Derenzo Environmental Services
Consulting and Testing

AIR EMISSION TEST REPORT

Title	AIR EMISSION TEST REPORT FOR THE VERIFICATION OF AIR POLLUTANT EMISSIONS FROM LANDFILL GAS FIRED ENGINE – GENERATOR SETS
Report Date	March 29, 2018
Test Dates	February 21-22, 2018

Facility Information	
Name	North American Natural Resources Autumn Hills Generating Station
Street Address	5615 Adams Street,
City, County, State	Zeeland, Ottawa, Michigan
Facility SRN	P0264
Phone	(616) 688-5180

Emission Unit and Permit Information	
Operating Permit No.:	MI-ROP-P0264-2012b
Emissions Unit ID Nos.	EUENGINE1, EUENGINE2, EUENGINE4

Testing Contractor	
Company	Derenzo Environmental Services
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FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM
LANDFILL GAS FIRED ENGINE – GENERATOR SETS

NORTH AMERICAN NATURAL RESOURCES
AUTUMN HILLS GENERATING STATION

1.0 INTRODUCTION

North American Natural Resources (NANR) operates gas-fired reciprocating internal combustion engine (RICE) electricity generator sets at the Autumn Hills Generating Station located in Zeeland, Ottawa County, Michigan. The RICE are fueled by landfill gas (LFG) that is recovered from the Autumn Hills Landfill, which is owned and operated by Waste Management of Michigan. The recovered gas is transferred to NANR where it is treated and used as fuel.

The Michigan Department of Environmental Quality-Air Quality Division (MDEQ-AQD) has issued to NANR a Renewable Operating Permit (MI-ROP-P0264-2012b) for operation of the renewable electricity generation facility, which consists of:

- Two (2) Caterpillar (CAT®) Model No. 3516LE RICE-generator sets identified as emission units EUENGINE1, EUENGINE2 (Flexible Group ID's: FGENGINES and FGSIRICEMACT)

- One (1) CAT® Model No. G3520C RICE-generator set identified as emission unit EUENGINE4 (Flexible Group ID: FGSIRICEMACT).

Air emission compliance testing was performed pursuant to the conditions of MI-ROP-P0264-2012b and the federal Standards of Performance for Stationary Spark Ignition Internal Combustion Engines (the SI-RICE NSPS; 40 CFR Part 60 Subpart JJJJ). The conditions of MI-ROP-P0264-2012b state:

> *... the permittee shall conduct an initial performance test for* [the engines] *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 permittee shall verify formaldehyde emission rates from one or more engines in FGENGINES once every 5 years, from the date of issuance of this permit, by testing at owner's expense, in accordance with Department requirements.*

The compliance testing presented in this report was performed by Derenzo Environmental Services (DES), a Michigan-based environmental consulting and testing company. DES representatives Tyler Wilson, Andrew Rusnak, and Blake Beddow performed the field sampling and measurements February 21-22, 2018. The emission testing was performed within 8,760 operating hours of the previous test, which was performed on September 13-14, 2016.

The engine emission performance tests consisted of triplicate, one-hour sampling periods for nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOC, as non-methane hydrocarbons). 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.

Formaldehyde (CH2O) emissions were last tested on February 17, 2015 for EUENGINE4, and on December 2, 2013 for EUENGINE1 and 2. The Caterpillar (CAT®) Model No. 3516LE RICE-generator set (EUENGINE2) was tested for formaldehyde to fulfill the 5 year testing requirement presented in MI-ROP-P0264-2012b. The formaldehyde emission performance tests consisted of triplicate, one-hour sampling periods performed simultaneous to the NOx, CO, and VOC tests.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan dated January 11, 2018 that was reviewed and approved by the MDEQ. Mr. David Patterson of the MDEQ-AQD observed portions of the compliance testing.

Questions regarding this emission test report should be directed to:

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Report Certification

This test report was prepared by Derenzo Environmental Services based on field sampling data collected by Derenzo Environmental Services. Facility process data were collected and provided NANR employees or representatives. This test report has been reviewed by NANR representatives and approved for submittal to the MDEQ.

I certify that the testing was conducted in accordance with the specified test methods and submitted test plan unless otherwise specified in this report. I believe the information provided in this report and its attachments are true, accurate, and complete.

Report Prepared By:

Blake Beddow
Environmental Consultant
Derenzo Environmental Services

Reviewed By:

Tyler Wilson
Livonia Office Supervisor
Derenzo Environmental Services.

2.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

2.1 Purpose and Objective of the Tests

The conditions of MI-ROP-P0264-2012b and 40 CFR Part 60 Subpart JJJJ require NANR to test engine EUENGINE1, EUENGINE2, and EUENGINE4 for CO, NOx and VOC emissions every 8,760 hours of operation. Formaldehyde (CH2O) tests must be performed once every five years.

2.2 Operating Conditions During the Compliance Tests

The testing was performed while the NANR engine/generator sets were operated at maximum operating conditions (within 10% of rated capacity). The rated capacities for the two types of CAT® engine generator sets are 800 kW for the 3516LE (EUENGINE1-2), and 1,600 kW electricity output for the 3520C (EUENGINE4). NANR representatives provided kW output in 15-minute increments for each test period. The EUEGINE1-2 generator kW output ranged between 800 and 812 kW, while the EUENGINE4 generator kW output ranged between 1,601 and 1,608 kW for each test period.

Fuel flowrate (cubic feet per minute), fuel methane content (%), fuel inlet pressure (psi) were also recorded by NANR representatives in 15-minute increments for each test period. In addition, the air-to-fuel ratio was recorded on EUENGINE4. The EUENGINE1-2 fuel consumption rate ranged between 301 and 326 scfm, fuel methane content was 53%, and fuel inlet pressure ranged from 32 to 39 psi. The EUENGINE4 fuel consumption rate ranged between 417 and 420 scfm, fuel methane content was 53%, fuel inlet pressure ranged between 48 and 49 psi and the air-to-fuel ratio ranged between 7.6 and 7.7 for each test period.

Appendix 2 provides operating records provided by NANR 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 3516LE generator efficiency (93.9%) or CAT® Model G3520C generator efficiency (96.1%), and the unit conversion factor for kW to horsepower (0.7457 kW/hp).

Engine output (bhp) = Electricity output (kW) / gen. efficiency / (0.7457 kW/hp)

Where gen. efficiency = 0.939 (CAT® 3516LE), or 0.961 (CAT® G3520C)

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

2.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the sampled LFG fueled RICE (EUENGINE1-2, EUENGINE4) were sampled for three (3) one-hour test periods during the compliance testing performed February 21-22, 2018.

Table 2.2 presents the average measured CO, NO_X, and VOC emission rates for each engine (average of the three test periods). CH2O emissions rates are presented for EUENGINE2.

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®3516 LE	EUENGINE2 CAT®3516 LE	EUENGINE4 CAT® G3520C
Generator output (kW)	804	803	1,604
Engine output (bhp)	1,148	1,147	2,239
Engine LFG fuel use (scfm)	308	319	419
LFG methane content (%)	53.1	53.2	52.9
Exhaust temperature (°F)	861	841	958
Inlet fuel pressure (psi)	37	34	48
Air to fuel ratio	--	--	7.7

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

Emission Unit	EUENGINE1		EUENGINE2		EUENGINE4	
	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)
CO Emission Rates	4.49	1.78	4.77	1.89	10.86	2.20
Permit Limit	--	*3.1*	--	*3.1*	*20.7.*	*5.0*
NOx Emission Rates	1.38	0.54	2.79	1.1	1.31	0.27
Permit Limit	--	*2.0*	--	*2.0*	*2.46*	*0.5*
VOC Emission Rates	0.31	0.12	0.30	0.12	0.68	0.14
Permit Limit	--	*0.41*	--	*0.41*	*2.46*	*1.0*
CH2O Emission Rates	--	--	0.67	0.26	--	--
Permit Limit	*1.72*	--	*1.72*	--	--	--

3.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

3.1 General Process Description

NANR operates three RICE-generator sets at its Auburn Hills Generating station; two (2) CAT® Model No. 3516LE and one (1) CAT® Model No. 3520C. The units are fired exclusively with LFG that is recovered from the Autumn Hills Landfill solid waste disposal facility and treated prior to use.

3.2 Rated Capacities and Air Emission Controls

The CAT® 3516LE engine generator sets have a rated design capacity of:

- Engine Power; 1,148 brake horsepower (bhp)
- Electricity Generation; 800 kilowatts (kW)

The CAT® G3520C engine generator set has a rated design capacity of:

- Engine Power; 2,242 bhp
- Electricity Generation; 1,600 kW

Each engine is equipped with an air-to-fuel ratio (AFR) controller that blends the appropriate ratio of combustion air and treated LFG fuel. For the CAT® G3516LE, the AFR controller is set based on the gas quality (methane or heat content) of the treated fuel. The CAT® G3520C engine is equipped with an electronic AFR controller that monitors engine performance parameters and automatically adjusts the AFR and ignition timing to maintain efficient fuel combustion.

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 a noise muffler and vertical exhaust stack.

3.3 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 sampling ports for the CAT® Model G3516LE engines (EUENGINE1-2) are located before the muffler in a horizontal exhaust duct with an inner diameter of 10.0 inches. The duct is equipped with two (2) sample ports, opposed 90°, that provide a sampling 34.5" inches (3.45 duct diameters) upstream and 293 inches (29.3 duct diameters) downstream from any flow disturbance.

The exhaust stack sampling ports for the CAT® Model G3520C engine (EUENGINE4) are located before the muffler in a horizontal exhaust duct with an inner diameter of 13.5 inches. The duct is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 40 inches (2.96 duct diameters) upstream and 120 inches (8.89 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 diagrams of the emission test sampling locations.

4.0 <u>SAMPLING AND ANALYTICAL PROCEDURES</u>

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 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.
USEPA 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
ASTM D6348	Exhaust gas HCOH concentration via Fourier transform infrared spectroscopy (FTIR)

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 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 single beam single wavelength (SBSW) 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 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.

Moisture content was determined by the FTIR instrument in engine exhaust gas that was tested for formaldehyde (EUENGINE2).

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 TEI Model 48i 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 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.

4.7 Determination of Formaldehyde Emissions (ASTM D6348)

Formaldehyde concentration in the RICE exhaust gas streams was determined using a MKS Multi-Gas 2030 Fourier transform infrared (FTIR) spectrometer.

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

A calibration transfer standard (CTS), ethylene standard, and nitrogen zero gas were analyzed before and after each test run. Analyte spiking, of each engine, with acetaldehyde was performed to verify the ability of the sampling system to quantitatively deliver a sample containing the compound of interest from the base of the probe to the FTIR. Data was collected at 0.5 cm^{-1} resolution. Instrument response was recorded using MKS data acquisition software.

Appendix 4 provides formaldehyde calculation sheets. Instrument response data for the FTIR is provided in Appendix 6.

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, pyrometer, and Pitot tube) 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 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 greater than 90% 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 FTIR QA/QC Activities

At the beginning of each day a calibration transfer standard (CTS, ethylene gas), analyte of interest (acetaldehyde) and nitrogen calibration gas were directly injected into the FTIR to evaluate the unit response.

Prior to and after each test run the CTS was analyzed. The ethylene was passed through the entire system (system purge) to verify the sampling system response and to ensure that the sampling system remained leak-free at the stack location. Nitrogen was also passed through the sampling system to ensure the system is free of contaminants.

Analyte spiking, of each emission unit, with acetaldehyde was performed to verify the ability of the sampling system to quantitatively deliver a sample containing the compound of interest from the base of the probe to the FTIR and assured the ability of the FTIR to quantify that compound in the presence of effluent gas. The spike target dilution ratio was 1:10 (1 part cal gas; 9 parts stack gas).

As part of the data validation procedure, reference spectra were manually fit to that of the sample spectra (two spectra from each test period) and a concentration was determined. Concentration data was manually validated using the MKS MG2000 method analyzer software. The software used multi-point calibration curves to quantify each spectrum. The software-calculated results were then compared with the measured concentrations to ensure the quality of the data.

5.7 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 O_2 and CO_2 concentrations did not vary by more than 5% of the mean across the stack diameter. Therefore, the RICE exhaust gas was considered to be unstratified and the compliance test sampling was performed at a single sampling location within each RICE exhaust stack.

5.8 Meter Box Calibrations

The dry gas meter and 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 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, and stratification checks).

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 6.3.

The measured air pollutant concentrations and emission rates for EUENGINE1-2, and EUENGINE4 are less than the allowable limits specified in MI-ROP-P0264-2012b.

EUENGINE1-2
- 3.1 g/bhp-hr for CO;
- 2.0 g/bhp-hr for NOx; and
- 0.41 g/bhp-hr for VOC.

EUENGINE4
- 5.0 g/bhp-hr and 20.7 lb/hr for CO;
- 0.5 g/bhb-hr and 2.46 lb/hr for NOx; and
- 1.0 g/bhb-hr and 3.2 lb/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 test protocol. The engine-generator sets were operated within 10% of maximum output (800 kW generator output for CAT® 3516LE and 1,600 kW generator output for CAT® 3520C) and no variations from normal operating conditions occurred during the engine test periods.

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

Test No. Test date Test period (24-hr clock)	1 2/21/18 1322-1422	2 2/21/18 1445-1545	3 2/21/18 1606-1706	Three Test Average
Fuel flowrate (scfm)	305	313	307	308
Generator output (kW)	803	806	802	804
Engine output (bhp)	1,147	1,151	1,145	1,148
LFG methane content (%)	53.1	53.2	53.1	53.1
Fuel inlet pressure (psi)	36.8	36.6	37.2	36.9
<u>Exhaust Gas Composition</u>				
CO_2 content (% vol)	12.2	12.2	12.2	12.2
O_2 content (% vol)	7.66	7.65	7.68	7.66
Moisture (% vol)	10.4	12.9	12.4	11.9
Exhaust gas temperature (°F)	862	861	859	861
Exhaust gas flowrate (dscfm)	2,618	2,471	2,349	2,479
Exhaust gas flowrate (scfm)	2,923	2,836	2,684	2,802
<u>Nitrogen Oxides</u>				
NO_X conc. (ppmvd)	81.1	77.2	73.5	77.3
NO_X emissions (lb/hr)	1.52	1.37	1.24	1.38
NO_X emissions (g/bhp*hr)	0.60	0.54	0.49	0.54
*Permitted emissions (g/bhp*hr)*	-	-	-	*2.0*
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	419	414	412	415
CO emissions (lb/hr)	4.79	4.46	4.23	4.49
CO emissions (g/bhp*hr)	1.90	1.76	1.67	1.78
*Permitted emissions (g/bhp*hr)*	-	-	-	*3.10*
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv)	15.6	16.5	16.8	16.3
VOC emissions (lb/hr)	0.31	0.32	0.31	0.31
VOC emissions (g/bhp*hr)	0.12	0.13	0.12	0.12
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.41*

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

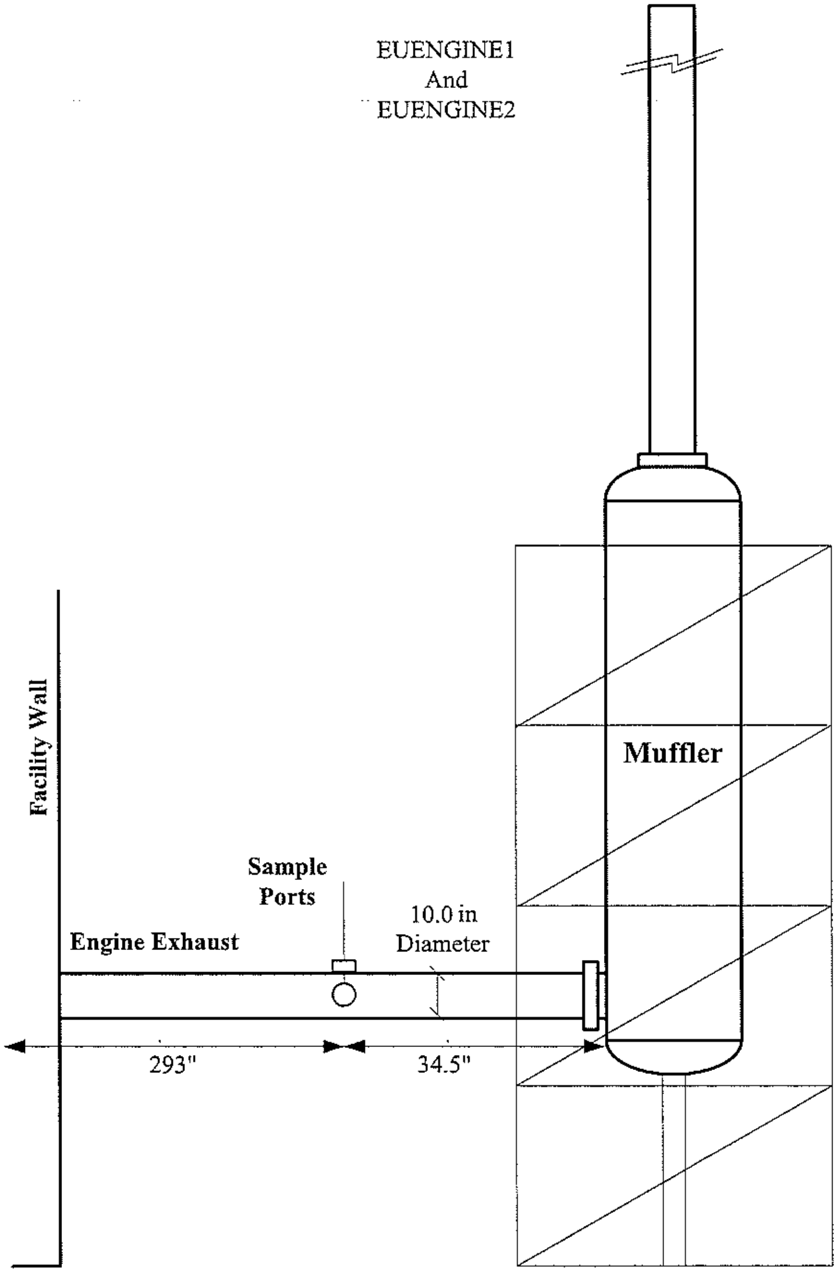
Test No. Test date Test period (24-hr clock)	1 2/21/18 0847-0947	2 2/21/18 1010-1110	3 2/21/18 1138-1238	Three Test Average
Fuel flowrate (scfm)	320	319	317	319
Generator output (kW)	803	803	803	803
Engine output (bhp)	1,147	1,147	1,147	1,147
LFG methane content (%)	53.2	53.3	53.1	53.2
Fuel inlet pressure (psi)	33.6	33.6	33.8	33.7
Exhaust Gas Composition				
CO_2 content (% vol)	11.6	12.1	12.3	12.0
O_2 content (% vol)	8.32	7.75	7.46	7.84
Moisture (% vol)	13.3	13.1	13.2	13.2
Exhaust gas temperature (^oF)	832	846	845	841
Exhaust gas flowrate (dscfm)	2,172	2,218	2,226	2,205
Exhaust gas flowrate (scfm)	2,504	2,553	2,564	2,540
Nitrogen Oxides				
NO_X conc. (ppmvd)	160	166	203	176
NO_X emissions (lb/hr)	2.49	2.63	3.24	2.79
NO_X emissions (g/bhp*hr)	0.98	1.04	1.28	1.10
*Permitted emissions (g/bhp*hr)*	-	-	-	*2.0*
Carbon Monoxide				
CO conc. (ppmvd)	474	492	521	495
CO emissions (lb/hr)	4.49	4.76	5.06	4.77
CO emissions (g/bhp*hr)	1.78	1.88	2.00	1.89
*Permitted emissions (g/bhp*hr)*	-	-	-	*3.10*
Volatile Organic Compounds				
VOC conc. (ppmv)	16.7	17.2	17.0	17.0
VOC emissions (lb/hr)	0.29	0.30	0.30	0.30
VOC emissions (g/bhp*hr)	0.11	0.12	0.12	0.12
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.41*
Formaldehyde				
CH2O conc. (ppmv)	56.5	56.4	55.1	55.8
CH2O emissions (lb/hr)	0.66	0.67	0.66	0.67
Permitted emissions (lb/hr)	-	-	-	*1.72*

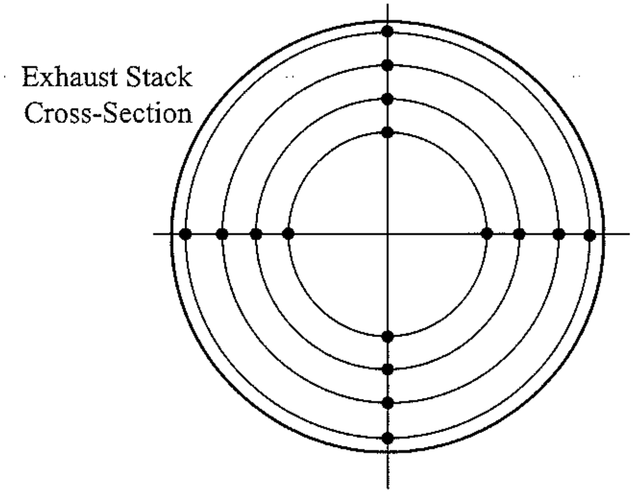
Table 6.3 Measured exhaust gas conditions and NO_x, CO and VOC air pollutant emission rates for Engine No. 4 (EUENGINE4)

Test No. Test date Test period (24-hr clock)	1 2/22/18 0723-0823	2 2/22/18 0841-0941	3 2/22/18 1001-1101	Three Test Average
Fuel flowrate (scfm)	420	418	417	419
Generator output (kW)	1,604	1,604	1,605	1,604
Engine output (bhp)	2,238	2,239	2,240	2,239
LFG methane content (%)	52.9	52.8	52.8	52.9
Fuel inlet pressure (psi)	48.4	48.4	48.1	48.3
Air to fuel ratio	7.7	7.7	7.6	7.7
Exhaust Gas Composition				
CO_2 content (% vol)	11.3	11.3	11.3	11.3
O_2 content (% vol)	8.52	8.56	8.55	8.54
Moisture (% vol)	11.1	10.9	10.6	10.9
Exhaust gas temperature (°F)	956	959	960	958
Exhaust gas flowrate (dscfm)	4,828	4,816	4,835	4,826
Exhaust gas flowrate (scfm)	5,428	5,404	5,409	5,413
Nitrogen Oxides				
NO_X conc. (ppmvd)	38.3	37.4	38.0	37.9
NO_X emissions (lb/hr)	1.33	1.29	1.32	1.31
Permitted emissions (lb/hr)	-	-	-	*2.46*
NO_X emissions (g/bhp*hr)	0.27	0.26	0.27	0.27
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.5*
Carbon Monoxide				
CO conc. (ppmvd)	518	514	514	516
CO emissions (lb/hr)	10.9	10.8	10.9	10.9
Permitted emissions (lb/hr)	-	-	-	*20.7*
CO emissions (g/bhp*hr)	2.21	2.19	2.20	2.20
*Permitted emissions (g/bhp*hr)*	-	-	-	*5.0*
Volatile Organic Compounds				
VOC conc. (ppmv)	18.2	18.4	18.6	18.4
VOC emissions (lb/hr)	0.68	0.68	0.69	0.68
Permitted emissions (lb/hr)	-	-	-	*3.20*
VOC emissions (g/bhp*hr)	0.14	0.14	0.14	0.14
*Permitted emissions (g/bhp*hr)*	-	-	-	*1.0*

APPENDIX 1

- RICE Engine Sample Port Diagram

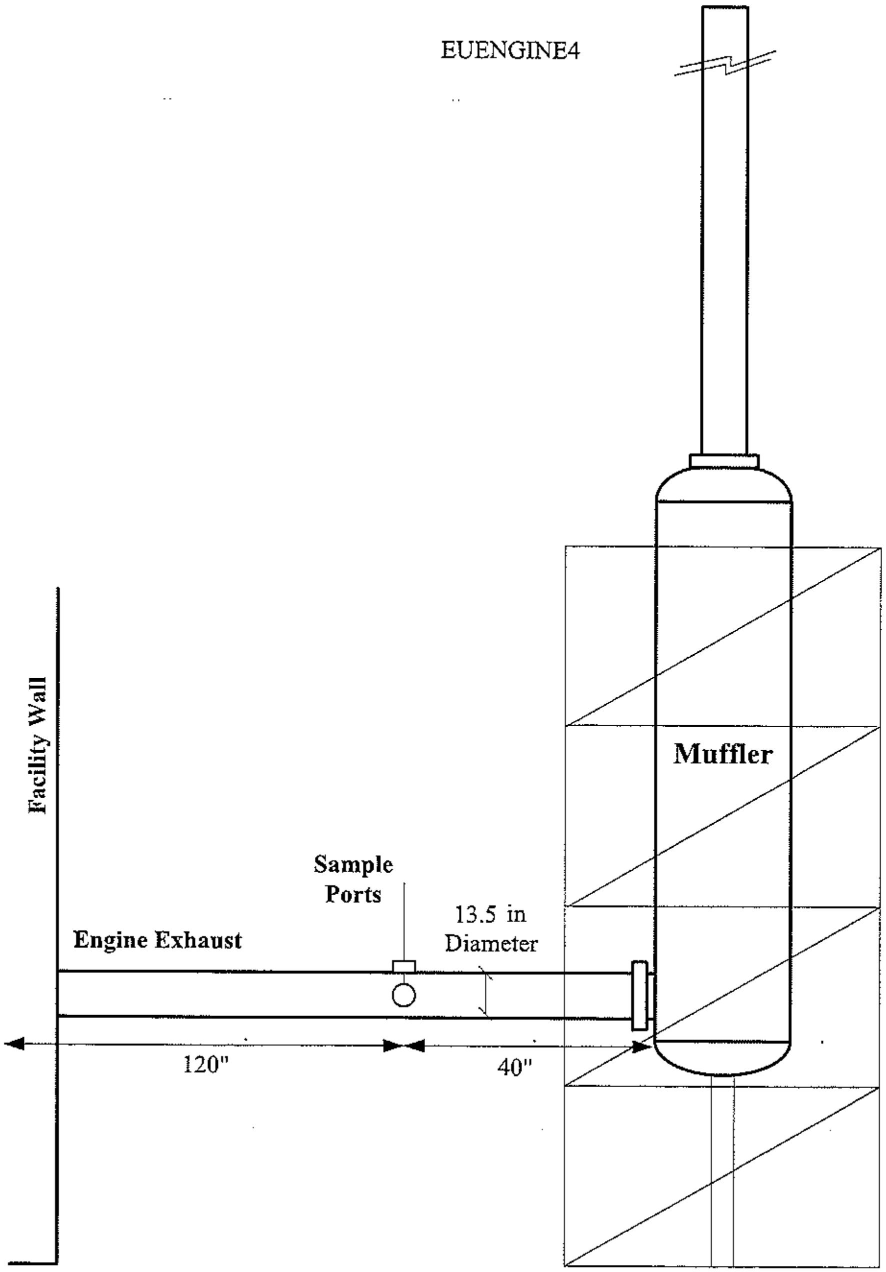


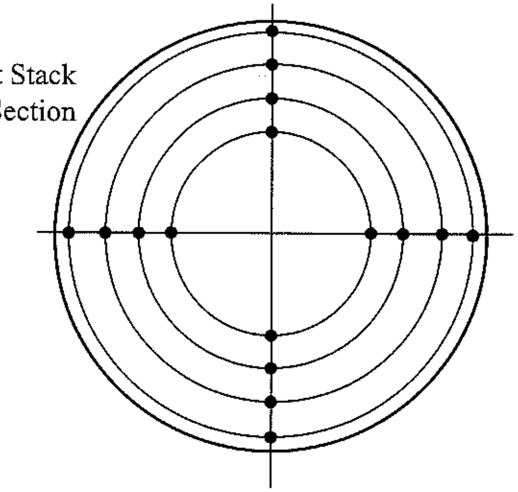


Velocity sample locations as measured from stack wall

Pt. #	in.
1	0.50
2	1.46
3	2.96
4	7.04
5	8.54
6	9.50

6/15/16 3/29/18	**North American Natural Resources (NANR)** **Exhaust Sample Location, CAT G3516 ICE**		
	Scale None	Sheet 1 of 1	Derenzo Env. Services Project No. 1711014





Velocity sample locations as measured from stack wall

Pt. #	in.
1	0.59
2	1.96
3	4.00
4	9.50
5	11.53
6	12.91

6/15/16	**North American Natural Resources (NANR)** **Exhaust Sample Location, CAT G3520 ICE**		
3/29/18			
	Scale None	Sheet 1 of 1	Derenzo Env. Services Project No. 1711014