1.0 Introduction

Alliance Source Testing, LLC (AST) was retained by Blue Water Renewables, LLC (BWR) to conduct compliance emissions testing at the Smiths Creek, Michigan facility. The facility operates under Michigan Department of Environment, Great Lakes, and Energy (EGLE) Permit No. MI-ROP-N6207-2018. Testing was conducted on two (2) landfill gas engines to demonstrate compliance with emission limits detailed in the facility's EGLE air permit and 40 CFR 60, Subpart JJJJ.

Compliance testing was conducted to determine the emission rates carbon monoxide (CO), nitrogen oxides (NOx) and non-methane volatile organic compounds (NMVOC). Testing consisted of three (3) 60-minute test runs for each source. 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.

1.1 Facility and Process Description

BWR operates a landfill gas-to-energy facility that uses landfill gas (LFG) collected from the Smiths Creek Landfill to generate electric power. The Facility is authorized under MI-ROP-N6207-2018 to operate two (2) landfill gas-fired 2,233 hp internal combustion (IC) engines (EU-ICENGINE1-BWR2 & EU-ICENGINE2-BWR2). LFG delivered to the engine is first routed to a treatment system that processes the collected gas for subsequent use. The pretreatment system includes de-watering and compression of the gas and filtering through a coalescing filter.

The Caterpillar G3520C engine is a four-stroke, lean-burn, reciprocating internal combustion engine fueled by treated LFG. The engine gensets have engine power ratings of 2,233 hp at 100% load, and generator power ratings of 1,600 kW.

Testing will be conducted while the units are operated at the maximum normal load of 1,600 kW (+/- 10%).

1.2 Project Team

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

Table 1-1
Project Team

Regulatory Personnel	Gina Angellotti
AST Personnel	Tyler Branca Samuel Hines

1.3 Test Protocol and Notification

Testing was conducted in accordance with the Site-Specific Test Plan submitted to EGLE by BWR.

b
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 C.

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	Gravimetric Analysis
Nitrogen Oxides	7E	Instrumental Analysis
Carbon Monoxide	10	Instrumental Analysis
Non-Methane Volatile Organic Compounds	ALT-096	Instrumental Analysis
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 1-1 (for isokinetic sampling) and/or Figure 1-2 (measuring velocity alone) 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

The oxygen (O_2) and carbon dioxide (CO_2) 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, 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. If an unheated Teflon sample line was used, then a portable non-contact condenser was placed in the system directly after the probe. Otherwise, a heated Teflon sample line was used. Sampling was conducted at three traverse points passing through the centroidal area of the duct (rake probe for strat). The quality control measures are described in Section 2.8.

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, 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. If an unheated Teflon sample line was used, then a portable non-contact condenser was placed in the system directly after the probe. Otherwise, a heated Teflon sample line was used. Sampling was conducted at three traverse points passing through the centroidal area of the duct (rake probe for strat). The quality control measures are described in Section 2.8.

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, 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. If an unheated Teflon sample line was used, then a portable non-contact condenser was placed in the system directly after the probe. Otherwise, a heated Teflon sample line was used. Sampling was conducted at three traverse points passing through the centroidal area of the duct (rake probe for strat). The quality control measures are described in Section 2.8.

2.6 U.S. EPA Alternative Test Method ALT-096 – Non-Methane Volatile Organic Compounds

The non-methane volatile organic compounds (NMVOC) testing was conducted in accordance with U.S. EPA Alternate Test Method ALT-096. EPA Method 25A is incorporated by reference. The sampling system consisted of a stainless steel probe, heated Teflon sample line(s) and the Thermo 55i analyzer. The quality control measures are described in Section 2.9.

2.7 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.

2.8 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.

If 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, then single point sampling was conducted during the test runs. If the pollutant concentration did not meet these specifications but differed less than 10% or 1.0 ppm from the average concentration, then three (3) point sampling was conducted (stacks less than 7.8 feet in diameter - 16.7, 50.0 and 83.3 percent of the measurement line; stacks greater than 7.8 feet in diameter – 0.4, 1.0, and 2.0 meters from the stack wall). If the pollutant concentration differed by more than 10% or 1.0 ppm from the average concentration, then sampling was conducted at a minimum of twelve (12) traverse points. Copies of stratification check data can be found in the Quality Assurance/Quality Control Appendix.

An NO_2 – 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 NOx 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 (Dutech Analog Signal Modules) 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.

2.9 Quality Assurance/Quality Control – U.S. EPA Reference Method ALT-096

EPA Protocol 1 Calibration Gases – Cylinder calibration gases used met EPA Protocol 1 (+/- 2%) standards. Copies of all calibration gas certificates are provided in the Quality Assurance/Quality Control Appendix.

Zero gas was introduced through the sampling system to the analyzer. After adjusting the analyzer to the Zero gas concentration and once the analyzer reading was stable, the analyzer value was recorded. This process was repeated for the High Level gas, and the time required for the analyzer reading to reach 95 percent of the gas concentration was recorded to determine the response time. Next, Mid and Low Level gases were introduced through the sampling system to the analyzer, and the response was recorded when it is stable. All values must be within +/- 5% of the calibration gas concentrations.

ALT-096: A separation efficiency check was performed using a certified (+/- 2%) blend of methane, ethane, acetylene, and propane in nitrogen. The recorded residual value must be within 5% of the predicted cylinder concentration.

Post Test Drift Checks – Mid Level gas were introduced through the sampling system. After the analyzer response was stable, the value was recorded. Next, Zero gas was introduced through the sampling system, and the analyzer value recorded once it reached a stable response. The Analyzer Drift must be less than 3 percent of the Calibration Span.

Data Collection – A Data Acquisition System with battery backup was used to record the instrument response (analog 0-10 volt signal) in one (1) minute averages. The data was continuously stored as a *.CSV file in Excel format on the hard drive of a desktop computer. At the completion of the emissions testing the data was also saved to disk.

Appendix A

Location: Blue Water Renewables, LLC - Blue Water Renewables - Smiths Creek, MI
Source: Eng 1
Project No.: 20AST-2022-0313
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} 658.7 = average analyzer value during test, ppmvd
C_o 1.6 = average of pretest & posttest zero responses, ppmvd
C_{MA} 800.0 = actual concentration of calibration gas, ppmvd
C_M 799.2 = average of pretest & posttest calibration responses, ppmvd
C_{CO} 659.0 = CO Concentration, ppmvd

CO - Outlet Concentration (C_{COc15}), ppmvd @ 15% O₂

$$C_{COc15} = C_{CO} \times \left(\frac{20.9 - 15}{20.9 - O_2} \right)$$

where,

C_{CO} 659.0 = CO - Outlet Concentration, ppmvd
C_{O_2} 8.3 = oxygen concentration, %
C_{COc15} 307.7 = ppmvd @15% O₂

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

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

where,

C_{CO} 659.0 = CO - Outlet Concentration, ppmvd
MW 28.01 = CO molecular weight, g/g-mole
Qs 4,584 = stack gas volumetric flow rate at standard conditions, dscfm
ER_{CO} 13.2 = lb/hr

CO - Outlet Emission Rate (ER_{COTPY}), ton/yr

$$ER_{COTPY} = \frac{ER_{CO} \times 8{,}760\ \frac{hr}{yr}}{2{,}000 \frac{lb}{ton}}$$

where,

ER_{CO} 13.17 = CO - Outlet Emission Rate, lb/hr
ER_{COTPY} 57.7 = ton/yr

CO - Outlet Emission Factor (EF_{CO}), g/hp-hr

$$EF_{CO} = \frac{ER_{CO} \times 454\ \frac{g}{lb}}{EBW}$$

where,

ER_{CO} 13.17 = CO - Outlet Emission Rate, lb/hr
EBW 2,246 = engine brake work, HP
EF_{CO} 2.7 = g/hp-hr

Location: Blue Water Renewables, LLC - Blue Water Renewables - Smiths Creek, MI
Source: Eng 1
Project No.: 20AST-2022-0313
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} 83.5 = average analyzer value during test, ppmvd
C_o 1.5 = average of pretest & posttest zero responses, ppmvd
C_{MA} 125.0 = actual concentration of calibration gas, ppmvd
C_M 128.4 = average of pretest & posttest calibration responses, ppmvd
C_{NOx} 80.7 = NOx Concentration, ppmvd

NOx - Outlet Concentration (C_{NOxc15}), ppmvd @ 15% O_2

$$C_{NOxc15} = C_{NOx} \times \left(\frac{20.9 - 15}{20.9 - O_2} \right)$$

where,

C_{NOx} 80.7 = NOx - Outlet Concentration, ppmvd
C_{O_2} 8.3 = oxygen concentration, %
C_{NOxc15} 37.7 = ppmvd @15% O_2

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} 80.7 = NOx - Outlet Concentration, ppmvd
MW 46.0055 = NOx molecular weight, g/g-mole
Qs 4,584 = stack gas volumetric flow rate at standard conditions, dscfm
ER_{NOx} 2.7 = lb/hr

NOx - Outlet Emission Rate (ER_{NOxTPY}), ton/yr

$$ER_{NOxTPY} = \frac{ER_{NOx} \times 8{,}760\ \frac{hr}{yr}}{2{,}000 \frac{lb}{ton}}$$

where,

ER_{NOx} 2.65 = NOx - Outlet Emission Rate, lb/hr
ER_{NOxTPY} 11.6 = ton/yr

NOx - Outlet Emission Factor (EF_{NOx}), g/hp-hr

$$EF_{NOx} = \frac{ER_{NOx} \times 454\ \frac{g}{lb}}{EBW}$$

where,

ER_{NOx} 2.65 = NOx - Outlet Emission Rate, lb/hr
EBW 2,246 = engine brake work, HP
EF_{NOx} 0.54 = g/hp-hr

Location: Blue Water Renewables, LLC - Blue Water Renewables - Smiths Creek, MI
Source: Eng 1
Project No.: 20AST-2022-0313
Run No. /Method Run 1 / Method Alt-096

NMHC - Outlet Concentration (as C3H8) (C_{NMHC}), ppmvd

$$C_{NMHC} = \frac{C_{NMHCw}}{1 - BWS}$$

where,

C_{NMHCw} 15.7 = NMHC - Outlet Concentration (as C3H8), ppmvw
BWS 0.114 = moisture fraction, unitless
C_{NMHC} 17.8 = ppmvd

NMHC - Outlet Concentration (as C3H8) ($C_{NMHCc15}$), ppmvd @ 15% O₂

$$C_{NMHCc15} = C_{NMHC} \times \left(\frac{20.9 - 15}{20.9 - O_2} \right)$$

where,

C_{NMHC} 17.8 = NMHC - Outlet Concentration (as C3H8), ppmvd
C_{O_2} 8.3 = oxygen concentration, %
$C_{NMHCc15}$ 8.3 = ppmvd @15% O_2

NMHC - Outlet Emission Rate (as C3H8) (ER_{NMHC}), lb/hr

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

where,

C_{NMHC} 17.8 = NMHC - Outlet Concentration (as C3H8), ppmvd
MW 44.1 = NMHC molecular weight, g/g-mole
Qs 4,584 = stack gas volumetric flow rate at standard conditions, dscfm
ER_{NMHC} 0.56 = lb/hr

NMHC - Outlet Emission Rate (as C3H8) ($ER_{NMHCTPY}$), ton/yr

$$ER_{NMHCTPY} = \frac{ER_{NMHC} \times 8{,}760\ \frac{hr}{yr}}{2{,}000 \frac{lb}{ton}}$$

where,

ER_{NMHC} 0.56 = NMHC - Outlet Emission Rate (as C3H8), lb/hr
$ER_{NMHCTPY}$ 2.5 = ton/yr

NMHC - Outlet Emission Factor (as C3H8) (EF_{NMHC}), g/hp-hr

$$EF_{NMHC} = \frac{ER_{NMHC} \times 454\ \frac{g}{lb}}{EBW}$$

where,

ER_{NMHC} 0.56 = NMHC - Outlet Emission Rate (as C3H8), lb/hr
EBW 2,246 = engine brake work, HP
EF_{NMHC} 0.11 = g/hp-hr

Location Blue Water Renewables, LLC - Blue Water Renewables - Smiths Creek, MI
Source Eng 1
Project No. 20AST-2022-0313
Run No. 1
Parameter(s) TBR

Meter Pressure (Pm), in. Hg

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

where,

Pb 29.36 = barometric pressure, in. Hg
ΔH 1.700 = pressure differential of orifice, in H_2O
Pm 29.5 = in. Hg

Absolute Stack Gas Pressure (Ps), in. Hg

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

where,

Pb 29.36 = barometric pressure, in. Hg
Pg 2.70 = static pressure, in. H_2O
Ps 29.6 = in. Hg

Standard Meter Volume (Vmstd), dscf

$$Vmstd = \frac{17.636 \times Vm \times Pm \times Y}{Tm}$$

where,

Y 0.980 = meter correction factor
Vm 24.800 = meter volume, cf
Pm 29.49 = absolute meter pressure, in. Hg
Tm 518.5 = absolute meter temperature, °R
Vmstd 24.4 = dscf

Standard Wet Volume (Vwstd), scf

$$Vwstd = 0.04716 \times Vlc$$

where,

Vlc 66.8 = Volume of H2O collected, ml
Vwstd 3.2 = scf

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

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

where,

Ts 841.3 = stack temperature, °F
Ps 29.6 = absolute stack gas pressure, in. Hg
BWSsat 358.7 = dimensionless

Moisture Fraction (BWS), dimensionless

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

where,

Vwstd 3.150 = standard wet volume, scf
Vmstd 24.372 = standard meter volume, dscf
BWS 0.11 = dimensionless

Moisture Fraction (BWS), dimensionless

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

where,

BWSsat 358.741 = moisture fraction (theoretical at saturated conditions)
BWSmsd 0.114 = moisture fraction (measured)
BWS 0.11

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,

CO2 11.1 = carbon dioxide concentration, %
O2 8.3 = oxygen concentration, %
Md 30.1 = lb/lb mol

Alliance
SOURCE TESTING

Location Blue Water Renewables, LLC - Blue Water Renewables - Smiths Creek, MI
Source Eng 1
Project No. 20AST-2022-0313
Run No. 1
Parameter(s) TBR

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

$$Ms = Md\,(1 - BWS) + 18.015\,(BWS)$$

where,

Md 30.10 = molecular weight (DRY), lb/lb mol
BWS 0.114 = moisture fraction, dimensionless
Ms 28.7 = lb/lb mol

Average Velocity (Vs), ft/sec

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

where,

Cp 0.84 = pitot tube coefficient
$\Delta P^{1/2}$ 1.734 = average pre/post test velocity head of stack gas, $(\text{in. H2O})^{1/2}$
Ts 1301.0 = average pre/post test absolute stack temperature, °R
Ps 29.56 = absolute stack gas pressure, in. Hg
Ms 28.72 = molecular weight of stack gas, lb/lb mol
Vs 154.2 = ft/sec

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

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

where,

Vs 154.2 = stack gas velocity, ft/sec
As 1.40 = cross-sectional area of stack, ft^2
Qa 12,918 = acfm

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

$$Qsd = 17.636 \times Qa \times (1 - BWS) \times \frac{Ps}{Ts}$$

where,

Qa 12,918 = average stack gas flow at stack conditions, acfm
BWS 0.114 = moisture fraction, dimensionless
Ps 29.56 = absolute stack gas pressure, in. Hg
Ts 1301.0 = average pre/post test absolute stack temperature, °R
Qs 4,584 = dscfm

Dry Gas Meter Calibration Check (Yqa), dimensionless

$$Yqa = \frac{Y - \left(\frac{\Theta}{Vm} \sqrt{\frac{0.0319 \times Tm \times 29}{\Delta H@ \times \left(Pb + \frac{\Delta H\ avg.}{13.6} \right) \times Md}} \sqrt{\Delta H}\ avg. \right)}{Y} \times 100$$

where,

Y 0.98 = meter correction factor, dimensionless
Θ 35 = run time, min.
Vm 24.8 = total meter volume, dcf
Tm 518.5 = absolute meter temperature, °R
ΔH@ 1.794 = orifice meter calibration coefficient, in. H_2O
Pb 29.36 = barometric pressure, in. Hg
ΔH avg 1.700 = average pressure differential of orifice, in H_2O
Md 30.10 = molecular weight (DRY), lb/lb mol
$(\Delta H)^{1/2}$ 1.304 = average squareroot pressure differential of orifice, $(\text{in. } H_2O)^{1/2}$
Yqa -3.1 = dimensionless

Appendix B

Emissions Calculations

Location Blue Water Renewables, LLC - Blue Water Renewables - Smiths Creek, MI
Source Eng 1
Project No. 20AST-2022-0313

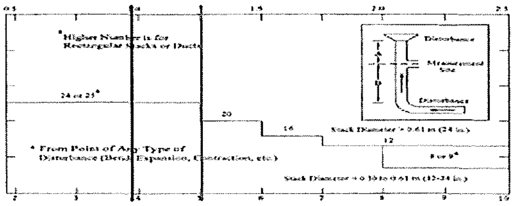
Run Number		Run 1	Run 2	Run 3	Average
Date		2/25/22	2/25/22	2/25/22	--
Start Time		7:05	8:20	9:33	--
Stop Time		8:05	9:20	10:33	--
Engine Data					
Engine Manufacturer		Caterpillar			
Engine Model		G3520C			
Engine Serial Number		GZJ00493			
Engine Type		Spark Ignition - 4SLB			
Engine Date of Manufacturer	DOM	6/1/2011			
Engine Hour Meter Reading	EMR	86,248			
Engine Speed, RPM	ES	1,200	1,200	1,200	1,200
Engine Brake Work, HP	EBW	2,246	2,251	2,229	2,242
Maximum Engine Brake Work, HP	MaxEBW	2,233	2,233	2,233	2,233
Engine Load, %	EL	101	101	100	100
Fuel Heating Value, Btu/scf	F_{HV}	1,040	1,040	1,040	1,040
Fuel Factor (O2 dry), dscf/MMBtu	Fd	8,710	8,710	8,710	8,710
Fuel Rate, scfh	F_R	32,772	32,964	32,904	32,880
Ambient Temperature	T_{Amb}	21	21	21	21
Relative Humidity, %	RH	89	86	81	85
Barometric Pressure, in. Hg	Pb	29.36	29.41	29.48	29.42
Input Data - Outlet					
Moisture Fraction, dimensionless	BWS	0.114	0.119	0.117	0.117
Volumetric Flow Rate (M1-4), dscfm	Qs	4,584	4,541	4,395	4,507
Calculated Data - Outlet					
O_2 Concentration, % dry	C_{O_2}	8.26	8.23	8.23	8.24
CO_2 Concentration, % dry	C_{CO_2}	11.08	11.08	11.10	11.09
CO Concentration, ppmvd	C_{CO}	659.0	670.1	665.3	664.8
CO Concentration, ppmvd @ 15 % O_2	C_{COc15}	307.7	312.1	309.8	309.9
CO Emission Rate, lb/hr	ER_{CO}	13.2	13.3	12.8	13.1
CO Emission Rate, ton/yr	ER_{COTPY}	57.7	58.1	55.8	57.2
CO Emission Factor, g/HP-hr	EF_{CO}	2.7	2.7	2.6	2.6
NOx Concentration, ppmvd	C_{NOx}	80.7	82.2	79.6	80.8
NOx Concentration, ppmvd @ 15 % O_2	C_{NOxc15}	37.7	38.3	37.1	37.7
NOx Emission Rate, lb/hr	ER_{NOx}	2.7	2.7	2.5	2.6
NOx Emission Rate, ton/yr	ER_{NOxTPY}	11.6	11.7	11.0	11.4
NOx Emission Factor, g/HP-hr	EF_{NOx}	0.54	0.54	0.51	0.53
NMHC (as C3H8) Concentration, ppmvd	C_{NMHC}	17.8	18.3	18.5	18.2
NMHC (as C3H8) Concentration, ppmvw	C_{NMHCw}	15.7	16.1	16.3	16.1
NMHC (as C3H8) Concentration, ppmvd @ 15 % O_2	$C_{NMHCc15}$	8.3	8.5	8.6	8.5
NMHC (as C3H8) Emission Rate, lb/hr	ER_{NMHC}	0.56	0.57	0.56	0.56
NMHC (as C3H8) Emission Rate, ton/yr	$ER_{NMHCTPY}$	2.5	2.5	2.4	2.5
NMHC (as C3H8) Emission Factor, g/HP-hr	EF_{NMHC}	0.11	0.11	0.11	0.11

Method 1 Data

Location Blue Water Renewables, LLC - Blue Water Renewables - Smiths Creek, MI
Source Eng 1
Project No. 20AST-2022-0313
Date: 02/23/22

Stack Parameters

Duct Orientation: Vertical
Duct Design: Circular
Distance from Far Wall to Outside of Port: 16.00 in
Nipple Length: 0.00 in
Depth of Duct: 16.00 in
Cross Sectional Area of Duct: 1.40 ft²
No. of Test Ports: 2
Distance A: 1.3 ft
Distance A Duct Diameters: 1.0 (must be > 0.5)
Distance B: 6.7 ft
Distance B Duct Diameters: 5.0 (must be > 2)
Measurer (Initial and Date): STH 2/23/22
Reviewer (Initial and Date): TBR 2/23/22



CIRCULAR DUCT

LOCATION OF STRATIFICATION POINTS

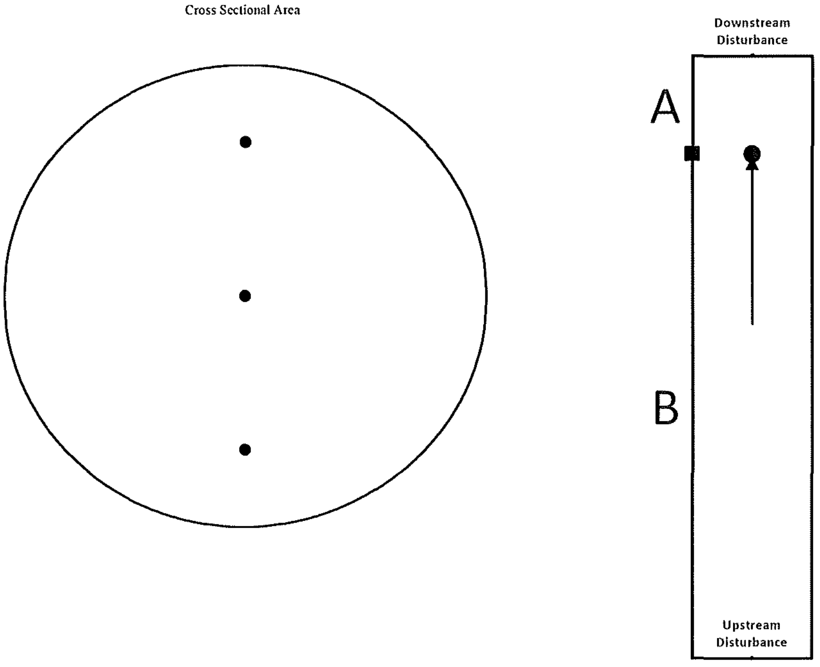
Number of traverse points on a diameter

	2	3	4	5	6	7	8	9	10	11	12
1	14.6	--	6.7	--	4.4	--	3.2	--	2.6	--	2.1
2	85.4	--	25.0	--	14.6	--	10.5	--	8.2	--	6.7
3	--	--	75.0	--	29.6	--	19.4	--	14.6	--	11.8
4	--	--	93.3	--	70.4	--	32.3	--	22.6	--	17.7
5	--	--	--	--	85.4	--	67.7	--	34.2	--	25.0
6	--	--	--	--	95.6	--	80.6	--	65.8	--	35.6
7	--	--	--	--	--	--	89.5	--	77.4	--	64.4
8	--	--	--	--	--	--	96.8	--	85.4	--	75.0
9	--	--	--	--	--	--	--	--	91.8	--	82.3
10	--	--	--	--	--	--	--	--	97.4	--	88.2
11	--	--	--	--	--	--	--	--	--	--	93.3
12	--	--	--	--	--	--	--	--	--	--	97.9

**Percent of stack diameter from inside wall to traverse point.*

Traverse Point	% of Diameter	Distance from inside wall	Distance from outside of port
1	16.7	2.67	2.67
2	50.0	8.00	8.00
3	83.3	13.33	13.33
4	--	--	--
5	--	--	--
6	--	--	--
7	--	--	--
8	--	--	--
9	--	--	--
10	--	--	--
11	--	--	--
12	--	--	--

Stack Diagram
A = 1.3 ft.
B = 6.7 ft.
Depth of Duct = 16 in.

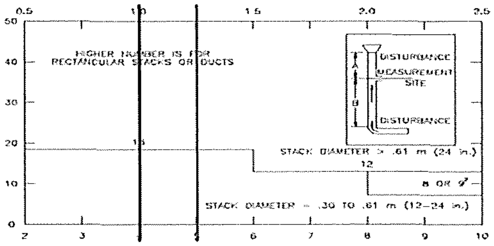


Method 1 Data

Location Blue Water Renewables, LLC - Blue Water Renewables - Smiths Creek, MI
Source Eng 1
Project No. 20AST-2022-0313
Date: 02/23/22

Stack Parameters

Duct Orientation: Vertical
Duct Design: Circular
Distance from Far Wall to Outside of Port: 16.00 in
Nipple Length: 0.00 in
Depth of Duct: 16.00 in
Cross Sectional Area of Duct: 1.40 ft^2
No. of Test Ports: 2
Number of Readings per Point: 1
Distance A: 1.3 ft
Distance A Duct Diameters: 1.0 (must be > 0.5)
Distance B: 6.7 ft
Distance B Duct Diameters: 5.0 (must be > 2)
Minimum Number of Traverse Points: 16
Actual Number of Traverse Points: 16
Measurer (Initial and Date): STH 2/23/2022
Reviewer (Initial and Date): TBR 2/23/2022



CIRCULAR DUCT

LOCATION OF TRAVERSE POINTS

Number of traverse points on a diameter

	2	3	4	5	6	7	8	9	10	11	12
1	14.6	--	6.7	--	4.4	--	3.2	--	2.6	--	2.1
2	85.4	--	25.0	--	14.6	--	10.5	--	8.2	--	6.7
3	--	--	75.0	--	29.6	--	19.4	--	14.6	--	11.8
4	--	--	93.3	--	70.4	--	32.3	--	22.6	--	17.7
5	--	--	--	--	85.4	--	67.7	--	34.2	--	25.0
6	--	--	--	--	95.6	--	80.6	--	65.8	--	35.6
7	--	--	--	--	--	--	89.5	--	77.4	--	64.4
8	--	--	--	--	--	--	96.8	--	85.4	--	75.0
9	--	--	--	--	--	--	--	--	91.8	--	82.3
10	--	--	--	--	--	--	--	--	97.4	--	88.2
11	--	--	--	--	--	--	--	--	--	--	93.3
12	--	--	--	--	--	--	--	--	--	--	97.9

**Percent of stack diameter from inside wall to traverse point.*

Traverse Point	% of Diameter	Distance from inside wall	Distance from outside of port
1	3.2	0.51	0.51
2	10.5	1.68	1.68
3	19.4	3.10	3.10
4	32.3	5.17	5.17
5	67.7	10.83	10.83
6	80.6	12.90	12.90
7	89.5	14.32	14.32
8	96.8	15.49	15.49
9	--	--	--
10	--	--	--
11	--	--	--
12	--	--	--

Stack Diagram
A = 1.333 ft.
B = 6.6666666
Depth of Duct = 16 in.

Cross Sectional Area