NSPS EMISSION TEST REPORT

Title	NSPS EMISSION TEST REPORT FOR A DIGESTER GAS FUELED INTERNAL COMBUSTION ENGINE – GENERATOR SET
Report Date	October 12, 2018
Test Dates	September 20, 2018

Facility Information	
Name	Michigan State University, South Campus Dairy Farm
Street Address	4261 Bennett Road
City, County	Lansing, Ingham

Facility Permit Information			
State Registration No.:	K3249	Permit No. :	MI-ROP-K3249-2016a

Testing Contractor	
Company	Derenzo Environmental Services
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Project No.	1808011

NSPS EMISSION TEST REPORT
FOR A
DIGESTER GAS FUELED INTERNAL COMBUSTION
ENGINE – GENERATOR SET

MICHIGAN STATE UNIVERSITY
SOUTH CAMPUS DAIRY FARM

1.0 INTRODUCTION

Michigan State University (MSU) operates a digester gas fired, spark-ignition reciprocating internal combustion engine (SI-RICE) generator set located at the South Campus Dairy Farm in Lansing, Ingham County.

The SI-RICE has a power generation rating of 510 brake-horsepower (BHP). 40 CFR 60.4243(b)(2)(ii) of the SI-RICE NSPS specifies that owners and operators of new stationary spark-ignited RICE with a power rating greater than 500 horsepower, that have not been certified by the manufacturer relative to the NSPS, must conduct an initial performance test and conduct subsequent performance testing every 8,760 hours of engine operation or 3 years, whichever comes first, thereafter to demonstrate compliance.

Emission testing for the SI-RICE was previously performed on September 21, 2017. The emission test was performed on September 20, 2018, which is within 8,760 run hours of the previous test event.

The testing consisted of triplicate, one-hour sampling periods for nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compound (VOC) emissions.

The compliance testing was performed by Derenzo Environmental Services (DES) representatives Andy Rusnak and Clay Gaffey. The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan dated August 14, 2018 that was submitted to the Michigan Department of Environmental Quality (MDEQ) prior to the test event. Mr. Dan McGeen and Mr. Tom Gasloli from the MDEQ-AQD were on-site to observe portions of the test event.

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 DES personnel. Facility process data were collected and provided by MSU employees or representatives. This test report has been reviewed by MSU representatives and approved for submittal to the MDEQ.

I certify that the testing was conducted in accordance with the approved 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:

Clay Gaffey
Environmental Consultant
Derenzo Environmental Services

Reviewed By:

Andy Rusnak, QSTI
Technical Manager
Derenzo Environmental Services

I certify that the facility operating conditions were at the maximum routine operating conditions for the facility. Based on information and belief formed after reasonable inquiry, the statements and information in this report are true, accurate and complete.

Thomas Grover
Environmental Health & Safety
Michigan State University

2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

Biogas containing methane is generated at the South Campus Dairy Farm from the anaerobic decomposition of a combination of feedstocks, including animal waste, food scraps, and waste grease from restaurants. The biogas (digester gas) is used to fuel the MAN Model No. E2842LE322 RICE (EUDIENGINE), which is connected to an electricity generator that produces electricity that is transferred to the local utility.

2.2 Rated Capacities and Air Emission Controls

The electricity generator has a rated electrical output of 380 kW.

EUDIENGINE is not equipped with add-on emission controls. Combustion air pollutant emissions are minimized by the design of the engine and the air to fuel ratio controller. Engine exhaust gas is released directly to atmosphere through a vertical release point without add-on post-combustion emission controls.

The fuel consumption rate is dependent on the fuel heat value (methane content). The engine will use an appropriate amount of fuel to maintain the desired output. The air-to-fuel ratio is set based on the gas quality (methane or heat content) of the digester gas that is used as fuel.

2.3 Sampling Locations

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

The sampling port for EUDIENGINE is located in a horizontal exhaust pipe prior to the muffler with an inner diameter of 8 inches. The section is equipped with a single sample port, providing a sampling location greater than 4 inches (>0.5 duct diameter) upstream and greater than 16 inches (>2.0 duct diameters) downstream from any flow disturbance and satisfies the USEPA Method 1 criteria for a representative sample location.

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

Pursuant to 40 CFR Part 60 Subpart JJJJ, MSU is required to test the RICE air pollutant emissions after initial startup and every 8,760 hours of operation to demonstrate compliance with the emission standards for CO, NOx, and VOC.

3.2 Operating Conditions During the Compliance Tests

The testing was performed while the RICE genset was operated at maximum operating conditions (380 kW electricity output +/- 10%). MSU representatives provided kW output data at 15-minute intervals for each test period.

Fuel flowrate (cubic feet per minute) was also recorded by MSU representatives at 15-minute intervals for each test period. The RICE fuel consumption rate ranged between 106 and 109 standard cubic feet per minute (scfm) during the test periods.

Appendix 2 provides operating records provided by MSU representatives for the test periods.

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 digester gas fueled RICE were sampled for three (3) one-hour test periods during the compliance testing performed September 20, 2018.

Table 3.2 presents the average measured CO, NOx and VOC exhaust gas concentrations for the engine (average of the three test periods) and applicable emission limits.

Results of the engine performance tests demonstrate compliance with emission limits specified in 40 CFR Part 60, Subpart JJJJ.

Results and data for each one-hour sampling period are presented in Section 6.0 of this report.

Table 3.1 Average engine operating conditions during the test periods

Emission Unit	Generator Output (kW)	Fuel Use (scfm)	Digester Gas CH_4 Content (%)
EUDIENGINE	360	107	66.3
Max Capacity	380	--	--

Table 3.2 Average measured exhaust gas concentrations for the RICE (three-test average)

Emission Unit	CO Emissions (ppmvd @15%O_2)	NOx Emissions (ppmvd @15%O_2)	VOC Emissions[1] (ppmvd @15%O_2)
EUDIENGINE	156	110	3.9
NSPS Limit	610	150	80

1. Measured as propane (C_3)

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A test protocol for the air emission testing was provided to MDEQ prior to performing the field sampling and testing. 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 3A	Exhaust gas O_2 content was determined using a zirconia ion/paramagnetic instrumental analyzers.
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 25A /ALT-096	Exhaust gas VOC (as NMHC) concentration was determined using a flame ionization analyzer equipped with a methane separation column.

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

O_2 and CO_2 content in the RICE exhaust gas stream was measured continuously throughout each test period in accordance with USEPA Method 3A. The O_2 content of the exhaust was monitored using a Servomex Model 4900 gas analyzer that uses a paramagnetic sensor. The CO_2 content of the exhaust gas was monitored using a Servomex Model 4900 gas analyzer that uses an infrared 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, O_2 and CO_2 content measurements corresponds 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 analyzer continuously and logged data as one-minute averages.

Prior to, and at the conclusion of each test, the instrument was 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 3 provides a summary of exhaust gas O_2 and CO_2 content measurements. Raw instrument response data are provided in Appendix 4.

4.3 Exhaust Gas Moisture Content (USEPA Method 4)

The 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 sampling was performed from a single centroid location.

4.4 NOx and CO Concentration Measurements (USEPA Methods 7E and 10)

NOx and CO pollutant concentrations in the RICE exhaust gas streams were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42c High Level chemiluminescence NOx analyzer and a Fuji Model ZRF non-dispersive infrared CO analyzer.

A continuous sample of the RICE exhaust gas was delivered to the instrumental analyzers using the sampling and conditioning system described previously in this section. Prior to, and at the conclusion of each test, the instruments were calibrated using appropriate upscale calibration and zero gas to determine analyzer calibration error and system bias.

Appendix 3 provides CO and NOx calculation sheets. Raw instrument response data are provided in Appendix 4.

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

VOC emissions were determined by measuring the non-methane hydrocarbon (NMHC) concentration in the RICE exhaust gas. NMHC pollutant concentration was determined using a Thermo Environmental Instruments (TEI) Model 55i Methane / Non-methane hydrocarbon analyzer. The TEI 55i analyzer contains an internal gas chromatograph column that separates methane from non-methane components and has been approved by the USEPA for measuring VOC relative to 40 CFR Part 60 Subpart JJJJ compliance test demonstrations (Alternative Test Method 096 or ALT-096). 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.

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 NMHC analyzer was not conditioned to remove moisture. Therefore, VOC measurements correspond to standard conditions with no moisture correction (wet basis). The measured VOC/NMHC concentration values were corrected to dry gas conditions (ppmvd) using the measured exhaust gas moisture content.

The instrumental analyzer was calibrated using certified propane concentrations in hydrocarbon-free air.

Appendix 3 provides VOC calculation sheets. Raw instrument response data for the NMHC analyzer is provided in Appendix 5.

5.0 QA/QC ACTIVITIES

5.1 NOx 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_x concentration is greater than 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (the measured NO_x concentration was 97.5% of the expected value).

5.2 Sampling System Response Time Determination

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

The TEI Model 42c analyzer exhibited the longest system response time at 62 seconds. Results of the response time determinations were recorded on field data sheets. For each test period, test data were collected once the sample probe was in position for at least twice the maximum system response time.

5.3 Gas Divider Certification (USEPA Method 205)

A STEC Model SGD-710C 10-step gas divider was used to obtain appropriate calibration span gases. The ten-step STEC gas divider was NIST certified 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.

5.4 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NOx, CO, O_2 and CO_2 have had an interference response test preformed prior to their use in the field, pursuant to the interference response test procedures specified in USEPA Method 7E. The appropriate interference test gases (i.e., gases that would be encountered in the exhaust gas stream) were introduced into each analyzer, separately and as a mixture with the analyte that each analyzer is designed to measure. All of analyzers exhibited a composite deviation of less than 3.0% of the span for all measured interferent gases. No major analytical components of the analyzers have been replaced since performing the original interference tests.

5.5 Instrument Calibration and System Bias Checks

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

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

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

5.6 Determination of Exhaust Gas Stratification

A stratification test for each RICE exhaust stack was performed prior to the first performance test sampling period. 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 data for each RICE exhaust stack gas indicate that the measured CO_2, CO and NOx concentrations did not vary by more than 5% of the mean across the stack diameter. Therefore, the RICE stack gas was considered to be non-stratified and the compliance test sampling was performed at a single sampling location within the RICE exhaust stack.

5.7 Meter Box Calibrations

The 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 5 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, 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 Table 6.1.

Table 1 of Subpart JJJJ indicates the following emission limits for stationary engines which are manufactured after July 1, 2011 and are between 500 and 1,350 Hp:

- 150 ppmvd NOx at 15% O_2;
- 610 ppmvd CO at 15% O_2; and
- 80 ppmvd VOC at 15% O_2.

The measured CO, NOx and VOC exhaust gas concentrations for EUDIENGINE are less than the limits specified in the SI-RICE NSPS.

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.

Table 6.1 Measured exhaust gas conditions and NOx, CO and VOC air pollutant emission rates for EUDIENGINE

Test Number: Test Date: Test Period Begin:	1 09/20/18 0941-1041	2 09/20/18 1102-1202	3 09/20/18 1221-1321	Three Test Average
Engine operating parameters				
Generator Output (kW)	359	362	360	360
Fuel Use Rate (scfm)	107	108	108	107
Exhaust gas composition				
O_2 content (% vol)	7.10	7.27	6.74	7.04
CO_2 content (% vol)	11.5	11.3	11.8	11.5
Moisture (% vol)	14.1	14.7	14.9	14.6
NOx emission rates				
NOx concentration (ppmvd)	263	254	259	259
NOx corrected to 15% O_2 (ppmvd)	113	110	108	110
NOx NSPS limit (ppmvd @15% O_2)	-	-	-	*150*
CO emission rates				
CO concentration (ppmvd)	364	361	377	367
CO corrected to 15% O_2 (ppmvd)	156	156	157	156
CO NSPS limit (ppmvd @ 15% O_2)	-	-	-	*610*
VOC emission rates				
VOC concentration (ppmv C_3)	7.96	7.64	7.68	7.76
VOC corrected to 15% O_2, dry (ppmvd)	3.96	3.88	3.76	3.87
VOC NSPS limit (ppmvd @15% O_2)	-	-	-	*80*