

1.0 Introduction

North American Natural Resources, Inc. (NANR) operates gas-fired reciprocating internal combustion engines (RICE) and electricity generator sets at the People's Generating Facility in Birch Run, Saginaw County, Michigan. The RICE are fueled by landfill gas (LFG) that is recovered from the People's Landfill. The recovered gas is transferred to the NANR facility where it is treated and used as fuel.

The Michigan Department of Environment, Great Lakes and Energy – Air Quality Division (EGLE-AQD) has issued to NANR a Renewable Operating Permit (MI-ROP-N5397-2019a) for operation of the renewable electricity generation facility, which consists of:

- Six (6) Caterpillar (CAT®) Model No. 3516 RICE-generator sets identified as emission units EUICE#1 – EUICE#6 (Flexible Group ID: FGRICEENG).

Air emission compliance testing was performed pursuant to MI-ROP-N5397-2019a. Conditions of the ROP for EUICE#6 state:

1. *Within every 5 years from the date of completion of the most recent stack test and on or before six months of the ROP expiration date, the permittee shall verify NO_x, CO, and VOC emission rates from EUICE#6 by testing at owner's expense, in accordance with Department requirements.*
2. *Within 180 days after initial startup of EUICE#6 and within every five years from the date of completion of the most recent stack test, the permittee shall verify formaldehyde emission rates, by testing at owner's expense, in accordance with Department requirements.*

The engine emission performance tests consisted of triplicate, one-hour sampling periods for nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOC, as non-methane hydrocarbons) and formaldehyde (CHOH). Exhaust gas velocity, moisture, oxygen (O₂) content, and carbon dioxide (CO₂) content were determined for each test period to calculate pollutant mass emission rates.

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 Andy Rusnak, Tyler Wilson, and Ryan Prchlik performed the field sampling and measurements April 27, 2021.

The engine emission performance tests consisted of triplicate, one-hour sampling periods for nitrogen oxides (NO_x), carbon monoxide (CO), formaldehyde (CHOH) and volatile organic compounds (VOC, as non-methane hydrocarbons). Exhaust gas velocity, moisture, oxygen (O₂) content, and carbon dioxide (CO₂) content were determined for each test period to calculate pollutant mass emission rates.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan dated March 26, 2021 that was reviewed and approved by the EGLE-AQD.

Questions regarding this emission test report should be directed to:

Andy Rusnak, QSTI
Technical Manager
Impact Compliance & Testing, Inc.
4180 Keller Rd., Ste. B
Holt, MI 48842
Ph: (517) 268-0043
andy.rusnak@impactcandt.com

Mr. Richard Spranger
Director of Operations
North American Natural Resources
300 North 5th Street, Suite 100
Ann Arbor, MI 48104
(517) 719-1322

2.0 Summary of Test Results and Operating Conditions

2.1 Purpose and Objective of the Tests

Conditions of MI-ROP-N5397-2019a and the SI-RICE NSPS require NANR to test EUICE#6 for CO, NO_x, CHOH and VOC emissions.

2.2 Operating Conditions During the Compliance Tests

The testing was performed while the NANR engine/generator set was operated at maximum operating conditions (within 10% of rated capacity). The rated capacity for the CAT® Model G3516 engine generator sets (EUICE#6) is 800 kW electricity output. NANR representatives provided kW output in 15-minute increments for each test period. The EUICE#6 generator kW output ranged between 806 and 820 kW.

Fuel flowrate (scfm), air to fuel ratio and fuel methane content (%) were also recorded by NANR representatives in 15-minute increments for each test period. The EUICE#6 recorded fuel consumption rate was 300 scfm, the air to fuel ratio ranged between 50 and 60 and the fuel methane content ranged between 53.0 and 54.5%.

Engine output (bhp) cannot be measured directly and was calculated based on the recorded electricity output, the calculated CAT® Model G3516 generator efficiency (93.9%), and the unit conversion factor for kW to horsepower (0.7457 kW/hp).

$$\text{Engine output (bhp)} = \text{Electricity output (kW)} / (0.939) / (0.7457 \text{ kW/hp})$$

Appendix 2 provides operating records provided by NANR 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 LFG fueled RICE (EUICE#6) were sampled for three (3) one-hour test periods during the compliance testing performed April 27, 2021.

Table 2.2 presents the average measured CO, NO_x, CHOH 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

Engine Parameter	EUICE#6 CAT® G3516
Generator output (kW)	814
Engine output (bhp)	1,162
Engine LFG fuel use (scfm)	300
Air to fuel ratio	55
LFG methane content (%)	53.6

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

	CO	NOx	CHOH	VOC
Emission Unit	(g/bhp-hr)	(g/bhp-hr)	(lb/hr)	(g/bhp-hr) ¹
EUICE#6	1.8	0.8	0.68	0.40
Permit Limit	2.7	1.5	0.71	1.12

Notes for Table 2.2:

1. Includes formaldehyde.

3.0 Source and Sampling Location Description

3.1 General Process Description

NANR operates six (6) RICE-generator sets at its facility; six (6) CAT® Model No. G3516 RICE. The units are fired exclusively with LFG that is recovered from the People's Landfill solid waste disposal facility and treated prior to use.

3.2 Rated Capacities and Air Emission Controls

The CAT® G3516 engine generator sets have a rated design capacity of:

- Engine Power: 1,148 bhp
- Electricity Generation: 800 kW

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

The RICE are 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 the atmosphere through a noise muffler and vertical exhaust stack.

3.3 Sampling Locations

The EUICE#6 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 EUICE#6 exhaust sampling ports are located in the duct before the muffler in a horizontal portion of the duct with an inner diameter of 10.25 inches. The duct is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 50 inches (4.9 duct diameters – A dimension) upstream and 260 inches (25.4 duct diameters – B dimension) 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 diagrams of the emission test sampling locations.

4.0 Sampling and Analytical Procedures

A test protocol for the air emission testing was reviewed and approved by the 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 3A	Exhaust gas O ₂ and CO ₂ content was determined using paramagnetic and infrared instrumental analyzers, respectively.
USEPA Method 7E	Exhaust gas NO _x 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.
ASTM Method D6348	Exhaust gas CHOH and moisture content were determined using a FTIR analyzer.

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 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)

CO₂ and O₂ content in the RICE exhaust gas stream was measured continuously throughout each test period in accordance with USEPA Method 3A. The CO₂ content of the exhaust was monitored using a Servomex 4900 infrared gas analyzer. The O₂ content of the exhaust was monitored using a Servomex 4900 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 O₂ and CO₂ 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 O₂ and CO₂ calculation sheets. Raw instrument response data are provided in Appendix 5.

4.4 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 42i High Level chemiluminescence NO_x analyzer and a Fuji ZRF 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 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 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 NMHC 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.

4.6 Measurement of CHOH and Moisture via FTIR (ASTM D6348)

Formaldehyde and moisture concentration in the exhaust gas streams was determined using an MKS Multi-Gas 2030 Fourier transform infrared (FTIR) spectrometer in accordance with test method ASTM D6348.

The USEPA New Source Performance Standard (NSPS) for landfill gas fired engines (Subpart JJJJ) specifies ASTM D6348 as an acceptable test method for moisture concentration determinations. Additionally, the USEPA National Emissions Standard for Hazardous Air Pollutants (NESHAP) for landfill gas fired engines (Subpart ZZZZ) specifies ASTM D6348 as an acceptable test method for moisture and formaldehyde concentration determinations.

Samples of the exhaust gas were delivered directly to the instrumental analyzer using a Teflon® heated sample line to prevent condensation. The sample to the FTIR analyzer was not conditioned to remove moisture. Therefore, measurements correspond to standard conditions with no moisture correction (wet basis).

A calibration transfer standard (CTS), ethylene standard, and nitrogen zero gas were analyzed before and after each test run. Analyte spiking, of each engine, with acetaldehyde was performed to verify the ability of the sampling system to quantitatively deliver a sample containing the compound of interest from the base of the probe to the FTIR. Data was collected at 0.5 cm⁻¹ resolution. Instrument response was recorded using MG2000 data acquisition software.

Appendix 4 provides CHOH calculation sheets. Raw instrument response data for the FTIR analyzer is provided in Appendix 6.

5.0 QA/QC Activities

5.1 Flow Measurement Equipment

Prior to arriving onsite, the instruments used during the source test to measure exhaust gas properties and velocity (barometer and Pitot tube) were calibrated to specifications in the sampling methods.

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

5.2 NO_x Converter Efficiency Test

The NO₂ – NO conversion efficiency of the Model 42c analyzer was verified prior to the testing program. A USEPA Protocol 1 certified concentration of NO₂ was injected directly into the analyzer, following the initial three-point calibration, to verify the analyzer's conversion efficiency. The analyzer's NO₂ – NO converter uses a catalyst at high temperatures to convert the NO₂ 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 NO₂ – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_x concentration was 93.1% 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, O₂ and CO₂ 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.

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, CO₂ and O₂ 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 CO₂, O₂, 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 stacks indicated that the measured CO, NO_x, O₂ and CO₂ 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 each RICE exhaust stack.

5.7 FTIR QA/QC Activities

At the beginning of each day a calibration transfer standard (CTS, ethylene gas), analyte of interest (acetaldehyde) and nitrogen calibration gas was directly injected into the FTIR to evaluate the unit response.

Prior to and after each test run the CTS was analyzed. The ethylene was passed through the entire system (system purge) to verify the sampling system response and to ensure that the sampling system remained leak-free at the stack location. Nitrogen was also be passed through the sampling system to ensure the system is free of contaminants.

Analyte spiking, of the emission unit, with acetaldehyde was performed to verify the ability of the sampling system to quantitatively deliver a sample containing the compound of interest from the base of the probe to the FTIR and assure the ability of the FTIR to quantify that compound in the presence of effluent gas.

As part of the data validation procedure, reference spectra were manually fit to that of the sample spectra (two spectra from each test period) and a concentration was determined. Concentration data was manually validated using the MKS MG2000 method analyzer software. The software used multi-point calibration curves to quantify each spectrum. The software-calculated results were compared with the measured concentrations to ensure the quality of the data.

Appendix 7 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, FTIR QA/QC data, 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 Table 6.1.

EUICE#6 has the following allowable emission limits specified for each engine in MI-ROP-N5397-2019a:

- 2.7 g/bhp-hr for CO;
- 1.5 g/bhp-hr for NO_x;
- 0.71 lb/hr for CHOH; and
- 1.12 g/bhp-hr for VOC (includes formaldehyde).

The measured air pollutant concentrations and emission rates for EUICE#6 are less than the allowable limits specified in MI-ROP-N5397-2019a.

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. The engine-generator set was operated within 10% of maximum output (800 kW generator output for CAT® G3516 RICE) and no variations from normal operating conditions occurred during the engine test periods.

Table 6.1 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 6 (EUICE#6)

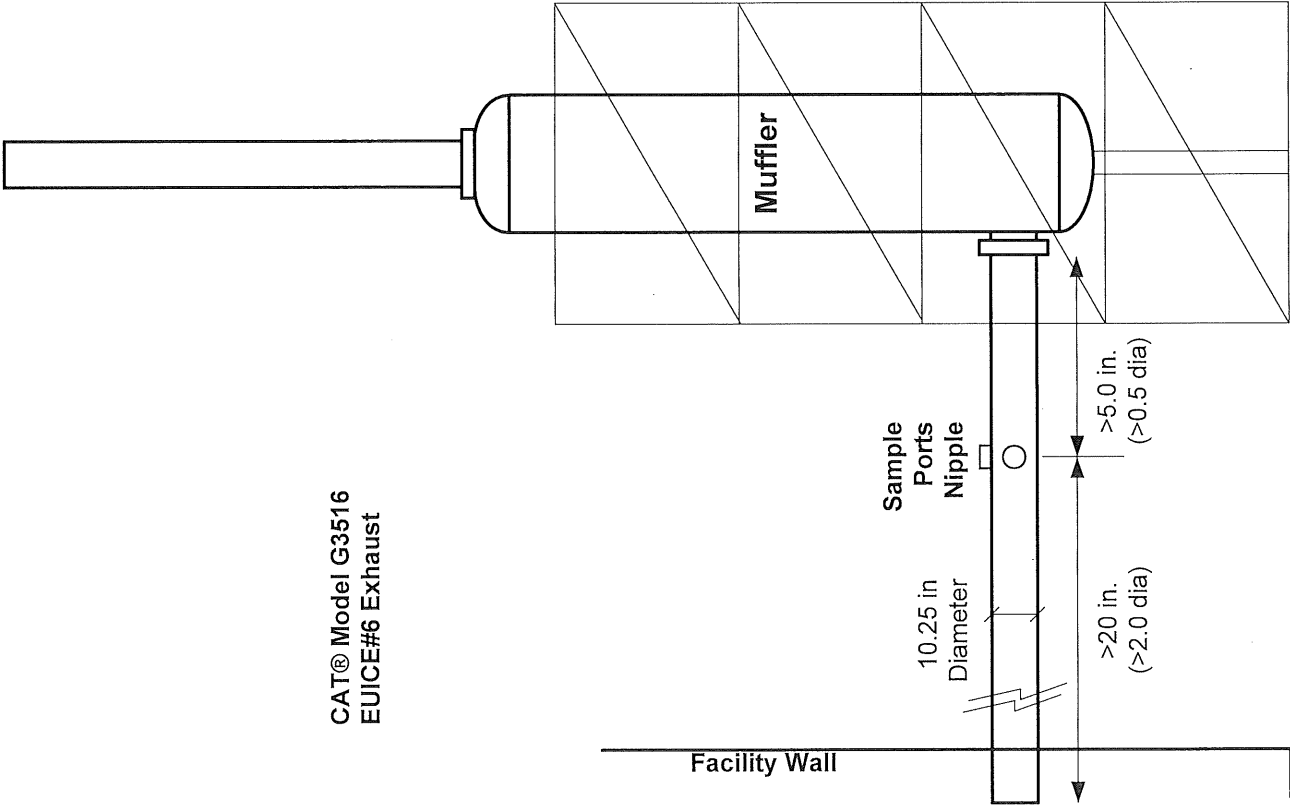
Test No.	1	2	3	
Test date	4/27/21	4/27/21	4/27/21	Three Test
Test period (24-hr clock)	933-1033	1050-1150	1210-1310	Average
Fuel flowrate (scfm)	300	300	300	300
Generator output (kW)	812	812	817	814
Engine output (bhp-hr)	1,159	1,160	1,167	1,162
Air to fuel ratio	52	56	56	55
LFG methane content (%)	54.3	53.4	53.0	53.6
<u>Exhaust Gas Composition</u>				
CO ₂ content (% vol)	12.2	12.2	12.3	12.2
O ₂ content (% vol)	7.50	7.60	7.58	7.56
Moisture (% vol)	12.9	13.2	13.2	13.1
Exhaust gas flowrate (dscfm)	2,344	2,325	2,326	2,332
Exhaust gas flowrate (scfm)	2,691	2,677	2,681	2,683
<u>Nitrogen Oxides</u>				
NO _x conc. (ppmvd)	116	111	118	115
NO _x emissions (lb/hr)	1.95	1.85	1.96	1.92
NO _x emissions (g/bhp-hr)	0.8	0.7	0.8	0.8
Permit Limit (g/bhp-hr)	-	-	-	1.5
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	443	440	446	443
CO emissions (lb/hr)	4.53	4.46	4.52	4.51
CO emissions (g/bhp-hr)	1.8	1.7	1.8	1.8
Permit Limit (g/bhp-hr)	-	-	-	2.7
<u>Formaldehyde</u>				
CHOH conc. (ppmvd)	54.0	54.4	54.9	54.4
CHOH emissions (lb/hr)	0.68	0.68	0.69	0.68
Permit Limit (lb/hr)	-	-	-	0.71
<u>Volatile Organic Compounds</u>				
VOC emissions (ppmv)	17.6	18.0	17.9	17.9
VOC emissions (lb/hr)	0.33	0.33	0.33	0.33
VOC emissions (g/bhp-hr) ¹	0.39	0.40	0.40	0.40
Permit Limit (g/bhp-hr) ¹	-	-	-	1.12

Notes for table 6.1:

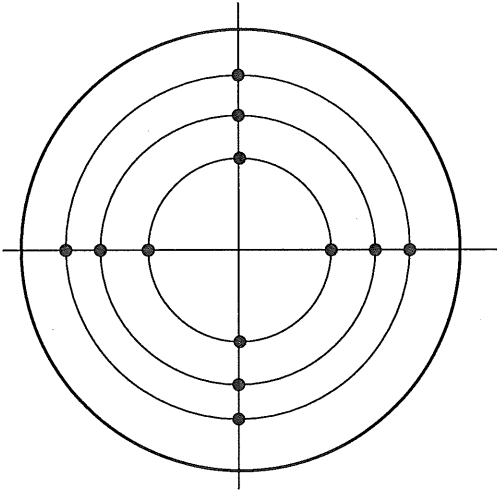
1. Includes formaldehyde.

APPENDIX 1

- RICE Engine Sample Port Diagram



Exhaust Stack
Cross-Section
with Traverse
Points



Velocity sample locations as
measured from stack wall

Pt. #	in.
1	0.50
2	1.50
3	3.03
4	7.22
5	8.75
6	9.75

5/4/21 ALR	NANR People's Facility Exhaust Sample Location, CAT® G3516 ICE		
	Scale None	Sheet 1 of 1	Impact Comp. & Testing, Inc. Dwg. No. NANR-PEO-1