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

Prepared for:

Energy Developments Coopersville, LLC
at the
Ottawa County Farms Landfill
SRN N3294

ICT Project No.: 2200011
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IMPACT
COMPLIANCE & TESTING

Report Certification

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Energy Developments Coopersville, LLC
at the Ottawa County Farms Landfill
Coopersville, MI

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

Report Prepared By:
Tyler J. Wilson Senior Project Manager Impact Compliance & Testing, Inc.

Executive Summary

ENERGY DEVELOPMENTS COOPERSVILLE, LLC
AT THE OTTAWA COUNTY FARMS LANDFILL
LFG FUELED IC ENGINES
EMISSION TEST RESULTS

Energy Developments Coopersville, LLC (EDL) contracted Impact Compliance & Testing, Inc. (ICT) to conduct a performance demonstration for the determination of nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOC), sulfur dioxide (SO_2), and formaldehyde (HCOH) concentrations and emission rates from one (1) Caterpillar (CAT®) Model No. G3520C gas-fired reciprocating internal combustion engine and electricity generator set (RICE genset) identified as EUENGINE7, and five (5) CAT® Model No. G3516 gas-fired RICE gensets identified as EUENGINE1 and EUENGINE3-EUENGINE6, operated at the Energy Developments Coopersville, LLC facility located in Coopersville, Ottawa County, Michigan. The RICE are fueled with landfill gas (LFG) that is produced at the Ottawa County Farms Landfill.

Compliance testing was performed with regards to conditions specified in The State of Michigan Department of Environment, Great Lakes, and Energy-Air Quality Division (EGLE-AQD) Renewable Operating Permit (ROP) No. MI-ROP-N3294-2019, Permit to Install (PTI) No. 118-20, and the federal Standards of Performance for Stationary Spark Ignition Internal Combustion Engines (the SI-RICE NSPS; 40 CFR Part 60 Subpart JJJJ). The performance testing was conducted May 10-12, 2022.

The following table presents the CAT® G3516 emissions results from the performance demonstration.

Emission Unit	NO_x (lb/hr)	CO (lb/hr)	VOC (lb/hr)	HCOH (lb/hr)	SO_2 (lb/hr)
EUENGINE1	1.06	4.57	1.01	0.60	0.27
EUENGINE3	1.00	4.72	1.09	0.70	0.24
EUENGINE4	0.34	5.22	1.40	0.70	0.11
EUENGINE5	2.87	4.29	0.80	0.55	0.33
EUENGINE6	1.23	5.11	1.16	0.73	0.16
Permit Limits	*4.56*	*7.8*	*1.7**	*0.76*	*1.1*

Note*: This VOC limit includes HCOH.

The following table presents the CAT® G3520C emissions results from the performance demonstration.

Emission Unit	NO_x (lb/hr)	NO_x (g/bhp-hr)	CO (lb/hr)	CO (g/bhp-hr)	VOC (lb/hr)	VOC (g/bhp-hr)	HCOH (lb/hr)	SO_2 (lb/hr)
EUENGINE7	3.42	0.71	12.0	2.50	2.09	0.11	1.56	0.40
Permit Limits	*4.94*	*3.0*	*16.3*	*5.0*	*3.2**	*1.0***	*2.1*	*1.91*

Note*: This VOC limit includes HCOH.
Note**: This VOC limit does not include HCOH.

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

Emission Unit	Generator Output (kW)	Engine Output (bhp)	LFG Fuel Use (scfm)	LFG Fuel Use (lb/hr)	Fuel CH_4 Content (%)	Fuel Inlet Pressure (psi)
EUENGINE1	739	N/A	300	-	56.3	3
EUENGINE3	737	N/A	300	-	53.3	3
EUENGINE4	738	N/A	300	-	54.0	3
EUENGINE5	767	N/A	300	-	50.6	3
EUENGINE6	740	N/A	300	-	49.7	3
EUENGINE7	1,561	2,178	-	2,215	48.8	3

The data presented above indicates that EUENGINE7, EUENGINE1, and EUENGINE3-EUENGINE6 were tested while the units operated within 10% of maximum capacity and are in compliance with the emission standards specific to each unit.

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1.0 Introduction

Energy Developments Coopersville, LLC (EDL) owns and operates one (1) Caterpillar (CAT®) Model No. G3520C gas-fired reciprocating internal combustion engine and electricity generator set (RICE genset) identified as EUENGINE7, and five (5) CAT® Model No. G3516 gas-fired RICE gensets identified as EUENGINE1 and EUENGINE3-EUENGINE6 at the Ottawa County Farms Landfill in Coopersville, Ottawa County, Michigan. The State of Michigan Department of Environment, Great Lakes, and Energy-Air Quality Division (EGLE-AQD) has issued EDL Renewable Operating Permit (ROP) No. MI-ROP-N3294-2019 and Permit to Install (PTI) No. 118-20 for operation of the RICE gensets.

Air emission compliance testing was performed pursuant to conditions specified in ROP No. MI-ROP-N3294-2019, PTI No. 118-20, 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 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, Andy Rusnak, Andrew Eisenberg, and Chiren Moore performed the field sampling and measurements May 10-12, 2022.

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

The exhaust gas sampling and analysis was performed using procedures specified in the Stack Test Protocol dated March 29, 2022, 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 ROP No. MI-ROP-N3294-2019, PTI No. 118-20, and 40 CFR Part 60, Subpart JJJJ, Standards of Performance for New Stationary Sources for Stationary Spark Ignition Internal Combustion Engines require EDL to test EUENGINE1 and EUENGINE3-EUENGINE7 for CO, NOx, VOC, SO_2, and HCOH emissions. Engine Nos. 1 and 3-7 (Emission Units EUENGINE1 and EUENGINE3-EUENGINE7) were tested during this compliance test event.

2.2 Operating Conditions During the Compliance Tests

The testing was performed while the EDL engine/generator sets were operated at maximum operating conditions. EDL representatives provided kW output in 15-minute increments for each test period.

Landfill Gas (LFG) fuel flowrate (standard cubic feet per minute (scfm) or pounds per hour (lb/hr)), fuel methane content (%), and fuel inlet pressure (psi) were also recorded by EDL representatives in 15-minute increments for each test period. In addition, ICT representatives performed LFG total reduced sulfur (TRS) sampling using a tedlar bag with regards to Reference Test Methods D5504 and GPA 2261, and EDL representatives monitored LFG hydrogen sulfide (H_2S) content once for each engine using Draeger® tubes.

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

Appendix 7 provides the TRS Report and photos of the H_2S Draeger® tubes.

Average output, fuel consumption, fuel methane content, and fuel inlet pressure for each RICE is presented in Table 2.1 and Tables 6.1-6.6.

2.3 Summary of Air Pollutant Sampling Results

The gases exhausted from each RICE were sampled for three (3) one-hour test periods during the compliance testing performed May 10-12, 2022.

Table 2.2 presents the average measured CO, NO_X, VOC, SO_2, and HCOH 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	Engine No. 1	Engine No. 3	Engine No. 4	Engine No. 5	Engine No. 6	Engine No. 7
Generator output (kW)	739	737	738	767	740	1,561
Engine output (bhp)	N/A	N/A	N/A	N/A	N/A	2,178
Engine LFG fuel use	300 scfm	300 scfm	300 scfm	300 scfm	300 scfm	2,215 lb/hr
LFG methane content (%)	56.3	53.3	54.0	50.6	49.7	48.8
Exhaust temperature (°F)	807	834	824	813	849	867
Fuel inlet pressure (psi)	3	3	3	3	3	3

Table 2.2 Measured CAT® G3516 air pollutant emission rates (three-test average)

Emission Unit	CO (lb/hr)	NOx (lb/hr)	VOC (lb/hr)	HCOH (lb/hr)	SO_2 (lb/hr)
EUENGINE1	4.57	1.06	1.01	0.60	0.27
EUENGINE3	4.72	1.00	1.09	0.70	0.24
EUENGINE4	5.22	0.34	1.40	0.70	0.11
EUENGINE5	4.29	2.87	0.80	0.55	0.33
EUENGINE6	5.11	1.23	1.16	0.73	0.16
Permit Limit	***7.8***	***4.56***	***1.7****	***0.76***	***1.1***

Note*: This VOC limit includes HCOH.

Table 2.3 Measured CAT® G3520C air pollutant emission rates (three-test average)

	CO		NOx		VOC		HCOH	SO_2
Emission Unit	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(lb/hr)	(lb/hr)
EUENGINE7	12.0	2.50	3.42	0.71	2.09	0.11	1.56	0.40
Permit Limit	***16.3***	***5.0***	***4.94***	***3.0***	***3.2****	***1.0*****	***2.1***	***1.91***

Note*: This VOC limit includes HCOH.
Note**: This VOC limit does not include HCOH.

3.0 Source and Sampling Location Description

3.1 General Process Description

LFG containing methane is produced in the Ottawa County Farms Landfill from the anaerobic decomposition of waste materials. The gas is collected and directed to the Energy Developments Coopersville, LLC gas-to-energy facility where it is used as fuel for the RICE gensets that produce electricity.

The gas-to-energy facility primarily consists of gas treatment equipment, five (5) CAT® Model No. G3516 RICE, and one (1) CAT® Model No. G3520C RICE that are each connected an electricity generator.

3.2 Rated Capacities and Air Emission Controls

The CAT® G3516 engine generator sets each have a rated design capacity of 800 kW.

The CAT® G3520C engine generator set has a rated design capacity of 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 noise mufflers and vertical exhaust stacks.

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® G3516 engines are located in an individual exhaust stack (horizontal section of the stack before the noise muffler) with an inner diameter of 10.0 inches. The stacks are each equipped with two (2) sample ports, opposed 90°, that provide a sampling location 13.0 inches (1.30 duct diameters) upstream and >62.0 inches (>6.20 duct diameters) downstream from any flow disturbance and satisfies the USEPA Method 1 criteria for a representative sample location.

The exhaust stack sampling ports for the CAT® G3520C engine are located in an individual exhaust stack (horizontal section of the stack before the noise muffler) with an inner diameter of 14.0 inches. The stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 21.0 inches (1.50 duct diameters) upstream and >144 inches (>10.3 duct diameters) downstream from any flow disturbance and satisfies the USEPA Method 1 criteria for a representative sample location.

Individual traverse points were determined in accordance with USEPA Method 1.

Appendix 1 provides diagrams of the 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.
USEPA Method 25A / ALT-096	Exhaust gas VOC (as NMHC) concentration was determined using a flame ionization analyzer equipped with methane separation column.
ASTM D6348	Exhaust gas HCOH, SO_2, and moisture content were measured using a Fourier transform infrared spectroscopy (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 for 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)

CO_2 and O_2 content in each RICE exhaust gas stream were measured continuously throughout each test period in accordance with USEPA Method 3A. The CO_2 content of the exhaust was monitored using a Servomex 1440D infrared gas analyzer. The O_2 content of the exhaust was monitored using a Servomex 1440D gas analyzer that uses a paramagnetic sensor.

During each sampling period, a continuous sample of the 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 each RICE exhaust gas stream were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42i High Level chemiluminescence NO_X analyzer and a TEI Model 48i 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 VOC (USEPA Method 25A/ALT-096)

The VOC emission rate was determined by measuring the nonmethane hydrocarbon (NMHC or NMOC) concentration in each RICE 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.

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

HCOH and SO_2 concentrations, and moisture content in each 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 each engine, with acetaldehyde, sulfur hexafluoride, and sulfur dioxide 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.

Appendix 4 provides HCOH and SO_2 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 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 (barometer, Pitot tube, and scale) were calibrated to specifications in the sampling methods.

5.2 NO_x Converter Efficiency Test

The NO_2 – NO conversion efficiency of the TEI 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 NOx concentration was 101.5% 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 and CO_2 concentrations did not vary by more than 5% of the mean across each stack diameter. Therefore, each 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.

5.9 FTIR QA/QC Activities

At the beginning of each day a calibration transfer standard (CTS, ethylene gas), analyte of interest (acetaldehyde, sulfur hexafluoride, and sulfur dioxide) 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 sulfur dioxide 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 6 presents test equipment quality assurance data (NO_2 – NO conversion efficiency test data, instrument calibration and system bias check records, calibration gas and gas divider certifications, interference test results, meter box calibration records, 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 Tables 6.1-6.6.

The RICE have the following allowable emission limits specified in ROP No. MI-ROP-N3294-2019, PTI No. 118-20, and/or the federal Standards of Performance for Stationary Spark Ignition Internal Combustion Engines (the SI-RICE NSPS; 40 CFR Part 60 Subpart JJJJ):

Emission Unit ID	CO Limits	NOx Limits	VOC Limits	SO_2 Limits	HCOH Limits
EUENGINE1 & EUENGINE3-EUENGINE6	7.8 lb/hr	4.56 lb/hr	1.7 lb/hr*	1.1 lb/hr	0.76 lb/hr
EUENGINE7	16.3 lb/hr & 5.0 g/bhp-hr	4.94 lb/hr & 3.0 g/bhp-hr	3.2 lb/hr* & 1.0 g/bhp-hr**	1.91 lb/hr	2.1 lb/hr

Note*: This VOC limit includes HCOH.
Note**: This VOC limit does not include HCOH.

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-generator sets were operated within 10% of maximum output and no variations from normal operating conditions occurred during the engine test periods.

Test No. 2 for Engine No. 1 was paused from 12:52-14:42 due to a facility power outage. Once the facility regained power, and Engine No. 1 was powered back up and running at load, Test No. 2 was resumed until at least 60-minutes of raw analyzer air pollutant data was collected. This procedure was discussed with and approved by Mr. Trevor Drost of EGLE-AQD.

Table 6.1 Measured exhaust gas conditions and NOx, CO, VOC, SO_2, and HCOH air pollutant emission rates for Engine No. 1 (EUENGINE1)

Test No. Test date Test period (24-hr clock)	1 5/11/2022 1043-1143	2 5/11/2022 1201-1452*	3 5/11/2022 1641-1741	Three Test Average
LFG flowrate (scfm)	300	300	300	300
Generator output (kW)	740	738	739	739
LFG methane content (%)	54.8	56.6	57.5	56.3
Fuel inlet pressure (psi)	3	3	3	3
Exhaust Gas Composition				
CO_2 content (% vol)	11.4	11.4	11.1	11.3
O_2 content (% vol)	8.19	8.30	8.64	8.38
Moisture (% vol)	13.7	13.9	13.1	13.6
Exhaust gas temperature (°F)	817	807	798	807
Exhaust gas flowrate (dscfm)	1,987	2,068	2,269	2,108
Exhaust gas flowrate (scfm)	2,308	2,403	2,612	2,439
Nitrogen Oxides				
NO_X conc. (ppmvd)	84.3	88.9	40.2	71.1
NO_X emissions (lb/hr)	1.20	1.32	0.65	1.06
Permit limit (lb/hr)	-	-	-	*4.56*
Carbon Monoxide				
CO conc. (ppmvd)	509	535	451	499
CO emissions (lb/hr)	4.42	4.83	4.47	4.57
Permit limit (lb/hr)	-	-	-	*7.8*
Volatile Organic Compounds				
VOC conc. (ppmv C_3)	23.9	25.0	23.9	24.3
VOC emissions (lb/hr)	0.38	0.41	0.43	0.41
VOC+HCOH emissions (lb/hr)	0.95	1.03	1.04	1.01
Permit limit (lb/hr)	-	-	-	*1.7*
Formaldehyde				
HCOH conc. (ppmvd)	53.0	54.9	49.9	52.6
HCOH emissions (lb/hr)	0.57	0.62	0.61	0.60
Permit limit (lb/hr)	-	-	-	*0.76*
Sulfur Dioxide				
SO_2 conc. (ppmvd)	10.7	13.0	10.0	11.2
SO_2 emissions (lb/hr)	0.25	0.31	0.26	0.27
Permit limit (lb/hr)	-	-	-	*1.1*

Note: Test No. 2 was paused from 12:52-14:42 due to a facility power outage.

Table 6.2 Measured exhaust gas conditions and NOx, CO, VOC, SO_2, and HCOH air pollutant emission rates for Engine No. 3 (EUENGINE3)

Test No. Test date Test period (24-hr clock)	1 5/10/2022 1625-1725	2 5/11/2022 743-843	3 5/11/2022 858-958	Three Test Average
LFG flowrate (scfm)	300	300	300	300
Generator output (kW)	739	737	736	737
LFG methane content (%)	50.1	55.0	54.9	53.3
Fuel inlet pressure (psi)	3	3	3	3
Exhaust Gas Composition				
CO_2 content (% vol)	11.3	11.2	11.3	11.3
O_2 content (% vol)	8.40	8.52	8.38	8.43
Moisture (% vol)	13.1	13.3	13.5	13.3
Exhaust gas temperature (°F)	840	823	840	834
Exhaust gas flowrate (dscfm)	1,999	2,057	2,175	2,077
Exhaust gas flowrate (scfm)	2,300	2,372	2,513	2,395
Nitrogen Oxides				
NO_X conc. (ppmvd)	70.6	59.9	71.2	67.3
NO_X emissions (lb/hr)	1.01	0.88	1.11	1.00
Permit limit (lb/hr)	-	-	-	*4.56*
Carbon Monoxide				
CO conc. (ppmvd)	516	521	524	520
CO emissions (lb/hr)	4.50	4.68	4.97	4.72
Permit limit (lb/hr)	-	-	-	*7.8*
Volatile Organic Compounds				
VOC conc. (ppmv C_3)	23.7	23.8	23.2	23.6
VOC emissions (lb/hr)	0.37	0.39	0.40	0.39
VOC+HCOH emissions (lb/hr)	1.05	1.08	1.15	1.09
Permit limit (lb/hr)	-	-	-	*1.7*
Formaldehyde				
HCOH conc. (ppmvd)	62.7	62.5	63.4	62.9
HCOH emissions (lb/hr)	0.68	0.69	0.75	0.70
Permit limit (lb/hr)	-	-	-	*0.76*
Sulfur Dioxide				
SO_2 conc. (ppmvd)	10.3	9.81	10.6	10.2
SO_2 emissions (lb/hr)	0.24	0.23	0.26	0.24
Permit limit (lb/hr)	-	-	-	*1.1*

Table 6.3 Measured exhaust gas conditions and NOx, CO, VOC, SO_2, and HCOH air pollutant emission rates for Engine No. 4 (EUENGINE4)

Test No. Test date Test period (24-hr clock)	1 5/12/2022 735-835	2 5/12/2022 850-950	3 5/12/2022 1004-1104	Three Test Average
LFG flowrate (scfm)	300	300	300	300
Generator output (kW)	739	737	739	738
LFG methane content (%)	54.7	54.0	53.2	54.0
Fuel inlet pressure (psi)	3	3	3	3
Exhaust Gas Composition				
CO_2 content (% vol)	10.9	10.8	10.8	10.8
O_2 content (% vol)	8.87	8.97	8.98	8.94
Moisture (% vol)	11.9	12.0	12.0	12.0
Exhaust gas temperature (°F)	819	825	827	824
Exhaust gas flowrate (dscfm)	2,072	2,141	2,133	2,115
Exhaust gas flowrate (scfm)	2,352	2,433	2,424	2,403
Nitrogen Oxides				
NO_X conc. (ppmvd)	24.2	21.7	21.9	22.6
NO_X emissions (lb/hr)	0.36	0.33	0.34	0.34
Permit limit (lb/hr)	-	-	-	*4.56*
Carbon Monoxide				
CO conc. (ppmvd)	552	572	570	565
CO emissions (lb/hr)	4.99	5.35	5.31	5.22
Permit limit (lb/hr)	-	-	-	*7.8*
Volatile Organic Compounds				
VOC conc. (ppmv C_3)	40.3	42.7	42.9	42.0
VOC emissions (lb/hr)	0.65	0.71	0.71	0.69
VOC+HCOH emissions (lb/hr)	1.32	1.44	1.43	1.40
Permit limit (lb/hr)	-	-	-	*1.7*
Formaldehyde				
HCOH conc. (ppmvd)	61.0	63.4	63.3	62.6
HCOH emissions (lb/hr)	0.67	0.72	0.72	0.70
Permit limit (lb/hr)	-	-	-	*0.76*
Sulfur Dioxide				
SO_2 conc. (ppmvd)	4.38	4.77	4.68	4.61
SO_2 emissions (lb/hr)	0.10	0.12	0.11	0.11
Permit limit (lb/hr)	-	-	-	*1.1*

Table 6.4 Measured exhaust gas conditions and NOx, CO, VOC, SO_2, and HCOH air pollutant emission rates for Engine No. 5 (EUENGINE5)

Test No. Test date Test period (24-hr clock)	1 5/10/2022 750-850	2 5/10/2022 907-1007	3 5/10/2022 1040-1140	Three Test Average
LFG flowrate (scfm)	300	300	300	300
Generator output (kW)	768	768	766	767
LFG methane content (%)	51.0	50.5	50.3	50.6
Fuel inlet pressure (psi)	3	3	3	3
Exhaust Gas Composition				
CO_2 content (% vol)	12.6	12.2	12.6	12.5
O_2 content (% vol)	6.86	7.31	6.75	6.97
Moisture (% vol)	13.6	13.7	14.0	13.8
Exhaust gas temperature (°F)	814	810	814	813
Exhaust gas flowrate (dscfm)	2,108	2,136	2,062	2,102
Exhaust gas flowrate (scfm)	2,439	2,475	2,398	2,437
Nitrogen Oxides				
NO_X conc. (ppmvd)	188	164	220	191
NO_X emissions (lb/hr)	2.85	2.51	3.26	2.87
Permit limit (lb/hr)	-	-	-	*4.56*
Carbon Monoxide				
CO conc. (ppmvd)	443	522	436	467
CO emissions (lb/hr)	4.07	4.87	3.93	4.29
Permit limit (lb/hr)	-	-	-	*7.8*
Volatile Organic Compounds				
VOC conc. (ppmv C_3)	15.3	15.4	15.0	15.2
VOC emissions (lb/hr)	0.26	0.26	0.25	0.26
VOC+HCOH emissions (lb/hr)	0.80	0.82	0.79	0.80
Permit limit (lb/hr)	-	-	-	*1.7*
Formaldehyde				
HCOH conc. (ppmvd)	47.9	47.9	48.3	48.0
HCOH emissions (lb/hr)	0.55	0.55	0.54	0.55
Permit limit (lb/hr)	-	-	-	*0.76*
Sulfur Dioxide				
SO_2 conc. (ppmvd)	13.5	13.2	13.6	13.4
SO_2 emissions (lb/hr)	0.33	0.32	0.33	0.33
Permit limit (lb/hr)	-	-	-	*1.1*

Table 6.5 Measured exhaust gas conditions and NOx, CO, VOC, SO_2, and HCOH air pollutant emission rates for Engine No. 6 (EUENGINE6)

Test No. Test date Test period (24-hr clock)	1 5/10/2022 1218-1318	2 5/10/2022 1334-1434	3 5/10/2022 1450-1550	Three Test Average
LFG flowrate (scfm)	300	300	300	300
Generator output (kW)	734	747	738	740
LFG methane content (%)	49.2	49.9	50.0	49.7
Fuel inlet pressure (psi)	3	3	3	3
Exhaust Gas Composition				
CO_2 content (% vol)	11.3	11.2	10.9	11.1
O_2 content (% vol)	8.40	8.55	8.94	8.63
Moisture (% vol)	12.7	12.8	12.5	12.7
Exhaust gas temperature (°F)	847	850	851	849
Exhaust gas flowrate (dscfm)	2,085	2,086	2,079	2,083
Exhaust gas flowrate (scfm)	2,389	2,394	2,378	2,387
Nitrogen Oxides				
NO_X conc. (ppmvd)	102	97.3	48.1	82.5
NO_X emissions (lb/hr)	1.53	1.45	0.72	1.23
Permit limit (lb/hr)	-	-	-	*4.56*
Carbon Monoxide				
CO conc. (ppmvd)	557	565	563	562
CO emissions (lb/hr)	5.07	5.14	5.11	5.11
Permit limit (lb/hr)	-	-	-	*7.8*
Volatile Organic Compounds				
VOC conc. (ppmv C_3)	24.4	24.9	28.8	26.0
VOC emissions (lb/hr)	0.40	0.41	0.47	0.43
VOC+HCOH emissions (lb/hr)	1.16	1.15	1.16	1.16
Permit limit (lb/hr)	-	-	-	*1.7*
Formaldehyde				
HCOH conc. (ppmvd)	67.4	66.3	62.1	65.3
HCOH emissions (lb/hr)	0.75	0.74	0.69	0.73
Permit limit (lb/hr)	-	-	-	*0.76*
Sulfur Dioxide				
SO_2 conc. (ppmvd)	6.63	7.13	6.10	6.62
SO_2 emissions (lb/hr)	0.16	0.17	0.14	0.16
Permit limit (lb/hr)	-	-	-	*1.1*

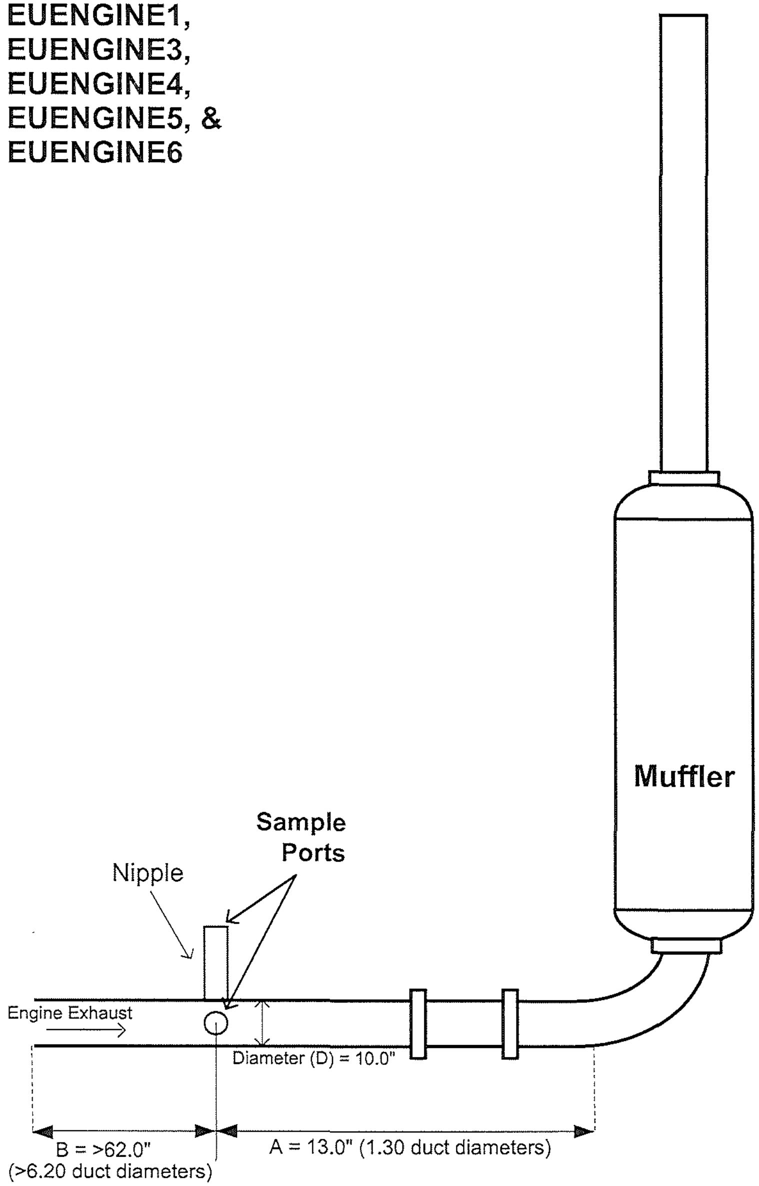
Table 6.6 Measured exhaust gas conditions and NOx, CO, VOC, SO_2, and HCOH air pollutant emission rates for Engine No. 7 (EUENGINE7)

Test No. Test date Test period (24-hr clock)	1 5/12/2022 1318-1418	2 5/12/2022 1439-1539	3 5/12/2022 1555-1655	Three Test Average
LFG flowrate (lb/hr)	2,219	2,216	2,211	2,215
Engine output (bhp)	2,178	2,176	2,179	2,178
Generator output (kW)	1,561	1,560	1,562	1,561
LFG methane content (%)	48.7	48.7	49.0	48.8
Fuel inlet pressure (psi)	3	3	3	3
<u>Exhaust Gas Composition</u>				
CO_2 content (% vol)	11.0	11.0	10.9	11.0
O_2 content (% vol)	8.74	8.80	8.81	8.78
Moisture (% vol)	12.2	12.1	12.1	12.1
Exhaust gas temperature (°F)	861	867	872	867
Exhaust gas flowrate (dscfm)	4,171	3,886	3,914	3,990
Exhaust gas flowrate (scfm)	4,751	4,422	4,452	4,542
<u>Nitrogen Oxides</u>				
NO_X conc. (ppmvd)	122	118	118	119
NO_X emissions (lb/hr)	3.65	3.29	3.31	3.42
Permit limit (lb/hr)	-	-	-	*4.94*
NO_X emissions (g/bhp*hr)	0.76	0.68	0.69	0.71
*Permit limit (g/bhp*hr)*	-	-	-	*3.0*
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	702	682	683	689
CO emissions (lb/hr)	12.8	11.6	11.7	12.0
Permit limit (lb/hr)	-	-	-	*16.3*
CO emissions (g/bhp*hr)	2.66	2.41	2.43	2.50
*Permit limit (g/bhp*hr)*	-	-	-	*5.0*
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv C_3)	16.7	17.0	17.0	16.9
VOC emissions (lb/hr)	0.54	0.52	0.52	0.53
VOC+HCOH emissions (lb/hr)	2.18	2.04	2.05	2.09
Permit limit (lb/hr)	-	-	-	*3.2*
VOC emissions (g/bhp*hr)	0.11	0.11	0.11	0.11
*Permit limit (g/bhp*hr)*	-	-	-	*1.0*
<u>Formaldehyde</u>				
HCOH conc. (ppmvd)	73.7	73.6	73.4	73.6
HCOH emissions (lb/hr)	1.64	1.52	1.53	1.56
Permit limit (lb/hr)	-	-	-	*2.1*
<u>Sulfur Dioxide</u>				
SO_2 conc. (ppmvd)	8.80	9.00	8.89	8.89
SO_2 emissions (lb/hr)	0.42	0.40	0.39	0.40
Permit limit (lb/hr)	-	-	-	*1.91*

APPENDIX 1

- RICE Engine Sample Port Diagrams

**EUENGINE1,
EUENGINE3,
EUENGINE4,
EUENGINE5, &
EUENGINE6**



EDL Coopersville Renewable Energy Power Station Exhaust Sample Location, CAT® RICE		
Scale None	Sheet 1 of 1	IMPACT COMPLIANCE & TESTING