NEW SOURCE PERFORMANCE STANDARD
AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM A
NATURAL GAS FIRED INTERNAL COMBUSTION ENGINE
EMERGENCY GENERATOR SET

Prepared for:

University of Michigan
Ross School of Business (Blau Hall)
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IMPACT COMPLIANCE & TESTING

Report Certification

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University of Michigan
Ross School of Business (Blau Hall)
Ann Arbor, MI

Report Certification

This test report was prepared by ICT based on field sampling data collected by ICT. 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 State of Michigan EGLE-AQD.

I certify that the testing was conducted in accordance with the Emission Test Plan and approved test plan approval letter 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
Sr. Project Manager
Impact Compliance & Testing, Inc.

Table of Contents

List of Tables

List of Appendices

1.0 Introduction

The University of Michigan (University) operates a natural gas fired, spark-ignition (SI) reciprocating internal combustion engine (RICE) emergency generator set located at Blau Hall, which is part of the Ross School of Business, 701 Tappan Avenue in Ann Arbor, Washtenaw County.

The Ross SI-RICE emergency generator set has a horsepower rating of 803 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 presented in this report was performed by Impact Compliance & Testing, Inc. (ICT), a Michigan-based environmental consulting and testing company. ICT representatives Tyler Wilson and Blake Beddow performed the field sampling and measurements on November 2, 2022.

The engine performance tests consisted of triplicate, one-hour sampling periods for nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOC, as non-methane hydrocarbons (NMHC or NMOC)). Exhaust gas moisture, oxygen (O_2) content was determined for each test period to calculate air pollutant concentrations for comparison to applicable SI-RICE NSPS (40 CFR Part 60 Subpart JJJJ) limits.

The exhaust gas sampling and analysis was performed using procedures specified in the Emission Test Plan (ICT) dated September 9, 2022 that was reviewed and approved by EGLE-AQD.

Questions regarding this air emission test report should be directed to:

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2.0 Summary of Test Results and Operating Conditions

2.1 Purpose and Objective of the Tests

The provisions of the SI-RICE NSPS (40 CFR Part 60 Subpart JJJJ) require University to test the RICE (EUROSS500KW Engine) for carbon monoxide (CO), nitrogen oxides (NOx), and volatile organic compounds (VOC) 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 or NMOC)) concentrations and diluent gas content (oxygen and carbon dioxide).

2.2 Operating Conditions During the Compliance Tests

The testing was performed while the engine/generator set was operated at maximum routine operating conditions (within 10% of 500 kW electricity output). Cummins representatives provided kW output in 15-minute increments for each test period. The RICE generator kW output was 497 kW throughout the test periods.

Fuel flowrate (cubic feet per hour (CFH)) was also recorded by Cummins representatives in 15-minute increments for each test period. The RICE fuel consumption rate was 6,969 CFH throughout the test periods.

Appendix 2 provides operating records provided by Cummins 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 sampled natural gas fueled RICE were sampled for three (3) one-hour test periods during the compliance testing performed November 2, 2022.

Table 2.2 presents the average measured CO, NO_X, and VOC concentrations for the EUROSS500KW Engine (average of the three test periods) and applicable limits.

Test results for each one-hour sampling period and comparison to the applicable concentration limits are presented in Section 6.0 of this report.

Table 2.1 Average engine operating conditions during the test periods

Engine Parameter	EUROSS500KW Engine Cummins GTA38 CC
Generator output (kW)	497
Engine fuel use (CFH)	6,969

Table 2.2 Average measured pollutant concentrations for the engine (3-test average)

	CO	NOx	VOC
Emission Unit	(ppmvd)†	(ppmvd)†	(ppmvd)†
EUROSS500KW Engine	401	32	2.79
Permit Limit	***540***	***160***	***86***

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

The data presented in Table 2.2 indicates that the EUROSS500KW Engine was tested while the unit operated within 10% of its maximum capacity (803 HP and 500 kW) and is in compliance with the emission standards specified in 40 CFR 60.4233(e).

3.0 Source and Sampling Location Description

3.1 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 Ross School of Business, Blau Hall during power outages and for periodic maintenance testing.

3.2 Rated Capacities and Air Emission Controls

The Cummins Model GTA38 CC SI-RICE generator set has a rated output of 803 HP and the connected generator has a rated electricity output of 500 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, VOC emissions. The NSCR system consists of two catalyst beds that allow CO and VOC 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.

3.3 Sampling Locations

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

The exhaust stack sampling ports for the Cummins Model GTA38 CC engine (EUROSS500KW Engine) 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 14.25 inches (1.78 duct diameters) upstream and >19.0 inches (>2.38 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 1 provides a diagram of the test sampling location.

4.0 Sampling and Analytical Procedures

An Emission Test Plan for the air compliance testing was reviewed and approved by 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 4	Exhaust gas moisture was determined based on the water weight gain in chilled impingers.
USEPA Method 3A	Exhaust gas O_2 content was determined using paramagnetic and infrared instrumental analyzers, respectively.
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 or NMOC) concentration was determined using a flame ionization analyzer equipped with methane separation column.

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

O_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 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 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 calculation sheets. Raw instrument response data are provided in Appendix 5.

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. Exhaust gas moisture content measurements were performed concurrently with the instrumental analyzer sampling periods. 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.

Appendix 3 provides moisture calculations and field data sheets.

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

NO_X and CO pollutant concentrations in the RICE exhaust gas stream was determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42i 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.

4.5 Measurement of VOC (USEPA Method 25A / ALT-096)

The VOC concentration rate was determined by measuring the nonmethane hydrocarbon (NMHC or NMOC) 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.

5.0 QA/QC Activities

5.1 NO_x Converter Efficiency Test

The NO_2 – NO conversion efficiency of the TEI Model 42i 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 within 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_2 concentration was 93.2% of the expected value).

5.2 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.

5.3 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.

5.4 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, 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 reintroduced 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.

5.5 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 each stack diameter. Pollutant concentration data were recorded at each sample point for a minimum of twice the maximum system response time for each RICE exhaust stack.

The recorded concentration data for each RICE exhaust stack indicated that the measured O_2 concentrations did not vary by more than 5% of the mean across each 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.

5.6 System Response Time

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.

Sampling periods did not commence until the sampling probe had been in place for at least twice the greatest system response time.

5.7 Meter Box Calibrations

The dry gas meter sampling console used for moisture testing 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 metering console was 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 certifications, interference test results, meter box calibration records, and field equipment calibration records).

6.0 Results

6.1 Test Results and Allowable Concentration Limits

Engine operating data and air pollutant concentration measurement results for each one-hour test period are presented in Table 6.1.

The EUROSS500KW Engine has the following allowable concentration limits specified in the SI-RICE NSPS (40 CFR Part 60 Subpart JJJJ):

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

The measured air pollutant concentrations for the EUROSS500KW Engine are less than the allowable limits specified in the SI-RICE NSPS (40 CFR Part 60 Subpart JJJJ).

6.2 Variations from Normal Sampling Procedures or Operating Conditions

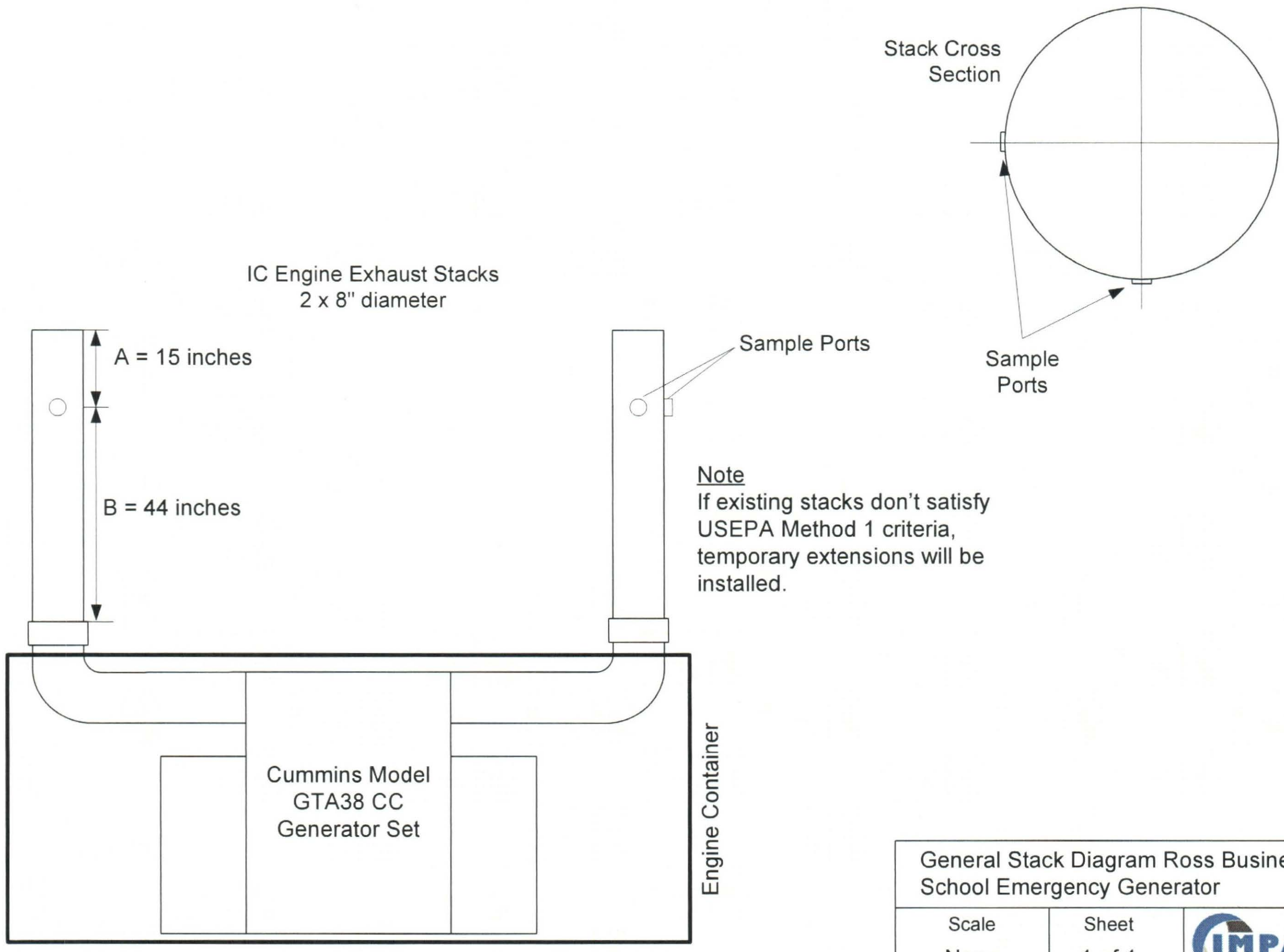
The testing for all pollutants was performed in accordance with USEPA methods and the approved Emission Test Plan. The engine-generator set was operated within 10% of maximum output (500 kW generator output for Cummins Model GTA38 CC RICE) and no variations from normal operating conditions occurred during the engine test periods.

Table 6.1 Measured exhaust gas conditions and pollutant concentrations for the EUROSS500KW Engine

Test No. Test date Test period (24-hr clock)	1 11/2/2022 0928-1034	2 11/2/2022 1115-1219	3 11/2/2022 1240-1345	Three Test Average
Fuel flowrate (CFH)	6,969	6,969	6,969	6,969
Generator output (kW)	497	497	497	497
Exhaust Gas Composition				
O_2 content (% vol)	0.67	0.55	0.64	0.62
Moisture (% vol)	18.2	20.3	19.2	19.2
Nitrogen Oxides				
NO_X conc. (ppmvd)	112	110	107	110
NO_X conc. corrected to 15% O_2	32.8	31.9	31.1	32.0
Permit limit @ 15% O_2 (ppmvd)	-	-	-	*160*
Carbon Monoxide				
CO conc. (ppmvd)	1,595	1,339	1,202	1,379
CO conc. corrected to 15% O_2	465	388	350	401
Permit limit @ 15% O_2 (ppmvd)	-	-	-	*540*
Volatile Organic Compounds				
VOC conc. (ppmv C_3)	7.98	7.67	7.61	7.75
VOC conc. corrected to 15% O_2 (dry)	2.85	2.79	2.74	2.79
Permit limit @ 15% O_2 (ppmvd)	-	-	-	*86*

APPENDIX 1

- RICE Engine Sample Port Diagram



General Stack Diagram Ross Business School Emergency Generator		
Scale	Sheet	IMPACT COMPLIANCE & TESTING
None	1 of 1	