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

Prepared for:

ENERGY DEVELOPMENTS
BYRON CENTER, LLC
SRN N1324

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IMPACT
COMPLIANCE & TESTING

Executive Summary

ENERGY DEVELOPMENTS BYRON CENTER, LLC
CAT® G3520C LANDFILL GAS FUELED IC ENGINES
EMISSIONS TEST RESULTS

Energy Developments Byron Center, LLC (EDL) contracted Impact Compliance & Testing, Inc. (ICT) to conduct a performance demonstration for the determination of nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOC) concentrations and emission rates from two (2) Caterpillar (CAT®) Model No. G3520C landfill gas-fired reciprocating internal combustion engines (RICE) and electricity generator sets (EUICEENGINE1 and EUICEENGINE2) operated at the EDL facility in Byron Center, Kent County, Michigan.

The State of Michigan Department of Environment, Great Lakes, and Energy-Air Quality Division (EGLE-AQD) Renewable Operating Permit (ROP) No. MI-ROP-N1324-2018b requires that emission testing be performed on the CAT® G3520C engines within 180 days of startup and every 8,760 hours of operation (or every three years) in accordance with the provisions of 40 CFR Part 60 Subpart JJJJ (NSPS for spark ignition RICE). The performance testing was conducted on November 1, 2022 and November 10, 2022.

The following table presents the emissions results from the performance demonstration.

Emission Unit	NO_x Emissions (lb/hr)	(g/bhp-hr)	CO Emissions (lb/hr)	(g/bhp-hr)	VOC Emissions (g/bhp-hr)
EUICEENGINE1	2.02	0.44	11.2	2.47	0.14
EUICEENGINE2	2.33	0.50	11.1	2.36	0.14
Permit Limits	4.92	1.0	16.23	3.3	1.0

The following table presents the operating data recorded during the performance demonstration.

Emission Unit	Generator Output (kW)	Engine Output (bhp)	LFG Fuel Use (lb/hr)	LFG CH_4 Content (%)
EUICEENGINE1	1,505	2,100	2,207	52.2
EUICEENGINE2	1,525	2,129	2,157	53.4

The data presented above indicates that EUICEENGINE1 and EUICEENGINE2 were tested while the units operated within 10% of maximum capacity (2,233 bhp and 1,600 kW) and are in compliance with the emission standards specified in 40 CFR 60.4233(e) and MI-ROP-N1324-2018b for NOx, CO, and VOC.

NSPS JJJJ (and the ROP) requires emission testing every 8,760 hours for NOx, CO, and VOC. The results show that the engines were in compliance with NOx, CO, and VOC emission limits of NSPS JJJJ and the ROP.

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1.0 Introduction

Energy Developments Byron Center, LLC (EDL) owns and operates landfill gas (LFG) fueled reciprocating internal combustion engine and electricity generator sets (RICE gensets) at the EDL facility in Byron Center, Kent County, Michigan. The RICE are fueled by LFG that is recovered from the South Kent Landfill and treated prior to use.

The State of Michigan Department of Environment, Great Lakes and Energy – Air Quality Division (EGLE-AQD) has issued to EDL a Renewable Operating Permit (MI-ROP-N1324-2018b) for operation of the renewable electricity generation facility, which consists of:

- Two (2) Caterpillar (CAT®) Model No. G3520C RICE gensets identified as emission units EUICEENGINE1 and EUICEENGINE2 (Flexible Group ID: FGICEENGINES)

Air emission compliance testing was performed pursuant to MI-ROP-N1324-2018b and the federal Standards of Performance for Stationary Spark Ignition Internal Combustion Engines (the SI-RICE NSPS; 40 CFR Part 60 Subpart JJJJ) which state:

1. *The permittee shall conduct a performance test for each engine in FGENGINES, to verify NOx, CO, and VOC emission rates. The permittee shall conduct a performance test within 8,760 hours of operation from December 20, 2016 or three years from December 20, 2016, whichever occurs first, to demonstrate compliance.*

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 Andrew Eisenberg and Max Fierro performed the field sampling and measurements for EUICEENGINE2 November 1, 2022. Max Fierro and Andy Rusnak performed field sampling and measurements for EUICEENGINE1 on November 10, 2022.

The engine emission performance tests consisted of triplicate, one-hour sampling periods for nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOC, as non-methane hydrocarbons (NMHC or NMOC)). 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.

The exhaust gas sampling and analysis was performed using procedures specified in the Stack Test Protocol dated September 13, 2022, that was reviewed and approved by EGLE-AQD. Engine 1 (EUICEENGINE1) experienced a major malfunction that prevented the engine from being tested on the proposed date. EGLE-AQD representative Trevor Drost approved the rescheduled testing date of November 10, 2022.

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Table 2.1 Average engine operating conditions during the test periods

Engine Parameter	EUICEENGINE1 CAT® G3520C	EUICEENGINE2 CAT® G3520C
Generator output (kW)	1,505	1,525
Engine output (bhp)	2,100	2,129
Engine LFG fuel use (lb/hr)	2,207	2,157
LFG methane content (%)	52.2	53.4
Exhaust temperature (°F)	827	822

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

	CO		NOx		VOC
Emission Unit	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(g/bhp-hr)
EUICEENGINE1	11.2	2.47	2.02	0.44	0.13
EUICEENGINE2	11.1	2.36	2.33	0.50	0.14
Permit Limit	***16.23***	***3.3***	***4.92***	***1.0***	***1.0***

4.0 Sampling and Analytical Procedures

A Stack Test Protocol for the air emission testing was reviewed and approved by the 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 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.

4.5 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 Model ZRF 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 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 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.

5.5 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 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.

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 Tables 6.1 and 6.2.

EUICEENGINE1 and EUICEENGINE2 each have the following allowable emission limits specified in MI-ROP-N1324-2018b:

- 16.23 lb/hr and 3.3 grams per brake horsepower hour (g/bhp-hr) for CO;
- 4.92 lb/hr and 1.0 g/bhp-hr for NOx; and
- 1.0 g/bhp-hr for VOC.

The measured air pollutant emission rates for EUICEENGINE1 and EUICEENGINE2 are less than the allowable limits specified in MI-ROP-N1324-2018b.

6.2 Variations from Normal Sampling Procedures or Operating Conditions

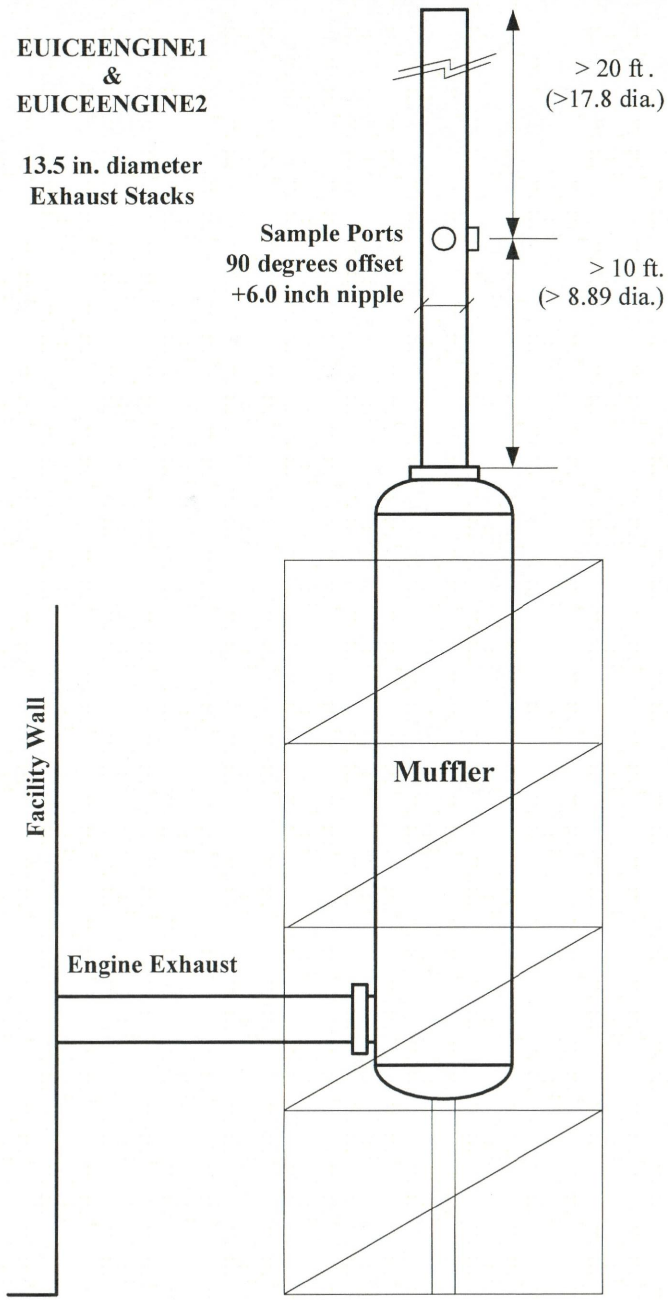
The testing for all pollutants was performed in accordance with USEPA methods and the approved Stack Test Protocol. The RICE gensets were operated within 10% of maximum output (1,600 kW generator output for CAT® G3520C RICE) and no variations from normal operating conditions occurred during the engine test periods. A test run for EUICEENGINE2 was aborted due to the operator accidentally shutting down the engine.

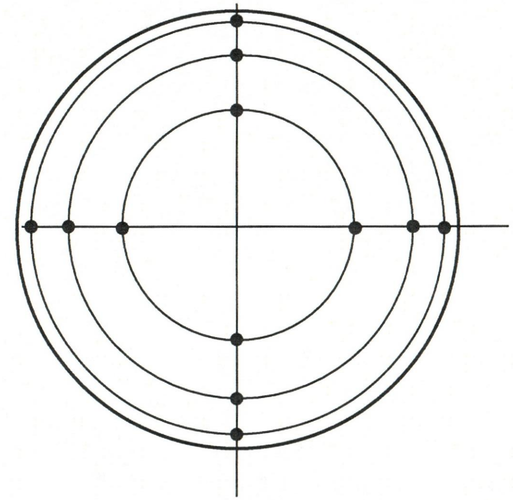
Table 6.2 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 2 (EUICEENGINE2)

Test No. Test date Test period (24-hr clock)	1 11/01/2022 0820-0920	2 11/01/2022 0944-1044	3 11/01/2022 1203-1303	Three Test Average
Fuel flowrate (lb/hr)	2,135	2,148	2,189	2,157
Generator output (kW)	1,512	1,527	1,538	1,525
Engine output (bhp)	2,110	2,130	2,146	2,129
LFG methane content (%)	53.5	53.4	53.4	53.4
Exhaust Gas Composition				
CO_2 content (% vol)	11.2	11.2	11.2	11.2
O_2 content (% vol)	8.92	8.94	8.93	8.93
Moisture (% vol)	12.9	11.6	12.2	12.2
Exhaust gas temperature (°F)	822	820	824	822
Exhaust gas flowrate (dscfm)	4,148	4,282	4,181	4,204
Exhaust gas flowrate (scfm)	4,762	4,842	4,760	4,788
Nitrogen Oxides				
NO_X conc. (ppmvd)	86.0	76.0	70.1	77.4
NO_X emissions (lb/hr)	2.56	2.33	2.10	2.33
Permit Limit (lb/hr)	-	-	-	*4.92*
NO_X emissions (g/bhp-hr)	0.55	0.50	0.44	0.50
Permit Limit (g/bhp-hr)	-	-	-	*3.0*
Carbon Monoxide				
CO conc. (ppmvd)	612	605	595	604
CO emissions (lb/hr)	11.08	11.31	10.86	11.08
Permit Limit (lb/hr)	-	-	-	*16.23*
CO emissions (g/bhp-hr)	2.38	2.41	2.30	2.36
Permit Limit (g/bhp-hr)	-	-	-	*5.0*
Volatile Organic Compounds				
NMHC conc. (ppmv)	19.6	20.2	19.8	19.9
VOC emissions (g/bhp-hr)	0.14	0.14	0.14	0.14
Permit Limit (g/bhp-hr)	-	-	-	*1.0*

APPENDIX 1

- RICE Engine Sample Port Diagram





Velocity sample locations as measured from stack wall

Pt. #	in.
1	0.59
2	1.97
3	4.00
4	9.50
5	11.53
6	12.91

EDL Byron Center
Exhaust Sample Locations, CAT® G3520C RICE

Scale	Sheet	
None	1 of 1	IMPACT COMPLIANCE & TESTING