

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

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**Prepared for:
MICHIGAN STATE UNIVERSITY
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October 26, 2021**



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Report Certification

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

**Michigan State University
East Lansing, Michigan**

The material and data in this document were prepared under the supervision and direction of the undersigned.

Impact Compliance and Testing, Inc.



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Technical Manager

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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 Anerobic Digester facility 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 October 13, 2020. The emission test was performed on October 12, 2021, 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 Impact Compliance and Testing, Inc. (ICT) representatives Andrew Eisenberg and Max Fierro. The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan dated June 16, 2021 that was submitted to the Michigan Department of Environment, Great Lakes and Energy (EGLE) Air Quality Department (AQD) prior to the test event. Mr. Dan McGeen and Mr. Matthew Karl from the EGLE-AQD were on-site to observe portions of the test event.

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2.0 Summary of Test Results and Operating Conditions

2.1 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, NO_x, and VOC. The purpose of this test event was to satisfy the requirement to complete subsequent testing within 8,760 hours of the previous test event.

2.2 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. The average kW output during the test event was 350 kW.

Fuel flowrate (cubic feet per minute), methane concentration (%) and hydrogen sulfide concentration (ppm) was also recorded by MSU representatives at 15-minute intervals for each test period. The RICE fuel consumption rate ranged between 103 and 106 standard cubic feet per minute (scfm), methane ranged between 66.8% and 67.4% and hydrogen sulfide was 1 ppm during the test periods.

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

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 digester gas fueled RICE were sampled for three (3) one-hour test periods during the compliance testing performed October 12, 2021.

Table 2.2 presents the average measured CO, NO_x 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 2.1 Average engine operating conditions during the test periods

Emission Unit	Generator Output (kW)	Fuel Use (scfm)	Digester Gas CH₄ Content (%)	Digester Gas H₂S Content (ppm)
EUDIENGINE	350	104	67.1	1.0
Max Capacity	380	--	--	--

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

Emission Unit	CO Emissions (ppmvd @15%O₂)	NOx Emissions (ppmvd @15%O₂)	VOC Emissions¹ (ppmvd @15%O₂)
EUDIENGINE	142	127	2.8
NSPS Limit	610	150	80

Notes for Table 2.2:

1. Measured as propane (C₃)

3.0 Source and Sampling Location Description

3.1 General Process Description

Biogas containing methane is generated at the South Campus Anerobic Digester facility 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.

3.2 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.

3.3 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 vertical 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 44 inches (>5.5 duct diameter) upstream and 36 inches (4.5 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.

4.0 Sampling and Analytical Procedures

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

4.1 Summary of Sampling Methods

USEPA Method 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 NO _x 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)

CO₂ and O₂ content in the RICE exhaust gas stream was measured continuously throughout each test period in accordance with USEPA Method 3A. The CO₂ content of the exhaust was monitored using a Servomex 4900 infrared gas analyzer. The O₂ 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 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 O₂ and CO₂ 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 3 provides O₂ and CO₂ calculation sheets. 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 NO_x and CO Concentration Measurements (USEPA Methods 7E and 10)

NO_x and CO pollutant concentrations in the RICE exhaust gas streams were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42i High Level chemiluminescence NO_x analyzer and a Fuji ZRF CO analyzer.

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

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

4.5 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 3 provides VOC calculation sheets. Raw instrument response data for the NMHC analyzer is provided in Appendix 4.

5.0 QA/QC Activities

5.1 NO_x Converter Efficiency Test

The NO₂ – NO conversion efficiency of the Model 42i analyzer was verified prior to the testing program. A USEPA Protocol 1 certified concentration of NO₂ was injected directly into the analyzer, following the initial three-point calibration, to verify the analyzer's conversion efficiency. The analyzer's NO₂ – NO converter uses a catalyst at high temperatures to convert the NO₂ to NO for measurement. The conversion efficiency of the analyzer is deemed acceptable if the measured NO_x concentration is within 90% of the expected value.

The NO₂ – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_x concentration was 93.8% 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 42i analyzer exhibited the longest system response time at 117 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 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, O₂ and CO₂ have had an interference response test performed 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, CO₂ and O₂ 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 CO₂, O₂, NO_x, and CO in nitrogen and zeroed using hydrocarbon free nitrogen. The NMHC (VOC) instrument was calibrated with USEPA Protocol 1 certified concentrations of propane in air and zeroed using hydrocarbon-free air. A STEC Model SGD-710C ten-step gas divider was used to obtain intermediate calibration gas concentrations as needed.

5.6 Determination of Exhaust Gas Stratification

A stratification test was performed for the 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 stack indicated that the measured CO, NO_x, O₂ and CO₂ 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 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 (NO₂ – 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 NO_x at 15% O₂;
- 610 ppmvd CO at 15% O₂; and
- 80 ppmvd VOC at 15% O₂.

The measured CO, NO_x 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. The engine-generator set was operated within 10% of maximum output and no variations from normal operating conditions occurred during the engine test periods.

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

Test Number:	1	2	3	Three
Test Date:	10/12/21	10/12/21	10/12/21	Test
Test Period Begin:	0705-0805	0829-0929	0952-1052	Average
Engine operating parameters				
Generator Output (kW)	349	351	350	350
Fuel Use Rate (scfm)	105	104	104	104
Fuel CH ₄ Content (%)	66.8	67.1	67.4	67.1
Fuel H ₂ S Content (ppm)	1	1	1	1
Exhaust gas composition				
O ₂ content (% vol)	6.50	6.52	6.53	6.52
CO ₂ content (% vol)	11.88	11.88	11.83	11.86
Moisture (% vol)	9.91	17.75	13.55	13.74
NOx emission rates				
NOx concentration (ppmvd)	296	315	318	310
NOx corrected to 15% O ₂ (ppmvd)	121	129	130	127
<i>NOx NSPS limit (ppmvd @15% O₂)</i>	-	-	-	150
CO emission rates				
CO concentration (ppmvd)	347	346	344	345.5
CO corrected to 15% O ₂ (ppmvd)	142	142	141	142
<i>CO NSPS limit (ppmvd @ 15% O₂)</i>	-	-	-	610
VOC emission rates				
VOC concentration (ppmv C ₃)	6.17	5.88	5.73	5.92
VOC corrected to 15% O ₂ , dry (ppmvd)	2.81	2.93	2.72	2.82
<i>VOC NSPS limit (ppmvd @15% O₂)</i>	-	-	-	80

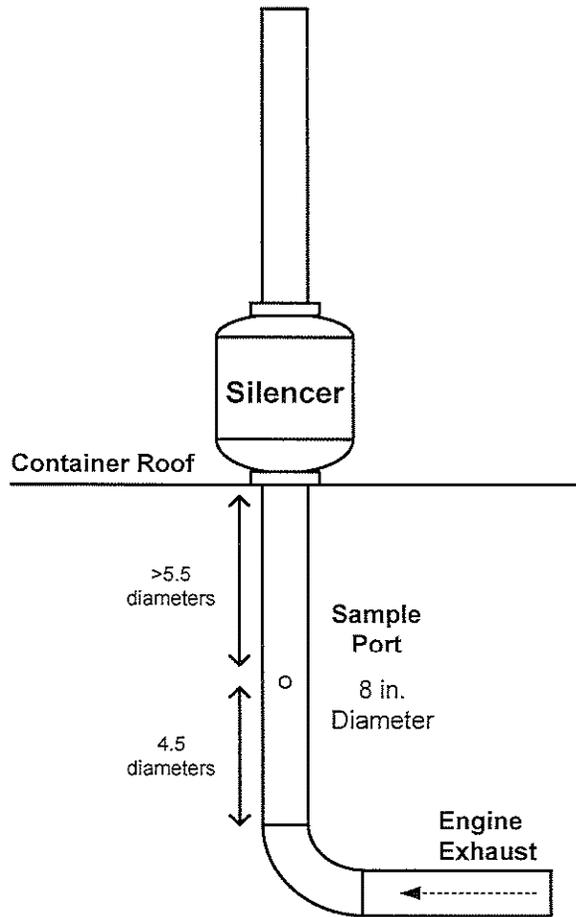
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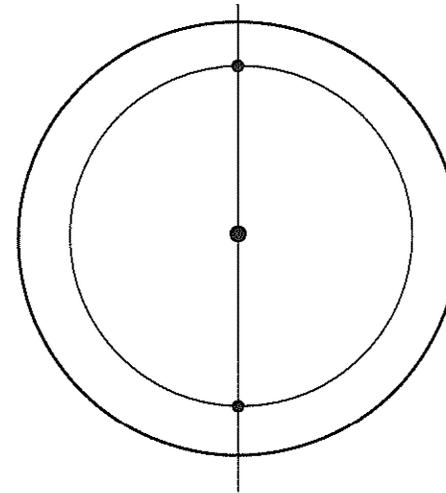
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APPENDIX 1

- RICE Engine Sample Port Diagram



Exhaust Stack Cross-Section



Stratification test locations as measured from stack wall

Pt. #	in.	% Diameter
1	1.34	16.7
2	4.00	50
3	6.66	83.3

10-16-20 ALR	Figure 1-1 MSU South Campus Anaerobic Digester Engine Exhaust Sample Location, MAN Model No. E2842LE322		
	Scale None	Sheet 1 of 1	ICT Drawing No.: MSU-01

