

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

**Prepared for:
Pine Tree Acres, Inc.
SRN N5984**

Test Dates: March 4-7, 2024

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Report Certification

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

Pine Tree Acres, Inc.
at the Pine Tree Acres Landfill
Lenox Township, MI

Report Certification

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

Impact Compliance & Testing, Inc.



Tyler J. Wilson
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Table of Contents

1.0 INTRODUCTION	2
2.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS	3
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
3.0 SOURCE AND SAMPLING LOCATION DESCRIPTION	5
3.1 General Process Description.....	5
3.2 Rated Capacities and Air Emission Controls.....	5
3.3 Sampling Locations.....	5
4.0 SAMPLING AND ANALYTICAL PROCEDURES	7
4.1 Summary of Sampling Methods.....	7
4.2 Exhaust Gas Velocity Determination (USEPA Method 2).....	8
4.3 Exhaust Gas Molecular Weight Determination (USEPA Method 3A).....	8
4.4 Exhaust Gas Moisture Content (USEPA Method 4).....	8
4.5 NO _x and CO Concentration Measurements (USEPA Methods 7E and 10).....	9
4.6 Measurement of VOC (USEPA Method 25A / ALT-096).....	9
5.0 QA/QC ACTIVITIES	10
5.1 Flow Measurement Equipment.....	10
5.2 NO _x Converter Efficiency Test.....	10
5.3 Gas Divider Certification (USEPA Method 205).....	10
5.4 Instrumental Analyzer Interference Check.....	10
5.5 Instrument Calibration and System Bias Checks.....	11
5.6 Determination of Exhaust Gas Stratification.....	11
5.7 System Response Time.....	11
5.8 Meter Box Calibrations.....	11
6.0 RESULTS	13
6.1 Test Results and Allowable Emission Limits.....	13
6.2 Variations from Normal Sampling Procedures or Operating Conditions.....	13

List of Tables

2.1	Average operating conditions during the test periods	4
2.2	Average measured emission rates for each engine (three-test average)	4
3.1	Engine Identification	5
6.1	Measured exhaust gas conditions and air pollutant emission rates for Engine No. 1 (EU-ICENGINE1).....	14
6.2	Measured exhaust gas conditions and air pollutant emission rates for Engine No. 2 (EU-ICENGINE2).....	15
6.3	Measured exhaust gas conditions and air pollutant emission rates for Engine No. 3 (EU-ICENGINE3).....	16
6.4	Measured exhaust gas conditions and air pollutant emission rates for Engine No. 4 (EU-ICENGINE4).....	17
6.5	Measured exhaust gas conditions and air pollutant emission rates for Engine No. 5 (EU-ICENGINE5).....	18
6.6	Measured exhaust gas conditions and air pollutant emission rates for Engine No. 6 (EU-ICENGINE6).....	19
6.7	Measured exhaust gas conditions and air pollutant emission rates for Engine No. 7 (EU-ICENGINE7).....	20
6.8	Measured exhaust gas conditions and air pollutant emission rates for Engine No. 8 (EU-ICENGINE8).....	21

List of Appendices

APPENDIX 1	SAMPLE PORT DIAGRAM
APPENDIX 2	OPERATING RECORDS AND DRAEGER® TUBE PHOTOS
APPENDIX 3	FLOWRATE CALCULATIONS AND DATA SHEETS
APPENDIX 4	CO ₂ , O ₂ , CO, NO _X , AND VOC CALCULATIONS
APPENDIX 5	INSTRUMENTAL ANALYZER RAW DATA
APPENDIX 6	QA/QC RECORDS

1.0 Introduction

Waste Management, Inc. (WM) operates gas-fired reciprocating internal combustion engine (RICE) and electricity generator sets (gensets) at the Pine Tree Acres, Inc. (PTA) facility located in Lenox Township, Macomb County, Michigan. The RICE are fueled by landfill gas (LFG) that is recovered from the Pine Tree Acres Landfill (PTAL) and treated prior to use.

The State of Michigan Department of Environment, Great Lakes, and Energy – Air Quality Division (EGLE-AQD) has issued to WM-PTA a Renewable Operating Permit (MI-ROP-N5984-2019) for operation of the renewable electricity generation facility, which consists of:

- Eight (8) Caterpillar (CAT®) Model No. G3520C RICE gensets identified as emission units EU-ICENGINE1 through EU-ICENGINE8 (Flexible Group ID FG-ICENGINES, FG-RICEMACT, and FG-RICENSPS).

Air emission compliance testing was performed pursuant to MI-ROP-N5984-2019. Conditions of MI-ROP-N5984-2019 for FG-ICENGINES state:

1. *Except as provided in 40 CFR 60.4243(b), the permittee shall conduct an initial performance test for each engine in FG-RICENSPS within one year of startup of the engine and every 8760 hours of operation (as determined through the use of a non-resettable hour meter) or three years, whichever occurs first, to demonstrate compliance with the emission limits in 40 CFR 60.4233(e)...*

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 Tyler Wilson and Josh Larson performed the field sampling and measurements March 4-7, 2024.

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 December 29, 2023, that was reviewed and approved by EGLE-AQD. Mr. Robert Joseph of EGLE-AQD observed portions of the compliance testing.

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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-N5984-2019 and 40 CFR Part 60, Subpart JJJJ, Standards of Performance for New Stationary Sources for Stationary Spark Ignition Internal Combustion Engines require WM-PTA to test each engine in FG-ICENGINES / FG-RICEMACT / FG-RICENSPS for CO, NO_x, and VOC emissions. Engine Nos. 1 – 8 (EU-ICENGINE1 – EU-ICENGINE8, respectively) were tested during this compliance test event.

2.2 Operating Conditions During the Compliance Tests

The testing was performed while the WM-PTA engine/generator sets were operated at maximum operating conditions (within 10% of 1,600-kilowatt (kW) electricity output). WM-PTA representatives provided kW output in 15-minute increments for each test period.

Fuel flowrate (standard cubic feet per minute (scfm)), fuel methane (CH₄) content (%), and air-to-fuel ratio were also recorded by WM-PTA representatives in 15-minute increments for each test period. In addition, WM-PTA representatives monitored LFG hydrogen sulfide (H₂S) content once per test day using Draeger® tubes.

Appendix 2 provides operating records provided by WM-PTA representatives for the test periods and photos of the H₂S Draeger® tubes.

Average generator output (kW), fuel consumption, fuel methane content, and air-to-fuel ratio for each RICE is presented in Table 2.1 and Tables 6.1-6.8.

2.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the sampled LFG fueled RICE (Engine Nos. 1 – 8 / EU-ICENGINE1 – EU-ICENGINE8) were each sampled for three (3) one-hour test periods during the compliance testing performed March 4-7, 2024.

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

Emission Unit	Generator Output (kW)	LFG Fuel Use (scfm)	LFG CH₄ Content (%)	Air / Fuel Ratio
Engine No. 1	1,636	614	49.5	7.0
Engine No. 2	1,631	617	49.8	7.1
Engine No. 3	1,623	585	50.1	7.2
Engine No. 4	1,628	594	49.7	6.5
Engine No. 5	1,636	607	49.9	7.0
Engine No. 6	1,624	618	49.3	6.9
Engine No. 7	1,621	617	49.5	7.7
Engine No. 8	1,629	624	49.1	6.8

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

Emission Unit	CO		NO_x		VOC	
	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)
Engine No. 1	16.0	3.17	2.13	0.42	0.82	0.16
Engine No. 2	13.9	2.77	1.68	0.33	0.71	0.14
Engine No. 3	13.4	2.69	2.62	0.52	0.95	0.19
Engine No. 4	13.9	2.77	1.94	0.39	0.48	0.10
Engine No. 5	15.2	3.02	1.44	0.29	0.67	0.13
Engine No. 6	16.0	3.19	1.62	0.32	0.71	0.14
Engine No. 7	14.2	2.84	1.21	0.24	0.65	0.13
Engine No. 8	12.5	2.50	1.92	0.38	0.77	0.15
Permit Limit	16.3	3.3	3.0	0.6	1.0	1.0

3.0 Source and Sampling Location Description

3.1 General Process Description

WM-PTA is permitted to operate eight (8) RICE-generator sets (CAT® Model No. G3520C) at its facility. The units are fired exclusively with LFG that is recovered from the PTAL and treated prior to use.

Table 3.1 Engine Identification

Emission Unit	ROP Identification	Serial Number
Engine No. 1	EU-ICENGINE1	GZJ00463
Engine No. 2	EU-ICENGINE2	GZJ00462
Engine No. 3	EU-ICENGINE3	GZJ00465
Engine No. 4	EU-ICENGINE4	GZJ00464
Engine No. 5	EU-ICENGINE5	GZJ00456
Engine No. 6	EU-ICENGINE6	GZJ00466
Engine No. 7	EU-ICENGINE7	GZJ00467
Engine No. 8	EU-ICENGINE8	GZJ00457

3.2 Rated Capacities and Air Emission Controls

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

- Engine Power: 2,233 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 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 for each engine.

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 stacks for Engine Nos. 1 – 8 / EU-ICENGINE1 – EU-ICENGINE8 are identical. The exhaust stack sampling ports are located in individual horizontal exhaust ducts, located before each engine muffler, with an inner diameter of 15.0 inches. After the engine muffler, each exhaust stack diameter is reduced to 14.0 inches as specified in MI-ROP-N5984-2019. Each 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

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 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 each 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 TEI 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 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 (or onsite prior to beginning compliance testing), 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.

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 NO_x concentration is at least 90% of the expected value (within 10%).

The NO₂ – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_x concentration was 100.7% 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 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 the 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 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 6 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 Tables 6.1 through 6.8.

Engine Nos. 1 – 8 / EU-ICENGINE1 – EU-ICENGINE8 each have the following allowable emission limits specified in MI-ROP-N5984-2019:

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

The measured air pollutant concentrations and emission rates for Engine Nos. 1 – 8 / EU-ICENGINE1 – EU-ICENGINE8 are less than the allowable limits specified in MI-ROP-N5984-2019 and 40 CFR Part 60, Subpart JJJJ, Standards of Performance for New Stationary Sources for Stationary Spark Ignition Internal Combustion Engines.

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) during the engine test periods.

Test No. 3 for Engine No. 1 / EU-ICENGINE1 was paused for twenty-one (21) minutes, due to the RICE genset unexpectedly shutting down. WM-PTA representatives restarted the RICE genset and testing resumed once the RICE genset achieved maximum output (within 10% of 1,600-kW electricity output), and once the air pollutant sampling probe had been in the exhaust stack for at least twice the greatest system response time. Testing continued until at least sixty (60) minutes of air pollutant concentration data was logged.

The EGLE-AQD testing approval letter dated February 23, 2024, noted the following testing requirement: *weekly LFG Total Reduced Sulfur (TRS) content sampling will be done on each source during the second run.* While onsite, Mr. Robert Joseph of EGLE-AQD instead requested that one (1) LFG H₂S Draeger® tube sample be obtained per test day. This compliance test event took place over four (4) days. Therefore, a total of four (4) LFG H₂S Draeger® tube samples were obtained during this compliance test event (one (1) per test day) and are presented in this air emission test report.

Table 6.1 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 1 (EU-ICENGINE1)

Test No.	1	2	3	Three Test Average
Test date	3/4/2024	3/4/2024	3/4/2024	
Test period (24-hr clock)	848-948	1015-1115	1142-1204; 1226-1303	
Fuel flowrate (scfm)	612	616	615	614
Generator output (kW)	1,635	1,631	1,643	1,636
Engine output (bhp)	2,284	2,279	2,295	2,286
LFG methane content (%)	49.3	49.4	49.7	49.5
Air-to-fuel ratio	7.0	7.0	7.0	7.0
<u>Exhaust Gas Composition</u>				
CO ₂ content (% vol)	11.5	11.5	11.5	11.5
O ₂ content (% vol)	8.99	8.96	8.97	8.97
Moisture (% vol)	12.6	11.8	11.7	12.0
Exhaust gas temperature (°F)	898	896	898	897
Exhaust gas flowrate (dscfm)	4,461	4,530	4,490	4,494
Exhaust gas flowrate (scfm)	5,106	5,134	5,088	5,109
<u>Nitrogen Oxides</u>				
NO _x conc. (ppmvd)	63.4	67.0	67.5	66.0
NO _x emissions (lb/hr)	2.03	2.17	2.17	2.13
NO _x permit limit (lb/hr)	-	-	-	3.0
NO _x emissions (g/bhp-hr)	0.40	0.43	0.43	0.42
NO _x permit limit (g/bhp-hr)	-	-	-	0.6
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	812	819	813	814
CO emissions (lb/hr)	15.8	16.2	15.9	16.0
CO permit limit (lb/hr)	-	-	-	16.3
CO emissions (g/bhp-hr)	3.14	3.22	3.15	3.17
CO permit limit (g/bhp-hr)	-	-	-	3.3
<u>Volatile Organic Compounds</u>				
NMHC conc. (ppmv)	22.7	22.9	24.4	23.3
NMHC emissions (lb/hr)	0.80	0.81	0.85	0.82
NMHC permit limit (lb/hr)	-	-	-	1.0
NMHC emissions (g/bhp-hr)	0.16	0.16	0.17	0.16
NMHC permit limit (g/bhp-hr)	-	-	-	1.0

Table 6.2 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 2 (EU-ICENGINE2)

Test No.	1	2	3	Three Test Average
Test date	3/5/2024	3/5/2024	3/5/2024	
Test period (24-hr clock)	702-802	824-924	945-1045	
Fuel flowrate (scfm)	618	617	615	617
Generator output (kW)	1,632	1,628	1,633	1,631
Engine output (bhp)	2,279	2,274	2,281	2,278
LFG methane content (%)	49.6	49.9	50.0	49.8
Air-to-fuel ratio	7.1	7.1	7.1	7.1
<u>Exhaust Gas Composition</u>				
CO ₂ content (% vol)	11.9	11.8	11.9	11.9
O ₂ content (% vol)	8.44	8.42	8.42	8.43
Moisture (% vol)	10.9	11.9	10.4	11.1
Exhaust gas temperature (°F)	929	934	940	934
Exhaust gas flowrate (dscfm)	4,513	4,387	4,304	4,401
Exhaust gas flowrate (scfm)	5,067	4,981	4,802	4,950
<u>Nitrogen Oxides</u>				
NO _x conc. (ppmvd)	54.3	52.8	52.3	53.1
NO _x emissions (lb/hr)	1.76	1.66	1.62	1.68
NO _x permit limit (lb/hr)	-	-	-	3.0
NO _x emissions (g/bhp-hr)	0.35	0.33	0.32	0.33
NO _x permit limit (g/bhp-hr)	-	-	-	0.6
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	727	725	719	724
CO emissions (lb/hr)	14.3	13.9	13.5	13.9
CO permit limit (lb/hr)	-	-	-	16.3
CO emissions (g/bhp-hr)	2.85	2.77	2.69	2.77
CO permit limit (g/bhp-hr)	-	-	-	3.3
<u>Volatile Organic Compounds</u>				
NMHC conc. (ppmv)	20.8	20.7	20.9	20.8
NMHC emissions (lb/hr)	0.72	0.71	0.69	0.71
NMHC permit limit (lb/hr)	-	-	-	1.0
NMHC emissions (g/bhp-hr)	0.14	0.14	0.14	0.14
NMHC permit limit (g/bhp-hr)	-	-	-	1.0

Table 6.3 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 3 (EU-ICENGINE3)

Test No.	1	2	3	Three Test Average
Test date	3/5/2024	3/5/2024	3/5/2024	
Test period (24-hr clock)	1110-1210	1232-1332	1355-1455	
Fuel flowrate (scfm)	590	585	582	585
Generator output (kW)	1,621	1,623	1,624	1,623
Engine output (bhp)	2,265	2,267	2,269	2,267
LFG methane content (%)	50.1	50.3	49.8	50.1
Air-to-fuel ratio	7.2	7.2	7.1	7.2
<u>Exhaust Gas Composition</u>				
CO ₂ content (% vol)	11.6	11.7	11.7	11.7
O ₂ content (% vol)	8.86	8.69	8.70	8.75
Moisture (% vol)	10.9	11.9	11.7	11.5
Exhaust gas temperature (°F)	878	885	890	893
Exhaust gas flowrate (dscfm)	4,473	4,381	4,379	4,411
Exhaust gas flowrate (scfm)	5,020	4,970	4,961	4,984
<u>Nitrogen Oxides</u>				
NO _x conc. (ppmvd)	70.8	90.0	88.3	83.0
NO _x emissions (lb/hr)	2.27	2.83	2.77	2.62
NO _x permit limit (lb/hr)	-	-	-	3.0
NO _x emissions (g/bhp-hr)	0.45	0.57	0.55	0.52
NO _x permit limit (g/bhp-hr)	-	-	-	0.6
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	688	708	699	698
CO emissions (lb/hr)	13.4	13.5	13.4	13.4
CO permit limit (lb/hr)	-	-	-	16.3
CO emissions (g/bhp-hr)	2.69	2.71	2.67	2.69
CO permit limit (g/bhp-hr)	-	-	-	3.3
<u>Volatile Organic Compounds</u>				
NMHC conc. (ppmv)	28.7	27.5	27.4	27.8
NMHC emissions (lb/hr)	0.99	0.94	0.93	0.95
NMHC permit limit (lb/hr)	-	-	-	1.0
NMHC emissions (g/bhp-hr)	0.20	0.19	0.19	0.19
NMHC permit limit (g/bhp-hr)	-	-	-	1.0

Table 6.4 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 4 (EU-ICENGINE4)

Test No.	1	2	3	Three Test
Test date	3/5/2024	3/5/2024	3/5/2024	Average
Test period (24-hr clock)	1519-1619	1641-1741	1802-1902	
Fuel flowrate (scfm)	594	596	594	594
Generator output (kW)	1,625	1,626	1,632	1,628
Engine output (bhp)	2,270	2,271	2,280	2,274
LFG methane content (%)	49.8	49.7	49.5	49.7
Air-to-fuel ratio	6.6	6.5	6.5	6.5
<u>Exhaust Gas Composition</u>				
CO ₂ content (% vol)	12.2	12.2	12.2	12.2
O ₂ content (% vol)	8.01	8.01	8.01	8.01
Moisture (% vol)	12.0	11.9	11.3	11.7
Exhaust gas temperature (°F)	963	958	962	961
Exhaust gas flowrate (dscfm)	3,978	3,946	4,113	4,012
Exhaust gas flowrate (scfm)	4,523	4,481	4,637	4,547
<u>Nitrogen Oxides</u>				
NO _x conc. (ppmvd)	66.3	66.7	68.8	67.3
NO _x emissions (lb/hr)	1.89	1.89	2.03	1.94
NO _x permit limit (lb/hr)	-	-	-	3.0
NO _x emissions (g/bhp-hr)	0.38	0.38	0.40	0.39
NO _x permit limit (g/bhp-hr)	-	-	-	0.6
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	793	793	793	793
CO emissions (lb/hr)	13.8	13.7	14.2	13.9
CO permit limit (lb/hr)	-	-	-	16.3
CO emissions (g/bhp-hr)	2.75	2.73	2.83	2.77
CO permit limit (g/bhp-hr)	-	-	-	3.3
<u>Volatile Organic Compounds</u>				
NMHC conc. (ppmv)	15.3	15.3	15.4	15.3
NMHC emissions (lb/hr)	0.48	0.47	0.49	0.48
NMHC permit limit (lb/hr)	-	-	-	1.0
NMHC emissions (g/bhp-hr)	0.09	0.09	0.10	0.10
NMHC permit limit (g/bhp-hr)	-	-	-	1.0

Table 6.5 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 5 (EU-ICENGINE5)

Test No.	1	2	3	Three Test Average
Test date	3/4/2024	3/4/2024	3/4/2024	
Test period (24-hr clock)	1334-1434	1503-1603	1630-1730	
Fuel flowrate (scfm)	610	605	605	607
Generator output (kW)	1,631	1,625	1,653	1,636
Engine output (bhp)	2,278	2,270	2,309	2,286
LFG methane content (%)	49.8	50.1	49.6	49.9
Air-to-fuel ratio	7.0	7.0	7.0	7.0
<u>Exhaust Gas Composition</u>				
CO ₂ content (% vol)	12.1	12.0	12.1	12.1
O ₂ content (% vol)	8.17	8.20	8.18	8.18
Moisture (% vol)	11.0	13.3	10.8	11.7
Exhaust gas temperature (°F)	935	934	935	935
Exhaust gas flowrate (dscfm)	4,677	4,461	4,515	4,551
Exhaust gas flowrate (scfm)	5,255	5,147	5,063	5,155
<u>Nitrogen Oxides</u>				
NO _x conc. (ppmvd)	44.0	44.0	44.1	44.0
NO _x emissions (lb/hr)	1.48	1.41	1.43	1.44
NO _x permit limit (lb/hr)	-	-	-	3.0
NO _x emissions (g/bhp-hr)	0.29	0.28	0.28	0.29
NO _x permit limit (g/bhp-hr)	-	-	-	0.6
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	766	766	764	765
CO emissions (lb/hr)	15.6	14.9	15.1	15.2
CO permit limit (lb/hr)	-	-	-	16.3
CO emissions (g/bhp-hr)	3.11	2.98	2.96	3.02
CO permit limit (g/bhp-hr)	-	-	-	3.3
<u>Volatile Organic Compounds</u>				
NMHC conc. (ppmv)	18.9	18.8	18.8	18.8
NMHC emissions (lb/hr)	0.68	0.67	0.66	0.67
NMHC permit limit (lb/hr)	-	-	-	1.0
NMHC emissions (g/bhp-hr)	0.14	0.13	0.13	0.13
NMHC permit limit (g/bhp-hr)	-	-	-	1.0

Table 6.6 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 6 (EU-ICENGINE6)

Test No.	1	2	3	Three Test
Test date	3/6/2024	3/6/2024	3/6/2024	Average
Test period (24-hr clock)	720-820	844-944	1005-1105	
Fuel flowrate (scfm)	618	620	615	618
Generator output (kW)	1,622	1,629	1,621	1,624
Engine output (bhp)	2,266	2,276	2,265	2,269
LFG methane content (%)	49.3	49.3	49.3	49.3
Air-to-fuel ratio	6.9	7.0	7.0	6.9
<u>Exhaust Gas Composition</u>				
CO ₂ content (% vol)	11.8	11.7	11.7	11.7
O ₂ content (% vol)	8.54	8.62	8.65	8.60
Moisture (% vol)	11.2	11.0	11.3	11.2
Exhaust gas temperature (°F)	912	915	914	914
Exhaust gas flowrate (dscfm)	4,399	4,293	4,336	4,343
Exhaust gas flowrate (scfm)	4,951	4,826	4,890	4,889
<u>Nitrogen Oxides</u>				
NO _x conc. (ppmvd)	54.9	50.4	51.2	52.2
NO _x emissions (lb/hr)	1.73	1.55	1.59	1.62
NO _x permit limit (lb/hr)	-	-	-	3.0
NO _x emissions (g/bhp-hr)	0.35	0.31	0.32	0.32
NO _x permit limit (g/bhp-hr)	-	-	-	0.6
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	854	834	837	841
CO emissions (lb/hr)	16.4	15.6	15.8	16.0
CO permit limit (lb/hr)	-	-	-	16.3
CO emissions (g/bhp-hr)	3.28	3.12	3.17	3.19
CO permit limit (g/bhp-hr)	-	-	-	3.3
<u>Volatile Organic Compounds</u>				
NMHC conc. (ppmv)	20.3	21.5	21.8	21.2
NMHC emissions (lb/hr)	0.69	0.71	0.73	0.71
NMHC permit limit (lb/hr)	-	-	-	1.0
NMHC emissions (g/bhp-hr)	0.14	0.14	0.15	0.14
NMHC permit limit (g/bhp-hr)	-	-	-	1.0

Table 6.7 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 7 (EU-ICENGINE7)

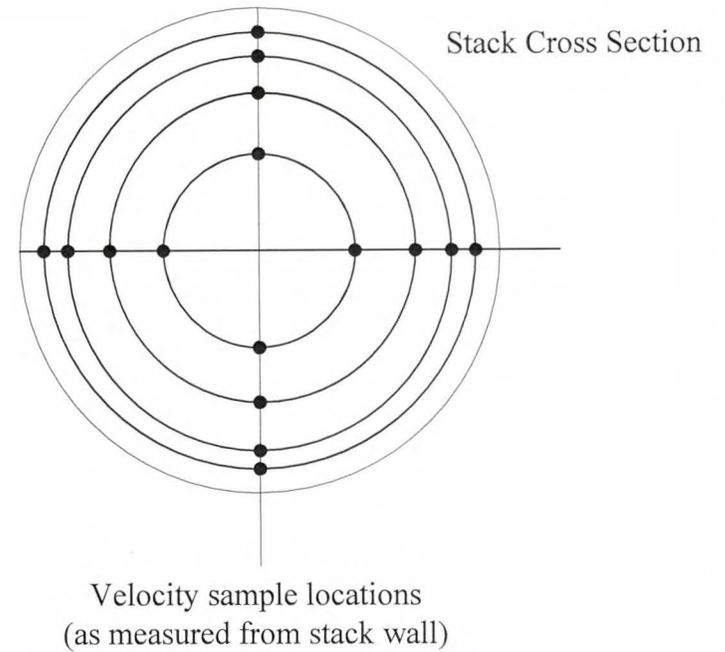
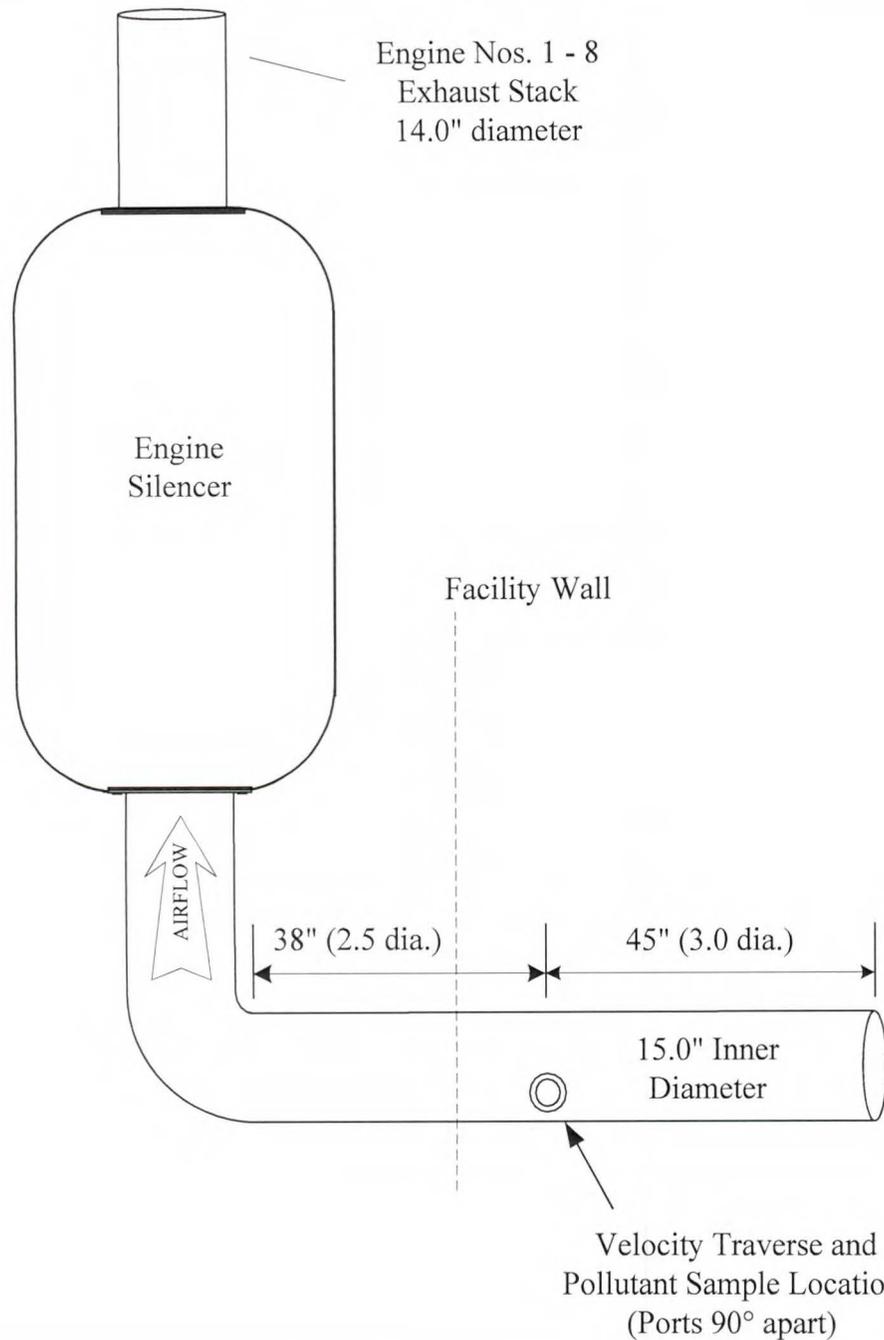
Test No.	1	2	3	Three Test
Test date	3/6/2024	3/6/2024	3/6/2024	Average
Test period (24-hr clock)	1132-1232	1256-1356	1417-1517	
Fuel flowrate (scfm)	618	614	620	617
Generator output (kW)	1,621	1,620	1,622	1,621
Engine output (bhp)	2,265	2,262	2,266	2,264
LFG methane content (%)	49.4	49.6	49.6	49.5
Air-to-fuel ratio	7.7	7.7	7.8	7.7
<u>Exhaust Gas Composition</u>				
CO ₂ content (% vol)	11.8	11.8	11.8	11.8
O ₂ content (% vol)	8.45	8.44	8.44	8.45
Moisture (% vol)	11.2	11.9	11.2	11.4
Exhaust gas temperature (°F)	938	942	945	942
Exhaust gas flowrate (dscfm)	4,590	4,413	4,614	4,539
Exhaust gas flowrate (scfm)	5,168	5,008	5,198	5,125
<u>Nitrogen Oxides</u>				
NO _x conc. (ppmvd)	36.9	37.0	37.3	37.1
NO _x emissions (lb/hr)	1.22	1.17	1.24	1.21
NO _x permit limit (lb/hr)	-	-	-	3.0
NO _x emissions (g/bhp-hr)	0.24	0.23	0.25	0.24
NO _x permit limit (g/bhp-hr)	-	-	-	0.6
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	716	716	713	715
CO emissions (lb/hr)	14.3	13.8	14.4	14.2
CO permit limit (lb/hr)	-	-	-	16.3
CO emissions (g/bhp-hr)	2.87	2.77	2.87	2.84
CO permit limit (g/bhp-hr)	-	-	-	3.3
<u>Volatile Organic Compounds</u>				
NMHC conc. (ppmv)	18.6	18.6	18.5	18.6
NMHC emissions (lb/hr)	0.66	0.64	0.66	0.65
NMHC permit limit (lb/hr)	-	-	-	1.0
NMHC emissions (g/bhp-hr)	0.13	0.13	0.13	0.13
NMHC permit limit (g/bhp-hr)	-	-	-	1.0

Table 6.8 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 8 (EU-ICENGINE8)

Test No.	1	2	3	
Test date	3/7/2024	3/7/2024	3/7/2024	Three Test
Test period (24-hr clock)	702-802	827-927	953-1053	Average
Fuel flowrate (scfm)	623	624	625	624
Generator output (kW)	1,629	1,627	1,629	1,629
Engine output (bhp)	2,276	2,273	2,276	2,275
LFG methane content (%)	49.3	48.9	49.1	49.1
Air-to-fuel ratio	6.8	6.8	6.8	6.8
<u>Exhaust Gas Composition</u>				
CO ₂ content (% vol)	11.8	11.7	11.8	11.8
O ₂ content (% vol)	8.68	8.68	8.68	8.68
Moisture (% vol)	10.3	10.3	11.7	10.8
Exhaust gas temperature (°F)	899	907	910	905
Exhaust gas flowrate (dscfm)	4,626	4,360	4,459	4,482
Exhaust gas flowrate (scfm)	5,154	4,862	5,049	5,022
<u>Nitrogen Oxides</u>				
NO _x conc. (ppmvd)	60.6	59.2	59.4	59.7
NO _x emissions (lb/hr)	2.01	1.85	1.90	1.92
NO _x permit limit (lb/hr)	-	-	-	3.0
NO _x emissions (g/bhp-hr)	0.40	0.37	0.38	0.38
NO _x permit limit (g/bhp-hr)	-	-	-	0.6
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	640	635	646	640
CO emissions (lb/hr)	12.9	12.1	12.6	12.5
CO permit limit (lb/hr)	-	-	-	16.3
CO emissions (g/bhp-hr)	2.57	2.41	2.51	2.50
CO permit limit (g/bhp-hr)	-	-	-	3.3
<u>Volatile Organic Compounds</u>				
NMHC conc. (ppmv)	22.5	22.2	22.6	22.4
NMHC emissions (lb/hr)	0.80	0.74	0.78	0.77
NMHC permit limit (lb/hr)	-	-	-	1.0
NMHC emissions (g/bhp-hr)	0.16	0.15	0.16	0.15
NMHC permit limit (g/bhp-hr)	-	-	-	1.0

APPENDIX 1

- RICE Engine Sample Port Diagram



1	0.5"
2	1.6"
3	2.9"
4	4.8"
5	10.2"
6	12.1"
7	13.4"
8	14.5"

6/2/14 ALR	PTA Landfill IC Engine Nos. 1-8		
4/15/16 RLH	Exhaust Sample Locations		
	Scale	Sheet	
	None	1 of 1	