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**AIR EMISSION TEST REPORT**

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

Report Date    December 13, 2013

Test Dates     December 4, 2013

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

<b>Facility Permit Information</b>	
Permit No.:	45-10B
Facility SRN :	N6004

<b>Testing Contractor</b>	
Company	Derenzo and Associates, Inc.
Mailing Address	39395 Schoolcraft Road Livonia, MI 48150
Phone	(734) 464-3880
Project No.	1308007

TABLE OF CONTENTS

	Page
<b>1.0 INTRODUCTION</b> .....	1
<b>2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION</b> .....	3
2.1 General Process Description .....	3
2.2 Rated Capacities and Air Emission Controls.....	3
2.3 Sampling Locations.....	3
<b>3.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS</b> .....	4
3.1 Purpose and Objective of the Tests.....	4
3.2 Operating Conditions During the Compliance Tests .....	4
3.3 Summary of Air Pollutant Sampling Results.....	4
<b>4.0 SAMPLING AND ANALYTICAL PROCEDURES</b> .....	6
4.1 Summary of Sampling Methods.....	6
4.2 Exhaust Gas Velocity Determination (USEPA Method 2).....	7
4.3 Exhaust Gas Molecular Weight Determination (USEPA Methods 3A).....	7
4.4 Exhaust Gas Moisture Content (USEPA Method 4) .....	7
4.5 NO <sub>x</sub> and CO Concentration Measurements (USEPA Methods 7E and 10).....	8
4.6 Measurement of Volatile Organic Compounds (USEPA Method ALT-078).....	8
<b>5.0 QA/QC ACTIVITIES</b> .....	9
5.1 NO <sub>x</sub> Converter Efficiency Test .....	9
5.2 Gas Divider Certification (USEPA Method 205) .....	9
5.3 Instrumental Analyzer Interference Check .....	9
5.4 Instrument Calibration and System Bias Checks.....	9
5.5 Meter Box Calibrations .....	10
<b>6.0 RESULTS</b> .....	10
6.1 Test Results and Allowable Emission Limits .....	10
6.2 Variations from Normal Sampling Procedures or Operating Conditions.....	11

**LIST OF TABLES**

Table	Page
3.1 Average operating conditions during the test periods .....	5
3.2 Average measured emission rates for each tested City of Midland WWTP facility RICE (three-test average) .....	5
6.1 Measured exhaust gas conditions and NO <sub>x</sub> , CO and VOC air pollutant emission rates City of Midland WWTP Engine No. 1 (EUCENGINE1) .....	12
6.2 Measured exhaust gas conditions and NO <sub>x</sub> , CO and VOC air pollutant emission rates City of Midland WWTP Engine No. 2 (EUCENGINE2) .....	13

**LIST OF APPENDICES**

APPENDIX A	SAMPLING DIAGRAMS
APPENDIX B	OPERATING RECORDS
APPENDIX C	FLOWRATE CALCULATIONS AND DATA SHEETS
APPENDIX D	CO <sub>2</sub> , O <sub>2</sub> , CO, NO <sub>x</sub> AND VOC CALCULATIONS
APPENDIX E	INSTRUMENTAL ANALYZER RAW DATA
APPENDIX F	QA/QC RECORDS

## **Derenzo and Associates, Inc.**

*Environmental Consultants*

### AIR EMISSION TEST REPORT FOR THE INTERNAL COMBUSTION ENGINES 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 EUCENGINE1 and EUCENGINE2 in Permit to Install (PTI) 45-10B 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<sub>x</sub>) and carbon monoxide (CO) concentrations and emission rates from two Model No. G3520C IC engines (EUCENGINE1 – 2) pursuant to the testing requirements specified in PTI No. 45-10B.

Permit to Install No. 45-10B specifies that ... *the permittee shall conduct an initial performance test for EUCENGINE1 and EUCENGINE2 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 December 4, 2013 by Derenzo and Associates, Inc. representatives Andrew Rusnak and Tyler Wilson. The project was coordinated by City of Midland WWTP representative Mr. Steve Smith.

Mr. Thomas Gasloli 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 submitted to the MDEQ-AQD and approved by the regulatory agency on November 4, 2013.

Questions regarding this emission test report should be directed to:

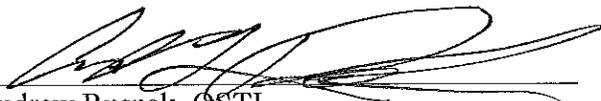
Andy Rusnak, QSTI  
Senior Environmental Engineer  
Derenzo and Associates, Inc.  
4990 Northwind Dr. Ste. 120  
East Lansing, MI 48823  
Ph: (517) 324-1880

Mr. Steve Smith  
Operations Supervisor  
City of Midland WWTP  
2125 Austin Street  
Midland, Michigan 48642  
(989) 837-3504

**Report Certification**

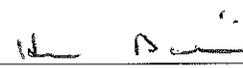
I certify under penalty of law that I believe the information provided in this document is true, accurate, and complete. I am aware that there are significant civil and criminal penalties, including the possibility of fine or imprisonment or both, for knowingly submitting false, inaccurate, or incomplete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

Report Prepared By:

  
\_\_\_\_\_  
Andrew Rusnak, QSTI  
Senior Environmental Engineer  
Derenzo and Associates, Inc.

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Responsible Official Certification:

  
\_\_\_\_\_  
Kevin Babinski  
Superintendent  
City of Midland Wastewater Treatment Plant

## **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 mufflers and is released to the atmosphere through dedicated vertical exhaust stacks with vertical release points. The two (2) CAT® Model G3520C RICE exhaust stacks are identical.

The exhaust stack sampling ports for the CAT® Model G3520C engines (EUCENGINE1 & 2) are located in individual exhaust stacks with an inner diameter of 15.5 inches. The ports are located upstream of the engine muffler in a horizontal section of stack. 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 and satisfies the USEPA Method 1 criteria for a representative sample location.

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**

The conditions of Permit to Install No. 45-10B and 40 CFR Part 60 Subpart JJJ require the City of Midland WWTP to test both engines contained in FGICENGINES for carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>) and volatile organic compounds (VOCs) every 8,760 hours of operation. Therefore, both engines contained in FGICENGINES was sampled for CO, NO<sub>x</sub> and VOC emissions and exhaust gas oxygen (O<sub>2</sub>) and carbon dioxide (CO<sub>2</sub>) content.

#### **3.2 Operating Conditions During the Compliance Tests**

The testing was performed while the City of Midland WWTP engine/generator sets were operated at maximum operating conditions (1,600 kW electricity output +/- 10%). City of Midland WWTP representatives provided the kW output in 5-minute increments for each test period. The average hourly generator kW output ranged between 1,441 and 1,482 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 5-minute increments for each test period. The average hourly LFG fuel consumption rate ranged between 466 and 471 scfm, average hourly digester gas fuel flowrate ranged between 29.6 and 43.2 and the average hourly methane content ranged between 52.0 and 52.3%.

Appendix B 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).

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

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 (EUCENGINE1 and EUCENGINE2) were each sampled for three (3) one-hour test periods during the compliance testing performed December 4, 2013.

Table 3.2 presents the average measured CO, NO<sub>x</sub> 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 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	Engine No. 2
Generator output (kW)	1,480	1,442
Engine output (bhp)	2,067	2,014
Engine LFG fuel use (scfm)	470	468
Engine Digester fuel use (scfm)	36.4	33.5
LFG methane content (%)	52.2	52.0

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

Emission Unit	CO Emission Rates		NOx Emission Rates		VOC Emission Rates	
	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)
Engine No. 1	10.7	2.35	2.70	0.59	0.44	0.10
Engine No. 2	10.9	2.45	3.31	0.75	0.40	0.09

#### 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 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 <sub>2</sub> and CO <sub>2</sub> content was determined using zirconia ion/paramagnetic and infrared instrumental analyzers, respectively.
USEPA Method 4	Exhaust gas moisture was determined based on the water weight gain in chilled impingers.
USEPA Method 7E	Exhaust gas NO <sub>x</sub> 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)**

The RICE exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 prior to and after each test. An S-type Pitot tube connected to a red-oil manometer was used to determine velocity pressure at each traverse point across the stack cross section. Gas temperature was measured using a K-type thermocouple mounted to the Pitot tube. The Pitot tube and connective tubing were 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).

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

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

CO<sub>2</sub> and O<sub>2</sub> content in the RICE exhaust gas streams were measured continuously throughout each test period in accordance with USEPA Method 3A. The CO<sub>2</sub> content of the exhaust was monitored using a Servomex 4100 single beam single wavelength (SBSW) infrared gas analyzer. The O<sub>2</sub> content of the exhaust was monitored using a Servomex 4100 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<sub>2</sub> and CO<sub>2</sub> 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 D provides O<sub>2</sub> and CO<sub>2</sub> calculation sheets. Raw instrument response data are provided in Appendix E.

#### **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<sub>x</sub> and CO Concentration Measurements (USEPA Methods 7E and 10)**

NO<sub>x</sub> 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<sub>x</sub> 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 D provides CO and NO<sub>x</sub> 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 Teflon® heated sample line 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 5.0 of this document).

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

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December 13, 2013

Page 9

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## 5.0 QA/QC ACTIVITIES

### 5.1 **NO<sub>x</sub> Converter Efficiency Test**

The NO<sub>2</sub> – NO conversion efficiency of the Model 42c analyzer was verified prior to the testing program. A USEPA Protocol 1 certified concentration of NO<sub>2</sub> was injected directly into the analyzer, following the initial three-point calibration, to verify the analyzer's conversion efficiency. The analyzer's NO<sub>2</sub> – NO converter uses a catalyst at high temperatures to convert the NO<sub>2</sub> to NO for measurement. The conversion efficiency of the analyzer is deemed acceptable if the measured NO<sub>2</sub> concentration is within 90% of the expected value.

The NO<sub>2</sub> – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO<sub>2</sub> concentration was -2.10% of the expected value, i.e., within 10% of the expected value as required by Method 7E).

### 5.2 **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 January 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.

### 5.3 **Instrumental Analyzer Interference Check**

The instrumental analyzers used to measure NO<sub>x</sub>, CO, O<sub>2</sub> and CO<sub>2</sub> have had an interference response test performed 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.

### 5.4 **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<sub>x</sub>, CO, CO<sub>2</sub> and O<sub>2</sub> 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<sub>2</sub>, O<sub>2</sub>, NO<sub>x</sub>, 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.

## 5.5 Meter Box Calibrations

The Nutech Model 2010 sampling console, which was used for exhaust gas moisture content sampling, was calibrated prior to and after the testing program. This calibration uses the critical orifice calibration technique presented in USEPA Method 5. The metering console calibration exhibited no data outside the acceptable ranges presented in USEPA Method 5.

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

Appendix F presents test equipment quality assurance data (NO<sub>2</sub> – 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 Tables 6.1 and 6.2.

The measured air pollutant concentrations and emission rates for Engine Nos. 1 and 2 are less than the allowable limits specified in Permit to Install No. 45-10B for Emission Units EUCENGINE1 through EUCENGINE2:

- 1.0 g/bhp-hr for NO<sub>x</sub>;
- 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<sub>x</sub>, CO and VOC air pollutant emission rates  
City of Midland WWTP Engine No. 1 (EUCENGINE1)

Test No.	1	2	3	Three Test
Test date	12/4/13	12/4/13	12/4/13	Average
Test period (24-hr clock)	1330 - 1430	1510 - 1610	1641 - 1741	
LFG flowrate (scfm)	470	471	468	470
Digester gas flowrate (scfm)	29.9	36.2	43.2	36.4
Generator output (kW)	1,482	1,480	1,477	1,480
Engine output (bhp)	2,070	2,067	2,064	2,067
LFG methane content (%)	52.3	52.3	52.2	52.2
<u>Exhaust Gas Composition</u>				
CO <sub>2</sub> content (% vol)	13.3	13.1	11.5	12.6
O <sub>2</sub> content (% vol)	7.86	7.87	7.99	7.91
Moisture (% vol)	13.1	11.7	11.8	12.2
Exhaust gas temperature (°F)	919	945	946	932
Exhaust gas flowrate (dscfm)	3,705	3,649	3,583	3,646
Exhaust gas flowrate (scfm)	4,232	4,136	4,073	4,147
<u>Nitrogen Oxides</u>				
NO <sub>x</sub> conc. (ppmvd)	106	104	100	103
NO <sub>x</sub> emissions (lb/hr)	2.82	2.71	2.58	2.70
NO <sub>x</sub> emissions (g/bhp*hr)	0.62	0.59	0.57	0.59
Permitted emissions (g/bhp*hr)	-	-	-	1.0
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	678	677	663	673
CO emissions (lb/hr)	11.0	10.8	10.4	10.7
CO emissions (g/bhp*hr)	2.40	2.37	2.28	2.35
Permitted emissions (g/bhp*hr)	-	-	-	4.2
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv)	15.3	15.4	15.5	15.4
VOC emissions (lb/hr)	0.44	0.44	0.43	0.44
VOC emissions (g/bhp*hr)	0.10	0.10	0.10	0.10
Permitted emissions (g/bhp*hr)	-	-	-	1.0

Table 6.2 Measured exhaust gas conditions and NO<sub>x</sub>, CO and VOC air pollutant emission rates  
City of Midland WWTP Engine No. 2 (EUCENGINE2)

Test No.	1	2	3	Three Test
Test date	12/4/13	12/4/13	12/4/13	Average
Test period (24-hr clock)	818 - 918	1005 - 1105	1147 - 1247	
LFG flowrate (scfm)	466	470	469	468
Digester gas flowrate (scfm)	40.2	29.6	30.8	33.5
Generator output (kW)	1,441	1,444	1,441	1,442
Engine output (bhp)	2,012	2,017	2,012	2,014
LFG methane content (%)	52.0	52.0	52.0	52.0
<u>Exhaust Gas Composition</u>				
CO <sub>2</sub> content (% vol)	13.0	13.1	13.4	13.2
O <sub>2</sub> content (% vol)	7.51	7.56	7.60	7.55
Moisture (% vol)	11.6	12.0	12.0	11.9
Exhaust gas temperature (°F)	918	948	949	934
Exhaust gas flowrate (dscfm)	3,612	3,567	3,529	3,569
Exhaust gas flowrate (scfm)	4,096	4,055	4,008	4,053
<u>Nitrogen Oxides</u>				
NO <sub>x</sub> conc. (ppmvd)	132	128	127	129
NO <sub>x</sub> emissions (lb/hr)	3.42	3.28	3.22	3.31
NO <sub>x</sub> emissions (g/bhp*hr)	0.77	0.74	0.73	0.75
Permitted emissions (g/bhp*hr)	-	-	-	1.0
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	698	698	699	698
CO emissions (lb/hr)	11.0	10.9	10.8	10.9
CO emissions (g/bhp*hr)	2.48	2.45	2.43	2.45
Permitted emissions (g/bhp*hr)	-	-	-	4.2
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv)	14.1	14.4	14.2	14.2
VOC emissions (lb/hr)	0.40	0.40	0.39	0.40
VOC emissions (g/bhp*hr)	0.09	0.09	0.09	0.09
Permitted emissions (g/bhp*hr)	-	-	-	1.0