IMPACT COMPLIANCE & TESTING

AIR EMISSION TEST REPORT

Title	AIR EMISSION TEST REPORT FOR THE VERIFICATION OF AIR POLLUTANT EMISSIONS FROM LANDFILL GAS FUELED INTERNAL COMBUSTION ENGINES
Report Date	October 28, 2019
Test Dates	October 24, 2019

Facility Information	
Name	North American Natural Resources Venice Park Renewable Energy Facility
Street Address	9536 East Lennon Road
City, County	Lennon, Shiawassee, Michigan

Facility Permit Information			
ROP No.:	MI-ROP-N5910-2015	Facility SRN :	N5910

Testing Contractor	
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Project No.	1900228

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IMPACT COMPLIANCE & TESTING

AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM
LANDFILL GAS FUELED INTERNAL COMBUSTION ENGINES

NORTH AMERICAN NATURAL RESOURCES
AT THE VENICE PARK RDF

1.0 INTRODUCTION

North American Natural Resources (NANR) operates gas-fired reciprocating internal combustion engine and electricity generator sets (RICE gensets) at the Venice Park Renewable Energy Facility in Lennon, Shiawassee County, Michigan. The RICE are fueled by landfill gas (LFG) that is recovered from the Venice Park RDF, which is owned and operated by Waste Management of Michigan. The recovered gas is transferred to NANR where it is treated and used as fuel in the RICE gensets.

The Michigan Department of Environment, Great Lakes and Energy Quality-Air Quality Division (EGLE-AQD) has issued a combined Renewable Operating Permit (MI-ROP-N5910-2015) to the Venice Park RDF and NANR. The renewable electricity generation equipment owned and operated by NANR and specified in Section 2 of the ROP consists of:

- Four (4) Caterpillar (CAT®) Model No. G3520C RICE gensets identified as emission units EUNANRENGINE7R, EUNANRENGINE8R, EUNANRENGINE9, and EUNANRENGINE10 (Flexible Group ID FGENGINES7R-10).

Air emission compliance testing was performed on EUNANRENGINE9 and EUNANRENGINE10 pursuant to ROP No. MI-ROP-N5910-2015 and the federal Standards of Performance for Stationary Spark Ignition Internal Combustion Engines (the SI-RICE NSPS; 40 CFR Part 60 Subpart JJJJ).

The compliance testing was performed by Impact Compliance and Testing, Inc., (ICT) a Michigan-based environmental consulting and testing company. ICT representatives Clay Gaffey and Andy Rusnak performed the field sampling October 24, 2019.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan dated September 17, 2019 that was reviewed and approved by the EGLE-AQD. EGLE representative Mr. Tom Gasloli 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 Impact Compliance and Testing, Inc. based on field sampling data collected by Impact Compliance and Testing, Inc. Facility process data were collected and provided by NANR employees or representatives. This test report has been reviewed by NANR representatives and approved for submittal to the EGLE.

I certify that the testing was conducted in accordance with the specified test methods and submitted 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:

____

Andy Rusnak, QSTI
Technical Manager
Impact Compliance and Testing, Inc.

2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

Landfill gas (LFG) containing methane is generated in the Venice Park RDF from the anaerobic decomposition of disposed waste materials. The LFG is collected from both active and capped landfill cells using a system of wells (gas collection system). The collected LFG is transferred to the NANR LFG power station facility where it is treated and used as fuel for the RICE. Each RICE is connected to an electricity generator that produces electricity that is transferred to the local utility.

2.2 Rated Capacities and Air Emission Controls

The CAT® Model No. G3520C RICE has a rated output of 2,233 brake-horsepower (bhp) and the connected generator has a rated electricity output of 1,600 kilowatts (kW). The 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.

The engine/generator sets are not equipped with add-on emission control devices. Air pollutant emissions are minimized through the proper operation of the gas treatment system and efficient fuel combustion in the engines.

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 Sampling Locations

The RICE exhaust gas is directed through mufflers and is released to the atmosphere through dedicated vertical exhaust stacks with vertical release points. The CAT® Model G3520C RICE exhaust stacks are identical.

The engine exhaust sampling ports for the CAT® Model G3520C engines (Engine Nos. 7R, 8R, 9 and 10) are located in the exhaust gas duct prior to the engine muffler and exhaust stack. The exhaust duct has an inner diameter of 13.5 inches. Each duct is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 41 inches (3.0 duct diameters) upstream and 112 inches (8.3 duct diameters) downstream from any flow disturbance and satisfies the USEPA Method 1 criteria for a representative sample location.

Individual traverse points were determined in accordance with USEPA Method 1.

Appendix 1 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 conditions for FGENGINES7R-10 in ROP No. MI-ROP-N5910-2015 state:

> *… the permittee shall conduct an initial performance test for* [the engines] *within one year after startup of the engine and every 8760 hours of operation … to demonstrate compliance with the emission limits in 40 CFR 60.4233(e) … If a performance test is required, the performance test shall be conducted according to 40 CFR 60.4244.*

Testing was performed, within 8,760 hours of the previous testing, to demonstrate compliance with the air pollutant emission limits specified in MI-ROP-N5910-2015 for the RICE-generator sets EUNANRENGINE9 and EUNANRENGINE10.

3.2 Operating Conditions During the Compliance Tests

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

Fuel flowrate and fuel methane content (%) were also recorded by NANR representatives in 15-minute increments for each test period.

Appendix 2 provides operating records provided by NANR representatives for the test periods.

Engine output (bhp) cannot be measured directly and was calculated based on the recorded electricity output, the calculated CAT® Model G3520C generator efficiency (96.1%), and the unit conversion factor for kW to horsepower (0.7457 kW/hp).

Engine output (bhp) = Electricity output (kW) / (0.961) / (0.7457 kW/hp)

Table 3.1 presents a summary of the average engine operating conditions during the test periods.

3.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the sampled LFG fueled RICE (Engine Nos. 9 and 10) were each sampled for three (3) one-hour test periods during the compliance testing performed October 24, 2019.

Table 3.2 presents the average measured emission rates for the engines (average of the three test periods for each engine).

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

Table 3.1 Average engine operating conditions during the test periods

Engine Parameter	Engine No. 9	Engine No. 10
Generator output (kW)	1,596	1,601
Engine output (bhp)	2,228	2,235
Engine LFG fuel use (scfm)	569	574
LFG methane content (%)	49.2	49.5

Table 3.2 Average measured emission rates for each engine (three-test average)

	CO Emission Rates		NO_x Emission Rates		VOC Emission Rates
Emission Unit	(lb/hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr)	(g/bhp-hr)
Engine No. 9	12.1	2.47	2.34	0.48	0.12
Engine No. 10	13.9	2.83	2.05	0.42	0.13
Permit Limit	16.3	3.3	2.97	2.0	0.63

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A test protocol for the air emission testing was reviewed and approved by the EGLE. This section provides a summary of the sampling and analytical procedures that were used during the NANR 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 3A	Exhaust gas O_2 and CO_2 content was determined using paramagnetic and infrared instrumental analyzer.
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 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 during each test. An S-type or standard Pitot tube connected to a slack tube 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 prior to each traverse to verify the integrity of the measurement system.

The absence of significant cyclonic flow for the exhaust configuration was verified using an S-type Pitot tube and slack tube manometer. The Pitot tube was positioned at each horizontal 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 1440 single beam single wavelength (SBSW) infrared gas analyzer. The O_2 content of the exhaust was monitored using a Servomex 1440 gas analyzer that uses 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 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 engine 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. 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.

4.5 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 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 Volatile Organic Compounds (USEPA Method 25A/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 an alternate test method (ALT-096) approving the use of the TEI 55i-series analyzer as an effective instrument for measuring NMOC from gas-fueled reciprocating internal combustion engines (RICE).

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 <u>QA/QC ACTIVITIES</u>

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 within 10% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_x concentration was 97.5% of the expected value, i.e., within 10% of the expected value as required by Method 7E).

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, O_2 and CO_2 have had an interference response test preformed prior to their use in the field (July 26, 2006, June 12, 2014 and April 19, 2016), 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, 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.

5.5 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.

The recorded concentration data for each RICE exhaust stack indicated that the measured CO, O_2 and CO_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 the RICE exhaust stack.

5.6 Meter Box Calibrations

The Nutech Model 2010 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.

Appendix 6 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, meter box calibration records, Pitot tube calibration records and stratification checks).

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 Tables 6.1 through 6.2.

The measured air pollutant concentrations and emission rates for Engine Nos. 9 and 10 are less than the allowable limits specified in ROP No. MI-ROP-N5910-2015 for FGENGINES7R-10:

- 2.97 lb/hr and 2.0 g/bhp-hr for NO_X;
- 16.3 lb/hr and 3.3 g/bhp-hr for CO; and
- 0.63 g/bhp-hr for VOC (includes formaldehyde emissions).

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 test protocol. Following the first test period the VOC analyzer drift exceeded 3.0% of the span and system bias was less than 5.0% of the span, therefore, the run was valid, however, prior to starting the second test period the VOC analyzer was recalibrated.

The engine-generator sets were operated within 10% of maximum output (1,600 kW generator output) and no variations from normal operating conditions occurred during the engine test periods.

Table 6.1 Measured exhaust gas conditions and NO_x, CO and VOC air pollutant emission rates for Engine No. 9 (EUNANRENGINE9)

Test No. Test date Test period (24-hr clock)	1 10/24/19 710-810	2 10/24/19 855-955	3 10/24/19 1017-1117	Three Test Average
Fuel flowrate (scfm)	565	572	571	569
Generator output (kW)	1,595	1,598	1,596	1,596
Engine output (bhp)	2,225	2,230	2,227	2,228
LFG methane content (%)	49.3	49.1	49.1	49.2
Exhaust Gas Composition				
CO_2 content (% vol)	11.5	11.5	11.5	11.5
O_2 content (% vol)	8.13	8.15	8.15	8.14
Moisture (% vol)	11.4	11.6	12.3	11.8
Exhaust gas flowrate (dscfm)	4,500	4,555	4,542	4,532
Exhaust gas flowrate (scfm)	5,080	5,151	5,179	5,137
Nitrogen Oxides				
NO_X conc. (ppmvd)	72.8	71.7	71.2	71.9
NO_X emissions (lb/hr)	2.35	2.34	2.32	2.34
Permitted emissions (lb/hr)	-	-	-	2.97
NO_X emissions (g/bhp*hr)				
Permitted emissions (g/bhp*hr)	-	-	-	2.0
Carbon Monoxide				
CO conc. (ppmvd)	614	614	613	613
CO emissions (lb/hr)	12.1	12.2	12.2	12.1
Permitted emissions (lb/hr)	-	-	-	16.3
CO emissions (g/bhp*hr)				
Permitted emissions (g/bhp*hr)	-	-	-	3.30
Volatile Organic Compounds				
VOC conc. (ppmv)	16.1	15.9	16.1	16.0
VOC emissions (g/bhp*hr) [1]	0.11	0.11	0.12	0.12
Permitted emissions (g/bhp*hr)	-	-	-	0.63

Table 6.2 Measured exhaust gas conditions and NOx, CO and VOC air pollutant emission rates for Engine No. 10 (EUNANRENGINE10)

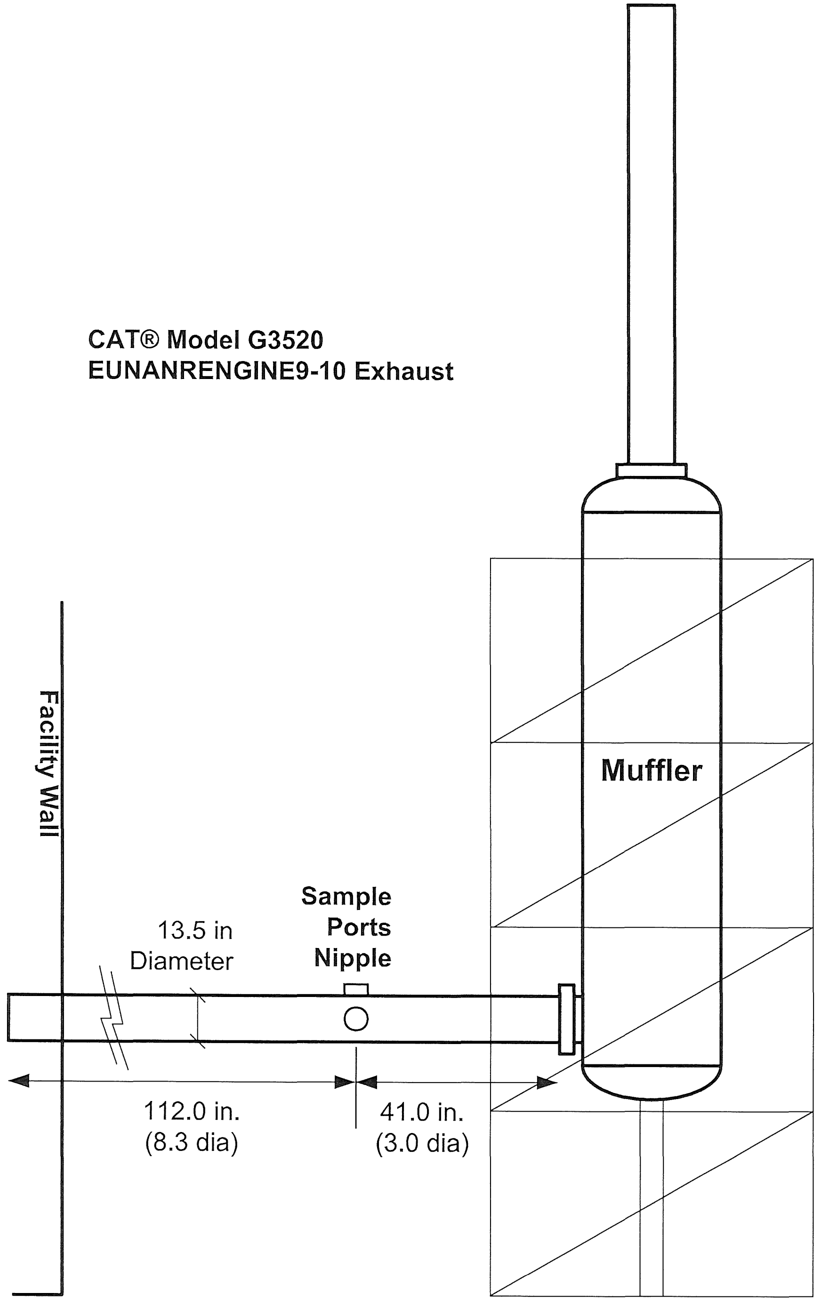
Test No. Test date Test period (24-hr clock)	1 10/24/19 1141-1241	2 10/24/19 1300-1400	3 10/24/19 1420-1520	Three Test Average
Fuel flowrate (scfm)	576	575	570	574
Generator output (kW)	1,598	1,605	1,600	1,601
Engine output (bhp)	2,230	2,240	2,233	2,235
LFG methane content (%)	49.2	49.4	49.7	49.5
Exhaust Gas Composition				
CO_2 content (% vol)	11.5	11.4	11.4	11.4
O_2 content (% vol)	8.22	8.27	8.34	8.28
Moisture (% vol)	10.5	12.8	10.6	11.3
Exhaust gas flowrate (dscfm)	4,641	4,619	4,709	4,656
Exhaust gas flowrate (scfm)	5,183	5,297	5,269	5,250
Nitrogen Oxides				
NO_X conc. (ppmvd)	65.0	59.4	60.2	61.5
NO_X emissions (lb/hr)	2.16	1.97	2.03	2.05
Permitted emissions (lb/hr)	-	-	-	2.97
NO_X emissions (g/bhp*hr)	0.44	0.40	0.41	0.42
Permitted emissions (g/bhp*hr)	-	-	-	2.0
Carbon Monoxide				
CO conc. (ppmvd)	703	679	674	685
CO emissions (lb/hr)	14.2	13.7	13.9	13.9
Permitted emissions (lb/hr)	-	-	-	16.3
CO emissions (g/bhp*hr)	2.90	2.77	2.81	2.83
Permitted emissions (g/bhp*hr)	-	-	-	3.30
Volatile Organic Compounds				
VOC conc. (ppmv)	17.6	18.2	18.2	18.0
VOC emissions (g/bhp*hr)	0.13	0.13	0.13	0.13
Permitted emissions (g/bhp*hr)	-	-	-	0.63

APPENDIX 1

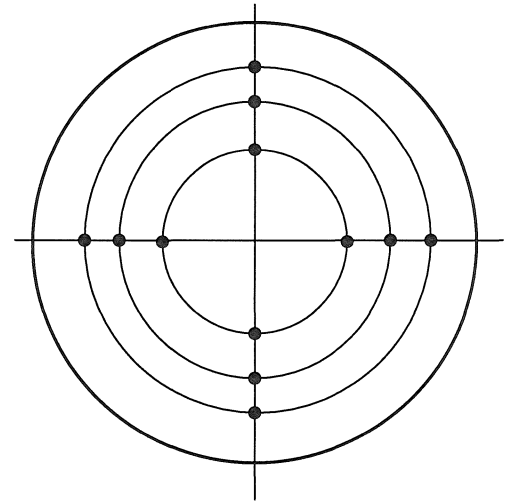
- IC Engine Nos. 9 and 10 Sample Port Diagram

Impact Compliance and Testing, Inc.

CAT® Model G3520
EUNANRENGINE9-10 Exhaust



Exhaust Stack Cross-Section with Traverse Points



Velocity sample locations as measured from stack wall

Pt. #	in.
1	0.59
2	1.97
3	4.00
4	9.50
5	11.53
6	12.91

11/6/19 ALR	**NANR Venice Park Facility** **Exhaust Sample Location, CAT® G3520 ICE**		
	Scale None	Sheet 1 of 1	Impact Comp. & Testing, Inc. Dwg. No. NANR-VP-1