AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM A
LANDFILL GAS FUELED TURBINE

C&C ENERGY, LLC

1.0 INTRODUCTION

C&C Energy, LLC (C&C Energy) operates a Solar Centaur Model T-4500 landfill gas (LFG) fired turbine at the C&C Expanded Sanitary Landfill (C&C Landfill) in Marshall, Calhoun County, Michigan (Facility SRN: P0222). The LFG fired turbine is identified as emission unit EU-TURBINE in Renewable Operating Permit (ROP) No. MI-ROP-P0222-2018 issued by the State of Michigan Department of Environment, Great Lakes, and Energy-Air Quality Division (EGLE-AQD). The turbine is also regulated under 40 CFR Part 60, Subpart KKKK – New Source Performance Standards (NSPS) for Stationary Combustion Turbines.

The conditions of 40 CFR Subpart KKKK and MI-ROP-P0222-2018 specify that:

1. Emission testing is required on an annual basis to verify the nitrogen oxides (NO_X) emission rate.

2. The sulfur content of the fuel must be determined using total sulfur methods described in 40 CFR 60.4415.

The emission test event presented in this report was performed by Impact Compliance & Testing, Inc. (ICT) on August 4, 2020. ICT representatives Andrew Eisenberg and Jake Spry performed the field sampling and measurements. Mr. Matt Deskins and Mr. Matt Karl of EGLE-AQD 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 personnel. Facility process data were collected and provided by C&C Energy employees or representatives. This test report has been reviewed by C&C Energy representatives and approved for submittal to EGLE-AQD. A signed ROP report certification (EQP 5736) accompanies this report.

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:

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2.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

Testing was performed to measure NOx emissions exhausted from the treated LFG fueled turbine (EU-TURBINE) and fuel sulfur content. The testing was performed while the gas turbine was operated at maximum achievable operating conditions. C&C Energy representatives provided generator electricity output and fuel use rate data at 15-minute intervals for each test period.

The exhaust gas from EU-TURBINE was sampled for three (3) one-hour test periods during the compliance testing performed August 4, 2020. In addition, two (2) fuel gas (treated LFG) samples were obtained during the test event for sulfur analysis.

Table 2.1 presents a summary of the average turbine emissions and operating conditions during the test periods. Test results for each one-hour sampling period are presented in Table 6.1 at the end of this report. The test results demonstrate compliance with the applicable permit limits and emission standards.

Table 2.1 Average turbine emissions and operating conditions during the test periods

Turbine Parameter	EU-TURBINE	Permit Limit
Generator Output (MW)	2.92	--
Turbine Fuel Use (scfm)	1,366	--
Exhaust Flowrate (dscfm)	30,178	--
NOx Emission Rate (lb/hr)	5.10	--
NOx Emission Rate (lb/MWhr)	1.75	5.5
Fuel Sulfur Content (ppmv TRS)	176	--

3.0 SOURCE DESCRIPTION

3.1 General Process Description and Sampling Location

C&C Energy operates a gas-fired turbine (EU-TURBINE) at the C&C Expanded Sanitary Landfill in Marshall, Michigan that is fueled exclusively with treated LFG. The gas turbine drives an electricity generator.

The turbine exhaust gas is released to the atmosphere through a vertical exhaust stack. The exhaust stack has an inner diameter of 42 inches, and is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 41 inches (~1 duct diameter) upstream and 168 inches (4 duct diameters) downstream from any flow disturbance. This satisfies the USEPA Method 1 criteria for a representative sample location.

Appendix 1 provides a diagram of the emission test sampling location.

3.2 Rated Capacities and Air Emission Controls

The Solar Centaur Model T-4500 turbine is a simple cycle turbine that is connected to an electricity generator that is rated to produce 3,500 kW (3.5 MW) of electricity. The turbine is not equipped with add-on emission control equipment. NO_X emissions are suppressed using a dry low-NO_X combustor within the gas turbine.

Turbine fuel use and generator electricity output were recorded by C&C Energy representatives at 15-minute intervals for each test period. The fuel consumption rate ranged between 1,347 and 1,381 scfm; the turbine generator output ranged between 2,893 and 2,964 kW (2.89 to 2.96 MW) during the test periods.

Appendix 2 provides operating records provided by C&C Energy representatives for the test periods.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A stack test protocol for the air emission testing was reviewed and approved by EGLE-AQD. This section provides a summary of the sampling and analytical procedures that were used during the testing periods.

4.1 Summary of Sampling Methods

USEPA Method 1	Exhaust gas velocity measurement locations were determined based on the physical stack arrangement and requirements in USEPA Method 1.
USEPA Method 2	Exhaust gas velocity pressure was determined using a Type-S Pitot tube connected to a red oil incline manometer; temperature was measured using a K-type thermocouple connected to the Pitot tube.
USEPA Method 3A	Exhaust gas O_2 and CO_2 content was determined using zirconia ion/paramagnetic and infrared instrumental analyzers, respectively.
USEPA Method 4	Exhaust gas moisture was determined based on the water weight gain in chilled impingers.
USEPA Method 7E	Exhaust gas NOx concentration was determined using chemiluminescence instrumental analyzer.
ASTM D5504	Fuel gas sulfur analysis by gas chromatography and chemiluminescence.

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

The turbine exhaust stack gas velocity and volumetric flowrate was determined using USEPA Method 2 during each test period. An S-type Pitot tube connected to a red-oil manometer was used to determine velocity pressure at each traverse point across the stack cross section. Gas temperature was measured using a K-type thermocouple mounted to the Pitot tube.

Appendix 3 provides exhaust gas flowrate calculations and field data sheets.

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

CO_2 and O_2 content in the turbine exhaust gas stream were measured continuously throughout each test period in accordance with USEPA Method 3A. The CO_2 content of the exhaust was monitored using a single beam single wavelength (SBSW) infrared gas analyzer. The O_2 content of the exhaust was monitored using a 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 the turbine exhaust gas was determined in accordance with USEPA Method 4 using a chilled impinger sampling train. The moisture sampling was performed concurrently with the instrumental analyzer sampling. During each sampling period a gas sample was extracted at a constant rate from the source where moisture was removed from the sampled gas stream using impingers that were submersed in an ice bath. At the conclusion of each sampling period, the moisture gain in the impingers was determined gravimetrically by weighing each impinger to determine net weight gain.

4.5 NO_x Concentration Measurements (USEPA Method 7E)

NO_X pollutant concentration in the turbine exhaust gas stream was determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42c High Level chemiluminescence NO_X analyzer.

The stack exhaust gas sample was delivered to the instrument using the sample line and conditioning system described in Section 4.3 of this document. Prior to, and at the conclusion of each test period, the instrument was calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias.

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

4.6 Sulfur Compounds (ASTM D5504)

Sulfur content analysis was performed for the treated LFG used as fuel. Two (2) samples of the treated LFG were collected during the test event using an evacuated, inert (silonite-coated) stainless steel canister. The sample Teflon tubing was connected to the fuel header at a location after the treatment system and gas blower. Sample canister vacuum was recorded before and after sampling and verified by the laboratory upon receipt.

The gas sample was analyzed by ALS Analytical (Simi Valley, CA) for sulfur bearing compounds by ASTM D5504.

Appendix 6 provides a copy of the laboratory analytical report for the treated LFG samples.

5.0 QA/QC ACTIVITIES

5.1 Exhaust Gas Flow

Prior to arriving onsite, or onsite prior to beginning compliance testing, the instruments used during the source test to measure exhaust gas properties and velocity (barometer, pyrometer, scale, and Pitot tube) were calibrated to specifications outlined in the sampling methods.

The Pitot tube and connective tubing were leak-checked periodically throughout the test event to verify the integrity of the measurement system.

The absence of significant cyclonic flow for the exhaust configurations were verified using an S-type Pitot tube and oil manometer. The Pitot tube was positioned at each velocity traverse point with the planes of the face openings of the Pitot tube perpendicular to the stack cross-sectional plane. The Pitot tube was then rotated to determine the null angle (rotational angle as measured from the perpendicular, or reference, position at which the differential pressure is equal to zero).

5.2 NO_x Converter Efficiency Test

The NO_2 – NO conversion efficiency of the chemiluminescence NOx analyzer was verified prior to the first test period. 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 instrument analyzer will be deemed acceptable if the calculated NO_2 – NO conversion efficiency is greater than or equal to 90%.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NOx concentration was greater than 90% of the expected value as required by Method 7E).

5.3 Gas Divider Certification (USEPA Method 205)

A STEC Model SGD-710C 10-step gas divider was used to obtain appropriate calibration span gases. The ten-step STEC gas divider was NIST certified (within the last 12 months) with a primary flow standard in accordance with Method 205. When cut with an appropriate zero gas, the ten-step STEC gas divider delivers calibration gas values ranging from 0% to 100% (in 10% step increments) of the USEPA Protocol 1 calibration gas that was introduced into the system. The field evaluation procedures presented in Section 3.2 of Method 205 were followed prior to use of gas divider. The field evaluation yielded no errors greater than 2% of the triplicate measured average and no errors greater than 2% from the expected values.

5.4 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NOx, O_2 and CO_2 have had an interference response test performed prior to their use in the field, pursuant to the interference response test procedures specified in USEPA Method 7E. The appropriate interference test gases (i.e., gases that would be encountered in the exhaust gas stream) were introduced into each analyzer, separately and as a mixture with the analyte that each analyzer is designed to measure. All of analyzers exhibited a composite deviation of less than 2.5% of the span for all measured interferent gases. No major analytical components of the analyzers have been replaced since performing the original interference tests.

5.5 Instrument Calibration and System Bias Checks

At the beginning of each day of the testing program, initial three-point instrument calibrations were performed for the NOx, 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.

The instruments were calibrated with USEPA Protocol 1 certified concentrations of CO_2, O_2, and NO_x in nitrogen and zeroed using hydrocarbon free nitrogen. A STEC Model SGD-710C ten-step gas divider was used to obtain intermediate calibration gas concentrations as needed.

5.6 Determination of Exhaust Gas Stratification

A stratification test was performed for the turbine exhaust stack. The stainless-steel sample probe was positioned at sample points correlating to 16.7, 50.0 (centroid), and 83.3% of the stack diameter. Pollutant concentration data were recorded at each sample point for a minimum of twice the maximum system response time.

The recorded concentration data for the turbine exhaust stack indicated that the measured NOx, CO_2, and O_2 concentration was not stratified (i.e. varied less than 5% of the mean).

Therefore, the sampling probe was placed at a single representative point during each one-hour test.

5.7 Meter Box Calibrations

The dry gas metering console, which was used for exhaust gas moisture content sampling, was calibrated prior to and after the test project. 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 metering console was calibrated using a NIST traceable Omega® Model CL 23A temperature calibrator.

Appendix 7 presents test equipment quality assurance data for the emission test equipment (NO_2 – NO conversion efficiency test data, instrument calibration and system bias check records, calibration gas and gas divider certifications, interference test results, meter box calibration records, and Pitot tube and scale calibration records).

6.0 RESULTS

6.1 Turbine Engine NO_X Test Results and Allowable Emission Limits

Turbine operating data and air pollutant emission measurement results for each one-hour test period are presented in Table 6.1. The measured NO_X concentration and emission rate for EU-TURBINE are less than the allowable limits specified in MI-ROP-P0222-2018 and 40 CFR Part 60 Subpart KKKK; 96 ppmvd at 15% O_2 or 5.5 lb/MWh.

Continuous operation at the measured emission rate (5.10 lb/hr) would result in annual NO_X emissions that are less than the 26 tons per year (TPY) permit limit.

6.2 Fuel Sulfur Analytical Results

Samples of the treated LFG fuel were obtained during the test periods on August 4, 2020 and analyzed by ASTM D5504.

The measured fuel sulfur content is presented in Table 6.2.

6.3 Variations from Normal Sampling Procedures or Operating Conditions

The testing for all pollutants was performed in accordance with the associated test methods and approved stack test protocol dated June 4, 2020.

The turbine operated normally, at maximum achievable output, throughout the test event.

Table 6.1 Measured exhaust gas conditions and air pollutant emission rates for EU-TURBINE

Test No.	1	2	3	
Test Date	8/4/2020	8/4/2020	8/4/2020	Test
Test Period (24-hr clock)	09:10-10:10	10:35-11:35	12:05-13:05	Avg.
Generator output (MW)	2.94	2.91	2.91	2.92
Turbine fuel consumption (scfm)	1,362	1,366	1,369	1,366
Fuel methane content (%)	52.7	51.9	51.7	52.1
Exhaust gas composition				
CO_2 content (% vol)	4.41	4.37	4.17	4.32
O_2 content (% vol)	16.6	16.6	16.7	16.6
Moisture (% vol)	5.3	6.3	6.1	5.9
Exhaust gas flowrate				
Standard conditions (scfm)	31,422	32,358	32,436	32,072
Dry basis (dscfm)	29,748	30,320	30,465	30,178
Nitrogen oxides emission rates				
NO_X conc. (ppmvd)	23.7	23.5	23.6	23.6
NO_X emissions (lb/hr as NO_2)	5.06	5.11	5.15	5.10
NO_X emissions (lb/MW-hr NO_2)	1.72	1.75	1.77	1.75
NO_X permit limit (lb/MW-hr)	-	-	-	*5.5*
NO_X emissions (TPY NO_2)[1]	22.2	22.4	22.6	22.4
NO_X permit limit (TPY)	-	-	-	*26*

Notes:
1. NOx emission rate (TPY) calculated for continuous operation, as a worst-case-scenario, for comparison to 26 TPY emission limit.

Table 6.2 Measured LFG fuel sulfur content for EU-TURBINE

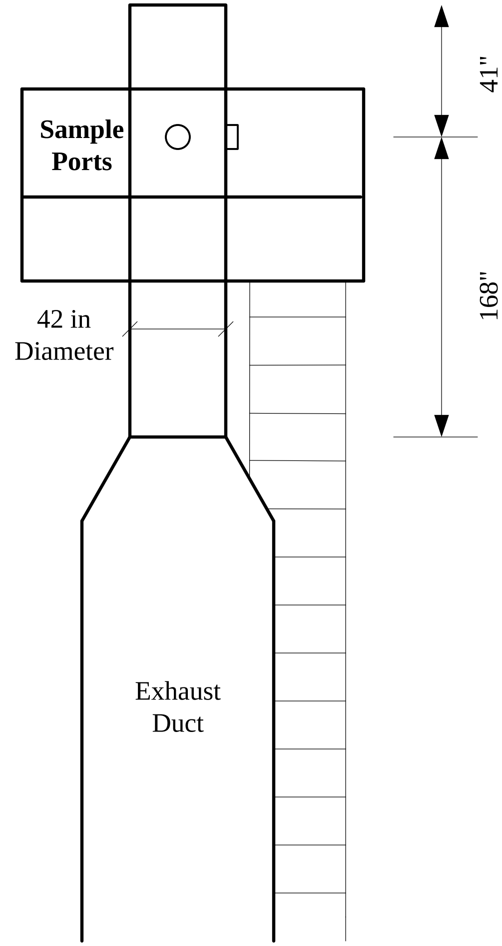
Total Sulfur Analysis (ASTM D5504)	
Total sulfur content (ppmv TRS)[1]	176
Sulfur weight percent (% wt)[2]	0.021

Notes:
1. Average of two (2) samples, see ALS laboratory report dated August 13, 2020.
2. Calculated from TRS concentration.

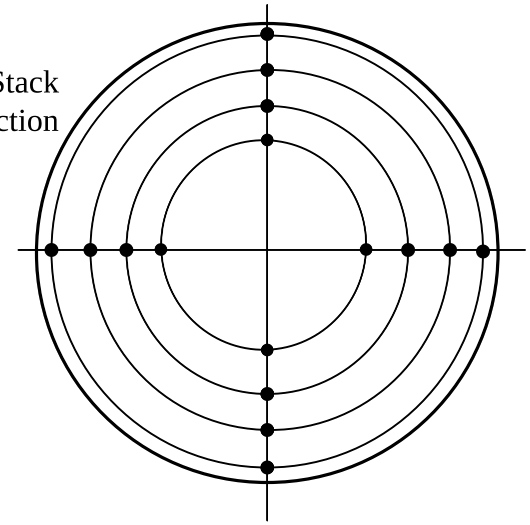
APPENDIX 1

Sample Port Diagram

EU-Turbine



Exhaust Stack
Cross-Section



Velocity sample locations as
measured from stack wall
(not including 6" sampling port nipple)

Pt. #	in.
1	1.34
2	4.41
3	8.15
4	13.52
5	28.43
6	33.85
7	37.59
8	40.66

8/2/18	**C&C Energy** **Exhaust Sampling Location – EU-TURBINE**		
	Scale None	Sheet 1 of 1	ICT