Derenzo Environmental Services
Consulting and Testing

Executive Summary

UNIVERSITY OF MICHIGAN, CAMPUS SAFETY SERVICES BUILDING CUMMINS MODEL GTA38 NATURAL GAS FUELED IC ENGINE EMISSION TEST RESULTS

University of Michigan contracted Derenzo Environmental Services, to conduct a performance demonstration for the determination of nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOC) concentrations from one (1) Cummins Model GTA38 natural gas-fired reciprocating internal combustion engine and electricity generator set EU-CSSB operated at the University of Michigan, Campus Safety Services Building in Ann Arbor, Michigan.

Michigan Department of Environmental Quality (MDEQ) Air Quality Division (AQD) Renewable Operating Permit (ROP) No. MI-ROP-M0675-2014a requires that performance testing be performed on the Cummins Model GTA38 engine within 1 year of startup and every 8,760 hours of operation (or every three years) in accordance with the provisions of 40 CFR Part 60 Subpart JJJ (NSPS for spark ignition internal combustion engines).

The following table presents the emissions results from the performance demonstration.

Emission Unit	NO_x Concentration (ppmvd @ 15% O_2)	CO Concentration (ppmvd @ 15% O_2)	VOC Concentration (ppmvd @ 15% O_2)
EU-CSSB	34.9	117	2.09
Permit Limits	160	540	86

Parts per million by volume, dry basis, corrected to 15% oxygen. VOC concentration is C_3 (propane).

The following table presents the operating data recorded during the performance demonstration.

Emission Unit	Generator Output (kW)
EU-CSSB	489

kW=kilowatt

The data presented above indicates that EU-CSSB was tested while the unit operated within 10% of its maximum capacity (800 HP and 500 kW) and is in compliance with the emission standards specified in 40 CFR 60.4233(e) and MDEQ-AQD ROP No. MI-ROP-M0675-2014a.

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR QUALITY DIVISION

RENEWABLE OPERATING PERMIT REPORT CERTIFICATION

Authorized by 1994 P.A. 451, as amended. Failure to provide this information may result in civil and/or criminal penalties.

Reports submitted pursuant to R 336.1213 (Rule 213), subrules (3)(c) and/or (4)(c), of Michigan's Renewable Operating (RO) Permit program must be certified by a responsible official. Additional information regarding the reports and documentation listed below must be kept on file for at least 5 years, as described in General Condition No. 22 in the RO Permit and be made available to the Department of Environmental Quality, Air Quality Division upon request.

Source Name: The University of Michigan — County: Washtenaw

Source Address: 1239 Kipke Drive — City: Ann Arbor

AQD Source ID (SRN): M0675 — RO Permit No.: MI-ROP-M0675-2014a — RO Permit Section No.:

Please check the appropriate box(es):

☐ **Annual Compliance Certification (General Condition No. 28 and No. 29 of the RO Permit)**

Reporting period (provide inclusive dates): From _____ To _____

☐ 1. During the entire reporting period, this source was in compliance with **ALL** terms and conditions contained in the RO Permit, each term and condition of which is identified and included by this reference. The method(s) used to determine compliance is/are the method(s) specified in the RO Permit.

☐ 2. During the entire reporting period this source was in compliance with all terms and conditions contained in the RO Permit, each term and condition of which is identified and included by this reference, **EXCEPT** for the deviations identified on the enclosed deviation report(s). The method used to determine compliance for each term and condition is the method specified in the RO Permit, unless otherwise indicated and described on the enclosed deviation report(s).

☐ **Semi-Annual (or More Frequent) Report Certification (General Condition No. 23 of the RO Permit)**

Reporting period (provide inclusive dates): From _____ To _____

☐ 1. During the entire reporting period, **ALL** monitoring and associated recordkeeping requirements in the RO Permit were met and no deviations from these requirements or any other terms or conditions occurred.

☐ 2. During the entire reporting period, all monitoring and associated recordkeeping requirements in the RO Permit were met and no deviations from these requirements or any other terms or conditions occurred, **EXCEPT** for the deviations identified on the enclosed deviation report(s).

☒ **Other Report Certification**

Reporting period (provide inclusive dates): From 03/27/2017 To 03/27/2017

Additional monitoring reports or other applicable documents required by the RO Permit are attached as described:

Campus Safety Services Building emergency generator emissions test report, 3/27/2017.

I certify that, based on information and belief formed after reasonable inquiry, the statements and information in this report and the supporting enclosures are true, accurate and complete.

Terrance G. Alexander	Executive Director	734-647-1143
Name of Responsible Official (print or type)	Title	Phone Number

Signature of Responsible Official — Date: 5/1/2017

* Photocopy this form as needed.

EQP 5736 (Rev 9/01)

NSPS EMISSION TEST REPORT

Title	NSPS EMISSION TEST REPORT FOR THE VERIFICATION OF AIR POLLUTANT EMISSIONS FROM A NATURAL GAS FIRED INTERNAL COMBUSTION ENGINE EMERGENCY GENERATOR SET
Report Date	April 25, 2017
Test Date(s)	March 27, 2017

Facility Information	
Name Street Address	University of Michigan, Campus Safety Services Building 1239 Kipke Drive
City, County	Ann Arbor, Washtenaw
SRN	M0675

Permit / Emission Unit Information	
Permit No.	MI-ROP-M0675-2014a
Emission Unit:	EU-CSSB, Cummins 500 kW, 800 HP SI-RICE genset

Testing Contractor	
Company	Derenzo Environmental Services
Mailing Address	39395 Schoolcraft Road Livonia, MI 48150
Phone	(734) 464-3880
Project No.	1701087

NSPS EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM A
NATURAL GAS FUELED INTERNAL COMBUSTION ENGINE
EMERGENCY GENERATOR SET

UNIVERSITY OF MICHIGAN, CAMPUS SAFETY SERVICES BUILDING

1.0 INTRODUCTION

University of Michigan (University) operates a natural gas fired, spark-ignition reciprocating internal combustion engine (RICE) emergency generator set located adjacent to the Campus Safety Services Building (CSSB) at the Ann Arbor South Campus in Washtenaw County. The Cummins Model GTA38 SI-RICE generator set is identified as emission unit EU-CSSB in Renewable Operating Permit (ROP) No. MI-ROP-M0675-2014a.

The SI-RICE emergency generator set has a horsepower rating of 800 HP and is subject to the SI-RICE New Source Performance Standard (NSPS) codified in 40 CFR Part 60 Subpart JJJJ. The SI-RICE NSPS specifies that:

1. *Owners and operators of stationary SI ICE with a maximum engine power greater than or equal to 75 kW (except gasoline and rich burn engines that use LPG) must comply with the emission standards in Table 1 to this subpart for their stationary SI ICE.*

2. *If you are an owner or operator of a stationary SI internal combustion engine greater than 500 HP...you must conduct an initial performance test within 1 year of engine startup and conduct subsequent performance testing every 8,760 hours or 3 years, whichever comes first, thereafter to demonstrate compliance.*

The compliance testing was performed by Derenzo Environmental Services (DES), a Michigan-based environmental consulting and testing company. DES representatives Tyler Wilson and Tom Andrews performed the field sampling and measurements March 27, 2017.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan that was reviewed and approved by the MDEQ-AQD in the March 7, 2017 test plan approval letter. MDEQ-AQD representatives Mr. Thomas Maza and Ms. Diane Kavanaugh-Vetort observed portions of the testing project.

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 by Cummins employees or representatives (hired by University of Michigan). This test report has been reviewed by University of Michigan representatives and approved for submittal to the Michigan Department of Environmental Quality.

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:

Tyler J. Wilson
Livonia Office Supervisor
Derenzo Environmental Services

Reviewed By:

Andy Rusnak, QSTI
Technical Manager
Derenzo Environmental Services

2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

Pipeline natural gas is used as fuel for the RICE. The RICE generator set is classified as an emergency generator and is only operated to provide electricity to the Campus Safety Services Building (CSSB) during power outages and for periodic maintenance testing.

2.2 Rated Capacities and Air Emission Controls

The Cummins Model GTA38 spark-ignited RICE generator set has a rated output of 800 horsepower (HP) and the connected generator has a rated electricity output of 500 kilowatts (kW). The engine is equipped with an air-to-fuel ratio controller, which is set to maintain efficient fuel combustion and maximize power output. Exhaust gas is released directly to atmosphere through two (2) identical vertical exhaust stacks.

The engine is equipped with a non-selective catalytic reduction (NSCR) system for passively controlling CO, NOx and hydrocarbon (HC) emissions. The NSCR system consists of two catalyst beds that allow CO and HC to be oxidized by the oxygen that is a component of the NOx. This system relies on a low concentration of oxygen at the catalyst bed inlet. The engine is equipped with controls to adjust the fuel-air-ratio of the engine intake manifold.

The NSCR is passive in nature and its efficiency is dependent on exhaust gas temperature and oxygen content as well as catalyst bed condition. In accordance with 40 CFR 60.4243, the air-to-fuel ration controller is optimized for emissions reduction.

2.3 Sampling Locations

The RICE exhaust gas is released to the atmosphere through two (2) identical vertical exhaust stacks with vertical release points.

Prior to the test event, two (2) identical vertical exhaust stack extensions were installed by DES personnel to meet USEPA Method 1 criteria. These stack extensions were removed following compliance testing.

The exhaust stack sampling ports for the Cummins Model GTA38 engine (EU-CSSB) are located in two (2) identical exhaust stack extensions with an inner diameter of 8.0 inches. Each stack extension is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 14.3 inches (1.8 duct diameters) upstream and 44.0 inches (5.5 duct diameters) downstream from any flow disturbance and satisfies the USEPA Method 1 criteria for a representative sample location.

Sample port locations 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 ROP No. MI-ROP-M0675-2014a require University to test the RICE (EU-CSSB) for carbon monoxide (CO), nitrogen oxides (NOx), and volatile organic compounds (VOC) emissions within 1 year after engine startup and every 8,760 hours of operation or 3 years, whichever comes first. Measurements were performed for the RICE exhaust to determine CO, NO_X, and VOC (as non-methane hydrocarbons (NMHC)) concentrations and diluent gas content (oxygen and carbon dioxide).

3.2 Operating Conditions During the Compliance Tests

The testing was performed while the engine/generator set was operated within at least 10% of maximum rated capacity of 500 kW electricity output. Cummins representatives (hired by University) provided kW output data at 15-minute intervals for each test period. The RICE generator kW output ranged between 489 and 490 kW (489 kW average) during the test periods (98% of maximum capacity).

Appendix B provides operating records provided by Cummins representatives for the test periods.

3.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the RICE generator set were sampled for three (3) one-hour test periods during the compliance testing performed March 27, 2017. Since the RICE has two (2) exhaust stacks, gases exhausted from each stack were sampled for 30-minutes during each one-hour test.

Table 3.1 presents the average measured CO, NO_X, and VOC emission rates for the engine (average of the three test periods for the engine) and applicable emission limits.

Results of the engine performance tests demonstrate compliance with emission limits specified in ROP No. MI-ROP- M0675-2014a. Test results for each one-hour sampling period are presented in Section 6.0 of this report.

Table 3.1 Average measured emission concentrations the RICE generator set (three-test average)

Emission Unit	CO Concentration (ppmvd)†	NOx Concentration (ppmvd)†	VOC Concentration (ppmvd)†
EU-CSSB	117	34.9	2.09
Emission Limit	540	160	86

† Parts per million by volume, dry basis, corrected to 15% oxygen. VOC concentration is C_3 (propane).

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A protocol for the air emission testing was reviewed and approved by the MDEQ-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 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 a chemiluminescence instrumental analyzer.
USEPA Method 10	Exhaust gas CO concentration was measured using an NDIR instrumental analyzer.
USEPA Method 25A /ALT-096	Exhaust gas VOC (as NMHC) concentration was determined using a flame ionization analyzer equipped with an internal methane separation GC column.

4.2 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 exhaust gas CO_2 content was monitored using a Servomex 1440D single beam single wavelength (SBSW) infrared gas analyzer. The exhaust gas O_2 content was monitored using a paramagnetic sensor within the Servomex 1440D gas analyzer.

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 D provides O_2 and CO_2 calculation sheets. Raw instrument response data are provided in Appendix E.

4.3 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 one (1) 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 the sampling period, the moisture gain in the impingers was determined gravimetrically by weighing each impinger to determine net weight gain.

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 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 heated sample line and gas conditioning system described previously in this section. 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_X calculation sheets. Raw instrument response data are provided in Appendix E.

4.5 Measurement of Volatile Organic Compounds (USEPA Methods 25A and 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 several alternate test methods approving the use of the TEI 55-series analyzer as an effective instrument for measuring NMOC from gas-fueled reciprocating internal combustion engines (RICE) in that it uses USEPA Method 25A and 18 (ALT-066, ALT-078 and 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.

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

5.0 QA/QC ACTIVITIES

5.1 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 greater than or equal to 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_2 concentration was 93.8% of the expected value, i.e., greater than 90% of the expected value as required by Method 7E).

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 55 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, 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 the 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 the 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 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_2 – NO conversion efficiency test data, instrument calibration and system bias check records, calibration gas and gas divider certifications, interference test results, and meter box calibration records).

6.0 RESULTS

6.1 Test Results and Allowable Emission Limits

Engine operating data and air pollutant emission measurement results for each one-hour test period are presented in Table 6.1. The serial number (SN) for the RICE is presented at the top of the table.

The measured average air pollutant concentrations for the RICE (EU-CSSB) are less than the allowable limits specified in ROP No. MI-ROP-M0675-2014a for the engines:

- 540 parts per million by volume, dry basis, corrected to 15% oxygen (ppmvd @ 15% O_2) CO;
- 160 ppmvd @ 15% O_2 NO_x; and
- 86 ppmvd @ 15% O_2 VOC.

6.2 Variations from Normal Sampling Procedures or Operating Conditions

The engine-generator set was operated within 10% of maximum output, and no variations from normal operating conditions of the RICE occurred.

The testing for all pollutants was performed in accordance with the approved test protocol except for the two (2) following variations, both recommended and approved by MDEQ-AQD representative Mr. Thomas Maza onsite on March 27, 2017:

- One (1) USEPA Method 4 RICE exhaust gas moisture content measurement was conducted during Test No. 1. The moisture content measurement consisted of a total of one-hour of sampling (30-minutes in each stack). The result of this measurement was 19.0% moisture content, and this was used for VOC concentration calculations for all three (3) tests.

- A stratification check was not performed prior to single point, air pollutant concentration sampling. It was assumed that the RICE exhaust gas was evenly mixed throughout each stack, so single point sampling was performed in both stacks.

Table 6.1 Measured exhaust gas conditions and NO_x, CO, and VOC air pollutant concentrations
University of Michigan RICE (EU-CSSB), SN: M10H340316/25345575

Test No.	1	2	3	
Test date	3/27/17	3/27/17	3/27/17	Three Test
Test period (24-hr clock)	1644 - 1749	1817 - 1921	1945 - 2049	Average
Generator output (kW)	489	489	489	489
Exhaust Gas Composition				
CO_2 content (% vol)	12.1	12.1	12.1	12.1
O_2 content (% vol)	-0.01	-0.01	-0.01	-0.01
Moisture (% vol)	19.0	-	-	19.0
Nitrogen Oxides				
NO_X conc. (ppmvd)	110	128	133	124
NO_X conc. corrected to 15% O_2	31.1	36.0	37.5	34.9
NO_X permit limit @ 15% O_2 (ppmvd)	-	-	-	160
Carbon Monoxide				
CO conc. (ppmvd)	369	373	498	414
CO conc. corrected to 15% O_2	104	105	141	117
CO permit limit @ 15% O_2 (ppmvd)	-	-	-	540
Volatile Organic Compounds				
VOC conc. (ppmv C_3)	5.43	5.84	6.74	6.00
VOC conc. corrected to 15% O_2 (dry)	1.89	2.03	2.35	2.09
VOC permit limit @ 15% O_2 (ppmvd)	-	-	-	86