

The logo for Consumers Energy, featuring the company name in a bold, italicized sans-serif font, enclosed within a stylized, swooping oval shape.

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**40 CFR Part 60, Subpart JJJJ  
40 CFR Part 63, Subpart ZZZZ  
Initial Compliance Demonstration  
Test Report**

**EUENGINE3-4**

**EUENGINE3-5**

Consumers Energy Company  
Freedom Compressor Station  
12201 Pleasant Lake Road  
Manchester, MI 49158  
SRN: N3920

February 18, 2021

**Test Date: January 6 and 7, 2021**

Test Performed by the Consumers Energy Company  
Regulatory Compliance Testing Section  
Air Emissions Testing Body  
Laboratory Services Section  
Work Order Nos. 34845296 and 30288139  
Version No.: 0

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## EXECUTIVE SUMMARY

Consumers Energy (CE) Regulatory Compliance Testing Section (RCTS) conducted nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO) and volatile organic compound (VOC) testing, and CO reduction efficiency testing at two (2), four-stroke, lean burn (4SLB) 3,750 brake horsepower (BHP) natural gas-fired, spark-ignition reciprocating internal combustion engines (RICE), identified as EUENGINE3-4 and EUENGINE3-5. The engines, listed in permit to install (PTI) No. 202-15A, are located and operating at the Freedom Compressor Station (FCS) in Manchester, Michigan.

The test program was conducted on January 6 and 7, 2021 to evaluate compliance with applicable emission limits in 40 CFR Part 60, Subpart JJJJ, *Standards of Performance for Stationary Spark Ignition Internal Combustion Engines*, (NSPS), 40 CFR Part 63, Subpart ZZZZ, *National Emission Standards for Hazardous Air Pollutants (NESHAP) for Stationary Reciprocating Internal Combustion Engines*, and PTI No. 202-15A. A test protocol was submitted to EGLE on August 6, 2020 and subsequently approved by Mr. Mark Dziadosz, Environmental Quality Analyst, in his letter dated September 24, 2020. There were no deviations from the approved stack test protocol or USEPA Reference Methods; however, please note that testing of EUENGINE3-3 was previously completed on December 2, 2020 (test report submitted on January 26, 2021).

Triplicate 60-minute test runs were conducted in the upstream and/or downstream exhaust of each engine oxidation catalyst following the applicable procedures in United States Environmental Protection Agency (USEPA) Reference Methods (RM) 1, 3A, 4/ALT-008, 7E, 10, 18, 19, and 25A/ALT-096 in 40 CFR Part 60, Appendix A. Please note that while ALT-096 is not found in 40 CFR Part 60, Appendix A, the method incorporates relevant Appendix A, Method 25A procedures and requirements for methane and non-methane organic compounds (NMOC) measurement using a Thermo-Electron (TECO) Model 55I at 40 CFR Part 60, Subpart JJJJ sources.

During testing, the engines operated at horsepower and torque conditions within plus or minus ( $\pm$ ) 10 percent of 100 percent peak (or the highest achievable) load, as specified in §60.4244(a). Based on pipeline pressures and site conditions during testing, the EUENGINE3-4 maximum achievable load was 91.8%, while the EUENGINE3-5 maximum achievable load was 92.1%. The average test results are summarized in Table E-1.

**Table E-1 Summary of Average Test Results**

Parameter	Units	ENGINE3-4 Results	ENGINE3-5 Results	Emission Limits		
				40 CFR Part 60, Subpart JJJJ <sup>1,2</sup>	40 CFR Part 63, Subpart ZZZZ	PTI 202-15A <sup>3</sup>
<b>NO<sub>x</sub></b>	g/HP-hr	<b>0.4</b>	<b>0.4</b>	<b>1.0</b>		<b>0.6</b>
	ppmvd at 15% O <sub>2</sub>	<b>37</b>	<b>35</b>	<b>82</b>		
<b>CO</b>	g/HP-hr	<b>0.06</b>	<b>0.05</b>	<b>2.0</b>		<b>0.14</b>
	ppmvd at 15% O <sub>2</sub>	<b>8</b>	<b>7</b>	<b>270</b>		
	Reduction, %	<b>96</b>	<b>96</b>		≥93 <sup>†</sup>	
	Catalyst Inlet Temperature, °F	<b>769</b>	<b>781</b>		≥450 & ≤1350	
	Catalyst Pressure Drop (in H <sub>2</sub> O)	<b>2.0</b>	<b>2.0</b>		0 – 4 (±2 in. from initial test)	
<b>VOC<sup>††</sup></b>	g/HP-hr	<b>0.1</b>	<b>0.1</b>	<b>0.7</b>		<b>0.2</b>
	ppmvd at 15% O <sub>2</sub>	<b>5</b>	<b>6</b>	<b>60</b>		

NO<sub>x</sub> nitrogen oxides  
 CO carbon monoxide  
 VOC volatile organic compounds (non-methane, non-ethane organic compounds), as propane  
 g/HP-hr grams per horsepower hour  
<sup>1</sup> Owners and operators of stationary non-certified SI engines may choose to comply with emission standards in units of either g/HP-hr or ppmvd at 15 percent O<sub>2</sub>.  
<sup>2</sup> 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.  
<sup>3</sup> Limits from PTI No. 202-15A, Flexible Group Conditions: FGENGINES-P3, FGNSPSJJJJ, and FGNEHAPZZZZ.  
<sup>†</sup> 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<sub>2</sub> or reducing CO emissions by ≥93%. Compliance using the CO reduction efficiency emission limit was evaluated.  
<sup>††</sup> 40 CFR Part 60, Subpart JJJJ refers to volatile organic compounds as defined in §51.100(s)(1) which defines VOC as "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 include only total non-methane, non-ethane organic compounds.

The results indicate EUENGINE3-4 and EUENGINE3-5 comply with 40 CFR Part 60, Subpart JJJJ, 40 CFR Part 63 Subpart ZZZZ, and PTI 202-15A limits.

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

## 1.0 INTRODUCTION

This report summarizes the results of compliance air emission tests on EUENGINE3-4 and EUENGINE3-5 located and operating at the Freedom Compressor Station (FCS) in Manchester, Michigan. This document follows the Michigan Department of Environment, Great Lakes and Energy (EGLE) format described in the November 2019, *Format for Submittal of Source Emission Test Plans and Reports*. Reproducing only a portion of this report may omit critical substantiating documentation or cause information to be taken out of context.

### 1.1 IDENTIFICATION, LOCATION, AND DATES OF TESTS

Consumers Energy (CE) Regulatory Compliance Testing Section (RCTS) conducted nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), volatile organic compound (VOC) and CO reduction efficiency testing at two (2), four-stroke, lean burn (4SLB) 3,750 brake horsepower (BHP) natural gas-fired, spark-ignition reciprocating internal combustion engines (RICE), identified as EUENGINE3-4 and EUENGINE3-5 on January 6 and 7, 2021. The engines, listed in permit to install (PTI) No. 202-15A, are located and operating at FCS in Manchester, Michigan.

A test protocol was submitted to EGLE on August 6, 2020 and subsequently approved by Mr. Mark Dziadosz, Environmental Quality Analyst, in his letter dated September 24, 2020. There were no deviations from the approved stack test protocol or USEPA Reference Methods; however, please note that testing of EUENGINE3-3 was previously completed on December 2, 2020 (test report submitted on January 26, 2021).

### 1.2 PURPOSE OF TESTING

The test program was conducted to evaluate compliance with applicable emission limits in 40 CFR Part 60, Subpart JJJJ, *Standards of Performance for Stationary Spark Ignition Internal Combustion Engines*, (NSPS), 40 CFR Part 63, Subpart ZZZZ, *National Emission Standards for Hazardous Air Pollutants (NESHAP) for Stationary Reciprocating Internal Combustion Engines*, and PTI No. 202-15A. The applicable operating requirements and emission limits are presented in Table 1-1.

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

Parameter	Units	Emission Limits and Operating Criteria		
		40 CFR Part 60, Subpart JJJJ	40 CFR Part 63, Subpart ZZZZ	PTI 202-15A
NO <sub>x</sub>	g/HP-hr	<b>1.0</b>		<b>0.6</b>
	ppmvd at 15% O <sub>2</sub>	<b>82</b>		
CO	g/HP-hr			<b>0.14</b>
	Reduction, %		≥93	
	Catalyst Inlet Temperature, °F		≥450 & ≤1350	
	Catalyst Pressure Drop (in H <sub>2</sub> O)		±2" from Initial Performance Test	
VOC	g/HP-hr	<b>0.7</b>		<b>0.2</b>
	ppmvd at 15% O <sub>2</sub>	<b>60</b>		
NO <sub>x</sub>	nitrogen oxides			
CO	carbon monoxide			
VOC	volatile organic compounds (non-methane, non-ethane organic compounds), as propane			
g/HP-hr	grams per horsepower hour			

### 1.3 BRIEF DESCRIPTION OF SOURCE

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

### 1.4 CONTACT INFORMATION

Table 1-3 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 1-3 Contact Information**

Program Role	Contact	Address
Regulatory Agency Representative	Ms. Karen Kajiya-Mills Technical Programs Unit Manager 517-335-4874 <a href="mailto:kajiya-millsk@michigan.gov">kajiya-millsk@michigan.gov</a>	EGLE - Technical Programs Unit 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
State Regulatory Inspector	Mr. Mike Kovalchick Environmental Quality Analyst 517-416-5025 <a href="mailto:kovalchickm@michigan.gov">kovalchickm@michigan.gov</a>	EGLE – Jackson District 301 East Louis Glick Highway Jackson, Michigan 49201
State Technical Programs Field Inspector	Mr. Mark Dziadosz Technical Programs Unit 586-854-1611 <a href="mailto:dziadoszm@michigan.gov">dziadoszm@michigan.gov</a>	EGLE – Air Quality Division SE Michigan District 27700 Donald Court Warren, MI 48092-2793
Responsible Official	Mr. Avelock Robinson Director of Gas Compression Operations 586-716-3326 <a href="mailto:avelock.robinson@cmsenergy.com">avelock.robinson@cmsenergy.com</a>	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 <a href="mailto:amy.kapuga@cmsenergy.com">amy.kapuga@cmsenergy.com</a>	Consumers Energy Company Environmental Services Department 1945 West Parnall Road Jackson, Michigan 49201
Field Environmental Coordinator	Mr. Gerald (Frank) Rand Sr. Environmental Analyst 734-850-4209 <a href="mailto:frank.randjr@cmsenergy.com">frank.randjr@cmsenergy.com</a>	Consumers Energy Company South Monroe Service Center 7116 Crabb Road Temperance, MI 48182
Test Facility	Mr. Vince Hittie Gas Field Lead 734-428-2050 <a href="mailto:vince.hittie@cmsenergy.com">vince.hittie@cmsenergy.com</a>	Consumers Energy Company Freedom Compressor Station 12201 Pleasant Lake Road Manchester, Michigan 48158
Test Team Representative	Mr. Joe Mason, QSTI Sr. Engineering Technical Analyst 616-738-3385 <a href="mailto:joe.mason@cmsenergy.com">joe.mason@cmsenergy.com</a>	Consumers Energy Company L & D Training Center 17010 Crowell Street West Olive, Michigan 49460

## 2.0 SUMMARY OF RESULTS

### 2.1 OPERATING DATA

During testing, the engines operated at horsepower and torque conditions within  $\pm 10\%$  of 100% peak (or the highest achievable) load, as specified in §60.4244(a) and within  $\pm 10\%$  of 100% load, as specified in §63.6620(b). Refer to Attachment D for detailed operating data.

### 2.2 APPLICABLE PERMIT INFORMATION

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

### 2.3 RESULTS

The NO<sub>x</sub>, CO, VOC and CO reduction efficiency results indicate compliance with 40 CFR Part 60, Subpart JJJJ, 40 CFR Part 63, Subpart ZZZZ and PTI 202-15A limits. Refer to Table 2-1 for the average test result summary.

Table 2-1 Summary of Average Test Results

Parameter	Units	ENGINE3-4 Results	ENGINE3-5 Results	Emission Limits		
				40 CFR Part 60, Subpart JJJJ <sup>1,2</sup>	40 CFR Part 63, Subpart ZZZZ	PTI 202-15A <sup>3</sup>
NO <sub>x</sub>	g/HP-hr	0.4	0.4	1.0		0.6
	ppmvd at 15% O <sub>2</sub>	37	35	82		
CO	g/HP-hr	0.06	0.05	2.0		0.14
	ppmvd at 15% O <sub>2</sub>	8	7	270		
	Reduction, %	96	96			≥93 <sup>†</sup>
	Catalyst Inlet Temperature, °F	769	781			≥450 & ≤1350
	Catalyst Pressure Drop (in H <sub>2</sub> O)	2.0	2.0			0 - 4 (±2 in. from initial test)
VOC <sup>++</sup>	g/HP-hr	0.1	0.1	0.7		0.2
	ppmvd at 15% O <sub>2</sub>	5	6	60		

NO<sub>x</sub> nitrogen oxides  
CO carbon monoxide  
VOC volatile organic compounds (non-methane, non-ethane organic compounds), as propane  
g/HP-hr grams per horsepower hour  
<sup>1</sup> Owners and operators of stationary non-certified SI engines may choose to comply with emission standards in units of either g/HP-hr or ppmvd at 15 percent O<sub>2</sub>.  
<sup>2</sup> 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.  
<sup>3</sup> Emissions limits from PTI No. 202-15A, Flexible Group Conditions: FGENGINES-P3, FGNSPSJJJJ, and FGNEHAPZZZZ.  
<sup>†</sup> 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<sub>2</sub> or reducing CO emissions by ≥93%. Compliance using the CO reduction efficiency emission limit was evaluated.  
<sup>++</sup> 40 CFR Part 60, Subpart JJJJ refers to volatile organic compounds as defined in §51.100(s)(1) which defines VOC as "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 include only total non-methane, non-ethane organic compounds.

Detailed results are discussed in Section 5.0 and shown in Appendix Table 1. Sample calculations and field data sheets are presented in Appendices A and B. Laboratory, engine operating data and supporting documentation are provided in Appendices C, D and E.



## 3.0 SOURCE DESCRIPTION

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

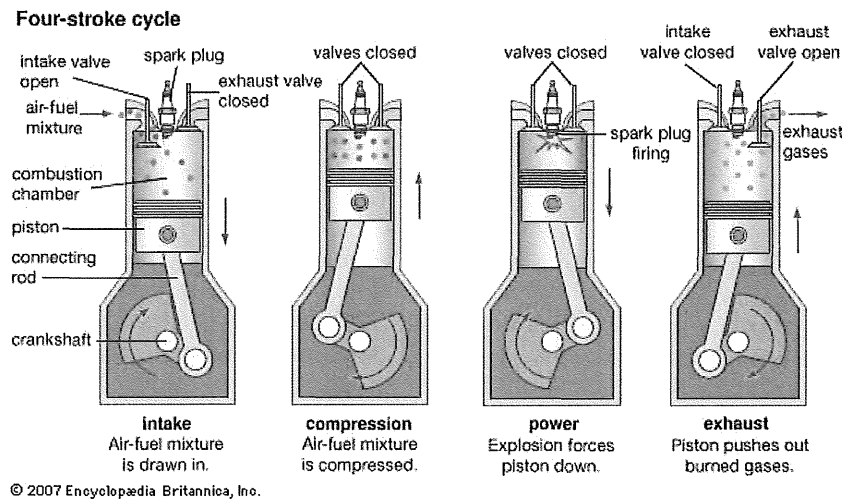
**Table 3-1 Engine Specifications**

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

### 3.1 PROCESS

The engines utilize the four-stroke engine cycle which starts with the downward air intake piston stroke which aspirates air through intake valves into the combustion chamber (cylinder). When the piston nears the bottom of the cylinder, fuel is injected and the intake valves close. As the piston travels upward, the air/fuel mixture is compressed and ignited, thus forcing the piston downward into the power stroke. At the bottom of the power stroke, exhaust valves open and the piston traveling upward expels the combustion by-products. Refer to Figure 3-1 for a four-stroke engine process diagram.

**Figure 3-1. Four-Stroke Engine Process Diagram**



The flue gas generated by natural gas combustion is controlled through parametric controls (i.e., timing and air-to-fuel ratio), lean burn combustion technology, and oxidation catalysts. The Waukesha engine includes a control module that monitors and adjusts engine parameters for optimal performance. The NO<sub>x</sub> emissions are minimized through the use of lean-burn combustion technology which is defined as a high level of excess air (generally 50% to 100% relative to the stoichiometric amount) in the combustion chamber. The excess air absorbs heat during the combustion process, thereby reducing the combustion temperature and pressure and resulting in lower NO<sub>x</sub> emissions.

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

### **3.2 PROCESS FLOW**

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

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

### **3.3 MATERIALS PROCESSED**

The engine fuel utilized is exclusively natural gas, as defined in 40 CFR Part 72.2. During testing the natural gas combusted within the engines was comprised of approximately 91.4% methane, 7.74% ethane, 0.4% nitrogen, and 0.2% carbon dioxide. The daily natural gas chromatograph analysis results used to calculate site-specific F factors for emission rate calculations in accordance with USEPA Method 19 are provided in Appendix D.

### **3.4 RATED CAPACITY**

The maximum engine power output is approximately 3,750 BHP, with a rated heat input of 27 million British thermal units per hour (mmBtu/hour). The normal rated engine capacities are governed by the connected compression equipment operated as a function of facility and gas transmission demand.

### **3.5 PROCESS INSTRUMENTATION**

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

- Fuel use (cfm)
- Engine speed (rpm)
- Power (BHP)
- Torque (% max)
- Catalyst input temperature (°F)
- Catalyst differential pressure (in. H<sub>2</sub>O)
- Engine hours

Refer to Appendix D for operating data.

## 4.0 SAMPLING AND ANALYTICAL PROCEDURES

NO<sub>x</sub>, CO, VOC, and oxygen (O<sub>2</sub>) concentrations, as applicable, were measured using the test methods shown in Table 4-1. The sampling and analytical procedures associated with each parameter are described in the following sections.

**Table 4-1 Test Methods**

Parameter	Method	USEPA Test Method
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 (ALT-008)	Determination of Moisture Content in Stack Gases Alternative Moisture Measurement Method – Midget Impingers
Nitrogen oxides (NO <sub>x</sub> )	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	25A Alt-096	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 Table 4-2 test matrix below summarizes the sample parameters and analytical methods employed.

**Table 4-2 Test Matrix**

Date (2021)	Run	Sample Type	Start Time (EST)	Stop Time (EST)	Test Duration (min)	EPA Test Method	Comment
<b>EUENGINE3-4</b>							
January 6	1	O <sub>2</sub> NO <sub>x</sub> CO VOC	10:30	11:29	60	1, 4/ALT-008 3A/7E/10 19 25A/18 Alt-096	Three-point traverse during Run 1; Single-point sample during Runs 2 and 3.
	2		12:00	12:59	60		
	3		13:30	14:29	60		
<b>EUENGINE3-5</b>							
January 7	1	O <sub>2</sub> NO <sub>x</sub> CO VOC	9:40	10:39	60	1, 4/ALT-008 3A/7E/10 19 25A/18 Alt-096	Three-point traverse during Run 1; Single-point sample during Runs 2 and 3.
	2		11:20	12:19	60		
	3		13:00	13:59	60		

## 4.2 SAMPLE LOCATION AND TRAVERSE POINTS (USEPA METHOD 1)

The number and location of traverse points was evaluated according to the requirements in Table 4 of 40 CFR Part 63, Subpart ZZZZ, and USEPA Method 1, *Sample and Velocity Traverses for Stationary Sources*. Sample ports are installed upstream and downstream (Pre and Post) of each engine oxidation catalyst.

### Pre-catalyst Sampling Ports:

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

- Approximately 347-inches or 21.7 duct diameters downstream of a duct bend disturbance in the engine exhaust duct, and
- Approximately 63-inches or 3.9 duct diameters upstream of the flow disturbance caused by a change in duct diameter and flow direction as it enters exhaust stack and oxidation catalyst.

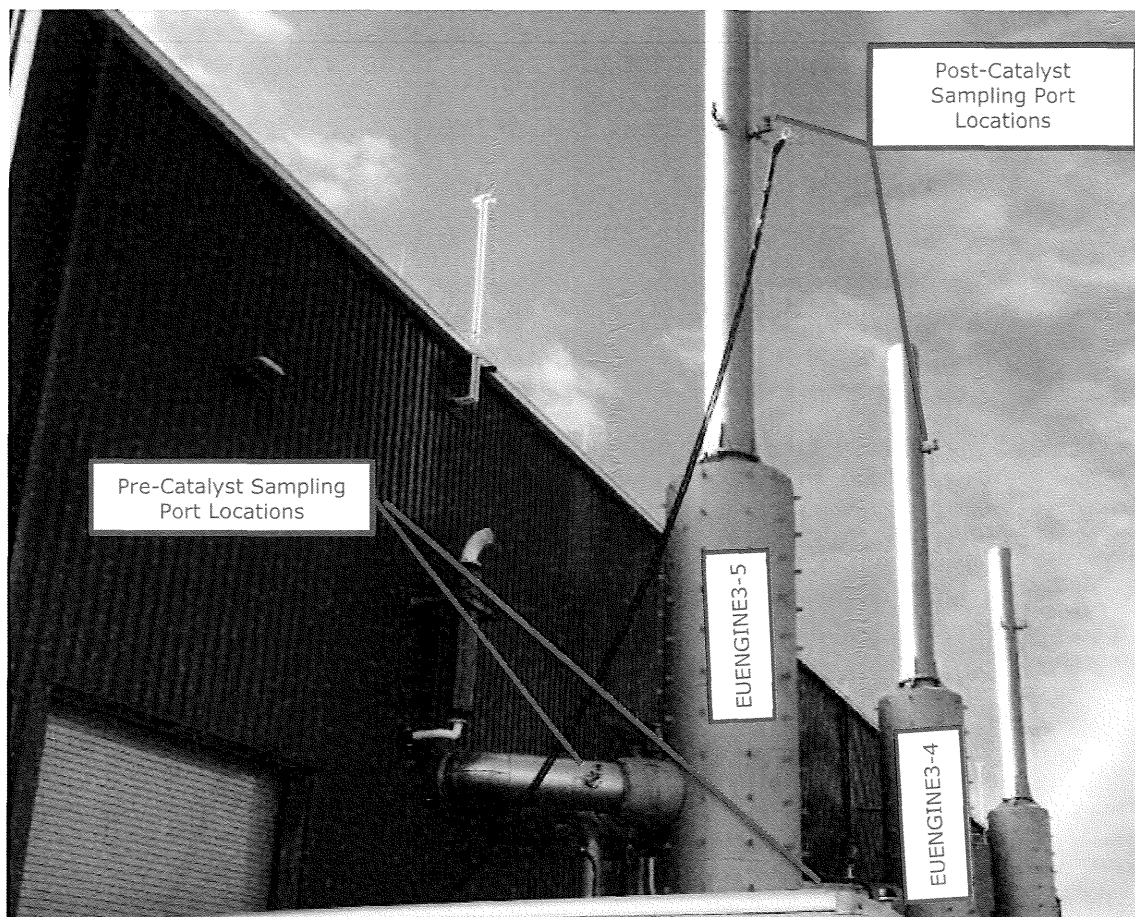
### Post-catalyst Sampling Ports:

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

- Approximately 240-inches or 8.0 duct diameters downstream of a duct diameter change flow disturbance, and
- Approximately 118-inches or 3.9 duct diameters upstream of the stack exit to atmosphere.

Because the ducts are >12 inches in diameter and the sampling port locations meet the two and half-diameter criterion of Section 11.1.1 of Method 1 of 40 CFR Part 60, Appendix A-1, each engine duct was sampled at 3 traverse points located at 16.7, 50.0, and 83.3% of the measurement line ('3-point long line'). The three-point traverse concentrations from each engine, sampled in accordance with USEPA Method 7E, §8.1.2, were calculated, and the gas stream was found unstratified; therefore, concentrations measured during runs 2 and 3 on each engine were sampled from a single point near the centroid of each duct. Pre-catalyst and post-catalyst sampling port locations are presented in Figure 4-1.

**Figure 4-1. FGENGINE3-P3 Pre- and Post-Catalyst Sampling Port Locations**

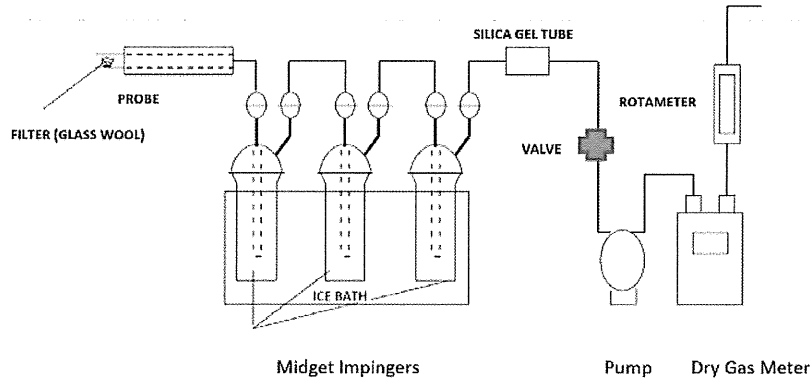


### **4.3 MOISTURE CONTENT (USEPA METHOD 4 / ALT-008)**

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, incorporated into Method 6A of 40 CFR Part 60, 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 follows the general guidelines found 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 at a constant rate from the stack through a sample probe, Teflon tubing, four midget impingers, and a metered pump console. Gas stream moisture is condensed in ice-bath chilled impingers and determined gravimetrically. The condensate mass collected and moisture sample volume are used to calculate moisture content. Refer to Figure 4-3 for a depiction of the Alternative Method 008 Moisture Sample Apparatus.

**Figure 4-3. Alternative Method 008 Moisture Sample Apparatus**



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

#### 4.4 O<sub>2</sub>, NO<sub>x</sub>, AND CO CONCENTRATIONS (USEPA METHODS 3A, 7E, AND 10)

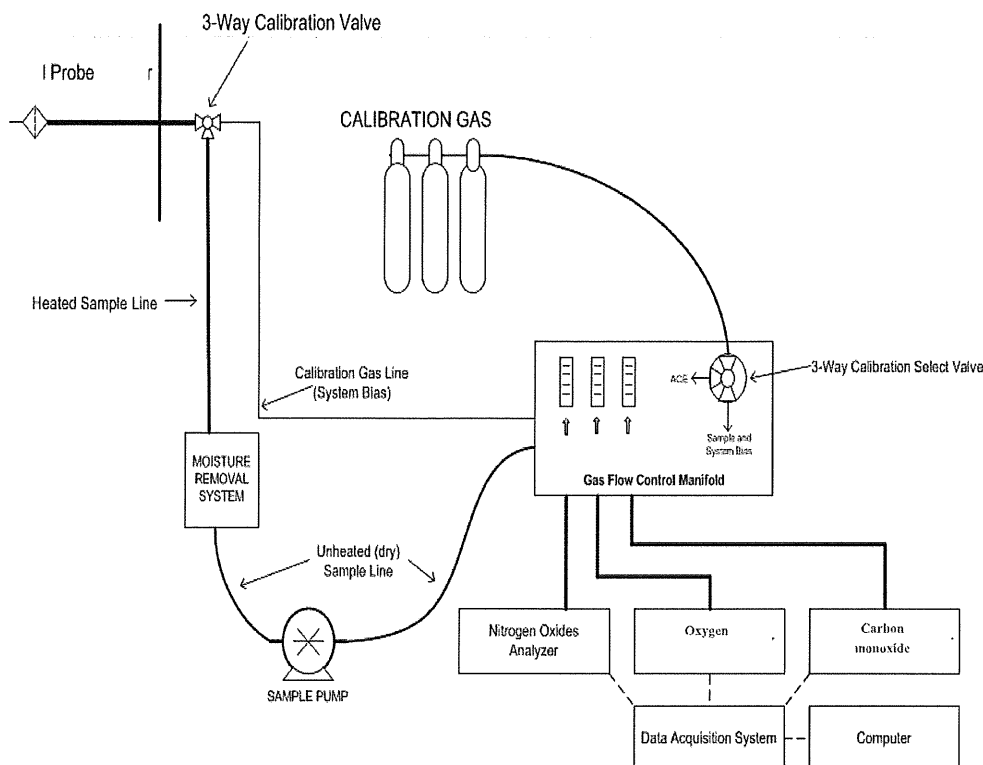
Oxygen, nitrogen oxides, and carbon monoxide concentrations were measured using the following sampling and analytical procedures:

- 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)*.

The sampling procedures of each method is similar, except for the analyzers and analytical technique used to quantify the parameters of interest. The measured oxygen concentrations were used to adjust the pollutant concentrations to 15% O<sub>2</sub> and calculate pollutant emission rates.

Engine exhaust gas was extracted from the stack through a stainless-steel probe, heated Teflon® sample line, and through a gas conditioning system to remove water 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. 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 were introduced directly to the back of the analyzers. The calibration error check was performed to evaluate if the analyzers response was within  $\pm 2.0\%$  of the calibration gas span or high calibration gas concentration. An initial system-bias test was performed where the zero- and mid- or high- calibration gases were introduced at the sample probe to measure the ability of the system to respond accurately to within  $\pm 5.0\%$  of span.

A  $\text{NO}_2$  to  $\text{NO}$  conversion efficiency test was performed on the  $\text{NO}_x$  analyzer prior to beginning the test program to evaluate the ability of the instrument to convert  $\text{NO}_2$  to  $\text{NO}$  before analyzing for  $\text{NO}_x$ . The test verified the analyzer response as  $\text{NO}_x$  was  $\geq 90\%$  of the certified  $\text{NO}_2$  calibration gas concentration.

Upon successful completion of the calibration error and initial system bias tests, sample flow rate and component temperatures were verified and the probe was inserted into the duct at the appropriate traverse point. After confirming the engine was operating at established conditions, the test run was initiated. Gas concentrations were recorded at 1-minute intervals throughout each 60-minute test run.

After the conclusion of each test run, a post-test system bias check was performed to evaluate analyzer bias and drift from the pre- and post-test system bias checks. The system-bias checks evaluated if the analyzers bias was within  $\pm 5.0\%$  of span and drift was within  $\pm 3.0\%$ . The analyzers responses were used to correct the measured gas concentrations for analyzer drift.

For the analyzer calibration error tests, bias tests and drift checks, these evaluations are also passed if the standard criteria are not achieved, but the absolute difference between the analyzer responses and calibration gas is less than or equal to 0.5 ppmv for  $\text{NO}_x$  and CO or 0.5% for  $\text{O}_2$ .

## 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 a fuel specific  $F_c$  factor and exhaust gas flowrate pursuant to guidance by USEPA to not use default published F factors for such Subpart JJJJ test events.

The natural gas fired by the engines is analyzed daily via gas chromatography (GC) for hydrocarbons, non-hydrocarbons, heating value, and other parameters. The daily GC results were obtained to calculate  $F_w$ ,  $F_d$ , and  $F_c$  factors (ratios of combustion gas volumes to heat inputs) using USEPA Method 19 Equations 19-13 ( $F_d$ ), 19-14 ( $F_w$ ), and 19-15 ( $F_c$ ). The  $F_d$  factor was used to calculate exhaust gas flow rates using *Equation 19-1* shown in Figure 4-5. The g/HP-hr emission rates were calculated using 40 CFR Part 60 Subpart JJJJ *Equations 1, 2, and 3*, shown in Figure 4-6.

### **Figure 4-5. USEPA Method 19 Exhaust Flow Rate Equation 19-1**

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

Where:

- $Q_s$  = stack flow rate (dscf/min)
- $F_d$  = fuel-specific oxygen-based F factor, dry basis, from Method 19 (dscf/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<sup>3</sup>/min) x (fuel heat content in mmBtu/ft<sup>3</sup>)
- $O_2$  = stack oxygen concentration, dry basis (%)

### **Figure 4-6. 40 CFR Part 60 Subpart JJJJ Emission Rates, Equations 1, 2, 3**

$$ER = \frac{C_d \times K \times Q \times T}{HP - hr}$$

Where:

- ER = Emission rate of pollutant in g/HP-hr
- $C_d$  = Measured pollutant concentration in parts per million by volume, dry basis (ppmvd)
- K = Conversion constant for ppm pollutant to grams per standard cubic meter at 20°C:
  - $KNO_x = 1.912 \times 10^{-3}$  (Equation 1)
  - $KCO = 1.164 \times 10^{-3}$  (Equation 2)
  - $KVOC = 1.833 \times 10^{-3}$  (Equation 3)
- Q = Stack gas volumetric flow rate, in cubic meter per hour, dry basis
- T = Time of test run, in hours



#### 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 and following the procedures 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 stainless steel and Teflon. Flue gas was collected from the stack via a sample probe and heated sample line and into the analyzer, which communicates with the data acquisition handling system (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 where methane's low molecular weight and high volatility allows for quicker movement through the column and FID analyses than other organic compounds. The column is then flushed with inert carrier gas and the FID analyzes the remaining non-methane organic compounds. This analytical technique allows separate measurements for methane and non-methane organic compounds via the use of a single FID. Refer to Figure 4-7 for a drawing of the USEPA Method 25A sampling apparatus.

The field VOC instrument was calibrated with a 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). Prior to testing, the analyzer was calibrated using hydrocarbon free zero and high-level methane and propane calibration gases, with its signal output adjusted accordingly. A calibration error test was conducted by introducing low- and mid-level calibration gases to the sample system to ensure the analyzer's response was within  $\pm 5\%$  of certified concentration. During this procedure, the measurement system response time for each calibration gas introduced to the system, equivalent to 95% of the step change, is observed. Note that since the field VOC instrument measures on a wet basis, exhaust gas moisture content is also determined via ALT-008 to convert the wet VOC concentrations to a dry basis and calculate VOC mass emission rates.

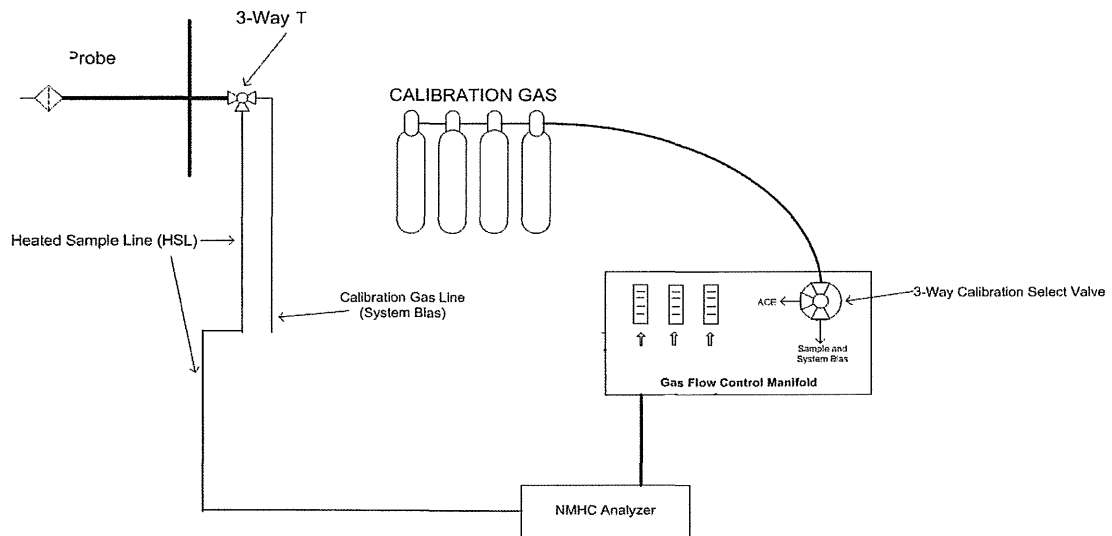
Immediately following each test run, zero and low-level calibration gases are introduced consecutively into the measurement system to ensure analyzer drift is within  $\pm 3\%$  of span, thereby validating each test run. As requested by EGLE, the NMOC run concentrations are also corrected for analyzer drift using USEPA Method 7E, *Equation 7E-5b*.

Please note that 40 CFR Part 60, Subpart JJJJ refers to the VOC definition in 40 CFR, Part 51 which 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 included ethane as part of the NMOC measurement. Therefore, duplicate 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*.

Bags manufactured from polyvinyl fluoride (PVF) film, also known as Tedlar film, were collected in the field from each engine exhaust. At the laboratory, the ethane concentrations were measured by separating the major organic components using a gas chromatograph (GC) column and 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 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 achieved the R value requirement which was accordingly applied to correct the reported concentrations. Note that the laboratory report provides the analyte concentration as ppmv and ppmv as propane. The USEPA Method 18 laboratory report is presented in Appendix C.

**Figure 4-7. USEPA Method 25A NMOG Sample Apparatus**



## 5.0 TEST RESULTS AND DISCUSSION

The test program was performed to evaluate compliance with emission limits in 40 CFR Part 60, Subpart JJJJ, 40 CFR Part 63, Subpart ZZZZ and PTI 202-15A.

### 5.1 TABULATION OF RESULTS

As summarized in Table 2-1, the engine test results indicate compliance with the preceding regulatory requirements. Appendix Table 1 and Table 2 contain detailed results, process operating conditions and exhaust gas conditions.

### 5.2 SIGNIFICANCE OF RESULTS

Compliance with the applicable regulatory criteria allows EUENGINE3-4 and EUENGINE3-5 to be operated for their intended purposes until the next scheduled test event.

### 5.3 VARIATIONS FROM SAMPLING OR OPERATING CONDITIONS

The non-methane VOC concentrations measured between the two engines averaged approximately 68 ppmv as propane, dry basis; 47 ppmv as propane, dry basis @ 15% O<sub>2</sub>; and 0.52 g/HP-hr. While these values comply with 40 CFR Part 60, Subpart JJJJ, they do not comply with PTI 202-15A limits, and as noted in Section 4.6 above, duplicate Tedlar bag samples were collected from each engine exhaust stream to quantify the non-VOC ethane contributions via USEPA Method 18 analysis. The ethane concentrations were then subtracted from the non-methane VOC concentrations for each test run to determine non-methane, non-ethane VOC emissions, to evaluate compliance with PTI 202-15A limits.

### 5.4 PROCESS OR CONTROL EQUIPMENT UPSET CONDITIONS

EUENGINE3-4 and EUENGINE3-5 and their associated gas compressor / pump equipment operated under maximum routine conditions with no upsets during testing.

### 5.5 AIR POLLUTION CONTROL DEVICE MAINTENANCE

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

### 5.6 RE-TEST DISCUSSION

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

- Semi-annually to evaluate the reduction of CO emissions across the oxidation catalyst in accordance with 40 CFR Part 63 Subpart ZZZZ and PTI-202A until two passing test events, after which testing will be conducted annually, and
- every 8,760 engine operating hours or 3 years (2024), whichever is first, to evaluate compliance with the NO<sub>x</sub>, CO, and VOC emission limits in 40 CFR Part 60, Subpart JJJJ and the PTI. The engine hours after the conclusion of testing were:
  - EUENGINE3-4: 627.70 hours
  - EUENGINE3-5: 370.00 hours

## 5.7 RESULTS OF AUDIT SAMPLES

Audit samples for this test program are not available from USEPA Stationary Source Audit Sample Program providers. The RM performed state reliable results are obtained by persons equipped with a thorough knowledge of the techniques associated with each method. Factors with the potential to cause measurement errors are minimized by implementing quality control (QC) and assurance (QA) programs into the applicable field test components. QA/QC components included in this test program are summarized in Table 5-1. Refer to Appendix E for supporting documentation.

**Table 5-1 QA/QC Procedures**

QA/QC Activity	Purpose	Procedure	Frequency	Acceptance Criteria
M1: Sampling Location	Evaluates sample location suitability	Measure downstream and upstream flow disturbances	Pre-test	≥2 diameters downstream; ≥0.5 diameter upstream
M1: Duct diameter/dimensions	Verifies accurate stack area measurement	Review as-built drawings and field measurement	Pre-test	Field measurement agreement with as-built drawings
M3A, 7E, 10, 25A: Calibration gas standards	Ensures accurate calibration standards	Calibration gas traceability protocol	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 span, 0.5 ppmv or 0.5% O <sub>2</sub> abs. difference
M3A, M7E, M10: System Bias and Analyzer Drift	Evaluates analyzer and sample system integrity/accuracy over test duration	Cal gas introduced at sample probe tip, heated sample line, and into analyzers	Pre- and Post-test	Bias: ±5.0% of span; Drift: ±3.0% of span or ≤ 0.5 ppmv/0.5% O <sub>2</sub> abs. difference
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 <sub>2</sub> -NO converter efficiency	Evaluates operation of NO <sub>2</sub> -NO converter	NO <sub>2</sub> calibration gas introduced directly into analyzer	Pre-test or Post-test	NO <sub>x</sub> response ≥90% of certified NO <sub>2</sub> calibration gas introduced
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. QA/QC procedures associated with laboratory ethane analyses are found in Appendix C.

## **5.12 QA/QC BLANKS**

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

# Appendix Tables

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