Derenzo and Associates, Inc.
*Environmental Consultants*

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EMISSIONS TEST REPORT

| | |
|---|---|
| Title | Emission Test Report for a Natural Gas-Fueled Internal Combustion Engine Operated at the Hayes 29 CPF/Wilderness $CO_2$ Central Production Facility |
| Report Date | June 5, 2015 |
| Test Date(s) | April 21, 2015 |

| Facility Information | |
|---|---|
| Name: | LINN Operating Inc.<br>Hayes 29 CPF/Wilderness $CO_2$ Central Production Facility |
| Street Address: | 10875 Geronimo Trail |
| City, County: | Gaylord, Otsego |
| Phone: | (231) 941-4772 |

| Facility Permit Information | | | |
|---|---|---|---|
| State Registration No.: | N5831 | ROP No.: | MI-ROP-N5831-2014 |

| Testing Contractor | |
|---|---|
| Company | Derenzo and Associates, Inc. |
| Mailing Address | 39395 Schoolcraft Road<br>Livonia, MI 48150 |
| Phone | (734) 464-3880 |
| Project No. | 1412013 |

DEQ

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR QUALITY DIVISION

# RENEWABLE OPERATING PERMIT
# REPORT CERTIFICATION

*Authorized by 1994 P.A. 451, as amended. Failure to provide this information may result in civil and/or criminal penalties.*

**Reports submitted pursuant to R 336.1213 (Rule 213), subrules (3)(c) and/or (4)(c), of Michigan's Renewable Operating Permit (ROP) program must be certified by a responsible official. Additional information regarding the reports and documentation listed below must be kept on file for at least 5 years, as specified in Rule 213(3)(b)(ii), and be made available to the Department of Environmental Quality, Air Quality Division upon request.**

Source Name: Linn Operating, Inc - Hayes 29 CPF    County: Otsego

Source Address: 10875 Geronimo Trail    City: Gaylord

AQD Source ID (SRN): N5831    ROP No.: N5831-2014    ROP Section No.: 02

Please check the appropriate box(es):

☐ **Annual Compliance Certification (Pursuant to Rule 213(4)(c))**

Reporting period (provide inclusive dates): From ________ To ________

☐ 1. During the entire reporting period, this source was in compliance with **ALL** terms and conditions contained in the ROP, each term and condition of which is identified and included by this reference. The method(s) used to determine compliance is/are the method(s) specified in the ROP.

☐ 2. During the entire reporting period this source was in compliance with all terms and conditions contained in the ROP, each term and condition of which is identified and included by this reference, **EXCEPT** for the deviations identified on the enclosed deviation report(s). The method used to determine compliance for each term and condition is the method specified in the ROP, unless otherwise indicated and described on the enclosed deviation report(s).

☐ **Semi-Annual (or More Frequent) Report Certification (Pursuant to Rule 213(3)(c))**

Reporting period (provide inclusive dates): From ________ To ________

☐ 1. During the entire reporting period, **ALL** monitoring and associated recordkeeping requirements in the ROP were met and no deviations from these requirements or any other terms or conditions occurred.

☐ 2. During the entire reporting period, all monitoring and associated recordkeeping requirements in the ROP were met and no deviations from these requirements or any other terms or conditions occurred, **EXCEPT** for the deviations identified on the enclosed deviation report(s).

☒ **Other Report Certification**

Reporting period (provide inclusive dates): From ________ To ________

Additional monitoring reports or other applicable documents required by the ROP are attached as described:

Test Report for natural gas fired IC enginee (EUENGINEH29).

The testing was conducted in accordance with the Test Plan dated March 6, 2015 and the facility was operated in compliance with the permit conditions or at the maximum routine operating conditions for the facility.

I certify that, based on information and belief formed after reasonable inquiry, the statements and information in this report and the supporting enclosures are true, accurate and complete

| Ryan Martin | Engineering/Prod Ops Manager | 281-840-4108 |
|---|---|---|
| Name of Responsible Official (~~print or type~~) | Title | Phone Number |

[signature] 6/8/15

Signature of Responsible Official    Date

* Photocopy this form as needed.

EQP 5736 (Rev 11-04)

EMISSION TEST REPORT
FORA
NATURAL GAS-FUELED
INTERNAL COMBUSTION ENGINE

LINN OPERATING INC.
HAYES 29 CENTRAL PRODUCTION FACILITY

## 1.0 INTRODUCTION

LINN Operating, Inc. (LINN) and Breitburn Operating, LP (Breitburn) own and operate stationary natural gas fired engines at a common facility located in Gaylord, Otsego County, Michigan. The Wilderness $CO_2$ Central Production Facility (CPF) / Hayes 29 CPF stationary source has been issued a Renewable Operating Permit (ROP, MI-ROP-N5831-2014) by the Michigan Department of Environmental Quality (MDEQ) that is divided into two sections and specifies equipment owned and operated by each company.

LINN operates one (1) natural gas fueled reciprocating internal combustion engine (RICE) designated as emission unit EUENGINEH29. Section 2, Special Condition V.1 of the Renewable Operating Permit (ROP) issued to Breitburn (MI-ROP-N5831-2014) specifies that:

> *The permitee shall verify NOx and CO emission rates from each EUENGINEH29, by testing at owners expense within 9 months of issuance of this permit* (i.e. by May 4, 2015) *and thereafter within every 5 years , in accordance with Department requirements.*

The performance testing consisted of triplicate, one-hour test runs for the determination of nitrogen oxides (NOx) and carbon monoxide (CO) emission rates from the engine identified in the ROP. Exhaust gas velocity, moisture, oxygen ($O_2$) content, and carbon dioxide ($CO_2$) content was determined for each test period to calculate volumetric exhaust gas flowrate and pollutant mass emission rates. Instrument analyzers were used for real time analysis of NOx and CO concentrations.

The compliance testing was performed on April 21, 2015, by Derenzo and Associates, Inc., an environmental consulting and testing company based in Livonia, Michigan. Daniel Wilson and Kalan Briggs of Derenzo and Associates performed the testing. Process operations were coordinated by Ms. Diane Lundin of LINN and Eric Vincke of Gosling Czubak. Mr. Jeremy Howe of the MDEQ observed portions of the testing.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Protocol dated March 6, 2015 and approved by the MDEQ.

Questions regarding this emission test report should be directed to:

Mr. Daniel Wilson
Environmental Consultant
Derenzo and Associates, Inc.
39395 Schoolcraft
Livonia, MI 48150
(734) 464-3880

Diane Lundin
EHS Advisor
LINN Energy, LLC
226 E Sixteenth St Ste A
Traverse City, Michigan 49684-4192
(231) 941-4772

**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 LINN Operating Inc. employees or representatives.

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:

Daniel Wilson
Environmental Consultant
Derenzo and Associates, Inc.

Reviewed By:

Robert L. Harvey, P.E.
General Manager
Derenzo and Associates, Inc.

This test report has been reviewed by LINN representatives and approved for submittal to the MDEQ. I certify that the facility operating conditions were in compliance with permit requirements and were at the maximum routine operating conditions for the facility. Based on information and belief formed after reasonable inquiry, the statements and information in this report are true, accurate and complete.

Diane Lundin
EHS Advisor
LINN Energy, Inc.

## 2.0 SUMMARY OF RESULTS

The exhaust gas from the natural gas-fueled RICE was monitored for three (3) one-hour test periods during which the NOx, CO, $O_2$, and $CO_2$ concentrations were measured using instrumental analyzers. Exhaust gas flowrate measurements were conducted prior to and following each one-hour test period to calculate average exhaust flowrates for the engine, and ultimately pollutant mass emission rates.

The testing was performed while the natural gas-fueled RICE was operated at the maximum conditions (maximum fuel use and horsepower output) allowed by the process, which is dependent on facility and gas well conditions. Fuel use data were recorded by facility operators to calculate CO and NOx emission factors per amount of fuel used (pounds per million cubic feet of natural gas fuel, lb/MMcf).

The following table presents a summary of the average measured CO and NOx emission rates for the engine and a comparison of the results to the permitted pollutant emission rates. Table 1 at the end of this report presents measured exhaust gas pollutant concentrations and mass emission rates for each one-hour test period.

| | NOx Emission Rates | | | CO Emission Rates | | |
|---|---|---|---|---|---|---|
| Emission Unit ID | (lb/hr) | (lb/MMscf) | (TpY)[1] | (lb/hr) | (lb/MMscf) | (TpY)[1] |
| EUENGINEH29 | 0.87 | 97.18 | 3.80 | 0.002 | 0.19 | <0.1 |
| *Permit Limit* | | | *24.60* | | | *41.10* |

1. Calculated ton per year (TpY) emission rate based on continuous operation at the measured emission rate.

## 3.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

### 3.1 General Process Description

The Hayes 29 CPF processes natural gas by removing moisture and compressing the processed gas into a sales pipeline.

LINN operates one (1) natural gas fueled RICE identified as EUENGINEH29 that is connected to an individual gas compressor. Facility operators refer to the engine as, No. 29. Therefore, both identifications are used throughout this report.

### 3.2 Rated Capacities, Type and Quantity of Raw Materials Used

The CAT® 3516 RICE has a design power rating of 1,085 brake horsepower. Fuel (natural gas) consumption and combustion air flowrate is regulated by the engine to maintain the required heat input rate and horsepower to drive the associated gas compressor. Facility operators recorded the fuel use rate (thousand standard cubic feet per day, Mscf/day) throughout each one-hour test period.

Appendix A provides engine process data collected during the compliance test.

### 3.3 Emission Control System Description

Air pollutant emissions are minimized by the lean-burn design of the CAT® 3516 RICE. Additionally, the RICE exhaust gas is directed through an add-on emission control catalyst (oxidation catalyst) that reduces CO and other hydrocarbon emissions prior to the release to the ambient air.

### 3.4 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 RICE exhaust stack is 12.25 inches. The stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location approximately 20 feet (19.6 duct diameters) downstream and 36 inches (2.9 duct diameters) upstream from any flow disturbance.

Velocity pressure traverse locations for the sampling points were determined in accordance with USEPA Method 1.

Figure 1 presents the performance test sampling and measurement locations.

## 4.0 TEST RESULTS AND DISCUSSION

### 4.1 Purpose and Objectives of the Tests

Compliance testing for EUENGINEH29 is required by MI-ROP-N5831-2014. The permit specifies that at least once every five (5) years NOx and CO emissions shall be measured to develop an emission factor to be used in calculating 12-month rolling total emission rates based on fuel use.

The exhaust from the natural gas-fueled RICE was monitored for three (3) one-hour test periods during which the NOx, CO, $O_2$, and $CO_2$ concentrations were measured using instrumental analyzers. Exhaust gas moisture content was determined by gravimetric analysis of the weight gain in chilled impingers in accordance with USEPA Method 4. Velocity and volumetric flow rates were measured near the beginning and ending of each one-hour sampling period.

### 4.2 Variations from Normal Sampling Procedures or Operating Conditions

The compliance tests for all pollutants were performed in accordance with the Test Protocol dated March 6, 2015; and the specified USEPA test methods.

Instrument calibrations and sampling period results satisfied the quality assurance verifications required by USEPA Methods 3A, 7E, and 10. No variations from the normal operating conditions of the RICE occurred during the testing program.

### 4.3 Operating Conditions during Compliance Tests

During the emission testing, the natural gas-fueled RICE was operated at the maximum conditions (maximum fuel use and horsepower output) allowed by the process, which is dependent on facility and gas well conditions. Facility operators recorded the fuel use rate (Mscf/day) throughout each one-hour test period.

Based on data provided by the facility operators, Engine #29 consumed an average of 214.3 thousand cubic feet per day (Mcf/d), which is equivalent to a flow of 8,929 standard cubic feet per hour.

### 4.4 Air Pollutant Sampling Results

The RICE emission measurements were performed on April 21, 2015. The average measured exhaust gas volumetric flow rate for Engine No. 29 (EUENGINEH29) was 2,107 dry standard cubic feet per minute (dscfm) and contained 57.5 parts per million by volume (ppmvd) NOx and 0.18 ppmvd CO. The average measured NOx and CO emission rates are equivalent to 97.2 pounds per million standard cubic feet (lb/MMscf) and 0.19 lb/MMscf, respectively.

Table 1 presents measured exhaust gas conditions and calculated air pollutant emission rates for Engine No. 29.

Appendix B provides computer calculated and field data sheets for the emission tests periods.

Appendix C provides raw instrumental analyzer response data for each test period.

## 5.0 SAMPLING AND ANALYTICAL PROCEDURES

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

Appendix D presents sample procedures and diagrams for the USEPA sampling methods.

### 5.1 Exhaust Gas Velocity and Flowrate Determination (USEPA Method 2)

The RICE exhaust stack gas velocity was determined using USEPA Method 2 prior to and following each 60-minute sampling period. An S-type Pitot tube connected to a red-oil manometer was used to determine velocity pressure. Gas temperature was measured using a K-type thermocouple mounted to the Pitot tube. The Pitot tube and connective tubing were leak-checked to verify the integrity of the measurement system.

The absence of cyclonic flow for each sampling location was verified using an S-type Pitot tube and oil manometer. The Pitot tube was positioned at all of the velocity traverse points 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). The calculated pre-test and post-test volumetric flowrate values were averaged and used for calculating the mass emission rate for each pollutant for that test period.

### 5.2 Exhaust Gas Molecular Weight Determination (USEPA Method 3A)

$CO_2$ and $O_2$ content in the RICE exhaust gas stream was measured continuously throughout each one-hour test period in accordance with USEPA Method 3A. The $CO_2$ content of the exhaust was monitored using a non-dispersive infrared (NDIR) gas analyzer. The $O_2$ content of the exhaust was monitored using a gas analyzer that utilizes a Paramagnetic sensor.

During each one-hour 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 analyzer. Therefore, measurement of $O_2$ and $CO_2$ concentrations correspond to standard dry gas conditions. The instrument was calibrated using appropriate calibration gases to determine accuracy and system bias (described in Section 6.4 of this document).

Figure 2 presents a diagram of the instrument analyzer train.

Appendix D presents detailed gas sampling procedures for the USEPA sampling trains.

### 5.3 Exhaust Gas Moisture Content Determinations (Method 4)

Moisture content of the RICE exhaust gas was determined in accordance with USEPA Method 4 using a chilled impinger sampling train, which was performed concurrently with the instrumental analyzer sampling methodologies. A non-heated probe was used for the moisture determinations as the engine exhaust temperature was approximately 700°F. During each sampling period, a gas sample was extracted at a predetermined 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. Gas moisture content was calculated based on the net water gain in the impinger train and the amount of dry gas metered through the sampling train.

Figure 3 presents a diagram of the moisture sampling train.

Appendix D presents detailed gas sampling procedures for the USEPA moisture sampling train.

### 5.4 NOx and CO Concentration Measurements (USEPA Methods 7E and 10)

NOx and CO pollutant concentrations in the RICE exhaust gas were determined using a chemiluminescence NOx analyzer and non-dispersive infrared (NDIR) CO analyzer.
Three (3) one-hour sampling periods were performed for the RICE exhaust testing. Throughout each one-hour 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 described in Section 5.2 of this document, and delivered to the instrumental analyzers. Sampling was performed at a single point in the exhaust stack that was closest to the mean, based on the results of the stratification test (the exhaust gases were determined to be unstratified).

Instrument response for each analyzer was recorded on a data logging 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 appropriate upscale calibration and zero gas to determine analyzer calibration error and system bias. Sampling times were recorded on field data sheets.

Appendix B presents the computer calculated and field data sheets from the testing program.

## 6.0 QA/QC ACTIVITIES

### 6.1 NOx Converter Efficiency Test

The $NO_2$ – NO conversion efficiency of the TEI Model 42C instrumental analyzer was verified prior to the commencement of the performance tests. The instrument analyzer $NO_2$ – NO converter uses a catalyst at high temperatures to convert the $NO_2$ to NO for measurement. A USEPA Protocol 1 certified $NO_2$ calibration gas was used to verify the efficiency of the $NO_2$ – NO converter.

The $NO_2$ – NO conversion efficiency test satisfied the USEPA Method 7E criteria (the calculated $NO_2$ – NO conversion efficiency is greater than or equal to 90%).

### 6.2 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.

Sampling periods did not commence until the sampling probe had been in place for at least twice the system response time.

### 6.3 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NOx, CO, $O_2$, 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 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.

### 6.4 Instrument Calibration and System Bias Checks

At the beginning of the test day, initial three-point instrument calibrations were performed by injecting calibration gas directly into the inlet sample port for each instrument. System bias checks were preformed prior to and at the conclusion of each sampling period by introducing the appropriate 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 verifying the instrument response against the initial instrument calibration readings. If the drift error is within 3% of the span over the period of the test run, the test run is considered acceptable.

The instruments were calibrated with USEPA Protocol 1 certified concentrations of $CO_2$, $O_2$, NOx, CO, and zeroed using pure nitrogen or hydrocarbon free air.

A ten-step gas dilution module (STEC Model SGD-710C) was used to provide intermediate calibration gas concentrations as needed. The ten-step gas divider was NIST certified within the previous year with a primary flow standard in accordance with Method 205. 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.

The CO analyzer was initially ranged for the expected concentration based on the previous test results (247 ppmv) and the allowable emission rate (which is equivalent to approximately 1,000 ppmv). The measured CO emission concentration was less than 1 ppmv due to the efficiency of the oxidation catalyst. The CO analyzer displayed acceptable linearity throughout the calibration range and remained at the higher range throughout the test. This was discussed with and approved by the on-site MDEQ representative (Jeremy Howe).

## 6.5 Meter Box Calibrations

The dry gas meter sampling console used for moisture testing was calibrated prior to and after the testing program. This calibration uses the critical orifice calibration technique presented in USEPA Method 5. The metering consol calibration exhibited no data outside the acceptable ranges presented in USEPA Method 5.

Appendix E presents test equipment quality assurance data ($NO_2$ – NO conversion efficiency test data, instrument calibration and system bias check records, calibration gas certifications, interference test results, meter box calibration records, and pitot tube calibration records).

Table 1. Summary of Engine No. 29 (EUENGINE19) exhaust gas conditions and air pollutant emission rate

| Test No.<br>Test date<br>Test period (24-hr clock) | 1<br>04/21/15<br>9:40-10:40 | 2<br>04/21/15<br>11:02-12:02 | 3<br>04/21/15<br>12:30-13:30 | Test<br>Avg. |
|---|---|---|---|---|
| **Fuel use data** | | | | |
| 1,000 cubic feet per day (Mscf/d) | 214.6 | 214.9 | 213.6 | 214.3 |
| Cubic feet per hour (scf/h) | 8,941 | 8,954 | 8,900 | 8,929 |
| **Exhaust gas composition** | | | | |
| $CO_2$ content (% vol) | 8.61 | 8.65 | 8.63 | 8.63 |
| $O_2$ content (% vol) | 8.37 | 8.35 | 8.33 | 8.35 |
| Moisture (% vol) | 10.9 | 9.6 | 12.3 | 10.9 |
| **Exhaust gas flowrate** | | | | |
| Standard conditions (scfm) | 2,380 | 2,366 | 2,368 | 2,371 |
| Dry basis (dscfm) | 2,136 | 2,107 | 2,077 | 2,107 |
| **Nitrogen oxides emission rates** | | | | |
| $NO_X$ conc. (ppmvd) | 56.99 | 57.01 | 58.39 | 57.46 |
| $NO_X$ emissions (lb/hr) | 0.87 | 0.86 | 0.87 | 0.87 |
| $NO_X$ emissions (ton/yr) | 3.82 | 3.77 | 3.81 | 3.80 |
| *$NO_X$ permit limit (ton/yr)* | | | | *24.60* |
| $NO_X$ emissions (lb/MMscf) | 97.64 | 96.17 | 97.73 | 97.18 |
| **Carbon monoxide emission rates** | | | | |
| CO conc. (ppmvd) | 0.13 | 0.05 | 0.37 | 0.18 |
| CO emissions (lb/hr) | 0.001 | <0.001 | 0.003 | 0.002 |
| CO emissions (ton/yr) | 0.005 | 0.002 | 0.015 | 0.007 |
| *CO permit limit (ton/yr)* | | | | *41.10* |
| CO emissions (lb/MMscf) | 0.13 | 0.05 | 0.38 | 0.19 |