Compliance Test Report

ST. CLAIR COMPRESSOR STATION
EUENGINES 2-2, 2-3 & 2-4

Consumers Energy Company
St. Clair Compressor Station
10021 Marine City Highway
Ira Township, Michigan 48023

Test Dates: March 31-April 1, 2014

Report Submitted:
May 30, 2014

Work Order No. 17420498
Report Revision 0

Test Performed by the Consumers Energy Company
Regulatory Compliance Testing Section
Laboratory Services Department

1.0 INTRODUCTION

Identification, location and dates of tests

This report summarizes the results of testing conducted March 31-April 1, 2014 at Consumers Energy Company's (CEC) St. Clair Compressor Station. CEC's Regulatory Compliance Testing Section (RCTS) conducted performance tests on three (3) 4-stroke lean burn (4SLB) natural gas-fired reciprocating internal combustion engines (RICE), identified as EUENGINE2-2, EUENGINE2-3 and EUENGINE2-4. The engines are located and operating at the St. Clair Compressor Station (St. Clair) in Ira Township, Michigan.

Purpose of testing

The purpose of testing was to evaluate initial compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP) for RICE, 40 CFR Part 63, Subpart ZZZZ.

Brief description of source

The St. Clair Compressor Station is a natural gas compressor station and an area source of hazardous air pollutants (HAPs). The natural gas-fired engines are used to maintain pressure of natural gas in order to move it in and out of storage reservoirs and along the pipeline system. Each RICE is of a 4SLB design and is exclusively fired with pipeline quality natural gas. The engines are Delaval Model HVC-16C and have been retrofitted with oxidation catalysts to reduce CO emissions (per §63.6603(a) and Table 2d).

Contact Names, addresses and phone numbers for information regarding the test and the test report, and names and affiliation of all personnel involved in conducting the testing

The following table contains the St. Clair test program participant contact information. Kenneth Gray and Allen Fox, St. Clair Gas Field Leaders, coordinated the test event. Lamont Mallett, CEC Engineer, gathered engine process data. Mr. Joe Iocca, Construction Manager, DJI & Associates, observed the test program in a support role on behalf of CEC. CEC RCTS staff Joe Mason, Brian Miska and Kavan Negaran conducted the tests. Representatives from the Michigan Department of Environmental Quality (MDEQ), Air Quality Division (AQD) did not observe the testing.

Test Program Participants
St. Clair Compressor Station

Responsible Party	Address	Contact
Test Facility	St. Clair Compressor Station 10021 Marine City Highway Ira Township, Michigan 48023	Mr. Kenneth Gray 586-716-3331 kenneth.gray@cmsenergy.com
		Mr. Allen Fox 231-357-7425 allen.fox@cmsenergy.com
Corporate Air Quality Contact	Consumers Energy Company Environmental Services Department 1945 West Parnall Road Jackson, Michigan 49201	Ms. Amy Kapuga 517-788-2201 amy.kapuga@cmsenergy.com
Process and Test Support	Consumers Energy Company 11801 Farmington Road Livonia, Michigan 48151	Mr. Lamont Mallett 517-788-0499 lamont.mallett@cmsenergy.com
	DJI & Associates 2324 Brooklyn Road Jackson, Michigan 49203	Mr. Joe Iocca joe.iocca@djiinc.com
Test Representative	Consumers Energy Company Regulatory Compliance Testing Section 17010 Croswell Street West Olive, Michigan 49460	Mr. Joe Mason, QSTI 231-720-4856 joe.mason@cmsenergy.com
State Representative	Michigan Department of Environmental Quality 525 W. Allegan, Constitution Hall Lansing, Michigan 48909	Ms. Karen Kajiya-Mills 517-284-6780 millsk@michigan.gov

2.0 SUMMARY OF RESULTS

Operating Data

Engine operating data collected during each test run included engine rpm, engine torque, ambient, compressor building and catalyst inlet temperature, barometric pressure, fuel flow rate, suction and discharge pressure.

Applicable Permit Number

The St. Clair Compressor Station is currently operating pursuant to the terms and conditions of Renewable Operating Permit (ROP) No. MI-ROP-B6637-2010.

Results

The purpose of the testing was to evaluate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP) for RICE, 40 CFR Part 63, Subpart ZZZZ. A summary of the test results are presented below.

Summary of RICE NESHAP Results
EUENGINE2-2, 2-3 & 2-4

Source	CO Reduction Efficiency (%)	40 CFR Part 63 Subpart ZZZZ Requirement (%)	Catalyst Inlet Temperature (°F)
EUENGINE2-2	98.7	≥ 93	832.8
EUENGINE2-3	97.8	≥ 93	843.5
EUENGINE2-4	96.2	≥ 93	828.2

Based on the dry CO concentrations measured at the oxidation catalyst inlet and outlet, in conjunction with the observed catalyst pressure drop and inlet temperature, the oxidation catalyst installed at each engine exhaust is in compliance with 40 CFR Part 63, Subpart ZZZZ.

3.0 SOURCE DESCRIPTION

Description of Process

The St. Clair Compressor Station is a natural gas compressor station and an area source of hazardous air pollutants (HAPs). The natural gas-fired engines are used to maintain pressure of natural gas in order to move it in and out of storage reservoirs and along the pipeline system. Three (3) existing natural gas-fired reciprocating engine driven compressor units, designated as EUENGINE2-2, EUENGINE2-3 and EUENGINE2-4 are operating at the station. Per §63.6603(a) and Table 2d, the units have been retrofitted with oxidation catalysts to reduce CO emissions.

Process Flow Sheet or Diagram

NA

Type and Quantity of Raw Material Processed During the Tests

NA

Maximum and Normal Rated Capacity of the Process

EUENGINE2-2, EUENGINE2-3 and EUENGINE2-4 are each rated at 4,000 horsepower.

Description of Process Instrumentation Monitored During the Test

Production engine process data collected included engine rpm, engine torque, ambient, compressor building and catalyst inlet temperature, barometric pressure, fuel flow rate, suction and discharge pressure. The preceding data was logged at least once every clock minute and then averaged to determine the per-test run values.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

Description of sampling train(s) and field procedures

Triplicate CO reduction efficiency runs of varying duration were performed on each engine by concurrently measuring O_2, CO_2 and CO concentrations at the catalytic oxidation inlet and outlet (engine exhaust) consistent with the U.S. EPA Methods and calculations specified in 40 CFR Part 63, Subpart ZZZZ §63.6620 Equation 1 and Table 4. Two of the runs were 15 minutes in duration, and a third run was 20 minutes.

Please note that RCTS measured O_2 and CO_2 diluent concentrations, which affords the use of either to satisfy Subpart ZZZZ requirements for correcting CO concentrations to 15% O_2 prior to determining percent CO reduction. The CO_2 correction factor is based on O_2 to CO_2 fuel factor ratios as described in §63.6620 (e)(2)(ii)(Eq.3), thereby allowing the CO concentrations to be corrected to 15% O_2 based on dry basis CO_2 concentrations as described in Equation 4, § 63.6620 (e)(2)(iii).

The sampling locations are a-typical (relative to U.S. EPA Method 1 *"Sample and Velocity Traverses for Stationary Sources"* criteria) at the oxidation catalyst inlet, due to the proprietary nature and design of the catalyst abatement equipment. Figure 2 of this report illustrates the path of engine effluent as it enters and exits the oxidation catalyst. In an attempt to meet the gas stratification requirements of U.S. EPA Method 7E, measurements at each engine catalyst inlet were performed by selecting and traversing 2 points within each of the two catalyst inlet "ducts". The design and dimension of these ducts precluded the use of more than 2 traverse points. Conversely, the engine exhaust traverse points were typical from a U.S. EPA Method 1 perspective. As illustrated in Figure 2, each engine exhaust consists of a straight single duct, so initial engine exhaust traverses incorporated 12 traverse points as specified in U.S. EPA Method 7E. During the initial stratification traverses at each location, it was apparent the gas stream concentrations varied significantly at each traverse point, rather than at consecutive traverse points. These findings essentially indicated the engine exhaust varied temporally at each traverse point such that the intent of the stratification test could not be satisfied, thus negating the purpose of the exercise. Subsequently, after establishing similarly varying effluent existed at each of the other engine sample locations, all test runs performed thereafter utilized a single traverse point, located as close to the middle of the duct as practicable.

All components of the CO_2, O_2, and CO extractive sample systems in contact with flue gas were constructed of Type 316 stainless steel and/or Teflon. The gas samples were routed to an ice/water bath to remove moisture from the gas prior to injection into the respective analyzer. The output signal from each analyzer was connected to a computerized data acquisition system (DAS). The analyzers were calibrated with U.S. EPA Protocol calibration gases at a minimum of three points: low (0-20% of calibration span), mid-level (40-60% of calibration span) and high-level gas (equal to the calibration span) following specifications in U.S. EPA Method 7E. All instruments were operated thereafter to insure that zero drift, calibration gas drift, bias and calibration error met the specified method requirements. The extractive sample system apparatus diagram is shown in Figure 1.

The data measured from the pollutant and diluent analyzers was averaged for each run and corrected for drift and bias. The inlet and outlet CO concentrations in part per million by volume (ppmv) used for determining CO reduction efficiency were also corrected to 15 percent O_2 using the CO_2 correction factor ratio equation in 40 CFR Part 63, Subpart ZZZZ, § 63.6620 (e)(2)(ii). Both CO_2 and O_2, concentrations were measured as percent by volume, dry basis.

CO_2 and O_2 diluent concentrations were monitored using a non-dispersive infrared (NDIR) and paramagnetic analyzer, respectively, following the guidelines of U.S. EPA Method 3A, *Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from a Stationary Source (Instrumental Analyzer Procedure).*

The CO concentrations were measured using an NDIR analyzer following the guidelines of U.S. EPA Reference Method 10, *Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure).*

Quality Assurance Procedures

Each U.S. EPA reference method performed during this test contains specific language stating that to obtain reliable results, persons using these methods should have a thorough knowledge of the techniques associated with each method. To that end, CEC RCTS attempts to minimize any factors which could cause sampling errors by implementing a quality assurance (QA) program into every component of field testing, including the following information.

U.S. EPA Protocol gas standards certified according to the U.S. EPA Traceability Protocol for Assay & Certification of Gaseous Calibration Standards; Procedure G-1; September, 1997 or May, 2012 version and certified to have a total relative uncertainty of ±1 percent were used to calibrate the analyzers during the test program. Although not required in the context of this test program, the calibration gas vendors also participate in the Protocol Gas Verification Program (PGVP), an EPA audited program recently developed for 40 CFR Part 75.

The extractive sample system instruments were calibrated and operated following the appropriate method guidelines, based on specifications contained in Method 7E (as referenced in Methods 3A and 10). Before daily testing began, an analyzer calibration error (ACE) test was conducted by introducing the calibration gases directly into each analyzer. If the measured response didn't meet the ±2 percent of instrument span specification or within 0.5 ppmv absolute difference to pass the ACE check, appropriate action was taken and the ACE was repeated. Prior to beginning the first run, an initial system bias was conducted by introducing the low and upscale calibration gases into the sampling system at the probe outlet and drawing them through the sample conditioning system in the same manner as the exhaust gas sample, while measuring the instrument response. Each instrument response must meet a specification of ≤ 5.0 percent of instrument span.

Low and upscale bias calibrations were performed after each run thereafter to quantify system calibration drift and bias. During the initial system bias tests, system response time was measured and the sample flow rate throughout the remainder of the test was monitored to maintain the sample flow rate within 10 percent of the average flow rate observed during the response time test. Sampling for each run was started after twice the system response time had elapsed.

Description of recovery and analytical procedures
NA

Dimensioned sketch showing all sampling ports in relation to breeching and to upstream and downstream disturbances or obstructions of gas flow and a sketch of cross-sectional view of stack indicating traverse point locations and exact stack dimensions
The exhaust stack configuration is shown in Figure 2.

5.0 TEST RESULTS AND DISCUSSION

Detailed tabulation of results, including process operating conditions and flue gas conditions

Tables 1-3 contain a summary of CO reduction efficiency from each engine. RICE operating data, calculation spreadsheets, field data sheets, calibration information, and calculations are contained in Attachments 1 - 5.

Discussion of significance of results relative to operating parameters and emission regulations

The average percent reduction of CO was greater than the minimum required reduction efficiency. Thus, EUENGINE2-2, EUENGINE2-3, and EUENGINE2-4 are in compliance with the CO percent reduction across the catalyst. In addition, the catalyst inlet temperatures and pressure drop across the catalyst were monitored continuously throughout testing and were shown to be within the required ranges.

Please note that on Tuesday, April 1, 2014, following Run 1 on EUENGINE2-4, the upscale CO_2 calibration revealed that the instrument had drifted beyond the allowed 3 percent specification in U.S. EPA Method 7E. As previously noted, Subpart ZZZZ allows the use of either CO_2 or O_2 for correcting CO concentrations to 15% O_2 prior to determining percent CO reduction. Therefore, RCTS utilized concurrently collected O_2 data in lieu of CO_2 data to correct the CO concentrations accordingly.

Discussion of any variations from normal sampling procedures or operating conditions, which could have affected the results

Number and Location of Sampling Points (All Engines)

Per the discussion in Section 4.0, gaseous sampling was ultimately conducted from a single sampling point at the catalyst inlet and the engine exhaust (downstream of the oxidation catalysts, as applicable). While this conforms to the identified sampling strategy within the test protocol dated August 30, 2013, 40 CFR Part 63, Subpart ZZZZ was revised on February 27, 2014. As part of the revisions to these rules, the EPA clarified the acceptable number and location of sampling points for gaseous measurements. For ducts greater than 12 inches in diameter and meeting the two and half-diameter criterion of Section 11.1.1 of Method 1 (which applies to all tested units), the revisions require that sampling be conducted at three traverse points located at 16.7%, 50.0% and 83.3% of the measurement line or that stratification testing be conducted, after which the number of sampling points would be selected consistent with Section 8.1.2 of Method 7E. If the stratification test is failed, Method 7E then requires sampling from 12 traverse points.

While performing initial stratification traverses at each location, it was apparent the gas stream concentrations varied significantly at each traverse point, rather than at consecutive traverse points. These findings essentially indicated the engine exhaust varied temporally at each traverse point such that the intent of the stratification test could not be satisfied, thus negating the purpose of the exercise. During previous 40 CFR Part 63, Subpart ZZZZ testing events on units with similar exhaust duct configurations, stratification testing had also been conducted and the same temporal variation was observed and discussed with the MDEQ-AQD, after which the MDEQ-AQD approved sampling from a single traverse point. Based upon the previous stratification testing, there is no evidence that exhaust gas concentrations are stratified across the measurement plane in a consistent manner, so sampling at a single traverse point is expected to yield results similar to what would be obtained by traversing the measurement plane. Thus, the use of a single sampling point in lieu of a 3 point traverse should not affect the test results.

Documentation of any process or control equipment upset condition which occurred during the testing

A process upset condition was observed during Run 1 on EUENGINE2-2, where the catalyst pressure drop data varied significantly throughout that run. Upon completion, the cause of the variation was found to be the inadvertent opening and use of the post catalyst pressure drop test port as a sampling location, which essentially negated the validity of that run due to that duct opening and the resulting inaccurate CPMS pressure drop measurements. After reinstalling the sampling equipment in the correct test port, and verifying the accuracy of the catalyst pressure drop gauge, three additional runs were performed to compensate for the upset. The results from the first run are contained in this report; however the data was not included in the final results.

Description of any major maintenance performed on the air pollution control device(s) during the three month period prior to testing

NA

In the event of a re-test, a description of any changes made to the process or air pollution control device(s)

NA

Results of any quality assurance audit sample analyses required by the reference method

NA

Calibration sheets for the dry gas meter, orifice meter, pitot tube, and any other equipment or analytical procedures which require calibration

Attachment 4 contains the analyzer calibration data, calibration gas Certificates of Analysis, and the results of stratification testing which was to be used to determine the appropriate number of traverse points. The stratification test requirements in Method 7E do not lend themselves well to the small-diameter stacks of stationary combustion engines, which are noted for well-mixed yet temporally varying effluent. These exhaust gas attributes rarely result in a meaningful stratification test because any measured stratification using Method 7E techniques is indistinguishable from the natural temporal "stratification" created by the process. Therefore, RCTS performed initial stratification tests at each source in an attempt to corroborate any stratification beyond existing temporal variations.

Sample calculations of all the formulas used to calculate the results
Sample calculations for all formulas used in the test report are contained in Attachment 5.

Copies of all field data sheets, including any pre-testing, aborted tests, and/or repeat attempts
Please refer to Attachment 1 for process data collected during the test runs; Attachment 2 for calculation spreadsheets for each of the test runs; and Attachment 3 for data sheets with the measured CO and CO_2 concentrations for each test run.

Copies of all laboratory data including QA/QC
NA

TABLE 1
SUMMARY OF RICE EFFICIENCY AND EMISSIONS
ST CLAIR COMPRESSOR STATION
EUENGINE2-2
March 31, 2014

Time Period	Run 2 1519-1534	Run 3 1545-1600	Run 4 1611-1626	Averages
Process Conditions		.		
Engine Speed, Revolutions Per Minute:	525	525	525	**525**
Engine Torque, Percent	91	92	92	**92**
Engine Brake Horsepower:	3,184	3,209	3,220	**3,205**
Engine Load, Percent:	79.6	80.2	80.5	**80.1**
Fuel Flow, SCFM	448.9	446.6	443.8	**446.4**
Catalyst Inlet Temperature, degrees F:	828.9	834.3	835.2	**832.8**
Inlet Gas Conditions				
Carbon Dioxide Concentration, percent:	5.7	5.8	5.9	**5.80**
Drift Corrected Carbon Monoxide Concentration (ppmdv):	253.6	258.5	260.7	**257.62**
Corrected Carbon Monoxide Concentration (ppmdv @ 15% O2):	148.7	150.1	150.0	**149.60**
Outlet Gas Conditions				
Carbon Dioxide Concentration, percent:	5.9	5.9	6.0	**5.94**
Drift Corrected Carbon Monoxide Concentration (ppmdv):	2.9	3.3	4.3	**3.49**
Corrected Carbon Monoxide Concentration (ppmdv @ 15% O2):	1.6	1.9	2.4	**1.98**
Percent Reduction Efficiency:	98.89	98.77	98.38	**98.7**

Run 1 was conducted from a sample port containing catalyst pressure drop instrumentation. Therefore, due to invalid CPMS data, Run 1 is not included in the three run average.

TABLE 2
SUMMARY OF RICE EFFICIENCY AND EMISSIONS
ST CLAIR COMPRESSOR STATION
EUENGINE2-3
April 1, 2014

Time Period	Run 1 1400-1415	Run 2 1425-1440	Run 3 1450-1505	Averages
Process Conditions				
Engine Speed, Revolutions Per Minute:	500	500	500	**500**
Engine Torque, Percent	103	103	103	**103**
Engine Brake Horsepower:	3,436	3,429	3,430	**3,432**
Engine Load, Percent:	85.9	85.7	85.7	**85.8**
Fuel Flow, SCFM	427.1	426.2	427.0	**426.8**
Catalyst Inlet Temperature, degrees F:	835.1	844.7	850.7	**843.5**
Inlet Gas Conditions				
Carbon Dioxide Concentration, Percent:	6.2	6.1	6.4	**6.2**
Drift Corrected Carbon Monoxide Concentration (ppmdv):	230.9	240.9	248.4	**240.1**
Corrected Carbon Monoxide Concentration (ppmdv @ 15% O2):	125.9	133.5	129.9	**129.8**
Outlet Gas Conditions				
Carbon Dioxide Concentration, Percent:	6.8	6.5	6.9	**6.7**
Drift Corrected Carbon Monoxide Concentration (ppmdv):	5.5	5.7	6.0	**5.7**
Corrected Carbon Monoxide Concentration (ppmdv @ 15% O2):	2.7	2.9	2.9	**2.9**
Reduction Efficiency, Percent:	97.8	97.8	97.7	**97.8**

TABLE 3
SUMMARY OF RICE EFFICIENCY AND EMISSIONS
ST CLAIR COMPRESSOR STATION
EUENGINE2-4
April 1, 2014

Time Period	Run 1 1630-1644	Run 2 1655-1709	Run 3 1717-1734	Averages
Process Conditions				
Engine Speed, Revolutions Per Minute:	500	500	500	**500**
Engine Torque, Percent:	99	99	99	**99**
Engine Brake Horsepower:	3,289	3,306	3,305	**3,300**
Engine Load, Percent:	82.2	82.7	82.6	**82.5**
Fuel Flow, SCFM	401.9	403.0	404.0	**403.0**
Catalyst Inlet Temperature, degrees F:	811.0	835.0	838.56	**828.2**
Inlet Gas Conditions				
Oxygen Concentration, percent:	9.75	9.59	9.60	**9.65**
Carbon Dioxide Concentration, percent:	6.29	6.43	6.48	**6.40**
Drift Corrected Carbon Monoxide Concentration (ppmdv):	183.83	185.13	182.91	**183.95**
Corrected Carbon Monoxide Concentration (ppmdv @ 15% O2):	97.28	96.60	95.49	**96.46**
Outlet Gas Conditions				
Oxygen Concentration, percent:	9.30	9.08	9.30	**9.23**
Carbon Dioxide Concentration, percent:	6.61	6.62	6.76	**6.66**
Drift Corrected Carbon Monoxide Concentration (ppmdv):	7.39	7.32	7.28	**7.33**
Corrected Carbon Monoxide Concentration (ppmdv @ 15% O2):	3.76	3.66	3.70	**3.71**
Percent Reduction Efficiency:	96.14	96.22	96.12	**96.2**