IMPACT COMPLIANCE & TESTING

AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM A
NATURAL GAS FUELED INTERNAL COMBUSTION ENGINE

LAMBDA ENERGY RESOURCES, LLC – RICCI 19

1.0 INTRODUCTION

Lambda Energy Resources, LLC (Lambda) operates a Caterpillar (CAT®) Model No. G3412C natural gas fueled reciprocating internal combustion engine (RICE) at Ricci 19 facility located in Kalkaska, Kalkaska County, Michigan. The natural fueled RICE is identified as emission unit SI-RICE in Permit to Install (PTI) No. 242-97.

The compliance testing was performed by Impact Compliance & Testing, Inc., a Michigan-based environmental consulting, and testing company. Impact Compliance & Testing, Inc. representatives Andrew Eisenberg and Ryan Prchlik performed the field sampling and measurements April 14, 2021.

The engine emission performance tests consisted of triplicate, one-hour sampling periods for nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOC). Exhaust gas velocity, moisture content, oxygen (O_2) content, and carbon dioxide (CO_2) 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 that was reviewed and approved by the EGLE-AQD in the March 12, 2021 Test Plan Approval Letters.

Questions regarding this emission test report should be directed to:

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Report Certification

This test report was prepared by Impact Compliance & Testing, Inc. based on field sampling data collected by ICT. Facility process data was collected and provided by Lambda employees or representatives. This test report has been reviewed by Lambda representatives and approved for submittal to EGLE.

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:

Andrew Eisenberg
Environmental Consultant
Impact Compliance & Testing, Inc.

I certify that the facility and emission units were operated at maximum routine operating conditions for the test event. Based on information and belief formed after reasonable inquiry, the statements and information in this report are true, accurate and complete.

Responsible Official Certification:

Nick Summerland
HSE Manager
Lambda Energy Resources, LLC

2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

One (1) CAT® Model No. G3412C RICE (Ricci 19 SI-RICE) was tested at the Ricci 19 facility.

2.2 Rated Capacities and Air Emission Controls

The CAT® Model No. G3412C RICE has a rated output of 637 brake-horsepower (bhp). The engine is designed to fire lean fuel mixtures and is equipped with an air-to-fuel ratio controller that monitors engine performance parameters and automatically adjusts the air-to-fuel ratio and ignition timing to maintain efficient fuel combustion.

2.3 Sampling Locations

The RICE exhaust gas is directed through a muffler and is released to the atmosphere through a dedicated vertical exhaust stack with a vertical release point.

The exhaust stack sampling ports for the SI-RICE are located upstream of the muffler in a vertical exhaust duct with an inner diameter of 10.25 inches. The exhaust duct is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 21 inches (2.1 duct diameters) downstream and 40 inches (3.9 duct diameters) upstream from any flow disturbance.

The 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 diagrams of the exhaust stack and emission test sampling locations.

3.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

3.1 Purpose and Objective of the Tests

The compliance emission testing was performed pursuant to conditions of Permit to Install (PTI) No. 242-97 and the federal Standards of Performance for Stationary Spark Ignition Internal Combustion Engines (the SI-RICE NSPS; 40 CFR Part 60 Subpart JJJJ), which requires that testing be performed every 8,760 operating hours or three years, whichever occurs first (unless the engine has been certified by the manufacturer as specified in the SI-RICE NSPS).

3.2 Operating Conditions During the Compliance Tests

The engine was operated under routine horsepower load as to maintain the required compression for the natural gas pipeline. The engine could not be operated under maximum load conditions due to pipeline requirements. Lambda representatives provided calculated engine horsepower (HP) and fuel flow (scfm) in 15-minute increments for each test period. The SI-RICE horsepower was a consistent 272 HP, and the fuel flow rate was a consistent 833 scfm for each test period.

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

Table 3.1 presents a summary of the average engine operating conditions during the test periods.

3.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the sampled natural gas-fueled RICE (SI-RICE) was sampled for three (3) one-hour test periods during the compliance testing performed April 14, 2021.

Table 3.2 presents the average measured NO_X, CO, and VOC emission rates for the engine (average of the three test periods).

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

Table 3.1 Average engine-operating conditions during the test periods

Emission Unit	Fuel Use Rate (scfm)	Engine Horsepower (HP)
SI-RICE	833	272

Table 3.2 Average measured emission rates for each engine (three-test average)

	CO Emission Rates	NOx Emission Rates	VOC Emission Rates
Emission Unit	(ppmvd @ 15% O_2)	(ppmvd @ 15% O_2)	(ppmvd @ 15% O_2)
SI-RICE	207	116	19
Permit Limit (No. 1)	*540*	*160*	*86*

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A 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 Lambda 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 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 analyzers.
USEPA Method 10	Exhaust gas CO concentration was measured using an infrared instrumental analyzer
USEPA Method 25A / ALT-096	Exhaust gas VOC (as NMHC) concentration was determined using a flame ionization analyzer equipped with methane separation column

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

The RICE exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 once for 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. The Pitot tube and connective tubing were leak-checked prior to the test event to verify the integrity of the measurement system.

The absence of significant cyclonic flow for the exhaust configuration 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_2 and O_2 content in the RICE 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 Servomex 1440D single beam single wavelength (SBSW) infrared gas analyzer. The O_2 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 IC engine 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 4 provides O_2 and CO_2 calculation sheets. Raw instrument response data are provided in Appendix 5.

4.4 Exhaust Gas Moisture Content (USEPA Method 4)

Moisture content of the RICE 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 and CO Concentration Measurements (USEPA Methods 7E and 10)

NO_X and CO pollutant concentrations in the RICE exhaust gas streams were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42i High Level chemiluminescence NO_X analyzer and a TEI Model 48i infrared CO analyzer.

Throughout each test period, a continuous sample of the engine 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 4 provides CO and NO_X calculation sheets. Raw instrument response data are provided in Appendix 5.

4.6 Measurement of Volatile Organic Compounds (USEPA Method 25A/ALT-096)

The VOC emission rate was determined by measuring the nonmethane hydrocarbon (NMHC) concentration in the engine exhaust gas. NMHC pollutant concentration was determined using a TEI Model 55i Methane / Nonmethane hydrocarbon analyzer. The TEI 55i analyzer contains an internal gas chromatograph column that separates methane from non-methane components. The concentration of NMHC in the sampled gas stream, after separation from methane, is determined relative to a propane standard using a flame ionization detector in accordance with USEPA Method 25A.

The USEPA Office of Air Quality Planning and Standards (OAQPS) has issued an alternate test method approving the use of the TEI 55i-series analyzer as an effective instrument for measuring NMOC from gas-fueled reciprocating internal combustion engines (RICE) in that it uses USEPA Method 25A and 18 (ALT-096).

Samples of the exhaust gas were delivered directly to the instrumental analyzer using the Teflon® heated sample line to prevent condensation. The sample to the NHMC analyzer was not conditioned to remove moisture. Therefore, VOC measurements correspond to standard conditions with no moisture correction (wet basis).

Prior to, and at the conclusion of each test, the instrument was calibrated using mid-range calibration (propane) and zero gas to determine analyzer calibration error and system bias (described in Section 5.0 of this document).

Appendix 4 provides VOC calculation sheets. Raw instrument response data for the NMHC analyzer is provided in Appendix 5.

5.0 QA/QC ACTIVITIES

5.1 NO_x Converter Efficiency Test

The NO_2 – NO conversion efficiency of the Model 42i 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 NO_x concentration is greater than or equal to 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_x concentration was 98.3% of the expected value, i.e., greater than 90% of the expected value as required by Method 7E).

5.2 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.

5.3 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NO_X, CO, O_2 and CO_2 have had an interference response test preformed 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.

5.4 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_x, CO, 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.

At the beginning of each test day, appropriate high-range, mid-range, and low-range span gases followed by a zero gas were introduced to the NMHC analyzer, in series at a tee connection, which is installed between the sample probe and the particulate filter, through a poppet check valve. After each one-hour test period, mid-range and zero gases were re-introduced in series at the tee connection in the sampling system to check against the method's performance specifications for calibration drift and zero drift error.

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

5.5 Determination of Exhaust Gas Stratification

A stratification test was performed for the RICE exhaust stack. The stainless-steel sample probe was positioned at sample points correlating to 16.7, 50.0 (centroid) and 83.3% of the stack diameter. 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 RICE exhaust stack indicated that the measured CO, O_2, and CO_2 concentrations did not vary by more than 5% of the mean across the stack diameter. Therefore, the RICE exhaust gas was considered to be unstratified and the compliance test sampling was performed at a single sampling location within the RICE exhaust stack.

5.6 Meter Box Calibrations

The Nutech Model 2010 sampling 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 Nutech metering consoles were calibrated using a NIST traceable Omega® Model CL 23A temperature calibrator.

Appendix 6 presents test equipment quality assurance data (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, and stratification checks).

6.0 RESULTS

6.1 Test Results and Allowable Emission Limits

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

The measured air pollutant concentrations and emission rates for Ricci 19 SI-RICE are less than the allowable limits specified by SI-RICE NSPS standards for Emission Unit Ricci 19 SI-RICE:

- 2.0 g/bhp-hr or 160 ppmvd @ 15% O_2 for NO_X;
- 4.0 g/bhp-hr or 540 ppmvd @ 15% O_2 for CO; and
- 1.0 g/bhp-hr or 86 ppmvd @ 15% O_2 for VOC.

6.2 Variations from Normal Sampling Procedures or Operating Conditions

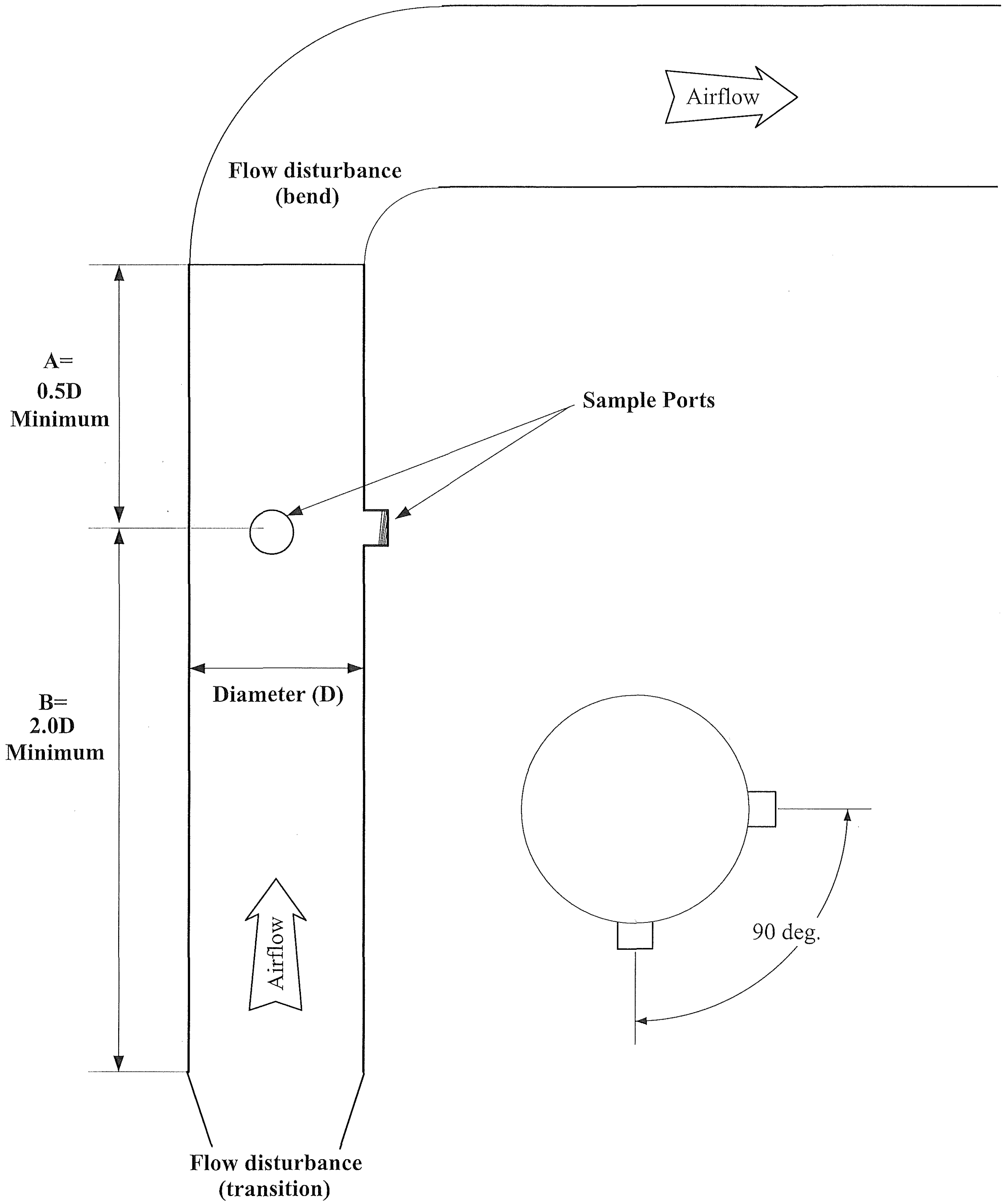
The testing for all pollutants was performed in accordance with USEPA methods and the approved test protocol. The engine was operated at routine horsepower and no variations from normal operating conditions occurred during the engine test periods.

Table 6.1 Measured exhaust gas conditions and NO_x, CO and VOC air pollutant emission rates for SI-RICE

Test No. Test date Test period (24-hr clock)	1 4/14/21 0800-0900	2 4/14/21 0930-1030	3 4/14/21 1055-1155	Three Test Average
Fuel flowrate (scfm)	833	833	833	833
Engine output (HP)	272	272	272	272
Exhaust Gas Composition				
CO_2 content (% vol)	9.93	9.61	9.67	9.74
O_2 content (% vol)	4.66	5.11	5.03	4.93
Moisture (% vol)	11.6	13.8	15.3	13.6
Exhaust gas temperature (°F)	927	928	934	930
Exhaust gas flowrate (dscfm)	760	774	773	769
Exhaust gas flowrate (scfm)	860	899	913	890
Nitrogen Oxides				
NO_X conc. (ppmvd)	356	277	310	314
NO_X emissions (ppmvd @ 15% O_2)	129	104	115	116
Permit limit (ppmvd @ 15% O_2)	-	-	-	160
Carbon Monoxide				
CO conc. (ppmvd)	578	545	556	560
CO emissions (ppmvd @ 15% O_2)	210	203	207	207
Permit limit (ppmvd @ 15% O_2)	-	-	-	540
Volatile Organic Compounds				
VOC conc. (ppmv)	47.8	50.6	50.6	49.7
VOC emissions (ppmvd @ 15% O_2)	19.6	18.9	18.8	19.1
Permit limit (ppmvd @ 15% O_2)	-	-	-	86

APPENDIX 1

- Sampling Diagrams



1/12/2021	Ricci 19 SI-RICE Sampling Location Diagram		
	Scale None	Sheet 1 of 1	ICT