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40 CFR Part 60 Subpart JJJJ Initial Compliance Demonstration Test Report

EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4

Consumers Energy Company
St. Clair Compressor Station
10021 Marine City Highway
Ira, Michigan 48023
SRN: B6637

March 13, 2018

Test Dates: January 9 through 17, 2018

Test Performed by the Consumers Energy Company
Regulatory Compliance Testing Section
Air Emissions Testing Body
Laboratory Services Section
Work Order No. 30122642
Version No.: 0

EXECUTIVE SUMMARY

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compound (VOC) testing at three, stationary, spark-ignition (SI) internal combustion engines (ICE), identified as EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4, installed and operating at the St. Clair Compressor Station, in Ira, Michigan. The facility is classified as an area source of hazardous air pollutants (HAP) and the engines are natural gas-fired, four-stroke lean burn (4SLB), 4,835 brake horsepower (BHP) engines which operate as needed to maintain natural gas pressure to move it in (injection) and out (withdrawal) of storage reservoirs and along the natural gas pipeline system. The test program was conducted from January 9 – 17, 2018 to satisfy initial performance testing requirements and evaluate compliance with 40 CFR 60, Subpart JJJJ, "Standards of Performance for Stationary Spark Ignition Internal Combustion Engines," (aka NSPS SI ICE) and Michigan Department of Environmental Quality (MDEQ) Permit to Install (PTI) 106-14.

Three, 60-minute test runs were conducted on each engine exhaust following the procedures in United States Environmental Protection Agency (USEPA) Reference Methods (RM) 1, 3A, 4, 7E, 10, 18, 19, and 25A/ALT-096 in 40 CFR 60, Appendix A. Please note that while ALT-096 is technically not named in 40 CFR 60, Appendix A; ALT-096 incorporates relevant Appendix A, Method 25A procedures and requirements specific to operating a Thermo-Electron Model (TECO) 55I for methane and non-methane organic compounds (NMOC) measurement at 40 CFR 60, Subpart JJJJ sources.

There were no deviations from the approved stack test protocol or associated USEPA Reference Methods, however test provisions existed in the protocol for conducting initial performance testing on EUEMERGEN3-1 and four Plant 3 engines within the flexible group (FG) FGENGINES-P3; however EUENGINE3-1 was not tested due to mechanical issues; thus that performance test will be re-scheduled to within 30 calendar days following the first operation of the engine for routine production purposes during the 2018 calendar year. Furthermore, EUEMERGEN3-1 underwent testing October 3, 2017; the results of which are presented in a separate report dated November 27, 2017.

During testing, EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4 operated at horsepower and torque conditions within plus or minus (±) 10 percent of 100 percent peak (or the highest achievable) load, as specified in 40 CFR 60.4244(a). The results of the emissions testing are summarized in Table E-1 on the following page.

Table E-1
Summary of Test Results

Parameter	Units	Average	Emission Limit	
			40 CFR 60, Subpart JJJJ[1]	PTI 106-14
EUENGINE3-2				
NO_x	g/HP-hr	**0.41**	**1.0**	**0.6**
	ppmvd at 15% O_2	**35.2**	**82**	
CO	g/HP-hr	**0.018**	**2.0**	**0.36**
	ppmvd at 15% O_2	**2.6**	**270**	
VOC[2]	g/HP-hr	**<0.02**	**0.7**	**0.2**
	ppmvd at 15% O_2	**<1.6**	**60**	
EUENGINE3-3				
NO_x	g/HP-hr	**0.46**	**1.0**	**0.6**
	ppmvd at 15% O_2	**38.5**	**82**	
CO	g/HP-hr	**0.027**	**2.0**	**0.36**
	ppmvd at 15% O_2	**3.7**	**270**	
VOC	g/HP-hr	**0.05**	**0.7**	**0.2**
	ppmvd at 15% O_2	**4.6**	**60**	
EUENGINE3-4				
NO_x	g/HP-hr	**0.55**	**1.0**	**0.6**
	ppmvd at 15% O_2	**47.3**	**82**	
CO	g/HP-hr	**0.022**	**2.0**	**0.36**
	ppmvd at 15% O_2	**3.1**	**270**	
VOC	g/HP-hr	**0.01**	**0.7**	**0.2**
	ppmvd at 15% O_2	**1.3**	**60**	

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] The EUENGINE3-2 VOC results are derived by subtracting ethane from field measured NMOC values yielding negative values for Runs 1 and 2. Therefore, NMNEOC results are based upon the sum of the minimum Method 18 ethane laboratory detection limit (MDL) and the Method 25A MDL.

The results of the EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4 testing indicate the NO_x, CO, and VOC exhaust emissions are in compliance with PTI 106-14 and NSPS SI ICE limits.

Detailed results are presented in Appendix Tables 1, 2, and 3. Sample calculations, field data sheets, and laboratory data are presented in Appendices A, B, and C. Engine operating data and supporting documentation are provided in Appendices D and E.

1.0 INTRODUCTION

This report summarizes the results of compliance air emissions testing conducted January 9 – 17, 2018 on EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4, installed and operating at the Consumers Energy St. Clair Compressor Station.

This document follows the Michigan Department of Environmental Quality (MDEQ) format described in the December 2013, Format for Submittal of Source Emission Test Plans and Reports. Reproducing only a portion of this report may omit critical substantiating documentation or cause information to be taken out of context. If any portion of this report is reproduced, please exercise due care in this regard.

1.1 Identification, Location, and Dates of Tests

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compound (VOC) testing of three, stationary, spark-ignition (SI), internal combustion engines (ICE), identified as EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4 installed and operating at the St. Clair Compressor Station in Ira, Michigan on January 9 through 17, 2018.

A test protocol submitted to the MDEQ on August 31, 2017 was subsequently approved by Mr. Tom Gasloli, MDEQ Environmental Quality Analyst, in a letter dated September 13, 2017. Note that provisions existed in the protocol to conduct initial performance testing on EUEMERGEN3-1 and the four Plant 3 engines comprising the flexible group (FG) FGENGINES-P3; however EUENGINE3-1 was not tested due to mechanical issues; thus that performance test will be re-scheduled to within 30 calendar days following the first operation of the engine for routine production purposes during the 2018 calendar year. Furthermore, EUEMERGEN3-1 underwent testing October 3, 2017; the results of which are presented in a separate report dated November 27, 2017.

1.2 Purpose of Testing

The test program was performed from January 9 – 17, 2018 to satisfy initial performance testing requirements and evaluate compliance with the applicable limits specified in 40 CFR Part 60, Subpart JJJJ, "Standards of Performance for Stationary Spark Ignition Internal Combustion Engines" (aka NSPS SI ICE) and in MDEQ Permit to Install (PTI) 106-14. The applicable emission limits are presented in Table 1-1.

Table 1-1
Applicable Emission Limits

Parameter	Emission Limit: 40 CFR 60, Subpart JJJJ [1]	Emission Limit: PTI 106-14	Units	Applicable Requirement
NO_x	1.0	0.6	g/HP-hr	R 336.1205(1)(a) 40 CFR 52.21(c) & (d) 40 CFR 60.4233(e) Table 1 to Subpart JJJJ of Part 60—NO_x, CO, and VOC Emission Standards for Stationary Non-Emergency SI Engines ≥100 HP (Except Gasoline and Rich Burning LPG), Stationary SI Landfill/Digester Gas Engines, and Stationary Emergency Engines >25HP
	82		ppmvd at 15% O_2	
CO	2.0	0.36	g/HP-hr	
	270		ppmvd at 15% O_2	
VOC	0.7	0.2	g/HP-hr	
	60		ppmvd at 15% O_2	

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

1.3 Brief Description of Source

EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4 are 4,835 brake horsepower, four-stroke lean burn (4SLB), SI ICEs located at an area source of hazardous air pollutant (HAP) emissions. The engines operate as needed to maintain natural gas pressure to move it in (injection) and out (withdrawal) of storage reservoirs and along the natural gas pipeline system.

1.4 Contact Information

Table 1-2 presents the names, addresses, and telephone numbers of the contacts for information regarding the test and the test report, and names and affiliation of personnel involved in conducting the testing.

Table 1-2
Contact Information

Program Role	Contact	Address
State Regulatory Administrator	Ms. Karen Kajiya-Mills Technical Programs Unit Manager 517-335-4874 kajiya-millsk@michigan.gov	Michigan Department of Environmental Quality Technical Programs Unit 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
State Technical Programs Field Inspector	Mr. Tom Gasloli Technical Programs Unit Field Operations Section 517-284-6778 gaslolit@michigan.gov	Michigan Department of Environmental Quality Technical Programs Unit 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	Michigan Department of Environmental Quality Southeast Michigan District 27700 Donald Court Warren, Michigan 48092
Responsible Official	Mr. Gregory Baustian Executive Director-Natural Gas Compression and Storage 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
Test Facility	Mr. Brian Mauzy Gas Field Leader III 586-716-3331 brian.mauzy@cmsenergy.com	Consumers Energy Company St. Clair Compressor Station 10021 Marine City Highway Ira, Michigan 48023
Test Team Representative	Mr. Thomas Schmelter, QSTI Engineering Technical Analyst II 616-738-3234 thomas.schmelter@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), the engine was 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 >95% torque and >96% horsepower, based on the maximum manufacturer's design capacity at engine and generator site conditions.

Refer to Attachment D for detailed operating data.

2.2 APPLICABLE PERMIT INFORMATION

The St. Clair Compressor Station has been assigned State of Michigan Registration Number (SRN) B6637 and operates Plant 3 in accordance with PTI 106-14. EUENGINE3-1, EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4 are the emission unit sources identified in the permit. Collectively they are included within the FGENGINES-P3 flexible group. Incorporated within the permit are the applicable requirements of NSPS SI ICE.

2.3 Results

The results of the EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4 testing indicate the NO_x, CO, and VOC exhaust emissions are in compliance with PTI 106-14 and NSPS SI ICE limits. Refer to Table 2-1 for the summary of test results.

Table 2-1
Summary of Test Results

Parameter	Units	Average	Emission Limit	
			40 CFR 60, Subpart JJJJ[1]	PTI 106-14
EUENGINE3-2				
NO_x	g/HP-hr	**0.41**	**1.0**	**0.6**
	ppmvd at 15% O_2	**35.2**	**82**	
CO	g/HP-hr	**0.018**	**2.0**	**0.36**
	ppmvd at 15% O_2	**2.6**	**270**	
VOC[2]	g/HP-hr	**<0.02**	**0.7**	**0.2**
	ppmvd at 15% O_2	**<1.6**	**60**	
EUENGINE3-3				
NO_x	g/HP-hr	**0.46**	**1.0**	**0.6**
	ppmvd at 15% O_2	**38.5**	**82**	
CO	g/HP-hr	**0.027**	**2.0**	**0.36**
	ppmvd at 15% O_2	**3.7**	**270**	
VOC	g/HP-hr	**0.05**	**0.7**	**0.2**
	ppmvd at 15% O_2	**4.6**	**60**	
EUENGINE3-4				
NO_x	g/HP-hr	**0.55**	**1.0**	**0.6**
	ppmvd at 15% O_2	**47.3**	**82**	
CO	g/HP-hr	**0.022**	**2.0**	**0.36**
	ppmvd at 15% O_2	**3.1**	**270**	
VOC	g/HP-hr	**0.01**	**0.7**	**0.2**
	ppmvd at 15% O_2	**1.3**	**60**	

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 The EUENGINE3-2 VOC results are derived by subtracting ethane from field measured NMOC values yielding negative values for Runs 1 and 2. Therefore, NMNEOC results are based upon the sum of the minimum Method 18 ethane laboratory detection limit (MDL) and the Method 25A MDL.

Detailed results are presented in Appendix Tables 1, 2, and 3. A discussion of the results is presented in Section 5.0. Sample calculations, field data sheets, and laboratory results are presented in Appendices A, B, and C. Engine operating data and supporting information are provided in Appendices E and E.

3.0 SOURCE DESCRIPTION

EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4 are operated as needed to maintain natural gas pressure in order to move it in (injection) and out (withdrawal) of storage reservoirs and along the natural gas pipeline system. A summary of the engine specifications are provided in Table 3-1.

Table 3-1
Engine Specifications

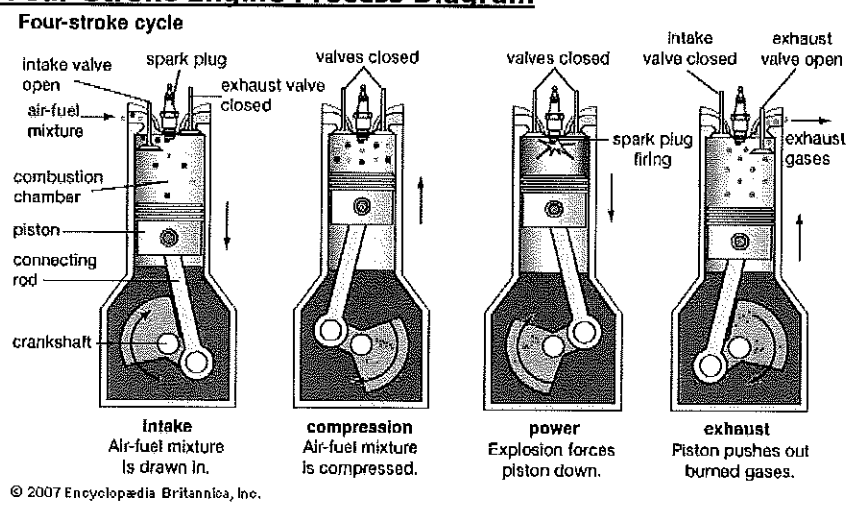
Engine ID	Engine Description		Site-Rated HP	Emission Control
	Manufacturer	Model		
EUENGINE3-2, EUENGINE3-3 & EUENGINE3-4	Waukesha	16V275GL+	4,835	Oxidation catalyst

3.1 Process

EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4 are natural gas-fired 4SLB SI ICEs constructed in 2017. In a four-stroke engine, air is aspirated into the cylinder during the downward travel of the piston on the intake stroke. The fuel charge is injected when the piston is near the bottom of the intake stroke; the intake ports are then closed as the piston moves to the top of the cylinder, compressing the air/fuel mixture. The ignition and combustion of the air/fuel charge begins the downward movement of the piston called the power stroke. As the piston reaches the bottom of the power stroke, valves are opened and combustion products are expelled from the cylinder as the piston travels upward. A new air-to-fuel charge is injected as the piston moves downward with a new intake stroke.

The engines provide mechanical shaft power to gas compressors and/or pumps. The compressors and/or pumps are used to withdrawal or inject natural gas into high pressure natural gas storage fields or to help move natural gas and maintain pressure within the natural gas pipeline transmission and distribution system. Refer to Figure 3-1 for a four-stroke engine process diagram.

Figure 3-1. Four-Stroke Engine Process Diagram



The natural gas-fired engine flue gas is controlled through parametric controls (i.e., timing and air-to-fuel ratio), lean burn combustion technology, and oxidation catalysts. The Waukesha engine includes a control module that monitors and adjusts engine parameters for optimal performance. The NO_x emissions from each of 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 and resulting in lower NO_x emissions.

The oxidation catalysts are manufactured by Powertherm Company Four catalyst modules are installed on each engine. The catalysts use propriety materials to lower the oxidation temperature of CO and other organic compounds, thus maximizing the catalyst efficiency specific to the exhaust gas temperatures generated by the engines. The catalyst also provides control of formaldehyde, as well as non-methane and non-ethane hydrocarbons.

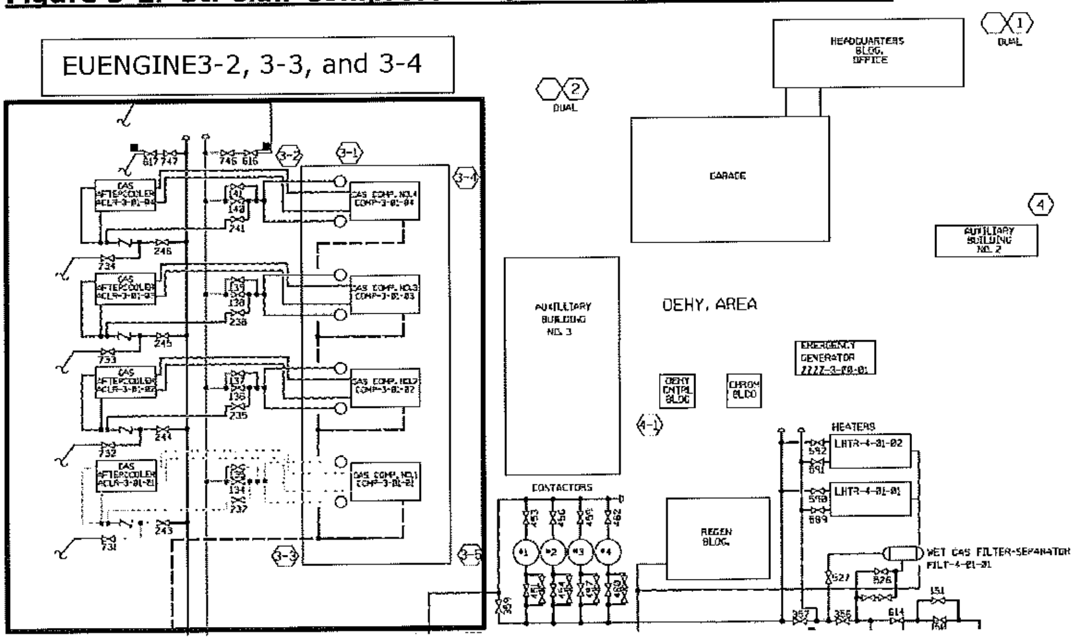
Detailed operating data recorded during testing are provided in Appendix D.

3.2 Process Flow

Located in southern St. Clair County, the St. Clair Compressor Station helps maintain natural gas pressures in southeast Michigan. The Hessen, Puttygut, Swan Creek, Four Corners, Ira, and Lenox gas storage fields are located in the Niagaran geologic formation and used to store and supply a capacity of approximately 45.6 billion cubic feet of natural gas. The station connects to these six underground storage fields, which provide enough natural gas to serve up to 20 percent of the supply to Consumers Energy's 1.7 million gas customers in winter.

The facility is divided into three plants comprising natural gas reciprocating compressor engines, combustion turbines, and associated equipment to maintain pressure and move natural gas in and out of the storage reservoirs. The Plant 3 natural gas compressor engines were the focus of this test program. Refer to Figure 3-2 for the St. Clair Compressor Station Plant 3 Process Flow. The green lines represent gas into the engine compression system, while the blue lines represent discharged gas. The gas can be routed through the plant, into underground storage reservoirs, or out to the distribution pipelines.

Figure 3-2. St. Clair Compressor Station Plant 3 Process Flow



3.3 Materials Processed

The fuel utilized in EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4 is exclusively natural gas, as defined in 40 CFR 72.2. During testing the natural gas combusted within the engines was comprised of approximately 94% methane, 4% ethane, 1% nitrogen, and 0.75% carbon dioxide.

3.4 Rated Capacity

The engines have a maximum power output of approximately 4,835 horsepower. The engines have a rated heat input of 27 million British thermal units per hour (mmBtu/hour). The normal rated capacities of the engines are a function of facility and gas transmission demand. The engine operating parameters were recorded and averaged for each test run. Refer to Appendix D for operating data recorded during testing.

3.5 Process Instrumentation

The engine processes were continuously monitored by GE Power engine controllers for the Waukesha engines, data acquisition systems, and by Consumers Energy operations personnel during testing. Data were collected at 1-minute intervals during each test for the following parameters:

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

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 United States Environmental Protection Agency (USEPA) test methods presented in Table 4-1. The sampling and analytical procedures associated with each parameter are described in the following sections.

Table 4-1
Test Methods

Parameter	Method	USEPA Title
Sample 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)
Ethane	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	Alt-096: 18/25A	Measurement of Gaseous Organic Compound Emissions by Gas Chromatography and Determination of Total Gaseous Organic Concentration Using A Flame Ionization Analyzer via TECO-55I for NSPS SI ICE

4.1 Description of Sampling Train and Field Procedures

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

Table 4-2
Test Matrix

Date (2018)	Run	Sample Type	Start Time (EDT)	Stop Time (EDT)	Test Duration (min)	EPA Test Method	Comment
EUENGINE3-2							
January 9	1	O_2 NO_x CO VOC	10:35	11:35	60	1 3A 4 7E 10 19 25A/18 Alt-096	Natural gas sample collected.
	2		12:10	13:10	60		
January 10	3		17:25	18:25	60		Natural gas sample and Flexible bags for ethane analysis collected.
EUENGINE3-3							
January 16	1	O_2 NO_x CO VOC	11:10	12:35	60	1 3A 4 7E 10 19 25A/18 Alt-096	Natural gas sample collected. Test paused from 11:20-11:45, sample system frozen.
	2		13:00	14:00	60		Flexible bags for ethane analysis collected.
January 17	3		14:45	15:45	60		
EUENGINE3-4							
January 11	1	O_2 NO_x CO VOC	10:50	11:50	60	1 3A 4 7E 10 19 25A/18 Alt-096	Natural gas sample collected.
	2		12:20	13:20	60		
	3		13:45	14:45	60		Flexible bags for ethane analysis collected.

4.2 Sample Location and Traverse Points (USEPA Method 1)

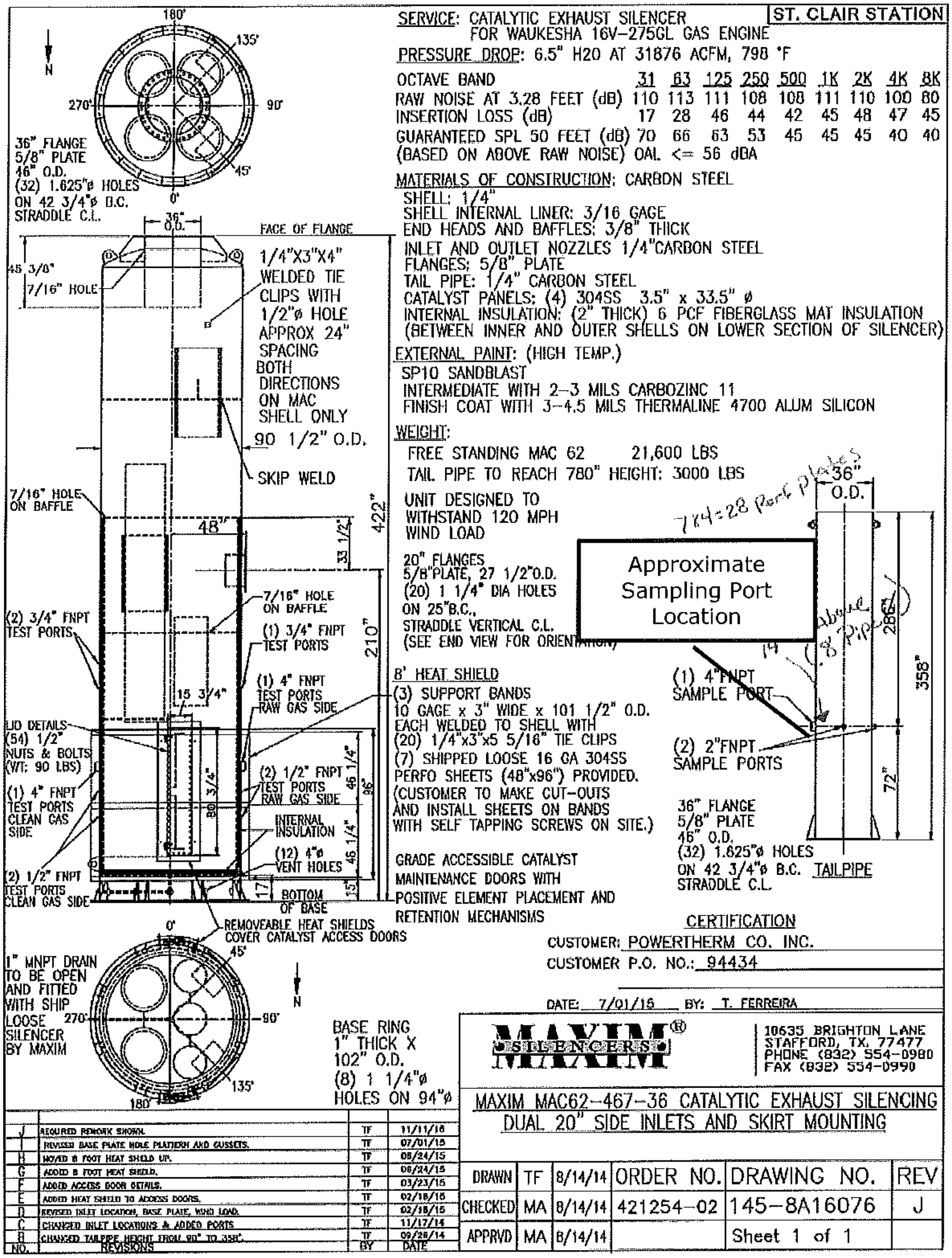
The number and location of traverse points was evaluated according to the requirements in USEPA Method 1, *Sample and Velocity Traverses for Stationary Sources.*

Two 4-inch diameter test ports protrude approximately 4-inches beyond a 36-inch diameter vertical exhaust stack exiting the engine. The exhaust stacks are designated as SVENGINE3-2, SVENGINE3-3 and SVENGINE3-4 as directed in PTI 106-14, *FGENGINES-P3, Section VIII, Stack/Vent Restrictions,* which require exhaust gases to discharge through stacks ≤36-inches in diameter and ≥65 feet above ground. The sampling ports are located:

- Approximately 117 inches or 3.25 duct diameters downstream from the confluence of the oxidation catalyst exhaust silencer to the vertical exhaust stack, and
- Approximately 286 inches or 7.9 duct diameters upstream of the stack exit. The stack exit is 65 feet above the ground surface.

Because the duct is >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 sample probe was marked at 3 traverse points located at 16.7, 50.0, and 83.3% of the measurement line ('3-point long line'). Gas was sampled from each of the three traverse points during the testing or a single point based on the results of the stratification test. A representative drawing of a tested engine's exhaust stack sampling locations are presented as Figure 4-1.

Figure 4-1. Exhaust Stack Sampling Port Locations

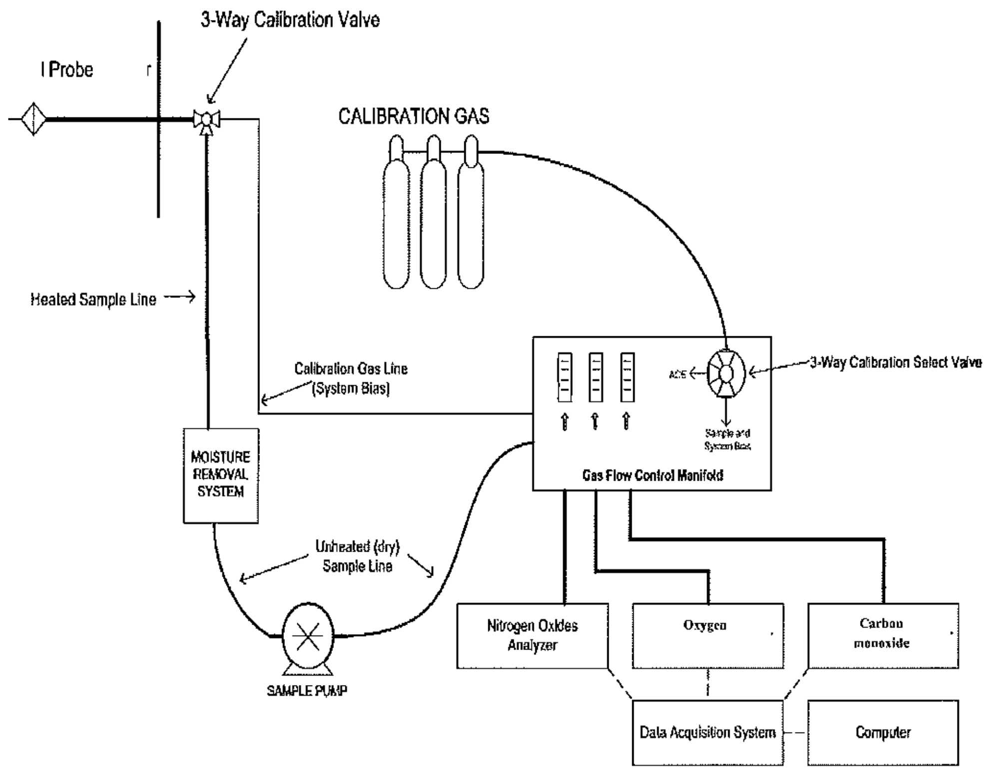


4.3 NO_x, CO, AND O_2 CONCENTRATIONS (USEPA METHODS 3A, 7E, AND 10)

Oxygen, nitrogen oxides, and carbon monoxide concentrations were measured using the sampling and analytical procedures of USEPA Methods 3A, *Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)*, 7E, "*Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)*, and 10, *Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure).* The sampling procedures of the methods are similar with the exception of the analyzers and analytical technique used to quantify the parameters of interest. The measured diluent concentrations were used to adjust measured pollutant concentrations to 15% O_2.

Engine exhaust gas was extracted from the stack through a stainless steel probe, heated sample line, and through a gas conditioning system to remove water and dry the sample before entering a sample pump, gas flow control manifold, and chemiluminescent, paramagnetic, and infrared gas filter correlation gas analyzers. Figure 4-2 depicts the Methods 3A, 7E, and 10 sampling system.

Figure 4-2. Methods 3A, 7E, 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 are 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 was introduced at the sample probe to measure the ability of the system to respond accurately to within ±5.0 percent of span.

An NO_2-NO conversion check was performed by introducing an approximate 50 ppmv NO_2 calibration gas into the NO_x analyzer. The NO_2-NO conversion check evaluates the ability of analyzer to accurately measure total nitrogen oxides. The NO_2-NO conversion results were acceptable because the analyzer's NOx concentration was ≥90% of the introduced NO_2 calibration gas concentration.

Upon successful completion of the calibration error and initial system bias tests, sample flow rates and component temperatures were verified and the probe was inserted into the duct. After confirming the engine was operating at established conditions the test run was initiated. NO_x, CO, and O_2 concentrations were recorded at 1-minute intervals throughout the 60-minute test duration.

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

4.4 Moisture Content (USEPA Method 4)

The alternative procedure in 40 CFR Part 60, Appendix A Method 4, *Determination of Moisture Content in Stack Gases*, §16.4 was used to calculate flue gas moisture content by summing the moisture mole fraction of the ambient air, the free water in the fuel fired, and the hydrogen in the fuel. This data was used to convert measured pollutant concentration from a wet basis to dry basis. The natural gas fuel sample laboratory analyses results and the water content from the 26-inch market main are contained in Appendix C of this report.

4.5 Ethane Concentrations (USEPA Method 18)

USEPA Method 18, *Measurement of Gaseous Organic Compound Emissions by Gas Chromatography*, was used to quantify the ethane component of the measured organic compound emissions. Engine exhaust gas samples were collected in flexible bags and submitted to a laboratory to measure ethane concentrations. The laboratory analyzed the samples by gas chromatography with flame ionization detector. The reported ethane concentration was converted from ethane to propane based on the number of carbon atoms in each compound. The ethane concentrations were subtracted from the measured non-methane hydrocarbon concentrations used to calculate the non-methane, non-ethane VOC emission rate. Refer to Appendix C for the USEPA Method 18 laboratory results.

4.6 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 a fuel specific F factor to calculate pollutant emission rates. A fuel sample was collected during testing and analyzed by to obtain hydrocarbons, non-hydrocarbon, and heating value of the natural gas sample. The results were used to calculate F_w and F_d factors (ratios of combustion gas volumes to heat inputs) using USEPA Method 19 Equations 19-13, 19-14, and 19-15. This F_d factor was then used to calculate the emission flow rate with the corresponding equation presented in Figure 4-3.

Figure 4-3. 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	=	fuel-specific oxygen based F factor, dry basis, from Method 19 (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 ft3/min)(fuel heat content in mmBtu/ft3)
O_2	=	stack oxygen concentration, dry basis (%)

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

VOC concentrations were measured using Approved Alternative Test Method 096 (ALT-096) as an alternative or modification to combine 40 CFR 60, Appendix A, reference method 25A, *Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer,* and reference method 18, *Measurement of Gaseous Organic Compound Emissions by Gas Chromatography*. Methane and non-methane organic compounds (NMOC) were measured using a Thermo Scientific 55I as specified in Alt-096. Figure 4-4 depicts the NMOC sample apparatus configuration.

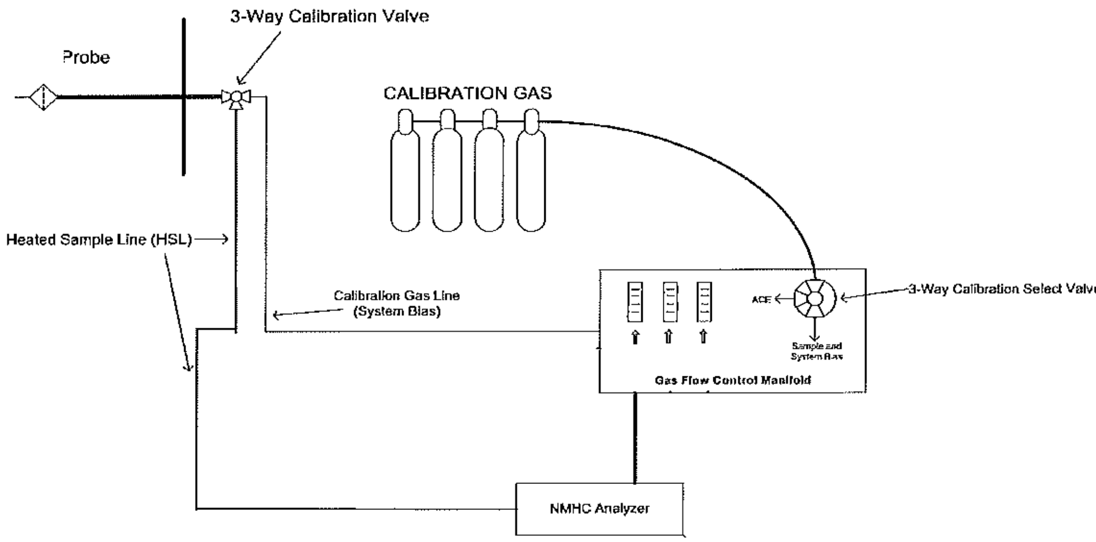
The components of the extractive NMOC sample interface apparatus are constructed of Type 316 stainless steel and Teflon. Flue gas was sampled from the stack via a sample probe and heated sample line and into the analyzer communicating with data acquisition handling systems (DAHS) via output signal cables. 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.

Prior to testing, the analyzer was calibrated by introducing known concentrations of hydrocarbon free zero gas and high-level methane and propane USEPA Protocol calibration gas standards to the analyzer and adjusting its signal output to appropriate levels. A method 25A calibration error test was completed by introducing low- and mid-level calibration gases to the sample system to evaluate if the analyzer's response was within ±5% of the calibration gas concentration. During this procedure the system response time was measured to determine the time from the concentration change to the measurement system response equivalent to 95% of the step change.

Immediately following the completion of the test period, the zero and low-level calibration gases, one at a time, were introduced into the measurement system to evaluate analyzer drift. The analyzer's response was recorded and if the drift values were within ±3% of span, the test data was validated.

As requested by the MDEQ, the measured NMOC concentrations were adjusted for analyzer bias using USEPA Method 7E equation 7E-5b. Ethane was subtracted from the measured NMOC concentrations and calculated moisture content of the exhaust gas was used to convert this concentration to a dry basis. The non-methane, non-ethane organic compound concentration (NMNEOC) and the calculated volumetric flowrate were used to calculate the VOC mass emission rate and evaluate compliance with the applicable permit limits.

Figure 4-4. USEPA Method 25A NMOC Sample Apparatus



5.0 TEST RESULTS AND DISCUSSION

The test program was performed to satisfy the initial performance testing requirements and evaluate compliance with the NSPS SI ICE and MDEQ PTI 106-14.

5.1 Tabulation of Results

The results of the EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4 testing indicate the NO_x, CO, and VOC exhaust emissions are in compliance with NSPS SI ICE and PTI 106-14 limits as summarized in Table 2-1. Appendix Tables 1, 2, and 3 contain detailed tabulation of results, process operating conditions, and exhaust gas conditions.

Please note that 40 CFR Part 60, Subpart JJJJ defers to 40 CFR Part 51 VOC definitions, 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...*, and (2), *Where such a method also measures compounds with negligible photochemical reactivity, these...compounds may be excluded as VOC if... accurately quantified, and such exclusion is approved by the enforcement authority.* The CECo test protocol included a request; subsequently granted by the MDEQ; to collect exhaust gas samples in flexible bags for Method 18 ethane analysis at an outside contracted laboratory, since the Thermo Scientific 55i NMOC measurement includes ethane, thus creating a positive ethane bias potential when testing natural gas-fired stationary sources.

The potential for a positive ethane bias was first observed on January 9th during EUENGINE3-2 run 1 and 2 when field measured NMOC results were less than the 0.7 g/HP-hr Subpart JJJJ Limit, but greater than the 0.2 g/HP-hr PTI-106-14 limit. After confirming agency approval for separate ethane analysis, RCTS collected one representative, "as fired" sample for ethane analysis in duplicate from the engine on January 10th during run 3. The duplicate sample was designated for backup analysis in the event of flexible sample bag shipping damage or if needed for quality assurance. Subsequent field NMOC measurements at EUENGINE3-3 and EUENGINE3-4 revealed NMOC values consistent with EUENGINE3-2, so duplicate bag samples from each were also collected.

The reported ethane laboratory result was converted to propane and subtracted from the field-measured NMOC concentrations measured as propane, thus yielding a more accurate, representative NMNEOC (VOC) result.

Please note that after subtracting the ethane from the NMNEOC values, EUENGINE3-2 run 1 and 2 NMNEOC values were less than zero. Rather than report negative values, the <2% detection limit in USEPA Method 25A (equivalent to 1.7 ppm during these tests) and laboratory reported detection limit from USEPA Method 18 analysis (0.26 ppmv) were summed to illustrate the EUENGINE3-2 NMNEOC values relative to the <2 ppmv Method 25A detection limit as well as the actual negative NMNEOC result.

Note that the duplicate bag sample was analyzed for EUENGINE3-2 and EUENGINE3-4 due to the first bag Method 18 spike recovery analysis not meeting QA requirements.

5.2 Significance of Results

The results of the testing indicate compliance with the PTI 106-14 and NSPS SI ICE limits.

5.3 Variations from Sampling or Operating Conditions

No operating condition variations were observed during the test program, with the exception of the EUENGINE3-4 test on January 11, 2018 when warm weather and reduced system demand required St. Clair Compressor gas control operators to halt discharge of natural gas from Plant 3 to the main distribution pipeline. Testing continued with the engine at >90% capacity after re-routing the natural gas throughout underground pipelines within Plant 3, thus recirculating the gas in lieu of distributing it to the main pipeline. This re-circulation activity, while an atypical exercise for the plant operators, had no impact on engine operating conditions or emissions as the engine continued to be operated at maximum capacity as if distributing gas to the main pipeline.

A minor sampling delay of roughly 25 minutes also occurred during Run 1 on EUENGINE3-3, when exhaust gas moisture condensed and froze in the sample system probe. The test was paused while the probe was removed, replaced and verified to be leak-free, after which the run continued uneventfully.

5.4 Process or Control Equipment Upset Conditions

The engine and gas compressor / pump equipment were operating under maximum routine conditions and no upsets were encountered during testing with the exception of EUENGINE3-1. As EUENGINE3-1 was being started and brought up to the desired test condition, a grid switch partial alarm hard stopped the engine. Testing of this engine was aborted because the engine could not be operated until the cause(s) of the failure were identified and repairs made. Repair and commissioning activities for this engine is tentatively expected to be complete by June 30, 2018.

5.5 Air Pollution Control Device Maintenance

Startup and commissioning of the engines occurred during the three months prior to the test. Engine optimization is 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 every 8,760 engine operating hours or 3 years, whichever is first, thereafter to demonstrate compliance. The engine hours at the conclusion of testing were: 93.76 for EUENGINE3-2, 106.77 for EUENGINE3-3, and 122.65 for EUENGINE3-4.

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 if the sampling location is suitable for sampling	Measure distance from ports to downstream and upstream flow disturbances	Pre-test	≥2 diameters downstream; ≥0.5 diameter upstream.
M1: Duct diameter/ dimensions	Verifies area of stack is accurately measured	Review as-built drawings and field measurement	Pre-test	Field measurement agreement with as-built drawings
M3A, M7E, M10: Calibration gas standards	Ensures accurate calibration standards	Traceability protocol of calibration gases	Pre-test	Calibration gas uncertainty ≤2.0%
M3A, M7E, M10: Calibration Error	Evaluates operation of analyzers	Calibration gases introduced directly into analyzers	Pre-test	±2.0% of the calibration span
M3A, M7E, M10: System Bias and Analyzer Drift	Evaluates analyzer and sample system integrity and accuracy over test duration	Calibration gases introduced at sample probe tip, heated sample line, and into analyzers	Pre-test and Post-test	±5.0% of the analyzer calibration span for bias and ±3.0% of analyzer calibration span for drift
M7E: NO_2-NO converter efficiency	Evaluates operation of NO_2-NO converter	NO_2 calibration gas introduced directly into analyzer	Pre-test or Post-test	NO_x response ≥90% of certified NO_2 calibration gas introduced
M25A: Calibration Error	Evaluates operation of analyzer and sample system	Calibration gases introduced through sample system	Pre-test	±5.0% of the calibration gas value
M25A: Zero and Calibration Drift	Evaluates analyzer and 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.

5.12 QA/QC Blanks

Other than Method 18 QA/QC and calibration gases used for zero calibrations, no other reagent or media blanks were used. Laboratory QA/QC data is contained in Appendix C.