

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

**Prepared for:
North American Natural Resources
Autumn Hills Generating Station
SRN N6006**

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Report Certification

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**North American Natural Resources
Autumn Hills Generating Station
Zeeland, 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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1.0 Introduction

North American Natural Resources (NANR) operates gas-fired reciprocating internal combustion engine (RICE), and electricity generator sets at the Autumn Hills Generating Station in Zeeland, Ottawa County, Michigan. The RICE are fueled by landfill gas (LFG) that is recovered from the Autumn Hills Landfill solid waste disposal facility and treated prior to use.

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-N6006-2018a for operation of the renewable electricity generation facility, which consists of:

- Two (2) Caterpillar (CAT®) Model No. G3520C RICE gensets identified as emission units EUENGINE2R (Engine No. 2) and EUENGINE4 (Engine No. 4) and one (1) Caterpillar (CAT®) Model No. G3516LE RICE genset identified as emission unit EUENGINE1 (Engine No. 1). The RICE gensets are identified as Flexible Group (FGSIRICEMACT).

The compliance emission testing was performed pursuant to conditions of ROP No. MI-ROP-N6006-2018a, 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). The limits presented in this report are the most stringent for each pollutant and may be less than the SI-RICE NSPS standards.

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 Clay Gaffey performed the field sampling and measurements February 18, 2021.

The engine emission performance tests consisted of triplicate, one-hour sampling periods for nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOC, as non-methane hydrocarbons (NMHC or NMOC)). Exhaust gas velocity, moisture, oxygen (O₂) content, and carbon dioxide (CO₂) 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 August 27, 2020 that was reviewed and approved by EGLE-AQD.

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

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2.0 Summary of Test Results and Operating Conditions

2.1 Purpose and Objective of the Tests

Conditions of MI-ROP-N6006-2018a, and the SI-RICE NSPS; 40 CFR Part 60 Subpart JJJJ require NANR to test each engine in FGRICEMACT for CO, NO_x, and VOC emissions.

EUENGINE4 (Engine No. 4) was tested during this compliance event. EUENGINE1 (Engine No. 1), and EUENGINE2R (Engine No. 2) were tested on December 15, 2020. The emissions test results were presented in the test report dated January 13, 2021.

2.2 Operating Conditions During the Compliance Tests

The testing was performed while the NANR engine/generator sets were operated at maximum operating conditions (1,600 kW). NANR representatives provided kW output in 15-minute increments for each test period. EUENGINE4 generator kW output ranged between 1,601 and 1,608 kW.

Fuel flowrate (standard cubic feet per minute (scfm)), fuel methane content (%), inlet pressure (psi), and air / fuel ratio (for EUENGINE2R) were also recorded by NANR representatives in 15-minute increments for each test period and are presented in Appendix 2.

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.

2.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the sampled LFG fueled RICE (EUENGINE4) were each sampled for three (3) one-hour test periods during the compliance testing performed February 18, 2021.

Table 2.2 presents the average measured CO, NO_x, and VOC emission rates for each 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	EUENGINE4 CAT® G3520C
Generator output (kW)	1,603
Engine LFG fuel use (scfm)	347
LFG methane content (%)	50.5
Inlet pressure (psi)	45.6
Air / fuel ratio	6.9

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

Emission Unit	CO		NOx		VOC	
	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)
EUENGINE4	9.70	1.96	1.83	0.37	0.36	0.07
Permit Limit	16.3	3.3	2.97	0.6	3.20	1.0

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. Each RICE is applicable to SI-RICE NSPS; 40 CFR Part 60 Subpart JJJJ. The units are fired exclusively with LFG that is recovered from the Autumn Hills Landfill solid waste disposal facility and treated prior to use.

EUENGINE4 (Engine No. 4) was tested during this compliance event. EUENGINE1 (Engine No. 1), and EUENGINE2R (Engine No. 2) were tested on December 15, 2020. The emissions test results were presented in the test report dated January 13, 2021.

3.2 Rated Capacities and Air Emission Controls

The CAT® G3520C engine generator sets have a rated design capacity of:

- Engine Power: 2,242 brake horsepower (bhp)
- Electricity Generation: 1,600 kW

Each engine is equipped with an air-to-fuel ratio (AFR) controller that automatically blends the appropriate ratio of combustion air and treated LFG fuel. The CAT® G3520C engine is equipped with an electronic AFR controller that monitors engine performance parameters and automatically adjusts the AFR and ignition timing to maintain efficient fuel combustion.

The RICE are not equipped with add-on emission control devices. The AFR controller maintains efficient fuel combustion, which minimizes air pollutant emissions. Exhaust gas is exhausted directly to atmosphere through a noise muffler and vertical exhaust stack.

3.3 Sampling Locations

Each 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 CAT® Model G3520C engine (EUENGINE4) are located before the muffler in a horizontal exhaust duct with an inner diameter of 13.0 inches. The duct is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 40 inches (3.1 duct diameters) upstream and 240 inches (18.5 duct diameters) downstream 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 a diagram of the emission test sampling location 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 4	Exhaust gas moisture was determined based on the water weight gain in chilled impingers.
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 NO _x 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 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)

CO₂ and O₂ content in the RICE exhaust gas stream was measured continuously throughout each test period in accordance with USEPA Method 3A. The CO₂ content of the exhaust was monitored using a Servomex 1440D infrared gas analyzer. The O₂ 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 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 O₂ and CO₂ 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 O₂ and CO₂ calculation sheets. Raw instrument response data are provided in Appendix 5.

4.4 Exhaust Gas Moisture Content (USEPA Method 4)

Moisture content of each RICE 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_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 Fuji ZRF 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 VOC (USEPA Method 25A / ALT-096)

The VOC emission rate was determined by measuring the nonmethane hydrocarbon (NMHC or NMOC) 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 RICE (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 NMHC 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 Flow Measurement Equipment

Prior to arriving onsite, the instruments used during the source test to measure exhaust gas properties and velocity (barometer, 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_x Converter Efficiency Test

The NO₂ – NO conversion efficiency of the Model 42i analyzer was verified prior to the testing program. A USEPA Protocol 1 certified concentration of NO₂ was injected directly into the analyzer, following the initial three-point calibration, to verify the analyzer's conversion efficiency. The analyzer's NO₂ – NO converter uses a catalyst at high temperatures to convert the NO₂ to NO for measurement. The conversion efficiency of the analyzer is deemed acceptable if the measured NO₂ concentration is within 90% of the expected value.

The NO₂ – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO₂ concentration was 98.2% 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, O₂, and CO₂ 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_x, CO, CO₂, and O₂ 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 CO₂, O₂, 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 CO, O₂, and CO₂ 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 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 (NO₂ – 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

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.

EUENGINE4 has the following allowable emission limits specified in MI-ROP-N6006-2018a:

- 16.3 pounds per hour (lb/hr) and 3.3 grams per brake horsepower hour (g/bhp-hr) for CO;
- 2.97 lb/hr and 0.6 g/bhp-hr for NO_x; and
- 3.20 lb/hr and 1.0 g/bhp-hr for VOC.

The measured air pollutant concentrations and emission rates for each RICE are less than the allowable limits specified in MI-ROP-N6006-2018a.

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 engine-generator sets were operated within 10% of maximum output (1,600 kW generator output for CAT® G3520C RICE, 800 kW for CAT® 3516LE) and no variations from normal operating conditions occurred during the engine test periods.

The test protocol for this test event, dated August 27, 2020, specified the testing of all three permitted engines. However, during the original scheduled test date (December 15, 2020) EUENGINE4 could not be started to be tested. EUENGINE4 (Engine No. 4) was tested during the compliance event presented in this test report. EUENGINE1 (Engine No. 1), and EUENGINE2R (Engine No. 2) were tested on December 15, 2020. The emissions test results were presented in the test report dated January 13, 2021.

Table 6.2 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 4 (EUENGINE4)

Test No.	1	2	3	Three Test
Test date	2/18/2021	2/18/2021	2/18/2021	Average
Test period (24-hr clock)	0743-0843	0900-1000	1022-1122	
Fuel flowrate (scfm)	349	346	345	347
Generator output (kW)	1,604	1,604	1,603	1,603
Engine output (bhp)	2,247	2,247	2,246	2,247
LFG methane content (%)	50.4	50.5	50.6	50.5
Inlet pressure (psi)	46.2	45.3	45.4	45.6
Air / fuel ratio	6.9	6.9	6.9	6.9
<u>Exhaust Gas Composition</u>				
CO ₂ content (% vol)	12.1	12.1	12.1	12.1
O ₂ content (% vol)	7.56	7.82	7.98	7.79
Moisture (% vol)	11.7	11.6	11.7	11.7
Exhaust gas temperature (°F)	982	875	911	923
Exhaust gas flowrate (dscfm)	4,120	4,149	4,140	4,136
Exhaust gas flowrate (scfm)	4,664	4,692	4,691	4,682
<u>Nitrogen Oxides</u>				
NO _x conc. (ppmvd)	62.6	61.6	61.1	61.8
NO _x emissions (lb/hr)	1.85	1.83	1.81	1.83
NO _x permit limit (lb/hr)	-	-	-	2.97
NO _x emissions (g/bhp-hr)	0.37	0.37	0.37	0.37
NO _x permit limit (g/bhp-hr)	-	-	-	0.6
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	535	536	540	537
CO emissions (lb/hr)	9.62	9.70	9.76	9.70
CO permit limit (lb/hr)	-	-	-	16.3
CO emissions (g/bhp-hr)	1.94	1.96	1.97	1.96
CO permit limit (g/bhp-hr)	-	-	-	3.3
<u>Volatile Organic Compounds</u>				
NMHC conc. (ppmv)	11.0	11.2	11.3	11.2
NMHC emissions (lb/hr)	0.35	0.36	0.36	0.36
NMHC permit limit (lb/hr)	-	-	-	3.20
NMHC emissions (g/bhp-hr)	0.07	0.07	0.07	0.07
NMHC permit limit (g/bhp-hr)	-	-	-	1.0

APPENDIX 1

- RICE Engine Sample Port Diagrams

