Derenzo and Associates, Inc.
Environmental Consultants

EMISSION TEST REPORT

Title	NSPS TEST REPORT FOR THE VERIFICATION OF AIR POLLUTANT EMISSIONS FROM A BIOGAS FUELED INTERNAL COMBUSTION ENGINE
Report Date	May 26, 2015
Test Date(s)	April 22, 2015

Facility Information	
Name:	Bell's Brewery, Inc.
Street Address:	8938 Krum Ave.
City, County:	Galesburg, Kalamazoo

Facility Permit Information			
Facility SRN:	P0516	Permit to Install No.:	102-14

Testing Contractor	
Company:	Derenzo and Associates, Inc.
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Project No.:	1411007

NSPS TEST REPORT
FOR THE VERIFICATION OF
AIR POLLUTANT EMISSIONS
FROM A
BIOGAS FUELED INTERNAL COMBUSTION ENGINE
OPERATED AT
BELL'S BREWERY

1.0 INTRODUCTION

Bell's Brewery, Inc. (Bell's Brewery) installed one (1) Caterpillar (CAT®) Model No. G3406 biogas fueled reciprocating internal combustion engine (RICE) and generator set at its facility (Facility SRN: P0516) in Galesburg, Kalamazoo County, Michigan. The RICE is fueled with biogas that is produced in a wastewater digester (EUDIGESTER). The facility has been issued Permit to Install (PTI) No. 102-14 by the Michigan Department of Environmental Quality – Air Quality Division (MDEQ-AQD).

The CAT® Model No. G3406 engine is exempt from the requirement to obtain a PTI (Rule 285(g)), however, the engine is identified in PTI No. 102-14 as a pollution control device for biogas produced in EUDIGESTER.

Air emission compliance testing was performed to demonstrate initial compliance with 40 CFR 60, Subpart JJJJ which states:

> *... if you are an owner or operator of a stationary SI internal combustion engine greater than 25 HP and less than or equal to 500 HP, you must keep a maintenance plan and records of conducted maintenance and must, to the extent practicable, maintain and operate the engine in a manner consistent with good air pollution control practice for minimizing emissions. In addition, you must conduct an initial performance test to demonstrate compliance.*

The initial compliance testing was performed by Derenzo and Associates, Inc. (Derenzo and Associates), an environmental consulting and testing company founded in 1989. Derenzo and Associates representative Andy Rusnak performed the field sampling and measurements on April 22, 2015. Ms. Dorothy Bohn from the MDEQ-AQD was on-site to witness the performance demonstration.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Protocol dated February 9, 2015.

1.1 Project Contact Information

Questions regarding this emission test report should be directed to:

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Sustainability Specialist
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1.2 Report Certification

This test report was prepared by Derenzo, Associates, Inc. based on field sampling data collected by Derenzo and Associates, Inc. Facility process data were collected and provided by Bell's Brewery employees or representatives. This test report has been reviewed by Bell's Brewery representatives and approved for submittal to the MDEQ-AQD.

I certify that the testing was conducted in accordance with the approved 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:

Andy Rusnak, QSTI
Technical Manager
Derenzo and Associates, Inc.

I certify that the facility and emission units were operated at maximum routine operating conditions for the test event. Based on information and belief formed after reasonable inquiry, the statements and information in this report are true, accurate and complete.

Walker Modic
Sustainability Specialist
Bell's Brewery, Inc.

2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

Biogas containing methane is produced in the Bell's Brewery wastewater digester (EUDIGESTER) from the anaerobic decomposition of waste materials. The biogas is collected and is directed to the engine facility where it is treated and used as fuel for the RICE generator that produces electricity for transfer to the local utility. In addition to the RICE, the facility operates an enclosed flare which also combusts the biogas.

Appendix 1 provides a process flow diagram of the engine tested.

2.2 Rated Capacities, Type and Quantity of Raw Materials Used

The CAT® G3406 RICE has a rated output of 214 brake-horsepower (bhp) and the connected generator has a rated electricity output of 150 kilowatts (kW). The engine is designed to fire low-pressure, lean fuel mixtures (e.g., biogas). A certain heat input rate is required to maintain base load conditions. Therefore, the actual volumetric flowrate of treated fuel is dependent on the fuel heating value, or methane content.

2.3 Emission Control System Description

The CAT® G3406 engine does not have any add-on emission control equipment. The air-to-fuel ratio and ignition timing are set to maintain efficient fuel combustion, which minimizes air pollutant emissions. Exhaust gas is exhausted directly to atmosphere through a noise muffler and vertical exhaust stack.

2.4 Sampling Locations (USEPA Method 1)

The exhaust stack sampling ports for the RICE satisfied the USEPA Method 1 criteria for a representative sample location. The inner diameter of the engine exhaust stack is 8.0 inches. The engine stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location >120 inches (>15.0 diameters) downstream and >36 inches (>4.5 diameters) upstream from the nearest flow disturbance.

Appendix 1 provides diagrams of the performance test sampling locations.

3.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

3.1 Purpose and Objectives of the Tests

Table 1 of the SI-RICE NSPS (40 CFR Part 60, Subpart JJJJ) requires that a performance test be conducted on new SI RICE. Specifically 40 CFR Part 60.4243(b)(2)(i) states:

> *...if you are an owner or operator of a stationary SI internal combustion engine greater than 25 HP and less than or equal to 500 HP, you must keep a maintenance plan and records of conducted maintenance and must, to the extent practicable, maintain and operate the engine in a manner consistent with good air pollution control practice for minimizing emissions. In addition, you must conduct an initial performance test to demonstrate compliance.*

The exhaust from the biogas fueled RICE was monitored for three (3) one-hour test periods during which the VOC, NO_x, CO, oxygen (O_2) and carbon dioxide (CO_2) exhaust gas concentrations were measured using instrumental analyzers. Exhaust gas moisture content for the engine was determined by gravimetric weight gain in chilled impingers.

The measured exhaust concentrations were corrected to 15% O_2 on a dry basis for compliance determinations (i.e., exhaust gas flowrate measurements were not performed on the IC engine exhaust stack).

3.2 Variations from Normal Sampling Procedures or Operating Conditions

The testing was performed in accordance with the Test Protocol dated February 9, 2015 and specified USEPA test methods. All instrument calibrations and sampling period results satisfied the quality assurance verifications required by USEPA Methods 3A, 7E, 10, 25A and ALT-096. No variations from the normal operating conditions of the RICE occurred during the testing program.

3.3 Operating Conditions During the Compliance Test

The testing was performed while the engine/generator set was operated at maximum operating conditions (within 10% of maximum rated electricity output of 150 kW). Facility representatives provided generator kW output data at 15-minute intervals for each test period. The generator kW output ranged between 146 and 153 kW during the test periods.

Fuel flowrate (cubic feet per minute) and fuel CO_2 content (%) were also recorded by facility representatives at 15-minute intervals for each test period. The fuel consumption rate ranged between 45 and 47 scfm and the fuel CO_2 content ranged between 26 and 30% during the test periods.

Appendix 2 provides operating records provided by facility representatives for the test periods.

Engine output (bhp) cannot be measured directly and was calculated based on the recorded electricity output, the calculated CAT® G3406 generator efficiency (94.0%), and the unit conversion factor for kW to horsepower (0.7457 kW/hp).

Engine output (bhp) = Electricity output (kW) / (0.940) / (0.7457 kW/hp)

Table 3.1 presents a summary of the average engine operating conditions during the test periods.

3.4 Summary of Air Pollutant Sampling Results

The gases exhausted from the sampled biogas fueled RICE were sampled for three (3) one-hour test periods during the compliance testing performed April 22, 2015.

Table 3.2 presents the average measured CO, NO_x and VOC emission rates for the engine (average of the three test periods for the engine).

The SI-RICE NSPS (40 CFR Part 60 Subpart JJJJ Table 1) specifies the following emission standards for a landfill/digester gas fueled engine with a power rating greater than 25 bhp but less than or equal to 500 bhp:

- CO emissions shall not exceed 5.0 grams per bhp-hour (g/bhp-hr), or an exhaust gas concentration of 610 parts per million by volume, dry basis, corrected to 15% oxygen (ppmvd at 15% O_2).

- NO_X emissions shall not exceed 2.0 g/bhp-hr or an exhaust gas concentration of 150 ppmvd at 15% O_2.

- VOC emissions shall not exceed 1.0 g/bhp-hr or an exhaust gas concentration of 80 ppmvd at 15% O_2.

Results of the engine performance tests demonstrate compliance with emission limits specified in 40 CFR 60, Subpart JJJJ.

Test results for each one hour sampling period are presented in Section 6.0 of this report.

Table 3.1 Average process operating conditions during the test periods

Engine Parameter	CAT Model G3406 RICE
Generator output (kW)	149.5
Engine output (bhp)	213.2
Engine biogas fuel use (scfm)	45.7
Biogas CO_2 content (%)	29.5

Table 3.2 Average measured exhaust gas pollutant concentrations for the Bell's Brewery biogas-fueled RICE generator set (three-test average)

Emission Unit	CO (ppmvd @ 15% O_2)	NOx (ppmvd @ 15% O_2)	VOC[1] (ppmvd @ 15% O_2)
Engine	182	120	10.0
NSPS Standard	*610*	*150*	*80*

1. Measured as propane

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A test protocol for the compliance testing was prepared by Bell's Brewery and Derenzo and Associates and reviewed by the MDEQ-AQD. This section provides a summary of the sampling and analytical procedures that were used during the tests and presented in the test plan.

4.1 Summary of Sampling Methods

USEPA Method 3A	Exhaust gas O_2 and CO_2 content was determined using 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 NO_x concentration was determined using chemiluminescence instrumental analyzers.
USEPA Method 10	Exhaust gas CO concentration was measured using infrared instrumental analyzers.
USEPA Method 25A / ALT-096	Exhaust gas VOC (as NMHC) concentration was determined using flame ionization analyzers equipped with GC columns.

4.2 Exhaust Gas Molecular Weight Determination (USEPA Methods 3A)

CO_2 and O_2 content in the RICE 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 Servomex 1440D single beam single wavelength (SBSW) infrared gas analyzer. The O_2 content of the exhaust was monitored using a Servomex 1440D gas analyzer that uses a paramagnetic sensor.

During each sampling period, a continuous sample of the RICE 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 3 provides O_2 and CO_2 calculation sheets. Raw instrument response data are provided in Appendix 4.

4.3 Exhaust Gas Moisture Content (USEPA Method 4)

Moisture content of the RICE 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.

4.4 NO_x and CO Concentration Measurements (USEPA Method 7E and 10)

NO_x and CO pollutant concentrations in the RICE exhaust gas stream were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42c High Level chemiluminescence NO_X analyzer and a TEI Model 48c infrared CO analyzer.

Throughout each test period, a continuous sample of the engine exhaust gas was extracted from the stack using the Teflon® heated sample line and gas conditioning system and delivered to the instrumental analyzers. Instrument response for each analyzer was recorded on an ESC Model 8816 data acquisition system that 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.

Appendix 3 provides CO and NO_X calculation sheets. Raw instrument response data are provided in Appendix 4.

4.5 VOC Concentration Measurements (USEPA Method ALT-096)

The VOC concentration was determined by measuring the nonmethane hydrocarbon (NMHC) concentration in the IC engine exhaust gas. NMHC pollutant concentration was determined using a TEI Model 55i Methane / Nonmethane hydrocarbon analyzer. The TEI 55i analyzer contains an internal gas chromatograph column that separates methane from non-methane components and has been approved by the USEPA for measuring VOC relative to 40 CFR Part 60 Subpart JJJJ compliance test demonstrations (Alternative Test Method 096 or ALT-096). The concentration of NMHC in the sampled gas stream, after separation from methane, is determined relative to a propane standard using a flame ionization detector in accordance with USEPA Method 25A.

Samples of the exhaust gas were delivered directly to the instrumental analyzer using the Teflon® heated sample line to prevent condensation. The sample to the NHMC analyzer was not conditioned to remove moisture. Therefore, VOC measurements correspond to standard conditions with no moisture correction (wet basis).

Appendix 3 provides VOC calculation sheets. Raw instrument response data for the NMHC analyzer is provided in Appendix 4.

5.0 QA/QC ACTIVITIES

5.1 NO_x Converter Test

The NO_2 – NO conversion efficiency of the Model 42c analyzer was verified prior to the testing program. 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 NO_2 concentration is within 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_2 concentration was -6.65% of the expected value, i.e., within 10% of the expected value as required by Method 7E).

5.2 Sampling System Response Time Determination

The response time of the sampling system was determined prior to the compliance test program by introducing upscale gas and zero gas, in series, into the sampling system using a tee connection at the base of the sample probe. The elapsed time for the analyzer to display a reading of 95% of the expected concentration was determined using a stopwatch.

The TEI Model 48c analyzer exhibited the longest system response time at 74 seconds. Results of the response time determinations were recorded on field data sheets. For each test period, test data were collected once the sample probe was in position for at least twice the maximum system response time.

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 previous 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 delivered 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 NO_X, CO, O_2 and CO_2 have had an interference response test preformed prior to their use in the field (July 26, 2006, June 21, 2011 and June 12, 2014), 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 3.0% 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 NO_x, CO, 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.

At the beginning of each test day, appropriate high-range, mid-range, and low-range span gases followed by a zero gas were introduced to the NMHC analyzer, in series at a tee connection, which is installed between the sample probe and the particulate filter, through a poppet check valve. After each one hour test period, mid-range and zero gases were re-introduced in series at the tee connection in the sampling system to check against the method's performance specifications for calibration drift and zero drift error.

The instruments were calibrated with USEPA Protocol 1 certified concentrations of CO_2, O_2, NO_x, and CO in nitrogen and zeroed using hydrocarbon free nitrogen. The NMHC (VOC) instrument was calibrated with USEPA Protocol 1 certified concentrations of propane in air and zeroed using hydrocarbon-free air. 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 on the RICE 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 RICE exhaust stack indicates that the measured NO_x, CO, O_2 and CO_2 concentrations did not vary by more than 5% of the mean across the stack diameter. Therefore, the RICE exhaust gas was considered to be unstratified and the compliance test sampling was performed at a single sampling location within the RICE exhaust stack.

5.7 Meter Box Calibrations

The Nutech Model 2010 sampling console, which was used for exhaust gas moisture content sampling, was calibrated prior to and after the testing program. 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 Nutech metering consoles were calibrated using a NIST traceable Omega® Model CL 23A temperature calibrator.

Appendix 5 presents test equipment quality assurance data (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 stratification checks).

6.0 RESULTS

Engine operating data and air pollutant emission measurement results for each one hour test period are presented in Tables 6.1.

The measured air pollutant concentrations for the RICE are less than the exhaust gas concentration limits specified in SI RICE NSPS:

- 610 ppmvd at 15% O_2 for CO;
- 150 ppmvd at 15% O_2 for NOx; and
- 80 ppmvd at 15% O_2 for VOC.

Table 6.1 Measured exhaust gas conditions and air pollutant emission concentrations for the Bell's Brewery IC engine

Test No. Test date Test period (24-hr clock)	1 4/22/2015 826 - 926	2 4/22/2015 1010 - 1110	3 4/22/2015 1135 - 1235	Three-Test Average
Generator output (kW)	148.8	149.8	149.8	149.5
Engine output (bhp)	212.3	213.7	213.7	213.2
LFG flowrate (scfm)	46.0	46.2	45.0	45.7
LFG CO_2 content (% vol)	29.2	29.2	30.0	29.5
Exhaust gas composition				
CO_2 content (% vol)	11.5	11.5	11.4	11.5
O_2 content (% vol)	6.16	6.18	6.33	6.22
Moisture (% vol)	13.4	11.6	12.8	12.6
Carbon monoxide emission rates				
CO conc. (ppmvd)	456	450	451	452
CO conc. (ppmvd@ 15% O_2)	182	181	183	182
CO NSPS limit (ppmvd@ 15% O_2)	--	--	--	610
Nitrogen oxides emission rates				
NO_X conc. (ppmvd)	315	297	283	298
NO_X conc. (ppmvd@ 15% O_2)	126	119	115	120
NO_X NSPS limit (ppmvd@ 15% O_2)	--	--	--	150
VOC emission rates				
VOC conc. (ppmv)	21.7	21.8	21.7	21.7
VOC conc. (ppmvd@ 15% O_2)	10.0	9.90	10.1	10.0
VOC NSPS limit (ppmvd@ 15% O_2)	--	--	--	80