Consumers Energy

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40 CFR Part 60 Subpart JJJJ
40 CFR Part 63 Subpart ZZZZ
Continuous Compliance Test Report

EUENGINE31, EUENGINE32, EUENGINE33 and EUENGINE34

Consumers Energy Company
Ray Compressor Station
69333 Omo Road
Armada, Michigan 48005
SRN: B6636

August 5, 2021

Test Dates: June 15 – 17, 2021

Test Performed by the Consumers Energy Company
Regulatory Compliance Testing Section
Air Emissions Testing Body
Laboratory Services Section
Work Order No. 38483901
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TABLE OF CONTENTS

EXECUTIVE SUMMARY IV

1.0 INTRODUCTION 1

1.1 IDENTIFICATION, LOCATION, AND DATES OF TESTS 1
1.2 PURPOSE OF TESTING 1
1.3 BRIEF DESCRIPTION OF SOURCE 2
1.4 CONTACT INFORMATION 2

2.0 SUMMARY OF RESULTS 3

2.1 OPERATING DATA 3
2.2 APPLICABLE PERMIT INFORMATION 3
2.3 RESULTS 3

3.0 SOURCE DESCRIPTION 4

3.1 PROCESS 4
3.2 PROCESS FLOW 5
3.3 MATERIALS PROCESSED 6
3.4 RATED CAPACITY 6
3.5 PROCESS INSTRUMENTATION 6

4.0 SAMPLING AND ANALYTICAL PROCEDURES 7

4.1 DESCRIPTION OF SAMPLING TRAIN AND FIELD PROCEDURES 7
4.2 SAMPLE LOCATION AND TRAVERSE POINTS (USEPA METHOD 1) 8
4.3 MOISTURE CONTENT (USEPA ALT-008) 10
4.4 O_2, NO_X, AND CO (USEPA METHODS 3A, 7E, AND 10) 11
4.5 EMISSION RATES (USEPA METHOD 19) 12
4.6 VOLATILE ORGANIC COMPOUNDS (ALT-096: USEPA METHODS 18/25A) 12

5.0 TEST RESULTS AND DISCUSSION 14

5.1 TABULATION OF RESULTS 14
5.2 SIGNIFICANCE OF RESULTS 14
5.3 VARIATIONS FROM SAMPLING OR OPERATING CONDITIONS 14
5.4 PROCESS OR CONTROL EQUIPMENT UPSET CONDITIONS 14
5.5 AIR POLLUTION CONTROL DEVICE MAINTENANCE 14
5.6 RE-TEST DISCUSSION 14
5.7 RESULTS OF AUDIT SAMPLES 15
5.8 CALIBRATION SHEETS 15
5.9 SAMPLE CALCULATIONS 16
5.10 FIELD DATA SHEETS 16
5.11 LABORATORY QUALITY ASSURANCE / QUALITY CONTROL PROCEDURES 16
5.12 QA/QC BLANKS 16

FIGURES

FIGURE 3-1. FOUR-STROKE ENGINE PROCESS DIAGRAM 4
FIGURE 3-2. RAY COMPRESSOR STATION NATURAL GAS PROCESS FLOW 5
FIGURE 4-1. PRE-CATALYST SAMPLING PORT LOCATION 9
FIGURE 4-2. POST-CATALYST SAMPLING PORT LOCATION 10
FIGURE 4-3. ALTERNATIVE METHOD 008 MOISTURE SAMPLE APPARATUS 10
FIGURE 4-4. USEPA METHODS 3A, 7E, AND 10 SAMPLING SYSTEM 11
FIGURE 4-5. USEPA METHOD 19 EMISSION FLOW RATE EQUATION 12
FIGURE 4-6. USEPA METHOD 25A SAMPLE APPARATUS 12

TABLES

TABLE E-1 SUMMARY OF AVERAGE TEST RESULTS v
TABLE 1-1 FGENGINES EMISSION LIMITS 1
TABLE 1-2 CONTACT INFORMATION 2
TABLE 2-1 SUMMARY OF AVERAGE TEST RESULTS 3
TABLE 1-3 SUMMARY OF ENGINE SPECIFICATIONS 4
TABLE 4-1 TEST METHODS 7
TABLE 4-2 TEST MATRIX 8
TABLE 5-1 QA/QC PROCEDURES 15

APPENDICES

Appendix Table 1 EUENGINE31 Emission Rates and Process Data
Appendix Table 2 EUENGINE32 Emission Rates and Process Data
Appendix Table 3 EUENGINE33 Emission Rates and Process Data
Appendix Table 4 EUENGINE34 Emission Rates and Process Data

Appendix A Sample Calculations
Appendix B Field Data Sheets
Appendix C Laboratory Data Sheets
Appendix D Operating Data
Appendix E Supporting Documentation

EXECUTIVE SUMMARY

Consumers Energy Company (Consumers Energy) Regulatory Compliance Testing Section (RCTS) conducted nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compound (VOC) testing upstream and/or downstream of oxidation catalysts installed in the exhausts of EUENGINE31, EUENGINE32, EUENGINE33 and EUENGINE34 operating at the Ray Compressor Station (RCS) a major source of hazardous air pollutant (HAP) emissions in Armada, Michigan. The 4- stroke, lean burn, (4SLB), spark ignited (SI), natural gas fired, reciprocating internal combustion engines (RICE) power compressors to maintain natural gas pipeline pressure for movement into and out of underground storage reservoirs and along the pipeline system. The engines are subject to federal air emission regulations and are collectively part of FGENGINES3 described within the Facility Michigan Department of Environment, Great Lakes and Energy (EGLE), renewable operating permit (ROP) MI-ROP-B6636-2020.

The test program was performed on June 15 - 17, 2021 to evaluate continuous compliance with United States Environmental Protection Agency (USEPA) 40 CFR Part 60, Subpart JJJJ, ***Standards of Performance for Stationary Spark Ignition Internal Combustion Engines***, and 40 CFR Part 63, Subpart ZZZZ, ***National Emission Standards for Hazardous Air Pollutants*** (NESHAP) ***for Stationary Reciprocating Internal Combustion Engines***, as noted in the Facility EGLE ROP MI-ROP-B6636-2020.

A test protocol was submitted to EGLE on April 9, 2021 and subsequently approved by Mr. Matthew Karl, Environmental Quality Analyst, in his letter dated June 11, 2021. Please note that, due to unforeseen mechanical issues, EUENGINE35, one of the engines named in the protocol and contained within the ROP FGENGINES, was not available during this test event. Testing for EUENGINE35 occurred on July 13, 2021. A separate test report will be prepared and submitted that documents the EUENGINE35 results.

This test program consisted of triplicate 60-minute test runs performed at each engine following the procedures in USEPA Reference Methods (RM) 1, 3A, 4 (Alt-008), 7E, 10, 18, 19, and 25A in 40 CFR Part 60, Appendix A. During testing, the engines operated within ± 10 percent of 100 percent peak (or the highest achievable) load, as specified in 40 CFR §60.4244(a). Aside from the EUENGINE35 test postponement, there were no deviations from the approved protocol or associated RM.

The test results summarized in Table E-1 indicate the NO_x, CO, and VOC emissions comply with the applicable emissions limits.

Table E-1
Summary of Average Test Results

Engine	NO_x (g/hp-hr)	CO (g/hp-hr)	CO (% reduction)	VOC[1] (g/hp-hr)	Catalyst Inlet Temperature[2] (°F)	Catalyst Pressure Drop (inches)	Initial Catalyst Pressure Drop (inches)
EUENGINE31	0.36	0.04	97.8	0.01	841	2.5	2.1
EUENGINE32	0.31	0.01	99.2	<0.024	860	2.0	2.3
EUENGINE33	0.39	0.03	98.7	0.02	817	2.2	2.0
EUENGINE34	0.41	0.06	96.7	0.02	844	2.9	2.7
JJJJ Limits	1.0	2.0		0.7			
ZZZZ Limits			≥93		450-1350	±2 (from initial)	
ROP Limits	0.5	0.2	≥93	0.19	450-1350	±2 (from initial)	

NO_x nitrogen oxides
CO carbon monoxide
VOC volatile organic compounds (non-methane, non-ethane organic compounds), as propane
g/HP-hr grams per horsepower hour
[1]40 CFR Part 60 Subpart JJJJ refers to volatile organic compounds as defined in 40 CFR §51.100(s)(1), which specifies a VOC definition including "*any compound of carbon...other than the following, which have been determined to have negligible photochemical reactivity: methane, ethane...*" Therefore, Subpart JJJJ exhaust gas VOC measurements reported herein include total *non-methane, non-ethane* (C_2H_6) organic compounds only.
[2]Compliance with the catalyst inlet temperature operating range is based on a 4-hour rolling average

Detailed results are presented in Appendix Tables 1 – 4. 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.

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1.0 INTRODUCTION

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

1.1 IDENTIFICATION, LOCATION, AND DATES OF TESTS

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compound (VOC) tests on emission units (EU) EUENGINE31, EUENGINE32, EUENGINE33 and EUENGINE34, operating at the RCS facility, a major source of hazardous air pollutant (HAP) emissions in Armada, Michigan.

The test program was performed on June 15 - 17, 2021. A test protocol was submitted to EGLE on April 9, 2021 and subsequently approved by Mr. Matthew Karl, Environmental Quality Analyst, in his letter dated June 11, 2021. Please note that due to unforeseen mechanical issues, EUENGINE35, an engine named in the protocol and within FGENGINES3, was not available during the test event. Testing for EUENGINE35 occurred on July 13, 2021. A separate test report will be prepared and submitted that documents the EUENGINE35 results.

1.2 PURPOSE OF TESTING

The purpose of the test program was to evaluate continuous compliance with United States Environmental Protection Agency (USEPA) 40 CFR Part 60, Subpart JJJJ, ***Standards of Performance for Stationary Spark Ignition Internal Combustion Engines***, and 40 CFR Part 63, Subpart ZZZZ, ***National Emission Standards for Hazardous Air Pollutants*** (NESHAP) ***for Stationary Reciprocating Internal Combustion Engines***, as incorporated in State of Michigan, Renewable Operating Permit (ROP) MI-ROP-B6636-2020. The applicable emission limits are shown in Table 1-1.

Table 1-1
FGENGINES3 Emission Limits

Parameter	Emission Limit	Units	Applicable Requirement
NO_x	0.5	g/HP-hr	MI-ROP-B6636-2020, Flexible Group Conditions: FGENGINES
	1.0	g/HP-hr	40 CFR Part 60, Subpart JJJJ, Table 1
	160	ppmvd at 15% O_2	40 CFR Part 60, Subpart JJJJ, Table 1
CO	0.2	g/HP-hr	MI-ROP-B6636-2020, Flexible Group Conditions: FGENGINES3
	2.0	g/HP-hr	40 CFR Part 60, Subpart JJJJ, Table 1
	540	ppmvd at 15% O_2	40 CFR Part 60, Subpart JJJJ, Table 1
	93	% Reduction across oxidation catalyst	MI-ROP-B6636-2020, Flexible Group Conditions: FGENGINES; 40 CFR §63.6300(b) – 40 CFR Part 63, Subpart ZZZZ, Table 2a
VOC	0.19	g/HP-hr	MI-ROP-B6636-2020, Flexible Group Conditions: FGENGINES
	0.7	g/HP-hr	40 CFR Part 60, Subpart JJJJ, Table 1
	86	ppmvd at 15% O_2	40 CFR Part 60, Subpart JJJJ, Table 1

1.3 Brief Description of Source

EUENGINE31, EUENGINE32, EUENGINE33 and EUENGINE34 are natural gas-fired, 4SLB SI RICE coupled to compressors to transport natural gas into storage fields or into transmission lines. The engines are part of the FGENGINES3 group within MI-ROP-B6636-2020.

1.4 Contact Information

Table 1-2 contains the affiliated persons names, addresses and telephone numbers for further information regarding 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 Environment, Great Lakes and Energy 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
State District Manager	Ms. Joyce Zhu Environmental Manager 586-606-2572 zhuj@michigan.gov	EGLE – Air Quality Division Warren District SE Michigan Office 27700 Donald Court Warren, Michigan 48092
State Technical Programs Field Inspector	Mr. Matt Karl Technical Programs Unit 517-282-2126 karlm@michigan.gov	EGLE 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
State Regulatory Inspector	Mr. Robert Elmouchi Environmental Quality Analyst 586-753-3736 elmouchir@michigan.gov	EGLE – Air Quality Division Warren District SE Michigan Office 27700 Donald Court Warren, Michigan 48092
Responsible Official	Mr. Avelock Robinson Director of Gas Compression 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. Thomas Fox Senior Engineer II 989-667-5153 thomas.fox@cmsenergy.com	Consumers Energy Company Bay City Customer Service Center 4141 E. Wilder Road Bay City, MI 48706
Test Facility	Mr. William F. Harvey Gas Field Leader 586-784-2096 william.f.harvey@cmsenergy.com	Consumers Energy Company Ray Compressor Station 69333 Omo Road Armada, Michigan 48005
Test Team Representative	Mr. Joe Mason, QSTI Sr. Engineering Technical Analyst 231-720-4856 joe.mason@cmsenergy.com	Consumers Energy Company D.E. Karn Power Plant 2742 N. Weadock Hwy., ESD Trailer #4 Essexville, Michigan 48732

2.0 SUMMARY OF RESULTS

2.1 Operating Data

During the performance test, the engines fired natural gas, and pursuant to §60.4244(a), operated within 10% of 100% peak (or the highest achievable) load. The performance testing was conducted with the engines operating at an average load >93% torque and >90% horsepower, based on the maximum manufacturer's design capacity at engine and compressor site conditions. Refer to Appendix D for detailed operating data.

2.2 Applicable Permit Information

RCS operates in accordance with MI-ROP- B6636-2020, which incorporates 40 CFR Part 60, Subpart JJJJ and 40 CFR Part 63, Subpart ZZZZ requirements specific to EUENGINE31, EUENGINE32, EUENGINE33 and EUENGINE34, collectively part of FGENGINES3.

2.3 Results

The test results (Table 2-1) indicate each engine and associated oxidation catalyst complies with applicable NO_x, CO and VOC emission and percent CO reduction limits in 40 CFR Part 60, Subpart JJJJ, 40 CFR Part 63, Subpart ZZZZ, and MI-ROP-B6636-2020.

Table 2-1
Summary of Average Test Results

Engine	NO_x (g/hp-hr)	CO (g/hp-hr)	CO (% reduction)	VOC[1] (g/hp-hr)	Catalyst Inlet Temperature[2] (°F)	Catalyst Pressure Drop (inches)	Initial Catalyst Pressure Drop (inches)
EUENGINE31	0.36	0.04	97.8	0.01	841	2.5	2.1
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EUENGINE33	0.39	0.03	98.7	0.02	817	2.2	2.0
EUENGINE34	0.41	0.06	96.7	0.02	844	2.9	2.7
JJJJ Limits	1.0	2.0		0.7			
ZZZZ Limits			≥93		450-1350	±2 (from initial)	
ROP Limits	0.5	0.2	≥93	0.19	450-1350	±2 (from initial)	

NO_x nitrogen oxides
CO carbon monoxide
VOC volatile organic compounds (non-methane, non-ethane organic compounds), as propane
g/hp-hr grams per horsepower hour

[1] 40 CFR Part 60 Subpart JJJJ refers to volatile organic compounds as defined in 40 CFR §51.100(s)(1), ,which specifies a VOC definition including "*any compound of carbon....other than the following, which have been determined to have negligible photochemical reactivity: methane, ethane...*" Therefore, Subpart JJJJ exhaust gas VOC measurements reported herein include total *non-methane (CH_4), non-ethane (C_2H_6)* organic compounds only.
[2] Compliance with the catalyst inlet temperature operating range is base on a 4-hour rolling average

Detailed results are presented in Appendix Tables 1 – 4, with further discussion in Section 5.0 of this report. Sample calculations, field data, laboratory data, engine operating data and supporting documentation are presented in Appendices A through E.

3.0 SOURCE DESCRIPTION

EUENGINE31, EUENGINE32, EUENGINE33 and EUENGINE34 were constructed in 2013. Significant maintenance has not been performed on the engines or oxidation catalysts within the past three months. A summary of the engine specifications is presented in Table 3-1.

Table 3-1
Summary of Engine Specifications

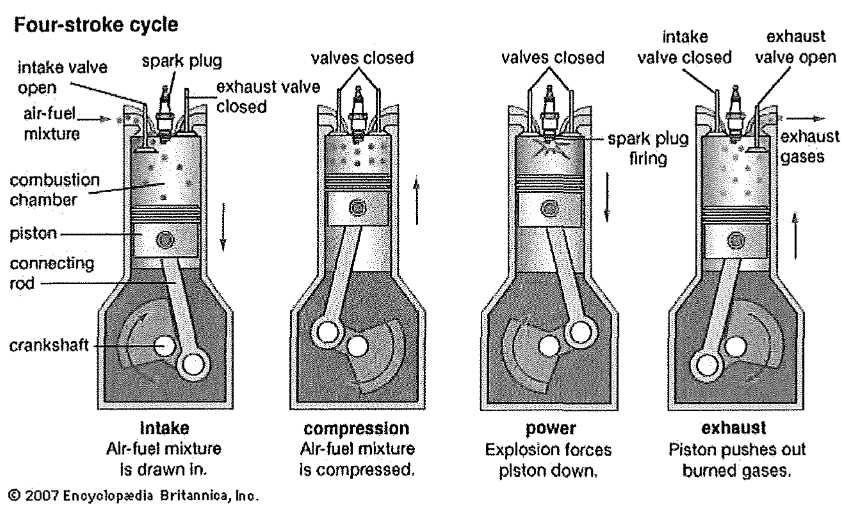
Parameter[1]	EUENGINE31 through EUENGINE34
Make	Caterpillar
Model	G3616
Output (brake-horsepower)	4,735
Heat Input (mmBtu/hr)	32.0
Exhaust Flow Rate (ACFM, wet)	32,100
Exhaust Gas Temp.	856
Engine Outlet O_2 (Vol-%, dry)	12.00
Engine Outlet CO_2 (Vol-%, dry)	5.81
CO, Uncontrolled (ppmv, dry)	572.0
CO, 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 (Figure 3-1) which begins with a downward air intake valve piston stroke, aspirating air into combustion chambers (cylinder). When the piston nears the cylinder bottom, fuel is injected and the intake valves close. As the piston travels upward, the air/fuel mixture compresses and ignites, forcing the piston downward into the power stroke. At the bottom of the power stroke, exhaust valves open and the upward traveling piston expels the combustion by-products.

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.

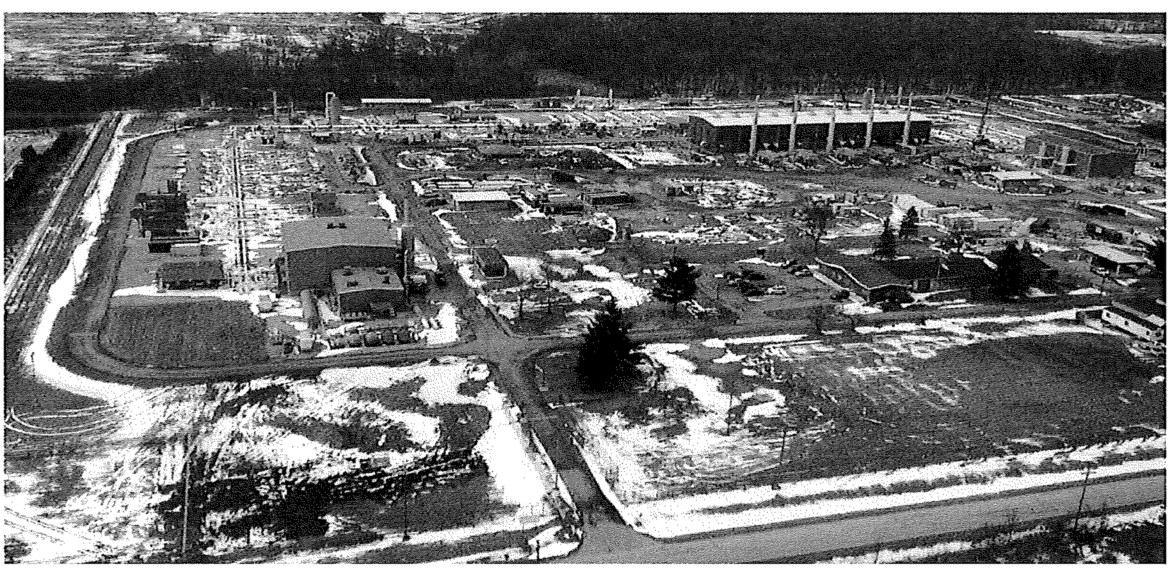
A continuous parameter monitoring system (CPMS) monitors catalyst inlet temperature per Table 5 (1) of 40 CFR Part 63, Subpart ZZZZ requirements and in accordance with the site-specific preventative maintenance / malfunction and abatement plan which evaluates efficient catalytic reaction and pollution control equipment performance. Detailed operating data are provided in Appendix D.

3.2 Process Flow

Located in northern Macomb County, the Ray Compressor Station (Figure 3-2) helps maintain natural gas pressure along pipeline systems and for gas injection and withdrawal.

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

Figure 3-2. Ray Compressor Station Natural Gas Process Flow



3.3 Materials Processed

The engine fuel utilized is exclusively natural gas, as defined in 40 CFR §72.2. Recent natural gas sample analyses reveal this composition is approximately 92.3% methane, 6.73% ethane, 0.25% propane, 0.4% nitrogen, and 0.26% 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, both of which are a function of facility and gas transmission extraction and/or storage demand.

3.5 Process Instrumentation

The following engine operating parameters were continuously monitored and collected in one-minute increments during the test:

- 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)

4.0 SAMPLING AND ANALYTICAL PROCEDURES

RCTS tested for NO_x, CO, VOC, and O_2 concentrations using the USEPA test methods presented in Table 4-1. The sampling and analytical procedures associated with each 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)
Moisture content	4	Determination of Moisture Content in Stack Gases
Nitrogen oxides	7E	Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)
Carbon monoxide	10	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
Methane (CH_4)	18	Measurement of Gaseous Organic Compound Emissions by Gas Chromatography
Emission rates	19	Sulfur Dioxide Removal and Particulate, Sulfur Dioxide and Nitrogen Oxides from Electric Utility Steam Generators
Volatile organic compounds	25A	Measurement of Gaseous Organic Compound Emissions by Gas Chromatography

4.1 Description of Sampling Train and Field Procedures

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

Table 4-2
Test Matrix

Date (2021)	Run	Sample Type	Start Time (EDT)	Stop Time (EDT)	Test Duration (min)	EPA Test Method	Comment
EUENGINE31							
June 17	1	O_2 NO_x CO Ethane VOC	8:10	9:09	60	1 3A 4 7E 10 18 19 25A	3-point traverse conducted at each sample location at 16.7, 50.0 & 83.3 % of the measurement line
	2		9:32	10:31	60		
	3		10:51	11:50	60		
EUENGINE32							
June 16	1	O_2 NO_x CO Ethane VOC	11:00	11:59	60	1 3A 4 7E 10 18 19 25A	3-point traverse conducted at each sample location at 16.7, 50.0 & 83.3 % of the measurement line
	2		12:23	13:22	60		
	3		14:37	15:36	60		
EUENGINE33							
June 15	1	O_2 NO_x CO Ethane VOC	13:52	14:51	60	1 3A 4 7E 10 18 19 25A	3-point traverse conducted at each sample location at 16.7, 50.0 & 83.3 % of the measurement line
	2		15:10	16:09	60		
June 16	3		8:05	9:04	60		
EUENGINE34							
June 15	1	O_2 NO_x CO Ethane VOC	9:00	9:59	60	1 3A 4 7E 10 18 19 25A	3-point traverse conducted at each sample location at 16.7, 50.0 & 83.3 % of the measurement line
	2		10:25	11:24	60		
	3		11:52	12:51	60		

4.2 Sample Location and Traverse Points (USEPA Method 1)

The number and location of traverse points for each engine followed requirements in Table 4 of 40 CFR Part 63, Subpart ZZZZ, Table 2 of 40 CFR Part 60, Subpart JJJJ, and USEPA Method 1, *Sample and Velocity Traverses for Stationary Sources*.

Pre-catalyst Sampling Ports

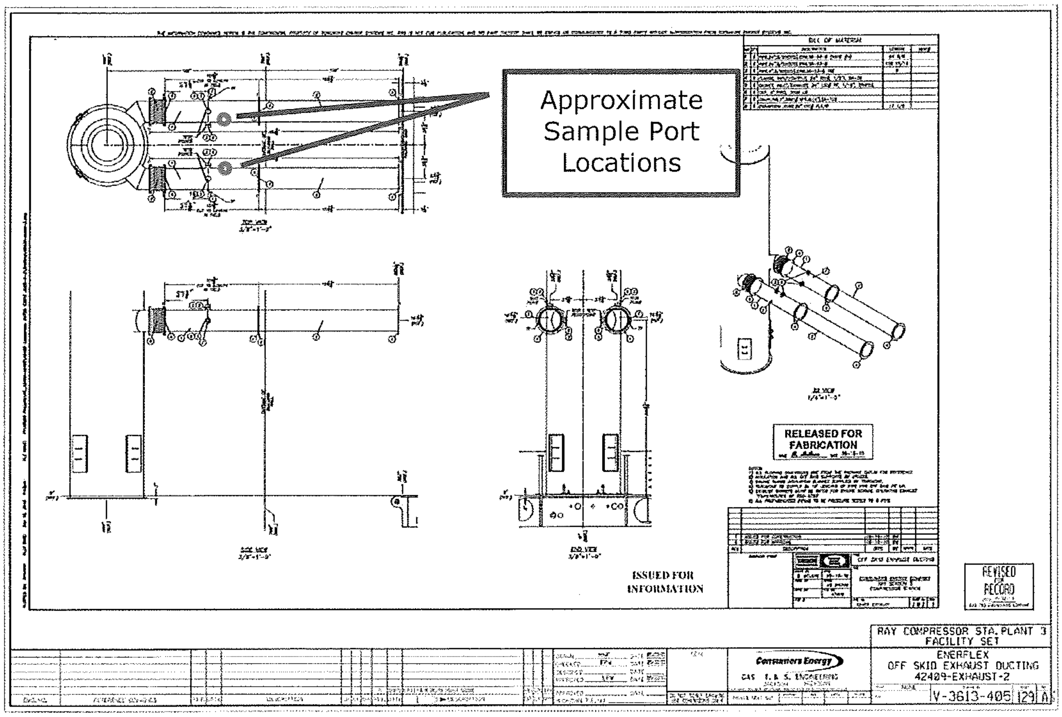
Each engine is equipped with two 24-inch horizontal exhaust ducts exiting the engine and building. Each duct has two pre-catalyst test ports located

1. At least 208 inches (8.7 duct diameters) downstream of a duct bend disturbance at the engine exhaust, and

2. 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.

The pre-catalyst sample ports are 4-inch in diameter and extend approximately 2-inches beyond the stack wall (Figure 4-1).

Figure 4-1. Pre-Catalyst Sampling Port Location



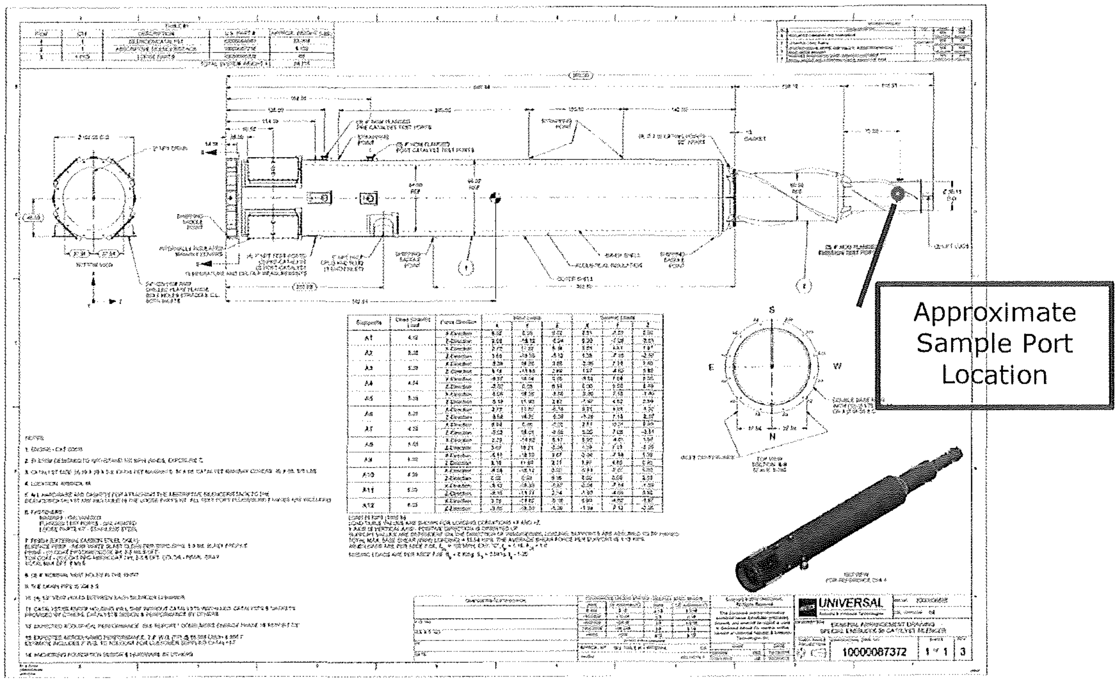
Post-catalyst Sampling Ports

Each engine is equipped with a 36-inch vertical exhaust duct exiting the engine and oxidation catalyst. The duct has two test ports located

1. Approximately 72 inches or 2.0 duct diameters downstream of a duct diameter change/flow disturbance, and
2. Approximately 43 inches or 1.2 duct diameters upstream of the stack exit.

The post-catalyst sample ports are 4-inch in diameter and extend approximately 4-inches beyond the stack wall (Figure 4-2).

Figure 4-2. Post-Catalyst Sampling Port Location

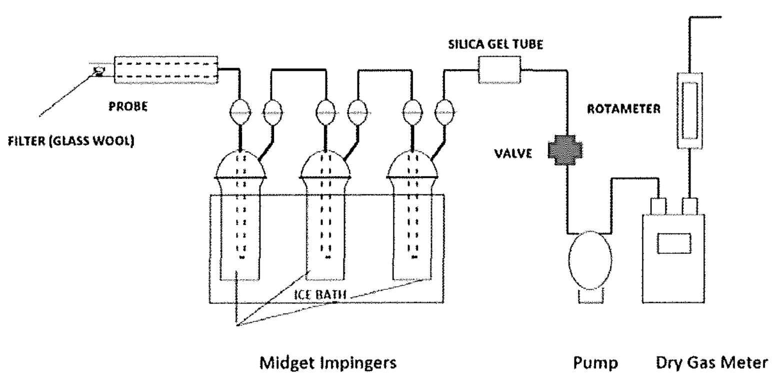


Because the ducts are >12 inches in diameter and the sample locations meet the 40 CFR Part 60, Appendix A-1, Method 1, Section 11.1.1 two and half-diameter criterion, the ducts were sampled at equal time intervals from each of three traverse points located at 16.7, 50.0, and 83.3% of the measurement line ('3-point long line') during each test.

4.3 Moisture Content (USEPA ALT-008)

Exhaust gas moisture content was determined at each engine following specifications in USEPA Method 4, *Determination of Moisture Content in Stack Gases*, or equivalent alternate moisture methodology, such as ALT - 008, to convert wet-basis volatile organic compound measurements to a dry basis. Exhaust gas is drawn from the stack into impingers immersed in an ice-bath, condensing any water therein, after which the condensed water is measured gravimetrically to calculate the percent moisture content (Figure 4-3).

Figure 4-3. Alternative Method 008 Moisture Sample Apparatus



The silica gel tube depicted in this figure was replaced with a midget impinger (bubbler) with a straight tube insert, as allowed in ALT-008, §1

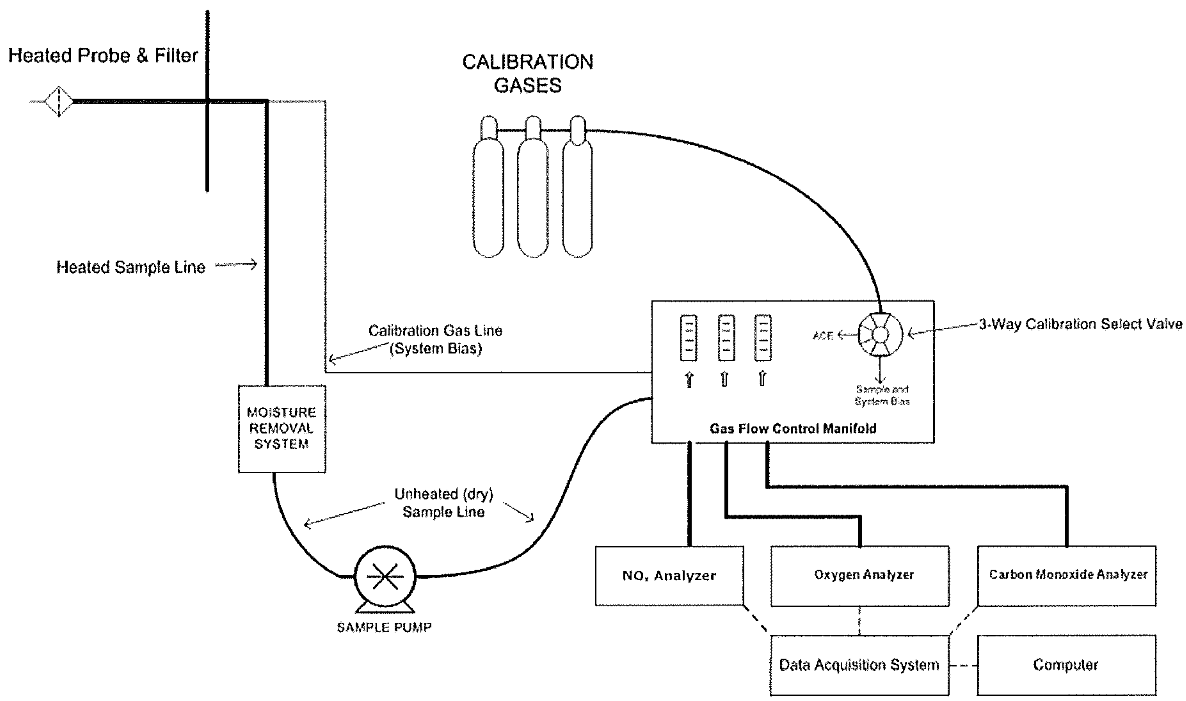
4.4 O_2, NO_X, AND CO (USEPA METHODS 3A, 7E, AND 10)

Oxygen, nitrogen oxides, 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 7E, *Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)*, and
- USEPA Method 10, *Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure).*

Each cited method sampling is procedurally similar apart from the analyzer and analytical technique used. 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 4-4).

Figure 4-4. USEPA Methods 3A, 7E, 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.

A NO_2 to NO conversion efficiency test is performed on the NO_X analyzer prior to beginning the test program to evaluate the ability of the instrument to convert NO_2 to NO before analyzing for NO_x.

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. Oxygen concentrations are measured to adjust the pollutant concentrations to 15% O_2 and calculate pollutant emission rates.

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.

4.5 Emission Rates (USEPA Method 19)

USEPA Method 19, *Determination of Sulfur Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide, and Nitrogen Oxide Emission Rates*, was used to calculate exhaust gas flowrate. The default natural gas fuel factor from Method 19 is used to calculate the emission flow rate with the corresponding equation (Figure 4-5). The flow rate was used in calculations to present emissions in units of g/HP-hr.

Figure 4-5. USEPA Method 19 Emission Flow Rate Equation

$$E = C_d F_d \frac{20.9}{(20.9 - \%O_{2d})}$$

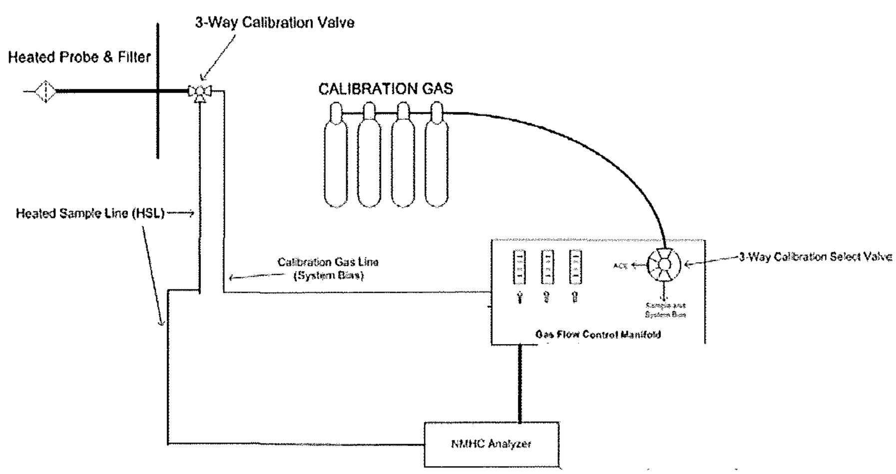
Where:

E	=	Pollutant emission rate (lb/mmBtu)
C_d	=	Pollutant concentration, dry basis (lb/dscf)
F_d	=	Volumes of combustion components per unit of heat content, 8,710 dscf/mmBtu for natural gas (F_d from fuel analysis was used)
$\%O_{2d}$	=	Concentration of oxygen on a dry basis (%, dry)

4.6 Volatile Organic Compounds (ALT-096: USEPA Methods 18/25A)

VOC concentrations were measured using a Thermo Model 55i Direct Methane and Non-methane Analyzer as approved in alternative test method (ALT)-096, following the procedures of USEPA Method 25A, *Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer (FIA)* (Figure 4-6).

Figure 4-6. USEPA Method 25A Sample Apparatus



The instrument uses a flame ionization detector (FID) to measure the exhaust gas total hydrocarbon concentration in conjunction with a gas chromatography column that separates methane from other organic compounds. Note that the instrument measures on a wet basis, and 40 CFR Subpart JJJJ requires VOC reporting on a dry basis. Therefore, the exhaust gas moisture content was determined to convert VOC measurements to a dry basis.

The components of the extractive sample interface apparatus are constructed of Type 316 stainless steel and Teflon. Flue gas was sampled from the stack via a sample probe and heated sample line and into the analyzer, which communicates with data acquisition handling systems (DAHS) via output signal cables. The analyzer uses a rotary valve and gas chromatograph column to separate methane from hydrocarbons in the sample and quantifies these components using a flame ionization detector.

The instrument is calibrated with USEPA Protocol Gases consisting of zero air and three propane/methane blends in air, following USEPA Method 25A procedures at the zero level, low (25 to 35 percent of calibration span), mid (45 to 55 percent of calibration span) and high (equivalent to 80 to 90 percent of instrument span).

Sample gas is injected into the column and due to methane's low molecular weight and high volatility, the compound moves through the column more quickly than other organic compounds that may be present and is quantified by the FID. The column is then flushed with inert carrier gas and the remaining non-methane organic compounds are analyzed in the FID. This analytical technique allows separate measurements for methane and non-methane organic compounds via the use of a single FID.

The Thermo 55i analyzer measures methane and non-methane organic compounds (NMOC) separately, however ethane is a component of the NMOC measurement. Since 40 CFR Part 60, Subpart JJJJ defaults to 40 CFR, Part 51.100(s)(1) VOC definitions classifying VOC as *any compound of carbon...other than the following, which have been determined to have negligible photochemical reactivity: methane, ethane...,* duplicate exhaust gas samples were collected from each engine exhaust to quantify the ethane fraction of the NMOC concentration using USEPA Method 18, *Measurement of Gaseous Organic Compound Emissions by Gas Chromatography*.

These exhaust gas samples were collected in bags manufactured from polyvinyl fluoride (PVF) film, also known as Tedlar film, and sent to an outside contracted laboratory for analysis. The ethane concentrations in each bag were measured by separating the major organic components using a gas chromatograph (GC) column and measuring them with a suitable detector. The retention times of each separated component were compared with those of known compounds under identical conditions to identify and quantify the major components. The approximate concentrations were estimated before analysis and standard mixtures prepared so the GC/detector was calibrated under physical conditions identical to those used for the samples.

Method 18 requires the sample results be adjusted to results obtained from a spike recovery study. For the bag sampling technique to be considered valid, the spike recovery must be between 70% <R < 130%. The recovery study performed on the RCS engine Tedlar bag samples successfully achieved the R value requirement and that value was applied to the reported ethane concentrations as propane. The USEPA Method 18 laboratory report is presented in Appendix E.

5.0 TEST RESULTS AND DISCUSSION

The test program performed from June 15 – 17 satisfies the continuous compliance evaluation requirements in 40 CFR Part 60, Subpart JJJJ, *Standards of Performance for Stationary Spark Ignition Internal Combustion Engines*, 40 CFR Part 63, Subpart ZZZZ, *National Emission Standards for Hazardous Air Pollutants for Reciprocating Internal Combustion Engines* and MI-ROP-B6636-2020. The test results also indicate the NO_x, CO, and VOC engine emissions are compliant with the applicable emissions limits summarized in Table 2-1 of this report.

5.1 Tabulation of Results

Appendix Tables 1 through 4 contain detailed tabulation of results, process operating conditions, and exhaust gas conditions for each respective RICE.

5.2 Significance of Results

The test results indicate each engine is achieving continuous compliance requirements and meeting applicable emissions limits.

5.3 Variations from Sampling or Operating Conditions

As stated in Section 4.6 above, exhaust gas samples were collected in Tedlar bags and sent to an outside contracted laboratory to verify the ethane content using Method 18 analysis. The laboratory reported ethane ppmv concentrations (as propane) were subtracted from field measured NMOC ppmv (as propane) to achieve the final non-methane, non-ethane organic compound (NMNEOC) result.

Note that for EUENGINE32, this ethane subtraction resulted in negative NMNEOC concentrations for Runs 1 and 3, and in these instances, a non-detect value of <4 ppm (derived from the manufactures accuracy specification of 2% of the span in use, or 200 ppm) was reported (in lieu of a negative concentration) to calculate the VOC emission rate.

5.4 Process or Control Equipment Upset Conditions

The engines and gas compressors operated under maximum routine conditions during the test and no upsets were encountered.

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 test program results, a re-test is not required. Subsequent air emissions testing on the engines will be performed:

- annually to evaluate the reduction of CO emissions across the oxidation catalyst in accordance with 40 CFR Part 63 Subpart ZZZZ and the facility ROP; and
- every 8,760 engine operating hours or 3 years, whichever is first, thereafter, to evaluate compliance with NO_x, CO, and VOC emission limits in 40 CFR Part 60, Subpart JJJJ and the ROP. The engine hours on June 1st were:
    - EUENGINE31: 14,439.2 hours
    - EUENGINE32: 12,996 hours
    - EUENGINE33: 15,857.8 hours
    - EUENGINE34: 14,834.7 hours

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 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 components of field testing. QA/QC components were included in this test program (Table 5-1). Refer to Appendix E 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, M25A: 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
M4 (ALT-008): Field balance calibration	Verifies moisture measurement accuracy	Class 6 weight used to check balance accuracy	Daily before use	Balance must measure weight within ±0.5 gram of certified mass
M7E: NO_2-NO converter efficiency	Evaluates NO_2-NO converter operation	NO_2 calibration gas introduced directly into analyzer	Pre-test or Post-test	NO_x response ≥90% of certified NO_2 calibration gas
M25A/ALT096: Calibration Error	Evaluates operation of analyzer and sample system	Cal gas introduced through sample system	Pre-test	±5.0% of calibration gas value
M25A/ALT096: Zero and Calibration Drift	Evaluates analyzer and sample system integrity/accuracy over test duration	Cal gas introduced through sample system	Pre and Post-test	±3.0% of analyzer span

5.8 Calibration Sheets

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

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. Refer to Appendix C for the laboratory data sheets associated with the natural gas fuel samples collected during the test program.

5.12 QA/QC BLANKS

The Method 3A, 7E, 10, and 25A 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 E.

Appendix Tables