AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM A
LANDFILL GAS FIRED ENGINE – GENERATOR SET

Prepared for:

Waste Management of Michigan, Inc.
SRN N3845

Test Date: October 25, 2022

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IMPACT COMPLIANCE & TESTING

Report Certification

AIR EMISSION TEST REPORT
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FROM A
LANDFILL GAS FIRED ENGINE – GENERATOR SET

Waste Management of Michigan, Inc.
at the Eagle Valley Landfill
Orion, MI

Report Certification

The material and data in this document were prepared under the supervision and direction of the undersigned.

Impact Compliance & Testing, Inc.

Tyler J. Wilson
Senior Project Manager

Table of Contents

List of Tables

List of Appendices

1.0 Introduction

Waste Management of Michigan, Inc. (WMI) operates landfill gas (LFG)-fired reciprocating internal combustion engine and electricity generator sets (RICE gensets) at the Eagle Valley Landfill located in Orion, Oakland County, Michigan. The RICE are fueled by LFG that is recovered from the Eagle Valley Landfill and treated prior to use.

The State of Michigan Department of Environment, Great Lakes, and Energy – Air Quality Division (EGLE-AQD) has issued to WMI Renewable Operating Permit ROP No. MI-ROP-N3845-2022 for operation of the renewable electricity generation facility, which consists of:

- Two (2) Caterpillar (CAT®) Model No. G3520C RICE gensets identified as emission units EU-ICENGINE1 and EU-ICENGINE2 (Flexible Group ID FG-ICENGINES and FG-RICEMACT).

Air emission compliance testing was performed pursuant to MI-ROP-N3845-2022. Conditions of MI-ROP-N3845-2022 for FG-ICENGINES state:

1. *Except as provided in 40 CFR 60.4243(b), the permittee shall conduct an initial performance test for each engine in FG-RICENSPS within one year of startup of the engine and every 8760 hours of operation (as determined through the use of a non-resettable hour meter) or three years, whichever occurs first, to demonstrate compliance with the emission limits in 40 CFR 60.4233(e)…*

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 Andrew Eisenberg performed the field sampling and measurements October 25, 2022.

The engine emission 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)) for EU-ICENGINE2. Exhaust gas velocity, moisture, oxygen (O_2) content, and carbon dioxide (CO_2) content were determined for each test period to calculate pollutant mass emission rates EU-ICENGINE2.

Due to repair needs, Engine No. 2 / EU-ICENGINE2 (Serial No. GZJ00443) was not tested September 21, 2022 (originally scheduled test date). WMI notified EGLE-AQD of the postponement September 21, 2022. Engine No. 2 / EU-ICENGINE2 (Serial No. GZJ00443) remained offline after September 21, 2022. WMI removed/swapped Engine No. 2 / EU-ICENGINE2 (Serial No. GZJ00443) with Engine No. 2 / EU-ICENGINE2 (Serial No. GZJ00672) in early October 2022. WMI and ICT coordinated the soonest possible test date for Engine No. 2 / EU-ICENGINE2 (Serial No. GZJ00672); October 25, 2022. EGLE-AQD was notified of the October 25, 2022 test date September 30, 2022, via e-mail. Engine No. 1 / EU-ICENGINE1 was tested September 21, 2022.

The exhaust gas sampling and analysis was performed using procedures specified in the Stack Test Protocol dated August 10, 2022, that was reviewed and approved by EGLE-AQD. Mr. Robert Joseph of EGLE-AQD observed portions of the compliance testing.

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

Conditions of MI-ROP-N3845-2022 and 40 CFR Part 60, Subpart JJJJ, Standards of Performance for New Stationary Sources for Stationary Spark Ignition Internal Combustion Engines require WMI to test each engine in FG-ICENGINES / FG-RICEMACT for CO, NOx, and VOC emissions. Engine No. 2 (EU-ICENGINE2) was tested during this compliance test event. Engine No. 1 (EU-ICENGINE1) was tested September 21, 2022.

2.2 Operating Conditions During the Compliance Tests

The testing was performed while the WMI engine/generator set was operated at maximum operating conditions (within 10% of 1,600-kilowatt (kW) electricity output). WMI representatives provided kW output in 15-minute increments for each test period.

Fuel flowrate (standard cubic feet per minute (scfm)), fuel methane (CH_4) content (%), and air-to-fuel ratio were also recorded by WMI representatives in 15-minute increments for each test period. In addition, WMI representatives monitored LFG hydrogen sulfide (H_2S) content once per test using Draeger® tubes.

Appendix 2 provides operating records provided by WMI representatives for the test periods and a photo of the H_2S Draeger® tubes.

Average generator output (kW), fuel consumption, fuel methane content, and air-to-fuel ratio for the RICE is presented in Table 2.1 and Table 6.1.

2.3 Summary of Air Pollutant Sampling Results

The gas exhausted from the sampled LFG fueled RICE (Engine No. 2 / EU-ICENGINE2) was sampled for three (3) one-hour test periods during the compliance testing performed October 25, 2022.

Table 2.2 presents the average measured CO, NO_X, and VOC emission rates for the engine (average of the three test periods).

Test results for each one-hour sampling period and comparison to the permitted emission rates are presented in Section 6.0 of this report.

Table 2.1 Average engine operating conditions during the test periods

Emission Unit	Generator Output (kW)	Engine HP*	LFG Fuel Use (scfm)	LFG CH_4 Content (%)	Air / Fuel Ratio
Engine No. 2	1,633	2,289	547	51.6	7.3

*Engine horsepower (HP) is calculated.

Table 2.2 Average measured emission rates for the engine (three-test average)

	CO	NOx	VOC
Emission Unit	(g/bhp-hr)	(g/bhp-hr)	(g/bhp-hr)
Engine No. 2	2.55	0.52	0.10
Permit Limit	***4.13***	***0.9***	***1.0***

3.0 Source and Sampling Location Description

3.1 General Process Description

WMI is permitted to operate two (2) RICE-generator sets (CAT® Model No. G3520C) at its facility. The units are fired exclusively with LFG that is recovered from the Eagle Valley Landfill and treated prior to use.

Table 3.1 Engine Identification

Emission Unit	ROP Identification	Serial Number
Engine No. 2	EU-ICENGINE2	GZJ00672

3.2 Rated Capacities and Air Emission Controls

The CAT® G3520C engine generator set has a rated design capacity of:

- Engine Power: 2,242 brake horsepower (bhp)
- Electricity Generation: 1,600 kW

Note: In 2012 CAT® updated the Generator Efficiency from 96.1% to 95.7% which resulted in a HP rating of 2,242. Engine output (HP) = Electricity output (1,600 kW) / (0.957) / (0.7457 kW/HP).

The engine is equipped with an air-to-fuel ratio (AFR) controller that automatically blends the appropriate ratio of combustion air and treated LFG fuel.

The RICE is not equipped with add-on emission control devices. The AFR controller maintains efficient fuel combustion, which minimizes air pollutant emissions. Exhaust gas is exhausted directly to atmosphere through a noise muffler and vertical exhaust stack for the engine.

3.3 Sampling Locations

The RICE exhaust gas is directed through a muffler and is released to the atmosphere through a dedicated vertical exhaust stack with a vertical release point.

The exhaust stack sampling ports for Engine No. 2 / EU-ICENGINE2 are located in an individual horizontal exhaust duct, located before the engine muffler, with an inner diameter of 16.0 inches. The stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 60.0 inches (3.8 duct diameters) upstream and 54.0 inches (3.4 duct diameters) downstream from any flow disturbance.

All sample port locations satisfy the USEPA Method 1 criteria for a representative sample location. Individual traverse points were determined in accordance with USEPA Method 1.

Appendix 1 provides a diagram of the emission test sampling location with actual stack dimension measurements.

4.0 Sampling and Analytical Procedures

A Stack Test Protocol for the air emission 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 1	Exhaust gas velocity measurement locations were determined based on the physical stack arrangement and requirements in USEPA Method 1.
USEPA Method 2	Exhaust gas velocity pressure was determined using a Type-S Pitot tube connected to a red oil incline manometer; temperature was measured using a K-type thermocouple connected to the Pitot tube.
USEPA Method 4	Exhaust gas moisture was determined based on the water weight gain in chilled impingers.
USEPA Method 3A	Exhaust gas O_2 and CO_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) concentration was determined using a flame ionization analyzer equipped with methane separation column.

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

The RICE exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 once during each test period. An S-type Pitot tube connected to a red-oil manometer was used to determine velocity pressure at each traverse point across the stack cross section. Gas temperature was measured using a K-type thermocouple mounted to the Pitot tube. The Pitot tube and connective tubing were leak-checked periodically throughout the test periods to verify the integrity of the measurement system.

The absence of significant cyclonic flow at the sampling location was verified using an S-type Pitot tube and oil manometer. The Pitot tube was positioned at each velocity traverse point 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).

Appendix 3 provides exhaust gas flowrate calculations and field data sheets.

4.3 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 CO_2 content of the exhaust was monitored using a Servomex 1440D infrared gas analyzer. 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 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 4 provides O_2 and CO_2 calculation sheets. Raw instrument response data are provided in Appendix 5.

4.4 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.

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

NO_X and CO pollutant concentrations in the RICE exhaust gas stream were 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.

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

The VOC emission 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 Flow Measurement Equipment

Prior to arriving onsite (or onsite prior to beginning compliance testing), the instruments used during the source test to measure exhaust gas properties and velocity (pyrometer, Pitot tube, and scale) were calibrated to specifications in the sampling methods.

5.2 NO_x Converter Efficiency Test

The NO_2 – NO conversion efficiency of the 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 at least 90% of the expected value (within 10%).

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_X concentration was 101.2% of the expected value).

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 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 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 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 and CO_2 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.

5.7 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.

5.8 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 Emission Limits

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

Engine No. 2 / EU-ICENGINE2 has the following allowable emission limits specified in MI-ROP-N3845-2022:

- 4.13 grams per brake horsepower hour (g/bhp-hr) for CO;
- 0.9 g/bhp-hr for NOx; and
- 1.0 g/bhp-hr for VOC.

The measured air pollutant emission rates for Engine No. 2 / EU-ICENGINE2 are less than the allowable limits specified in MI-ROP-N3845-2022 and 40 CFR Part 60, Subpart JJJJ, Standards of Performance for New Stationary Sources for Stationary Spark Ignition Internal Combustion Engines.

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 Stack Test Protocol. The engine-generator set was operated within 10% of maximum output (1,600 kW generator output for CAT® G3520C RICE) during the engine test periods.

As discussed in Section 1.0 of this Air Emission Test Report, only Engine No. 2 / EU-ICENGINE2 was tested during this compliance test event. Engine No. 1 / EU-ICENGINE1 was tested September 21, 2022.

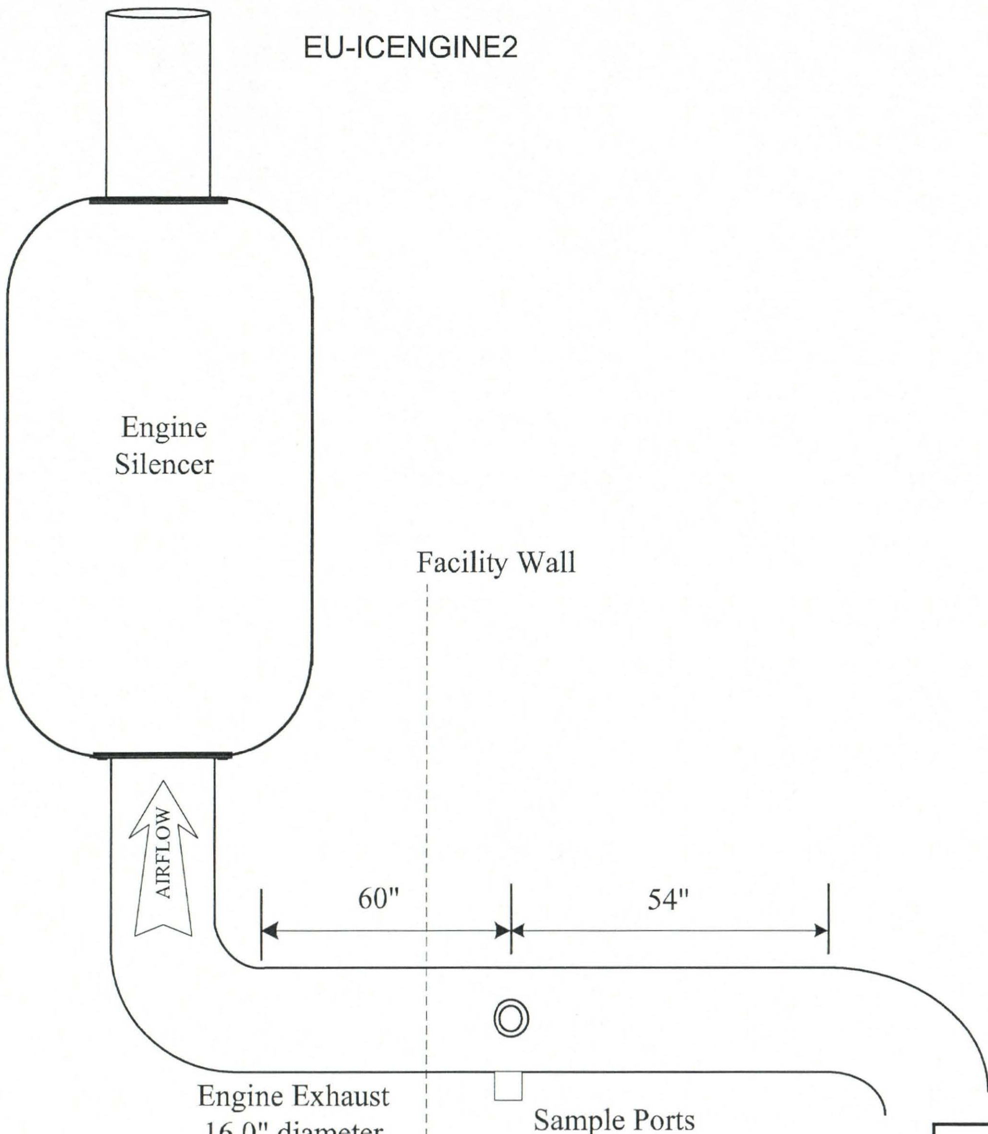
Table 6.1 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 2 (EU-ICENGINE2)

Test No. Test date Test period (24-hr clock)	1 10/25/2022 720-820	2 10/25/2022 838-938	3 10/25/2022 955-1055	Three Test Average
Fuel flowrate (scfm)	547	546	549	547
Generator output (kW)	1,634	1,633	1,633	1,633
Engine output (bhp)	2,290	2,288	2,288	2,289
LFG methane content (%)	51.6	51.6	51.6	51.6
Air-to-fuel ratio	7.3	7.3	7.3	7.3
Exhaust Gas Composition				
CO_2 content (% vol)	12.1	12.1	12.0	12.0
O_2 content (% vol)	7.99	8.02	8.11	8.04
Moisture (% vol)	12.0	12.3	12.4	12.2
Exhaust gas temperature (°F)	935	936	937	936
Exhaust gas flowrate (dscfm)	4,811	4,798	4,791	4,800
Exhaust gas flowrate (scfm)	5,469	5,470	5,470	5,470
Nitrogen Oxides				
NO_X conc. (ppmvd)	76.2	74.3	76.8	75.8
NO_X emissions (lb/hr)	2.63	2.56	2.64	2.61
NO_X emissions (g/bhp-hr)	0.52	0.51	0.52	0.52
NO_X permit limit (g/bhp-hr)	-	-	-	*0.9*
Carbon Monoxide				
CO conc. (ppmvd)	620	617	609	615
CO emissions (lb/hr)	13.0	12.9	12.7	12.9
CO emissions (g/bhp-hr)	2.58	2.56	2.52	2.55
CO permit limit (g/bhp-hr)	-	-	-	*4.13*
Volatile Organic Compounds				
NMHC conc. (ppmv)	13.4	13.7	13.9	13.7
NMHC emissions (lb/hr)	0.50	0.52	0.52	0.51
NMHC emissions (g/bhp-hr)	0.10	0.10	0.10	0.10
NMHC permit limit (g/bhp-hr)	-	-	-	*1.0*

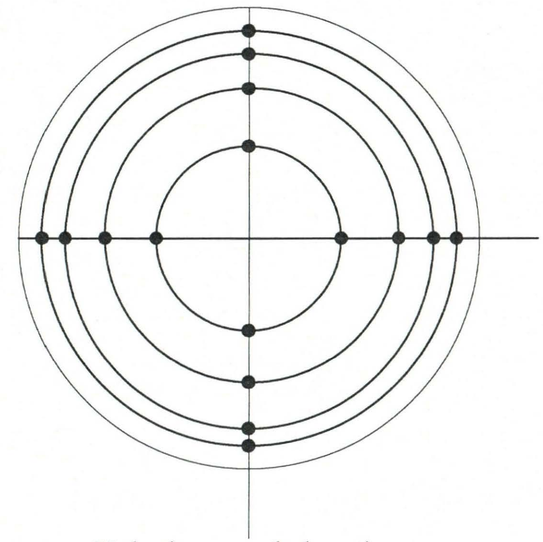
APPENDIX 1

- RICE Engine Sample Port Diagram

EU-ICENGINE2



Stack Cross Section



Velocity sample locations
(as measured from stack wall)

1	0.5"
2	1.7"
3	3.1"
4	5.2"
5	10.8"
6	12.9"
7	14.3"
8	15.5"

11/4/2015	**Eagle Valley Landfill Gas Fueled Engine Exhaust Sample Location**

Scale	Sheet
None	1 of 1

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