Derenzo Environmental Services
Consulting and Testing

AIR EMISSION TEST REPORT

Title	TEST REPORT FOR THE VERIFICATION OF AIR POLLUTANT EMISSIONS FROM LANDFILL GAS-FUELED RECIPROCATING ENGINES
Report Date	March 30, 2017
Test Dates	February 13-16, 2017

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Facility Information	
Name	Pine Tree Acres, Inc. (Landfill)
Street Address	36600 29-Mile Rd.
City, County	Lenox Township, Macomb
SRN	N5984

Permit Information	
Permit to Install No.:	MI-PTI-N5984-2013a
Operating Permit No.:	MI-ROP-N5984-2013a

Source Information				
Emission Unit	EUICENGINE1	EUICENGINE2	EUICENGINE3	EUICENGINE4
Serial No.	GZJ00469	GZJ00464	GZJ00467	GZJ00466
Emission Unit	EUICENGINE5	EUICENGINE6	EUICENGINE7	EUICENGINE8
Serial No.	GZJ00462	GZJ00468	GZJ00463	GZJ00465

Testing Contractor	
Company	Derenzo Environmental Services
Mailing Address	39395 Schoolcraft Road Livonia, MI 48150
Phone	(734) 464-3880
Project No.	1611008

DEQ

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR QUALITY DIVISION

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RENEWABLE OPERATING PERMIT REPORT CERTIFICATION

Authorized by 1994 P.A. 451, as amended. Failure to provide this information may result in civil and/or criminal penalties.

Reports submitted pursuant to R 336.1213 (Rule 213), subrules (3)(c) and/or (4)(c), of Michigan's Renewable Operating Permit (ROP) program must be certified by a responsible official. Additional information regarding the reports and documentation listed below must be kept on file for at least 5 years, as specified in Rule 213(3)(b)(ii), and be made available to the Department of Environmental Quality, Air Quality Division upon request.

Source Name: Pine Tree Acres, Inc. County: Macomb

Source Address: 36600 29 Mile Rd City: Lenox Twp

AQD Source ID (SRN): N5984 ROP No.: MI-ROP-N5984-2013a ROP Section No.:

Please check the appropriate box(es):

☐ **Annual Compliance Certification (Pursuant to Rule 213(4)(c))**

Reporting period (provide inclusive dates): From ________ To ________

☐ 1. During the entire reporting period, this source was in compliance with **ALL** terms and conditions contained in the ROP, each term and condition of which is identified and included by this reference. The method(s) used to determine compliance is/are the method(s) specified in the ROP.

☐ 2. During the entire reporting period this source was in compliance with all terms and conditions contained in the ROP, each term and condition of which is identified and included by this reference, **EXCEPT** for the deviations identified on the enclosed deviation report(s). The method used to determine compliance for each term and condition is the method specified in the ROP, unless otherwise indicated and described on the enclosed deviation report(s).

☐ **Semi-Annual (or More Frequent) Report Certification (Pursuant to Rule 213(3)(c))**

Reporting period (provide inclusive dates): From ________ To ________

☐ 1. During the entire reporting period, **ALL** monitoring and associated recordkeeping requirements in the ROP were met and no deviations from these requirements or any other terms or conditions occurred.

☐ 2. During the entire reporting period, all monitoring and associated recordkeeping requirements in the ROP were met and no deviations from these requirements or any other terms or conditions occurred, **EXCEPT** for the deviations identified on the enclosed deviation report(s).

☒ **Other Report Certification**

Reporting period (provide inclusive dates): From 2/13/2017 To 2/16/2017

Additional monitoring reports or other applicable documents required by the ROP are attached as described:

Test Report for landfill gas fired IC engines EUICENGINE1-EUICENGINE8 (FGICENGINES). The testing was conducted in accordance with the Test Plan dated December 9, 2016 and MI-ROP-N5984-2013a. The facility was operated in compliance with the permit conditions or at the maximum routine operating conditions for the facility.

I certify that, based on information and belief formed after reasonable inquiry, the statements and information in this report and the supporting enclosures are true, accurate and complete

David R. Rogers	District Manager	586-634-8143
Name of Responsible Official (print or type)	Title	Phone Number

DRR

Signature of Responsible Official

3/30/17

Date

* Photocopy this form as needed.

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AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS FROM
LANDFILL GAS-FUELED RECIPROCATING ENGINES

PINE TREE ACRES LANDFILL

1.0 INTRODUCTION

Pine Tree Acres, Inc. (PTA) operates eight (8) Caterpillar (CAT®) Model No. G3520C landfill gas (LFG) fueled reciprocating internal combustion engine (RICE) generator sets, two (2) enclosed flares and two open flares at the Pine Tree Acres Landfill (PTAL, Facility SRN: N5984) in Lenox Township, Macomb County, Michigan. The facility has been issued Renewable Operating Permit (ROP) No. MI-ROP-N5984-2013a and Permit to Install (PTI) No. MI-PTI-N5984-2013a by the Michigan Department of Environmental Quality (MDEQ).

Air emission testing was performed to demonstrate compliance with conditions of ROP No. MI-ROP-N5984-2013a, PTI No. MI-PTI-N5984-2013a, and 40 CFR Part 60 Subpart JJJJ.

All eight (8) of the RICE generator sets, identified as emission units EUICENGINE1 through EUICENGINE8 and flexible group FGICENGINES, were tested for carbon monoxide (CO), nitrogen oxide (NO_x), and volatile organic compound (VOC) emissions.

The compliance testing was performed by Derenzo Environmental Services (DES), a Michigan-based environmental consulting and testing company. DES representatives Tyler Wilson and Blake Beddow performed the field sampling and measurements February 13 through 16, 2017. The engine performance tests were completed within 8,760 engine operating hours of the previous performance tests completed February 8-11, 2016.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan, dated December 9, 2016, that was reviewed and approved by the MDEQ in the February 7, 2017 test plan approval letter. MDEQ representatives Mr. Mark Dziadosz and Mr. Iranna Konanahalli observed portions of the testing project.

Questions regarding this emission test report should be directed to:

Tyler J. Wilson
Livonia Office Supervisor
Derenzo Environmental Services
39395 Schoolcraft Road
Livonia, MI 48150
Ph: (734) 464-3880

Mr. Steve Walters
Environmental Engineer
Waste Management of Michigan, Inc.
36600 29-Mile Rd.
Lenox Twp., MI 48048
Ph: (586) 634-8085

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 Waste Management / Pine Tree Acres, Inc employees or representatives. This test report has been reviewed by Waste Management / Pine Tree Acres, Inc. 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:

Tyler J. Wilson
Livonia Office Supervisor
Derenzo Environmental Services

Reviewed By:

Andy Rusnak, QSTI
Technical Manager
Derenzo Environmental Services

A Renewable Operating Permit Report Certification form signed by the source responsible official accompanies this report.

2.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

2.1 Purpose and Objective of the Tests

Each LFG-fueled RICE (EUICENGINE1 through EUICENGINE8) was tested for CO, NO_x, and VOC emissions pursuant to the conditions of MI-ROP-N5984-2013a, MI-PTI-N5984-2013a, and 40 CFR Part 60 Subpart JJJJ, which require the SI-RICE to be tested every 8,760 hours of operation.

2.2 Operating Conditions During the Compliance Tests

The engine testing was performed while the RICE-generator sets were operated at maximum operating conditions (within 10% of the rated electricity output of 1,600 kW). PTAL representatives monitored and recorded the kW output at 15-minute intervals for each test period. The RICE generator kW output ranged between 1,605 and 1,655 kW during the test periods.

Fuel flowrate (cubic feet per minute) and fuel methane content (%) were also recorded during the RICE test periods by PTAL representatives at 15-minute intervals. The RICE fuel consumption rate ranged between 520 and 595 scfm and fuel methane content ranged between 45.9 and 55.1% during the test periods. Other operating data (air-to-fuel ratio, fuel header inlet pressure, and engine operating hours) were recorded as required by the test plan approval letter.

Engine output (bhp) cannot be measured directly and was calculated based on the recorded electricity output, the calculated CAT® Model G3520C generator efficiency (96%), and the unit conversion factor for kW to horsepower (0.7457 kW/hp).

Engine output (bhp) = Electricity output (kW) / (0.96) / (0.7457 kW/hp)

Table 2.1 presents a summary of the average engine operating conditions during the test periods.

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

2.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the treated LFG fueled RICE were sampled for three (3) one-hour test periods per unit during the compliance testing performed February 13 through 16, 2017.

Table 2.2 presents the average measured CO, NO_x, and VOC emission rates for the engines (average of the three test periods for each engine) and applicable emission limits.

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

2.4 Measured Emission Rates Compared to Permitted Emission Limits

Results of the RICE performance tests demonstrate compliance with emission standards specified in 40 CFR Part 60 Subpart JJJJ (SI RICE NSPS).

The measured RICE CO, NO_x, and VOC emissions demonstrate compliance with the applicable limits specified in MI-ROP-N5984-2013a, MI-PTI-N5984-2013a, and 40 CFR Part 60 Subpart JJJJ.

Table 2.1 Average engine operating conditions during the RICE test periods

Emission Unit	Gen. Output (kW)	Engine Output (bHp)	Fuel Use (scfm)	LFG CH_4 Content (%)	LFG Btu Content (Btu/scf)	Exhaust Temp. (°F)	Air to Fuel Ratio	Inlet Press. (psi)
EUICENGINE1	1,625	2,270	571	49.4	450	922	8.0	47.9
EUICENGINE2	1,630	2,277	544	51.3	467	917	8.7	48.9
EUICENGINE3	1,630	2,277	548	51.6	470	929	8.1	48.2
EUICENGINE4	1,632	2,280	554	50.5	460	926	8.0	46.4
EUICENGINE5	1,634	2,283	586	50.1	456	915	8.4	54.3
EUICENGINE6	1,633	2,281	556	50.2	457	927	8.1	48.0
EUICENGINE7	1,631	2,278	567	49.6	451	902	8.2	50.2
EUICENGINE8	1,637	2,287	565	50.1	456	915	8.4	51.6

Table 2.2 Average measured CO, NO_x, and VOC emission rates for each RICE generator set (three-test average)

	CO Emission Rates		NO_x Emission Rates		VOC Emission Rates	
Emission Unit	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)
EUICENGINE1	10.9	2.18	2.21	0.44	0.53	0.11
EUICENGINE2	13.7	2.72	2.17	0.43	0.69	0.14
EUICENGINE3	9.52	1.90	1.93	0.38	0.48	0.10
EUICENGINE4	11.1	2.21	2.43	0.48	0.56	0.11
EUICENGINE5	13.7	2.72	1.85	0.37	0.61	0.12
EUICENGINE6	13.8	2.75	2.44	0.48	0.55	0.11
EUICENGINE7	12.3	2.44	2.28	0.45	0.44	0.09
EUICENGINE8	12.1	2.40	2.14	0.42	0.45	0.09
NSPS Standard	--	*5.0*	--	*2.0*	--	*1.0*
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

LFG recovered from the PTAL is treated and used as fuel in the renewable energy facility or combusted in flaring systems. The renewable energy facility consists of eight (8) Caterpillar (CAT®) Model No. G3520C RICE-generator sets identified as emission units EUICENGINE1 through EUICENGINE8. Excess LFG (gas that is recovered but not used for electricity generation) is controlled in two (2) enclosed flares identified as EUFLARE4 and EUFLARE6.

3.2 Rated Capacities and Air Emission Controls

The CAT® Model No. G3520C RICE have a rated output of 2,233 brake-horsepower (bhp) and the connected generators have a rated electricity output of 1,600 kilowatts (kW). The engines are designed to fire low-pressure, lean fuel mixtures (e.g., treated LFG) and are equipped with air-to-fuel ratio controllers that monitor engine performance parameters and automatically adjust the air-to-fuel ratio to maintain efficient fuel combustion. 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.

The RICE 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.

3.3 Sampling Locations

The RICE exhaust gas is directed through mufflers and is released to the atmosphere through dedicated vertical exhaust stacks. The eight (8) CAT® Model G3520C RICE exhaust stacks are identical. The exhaust sampling ports for the CAT® Model G3520C engines (EUICENGINE1 through EUICENGINE8) are located in individual horizontal exhaust ducts, located before the engine silencer, with an inner diameter of 15.0 inches. After the engine silencer the exhaust stack diameter is reduced to 14.0 inches as specified in the permit. Each duct is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 38.0 inches (2.5 duct diameters) upstream and 45.0 inches (3.0 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.

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 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 zirconia ion/paramagnetic and infrared instrumental analyzers, respectively.
USEPA Method 4	Exhaust gas moisture was determined based on the water weight gain in chilled impingers.
USEPA Method 7E	Exhaust gas NO_x concentration was determined using a chemiluminescence instrumental analyzer.
USEPA Method 10	Exhaust gas CO concentration was measured using an NDIR instrumental analyzer.
USEPA Method 25A / ALT-096	Exhaust gas VOC (as NMHC) concentration was determined using a flame ionization analyzer equipped with a GC column.

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

The 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 periodically leak-checked 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 exhaust gas streams 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 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 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 exhaust gas streams were 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.

4.5 NO_x and CO Concentration Measurements (USEPA Methods 7E and 10)

NO_x and CO pollutant concentrations in the 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)

VOC emission rate was determined by measuring the nonmethane hydrocarbon (NMHC) concentration in each 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 several alternate test methods approving the use of the TEI 55-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-066, ALT-078 and ALT-096).

Samples of the exhaust gas were delivered directly to the instrumental analyzer using the Teflon® heated sample line to prevent condensation. The sample to the NHMC analyzer was not conditioned to remove moisture. Therefore, VOC measurements correspond to standard conditions with no moisture correction (wet basis).

Prior to, and at the conclusion of each test, the instrument was calibrated using mid-range calibration (propane) and zero gas to determine analyzer calibration error and system bias (described in Section 5.0 of this document).

Appendix 4 provides VOC calculation sheets. Raw instrument response data for the NMHC analyzer is provided in Appendix 5.

5.0 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 greater than or equal to 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_2 concentration was 105.2% of the expected value, i.e., greater than 90% of the expected value as required by Method 7E).

5.2 Sampling System Response Time Determination

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.

Results of the response time determinations were recorded on field data sheets. For each test period, test data were collected once the sample probe was in position for at least twice the maximum system response time.

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, CO_2, and O_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 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 each exhaust stack indicated that the measured CO_2 and O_2 concentrations did not vary by more than 5% of the mean across the stack diameter. Therefore, the exhaust gas was considered to be unstratified and the compliance test sampling was performed at a single sampling location within each exhaust stack.

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 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, Pitot tube calibration records).

6.0 RESULTS

6.1 RICE NO_x, CO, and VOC Emissions

All eight (8) RICE generator sets (EUICENGINE1 through EUICENGINE8) were tested for NO_x, CO, and VOC emission rates. The measured air pollutant concentrations and emission rates for each one-hour test period are presented in Tables 6.1 through 6.8.

The measured emission rates are less than 40 CFR Part 60 Subpart JJJJ (SI RICE NSPS) emission standards; 2.0 g/bhp-hr NO_x, 5.0 g/bhp-hr CO and 1.0 g/bhp-hr VOC.

The measured emission rates are less than the allowable rates specified in MI-ROP-N5984-2013a and MI-PTI-N5984-2013a:

- 3.0 lb/hr and 0.6 g/bhp-hr for NO_x;
- 16.3 lb/hr and 3.3 g/bhp-hr for CO; and
- 1.0 lb/hr and 1.0 g/bhp-hr for VOC.

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 (1,600 kW generator output) during the engine test periods.

Table 6.1 Measured exhaust gas conditions and NO_x, CO, and VOC emission rates
Engine No. 1 (EUICENGINE1, SN: GZJ00469)

Test No. Test date Test period (24-hr clock)	1 2/13/17 800 - 900	2 2/13/17 930 - 1030	3 2/13/17 1056 - 1156	Three Test Average
Fuel flowrate (scfm)	570	570	572	571
Generator output (kW)	1,626	1,626	1,623	1,625
Engine output (bhp)	2,271	2,271	2,268	2,270
LFG methane content (%)	49.3	49.5	49.5	49.4
LFG LHV heat content (Btu/scf)	449	450	450	450
Air / Fuel Ratio	8.0	8.0	8.0	8.0
Inlet Pressure (psi)	48.1	47.9	47.6	47.9
<u>Exhaust Gas Composition</u>				
CO_2 content (% vol)	11.4	11.5	11.5	11.5
O_2 content (% vol)	8.3	8.3	8.3	8.3
Moisture (% vol)	10.8	9.8	12.3	11.0
Exhaust gas temperature (°F)	921	920	922	921
Exhaust gas flowrate (dscfm)	3,817	4,237	3,895	3,983
Exhaust gas flowrate (scfm)	4,252	4,761	4,441	4,484
<u>Nitrogen Oxides</u>				
NO_x conc. (ppmvd)	78.4	77.8	76.3	77.5
NO_x emissions (g/bhp*hr)	0.43	0.47	0.43	0.44
Permitted emissions (g/bhp*hr)	-	-	-	0.6
NO_x emissions (lb/hr)	2.14	2.36	2.13	2.21
Permitted emissions (lb/hr)	-	-	-	3.0
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	628	626	625	626
CO emissions (g/bhp*hr)	2.09	2.31	2.13	2.18
Permitted emissions (g/bhp*hr)	-	-	-	3.3
CO emissions (lb/hr)	10.5	11.6	10.6	10.9
Permitted emissions (lb/hr)	-	-	-	16.3
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv)	18.6	16.4	16.4	17.1
VOC emissions (g/bhp*hr)	0.11	0.11	0.10	0.11
Permitted emissions (g/bhp*hr)	-	-	-	1.0
VOC emissions (lb/hr)	0.54	0.54	0.50	0.53
Permitted emissions (lb/hr)	-	-	-	1.0

Table 6.2 Measured exhaust gas conditions and NO_x, CO, and VOC emission rates
Engine No. 2 (EUICENGINE2, SN: GZJ00464)

Test No. Test date Test period (24-hr clock)	1 2/14/17 740 - 840	2 2/14/17 901 - 1001	3 2/14/17 1025 - 1125	Three Test Average
Fuel flowrate (scfm)	542	543	547	544
Generator output (kW)	1,627	1,635	1,628	1,630
Engine output (bhp)	2,272	2,283	2,275	2,277
LFG methane content (%)	51.5	51.1	51.1	51.3
LFG LHV heat content (Btu/scf)	469	465	465	466
Air / Fuel Ratio	8.7	8.7	8.7	8.7
Inlet Pressure (psi)	48.7	48.8	49.1	48.9
Exhaust Gas Composition				
CO_2 content (% vol)	14.2	13.7	13.1	13.7
O_2 content (% vol)	8.5	8.5	8.6	8.6
Moisture (% vol)	8.9	12.2	10.1	10.4
Exhaust gas temperature (^oF)	914	918	920	917
Exhaust gas flowrate (dscfm)	4,229	4,074	3,913	4,072
Exhaust gas flowrate (scfm)	4,727	4,586	4,353	4,555
Nitrogen Oxides				
NO_x conc. (ppmvd)	74.3	74.3	74.1	74.2
NO_x emissions (g/bhp*hr)	0.45	0.43	0.41	0.43
Permitted emissions (g/bhp*hr)	-	-	-	0.6
NO_x emissions (lb/hr)	2.25	2.17	2.08	2.17
Permitted emissions (lb/hr)	-	-	-	3.0
Carbon Monoxide				
CO conc. (ppmvd)	768	769	766	768
CO emissions (g/bhp*hr)	2.83	2.72	2.61	2.72
Permitted emissions (g/bhp*hr)	-	-	-	3.3
CO emissions (lb/hr)	14.2	13.7	13.1	13.7
Permitted emissions (lb/hr)	-	-	-	16.3
Volatile Organic Compounds				
VOC conc. (ppmv)	22.1	22.2	21.5	21.9
VOC emissions (g/bhp*hr)	0.14	0.14	0.13	0.14
Permitted emissions (g/bhp*hr)	-	-	-	1.0
VOC emissions (lb/hr)	0.72	0.70	0.64	0.69
Permitted emissions (lb/hr)	-	-	-	1.0

Table 6.3 Measured exhaust gas conditions and NO_x, CO, and VOC emission rates
Engine No. 3 (EUICENGINE3, SN: GZJ00467)

Test No. Test date Test period (24-hr clock)	1 2/14/17 1152 - 1252	2 2/14/17 1315 - 1415	3 2/14/17 1441 - 1541	Three Test Average
Fuel flowrate (scfm)	549	548	549	548
Generator output (kW)	1,629	1,627	1,633	1,630
Engine output (bhp)	2,276	2,272	2,282	2,277
LFG methane content (%)	51.1	51.9	51.9	51.6
LFG LHV heat content (Btu/scf)	465	472	472	470
Air / Fuel Ratio	8.1	8.1	8.1	8.1
Inlet Pressure (psi)	48.1	48.2	48.4	48.2
Exhaust Gas Composition				
CO_2 content (% vol)	11.3	11.3	11.3	11.3
O_2 content (% vol)	8.5	8.5	8.6	8.5
Moisture (% vol)	9.3	11.1	11.6	10.6
Exhaust gas temperature (°F)	928	930	931	930
Exhaust gas flowrate (dscfm)	3,821	3,754	3,729	3,768
Exhaust gas flowrate (scfm)	4,254	4,233	4,217	4,235
Nitrogen Oxides				
NO_x conc. (ppmvd)	71.0	72.0	71.3	71.4
NO_x emissions (g/bhp*hr)	0.39	0.39	0.38	0.38
Permitted emissions (g/bhp*hr)	-	-	-	0.6
NO_x emissions (lb/hr)	1.95	1.94	1.91	1.93
Permitted emissions (lb/hr)	-	-	-	3.0
Carbon Monoxide				
CO conc. (ppmvd)	578	577	582	579
CO emissions (g/bhp*hr)	1.92	1.89	1.88	1.90
Permitted emissions (g/bhp*hr)	-	-	-	3.3
CO emissions (lb/hr)	9.63	9.45	9.47	9.52
Permitted emissions (lb/hr)	-	-	-	16.3
Volatile Organic Compounds				
VOC conc. (ppmv)	16.6	16.3	16.5	16.5
VOC emissions (g/bhp*hr)	0.10	0.09	0.10	0.10
Permitted emissions (g/bhp*hr)	-	-	-	1.0
VOC emissions (lb/hr)	0.49	0.48	0.48	0.48
Permitted emissions (lb/hr)	-	-	-	1.0

Table 6.4 Measured exhaust gas conditions and NO_x, CO, and VOC emission rates
Engine No. 4 (EUICENGINE4, SN: GZJ00466)

Test No.	1	2	3	
Test date	2/15/17	2/15/17	2/15/17	Three Test
Test period (24-hr clock)	742 - 842	908 - 1008	1030 - 1130	Average
Fuel flowrate (scfm)	553	551	557	554
Generator output (kW)	1,637	1,635	1,624	1,632
Engine output (bhp)	2,287	2,284	2,269	2,280
LFG methane content (%)	50.8	50.6	50.1	50.5
LFG LHV heat content (Btu/scf)	462	460	456	459
Air / Fuel Ratio	8.0	8.0	7.9	8.0
Inlet Pressure (psi)	46.6	46.3	46.3	46.4
Exhaust Gas Composition				
CO_2 content (% vol)	11.5	11.5	11.5	11.5
O_2 content (% vol)	8.2	8.3	8.2	8.2
Moisture (% vol)	10.4	9.0	13.1	10.8
Exhaust gas temperature (^oF)	925	926	927	926
Exhaust gas flowrate (dscfm)	4,368	4,098	3,825	4,097
Exhaust gas flowrate (scfm)	4,836	4,604	4,399	4,613
Nitrogen Oxides				
NO_x conc. (ppmvd)	82.4	81.8	839.9	82.7
NO_x emissions (g/bhp*hr)	0.51	0.48	0.46	0.48
Permitted emissions (g/bhp*hr)	-	-	-	0.6
NO_x emissions (lb/hr)	2.58	2.40	2.30	2.43
Permitted emissions (lb/hr)	-	-	-	3.0
Carbon Monoxide				
CO conc. (ppmvd)	617	618	628	621
CO emissions (g/bhp*hr)	2.33	2.19	2.09	2.21
Permitted emissions (g/bhp*hr)	-	-	-	3.3
CO emissions (lb/hr)	11.8	11.1	10.5	11.1
Permitted emissions (lb/hr)	-	-	-	16.3
Volatile Organic Compounds				
VOC conc. (ppmv)	21.1	15.8	16.2	17.7
VOC emissions (g/bhp*hr)	0.14	0.14	0.10	0.11
Permitted emissions (g/bhp*hr)	-	-	-	1.0
VOC emissions (lb/hr)	0.70	0.50	0.49	0.56
Permitted emissions (lb/hr)	-	-	-	1.0

Table 6.5 Measured exhaust gas conditions and NO_x, CO, and VOC emission rates
Engine No. 5 (EUICENGINE5, SN: GZJ00462)

Test No. Test date Test period (24-hr clock)	1 2/13/17 1225 - 1325	2 2/13/17 1350 - 1450	3 2/13/17 1517 - 1617	Three Test Average
Fuel flowrate (scfm)	593	576	588	586
Generator output (kW)	1,633	1,634	1,635	1,634
Engine output (bhp)	2,281	2,283	2,284	2,283
LFG methane content (%)	49.9	50.1	50.2	50.1
LFG LHV heat content (Btu/scf)	454	456	457	456
Air / Fuel Ratio	8.4	8.4	8.5	8.4
Inlet Pressure (psi)	54.3	54.2	54.4	54.3
Exhaust Gas Composition				
CO_2 content (% vol)	11.1	11.1	11.1	11.1
O_2 content (% vol)	8.7	8.7	8.7	8.7
Moisture (% vol)	11.3	9.8	10.6	10.6
Exhaust gas temperature (°F)	918	914	912	914
Exhaust gas flowrate (dscfm)	4,044	3,902	3,851	3,932
Exhaust gas flowrate (scfm)	4,523	4,346	4,308	4,392
Nitrogen Oxides				
NO_x conc. (ppmvd)	66.2	64.8	66.1	65.7
NO_x emissions (g/bhp*hr)	0.38	0.36	0.36	0.37
Permitted emissions (g/bhp*hr)	-	-	-	0.6
NO_x emissions (lb/hr)	1.92	1.81	1.83	1.85
Permitted emissions (lb/hr)	-	-	-	3.0
Carbon Monoxide				
CO conc. (ppmvd)	805	791	797	797
CO emissions (g/bhp*hr)	2.82	2.68	2.66	2.72
Permitted emissions (g/bhp*hr)	-	-	-	3.3
CO emissions (lb/hr)	14.2	13.5	13.4	13.7
Permitted emissions (lb/hr)	-	-	-	16.3
Volatile Organic Compounds				
VOC conc. (ppmv)	20.0	20.2	20.2	20.1
VOC emissions (g/bhp*hr)	0.12	0.12	0.12	0.12
Permitted emissions (g/bhp*hr)	-	-	-	1.0
VOC emissions (lb/hr)	0.62	0.60	0.60	0.61
Permitted emissions (lb/hr)	-	-	-	1.0

Table 6.6 Measured exhaust gas conditions and NO_x, CO, and VOC emission rates
Engine No. 6 (EUICENGINE6, SN: GZJ00468)

Test No. Test date Test period (24-hr clock)	1 2/15/17 1152 - 1252	2 2/15/17 1314 - 1414	3 2/15/17 1435 - 1535	Three Test Average
Fuel flowrate (scfm)	556	553	559	556
Generator output (kW)	1,635	1,626	1,637	1,633
Engine output (bhp)	2,284	2,272	2,286	2,281
LFG methane content (%)	50.2	50.3	50.1	50.2
LFG LHV heat content (Btu/scf)	457	458	456	457
Air / Fuel Ratio	8.2	8.2	8.0	8.1
Inlet Pressure (psi)	48.0	47.8	48.1	48.0
Exhaust Gas Composition				
CO_2 content (% vol)	11.4	11.4	11.4	11.4
O_2 content (% vol)	8.3	8.4	8.4	8.3
Moisture (% vol)	8.9	12.2	11.8	11.0
Exhaust gas temperature (^oF)	923	928	930	927
Exhaust gas flowrate (dscfm)	4,351	4,149	4,133	4,211
Exhaust gas flowrate (scfm)	4,862	4,715	4,685	4,754
Nitrogen Oxides				
NO_x conc. (ppmvd)	81.3	80.4	80.5	80.7
NO_x emissions (g/bhp*hr)	0.50	0.48	0.47	0.48
Permitted emissions (g/bhp*hr)	-	-	-	0.6
NO_x emissions (lb/hr)	2.54	2.39	2.39	2.44
Permitted emissions (lb/hr)	-	-	-	3.0
Carbon Monoxide				
CO conc. (ppmvd)	751	750	751	751
CO emissions (g/bhp*hr)	2.83	2.71	2.69	2.75
Permitted emissions (g/bhp*hr)	-	-	-	3.3
CO emissions (lb/hr)	14.3	13.6	13.6	13.8
Permitted emissions (lb/hr)	-	-	-	16.3
Volatile Organic Compounds				
VOC conc. (ppmv)	17.0	17.0	16.9	17.0
VOC emissions (g/bhp*hr)	0.11	0.11	0.11	0.11
Permitted emissions (g/bhp*hr)	-	-	-	1.0
VOC emissions (lb/hr)	0.57	0.55	0.55	0.55
Permitted emissions (lb/hr)	-	-	-	1.0

Table 6.7 Measured exhaust gas conditions and NO_x, CO, and VOC emission rates
Engine No. 7 (EUICENGINE7, SN: GZJ00463)

Test No. Test date Test period (24-hr clock)	1 2/16/17 732 - 832	2 2/16/17 851 - 951	3 2/16/17 1011 - 1111	Three Test Average
Fuel flowrate (scfm)	565	570	567	567
Generator output (kW)	1,625	1,633	1,635	1,631
Engine output (bhp)	2,270	2,281	2,283	2,278
LFG methane content (%)	49.6	49.6	49.7	49.6
LFG LHV heat content (Btu/scf)	451	451	452	451
Air / Fuel Ratio	8.2	8.2	8.2	8.2
Inlet Pressure (psi)*	50.1	50.4	50.2	50.2
Exhaust Gas Composition				
CO_2 content (% vol)	11.2	11.2	11.2	11.2
O_2 content (% vol)	8.6	8.7	8.6	8.6
Moisture (% vol)	10.1	9.7	8.8	9.5
Exhaust gas temperature (^oF)	903	903	901	902
Exhaust gas flowrate (dscfm)	4,077	3,911	3,856	3,948
Exhaust gas flowrate (scfm)	4,525	4,310	4,228	4,354
Nitrogen Oxides				
NO_x conc. (ppmvd)	81.2	79.2	81.0	80.5
NO_x emissions (g/bhp*hr)	0.47	0.44	0.44	0.45
Permitted emissions (g/bhp*hr)	-	-	-	0.6
NO_x emissions (lb/hr)	2.37	2.22	2.24	2.28
Permitted emissions (lb/hr)	-	-	-	3.0
Carbon Monoxide				
CO conc. (ppmvd)	734	700	700	711
CO emissions (g/bhp*hr)	2.61	2.38	2.34	2.44
Permitted emissions (g/bhp*hr)	-	-	-	3.3
CO emissions (lb/hr)	13.1	12.0	11.8	12.3
Permitted emissions (lb/hr)	-	-	-	16.3
Volatile Organic Compounds				
VOC conc. (ppmv)	12.8	15.1	16.0	14.6
VOC emissions (g/bhp*hr)	0.08	0.09	0.09	0.09
Permitted emissions (g/bhp*hr)	-	-	-	1.0
VOC emissions (lb/hr)	0.40	0.45	0.46	0.44
Permitted emissions (lb/hr)	-	-	-	1.0

Table 6.8 Measured exhaust gas conditions and NO_x, CO, and VOC emission rates
Engine No. 8 (EUICENGINE8, SN: GZJ00465)

Test No.	1	2	3	
Test date	2/16/17	2/16/17	2/16/17	Three Test
Test period (24-hr clock)	1134 - 1234	1254 - 1354	1415 - 1515	Average
Fuel flowrate (scfm)	569	562	564	565
Generator output (kW)	1,637	1,636	1,638	1,637
Engine output (bhp)	2,287	2,286	2,288	2,287
LFG methane content (%)	49.9	50.2	50.1	50.1
LFG LHV heat content (Btu/scf)	454	457	456	456
Air / Fuel Ratio	8.3	8.4	8.4	8.4
Inlet Pressure (psi)	51.9	51.5	51.5	51.6
<u>Exhaust Gas Composition</u>				
CO_2 content (% vol)	11.3	11.3	11.2	11.3
O_2 content (% vol)	8.5	8.5	8.5	8.5
Moisture (% vol)	11.4	11.7	9.3	10.8
Exhaust gas temperature (^oF)	915	915	915	915
Exhaust gas flowrate (dscfm)	3,697	3,638	3,645	3,660
Exhaust gas flowrate (scfm)	4,179	4,067	4,020	4,088
<u>Nitrogen Oxides</u>				
NO_x conc. (ppmvd)	81.7	80.8	82.4	81.6
NO_x emissions (g/bhp*hr)	0.43	0.42	0.43	0.42
Permitted emissions (g/bhp*hr)	-	-	-	0.6
NO_x emissions (lb/hr)	2.17	2.11	2.15	2.14
Permitted emissions (lb/hr)	-	-	-	3.0
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	760	753	756	756
CO emissions (g/bhp*hr)	2.43	2.37	2.38	2.40
Permitted emissions (g/bhp*hr)	-	-	-	3.3
CO emissions (lb/hr)	12.3	12.0	12.0	12.1
Permitted emissions (lb/hr)	-	-	-	16.3
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv)	16.0	16.3	16.3	16.2
VOC emissions (g/bhp*hr)	0.09	0.09	0.09	0.09
Permitted emissions (g/bhp*hr)	-	-	-	1.0
VOC emissions (lb/hr)	0.46	0.46	0.45	0.45
Permitted emissions (lb/hr)	-	-	-	1.0