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, EUENGINE34, and EUENGINE35

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

July 29, 2019

Test Dates: June 11, 12, and 13, 2019

Test Performed by the Consumers Energy Company
Regulatory Compliance Testing Section
Air Emissions Testing Body
Laboratory Services Section
Work Order No. 34432206
Version No.: 0

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

EXECUTIVE SUMMARY

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

The test program was performed to satisfy performance test requirements and verify compliance with United States Environmental Protection Agency (USEPA) 40 CFR Part 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*, (aka the RICE MACT), as incorporated in Michigan Department of Environmental Quality (MDEQ), Renewable Operating Permit (ROP) MI-ROP-B6636-2015a. Note that as of April 22, 2019, the MDEQ was re-organized and re-named the Michigan Department of Environment, Great Lakes, and Energy (EGLE). A test protocol was submitted to EGLE on April 9, 2019 and subsequently approved by Ms. Regina Angellotti, Environmental Quality Analyst, in her letter dated May 28, 2019.

The test program was conducted on June 11, 12 and 13, 2019. Triplicate 60-minute test runs were conducted 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. There were no deviations from the approved test protocol or associated Reference Methods. During testing, the engines operated within ± 10 percent of 100 percent peak (or the highest achievable) load, as specified in 40 CFR §60.4244(a).

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

Parameter	Units	EUENGINE					Emission Limit		
		31	32	33	34	35	40 CFR Part 60, Subpart JJJJ[1, 2]	40 CFR Part 63, Subpart ZZZZ	MI-ROP-B6636-2015a
NO_x	g/HP-hr	0.32	0.30	0.36	0.43	0.35	2.0		0.5
	ppmvd at 15% O_2	29.2	26.9	32.5	39.4	32.1	160		
CO	g/HP-hr	0.03	0.01	0.02	0.04	0.02	4.0		0.2
	ppmvd at 15% O_2	4.0	1.8	2.6	6.7	3.1	540		
	% reduction	98.5	99.3	99.0	97.3	98.8		≥93	≥93
VOC	g/HP-hr	0.044	0.041	0.074	0.048	<0.03	1.0		0.19
	ppmvd at 15% O_2	4.2	3.8	7.0	4.6	<3.1	86		

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] Owners and operators of stationary non-certified SI engines may choose to comply with the emission standards in units of either g/HP-hr or ppmvd at 15 percent O_2
[2] Owners and operators of new lean burn SI stationary engines with a site rating ≥250 brake HP located at a major source that are meeting the requirements of 40 CFR Part 63, Subpart ZZZZ, Table 2a do not have to comply with the CO emission standards in 40 CFR Part 60, Subpart JJJJ, Table 1.

Detailed results are presented in Appendix Tables 1 – 5. 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) testing on emission units (EU) EUENGINE31, EUENGINE32, EUENGINE33, EUENGINE34 and EUENGINE35, operating at the RCS facility in Armada, MI.

A test protocol was submitted to EGLE on April 9, 2019 and subsequently approved by Ms. Regina Angellotti, Environmental Quality Analyst, in her letter dated May 28, 2019. The test program was conducted on June 11, 12 and 13, 2019. There were no deviations from the approved stack test protocol or associated United States Environmental Protection Agency (USEPA) Reference Methods (RM).

1.2 Purpose of Testing

The purpose of the test program was to satisfy performance test requirements and verify compliance with USEPA 40 CFR Part 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*, (aka RICE MACT), as incorporated in State of Michigan, Renewable Operating Permit (ROP) MI-ROP-B6636-2015a. The applicable emission limits are shown in Table 1-1.

Table 1-1
FGENGINES Emission Limits

Parameter	Emission Limit	Units	Applicable Requirement
NO_x	0.5	g/HP-hr	MI-ROP-B6636-2015a, 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-B6636-2015a, 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-B6636-2015a, 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-B6636-2015a, 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

* Owners and operators of new lean burn SI stationary engines with a site rating ≥250 brake HP located at a major source that are meeting the requirements of 40 CFR Part 63, Subpart ZZZZ, Table 2a do not have to comply with the CO emission standards in 40 CFR Part 60, Subpart JJJJ, Table 1.

† 40 CFR Part 63, Subpart ZZZZ, Table 2a allows compliance to be demonstrated by limiting the concentration of formaldehyde in the stationary RICE exhaust to 14 ppmvd or less at 15 percent O_2 or reducing CO emissions by ≥93%. Consumers Energy intends to demonstrate compliance using the CO reduction efficiency emission limit.

‡ 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 measurements of VOC will include only the total non-methane, non-ethane organic compounds

1.3 Brief Description of Source

EUENGINE31, EUENGINE32, EUENGINE33, EUENGINE34 and EUENGINE35 are natural gas-fired, 4SLB SI RICE, coupled to compressors, used to transport natural gas into storage fields or into transmission lines. The engines are collectively grouped as FGENGINES3 within MI-ROP-B6636-2015a.

1.4 Contact Information

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

Table 1-2
Contact Information

Program Role	Contact	Address
State Regulatory Administrator	Ms. Karen Kajiya-Mills Technical Programs Unit Manager 517-335-4874 kajiya-millsk@michigan.gov	Michigan Department of Environment, Great Lakes and Energy 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
State Technical Programs Field Inspector	Ms. Regina Angellotti Technical Programs Unit Field Operations Section 313-418-0895 angellottir1@michigan.gov	Michigan Department of Environment, Great Lakes and Energy Detroit District 3058 West Grand Blvd. Detroit, Michigan 48202-6058
State Regulatory Inspector	Mr. Robert Elmouchi Environmental Quality Analyst 586-753-3736 elmouchir@michigan.gov	Michigan Department of Environment, Great Lakes and Energy Southeast Michigan District 27700 Donald Court Warren, Michigan 48092
Responsible Official	Mr. Gregory Baustian Executive Director Natural 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 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. Frank Rand Senior Environmental Analyst 734-850-4209 frank.randjr@cmsenergy.com	Consumers Energy Company South Monroe Customer Service Center 7216 Crabb Road Temperance, MI 48182
Test Facility	Mr. Charles Kelly Gas Field Lead 586-784-2096 Charles.Kelly@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 616-738-3385 joe.mason@cmsenergy.com	Consumers Energy Company L&D Training Center 17010 Croswell Street West Olive, Michigan 49460

2.0 SUMMARY OF RESULTS

2.1 Operating Data

During the performance test, the engines fired natural gas, and pursuant to §60.4244(a), operated within 10% of 100 percent 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- B6636-2015a. EUENGINE31, EUENGINE32, EUENGINE33, EUENGINE34 and EUENGINE35 are emission units identified in the permit, incorporated collectively as FGENGINES. 40 CFR Part 60, Subpart JJJJ and 40 CFR Part 63, Subpart ZZZZ requirements are also incorporated into the permit.

2.3 Results

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

Table 2-1
Summary of Average Test Results

Parameter	Units	EUENGINE					Emission Limit		
		31	32	33	34	35	40 CFR Part 60, Subpart JJJJ*, ‡	40 CFR Part 63, Subpart ZZZZ†	MI-ROP-B6636-2015a
NO_x	g/HP-hr	0.32	0.30	0.36	0.43	0.35	1.0		0.5
	ppmvd at 15% O_2	29.2	26.9	32.5	39.4	32.1	160		
CO	g/HP-hr	0.03	0.01	0.02	0.04	0.02	2.0		0.2
	ppmvd at 15% O_2	4.0	1.8	2.6	6.7	3.1	540		
	% reduction	98.5	99.3	99.0	97.3	98.8		≥93	≥93
VOC	g/HP-hr	0.044	0.041	0.074	0.048	<0.03	0.7		0.19
	ppmvd at 15% O_2	4.2	3.8	7.0	4.6	<3.1	86		

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

* Owners and operators of new lean burn SI stationary engines with a site rating ≥250 brake HP located at a major source that are meeting the requirements of 40 CFR Part 63, Subpart ZZZZ, Table 2a do not have to comply with the CO emission standards in 40 CFR Part 60, Subpart JJJJ, Table 1.

† 40 CFR Part 63, Subpart ZZZZ, Table 2a allows compliance to be demonstrated by limiting the concentration of formaldehyde in the stationary RICE exhaust to 14 ppmvd or less at 15 percent O_2 or reducing CO emissions by ≥93%. Consumers Energy is demonstrating compliance using the CO reduction efficiency emission limit.

‡ 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* organic compounds only.

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

3.0 SOURCE DESCRIPTION

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

Table 1-3
Summary of Engine Specifications

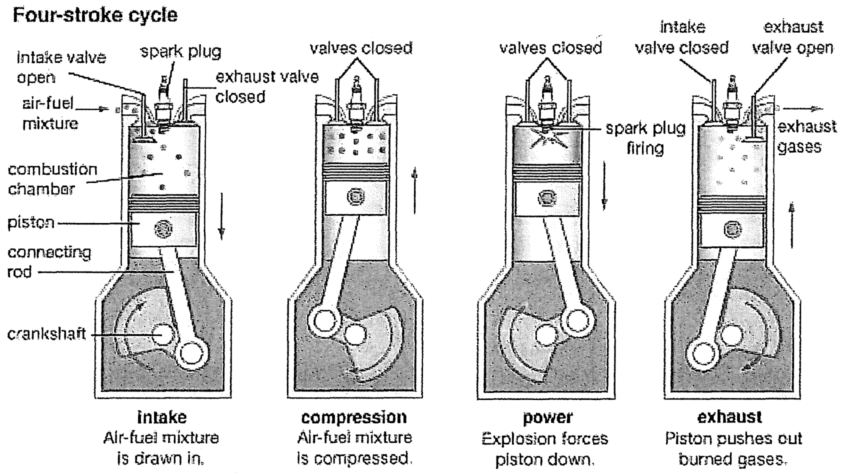
Parameter[1]	EUENGINE31 through EUENGINE35
Make	Caterpillar
Model	G3616
Output (brake-horsepower)	4,735
Heat Input (mmBtu/hr)	32.0
Exhaust Flow Rate (ACFM, wet)	32,100
Exhaust Gas Temp.	856
Engine Outlet O_2 (Vol-%, dry)	12.00
Engine Outlet CO_2 (Vol-%, dry)	5.81
CO, Uncontrolled (ppmv, dry)	572.0
CO,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

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

3.1 PROCESS

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

Figure 3-1. Four-Stroke Engine Process Diagram



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

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

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

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

3.2 Process Flow

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

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

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

3.3 Materials Processed

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

3.4 Rated Capacity

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

3.5 Process Instrumentation

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

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

Refer to Appendix D for operating data.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

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

Table 4-1
Test Methods

Parameter	Method	USEPA Title
Sample traverses	1	Sample and Velocity Traverses for Stationary Sources
Oxygen	3A	Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)
Moisture content	4	Determination of Moisture Content in Stack Gases
Nitrogen oxides (NO_x)	7E	Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)
Carbon monoxide (CO)	10	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
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 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 (2019)	Run	Sample Type	Start Time (EDT)	Stop Time (EDT)	Test Duration (min)	EPA Test Method	Comment
EUENGINE31							
June 13	1	O_2 NO_x CO CH_4 VOC	8:30	9:29	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		9:55	10:54	60		
	3		11:25	12:24	60		
EUENGINE32							
June 12	1	O_2 NO_x CO CH_4 VOC	13:51	14:50	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		15:15	16:14	60		
	3		16:35	17:34	60		
EUENGINE33							
June 12	1	O_2 NO_x CO CH_4 VOC	8:45	9:44	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		10:10	11:09	60		
	3		11:35	12:34	60		
EUENGINE34							
June 11	1	O_2 NO_x CO CH_4 VOC	15:26	16:25	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		17:00	17:59	60		
	3		18:25	19:24	60		
EUENGINE35							
June 11	1	O_2 NO_x CO CH_4 VOC	9:25	10:24	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		11:00	11:59	60		
	3		12:40	13:39	60		

4.2 Sample Location and Traverse Points (USEPA Method 1)

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

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

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

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

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

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

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

Figure 4-1. Pre-Catalyst Sampling Port Location

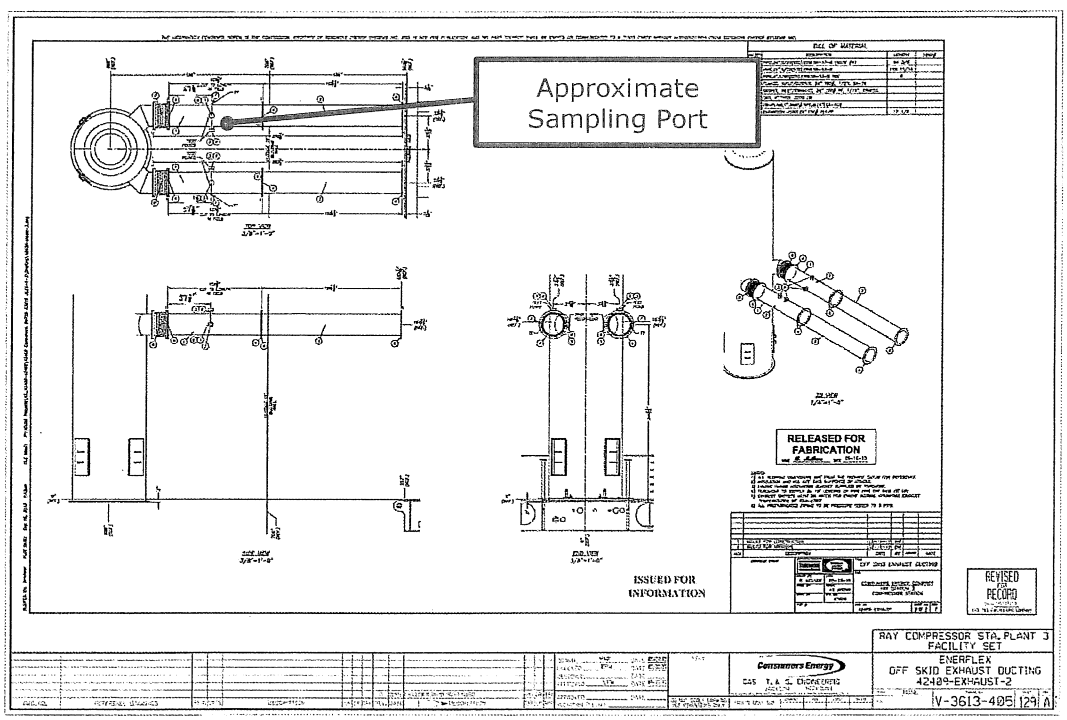
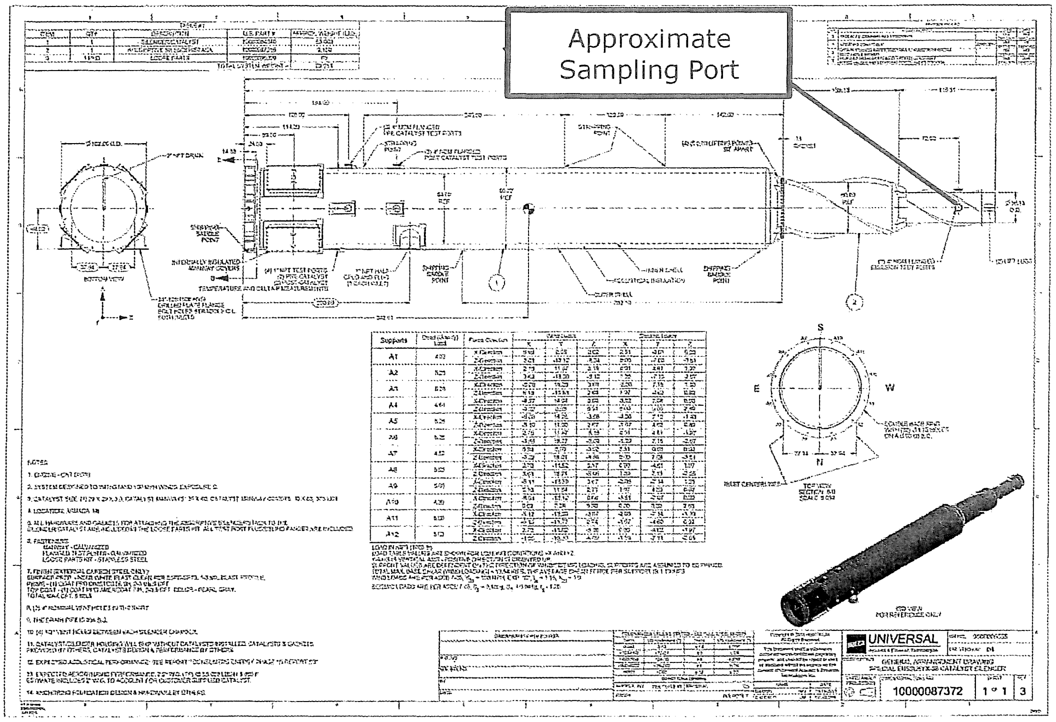


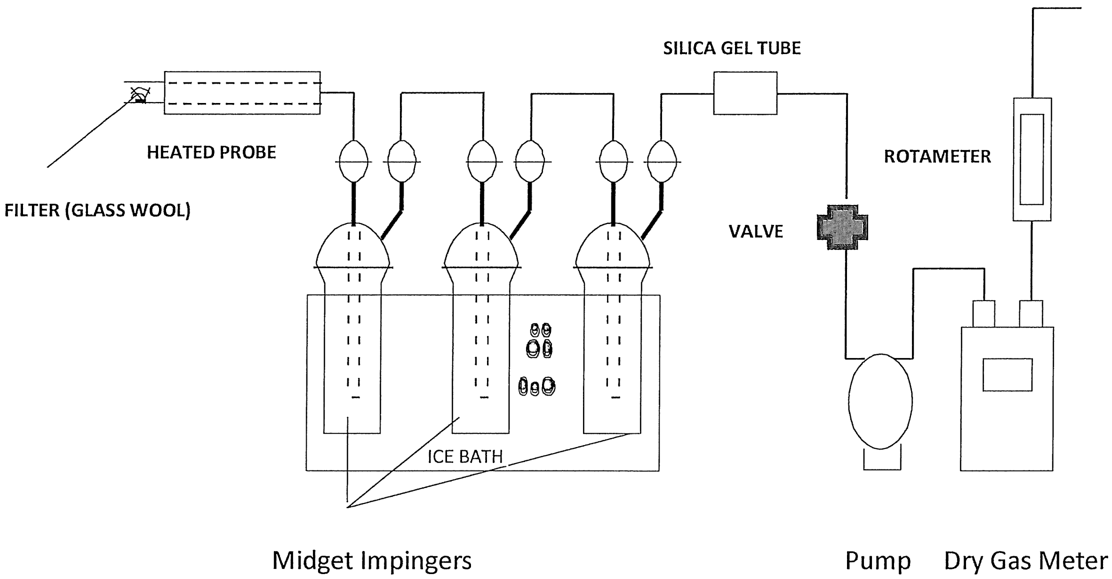
Figure 4-2. Post-Catalyst Sampling Port Location



4.3 Moisture Content (USEPA ALT-008)

Exhaust gas moisture content was determined in accordance with USEPA ALT-008, *Alternative Moisture Measurement Method Midget Impingers*, an alternative method for correcting pollutant concentration data to appropriate moisture conditions (e.g. pollutant and/or air flow data on a dry or wet basis) validated May 19, 1993 by the USEPA Emission Measurement Branch. The procedure is incorporated into Method 6A of 40 CFR Part 60 and is based on field validation tests described in *An Alternative Method for Stack Gas Moisture Determination* (Jon Stanley, Peter Westlin, 1978, USEPA Emissions Measurement Branch). The sample apparatus configuration follows the general guidelines contained in Figure 4-2 and § 8.2 of USEPA Method 4, *Determination of Moisture Content in Stack Gases,* and ALT-008 Figure 1 or 2. The flue gas is withdrawn from the stack at a constant rate through a heated sample probe, umbilical, four midget impingers, and a metering console with pump. The moisture is removed from the gas stream in the ice-bath chilled impingers and determined gravimetrically. Refer to Figure 4-3 for a figure of the Alternative Method 008 Moisture Sample Apparatus.

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)

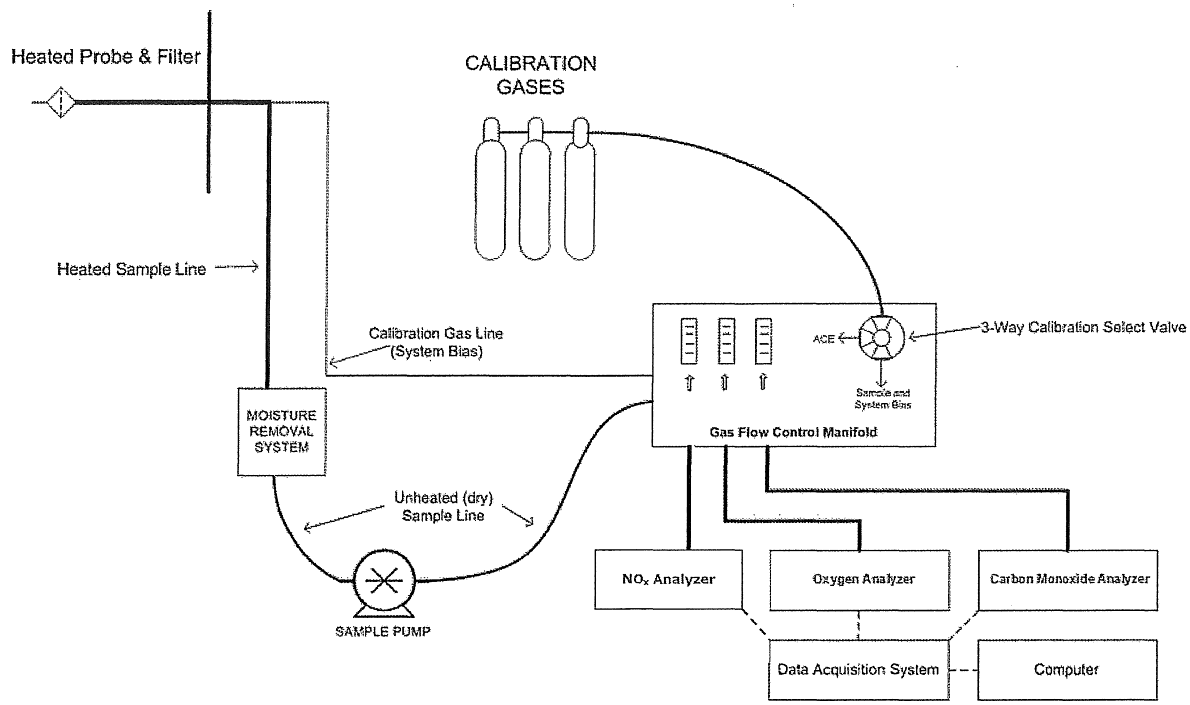
Oxygen, nitrogen oxides, and/or carbon monoxide concentrations were measured using the following sampling and analytical procedures:

- 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 with the exception of 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 depicts a drawing of the Methods 3A, 7E, and 10 sampling system.

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 in Method 19 is then used to calculate the emission flow rate with the corresponding equation presented in 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

$$Q_s = F_d H \frac{20.9}{20.9 - O_2}$$

Where:

Q_s = stack flow rate (dscf/min)
F_d = Volumes of combustion components per unit of heat content (scf/mmBtu)
H = fuel heat input rate, (mmBtu/min), at the higher heating value (HHV) measured at engine fuel feed line, calculated as (fuel feed rate in ft^3/min) x (fuel heat content in mmBtu/ft^3)
O_2 = stack oxygen concentration, dry basis (%)

4.6 Volatile Organic Compounds (USEPA Methods 18 and 25A)

VOC concentrations were measured from each engine using a Thermo Model 55i Direct Methane and Non-methane Analyzer following the guidelines of USEPA Method 25A, *Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer (FIA)*. 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.

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.

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. Refer to Figure 4-6 for a drawing of the USEPA Method 25A sampling apparatus.

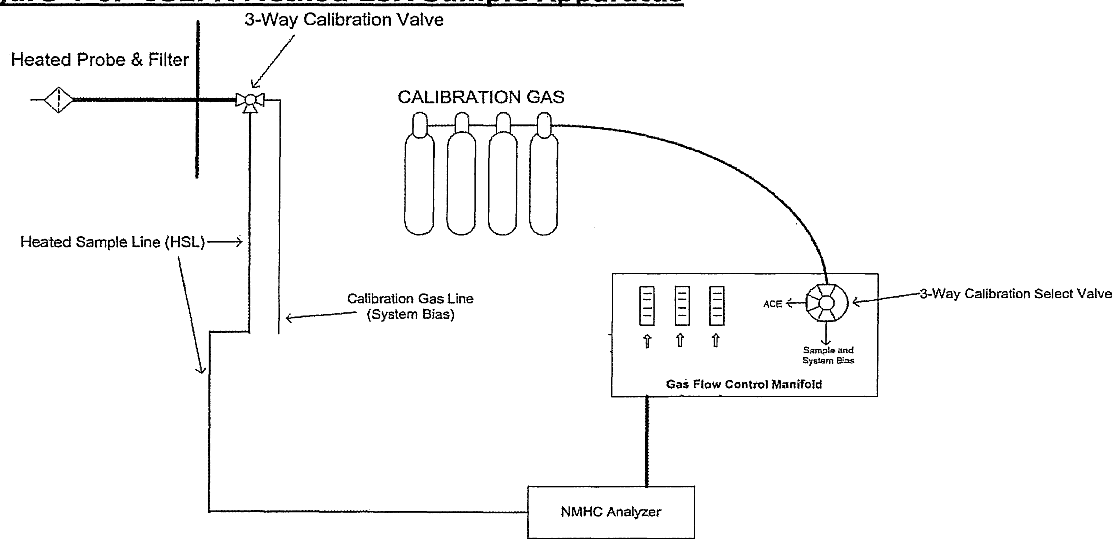
The field VOC instrument was calibrated with zero air and three propane and methane in air calibration gases following USEPA Method 25A procedures at the zero level, low (25 to 35 percent of calibration span), mid (45 to 55 percent of calibration span) and high (equivalent to 80 to 90 percent of instrument span). Note that the field VOC instrument measures on a wet basis, therefore measured exhaust gas moisture content was used to convert wet basis VOC concentrations to dry and calculate VOC mass emission rates.

Please note that 40 CFR Part 60, Subpart JJJJ refers to the definition of VOC found in 40 CFR, Part 51 and does not include methane or ethane. Specifically, §51.100(s)(1) defines VOC as "*any compound of carbon…other than the following, which have been determined to have negligible photochemical reactivity: methane, ethane…*" The Thermo 55i analyzer used measured exhaust gas ethane as part of the NMOC measurement. Therefore, tedlar bag samples were collected to quantify the ethane fraction of the NMOC concentration using USEPA Method 18, *Measurement of Gaseous Organic Compound Emissions by Gas Chromatography*.

Triplicate bags manufactured from polyvinyl fluoride (PVF) film, also known as Tedlar film, were collected in the field directly from each engine exhaust. The methane and 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. To identify and quantify the major components, the retention times of each separated component were compared with those of known compounds under identical conditions. 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 to be corrected based on results obtained from a spike recovery study. For the bag sampling technique to be considered valid for a compound, the recovery must be between 70% $<R < 130\%$. The recovery study performed on the Ray Compressor engine Tedlar bag samples successfully achieved the R value requirement and that value was applied to correct the reported methane and ethane concentrations as propane. The USEPA Method 18 laboratory report is presented in Appendix E.

Figure 4-6. USEPA Method 25A Sample Apparatus



5.0 TEST RESULTS AND DISCUSSION

The test program conducted June 11, 12, and 13, 2019, satisfies the performance testing and 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-B6636-2015a.

5.1 Tabulation of Results

The results of the testing indicate the NO_x, CO, and VOC engine emissions are compliant with the applicable emissions limits summarized in Table 2-1. Appendix Tables 1 through 5 contain detailed tabulation of results, process operating conditions, and exhaust gas conditions for each respective RICE.

5.2 Significance of Results

The results of the testing indicate compliance with the applicable emission limits.

5.3 Variations from Sampling or Operating Conditions

During testing of EUENGINE35 on June 11, 2019, higher than anticipated VOC concentrations were observed (approximately 200 ppmv as propane), thereby exceeding the 86.03 high calibration span gas of propane and methane in air in use. However, the instrument manufacturer states the VOC analyzer in use is linear over the 0 – 200 ppm span range, and the instrument responded accurately when challenged by four calibration gases. Therefore, the VOC concentrations measured are presumed to be accurate. RCTS staff reported the elevated VOC concentrations at that time to the facility who investigated the engine operating parameters.

Please note the approved test protocol contains a statement that in the event of elevated VOC concentrations, one Tedlar bag sample may be collected to verify the methane and ethane using Method 18 analysis. Based on discussions with onsite EGLE representatives, and in light of the EUENGINE35 VOC concentrations, this approach was expanded to include the collection of one Tedlar bag sample for each run performed at the engine exhausts, with the exception of EUENGINE35, where one Tedlar bag was collected at the conclusion of Run 2 and during Run 3. The analytical results from the Run 2 Tedlar bag sample collected was used to estimate ethane concentrations for Run 1.

5.4 Process or Control Equipment Upset Conditions

The engine and gas compressor were operating under maximum routine conditions and no upsets were encountered during testing with the exception of EUENGINE35.

The facility identified an issue with cylinder 11 misfiring in EUENGINE35. The temperature of the cylinder head was approximately 200°F, whereas if the cylinder and spark plug were firing correctly, the temperature would be approximately 800°F. The misfiring cylinder likely caused some un-combusted natural gas to exit the engine, which were measured by the VOC analyzer.

Subsequent laboratory analysis of Tedlar bag samples collected from the exhaust of EUENGINE35 reveal elevated concentrations of ethane and methane in comparison to those measured from EUENGINE31, EUENGINE32, EUENGINE33, and EUENGINE34. Subtracting the ethane fraction of the VOC concentrations measured to report non-methane, non-ethane VOCs resulted in a negative concentration for Runs 1, 2, and 3. For these runs, a non-detect value of <4 ppm derived from the manufactures accuracy specification of 2% of span (200 ppm) was reported to calculate the VOC emission rate.

5.5 Air Pollution Control Device Maintenance

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

5.6 Re-Test Discussion

Based on the results of this test program, a re-test is not required. Subsequent 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 60 Subpart JJJJ and the ROP

- every 8,760 engine operating hours or 3 years (2022), whichever is first, thereafter to evaluate compliance with NO_x, CO, and VOC emission limits in 40 CFR Part 63, Subpart ZZZZ and the ROP. The engine hours after the conclusion of testing were:
  - EUENGINE31: 11,135.5 hours
  - EUENGINE32: 10,010.3 hours
  - EUENGINE33: 10,856.3 hours
  - EUENGINE34: 10,820.7 hours
  - EUENGINE35: 9,484.3 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 reference methods performed state reliable results are obtained by persons equipped with a thorough knowledge of the techniques associated with each method. Factors with the potential to cause measurement errors are minimized by implementing quality control (QC) and assurance (QA) programs into the applicable components of field testing. QA/QC components were included in this test program. Table 5-1 summarizes the primary field quality assurance and quality control activities that were performed. Refer to Appendix 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
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: Calibration Error	Evaluates analyzer and sample system operation	Calibration gases introduced through sample system	Pre-test	±5.0% of the calibration gas value
M25A: Zero and Calibration Drift	Evaluates analyzer/sample system integrity and accuracy over test duration	Calibration gases introduced through sample system	Pre-test and Post-test	±3.0% of the analyzer calibration 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.