AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM A
LANDFILL GAS FIRED ENGINE – GENERATOR SET

Prepared for:

North American Natural Resources, Inc.
Central Generating Facility
SRN N2804

ICT Project No.: 2300151
December 19, 2023

IMPACT COMPLIANCE & TESTING

Executive Summary

NORTH AMERICAN NATURAL RESOURCES, INC. AT THE CENTRAL GENERATING STATION
CAT® G3520C LANDFILL GAS FUELED IC ENGINE EMISSIONS TEST RESULTS

North American Natural Resources, Inc. (NANR) contracted Impact Compliance & Testing, Inc. (ICT) to conduct a performance demonstration for the determination of carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO_2), and formaldehyde (HCOH) concentrations and emission rates from one (1) landfill gas-fired reciprocating internal combustion engine (RICE) and electricity generator set (genset) operated at the NANR Central Generating Station (Central) in Pierson, Michigan.

The compliance emission testing was performed pursuant to conditions of Michigan Department of Environment, Great Lakes and Energy – Air Quality Division (EGLE-AQD) Renewable Operating Permit (ROP) No. MI-ROP-N2804-2020a. The testing was required to be performed within five (5) years from the date of the most recent stack test. The most recent stack test was performed September 11, 2018. The compliance test performed on November 30, 2023, was rescheduled from the original test date of September 6, 2023. Mr. Trevor Drost and Mr. Chris Robinson of EGLE-AQD were informed of the postponement. The following table presents the emissions results and operating data from the performance demonstration.

Unit ID	Generator Output kW	CO lb/hr	NO_x lb/hr	SO_2 lb/hr	HCOH lb/hr
EUENGINE1	1644	13.5	2.28	2.22	1.99
Permit Limit	-	*16.3*	*4.94*	*5.8*	*2.1*

kW=kilowatt, lb/hr = pounds per hour

The data above indicates that the engine was tested while the unit operated within 10% of the maximum capacity (1600 kW) and is in compliance with the emission standards specified in MI-ROP-N2804-2020a.

Report Certification

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Pierson, MI

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

Impact Compliance & Testing, Inc.

Max Fierro
Environmental Consultant

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1.0 Introduction

North American Natural Resources (NANR) operates gas-fired reciprocating internal combustion engines (RICE) and electricity generator sets at the Central Generating Facility in Pierson, Montcalm County, Michigan. The RICE are fueled by landfill gas (LFG) that is recovered from the Central Landfill. The recovered gas is transferred to the NANR facility where it is treated before being used as fuel.

The State of Michigan Department of Environment, Great Lakes and Energy – Air Quality Division (EGLE-AQD) has issued to NANR Renewable Operating Permit (ROP) No. MI-ROP-N2804-2020a for operation of the renewable electricity generation facility, which consists of:

- One (1) Caterpillar (CAT®) Model No. 3516 RICE-generator set identified as emission unit EUENGINE2 (Flexible Group ID: FGRICEENG); and
- Two (2) Caterpillar (CAT®) Model No. 3520C RICE-generator set identified as emission units EUENGINE1 and EUENGINE3 (Flexible Group ID: FGRICEENG).

Air emission compliance testing was performed pursuant to MI-ROP-N2804-2020a that states:

1. *Within 180 days after initial startup of each engine in FGRICEENG and within every 5 years from the date of completion of the most recent stack test, the permittee shall verify NOx, CO, and SO2 emission rates from each engine in FGRICEENG, by testing at owner's expense, in accordance with Department requirements.*
2. *Within 180 days after initial startup of any engine and within every 5 years from the date of completion of the most recent stack test, thereafter, the permittee shall verify formaldehyde emission rates from each engine in FGRICEENG at maximum routine operating conditions, by testing at owner's expense, in accordance with Department requirements.*

EUENGINE1 compliance testing presented in this report was performed by Impact Compliance & Testing, Inc. (ICT), a Michigan-based environmental consulting and testing company. ICT representatives Max Fierro, Andy Rusnak, and Christian Smith performed the field sampling and measurements November 30, 2023.

The engine emission performance tests consisted of triplicate, one-hour sampling periods for nitrogen oxides (NOx), carbon monoxide (CO), sulfur dioxide (SO_2), and formaldehyde (HCOH). Exhaust gas velocity, moisture, oxygen (O_2) content, and carbon dioxide (CO_2) content were determined for each test period to calculate volumetric exhaust gas flowrate and pollutant mass emission rates.

Additionally, EGLE-AQD requested that inlet LFG be sampled for hydrogen sulfide (H_2S) concentration during each day of testing by using Draeger® tubes.

The exhaust gas sampling and analysis was performed using procedures specified in the Stack Test Protocol dated June 30, 2023, that was reviewed and approved by EGLE-AQD on August 21, 2023.

Questions regarding this air emission test report should be directed to:

Max Fierro Environmental Consultant Impact Compliance & Testing, Inc. 4180 Keller Rd. STE B Holt, MI 48842 (734) 357-8397 Max.Fierro@ImpactCandT.com	Mr. Mike Williams Specialist-Engineer/Tech Sr II Kinder Morgan 1001 Louisiana Street Houston, TX 77002 (281) 725-1383 Michael_J_Williams@kindermorgan.com

2.0 Summary of Test Results and Operating Conditions

2.1 Purpose and Objective of the Tests

Conditions of MI-ROP-N2804-2020a require NANR to test Engine Nos. 1 and 2 (Emission Unit: EUENGINE1 and EUENGINE2) for CO, NOx, SO_2, and HCOH emissions. Engine No. 1 / EUENGINE1 was tested during this compliance test event.

2.2 Operating Conditions During the Compliance Tests

The testing was performed while the NANR engine/generator set was operated at maximum operating conditions (within 10% of 1,600-kilowatt (kW) electricity output). NANR representatives monitored and recorded generated power output (kW), fuel use (standard cubic feet per minute, scfm), and fuel methane content (%) at 15-minute increments for each test period.

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

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

Average output, fuel consumption, and fuel methane content for the RICE are presented in Table 2.1 and Table 6.1.

2.3 Summary of Air Pollutant Sampling Results

The gas exhausted from the sampled LFG fueled RICE (Engine No. 1 / EUENGINE1) was sampled for three (3) one-hour test periods during the compliance testing performed November 30, 2023.

Additionally, EGLE-AQD requested that inlet LFG be sampled for hydrogen sulfide (H_2S) concentration during each day of testing by using Draeger® tubes.

Table 2.1 presents the tested LFG sample results. Appendix 7 provides an image of the Draeger® tubes, and a field data sheet for the sample.

Table 2.2 presents the average measured CO, NO_X, SO_2 and HCOH 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 2.1 Average engine operating conditions during the test periods

Engine Parameter	EUENGINE1 CAT® G3520C
Generator output (kW)	1,644
Engine LFG fuel use (scfm)	589
LFG methane content (%)	53.5
Exhaust temperature (°F)	874
LFG H_2S Content (ppm)	410

Table 2.2 Average measured emission rates for the engine (three-test average)

	CO	NO_x	SO_2	HCOH
Emission Unit	(lb/hr)	(lb/hr)	(lb/hr)	(lb/hr)
EUENGINE1	13.5	2.28	2.22	1.99
Permit Limit	***16.3***	***4.94***	***5.8***	***2.1***

3.0 Source and Sampling Location Description

3.1 General Process Description

NANR is permitted to operate three (3) RICE-generator sets at its facility; two (2) CAT® Model No. G3520C RICE and one (1) CAT® Model No. G3516 RICE. The units are fired exclusively with LFG that is recovered from the Central Landfill solid waste disposal facility and treated prior to use. Only one (1) CAT® Model No. G3520C RICE (EUENGINE1) was tested for this event.

3.2 Rated Capacities and Air Emission Controls

The CAT® G3520C engine generator set has a rated design capacity of:

- Engine Power: 2,242 brake horsepower (bhp)
- Electricity Generation: 1600 kW

The RICE is not equipped with add-on emission control devices. Exhaust gas is exhausted directly to the atmosphere through noise mufflers and vertical exhaust stacks.

3.3 Sampling Locations

The Engine No. 1 / EUENGINE1 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 Engine No. 1/ EUENGINE1 exhaust stack sampling ports are located after the muffler in a horizontal portion of the stack with an inner diameter of 13.5 inches. The stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 39.0 inches (2.9 duct diameters) upstream and >140.0 inches (>10.4 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

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 3A	Exhaust gas O_2 and CO_2 content was determined using paramagnetic and infrared instrumental analyzers, respectively.
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.
ASTM D6348	Exhaust gas formaldehyde and SO_2 concentrations and moisture content were determined using an FTIR instrumental analyzer.

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 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 previously 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 an M&C GenTwo infrared gas analyzer. The O_2 content of the exhaust was monitored using an M&C GenTwo gas analyzer that uses a paramagnetic sensor.

During each sampling period, a continuous sample of the RICE 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 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 an M&C GenTwo infared 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.

4.5 Measurement of SO_2, HCOH and Moisture Content via FTIR (ASTM D6348)

SO_2 and HCOH concentrations, and moisture content in the RICE exhaust gas stream were determined using an MKS Multi-Gas 2030 Fourier transform infrared (FTIR) spectrometer in accordance with test method ASTM D6348.

The USEPA New Source Performance Standard (NSPS) for landfill gas fired engines (Subpart JJJJ) specifies ASTM D6348 as an acceptable test method for moisture concentration determinations. Additionally, the USEPA National Emissions Standard for Hazardous Air Pollutants (NESHAP) for landfill gas fired engines (Subpart ZZZZ) specifies ASTM D6348 as an acceptable test method for moisture and formaldehyde concentration determinations.

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

A calibration transfer standard (CTS), ethylene standard, and nitrogen zero gas were analyzed before and after each test run. Analyte spiking, of the engine, with acetaldehyde, SO_2, and sulfur hexafluoride was performed to verify the ability of the sampling system to quantitatively deliver a sample containing the compound of interest from the base of the probe to the FTIR. Data was collected at 0.5 cm-1 resolution. Instrument response was recorded using MG2000 data acquisition software.

In addition to the exhaust gas SO_2 analysis as previously described, EGLE-AQD requested that inlet LFG be sampled for hydrogen sulfide (H_2S) concentration during each day of testing by using Draeger® tubes.

Appendix 7 provides photos of the Draeger® tubes, and a field data sheet for the Draeger® tube sampling.

Appendix 4 provides HCOH calculation sheets. Moisture content data is provided in the flowrate calculations presented in Appendix 3. Raw instrument response data for the FTIR analyzer is provided in Appendix 6.

5.0 QA/QC Activities

5.1 Flow Measurement Equipment

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

Periodically throughout the test event, the pitot tube, manometer, and flexible Teflon tubing was leak checked by blowing in the positive end of the pitot tube until greater than 5 in. of water column was displayed on the manometer. The positive end of the pitot tube was then capped off to verify the pressure on the water column did not drop. While pressure was still on the water column the cap was switched to the negative side of the pitot tube to verify the water column did not drop. This verified that the flow measurement equipment was not leaking.

5.2 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 instrumental analyzer will be deemed acceptable if the measured NOx concentration is at least 90% of the expected value (within 10%).

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_x concentration was 93.1% 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_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.

5.5 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_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.

5.6 Determination of Exhaust Gas Stratification

A stratification test was performed for each 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 stacks indicated that the measured O_2, CO_2, CO, and NOx 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 each RICE exhaust stack.

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 FTIR QA/QC Activities

At the beginning of each day a calibration transfer standard (CTS, ethylene gas), analyte of interest (acetaldehyde and sulfur hexafluoride) and nitrogen calibration gas was directly injected into the FTIR to evaluate the unit response.

Prior to and after each test run the CTS was analyzed. The ethylene was passed through the entire system (system purge) to verify the sampling system response and to ensure that the sampling system remained leak-free at the stack location. Nitrogen was also passed through the sampling system to ensure the system was free of contaminants.

Analyte spiking, of each emission unit, with acetaldehyde and SO_2 was performed to verify the ability of the sampling system to quantitatively deliver a sample containing the compound of interest from the base of the probe to the FTIR and assure the ability of the FTIR to quantify that compound in the presence of effluent gas.

As part of the data validation procedure, reference spectra were manually fit to that of the sample spectra (two spectra from each test period) and a concentration was determined. Concentration data was manually validated using the MKS MG2000 method analyzer software. The software used multi-point calibration curves to quantify each spectrum. The software-calculated results were compared with the measured concentrations to ensure the quality of the data.

Appendix 7 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, FTIR QA/QC data, stratification checks, and field equipment calibration records).

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.

Engine No. 1 / EUENGINE1 has the following allowable emission limits specified in MI-ROP-N2804-2020a:

- 16.3 lb/hr for CO;
- 4.94 lb/hr for NOx;
- 5.8 lb/hr for SO_2; and
- 2.1 lb/hr for HCOH.

The measured air pollutant emission rates for Engine No. 1 / EUENGINE1 are less than the allowable limits specified in MI-ROP-N2804-2020a.

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 RICE genset was operated within 10% of maximum output (1,600 kW generator output for CAT® G3520C RICE) and no variations from normal operating conditions occurred during the engine test periods.

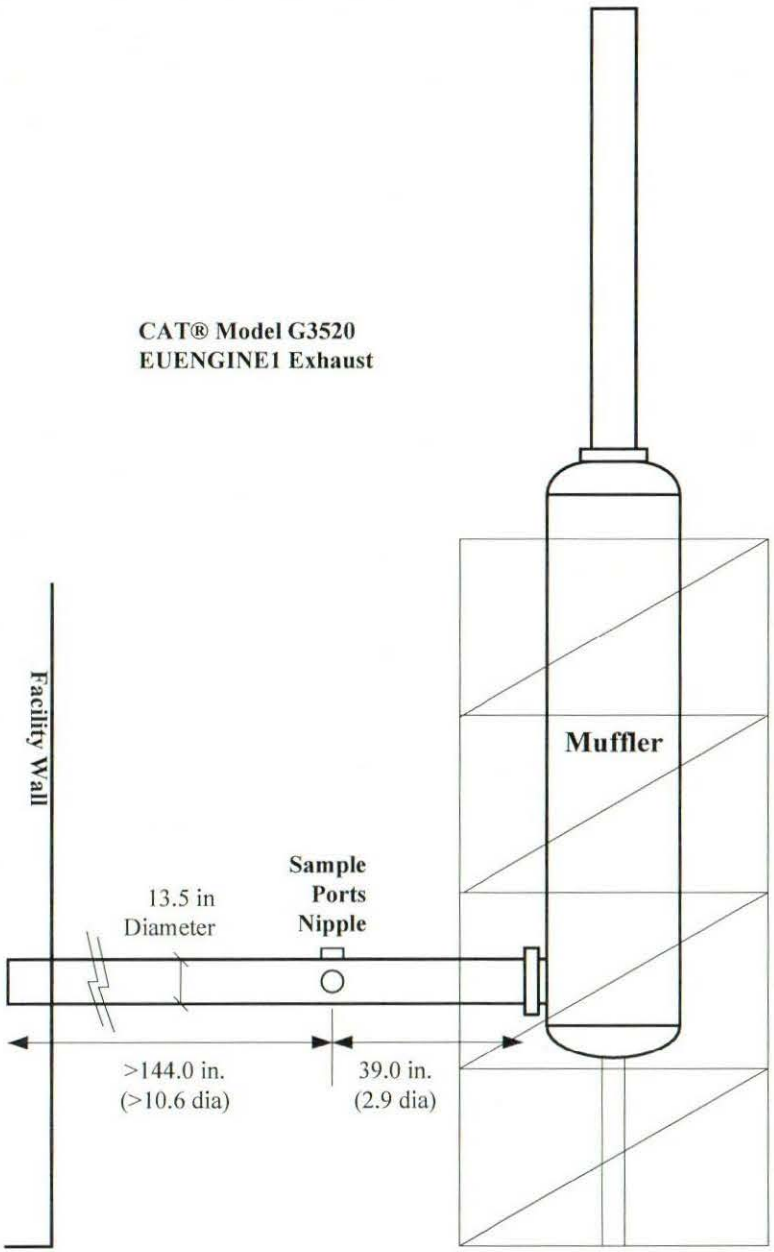
Testing for EUENGINE1, as described in the approved protocol, will be coordinated, and scheduled once the RICE becomes available for testing.

Table 6.1 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 1 (EUENGINE1)

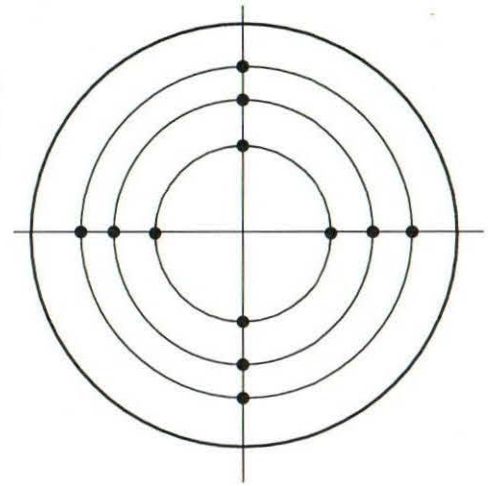
Test No. Test date Test period (24-hr clock)	1 11/30/2023 0800-0900	2 11/30/2023 0916-1016	3 11/30/2023 1033-1133	Three Test Average
Fuel flowrate (scfm)	590	587	589	589
Generator output (kW)	1645	1643	1645	1644
LFG methane content (%)	53.5	53.5	53.5	53.5
AFR Setting				
Exhaust Gas Composition				
CO_2 content (% vol)	10.9	10.9	10.9	10.9
O_2 content (% vol)	9.14	9.14	9.13	9.14
Moisture (% vol)	11.3	11.4	11.5	11.4
Exhaust gas temperature (°F)	874	873	876	874
Exhaust gas flowrate (dscfm)	4,453	4,427	4,399	4,426
Exhaust gas flowrate (scfm)	5,023	4,994	4,968	4,995
Nitrogen Oxides				
NO_X conc. (ppmvd)	74.5	70.5	70.7	71.9
NO_X emissions (lb/hr)	2.38	2.24	2.23	2.28
Permit Limit (lb/hr)	-	-	-	*4.94*
Carbon Monoxide				
CO conc. (ppmvd)	698	695	696	696
CO emissions (lb/hr)	13.6	13.4	13.4	13.5
Permit Limit (lb/hr)	-	-	-	*16.3*
Sulfur Dioxide				
SO_2 conc. (ppmv)	45.17	44.46	44.03	44.55
SO_2 emissions (lb/hr)	2.27	2.22	2.18	2.22
Permit Limit (lb/hr)	-	-	-	*5.8*
Formaldehyde				
HCOH conc. (ppmv)	84.46	85.30	85.72	85.16
HCOH emissions (lb/hr)	1.99	1.99	1.99	1.99
Permit Limit (lb/hr)	-	-	-	*2.1*

APPENDIX 1

- RICE Engine Sample Port Diagram



Exhaust Stack Cross-Section with Traverse Points



Velocity sample locations as measured from stack wall

Pt. #	in.
1	0.59
2	1.97
3	4.00
4	9.50
5	11.5
6	12.9

9/25/18 ALR	**NANR Central Generating Station Exhaust Sample Location, CAT® G3520 ICE**		
	Scale None	Sheet 1 of 1	Dwg. No. NANR-CGS-1