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Executive Summary

GRANGER ELECTRIC OF PINCONNING, LLC
CAT® G3520C LANDFILL GAS FUELED IC ENGINES EMISSIONS RESULTS

Granger Energy and Electric contracted Derenzo and Associates, Inc., to conduct a performance demonstration for the determination of nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOC) concentrations and emission rates from two (2) Caterpillar (CAT®) Model No. G3520C landfill gas-fired reciprocating internal combustion engines and electricity generator sets operated at the Granger Electrical Generation Station located in Pinconning, Bay County.

Michigan Department of Environmental Quality (MDEQ) Air Quality Division (AQD) Renewable Operating Permit (ROP) No. MI-ROP-N5985-2013 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). The annual performance testing was conducted on April 3, 2014.

The following table presents the emissions results from the performance demonstration.

Emission Unit Identification	NOx Emission Rate (lbs/hr)	NOx Emission Factor (g/bhp-hr)	CO Emission Rate (lbs/hr)	CO Emission Factor (g/bhp-hr)	VOC Emission Rate (lbs/hr)	VOC Emission Factor (g/bhp-hr)
EUICEENGINE1	2.93	0.61	14.25	2.98	0.84	0.20
EUICEENGINE2	3.16	0.66	13.68	2.87	0.75	0.16
Permit Limits	4.92	1.00	16.23	3.3	-	1.0

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

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

Emission Unit Identification	Fuel Usage (scfm)	Fuel Quality (Btu/scf)	Electricity Generation (kW)	Engine Output (bHp-hr)	Exhaust Flowrate (scfm)	Exhaust Flowrate (dscfm)
EUICEENGINE1	509	451	1,546	2,167	4,866	4,358
EUICEENGINE2	500	466	1,542	2,161	4,767	4,234

scfm=standard cubic feet per minute, Btu/scf= British thermal unit per standard cubic foot, kW=kilowatt, bHp-hr=brake horse power hour, dscfm=dry standard cubic feet per minute

The data above indicates EUICEENGINE1 and EUICEENGINE2 operated at normal base load conditions during the performance demonstration and are in compliance with the emission standards presented in 40 CFR 60.4233(e) and MDEQ-AQD Permit to Install (PTI) No. 130-08A.

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AIR EMISSIONS TEST REPORT

Title	Compliance Emissions Testing Report for the Landfill Gas Fueled, Internal Combustion Engines, Operated at the Granger Electric of Pinconning, LLC Facility – Pinconning, Michigan
Report Date	May 16, 2014
Test Dates	April 3, 2014

Facility Information	
Name	Granger Electric of Pinconning, LLC
Street Address	2401 East Whitefeather Road
City, County, Zip	Pinconning, MI 48650

Facility Permit Information	
Facility SRN: N5985	ROP No.: MI-ROP-N5985-2013

Testing Contractor	
Company	Derenzo and Associates, Inc.
Mailing Address	39395 Schoolcraft Road Livonia, MI 48150
Phone	(734) 464-3880
Project No.	1310010

2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

Landfill gas (LFG) is produced at the Pinconning 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 that are connected to a central header (gas collection system). The collected LFG is treated and then directed to the Granger Electrical Generation Station where it is used as fuel for the IC engine generator that produce electricity for transfer to the local utility.

2.2 Rated Capacities and Air Emission Controls

The two (2) CAT® Model No. G3520C RICE each has a rated output of 2,242 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., 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 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 exhaust stack sampling port for the Model G3520C IC engines tested satisfied the USEPA Method 1 criteria for a representative sample location. The inner diameter of each engine exhaust stack is 13.5 inches. Each stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location >25 feet (>21.4 duct diameters) downstream and 126 inches (9 duct diameters) upstream from any flow disturbance.

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

Appendix A 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

Compliance testing for FGICENGINES is required by MI-ROP-N5985-2013 and 40 CFR Part 60 Subpart JJJJ initially and every 8,760 hours of operation (as determined through the use of a non-resettable hour meter) or three years, whichever occurs first. This compliance demonstration satisfied the subsequent annual performance testing.

The exhaust from each LFG-fueled IC engine was monitored for three (3) one-hour test periods during which the NOx, CO, VOC, O_2, and CO_2 concentrations were measured using instrumental analyzers.

Exhaust gas moisture content was determined by gravimetric analysis of the weight gain in chilled impingers in accordance with USEPA Method 4. Velocity and volumetric flow rates were measured during pre-test and post-test times for the gaseous samples in accordance with USEPA Method 2.

3.2 Operating Conditions During the Compliance Tests

The LFG-fueled IC engines were operated at base conditions load (within +/-10% of maximum design capacity) during the compliance testing. The average electricity generator output and fuel use values were recorded by the facility during each test event. Based on data provided by the facility operators, EUICEENGINE1 operated at an average electricity generation rate of 1,546 kW during the test periods and consumed an average of 510.3 scfm of treated. EUICEENGINE2 operated at an average electricity generation rate of 1,542 kW during the test periods and consumed an average of 500.2 scfm of treated LFG.

Appendix B 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 (95.7%), and the unit conversion factor for kW to horsepower (0.7457 kW/hp).

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

A lower heating value of 910 Btu/scf 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's were each sampled for three (3) one-hour test periods during the compliance testing performed April 3, 2014.

Table 3.2 presents the average measured CO, NOx, and VOC 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	EUICEENGINE1	EUICEENGINE2
Generator output (kW)	1,546	1,542
Engine output (bhp)	2,167	2,161
Engine LFG fuel use (scfm)	510.3	500.2
LFG methane content (%)	49.5	51.2
LFG lower heating value (Btu)	450.5	465.9
Exhaust temperature (°F)	763	778

Table 3.2 Average measured emission rates for the Granger Pinconning facility RICE's (three-test averages)

	CO Emission Rates		NOx Emission Rates		VOC Emission Rates	
Emission Unit	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)
EUICEENGINE1	14.25	2.98	2.93	0.61	0.93	0.20
EUICEENGINE2	13.68	2.87	3.16	0.66	0.75	0.16

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 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 NOx concentration was determined using chemiluminescence instrumental analyzers.
USEPA Method 10	Exhaust gas CO concentration was measured using NDIR instrumental analyzers.
USEPA Method ALT-096	Exhaust gas VOC (as NMHC) concentration was determined using flame ionization analyzers equipped with GC columns.

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

Each RICE exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 prior to and after each 60-minute 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 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 C provides exhaust gas flowrate calculations and field data sheets.

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

CO_2 and O_2 content in each RICE exhaust gas stream 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 4900 single beam single wavelength (SBSW) infrared gas analyzer. The O_2 content of the exhaust was monitored using a Servomex 4900 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 and heated stainless steel filter. 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 5.5 of this document). Sampling times were recorded on field data sheets.

Appendix D provides O_2 and CO_2 calculation sheets. Raw instrument response data are provided in Appendix E.

4.4 Exhaust Gas Moisture Content (USEPA Method 4)

Moisture content of each RICE exhaust 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 NOx and CO Concentration Measurements (USEPA Methods 7E and 10)

NOx and CO pollutant concentrations in the RICE exhaust gas streams were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42c High Level chemiluminescence NOx analyzer and a FUJI Model ZRF Non-Dispersive Infrared (NDIR) Gas CO analyzer.

Throughout each test period, a continuous sample of the engine exhaust gas was extracted from the stack using the stainless steel probe, Teflon® heated sample line, heated stainless steel filter 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 D provides CO and NOx calculation sheets. Raw instrument response data are provided in Appendix E.

4.6 Measurement of Volatile Organic Compounds (USEPA Method ALT-096)

VOC emission rate was determined by measuring the nonmethane hydrocarbon (NMHC) concentration in the exhaust gas for each RICE. NMHC pollutant concentration was determined using TEI Model 55i Methane / Nonmethane hydrocarbon analyzer.

Throughout each one-hour test period, a continuous sample of the IC engine exhaust gas was extracted from the stack using the system described in Section 4.3 of this document, and delivered to the instrumental analyzer. The sampled gas was not conditioned prior to being introduced to the analyzer; therefore, the measurement of NMHC concentration corresponds to standard wet gas conditions. Instrument NMHC (VOC) response for the analyzer was recorded on an ESC Model 8816 data logging 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 instrument was calibrated using mid-range calibration and zero gas to determine analyzer calibration error and system bias (described in Section 5.5 of this document).

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

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 2.0% of the expected value, i.e., within 10% 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.

The TEI Model 42c analyzer exhibited the longest system response time at 120 seconds. 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 (on July 11, 2013) 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 NOx, CO, O_2 and CO_2 have had an interference response test preformed prior to their use in the field (July 26, 2006, June 21, 2011 and April 3, 2012), 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 3.0% 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 NOx, 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, NOx, 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 Meter Box Calibrations

The Clean Air Express Model #0028 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 Clean Air metering console was calibrated using a NIST traceable Omega® Model CL 23A temperature calibrator.

Appendix F 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, cyclonic flow determinations sheets, Pitot tube and probe assembly calibration records).

6.0 RESULTS

6.1 Test Results and Allowable Emission Limits

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

The measured air pollutant concentrations and emission rates for EUICEENGINE1 and EUICEENGINE2 are less than the allowable limits specified in MI-ROP-N5985-2013.

- 4.92 lb/hr and 1.0 g/bhp-hr for NOx;
- 16.23 lb/hr and 3.3 g/bhp-hr for CO; 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 the approved test protocols. The engine-generator sets were operated within 10% of maximum output (1,600 kW generator output) and no variations from the normal operating conditions of the RICE occurred during the engine test periods.

Table 6.1 Measured exhaust gas conditions and NOx, CO and VOC air pollutant emission rates Granger-Pinconning Facility EUICEENGINE1

Test No. Test date Test period (24-hr clock)	1 4/3/14 8:40-9:40	2 4/3/14 10:15-11:15	3 4/3/14 11:46-12:46	Three Test Average
Fuel flowrate (scfm)	520	505	506	509
Generator output (kW)	1,545	1,548	1,546	1,546
Engine output (bhp)	2,165	2,169	2,166	2,167
LFG methane content (%)	49.0	49.6	50.0	53.1
LFG heat content (Btu/scf)	446	451	455	451
Exhaust Gas Composition				
CO_2 content (% vol)	10.7	10.6	10.6	10.6
O_2 content (% vol)	9.00	8.94	8.95	8.96
Moisture (% vol)	9.8	10.7	10.8	10.4
Exhaust gas temperature (°F)	769	764	758	763
Exhaust gas flowrate (dscfm)	4,378	4,360	4,337	4,358
Exhaust gas flowrate (scfm)	4,853	4,881	4,863	4,866
Nitrogen Oxides				
NO_X concentration (ppmvd)	97.8	90.9	92.3	93.7
NO_X emissions (g/bhp*hr)	0.64	0.59	0.60	0.61
Permitted emissions (g/bhp*hr)	-	-	-	1.0
NO_X emissions (lb/hr)	3.07	2.84	2.87	2.93
Permitted emissions (lb/hr)	-	-	-	4.92
Carbon Monoxide				
CO concentration (ppmvd)	745.8	744.6	757.4	749.2
CO emissions (g/bhp*hr)	2.99	2.96	3.00	2.98
Permitted emissions (g/bhp*hr)	-	-	-	3.30
CO emissions (lb/hr)	14.25	14.17	14.34	14.25
Permitted emissions (lb/hr)	-	-	-	16.23
Volatile Organic Compounds				
VOC concentration (ppmv)	27.7	27.9	28.1	27.9
VOC emissions (g/bhp*hr)	0.19	0.20	0.20	0.20
Permitted emissions (g/bhp*hr)	-	-	-	0.65
VOC emissions (lb/hr)	0.92	0.93	0.94	0.84

Table 6.2 Measured exhaust gas conditions and NOx, CO and VOC air pollutant emission rates
Granger-Pinconning Facility EUICEENGINE2

Test No.	1	2	3	Three Test Average
Test date	4/3/14	4/3/14	4/3/14	
Test period (24-hr clock)	14:10-15:10	15:50-16:50	17:24-18:24	
Fuel flowrate (scfm)	502	498	500	500
Generator output (kW)	1,535	1,539	1,553	1,542
Engine output (bhp)	2,152	2,157	2,176	2,161
LFG methane content (%)	50.4	51.3	51.8	51.2
LFG heat content (Btu/scf)	459	467	472	466
Exhaust Gas Composition				
CO_2 content (% vol)	10.8	10.9	10.8	10.8
O_2 content (% vol)	8.65	8.67	8.68	8.67
Moisture (% vol)	11.4	11.1	11.1	11.2
Exhaust gas temperature (°F)	776	783	776	778
Exhaust gas flowrate (dscfm)	4,225	4,232	4,244	4,234
Exhaust gas flowrate (scfm)	4,766	4,760	4,774	4,767
Nitrogen Oxides				
NO_X concentration (ppmvd)	101.5	107.8	102.9	104.1
NO_X emissions (g/bhp*hr)	0.65	0.69	0.65	0.66
Permitted emissions (g/bhp*hr)	-	-	-	1.0
NO_X emissions (lb/hr)	3.07	3.27	3.13	3.16
Permitted emissions (lb/hr)	-	-	-	4.92
Carbon Monoxide				
CO concentration (ppmvd)	738.4	741.1	740.3	740.0
CO emissions (g/bhp*hr)	2.87	2.88	2.86	2.87
Permitted emissions (g/bhp*hr)	-	-	-	3.30
CO emissions (lb/hr)	13.62	13.69	13.72	13.68
Permitted emissions (lb/hr)	-	-	-	16.23
Volatile Organic Compounds				
VOC concentration (ppmv)	23.1	22.9	23.1	23.0
VOC emissions (g/bhp*hr)	0.16	0.16	0.16	0.16
Permitted emissions (g/bhp*hr)	-	-	-	0.65
VOC emissions (lb/hr)	0.76	0.75	0.76	0.75