Consumers Energy

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Compliance Test Report

WHITE PIGEON COMPRESSOR STATION
EUENGINES 2 & 4

White Pigeon Compressor Station
68536 A Road, Route 1
White Pigeon, Michigan 49099

Test Dates: August 26 and September 3, 2014

Report Submitted:
October 16, 2014

Work Order No. 23074191
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 on August 26 and September 3, 2014 at Consumers Energy Company's (CEC) White Pigeon Compressor Station. CEC's Regulatory Compliance Testing Section (RCTS) conducted performance tests on two (2) 4-stroke lean burn (4SLB) natural gas-fired, reciprocating internal combustion engines (RICE), identified as EUENGINE2 and EUENGINE4. The engines are located and operating at the White Pigeon Compressor Station in White Pigeon, Michigan.

Purpose of testing

The purpose of the testing was to evaluate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP) for Reciprocating Internal Combustion Engines (RICE), 40 CFR Part 63, Subpart ZZZZ. This testing event represented the second semi-annual performance test, following the installation of new catalyst modules in Engine 2 (all 4 modules) and Engine 4 (2 of the 4 modules) in March 2014, and consisted of the following:

Unit	Parameter to be Tested	Underlying Regulation
EUENGINE2 & EUENGINE4	Carbon Monoxide (CO) & diluent gas (Oxygen (O_2)or Carbon Dioxide (CO_2)) both upstream and downstream from the oxidation catalyst (% reduction)	Subpart ZZZZ

Brief description of source

The White Pigeon Compressor Station is a natural gas compressor station. The purpose of the facility is to compress and maintain natural gas pipeline system pressure along the pipeline system. Each RICE is of a 4SLB design and is exclusively fired with pipeline quality natural gas. EUENGINE2 and EUENGINE4 are Caterpillar Model G3616 engines. Each of these engines is equipped with oxidation catalysts to reduce CO and VOC emissions.

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

The testing was performed by CEC RCTS employees Brian Glendening, Joe Mason and Greg Koteskey. MDEQ representative Mr. Tom Gasloli observed portions of the test. White Pigeon Field Leader, Mr. Timothy Wolf, coordinated the test and CEC Senior Technician, Craig Jaeger, collected operating data. The following table contains the test program participant contact information.

Test Program Participants
White Pigeon Compressor Station

Responsible Party	Address	Contact
Test Facility	White Pigeon Compressor Station 68536 A Road White Pigeon, Michigan 49099	Mr. Timothy Wolf 269-483-2902 timothy.wolf@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
Test Representative	Consumers Energy Company Regulatory Compliance Testing Section 17010 Croswell Street West Olive, Michigan 49460	Mr. Brian Glendening, QSTI 616-738-3234 brian.glendening@cmsenergy.com
State Representative	Michigan Department of Environmental Quality 525 W. Allegan, Constitution Hall Lansing, Michigan 48909	Mr. Tom Gasloli 517-284-6778 gasloli@michigan.gov

2.0 SUMMARY OF RESULTS

Operating Data

Operating data collected during each test run included catalyst inlet temperature, pressure drop across catalyst, engine load, ambient temperature, barometric pressure, humidity, fuel flow rate, suction pressure, discharge pressure, and horsepower. The purpose of documenting engine horsepower is to verify engine load during the performance test, as Subpart ZZZZ § 63.6620 (b) states *the test must be conducted at any load condition within plus or minus 10 percent of 100 percent load.* Engine load was obtained by dividing the recorded horsepower value observed during each test run by the rated engine horse power.

Applicable Permit Number

The White Pigeon Compressor Station is currently operating pursuant to the terms and conditions of Renewable Operating Permit (ROP) No. MI-ROP-N5573-2013. Performance tests were conducted, as required, on two (2) 4SLB natural gas-fired RICE, identified as EUENGINE2 and EUENGINE4.

Results

The purpose of the testing was to evaluate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP) for Reciprocating Internal Combustion Engines (RICE), 40 CFR Part 63, Subpart ZZZZ. This testing event represented the second semi-annual performance test, following the installation of new catalyst modules in Engine 2 (all 4 modules) and Engine 4 (2 of the 4 modules) in March 2014. A summary of the test results are presented below.

Summary of 40 CFR 63 Subpart ZZZZ RICE Carbon Monoxide Reduction, Catalyst Pressure Drop & Catalyst Inlet Temperature Results

Source	CO Reduction Efficiency (%) [ZZZZ Limit = ≥93%]	Catalyst Pressure Drop (Inches Water Gauge)	Catalyst Inlet Temperature (°F)
EUENGINE2	98.9	3.1	770.6
EUENGINE4	98.9	3.1	788.0

Based on the dry CO concentrations measured at the oxidation catalyst inlet and outlet corrected to 15% O_2, the above results indicate the oxidation catalysts are operating at a CO reduction efficiency greater than the 93 percentage requirement in Subpart ZZZZ.

3.0 SOURCE DESCRIPTION

Description of Process

The White Pigeon Compressor Station is a natural gas compressor station. The purpose of the facility is to maintain pressure of natural gas in order to move it along the pipeline system. EUENGINE2 and EUENGINE4 were installed in 2010, along with two (2) additional RICE, to maintain station reliability.

The NO_x emissions from each of the engines are minimized through the use of lean-burn combustion technology. Lean-burn combustion refers to a high level of excess air (generally 50% to 100% relative to the stoichiometric amount) in the combustion chamber. The excess air absorbs heat during the combustion process, thereby reducing the combustion temperature and pressure and resulting in lower NO_x emissions.

Each of the engines is also equipped with oxidation catalysts. The catalysts are designed in a modular manner, and each engine is equipped with four catalyst modules. The catalysts use proprietary materials in order to lower the temperature at which the oxidation process occurs for CO and other organic compounds. As a result, the oxidation process will occur at the exhaust gas temperatures generated by the engines. The catalyst vendor has guaranteed a minimum CO destruction efficiency of 93%. The estimated formaldehyde and non-methane, non-ethane hydrocarbon (NMNEHC) destruction efficiencies are 85% and 75%, respectively.

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

The following table contains pertinent engine specifications for EUENGINE2 and EUENGINE4.

Summary of Specifications for EUENGINE2 and EUENGINE4

Parameter [1]	EUENGINES2&4
Make	Caterpillar
Model	G3616
Output (brake-horsepower)	4,735
Heat Input, LHV (mmBtu/hour)	32.0
Exhaust Gas Temp. (°F)	856

[1] All engine specifications are based upon vendor data for operation at 100% of rated engine capacity.

Description of Process Instrumentation Monitored During the Test

Engine process data collected included catalyst inlet temperature, pressure drop across the catalyst, engine load, horsepower, ambient temperature, barometric pressure, humidity, fuel flow rate, suction pressure 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 one-hour runs were performed on each production engine to determine CO reduction efficiency by concurrently measuring O_2, CO_2 and CO concentrations at the oxidation catalyst inlet and outlet (engine exhaust). The U.S. EPA Test Methods were used exclusively, as described within the test protocol. The CO reduction efficiency test methods and calculations were consistent with those specified in 40 CFR Part 63, Subpart ZZZZ §63.6620 Equation 1 and Table 4.

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), which allows 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 F_c and F_d fuel factors used to derive the CO_2 correction factors were based on the daily natural gas fuel samples and analyses.

The sampling locations at EUENGINES 2 & 4 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 that 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 exhausts via a single duct, so the initial engine exhaust traverses included 12 traverse points, meeting U.S. EPA Method 7E requirements. 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. 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. Engine exhaust gas was drawn from the stack via a sample probe and line and routed through an ice bath gas dryer for moisture removal prior to be distributed from a gas manifold into individual analyzers. 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) and operated 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, while NO_x concentrations were measured as ppmv, 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 Parts 60 and 63 test program, the vendors providing the calibration gases 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 check 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 for EUENGINE2 and EUENGINE4, including hand markups which are intended to provide an illustration of the flue gas path through the stack, 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 and 2 contain a summary of the CO percent reductions and emission rates observed for each of the units during testing conducted on August 26 and September 3, 2014. RICE operating data, calculation spreadsheets, field data sheets and calibration information are contained in Attachments 1 - 4.

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

The average percent reduction of CO for each of the engines was greater than the minimum required destruction efficiency. Thus, EUENGINE2 and EUENGINE4 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.

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

NA

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

NA

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, response time test results, NO_2 to NO converter efficiency check and calibration gas Certificates of Analysis. The results of stratification testing are not included as they ultimately were not 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 concentrations for each test run.

Copies of all laboratory data including QA/QC

NA

TABLE 1
SUMMARY OF CO REDUCTION EFFICIENCY
WHITE PIGEON COMPRESSOR STATION
EUENGINE2
August 26, 2014

Time Period	Run 1 1002-1101	Run 2[1] 1110-1209	Run 3 1248-1347	Run 4 1353-1458	Averages
Process Conditions					
Engine Speed, Revolutions Per Minute:	994	997	979	985	**986**
Brake Horsepower:	4595	4636	4630	4569	**4628**
Load, Percent:	97.0	97.9	97.8	96.5	**97.1**
Fuel Flow, SCFM	573.1	578.3	582.0	582.6	**579.2**
Suction Pressure, PSIG:	651.0	648.6	634.9	625.0	**637.0**
Catalyst Delta P, Inches of Water:	3.1	3.2	3.2	3.2	**3.1**
Catalyst Inlet Temperature, degrees F:	776.0	782.5	773.1	762.6	**770.6**
Inlet Gas Conditions					
Drift Corrected Oxygen Concentration, Dry (Percent):	11.5	11.6	11.6	11.6	**11.6**
Drift Corrected Carbon Monoxide Concentration, Dry (ppmdv):	457.5	453.5	440.0	440.0	**445.8**
Corrected Carbon Monoxide Concentration (ppmdv @ 15% O2):	287.3	288.0	280.3	279.3	**282.3**
Outlet Gas Conditions					
Drift Corrected Oxygen Concentration, Dry (Percent):	11.6	11.6	11.8	11.8	**11.7**
Drift Corrected Carbon Monoxide Concentration, Dry (ppmdv):	1.2	1.3	4.7	8.1	**4.7**
Drift Corrected Carbon Monoxide Concentration (ppmdv @ 15% O2):	0.7	0.8	3.0	5.3	**3.0**
CO Percent Reduction Efficiency (≥ 93% Per 40 CFR Part 63, Subpart ZZZZ):	99.7	99.7	98.9	98.1	**98.9**

[1] The instrument measuring catalyst exhaust CO concentrations during Run 2 did not meet Method 7E calibration drift requirements. The data is provided for informational purposes only and is not included in the average results.

TABLE 2
SUMMARY OF CO REDUCTION EFFICIENCY
WHITE PIGEON COMPRESSOR STATION
EUENGINE4
September 3, 2014

Time Period	Run 1	Run 2	Run 3	Averages
	942-1041	1052-1151	1202-1301	
Process Conditions				
Engine Speed, Revolutions Per Minute:	993	998	998	**997**
Brake Horsepower:	4628	4608	4617	**4617**
Load, Percent:	97.7	97.3	97.5	**97.5**
Fuel Flow, SCFM	582.6	580.1	580.9	**581.2**
Suction Pressure, PSIG:	603.7	606.3	611.8	**607.3**
Catalyst Delta P, Inches of Water:	3.1	3.1	3.1	**3.1**
Catalyst Inlet Temperature, degrees F:	789.1	788.8	786.1	**788.0**
Inlet Gas Conditions				
Drift Corrected Oxygen Concentration, Dry (Percent):	11.4	11.4	11.4	**11.4**
Drift Corrected Carbon Monoxide Concentration, Dry (ppmdv):	406.1	404.8	403.6	**404.8**
Corrected Carbon Monoxide Concentration (ppmdv @ 15% O2):	252.2	251.3	250.9	**251.5**
Outlet Gas Conditions				
Drift Corrected Oxygen Concentration, Dry (Percent):	11.4	11.4	11.4	**11.4**
Drift Corrected Carbon Monoxide Concentration, Dry (ppmdv):	1.2	4.0	4.8	**4.3**
Drift Corrected Carbon Monoxide Concentration (ppmdv @ 15% O2):	2.6	2.5	3.0	**2.7**
CO Percent Reduction Efficiency (≥ 93% Per 40 CFR Part 63, Subpart ZZZZ):	99.0	99.0	98.8	**98.9**

FIGURE 1

Sampling Apparatus Schematic

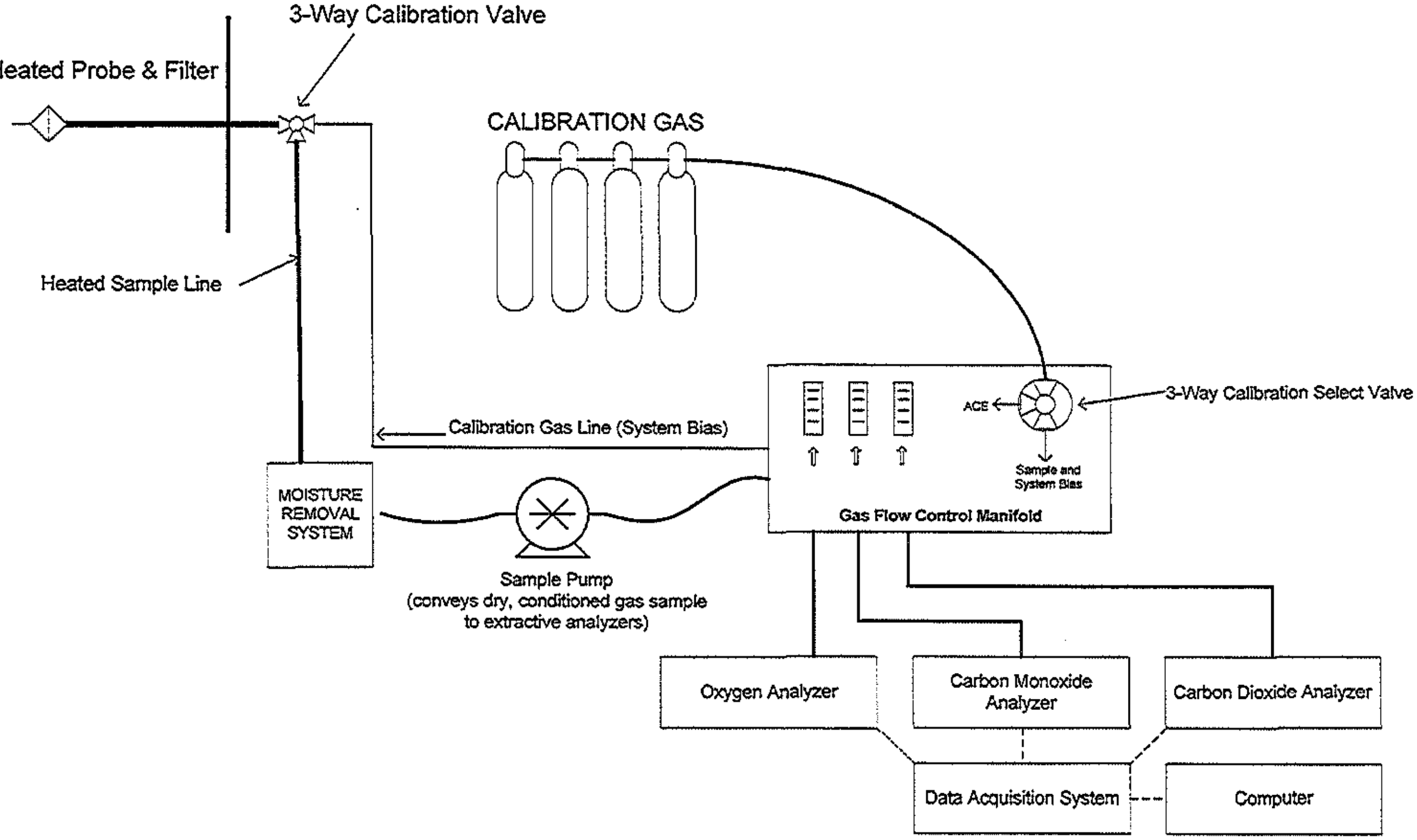

FIGURE 1

DRY EXTRACTIVE GASEOUS SAMPLE APPARATUS