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**EMISSION TEST REPORT**

**COMPLIANCE TESTING  
EUTURBINE**

**C & C ENERGY  
MARSHALL, MICHIGAN**

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*Prepared for:*

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**Project No. 249433.0000**

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## SECTION 1 INTRODUCTION

C & C Energy, LLC operates a landfill gas-to-energy (LFGTE) plant at the landfill on 19401 15 Mile Road in Marshall, Michigan. C & C Energy retained TRC Environmental Corporation (TRC) to conduct emissions testing on the stack emissions for EUTURBINE (Solar Centaur Model T-4500). The testing contract was managed and staffed from TRC's Raleigh, North Carolina and Burr Ridge, Illinois offices. The project participants and their responsibilities are presented in Table 1-1. Emissions testing was performed on September 29, 2016 for Solar Centaur Turbine. Table 1-2 contains test methods and parameters.

This document presents the results of the emission testing conducted on Solar Centaur Turbine. Section 2 presents a summary of results of the emissions testing. Section 3 presents a discussion of the process, and Section 4 discusses the sampling and analytical procedures. Quality assurance control (QA/QC) procedures are presented in Section 5. Detailed test summaries are in Appendix A; field data sheets are included in Appendix B; source data is located in Appendix C; analytical data is in Appendix D; equipment calibrations and cylinder certifications are presented in Appendix E; and AETB information is located Appendix F.

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**Section 1**  
**Introduction**

**TABLE 1-1. TEST PARTICIPANTS**

<b>Organization</b>	<b>Personnel</b>	<b>Responsibilities</b>
Arbor Hills Energy	Andrew Zalenski	Test Coordinator
	Carlos Wilson	Site Contact
Michigan Department of Environmental Quality	David Patterson	Observer-Environmental Quality Analyst
TRC	Mark Winter	Project Manager
	Gavin Lewis	CEM Operator

**TABLE 1-2. SUMMARY OF SAMPLING METHODS**

<b>Test Methods</b>	<b>Parameters</b>
EPA Test Method 2	Stack Gas Velocity
EPA Test Method 3A	Stack Gas Molecular Weight; O <sub>2</sub> , CO <sub>2</sub>
EPA Test Method 4	Stack Gas Moisture
EPA Test Method 7E	Oxides of Nitrogen (NO <sub>x</sub> )
ASTM D6288	Fuel Analysis for Sulfur Dioxide (SO <sub>2</sub> )

**SECTION 2**  
**SUMMARY OF RESULTS**

Emission rates and concentrations of the compounds are summarized in Table 2-1. The emission rates are presented in concentration at 15%O<sub>2</sub>. Detailed results of each run are presented in Appendix A of this report.

**TABLE 2-1. SUMMARY OF SOLAR CENTAUR EMISSIONS DATA**

<b>Test Parameter</b>	<b>Run 1</b>	<b>Run 2</b>	<b>Run 3</b>	<b>Average</b>	<b>Permit Limit</b>
Date	9/29/16	9/29/16	9/29/16		
Run Time	10:05-11:05	11:35-12:35	13:05-14:05		
Oxygen (%)	15.8	15.8	15.8	15.8	--
Carbon Dioxide (%)	4.8	4.8	4.8	4.8	--
Volumetric Flow, dscfm	32,204	33,082	33,988	33,092	--
Turbine Load, ~KW	3,000	3,000	3,000	3,000	--
Sulfur Dioxide <sup>(1)</sup>					
ppm, dry volume				0.0	--
lbs/mmBtu				0.000	0.15
Oxides of Nitrogen					
ppm, dry volume	24.5	24.7	24.9	24.7	--
ppm, dry volume @15% O <sub>2</sub>	28.1	28.4	28.5	28.3	96

(1) Fuel analysis

### **SECTION 3**

#### **PROCESS DESCRIPTION AND OPERATION**

The C & C Energy, LLC facility utilizes landfill gas for the beneficial use of producing electricity in Marshall, Michigan. The facility operates under the terms and conditions of the Permit No. MI-ROP-P0222-2012A issued by the Michigan Department of Environmental Quality (MDEQ). The facility consists of multiple landfill gas fired turbine generators and gas skids containing moisture separators and blowers, step-up and station transformers mounted on concrete pads, and all necessary electrical switchgear.

Any excess landfill gas collected and not combusted in the turbines, as well generated during periods when the turbines may be off-line, is routed to an on-site flare to ensure continued combustion of the landfill gas.

## SECTION 4

### SAMPLING AND ANALYTICAL PROCEDURES

Prior to mobilizing to the site, all equipment used in the field testing program was checked for proper operation. Analyzers, meter boxes, probe and filter box heaters, and sample umbilical lines were checked to ensure that all electrical components worked properly. All glassware used in the sampling program was pre-cleaned to eliminate the possibility of contamination from previous projects. Method 4 glassware was rinsed and brushed with hot soapy water and then rinsed with distilled, deionized water. The glassware was set aside and allowed to air-dry, the openings were covered, and the glassware was packed into shipping cases for transport to the job site.

Upon arrival at the site, the sampling locations were surveyed and the required complement of sampling equipment was moved to the sampling locations. Prior to each run, the mass of each impinger was measured and recorded. Prior to beginning a sample run, the impinger trains were leak-checked.

All sampling and analytical procedures used in this test program were those generally recommended by the Environmental Protection Agency (EPA) and the Michigan Department of Natural Resources & Environment. The sampling and analytical procedures are contained in 40 CFR Part 60, Appendix A. Volumetric flows corrected to standard conditions of 68°F and 29.92 inches Hg.

#### **4.1 U.S. EPA METHOD 1: SAMPLING AND VELOCITY TRAVERSES**

Method 1 was used to evaluate the location of the test ports. The number of traverse points was selected based on the number of diameters from each flow disturbance as referenced in the method. The sample ports for all of the sampling locations are more than 2 diameters past

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a flow disturbance and more than 2 diameters before the nearest downstream disturbance. A cyclonic flow check showed the average absolute yaw angle to be  $\leq 20$  degrees, indicating non-cyclonic flow. A total of 16 traverse points were sampled with 8 traverse points on each axis at each boiler test location. Figure 4-1 contains a schematic of the test location.

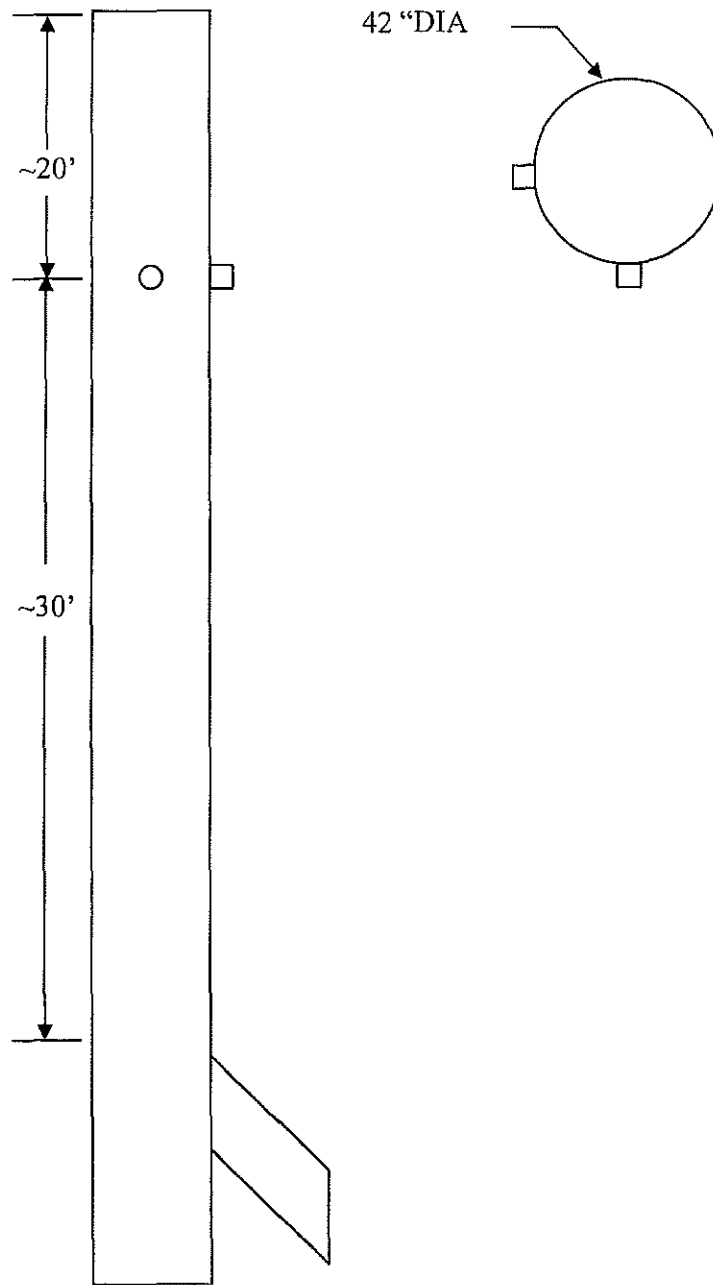
#### **4.2 U.S. EPA METHOD 2: DETERMINATION OF VOLUMETRIC FLOW**

Method 2 was used to determine the average gas stream velocity and to quantify the gas flow at each of the sampling locations. Flow rates were measured by inserting an S-type pitot tube directly into the gas stream and orienting the tube openings to the gas flow. The differential pressure and the temperature were recorded at each traverse point. Velocity head pressures were measured with an inclined manometer having a full range of 0 to 10 inches of water column. Gas temperatures were measured with Type K thermocouples as described in Method 2. The gas volumetric flow rates were reported at actual wet conditions, and then calculated and reported at dry standard conditions of 29.92 inches Hg. and 68°F using the measured data corrected to these standard conditions. A pre-CEM run gas flow rate was recorded and averaged with a post-CEM run gas flow rate to give an average flow rate for each run.

#### **4.3 CEM PARAMETERS**

The gas samples were drawn through a single-point, heated, stainless steel sample probe assembly with a heated out-of-stack particulate filter. The sample stream then passed through a heated Teflon sample line to an ice-bath condenser or a chiller unit where the moisture in the gas stream was removed. The dry sample was delivered through an unheated sample line to the instrument laboratory, where it was passed through an additional moisture knockout before entering a Teflon-lined pump and a manifold board where the gas sample was distributed to the

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**Figure 4-1. Stack Test Location.**



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individual gas analyzers at near atmospheric pressure. Excess sample flow from the system was vented outside the trailer.

A second Teflon sample line was also connected to the back end of the sample probe using a stainless steel tee. This second line was used to transport calibration gases from the control panel inside the trailer to the probe. During bias calibration checks, the gas flow was slightly greater than the total sample collection system flow and the small amount of excess calibration gas was vented through the probe assembly.

Signal outputs from the gas analyzers were sent to a computer utilizing a custom data acquisition software. Data for each analyzer were collected every second with one-minute averages written to the PC hard-drive. Data for the test period were averaged and corrected for calibration error, bias, and drift using a Microsoft Excel spreadsheet program.

Calibration of the gas analyzers was performed in accordance with the procedures outlined in EPA Reference Methods 3A for oxygen (O<sub>2</sub>) and carbon dioxide (CO<sub>2</sub>), and 7E for oxides of nitrogen (NO<sub>x</sub>). Before testing, a Calibration Error Test was performed where the gas analyzers were calibrated and linearity checked by introducing the calibration gases directly to the analyzer. Before the first run a System Bias Check was performed. At the completion of each run another System Bias and Drift Check was performed. The run average was then corrected for bias and drift. After completion of the Calibration Error Test, the CEM system was ready to collect emission data. No further adjustments of critical operating parameters were made for the duration of testing. A CEM stratification test was conducted during first test run. The results indicated the turbine was not stratified and the results are contained in Appendix E.

#### **4.3.1 U.S. EPA Method 3A: Determination Of Oxygen And Carbon Dioxide Concentrations**

Determination of the oxygen (O<sub>2</sub>) and carbon dioxide (CO<sub>2</sub>) concentrations in the exhaust gas samples were made using instrumentation and test procedures outlined in EPA Method 3A. This

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data was used for calculating the exhaust gas molecular weight.

A California Analytical Model 200 O<sub>2</sub> analyzer, or similar, was used to determine the concentration of O<sub>2</sub> in the flue gas stream. This instrument measures the paramagnetic susceptibility of the sample gas by means of a magneto-dynamic type measuring cell. The CAI measuring cell consists of a dumbbell of diamagnetic material, which is temperature controlled electronically at 50 °C. The higher the oxygen concentration, the greater the dumbbell is deflected from its rest position. This deflection is detected by an optical system connected to an amplifier. Surrounding the dumbbell is a coil of wire. A current is passed through this coil to return the dumbbell to the rest position. The current applied is linearly proportional to the percent oxygen concentration in the sample gas. This concentration is displayed on the front meter and a proportional analog output signal is generated

A Servomex, or similar, nondispersive infrared (NDIR) analyzer was used to continuously monitor the CO<sub>2</sub> concentration in the flue gas stream. The theory of operation for this analyzer is based on the principle that CO<sub>2</sub> gas has a unique absorption line spectrum in the infrared region. The instrument consists of an infrared light source, a chopper, a measuring cell, and a detector. The infrared light beam emitted by the source passes through the measuring cell filled with a continuously flowing gas sample. The light beam is partially absorbed or attenuated by the gas species of interest in this cell before reaching the front chamber of the detector.

Both the front and rear chambers of the sealed detector are filled with a reference gas. The difference in the amount of light absorbed between the front and rear chambers is dependent on the concentration of the gas species of interest within the sample measuring cell and creates a pressure differential between the two chambers. This pressure difference is then observed as gas flow by the micro-flow sensor located in a channel communicating the two chambers. The resulting AC signal from the micro-flow sensor is rectified, amplified, and linearized into a DC voltage signal for output.

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**4.3.2 U.S. EPA Method 7E: Determination of Oxides of Nitrogen Emissions from Stationary Sources (Instrumental Analyzer Procedure)**

The analyzer used was the Thermo Environmental (TECO) Model 42CHL chemiluminescent NO/NO<sub>x</sub> monitor. The instrument operation is based on the principal of the chemiluminescent reaction of nitric oxide (NO) and ozone. Light emission results when electronically excited nitrogen dioxide (NO<sub>2</sub>) molecules revert to their ground state. To measure NO concentrations, the gas sample to be analyzed is blended with ozone (O<sub>3</sub>) in the instrument's reaction chamber. The resulting chemiluminescence is monitored through an optical filter by a highly sensitive photomultiplier tube (PMT) positioned at one end of the reaction chamber. The filter/photomultiplier combination responds to light in a narrow wavelength band unique to this chemiluminescent reaction (detailed below). The filter assists in eliminating interference in this wavelength:



To measure NO<sub>x</sub> concentrations (NO plus NO<sub>2</sub>), the sample gas flow is diverted through a NO<sub>2</sub>-to-NO converter. The chemiluminescent response to the converter effluent in the reaction chamber is linearly proportional to the NO<sub>x</sub> concentration entering the converter (sample gas). The system was operated in the NO<sub>x</sub> mode during all phases of the program.

**4.4 U.S. EPA METHOD 4: DETERMINATION OF MOISTURE CONTENT**

The moisture content of the gas stream was determined according to EPA Method 4. The impinger contents were gravimetrically measured before and after completion of each sampling run. The net increase in the weight of each impinger was recorded to the nearest 0.1 gram using a digital balance. Calculations of the gas flow rates and sample volumes were adjusted to dry conditions based on the results from EPA Method 4.

## SECTION 5

### QUALITY ASSURANCE CONTROL

The objective of a QA/QC program is to assure that the precision and accuracy of all generated data is scientifically sound and documented to be in “in control.” To accomplish this, standardized methods or procedures are used. They must be validated for their intended use, rigorously followed, and data reported with quality indicators (precision, accuracy, completeness, representativeness, etc.).

The field sampling equipment, including dry gas meter orifices, pitot tubes, thermocouples, and other related equipment, are each assigned a unique, permanent identification number. Audit calibrations and preventive maintenance are performed prior to, and upon completion of sampling. Full calibrations are conducted on an annual basis with standards traceable to the National Institute of Technology and Standards (NIST). Calibration documentation is maintained by TRC’s Burr Ridge, Illinois office.

All sampling activities were well documented. Field sampling logs were maintained during field operations by the senior test member. Any anomalies incurred during testing are reported and recorded in the field logs. Sampling data were recorded on specific data sheets for each sampling method conducted. The senior test member was also responsible for all data sheets, which were collected immediately after completion, duplicated, and filed.

Sampling results and calculations were audited and/or automated in such a manner that human error is minimized. Data entry and calculations were audited by a team member other than the original author. If a difference greater than a typical round-off error was detected, all respective calculations were repeated. Final results were then submitted to a senior level engineer, who spot-checked a series of sampling runs.

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TRC's test teams are comprised of qualified, experienced professionals. Our experience enables us to implement the use of validated and standardized test methods and to modify these methods to meet unusual or complex testing requirements. TRC's Quality Assurance/Quality Control (QA/QC) Program is designed to guarantee measurement results that are legally defensible and within specified protocol.

As a guide, TRC uses the EPA document "Quality Assurance Handbook for Air Pollution Measurement System," Volume III (EPA-600/4-77-027b). TRC's QA/QC plan has incorporated certain considerations to the production of quality data in all of its sampling work regardless of the scope and purpose of the testing. These considerations include:

1. Planning the testing program;
2. Using reliable and well-maintained equipment;
3. Using appropriate forms for recording sampling data;
4. Establishing a sample coding system to ensure proper chain of custody (i.e., sample identification, laboratory tracing and storage, analysis and reporting);
5. Using calibration and audit gases traceable to the National Institute of Standards and Technology (NIST);
6. Controlling errors by checking data inputs and performing redundant calculations;
7. Adhering to established protocol.

## **5.1 SAMPLING TRAIN**

In order to maintain high analytical quality while reducing the chance of cross-contamination, TRC employed the use of a separate, pre-cleaned sample collection apparatus for each of the three test runs. All sample train glassware were pre-cleaned and sealed with Parafilm prior to field use.

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## 5.2 BAROMETER

Barometric pressure values for the testing period were recorded from the local Weather Service.

## 5.3 PITOT TUBES

Each Pitot tube used in sampling met the design specifications for Type S Pitot tubes in EPA Method 2. Therefore, in accordance with Method 2 procedures, a baseline coefficient ( $C_p$ ) of 0.84 was assigned to each Pitot tube. Calibration at the manufacturer for Pitot face-opening alignment included measuring the external tubing diameter (dimension  $D_t$ ), and the base-to-opening misalignment angles, with all terms as described in Figures 2-2 and 2-3 of EPA Method 2. Pitot tubes were visually inspected at the completion of the test to insure structural integrity. Pitot tube inspection sheets are presented in Appendix E of this final report.

## 5.4 CALIBRATION METER AND METERING SYSTEM

The calibration description for the dry gas metering system using critical orifices in lieu of the wet test meter is given in Section 7.2 of EPA Method 5. A leak check of the metering system before calibration was performed as shown in Figure 5.4 of EPA Method 5. The metering system's pump is operated for 5 minutes using the smallest orifice to heat up the pump and system to stabilize the meter inlet and outlet temperatures. Values for the orifice meter setting ( $\Delta H$ ), corresponding dry test meter volume ( $V_d$ ), dry test meter inlet and outlet gas temperatures ( $t_{di}$  and  $t_{dn}$ ), and time were recorded for the initial calibration. The ratio of the critical orifice volume to the dry test meter volume ( $\gamma$  or gamma) and the orifice pressure differential that equates to 0.75 cfm at standard conditions ( $\Delta H@$ ) were then calculated. A copy of the metering system calibration is included in Appendix E of this Test Report.

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**5.5 THERMOCOUPLES AND DIGITAL INDICATORS**

Thermocouples were originally calibrated by comparing them against an ASTM-3F mercury-in-glass thermometer at approximately 32°F (ice water), ambient temperature and approximately 212°F (boiling water). Each thermocouple was calibrated against temperature ranges to which it was to be typically exposed during test conditions, and they must agree within 1.5 percent (expressed in °K) of the reference thermometer throughout the entire calibration range. A post calibration was performed in accordance with EPA ALT-011 using a single point calibration against an ASTM mercury-in-glass thermometer in addition to a continuity check of the thermocouple. The continuity check involved verifying that the thermocouple read-out trended in the appropriate direction when exposed to a temperature change. The calibration check is included in Appendix E.

Digital indicators were checked by introducing a series of millivolt signal strengths to the input and comparing the indicator reading with the actual signal strength. Acceptable calibration error does not exceed 0.5 percent when temperatures are expressed in °R.

**5.6 POST-TEST METER CALIBRATION CHECK**

Post-test meter calibrations to determine the  $\gamma$  (or Yqa) were conducted on the dry gas to check their accuracy against the original pretest calibration. This post-test calibration was made using the alternative procedure defined by EPA as ALT-009. This procedure is performed on-site using the data collected for each of the test runs. It is preferred by EPA because it eliminates the questions about possible meter damage during transport *after* the emission test and, because the calibration data are available in the field immediately following the test, it eliminates the costly travel, remobilization, and scheduling of a retest should the meter fail the post-test calibration. Additionally, the metering system was subjected to and passed the leak check procedure defined in Method 5 Item 5.6. A copy of pre-test meter calibrations is included in Appendix E of this Test Report. The post-test calibrations are also included in Appendix E. A complete copy of EPA ALT-009 is available from EPA from the EMC website at <http://www.epa.gov/ttn/emc/>.

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**5.7 CONTINUOUS EMISSION MONITORING SYSTEM QA/QC**

The CEMS was calibrated in accordance with the specific test methods referenced in Section 4. The system response time was determined to be less than 2 minutes. In general, the QA/QC measures included the use of Protocol 1 calibration gases, Calibration Error Tests, pre and post-run System Bias and Drift Checks. Copies of the certifications for the Protocol 1 gas standards are included in Appendix D. Copies of the CEMS Calibration Error Tests and System Bias Checks are included with the field data in Appendix B. Copies of each post-run System Bias Check include the corrected test run averages.

**5.8 DATA REDUCTION AND VALIDATION**

The data collected in the field were recorded on standardized data sheets or printed directly from the reference method CEM system. The Field Team Leader reviewed the collected data in the field and made note of any discrepancies or errors. TRC CEMS Supervisors and/or QC Coordinator validated the field data based on the test plan and the standard operating procedures for each method. They also checked the calculation spreadsheets for correct data entry and calculation equations

**5.9 AETB INFORMATION**

TRC is operating in conformance with ASTM D7036-04, Standard Practice for Competence of Air Emission Testing Bodies (AETB). A certificate of interim accreditation, issued by the Stack Testing Accreditation Council (STAC) is included in Appendix F. The testing was overseen and supervised on site by at least one TRC Qualified Individual. Copies of the Qualified Individual certificates are also included in Appendix F.