Consumers Energy

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40 CFR Part 63, Subpart ZZZZ Test Report

EUENGINE3-3, EUENGINE3-4, and EUENGINE3-5

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

June 21, 2022

Test Date: May 3, 4, and 5, 2022

Test Performed by the Consumers Energy Company
Regulatory Compliance Testing Section
Air Emissions Testing Body
Laboratory Services Section

Work Order No. 3610013
Version No.: 0

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EXECUTIVE SUMMARY

Consumers Energy (CE) Regulatory Compliance Testing Section (RCTS) conducted carbon monoxide (CO) reduction efficiency testing of three (3), four-stroke, lean burn (4SLB) 3,750 brake horsepower (BHP) natural gas-fired, spark-ignition reciprocating internal combustion engine (RICE), identified as EUENGINE3-3, EUENGINE3-4, and EUENGINE3-5 operating at the Freedom Compressor Station (FCS) in Manchester, Michigan.

The test program was conducted on May 3 through 5, 2022 to evaluate continued compliance with the CO reduction efficiency emission limit in 40 CFR Part 63, Subpart ZZZZ, *National Emission Standards for Hazardous Air Pollutants* (NESHAP) *for Stationary Reciprocating Internal Combustion Engines* as incorporated in the facility's permit to install (PTI) No. 202-15A issued by the Michigan Department of Environment, Great Lakes, and Energy (EGLE). A test protocol was submitted to EGLE on February 25, 2022 and subsequently approved by Ms. Regina Angellotti, Environmental Quality Analyst, in her letter dated April 4, 2022.

Triplicate 60-minute test runs were conducted at the upstream and downstream exhaust ducts of each engine's oxidation catalyst following the applicable procedures in United States Environmental Protection Agency (USEPA) Reference Methods (RM) 1, 3A, and 10 in 40 CFR Part 60, Appendix A. There were no deviations from the approved stack test protocol or associated USEPA Reference Methods.

During testing, the engines operated at load conditions within plus or minus (±) 10 percent of 100 percent load, as specified in §63.6620(b). The test results are summarized in Table E-1.

Table E-1
Summary of Engine Operating Requirements and Emission Limits

Engine	CO (% Reduction)	Catalyst Inlet Temperature[1] (°F)	Catalyst Pressure Drop (inches)	Initial Catalyst Pressure Drop (inches)
EUENGINE3-3	96	688	1	2
EUENGINE3-4	96	722	1	2
EUENGINE3-5	98	789	2	2
ZZZZ/PTI Limits	**≥93**	**450°F - 1350°F**	**±2 (from initial)**	
[1]Compliance is based on a 4-hour rolling average				

The EUENGINE3-3, EUENGINE3-4, and EUENGINE3-5 results indicate compliance with the applicable CO reduction efficiency limit in 40 CFR Part 63, Subpart ZZZZ as incorporated within PTI 202-15A.

Detailed results are presented in Appendix Tables 1 through 3. 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 compliance air emission tests on EUENGINE3-3, EUENGINE3-4, and EUENGINE3-5 operating at the Freedom Compressor Station (FCS) in Manchester, Michigan. This document follows the Michigan Department of Environment, Great Lakes and Energy (EGLE) format described in the November 2019, *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.

1.1 Identification, Location, and Dates of Tests

Consumers Energy (CE) Regulatory Compliance Testing Section (RCTS) conducted carbon monoxide (CO) reduction efficiency testing at three (3), four-stroke, lean burn (4SLB) 3,750 brake horsepower (BHP) natural gas-fired, spark-ignition reciprocating internal combustion engines (RICE), identified as EUENGINE3-3, EUENGINE3-4, and EUENGINE3-5 operating at FCS in Manchester, Michigan. The test program was conducted May 3, 4 and 5, 2022.

1.2 Purpose of Testing

The test program was conducted to evaluate continued compliance with the CO reduction efficiency emission limit in 40 CFR Part 63, Subpart ZZZZ, *National Emission Standards for Hazardous Air Pollutants* (NESHAP) *for Stationary Reciprocating Internal Combustion Engines* as incorporated in the facility's permit to install (PTI) No. 202-15A issued by the EGLE. The applicable operating requirements and emission limits evaluated during this test program are presented in Table 1-1.

Table 1-1
Summary of Engine Operating Requirements and Emission Limits

Parameter	Units	Emission Limits and Operating Criteria[1]
CO	Reduction, %	≥93
	Catalyst Inlet Temperature, °F	≥450 & ≤1350 (based on 4-hour rolling average)
	Catalyst Pressure Drop (in H_2O)	±2" from Initial Performance Test

CO carbon monoxide
[1] emission limits from PTI No. 202-15A, Flexible Group Conditions: FGNESHAPZZZZ. 40 CFR Part 63, Subpart ZZZZ, Table 2a allows formaldehyde stationary RICE compliance concentrations of 14 ppmvd or less at 15 percent O_2, or a CO reduction efficiency ≥93%. Compliance using the CO reduction efficiency limit was evaluated.

1.3 Brief Description of Source

EUENGINE3-3, EUENGINE3-4, and EUENGINE3-5 are 3,750 BHP, 4SLB RICE providing compressor mechanical shaft power as needed to maintain natural gas pipeline pressure for movement along the pipeline system.

1.4 Contact Information

Table 1-2 presents the names, addresses, and telephone numbers of the personnel involved in this test program.

Table 1-2
Contact Information

Program Role	Contact	Address
Regulatory Agency Representative	Technical Programs Unit Supervisor c/o Diane Eisinger 517-242-3299 eisingerD1@michigan.gov	EGLE - Technical Programs Unit 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
State Regulatory Inspector	Mr. Mike Kovalchick Environmental Engineer 517-416-5025 kovalchickm@michigan.gov	EGLE – Jackson District State Office Bldg., 4th Floor 301 East Louis Glick Highway Jackson, Michigan 49201
State Technical Programs Field Inspector	Ms. Regina Angellotti Environmental Quality Analyst 313-418-0895 angellottir1@michigan.gov	EGLE – Detroit District Cadillac Place, Suite 2-300 3048 West Grand Blvd. Detroit, MI 48202-6058
State Field Inspector	Mr. Andrew Riley Environmental Quality Analyst 586-565-7379 rileya8@michigan.gov	EGLE – Warren District 27700 Donald Court Warren, MI 48092-2793
Responsible Official	Mr. Avelock Robinson Director of 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 Senior Engineer 517-788-2201 amy.kapuga@cmsenergy.com	Consumers Energy Company Environmental Services Department 1945 West Parnall Road Jackson, Michigan 49201
Field Environmental Coordinator	Mr. Gerald (Frank) Rand Senior Environmental Analyst 734-807-0935 frank.randjr@cmsenergy.com	Consumers Energy Company South Monroe Service Center 7216 Crabb Road Temperance, MI 48182
Facility Leader	Ms. Tara Guenther Principle Technical Analyst Lead 734-482-2042 tara.guenther@cmsenergy.com	Consumers Energy Company Freedom Compressor Station 12201 Pleasant Lake Road Manchester, Michigan 48158
Test Team Representative	Mr. Thomas Schmelter, QSTI Engineering Technical Analyst 616-738-3234 thomas.schmelter@cmsenergy.com	Consumers Energy Company J.H. Campbell Plant 17010 Croswell Street West Olive, Michigan 49460

2.0 SUMMARY OF RESULTS

2.1 OPERATING DATA

During testing, EUENGINE3-3, EUENGINE3-4, and EUENGINE3-5 operated at load conditions within plus or minus (±) 10 percent of 100 percent load, as specified in §63.6620(b). Based on site conditions during testing, the maximum achievable load was ≥91% for each engine. Refer to Attachment C for detailed operating data.

2.2 Applicable Permit Information

FCS is assigned State of Michigan Registration Number (SRN) N3920 and operates Plant 3 in accordance with PTI No. 202-15A. EUENGINE3-3, EUENGINE3-4, and EUENGINE3-5 are collectively grouped within the PTI, along with sources EUENGINE3-1 and EUENGINE3-2, as FGENGINES-P3. The PTI also incorporates the applicable federal requirements in 40 CFR Part 60, Subpart JJJJ and 40 CFR Part 63, Subpart ZZZZ. Subpart ZZZZ requirements were the focus of this test program.

2.3 Results

The EUENGINE3-3, EUENGINE3-4, AND EUENGINE3-5 CO reduction efficiency results indicate compliance with 40 CFR Part 63, Subpart ZZZZ as incorporated within PTI 202-15A. Refer to Table 2-1 for the average test result summary.

Table 2-1
Summary of Average Test Results

Engine	CO (% Reduction)	Catalyst Inlet Temperature[1] (°F)	Catalyst Pressure Drop (inches)	Initial Catalyst Pressure Drop (inches)
EUENGINE3-3	96	688	1	2
EUENGINE3-4	96	722	1	2
EUENGINE3-5	98	789	2	2
ZZZZ/PTI Limits	**≥93**	**450°F - 1350°F**	**±2 (from initial)**	

[1]Compliance is based on a 4-hour rolling average

Detailed results are discussed in Section 5.0 and shown in Appendix Tables 1 through 3. 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

EUENGINE3-3, EUENGINE3-4, and EUENGINE3-5 provide compressor mechanical shaft power to maintain natural gas pipeline pressure for movement along the natural gas pipeline system. Significant maintenance has not been performed on the engines within the past three months. A summary of engine specifications is provided in Table 3-1.

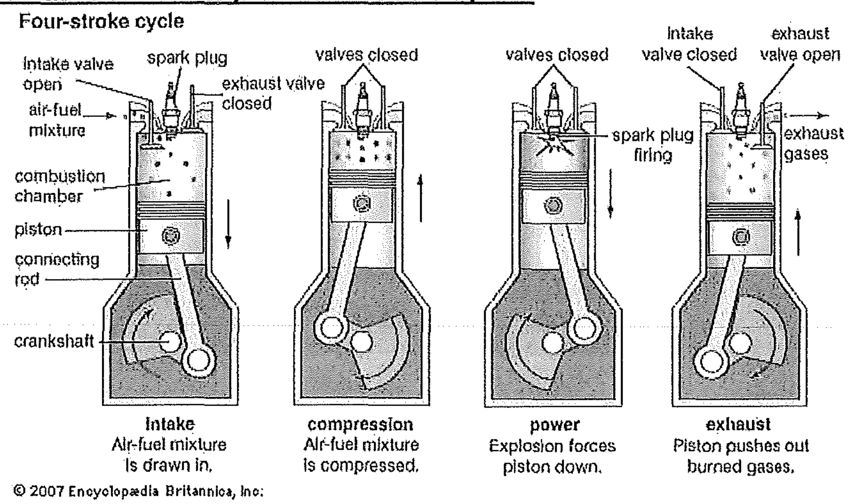
Table 3-1
Engine Specifications

Engine ID	Engine Description		Site-Rated HP	Heat Input, LHV (mmBtu/hr)	Exhaust Gas Temp. (°F)
	Manufacturer	Model			
EUENGINE3-3 EUENGINE3-4 EUENGINE3-5	Waukesha	12V275GL+	3,750	29	828

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. 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 air-to-fuel ratio), lean burn combustion technology, and oxidation catalysts. The Waukesha engines include control modules that monitors and adjusts engine parameters for optimal performance. The NO_x emissions are minimized using lean-burn combustion technology which is defined as 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.

The four catalyst modules installed in the engine's exhaust use propriety materials to lower the oxidation temperature of CO and other organic compounds within the range of exhaust gas temperatures generated by the engines. The catalyst also provides control of formaldehyde, non-methane, and non-ethane hydrocarbons. Detailed operating data recorded during testing are provided in Appendix C.

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 from the Panhandle Eastern Pipeline Company's supply lines to Consumers Energy's pipeline system.

The engines are used to drive two-stage compressors to maintain pressure and move natural gas through the pipeline system. The bottom portion of the exhaust stacks incorporate an annulus where an outer stack surrounds an inner circular stack (shaped like a doughnut if viewed looking down from the top of the stack). The engine exhaust gases enter the annulus via two horizontal ducts into the outer stack, flowing downward through oxidation catalysts placed at the bottom of the annulus. After passing through the catalysts, the gases enter the inner stack through an opening located near the base of the freestanding stack. The gases then travel vertically through the freestanding stack, (via the inner stack) until they discharge unobstructed to atmosphere through the 65-feet high stack.

3.3 Materials Processed

The fuel utilized is exclusively natural gas, as defined in 40 CFR Part 72.2. During testing the natural gas combusted within the engines was comprised of approximately 92% methane, 7% ethane, 0.4% nitrogen, and 0.2% carbon dioxide. The daily natural gas chromatograph analysis results are provided in Appendix C. The gas composition and Btu content were used to calculate site-specific F factors for emission rate calculations in accordance with USEPA Method 19.

3.4 Rated Capacity

The maximum power output of each engine is approximately 3,750 BHP, with a rated heat input of 29 million British thermal units per hour (mmBtu/hour). The normal rated engine capacities are governed by the connected compression equipment operated as a function of facility and gas transmission demand.

3.5 Process Instrumentation

Process instrumentation were continuously monitored by engine controllers, data acquisition systems, and Consumers Energy operations personnel during testing. The following data parameters were collected at 1-minute intervals during each test:

- Fuel use (cfm)
- Engine speed (rpm)
- Horsepower (BHP)
- Torque (% max)
- Catalyst input temperature (°F)
- Catalyst differential pressure (in. H_2O)
- Engine hours

Refer to Appendix C for operating data.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

CO and oxygen (O_2) concentrations were measured using the test methods shown 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	USEPA	
	Method	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)
Carbon monoxide (CO)	10	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)

4.1 DESCRIPTION OF SAMPLING TRAIN AND FIELD PROCEDURES

The Table 4-2 test matrix below summarizes the sample parameters and analytical methods employed.

Table 4-2
Test Matrix

Date (2022)	Run	Sample Type	Start Time (EST)	Stop Time (EST)	Test Duration (min)	EPA Test Method	Comment
EUENGINE3-4							
May 3	1	O_2 CO	09:00	09:59	60	1, 3A, 10	Three-point traverse during Run 1; Single-point sample during Runs 2 and 3.
	2		10:30	11:29	60		
	3		12:00	12:59	60		
EUENGINE3-5							
May 4	1	O_2 CO	08:15	09:14	60	1, 3A, 10	Three-point traverse during Run 1; Single-point sample during Runs 2 and 3.
	2		09:30	10:29	60		
	3		10:45	11:44	60		
EUENGINE3-3							
May 5	1	O_2 CO	10:00	10:59	60	1, 3A, 10	Three-point traverse during Run 1; Single-point sample during Runs 2 and 3.
	2		11:15	12:14	60		
	3		12:30	13:29	60		

4.2 SAMPLE LOCATION AND TRAVERSE POINTS (USEPA METHOD 1)

The number and location of traverse points was evaluated 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*. Sample ports are installed upstream and downstream (Pre and Post) of the oxidation catalyst.

<u>Pre-catalyst Sampling Ports:</u>

Two test ports, 4-inches in diameter and sealed by 2-inch gate valves approximately 4-inches outside the duct wall, are installed in each of two 16-inch diameter horizontal exhaust ducts exiting the engine. The pre-catalyst sampling ports are located:

- 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 the flow disturbance caused by a change in duct diameter and flow direction as it enters exhaust stack and oxidation catalyst.

<u>Post-catalyst Sampling Ports:</u>

Likewise, two test ports, 4-inches in diameter and sealed by 2-inch gate valves approximately 4-inches outside the duct wall, are installed in a 30-inch vertical exhaust stack exiting the oxidation catalyst. The post-catalyst sampling ports are located:

- 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.

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 three-point traverse concentrations, sampled in accordance with USEPA Method 7E, §8.1.2, were calculated and the gas streams were found unstratified; therefore, subsequent measurements during runs 2 and 3 were obtained from a single point near the centroid of the stack.

Please note that during Run 1 on EUENGINE3-3, a brief loss of engine torque during the last 15 minutes caused the stratification test to be aborted. The test was re-run during Run 2 with the gas stream found unstratified and Run 3 measurements were conducted from a single point near the centroid of the stack.

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

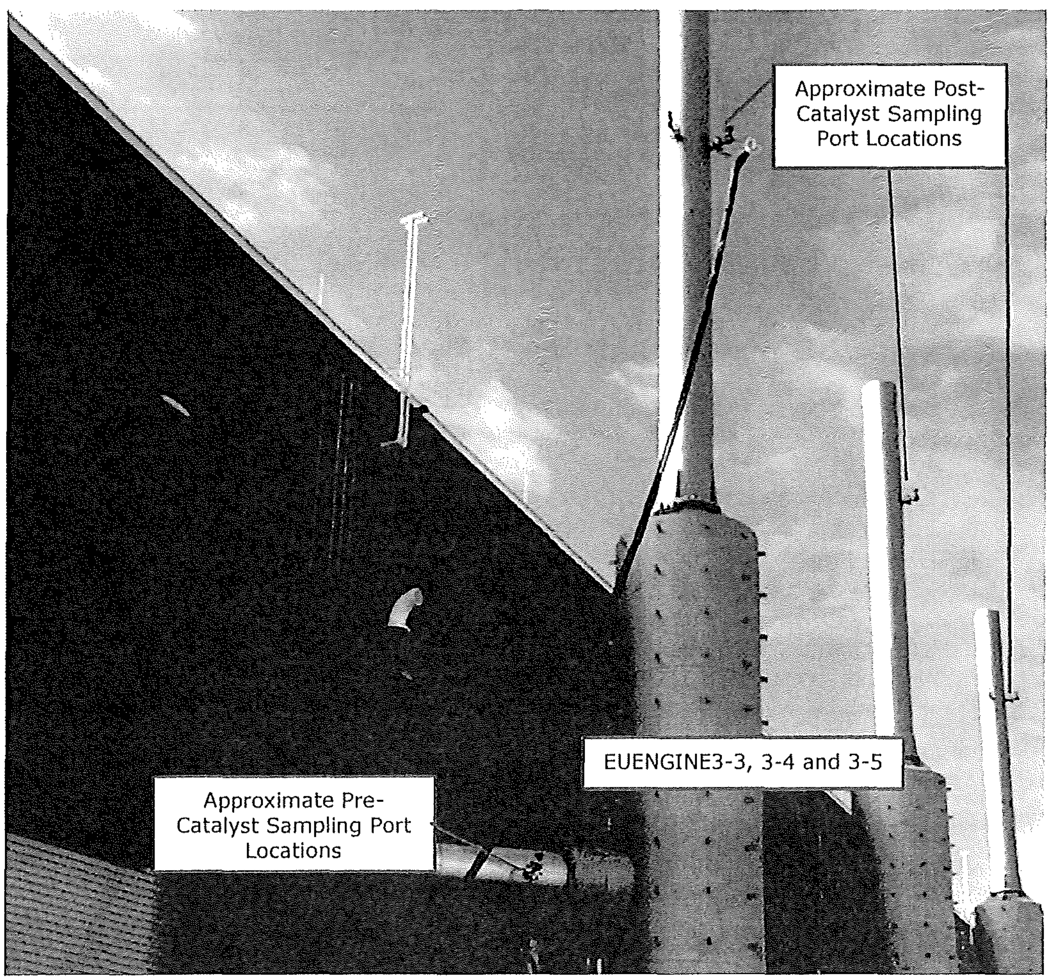
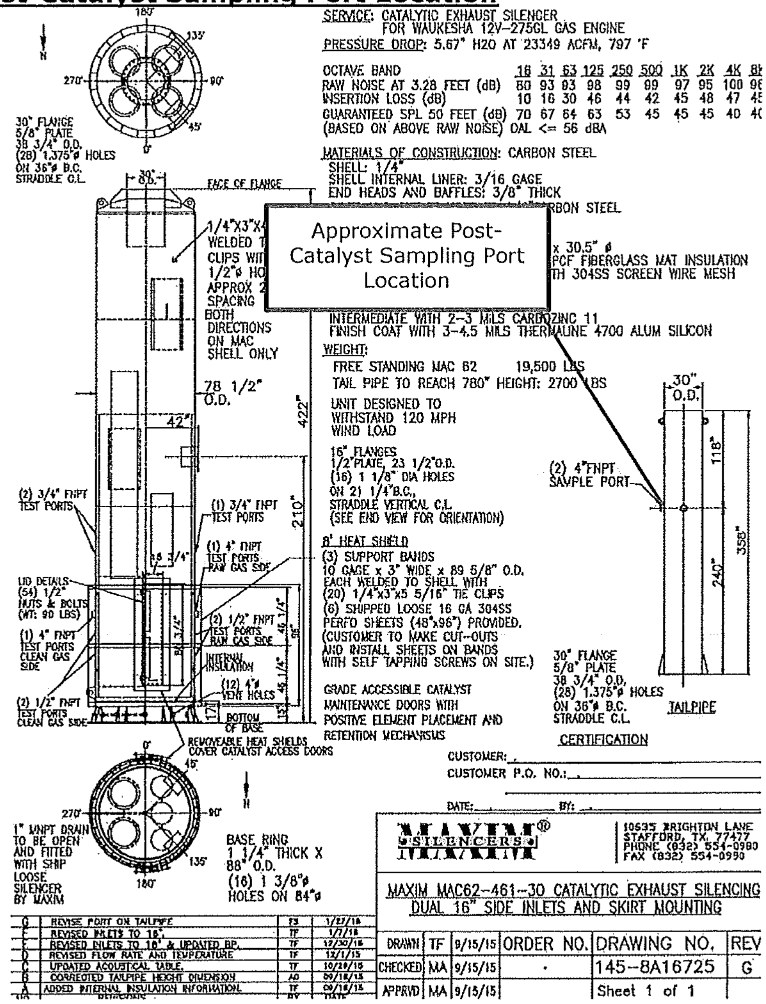


Figure 4-2. Post-Catalyst Sampling Port Location



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

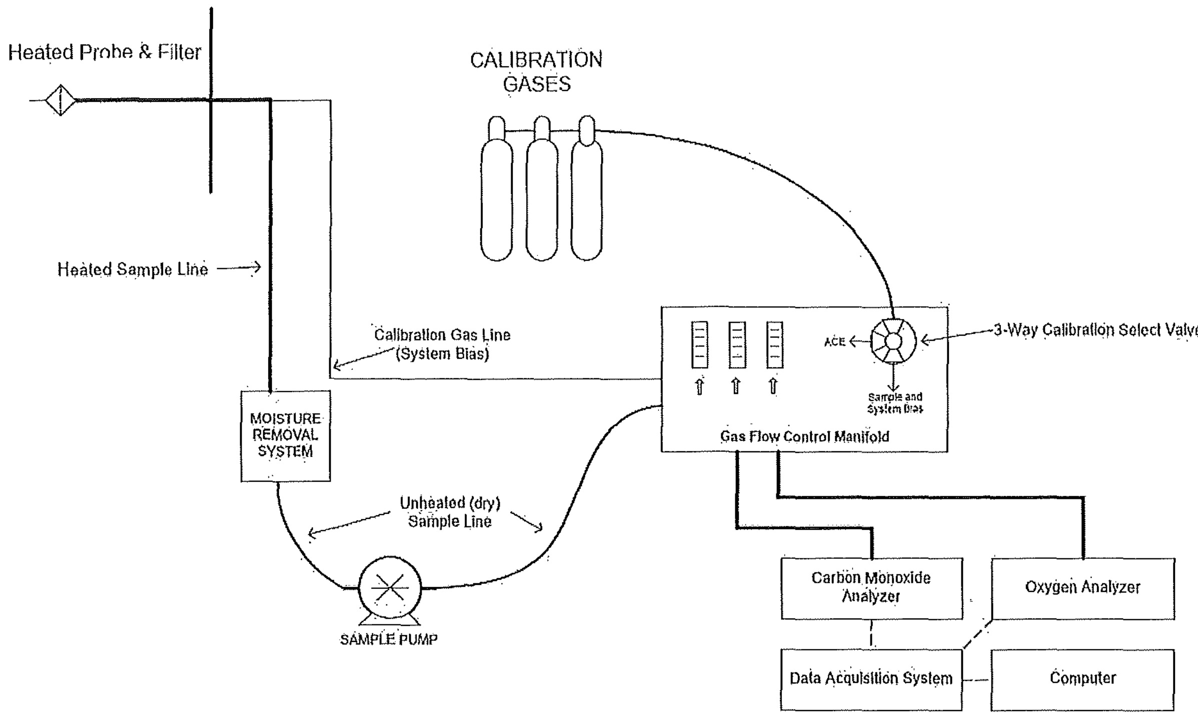
Oxygen and carbon monoxide concentrations were measured using the following sampling and analytical procedures:

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

The sampling procedures of each method is similar, except for the analyzers and analytical technique used to quantify the parameters of interest. The measured oxygen concentrations were used to adjust the pollutant concentrations to 15% O_2 and calculate pollutant emission rates.

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, flow control manifold, and gas analyzers. Figure 4-3 depicts a drawing of the Methods 3A and 10 sampling system.

Figure 4-3. Methods 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 were 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 were verified, and the probe was inserted into the duct at the appropriate traverse point. After confirming the engine was operating at established conditions, the test run was initiated. Gas concentrations were recorded at 1-minute intervals throughout each 60-minute test run.

After the conclusion of each 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 evaluated if the analyzers bias was within ±5.0% of span and drift was within ±3.0%. The analyzers responses were used to correct the measured gas concentrations for analyzer drift.

For the analyzer calibration error tests, bias tests and drift checks, these evaluations are also passed if the standard criteria are not achieved, but the absolute difference between the analyzer responses and calibration gas is less than or equal to 0.5 ppmv for CO or 0.5% for O_2.

5.0 TEST RESULTS AND DISCUSSION

The test program was performed to evaluate compliance with emission limits in 40 CFR Part 63, Subpart ZZZZ as incorporated in PTI 202-15A.

5.1 Tabulation of Results

As summarized in Table 2-1, the emission test results indicate EUENGINE3-3, EUENGINE3-4, and EUENGINE3-5 comply with the applicable regulatory requirements. Appendix Tables 1, 2, and 3 contain detailed results.

5.2 Significance of Results

Compliance with the applicable regulatory requirements allows EUENGINE3-3, EUENGINE3-4, and EUENGINE3-5 to be operated for their intended purpose until the next scheduled test event.

5.3 Variations from Sampling or Operating Conditions

No variations from sampling or operating conditions occurred during this test program.

5.4 Process or Control Equipment Upset Conditions

The engines, gas compressors, and pump equipment operated under maximum routine conditions with no upsets during the test.

5.5 Air Pollution Control Device Maintenance

Ongoing engine optimization is performed to ensure lean-burn combustion and continuous regulatory emission limit compliance.

5.6 Re-Test Discussion

An engine re-test is not required based on these test program results. Subsequent air emissions testing on the engines will be performed:

- Annually (since two passing events have occurred) to evaluate the reduction of CO emissions across the oxidation catalyst in accordance with 40 CFR Part 63 Subpart ZZZZ and PTI202-15A.

5.7 Results of Audit Samples

Audit samples for this test program are not available from USEPA Stationary Source Audit Sample Program providers. The RM 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 field test components. QA/QC components included in this test program are summarized in Table 5-1. 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 sample location suitability	Measure downstream and upstream flow disturbances	Pre-test	≥2 diameters downstream; ≥0.5 diameter upstream
M1: Duct diameter/ dimensions	Verifies accurate stack area measurement	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	Calibration gas traceability protocol	Pre-test	Calibration gas uncertainty ≤2.0%
M3A and M10: Calibration Error	Evaluates analyzer operation	Calibration gases introduced directly into analyzers	Pre-test	±2.0% of span, 0.5 ppmv or 0.5% O_2 abs. difference
M3A and M10: System Bias and Analyzer Drift	Evaluates analyzer and sample system integrity/accuracy over test duration	Cal gas introduced at sample probe tip, heated sample line, and into analyzers	Pre- and Post-test	Bias: ±5.0% of span; Drift: ±3.0% of span or ≤ 0.5 ppmv/0.5% O_2 abs. difference

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

The method specific quality assurance and quality control procedures in each method employed during this test program were followed without deviation. QA/QC procedures. External laboratory analysis was not applicable to this test program.

5.12 QA/QC Blanks

Other than calibration gases used for instrument calibrations, no other reagent or media blanks were used.

Appendix Tables