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

WASTE MANAGEMENT, INC.
PINE TREE ACRES LANDFILL

1.0 INTRODUCTION

Waste Management, Inc. (WM) owns and operates the Pine Tree Acres (PTA) municipal solid waste landfill located in Lenox Township, Macomb County.

The conditions of Permit MI-ROP-N5984-2019 that was issued July 30, 2019 specify that within 180 days of permit issuance or five years from the last test date, whichever is later, the permittee shall verify:

- Visible emissions from EU-FLARE3 and EU-FLARE5.
- The NMOC reduction efficiency or ppmv from EU-FLARE4 and EU-FLARE6.
- Visible emissions (per a USEPA Method 9 certified visible emissions observation shall be conducted for a minimum of 15 minutes to determine the actual opacity from that emission point), NOx, SO_2, and CO emission rates from EU-FLARE4 and EU-FLARE6, by testing at owner's expense, in accordance with Department requirements.
- PM and PM10 emission rates from EU-FLARE4 and EU-FLARE6.
- Visible emissions (per a USEPA Method 9 certified visible emissions observation shall be conducted for a minimum of 15 minutes to determine the actual opacity from that emission point), NOx, PM, PM-10, VOC, SO_2, and CO emission rates from each engine in FG-ICENGINES.
- Formaldehyde emission rates from each engine in FG-ICENGINES.

The compliance testing was performed by Impact Compliance & Testing, Inc. (ICT). ICT representatives Tyler Wilson, Rob Harvey, Andy Rusnak, Blake Beddow, Clay Gaffey, Tom Andrews, and Summer Hitchens performed the field sampling and measurements January 14, 2020; January 20-24, 2020; and January 27, 2020.

Testing for EU-FLARE6 was postponed and those results will be presented in a separate report at a later date.

The exhaust gas sampling and analysis was performed using procedures specified in the Stack Test Protocol, dated December 20, 2019, that was reviewed and approved by the State of Michigan Department of Environment, Great Lakes, and Energy-Air Quality Division (EGLE-AQD) in the January 7, 2020 Test Plan Approval Letters. EGLE-AQD representatives Ms. Lindsey Wells, Ms. Gina Angellotti, Mr. Matthew Karl, and Mr. Robert Joseph 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 ICT based on field sampling data collected by ICT. Facility process data were collected and provided WM-PTA employees or representatives. This test report has been reviewed by WM-PTA representatives and approved for submittal to the EGLE-AQD.

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:

Tyler J. Wilson
Senior Project Manager
Impact Compliance & Testing, Inc.

A Renewable Operating Permit Report Certification form signed by the source responsible official accompanies this report.

2.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

2.1 Purpose and Objective of the Tests

The conditions of MI-ROP-N5984-2019 require WM-PTA to test:

- EU-FLARE3 and EU-FLARE5 for visible emissions (VE; USEPA Method 22).
- EU-FLARE4 and EU-FLARE6 for VE (USEPA Method 9), carbon monoxide (CO), nitrogen oxides (NOx), NMOC, sulfur dioxide (SO_2), and particulate matter (PM/PM10) emission rates.
- Each engine in FG-ICENGINES (EU-ICENGINE1 through EU-ICENGINE8) for VE (USEPA Method 9), CO, NOx, volatile organic compound (VOC), SO_2, formaldehyde (HCOH), and PM/PM10 emission rates.

The testing performed for the engines also satisfies the periodic emission tests required by the federal New Source Performance Standards to Spark-Ignition Reciprocating Internal Combustion Engines (SI-RICE NSPS; 40 CFR Part 60 Subpart JJJJ).

2.2 Operating Conditions During the Compliance Tests

The flare testing was performed while the flares were operated at normal routine operating conditions. For the enclosed flares, WM-PTA representatives monitored and recorded the combustion zone temperature (°F), fuel use (scfm), and fuel methane content (%) at 15-minute intervals for each test period.

The engine testing was performed while the RICE-generator sets were operated at maximum operating conditions (within 10% of the rated electricity output of 1,600 kW). WM-PTA representatives monitored and recorded the generated power output (kW), fuel use (scfm), fuel methane content (%), inlet pressure (psi), and air-to-fuel ratio at 15-minute intervals for each test period.

Engine output (bhp) cannot be measured directly and was calculated based on the recorded electricity output, the calculated CAT® Model G3520C generator efficiency (96%), and the unit conversion factor for kW to horsepower (0.7457 kW/hp).

Engine output (bhp) = Electricity output (kW) / (0.96) / (0.7457 kW/hp)

Tables 2.1 and 2.2 present a summary of the average flare and engine operating conditions during the test periods.

Appendix 2 provides operating records provided by WM-PTA representatives for the test periods.

Table 2.1 Average enclosed flare operating conditions during the test periods

Flare Parameter	Flare No. 4
Combustion zone temperature (°F)	1,638
Flare LFG use (scfm)	2,625
LFG methane content (%)	54.2
LFG LHV (Btu/scf)	493
Exhaust temperature (°F)	1,633

Table 2.2 Average engine operating conditions during the test periods

Engine Parameter	Engine No. 1	Engine No. 2	Engine No. 3	Engine No. 4
CAT® Model No.	G3520C	G3520C	G3520C	G3520C
Generator output (kW)	1,624	1,627	1,630	1,626
Engine output (bhp)	2,269	2,273	2,276	2,272
Engine LFG use (scfm)	533	535	534	537
Inlet pressure (psi)	45.6	46.4	47.4	46.4
Air-to-fuel ratio	7.6	7.8	8.2	7.7
LFG methane content (%)	52.2	52.0	52.4	52.3
LFG LHV (Btu/scf)	475	473	477	476
Exhaust temperature (°F)	957	934	931	953

Engine Parameter	Engine No. 5	Engine No. 6	Engine No. 7	Engine No. 8
CAT® Model No.	G3520C	G3520C	G3520C	G3520C
Generator output (kW)	1,627	1,637	1,643	1,628
Engine output (bhp)	2,273	2,286	2,295	2,274
Engine LFG use (scfm)	547	536	557	545
Inlet pressure (psi)	47.9	46.0	46.9	46.9
Air-to-fuel ratio	7.6	7.8	7.4	7.4
LFG methane content (%)	52.4	52.3	51.4	52.5
LFG LHV (Btu/scf)	477	476	468	478
Exhaust temperature (°F)	946	951	953	951

2.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the LFG flares and RICE were each sampled for three (3) one-hour test periods during the compliance testing performed January 14, 2020; January 20-24, 2020; and January 27, 2020.

Tables 2.3 and 2.4 present the average measured air pollutant emission rates for the flares and engines (average of the three test periods for each emission unit) and applicable emission limits.

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 2.3 Average measured air pollutant emission rates for flares (three-test average)

Pollutant	EU-FLARE4	EU-FLARE5	EU-FLARE3	Permit Limit
NOx (lb/MMBtu)	0.05	-	-	0.06
CO (lb/MMBtu)	0.08	-	-	0.2
NMOC (ppmvd)[1]	0.54	-	-	20
SO_2 (lb/hr)	3.11	-	-	8.1
PM/PM10 (lb/hr)	1.02	-	-	1.4
VE-Method 9 (%)	0	-	-	20
VE-Method 22 (min)	-	0	0	0

Notes:

1. NMOC limit is 20 ppmvd corrected to 15% oxygen.

Table 2.4 Average measured air pollutant emission rates for the CAT® G3520C engines (three-test average)

Pollutant	Engine 1	Engine 2	Engine 3	Engine 4	Permit Limit
NOx (lb/hr)	2.15	2.30	2.14	2.01	3.0
CO (lb/hr)	10.4	10.5	12.4	10.9	16.3
HCOH (lb/hr)	1.58	1.51	1.83	1.71	2.07
VOC (lb/hr)	0.42	0.58	0.74	0.54	1.0
SO_2 (lb/hr)	1.18	1.12	1.15	1.34	1.57
PM/PM10 (lb/hr)	0.35	0.37	0.46	0.61	1.2
VE (%)	0	0	0	0	10
NOx (g/bhp-hr)	0.43	0.46	0.43	0.40	0.6
CO (g/bhp-hr)	2.08	2.10	2.47	2.17	3.3
PM/PM10 (g/bhp-hr)	0.07	0.07	0.09	0.12	0.24

Pollutant	Engine 5	Engine 6	Engine 7	Engine 8	Permit Limit
NOx (lb/hr)	2.05	2.03	2.09	2.07	3.0
CO (lb/hr)	11.4	9.75	10.8	11.4	16.3
HCOH (lb/hr)	1.65	1.49	1.72	1.87	2.07
VOC (lb/hr)	0.52	0.44	0.52	0.65	1.0
SO_2 (lb/hr)	1.18	1.19	1.38	1.25	1.57
PM/PM10 (lb/hr)	0.56	0.47	0.44	0.52	1.2
VE (%)	0	0	0	0	10
NOx (g/bhp-hr)	0.41	0.40	0.41	0.41	0.6
CO (g/bhp-hr)	2.27	1.93	2.13	2.26	3.3
PM/PM10 (g/bhp-hr)	0.11	0.09	0.09	0.10	0.24

3.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

3.1 General Process Description

WM-PTA operates an active landfill gas (LFG) collection and control system. Most of the collected gas is treated and used as fuel in electricity generation processes (RICE) operated by WM-PTA and Aria Energy, Sumpter Energy Associates-Pine Tree Acres (SEA-PTA).

Excess collected gas (that exceeds the capacity of the renewable energy facilities or during generating plant downtime) is controlled by Waste Management in two open flares (EU-FLARE3 and EU-FLARE5) and two enclosed flares (EU-FLARE4 and EU-FLARE6).

3.2 Rated Capacities and Air Emission Controls

The following equipment descriptions are from Permit MI-ROP-N5984-2019.

EU-FLARE3	A 3,000 CFM open flare. Open flare is an open combustor without enclosure or shroud.
EU-FLARE4	A 3,000 CFM enclosed flare with a sulfur removal system for reducing sulfur content of landfill gas prior to combustion. An enclosed flare is an enclosed combustor or firebox which maintains a relatively constant limited peak temperature generally using a limited supply of combustion air.
EU-FLARE5	A 2,100 CFM portable, back-up only, open flare. Open flare is an open combustor without enclosure or shroud.
EU-ICENGINE1	Spark ignition, lean burn, reciprocating internal combustion engine (Caterpillar G3520C, 2,233 bhp at 100% load) and associated generator set for combusting treated landfill gas to produce electricity (1.6-megawatt gross electrical output). This emission unit, and any replacement of this unit as applicable under R 336.1285(2)(a)(vi), is for a Caterpillar G3520C internal combustion engine greater than 500hp fueled with treated landfill/digester gas to produce electricity.
EU-ICENGINE2 through EU-ICENGINE8	Identical to EU-ICENGINE1

3.3 Sampling Locations

The EU-FLARE4 exhaust gas is released to the atmosphere through a dedicated vertical exhaust stack. The vertical exhaust stack has an inner diameter of 144 inches. The vertical exhaust stack is equipped with four (4) sample ports, each opposed 90° from the previous, that provide a sampling location 72.0 inches (0.5 duct diameters) upstream and 528 inches

(3.7 duct diameters) downstream from any flow disturbance and satisfies the USEPA Method 1 criteria for a representative sample location.

The RICE exhaust gas is directed through mufflers and is released to the atmosphere through dedicated vertical exhaust stacks. The eight (8) CAT® Model G3520C RICE exhaust stacks are identical. The exhaust sampling ports for the CAT® Model G3520C engines (EU-ICENGINE1 through EU-ICENGINE8) are located in individual horizontal exhaust ducts, located before the engine silencer, with an inner diameter of 15.0 inches. After the engine silencer the exhaust stack diameter is reduced to 14.0 inches as specified in the permit. Each duct is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 38.0 inches (2.5 duct diameters) upstream and 45.0 inches (3.0 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.

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 [Flare 4 & Engines]	Exhaust gas velocity measurement locations were determined based on the physical stack arrangement and requirements in USEPA Method 1.
USEPA Method 2 [Flare 4 & Engines]	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 [Flare 4 & Engines]	Exhaust gas O_2 and CO_2 content was determined using zirconia ion/paramagnetic and infrared instrumental analyzers, respectively.
USEPA Method 4 [Flare 4 & Engines]	Exhaust gas moisture was determined based on the water weight gain in chilled impingers.
USEPA Method 5/202 [Flare 4 & Engines]	Exhaust gas filterable and condensable particulate matter was determined using an isokinetic sampling train.
USEPA Method 6C [Flare 4 & Engines]	Exhaust gas SO_2 concentration was determined using a pulsed ultraviolet fluorescence instrumental analyzer.
USEPA Method 7E [Flare 4 & Engines]	Exhaust gas NO_x concentration was determined using a chemiluminescence instrumental analyzer.
USEPA Method 9 [Flare 4 & Engines]	Exhaust gas plume observations were made by a certified observer of visible emissions.
USEPA Method 10 [Flare 4 & Engines]	Exhaust gas CO concentration was measured using an NDIR instrumental analyzer.
USEPA Method 22 / ALT-042 [Flares 3&5]	Exhaust gas plume observations were made by a competent observer of visible emissions.
USEPA Method 25A / ALT-097 [Flare 4]	Exhaust gas VOC (as NMHC) concentration was determined using a flame ionization analyzer equipped with a GC column.
USEPA Method 25A / ALT-096 [Engines]	Exhaust gas VOC (as NMHC) concentration was determined using a flame ionization analyzer equipped with a GC column.
ASTM Method D6348 [Flare 4 & Engines]	Exhaust gas HCOH concentration was measured using fourier transform infrared spectroscopy (FITR instrumental analyzer).

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

Exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 during the isokinetic sampling periods. 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 periodically leak-checked to verify the integrity of the measurement system.

The absence of significant cyclonic flow for each exhaust configuration was verified using an S-type Pitot tube and oil manometer.

Appendix 3 provides field data sheets (isokinetic PM/PM10).

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

CO_2 and O_2 content in the exhaust gas streams were 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 single beam single wavelength (SBSW) 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 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 each exhaust gas stream was determined in accordance with USEPA Method 4 as a component of the particulate matter sampling train. The moisture sampling was performed concurrently with the instrumental analyzer sampling. During each sampling period, a gas sample was extracted at an isokinetic rate from the source where moisture was removed from the sampled gas stream using a knockout impinger and 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.

Appendix 3 provides exhaust gas moisture gain field data sheets (isokinetic PM/PM10).

4.5 Measurement of Particulate Matter Emissions (USEPA Method 5/202)

The conditions of ROP No. MI-ROP-N5984-2019 specifies PM/PM10 emission limits for the EU-FLARE4 and each engine in FG-ICENGINES. The testing was performed using a combined filterable and condensable particulate matter (PM) sampling train. The filterable and condensable fractions were added to calculate total PM10 emissions (i.e., all filterable and condensable PM emissions were assumed to be in the PM10 size range).

4.8.1 Filterable Particulate Matter Sample Train (USEPA Method 5)

Filterable PM was determined using USEPA Method 5. Exhaust gas was withdrawn from each exhaust stack at an isokinetic sampling rate using an appropriately-sized stainless steel sample nozzle and heated probe. The collected exhaust gas was passed through a pre-tared glass fiber filter that was housed in an independent heated filter box. The back half of the filter housing was connected to the condensable PM impinger train.

4.8.2 Condensable Particulate Matter Sample Train (USEPA Method 202)

Condensable PM (CPM) concentrations were measured in accordance with USEPA Method 202. Following the Method 5 filter assembly, the sample gas travelled through the impinger train which consisted of a condenser, a knock-out impinger, a standard Greenberg-Smith (G-S) impinger (dry), a Teflon-coated CPM filter (with exhaust thermocouple), a modified G-S impinger containing 100 milliliters of deionized water, and a modified G-S impinger containing a known amount of indicating silica gel.

The CPM components of the Method 202 sampling train (dry knockout impinger and dry GS impinger) were placed in a tempered water bath and a pump was used to circulate water through the condenser. The temperature of the bath was maintained such that the CPM filter outlet temperature remained between 65 and 85°F. Crushed ice was placed around the last two impingers to chill the gas to below 68°F.

4.8.3 Sample Recovery and Analysis (USEPA Method 5/202)

At the conclusion of each one-hour test period, the sample train was leak-checked and disassembled. The sample nozzle, probe liner, and filter holder were brushed and rinsed with acetone. The recovered particulate filter and acetone rinses were stored in sealed containers and transferred to Enthalpy Analytical, Inc. (Durham, North Carolina) for gravimetric measurements.

The impingers were transported to the recovery area where they were weighed. The exhaust gas contained significant amounts of moisture. Therefore, prior to recovery, the CPM portion of the sample train underwent the nitrogen purge step of Method 202. The glassware (between the particulate filter and CPM filter) was rinsed with DI water, acetone, and hexane in accordance with the Method 202 sample recovery procedures. The CPM filter and recovered rinses were clearly and uniquely labeled and transferred to Enthalpy Analytical, Inc. for analysis.

Diluent gas content (Method 3A O_2 and CO_2) measurements were performed with each of the PM/PM10 isokinetic sampling periods.

Appendix 4 provides PM/PM10 calculation sheets. The PM/PM10 laboratory report is provided in Appendix 7.

4.6 Sulfur Dioxide Concentration Measurements (USEPA Method 6C)

Exhaust gas SO_2 concentration measurements were performed using a Thermo Environmental Instruments, Inc. (TEI) Model 43i that uses pulsed ultraviolet fluorescence technology in accordance with USEPA Method 6C for the measurement of SO_2 concentration.

Appendix 4 provides SO_2 calculation sheets. Raw instrument response data are provided in Appendix 5.

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

NO_x and CO pollutant concentrations in the 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 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.

4.8 Visible Emissions Observations (USEPA Method 9)

USEPA Method 9 procedures were used to evaluate the opacity of each exhaust gas during the emission sampling periods.

In accordance with USEPA Method 9, the qualified observer stood at a distance sufficient to provide a clear view of the emissions with the sun oriented in the 140° sector to his back.

Opacity observations were made at the point of greatest opacity in the portion of the plume where condensed water vapor was not present. Observations were made at 15-second intervals for at least 15-minutes for EUFLARE-4 and each engine in FG-ICENGINES.
All visual opacity determinations were performed by a qualified observer in accordance with USEPA Method 9, Section 3.

Opacity test data and the observer certificate are presented in Appendix 8.

4.9 Visible Emissions Observations (USEPA Method 22)

A two-hour observation period was conducted on each open flare (EU-FLARE3 and EU-FLARE5) while in normal operation. Field records of the observation were completed which incorporate the data requirements of USEPA Method 22. Quality assurance/quality control (QA/QC) procedures and observation guidelines presented in USEPA Method 22 were followed for the proper execution of this portion of the test program.

Opacity test data are presented in Appendix 8.

4.10 Measurement of Volatile Organic Compounds (USEPA Method 25A/ALT-097)

The VOC emission rate was determined by measuring the nonmethane hydrocarbon (NMHC) concentration in the EU-FLARE4 exhaust gas. NMHC pollutant concentration was determined using 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 several alternate test methods approving the use of the TEI 55-series analyzer as an effective instrument for measuring NMOC from gas-fueled reciprocating internal combustion engines (RICE) in that it uses USEPA Method 25A and 18 (ALT-066, ALT-078 and 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.

4.11 Measurement of Volatile Organic Compounds (USEPA Method 25A/ALT-096)

The VOC emission rate was determined by measuring the nonmethane hydrocarbon (NMHC) concentration in each RICE 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 several alternate test methods approving the use of the TEI 55-series analyzer as an effective instrument for measuring NMOC from gas-fueled reciprocating internal combustion engines (RICE) in that it uses USEPA Method 25A and 18 (ALT-066, ALT-078 and 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.

4.12 Measurement of Formaldehyde (ASTM Method D6348)

Formaldehyde concentration in each RICE exhaust gas stream was determined using a MKS Multi-Gas 2030 Fourier transform infrared (FTIR) spectrometer.

Samples of the exhaust gas were delivered directly to the instrumental analyzer using a Teflon® heated sample line, heated head pump and heated filter to prevent condensation. The sample to the FTIR analyzer was not conditioned to remove moisture. Therefore, formaldehyde 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 and sulfur hexafluoride 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 MKS data acquisition software.

Appendix 4 provides HCOH calculation sheets. Raw instrument response data for the FTIR instrument is provided in Appendix 5.

4.13 Fuel Gas Measurement for H_2S (Draeger Tubes)

The EGLE-AQD Test Protocol Approval Letter required the following additional process data to be recorded during the test program:

- *One fuel gas sample per test day, collected during active testing using a Draeger tube, for H2S determination.*

ICT and/or WM-PTA satisfied the additional process data request by performing one Draeger tube measurement per test day (photos included in Appendix 7).

Appendix 7 provides photos of the seven (7) Draeger® tubes.

5.0 QA/QC ACTIVITIES

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 (once at each testing location – enclosed flares (1/10/2020) and engines (1/16/2020)). 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 greater than or equal to 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_x concentrations were 97.7% and 99.7% of the expected value, i.e., greater than 90% of the expected value as required by Method 7E).

5.2 Methane/NMHC Separation Verification

A demonstration of the TEI Model 55i methane / non-methane organic compound separation efficiency was performed in-house on January 30, 2020, following the test event. The analyzer was challenged with a Certified Standard Spec blend gas containing 1,004 ppmv methane and 10.94 ppmv non-methane compounds (specifically propane) for the demonstration. The TEI Model 55i instrumental analyzer was calibrated using certified cylinders of 2,538 ppmv methane and 86.03 ppmv propane. The blend gas was then injected into the analyzer and the measured methane and non-methane concentrations were recorded using a data logger. The measured methane concentration stabilized at 1,022 ppmv and the measured NMOC concentration stabilized at 11.2 ppm. The demonstration indicates that the non-methane components (propane) did not elute with the methane (i.e., the internal column is highly efficient in separating methane and non-methane compounds).

5.3 Particulate Matter Recovery and Analysis

All recovered particulate matter samples were stored and shipped in certified trace clean amber glass sample bottles with Teflon® lined caps. The liquid level on each bottle was marked with a permanent marker prior to pick-up and the caps were secured closed with tape. Samples of the reagents used in the test event (200 milliliters each of deionized high-purity water, acetone and hexane) were submitted with the samples for analysis to verify that the reagents used to recover the samples have low particulate matter residues.

The glassware used in the condensable PM impinger trains was washed and rinsed prior to use in accordance with the procedures of USEPA Method 202. The glassware was not baked prior to use; therefore, ICT used the field train proof blank option provided in USEPA Method 202. Analysis of the collected field train proof blank rinses (sample train rinse performed prior to use) indicated a total of 2.6 milligrams (mg) of recovered PM from the sample train. In addition, a field train recovery proof blank was performed following the second sampling period. Analysis of the field train recovery proof blank resulted in 2.6 mg of recovered PM from the sample train. The reported condensable PM test results were blank-corrected according to the method (USEPA Method 202 allows a blank correction of up to 2 mg).

5.4 Laboratory QA/QC Procedures

The particulate matter analyses were conducted by a qualified third-party laboratory according to the appropriate QA/QC procedures specified in the USEPA Methods 5 and 202 and are included in the final report provided by Enthalpy Analytical.

5.5 FTIR QA/QC Activities

At the beginning of each engine test day a calibration transfer standard (CTS, ethylene gas), analyte of interest (acetaldehyde) and nitrogen calibration gas were 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 passed through the sampling system to ensure the system is free of contaminants.

Analyte spiking, of each 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 assured the ability of the FTIR to quantify that compound in the presence of effluent gas. The spike target dilution ratio was 1:10 (1 part cal gas; 9 parts stack gas).

5.6 Sampling System Response Time Determination

The response time of the sampling system was determined prior to the compliance test program (each test day) 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.

Results of the response time determinations were recorded on field data sheets. For each test period, test data were collected once the sample probe was in position for at least twice the maximum system response time.

5.7 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 (once at each testing location – enclosed flares (1/10/2020) and engines (1/16/2020)). The field evaluations yielded no errors greater than 2% of the triplicate measured average and no errors greater than 2% from the expected values.

5.8 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NO_x, CO, SO_2, CO_2, and O_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.

5.9 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, SO_2, 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, CO, and SO_2 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.

5.10 Determination of Exhaust Gas Stratification

A stratification test was performed for each 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 each exhaust stack indicated that the measured CO_2 and O_2 concentrations did not vary by more than 5% of the mean across the stack diameter. Therefore, the exhaust gas was considered to be unstratified and the compliance test sampling was performed at a single sampling location within each exhaust stack.

5.11 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, methane/NMHC separation study records, instrument calibration and system bias check records, calibration gas and gas divider certifications, interference test results, meter box calibration records, and scale, pyrometer, barometer, Pitot tube, probe, and nozzle calibration records).

6.0 RESULTS

6.1 Test Results and Allowable Emission Limits

Flare and engine operating data and air pollutant emission measurement results for each one-hour test period are presented in Tables 6.1 through 6.11.

The measured air pollutant emission rates for each emission unit are less than the allowable limits specified in MI-ROP-N5984-2019. The allowable limits specified in MI-ROP-N5984-2019 are listed in the following tables.

Emission Unit	NMOC	SO_2 (lb/hr)[1]	NOx (lb/MMBtu)	CO (lb/MMBtu)	PM/ PM10 (lb/hr)	VE
EU-FLARE3	NA	NA	NA	NA	NA	Note 2
EU-FLARE4	98% DE, or 20 ppmvd C_6 @ 3% O_2	8.1	0.06	0.2	1.4	20% 6-min avg [Note 3]
EU-FLARE5	NA	NA	NA	NA	NA	Note 2

Notes:
1. There are two SO_2 limits specified in FG-FLARES. The limit presented is the more stringent.
2. There shall be no visible emissions from EU-FLARE3 and EU-FLARE5 except for periods not to exceed a total of five minutes during any two consecutive hours
3. The VE limit for Flare 4 and Flare 6 based on USEPA Method 9 for at least 15 minutes.

EU-ICENGINE1 through EU-ICENGINE8	Emission Limit (lb/hr)	Emission Limit (g/bhp-hr)	Emission Limit Other
CO	16.3	3.3	--
NOx	3.0	0.6	--
PM/PM10	1.2	0.24	--
VOC	1.0	--	--
Formaldehyde	2.07	--	--
SO_2	1.57	--	--
VE	--	--	10% Opacity 6-min avg

Notes:

1. The limits for CO, NOx and VOC are equal to, or more stringent than, the emission standards in 40 CFR Part 60 Subpart JJJJ.

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 flares were operated at normal routine operating conditions during the flare test periods. The engine-generator sets were operated within 10% of maximum output (1,600 kW generator output) during the engine test periods.

Flare No. 6 was originally scheduled to be tested during this test event. Testing of Flare No. 6 was postponed due to a failing burner. Testing of Flare No. 6 is scheduled to be performed following repair of the failing burner. This plan of action has been discussed with and approved by EGLE-AQD.

The first test for Engine No. 8 was discarded due to the PM10/PM2.5 sample train failing the post-test leak check. All collected data for this test is included in this Test Report. An additional test period for all pollutants was performed to satisfy the three-test average requirement for all pollutant emissions.

Table 6.1 Measured exhaust gas conditions and air pollutant emission rates for Flare No. 4 (EU-FLARE4)

Test No. Test date Test period (24-hr clock)	1 1/14/2020 10:12-11:59	2 1/14/2020 13:20-15:02	3 1/14/2020 15:55-18:16	Three Test Average
Fuel flowrate (scfm)	2,773	2,572	2,529	2,625
Combustion Zone Temp. (°F)	1,625	1,640	1,648	1,638
LFG methane content (%)	54.0	54.5	54.1	54.2
LFG heat content (Btu/scf)	491	496	492	493
<u>Exhaust Gas Composition</u>				
CO_2 content (% vol)	7.35	7.49	7.35	7.40
O_2 content (% vol)	13.4	13.2	13.4	13.3
Moisture (% vol)	7.90	8.04	7.45	7.80
Exhaust gas temperature (°F)	1,636	1,638	1,627	1,633
Exhaust gas flowrate (dscfm)	39,218	36,519	34,020	36,585
Exhaust gas flowrate (scfm)	42,583	39,712	36,758	39,684
<u>Nitrogen Oxides</u>				
NO_X conc. (ppmvd)	13.8	14.6	13.9	14.1
NO_X emissions (lb/hr)	3.87	3.82	3.38	3.69
NO_X emissions (lb/MMBtu)	0.05	0.05	0.05	0.05
Permitted emissions (lb/MMBtu)	-	-	-	*0.06*
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	21.1	37.0	53.3	37.1
CO emissions (lb/hr)	3.61	5.90	7.91	5.81
Permitted emissions (lb/hr)	-	-	-	*16.30*
CO emissions (lb/MMBtu)	0.04	0.08	0.11	0.08
Permitted emissions (lb/MMBtu)	-	-	-	*0.2*
<u>Non-Methane Organic Compounds</u>				
NMOC conc. (ppmv)[1]	0.5	0.4	0.4	0.4
NMOC conc. (ppmvd as C_6)[2]	0.6	0.5	0.5	0.5
Permitted conc. (ppmvd)[2]	-	-	-	*20*

Table 6.1 Measured exhaust gas conditions and air pollutant emission rates for Flare No. 4 (EU-FLARE4) [Continued]

Test No. Test date Test period (24-hr clock)	1 1/14/2020 11:44-12:54	2 1/14/2020 14:33-15:40	3 1/14/2020 16:25-17:32	Three Test Average
Particulate Matter				
Sampled volume (dscf)	38.0	35.4	33.2	35.5
Filterable catch (mg)	4.79	4.31	4.16	4.42
Condensable catch (mg)	3.23	3.38	1.67	2.76
Total catch (mg)	8.02	7.69	5.83	7.18
PM10 emissions (lb/hr)	1.14	1.10	0.83	1.02
Permitted emissions (lb/hr)	-	-	-	*1.4*
Sulfur Dioxide				
SO_2 conc. (ppmv)	9.71	8.11	7.55	8.45
SO_2 emissions (lb/hr)	3.80	2.96	2.56	3.11
Permitted emissions (lb/hr)	-	-	-	*8.1*
Visible Emissions				
Highest 6-minute average (%)	0.0	0.0	0.0	0.0
Permitted emissions (%)	-	-	-	*20%*

1. Measured as nonmethane hydrocarbons as propane.
2. Parts per million by volume (ppmvd) as hexane (C_6) @ 3% oxygen.

Table 6.2 Measured VE for Flare No. 5 (USEPA Method 22)

Test date	1/16/2020
Test period (24-hr clock)	11:05-13:30
Visible Emissions	
Time exceeding zero percent opacity (min)	0.0
Permitted emissions (min)	*0.0*

Table 6.3 Measured VE for Flare No. 3 (USEPA Method 22)

Test date	1/16/2020
Test period (24-hr clock)	14:05-16:30
Visible Emissions	
Time exceeding zero percent opacity (min)	0.0
Permitted emissions (min)	*0.0*

Table 6.4 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 1 (EU-ICENGINE1)

Test No. Test date Test period (24-hr clock)	1 1/23/2020 7:42-8:53	2 1/23/2020 10:05-11:22	3 1/23/2020 12:08-13:22	Three Test Average
Fuel flowrate (scfm)	538	529	533	533
Generator output (kW)	1,626	1,624	1,622	1,624
Engine output (bhp)	2,272	2,269	2,265	2,269
LFG methane content (%)	52.2	52.6	51.9	52.2
LFG heat content (Btu/scf)	475	479	472	475
Inlet pressure (psi)	45.6	45.6	45.7	45.6
Air / fuel ratio	7.5	7.6	7.7	7.6
<u>Exhaust Gas Composition</u>				
CO_2 content (% vol)	11.7	11.6	11.6	11.7
O_2 content (% vol)	8.36	8.44	8.41	8.40
Moisture (% vol)	10.9	10.9	11.2	11.0
Exhaust gas temperature (°F)	957	958	955	957
Exhaust gas flowrate (dscfm)	4,211	4,132	4,059	4,134
Exhaust gas flowrate (scfm)	4,727	4,636	4,570	4,644
<u>Nitrogen Oxides</u>				
NO_X conc. (ppmvd)	73.6	71.6	72.1	72.4
NO_X emissions (lb/hr)	2.22	2.12	2.10	2.15
Permitted emissions (lb/hr)	-	-	-	*3.0*
NO_X emissions (g/bhp*hr)	0.44	0.42	0.42	0.43
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.6*
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	576	573	576	575
CO emissions (lb/hr)	10.6	10.3	10.2	10.4
Permitted emissions (lb/hr)	-	-	-	*16.3*
CO emissions (g/bhp*hr)	2.11	2.07	2.04	2.08
*Permitted emissions (g/bhp*hr)*	-	-	-	*3.3*
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv as C_3)[1]	13.0	12.8	13.3	13.0
VOC emissions (lb/hr)	0.42	0.41	0.42	0.42
Permitted emissions (lb/hr)	-	-	-	*1.0*
VOC emissions (g/bhp*hr)	0.08	0.08	0.08	0.08

Table 6.4 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 1 (EU-ICENGINE1) [Continued]

Test No. Test date Test period (24-hr clock)	1 1/23/2020 7:42-8:53	2 1/23/2020 10:05-11:22	3 1/23/2020 12:08-13:22	Three Test Average
Particulate Matter				
Sampled volume (dscf)	36.0	35.5	34.8	35.4
Filterable catch (mg)	11.1	9.88	7.76	9.57
Condensable catch (mg)	17.9	10.8	11.3	13.3
Total catch (mg)	29.0	20.7	19.1	22.9
PM10 emissions (lb/hr)	0.44	0.32	0.29	0.35
Permitted emissions (lb/hr)	-	-	-	*1.2*
PM10 emissions (g/bhp*hr)	0.09	0.06	0.06	0.07
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.24*
Formaldehyde				
HCOH conc. (ppmv)	72.6	73.5	72.0	72.7
HCOH emissions (lb/hr)	1.61	1.59	1.54	1.58
Permitted emissions (lb/hr)	-	-	-	*2.07*
Sulfur Dioxide				
SO_2 conc. (ppmv)	29.2	28.3	28.5	28.6
SO_2 emissions (lb/hr)	1.23	1.17	1.15	1.18
Permitted emissions (lb/hr)	-	-	-	*1.57*
Visible Emissions				
Highest 6-minute average (%)	0.0	0.0	0.0	0.0
Permitted emissions (%)	-	-	-	*10%*

1. VOC measured as nonmethane hydrocarbons.

Table 6.5 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 1/23/2020 14:18-15:32	2 1/23/2020 16:15-17:26	3 1/24/2020 7:27-8:39	Three Test Average
Fuel flowrate (scfm)	535	536	535	535
Generator output (kW)	1,624	1,631	1,626	1,627
Engine output (bhp)	2,269	2,278	2,271	2,273
LFG methane content (%)	51.9	51.8	52.4	52.0
LFG heat content (Btu/scf)	472	471	477	473
Inlet pressure (psi)	46.5	46.5	46.3	46.4
Air / fuel ratio	7.8	7.8	7.8	7.8
Exhaust Gas Composition				
CO_2 content (% vol)	11.6	11.3	11.6	11.5
O_2 content (% vol)	8.51	8.41	8.47	8.46
Moisture (% vol)	10.6	10.8	10.8	10.7
Exhaust gas temperature (°F)	932	933	937	934
Exhaust gas flowrate (dscfm)	3,683	4,075	4,054	3,938
Exhaust gas flowrate (scfm)	4,120	4,566	4,545	4,410
Nitrogen Oxides				
NO_X conc. (ppmvd)	82.0	80.5	81.5	81.3
NO_X emissions (lb/hr)	2.17	2.35	2.37	2.30
Permitted emissions (lb/hr)	-	-	-	*3.0*
NO_X emissions (g/bhp*hr)	0.43	0.47	0.47	0.46
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.6*
Carbon Monoxide				
CO conc. (ppmvd)	607	607	621	612
CO emissions (lb/hr)	9.76	10.8	11.0	10.5
Permitted emissions (lb/hr)	-	-	-	*16.3*
CO emissions (g/bhp*hr)	1.95	2.15	2.19	2.10
*Permitted emissions (g/bhp*hr)*	-	-	-	*3.3*
Volatile Organic Compounds				
VOC conc. (ppmv as C_3)[1]	19.8	19.7	18.3	19.3
VOC emissions (lb/hr)	0.56	0.62	0.57	0.58
Permitted emissions (lb/hr)	-	-	-	*1.0*
VOC emissions (g/bhp*hr)	0.11	0.12	0.11	0.12

Table 6.5 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 2 (EU-ICENGINE2) [Continued]

Test No. Test date Test period (24-hr clock)	1 1/23/2020 14:18-15:32	2 1/23/2020 16:15-17:26	3 1/24/2020 7:27-8:39	Three Test Average
Particulate Matter				
Sampled volume (dscf)	31.9	35.2	35.1	34.1
Filterable catch (mg)	13.0	9.46	9.91	10.8
Condensable catch (mg)	12.5	14.8	14.4	13.9
Total catch (mg)	25.5	24.3	24.3	27.3
PM10 emissions (lb/hr)	0.39	0.37	0.37	0.37
Permitted emissions (lb/hr)	-	-	-	*1.2*
PM10 emissions (g/bhp*hr)	0.08	0.07	0.07	0.07
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.24*
Formaldehyde				
HCOH conc. (ppmv)	74.4	71.9	73.2	73.2
HCOH emissions (lb/hr)	1.43	1.54	1.56	1.51
Permitted emissions (lb/hr)	-	-	-	*2.07*
Sulfur Dioxide				
SO_2 conc. (ppmv)	30.7	27.9	27.3	28.6
SO_2 emissions (lb/hr)	1.13	1.14	1.11	1.12
Permitted emissions (lb/hr)	-	-	-	*1.57*
Visible Emissions				
Highest 6-minute average (%)	0.0	0.0	0.0	0.0
Permitted emissions (%)	-	-	-	*10%*

1. VOC measured as nonmethane hydrocarbons.

Table 6.6 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 3 (EU-ICENGINE3)

Test No. Test date Test period (24-hr clock)	1 1/24/2020 9:39-10:52	2 1/24/2020 11:19-12:33	3 1/24/2020 12:57-14:08	Three Test Average
Fuel flowrate (scfm)	537	536	529	534
Generator output (kW)	1,626	1,633	1,630	1,630
Engine output (bhp)	2,272	2,281	2,276	2,276
LFG methane content (%)	52.3	52.5	52.4	52.4
LFG heat content (Btu/scf)	476	478	477	477
Inlet pressure (psi)	47.1	47.6	47.4	47.4
Air / fuel ratio	8.2	8.2	8.3	8.2
<u>Exhaust Gas Composition</u>				
CO_2 content (% vol)	11.6	11.6	11.5	11.6
O_2 content (% vol)	8.55	8.52	8.61	8.56
Moisture (% vol)	10.9	10.6	10.8	10.8
Exhaust gas temperature (°F)	931	932	929	931
Exhaust gas flowrate (dscfm)	4,085	4,010	4,132	4,075
Exhaust gas flowrate (scfm)	4,583	4,486	4,634	4,568
<u>Nitrogen Oxides</u>				
NO_X conc. (ppmvd)	73.1	73.9	73.1	73.4
NO_X emissions (lb/hr)	2.14	2.12	2.16	2.14
Permitted emissions (lb/hr)	-	-	-	*3.0*
NO_X emissions (g/bhp*hr)	0.43	0.42	0.43	0.43
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.6*
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	693	700	695	696
CO emissions (lb/hr)	12.4	12.3	12.5	12.4
Permitted emissions (lb/hr)	-	-	-	*16.3*
CO emissions (g/bhp*hr)	2.47	2.44	2.50	2.47
*Permitted emissions (g/bhp*hr)*	-	-	-	*3.3*
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv as C_3)[1]	23.7	23.4	24.0	23.7
VOC emissions (lb/hr)	0.75	0.72	0.76	0.74
Permitted emissions (lb/hr)	-	-	-	*1.0*
VOC emissions (g/bhp*hr)	0.15	0.14	0.15	0.15

Table 6.6 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 3 (EU-ICENGINE3) [Continued]

Test No. Test date Test period (24-hr clock)	1 1/24/2020 9:39-10:52	2 1/24/2020 11:19-12:33	3 1/24/2020 12:57-14:08	Three Test Average
Particulate Matter				
Sampled volume (dscf)	34.6	34.5	35.5	34.9
Filterable catch (mg)	12.8	6.79	10.3	9.97
Condensable catch (mg)	20.9	19.5	20.2	20.2
Total catch (mg)	33.7	26.3	30.5	30.2
PM10 emissions (lb/hr)	0.52	0.40	0.47	0.46
Permitted emissions (lb/hr)	-	-	-	*1.2*
PM10 emissions (g/bhp*hr)	0.10	0.08	0.09	0.09
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.24*
Formaldehyde				
HCOH conc. (ppmv)	88.4	88.0	80.8	85.7
HCOH emissions (lb/hr)	1.90	1.85	1.75	1.83
Permitted emissions (lb/hr)	-	-	-	*2.07*
Sulfur Dioxide				
SO_2 conc. (ppmv)	28.1	28.0	28.7	28.3
SO_2 emissions (lb/hr)	1.15	1.12	1.18	1.15
Permitted emissions (lb/hr)	-	-	-	*1.57*
Visible Emissions				
Highest 6-minute average (%)	0.0	0.0	0.0	0.0
Permitted emissions (%)	-	-	-	*10%*

1. VOC measured as nonmethane hydrocarbons.

Table 6.7 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 4 (EU-ICENGINE4)

Test No. Test date Test period (24-hr clock)	1 1/27/2020 9:21-10:38	2 1/27/2020 11:03-12:13	3 1/27/2020 12:37-13:46	Three Test Average
Fuel flowrate (scfm)	537	538	536	537
Generator output (kW)	1,628	1,621	1,630	1,626
Engine output (bhp)	2,274	2,264	2,277	2,272
LFG methane content (%)	52.2	52.3	52.3	52.3
LFG heat content (Btu/scf)	475	476	476	476
Inlet pressure (psi)	46.4	46.4	46.5	46.4
Air / fuel ratio	7.7	7.7	7.7	7.7
<u>Exhaust Gas Composition</u>				
CO_2 content (% vol)	11.7	11.7	11.7	11.7
O_2 content (% vol)	8.39	8.41	8.40	8.40
Moisture (% vol)	11.4	10.8	11.5	11.2
Exhaust gas temperature (^oF)	953	953	953	953
Exhaust gas flowrate (dscfm)	4,117	4,162	4,085	4,121
Exhaust gas flowrate (scfm)	4,647	4,665	4,614	4,642
<u>Nitrogen Oxides</u>				
NO_X conc. (ppmvd)	68.5	67.9	67.9	68.1
NO_X emissions (lb/hr)	2.02	2.03	1.99	2.01
Permitted emissions (lb/hr)	-	-	-	*3.0*
NO_X emissions (g/bhp*hr)	0.40	0.41	0.40	0.40
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.6*
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	604	603	605	604
CO emissions (lb/hr)	10.9	11.0	10.8	10.9
Permitted emissions (lb/hr)	-	-	-	*16.3*
CO emissions (g/bhp*hr)	2.16	2.20	2.15	2.17
*Permitted emissions (g/bhp*hr)*	-	-	-	*3.3*
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv as C_3)[1]	16.7	16.9	16.8	16.8
VOC emissions (lb/hr)	0.53	0.54	0.53	0.54
Permitted emissions (lb/hr)	-	-	-	*1.0*
VOC emissions (g/bhp*hr)	0.11	0.11	0.11	0.11

Table 6.7 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 4 (EU-ICENGINE4) [Continued]

Test No. Test date Test period (24-hr clock)	1 1/27/2020 9:21-10:38	2 1/27/2020 11:03-12:13	3 1/27/2020 12:37-13:46	Three Test Average
Particulate Matter				
Sampled volume (dscf)	34.1	34.8	34.4	34.4
Filterable catch (mg)	24.6	18.0	9.24	17.3
Condensable catch (mg)	17.9	20.7	28.1	22.2
Total catch (mg)	42.5	38.7	37.3	39.5
PM10 emissions (lb/hr)	0.66	0.60	0.58	0.61
Permitted emissions (lb/hr)	-	-	-	*1.2*
PM10 emissions (g/bhp*hr)	0.13	0.12	0.12	0.12
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.24*
Formaldehyde				
HCOH conc. (ppmv)	82.2	70.7	82.8	78.5
HCOH emissions (lb/hr)	1.79	1.54	1.79	1.71
Permitted emissions (lb/hr)	-	-	-	*2.07*
Sulfur Dioxide				
SO_2 conc. (ppmv)	32.7	32.6	32.6	32.7
SO_2 emissions (lb/hr)	1.34	1.36	1.33	1.34
Permitted emissions (lb/hr)	-	-	-	*1.57*
Visible Emissions				
Highest 6-minute average (%)	0.0	0.0	0.0	0.0
Permitted emissions (%)	-	-	-	*10%*

1. VOC measured as nonmethane hydrocarbons.

Table 6.8 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 5 (EU-ICENGINE5)

Test No. Test date Test period (24-hr clock)	1 1/22/2020 11:56-13:14	2 1/22/2020 13:52-15:04	3 1/22/2020 15:38-16:51	Three Test Average
Fuel flowrate (scfm)	548	542	552	547
Generator output (kW)	1,623	1,623	1,635	1,627
Engine output (bhp)	2,267	2,267	2,284	2,273
LFG methane content (%)	52.3	52.5	52.4	52.4
LFG heat content (Btu/scf)	476	478	477	477
Inlet pressure (psi)	47.8	48.0	48.0	47.9
Air / fuel ratio	7.6	7.7	7.6	7.6
Exhaust Gas Composition				
CO_2 content (% vol)	11.7	11.7	11.8	11.7
O_2 content (% vol)	8.40	8.34	8.32	8.35
Moisture (% vol)	11.5	11.7	10.9	11.4
Exhaust gas temperature (^oF)	946	946	947	946
Exhaust gas flowrate (dscfm)	4,082	4,006	3,872	3,987
Exhaust gas flowrate (scfm)	4,613	4,538	4,344	4,498
Nitrogen Oxides				
NO_X conc. (ppmvd)	72.5	71.6	70.9	71.7
NO_X emissions (lb/hr)	2.12	2.06	1.97	2.05
Permitted emissions (lb/hr)	-	-	-	*3.0*
NO_X emissions (g/bhp*hr)	0.42	0.41	0.39	0.41
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.6*
Carbon Monoxide				
CO conc. (ppmvd)	646	654	657	652
CO emissions (lb/hr)	11.5	11.4	11.1	11.4
Permitted emissions (lb/hr)	-	-	-	*16.3*
CO emissions (g/bhp*hr)	2.30	2.29	2.21	2.27
*Permitted emissions (g/bhp*hr)*	-	-	-	*3.3*
Volatile Organic Compounds				
VOC conc. (ppmv as C_3)[1]	16.4	16.8	16.9	16.7
VOC emissions (lb/hr)	0.52	0.52	0.50	0.52
Permitted emissions (lb/hr)	-	-	-	*1.0*
VOC emissions (g/bhp*hr)	0.10	0.10	0.10	0.10

Table 6.8 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 5 (EU-ICENGINE5) [Continued]

Test No. Test date Test period (24-hr clock)	1 1/22/2020 11:56-13:14	2 1/22/2020 13:52-15:04	3 1/22/2020 15:38-16:51	Three Test Average
Particulate Matter				
Sampled volume (dscf)	34.1	33.8	32.5	33.5
Filterable catch (mg)	7.23	22.3	33.7	21.0
Condensable catch (mg)	16.8	15.4	16.3	16.2
Total catch (mg)	24.0	37.7	50.0	37.2
PM10 emissions (lb/hr)	0.36	0.57	0.76	0.56
Permitted emissions (lb/hr)	-	-	-	*1.2*
PM10 emissions (g/bhp*hr)	0.07	0.11	0.15	0.11
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.24*
Formaldehyde				
HCOH conc. (ppmv)	79.8	74.8	80.1	78.2
HCOH emissions (lb/hr)	1.72	1.59	1.63	1.65
Permitted emissions (lb/hr)	-	-	-	*2.07*
Sulfur Dioxide				
SO_2 conc. (ppmv)	30.2	28.1	30.7	29.6
SO_2 emissions (lb/hr)	1.23	1.12	1.19	1.18
Permitted emissions (lb/hr)	-	-	-	*1.57*
Visible Emissions				
Highest 6-minute average (%)	0.0	0.0	0.0	0.0
Permitted emissions (%)	-	-	-	*10%*

1. VOC measured as nonmethane hydrocarbons.

Table 6.9 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 6 (EU-ICENGINE6)

Test No. Test date Test period (24-hr clock)	1 1/21/2020 16:10-17:27	2 1/22/2020 8:06-9:22	3 1/22/2020 9:51-11:06	Three Test Average
Fuel flowrate (scfm)	536	535	539	536
Generator output (kW)	1,636	1,632	1,641	1,637
Engine output (bhp)	2,286	2,280	2,293	2,286
LFG methane content (%)	52.4	52.2	52.4	52.3
LFG heat content (Btu/scf)	477	475	477	476
Inlet pressure (psi)	45.9	45.8	46.2	46.0
Air / fuel ratio	7.7	7.8	7.8	7.8
Exhaust Gas Composition				
CO_2 content (% vol)	11.7	11.7	11.6	11.7
O_2 content (% vol)	8.40	8.41	8.45	8.42
Moisture (% vol)	10.8	10.6	10.9	10.8
Exhaust gas temperature (^oF)	952	950	950	951
Exhaust gas flowrate (dscfm)	4,155	3,960	4,000	4,038
Exhaust gas flowrate (scfm)	4,657	4,432	4,489	4,526
Nitrogen Oxides				
NO_X conc. (ppmvd)	70.4	70.5	69.8	70.2
NO_X emissions (lb/hr)	2.10	2.00	2.00	2.03
Permitted emissions (lb/hr)	-	-	-	*3.0*
NO_X emissions (g/bhp*hr)	0.42	0.40	0.40	0.40
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.6*
Carbon Monoxide				
CO conc. (ppmvd)	550	554	555	553
CO emissions (lb/hr)	10.0	9.59	9.68	9.75
Permitted emissions (lb/hr)	-	-	-	*16.3*
CO emissions (g/bhp*hr)	1.98	1.91	1.92	1.93
*Permitted emissions (g/bhp*hr)*	-	-	-	*3.3*
Volatile Organic Compounds				
VOC conc. (ppmv as C_3)[1]	14.7	13.6	13.7	14.0
VOC emissions (lb/hr)	0.47	0.41	0.42	0.44
Permitted emissions (lb/hr)	-	-	-	*1.0*
VOC emissions (g/bhp*hr)	0.09	0.08	0.08	0.09

Table 6.9 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 6 (EU-ICENGINE6) [Continued]

Test No. Test date Test period (24-hr clock)	1 1/21/2020 16:10-17:27	2 1/22/2020 8:06-9:22	3 1/22/2020 9:51-11:06	Three Test Average
Particulate Matter				
Sampled volume (dscf)	34.9	33.0	33.8	33.9
Filterable catch (mg)	11.7	16.3	21.2	16.4
Condensable catch (mg)	19.6	11.1	13.5	14.7
Total catch (mg)	31.3	27.4	34.7	31.1
PM10 emissions (lb/hr)	0.47	0.41	0.52	0.47
Permitted emissions (lb/hr)	-	-	-	*1.2*
PM10 emissions (g/bhp*hr)	0.09	0.08	0.10	0.09
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.24*
Formaldehyde				
HCOH conc. (ppmv)	69.6	69.9	71.3	70.3
HCOH emissions (lb/hr)	1.52	1.45	1.50	1.49
Permitted emissions (lb/hr)	-	-	-	*2.07*
Sulfur Dioxide				
SO_2 conc. (ppmv)	32.2	27.9	28.1	29.4
SO_2 emissions (lb/hr)	1.34	1.10	1.12	1.19
Permitted emissions (lb/hr)	-	-	-	*1.57*
Visible Emissions				
Highest 6-minute average (%)	0.0	0.0	0.0	0.0
Permitted emissions (%)	-	-	-	*10%*

1. VOC measured as nonmethane hydrocarbons.

Table 6.10 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 7 (EU-ICENGINE7)

Test No. Test date Test period (24-hr clock)	1 1/20/2020 11:37-13:01	2 1/20/2020 14:04-15:29	3 1/20/2020 16:09-17:23	Three Test Average
Fuel flowrate (scfm)	562	556	552	557
Generator output (kW)	1,643	1,643	1,642	1,643
Engine output (bhp)	2,295	2,295	2,294	2,295
LFG methane content (%)	51.1	51.5	51.5	51.4
LFG heat content (Btu/scf)	465	469	469	468
Inlet pressure (psi)	47.2	46.8	46.7	46.9
Air / fuel ratio	7.4	7.4	7.5	7.4
<u>Exhaust Gas Composition</u>				
CO_2 content (% vol)	11.9	11.8	11.7	11.8
O_2 content (% vol)	8.20	8.35	8.40	8.32
Moisture (% vol)	10.3	10.8	10.2	10.4
Exhaust gas temperature (^oF)	953	954	952	953
Exhaust gas flowrate (dscfm)	4,458	4,230	4,513	4,400
Exhaust gas flowrate (scfm)	4,969	4,742	5,026	4,912
<u>Nitrogen Oxides</u>				
NO_X conc. (ppmvd)	67.9	65.7	65.3	66.3
NO_X emissions (lb/hr)	2.17	1.99	2.11	2.09
Permitted emissions (lb/hr)	-	-	-	*3.0*
NO_X emissions (g/bhp*hr)	0.43	0.39	0.42	0.41
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.6*
<u>Carbon Monoxide</u>				
CO conc. (ppmvd)	561	561	558	560
CO emissions (lb/hr)	10.9	10.4	11.0	10.8
Permitted emissions (lb/hr)	-	-	-	*16.3*
CO emissions (g/bhp*hr)	2.16	2.05	2.17	2.13
*Permitted emissions (g/bhp*hr)*	-	-	-	*3.3*
<u>Volatile Organic Compounds</u>				
VOC conc. (ppmv as C_3)[1]	15.5	15.6	15.6	15.6
VOC emissions (lb/hr)	0.53	0.51	0.54	0.52
Permitted emissions (lb/hr)	-	-	-	*1.0*
VOC emissions (g/bhp*hr)	0.10	0.10	0.11	0.10

Table 6.10 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 7 (EU-ICENGINE7) [Continued]

Test No. Test date Test period (24-hr clock)	1 1/20/2020 11:37-13:01	2 1/20/2020 14:04-15:29	3 1/20/2020 16:09-17:23	Three Test Average
Particulate Matter				
Sampled volume (dscf)	36.9	34.7	36.5	36.0
Filterable catch (mg)	20.3	15.6	13.5	16.5
Condensable catch (mg)	8.48	15.0	13.2	12.2
Total PM/PM10 catch (mg)	28.8	30.6	26.7	28.7
PM10 emissions (lb/hr)	0.43	0.46	0.41	0.44
Permitted emissions (lb/hr)	-	-	-	*1.2*
PM10 emissions (g/bhp*hr)	0.09	0.09	0.08	0.09
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.24*
Formaldehyde				
HCOH conc. (ppmv)	75.5	74.8	74.5	74.9
HCOH emissions (lb/hr)	1.76	1.66	1.75	1.72
Permitted emissions (lb/hr)	-	-	-	*2.07*
Sulfur Dioxide				
SO_2 conc. (ppmv)	31.2	31.8	31.0	31.4
SO_2 emissions (lb/hr)	1.39	1.34	1.40	1.38
Permitted emissions (lb/hr)	-	-	-	*1.57*
Visible Emissions				
Highest 6-minute average (%)	0.0	0.0	0.0	0.0
Permitted emissions (%)	-	-	-	*10%*

1. VOC measured as nonmethane hydrocarbons.

Table 6.11 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 8 (EU-ICENGINE8)

Test No.	1	2	3	Three
Test date	1/21/2020	1/21/2020	1/21/2020	Test
Test period (24-hr clock)	9:45-11:00	11:36-12:56	13:36-14:55	Average
Fuel flowrate (scfm)	547	545	544	545
Generator output (kW)	1,626	1,630	1,627	1,628
Engine output (bhp)	2,271	2,277	2,273	2,274
LFG methane content (%)	52.2	52.5	52.8	52.5
LFG heat content (Btu/scf)	475	478	480	478
Inlet pressure (psi)	46.6	46.7	47.3	46.9
Air / fuel ratio	7.3	7.4	7.5	7.4
Exhaust Gas Composition				
CO_2 content (% vol)	11.9	11.8	11.7	11.8
O_2 content (% vol)	8.18	8.27	8.45	8.30
Moisture (% vol)	10.7	11.0	10.7	10.8
Exhaust gas temperature (^oF)	953	952	949	951
Exhaust gas flowrate (dscfm)	4,144	3,983	4,101	4,076
Exhaust gas flowrate (scfm)	4,643	4,477	4,593	4,571
Nitrogen Oxides				
NO_X conc. (ppmvd)	74.2	71.6	66.3	70.7
NO_X emissions (lb/hr)	2.21	2.05	1.95	2.07
Permitted emissions (lb/hr)	-	-	-	*3.0*
NO_X emissions (g/bhp*hr)	0.44	0.41	0.39	0.41
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.6*
Carbon Monoxide				
CO conc. (ppmvd)	647	643	625	638
CO emissions (lb/hr)	11.7	11.2	11.2	11.4
Permitted emissions (lb/hr)	-	-	-	*16.3*
CO emissions (g/bhp*hr)	2.34	2.23	2.23	2.26
*Permitted emissions (g/bhp*hr)*	-	-	-	*3.3*
Volatile Organic Compounds				
VOC conc. (ppmv as C_3)[1]	20.5	20.7	21.3	20.8
VOC emissions (lb/hr)	0.65	0.64	0.67	0.65
Permitted emissions (lb/hr)	-	-	-	*1.0*
VOC emissions (g/bhp*hr)	0.13	0.13	0.13	0.13

Table 6.11 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 8 (EU-ICENGINE8) [Continued]

Test No. Test date Test period (24-hr clock)	1 1/21/2020 9:45-11:00	2 1/21/2020 11:36-12:56	3 1/21/2020 13:36-14:55	Three Test Average
Particulate Matter				
Sampled volume (dscf)	34.8	33.5	34.0	34.1
Filterable catch (mg)	18.9	15.4	15.8	16.7
Condensable catch (mg)	15.6	20.4	16.1	17.4
Total catch (mg)	34.5	35.8	31.9	34.1
PM10 emissions (lb/hr)	0.53	0.54	0.49	0.52
Permitted emissions (lb/hr)	-	-	-	*1.2*
PM10 emissions (g/bhp*hr)	0.10	0.11	0.10	0.10
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.24*
Formaldehyde				
HCOH conc. (ppmv)	86.3	86.2	89.7	87.4
HCOH emissions (lb/hr)	1.88	1.81	1.93	1.87
Permitted emissions (lb/hr)	-	-	-	*2.07*
Sulfur Dioxide				
SO_2 conc. (ppmv)	28.9	32.0	31.1	30.7
SO_2 emissions (lb/hr)	1.20	1.27	1.27	1.25
Permitted emissions (lb/hr)	-	-	-	*1.57*
Visible Emissions				
Highest 6-minute average (%)	0.0	0.0	0.0	0.0
Permitted emissions (%)	-	-	-	*10%*

1. VOC measured as nonmethane hydrocarbons.

Table 6.12 Summary of LFG fuel H_2S Measurements (Draeger Tubes)

Test No.	1/14/2020	1/20/2020	1/21/2020	1/22/2020	1/23/2020	1/24/2020	1/27/2020
H_2S (ppm)	90	170	190	180	85	105	100

1. Estimated from observation of Draeger tubes. Photos are provided in Appendix 7.