Derenzo Environmental Services
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AIR EMISSION TEST REPORT

Title	AIR EMISSION TEST REPORT FOR THE VERIFICATION OF NO_X AND SO_2 EMISSIONS FROM A LANDFILL GAS FUELED TURBINE
Report Date	August 2, 2018
Test Date	June 12, 2018

Facility Information	
Name	C&C Energy LLC
Street Address	19401 15 Mile Road
City, County	Marshall, Calhoun
SRN	P0222

Facility Permit Information	
Permit No.:	MI-ROP-P0222-2018
Emission Unit	EU-TURBINE

Testing Contractor	
Company	Derenzo Environmental Services
Mailing Address	39395 Schoolcraft Road Livonia, MI 48150
Phone	(734) 464-3880
Project No.	1803021

AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF NO_X AND SO_2 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 Michigan Department of Environmental Quality (MDEQ). The turbine is also regulated under 40 CFR Part 60, Subpart KKKK – New Source Performance Standards (NSPS) for Stationary Combustion Turbines.

The conditions of MI-ROP-P0222-2018 specify that:

1. Annual performance tests shall be conducted to demonstrate compliance with nitrogen oxides (NOx) emissions of 5.5 pounds per megawatt-hour (lb/MWh).

2. The NOx testing frequency can be reduced to once every two years if the emission test results are less than or equal to 4.1 lb/MWhr.

3. The SO_2 emissions for fuel fired in EU-TURBINE are limited to 0.9 lb/MWh or 0.15 lb/MMBtu SO_2.

The conditions of 40 CFR Subpart KKKK specify that:

1. For new turbines fired by fuels other than natural gas, NOx emission standards are 96 parts per million by volume dry (ppmvd) at 15% O_2, or 5.5 lb/MWh.

2. The performance test must be done at any load condition within plus or minus 25 percent of 100 percent of peak load. You may perform testing at the highest achievable load point, if at least 75 percent of peak load cannot be achieved in practice.

The emission test event presented in this report was performed by Derenzo Environmental Services (DES) on June 12, 2018. DES representatives Blake Beddow and Clay Gaffey performed the field sampling and measurements. Mr. Tom Gasoli of the MDEQ Technical Programs Unit 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 Derenzo Environmental Services based on field sampling data collected by DES 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 the MDEQ. 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:

Blake Beddow
Environmental Consultant
Derenzo Environmental Services

Reviewed by:

Robert L. Harvey, P.E.
General Manager
Derenzo Environmental Services

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 SO_2 emissions based on 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 June 12, 2018. In addition, a representative fuel gas (treated LFG) sample was 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)	2.77	--
Turbine fuel use (scfm)	1,394	--
Exhaust Flowrate (scfm)	31,322	--
NOx Emission Rate (lb/MWhr)	1.8	5.5
SO_2 Emission Rate (lb/MMBtu)[1]	0.11	0.15

1. Based on sulfur analysis of the treated landfill gas used as fuel.

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 diameters) 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 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 by the use of 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 1,387 and 1,416 scfm; the turbine generator output ranged between 2,758 and 2,803 kW (2.76 to 2.80 MW) for each test period.

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

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A test protocol for the air emission testing was reviewed and approved by the MDEQ. 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.
USEPA Method 19	SO_2 mass emission determination based on gas use and LFG fuel heating value analysis by ASTM D-3588
ASTM D-5504/3588	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 was 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 and SO_2 Emissions (ASTM D5504/3588, USEPA Method 19)

SO_2 emissions were calculated based on the measured fuel heating value and sulfur content analysis for the treated LFG used as fuel. A representative sample of the treated LFG was collected during the test period 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 gross heating value by ASTM D3588 and sulfur bearing compounds by ASTM D-5504-12. USEPA Method 19 equation 19-25 was used to calculate SO_2 emissions per million British thermal units (lb/MMBtu). Based on the measured gross calorific value (GCV) of the gas and measured fuel flowrate, the engine heat input rate (MMBtu/hr) and SO_2 emission rate (lb/hr) were calculated.

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

5.0 QA/QC ACTIVITIES

5.1 Exhaust Gas Flow

Prior to arriving onsite, the instruments used during the source test to measure exhaust gas properties and velocity (barometer, pyrometer, 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 analyzer is deemed acceptable if the measured NOx concentration is at least 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NOx concentration was 99% of the expected value, i.e., 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 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, Pitot tube calibration records).

6.0 <u>RESULTS</u>

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 (4.95 lb/hr) would result in annual NO_X emissions that are less than the 26 tons per year (TPY) permit limit.

6.2 SO_2 Emissions and Fuel Sulfur Analytical Results

A representative samples of the treated LFG fuel was obtained during the test periods on June 12, 2018 and analyzed by ASTM D3588 and ASTM D5504. Equations from USEPA Method 19 were used to calculate an SO_2 emission factor (lb/MMBtu), which was multiplied by the calculated gross heat input rate to the gas turbine engine to determine SO_2 mass emission rate (lb/hr).

The measured fuel content and calculated SO_2 emission rates are presented in Table 6.2.

The calculated SO_2 emission rate for EU-TURBINE is less than the allowable limits specified in MI-ROP-P0222-2018 and 40 CFR Part 60 Subpart KKKK; 0.9 lb/MWh, or 0.15 lb/MMBtu SO_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 test protocol dated April 12, 2018 unless specified in this section.

The turbine was operated normally at maximum achievable output except for one instance during the second test run. Partway through the second test run, C&C Energy representatives reported a fuel delivery issue that impacted the turbine emissions. The test was paused at 9:10 AM and resumed at 9:20 AM after the turbine emissions stabilized. The instrumental analyzer data recorded during this time period were excluded from the test run data set and the test run was extended by 10 minutes.

At the end of the third test period, the USEPA Method 4 moisture sampling train failed the post-test leak check. As a recommendation of MDEQ representative Tom Gasloli, the moisture content from the first and second test runs were averaged and used as the moisture content for the third test run.

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

Test No. Test Date Test Period (24-hr clock)	1 6/12/18 7:30-8:30	2 6/12/18 8:48:-9:58*	3 6/12/18 10:16-11:16	Test Avg.
Generator uutput (MW)	2.78	2.75	2.79	2.77
Turbine fuel consumption (scfm)	1,392	1,396	1,394	1,394
Fuel methane content (%)	49.1	48.1	47.9	48.1
Exhaust gas composition				
CO_2 content (% vol)	4.07	4.03	4.14	4.08
O_2 content (% vol)	16.5	16.6	16.5	16.5
Moisture (% vol)	6.7	6.2	6.5	6.5
Exhaust gas flowrate				
Standard conditions (scfm)	31,251	31,351	31,365	31,322
Dry basis (dscfm)	29,152	29,397	29,335	29,295
Nitrogen oxides emission rates				
NO_X conc. (ppmvd)	23.6	23.1	24.0	23.6
NO_X emissions (lb/hr as NO_2)	4.92	4.88	5.05	4.95
NO_X emissions (lb/MW-hr NO_2)	1.77	1.77	1.81	1.79
NO_X permit limit (lb/MW-hr)	-	-	-	*5.5*

*Run 2 paused at 9:10, resumed at 9:20

Table 6.2 Measured LFG fuel sulfur content and calculated SO_2 emission rate for EU-TURBINE

Fuel Analysis (ASTM D3588)		
Gross heating value LFG (Btu/scf)[1]	497	
Gross heating value LFG (Btu/lb)[1]	6,842	
Total Sulfur Analysis (ASTM D5504)		
Total sulfur content (ppmv TRS)[1]	320	
Sulfur weight percent (% wt)[2]	0.038	
SO_2 Emission Calculations		
SO_2 Emissions (lb/MMBtu)[3]	0.11	(Limit = 0.15)
Turbine fuel flowrate (scfm)	1,394	
Turbine heat input rate (MMBtu/hr, HHV)	41.6	
SO_2 Emissions (lb/hr)[4]	4.60	

1. As measured by ALS laboratory, report dated June 28, 2018.

2. Calculated from TRS concentration.

3. Based on USEPA Method 19 equation 19-25
   E_{di} = K (%S) / GCV = (2 x 10^4 lb SO_2/%S) x (0.038 %S) / (6,842 GCV, Btu/lb fuel)

4. Calculated hourly emission rate using Method 19 equation and heat input rate.
   Heat input rate (MMBtu/hr) x SO_2 emissions (lb/MMBtu)