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EMISSIONS TEST REPORT

Title	NSPS TEST REPORT FOR THE LFG-FIRED IC ENGINE GENERATOR SET AT THE WASTE MANAGEMENT OF MICHIGAN NORTHERN OAKS RECYCLING AND DISPOSAL FACILITY
Report Date	April 18, 2014
Test Date(s)	March 12, 2014

Facility Information	
Name	Waste Management of Michigan, Inc. Northern Oaks Recycling and Disposal Facility
Street Address	513 County Farm Road
City, County	Harrison, Clare
Phone	(989) 539-6111

Facility Permit Information	
State Registration No.: N6010	Permit No.: MI-ROP-N6010-2013

Tested Process Information		
Emission Unit Identification	EUICENGINE1	Model: CAT®G3520C Serial No.: GZJ00226

Testing Contractor	
Company	Derenzo and Associates, Inc.
Mailing Address	39395 Schoolcraft Road Livonia, MI 48150
Phone	(734) 464-3880
Project No.	1410100

2.0 EMISSION SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

Landfill gas (LFG) is produced in the WMMI Northern Oaks RDF from the anaerobic decomposition of disposed waste materials. The LFG is collected from landfill waste placement cells using a system of wells that are connected to a central header (gas collection system). The collected LFG is treated and then directed to the Northern Oaks electricity generation facility where it is used as fuel for the IC engine generator that produces electricity for transfer to the local utility.

2.2 Rated Capacities, Type and Quantity of Raw Materials Used

EUICENGINE1 is a spark ignition, lean burn, CAT® Model No. G3520C reciprocating internal combustion engine fueled by treated landfill gas. The engine/generator set has an engine power rating of 2,233 brake-horsepower (bhp) at 100% load and a generator output rating of 1,600 kilowatts (kW). The fuel consumption rate is regulated automatically to maintain the heat input rate required to support engine operations and is dependent on the fuel heat value (methane content) of the treated LFG.

2.3 Emission Control System Description

The IC engine is not equipped with an add-on emission control device. The CAT® Model No. G3520C IC engine is designed to fire low-pressure, lean fuel mixtures (e.g., LFG) and is equipped with an air-to-fuel ratio controller that monitors engine performance parameters and automatically adjusts the air-to-fuel ratio and ignition timing to maintain efficient fuel combustion. Therefore, air pollutant emissions are minimized through the proper operation of the gas treatment system and efficient fuel combustion in the engine.

2.4 Sampling Location

The exhaust stack sampling location for the CAT® Model G3520C IC engine satisfied the USEPA Method 1 criteria for a representative sample location. The inner diameter of the engine exhaust stack at the sampling location is 15.5 inches. The stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 36 inches (2.3 duct diameters) downstream and 76 inches (4.9 duct diameters) upstream from any flow disturbance.

Appendix A presents a diagram of the performance test sampling and measurement location.

3.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

3.1 Purpose and Objectives of the Tests

In accordance with the current Renewable Operating Permit and 40 CFR 60.4243(b)(2)(ii) owners and operators of new stationary spark-ignited IC engines 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 with NOx, CO, and VOC emission limits.

The previous performance test for EUICENGINE1 (Serial No. GZJ00226) was performed on March 12, 2013 (18,446 hrs). This most recent test was completed on March 12, 2014, which is within 8,760 engine operating hours from the previous test event (the recorded engine run time at the beginning of Test 1 was 26,713 hours).

3.2 Operating Conditions During the Compliance Tests

The testing was performed while the engine/generator set operated at maximum operating conditions (1,600 kW electricity output +/- 10%). WMMI representatives provided kW output data in 15-minute intervals for each test period. The EUICENGINE1 generator kW output averaged 1,597 kW over the three test periods.

Fuel flowrate (cubic feet per minute) and fuel methane content (%) were also recorded by WMMI operators in 15-minute intervals for each test period. The EUICENGINE1 fuel consumption rate averaged 521 scfm and fuel methane content averaged 51.3%. WMMI operators also recorded the engine serial number and the run-hour meter reading at the beginning of Test No. 1.

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

Engine output (bhp) cannot be measured directly. Therefore, it is calculated based on the recorded electricity output, the generator efficiency (96.1%), and the unit conversion factor for kW to horsepower (0.7457 kW/hp). The following equation was used to calculate average engine horsepower for each test period based on a linear relationship between engine output and electricity generator output:

$$\text{Engine output (bhp)} = \text{Electricity output (kW)} / (0.961) / (0.7457 \text{ kW/hp})$$

Table 1 presents a summary of the average engine operating conditions during the test periods.

Table 1 Average engine operating conditions during the test periods

Engine Parameter	EUICENGINE1
Generator output (kW)	1,597
Engine output (bhp)	2,228
Engine LFG fuel use (scfm)	521
LFG methane content (%)	51.3

3.3 Air Pollutant Sampling Results

The exhaust from the LFG-fueled IC engine was monitored for three (3) one-hour test periods during which the NOx, CO, VOC, O_2, and CO_2 concentrations were measured using instrumental analyzers. Exhaust gas moisture content from the IC engine was determined by gravimetric and/or volumetric analysis of the water gain in chilled impingers in accordance with USEPA Method 4. Velocity and volumetric flow rates were measured before and after each test run.

Table 2 presents the average measured NO_X, CO and VOC emission rates for the engine (average of the three test periods for each engine) and applicable emission limits.

Test results for each one hour sampling period are presented in Table 3 at the end of this report.

The results of the March 12, 2014 performance tests demonstrate compliance with the emission standards in 40 CFR Part 60 Subpart JJJJ and the emission limits in MI-ROP-N6010-2013.

Table 2 Average measured emission rates for EUICENGINE1 (three-test average)

	NO_X Emission Rates		CO Emission Rates		VOC Emission Rates	
Emission Unit	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)
EUICENGINE1	5.68	1.16	11.5	2.34	0.31	0.06
ROP Limit	--	1.50	--	4.15	--	1.0
JJJJ Limit		3.0		5.0		1.0

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A test protocol for the compliance testing was prepared by Derenzo and Associates and reviewed by the MDEQ-AQD prior to performing the tests. This section provides a summary of the sampling and analytical procedures that were used during the test and presented in the test plan.

4.1 Exhaust Gas Velocity and Flowrate Determination (USEPA Method 2)

To determine air pollutant emission rates on a mass basis (e.g., pound per hour), the IC engine exhaust stack gas velocity, and volumetric flow rate were determined using USEPA Method 2 during each 60-minute test. An S-type Pitot tube connected to a red-oil manometer was used to determine velocity pressure. Gas temperature was measured using a K-type thermocouple mounted to the Pitot tube. The Pitot tube and connective tubing were leak-checked to verify the integrity of the measurement system.

The absence of cyclonic flow for each velocity measurement location was verified using an S-type Pitot tube and oil manometer. The Pitot tube was positioned at all of the velocity traverse points with the planes of the face openings of the Pitot tube perpendicular to the stack cross-sectional plane. The Pitot tube was then rotated to determine the null angle (rotational angle as measured from the perpendicular, or reference, position at which the differential pressure is equal to zero). The resultant average null angle from all 16 points was less than 20°.

Exhaust gas velocity pressure and temperature were measured before and after each one-hour sampling period in accordance with USEPA Method 2. The pre-test and post-test velocity measurements were averaged to calculate the engine exhaust flowrate.

Appendix C provides computer calculated and field data sheets for the IC engine test periods.

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

CO_2 and O_2 content in the IC engine exhaust was measured continuously throughout each one-hour test period in accordance with USEPA Method 3A. The CO_2 content of the exhaust was monitored using a non-dispersive infrared (NDIR) gas analyzer. The O_2 content of the exhaust was monitored using a gas analyzer that utilizes a paramagnetic sensor.

During each sampling period, a continuous sample of the IC engine 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 content 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 5.5 of this document).

A diagram of the instrumental analyzer sampling system is provided in Appendix B.

Appendix D provides raw instrumental analyzer response data for each test period.

Appendix E presents detailed gas sampling procedures for the USEPA sampling trains.

4.3 Exhaust Gas Moisture Content Determinations (Method 4)

Moisture content of the IC engine exhaust gas was determined in accordance with USEPA Method 4 using a chilled impinger sampling train, which was performed concurrently with the instrumental analyzer sampling methodologies. At the conclusion of each sampling period, the moisture gain in the impingers was determined volumetrically or gravimetrically to determine net water gain. Exhaust gas moisture was calculated based on the total moisture catch in the sampling train and the amount of dry gas metered through the sampling console.

A diagram of the moisture sampling train is provided in Appendix B.

4.4 NOx and CO Concentration Measurements (USEPA Method 7E and 10)

NOx and CO concentrations in the IC engine exhaust were determined using a chemiluminescence NOx analyzer and NDIR CO analyzer.

Throughout each one-hour 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 described previously in this section. Prior to, and at the conclusion of each test, the instruments were calibrated using appropriate upscale calibration and zero gas to determine analyzer calibration error and system bias.

CO and NO_X calculation sheets are provided in Appendix C; raw instrument response data are provided in Appendix D.

4.5 VOC Concentration Measurements (USEPA Method 25A / ALT 096)

VOC emission rate was determined by measuring the nonmethane hydrocarbon (NMHC) concentration in the IC engine exhaust gas. NMHC pollutant concentration was determined using a Thermo Environmental Instruments (TEI) Model 55i Methane / Nonmethane hydrocarbon analyzer. The TEI 55i analyzer contains an internal gas chromatograph column that separates methane from non-methane components and has been approved by the USEPA for measuring VOC relative to 40 CFR Part 60 Subpart JJJJ compliance test demonstrations (Alternative Test Method 096 or ALT-096). 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.

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).

The instrumental analyzer was calibrated using certified propane concentrations in hydrocarbon-free air to demonstrate detector linearity and determine calibration drift and zero drift error.

4.6 Variations from Normal Sampling Procedures or Operating Conditions

The compliance tests for all pollutants were performed in accordance with the Test Protocol dated January 30, 2014; the USEPA Approval Letter dated November 8, 2012 (approval to perform Method ALT-096 for VOC determination), and the specified USEPA test methods.

Instrument calibrations and sampling period results satisfied the quality assurance verifications required by USEPA Methods 3A, 7E, 10, and ALT 096. No variations from the normal operating conditions of the IC engines occurred during the testing program.

Each engine test period was 60 minutes in length. Test 2 was paused for 12 minutes due to a frozen sample line (the difference between the test start time and test end time is 72 minutes).

5.0 QA/QC ACTIVITIES

5.1 NOx 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 within 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_2 concentration was 0.1% of the expected value, i.e., within 10% of the expected value as required by Method 7E).

5.2 Calibration Gas Divider Field Validation

In accordance with USEPA Method 205, a field evaluation of the calibration gas divider was performed prior to commencement of the compliance testing. Triplicate injections were performed at two separate dilution ratios (60% and 40%) through the gas divider, followed by triplicate injections of mid-level calibration gas into the instrument directly (bypassing the gas divider). Calculations were performed to verify the gas divider met all acceptable criteria presented in Method 205. The gas divider satisfied the method requirements and was used throughout the compliance demonstration.

5.3 Sampling System Response Time Determination

The response time of the sampling system was determined prior to the performance testing 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.

Each sampling period did not commence until the sampling probe had been in place for at least twice the system response time.

5.4 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NOx, CO, O_2 and CO_2 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 3.0% 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, 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 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 Method 3A, 7E and 10 instruments were calibrated with USEPA Protocol 1 certified concentrations of CO_2, O_2, NO_x, and CO in nitrogen and zeroed using 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 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 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 certifications, interference test results, meter box calibration records, Pitot tube, and thermometer calibration records).

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Table 3 Measured exhaust gas conditions and NO_x, CO and VOC air pollutant emission rates EUICEENGINE1, CAT® G3520C, Serial No. GZJ00226

Test No. Test date Test period (24-hr clock)	1 03/12/14 09:35-10:35	2 03/12/14 11:20-12:32	3 03/12/14 13:15-14:15	Three Test Average
Generator output (kW)	1,601	1,577	1,614	1,597
Engine output (bhp)	2,233	2,200	2,252	2,228
Fuel flowrate (scfm)	521	521	522	521
<u>Exhaust Gas Composition</u>				
CO_2 content (% vol)	10.8	11.1	11.4	11.1
O_2 content (% vol)	8.7	8.3	7.9	8.3
Moisture (% vol)	10.6	11.2	11.9	11.2
<u>Exhaust Gas Flowrate</u>				
Standard flowrate (scfm)	4,552	4,556	4,582	4,563
Dry gas flowrate (dscfm)	4,057	4,031	4,038	4,042
<u>Nitrogen Oxides</u>				
NO_X conc. (ppmvd)	187.7	195.6	205.1	196.1
NO_X emissions (lb/hr as NO_2)	5.46	5.65	5.94	5.68
NO_X emissions (g/bhp*hr)	1.11	1.17	1.20	1.16
Permitted emissions (g/bhp*hr)	-	-	-	1.50
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	637	648	669	651
CO emissions (lb/hr)	11.3	11.4	11.8	11.5
CO emissions (g/bhp*hr)	2.29	2.35	2.37	2.34
Permitted emissions (g/bhp*hr)	-	-	-	4.15
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv as C_3)	9.3	9.7	10.4	9.8
VOC emissions (lb/hr)	0.29	0.30	0.33	0.31
VOC emissions (g/bhp*hr)	0.06	0.06	0.07	0.06
Permitted emissions (g/bhp*hr)	-	-	-	1.0

<u>Notes</u>
Test 2 was paused for 12 minutes due to a frozen sample line.