IMPACT COMPLIANCE & TESTING

AIR EMISSION TEST REPORT

Title	AIR EMISSION TEST REPORT FOR THE VERIFICATION OF NITROGEN OXIDE EMISSIONS FROM A NATURAL GAS FUELED TURBINE
Report Date	May 31, 2019
Test Date	May 14, 2019

Facility Information	
Name	Lambda Energy Resources, LLC – Kalkaska Gas Plant
Street Address	1080 Prough Road SW
City, County	Kalkaska, Kalkaska
SRN	B4292

Facility Permit Information	
ROP No.:	MI-ROP-B4292-2014a
Emission Unit:	EU-KGPN-TURB-C

Testing Contractor	
Company	Impact Compliance & Testing, Inc.
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Project No.	1900130

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LAMBDA ENERGY RESOURCES, LLC – KALKASKA GAS PLANT

1.0 INTRODUCTION

Lambda Energy Resources, LLC (Lambda) owns and operates a natural gas fired turbine and waste heat recovery unit (WHRU) at the Kalkaska Gas Plant in Kalkaska, Kalkaska County, Michigan (Facility SRN: B4292). The natural gas fired turbine and associated WHRU are identified as emission unit EU-KGPN-TURB-C in Renewable Operating Permit (ROP) No. MI-ROP-B4292-2014a issued by the Michigan Department of Environmental Quality (MDEQ). The turbine is also regulated under 40 CFR Part 60, Subpart KKKK, the New Source Performance Standards (NSPS) for Stationary Combustion Turbines.

The conditions of MI-ROP-B4292-2014 specify that:

1. Annual performance tests shall be conducted to demonstrate compliance with nitrogen oxides (NOx) emissions of 1.2 lb/MW-hr.

2. The NOx testing frequency can be reduced to once every two years if the emission test results are less than or equal to 0.9 lb/MW-hr.

The conditions of 40 CFR Subpart KKKK specify that:

1. For new turbines fired by natural gas with peak heat input rate > 55 million British Thermal Units per hour (MMBtu/hr) and < 850 MMbtu/hr, NOx emission standards are 15 ppm at 15% O_2 or 1.2 lb/MW-hr

2. The testing must be performed at any load condition within plus or minus 25 percent of 100 percent of peak load. The testing may be performed at the highest achievable load point, if at least 75 percent of peak load cannot be achieved in practice.

This test report presents the results of emission testing performed by Impact Compliance and Testing, Inc. (ICT) on May 14, 2019. ICT representatives Blake Beddow and Jory VanEss performed the field sampling and measurements. Mr. Kurt Childs of the Michigan Department of Environment, Great Lakes, and Energy (EGLE) Cadillac District observed portions of the testing project.

Questions regarding this emission test report should be directed to:

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Report Certification

This test report was prepared by ICT based on field sampling data collected by ICT personnel. Facility process data were collected and provided by Lambda employees or representatives. This test report has been reviewed by Lambda representatives and approved for submittal to the EGLE. A signed ROP report certification (EQP 5736) accompanies this report.

I certify that the testing was conducted in accordance with the specified test methods and submitted test plan unless otherwise specified in this report. I believe the information provided in this report and its attachments are true, accurate, and complete.

Report Prepared By:

Blake Beddow
Project Manager
Impact Compliance & Testing, Inc.

Reviewed by:

Andy Rusnak, QSTI
Technical Manager
Impact Compliance & Testing, Inc.

2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

Lambda operates a gas-fired turbine (EU-KGPN-TURB-C) at the Kalkaska Gas Plant in Kalkaska, Michigan that is fueled exclusively with natural gas. In addition, a natural gas-fired duct burner is used with the WHRU to heat thermal oil for other processes at the facility.

The operating parameters (i.e., turbine load and natural gas use rate) are synchronized with the Great Lakes Power Grid. The turbine control system automatically adjusts power output depending on the needs of the power grid. The WHRU operates as necessary when there is a demand for heated oil in the facility.

2.2 Rated Capacities and Air Emission Controls

The natural gas fueled turbine has a rated heat input of 60.2 MMBtu/hr and the duct burner associated with the WHRU has a rated heat input rate of 28.0 MMBtu/hr. The turbine is equipped with dry low NOx combustors that are designed to pre-mix the fuel and combustion air at a controlled ratio that minimizes combustor temperature and NOx formation. The exhaust gas is used to heat oil in the WHRU and is released to atmosphere without additional add-on emission controls.

2.3 Sampling Locations

The turbine exhaust gas is released to the atmosphere through a dedicated vertical exhaust stack.

The exhaust stack has an inner diameter of 45 inches and is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 48 inches (~1 duct diameters) upstream and 180 inches (4 duct diameters) downstream from any flow disturbance. This satisfies the USEPA Method 1 criteria for a representative sample location.

Appendix A provides diagrams of the emission test sampling location.

3.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

3.1 Purpose and Objective of the Tests

The conditions of Renewable Operating Permit (ROP) No. MI-ROP-B4292-2014a and 40 CFR Part 60 Subpart KKKK require Lambda to test nitrogen oxides (NOx) emissions from EU-KGPN-TURB-C annually, or bi-annually, depending on the results of the previous stack test event.

3.2 Operating Conditions During the Compliance Tests

The testing was performed while the turbine was operated at maximum achievable operating conditions. Lambda representatives provided generator output data (MW) in 15-minute intervals for each test period. The turbine generator output ranged between 4.48 and 4.62 MW for each test period.

Fuel feed rate (cubic feet per minute) was recorded by Merit representatives in 15-minute intervals for each test period. The average fuel consumption rate of the turbine ranged between 1,359 and 1,386 mcf/d. The average fuel consumption rate of the WHRU ranged between 269 and 345 mcf/d.

Appendix B provides operating records provided by Merit representatives for the test periods.

3.3 Summary of Air Pollutant Sampling Results

The gas exhausted from the natural gas fueled turbine (EU-KGPN-TURB-C) was sampled for three (3) one-hour test periods during the compliance testing performed May 14, 2019.

Table 3.1 presents a summary of the average turbine emissions and operating conditions during the test periods. Test results for each one hour sampling period are presented in Table 6.1 of this report.

The heat input for the turbine and WHRU was calculated using the measured fuel consumption rate and the USEPA AP-42 default higher heating value for natural gas (1,050 Btu/scf).

Table 3.1 Average turbine emissions and operating conditions during the test periods

Turbine Parameter	EU-KBPN-TURB-C
Generator output (MW)	4.54
Turbine fuel use (mcf/d)	1,370
Turbine heat input (MMBtu/hr)	59.9
WHRU fuel use (mcf/d)	309
WHRU heat input (MMBtu/hr)	13.5
Exhaust Flowrate (dscfm)	28,253
NOx Emission Rate (lb/MW-hr)	0.49

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A test protocol for the air emission testing was reviewed and approved by the EGLE. This section provides a summary of the sampling and analytical procedures that were used during the testing periods.

4.1 Summary of Sampling Methods

USEPA Method 1	Exhaust gas velocity measurement locations were determined based on the physical stack arrangement and requirements in USEPA Method 1
USEPA Method 2	Exhaust gas velocity pressure was determined using a Type-S Pitot tube connected to a red oil incline manometer; temperature was measured using a K-type thermocouple connected to the Pitot tube.
USEPA Method 3A	Exhaust gas O_2 and CO_2 content was determined using zirconia ion/paramagnetic and infrared instrumental analyzers, respectively.
USEPA Method 4	Exhaust gas moisture was determined based on the water weight gain in chilled impingers.
USEPA Method 7E	Exhaust gas NOx concentration was determined using chemiluminescence instrumental analyzer.
USEPA Method 205	Verification of Dilution Systems for Field Instrument Calibrations

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

The turbine exhaust stack gas velocity and volumetric flowrate was determined using USEPA Method 2 during each test. An S-type Pitot tube connected to a red-oil manometer was used to determine velocity pressure at each traverse point across the stack cross section. Gas temperature was measured using a K-type thermocouple mounted to the Pitot tube.

Appendix C provides exhaust gas flowrate calculations and field data sheets.

4.3 Exhaust Gas Molecular Weight Determination (USEPA Method 3A)

CO_2 and O_2 content in the turbine exhaust gas stream was measured continuously throughout each test period in accordance with USEPA Method 3A. The CO_2 content of the exhaust was monitored using a single beam single wavelength (SBSW) infrared gas analyzer. The O_2 content of the exhaust was monitored using a gas analyzer that uses a paramagnetic sensor.

During each sampling period, a continuous sample of the turbine exhaust gas stream was extracted from the stack using a stainless steel probe connected to a Teflon® heated sample line. The sampled gas was conditioned by removing moisture prior to being introduced to the analyzers; therefore, measurement of O_2 and CO_2 concentrations correspond to standard dry gas conditions. Instrument response data were recorded using an ESC Model 8816 data acquisition system that monitored the analog output of the instrumental analyzers continuously and logged data as one-minute averages.

Prior to, and at the conclusion of each test, the instruments were calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias (described in Section 5.0 of this document). Sampling times were recorded on field data sheets.

Appendix D provides O_2 and CO_2 calculation sheets. Raw instrument response data are provided in Appendix E.

4.4 Exhaust Gas Moisture Content (USEPA Method 4)

Moisture content of the turbine exhaust gas was determined in accordance with USEPA Method 4 using a chilled impinger sampling train. The moisture sampling was performed concurrently with the instrumental analyzer sampling. During each sampling period a gas sample was extracted at a constant rate from the source where moisture was removed from the sampled gas stream using impingers that were submersed in an ice bath. At the conclusion of each sampling period, the moisture gain in the impingers was determined gravimetrically by weighing each impinger to determine net weight gain.

4.5 NO_x Concentration Measurements (USEPA Method 7E)

NO_X pollutant concentrations in the turbine exhaust gas streams were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42c High Level chemiluminescence NO_X analyzer.

Throughout each test period, a continuous sample of the turbine exhaust gas was extracted from the stack using the Teflon® heated sample line and gas conditioning system and delivered to the instrumental analyzers. Instrument response for each analyzer was recorded on an ESC Model 8816 data acquisition system that logged data as one-minute averages. Prior to, and at the conclusion of each test, the instruments were calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias.

Appendix D provides NO_X calculation sheets. Raw instrument response data are provided in Appendix E.

5.0 QA/QC ACTIVITIES

5.1 Exhaust Gas Flow

Prior to arriving onsite, the instruments used during the source test to measure exhaust gas properties and velocity (barometer, pyrometer, and Pitot tube) were calibrated to specifications outlined in the sampling methods.

The Pitot tube and connective tubing were leak-checked periodically throughout the test event to verify the integrity of the measurement system.

The absence of significant cyclonic flow for the exhaust configurations were verified using an S-type Pitot tube and oil manometer. The Pitot tube was positioned at each velocity traverse point with the planes of the face openings of the Pitot tube perpendicular to the stack cross-sectional plane. The Pitot tube was then rotated to determine the null angle (rotational angle as measured from the perpendicular, or reference, position at which the differential pressure is equal to zero).

5.2 NO_x Converter Efficiency Test

The NO_2 – NO conversion efficiency of the chemiluminescence NOx analyzer was verified prior to the testing program. A USEPA Protocol 1 certified concentration of NO_2 was injected directly into the analyzer, following the initial three-point calibration, to verify the analyzer's conversion efficiency. The analyzer's NO_2 – NO converter uses a catalyst at high temperatures to convert the NO_2 to NO for measurement. The conversion efficiency of the analyzer is deemed acceptable if the measured NOx concentration is at least 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NOx concentration was 96% of the expected value, i.e., greater than 90% of the expected value as required by Method 7E).

5.3 Gas Divider Certification (USEPA Method 205)

A STEC Model SGD-710C 10-step gas divider was used to obtain appropriate calibration span gases. The ten-step STEC gas divider was NIST certified (within the last 12 months) with a primary flow standard in accordance with Method 205. When cut with an appropriate zero gas, the ten-step STEC gas divider delivers calibration gas values ranging from 0% to 100% (in 10% step increments) of the USEPA Protocol 1 calibration gas that was introduced into the system. The field evaluation procedures presented in Section 3.2 of Method 205 were followed prior to use of gas divider. The field evaluation yielded no errors greater than 2% of the triplicate measured average and no errors greater than 2% from the expected values.

5.4 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NOx, O_2 and CO_2 have had an interference response test performed prior to their use in the field, pursuant to the interference response test procedures specified in USEPA Method 7E. The appropriate interference test gases (i.e., gases that would be encountered in the exhaust gas stream) were introduced into each analyzer, separately and as a mixture with the analyte that each analyzer is designed to measure. All of analyzers exhibited a composite deviation of less than 2.5% of the span for all measured interferent gases. No major analytical components of the analyzers have been replaced since performing the original interference tests.

5.5 Instrument Calibration and System Bias Checks

At the beginning of each day of the testing program, initial three-point instrument calibrations were performed for the NOx, CO_2 and O_2 analyzers by injecting calibration gas directly into the inlet sample port for each instrument. System bias checks were performed prior to and at the conclusion of each sampling period by introducing the upscale calibration gas and zero gas into the sampling system (at the base of the stainless steel sampling probe prior to the particulate filter and Teflon® heated sample line) and determining the instrument response against the initial instrument calibration readings.

The instruments were calibrated with USEPA Protocol 1 certified concentrations of CO_2, O_2, and NO_x in nitrogen and zeroed using hydrocarbon free nitrogen. A STEC Model SGD-710C ten-step gas divider was used to obtain intermediate calibration gas concentrations as needed.

5.6 Determination of Exhaust Gas Stratification

A stratification test was performed for the turbine exhaust stack. The stainless steel sample probe was positioned at sixteen (16) sample points. The stratification sample points were determined by USEPA Method 1, so eight (8) points were used along each diameter that were accessed by the two samples ports that are opposed 90°. Pollutant concentration data were recorded at each sample point for a minimum of twice the maximum system response time.

The recorded concentration data for the turbine exhaust stack indicated that the measured NOx concentrations were stratified (i.e. varied by more than 10% of the mean). Therefore, the sampling for each one-hour test period was performed at 16 points and each point was sampled for an equal amount of time (i.e. 3.75 minutes per point). Data from the port change was not included in the run average, and testing was resumed once the sample probe had been in place for a minimum of twice the maximum system response time.

5.7 Meter Box Calibrations

The dry gas metering console, which was used for exhaust gas moisture content sampling, was calibrated prior to and after the testing program. This calibration uses the critical orifice calibration technique presented in USEPA Method 5. The metering console calibration exhibited no data outside the acceptable ranges presented in USEPA Method 5.

The digital pyrometer in the metering console was calibrated using a NIST traceable Omega® Model CL 23A temperature calibrator.

Appendix F presents test equipment quality assurance data for the emission test equipment (NO_2 – NO conversion efficiency test data, instrument calibration and system bias check records, calibration gas and gas divider certifications, interference test results, meter box calibration records, Pitot tube calibration records).

6.0 RESULTS

6.1 Test Results and Allowable Emission Limits

Turbine operating data and air pollutant emission measurement results for each one-hour test period are presented in Table 6.1.

The tests were performed with the gas fired turbine operating at greater than 75% load. The measured NOx emission rate for EU-KGPN-TURB-C is less than 1.2 lb/MW-hr as required by the Renewable Operating Permit (ROP) No. MI-ROP-B4292-2014 and 40 CFR Part 60 Subpart KKKK.

Based on these test results, the measured emission rate is less than 0.9 lb/MW-hr and the required testing frequency remains once every two years.

6.2 Variations from Normal Sampling Procedures or Operating Conditions

The testing for all pollutants was performed in accordance with the associated test methods and approved test protocol. The turbine was operated maximum achievable operating conditions and no variations from the normal operating conditions occurred during the test periods.

Table 6.1 Summary of EU-KGPN-TURB-C Test Results
Lambda Energy – Kalkaska Gas Plant, Kalkaska, Kalkaska County, Michigan

Test No.	1	2	3	
Test Date	5/14/19	5/14/19	5/14/19	
Test Period (24-hr clock)*	0720-0750, 0753-0824	0843-0913, 0917-0948	1005-1035, 1038-1109	Test Avg.
Turbine Output (MW)	4.54	4.53	4.55	4.54
Turbine Fuel Consumption (mcf/d)	1,371	1,368	1,372	1,370
Turbine Heat Input (MMBtu/hr)	60.0	59.8	60.0	59.9
WHRU Fuel Consumption (mcf/d)	330	315	282	309
WHRU Heat Input (MMBtu/hr)	14.4	13.8	12.3	13.5
Exhaust gas composition				
CO_2 content (% vol)	4.49	4.22	4.07	4.26
O_2 content (% vol)	14.0	14.3	14.6	14.3
Moisture (% vol)	7.8	7.5	6.9	7.4
Exhaust gas flowrate				
Standard conditions (scfm)	29,092	31,392	31,046	30,509
Dry basis (dscfm)	26,837	29,022	28,902	28,253
Nitrogen oxides emission rates				
NO_X conc. (ppmvd)	12.3	10.8	9.68	10.9
NO_X emissions (lb/hr NO_2)	2.36	2.24	2.01	2.20
NO_X emissions (lb/MW-hr NO_2)	0.52	0.50	0.44	0.49
NO_X permit limit (lb/MW-hr)				*1.20*

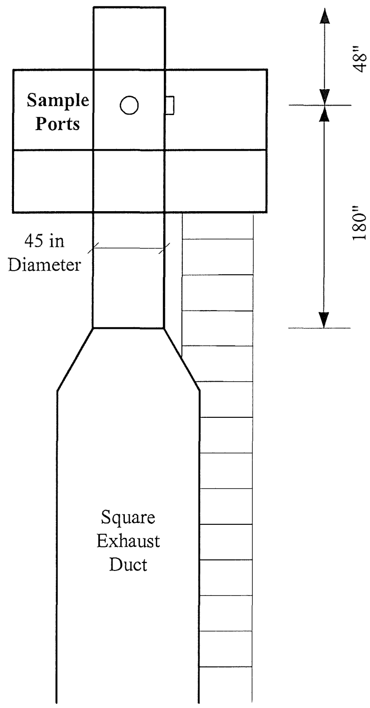
*Test was paused during sampling port changes.

APPENDIX A

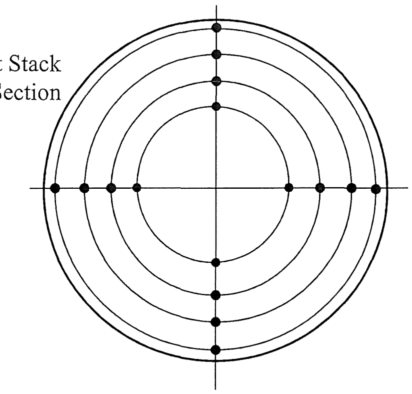
- Sample Port Diagram

Impact Complianct & Testing, Inc.

Turbine C
(EU-KGPN-TURB-C)



Exhaust Stack
Cross-Section



Velocity sample locations as measured from stack wall (not including 1" sampling port nipple)

Pt. #	in.
1	1.44
2	4.73
3	8.73
4	14.54
5	30.47
6	36.27
7	40.28
8	43.56

5/14/15	**Lambd a Energy – Kalkaska Gas Plant** **Exhaust Sample Location, Turbine C**		
	Scale None	Sheet 1 of 1	ICT