AIR EMISSION TEST REPORT

Title	AIR EMISSION TEST REPORT FOR AN INTERNAL COMBUSTION ENGINE OPERATED AT THE CITY OF MIDLAND WASTEWATER TREATMENT PLANT
Report Date	July 14, 2017
Test Date	June 27, 2017

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AIR QUALITY DIVISION

Facility Information	
Name	City of Midland Wastewater Treatment Plant
Street Address	2125 Austin St.
City, County	Midland, Midland

Facility Permit Information			
Permit No.:	MI-ROP-N6004-2014	Facility SRN :	N6004

Testing Contractor	
Company	Derenzo Environmental Services
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Project No.	1706001

AIR EMISSION TEST REPORT
FOR AN
INTERNAL COMBUSTION ENGINE
OPERATED AT THE
CITY OF MIDLAND
WASTEWATER TREATMENT PLANT

1.0 INTRODUCTION

The City of Midland operates two (2) Caterpillar (CAT®) Model No. G3520C gas-fired reciprocating internal combustion (IC) engines and electricity generator sets at the City of Midland Wastewater Treatment Plant (WWTP) in Midland, Midland County, Michigan. The IC engines are fueled with digester gas produced at the treatment plant and by landfill gas (LFG) that is produced at the City of Midland Landfill. The digester gas and LFG fueled IC engine generator sets are identified as emission units EUICENGINE1 and EUICENGINE2 in Renewable Operating Permit (ROP) MI-ROP-N6004-2014 issued by the Michigan Department of Environmental Quality-Air Quality Division (MDEQ-AQD).

Compliance testing was performed to measure volatile organic compounds (VOC), nitrogen oxides (NO_x) and carbon monoxide (CO) concentrations and emission rates from EUICENGINE1 pursuant to the testing requirements specified in MI-ROP-N6004-2014. EUICENGINE2 had not reached 8,760 hours of operation (or three (3) years) since the previous emissions test and therefore did not require testing.

MI-ROP-N6004-2014 specifies that ... *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)* (40 CFR Part 60 Subpart JJJJ) ... *If a performance test is required, the performance test shall be conducted according to 40 CFR 60.4244.*

The compliance testing was performed June 27, 2017 by Derenzo Environmental Services representatives Jason Logan and Clay Gaffey. The project was coordinated by City of Midland WWTP representative Mr. Scott O'Laughlin

Ms. Karen Kajiya-Mills and Ms. Gina McCann of the MDEQ-AQD were on-site to observe portions of the compliance testing. The sampling and analysis was performed using procedures specified in the Test Plan dated June 5, 2017, and approved by MDEQ-AQD on June 7, 2017.

Questions regarding this emission test report should be directed to:

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Report Certification

I certify under penalty of law that I believe the information provided in this document is true, accurate, and complete. I am aware that there are significant civil and criminal penalties, including the possibility of fine or imprisonment or both, for knowingly submitting false, inaccurate, or incomplete information.

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Report Reviewed By:

for Andy Rusnak, QSTI
Technical Manager
Derenzo Environmental Services

Responsible Official Certification:

Scott O'Laughlin
Superintendent
City of Midland Landfill

2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

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

The IC engine facility consists of two (2) CAT Model No. G3520C IC engines that are connected to individual electricity generators.

2.2 Rated Capacities and Air Emission Controls

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

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

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

2.3 Sampling Locations

The 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 duct sampling ports for the CAT® Model G3520C engine (EUICENGINE1) are located in an exhaust duct with an inner diameter of 15.5 inches. The ports are located upstream of the engine muffler in a horizontal section of duct. The duct 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 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 a diagram of the emission test sampling location.

3.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

3.1 Purpose and Objective of the Tests

The conditions of MI-ROP-N6004-2014 and 40 CFR Part 60 Subpart JJJJ require the City of Midland WWTP to test both engines contained in FGICENGINES for carbon monoxide (CO), nitrogen oxides (NOx) and volatile organic compounds (VOCs) every 8,760 hours of operation. EUICENGINE1 was near 8,760 hours since the previous emissions test and was sampled for CO, NO_X and VOC emissions and exhaust gas oxygen (O_2) and carbon dioxide (CO_2) content.

3.2 Operating Conditions During the Compliance Tests

The testing was performed while the City of Midland WWTP engine/generator set was operated at maximum operating conditions (1,600 kW electricity output +/- 10%). City of Midland WWTP representatives provided the kW output in 15-minute increments for each test period. The average hourly generator kW output ranged between 1,590 and 1,598 kW for the test periods.

Landfill gas and digester gas fuel flowrate (cubic feet per minute) and fuel methane content (%) were also recorded by City of Midland WWTP representatives in 15-minute increments for each test period. The average hourly LFG fuel consumption rate ranged between 455 and 456 scfm, average hourly digester gas fuel flowrate was consistently 64.7 and the average hourly methane content was consistently 60.2%.

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

Engine output (bhp) cannot be measured directly and was calculated based on the recorded electricity output, the calculated CAT® Model G3520C generator efficiency (96.0%), and the unit conversion factor for kW to horsepower (0.7457 kW/hp).

Engine output (bhp) = Electricity output (kW) / (0.960) / (0.7457 kW/hp)

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 (EUICENGINE1) were sampled for three (3) one-hour test periods during the compliance testing performed June 27, 2017.

Table 3.2 presents the average measured CO, NO_X and VOC emission rates for the 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 3.1 Average engine operating conditions during the test periods

Engine Parameter	Engine No. 1
Generator output (kW)	1,595
Engine output (bhp)	2,228
Engine LFG fuel use (scfm)	456
Engine Digester fuel use (scfm)	64.7
Fuel methane content (%)	60.2

Table 3.2 Average measured emission rates for each tested City of Midland WWTP RICE (three-test average)

	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)
Engine No. 1	13.8	2.81	3.14	0.64	0.70	0.14

4.0 SAMPLING AND ANALYTICAL PROCEDURES

Test protocols for the air emission testing were 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 wer 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 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 Methods 1 and 2)

The RICE exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 during each test. An S-type or standard 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.

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 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 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. The sampled gas was conditioned by removing moisture prior to being introduced to the analyzers; therefore, measurement of O_2 and CO_2 concentrations correspond to standard dry gas conditions. Instrument response data were recorded using an ESC Model 8816 data acquisition system that monitored the analog output of the instrumental analyzers continuously and logged data as one-minute averages.

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

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

4.4 Exhaust Gas Moisture Content (USEPA Method 4)

Moisture content of the RICE exhaust gas 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 the RICE exhaust gas streams were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42c High Level chemiluminescence NO_X analyzer and a California Analytics / Fuji ZRF non-dispersive infrared CO analyzer

Throughout each test period, a continuous sample of the engine exhaust gas was extracted from the stack using the Teflon® heated sample line and gas conditioning system and delivered to the instrumental analyzers. Instrument response for each analyzer was recorded on an ESC Model 8816 data acquisition system that logged data as one-minute averages. Prior to, and at the conclusion of each test, the instruments were calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias.

Appendix 4 provides CO and NO_X calculation sheets. Raw instrument response data are provided in Appendix 5.

4.6 Measurement of Volatile Organic Compounds (USEPA Method 25A / ALT-096)

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

The USEPA Office of Air Quality Planning and Standards (OAQPS) has issued an alternate test method approving the use of the TEI 55i-series analyzer as an effective instrument for measuring NMOC from gas-fueled reciprocating internal combustion engines (RICE) in that it uses USEPA Method 25A and 18 (ALT-096).

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

The instrumental analyzer was calibrated using certified propane concentrations in hydrocarbon-free air to demonstrate detector linearity and determine calibration drift and zero drift error. 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 Exhaust Gas 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 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).

5.2 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_x concentration was 94% of the expected value, as required by Method 7E).

5.3 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 55i VOC analyzer exhibited the longest system response time at 130 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.

5.4 Determination of Exhaust Gas Stratification

A stratification test was performed for the engine 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 engine exhaust stack indicate that the measured NO_X concentrations did not vary by more than 5% of the mean across the stack diameter. Therefore, the engine exhaust gas was considered to be unstratified and the compliance test sampling was performed at a single representative sampling location within each engine exhaust stack.

5.5 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 previous 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.

5.6 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 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.

5.7 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.

5.8 Meter Box Calibrations

The Clean Air Model #0028 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 Clean Air metering console was 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 Test Results and Allowable Emission Limits

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

The measured air pollutant concentrations and emission rates for Engine No. 1 are less than the allowable limits specified in MI-ROP-N6004-2014 for Emission Unit EUICENGINE1:

- 1.0 g/bhp-hr for NO_X;
- 4.2 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. There were no variations from the approved sampling procedures during the engine test periods.

Table 6.1 Measured exhaust gas conditions and NO_x, CO and VOC air pollutant emission rates City of Midland WWTP Engine No. 1 (EUICENGINE1)

Test No. Test date Test period (24-hr clock)	1 6/27/17 838 - 938	2 6/27/17 1005 - 1105	3 6/27/17 1130 - 1230	Three Test Avg.
LFG flowrate (scfm)	455	456	456	456
Digester gas flowrate (scfm)	64.7	64.7	64.7	64.7
Generator output (kW)	1,590	1,597	1,598	1,595
Engine output (bhp)	2,221	2,231	2,233	2,228
LFG methane content (%)	60.2	60.2	60.2	60.2
Exhaust Gas Composition				
CO_2 content (% vol)	10.8	10.7	10.7	10.7
O_2 content (% vol)	8.77	8.78	8.84	8.80
Moisture (% vol)	12.4	12.4	11.6	12.1
Exhaust gas flowrate				
Exhaust gas temperature (°F)	917	918	917	917
Exhaust gas flowrate (dscfm)	4,228	4,108	4,215	4,184
Exhaust gas flowrate (scfm)	4,827	4,692	4,767	4,762
Nitrogen oxides emission rates				
NO_X conc. (ppmvd)	105	104	105	105
NO_X emissions (lb/hr)	3.19	3.05	3.18	3.14
NO_X emissions (g/bhp-hr)	0.65	0.62	0.65	0.64
NO_X permit limit (g/bhp-hr)	-	-	-	*1.0*
Carbon monoxide emission rates				
CO conc. (ppmvd)	763	759	747	757
CO emissions (lb/hr)	14.1	13.6	13.8	13.8
CO emissions (g/bhp-hr)	2.88	2.77	2.79	2.81
CO permit limit (g/bhp-hr)	-	-	-	*4.2*
VOC/NMHC emission rates				
VOC conc. (ppmv)	21.7	21.5	20.8	21.4
VOC emissions (lb/hr)	0.72	0.69	0.68	0.70
VOC emissions (g/bhp-hr)	0.15	0.14	0.14	0.14
VOC permit limit (g/bhp-hr)	-	-	-	*1.0*