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CO Reduction Efficiency 40 CFR Part 63, Subpart ZZZZ Test Report

EUENGINE3-2

Consumers Energy Company
Freedom Compressor Station
12201 Pleasant Lake Road
Manchester, Michigan 48158
SRN: N3920

November 27, 2018

Test Date: October 10, 2018

Test Performed by the Consumers Energy Company
Regulatory Compliance Testing Section
Air Emissions Testing Body
Laboratory Services Section
Work Order No. 32598733
Version No.: 0

EXECUTIVE SUMMARY

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted carbon monoxide reduction efficiency testing of oxidation catalysts installed to control exhaust emissions of one natural gas fired, reciprocating internal combustion engine (RICE) identified as EUENGINE3-2 operating at the Freedom Compressor Station in Manchester, Michigan. (A second engine, identified as EUENGINE3-1, was not available and will be tested at a later date.) The engine is classified as a new (installed 2016), four-stroke lean burn (4SLB), spark ignited, 3,750 brake horsepower (BHP) engine, located at a major source of hazardous air pollutant (HAP) emissions. The engine is used to maintain pressure of natural gas in order to move it along the pipeline system.

The test program was performed to satisfy the performance testing requirements and evaluate compliance with 40 CFR Part 63, Subpart ZZZZ, "National Emissions Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines," (aka RICE MACT), as identified in Permit to Install (PTI) No. 202-15A. Initial startup of the engine occurred on October 24, 2016.

On October 10, 2018, triplicate 60-minute tests were performed as proposed in the July 9, 2018 Test Protocol submitted to United States Environmental Protection Agency (USEPA) and MDEQ. The testing followed the procedures in USEPA Reference Methods (RM) 1, 3A, and 10 in 40 CFR Part 60, Appendix A with no deviations from the approved stack test protocol with the exception of engine load. Although 40 CFR §63.6620(b) specifies the test must be performed at any load condition within plus or minus 10 percent of 100 percent load, the maximum achievable load during testing was 81% of the engine manufacturer's rated capacity for torque, based on pipeline pressures and site conditions.

The results of the emissions testing are summarized in the following table:

Table E-1
Summary of Results

Engine	Parameter	Run			Average	Emission Limit[1]
		1	2	3		
EUENGINE3-2	CO Reduction Efficiency (%)	94.7	94.6	94.6	**94.6**	**≥93**

[1] Table 2a to Subpart ZZZZ of Part 63—Emission Limitations for New and Reconstructed 2SLB and Compression Ignition Stationary RICE >500 HP and New and Reconstructed 4SLB Stationary RICE ≥250 HP Located at a Major Source of HAP Emissions.

The results of the testing indicate the engine is operating in compliance with the applicable limit. Because the engine operating load was limited during the test, the facility will restrict the operation of the engine to ±10 percent of the tested operating load until such time the engine can be safely operated within ±10 percent of 100 percent load and additional testing is conducted to demonstrate compliance with 40 CFR Part 63, Subpart ZZZZ.

Detailed results are presented in Appendix Table 1. Sample calculations and field data sheets are presented in Appendices A and B. Engine operating data and supporting documentation are provided in Appendices C and D.

1.0 INTRODUCTION

This report summarizes the results of the October 10, 2018 compliance air emissions testing of one natural gas fired engine, identified as EUENGINE3-2, operating at the Freedom Compressor Station in Manchester, Michigan.

This document was prepared following guidance in Michigan Department of Environmental Quality (MDEQ) *Format for Submittal of Source Emission Test Plans and Reports* published in March of 2018. Please exercise due care if portions of this report are reproduced, as critical substantiating documentation and/or other information may be omitted or taken out of context.

1.1 Identification, Location, and Dates of Tests

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted compliance carbon monoxide reduction efficiency testing of oxidation catalysts installed to control exhaust emissions of one natural gas fired, reciprocating internal combustion engine (RICE), identified as EUENGINE3-2 operating at the Freedom Compressor Station in Manchester, Michigan. (A second engine, identified as EUENGINE3-1, was not available and will be tested at a later date.) A test protocol, describing the proposed testing, methods, and quality assurance procedures was submitted to the Michigan Department of Environmental Quality (MDEQ) and United States Environmental Protection Agency (USEPA) on July 9, 2018. Subsequently, Ms. Regina Hines, Environmental Quality Analyst with the MDEQ, approved the test protocol in her letter dated September 4, 2018. The testing was performed October 10, 2018.

1.2 Purpose of Testing

The test program was performed to satisfy the performance testing requirements and evaluate compliance with 40 CFR Part 63, Subpart ZZZZ, "National Emissions Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines," (aka RICE MACT), as identified in Permit to Install (PTI) 202-15A. The applicable 40 CFR Part 63, Subpart ZZZZ emission limit compliance options are presented in Table 1-1.

Table 1-1
Applicable 40 CFR Part 63, Subpart ZZZZ Emission Limit Compliance Options

Parameter	Emission Limit	Applicable Requirement
CO	Reduce CO emissions by 93 percent	40 CFR §63.6600(b) Table 2a to Subpart ZZZZ of Part 63
Or		
Formaldehyde	Limit concentration of formaldehyde in the stationary RICE exhaust to 14 ppmvd or less at 15 percent O_2	

Although compliance with 40 CFR Part 63, Subpart ZZZZ can be achieved by limiting engine exhaust formaldehyde concentrations, Consumers Energy Freedom Compressor Station has elected to evaluate compliance with the CO reduction efficiency limit.

1.3 Brief Description of Source

EUENGINE3-2 is classified as a new (installed 2016) four stroke lean burn (4SLB) spark-ignited 3,750 brake horsepower (BHP) engine located at a major source of hazardous air pollutant (HAP) emissions. The engine is used to maintain pressure of natural gas along the pipeline system.

1.4 Contact Information

Table 1-2 presents contact information of personnel involved in the test program.

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 Environmental Quality Technical Programs Unit 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
State Technical Programs Field Inspector	Ms. Regina Hines Environmental Quality Analyst 313-418-0895 hinesr2@michigan.gov	Michigan Department of Environmental Quality Detroit Field Office – Cadillac Place 3058 West Grand Boulevard; Suite 2-300 Detroit, Michigan 48202
State Regulatory Inspector	Mr. Mike Kovalchick Environmental Quality Analyst 517-416-5025 kovalchickm@michigan.gov	Michigan Department of Environmental Quality Jackson District Office 301 E. Louis Glick Highway Jackson, Michigan 49201
Responsible Official	Mr. Gregory Baustian Executive Director of Gas Compression 616-237-4009 gregory.baustian@cmsenergy.com	Consumers Energy Company Zeeland Generation 425 N. Fairview Road Zeeland, Michigan 49464
Corporate Air Quality Contact	Ms. Amy Kapuga Senior Environmental Engineer 517-788-2201 amy.kapuga@cmsenergy.com	Consumers Energy Company Environmental Services Department 1945 West Parnall Road; P22-330 Jackson, Michigan 49201
Test Facility	Mr. Simon Lato Sr. Field Leader 810-428-2053 simon.lato@cmsenergy.com	Consumers Energy Company Freedom Compressor Station 12201 Pleasant Lake Road Manchester, Michigan 48005
Test Facility	Mr. Vincent Hittie Gas Field Leader 586-784-2096 vincent.hittie@cmsenergy.com	Consumers Energy Company Freedom Compressor Station 12201 Pleasant Lake Road Manchester, Michigan 48005
Test Team Representative	Mr. Thomas Schmelter, QSTI Engineering Technical Analyst 616-738-3234 thomas.schmelter@cmsenergy.com	Consumers Energy Company J.H. Campbell Training Center 17010 Croswell Street West Olive, Michigan 49460

2.0 SUMMARY OF RESULTS

2.1 Operating Data

During the performance test, the engine fired natural gas and operated at maximum achievable operating load conditions. Although 40 CFR §63.6620(b) specifies the test must be performed at any load condition within plus or minus 10 percent of 100 percent load, the maximum achievable load during testing was 81% of the engine manufacturer's rated capacity for torque, based on pipeline pressures and site conditions.

Refer to Appendix C for detailed operating data.

2.2 Applicable Permit Information

The State of Michigan has assigned Registration Number (SRN) N3920 to the Freedom Compressor Station, which operates in accordance with air permits MI-ROP-N3920-2014b and PTI 202-15A. EUENGINE3-2 is grouped with EUENGINE3-1, along with EUENGINE3-3, EUENGINE3-4 and EUENGINE3-5 (which have not been installed yet) as the PTI emission unit sources associated with the FGENGINES-P3, FGNSPSJJJJ, and FGNESHAPZZZZ flexible groups. Incorporated within the permits are the applicable requirements of 40 CFR Part 63, Subpart ZZZZ – National Emission Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines.

2.3 Results

The results of the testing indicate the engine is operating in compliance with the applicable limit. Because the engine operating load was limited during test, the facility will restrict the operation of the engine to ±10 percent of the tested operating load until such time the engine can be safely operated within ±10 percent of 100 percent load and additional testing is conducted to demonstrate compliance with 40 CFR Part 63, Subpart ZZZZ. Refer to Table 2-1 for a summary of test results.

Table 2-1
Summary of Results

Engine	Parameter	Run			Average	Emission Limit[1]
		1	2	3		
EUENGINE3-2	CO Reduction Efficiency (%)	94.7	94.6	94.6	**94.6**	**≥93**

[1] Table 2a to Subpart ZZZZ of Part 63—Emission Limitations for New and Reconstructed 2SLB and Compression Ignition Stationary RICE >500 HP and New and Reconstructed 4SLB Stationary RICE ≥250 HP Located at a Major Source of HAP Emissions.

Detailed results are presented in Appendix Table 1. Sample calculations and field data sheets are presented in Appendices A and B. Engine operating data and supporting documentation are provided in Appendices C and D.

3.0 SOURCE DESCRIPTION

EUENGINE3-2 is a natural gas fired RICE used to maintain pressure of natural gas along the pipeline system. A summary of the engine specifications from vendor data are provided in Table 3-1.

Table 3-1
Summary of Engine Specifications

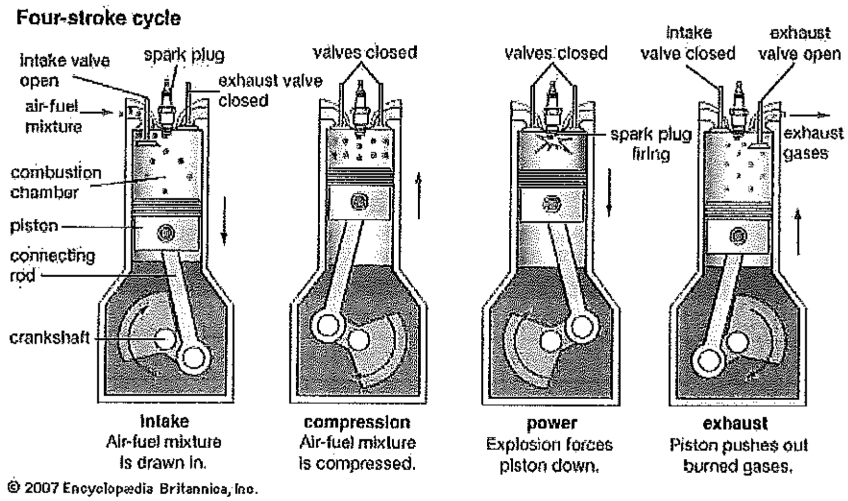
Parameter[1]	EUENGINE3-2
Make	Waukesha
Model	12V275GL
Output (brake-horsepower)	3,750
Heat Input, LHV (mmBtu/hr)	28.96
Exhaust Flow Rate (ACFM, wet)	23,373
Exhaust Gas Temp.	828
[1] Engine specifications are based upon vendor data for operation at 100% of rated engine capacity	

3.1 PROCESS

EUENGINE3-2 is a natural gas-fired, spark ignited, 4SLB RICE installed in 2016 with initial startup on October 24, 2016. In the four-stroke engine, air is aspirated into the cylinder during the downward travel of the piston on the intake stroke. The fuel charge is injected with the piston near the bottom of the intake stroke and the intake valves are then closed as the piston moves to the top of the cylinder, compressing the air/fuel mixture. A spark plug at the top of the cylinder ignites the air/fuel charge causing the charge to expand and initiate the downward movement of the piston, called the power stroke. As the piston reaches the bottom of the power stroke, valves open to exhaust combustion products from the cylinder as the piston travels upward. A new air-to-fuel charge is injected as the piston moves downward in a new intake stroke.

The engine provides mechanical shaft power for a gas compressor. The compressor is used to maintain pressure within the natural gas pipeline transmission and distribution system to consumers. Refer to Figure 3-1 for a four-stroke engine process diagram.

Figure 3-1. Four-Stroke Engine Process Diagram



The flue gas generated through 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 installed on the engine exhaust system. The RICE oxidation catalysts are manufactured by Advanced Catalyst Systems, Inc. Four catalyst modules are installed on each engine exhaust stack. The catalysts 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 engines. As carbon monoxide passes through the catalytic oxidation system, CO and volatile organic compounds are oxidized to CO_2 and water, while suppressing the conversion of NO to NO_2.

The catalyst vendor has guaranteed a CO destruction efficiency of 93%. Although Consumers Energy has chosen to comply with the CO reduction emission limit requirement, the catalyst also provides control of formaldehyde and non-methane and non-ethane hydrocarbons (NMNEHC). The estimated destruction efficiency for formaldehyde and NMNEHC is 80%. Although optimization of the engine programing and synchronization with the compressor was completed, no other significant maintenance was performed on the engine or oxidation catalysts within three months of the scheduled test.

Nitrogen oxides (NO_x) emissions from the engine are minimized using 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.

A continuous parameter monitoring system (CPMS) is installed to continuously monitor 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 D.

3.2 Process Flow

Located in southwest Washtenaw County, the Freedom Compressor Station helps maintain natural gas pressures in the natural gas pipeline system. The main function of the station is to transport natural gas primarily from the Panhandle Eastern Pipeline Company's supply lines to Consumers Energy's pipeline system. The Panhandle Eastern Pipeline is an approximate 6,000-mile system that extends from natural gas producing areas in the Anadarko Basin of Texas, Oklahoma and Kansas through Missouri, Illinois, Indiana, Ohio and into Michigan.

EUENGINE3-2 is a natural gas reciprocating compressor engine used to drive a two-stage compressor to maintain pressure and move natural gas through the pipeline system. The exhaust stack is of non-typical design. Specifically, the bottom portion of the stack incorporates an annulus, where an outer stack surrounds an inner circular stack (the shape is like a doughnut as viewed looking down from the top of the stack). The exhaust gases from the engine enter the annulus via two horizontal ducts exhausting the engine. Once the gases enter the outer stack, they flow downwards through the oxidation catalysts placed in the bottom of the annulus. After passing through the catalysts, the exhaust gases enter the inner stack through an opening located near the base of the freestanding stack. The exhaust gases then travel upwards, through the freestanding stack, (via the inner stack) until they are discharged unobstructed vertically upwards through the approximately 65-feet high stack to atmosphere.

3.3 Materials Processed

The fuel utilized in the engine is exclusively natural gas, as defined in 40 CFR §72.2. The unit is classified as a new (installed 2016) stationary RICE located at a major source of HAP emissions, non-emergency, non-black start 4SLB stationary RICE >500 HP that is not a remote stationary RICE and that operates more than 24 hours per calendar year as described in Table 2d (9) to Subpart ZZZZ.

3.4 Rated Capacity

EUENGINE3-2 has a maximum output of approximately 3,750 horsepower. At this achievable output, the heat input rating is approximately 28.96 mmBtu/hr. However, the maximum achievable operating condition of the engine is constrained by site and pipeline specific conditions.

3.5 Process Instrumentation

The process was continuously monitored by operators and data acquisition systems during testing. Data was collected at five-minute intervals during each test run for the following parameters:

- Date and time
- Engine brake horsepower (HP)
- Engine speed (RPM)
- Engine torque load (%)
- Fuel gas flow (scfm)
- Suction pressure (psi)
- Discharge pressure (psi)
- Catalyst inlet temperature (°F)
- Pressure differential pressure across catalyst (in H_2O)
- Barometric pressure (psi)
- Calorific value of natural gas (Btu/scf)

Refer to Appendix C for operating data.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

The Consumers Energy RCTS test team measured oxygen and carbon monoxide concentrations using the United States Environmental Protection Agency (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 location and traverse points	1	Sample and Velocity Traverses for Stationary Sources
Oxygen	3A	Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrument Analyzer Procedure)
Carbon monoxide	10	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)

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 (2018)	Engine	Run	Start Time (EDT)	Stop Time (EDT)	Test Duration (min)	EPA Test Method	Comment
October 10	3-2	1	10:01	11:01	60	1, 3A, 10	Engine at max achievable load
		2	11:25	12:25	60		No test or engine issues
		3	12:47	13:47	60		No test or engine issues

4.1.1 Sample Location and Traverse Points (USEPA Method 1)

The number and location of traverse points were selected according to the requirements in Table 4 of 40 CFR Part 63, Subpart ZZZZ and USEPA Method 1, *Sample and Velocity Traverses for Stationary Sources.*

Pre-catalyst Sampling Ports

Two test ports are located in each of two 16-inch diameter horizontal exhaust ducts exiting the engine. The pre-catalyst sampling ports are situated:

- Approximately 347-inches or 21.7 duct diameters downstream of a duct bend disturbance in the engine exhaust duct, and

- Approximately 63-inches or 3.9 duct diameters upstream of flow disturbance caused by a change in duct diameter and flow direction as it enters exhaust stack and oxidation catalyst.

The pre-catalyst sample ports are 4-inches in diameter and sealed by a bolted blank flange approximately 4-inches outside the duct wall.

Post-catalyst Sampling Ports

Two test ports are located in a 30-inch vertical exhaust stack exiting the engine and oxidation catalyst. The post-catalyst sampling ports are situated:

- Approximately 240-inches or 8.0 duct diameters downstream of a duct diameter change flow disturbance, and

- Approximately 118-inches or 3.9 duct diameters upstream of the stack exit to atmosphere.

The post-catalyst sample ports are 4-inches in diameter and sealed by a bolted blank flange approximately 4-inches outside the stack wall.

Because the ducts are >12 inches in diameter and the sampling port locations meet the two and half-diameter criterion of Section 11.1.1 of Method 1 of 40 CFR Part 60, Appendix A-1, the duct was sampled at 3 traverse points located at 16.7, 50.0, and 83.3% of the measurement line ('3-point long line'). The flue gas was sampled from the three traverse points at approximately equal intervals during the tests. Pre-catalyst and post-catalyst sampling port location drawings are presented as Figures 4-1 and 4-2.

Figure 4-1. Pre- and Post-Catalyst Sampling Port Locations

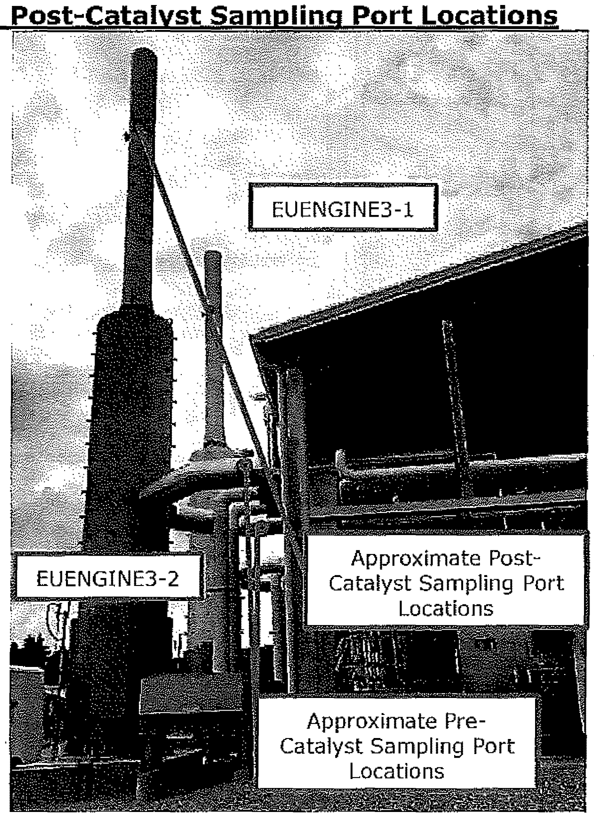
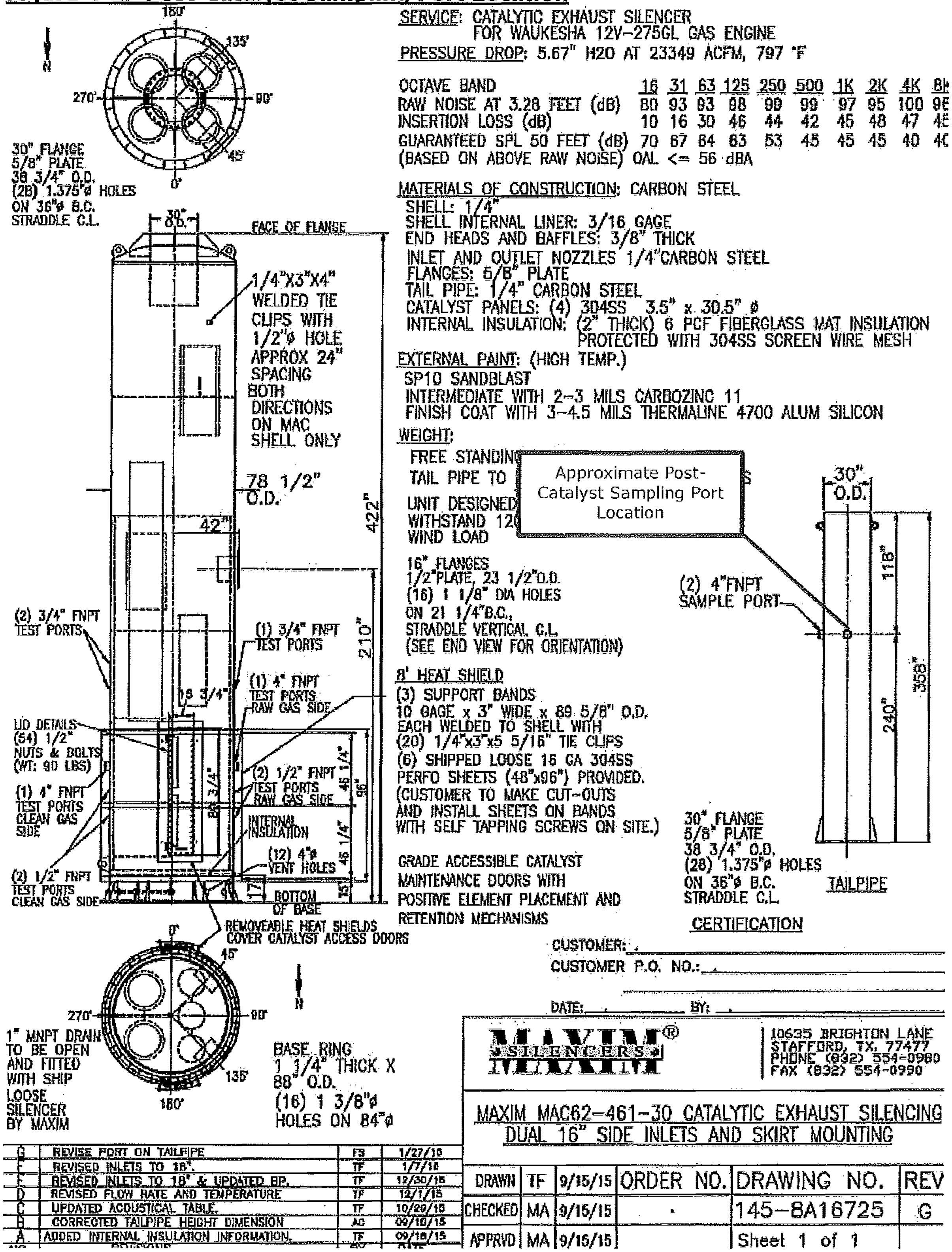


Figure 4-2. Post-Catalyst Sampling Port Location

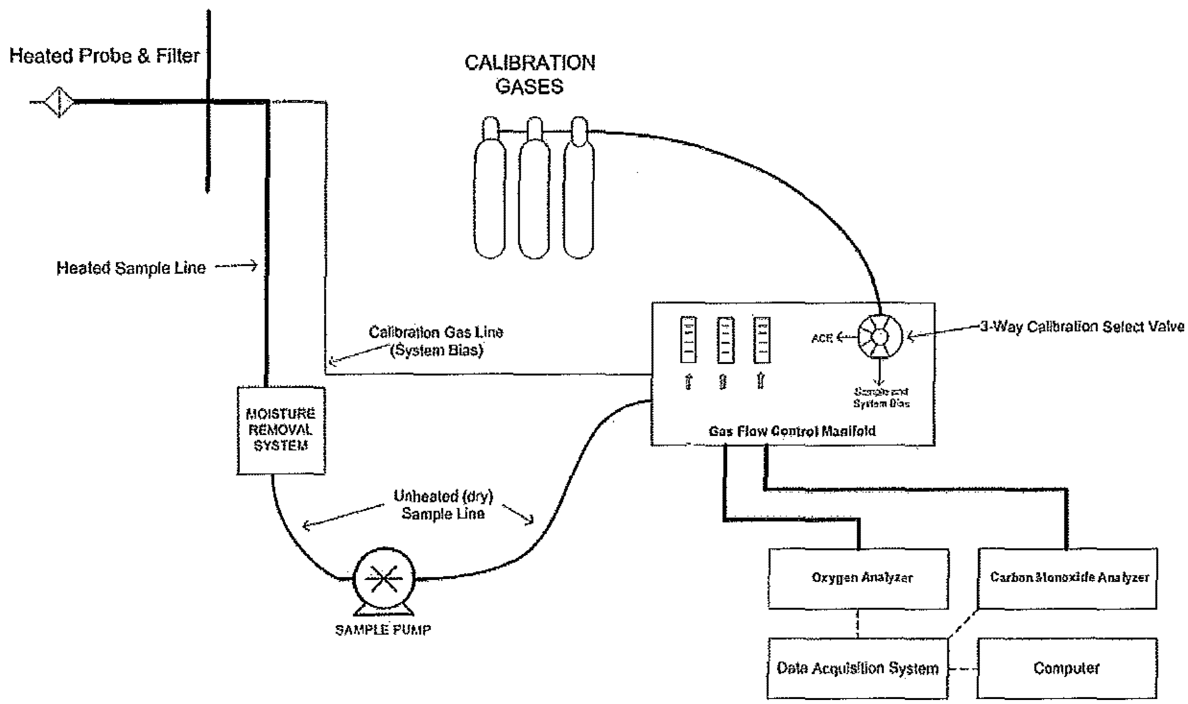


4.1.2 Oxygen and Carbon Monoxide (USEPA Methods 3A and 10)

Oxygen and carbon monoxide concentrations were measured using the sampling and analytical procedures of USEPA Methods 3A, *Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)* and 10, *Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)*. The sampling procedures of the methods are similar with the exception of the analyzers and analytical technique used to quantify the parameters of interest. The measured oxygen concentrations were used to adjust the carbon monoxide concentrations to 15% O_2.

Engine exhaust gas was extracted from the stacks 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, gas flow control manifold, and paramagnetic, and infrared gas filter correlation gas analyzers. Figure 4-3 depicts the Methods 3A and 10 sampling system.

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



Prior to sampling engine exhaust gas, the analyzers were calibrated by performing a calibration error test where zero-, mid-, and high-level calibration gases were introduced directly to the back of the analyzers. The calibration error check was 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 was 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 rates and component temperatures were verified and the probes were inserted into the ducts at the appropriate traverse point. After confirming the engine was operating at established conditions, the test run was initiated. Oxygen and carbon monoxide concentrations were recorded at 1-minute intervals throughout the 60-minute test run duration.

At the conclusion of the test run, a post-test system bias check was performed to evaluate analyzer bias and drift from the pre- and post-test system bias checks. The system-bias checks evaluate if the analyzers bias is within ±5.0% of span and drift is within ±3.0%. The analyzers responses were used to correct the measured oxygen and carbon monoxide concentrations for analyzer drift. Refer to Appendix D for analyzer calibration supporting documentation.

5.0 TEST RESULTS AND DISCUSSION

The test program was performed to satisfy the continuous performance test requirements and evaluate compliance with the RICE MACT, ROP, and PTI.

5.1 Tabulation of Results

The results of the testing indicate the CO reduction efficiency for EUENGINE3-2 complies with the applicable limit. Table 2-1 summarizes the results and Appendix Table 1 presents detailed test data, process operating conditions, and exhaust gas conditions.

5.2 Significance of Results

While the test results indicate compliance with the applicable emission limit, the engine operating load during the emission compliance demonstration test was 81% of the engine manufacturer's rated capacity for torque. Therefore, an engine operation restriction will be self-imposed to ±10 percent of this "as-tested" operating load until such time that the engine can be operated within ±10 percent of 100 percent load and compliance with 40 CFR Part 63, Subpart ZZZZ is demonstrated.

5.3 Variations from Sampling or Operating Conditions

No sampling or operating condition variations were encountered during the test program with the exception of operating load. 40 CFR §63.6620(b) specifies the test must be performed at any load condition within plus or minus 10 percent of 100 percent load, during testing the maximum achievable load was 81% of the engine manufacturer's rated capacity for torque, based on pipeline pressures and site conditions.

The engine and associated control equipment were operating under maximum achievable routine conditions and no upsets were encountered during testing.

5.4 Air Pollution Control Device Maintenance

No significant pollution control device maintenance occurred during the three months prior to the test. Engine optimization and continuous parametric monitoring of the air pollution control device are monitored to ensure compliance with regulatory emission limits.

5.5 Re-Test Discussion

Based on the results of this test program, a re-test is not required. Subsequent air emissions testing will be required in 2019, following the requirements in 40 CFR §63.6615 and 63.6620 (Table 3 to Subpart ZZZZ of Part 63—Subsequent Performance Tests). Because the facility has demonstrated compliance for two consecutive tests, the frequency of subsequent performance tests is annual.

Because the engine operating load was limited during test, and an operating load restriction has been self-imposed by the facility, subsequent testing may occur within one year in order to evaluate the engine emissions when operated within ±10 percent of 100 percent load.

5.6 Results of Audit Samples

Audit samples for the reference methods utilized during this test program are not available from EPA 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 QA/QC activities required by the reference methods that were performed. Refer to Appendix D for supporting documentation.

Table 5-1
Primary QA/QC Procedures

QA/QC Activity	Purpose	Procedure	Frequency	Acceptance Criteria
M1: Sampling Location	Evaluates if the sampling location is suitable for sampling	Measure distance from ports to downstream and upstream 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 and 10: Calibration gas standards	Ensures accurate calibration standards	Traceability protocol of calibration gases	Pre-test	Calibration gas uncertainty ≤2.0%
M3A and 10: Calibration Error	Evaluates operation of analyzers	Calibration gases introduced directly into analyzers	Pre-test	±2.0% of the calibration span
M3A and 10: System Bias and Analyzer Drift	Evaluates analyzer and sample system integrity and accuracy over test duration	Calibration gases introduced at sample probe tip, heated sample line, and into analyzers	Pre-test and Post-test	±5.0% of the analyzer calibration span for bias and ±3.0% of analyzer span for drift
M3A and 10: Multi-point samples	Ensure representative sample collection	Insert probe into stack and purge sample system	During test	Collect sample from 3 point "long line"

5.7 Calibration Sheets

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

5.8 Sample Calculations

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

5.9 Field Data Sheets

Field data sheets are presented in Appendix B.