Derenzo Environmental Services
Consulting and Testing

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Executive Summary

UNIVERSITY OF MICHIGAN, REASERCH MUSEUMS CENTER
CUMMINS MODEL GTA50 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 GTA50 natural gas-fired reciprocating internal combustion engine (RICE) and electricity generator set operated at the Research Museums Center in Ann Arbor, Washtenaw County.

The Research Museums Center emergency generator is identified in Renewable Operating Permit (ROP) No. MI-ROP-M0675-2014a as EU-VARSITYDR and is part of Flexible Group FG-EMERG-JJJJ. The engine is required to be tested every 8,760 hours of operation (or at least every three years) in accordance with the provisions of 40 CFR Part 60 Subpart JJJJ (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-VARSITYDR	40	235	2.1
Permit Limits	*160*	*540*	*86*

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

The EU-VARSITYDR generator has a maximum electricity generation rate of 600 kilowatts (kW) and was operated at an average of 592 kW during the test periods.

The data presented above indicate that the engine was tested while the unit operated within 10% of its maximum capacity (920 HP and 600 kW) and is in compliance with the emission standards specified in MI-ROP-M0675-2014a and 40 CFR 60.4233(e).

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Derenzo Environmental Services
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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	January 29, 2018
Test Date(s)	January 5, 2018

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

Emission Unit Information	
Location:	Research Museums Center 3600 Varsity Drive, Ann Arbor
Emission Unit:	EU-VARSITYDR Cummins GTA50 CC, 600 kW, 920 SI-RICE genset

Testing Contractor	
Company	Derenzo Environmental Services
Mailing Address	39395 Schoolcraft Road Livonia, MI 48150
Phone	(734) 464-3880
Project No.	1712006

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
REASERCH MUSEUMS CENTER

1.0 INTRODUCTION

The University of Michigan operates a natural gas fired, spark-ignition reciprocating internal combustion engine emergency generator set (SI-RICE genset) located behind the Research Museums Center on Varsity Drive in Ann Arbor in Washtenaw County. The Cummins Model GTA50 SI-RICE genset at the Research Museums Center is identified in the Renewable Operating Permit as Emission Unit EU-VARSITYDR.

The SI-RICE genset has a horsepower rating of 920 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 Jason Logan and Kevin Anderson performed the field sampling and measurements January 5, 2018.

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 December 5, 2017 test plan approval letter. MDEQ-AQD representative Mr. Mark Dziadosz observed portions of the testing project.

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. Facility process data were collected and provided by Cummins employees or representatives (hired by the 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:

KEVIN ANDERSON

Kevin Anderson
Environmental Consultant
Derenzo Environmental Services

Reviewed By:

RLHarvey

Robert L. Harvey, P.E.
General Manager
Derenzo Environmental Services

2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

The SI-RICE genset is classified as an emergency generator and is only operated to provide electricity to the Research Museums Center during power outages and for periodic maintenance testing.

2.2 Rated Capacities and Air Emission Controls

The Cummins Model GTA50 SI-RICE genset has a rated output of 920 horsepower (HP) and the connected generator has a rated electricity output of 600 kilowatts (kW). The engine is fueled exclusively with pipeline natural gas and equipped with an air-to-fuel ratio controller.

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 horizontal exhaust stacks with horizontal release points.

Prior to the test event, horizontal exhaust stack extensions were installed by DES personnel to provide sampling locations that meet USEPA Method 1 criteria. Each stack extension had an inner diameter of 8 inches and was 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. The stack extensions were removed following compliance testing.

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 provisions of 40 CFR Part 60 Subpart JJJJ require that SI-RICE be tested for carbon monoxide (CO), nitrogen oxides (NOx), and volatile organic compounds (VOC) emissions every 8,760 hours of operation or 3 years, whichever comes first. Emission tests were previously performed for this unit on January 6, 2015.

3.2 Operating Conditions During the Compliance Tests

The testing was performed while the SI-RICE genset was operated within 10% of the maximum rated capacity of 600 kW electricity output. Cummins representatives (hired by the University fo Michigan) provided kW output data at 15-minute intervals for each test period. The SI-RICE genset kW output was 592 kW during the test periods (93% 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 SI-RICE genset were sampled for three (3) one-hour test periods during the compliance testing performed January 5, 2018. Since the SI-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 40 CFR Part 60 Subpart JJJJ. Test results for each one-hour sampling period are presented in Section 6.0 of this report.

Table 3.1 Average measured emission concentrations for the SI-RICE genset (three-test average)

Emission Unit	NOx Concentration (ppmvd)†	CO Concentration (ppmvd)†	VOC Concentration (ppmvd)†
EU-VARSITYDR	40	235	2.1
Emission Standard	*160*	*540*	*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 C provides handwritten field data sheets and moisture calculation 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 (i.e., 30 minutes per exhaust stack). During each sampling period, a gas sample was extracted at a constant rate from the source where moisture was removed from the sampled gas stream using impingers that were submersed in an ice bath. At the conclusion of each sampling period, the moisture gain in the impingers was determined gravimetrically by weighing each impinger to determine net weight gain.

4.4 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 100% 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 59 seconds. Results of the response time determinations were recorded on field data sheets. For each test period, and whenever the sample probe was moved between stacks, 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, and O_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, 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 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 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 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.

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 each RICE exhaust stack indicate that the measured NO_X 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.

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 Table 6.1. The serial number (SN) for the RICE is presented at the top of the table.

Table 6.1 presents the average measured concentrations for the East and West exhausts and the average for the one-hour test period. The average one-hour concentration value was corrected by the average measured oxygen content to calculate pollutant concentrations corrected to 15% oxygen.

The average measured air pollutant concentrations for the SI-RICE are less than the allowable limits specified in 40 CFR Part 60 Subpart JJJJ for the EU-VARSITYDR engine:

- 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 testing for all pollutants was performed in accordance with the approved test protocol. The engine-generator set was operated within 10% of maximum output during the test periods.

Table 6.1 Measured NO_x, CO, and VOC air pollutant concentrations for EU-VARSITYDR; SN: GM11F239933

Test No. Test date Test period (24-hr clock)	1 1/5/18 953 - 1100	2 1/5/18 1122 - 1229	3 1/5/18 1248 – 1355	Three Test Average
Generator output (kW)	592	592	592	592
Exhaust Gas Composition				
West O_2 content (% vol)	0.03	0.07	0.52	0.21
East O_2 content (% vol)	0.05	0.13	0.15	0.11
Average O_2 content (% vol)	0.04	0.10	0.34	0.16
Moisture (% vol)	17.1	17.5	18.2	17.6
Nitrogen Oxides				
West NOx conc.(ppmvd)	84	86	83	84
East NOx conc. (ppmvd)	197	198	199	198
Average NOx conc. (ppmvd)	140	142	141	141
NOx conc. corrected to 15% O_2	40	40	40	40
NOx permit limit @ 15% O_2 (ppmvd)	-	-	-	*160*
Carbon Monoxide				
West CO conc. (ppmvd)	952	909	867	909
East CO conc. (ppmvd)	715	778	738	744
Average CO conc. (ppmvd)	834	844	802	827
CO conc. corrected to 15% O_2	236	239	230	235
CO permit limit @ 15% O_2 (ppmvd)	-	-	-	*540*
Volatile Organic Compounds				
West VOC conc.(ppmv C_3)	6.1	5.3	5.3	5.6
East VOC conc.(ppmv C_3)	6.2	6.5	6.6	6.5
Average VOC conc. (ppmv C_3)	6.2	5.9	6.0	6.0
VOC conc. corrected to 15% O_2 (dry)	2.1	2.0	2.1	2.1
VOC permit limit @ 15% O_2 (ppmvd)	-	-	-	*86*