1.0 Introduction

The City of Midland owns and operates gas-fired reciprocating internal combustion engine (RICE) and electricity generator sets at the City of Midland Wastewater Treatment Plant (WWTP) located in Midland, Midland County, Michigan. The RICE are fueled by landfill gas (LFG) that is recovered from the City of Midland Landfill, and Digester Gas from the WWTP. The gas is treated prior to use.

The State of Michigan Department of Environment, Great Lakes, and Energy-Air Quality Division (EGLE-AQD) has issued EDL Renewable Operating Permit (ROP) No. MI-ROP-N6004-2019 for the operation of the renewable electricity generation facility, which consists of:

- Two (2) Caterpillar (CAT®) Model No. G3520C RICE gensets identified as emission units EUENGINE1 and EUENGINE2.

Air emission compliance testing was performed pursuant to MI-ROP-N6004-2019. Conditions of N6004-2019 state:

> *… the permittee shall conduct an initial performance test for EUICENGINE1 and EUICENGINE2 within one year after startup of the engine and every 8760 hours of operation … to demonstrate compliance with the emission limits in 40 CFR 60.4233(e) … If a performance test is required, the performance test shall be conducted according to 40 CFR 60.4244.*

The compliance testing presented in this report was performed by Impact Compliance & Testing, Inc. (ICT), a Michigan-based environmental consulting and testing company. ICT representatives Blake Beddow and Clay Gaffey performed the field sampling and measurements February 16, 2021.

The engine emission performance tests consisted of triplicate, one-hour sampling periods for nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOC, as non-methane hydrocarbons (NMHC or NMOC)). Exhaust gas velocity, moisture, oxygen (O_2) content, and carbon dioxide (CO_2) content were determined for each test period to calculate pollutant mass emission rates.

The exhaust gas sampling and analysis was performed using procedures specified in the Stack Test Protocol dated November 24, 2020 that was reviewed and approved by EGLE-AQD.

Questions regarding this air emission test report should be directed to:

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2.0 Summary of Test Results and Operating Conditions

2.1 Purpose and Objective of the Tests

Conditions of ROP No. MI-ROP-N6004-2019 and 40 CFR Part 60, Subpart JJJJ, Standards of Performance for New Stationary Sources for Stationary Spark Ignition Internal Combustion Engines require the City of Midland to test each engine for CO, NOx, and VOC emissions. Engine Nos. 1 and 2 (Emission Units EUENGINE1 and EUENGINE2) were tested during this compliance test event.

2.2 Operating Conditions During the Compliance Tests

The testing was performed while the City of Midland engine/generator sets were operated at maximum operating conditions (within 10% of 1,600-kilowatt (kW) electricity output). City of Midland representatives provided kW output in 15-minute increments for each test period.

Digester gas and LFG fuel flowrate (standard cubic feet per minute (scfm)), fuel methane content (%), and air-to-fuel ratio were also recorded by City of Midland representatives in 15-minute increments for each test period.

Appendix 2 provides operating records provided by City of Midland representatives for the test periods.

Average output, fuel consumption, fuel methane content, and air-to-fuel ratio for each RICE is presented in Table 2.1 and Tables 6.1-6.2.

2.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the RICE (Engine Nos. 1 & 2) were each sampled for three (3) one-hour test periods during the compliance testing performed February 16, 2021.

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

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

Table 2.1 Average engine operating conditions during the test periods

Engine Parameter	EUENGINE1 CAT® G3520C	EUENGINE2 CAT® G3520C
Generator output (kW)	1,577	1,548
Engine output (bhp)	2,202	2,163
Engine LFG fuel use (scfm)	499	485
Digester gas fuel use (scfm)	36.1	35.4
LFG methane content (%)	56.6	56.3
Exhaust temperature (°F)	917	918
Air-to-Fuel Ratio	8.7	8.7

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

Emission Unit	CO Emissions		NOx Emissions		VOC Emissions	
	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)
EUENGINE1	12.7	2.62	3.15	0.68	0.46	0.09
EUENGINE2	11.2	2.35	3.34	0.70	0.43	0.09
Permit Limit	-	***4.2***	-	***1.0***	-	***1.0***

3.0 Source and Sampling Location Description

3.1 General Process Description

Gas containing methane is produced in the City of Midland WWTP and City of Midland Landfill from the anaerobic decomposition of waste materials. The gas is collected and directed to the City of Midland gas-to-energy facility where it is used as fuel for the RICE generators that produce electricity.

The gas-to-energy facility primarily consists of gas treatment equipment and two (2) CAT® Model No. G3520C RICE that are connected to individual electricity generators.

3.2 Rated Capacities and Air Emission Controls

The CAT® G3520C engine generator sets each have a rated design capacity of:

- Engine Power: 2,233 brake horsepower (bhp)
- Electricity Generation: 1,600 kW

Each engine is equipped with an air-to-fuel ratio (AFR) controller that automatically blends the appropriate ratio of combustion air and treated LFG fuel.

The RICE are not equipped with add-on emission control devices. The AFR controller maintains efficient fuel combustion, which minimizes air pollutant emissions. Exhaust gas is exhausted directly to atmosphere through noise mufflers and vertical exhaust stacks.

3.3 Sampling Locations

Each RICE exhaust gas is directed through a muffler and is released to the atmosphere through a dedicated vertical exhaust stack with a vertical release point.

The exhaust stacks for Engine Nos. 1 & 2 / EUENGINE1 & EUENGINE2 are identical with a 15.5 inch duct diameter. The ports are located upstream of the engine muffler in a horizontal section of the exhaust pipe. Each stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 52 inches (3.35 duct diameters) upstream and 60 inches (3.87 duct diameters) downstream from any flow disturbance.

All sample port locations satisfy the USEPA Method 1 criteria for a representative sample location. Individual traverse points were determined in accordance with USEPA Method 1.

Appendix 1 provides a diagram of the emission test sampling locations with actual stack dimension measurements.

4.0 Sampling and Analytical Procedures

A Stack Test Protocol for the air emission testing was reviewed and approved by EGLE-AQD. This section provides a summary of the sampling and analytical procedures that were used during the testing periods.

4.1 Summary of Sampling Methods

USEPA Method 1	Exhaust gas velocity measurement locations were determined based on the physical stack arrangement and requirements in USEPA Method 1.
USEPA Method 2	Exhaust gas velocity pressure was determined using a Type-S Pitot tube connected to a red oil incline manometer; temperature was measured using a K-type thermocouple connected to the Pitot tube.
USEPA Method 3A	Exhaust gas O_2 and CO_2 content was determined using paramagnetic and infrared instrumental analyzers, respectively.
USEPA Method 4	Exhaust gas moisture was determined based on the water weight gain in chilled impingers.
0USEPA Method 7E	Exhaust gas NOx concentration was determined using chemiluminescence instrumental analyzers.
USEPA Method 10	Exhaust gas CO concentration was measured using an infrared instrumental analyzer.
USEPA Method 25A / ALT-096	Exhaust gas VOC (as NMHC) concentration was determined using a flame ionization analyzer equipped with methane separation column.

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

The RICE exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 for each test period. An S-type Pitot tube connected to a red-oil manometer was used to determine velocity pressure at each traverse point across the stack cross section. Gas temperature was measured using a K-type thermocouple mounted to the Pitot tube. The Pitot tube and connective tubing were leak-checked periodically throughout the test periods to verify the integrity of the measurement system.

The absence of significant cyclonic flow at the sampling location was verified using an S-type Pitot tube and oil manometer. The Pitot tube was positioned at each velocity traverse point with the planes of the face openings of the Pitot tube perpendicular to the stack cross-sectional plane. The Pitot tube was then rotated to determine the null angle (rotational angle as measured from the perpendicular, or reference, position at which the differential pressure is equal to zero).

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

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

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

During each sampling period, a continuous sample of the RICE exhaust gas stream was extracted from the stack using a stainless-steel probe connected to a Teflon® heated sample line. The sampled gas was conditioned by removing moisture prior to being introduced to the analyzers; therefore, measurement of O_2 and CO_2 concentrations correspond to standard dry gas conditions. Instrument response data were recorded using an ESC Model 8816 data acquisition system that monitored the analog output of the instrumental analyzers continuously and logged data as one-minute averages.

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

Appendix 4 provides O_2 and CO_2 calculation sheets. Raw instrument response data are provided in Appendix 5.

4.4 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. Exhaust gas moisture content measurements were performed concurrently with the instrumental analyzer sampling periods. 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 RICE exhaust gas streams were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42i High Level chemiluminescence NO_X analyzer and a Fuji ZRF 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 VOC (USEPA Method 25A/ALT-096)

The VOC emission rate was determined by measuring the nonmethane hydrocarbon (NMHC or NMOC) concentration in the engine exhaust gas. NMHC pollutant concentration was determined using a TEI Model 55i Methane / Nonmethane hydrocarbon analyzer. The TEI 55i analyzer contains an internal gas chromatograph column that separates methane from non-methane components. The concentration of NMHC in the sampled gas stream, after separation from methane, is determined relative to a propane standard using a flame ionization detector in accordance with USEPA Method 25A.

The USEPA Office of Air Quality Planning and Standards (OAQPS) has issued an alternate test method approving the use of the TEI 55i-series analyzer as an effective instrument for measuring NMOC from gas-fueled RICE (ALT-096).

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

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

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

5.0 QA/QC Activities

5.1 Flow Measurement Equipment

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

The absence of cyclonic flow for each sampling location was verified using an S-type Pitot tube and oil manometer. The Pitot tube was positioned at each of the velocity traverse points 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 NO_2 – NO conversion efficiency of the Model 42i analyzer was verified prior to the testing program. A USEPA Protocol 1 certified concentration of NO_2 was injected directly into the analyzer, following the initial three-point calibration, to verify the analyzer's conversion efficiency. The analyzer's NO_2 – NO converter uses a catalyst at high temperatures to convert the NO_2 to NO for measurement. The conversion efficiency of the 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 99.1% of the expected value).

5.3 Gas Divider Certification (USEPA Method 205)

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

5.4 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NO_X, CO, O_2, and CO_2 have had an interference response test preformed prior to their use in the field, pursuant to the interference response test procedures specified in USEPA Method 7E. The appropriate interference test gases (i.e., gases that would be encountered in the exhaust gas stream) were introduced into each analyzer, separately and as a mixture with the analyte that each analyzer is designed to measure. All of analyzers exhibited a composite deviation of less than 2.5% of the span for all measured interferent gases. No major analytical components of the analyzers have been replaced since performing the original interference tests.

5.5 Instrument Calibration and System Bias Checks

At the beginning of each day of the testing program, initial three-point instrument calibrations were performed for the NO_x, CO, CO_2, and O_2 analyzers by injecting calibration gas directly into the inlet sample port for each instrument. System bias checks were performed prior to and at the conclusion of each sampling period by introducing the upscale calibration gas and zero gas into the sampling system (at the base of the stainless-steel sampling probe prior to the particulate filter and Teflon® heated sample line) and determining the instrument response against the initial instrument calibration readings.

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

The instruments were calibrated with USEPA Protocol 1 certified concentrations of CO_2, O_2, NO_x, and CO in nitrogen and zeroed using hydrocarbon free nitrogen. The NMHC (VOC) instrument was calibrated with USEPA Protocol 1 certified concentrations of propane in air and zeroed using hydrocarbon-free air. A STEC Model SGD-710C ten-step gas divider was used to obtain intermediate calibration gas concentrations as needed.

5.6 Determination of Exhaust Gas Stratification

A stratification test was performed for each RICE exhaust stack. The stainless-steel sample probe was positioned at sample points correlating to 16.7, 50.0 (centroid), and 83.3% of the stack diameter. Pollutant concentration data were recorded at each sample point for a minimum of twice the maximum system response time.

The recorded concentration data for the RICE exhaust stacks indicated that the measured CO concentration 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 System Response Time

The response time of the sampling system was determined prior to the compliance test program by introducing upscale gas and zero gas, in series, into the sampling system using a tee connection at the base of the sample probe. The elapsed time for the analyzer to display a reading of 95% of the expected concentration was determined using a stopwatch.

Sampling periods did not commence until the sampling probe had been in place for at least twice the greatest system response time.

5.8 Meter Box Calibrations

The dry gas meter sampling console used for moisture testing was calibrated prior to and after the testing program. This calibration uses the critical orifice calibration technique presented in USEPA Method 5. The metering console calibration exhibited no data outside the acceptable ranges presented in USEPA Method 5.

The digital pyrometer in the metering console was calibrated using a NIST traceable Omega® Model CL 23A temperature calibrator.

Appendix E presents test equipment quality assurance data (NO_2 – NO conversion efficiency test data, instrument calibration and system bias check records, calibration gas certifications, interference test results, meter box calibration records, and field equipment calibration records).

6.0 Results

6.1 Test Results and Allowable Emission Limits

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

EUENGINE1 and EUENGINE2 each have the following allowable emission limits specified in MI-ROP-N6004-2019:

- 4.2 grams per brake horsepower hour (g/bhp-hr) for CO;
- 1.0 g/bhp-hr for NO_X; 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 Stack Test Protocol. The RICE-generator sets were operated within 10% of maximum output (1,600 kW generator output for CAT® G3520C RICE) and no variations from normal operating conditions occurred during the engine test periods.

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

Test No. Test date Test period (24-hr clock)	1 2/16/2021 0728-0828	2 2/16/2021 0843-0943	3 2/16/2021 0957-1057	Three Test Average
LFG flowrate (scfm)	500	500	496	499
Digester gas flowrate (scfm)	35.7	36.3	36.2	36.1
Generator output (kW)	1,578	1,589	1,563	1,577
Engine output (bhp)	2,204	2,220	2,183	2,202
LFG methane content (%)	56.8	56.5	56.5	56.6
Air-to-fuel ratio	8.7	8.6	8.7	8.7
Exhaust Gas Composition				
CO_2 content (% vol)	11.3	11.4	11.3	11.4
O_2 content (% vol)	8.46	8.43	8.44	8.44
Moisture (% vol)	6.44	10.7	10.9	9.35
Exhaust gas temperature (^oF)	909	921	921	917
Exhaust gas flowrate (dscfm)	4,501	4,152	4,432	4,362
Exhaust gas flowrate (scfm)	4,811	4,650	4,972	4,811
Nitrogen Oxides				
NO_X conc. (ppmvd)	99.0	101	102	101
NO_X emissions (lb/hr)	3.19	3.00	3.25	3.15
NO_X emissions (g/bhp*hr)	0.66	0.61	0.68	0.65
*Permit limit (g/bhp*hr)*	-	-	-	*1.0*
Carbon Monoxide				
CO conc. (ppmvd)	674	667	663	668
CO emissions (lb/hr)	13.2	12.1	12.8	12.7
CO emissions (g/bhp*hr)	2.72	2.47	2.67	2.62
*Permit limit (g/bhp*hr)*	-	-	-	*4.2*
Volatile Organic Compounds				
VOC conc. (ppmv C_3)	13.2	14.0	14.3	13.8
VOC emissions (lb/hr)	0.44	0.45	0.49	0.46
VOC emissions (g/bhp*hr)	0.09	0.09	0.10	0.09
*Permit limit (g/bhp*hr)*	-	-	-	*1.0*

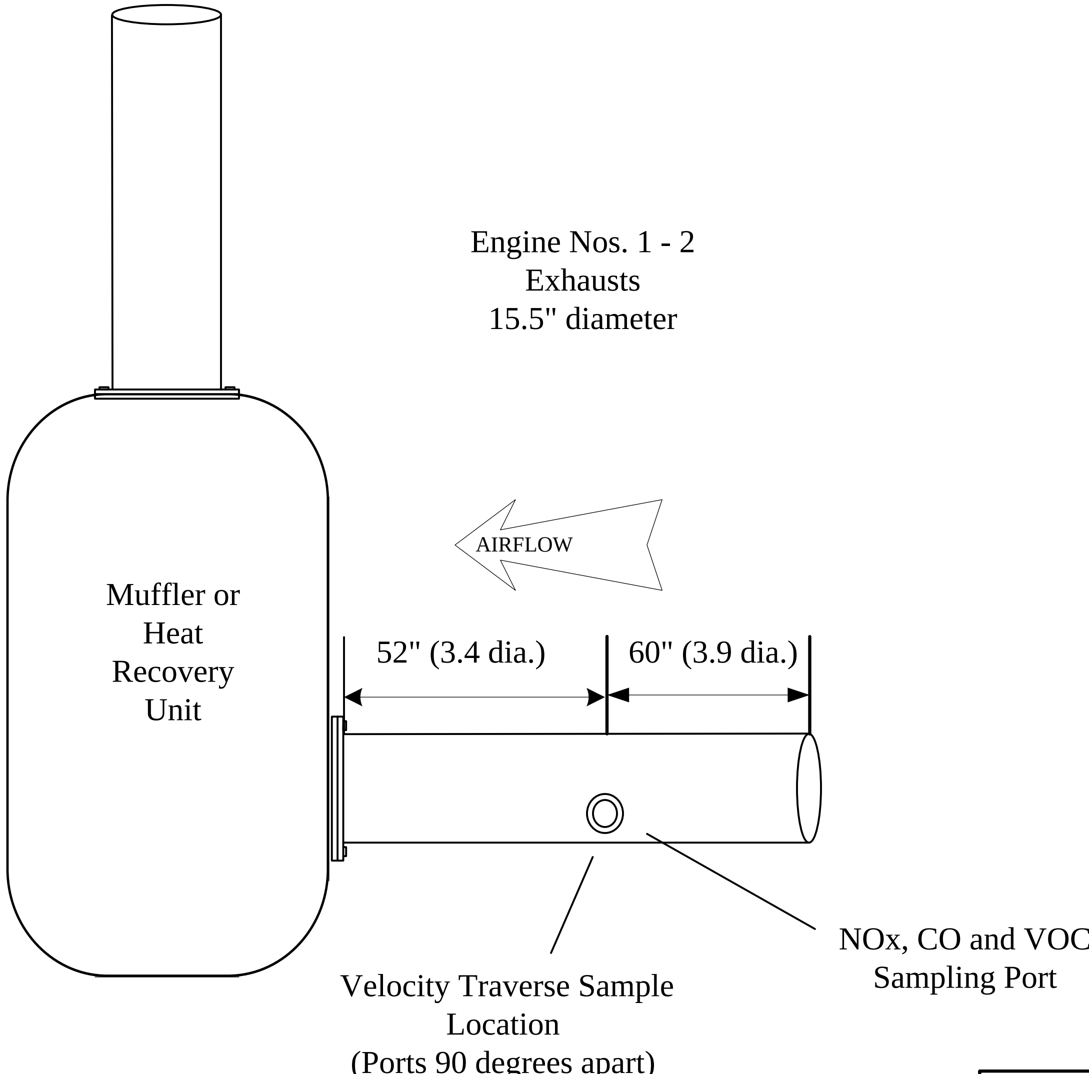
Table 6.2 Measured exhaust gas conditions and NOx, CO, and VOC air pollutant emission rates for Engine No. 2 (EUENGINE2)

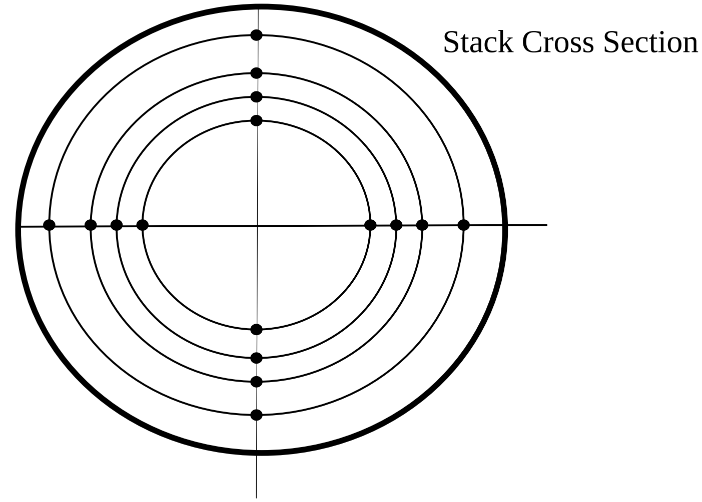
Test No. Test date Test period (24-hr clock)	1 2/16/2021 1120-1220	2 2/16/2021 1235-1335	3 2/16/2021 1347-1447	Three Test Average
LFG flowrate (scfm)	482	484	489	485
Digester gas flowrate (scfm)	35.9	35.4	35.0	35.4
Generator output (kW)	1,540	1,541	1,564	1,548
Engine output (bhp)	2,151	2,153	2,185	2,163
LFG methane content (%)	56.4	56.3	56.3	56.3
Air-to-fuel ratio	8.7	8.7	8.7	8.7
Exhaust Gas Composition				
CO_2 content (% vol)	11.5	11.5	10.1	11.0
O_2 content (% vol)	8.32	8.33	8.89	8.51
Moisture (% vol)	11.0	10.3	9.67	10.3
Exhaust gas temperature (°F)	891	930	933	918
Exhaust gas flowrate (dscfm)	4,354	4,384	4,317	4,352
Exhaust gas flowrate (scfm)	4,891	4,888	4,780	4,853
Nitrogen Oxides				
NO_X conc. (ppmvd)	112	110	98.3	107
NO_X emissions (lb/hr)	3.50	3.46	3.04	3.34
NO_X emissions (g/bhp*hr)	0.74	0.73	0.63	0.70
*Permit limit (g/bhp*hr)*	-	-	-	*1.0*
Carbon Monoxide				
CO conc. (ppmvd)	611	611	543	588
CO emissions (lb/hr)	11.6	11.7	10.2	11.2
CO emissions (g/bhp*hr)	2.45	2.46	2.12	2.35
*Permit limit (g/bhp*hr)*	-	-	-	*4.2*
Volatile Organic Compounds				
VOC conc. (ppmv C_3)	12.3	12.6	14.1	13.0
VOC emissions (lb/hr)	0.41	0.42	0.46	0.43
VOC emissions (g/bhp*hr)	0.09	0.09	0.10	0.09
*Permit limit (g/bhp*hr)*	-	-	-	*1.0*

APPENDIX 1

- RICE Engine Sample Port Diagram

Impact Compliance & Testing, Inc.





Velocity sample locations
(not including sampling port nipple)

1	0.50"
2	1.63"
3	3.01"
4	5.01"
5	10.5"
6	12.5"
7	13.9"
8	15.0"

7/16/15	**Midland WWTP IC Engine Nos. 1 - 2 Exhaust Sample Locations**		
	Scale None	Sheet 1 of 1	Impact Compliance Project No.1900131