BTEC Inc.

Athens Compressor Station
Turbine Emissions Test Report

Prepared for:

Vector Pipeline L.P.

Athens Compressor Station
4981 Two Mile Road
Athens, Michigan 49011

Project No. 14-4500.01
May 2, 2014

BT Environmental Consulting, Inc.
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Royal Oak, Michigan 48073
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EXECUTIVE SUMMARY

BT Environmental Consulting, Inc. (BTEC) was retained by Vector Pipeline L.P. (Vector) to evaluate oxides of nitrogen (NOx) emission rates from a single turbine operating at 100% load condition at the Vector facility located in Athens Township, Michigan. The emissions test program was conducted on March 26, 2014.

Testing consisted of triplicate 20-minute test runs at a single load condition (99% NGP). The emissions test program is required by Title 40, Part 60, Subpart KKKK of the Code of Federal Regulations. The results of the emission test program are summarized by Table I.

Table I
Turbine Emission Summary
Test Date: March 26, 2014

Load	Pollutant	Emission Rate	Emission Limit
		ppmv[1]	ppmv[1]
99%	NOx	7.6	25

1: Corrected to 15% O_2

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1. Introduction

BT Environmental Consulting, Inc. (BTEC) was retained by Vector Pipeline L.P. (Vector) to evaluate oxides of nitrogen (NOx) emission rates from a single turbine operating at 100% load conditions at the Vector facility located in Athens Township, Michigan. The emissions test program was conducted on March 26, 2014. 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" (February 2008). This document is provided as Appendix A. 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 March 26, 2014 at the Vector facility located in Athens Township, Michigan. The test program included evaluation of NOx emissions from Turbine 1.

1.b Purpose of Testing

Annual or biannual verification of NOx emission rates is required by Title 40, Part 60, Subpart KKKK of the Code of Federal Regulations.

1.c Source Description

Vector's Athens Township Compressor Station is used to compress natural gas for transmission through the Vector pipeline.

1.d Test Program Contacts

The contact for the source and test report is:

Mr. Terry McMillin
Senior EHS Coordinator
Vector Pipeline
1100 Louisiana, Suite 3300
Houston, Texas 77002
(753) 353-5620

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

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 included power turbine operating speed (%), percent natural gas producer speed (%), turbine natural gas firing rate (kscfh), and natural gas higher heating value (Btu/scf). This data is summarized in Appendix B.

2.b Applicable Permit

Michigan Permit No. MI-ROP-N8151-2011 limits the turbine to 25 ppm NOx corrected to 15% O_2.

2.c Results

The overall results of the emission test program are summarized by Table 2.

3. Source Description

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

3.a Process Description

A single natural gas compressor turbine was evaluated for NOx emission rates in terms of parts per million. The Solar Mars 100 turbine fires only natural gas and is rated at 15,000 horsepower at a heat input rate of 120 MMBtu/hr. The turbine exhausts to a single, independent exhaust stack and is equipped with dry low-NOx emission controls.

3.b Process Flow Diagram

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

3.c Raw and Finished Materials

The raw material used by the process is natural gas and turbine natural gas firing rates during the emissions test program are summarized in Appendix B.

3.d Process Capacity

The turbine is rated at 15,000 horsepower and 120 MMBtu/hr. However, maximum turbine power output and heat input capacity at any given time are variable depending on ambient air temperature and pressure as well as pipeline gas pressure.

3.e Process Instrumentation

Process data monitored during the emissions test program included power turbine operating speed (%), percent natural gas producer speed (%), turbine natural gas firing rate (kscfh), and natural gas higher heating value (Btu/scf). This data is summarized in Appendix B.

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 of the gas stream was measured using a TECO Model 42i NOx gas analyzer, and the O_2 content was measured using a M&C Products PMA 100-L O_2 gas analyzer (or equivalent). 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.

For analyzer calibrations, calibration gases were mixed to desired concentrations using an Environics Series 4040 Computerized Gas Dilution System. The Series 4040 consists of a single chassis with four mass flow controllers. The mass flow controllers are factory-calibrated using a primary flow standard traceable to the United State's National Institute of Standards and Technology (NIST). Each flow controller utilizes an 11-point calibration table with linear interpolation, to increase accuracy and reduce flow controller nonlinearity. A schematic of the sampling train is provided as Figure 1.

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 19, *"Determination of Sulfur Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide, and Nitrogen Oxide Emission Rates"*, was used to determine the exhaust gas NOx emission rates.

The accuracy of the gas dilution system was verified using the procedures detailed by Method 205 and the NOx converter efficiency was verified as specified by Method 7E.

Exhaust gas flowrates were calculated using pollutant and diluent concentrations as well as turbine natural gas flowrate and average natural gas heating value data. A Method 7E exhaust gas stratification check was performed prior to the first test run and subsequent test runs were conducted using a three-point duct traverse for Turbine 1.

4.b Recovery and Analytical Procedures

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

4.c Sampling Ports

Figure 2 shows relevant sampling port and traverse point locations.

4.d Traverse Points

The sampling location met the minimum criteria specified by Method 1. During the first test run, the sample probe was moved to fifteen sampling locations to check for stratification. Since the individual traverse point diluent (O_2) concentrations differed by no more than ±0.3 percent O_2 from the mean for all traverse points, the subsequent two test runs utilized single point sampling.

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 Table 2.

5.b Discussion of Results

Title 40, Part 60, Subpart KKKK of the Code of Federal Regulations limits NOx emissions from the gas turbine to 25 ppmv at 15% O_2. The average NOx emission rate during the emissions test program was 7.6 ppmv at 15% O_2.

5.c Sampling Procedure Variations

There were no sampling procedure 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

The turbine is not equipped with emissions control equipment.

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 E.

5.k Laboratory Data

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

TABLES

Table 1
Test Personnel

Name	Affiliation
Jamie Van Valkenburg	Vector Pipeline
Mike Betzold	Vector Pipeline
Nathan Hude	MDEQ-AQD
Rex Lane	MDEQ-AQD
Todd Wessel	BTEC
Randal Tysar	BTEC

Table 2
Turbine 1 Detailed Emission Test Results Summary
Vector Pipeline
BTEC Project No. 14-4500.01
Sampling Date: March 26, 2014

	Parameter	Run 1	Run 2	Run 3	Average
	Test Run Date	3/26/2014	3/26/2014	3/26/2014	
99% Load	Oxides of Nitrogen Concentration (ppmv)	6.9	5.7	7.4	6.7
	Oxygen concentration (%)	15.8	15.6	15.6	15.7
	Oxygen concentration (%) (corrected as per USEPA 7E)	16.3	16.0	16.0	16.1
	Natural Gas Flowrate (kscf/hr)	114.6	114.2	113.3	114.0
	Natural Gas Heating Value (Btu/scf)	1037.6	1037.5	1037.5	1038
	NOx Concentration (ppmv, corrected as per USEPA 7E)	6.4	5.1	6.9	6.1
	NOx Concentration (lb/dscf, corrected as per USEPA 7E)	7.6E-07	6.1E-07	8.2E-07	7.3E-07
	NOx Emission Factor (lb/MMBtu, corrected as per USEPA 7E)	0.030	0.023	0.031	0.028
	NOx Emission Rate (lb/hr) (corrected as per USEPA 7E)	**3.6**	**2.7**	**3.6**	**3.3**
	Nox Concentration (ppmv@15% O2)	**8.2**	**6.2**	**8.4**	**7.6**

NOx Correction			
Co	0.35	0.36	0.33
Cma	25.00	25.00	25.00
Cm	26.12	26.32	25.95

O_2 Correction			
Co	0.19	0.17	0.18
Cma	9.90	9.90	9.90
Cm	9.69	9.68	9.68

Calculated using USEPA Method 19 equation 19-1

dscf = dry standard cubic feet
ppmv = parts per million on a volume-to-volume basis
lb/hr = pounds per hour
MW = molecular weight (NOx = 46.01)
24.14 = molar volume of air at standard conditions (70°F, 29.92" Hg)
35.31 = ft^3 per m^3
453600 = mg per lb
10^6 = Btu per MMBtu
3785.4 = mL per gallon

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

Equations

lb/dscf = ppmv * MW/24.14 * 1/35.31 * 1/453,600

eq 19-1: $E = C_d F_d * 20.9 / (20.9 - \%O_{2d})$

NOx @ 15% O2 = NOx measured (ppm) X (5.9/(20.9-O2% measured))

Nox corrected to ISO standard day conditions = (Nox @15%) x $(P_{std}/P_{amb})^{0.5}$ x $2.718^{(19x(H-0.00633))}$ x $(T_{std}/T_{amb})^{1.53}$

Ambient pressure and relative humidty obtained from www.wunderground.com
Ambient humidity in g H2O/g air obtained from psychrometric chart

FIGURES

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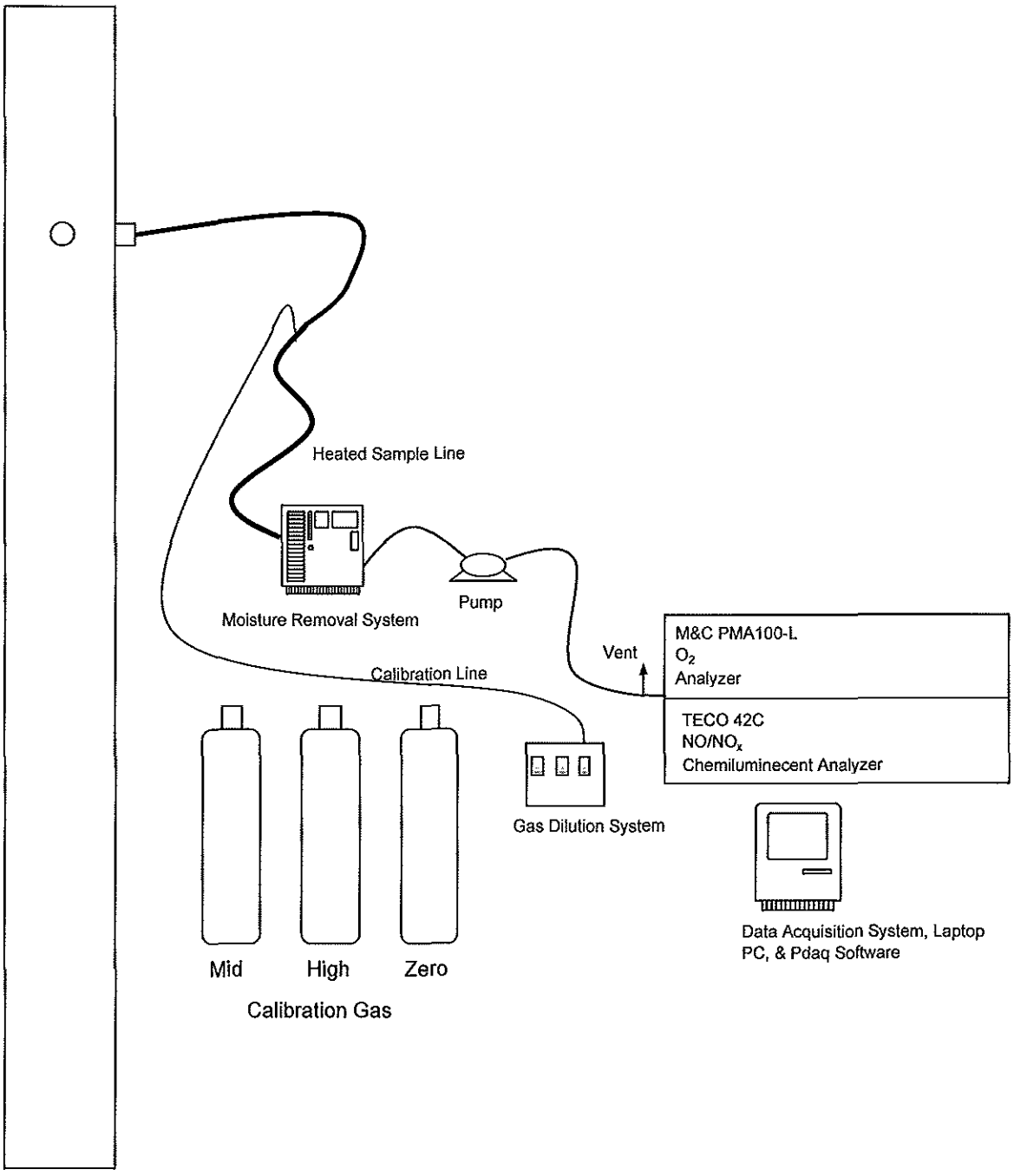

Figure 1

Site: **USEPA Method 3A and 7E** **Vector Pipeline** **Athens, Michigan**	**Sampling Date:** **March 26, 2014**	**BT Environmental Consulting Inc.** **4949 Fernlee Avenue** **Royal Oak, MI 48073**

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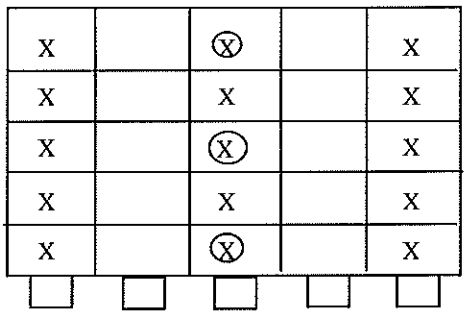
Stack Dimensions: 91" X 91"

Not to Scale

Points	Distance "
1	9.1
2	27.3
3	45.5
4	63.7
5	81.9



X = Initial Stratification Traverse Points (15)
◯ = Turbine 1 Sample Points (3)

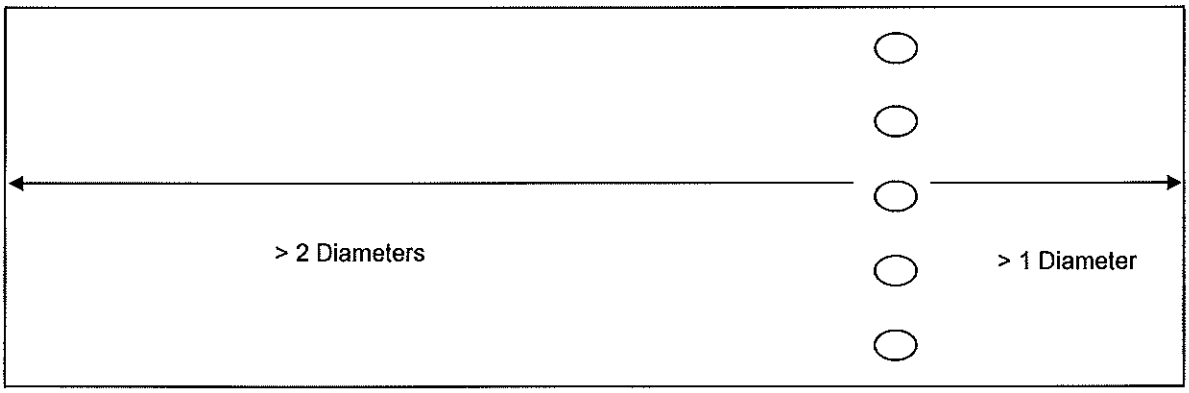


Figure 2

Site: **Turbine 1** **Vector Pipeline** **Athens Twp, Michigan**	**Sampling Dates:** **March 26, 2014**	**BT Environmental Consulting, Inc.** **4949 Fernlee Avenue** **Royal Oak, Michigan 48073**