Introduction

Pace Analytical Services, LLC personnel conducted nitrogen oxides (NO_x) emission compliance testing on the Natural Gas-Fired Combustion Turbine Stacks (EUTURBINE1 and EUTURBINE2) at the Northern Natural Gas - East Wakefield Compressor Station located in Wakefield, Michigan. Matt McDermott performed on-site testing activities on February 10, 2021. Terry Borgerding provided administrative project management. Kelly Henry and Andrew Curry with Northern Natural Gas coordinated plant activities during testing. Pace Analytical Services, LLC prepared a comprehensive test protocol that was submitted to the Michigan Department of Environment, Great Lakes, and Energy (EGLE) and approved prior to testing. On-site activities consisted of the following measurements on each source:

- Oxygen (O_2), three independent 20-minute monitoring periods.
- Nitrogen oxides (NO_x), three independent 20-minute monitoring periods.
- Fuel sample for sulfur content.

The project objectives were to quantify NO_x emission constituents and compare them to applicable air emissions regulations stipulated by EGLE and the facility permit. These measurements were performed while the turbine was operating at or above 75% peak load and the ambient temperature was above 0°F. Quality protocols comply with regulatory compliance testing requirements.

Subsequent sections summarize the test results and provide descriptions of the process and test methods. Supporting information and raw data are in the appendices.

Results Summary

Results of NO_x determinations for Turbine No. 1 are summarized in Table 1. The NO_x concentration averaged 71.1 PPM, Dry @ 15% O_2 and the emission rate averaged 4.39 LB/HR. The NO_x emission limits for this source are 100 PPM @ 15% O_2 and 7.24 LB/HR.

Results of NO_x determinations for Turbine No. 2 are summarized in Table 2. The NO_x concentration averaged 67.8 PPM, Dry @ 15% O_2 and the emission rate averaged 3.85 LB/HR. The NO_x emission limits for this source are 100 PPM @ 15% O_2 and 7.24 LB/HR.

The NO_x emission rate (LB/HR) was calculated using EPA Method 19 procedures and the engine fuel flow (MMBTU/HR).

The laboratory report of the sulfur analyses performed on a fuel gas sample collected during testing is included in Appendix B. The sulfur content was <4.44E-05 LB/MMBTU.

The data in this report are indicative of emission characteristics of the measured sources for process conditions at the time of the test. Representations to other sources and test conditions are beyond the scope of this report.

Summary Tables

Northern Natural Gas

East Wakefield Compressor Station
Wakefield, MI
Pace Project No. 21-04237

Table 1

Gas Monitoring Results
NG Fired Combustion Turbine No. 1 Stack
Test 1

Parameter	**Run 1**	**Run 2**	**Run 3**	**Average**
Date of Run	2/10/21	2/10/21	2/10/21	
Time of Run	1152-1215	1220-1244	1247-1307	
Sample Duration (Minutes)	23	24	20	
Compressor Flow, MMscfd	91.05	91.18	90.60	90.94
Oxygen, %v/v - Dry	16.23	16.44	16.30	16.32
Constituent Concentration, PPMv - Dry				
Nitrogen Oxides as NO2	55.3	55.1	55.1	55.2
Corrected Constituent Concentrations, PPM, dry @ 15% Oxygen				
Nitrogen Oxides as NO2	69.9	72.9	70.6	71.1
Constituent Emission Factors, LB/MMBTU (F-factor = 8710)				
Nitrogen Oxides as NO2	0.258	0.269	0.260	0.262
Fuel Flow, MMBTU/HR	16.75	16.80	16.74	16.76
Fuel Flow, MSCF/HR	16.15	16.20	16.14	16.16
NOx, LB/HR (LB/MMBTU x MMBTU/HR)	4.31	4.51	4.35	4.39

Northern Natural Gas

East Wakefield Compressor Station
Wakefield, MI
Pace Project No. 21-04237

Table 2

Gas Monitoring Results
NG Fired Combustion Turbine No. 2 Stack
Test 1

Parameter	**Run 4**	**Run 5**	**Run 6**	**Average**
Date of Run	2/10/21	2/10/21	2/10/21	
Time of Run	1425-1449	1455-1518	1518-1538	
Sample Duration (Minutes)	24	23	20	
Compressor Flow, MMscfd	91.15	90.92	90.94	91.00
Oxygen, %v/v - Dry	16.65	16.65	16.65	16.65
Constituent Concentration, PPMv - Dry				
Nitrogen Oxides as NO2	48.8	48.8	49.0	48.9
Corrected Constituent Concentrations, PPM, dry @ 15% Oxygen				
Nitrogen Oxides as NO2	67.7	67.7	68.0	67.8
Constituent Emission Factors, LB/MMBTU (F-factor = 8710)				
Nitrogen Oxides as NO2	0.250	0.250	0.251	0.250
Fuel Flow, MMBTU/HR	15.44	15.41	15.39	15.41
Fuel Flow, MSCF/HR	14.89	14.86	14.84	14.86
NOx, LB/HR (LB/MMBTU x MMBTU/HR)	3.85	3.85	3.86	3.85

Northern Natural Gas

East Wakefield Compressor Station
Wakefield, MI
Pace Project No. 21-04237

Table 3

Sulfur Analysis of Fuel
Stack
Test 1

Sampling Information

Sampled By:	Matt McDermott
Date Collected:	2/10/2021
Time Collected:	1530
Fuel Type:	Natural Gas

Analysis Information

Total Sulfur by UV:	<1.0	PPMw
Total Sulfur by UV:	<0.00010	%w/w
Total Sulfur by UV:	<0.032	GR/100 CF

Regulatory Units

Sulfur LB/MMBTU[1]	<4.44E-05
Sulfur ng/Joule[1]	<0.01908

[1] Gross Heating Value 1030 BTU/CF (Assumed)

Process Description

Northern Natural Gas - East Wakefield Compressor Station is a natural gas compressor station located in Wakefield, Michigan. Compressor stations compress natural gas to specified pressure along natural gas pipelines allowing the gas to continue moving through the pipeline to the intended recipient. The facility consists of two 1,679 HP simple-cycle natural gas-fired combustion turbines for compressing natural gas.

Test related process and operational details were collected by Northern Natural Gas personnel and included in Appendix E.

Test Procedures

EPA Method 1 specifies test location acceptability criteria and defines the minimum number of traverse points for representative sampling. Linear measurements from upstream and downstream flow disturbances and the duct equivalent diameter are compared and the distances related to number of diameters. A flow disturbance can be defined as anything that changes or upsets the direction of flow within the duct including bends, dampers, fans, shape or size transitions, and open flames. Method 1 stipulates that test ports should be located at least eight diameters downstream and two diameters upstream of any flow disturbance. The minimum acceptable criteria are two diameters downstream and 0.5 diameters upstream of flow disturbances. The test location must also be free of cyclonic or multidirectional flow. Once the distances have been determined, the values are used to select the minimum number of traverse points for representative sampling. Shorter distances require a greater number of traverse points. The test site configuration and measurement details are documented on EPA Method 1 Field Data Sheet.

Pace FSD conducts the method as written with no routine deviations.

EPA Method 3A defines procedures to measure carbon dioxide (CO_2) and oxygen (O_2) concentrations from stationary sources. A stainless steel sampling probe and a sampling line draw a sample of the gas stream from the duct to a thermo-electric gas conditioner to remove moisture. The conditioned gas stream is delivered to an infrared gas analyzer to quantify CO_2 concentrations and paramagnetic gas analyzer to quantify O_2 concentrations. Zero grade cylinder air or a zero gas generator provides zero gas. Span gases include varying concentrations of EPA Protocol 1 CO_2/O_2 mixed standards specific to the target calibration range. A computerized data acquisition system logs CO_2/O_2 concentrations for one-minute averages. The logged results are integrated to test periods and tabulated with standardized and validated spreadsheets in Microsoft Excel. The operator also maintains comprehensive test records in the electronic Project Results Instrumental Workbook. Equipment used for CO_2/O_2 testing includes:

Probe Material:	Stainless Steel
Moisture Removal:	Thermo-electric
Transfer Line:	Teflon™
Analytical Technique:	Non-dispersive Infrared Detector (CO_2)
	Paramagnetic Detector (O_2)
Calibration Gas:	EPA Protocol 1

Method Defined Quality Control:

- Sampling system leak-checks are performed before each test and following any component change. Absence of leaks is confirmed through the bias check after each run.

- Calibration gas standards of the highest quality, Protocol 1 or traceable to NIST, are used in calibrations.
- Analyzer calibration error is determined before initial run and after any failed bias or drift test.
- Analyzer bias is verified once per test.
- System bias check is performed before and after each test.
- Calibration drift test is performed after each test run.
- System response time is determined during initial sampling system bias test.
- Stratification test is performed prior to first run.
- Purge time of ≥ 2x the response time observed before starting data collection and recording stratification traverse point values.

Pace FSD conducts the method as written with no routine deviations.

EPA Method 7E defines procedures to measure nitrogen oxide (NO_x) emissions from stationary sources. A stainless steel sampling probe and a heat-traced Teflon™ sampling line draw a sample of the gas stream from the duct to a thermo-electric gas conditioner to remove moisture. The sample gas stream is delivered to a chemiluminescence NO-NO_2-NO_x analyzer to quantify NO_x emissions. Zero grade cylinder air or a zero gas generator provides zero gas. Span gases include varying concentrations of EPA NO_x standards specific to the target calibration range. A computerized data acquisition system logs NO_x concentrations for one-minute averages. The logged results are integrated to test periods and tabulated with standardized and validated spreadsheets in Microsoft Excel. The operator also maintains comprehensive test records in the electronic Project Results Instrumental Workbook. Equipment used for NO_x testing includes:

Probe Material:	Stainless Steel
Moisture Removal:	Thermo-electric
Transfer Line:	Teflon™
Analytical Technique:	Chemiluminescence
Calibration Gas:	EPA Protocol 1

Method Defined Quality Control:

- Sampling system leak-checks are performed before each test and following any component change. Absence of leaks is confirmed through the bias check after each run.
- Calibration gas standards of the highest quality, Protocol 1 or traceable to NIST, are used in calibrations.
- Analyzer calibration error is determined before initial run and after any failed bias or drift test.
- Analyzer bias is verified once per test.
- System bias check is performed before and after each test.
- Calibration drift test is performed after each test run.

- System response time is determined during initial sampling system bias test.
- Stratification test is performed prior to first run.
- Purge time of ≥ 2x the response time observed before starting data collection and recording stratification traverse point values.
- NO2 to NO converter efficiency verified ≥ 90% before or after each test.

Pace FSD conducted this method with the following project situational deviations:

- A 12-point stratification traverse was performed per Subpart KKKK.
- The NO_x values were within 5% of the mean concentration and differed by no more than ±3 PPM from the mean. A single sample point was used and 3 runs with a minimum sample time of 20 minutes were performed.

EPA Method 19 describes data reduction procedures relating to particulate matter (PM), sulfur dioxide (SO_2), and nitrogen oxide (NO_x). This method is used to determine emission rates, overall reduction of potential SO_2 emissions, and SO_2 removal efficiency. Oxygen (O_2) or carbon dioxide (CO_2) concentrations and appropriate F-factors (ratios of combustion gas volumes to heat inputs) are used to calculate pollutant emission rates from pollutant concentrations. An overall SO_2 emission reduction efficiency is computed from the efficiency of fuel pretreatment systems, where applicable, and the efficiency of SO_2 control devices. The sulfur removal efficiency of a fuel pretreatment system is determined by fuel sampling and analysis of the sulfur and heat contents of the fuel before and after the pretreatment system. The SO_2 removal efficiency of a control device is determined by measuring the SO_2 rates before and after the control device. The inlet rates to SO_2 control systems are determined by fuel sampling and analysis; when SO_2 control systems are not used, SO_2 emission rates to the atmosphere are determined.

Pace FSD conducts the method as written with no routine deviations.

Reference Standards. Pace implements a comprehensive program to verify and validate reference standards to further enhance and support method standards. Primary reference standards are directly comparable to a reference base. The National Institute of Standards and Technology (NIST) maintains primary reference materials or very closely traceable secondary standards. These materials are then used to certify secondary or transfer standards for use in quality management programs. Secondary reference standards are calibrated with primary standards using a high precision comparator. Materials that have a documented path to the primary standard are often referred to as traceable to NIST or NIST traceable. Where commercially and feasibly available, Pace uses primary reference standards to perform calibrations and verifications. In other cases, Pace maintains traceable secondary reference standards. Primary and secondary reference standards are used to calibrate and verify equipment and materials. Pace reference standards are calibrated by external vendors that have a formal, registered quality system. Calibrations are performed with equipment and materials that are traceable to NIST.

Quality Controls (not defined in test methods):

- Sampling/Recovery Reagents are Reagent Grade or better.
- Reference Temperature Simulator is calibrated annually.
- Reference Pressure Transducer is calibrated annually.
- Reference DryCal airflow meter is calibrated annually.
- Mercury Barometer is a primary reference standard.
- Liquid Manometers are primary reference standards.
- Angle Blocks, Gauge Blocks, and Measuring Rods are verified every five years.
- Angle Gauges are verified each day of use.
- Calipers are verified annually.
- Stainless steel reference weights are verified every five years.
- Analytical balances are calibrated annually and verified at each use.
- Field balances are calibrated annually and verified at each use.

Quality Management System. To produce data that is complete, representative, and of known precision and accuracy, Pace Analytical Field Services Division has designed and implemented a rigorous and innovative quality management system. The system was initially based on the USEPA Quality Assurance Handbook for Air Pollution Measurement Systems and continually developed as procedural complexities and standards progressed. The Field Services Division Quality Management System (Pace FSD QMS) is now accredited by the American Association of Laboratory Accreditation (A2LA) to comply with three national accreditation standards:

- ASTM D7036 - Standard Practice for Competence of Air Emission Testing Bodies (AETB).
- ISO 17025 - General Requirements for the Competence of Testing and Calibration Laboratories
- The NELAC Institute - General Requirements for Field Sampling and Measurement Organizations (FSMO)

The Pace FSD QMS includes:

- Quality Programs
  - Ethics policy and training.
  - Corrective Action and Preventative Action (CAPA).
  - Continuous Process Improvement.
  - Documented Demonstrations of Capability.
  - Internal and third party proficiency testing.
  - Qualified Individual program (QI)
  - Internal and external audits.
  - Annual management reviews.
- Documentation and Traceability
  - High quality traceable standards and reagents.
  - Reagent tracking and management system.
  - Use of matrix spikes, duplicate analysis, internal standards, and blanks.

  - Validated workbooks for data collection and results reporting.
  - Electronic quality, training, and safety documents available in-field.
  - Sample security and preservation procedures.
  - Chain of custody maintained from sample collection through laboratory analysis.
- Equipment Calibration
  - Full time staff dedicated to equipment maintenance and calibration.

All equipment and instruments are calibrated by trained personnel on a frequency that meets or exceeds method requirements.

Report Signatures

Field Testing and Reporting Performed by: Pace Analytical Services, LLC
Field Services Division
1700 Elm Street, Suite 200
Minneapolis, MN 55414

Field Testing Affirmation

All field testing was performed in accordance with stated test methods subject to modifications and deviations listed herein. Raw field data presented in this report accurately reflects results and information as recorded at the time of tests or otherwise noted.

Date 3/11/21

Mathew A. McDermott, QSTI
Field Scientist III

Report Affirmation

To the best of my knowledge, this report accurately represents the compiled field and laboratory information with no material omissions, alterations or misrepresentations.

Beth Kelm Date 3/10/2021

Beth Kelm
Project Manager

Responsible Charge Affirmation

I have reviewed the information herein and it is approved for distribution.

Date 3/10/21

Terence J. Borgerding, QSTI
Operations Manager, Air