

**AIR EMISSION TEST REPORT  
FOR THE  
VERIFICATION OF NITROGEN OXIDES EMISSIONS  
FROM A  
NATURAL GAS FUELED TURBINE**

**Prepared for:  
Lambda Energy Resources, LLC  
Kalkaska Gas Plant  
SRN B4292**

**ICT Project No.: 2300066  
June 14, 2023**



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## Report Certification

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**Lambda Energy Resources, LLC  
at the Kalkaska Gas Plant  
Kalkaska, MI**

The material and data in this document were prepared under the supervision and direction of the undersigned.

Impact Compliance & Testing, Inc.



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Blake Beddow  
Senior Project Manager

## Table of Contents

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<b>1.0 INTRODUCTION.....</b>	<b>2</b>
<b>2.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS .....</b>	<b>3</b>
2.1 Purpose and Objective of the Tests.....	3
2.2 Operating Conditions During the Compliance Tests.....	3
2.3 Summary of Air Pollutant Sampling Results .....	3
<b>3.0 SOURCE AND SAMPLING LOCATION DESCRIPTION.....</b>	<b>5</b>
3.1 General Process Description.....	5
3.2 Rated Capacities and Air Emission Controls .....	5
3.3 Sampling Locations .....	5
<b>4.0 SAMPLING AND ANALYTICAL PROCEDURES .....</b>	<b>6</b>
4.1 Summary of Sampling Methods.....	6
4.2 Exhaust Gas Velocity Determination (USEPA Method 2) .....	7
4.3 Exhaust Gas Molecular Weight Determination (USEPA Method 3A).....	7
4.4 Exhaust Gas Moisture Content (USEPA Method 4).....	7
4.5 NOx Concentration Measurements (USEPA Method 7E).....	8
<b>5.0 QA/QC ACTIVITIES.....</b>	<b>9</b>
5.1 Flow Measurement Equipment.....	9
5.2 NOx Converter Efficiency Test .....	9
5.3 Gas Divider Certification (USEPA Method 205).....	9
5.4 Instrumental Analyzer Interference Check.....	9
5.5 Instrument Calibration and System Bias Checks .....	10
5.6 Determination of Exhaust Gas Stratification .....	10
5.7 System Response Time .....	10
5.8 Meter Box Calibrations .....	10
<b>6.0 RESULTS .....</b>	<b>11</b>
6.1 Test Results and Allowable Emission Limits.....	11
6.2 Variations from Normal Sampling Procedures or Operating Conditions .....	11

## List of Tables

---

2.1	Average turbine operating conditions during the test periods .....	4
2.2	Average measured NO <sub>x</sub> concentrations and emission rates (three-test average) .....	4
6.1	Measured exhaust gas conditions and NO <sub>x</sub> concentrations and emission rates for the KGP Turbine (EU-KGPN-TURB-C) .....	12

## List of Appendices

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APPENDIX 1	SAMPLE PORT DIAGRAM
APPENDIX 2	OPERATING RECORDS
APPENDIX 3	FLOWRATE CALCULATIONS AND DATA SHEETS
APPENDIX 4	CO <sub>2</sub> , O <sub>2</sub> , AND NO <sub>x</sub> CALCULATIONS
APPENDIX 5	INSTRUMENTAL ANALYZER RAW DATA
APPENDIX 6	QA/QC RECORDS

## 1.0 Introduction

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Lambda Energy Resources, LLC (Lambda) operates one (1) natural gas fueled turbine, equipped with a waste heat recovery unit (WHRU) at the Lambda Energy Resource, LLC (Lambda) facility located at the Kalkaska Gas Plant (KGP) in Kalkaska, Kalkaska County, Michigan.

The State of Michigan Department of Environment, Great Lakes, and Energy – Air Quality Division (EGLE-AQD) has issued to Lambda a Renewable Operating Permit (MI-ROP-N4292-2014a) for operation of the Kalkaska Gas Plant facility. A renewal application for this permit was submitted to EGLE-AQD on March 18, 2019. The tested source that is operated under this permit is:

- One (1) natural gas fueled turbine (equipped with a WHRU) identified as emission unit EU-KGPN-TURB-C (KGP Turbine).

Air emission compliance testing was performed pursuant to conditions of MI-ROP- N4292-2014a and the New Source Performance Standards for Stationary Combustion Turbines (the NSPS; 40 CFR Part 60, Subpart KKKK), which requires that testing be performed annually to demonstrate compliance with nitrogen oxides (NO<sub>x</sub>) emissions 1.2 lb/MW-hr, or once every two years if the emission test results (from the previous testing event) are less than or equal to 0.9 lb/MW-hr.

The compliance testing presented in this report was performed by Impact Compliance & Testing, Inc. (ICT), a Michigan-based environmental consulting and testing company. ICT representatives Blake Beddow and Nick Steinthal performed the field sampling and measurements on May 03, 2023.

The turbine emission performance tests consisted of triplicate, one-hour sampling periods for nitrogen oxides (NO<sub>x</sub>). Exhaust gas velocity, moisture, oxygen (O<sub>2</sub>) content, and carbon dioxide (CO<sub>2</sub>) content were determined for each test period to calculate pollutant mass emission rates.

The exhaust gas sampling and analysis was performed using procedures specified in the Stack Test Protocol dated January 20, 2023, that was reviewed and approved by EGLE-AQD.

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## **2.0 Summary of Test Results and Operating Conditions**

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### **2.1 Purpose and Objective of the Tests**

Conditions of MI-ROP-N4292-2014a and the New Source Performance Standards for Stationary Combustion Turbines (the NSPS; 40 CFR Part 60, Subpart KKKK) require Lambda to test the KGP turbine for NO<sub>x</sub> emissions. EU-KGPN-TURB-C (KGP Turbine) was tested during this compliance test event.

### **2.2 Operating Conditions During the Compliance Tests**

Testing was performed while the Lambda KGP turbine was operated at maximum achievable operating conditions. Lambda representatives provided kW output in 15-minute increments for each test period. The KGP turbine kW output ranged between 3,924 and 4,082 kW during the test periods.

Turbine fuel use (thousand cubic feet per day (mcf/d)) and duct burner fuel use (mcf/d) were also recorded by Lambda representatives in 15-minute increments for each test period. For the KGP Turbine, turbine fuel use ranged between 1,261 and 1,302 mcf/d and duct burner fuel use ranged between 147 and 347 mcf/d.

Appendix 2 provides operating records provided by Lambda representatives for the test periods.

Table 2.1 presents a summary of the average turbine operating conditions during the test periods.

### **2.3 Summary of Air Pollutant Sampling Results**

The gases exhausted from the sampled natural gas fueled turbine (EU-KGPN-TURB-C; KGP Turbine) were sampled for three (3) one-hour test periods during the compliance testing performed May 03, 2023.

Table 2.2 presents the average measured NO<sub>x</sub> concentrations and emission rates for the KGP Turbine (average of the three test periods).

Test results for each one-hour sampling period and comparison to the permitted concentrations and emission rates are presented in Section 6.0 of this report.

**Table 2.1 Average turbine operating conditions during the test periods**

<b>Turbine Parameter</b>	<b>EU-KGPN-TURB-C (KGP Turbine)</b>
Electricity production (kW)	4,003
Electricity production (MW)	4.00
Turbine natural gas use (mcf/d)	1,275
Duct burner natural gas use (mcf/d)	254

**Table 2.2 Average measured NOx concentrations and emission rates (three-test average)**

<b>Emission Unit</b>	<b>NOx</b>	
	<b>(ppmvd @ 15% O<sub>2</sub>)</b>	<b>(lb/MW-hr)</b>
EU-KGPN-TURB-C	8.77	0.47
<b>Limits*</b>	<b>15</b>	<b>1.2</b>

Note: Only one (1) of the two (2) NOx limits must be met.

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## 3.0 Source and Sampling Location Description

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### 3.1 General Process Description

Lambda is permitted to operate one (1) natural gas fueled turbine (equipped with a WHRU that is used to heat thermal oil for other processes at the facility) at its Kalkaska Gas Plant facility. The unit is fueled exclusively with natural gas.

### 3.2 Rated Capacities and Air Emission Controls

The natural gas fueled turbine has a rated heat input of 60.2 MMBtu/hr. In addition, a natural gas-fired duct burner associated with the WHRU has a rated heat input of 28.0 MMBtu/hr.

The turbine is equipped with dry low NOx burners that are designed to pre-mix the fuel and combustion air at a ratio that minimizes burners temperatures 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.

### 3.3 Sampling Locations

The turbine exhaust gas is released to the atmosphere through a vertical exhaust stack with a vertical release point.

The exhaust stack sampling ports are located in the vertical exhaust stack, with an inner diameter of 45.0 inches. The stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location at least 0.5 duct diameters upstream and at least 2.0 duct diameters downstream from any flow disturbance.

All sample port locations satisfy the USEPA Method 1 criteria for a representative sample location. Individual traverse points were determined in accordance with USEPA Method 1.

Appendix 1 provides a diagram of the emission test sampling locations with actual stack dimension measurements.



## 4.0 Sampling and Analytical Procedures

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A Stack Test Protocol for the air emission testing was reviewed and approved by EGLE-AQD. 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 4	Exhaust gas moisture was determined based on the water weight gain in chilled impingers.
USEPA Method 3A	Exhaust gas O <sub>2</sub> and CO <sub>2</sub> content was determined using paramagnetic and infrared instrumental analyzers, respectively.
USEPA Method 7E	Exhaust gas NO <sub>x</sub> concentration was determined using a chemiluminescence instrumental analyzer.

## **4.2 Exhaust Gas Velocity Determination (USEPA Method 2)**

The turbine exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 once during each test period. 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. The Pitot tube and connective tubing were leak-checked periodically throughout the test periods to verify the integrity of the measurement system.

The absence of significant cyclonic flow at the sampling location was 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).

Appendix 3 provides exhaust gas flowrate calculations and field data sheets.

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

CO<sub>2</sub> and O<sub>2</sub> content in the turbine exhaust gas stream was measured continuously throughout each test period in accordance with USEPA Method 3A. The CO<sub>2</sub> content of the exhaust was monitored using a Servomex 1440D infrared gas analyzer. The O<sub>2</sub> content of the exhaust was monitored using a Servomex 1440D 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<sub>2</sub> and CO<sub>2</sub> 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 4 provides O<sub>2</sub> and CO<sub>2</sub> calculation sheets. Raw instrument response data are provided in Appendix 5.

## **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. Exhaust gas moisture content measurements were performed concurrently with the instrumental analyzer sampling periods. 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<sub>x</sub> Concentration Measurements (USEPA Method 7E)**

NO<sub>x</sub> pollutant concentrations in the turbine exhaust gas streams were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42i High Level chemiluminescence NO<sub>x</sub> 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 analyzer. Instrument response for the 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 instrument was calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias.

Appendix 4 provides NO<sub>x</sub> calculation sheets. Raw instrument response data are provided in Appendix 5.

## 5.0 QA/QC Activities

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### 5.1 Flow Measurement Equipment

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

The absence of cyclonic flow for each sampling location was verified using an S-type Pitot tube and oil manometer. The Pitot tube was positioned at each of the velocity traverse points 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<sub>x</sub> Converter Efficiency Test

The NO<sub>2</sub> – NO conversion efficiency of the Model 42i analyzer was verified prior to the testing program. A USEPA Protocol 1 certified concentration of NO<sub>2</sub> was injected directly into the analyzer, following the initial three-point calibration, to verify the analyzer's conversion efficiency. The analyzer's NO<sub>2</sub> – NO converter uses a catalyst at high temperatures to convert the NO<sub>2</sub> to NO for measurement. The conversion efficiency of the analyzer is deemed acceptable if the measured NO<sub>x</sub> concentration is within 90% of the expected value.

The NO<sub>2</sub> – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO<sub>2</sub> concentration was 102.6% of the expected value).

### 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 delivered 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 NO<sub>x</sub>, O<sub>2</sub>, and CO<sub>2</sub> 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 NO<sub>x</sub>, CO<sub>2</sub>, and O<sub>2</sub> 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<sub>2</sub>, O<sub>2</sub>, and NO<sub>x</sub> 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 during Test No. 1. The stainless-steel sample probe was positioned at sixteen (16) sample points inside the turbine exhaust stack (eight (8) points per sample port). 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 NO<sub>x</sub> concentrations did not satisfy requirements in 40 CFR, Part 60, Subpart KKKK, Section 60.4400 for use of a single sampling location.

Therefore, the turbine exhaust gas compliance test sampling was performed at sixteen (16) sampling locations within the turbine exhaust stack, for each test period.

## 5.7 System Response Time

The response time of the sampling system was determined prior to the compliance test program by introducing upscale gas and zero gas, in series, into the sampling system using a tee connection at the base of the sample probe. The elapsed time for the analyzer to display a reading of 95% of the expected concentration was determined using a stopwatch.

Sampling periods did not commence until the sampling probe had been in place for at least twice the greatest system response time.

## 5.8 Meter Box Calibrations

The dry gas meter sampling console used for moisture testing 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 E presents test equipment quality assurance data (NO<sub>2</sub> – NO conversion efficiency test data, instrument calibration and system bias check records, calibration gas certifications, interference test results, meter box calibration records, and field equipment calibration records).

## 6.0 Results

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### 6.1 Test Results and Allowable Emission Limits

Turbine operating data and NO<sub>x</sub> concentrations and emission measurement results for each one-hour test period are presented in Table 6.1.

The KGP Turbine has the following allowable NO<sub>x</sub> concentration limits and emission limits:

- 15 parts per million by volume, dry basis, corrected to 15 percent oxygen (ppmvd @ 15% O<sub>2</sub>); or
- 1.2 pounds per megawatt hour (lb/MW-hr).

The measured air pollutant concentrations and emission rates for EU-KGPN-TURB-C are less than the allowable limits specified in MI-ROP-N4292-2014a and the New Source Performance Standards for Stationary Combustion Turbines (the NSPS; 40 CFR Part 60, Subpart KKKK).

### 6.2 Variations from Normal Sampling Procedures or Operating Conditions

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

**Table 6.1 Measured exhaust gas conditions and NO<sub>x</sub> concentrations and emission rates for the KGP Turbine (EU-KGPN-TURB-C)**

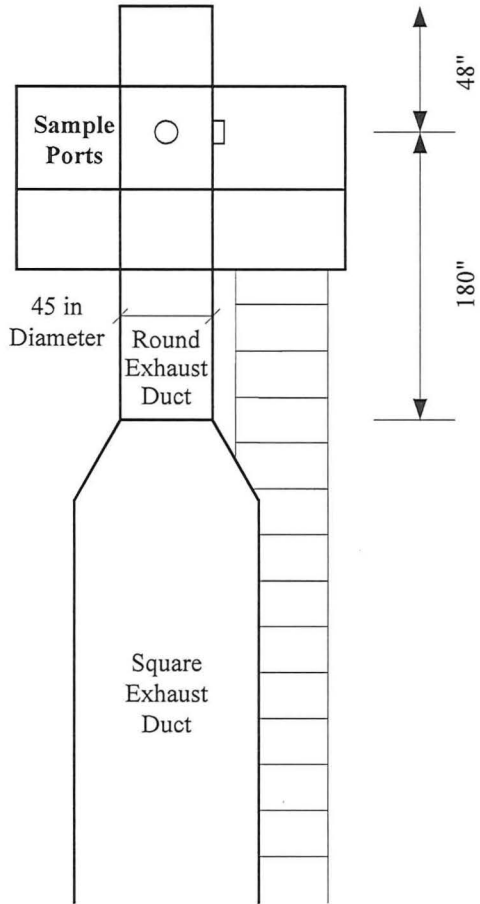
Test No.	1	2	3	
Test date	5/03/2023	5/03/2023	5/03/2023	
Test period (24-hr clock)	0800-0830, 0834-0904	0915-0945, 0952-1022	1033-1103, 1108-1138	Three Test Average
Electricity production (kW)	4,048	3,984	3,978	4,003
Electricity production (MW)	4.05	3.98	3.98	4.00
Turbine fuel use (mcf/d)	1,285	1,273	1,271	1,276
Duct burner fuel use (mcf/d)	262	242	259	254
<u>Exhaust Gas Composition</u>				
CO <sub>2</sub> content (% vol)	4.22	4.24	4.15	4.20
O <sub>2</sub> content (% vol)	14.2	14.3	14.4	14.3
Moisture (% vol)	5.2	9.1	9.0	7.8
Exhaust gas flowrate (dscfm)	27,487	26,622	25,933	26,681
Exhaust gas temperature (°F)	336	343	343	341
<u>Nitrogen Oxides</u>				
NO <sub>x</sub> conc. (ppmvd)	10.2	9.96	9.29	9.83
NO <sub>x</sub> conc. (ppmvd @ 15% O <sub>2</sub> )	9.03	8.85	8.41	8.77
<i>Limit (ppmvd @ 15% O<sub>2</sub>)</i>	-	-	-	15
NO <sub>x</sub> emissions (lb/MW-hr)	0.50	0.48	0.43	0.47
<i>Limit (lb/MW-hr)</i>	-	-	-	1.2

## APPENDIX 1

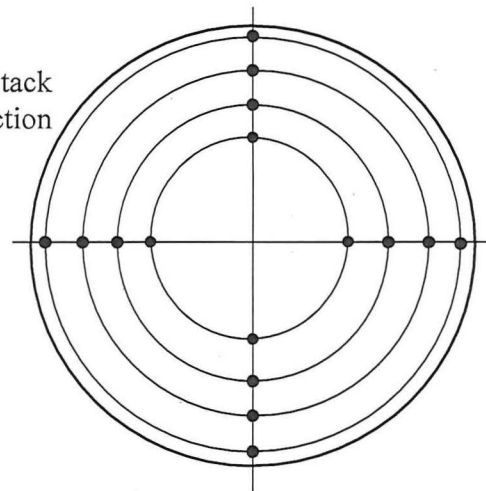
- Turbine Sample Port Diagram



KGP Turbine  
(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

6/10/2021	<b>Lambda Energy – Kalkaska Gas Plant Exhaust Sample Location, KGP Turbine</b>		
	Scale None	Sheet 1 of 1	