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RICE NESHAP STACK TEST REPORT

Report Title:	RICE NESHAP STACK TEST REPORT FOR THE VERIFICATION OF CARBON MONOXIDE EMISSIONS FROM DIESEL-FUELED COMPRESSION IGNITION ENGINE-GENERATOR SETS
Report Date:	July 21, 2017
Test Date(s):	June 27-28, 2017

Facility Information	
Name	Michigan Technological University
Street Address	1400 Townsend Drive
City, County	Houghton, Houghton

Facility Permit Information			
State Registration No.:	N7350	Permit to Install No.:	91-04A

Testing Contractor	
Company	Derenzo Environmental Services
Mailing Address	39395 Schoolcraft Road Livonia, Michigan 48150
Phone	(734) 464-3880
Project No.	1703015

RICE NESHAP STACK TEST REPORT FOR THE VERIFICATION OF CARBON MONOXIDE EMISSIONS FROM DIESEL FUELED COMPRESSION IGNITION ENGINES

MICHIGAN TECHNOLOGICAL UNIVERSITY

Test Dates: June 27-28, 2017

1.0 INTRODUCTION

Michigan Technological University (Michigan Tech) located in Houghton, Houghton County, Michigan operates a powerhouse that supplies its campus with steam and electricity. The facility has the ability to generate electricity using four (4) Caterpillar (CAT®) Model 3516B diesel-fueled compression-ignition (CI) engine-generator sets (gensets) rated at 2,250 kW each.

The CI gensets are identified as emission units EUGENERATOR1 through EUGENERATOR4 in Michigan Department of Environmental Quality Air Quality Division (MDEQ-AQD) Permit to Install 91-04A. The CI gensets at the Michigan Tech facility are categorized as existing engines and are not subject to the New Source Performance Standards (NSPS) for CI engines. The gensets sets have traditionally been used only for emergency purposes. However, Michigan Tech recently negotiated an interruptible contract with its electricity supplier effective June 1, 2017. Therefore, the gensets may be required to operate on a limited basis in non-emergency service to supply electricity to the campus.

Due to the reclassification to non-emergency engines, the engine gensets will be subject to certain emission standards, monitoring, and testing requirements specified by the National Emission Standards for Hazardous Air Pollutants (NESHAP) for Stationary Reciprocating Internal Combustion Engines (RICE NESHAP) in 40 CFR 63 Subpart ZZZZ.

This test report is being submitted for the verification of carbon monoxide (CO) emissions that were measured at the outlet of each of the four (4) gensets, downstream of the emission reduction catalyst. The emission testing was performed by Derenzo Environmental Services (DES), a Michigan-based environmental consulting and testing company.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan dated May 20, 2017 that was reviewed and approved by the MDEQ-AQD. Mr. Tom Gasloli of the MDEQ-AQD was on-site to observe portions of the compliance testing.

1.1 Purpose and Objectives of Testing

DES was contracted to perform the CI genset CO emissions testing specified in 40 CFR Part 63 Subpart ZZZZ. Installation and operation of the existing CAT® Model 3516B CI gensets is described in MDEQ-AQD PTI No. 91-04A. The PTI specifies emission limits for CO and nitrogen oxides (NOx) when burning distillate fuel oil and biodiesel.

However, the emission testing procedures presented in this test report were performed to satisfy the requirements of 40 CFR §63.6603(a), which states:

> *If you own or operate an existing stationary RICE located at an area source of HAP emissions, you must comply with the requirements in Table 2d to this subpart and the operating limitations in Table 2b to this subpart that apply to you.*

Table 2d of Subpart ZZZZ specifies that non-emergency generator CI RICE performance tests can be conducted to demonstrate CO:

- Emissions exhausted from the CI RICE emission control oxidation catalyst are reduced to 23 parts per million by volume dry (ppmvd) at 15% oxygen (O2); or

- Emission reduction achieved by the CI RICE emission control oxidation catalyst is 70% or more.

The emissions testing was performed by DES representatives Blake Beddow and Tom Andrews on June 27-28, 2017.

1.2 Project Contacts and Report Certification

Questions regarding this emission test report should be directed to:

Blake Beddow
Environmental Consultant
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Mr. Larry Hermanson, P.E.
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This test report was prepared by Derenzo Environmental Services based on the emission measurements and field sampling data collected by Derenzo Environmental Services. Facility process and operating data were collected and provided by representatives of Michigan Technological University.

The information presented in this report follows the Michigan Department of Environmental Quality (MDEQ) Air Quality Division (AQD) *Format for Submittal of Source Emission Test Plans and Reports, December 2013.*

Report Prepared By:

Blake Beddow
Environmental Consultant
Derenzo Environmental Services

Reviewed By:

Tyler J. Wilson
Livonia Office Supervisor
Derenzo Environmental Services

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

Responsible Official Certification:

Larry Hermanson, P.E.
Energy Management Engineer
Michigan Technological University

2.0 SUMMARY OF TEST RESULTS

The exhaust gas from the diesel-fueled CI gensets is routed to an oxidation catalyst for the control of CO and hydrocarbons in the exhaust gas. The exhaust gas downstream of the emission control catalyst was sampled for three (3) one-hour test periods per genset, during the compliance testing performed on June 27-28, 2017. Instrumental analyzers were used to measure concentrations of CO and O_2 in the catalyst exhaust gas. Table 1 below presents a summary of the compliance test results.

The testing was performed while the CI gensets were operated at maximum operating capacity (within 10% of 2,250 kW). Table 2 below presents a summary of the emission unit operating conditions during the test periods.

The test results verify compliance with the emission standard of 23 ppmvd at 15% O_2 for an existing non-emergency generator CI RICE located at an area source of HAP emissions.

Table 2.1. Summary of compliance test results, catalyst outlet

Emission Unit ID	CO Concentration (ppmvd)	Oxygen Content (% vol)	CO Concentration (ppmvd @15% O_2)
EUGENERATOR1	9.23	10.2	5.10
EUGENERATOR2	9.62	10.4	5.39
EUGENERATOR3	11.3	9.95	6.08
EUGENERATOR4	15.1	9.88	8.08
Emission Standard	--	--	23

Table 2.2. Summary of emission unit operating conditions

Emission Unit ID	Operating Hours[†]	Average Output (kW)	Catalyst Inlet (°F)		Pressure Drop Catalyst ("H2O)	
			Right	Left	Right	Left
EUGENERATOR1	671.9	2,155	856	885	9.6	10
EUGENERATOR2	656.3	2,124	894	924	9.9	10
EUGENERATOR3	567.2	2,168	887	901	10	9.8
EUGENERATOR4	493.6	2,146	879	898	10	8.4

[†] Engine run hour meter reading at the beginning of Test 1

3.0 SOURCE DESCRIPTION

3.1 Emission Unit Location and Description

The Michigan Tech powerhouse is located at 1400 Townsend Drive in Houghton, Houghton County, Michigan.

Michigan Tech uses diesel fuel to power four (4) CAT® Model 3516B CI engines that are each connected to a generator rated to 2,250 kW.

The table below provides the serial number and manufacture date for each unit.

Emission Unit	Model No.	Serial No.	Manufacture Date (dd/mm/yy)
EUGENERATOR1	3516B	PBR00196	03/03/06
EUGENERATOR2	3516B	PBR00192	28/02/06
EUGENERATOR3	3516B	PBR00193	27/02/06
EUGENERATOR4	3516B	PBR00191	27/02/06

3.2 Rated Capacities, Type and Quantity of Raw Materials Used

The CAT® Model 3516B CI engines were fueled with diesel during the emissions tests, but they have the capability to burn distillate fuel oil. Each engine has a maximum rated output of 2,250 kW.

The emissions testing was performed while the gensets were operated within 10% of full operating load (2,250 kW).

Appendix A provides operating records recorded by Michigan Tech representatives.

3.3 Emission Control System Description

The exhaust gases from each engine are directed to a Emerachem SPH-1950-10 catalytic converter for the reduction of hydrocarbons and CO emissions prior to release to the ambient air.

The temperature at the catalyst inlet is monitored continuously to verify that the catalyst inlet temperature is within the proper range for the catalytic reaction. Table 2b of 40 CFR Part 63 Subpart ZZZZ specifies that the catalyst inlet temperature must be maintained between 450 and 1350°F for a CI RICE with a power output greater than 500 hp.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

This section provides a summary of the exhaust gas sampling and analytical procedures that were used during the test event.

4.1 Testing Location and Sampling System

A continuous sample of the RICE exhaust gas was obtained from the sampling ports installed downstream of the emission control catalyst. During each one-hour pollutant 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 instrumental analyzers.

Appendix B provides a diagram of the sampling locations.

4.2 Exhaust Gas Oxygen and CO Concentration (USEPA Methods 3A and 10)

The O_2 content and CO concentration in the RICE exhaust gas stream was measured continuously throughout each one-hour test period in accordance with USEPA Methods 3A and 10. A Servomex 1440D oxygen analyzer with a paramagnetic sensor was used to measure the O_2 content; CO concentration was measured using a Thermo Environmental Instruments, Inc. Model 48i non-dispersive infrared (NDIR) analyzer. Sampling times were recorded on field data sheets.

Instrument response for each analyzer was recorded on an ESC Model 8816 data logging 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, instrument calibration was verified using appropriate calibration gases to determine accuracy and system bias (described in Section 4.3 of this document).

Appendix C provides field data sheets and calculations.

Appendix D provides raw (one-minute average) instrumental analyzer response data for each test period.

5.0 QUALITY ASSURANCE PROCEDURES

5.1 Instrument Calibration and System Bias Checks

At the beginning of each day, initial three-point instrument calibrations were performed 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 appropriate 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 verifying the instrument response against the initial instrument calibration readings.

The instrument analyzers were calibrated with USEPA Protocol 1 certified O_2 and CO concentrations in nitrogen and zeroed using nitrogen. A STEC ten-step gas divider was used (as needed) to obtain intermediate calibration gas concentrations.

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 Thermo Environmental Instruments, Inc. Model 48i analyzer exhibited the longest system response time at 90 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)

The STEC 10-step gas divider was used in the field to obtain appropriate calibration span gases. The 10-step 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 gas divider delivers calibration gas values of 0 to 100% in (10% increments) of the USEPA Protocol 1 calibration gas that is introduced into the system. The field evaluation procedures presented in Section 3.2 of Method 205 were followed prior to use of the 10-step 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 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 O_2 concentrations did not vary by more than 5% of the mean across the stack diameter. Therefore, the RICE exhaust gas for EUGENERATOR1-4 was considered to be unstratified and the compliance test sampling was performed at a single sampling location within each RICE exhaust stack.

5.5 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure CO and O_2 concentrations 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.

Appendix E presents test equipment quality assurance data (instrument calibration and system bias check records, calibration gas and gas divider certifications, interference test results).

6.0 DISCUSSION OF TEST RESULTS

6.1 Results Summary and Comparison to Emission Standard

The measured air pollutant concentrations and emission rates for EUGENERATOR1-4 are less than the allowable limits specified in 40 CFR Part 63 Subpart ZZZZ.

The measured exhaust gas CO concentration at the outlet of the catalyst for all four (4) gensets (60-minute average) ranged between 5.10 and 8.08 ppmvd at 15% oxygen, which is less than the emission standard specified for a CI RICE (i.e., less than 23 ppmvd at 15% oxygen).

Engine operating data and air pollutant emission measurement results for each one-hour test period are presented in Tables 6.1-6.4.

6.2 Operating Conditions During the Compliance Test

Operating data were recorded in 15-minute increments during each one-hour sampling run. The emissions testing was performed while the CI gensets were operated at full operating load (within 10% of 2,250 kW).

All four (4) gensets had an output ranging between 2,100 and 2,195 kW during compliance testing as determined by Michigan Tech personnel.

Catalyst inlet temperature for all four (4) gensets during the three (3) test periods ranged between 842 and 929 °F. Table 6 of 40 CFR Part 63 Subpart ZZZZ specifies that the catalyst inlet temperature must be maintained between 450 and 1350°F for a CI RICE.

The engine operating hours (run hour meter) were recorded at the beginning of the first sampling run for each genset.

Operating data are provided in Appendix A.

6.3 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 gensets were operated within 10% of maximum output (2,250 kW generator output) and no variations from normal operating conditions occurred during the engine test periods.

Table 6.1. Measured exhaust gas CO and O_2 concentrations for the Michigan Technological for EUGENERATOR1

Test Number	1	2	3	Three
Test Date	6/27/17	6/27/17	6/27/17	Test
Test Period (24-hr)	0810-0910	0930-1030	1045-1145	Average
Engine Operating Parameters				
Engine output (kW)	2,155	2,154	2,157	2,155
Catalyst Data				
Inlet Temperature – Right (°F)	844	852	872	856
Inlet Temperature – Left (°F)	872	882	902	885
Pressure Drop – Right ("H2O)	9.5	9.6	9.6	9.6
Pressure Drop – Left ("H2O)	10	10	10	10
Exhaust Gas Measurements[1]				
Oxygen content (%vol)	10.3	10.3	10.0	10.2
CO concentration (ppmvd)	9.37	9.14	9.16	9.23
CO concentration (ppmvd 15% O_2)[2]	5.24	5.08	4.98	5.10

Notes
1. Measured at the catalyst outlet.
2. 40 CFR Part 63 Subpart ZZZZ emission standard is 23 ppmvd at 15% O_2.

Table 6.2. Measured exhaust gas CO and O_2 concentrations for the Michigan Technological for EUGENERATOR2

Test Number	1	2	3	Three
Test Date	6/27/18	6/27/18	6/27/18	Test
Test Period (24-hr)	1212-1312	1327-1427	1442-1542	Average
Engine Operating Parameters				
Engine output (kW)	2,119	2,129	2,124	2,124
Catalyst Data				
Inlet Temperature – Right (°F)	878	889	914	894
Inlet Temperature – Left (°F)	919	926	927	924
Pressure Drop – Right ("H2O)	9.9	9.9	9.9	9.9
Pressure Drop – Left ("H2O)	10	10	10	10
Exhaust Gas Measurements[1]				
Oxygen content (%vol)	10.6	10.3	10.2	10.4
CO concentration (ppmvd)	9.47	9.53	9.87	9.62
CO concentration (ppmvd 15% O_2)[2]	5.42	5.30	5.45	5.39

Notes
1. Measured at the catalyst outlet.
2. 40 CFR Part 63 Subpart ZZZZ emission standard is 23 ppmvd at 15% O_2.

Table 6.3. Measured exhaust gas CO and O_2 concentrations for the Michigan Technological for EUGENERATOR3

Test Number	1	2	3	Three
Test Date	6/28/18	6/28/18	6/28/18	Test
Test Period (24-hr)	0745-0845	0900-1000	1015-1115	Average
Engine Operating Parameters				
Engine output (kW)	2,171	2,168	2,167	2,168
Catalyst Data				
Inlet Temperature – Right (°F)	881	887	892	887
Inlet Temperature – Left (°F)	893	902	909	901
Pressure Drop – Right ("H2O)	10	10	10	10
Pressure Drop – Left ("H2O)	9.8	938	9.8	9.8
Exhaust Gas Measurements[1]				
Oxygen content (%vol)	10.0	9.95	9.88	9.95
CO concentration (ppmvd)	11.7	11.3	10.9	11.3
CO concentration (ppmvd 15% O_2)[2]	6.34	6.07	5.83	6.08

Notes
1. Measured at the catalyst outlet.
2. 40 CFR Part 63 Subpart ZZZZ emission standard is 23 ppmvd at 15% O_2.

Table 6.4. Measured exhaust gas CO and O_2 concentrations for the Michigan Technological for EUGENERATOR4

Test Number	1	2	3	Three
Test Date	6/28/18	6/28/18	6/28/18	Test
Test Period (24-hr)	1135-1235	1300-1400	1415-1515	Average
Engine Operating Parameters				
Engine output (kW)	2,144	2,152	2,143	2,146
Catalyst Data				
Inlet Temperature – Right (°F)	872	880	885	879
Inlet Temperature – Left (°F)	894	898	903	898
Pressure Drop – Right ("H2O)	10	10	10	10
Pressure Drop – Left ("H2O)	8.4	8.4	8.4	8.4
Exhaust Gas Measurements[1]				
Oxygen content (%vol)	10.0	9.95	9.88	9.95
CO concentration (ppmvd)	14.9	14.8	15.6	15.1
CO concentration (ppmvd 15% O_2)[2]	8.02	7.92	8.32	8.08

Notes
1. Measured at the catalyst outlet.
2. 40 CFR Part 63 Subpart ZZZZ emission standard is 23 ppmvd at 15% O_2.