Derenzo Environmental Services
Consulting and Testing

AIR EMISSION TEST REPORT

Title	AIR EMISSION TEST REPORT FOR THE VERIFICATION OF AIR POLLUTANT EMISSIONS FROM LANDFILL GAS FUELED INTERNAL COMBUSTION ENGINES
Report Date	March 27, 2018
Test Dates	March 6 & 7, 2018

Facility Information	
Name	Granger Electric at the Lansing Wood Street Landfill
Street Address	16980 Wood Rd
City, County	Lansing, Ingham

Facility Permit Information			
ROP No.:	MI-ROP-N5997-2013	Facility SRN :	N5997

Testing Contractor	
Company	Derenzo Environmental Services
Mailing Address	39395 Schoolcraft Road Livonia, MI 48150
Phone	(734) 464-3880
Project No.	1710016

Executive Summary

GRANGER ELECTRIC AT THE LANSING WOOD STREET LANDFILL
CAT® G3520C LANDFILL GAS FUELED IC ENGINE EMISSIONS RESULTS

Granger Electric contracted Derenzo Environmental Services, to conduct a performance demonstration for the determination of nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOC) and formaldehyde (CH_2O) concentrations and emission rates from three (3) Caterpillar (CAT®) Model No. G3520C (Engine Nos. 5, 6 and 7) and CH_2O concentration and emission rate from one (1) CAT® Model G3516 (Engine No. 3) landfill gas-fired reciprocating internal combustion engines and electricity generator sets operated at the Lansing Wood Street Landfill in Lansing, Michigan.

Michigan Department of Environmental Quality (MDEQ) Air Quality Division (AQD) Renewable Operating Permit No. MI-ROP-N5997-2013 requires that performance 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 internal combustion engines). CH_2O testing of one (1) CAT® G3520C and one (1) CAT® G3516 engine is required once during the term of the ROP. The performance testing was conducted on March 6 – 7, 2018. The following tables presents the emissions results and operating data from the performance demonstration.

Emission Unit	CO Emission Rates		NOx Emission Rates		VOC Emission Rates	CH_2O Emission Rates
	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(g/bhp-hr)	(lb/hr)
Engine No. 3	-	-	-	-	-	0.53^A
Engine No. 5	11.17	2.26	2.71	0.55	0.09	1.60^B
Engine No. 6	13.08	2.63	2.92	0.59	0.10	-
Engine No. 7	12.10	2.43	2.51	0.50	0.13	-
Permit Limit	16.23	3.30	4.92	1.0	1.0	0.75^A / 2.10^B

lb/hr = pounds per hour, g/bhp-hr = grams per brake horse power-hour

Emission Unit	Generator Output (kW)	Engine Output (bhp)	LFG Fuel Use (scfm)	LFG CH_4 Content (%)	Exhaust Temp. (°F)	In. Fuel Press. (psi)	Air to Fuel Ratio
Engine No. 3	807	-	1,144*	55.3	675	-	-
Engine No. 5	1,608	2,244	512	55.8	837	3	8.2
Engine No. 6	1,616	2,256	517	55.5	849	3	8.4
Engine No. 7	1,615	2,254	516	55.0	809	3	8.7

scfm=standard cubic feet per minute, kW=kilowatt, bHp-hr=brake horse power hour, psi=pounds per square inch
* - total plant fuel use

The data above indicate that Engines 3, 5, 6 and 7 were tested while the units operated within 10% of its maximum capacity (800 kW or 1,600 kW) and are in compliance with the emission standards specified in 40 CFR 60.4233(e) and MDEQ-AQD ROP No. MI-ROP-N5997-2013.

AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM
LANDFILL GAS FUELED INTERNAL COMBUSTION ENGINES

GRANGER ELECTRIC AT THE LANSING WOOD STREET LANDFILL

1.0 INTRODUCTION

Granger Electric Company (Granger) (Facility SRN: N5997) owns and operates four (4) Caterpillar (CAT®) Model No. G3516 landfill gas (LFG) fueled reciprocating internal combustion engines (RICE) and three (3) CAT® Model No. G3520C LFG fueled RICE at the Granger Wood St. Landfill in Lansing, Clinton County, Michigan. The CAT® Model No. G3516 engines are identified as Emission Unit ID: EUICE1-S1 – EUICE4-S1 (FGICE-S1) and the CAT® Model No. G3520C engines are identified as Emission Unit ID: EUICEENGINE1-S1 – EUICEENGINE3-S1 (FGICEENGINES-S1) in Renewable Operating Permit (ROP) No. MI-ROP-N5997-2013. EUICE1-S1 through EUICE4-S1 are also referred to as Engine Nos. 1 through 4, respectively and EUICEENGINE1-S1 through EUICEENGINE3-S1 are also referred to as Engine Nos. 5 through 7, respectively, in this report and by facility representatives.

Air emission compliance testing was performed to satisfy the following requirements contained in ROP No. MI-ROP-N5997-2013:

- Test air pollutant emissions for FGICEENGINES-S1 in accordance with 40 CFR Part 60 Subpart JJJJ; and
- Test one (1) engine from FGICE-S1 and one (1) engine from FGICEENGINES-S1 for emissions of formaldehyde.

The compliance testing was performed by Derenzo Environmental Services, a Michigan-based environmental consulting and testing company. Derenzo Environmental Services representatives Tyler Wilson, Robert Harvey and Andrew Rusnak performed the field sampling and measurements March 6 – 7, 2018.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan dated January 19, 2018 that was reviewed and approved by the Michigan Department of Environmental Quality (MDEQ). MDEQ representatives Mr. David Patterson and Ms. Michelle Luplow observed portions of the testing project.

Questions regarding this emission test report should be directed to:

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Report Certification

This test report was prepared by Derenzo Environmental Services based on field sampling data collected by Derenzo Environmental Services. Facility process data were collected and provided by Granger employees or representatives. This test report has been reviewed by Granger representatives and approved for submittal to the MDEQ.

I certify that the testing was conducted in accordance with the specified test methods and submitted test plan unless otherwise specified in this report. I believe the information provided in this report and its attachments are true, accurate, and complete.

Report Prepared By:

Andy Rusnak, QSTI
Technical Manager
Derenzo Environmental Services

I certify that the facility and emission units were operated at maximum routine operating conditions for the test event. Based on information and belief formed after reasonable inquiry, the statements and information in this report are true, accurate and complete.

Responsible Official Certification:

Todd Davlin
Director of Operations
Energy Developments, Ltd.

2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

Landfill gas (LFG) containing methane is generated in the Granger Wood Street Landfill from the anaerobic decomposition of disposed waste materials. The LFG is collected from both active and capped landfill cells using a system of wells (gas collection system). The collected LFG is transferred to the Granger LFG power station facility where it is treated and used as fuel for the seven (7) RICE. Each RICE is connected to an electricity generator that produces electricity that is transferred to the local utility.

2.2 Rated Capacities and Air Emission Controls

The CAT® Model No. G3516 RICE has a rated output of 1,148 brake-horsepower (bhp) and the connected generator has a rated electricity output of 800 kilowatts (kW). The engine is designed to fire low-pressure, lean fuel mixtures (e.g., LFG).

The CAT® Model No. G3520C RICE has a rated output of 2,233 brake-horsepower (bhp) and the connected generator has a rated electricity output of 1,600 kilowatts (kW). The engine is designed to fire low-pressure, lean fuel mixtures (e.g., LFG) and is equipped with an air-to-fuel ratio controller that monitors engine performance parameters and automatically adjusts the air-to-fuel ratio and ignition timing to maintain efficient fuel combustion.

The engine/generator sets are not equipped with add-on emission control devices. Air pollutant emissions are minimized through the proper operation of the gas treatment system and efficient fuel combustion in the engines.

The fuel consumption rate is regulated automatically to maintain the heat input rate required to support engine operations and is dependent on the fuel heat value (methane content) of the treated LFG.

2.3 Sampling Locations

The RICE exhaust gas is directed through mufflers and is released to the atmosphere through dedicated vertical exhaust stacks with vertical release points. The four (4) CAT® Model G3516 exhaust stacks are identical. The three (3) CAT® Model G3520C RICE exhaust stacks are identical.

The exhaust stack sampling ports for the CAT® Model G3516 engines (Engine Nos. 1 – 4) are located in individual exhaust stacks with an inner diameter of 12.0 inches. Each stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location greater than 120 inches (>10 duct diameters) upstream and 120.0 inches (10 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® Model G3520C engines (Engine Nos. 5, 6 and 7) are located in individual exhaust stacks with an inner diameter of 13.5 inches. Each stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location greater than 120 inches (>9 duct diameters) upstream and greater than 120.0 inches (>9 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.

3.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

3.1 Purpose and Objective of the Tests

The conditions of MI-ROP-N5997-2013 and 40 CFR Part 60 Subpart JJJJ require Granger to test each engine contained in FGICEENGINES-S1 for carbon monoxide (CO), nitrogen oxides (NOx) and volatile organic compounds (VOCs) every 8,760 hours of operation. Therefore, each engine contained in FGICEENGINES-S1 was sampled for CO, NO_X and VOC emissions and exhaust gas oxygen (O_2) and carbon dioxide (CO_2) content.

Conditions of MI-ROP-N5997-2013 require Granger to test one (1) engine contained in FGICE-S1 and one (1) engine in FGICEENGINES-S1 for formaldehyde (CH_2O) once during the term of the ROP.

3.2 Operating Conditions During the Compliance Tests

The testing was performed while the Granger engine/generator sets were operated at maximum operating conditions (800 kW or 1,600 kW electricity output +/- 10%). Granger representatives provided the kW output in 15-minute increments for each test period. The EU-ICE3-S1 generator kW output ranged between 795 and 830 kW for each test period. The FGICEENGINES-S1 generator kW output ranged between 1,594 and 1,635 kW for each test period.

For the testing performed on FGICEENGINES-S1 fuel flowrate (pounds per hour), fuel methane content (%), fuel inlet pressure (psi) and the air to fuel ratio were recorded by Granger representatives in 15-minute increments for each test period. The FGICEENGINES-S1 fuel consumption rate ranged between 2,150 and 2,200 pph, fuel methane content ranged between 54.9 and 56.0%, fuel inlet pressure was 3.0 psi and the air to fuel ratio ranged from 8.1 to 8.7 during the test periods.

For the testing performed on EU-ICE3-S1 total plant fuel flowrate (scfm) and fuel methane content (%) were recorded by Granger representatives in 15-minute increments for each test period. The total plant fuel consumption rate ranged between 1,125 and 1,166 scfm and the fuel methane content ranged between 55.0 and 55.6% during the test periods.

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

Engine output (bhp) cannot be measured directly and was calculated based on the recorded electricity output, the calculated CAT® Model G3520C generator efficiency (96.1%), and the unit conversion factor for kW to horsepower (0.7457 kW/hp).

Engine output (bhp) = Electricity output (kW) / (0.961) / (0.7457 kW/hp)

The facility records fuel use rate in units of pounds per hour. To convert to units of standard cubic feet of gas consumed per minute (scfm) the following equation was used:

Fuel Use (scfm) = Fuel Use (pph) / LFG MW (lb/lb-mol) * 385 scf LFG/lb-mol / 60 min/hr

A lower heating value of 909 Btu/ft^3 was used to calculate the LFG heating value.

Table 3.1 presents a summary of the average engine operating conditions during the test periods.

3.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the sampled LFG fueled RICE (Engine Nos. 3, 5, 6 and 7) were each sampled for three (3) one-hour test periods during the compliance testing performed March 6 through March 7, 2018.

Table 3.2 presents the average measured CO, NO_X, VOC and CH_2O emission rates for the engines (average of the three test periods for each engine).

Test results for each one hour sampling period and comparison to the permitted emission rates is presented in Section 6.0 of this report.

Table 3.1 Average engine operating conditions during the test periods

Engine Parameter	Engine No. 3	Engine No. 5	Engine No. 6	Engine No. 7
Generator output (kW)	807	1,608	1,616	1,615
Engine output (bhp)	-	2,244	2,256	2,254
Engine LFG fuel use (pph)	-	2,169	2,190	2,189
Engine LFG fuel use (scfm)	-	512	517	516
Plant LFG fuel use (scfm)	1,144	-	-	-
LFG methane content (%)	55.3	55.8	55.5	55.0
LFG lower heating value (Btu/ft^3)	503	507	505	500
Exhaust temperature (°F)	675	837	849	809
Inlet fuel pressure (psi)	-	3	3	3
Air to fuel ratio	-	8.2	8.4	8.7

Table 3.2 Average measured emission rates for each engine (three-test average)

Emission Unit	CO Emission Rates		NOx Emission Rates		VOC Emission Rates	CH_2O Emission Rates
	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(g/bhp-hr)	(lb/hr)
Engine No. 3	-	-	-	-	-	0.53^A
Engine No. 5	11.17	2.26	2.71	0.55	0.09	1.60^B
Engine No. 6	13.08	2.63	2.92	0.59	0.10	-
Engine No. 7	12.10	2.43	2.51	0.50	0.13	-
Permit Limit	16.23	3.30	4.92	1.0	1.0	0.75^A / 2.10^B

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A test protocol for the air emission testing was reviewed and approved by the MDEQ. This section provides a summary of the sampling and analytical procedures that were used during the Granger 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 analyzer.
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
ASTM D6348	Exhaust gas formaldehyde concentration via Fourier transform infrared spectroscopy (FTIR)

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 prior to and after each test. 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 prior to each traverse to verify the integrity of the measurement system.

The absence of significant cyclonic flow for the exhaust configuration 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 the RICE exhaust gas stream was measured continuously throughout each test period in accordance with USEPA Method 3A. The CO_2 content of the exhaust was monitored using a Servomex 1440D single beam single wavelength (SBSW) 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 IC engine 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 Exhaust Gas Moisture Content (USEPA Method 4)

Moisture content of the RICE exhaust gas (Engine Nos. 6 and 7) was determined in accordance with USEPA Method 4 using a chilled impinger sampling train. The moisture sampling was performed concurrently with the instrumental analyzer sampling. During each sampling period a gas sample was extracted at a constant rate from the source where moisture was removed from the sampled gas stream using impingers that were submersed in an ice bath. 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.

Moisture content of the RICE exhaust gas (Engine Nos. 3 and 5) was determined as part of the formaldehyde concentration determination (i.e., using the FTIR instrumental analyzer). Discussion of the FTIR testing procedures is contained in Section 4.7 of this document.

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 42c High Level chemiluminescence NO_X analyzer and a TEI Model 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 Volatile Organic Compounds (USEPA Method 25A/ALT-096)

The VOC emission rate was determined by measuring the nonmethane hydrocarbon (NMHC) 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 reciprocating internal combustion engines (RICE) in that it uses USEPA Method 25A and 18 (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.

4.7 Determination of Formaldehyde Emissions (ASTM D6348)

Formaldehyde concentration in the RICE exhaust gas streams was determined using a MKS Multi-Gas 2030 Fourier transform infrared (FTIR) spectrometer.

Samples of the exhaust gas were delivered directly to the instrumental analyzer using a Teflon® heated sample line, heated head pump and heated filter to prevent condensation. The sample to the FTIR analyzer was not conditioned to remove moisture. Therefore, formaldehyde 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 and sulfur hexafluoride was performed to verify the ability of the sampling system to quantitatively deliver a sample containing the compound of interest from the base of the probe to the FTIR. Data was collected at 0.5 cm^{-1} resolution. Instrument response was recorded using MKS data acquisition software.

Appendix 4 provides formaldehyde calculation sheets. Instrument response data for the FTIR is provided in Appendix 6.

5.0 QA/QC ACTIVITIES

5.1 NO_x Converter Efficiency Test

The NO_2 – NO conversion efficiency of the Model 42c 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 analyzer is deemed acceptable if the measured NO_2 concentration is within 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_2 concentration was 97.6% of the expected value, i.e., within 10% of the expected value as required by Method 7E).

5.2 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.

5.3 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 (July 26, 2006, June 12, 2014 and April 19, 2016), 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.

5.4 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.

5.5 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 each 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 each RICE exhaust stack indicated that the measured NO_x, CO, O_2 and CO_2 concentrations did not vary by more than 5% of the mean across each 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 the RICE exhaust stack.

5.6 FTIR QA/QC Activities

At the beginning of each day a calibration transfer standard (CTS, ethylene gas), analyte of interest (acetaldehyde) and nitrogen calibration gas were 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 is free of contaminants.

Analyte spiking, of each emission unit, prior to and after sampling, with acetaldehyde 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 assured the ability of the FTIR to quantify that compound in the presence of effluent gas. The spike target dilution ratio was 1:10 (1 part cal gas; 9 parts stack 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 then compared with the measured concentrations to ensure the quality of the data.

5.7 Meter Box Calibrations

The Nutech Model 2010 sampling console, which was used for exhaust gas moisture content sampling, 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 Nutech metering consoles were calibrated using a NIST traceable Omega® Model CL 23A temperature calibrator.

Appendix 7 presents test equipment quality assurance data (NO_2 – NO conversion efficiency test data, instrument calibration and system bias check records, calibration gas and gas divider certifications, interference test results, meter box calibration records, Pitot tube calibration records, stratification checks and FTIR QA/QC data).

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 6.4.

The measured air pollutant concentrations and emission rates for Engine No. 3 are less than the allowable limits specified in Permit to Install No. MI-ROP-N5997-2013 for Emission Unit No. EU-ICE3-S1:

- 0.75 lb/hr for CH_2O.

The measured air pollutant concentrations and emission rates for Engine Nos. 5 – 7 are less than the allowable limits specified in Permit to Install No. MI-ROP-N5997-2013 for Emission Unit Nos. EUICEENGINE1-S1 through EUICEENGINE3-S1:

- 4.92 lb/hr and 1.0 g/bhp-hr for NO_X;
- 16.23 lb/hr and 3.3 g/bhp-hr for CO;
- 1.0 g/bhp-hr for VOC; and
- 2.10 lb/hr for CH_2O.

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 test protocol. The engine-generator sets were operated within 10% of maximum output (800 kW or 1,600 kW generator output) and no variations from normal operating conditions occurred during the engine test periods.

Test Period No. 2 performed on Engine No. 3 was discarded. Midway through the 60-minute test period the FTIR exhaust line was plugged with ice that had formed during the run. This prevented the system from continuously and actively sampling the exhaust gas and pressurized the sampling system (i.e., biased the results high by forcing additional pollutants into the measurement chamber). The ice was removed from the exhaust line and a fourth sampling period was performed on the engine. Raw data from the discarded second run is provided in Appendix 6.

Table 6.1 Measured exhaust gas conditions and CH_2O air pollutant emission rates for Engine No. 3 (EUICE3-S1)

Test No. Test date Test period (24-hr clock)	1 3/7/18 1232-1332	3 3/7/18 1500-1600	4 3/7/18 1619-1719	Three Test Average
Plant Fuel flowrate (scfm)	1,144	1,148	1,138	1,144
Generator output (kW)	813	802	805	807
LFG methane content (%)	55.2	55.4	55.3	55.3
LFG heat content (Btu/scf)	502	504	503	503
Exhaust Gas Composition				
CO_2 content (% vol)	13.4	13.5	13.5	13.5
O_2 content (% vol)	5.92	5.88	5.83	5.88
Moisture (% vol)	14.1	13.4	13.4	13.6
Exhaust gas temperature (°F)	667	679	680	675
Exhaust gas flowrate (scfm)	2,299	2,214	2,236	2,250
Formaldehyde				
CH_2O conc. (ppmd)	52.9	49.0	50.2	50.7
CH_2O emissions (lb/hr)	0.57	0.51	0.53	0.53
Permitted emissions (lb/hr)	-	-	-	0.75

Table 6.2 Measured exhaust gas conditions and NO_x, CO, VOC and CH_2O air pollutant emission rates for Engine No. 5 (EUICEENGINE1-S1)

Test No. Test date Test period (24-hr clock)	1 3/6/18 0759-0859	2 3/6/18 0929-1029	3 3/6/18 1051-1151	Three Test Average
Fuel flowrate (scfm)	510	513	513	512
Generator output (kW)	1,604	1,605	1,615	1,608
Engine output (bhp)	2,238	2,239	2,254	2,244
LFG methane content (%)	55.8	55.8	55.8	55.8
LFG heat content (Btu/scf)	507	507	507	507
Fuel inlet pressure (psi)	3	3	3	3
Air to fuel ratio	8.2	8.2	8.2	8.2
Exhaust Gas Composition				
CO_2 content (% vol)	10.3	10.8	10.5	10.6
O_2 content (% vol)	9.52	9.20	9.47	9.40
Moisture (% vol)	11.5	11.6	11.9	11.7
Exhaust gas temperature (°F)	835	842	833	837
Exhaust gas flowrate (dscfm)	4,389	4,413	4,418	4,407
Exhaust gas flowrate (scfm)	4,959	4,992	5,015	4,989
Nitrogen Oxides				
NO_X conc. (ppmvd)	83.4	88.0	85.8	85.7
NO_X emissions (lb/hr)	2.63	2.78	2.72	2.71
Permitted emissions (lb/hr)	-	-	-	4.92
NO_X emissions (g/bhp*hr)	0.53	0.56	0.55	0.55
Permitted emissions (g/bhp*hr)	-	-	-	1.0
Carbon Monoxide				
CO conc. (ppmvd)	564	599	579	581
CO emissions (lb/hr)	10.81	11.53	11.16	11.17
Permitted emissions (lb/hr)	-	-	-	16.23
CO emissions (g/bhp*hr)	2.19	2.34	2.25	2.26
Permitted emissions (g/bhp*hr)	-	-	-	3.30
Volatile Organic Compounds				
VOC conc. (ppmv)	13.5	14.0	13.5	13.7
VOC emissions (g/bhp*hr)	0.09	0.10	0.09	0.09
Permitted emissions (g/bhp*hr)	-	-	-	1.0

Table 6.2 Measured exhaust gas conditions and NO_x, CO, VOC and CH_2O air pollutant emission rates for Engine No. 5 (EUICEENGINE1-S1) (Continued)

Test No. Test date Test period (24-hr clock)	1 3/6/18 0759-0859	2 3/6/18 0929-1029	3 3/6/18 1051-1151	Three Test Average
Formaldehyde				
CH_2O conc. (ppmd)	66.5	69.0	69.8	68.4
CH_2O emissions (lb/hr)	1.54	1.61	1.64	1.60
Permitted emissions (lb/hr)	-	-	-	2.10

Table 6.3 Measured exhaust gas conditions and NO_x, CO and VOC air pollutant emission rates for Engine No. 6 (EUICEENGINE2-S1)

Test No. Test date Test period (24-hr clock)	1 3/6/18 1212-1312	2 3/6/18 1333-1433	3 3/6/18 1451-1551	Three Test Average
Fuel flowrate (scfm)	517	516	517	517
Generator output (kW)	1,619	1,619	1,611	1,616
Engine output (bhp)	2,260	2,259	2,248	2,256
LFG methane content (%)	55.6	55.5	55.4	55.5
LFG heat content (Btu/scf)	505	504	504	504
Fuel inlet pressure (psi)	3	3	3	3
Air to fuel ratio	8.4	8.4	8.4	8.4
Exhaust Gas Composition				
CO_2 content (% vol)	10.9	10.5	11.0	10.8
O_2 content (% vol)	8.94	9.48	8.82	9.08
Moisture (% vol)	12.0	11.9	11.5	11.8
Exhaust gas temperature (°F)	850	841	855	849
Exhaust gas flowrate (dscfm)	4,388	4,426	4,333	4,382
Exhaust gas flowrate (scfm)	4,988	5,024	4,895	4,969
Nitrogen Oxides				
NO_X conc. (ppmvd)	94.5	91.1	92.9	92.8
NO_X emissions (lb/hr)	2.97	2.89	2.89	2.92
Permitted emissions (lb/hr)	-	-	-	4.92
NO_X emissions (g/bhp*hr)	0.60	0.58	0.58	0.59
Permitted emissions (g/bhp*hr)	-	-	-	1.0
Carbon Monoxide				
CO conc. (ppmvd)	693	663	696	684
CO emissions (lb/hr)	13.28	12.81	13.16	13.08
Permitted emissions (lb/hr)	-	-	-	16.23
CO emissions (g/bhp*hr)	2.67	2.57	2.66	2.63
Permitted emissions (g/bhp*hr)	-	-	-	3.30
Volatile Organic Compounds				
VOC conc. (ppmv)	14.4	13.7	14.4	14.2
VOC emissions (g/bhp*hr)	0.10	0.10	0.10	0.10
Permitted emissions (g/bhp*hr)	-	-	-	1.0

Table 6.4 Measured exhaust gas conditions and NO_x, CO and VOC air pollutant emission rates for Engine No. 7 (EUICEENGINE3-S1)

Test No. Test date Test period (24-hr clock)	1 3/7/18 0729-0829	2 3/7/18 0848-0948	3 3/7/18 1009-1109	Three Test Average
Fuel flowrate (scfm)	516	516	517	516
Generator output (kW)	1,616	1,614	1,617	1,615
Engine output (bhp)	2,255	2,252	2,256	2,254
LFG methane content (%)	55.0	55.1	55.1	55.0
LFG heat content (Btu/scf)	500	501	501	500
Fuel inlet pressure (psi)	3	3	3	3
Air to fuel ratio	8.7	8.7	8.7	8.7
<u>Exhaust Gas Composition</u>				
CO_2 content (% vol)	11.1	11.1	11.1	11.1
O_2 content (% vol)	8.82	8.81	8.83	8.82
Moisture (% vol)	11.0	11.5	11.2	11.2
Exhaust gas temperature (°F)	807	811	811	810
Exhaust gas flowrate (dscfm)	4,359	4,283	4,399	4,382
Exhaust gas flowrate (scfm)	4,895	4,840	4,956	4,969
<u>Nitrogen Oxides</u>				
NO_X conc. (ppmvd)	82.2	78.2	78.9	79.8
NO_X emissions (lb/hr)	2.59	2.48	2.45	2.51
Permitted emissions (lb/hr)	-	-	-	4.92
NO_X emissions (g/bhp*hr)	0.52	0.50	0.49	0.50
Permitted emissions (g/bhp*hr)	-	-	-	1.0
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	632	631	634	632
CO emissions (lb/hr)	12.11	12.19	11.99	12.10
Permitted emissions (lb/hr)	-	-	-	16.23
CO emissions (g/bhp*hr)	2.44	2.45	2.41	2.43
Permitted emissions (g/bhp*hr)	-	-	-	3.30
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv)	18.9	19.1	19.0	19.0
VOC emissions (g/bhp*hr)	0.13	0.13	0.13	0.13
Permitted emissions (g/bhp*hr)	-	-	-	1.0