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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 January 13, 2017

Test Dates December 8, 2016

Facility Information	
Name	Granger Electric at the Brent Run Landfill
Street Address	8247 W. Vienna Road
City, County	Montrose, Genesee
Facility SRN	N5987

Facility Permit Information		
ROP No.:	MI-ROP-N5987-2015	PTI No. : 78-16

Testing Contractor	
Company	Derenzo Environmental Services
Mailing Address	39395 Schoolcraft Road Livonia, MI 48150
Phone	(734) 464-3880
Project No.	1606017



MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR QUALITY DIVISION

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RENEWABLE OPERATING PERMIT
REPORT CERTIFICATION

AIR QUALITY DIV.

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 Granger Electric at the Brent Run Landfill County Genesee
Source Address 8247 W. Vienna Road City Montrose
AQD Source ID (SRN) N5987 ROP No. N5987-2015 ROP Section No. 02

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 _____ To _____

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

Test Report for landfill gas fired IC engines (EUENGINE3 and EUENGINE6). Emissions testing was performed 12-8-16. The testing was conducted in accordance with the Test Plan and 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

Todd Davlin Director - Energy Operations (517) 372-2800
Name of Responsible Official (print or type) Title Phone Number

Todd Davlin Signature of Responsible Official 1-26-2017 Date

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Executive Summary
**GRANGER ELECTRIC AT THE BRENT RUN LANDFILL
 CAT® G3520C LANDFILL GAS FUELED IC ENGINES
 EMISSION TEST RESULTS**
AIR QUALITY DIV.

Granger Electric contracted Derenzo Environmental Services to conduct a performance demonstration for the determination of pollutant concentrations and emission rates from two (2) Caterpillar (CAT®) Model No. G3520C landfill gas-fired reciprocating internal combustion engines (RICE) and electricity generator sets (EUENGINE3 and EUENGINE6) operated at the Brent Run Landfill in Montrose, Michigan.

Michigan Department of Environmental Quality (MDEQ) Air Quality Division (AQD) Renewable Operating Permit No. MI-ROP-N5987-2015 requires that performance testing be performed on EUENGINE3 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 RICE) for nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOC). MDEQ-AQD PTI No. 78-16 requires that performance testing be performed on EUENGINE6 within 180 days of startup and within every five (5) years of completion of the most recent stack test for NO_x, CO, VOC, sulfur dioxide (SO₂), and formaldehyde (HCOH). EUENGINE6 is also subject to the periodic testing requirements of 40 CFR Part 60 Subpart JJJJ. The performance testing was conducted on December 8, 2016.

The following tables present the emissions results from the performance demonstration and engine operating data recorded during the test periods.

Emission Unit	Pollutant	Measured Emissions (lb/hr)	Permit Limit (lb/hr)	Measured Emissions (g/bhp-hr)	Permit Limit (g/bhp-hr)
EUENGINE3	NO _x	3.00	4.94	0.60	1.0
	CO	13.7	16.3	2.74	3.3
	VOC	0.63	-	0.13	1.0
EUENGINE6	NO _x	2.78	4.94	0.55	2.0
	CO	11.7	16.3	2.31	5.0
	VOC	0.56	4.94	0.11	1.0
	SO ₂	4.33	7.73	0.86	-
	HCOH	1.76	2.1	0.35	-

Emission Unit	Generator Output (kW)	Engine Output (bhp)	LFG Fuel Use (scfm)	LFG Fuel Use (lb/hr)	LFG CH ₄ Content (%)	Exhaust Temp. (°F)
EUENGINE3	1,629	2,275	525	-	54.6	830
EUENGINE6	1,631	2,285	-	2,271	54.6	827

The data presented above indicates that EUENGINE3 and EUENGINE6 were tested while the units operated within 10% of maximum capacity (2,233 bhp (EUENGINE3), 2,242 bhp (ENGINE6), and 1,600 kW (EUENGINE3 and EUENGINE6)) and complies with the emission standards specified in 40 CFR 60.4233(e), MDEQ-AQD ROP No. MI-ROP-N5987-2015 and MDEQ-AQD PTI No. 78-16.

AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM
LANDFILL GAS FUELED INTERNAL COMBUSTION ENGINES
GRANGER ELECTRIC AT THE BRENT RUN LANDFILL

1.0 INTRODUCTION

Granger Electric (Granger) operates Caterpillar (CAT®) landfill gas-fired reciprocating internal combustion engines (RICE) and electricity generator sets at the Brent Run Landfill in Montrose, Genesee County, Michigan. The landfill gas (LFG) fueled RICE-generator sets are identified as emission units EUENGINE1 through EUENGINE5 in Section 2 of Michigan Renewable Operating Permit (ROP) No. MI-ROP-N5987-2015, and emission unit EUENGINE6 in Permit to Install (PTI) No. 78-16 that were issued by the Michigan Department of Environmental Quality (MDEQ).

The conditions of MI-ROP-N5987-2015 specify that:

1. EUENGINE3 is a CAT® Model G3520C RICE fueled with treated landfill gas for producing electricity.
2. *The permittee shall conduct an initial performance test for EUENGINE3 in FGICEENGINES, to verify NOx, CO, and VOC emission rates. The permittee shall conduct an initial performance test within 60 days after achieving the maximum production rate but not later than 180 days after initial startup of each engine in FGICEENGINES and subsequent performance testing for EUENGINE3 every 8760 hours of operation or three years, whichever occurs first, to demonstrate compliance. The performance tests shall be conducted according to 40 CFR 60.4244*

The conditions of PTI 78-16 specify that:

1. EUENGINE6 is a CAT® Model G3520C RICE fueled with treated landfill gas for producing electricity.
2. *The permittee shall conduct an initial performance test for EUENGINE6 within one year after startup of the engine and every 8760 hours of operation or three years, whichever occurs first, to demonstrate compliance with the emission limits in 40 CFR 60.4243(b). The performance tests shall be conducted according to 40 CFR 60.4244.*

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3. *Within 180 days after initial startup of EUENGINE6 and within every 5 years from the date of completion of the most recent stack test, thereafter, the permittee shall verify NO_x, CO, SO₂, and VOC emission rates, from EUENGINE6 at maximum routine operating conditions, by testing at owner's expense, in accordance with Department requirements.*
4. *Within 180 days after initial startup of EUENGINE6 and within every 5 years from the date of completion of the most recent stack test, thereafter, the permittee shall verify formaldehyde emission rates from EUENGINE6 at maximum routine operating conditions, by testing at owner's expense, in accordance with Department requirements.*

The compliance testing was performed by Derenzo Environmental Services (DES), a Michigan-based environmental consulting and testing company. DES representatives Tyler J. Wilson and Dan Wilson performed the field sampling and measurements December 8, 2016.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan dated October 27, 2016 that was reviewed and approved by the MDEQ-AQD. MDEQ representatives Mr. David Patterson and Ms. Michelle Luplow observed portions of the testing project.

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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. Dan Zimmerman
Director of Operations and Compliance
Granger Electric Company
16980 Wood Road
Lansing, MI 48906
Ph: (517) 371-9711

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:

Reviewed By:



Tyler J. Wilson
Livonia Office Supervisor
Derenzo Environmental Services

Robert L. Harvey, P.E.
General 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
Operations Manager
Granger Electric Company

2.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

2.1 Purpose and Objective of the Tests

The conditions of ROP No. MI-ROP-N5987-2015 and 40 CFR Part 60 Subpart JJJJ require Granger to test EUENGINE3 for carbon monoxide (CO), nitrogen oxides (NOx) and volatile organic compounds (VOCs) every 8,760 hours of operation.

The conditions of PTI No. 78-16 require Granger to test EUCENGINE6 for CO, NOx, VOC, SO₂, and formaldehyde (HCOH) within 180 days of startup. EUCENGINE6 is also subject to the periodic testing requirements of 40 CFR Part 60 Subpart JJJJ.

2.2 Operating Conditions During the Compliance Tests

The testing was performed while the RICE generator sets were operated at maximum operating conditions (1,600 kW electricity output +/- 10%). Granger representatives provided the generator electricity output (kW) in 15-minute increments for each test period. The generator kW output ranged between 1,611 and 1,651 kW during the test periods.

Fuel flowrate (standard cubic feet per minute (scfm) or pounds per hour (lb/hr) and fuel methane content were also recorded by Granger representatives in 15-minute increments for each test period. The EUENGINE3 fuel consumption rate ranged between 520 and 532 scfm and the EUENGINE6 fuel consumption rate ranged between 2,255 and 2,284 lb/hr for each test period. The treated LFG used to fuel the engines contained 54 to 55% methane. Fuel heat value was calculated using a lower heating value of 910 Btu/scf for methane.

In addition, the engine serial number and operating hours at the beginning of test No. 1 were recorded by the facility operators.

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 (%), and the unit conversion factor for kW to horsepower (0.7457 kW/hp).

$$\text{EUENGINE3 engine output (bhp)} = \text{Electricity output (kW)} / (0.960) / (0.7457 \text{ kW/hp})$$

$$\text{EUENGINE6 engine output (bhp)} = \text{Electricity output (kW)} / (0.957) / (0.7457 \text{ kW/hp})$$

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

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2.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the LFG fueled RICE were each sampled for three (3) one-hour test periods during the compliance testing performed December 8, 2016.

Tables 2.2 and 2.3 present the average measured pollutant emission rates for EUENGINE3 and EUENGINE6, respectively (average of the three test periods for each engine).

Test results for each one hour sampling period are presented in Section 6.0 of this report.

Table 2.1 Average engine operating conditions during the test periods

Engine Parameter	EUENGINE3	EUENGINE6
Generator output (kW)	1,629	1,631
Engine output (bhp)	2,275	2,285
Engine LFG fuel use (scfm)	525	-
Engine LFG fuel use (lb/hr)	-	2,271
LFG methane content (%)	54.6	54.6
LFG lower heating value (Btu/scf)	497	497
Exhaust temperature (°F)	830	827

Table 2.2 Average measured emission rates for EUENGINE3 (three-test average)

Emission Unit	CO		NOx		VOC
	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(g/bhp-hr)
Engine No. 3 Measured Rates	13.7	2.74	3.00	0.60	0.13
Permit Limit	16.3	3.3	4.94	1.0	1.0

Table 2.3 Average measured emission rates for EUENGINE6 (three-test average)

Emission Unit	CO		NOx		VOC		SO ₂	HCOH
	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(lb/hr)	(lb/hr)
Engine No. 6 Measured Rates	11.7	2.31	2.78	0.55	0.56	0.11	4.33	1.76
Permit Limit	16.3	5.0	4.94	2.0	4.94	1.0	7.73	2.1

3.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

3.1 General Process Description

Landfill gas (LFG) containing methane is generated in the Granger Brent Run 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 RICE. Each RICE is connected to an electricity generator that produces electricity that is transferred to the local utility.

3.2 Rated Capacities and Air Emission Controls

One (1) CAT® Model No. G3520C RICE (EUENGINE3) has a rated output of 2,233 brake-horsepower (bhp) and one (1) CAT® Model No. G3520C RICE (EUENGINE6) has a rated output of 2,242 brake-horsepower (bhp). The connected generators each have a rated electricity output of 1,600 kilowatts (kW). The engines are designed to fire low-pressure, lean fuel mixtures (e.g., LFG) and are 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 RICE generator sets are not equipped with an add-on emission control device. 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.

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 EUENGINE3 and EUENGINE6 are located in the exhaust stack 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 300 inches (22.2 duct diameters) upstream and greater than 114 inches (8.44 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 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 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 6C	Exhaust gas SO ₂ concentrations were determined using an ultraviolet (UV) fluorescence instrumental analyzer.
USEPA Method 7E	Exhaust gas NO _x concentration was determined using chemiluminescence instrumental analyzers.
USEPA Method 10	Exhaust gas CO concentration was measured using an NDIR 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.
USEPA Method 320	Exhaust gas formaldehyde concentration was measured using a FTIR spectrometer analyzer.

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

The exhaust stack gas velocities and volumetric flow rates for each RICE 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.

Appendix 3 provides exhaust gas flowrate calculations and field data sheets.

4.3 Exhaust Gas Molecular Weight Determination (USEPA Method 3A)

CO₂ and O₂ content in each RICE exhaust gas stream were measured continuously throughout each test period in accordance with USEPA Method 3A. The CO₂ content of the exhaust was monitored using a Servomex 1440D single beam single wavelength (SBSW) infrared gas analyzer. The O₂ content of the exhaust was monitored using a Servomex 1440D gas analyzer that uses a paramagnetic sensor.

During each sampling period, a continuous sample of the 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 O₂ and CO₂ concentrations correspond to standard dry gas conditions. Instrument response data were recorded using an ESC Model 8816 data acquisition system that monitored the analog output of the instrumental analyzers continuously and logged data as one-minute averages.

Prior to, and at the conclusion of each test, the instruments were calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias (described in Section 5.0 of this document). Sampling times were recorded on field data sheets.

Appendix 4 provides O₂ and CO₂ calculation sheets. Raw instrument response data are provided in Appendix 5.

4.4 Exhaust Gas Moisture Content (USEPA Method 4)

Moisture content of each RICE exhaust gas was determined in accordance with USEPA Method 4 using a chilled impinger sampling train. 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 each RICE exhaust gas stream were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42c High Level chemiluminescence NO_x analyzer and a TEI Model 48c 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 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 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.

4.7 SO₂ Concentration Measurements (USEPA Method 6C)

SO₂ content in the EUENGINE 6 exhaust gas stream was measured continuously throughout each test period in accordance with USEPA Method 6C. A Thermo Environmental, Inc. Model 43i pulsed ultraviolet fluorescence analyzer was used to determine SO₂ concentration.

Throughout each test period, a continuous sample of the 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 SO₂ emission calculation sheets. Raw instrument response data is provided in Appendix 5.

4.8 Measurement of Formaldehyde Emissions (USEPA Method 320)

The concentration of formaldehyde in the EUENGINE6 exhaust gas was determined by Extractive Fourier Transform Infrared (FTIR) using a MKS Multi-Gas 2030 FTIR spectrometer. Formaldehyde measurements were performed by Mr. Phil Kauppi of Prism Analytical (Prism).

Throughout each one-hour test period, a continuous sample of the engine exhaust gas was extracted from the stack using a Teflon® heated sample line and heated particulate filter, and delivered to FTIR instrument. The sampled gas was not conditioned prior to being introduced to the analyzer; therefore, the measurement of formaldehyde concentration corresponds to standard wet gas conditions. Instrument formaldehyde response for the analyzer was recorded with a data logging system. Prior to, and at the conclusion of each test, analyte spiking was performed to verify the ability of the sampling system to quantitatively deliver a sample from the base of the probe to the FTIR (described in Appendix 7).

Appendix 4 provides formaldehyde calculation sheets. The formaldehyde report prepared by Alliance is provided in Appendix 7.

5.0 QA/QC ACTIVITIES

5.1 Flow Measurement

Prior to arriving onsite, the instruments used during the source test to measure exhaust gas properties and velocity (barometer, pyrometer, and Pitot tube) were calibrated to specifications outlined in the sampling methods.

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).

5.2 NO_x Converter Efficiency Test

The NO₂ – NO conversion efficiency of the Model 42c analyzer was verified prior to the testing program. A USEPA Protocol 1 certified concentration of NO₂ was injected directly into the analyzer, following the initial three-point calibration, to verify the analyzer's conversion efficiency. The analyzer's NO₂ – NO converter uses a catalyst at high temperatures to convert the NO₂ to NO for measurement. The conversion efficiency of the analyzer is deemed acceptable if the measured NO₂ concentration is greater than or equal to 90% of the expected value.

The NO₂ – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO₂ concentration was 99.5% of the expected value, i.e., greater than 90% of the expected value as required by Method 7E).

5.3 Gas Divider Certification (USEPA Method 205)

A STEC Model SGD-710C 10-step gas divider was used to obtain appropriate calibration span gases. The ten-step STEC gas divider was NIST certified (within the last 12 months) with a primary flow standard in accordance with Method 205. When cut with an appropriate zero gas, the ten-step STEC gas divider delivered calibration gas values ranging from 0% to 100% (in 10% step increments) of the USEPA Protocol 1 calibration gas that was introduced into the system. The field evaluation procedures presented in Section 3.2 of Method 205 were followed prior to use of gas divider. The field evaluation yielded no errors greater than 2% of the triplicate measured average and no errors greater than 2% from the expected values.

5.4 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NO_x, CO, O₂, CO₂, and SO₂ have had an interference response test performed 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, CO₂, O₂, and SO₂ 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

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particulate filter and Teflon® heated sample line) and determining the instrument response against the initial instrument calibration readings.

At the beginning of each test day, appropriate high-range, mid-range, and low-range span gases followed by a zero gas were introduced to the NMHC analyzer, in series at a tee connection, which is installed between the sample probe and the particulate filter, through a poppet check valve. After each one hour test period, mid-range and zero gases were re-introduced in series at the tee connection in the sampling system to check against the method's performance specifications for calibration drift and zero drift error.

The instruments were calibrated with USEPA Protocol 1 certified concentrations of CO₂, O₂, NO_x, CO, and SO₂ in nitrogen or air and zeroed using hydrocarbon-free nitrogen or air. 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 stack indicated that the measured CO, O₂ and CO₂ concentrations did not vary by more than 5% of the mean across the stack diameter. Therefore, the RICE exhaust gas was considered to be unstratified and the compliance test sampling was performed at a single sampling location within each RICE exhaust stack.

5.7 Meter Box Calibrations

The dry gas metering 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 (NO₂ – 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

6.2 Test Results and Allowable Emission Limits

Engine operating data and air pollutant emission measurement results for each one hour test period are presented in Tables 6.1 and 6.2.

The measured air pollutant emission rates for Engine No. 3 are less than the allowable limits specified in ROP No. MI-ROP-N5987-2015 for Emission Unit No. EUENGINE3:

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

The measured air pollutant emission rates for Engine No. 6 are less than the allowable limits specified in PTI No. 78-16 for Emission Unit No. EUENGINE6:

- 4.94 lb/hr and 2.0 g/bhp-hr for NO_x;
- 16.3 lb/hr and 5.0 g/bhp-hr for CO;
- 4.94 lb/hr and 1.0 g/bhp-hr for VOC;
- 7.73 lb/hr for SO₂; and
- 2.1 lb/hr for HCOH.

6.3 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. Each RICE generator set was operated within 10% of maximum output (1,600 kW generator output) during the engine test periods.

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Table 6.1 Measured exhaust gas conditions and NO_x, CO, and VOC air pollutant emission rates
Granger Brent Run Facility Engine No. 3 (EUENGINE3)

Test No.	1	2	3	Three Test
Test date	12/8/16	12/8/16	12/8/16	Average
Test period (24-hr clock)	1207 - 1307	1331 - 1431	1452 - 1552	
Fuel flowrate (scfm)	522	526	526	525
Generator output (kW)	1,633	1,629	1,624	1,629
Engine output (bhp)	2,281	2,276	2,268	2,275
LFG methane content (%)	54.6	54.7	54.6	54.6
LFG heat content (Btu/scf)	497	498	497	497
<u>Exhaust Gas Composition</u>				
CO ₂ content (% vol)	11.0	11.0	11.0	11.0
O ₂ content (% vol)	8.86	8.91	8.91	8.89
Moisture (% vol)	11.4	10.9	11.2	11.2
Exhaust gas temperature (°F)	830	830	830	830
Exhaust gas flowrate (dscfm)	4,366	4,368	4,355	4,363
Exhaust gas flowrate (scfm)	4,912	4,909	4,905	4,909
<u>Nitrogen Oxides</u>				
NO _x conc. (ppmvd)	95.0	96.9	95.9	95.9
NO _x emissions (lb/hr)	2.97	3.03	2.99	3.00
Permitted emissions (lb/hr)	-	-	-	4.94
NO _x emissions (g/bhp*hr)	0.59	0.60	0.60	0.60
Permitted emissions (g/bhp*hr)	-	-	-	1.0
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	724	723	718	722
CO emissions (lb/hr)	13.8	13.8	13.7	13.7
Permitted emissions (lb/hr)	-	-	-	16.3
CO emissions (g/bhp*hr)	2.74	2.75	2.73	2.74
Permitted emissions (g/bhp*hr)	-	-	-	3.3
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv as C ₃) ¹	18.9	18.7	18.8	18.8
VOC emissions (lb/hr)	0.64	0.63	0.63	0.63
VOC emissions (g/bhp*hr)	0.13	0.13	0.13	0.13
Permitted emissions (g/bhp*hr)	-	-	-	1.0

1. VOC measured as nonmethane hydrocarbons.

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Table 6.2 Measured exhaust gas conditions and NO_x, CO, VOC, SO₂, and HCOH air pollutant emission rates Granger Brent Run Facility Engine No. 6 (EUENGINE6)

Test No.	1	2	3	Three Test
Test date	12/8/16	12/8/16	12/8/16	Average
Test period (24-hr clock)	740 - 840	906 - 1006	1034 - 1134	
Fuel flowrate (lb/hr)	2,266	2,270	2,277	2,271
Generator output (kW)	1,624	1,631	1,637	1,631
Engine output (bhp)	2,276	2,286	2,294	2,285
LFG methane content (%)	54.7	54.6	54.4	54.6
LFG heat content (Btu/scf)	498	497	495	497
<u>Exhaust Gas Composition</u>				
CO ₂ content (% vol)	11.2	11.2	11.2	11.2
O ₂ content (% vol)	8.63	8.62	8.63	8.62
Moisture (% vol)	11.5	11.5	11.5	11.5
Exhaust gas temperature (°F)	829	826	825	827
Exhaust gas flowrate (dscfm)	4,320	4,283	4,270	4,291
Exhaust gas flowrate (scfm)	4,882	4,840	4,825	4,849
<u>Nitrogen Oxides</u>				
NO _x conc. (ppmvd)	90.4	89.9	91.1	90.5
NO _x emissions (lb/hr)	2.80	2.76	2.79	2.78
Permitted emissions (lb/hr)	-	-	-	4.94
NO _x emissions (g/bhp*hr)	0.56	0.55	0.55	0.55
Permitted emissions (g/bhp*hr)	-	-	-	2.0
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	620	621	624	622
CO emissions (lb/hr)	11.7	11.6	11.6	11.7
Permitted emissions (lb/hr)	-	-	-	16.3
CO emissions (g/bhp*hr)	2.33	2.31	2.30	2.31
Permitted emissions (g/bhp*hr)	-	-	-	5.0
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv as C ₃) ¹	16.8	17.0	16.9	16.9
VOC emissions (lb/hr)	0.56	0.57	0.56	0.56
Permitted emissions (lb/hr)	-	-	-	4.94
VOC emissions (g/bhp*hr)	0.11	0.11	0.11	0.11
Permitted emissions (g/bhp*hr)	-	-	-	1.0

1. VOC measured as nonmethane hydrocarbons. Does not include formaldehyde.

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Table 6.2 Measured exhaust gas conditions and NO_x, CO, VOC, SO₂, and HCOH air pollutant emission rates Granger Brent Run Facility Engine No. 6 (EUENGINE6) [Continued]

Test No.	1	2	3	
Test date	12/8/16	12/8/16	12/8/16	Three Test
Test period (24-hr clock)	740 - 840	906 - 1006	1034 - 1134	Average
Fuel flowrate (lb/hr)	2,266	2,270	2,277	2,271
Generator output (kW)	1,624	1,631	1,637	1,631
Engine output (bhp)	2,276	2,286	2,294	2,285
LFG methane content (%)	54.7	54.6	54.4	54.6
LFG heat content (Btu/scf)	498	497	495	497
<u>Exhaust Gas Composition</u>				
CO ₂ content (% vol)	11.2	11.2	11.2	11.2
O ₂ content (% vol)	8.63	8.62	8.63	8.62
Moisture (% vol)	11.5	11.5	11.5	11.5
Exhaust gas temperature (°F)	829	826	825	827
Exhaust gas flowrate (dscfm)	4,320	4,283	4,270	4,291
Exhaust gas flowrate (scfm)	4,882	4,840	4,825	4,849
<u>Sulfur Dioxide</u>				
SO ₂ conc. (ppmvd)	97.4	102	104	101
SO ₂ emissions (lb/hr)	4.20	4.36	4.43	4.33
Permitted emissions (lb/hr)	-	-	-	7.73
SO ₂ emissions (g/bhp*hr)	0.84	0.86	0.88	0.86
<u>Formaldehyde</u>				
HCOH conc. (ppmv)	78.0	77.7	77.6	77.8
HCOH emissions (lb/hr)	1.78	1.76	1.75	1.76
Permitted emissions (lb/hr)	-	-	-	2.1
HCOH emissions (g/bhp*hr)	0.36	0.35	0.35	0.35