EXECUTIVE SUMMARY

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted carbon monoxide (CO), and oxygen (O_2) testing at five natural gas fired, reciprocating internal combustion engines (RICE) designated as EUENGINE31, EUENGINE32, EUENGINE33, EUENGINE34, and EUENGINE35, operating at the Ray Compressor Station in Armada, Michigan. Each engine is a four stroke lean burn (4SLB); spark ignited 4,735 brake horsepower (BHP) engine operating at a major source of hazardous air pollutant (HAP) emissions. The engines provide mechanical shaft power to compressors maintaining natural gas pipeline pressure for movement in and out of storage reservoirs and along the pipeline system.

The test program was performed to satisfy performance test requirements and verify compliance with United States Environmental Protection Agency (USEPA) 40 CFR Part 63, Subpart ZZZZ, *National Emission Standards for Hazardous Air Pollutants* (NESHAP) *for Stationary Reciprocating Internal Combustion Engines* as incorporated in Michigan Department of Environment, Great Lakes and Energy (EGLE), Renewable Operating Permit (ROP) MI-ROP-B6636-2015a. A test protocol was submitted to EGLE on April 14, 2020 and subsequently approved by Mr. David Patterson, Environmental Quality Analyst, in his letter dated May 21, 2020.

The test event was conducted June 16-19, 2020. Triplicate 60-minute test runs at each engine were conducted following procedures in USEPA Reference Methods (RM) 1, 3A, 7E and 10 in 40 CFR Part 60, Appendix A. Percent CO reduction efficiency was calculated using 40 CFR 63, § 63.6620, Equation 1. There were no deviations from the approved test protocol or associated Reference Methods. During testing, the engines operated within ± 10 percent of 100 percent peak (or highest achievable) load, as specified in 40 CFR §60.4244(a). The summary of results in Table E-1 indicate each engine and oxidation catalyst complies with applicable percent CO reduction limits.

Table E-1 Summary of 40 CFR Part 63 Subpart ZZZZ Test Results

Source	Engine Torque / Horsepower (%)	CO Reduction Efficiency (%)	Oxidation Catalyst Inlet Temperature (°F)	Oxidation Catalyst Pressure Drop Comparison (Inches Water Gauge)	
				Initial Test	2020 Results
	[Requirement: 100% ± 10%]	[Requirement: ≥93%]	[Requirement: ≥450°F & ≤1350°F]	[Requirement: ±2" from Initial Test]	
EUENGINE31	99.0 / 96.9	98.1	831.4	2.2	2.12
EUENGINE32	99.0 / 95.5	99.2	866.6	2.3	2.39
EUENGINE33	98.6 / 95.5	99.1	835.5	2.0	2.30
EUENGINE34	98.4 / 95.5	97.3	843.3	2.7	3.00
EUENGINE35	99.2 / 95.6	98.6	840.2	2.1	2.14

Detailed results are presented in Appendix Tables 1 – 5. Sample calculations, field data sheets, engine data and supporting documentation are provided in Appendices A - D.

1.0 INTRODUCTION

This report summarizes compliance air emission results from tests conducted at the Consumers Energy Ray Compressor Station (RCS) in Armada, Michigan.

This document follows the November 2019, Michigan Department of Environment, Great Lakes and Energy (EGLE) *Format for Submittal of Source Emission Test Plans and Reports.* Reproducing only a portion of this report may omit critical substantiating documentation or cause information to be taken out of context. If any portion of this report is reproduced, please exercise due care in this regard.

1.1 IDENTIFICATION, LOCATION, AND DATES OF TESTS

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted carbon monoxide (CO), and oxygen (O_2) testing on emission units (EU) EUENGINE31, EUENGINE32, EUENGINE33, EUENGINE34 and EUENGINE35, operating at the RCS facility in Armada, MI.

A test protocol was submitted to EGLE on April 14, 2020 and subsequently approved by Mr. David Patterson, Environmental Quality Analyst, in his letter dated May 21, 2020. The test program was conducted June 15-19, 2020. There were no deviations from the approved stack test protocol or associated United States Environmental Protection Agency (USEPA) Reference Methods (RM).

1.2 PURPOSE OF TESTING

The purpose of the test program was to satisfy performance test requirements and verify compliance with USEPA 40 CFR Part 63, Subpart ZZZZ, *National Emission Standards for Hazardous Air Pollutants* (NESHAP) *for Stationary Reciprocating Internal Combustion Engines*, (aka RICE MACT), as incorporated in State of Michigan, Renewable Operating Permit (ROP) MI-ROP-B6636-2015a.

The RICE MACT CO efficiency and equipment operating requirements are shown in Table 1-1.

Table 1-1
Summary of 40 CFR 63, Subpart ZZZZ Requirements

CO Reduction Efficiency (%)	**Oxidation Catalyst Pressure Drop Change** (Inches Water Gauge)
≥93	±2” from Initial Performance Test

1.3 BRIEF DESCRIPTION OF SOURCE

EUENGINE31, EUENGINE32, EUENGINE33, EUENGINE34 and EUENGINE35 are natural gas-fired, 4SLB spark ignition (SI) RICE coupled to compressors, which are used to transport natural gas into storage fields or into transmission lines. The engines are collectively grouped as FGENGINES3 within the ROP.

1.4 CONTACT INFORMATION

Table 1-2 contains the test affiliated persons names, addresses and telephone numbers for further information regarding the test and test report.

Table 1-2
Contact Information

Program Role	Contact	Address
State Regulatory Administrator	Ms. Karen Kajiya-Mills Technical Programs Unit Manager 517-335-4874 kajiya-millsk@michigan.gov	Michigan Department of Environment, Great Lakes and Energy 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
State Technical Programs Field Inspector	Mr. David Patterson Technical Programs Unit Field Operations Section 517-256-4388 pattersond@michigan.gov	
State Regulatory Inspector	Mr. Robert Elmouchi Environmental Quality Analyst 586-753-3736 elmouchir@michigan.gov	Michigan Department of Environment, Great Lakes and Energy Southeast Michigan District 27700 Donald Court Warren, Michigan 48092
Responsible Official	Mr. Avelock Robinson, Director Gas Compression Operations 586-716-3326 Avelock.Robinson@cmsenergy.com	Consumers Energy Company St. Clair Compressor Station 10021 Marine City Highway Ira, Michigan 48023
Corporate Air Quality Contact	Ms. Amy Kapuga, Sr. Engineer II 517-788-2201 amy.kapuga@cmsenergy.com	Consumers Energy Company Environmental Services Department 1945 West Parnall Road Jackson, Michigan 49201
Field Environmental Coordinator	Mr. Thomas Fox, Sr. Engineer II Field Environmental Coordinator 989-667-5153 thomas.fox@cmsenergy.com	Consumers Energy Company Bay City Service Center 4141 W. Wilder Road Bay City, MI 48706
Test Facility	Mr. Dominic Tomasino, Sr. Field Leader 586-716-3337 Dominic.Tomasino@cmsenergy.com	Consumers Energy Company St. Clair Compressor Station 10021 Marine City Highway Ira, Michigan 48023
Test Team Representative	Mr. Joe Mason, QSTI Sr. Engineering Technical Analyst 616-738-3385 joe.mason@cmsenergy.com	Consumers Energy Company L&D Training Center 17010 Croswell Street West Olive, Michigan 49460

2.0 SUMMARY OF RESULTS

2.1 Operating Data

During the compliance test, the engines fired natural gas, and pursuant to §60.4244(a), operated within 10% of 100 percent peak (or the highest achievable) load based on the maximum manufacturer's design capacity at engine and compressor site conditions. Refer to Appendix C for detailed operating data.

2.2 Applicable Permit Information

RCS operates EUENGINE31, EUENGINE32, EUENGINE33, EUENGINE34 and EUENGINE35 in accordance with the facility ROP, which incorporates 40 CFR Part 63, Subpart ZZZZ requirements are incorporated into the permit.

2.3 Results

The test results in Table 2-1 indicate each engine and oxidation catalyst complies with the applicable percent CO reduction limits.

Table 2-1
Summary of 40 CFR Part 63 Subpart ZZZZ Test Results

Source	Engine Torque / Horsepower (%)	CO Reduction Efficiency (%)	Oxidation Catalyst Inlet Temperature (°F)	Oxidation Catalyst Pressure Drop Comparison (Inches Water Gauge)	
				Initial Test	2020 Results
	[Requirement: 100% ± 10%]	[Requirement: ≥93%]	[Requirement: ≥450°F & ≤1350°F]	[Requirement: ±2" from Initial Test]	
EUENGINE31	99.0 / 96.9	98.1	831.4	2.2	2.12
EUENGINE32	99.0 / 95.5	99.2	866.6	2.3	2.39
EUENGINE33	98.6 / 95.5	99.1	835.5	2.0	2.30
EUENGINE34	98.4 / 95.5	97.3	843.3	2.7	3.00
EUENGINE35	99.2 / 95.6	98.6	840.2	2.1	2.14

Detailed results are presented in Appendix Tables 1 – 5. A discussion of the results is presented in Section 5.0. Sample calculations, field data sheets, and laboratory data sheets are presented in Appendices A, B, and C. Engine operating data and supporting documentation are provided in Appendices D and E.

3.0 SOURCE DESCRIPTION

EUENGINE31, EUENGINE32, EUENGINE33, EUENGINE34 and EUENGINE35 were constructed in 2013. A summary of the engine specifications is presented in Table 3-1.

Table 3-1
Summary of Engine Specifications

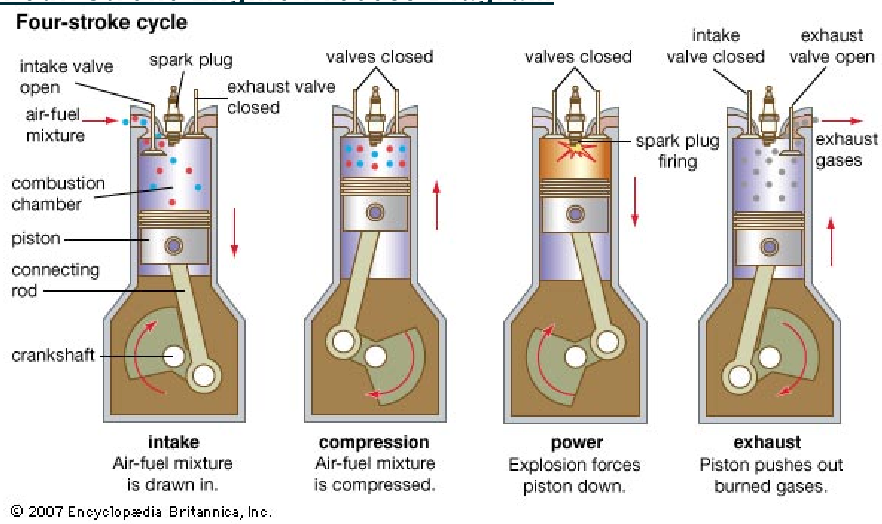
Parameter[1]	EUENGINE31 through EUENGINE35
Make	Caterpillar
Model	G3616
Output (brake-horsepower)	4,735
Heat Input (mmBtu/hr)	32.0
Exhaust Flow Rate (ACFM, wet)	32,100
Exhaust Gas Temp.	856
Engine Outlet O_2 (Vol-%, dry)	12.00
Engine Outlet CO_2 (Vol-%, dry)	5.81
CO, Uncontrolled (ppmv, dry)	572.0
CO, Controlled (ppmv, dry)[2]	40.0

[1] Engine specifications are based upon vendor data for operation at 100% of rated engine capacity
[2] The controlled CO concentrations are based upon the vendor not to exceed CO concentrations at 100% load, and a reduction 93% by volume for the associated oxidation catalysts.

3.1 PROCESS

The engines utilize the four-stroke engine cycle which starts with the downward air intake piston stroke which aspirates air through intake valves into the combustion chamber (cylinder). When the piston nears the bottom of the cylinder, fuel is injected and the intake valves close. As the piston travels upward, the air/fuel mixture is compressed and ignited, thus forcing the piston downward into the power stroke. At the bottom of the power stroke, exhaust valves open and the piston traveling upward expels the combustion by-products. Significant maintenance has not been performed on the engines or oxidation catalysts within the past three months. Refer to Figure 3-1 for a four-stroke engine process diagram.

Figure 3-1. Four-Stroke Engine Process Diagram



The flue gas generated by natural gas combustion is controlled through parametric controls (i.e., timing and operating at a lean air-to-fuel ratio) and by post-combustion oxidizing catalysts manufactured by EmeraChem, LLC (Part No. 28283.5-300CO). Four catalyst modules installed on each engine exhaust stack use proprietary materials to lower the oxidation temperature of CO and other organic compounds, thus maximizing the catalyst efficiency specific to the exhaust gas temperatures of the engines. As CO passes through the catalytic oxidation system, CO and VOC are oxidized to CO_2 and water, while suppressing the conversion of NO to NO_2.

Nitrogen oxides (NO_x) emissions from 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 resulting in lower NO_x emissions.

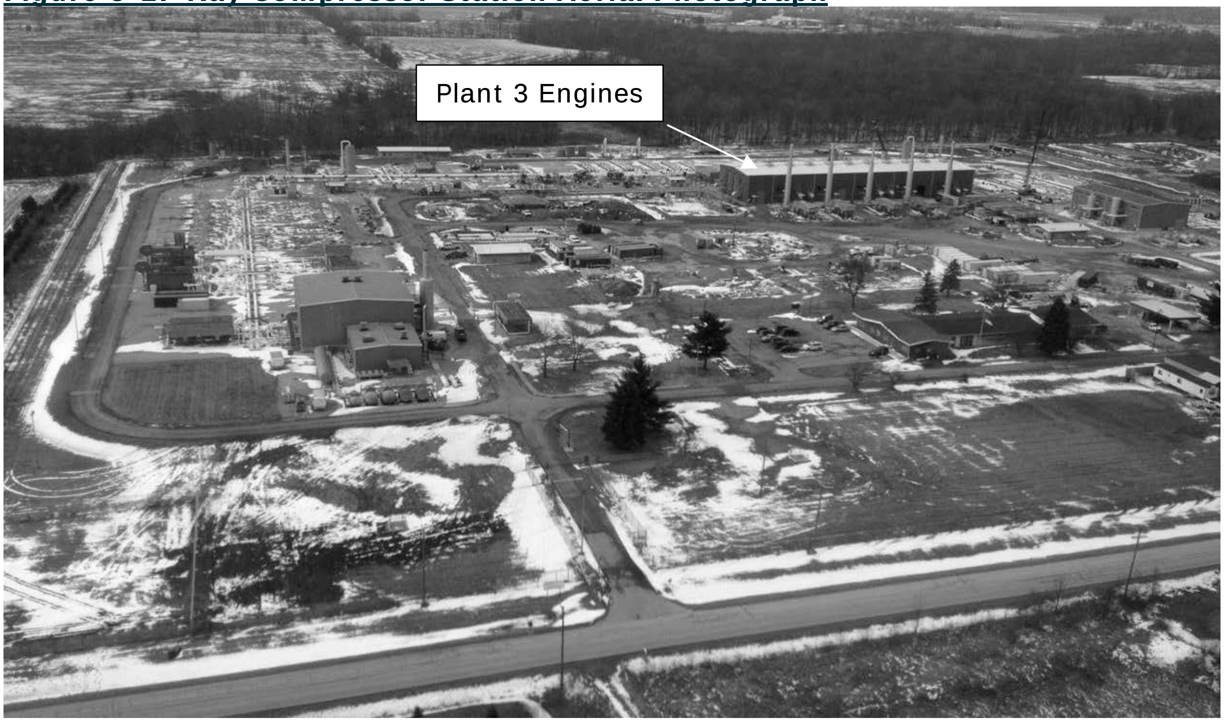
While the catalyst vendor guarantees 93% CO destruction efficiency, the catalyst also controls formaldehyde and non-methane, non-ethane hydrocarbons (NMNEHC). Estimated formaldehyde and NMNEHC destruction efficiencies are 85% and 75%, respectively.

A continuous parameter monitoring system (CPMS) monitors catalyst inlet temperature in accordance with the requirements specified in Table 5 (1) of 40 CFR Part 63, Subpart ZZZZ. This parameter is monitored in accordance with the site-specific preventative maintenance / malfunction and abatement plan as a means to evaluate an efficient catalytic reaction and the performance of the pollution control equipment. Detailed operating data are provided in Appendix C.

3.2 PROCESS FLOW

Located in northern Macomb County, the Ray Compressor Station helps maintain natural gas pressure along pipeline systems and for gas injection and withdrawal. An aerial photograph of the Ray Compressor Station is provided in Figure 3-2.

Figure 3-2. Ray Compressor Station Aerial Photograph



The engine exhaust stacks are of non-typical design. Specifically, the bottom portion of the stack contains an outer and an inner circular stack (similar to a doughnut if viewed from the top of the stack). Engine exhaust gas enters the free-standing outer stack via two horizontal ducts exiting the engine and flows downward through oxidation catalysts in the bottom of the outer stack. The gases are then directed into the inner stack through an opening near the stack base, traveling upwards approximately 95-feet to an unobstructed vertical discharge to atmosphere.

3.3 MATERIALS PROCESSED

The engine fuel fired is exclusively natural gas, as defined in 40 CFR §72.2. Recent natural gas sample analysis indicates this composition to be approximately 93% methane, 5% ethane, 1% nitrogen, and 0.5% carbon dioxide.

3.4 RATED CAPACITY

Each engine has a rated heat input of 32 mmBtu/hr and a maximum output of 4,735 horsepower. These input/output capacities are a function of facility and gas transmission extraction and/or storage demand. During testing, engine operating parameters were recorded and averaged for each test run. Refer to Appendix C for this operating data.

3.5 PROCESS INSTRUMENTATION

During testing, engine operating parameters were continuously monitored and collected in one-minute increments, for the following parameters:

- Discharge pressure (psi)
- Engine Load as Compressor Torque (% max)
- Engine speed (rpm)
- Power (BHP)
- Suction pressure (psi)
- Fuel use (scf/hr)
- Catalyst exhaust pressure (in. H_2O)
- Catalyst inlet / engine exhaust temperature (°F)

Refer to Appendix C for operating data.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

Consumers Energy RCTS tested for CO and oxygen (O_2) concentrations using the USEPA test methods presented in Table 4-1. The sampling and analytical procedures associated with each parameter are described in the following sections.

Table 4-1
Test Methods

Parameter	Method	USEPA Title
Sample traverses	1	Sample and Velocity Traverses for Stationary Sources
Oxygen	3A	Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)
Nitrogen oxides (NO_x)	7E [1]	Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)
Carbon monoxide (CO)	10	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)

[1] The Method 7E NO_x parameter was not measured, however Method 3A and 10 analyzers followed Method 7E quality assurance procedural and sample traverse point guidance.

4.1 Description of Sampling Train and Field Procedures

The test matrix presented in Table 4-2 summarizes the sampling and analytical methods performed for the specified parameters during this test program.

Table 4-2
Test Matrix

Date (2020)	Run	Sample Type	Start Time (EDT)	Stop Time (EDT)	Test Duration (min)	USEPA Test Method	Comment
EUENGINE31							
June 18	1	O_2 CO	11:33	12:32	60	1 3A 10	3-point traverse conducted at each sample location at 16.7, 50.0 & 83.3 % of the measurement line
	2		12:45	13:44	60		
	3		13:56	14:55	60		
EUENGINE32							
June 18	1	O_2 CO	07:40	08:39	60	1 3A 10	3-point traverse conducted at each sample location at 16.7, 50.0 & 83.3 % of the measurement line
	2		08:51	09:50	60		
	3		10:02	11:01	60		
EUENGINE33							
June 19	1	O_2 CO	7:54	8:53	60	1 3A 10	3-point traverse conducted at each sample location at 16.7, 50.0 & 83.3 % of the measurement line
	2		9:06	10:05	60		
	3		10:21	11:20	60		
EUENGINE34							
June 17	1	O_2 CO	10:34	11:33	60	1 3A 10	3-point traverse conducted at each sample location at 16.7, 50.0 & 83.3 % of the measurement line
	2		11:48	12:47	60		
	3		13:01	14:00	60		
EUENGINE35							
June 16	1	O_2 CO	9:14	10:13	60	1 3A 10	3-point traverse conducted at each sample location at 16.7, 50.0 & 83.3 % of the measurement line
	2		10:29	11:28	60		
	3		11:39	12:38	60		

4.2 Sample Location and Traverse Points (USEPA Method 1)

The number and location of traverse points for each engine was evaluated according to the requirements in Table 4 of 40 CFR Part 63 and USEPA Method 1, *Sample and Velocity Traverses for Stationary Sources*.

Each engine is equipped with sample ports located upstream of the oxidation catalyst in (two) horizontal 24-inch diameter ducts exiting the engine and building. The ports are:

- At least 208 inches (8.7 duct diameters) downstream of a duct bend disturbance at the engine exhaust, and
- At least 57 inches (2.4 duct diameters) upstream of flow disturbance caused by a change in duct diameter and flow direction as it enters the oxidation catalyst.

Each engine is also equipped with sample ports located downstream of the oxidation catalyst in (one) vertical 36-inch diameter stack at:

- Approximately 72-inches (2 stack diameters) downstream of a flow disturbance, and
- Approximately 43-inches (1.2 stack diameters) upstream of the stack exit.

The pre and post-catalyst sample ports presented as Figures 4-1 and 4-2 are 4-inch in diameter and extend approximately 4-inches beyond the stack wall.

Since each exhaust duct or stack is > 12 inches in diameter and the sample port locations meet the two and one-half diameter criterion in Section 11.1.1 of Method 1, exhaust gas was sampled at equal time intervals from each of three traverse points located at 16.7, 50.0, and 83.3% of the measurement line ('3-point long line') during each test.

Figure 4-1. Pre-Catalyst Sampling Port Location

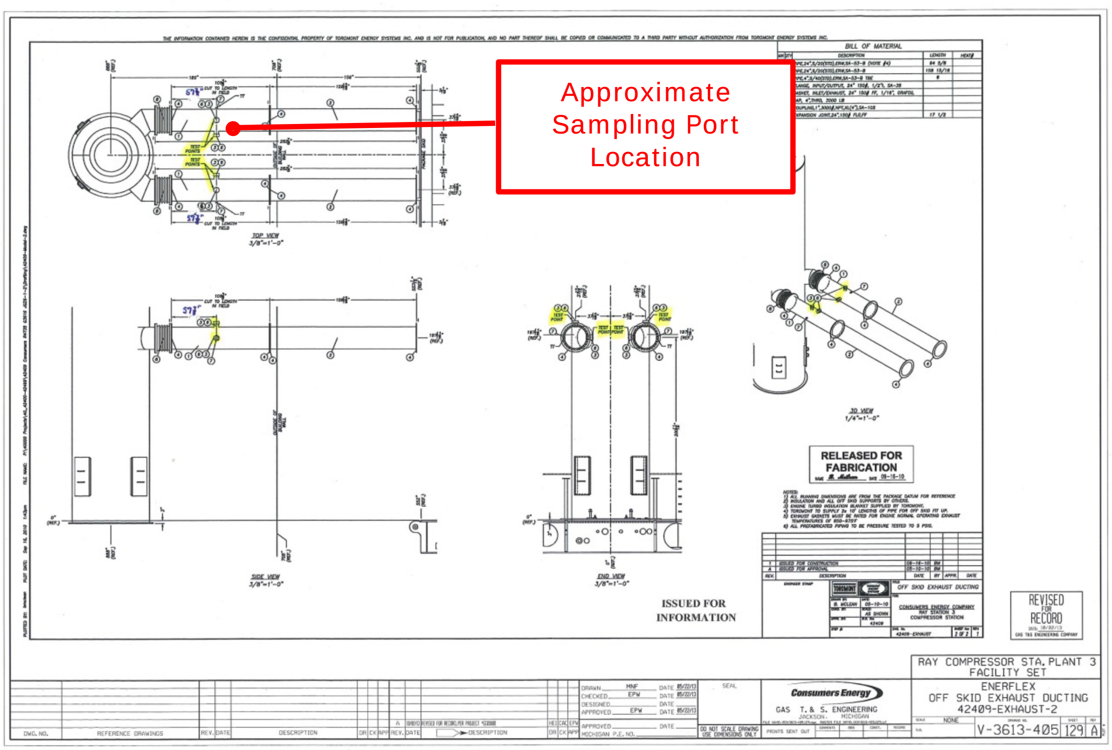
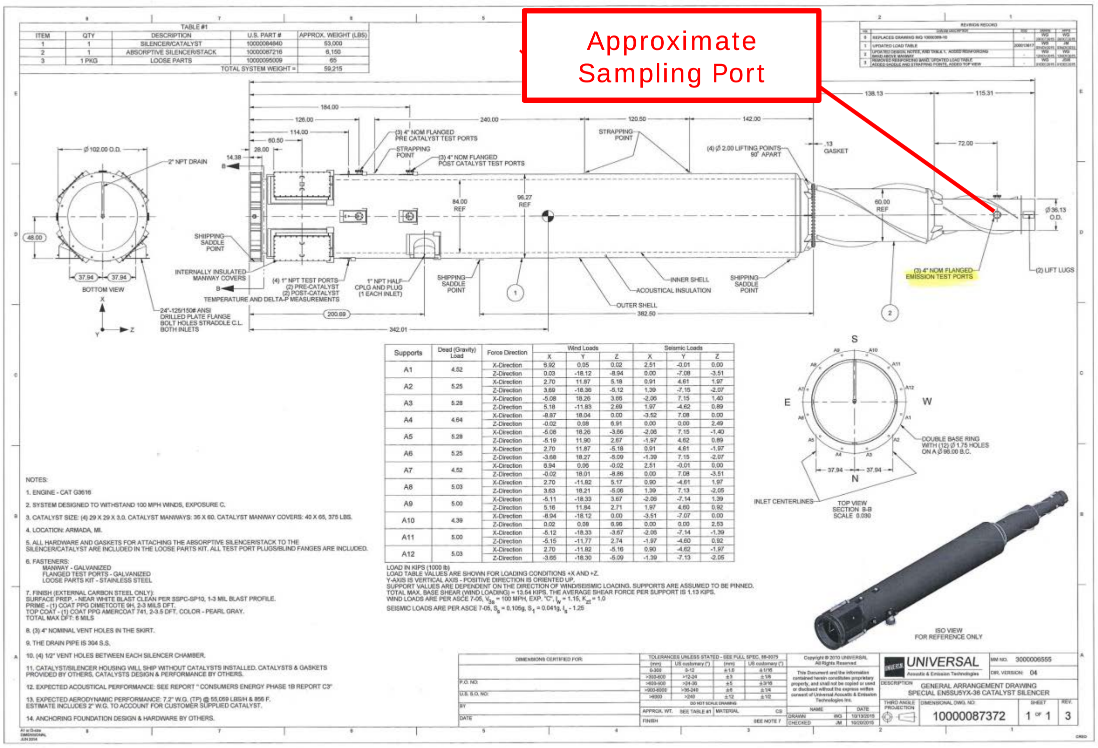


Figure 4-2. Post-Catalyst Sampling Port Location



4.3 O_2 AND CO (USEPA METHODS 3A AND 10)

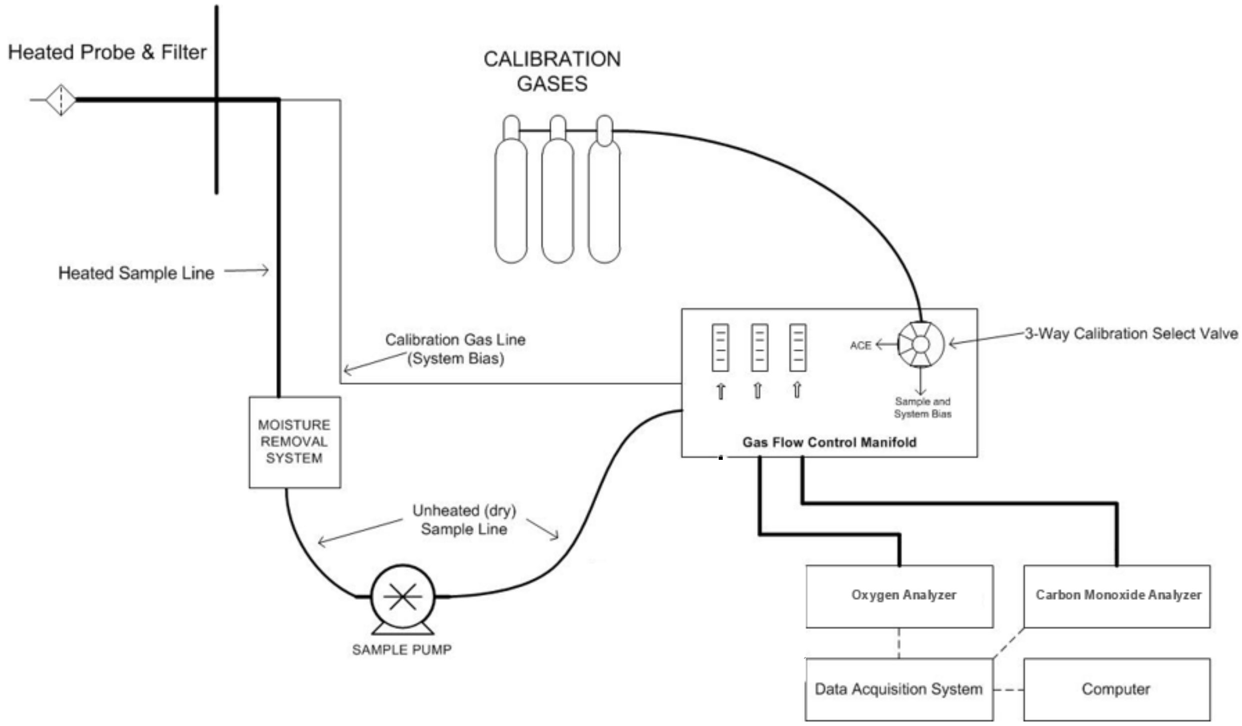
Oxygen and carbon monoxide concentrations were measured using the following sampling and analytical procedures:

- USEPA Method 3A, *Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure), and*
- USEPA Method 10, *Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure).*

Apart from the analyzers and analytical technique used, the sampling procedures of each method are similar. Oxygen concentrations were measured to adjust the pollutant concentrations to 15% O_2 and calculate pollutant emission rates.

Engine exhaust gas was extracted from the stacks or ducts through a stainless-steel probe, heated Teflon® sample line, and through a gas conditioning system to remove water and dry the sample before entering a sample pump, flow control manifold, and gas analyzers. Figure 4-3 depicts a drawing of the Methods 3A and 10 sampling system.

Figure 4-3. USEPA Methods 3A and 10 Sampling System



Prior to sampling engine exhaust gas, the analyzers are calibrated by performing a calibration error test where zero-, mid-, and high-level calibration gases are introduced directly to the back of the analyzers. The calibration error check is performed to evaluate if the analyzers response was within ±2.0% of the calibration gas span or high calibration gas concentration. An initial system-bias test is then performed where the zero- and mid- or high- calibration gases are introduced at the sample probe to measure the ability of the system to respond accurately to within ±5.0% of span.

Upon successful completion of the calibration error and initial system bias tests, sample flow rate and component temperatures are verified, and the probes inserted into the ducts at the appropriate traverse point. After confirming the engine is operating at established conditions, the test run is initiated. Gas concentrations are recorded at 1-minute intervals throughout each 60-minute test run.

At the conclusion of each test run, a post-test system bias check is performed to compare analyzer bias and drift relative to pre-test system bias checks, ensuring analyzer bias is within ±5.0% of span and drift is within ±3.0%. The analyzer response is also used to correct measured gas concentrations for analyzer drift.

5.0 TEST RESULTS AND DISCUSSION

The test program conducted June 16 – 19, 2020, satisfies the performance testing and compliance evaluation requirements in 40 CFR Part 63, Subpart ZZZZ, *National Emission Standards for Hazardous Air Pollutants for Reciprocating Internal Combustion Engines* and MI-ROP-B6636-2015a.

5.1 Tabulation of Results

The EUENGINE31, EUENGINE32, EUENGINE33, EUENGINE34, and EUENGINE35 CO destruction efficiency test results indicate the exhaust catalysts are compliant with the limits summarized in Table 2-1. Tabulated results, process operating conditions, and exhaust gas conditions for each respective RICE is shown in Appendix Tables 1 through 5.

5.2 Significance of Results

The test results indicate compliance with applicable CO destruction efficiency requirements.

5.3 Variations from Sampling or Operating Conditions

No sampling or operating condition variations occurred during the test event.

5.4 Process or Control Equipment Upset Conditions

Each engine and gas compressor were operating under maximum routine conditions and no upsets were encountered during testing.

5.5 Air Pollution Control Device Maintenance

No major air pollution control device maintenance was performed during the three-month period prior to the test event. Engine optimization is continuously performed to ensure lean-burn combustion and ongoing compliance with regulatory emission limits.

5.6 Re-Test Discussion

Based on the results of this test program, a re-test is not required. Subsequent 40 CFR Part 63 Subpart ZZZZ air emissions testing on the engines will be performed annually to evaluate reduction of CO emissions across the oxidation catalysts.

5.7 Results of Audit Samples

Audit samples for the reference methods utilized during this test program are not available from USEPA Stationary Source Audit Sample Program providers.

The USEPA reference methods performed state reliable results are obtained by persons equipped with a thorough knowledge of the techniques associated with each method. Factors with the potential to cause measurement errors are minimized by implementing quality control (QC) and assurance (QA) programs into the applicable components of field testing. QA/QC components were included in this test program. Table 5-1 summarizes the primary field quality assurance and quality control activities that were performed. Refer to Appendix D for supporting documentation.

Table 5-1
QA/QC Procedures

QA / QC Activity	Purpose	Procedure	Frequency	Acceptance Criteria
M1: Sampling Location	Evaluates sampling location suitability for sampling	Measure distance from ports to downstream and upstream flow disturbances	Pre-test	≥2 diameters downstream; ≥0.5 diameter upstream.
M1: Duct diameter/ dimensions	Verifies area of stack is accurately measured	Review as-built drawings and field measurement	Pre-test	Field measurement agreement with as-built drawings
M3A, M7E, M10: Calibration gas standards	Ensures accurate calibration standards	Traceability protocol of calibration gases	Pre-test	Calibration gas uncertainty ≤2.0%
M3A, M7E, M10: Calibration Error	Evaluates analyzer operation	Calibration gases introduced directly into analyzers	Pre-test	±2.0% of calibration span
M3A, M7E, M10: System Bias and Analyzer Drift	Evaluates analyzer/sample system integrity and accuracy over test duration	Calibration gas introduced at sample probe tip, HSL, and into analyzers	Pre-test and Post-test	Bias: ±5.0% of calibration span Drift: ±3.0% of calibration span

5.8 Calibration Sheets

Calibration sheets, including gas protocol sheets and analyzer quality control and assurance checks are presented in Appendix D.

5.9 Sample Calculations

Sample calculations and formulas used to compute emissions data are presented in Appendix A.

5.10 Field Data Sheets

Field data sheets are presented in Appendix B.

5.11 Laboratory Quality Assurance / Quality Control Procedures

Laboratory analysis was not required for this compliance demonstration.

5.12 QA / QC Blanks

The calibration gases described in Table 5-1 above were the only QA/QC media employed during the test event. QA/QC data are shown in Appendix D.