

1.0 Introduction

Alliance Source Testing, LLC (AST) was retained by Sumpter Energy Associates, LLC (SEA) to conduct compliance testing at the Carleton Farms Landfill (CFL) located in Wayne County, New Boston, Michigan. The facility operates under Michigan Department of Environment, Great Lakes, and Energy-Air Quality Division (EGLE-AQD) Renewable Operating Permit (ROP) No. MI-ROP-N5986-2015; Facility SRN N5986. The site operates eight (8) Caterpillar G3615 engines in Phase I and six (6) Caterpillar G3615 engines in Phase II. The worst case carbon monoxide (CO) and nitrogen oxides (NOx) emitting engine for each Phase was determined based on preliminary 15 minute test runs on all engines. Based on the preliminary results, compliance testing was conducted on two (2) engines – EUICENGINE_8, Phase I and EUICENGINE_9, Phase II.

Testing consisted of three (3) 60-minute test runs for each source to determine the emission rates and factors of NOx, CO and hydrogen chloride (HCl). Performance testing was conducted while the engines were operating at the highest achievable load at current site conditions. The Test Report Summary (TRS) provides the results from the compliance testing, including the three (3) run average, with comparisons to the applicable limits. Any difference between the summary results listed in the TRS and the detailed results contained in the appendices is due to rounding for presentation. In addition to the emissions testing, the treated landfill gas (LFG) was analyzed for sulfur content.

1.1 Facility and Process Description

SEA operates two (2) landfill gas (LFG) to energy facilities at the CFL in New Boston, Wayne County, Michigan. The two (2) Sumpter Energy facilities are referred to as SEA Phase I and Phase II. The SEA Phase I facility consists of eight (8) Caterpillar Model No. G3516 LFG-fueled reciprocating internal combustion engines (RICE) Emission Unit IDs: EUICENGINE_1 through EUICENGINE_8 (Flexible Group ID: FGICENGINES1-8). The SEA Phase II facility consists of six (6) Caterpillar Model No. G3516 LFG-fueled RICE Emission Unit IDs: EUICENGINE_9 through EUICENGINE_14 (Flexible Group ID: FGICENGINES9-14).

Special Condition No. V.1 of the ROP No. MI-ROP-N5986-2015 requires that performance tests be completed on the worst cast (i.e. highest mass emissions) carbon monoxide (CO) and nitrogen oxides (NOx) emitting IC engine from both FGICENGINES1-8 (Phase I) and FGICENGINES9-14 (Phase II) once during the term of the RO Permit, prior to July 22, 2020. In addition, the HCl emission rates associated with both engines must also be verified.

1.2 Project Team

Personnel involved in this project are identified in the following table.

**Table 1-1
Project Team**

Facility Personnel	Emily Zambuto – Aria Energy
Regulatory Personnel	Regina Angellotti – EGLE
AST Personnel	Adam Robinson Colin Brooks Ethan Sperfslage

1.3 Test Protocol and Notification

Testing was conducted in accordance with the test protocol submitted to the EGLE-AQD on April 29, 2020 by Aria.

Testing Methodology

2.0 Testing Methodology

The emissions testing program was conducted in accordance with the U.S. EPA Reference Test Methods listed in Table 2-1. Method descriptions are provided below while quality assurance/quality control data is provided in Appendix D.

**Table 2-1
Source Testing Methodology**

Parameter	U.S. EPA Reference Test Methods	Notes/Remarks
Volumetric Flow Rate	1 & 2	Full Velocity Traverses
Oxygen/Carbon Dioxide	3A	Instrumental Analysis
Moisture Content	4	Volumetric / Gravimetric Analysis
Nitrogen Oxides	7E	Instrumental Analysis
Carbon Monoxide	10	Instrumental Analysis
Hydrogen Chloride	26A	Isokinetic Sampling
Sulfur Content	ASTM D-5504	Fuel Gas Sampling
Gas Dilution System Certification	205	--

2.1 U.S. EPA Reference Test Methods 1 & 2 – Volumetric Flow Rate

The sampling location and number of traverse (sampling) points were selected in accordance with U.S. EPA Reference Test Method 1. To determine the minimum number of traverse points, the upstream and downstream distances were equated into equivalent diameters and compared to Figure 1-2 in U.S. EPA Reference Test Method 1.

Full velocity traverses were conducted in accordance with U.S. EPA Reference Test Method 2 to determine the average stack gas velocity pressure, static pressure and temperature. The velocity and static pressure measurement system consisted of a pitot tube and inclined manometer. The stack gas temperature was measured with a K-type thermocouple and pyrometer.

2.2 U.S. EPA Reference Test Method 3A – Oxygen/Carbon Dioxide

The oxygen (O₂) and carbon dioxide (CO₂) testing was conducted in accordance with U.S. EPA Reference Test Method 3A. Data was collected online and reported in one-minute averages. The sampling system consisted of a stainless-steel probe, heated Teflon sample line(s), gas conditioning system and the identified gas analyzer. The gas conditioning system was a non-contact condenser used to remove moisture from the stack gas. The quality control measures are described in Section 2.9.

2.3 U.S. EPA Reference Test Method 4 – Moisture Content

The stack gas moisture content was determined in accordance with U.S. EPA Reference Test Method 4. The gas conditioning train consisted of a series of chilled impingers. The impingers were pre and post-measured to determine the amount of moisture condensed during each test run.

2.4 U.S. EPA Reference Test Method 7E – Nitrogen Oxides

The nitrogen oxides (NO_x) testing was conducted in accordance with U.S. EPA Reference Test Method 7E. Data was collected online and reported in one-minute averages. The sampling system consisted of a stainless steel probe, heated Teflon sample line(s), gas conditioning system and the identified gas analyzer. The gas conditioning system was a non-contact condenser used to remove moisture from the stack gas. The quality control measures are described in Section 2.9.

2.5 U.S. EPA Reference Test Method 10 – Carbon Monoxide

The carbon monoxide (CO) testing was conducted in accordance with U.S. EPA Reference Test Method 10. Data was collected online and reported in one-minute averages. The sampling system consisted of a stainless steel probe, heated Teflon sample line(s), gas conditioning system, and the identified gas analyzer. The gas conditioning system was a non-contact condenser used to remove moisture from the gas. The quality control measures are described in Section 2.9.

2.6 U.S. EPA Reference Test Method 26 – Hydrogen Chloride

The hydrogen chloride (HCl) testing was conducted in accordance with U.S. EPA Reference Test Method 26A. The complete sampling system consisted of a heated glass-lined probe, heated Teflon filter, gas conditioning train, pump and calibrated dry gas meter. The gas conditioning train consisted of four (4) chilled impingers. The first and second impingers contained 100 mL of 0.1 N H₂SO₄, the third was initially empty and the fourth contained 200-300 grams of silica gel. The probe liner and filter heating systems were maintained at 248-273°F, and the impinger temperature was maintained at 20°C (68°F) or less throughout the testing.

Following the completion of each test run, the sampling train was leak checked at a vacuum pressure greater than or equal to the highest vacuum pressure observed during the run and the contents of the impingers were measured for moisture gain. The absorbing solution (0.1 N H₂SO₄) from the first and second impingers was placed into sample container 3. The back-half of the filter holder, first, second and third impingers and all glassware leading to the outlet of the third impinger were rinsed with de-ionized (DI) water. These rinses were also placed in container 3. All containers were sealed, labeled and liquid levels marked for transport to the identified laboratory for analysis.

2.7 ASTM Method D-5504 – Sulfur Content

The sulfur content of the LFG gas was determined in accordance with ASTM Method D-5504. The LFG gas was withdrawn through Teflon sample line and collected in a summa canister. All samples were sealed and labeled for transport to the identified laboratory for analysis.

2.8 U.S. EPA Reference Test Method 205 – Gas Dilution System Certification

A calibration gas dilution system field check was conducted in accordance with U.S. EPA Reference Method 205. Multiple dilution rates and total gas flow rates were utilized to force the dilution system to perform two dilutions on each mass flow controller. The diluted calibration gases were sent directly to the analyzer, and the analyzer response recorded in an electronic field data sheet. The analyzer response agreed within 2% of the actual diluted gas concentration. A second Protocol 1 calibration gas, with a cylinder concentration within 10% of one of the gas divider settings described above, was introduced directly to the analyzer, and the analyzer response recorded in an electronic field data sheet. The cylinder concentration and the analyzer response agreed within 2%. These steps were repeated three (3) times. Copies of the Method 205 data can be found in the Quality Assurance/Quality Control Appendix.

2.9 Quality Assurance/Quality Control – U.S. EPA Reference Methods 3A, 7E and 10

Cylinder calibration gases used met EPA Protocol 1 (+/- 2%) standards. Copies of all calibration gas certificates can be found in the Quality Assurance/Quality Control Appendix.

Low Level gas was introduced directly to the analyzer. After adjusting the analyzer to the Low Level gas concentration and once the analyzer reading was stable, the analyzer value was recorded. This process was repeated for the Mid Level gas. Next, High Level gas was introduced directly to the analyzer, and the response recorded when it was stable. All values were within 2.0 percent of the Calibration Span or 0.5 ppmv absolute difference.

High or Mid Level gas (whichever was closer to the stack gas concentration) was introduced at the probe and the time required for the analyzer reading to reach 95 percent or 0.5 ppm (whichever was less restrictive) of the gas concentration was recorded. The analyzer reading was observed until it reached a stable value, and this value was recorded. Next, Low Level gas was introduced at the probe and the time required for the analyzer reading to decrease to a value within 5.0 percent or 0.5 ppm (whichever was less restrictive) was recorded. If the Low Level gas was zero gas, the response was 0.5 ppm or 5.0 percent of the upscale gas concentration (whichever was less restrictive). The analyzer reading was observed until it reached a stable value and this value was recorded. The measurement system response time and initial system bias were determined from these data. The System Bias was within 5.0 percent of the Calibration Span or 0.5 ppmv absolute difference

High or Mid Level gas (whichever was closer to the stack gas concentration) was introduced at the probe. After the analyzer response was stable, the value was recorded. Next, Low Level gas was introduced at the probe, and the analyzer value recorded once it reached a stable response. The System Bias was within 5.0 percent of the Calibration Span or 0.5 ppmv absolute difference or the data was invalidated and the Calibration Error Test and System Bias were repeated.

Drift between pre- and post-run System Bias was within 0.5 ppmv absolute difference or the Calibration Error Test and System Bias were repeated.

To determine the number of sampling points, a gas stratification check was conducted prior to initiating testing. The pollutant concentrations were measured at three points (16.7, 50.0 and 83.3 percent of the measurement line). Each traverse point was sampled for a minimum of twice the system response time. The pollutant concentration at each traverse point did not differ more than 5% or 0.5 ppm (whichever was less restrictive) of the average pollutant concentration. Therefore, single point sampling was conducted during the test runs. Copies of stratification check data can be found in the Quality Assurance/Quality Control Appendix.

An NO₂ – NO converter check was performed on the analyzer prior to initiating testing. An approximately 50 ppm nitrogen dioxide cylinder gas was introduced directly to the NO_x analyzer and the instrument response was recorded in an electronic data sheet. The instrument response was within +/- 10 percent of the cylinder concentration.

A Data Acquisition System with battery backup was used to record the instrument response in one (1) minute averages. The data was continuously stored as a *.CSV file in Excel format on the hard drive of a computer. At the completion of testing, the data was also saved to the AST server. All data was reviewed by the Field Team Leader before leaving the facility. Once arriving at AST's office, all written and electronic data was relinquished to the report coordinator and then a final review was performed by the Project Manager.

Appendix A

Location Aria Energy - New Boston
Source Phase 1, Unit 8
Project No. 2020-1336
Run No. 1
Parameter(s) HCl

Meter Pressure (Pm), in. Hg

$$Pm = Pb + \frac{\Delta H}{13.6}$$

where,

Pb $\frac{29.99}{}$ = barometric pressure, in. Hg
 ΔH $\frac{1.500}{}$ = pressure differential of orifice, in H₂O
 Pm $\frac{30.10}{}$ = in. Hg

Absolute Stack Gas Pressure (Ps), in. Hg

$$Ps = Pb + \frac{Pg}{13.6}$$

where,

Pb $\frac{29.99}{}$ = barometric pressure, in. Hg
 Pg $\frac{1.00}{}$ = static pressure, in. H₂O
 Ps $\frac{30.06}{}$ = in. Hg

Standard Meter Volume (Vmstd), dscf

$$Vmstd = \frac{17.647 \times Vm \times Pm}{Tm}$$

where,

Y $\frac{0.991}{}$ = meter correction factor
 Vm $\frac{40.260}{}$ = meter volume, cf
 Pm $\frac{30.10}{}$ = absolute meter pressure, in. Hg
 Tm $\frac{538.2}{}$ = absolute meter temperature, °R
 $Vmstd$ $\frac{39.374}{}$ = dscf

Standard Wet Volume (Vwstd), scf

$$Vwstd = 0.04707 \times Vlc$$

where,

Vlc $\frac{141.1}{}$ = volume of H₂O collected, ml
 $Vwstd$ $\frac{6.653}{}$ = scf

Moisture Fraction (BWSsat), dimensionless (theoretical at saturated conditions)

$$BWSsat = \frac{10^{6.37 - \left(\frac{2,827}{Ts + 365}\right)}}{Ps}$$

where,

Ts $\frac{783.8}{}$ = stack temperature, °F
 Ps $\frac{30.1}{}$ = absolute stack gas pressure, in. Hg
 $BWSsat$ $\frac{269.6}{}$ = dimensionless

Moisture Fraction (BWS), dimensionless

$$BWS = \frac{Vwstd}{(Vwstd + Vmstd)}$$

where,

$Vwstd$ $\frac{6.653}{}$ = standard wet volume, scf
 $Vmstd$ $\frac{39.374}{}$ = standard meter volume, dscf
 BWS $\frac{0.145}{}$ = dimensionless

Location Aria Energy - New Boston
Source Phase 1, Unit 8
Project No. 2020-1336
Run No. 1
Parameter(s) HCl

Moisture Fraction (BWS), dimensionless

$$BWS = BWSmsd \text{ unless } BWSsat < BWSmsd$$

where,

$$\begin{array}{l}
 BWSsat \quad \frac{269.606}{\quad} = \text{moisture fraction (theoretical at saturated conditions)} \\
 BWSmsd \quad \frac{0.145}{\quad} = \text{moisture fraction (measured)} \\
 BWS \quad \frac{0.145}{\quad}
 \end{array}$$

Molecular Weight (DRY) (Md), lb/lb-mole

$$Md = (0.44 \times \% CO_2) + (0.32 \times \% O_2) + (0.28 (100 - \% CO_2 - \% O_2))$$

where,

$$\begin{array}{l}
 CO_2 \quad \frac{13.8}{\quad} = \text{carbon dioxide concentration, \%} \\
 O_2 \quad \frac{6.1}{\quad} = \text{oxygen concentration, \%} \\
 Md \quad \frac{30.45}{\quad} = \text{lb/lb mol}
 \end{array}$$

Molecular Weight (WET) (Ms), lb/lb-mole

$$Ms = Md (1 - BWS) + 18 (BWS)$$

where,

$$\begin{array}{l}
 Md \quad \frac{30.45}{\quad} = \text{molecular weight (DRY), lb/lb mol} \\
 BWS \quad \frac{0.145}{\quad} = \text{moisture fraction, dimensionless} \\
 Ms \quad \frac{28.65}{\quad} = \text{lb/lb mol}
 \end{array}$$

Average Velocity (Vs), ft/sec

$$Vs = 85.49 \times Cp \times (\Delta P^{1/2})_{avg} \times \sqrt{\frac{Ts}{Ps \times Ms}}$$

where,

$$\begin{array}{l}
 Cp \quad \frac{0.84}{\quad} = \text{pitot tube coefficient} \\
 \Delta P^{1/2} \quad \frac{1.534}{\quad} = \text{average pre/post test velocity head of stack gas, (in. H}_2\text{O)}^{1/2} \\
 Ts \quad \frac{1243.8}{\quad} = \text{average pre/post test absolute stack temperature, } ^\circ\text{R} \\
 Ps \quad \frac{30.06}{\quad} = \text{absolute stack gas pressure, in. Hg} \\
 Ms \quad \frac{28.65}{\quad} = \text{molecular weight of stack gas, lb/lb mol} \\
 Vs \quad \frac{132.4}{\quad} = \text{ft/sec}
 \end{array}$$

Average Stack Gas Flow at Stack Conditions (Qa), acfm

$$Qa = 60 \times Vs \times As$$

where,

$$\begin{array}{l}
 Vs \quad \frac{132.4}{\quad} = \text{stack gas velocity, ft/sec} \\
 As \quad \frac{0.79}{\quad} = \text{cross-sectional area of stack, ft}^2 \\
 Qa \quad \frac{6,240}{\quad} = \text{acfm}
 \end{array}$$

Location Aria Energy - New Boston
Source Phase 1, Unit 8
Project No. 2020-1336
Run No. 1
Parameter(s) HCl

Average Stack Gas Flow at Standard Conditions (Qs), dscfm

$$Q_{sd} = 17.647 \times Q_a \times (1 - BWS) \times \frac{P_s}{T_s}$$

where,

Q_a 6,240 = average stack gas flow at stack conditions, acfm
 BWS 0.145 = moisture fraction, dimensionless
 P_s 30.06 = absolute stack gas pressure, in. Hg
 T_s 1243.8 = average pre/post test absolute stack temperature, °R
 Q_s 2,277 = dscfm

Dry Gas Meter Calibration Check (Yqa), dimensionless

$$Y_{qa} = \frac{Y \cdot \left(\frac{\Theta}{V_m} \sqrt{\frac{0.0319 \times T_m \times 29}{\Delta H @ \times \left(P_b + \frac{\Delta H \text{ avg.}}{13.6} \right) \times M_d}} \sqrt{\Delta H \text{ avg.}} \right)}{Y} \times 100$$

where,

Y 0.991 = meter correction factor, dimensionless
 Θ 60 = run time, min.
 V_m 40.26 = total meter volume, def
 T_m 538.2 = absolute meter temperature, °R
 $\Delta H @$ 1.781 = orifice meter calibration coefficient, in. H₂O
 P_b 29.99 = barometric pressure, in. Hg
 $\Delta H \text{ avg}$ 1.500 = average pressure differential of orifice, in H₂O
 M_d 30.45 = molecular weight (DRY), lb/lb mol
 $(\Delta H)^{1/2}$ 1.225 = average squareroot pressure differential of orifice, (in. H₂O)^{1/2}
 Y_{qa} -1.7 = dimensionless

Hydrogen Chloride Concentration, ppmvd

$$C_{HCl} = \frac{M_{HCl} \times 24.04}{MW \times V_{mstd} \times 28.32}$$

$M(HCl)$ 13,159 = Hydrogen Chloride Mass, ug
 MW 36.5 = molecular weight, g/g mol
 V_{mstd} 39.374 = standard meter volume, dscf
 $C(HCl)$ 7.78 = ppmvd

Hydrogen Chloride Emission Rate, lb/hr

$$ER_{HCl} = \frac{M_{HCl} \times Q_s \times 60}{V_{mstd} \times 4.54 E + 08}$$

where,

$M(HCl)$ 13,159 = Hydrogen Chloride Mass, ug
 Q_s 2,277 = average stack gas flow at standard conditions, dscfm
 V_{mstd} 39.374 = standard meter volume, dscf
 $ER(HCl)$ 0.10 = lb/hr

Location Aria Energy - New Boston
 Source Phase 1, Unit 8
 Project No. 2020-1336
 Run No. 1
 Parameter(s) HCl

Hydrogen Chloride Emission Factor, lb/MMcf LFG

$$EF_{HCl} = \frac{ER_{HCl}}{FR}$$

where,

ER(HCl) 0.10 = Hydrogen Chloride Emission Rate, lb/hr
 FR 0.168 = LFG Rate, MMcf/hr
 EF(HCl) 0.60 = lb/MMscf LFG

Location: Aria Energy - New Boston

Source: Phase I, Unit 8

Project No.: 2020-1336

Run No. /Method: Run 1 / Method 10

CO - Outlet Concentration (C_{CO}), ppmvd

$$C_{CO} = (C_{obs} - C_0) \times \left(\frac{C_{MA}}{C_M - C_0} \right)$$

where,

C_{obs}	<u>652.8</u>	= average analyzer value during test, ppmvd
C_0	<u>0.4</u>	= average of pretest & posttest zero responses, ppmvd
C_{MA}	<u>600.0</u>	= actual concentration of calibration gas, ppmvd
C_M	<u>606.4</u>	= average of pretest & posttest calibration responses, ppmvd
C_{CO}	<u>645.9</u>	= CO Concentration, ppmvd

CO - Outlet Emission Rate (ER_{CO}), lb/hr

$$ER_{CO} = \frac{C_{CO} \times MW \times Q_s \times 60 \frac{min}{hr} \times 28.32 \frac{L}{ft^3}}{24.04 \frac{L}{g-mole} \times 1.0E06 \times 454 \frac{g}{lb}}$$

where,

C_{CO}	<u>645.9</u>	= CO - Outlet Concentration, ppmvd
MW	<u>28.01</u>	= CO molecular weight, g/g-mole
Q_s	<u>2,276</u>	= stack gas volumetric flow rate at standard conditions, dscfm
ER_{CO}	<u>6.4</u>	= lb/hr

Location: Aria Energy - New Boston

Source: Phase I, Unit 8

Project No.: 2020-1336

Run No. /Method: Run 1 / Method 7E

NOx - Outlet Concentration (C_{NOx}), ppmvd

$$C_{NOx} = (C_{obs} - C_0) \times \left(\frac{C_{MA}}{C_M - C_0} \right)$$

where,

C_{obs}	$\frac{130.5}{1.8}$	= average analyzer value during test, ppmvd
C_0	$\frac{1.8}{1.8}$	= average of pretest & posttest zero responses, ppmvd
C_{MA}	$\frac{125.0}{124.3}$	= actual concentration of calibration gas, ppmvd
C_M	$\frac{124.3}{124.3}$	= average of pretest & posttest calibration responses, ppmvd
C_{NOx}	$\frac{131.3}{131.3}$	= NOx Concentration, ppmvd

NOx - Outlet Emission Rate (ER_{NOx}), lb/hr

$$ER_{NOx} = \frac{C_{NOx} \times MW \times Qs \times 60 \frac{min}{hr} \times 28.32 \frac{L}{ft^3}}{24.04 \frac{L}{g-mole} \times 1.0E06 \times 454 \frac{g}{lb}}$$

where,

C_{NOx}	$\frac{131.3}{131.3}$	= NOx - Outlet Concentration, ppmvd
MW	$\frac{46.055}{46.055}$	= NOx molecular weight, g/g-mole
Qs	$\frac{2.276}{2.1}$	= stack gas volumetric flow rate at standard conditions, dscfm
ER_{NOx}	$\frac{2.1}{2.1}$	= lb/hr

Appendix B

Location Aria Energy - New Boston
Source Phase I, Unit 8
Project No. 2020-1336

Run Number		Run 1	Run 2	Run 3	Average
Date		6/30/20	6/30/20	6/30/20	--
Start Time		11:56	13:20	14:35	--
Stop Time		12:56	14:20	15:35	--
Engine Data					
Engine Manufacturer		Caterpillar			
Engine Model		G3516			
Engine Serial Number		4EK01591			
Engine Type		Compression Ignition			
Engine Hour Meter Reading	EMR	222,860			
Engine Brake Work, HP	EBW	1,122	1,125	1,122	1,123
Maximum Engine Brake Work, HP	MaxEBW	1,138	1,138	1,138	1,138
Engine Load, %	EL	99	99	99	99
Fuel Rate, scfh	F _R	2,795	2,805	2,755	2,785
Input Data - Outlet					
Volumetric Flow Rate (M1-4), dscfm	Q _s	2,276	2,264	2,241	2,260
Calculated Data - Outlet					
O ₂ Concentration, ppmvd	C _{O₂}	6.1	6.1	5.9	6.0
CO ₂ Concentration, ppmvd	C _{CO₂}	13.8	13.8	13.9	13.8
CO Concentration, ppmvd	C _{CO}	645.9	656.8	583.4	628.7
CO Emission Rate, lb/hr	ER _{CO}	6.4	6.5	5.7	6.2
NO _x Concentration, ppmvd	C _{NO_x}	131.3	145.5	190.7	155.8
NO _x Emission Rate, lb/hr	ER _{NO_x}	2.1	2.4	3.1	2.5

