-to-volume basis

lb/hr = pounds per hour



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 CEMS and process data are provided in Appendix D.

Table 5
Oil NO_x Emission Rates
U of M - NCRC
Ann Arbor, Michigan
BTEC Project No. 049AS-239750
Sampling Date: 2/16/2018

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	2/16/2018	2/16/2018	2/16/2018	
Test Run Time	10:15-10:35	10:50-11:10	11:27-11:47	
Outlet Flowrate (dscfm)	29,191	28,591	27,916	28,566
Outlet NO _x Concentration (ppmv, corrected as per USEPA 7E)	118.4	116.2	116.1	116.9
NO_x Emission Rate (lb/hr) (corrected as per USEPA 7E)	24.8	23.8	23.2	23.9

dscfm = dry standard cubic feet per minute

ppmv = parts per million on a volume-to-volume basis

lb/hr = pounds per hour

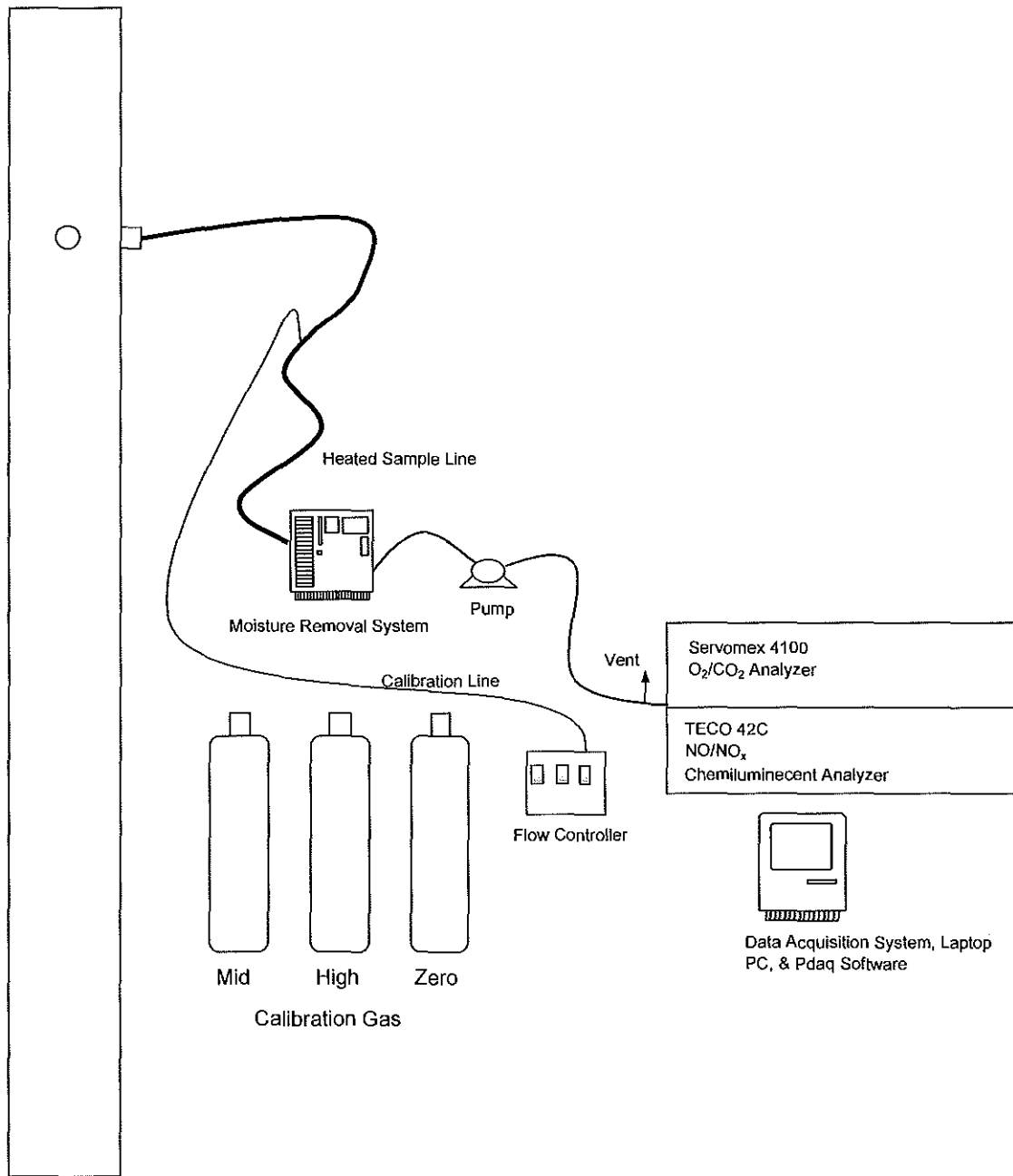


Figure No. 1

Site:
USEPA Method 3A and 7E
University of Michigan
Ann Arbor, Michigan

Sampling Date:
2/16/2018

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

BTEC Inc.

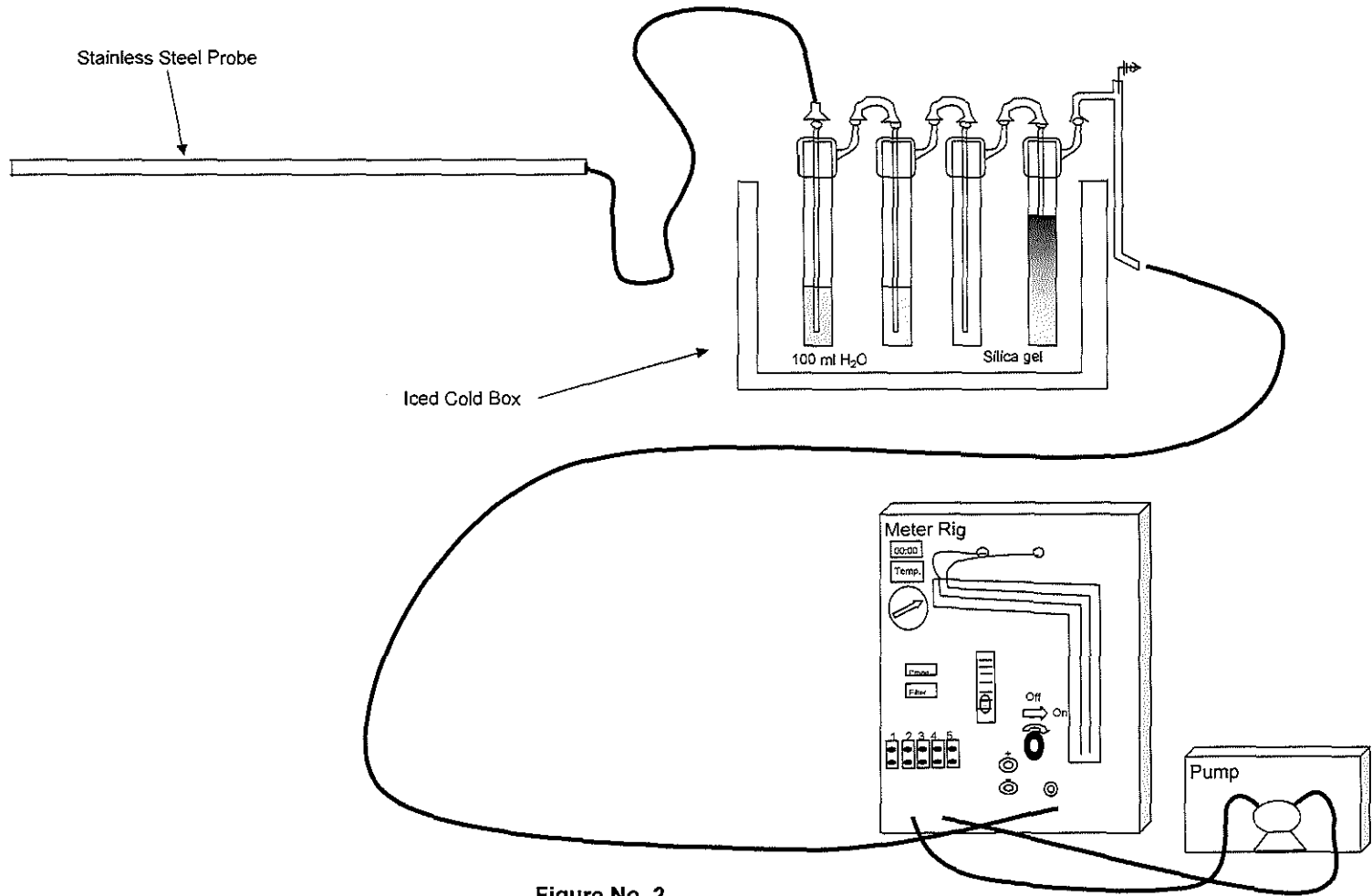


Figure No. 2

Site:
USEPA Method 4
University of Michigan
Ann Arbor, Michigan

Sampling Date:
2/16/2018

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

RECEIVED

APR 17 2018



AIR QUALITY DIVISION

diameter = 41 inches

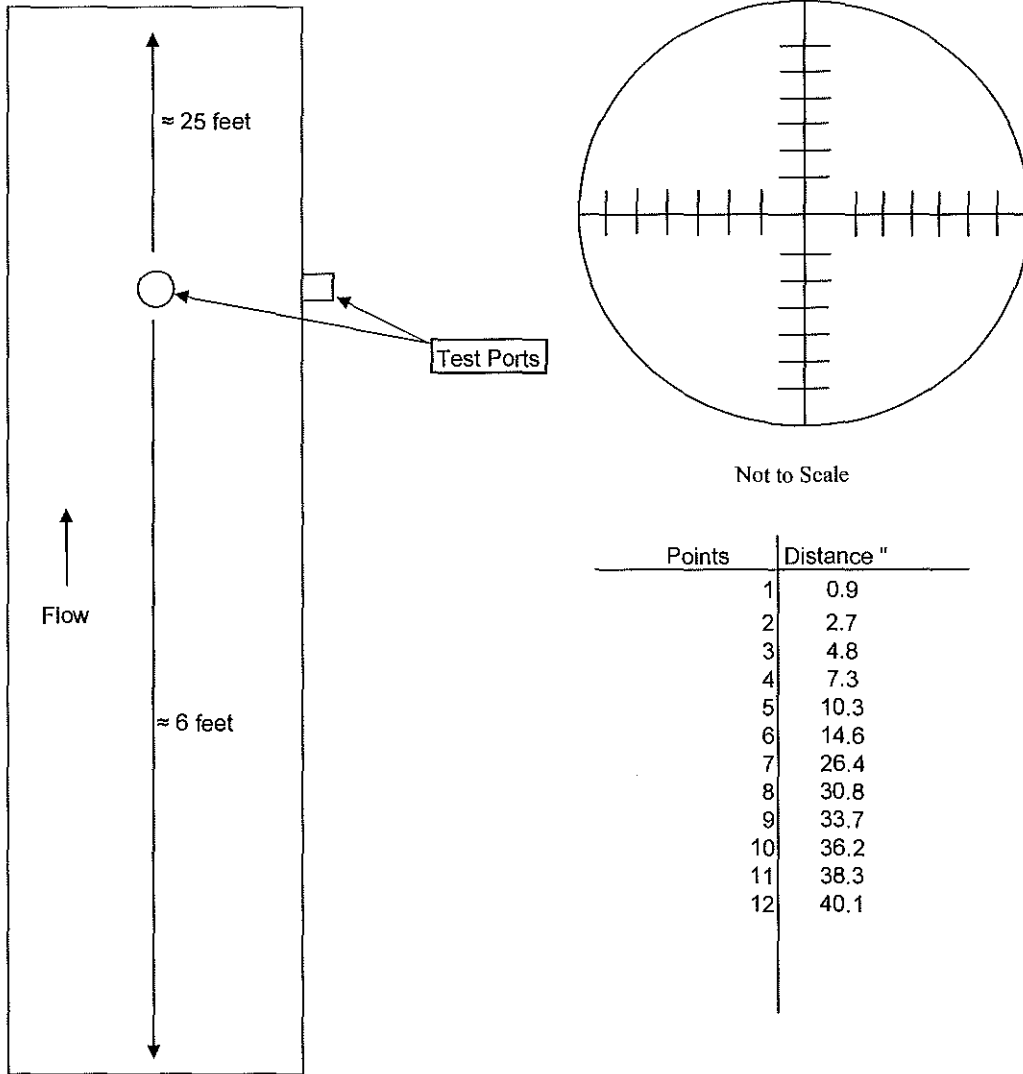


Figure No. 3

Site:
NCRC Turbine
University of Michigan
Ann Arbor, Michigan

Sampling Date:
2/16/2018

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