AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM
NATURAL GAS FUELED INTERNAL COMBUSTION ENGINE

CORE ENERGY, LLC
CHESTER 10 CPF

1.0 INTRODUCTION

Core Energy, LLC (Core Energy, SRN 5798) operates natural gas-fired reciprocating internal combustion engines (RICE) at the Chester 10 CPF facility in Chester Twp, Otsego County, Michigan. The RICE are fueled by natural gas and used to provide mechanical power to operate gas compressors. The facility compresses carbon dioxide gas prior to injecting it into oil wells.

The Michigan Department of Environment, Great Lakes, and Energy-Air Quality Division (EGLE-AQD) has issued Permit to Install (PTI) No. 579-95F to Core Energy for the operation of three (3) RICE. The units covered by PTI No. 579-95F consists of:

- Two (2) Caterpillar (CAT®) Model No. G3608 RICE identified as emission units EUENGINE1 (controlled) and EUENGINE2 (uncontrolled).
- One (1) Caterpillar (CAT®) Model No. G3612 RICE identified as emission unit EUENGINE3 (controlled).

EUENGINE3 is subject to periodic emission testing pursuant to the federal Standards of Performance for Stationary Spark Ignition Internal Combustion Engines (the SI-RICE NSPS; 40 CFR Part 60 Subpart JJJJ).

The compliance testing was performed by Impact Compliance & Testing, Inc., a Michigan-based environmental consulting and testing company. Impact Compliance & Testing, Inc. representatives Jory VanEss and Blake Beddow performed the field sampling June 18, 2019.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan dated April 18, 2019 that was reviewed and approved by the Michigan Department Environment, Great Lakes, and Energy (EGLE). EGLE representatives Mr. Jeremy Howe and Ms. Jodi Lindgren 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 Impact Compliance & Testing, Inc. based on field sampling data collected by Impact Compliance & Testing, Inc. Facility process data were collected and provided by Core Energy employees or representatives. This test report has been reviewed by Core Energy representatives and approved for submittal to the EGLE.

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:

Jory VanEss
Environmental Consultant
Impact Compliance & Testing, 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.

Responsible Official Certification:

Bob Tipsword
Operations Manager
Core Energy, L.L.C.

2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

Core Energy operates a gas compressor station at the Chester Twp. facility. Natural gas, which has been recovered from nearby wells, has the carbon dioxide removed at an adjacent facility. The removed carbon dioxide gas is routed to the Core Energy Chester 10 CPF facility. Core Energy operates three (3) natural gas fired RICE at the facility. The RICE provide mechanical power to attached gas compressors. The compressed carbon dioxide is injected back into oil wells.

2.2 Rated Capacities and Air Emission Controls

Core Energy operates one (1) CAT® Model No. G3612 RICE (EUENGINE3). The CAT® Model No. G3612 RICE has a rated output of 3,071 bhp at 865 rpm (3,550 bhp at 1,000 rpm).

The RICE and connected gas compressor is a continuous-type process. The engine isoperated at the load (percent output) needed to drive the gas compressor to provide the desired volumetric flow and compression ratio for the transport of carbon doxide. The engine is equippedwith an air-to-fuel ratio controller (AFRC) that manages the fuel flow and combustion air flowrates based on the engine load.

2.3 Sampling Locations

The RICE exhaust gas is directed through mufflers prior to being released to the atmosphere through dedicated vertical exhaust stacks with vertical release points.

The engine exhaust sampling ports for EUENGINE3 are located in the exhaust stack prior to release to the ambient air. The exhaust stack has an inner diameter of 26.0 inches. The stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 180 inches (6.9 duct diameters) upstream and 63.0 inches (2.4 duct diameters) downstream from any flow disturbance and satisfies the USEPA Method 1 criteria for a representative sample location.

Individual traverse points were determined in accordance with USEPA Method 1.

Appendix 1 provides diagrams of the emission test sampling locations.

3.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

3.1 Purpose and Objective of the Tests

The conditions for FGENGINES in PTI No. 579-95F state:

> *Unless EUENGINE3 is a certified engine according to procedures specified in 40 CFR Part 60 Subpart JJJJ, and is maintained and operated as such, the permittee shall conduct performance testing every 8,760 hours of operation or three years from the previous performance test, whichever comes first, for EUENGINE3 to verify compliance with the emission limits in SC I.4, SC I.8, and SC I.9.*

Testing was performed to demonstrate compliance with the air pollutant emission limits specified in PTI No. 579-95F for the RICE in FGENGINES.

3.2 Operating Conditions During the Compliance Tests

The testing was performed while the Core Energy RICE were operated at maximum routine operating conditions. Core Energy representatives provided the horsepower output in 15-minute increments for each test period.

Fuel flowrate, engine shaft rotation (rpm) and catalyst inlet temperature were also recorded by Core Energy representatives in 15-minute increments for each test period.

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

Engine output (bhp) cannot be measured directly and was calculated based on the recorded engine shaft rotation (rpm). Core Energy provided engine spec sheets that listed the horsepower produced and engine shaft rotation (rpm) at maximum load. To determine the horsepower output at a lower load the following equation was used:

Engine Output (bhp-hr) = Max Output (bhp-hr) * Measured rotation (rpm) / Max rotation (rpm)

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

3.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the sampled RICE (EUENGINE3) were each sampled for three (3) one-hour test periods during the compliance testing performed June18, 2019.

Table 3.2 presents the average measured emission rates for EUENGINE3 (average of the three test periods).

Test results for each one hour sampling period and comparison to the permitted emission rates is presented in Section 6.0 of this report.

Table 3.1 Average engine operating conditions during the test periods

Engine Parameter	EUENGINE3
Engine shaft rotation (rpm)	850
Engine output (bhp)	3,018
Fuel Use (scfm)	305
Catalyst inlet temperature (°F)	754

Table 3.2 Average measured emission rates for EUENGIE3 (three-test average)

	CO Emission Rates		NO_x Emission Rates		VOC Emission Rates
Emission Unit	(TpY)	(g/bhp-hr)	(TpY)	(g/bhp-hr)	(g/bhp-hr)
EUENGINE3	12.78	0.44	6.85	0.23	0.43
Permit Limit	*17.13*	*2.0*	*11.88*	*1.0*	*0.7*

Notes for Table No. 3.2:

1. Annual mass emission rates are based off of the tested emission rate (lb/hr) and a maximum of 8,760 annual operating hours.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A test protocol for the air emission testing was reviewed and approved by the EGLE. 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 paramagnetic and infrared instrumental analyzer.
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 analyzers.
USEPA Method 10	Exhaust gas CO concentration was measured using an infrared instrumental analyzer
USEPA Method 25A / ALT-096	Exhaust gas VOC (as NMHC) concentration was determined using a flame ionization analyzer equipped with methane separation column

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

The RICE exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 during each test. An S-type or standard 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. The Pitot tube and connective tubing were leak-checked to verify the integrity of the measurement system.

The absence of significant cyclonic flow for each exhaust configuration was 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).

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 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 IC engine 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 EUENGINE3 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 and CO Concentration Measurements (USEPA Methods 7E and 10)

NO_X and CO pollutant concentrations in the RICE exhaust gas streams were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42c High Level chemiluminescence NO_X analyzer and a TEI Model 48i 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 4 provides CO and NO_X calculation sheets. Raw instrument response data are provided in Appendix 5.

4.6 Measurement of Volatile Organic Compounds (USEPA Method 25A/ALT-096)

The VOC emission rate was determined by measuring the nonmethane hydrocarbon (NMHC) concentration in the 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. 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.

The USEPA Office of Air Quality Planning and Standards (OAQPS) has issued an alternate test method approving the use of the TEI 55i-series analyzer as an effective instrument for measuring NMOC from gas-fueled reciprocating internal combustion engines (RICE) in that it uses USEPA Method 25A and 18 (ALT-096).

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).

Prior to, and at the conclusion of each test, the instrument was calibrated using mid-range calibration (propane) and zero gas to determine analyzer calibration error and system bias (described in Section 5.0 of this document).

Appendix 4 provides VOC calculation sheets. Raw instrument response data for the NMHC analyzer is provided in Appendix 5.

5.0 QA/QC ACTIVITIES

5.1 NO_x Converter Efficiency 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 98.7% of the expected value, i.e., within 10% of the expected value as required by Method 7E).

5.2 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 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.

5.3 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, 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.

5.4 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.

5.5 Determination of Exhaust Gas Stratification

A stratification test was performed for each RICE exhaust stack. The stainless steel sample probe was positioned at sample points correlating to 16.7, 50.0 (centroid) and 83.3% of each 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 each RICE exhaust stack indicated that the measured NO_x, CO, O_2 and CO_2 concentrations did not vary by more than 5% of the mean across each 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.

5.6 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 7 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, Pitot tube calibration records, stratification checks, CTS results, spike results and manual FTIR data validation result

6.0 RESULTS

6.1 Test Results and Allowable Emission Limits

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

All one-hour test periods are less than or equal to the allowable limits specified in EGLE-AQD PTI No. 579-95F:

Engine No. 3

- 11.88 TpY and 1.0 g/bhp-hr for NO_x;
- 17.13 TpY and 2.0 g/bhp-hr for CO; and
- 0.7 g/bhp-hr for VOC.

6.2 Variations from Normal Sampling Procedures or Operating Conditions

The testing for all pollutants was performed in accordance with USEPA methods and the approved test protocol. The engine-generator set was operated at maximum routine operating conditions and no variations from normal operating conditions occurred during the engine test periods.

Table 6.1 Measured exhaust gas conditions and NOx, CO and VOC air pollutant emission rates for EUENGINE3

Test No. Test date Test period (24-hr clock)	1 6/18/2019 08:00-09:00	2 6/18/2019 09:23-10:23	3 6/18/2019 10:44-11:44	Three Test Average
Fuel flowrate (scfm)	305	305	306	305
Engine output (rpm)	850	850	850	850
Engine output (bhp)	3,018	3,018	3,019	3,018
Catalyst Inlet temperature (°F)	755	753	753	754
Exhaust Gas Composition				
CO_2 content (% vol)	5.27	5.25	5.29	5.27
O_2 content (% vol)	12.02	12.19	12.13	12.11
Moisture (% vol)	11.2	9.9	10.2	10.4
Exhaust gas temperature (°F)	647	631	641	640
Exhaust gas flowrate (dscfm)	6,638	6,813	6,715	6,722
Exhaust gas flowrate (scfm)	7,472	7,557	7,481	7,503
Nitrogen Oxides				
NO_X conc. (ppmvd)	33.6	31.9	31.9	32.4
NO_X emissions (lb/hr)	1.60	1.56	1.53	1.56
NO_X emissions (TpY)	6.99	6.82	6.72	6.85
Permitted emissions (TpY)	-	-	-	*11.88*
NO_X emissions (g/bhp*hr)	0.24	0.23	0.23	0.23
*Permitted emissions (g/bhp*hr)*	-	-	-	*1.0*
Carbon Monoxide				
CO conc. (ppmvd)	96.5	101.1	100.7	99.4
CO emissions (lb/hr)	2.80	3.01	2.95	2.92
CO emissions (TpY)	12.25	13.16	12.93	12.78
Permitted emissions (TpY)	-	-	-	*17.13*
CO emissions (g/bhp*hr)	0.42	0.45	0.44	0.43
*Permitted emissions (g/bhp*hr)*	-	-	-	*2.0*
Volatile Organic Compounds				
VOC conc. (ppmv)	54.1	57.0	55.2	55.4
VOC emissions (g/bhp*hr)[1]	0.42	0.45	0.43	0.43
*Permitted emissions (g/bhp*hr)*	-	-	-	*0.7*

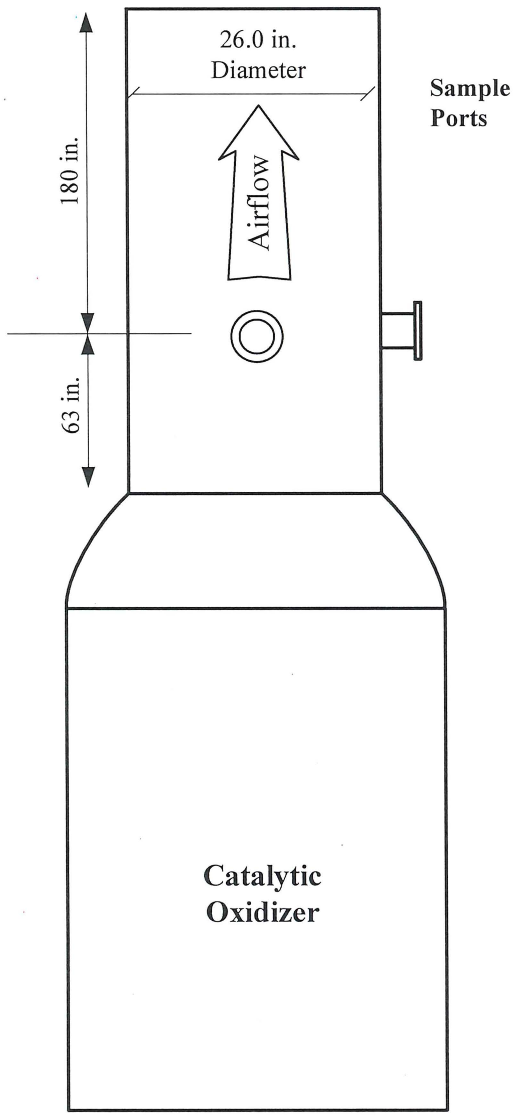
Notes for Table 6.3:

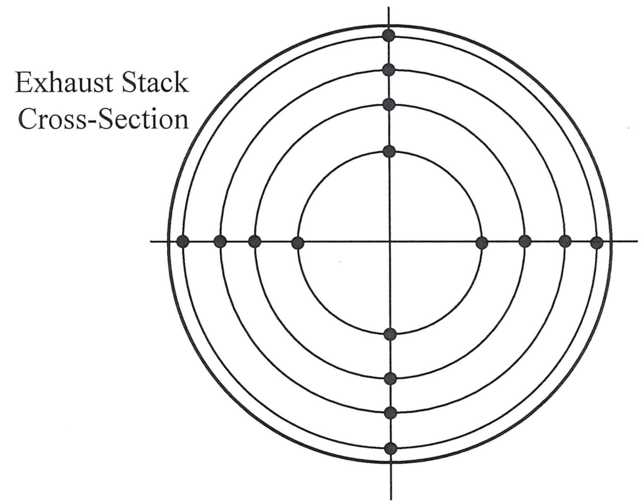
1. Presented TpY values are based on a maximum of 8,760 annual operating hours.

APPENDIX 1

- Figure 1-1 – Engine No. 3 Sample Port Diagram

Impact Compliance Testing, Inc.





Velocity sample locations as measured from stack wall (not including 1.25" sample port)

Pt. #	in.
1	0.83
2	2.73
3	5.04
4	8.37
5	17.6
6	21.0
7	23.3
8	25.2

7/18/2017 ALR	**Appendix 1-1 – Core Energy LLC** **Engine No. 3 Sampling Location**		
	Scale None	Sheet 1 of 1	Impact Compliance Project No. 1900148