EXECUTIVE SUMMARY

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted carbon monoxide (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 EUENGINE3-1 and EUENGINE3-2 (included in FGENGINES-P3). In addition, nitrogen oxides (NO_x), CO and volatile organic compound (VOC) testing was conducted at one (1) emergency 4SLB natural gas-fired RICE, identified as EUEGEN-3-25-01. All three engines are located and operating at the Freedom Compressor Station (FCS) in Manchester, Michigan and are included in permit to install (PTI) No. 202-15A.

The test program was conducted on October 16, 21 and 22, 2020 to evaluate compliance with applicable emission limits in 40 CFR Part 63, Subpart ZZZZ, *National Emission Standards for Hazardous Air Pollutants* (NESHAP) *for Stationary Reciprocating Internal Combustion Engines*. The EUEGEN test program was conducted on October 22, 2020 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). 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.

Triplicate 60-minute test runs were conducted upstream and/or downstream of oxidation catalysts installed in the exhausts of FGENGINES-P3, and at the outlet only of EUEGEN 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 measuring methane and non-methane organic compounds (NMOC) using a Thermo-Electron (TECO) Model 55I at 40 CFR Part 60, Subpart JJJJ sources.

There were no deviations from the approved stack test protocol or associated USEPA Reference Methods, however, note that testing at EUENGINE3-3, EUENGINE3-4, and EUENGINE3-5 was not conducted as the engines were under construction at the time.

During testing, EUEGEN operated at horsepower and torque conditions within plus or minus (±) 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 maximum achievable load for EUENGINE3-1 and EUENGINE3-2 were 73% and 82%, respectively. Because the engine operating load was limited during the test, the facility will restrict the operation of the engine until such time the engine can be safely operated within ±10% of 100% load, as specified in §63.6620(b). The emissions test results are summarized in Table E-1.

Table E-1 Summary of Average Test Results

Parameter	Units	Result	Emission Limits		
			40 CFR Part 60, Subpart JJJJ[1,2]	40 CFR Part 63, Subpart ZZZZ	PTI 202-15A
EUENGINE3-1					
CO	Reduction, %	**96**		≥93	
Catalyst Inlet Temperature	°F	**821**		≥450 & ≤1350	
Catalyst Pressure Drop	pressure (in H_2O)	**1.1**		0-3.3	
EUENGINE3-2					
CO	Reduction, %	**95**		≥93	
Catalyst Inlet Temperature	°F	**809**		≥450 & ≤1350	
Catalyst Pressure Drop	pressure (in H_2O)	**1.5**		0-3.8	
EUEGEN-3-25-01					
NO_x	g/HP-hr	**0.3**	**2.0**		
	ppmvd at 15% O_2	**19**	**160**		
CO	g/HP-hr	**2.7**	**4.0**		
	ppmvd at 15% O_2	**285**	**540**		
VOC	g/HP-hr	**0.6**	**1.0**		
	ppmvd at 15% O_2	**40**	**86**		

NO_x nitrogen oxides
CO carbon monoxide
VOC volatile organic compounds (non-methane 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 emission standards in units of either g/HP-hr or ppmvd at 15 percent O_2.
2 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 measurements of VOC include only the total non-methane organic compounds.

The EUENGINE3-1 and EUENGINE3-2 CO reduction efficiency results indicate compliance with Subpart ZZZZ and PTI 202-15A limits, while the EUEGEN-3-25-01 NO_x, CO, and VOC results indicate compliance with 40 CFR Part 60, Subpart JJJJ limits.

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

1.0 INTRODUCTION

This report summarizes the results of compliance air emission tests on EUENGINE3-1, EUENGINE3-2, and EUEGEN-3-25-01 (EUEGEN) 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. 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 carbon monoxide (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 EUENGINE3-1 and EUENGINE3-2 (included in FGENGINES-P3). In addition, nitrogen oxides (NO_x), CO and volatile organic compound (VOC) testing was conducted at one (1) emergency 4SLB natural gas-fired RICE, identified as EUEGEN-3-25-01. All three engines are located and operating at the Freedom Compressor Station (FCS) in Manchester, Michigan and are included in permit to install (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 associated USEPA Reference Methods; however, note that testing at EUENGINE3-3, EUENGINE3-4, and EUENGINE3-5 was not conducted as the engines were under construction at the time. EGLE representative Mr. Mark Dziadosz, witnessed portions of the test event.

1.2 PURPOSE OF TESTING

The test program was conducted on October 16, 21 and 22, 2020 to evaluate compliance with applicable emission limits in 40 CFR Part 63, Subpart ZZZZ, *National Emission Standards for Hazardous Air Pollutants* (NESHAP) *for Stationary Reciprocating Internal Combustion Engines*. The EUEGEN test program was conducted on October 22, 2020 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). The applicable emission limits are presented in Tables 1-1 and 1-2.

Table 1-1
FGENGINES-P3 40 CFR Part 63 Subpart ZZZZ Requirements

CO Reduction Efficiency (%)	Oxidation Catalyst Inlet Temperature (°F)	Oxidation Catalyst Pressure Drop Change (Inches Water Gauge)	Applicable Requirement
≥93†	≥450°F and ≤1350°F	±2” from Initial Performance Test	PTI No. 202-15A, 40 CFR §63.6300(b) and Table 2a

Table 1-2
EUEGEN-3-25-01 Subpart JJJJ Requirements

Parameter	Emission Limit	Units	Applicable Requirements
NO_x	2.0	g/HP-hr	PTI No. 202-15A 40 CFR Part 60, Subpart JJJJ, Table 1
	160	ppmvd@15% O_2	
CO	4.0	g/HP-hr	
	540	ppmvd@15% O_2	
VOC	1.0	g/HP-hr	
	86	ppmvd at 15% O_2	

1.3 Brief Description of Source

EUENGINE3-1 and EUENGINE3-2 are 3,750 brake horsepower, 4SLB RICE operating as needed to provide mechanical shaft power to compressors to maintain natural gas pipeline pressure for movement along the pipeline system. EUEGEN-3-25-01 is operated for emergency power only.

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 kajiya-millsk@michigan.gov	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 kovalchickm@michigan.gov	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 dziadoszm@michigan.gov	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 avelock.robinson@cmsenergy.com	Consumers Energy Company St. Clair Compressor Station 10021 Marine City Highway Ira, Michigan 48023
Corporate Air Quality Contact	Ms. Amy Kapuga Senior Engineer 517-788-2201 amy.kapuga@cmsenergy.com	Consumers Energy Company Environmental Services Department 1945 West Parnall Road Jackson, Michigan 49201

Table 1-3
Contact Information

Program Role	Contact	Address
Field Environmental Coordinator	Mr. Gerald (Frank) Rand Sr. Environmental Analyst 989-667-5153 frank.randjr@cmsenergy.com	Consumers Energy Company South Monroe Service Center 7216 Crabb Road Temperance, MI 48182
Test Facility	Mr. Vince Hittie Gas Field Lead 734-428-2050 vince.hittie@cmsenergy.com	Consumers Energy Company Freedom Compressor Station 12201 Pleasant Lake Road Manchester, Michigan 48158
Test Team Representative	Mr. Thomas Schmelter, QSTI Sr. Engineering Technical Analyst 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 testing, EUEGEN operated at horsepower and torque conditions within plus or minus (±) 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 maximum achievable load for EUENGINE3-1 and EUENGINE3-2 were 73% and 82%, respectively. Because the engine operating load was limited during the test, the facility will restrict the operation of the engine until such time the engine can be safely operated and tested within ±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. Sources EUENGINE3-1 and EUENGINE3-2 (along with EUENGINES 3-3, 3-4 and 3-5) are collectively grouped within the permit as FGENGINES-P3. The PTI also incorporates the applicable federal requirements of 40 CFR Part 60, Subpart JJJJ and 40 CFR Part 63, Subpart ZZZZ.

2.3 Results

EUEGEN-3-25-01 NO_x, CO, and VOC results indicate compliance with 40 CFR Part 60, Subpart JJJJ and PTI 202-15A limits, while the EUENGINE3-1 and EUENGINE3-2 CO reduction efficiency results indicate compliance with Subpart ZZZZ and PTI 202-15A. Refer to Table 2-1 for a test result summary.

Table 2-1
Summary of Average Test Results

Parameter	Units	Result	Emission Limits: 40 CFR Part 60, Subpart JJJJ[1]	Emission Limits: 40 CFR Part 63, Subpart ZZZZ	Emission Limits: PTI 202-15A
EUENGINE3-1					
CO	Reduction, %	**96**		≥93	
Catalyst Inlet Temperature	°F	**821**		≥450 & ≤1350	
Catalyst Pressure Drop	pressure (in H_2O)	**1.1**		0-3.3	
EUENGINE3-2					
CO	Reduction, %	**95**		≥93	
Catalyst Inlet Temperature	°F	**809**		≥450 & ≤1350	
Catalyst Pressure Drop	pressure (in H_2O)	**1.5**		0-3.8	
EUEGEN-3-25-01					
NO_x	g/HP-hr	**0.3**	**2.0**		
	ppmvd at 15% O_2	**19**	**160**		
CO	g/HP-hr	**2.7**	**4.0**		
	ppmvd at 15% O_2	**285**	**540**		
VOC	g/HP-hr	**0.6**	**1.0**		
	ppmvd at 15% O_2	**40**	**86**		

NO_x nitrogen oxides
CO carbon monoxide
VOC volatile organic compounds (non-methane 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 emission standards in units of either g/HP-hr or ppmvd at 15 percent O_2.
[2] 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 measurements of VOC include only the total non-methane organic compounds.

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

3.0 SOURCE DESCRIPTION

EUEGEN is an engine which turns an emergency generator for use during power outages. FGENGINES-P3 provide mechanical shaft power to compressors to maintain natural gas pipeline pressure for movement along the pipeline system. Significant maintenance has not been performed on the engines within the past three months. A summary of the engine specifications is provided in Table 3-1.

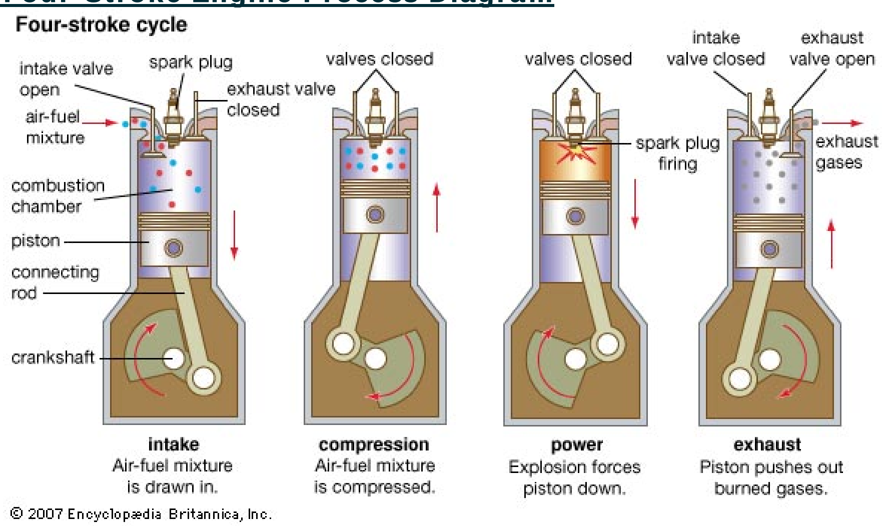
Table 3-1
Engine Specifications

Engine ID	Engine Description		Site-Rated HP	Heat Input, LHV (mmBtu/hr)	Exhaust Gas Temp. (°F)
	Manufacturer	Model			
EUENGINE3-1 EUENGINE3-2	Waukesha	16V275GL+	4,835	27	828
EUEGEN-3-25-01	Caterpillar	G3516B	1,818	12.25	986

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_x 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_x emissions.

The four catalyst modules installed on each engine 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, 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 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.

EUEGEN maintains station electric power during a commercial power outage. The natural gas engine generator set is designed to start and supply power before equipment shuts down to maintain station flow rate.

EUENGINE3-1 and EUENGINE3-2 are used to drive two-stage compressors to maintain pressure and move natural gas through the pipeline system. The exhaust stacks are of non-typical design. Specifically, the bottom portion of the stack incorporates an annulus, where an outer stack surrounds an inner circular stack (shaped like a doughnut if viewed looking down from the top of the stack). The exhaust gases from the engine enter the annulus via two horizontal ducts exhausting the engine. Once the gases enter the outer stack, they flow downwards through the oxidation catalysts placed in the bottom of the annulus. After passing through the catalysts, the exhaust gases enter the inner stack through an opening located near the base of the freestanding stack. The exhaust gases then travel upwards, through the freestanding stack, (via the inner stack) until they discharge unobstructed vertically to atmosphere through the 65-feet high stack.

3.3 Materials Processed

The fuel utilized is exclusively natural gas, as defined in 40 CFR Part 72.2. During testing the natural gas combusted within the engines was comprised of approximately 91.3% methane, 7.75% ethane, 0.4% nitrogen, and 0.2% carbon dioxide. The daily natural gas chromatograph analysis results are provided in Appendix D. The gas composition and Btu content were used to calculate site-specific F factors in accordance with United States Environmental Protection Agency (USEPA) Method 19 and used in emission rate calculations.

3.4 Rated Capacity

The maximum EUEGEN engine power output is approximately 1,818 horsepower, and as equipped with the electric generator, a maximum electrical output of 1,318 kilowatts. The engine has a rated heat input of 12.8 mmBtu/hour.

The maximum FGENGINES-P3 engine power output is approximately 3,750 horsepower each, 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 EUEGEN operating parameters were continuously monitored by a distributed control system for the Caterpillar engine, data acquisition systems, the Caterpillar Load Bank operator, and Consumers Energy personnel during testing. Data were collected during each test for the following parameters:

- Phase A, B, C, and total current (amps)
- Engine speed (rpm)
- Engine Torque / Power Rate (% max)
- Power (Kilowatts)
- Fuel flow (scfm)

- Electric potential (Volts)

Engine horsepower was calculated as follows:

1 kilowatt (kW) = 1.35962 Horsepower (HP)

FGENGINES-P3 process instrumentation 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 C for operating data.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

Consumers Energy RCTS measured NO_x, CO, VOC, and oxygen (O_2) concentrations, as applicable, using the 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	USEPA 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 (ALT-008)	Determination of Moisture Content in Stack Gases Alternative Moisture Measurement Method – Midget Impingers
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	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 (2020)	Run	Sample Type	Start Time (EDT)	Stop Time (EDT)	Test Duration (min)	EPA Test Method	Comment
EUENGINE3-1							
October 21	1	O_2 CO	09:45	10:44	60	1, 3A,10 19	Three-point traverses during Run 1 – 3
	2		11:05	12:04	60		
	3		12:25	13:24	60		
EUENGINE3-2							
October 16	1	O_2 CO	10:45	11:44	60	1, 3A,10 19	Three-point traverses during Run 1 – 3
	2		12:05	13:04	60		
	3		13:20	14:19	60		
EUEGEN-3-25-01							
October 22	1	O_2 NO_x CO VOC	10:25	11:24	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		13:39	14:43	60		

4.2 Sample Location and Traverse Points (USEPA Method 1)

EUEGEN (exhaust only)**:** The number and location of traverse points was evaluated according to requirements in 40 CFR Part 60, Subpart JJJJ, Table 2, and USEPA Method 1, *Sample and Velocity Traverses for Stationary Sources*.

The sampling location is described as two test ports, 4-inches in diameter, sealed by 2-inch gate valves approximately 4-inches outside the duct wall and installed in a 14-inch diameter exhaust stack. The ports are located:

- Approximately 24-feet or 20 duct diameters downstream of a flow disturbance where the engine exhaust makes a 90-degree turn, and
- Approximately 60-inches or 4 duct diameters upstream of the exit to atmosphere.

Because the duct is >12 inches in diameter and the sampling port location meets the two and one-half diameter criterion of Section 11.1.1 of Method 1 of 40 CFR Part 60, Appendix A-1, the exhaust duct was sampled during run 1 for equal intervals at 3 traverse points located at 16.7, 50.0, and 83.3% of the measurement line ('3-point long line'). The three-point traverse concentrations, sampled in accordance with USEPA Method 7E, §8.1.2, were calculated and the gas stream was found unstratified; therefore, concentrations measured during runs 2 and 3 were sampled from a single point near the centroid of the stack.

FGENGINES-P3: 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*. Each engine is equipped with sample ports located upstream and downstream (Pre and Post) of the oxidation catalyst.

Pre-catalyst Sampling Ports:

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

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

Post-catalyst Sampling Ports:

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

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

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

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

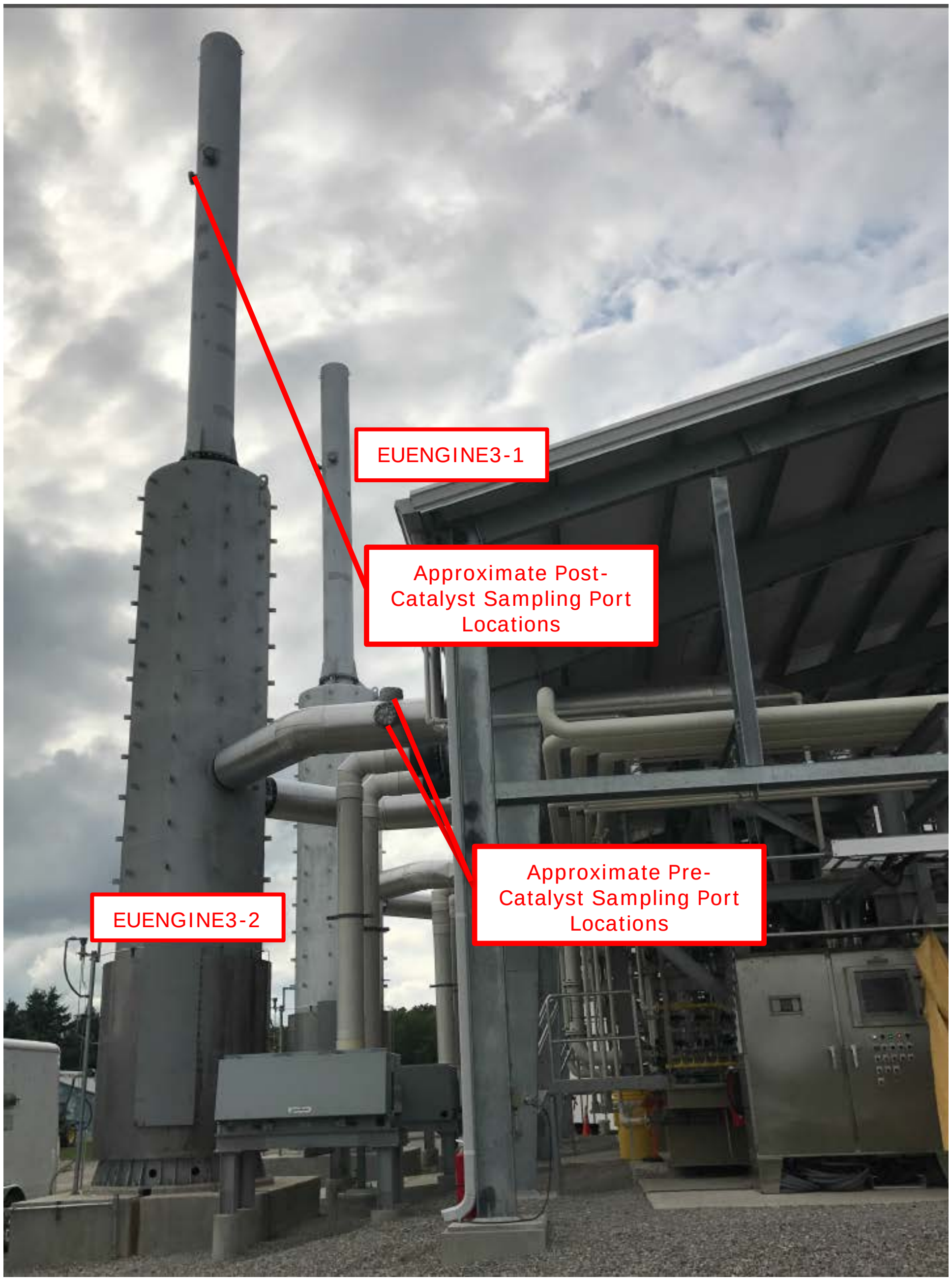
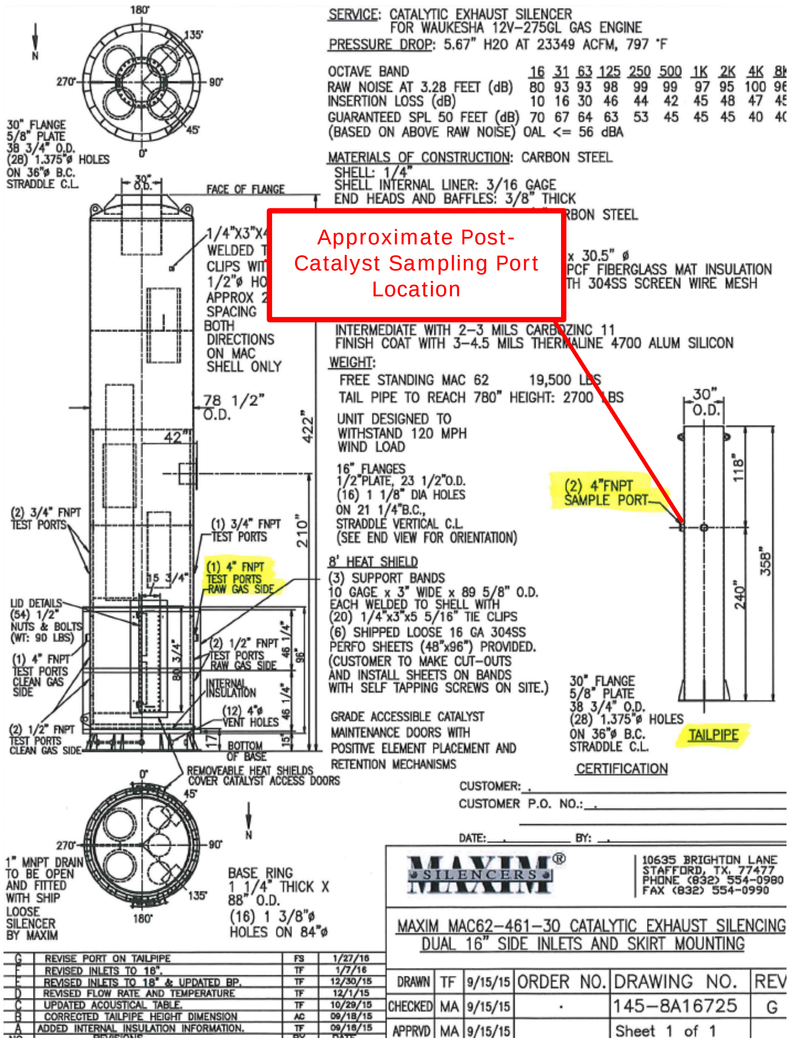


Figure 4-2. Post-Catalyst Sampling Port Location

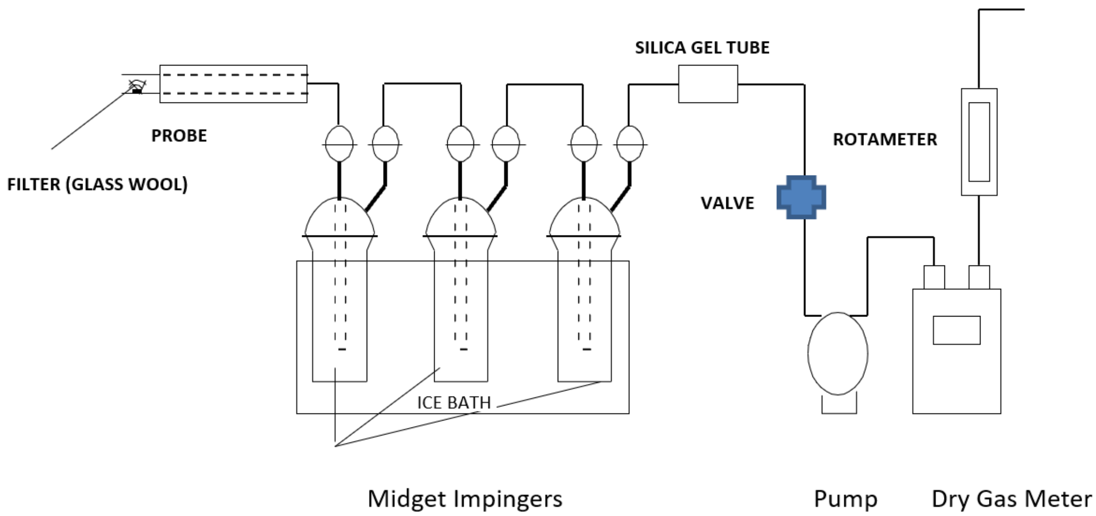


4.3 Moisture Content (USEPA Method 4 / ALT-008)

Exhaust gas moisture content was determined on EUEGEN 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 O2, NO_X, AND CO CONCENTRATIONS (USEPA METHODS 3A, 7E, AND 10)

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

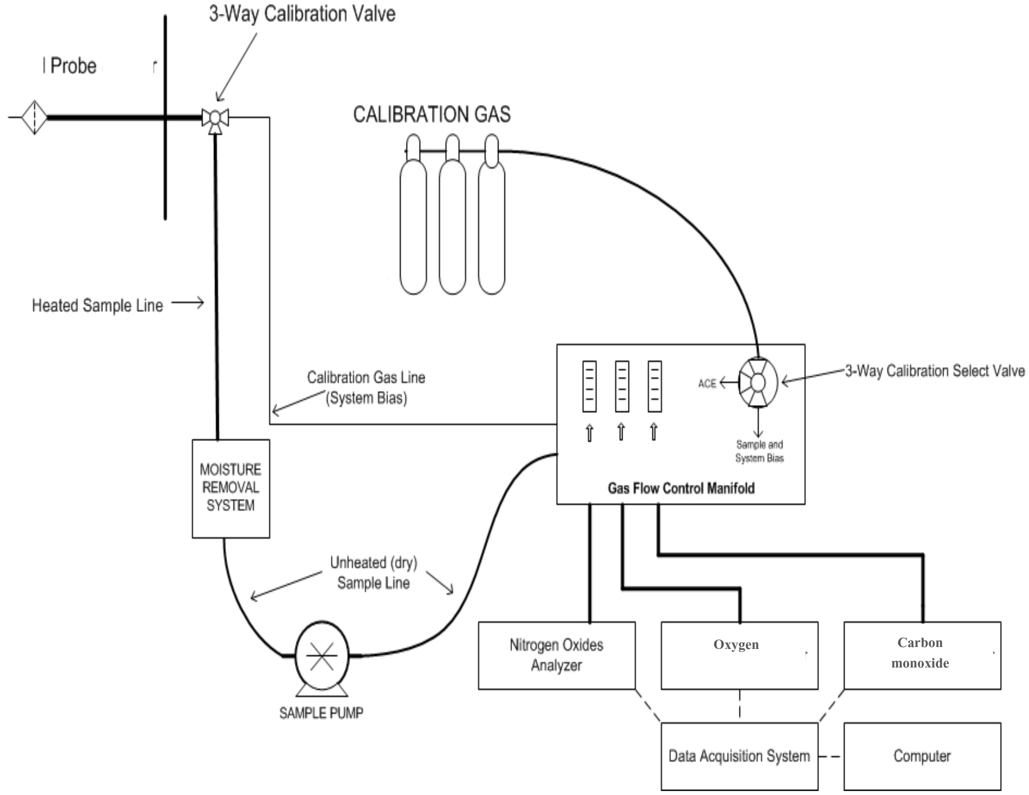
- USEPA Method 3A, *Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure),*
- USEPA Method 7E, Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure), and
- USEPA Method 10, *Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure).*

Please note that for FGENGINES-P3, just O_2 and CO (no NOx) were measured at the catalyst inlet and outlet stacks, per criteria in 40 CFR part 63, Subpart ZZZZ.

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

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

Figure 4-3. 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 ±2.0% of the calibration gas span or high calibration gas concentration. An initial system-bias test was performed where the zero- and mid- or high- calibration gases were introduced at the sample probe to measure the ability of the system to respond accurately to within ±5.0% of span.

A NO_2 to NO conversion efficiency test was 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. The test verified the analyzer response as NO_x was ≥90% of the certified 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 ±5.0% of span and drift was within ±3.0%. The analyzers responses were used to correct the measured gas concentrations for analyzer drift.

For the analyzer calibration error tests, bias tests and drift checks, these evaluations are also passed if the standard criteria are not achieved, but the absolute difference between the analyzer responses and calibration gas is less than or equal to 0.5 ppmv for NO_x and CO or 0.5% for 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 processed by FCS is the same gas used for firing FGENGINES-P3 and EUEGEN. The facility collects a daily sample of this gas and analyzes it via gas chromatography (GC) for hydrocarbons, non-hydrocarbons, heating value, and other parameters. The test day 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 the exhaust gas flow rate using *Equation 19-1* presented in Figure 4-4, which was incorporated into 40 CFR Part 60 Subpart JJJJ *Equations 1, 2, and 3* to calculate g/HP-hr emission rates.

<u>Figure 4-4. USEPA Method 19 Exhaust Flow Rate Equation 19-1</u>

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

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^3/min) x (fuel heat content in mmBtu/ft^3)
- O_2 = stack oxygen concentration, dry basis (%)

<u>Figure 4-5. 40 CFR Part 60 Subpart JJJJ Emission Rates, Equations 1, 2, 3</u>

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

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 = 1.912×10^{-3} (Equation 1)
- KCO = 1.164×10^{-3} (Equation 2)
- KVOC = 1.833×10^{-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)

EUEGEN 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.

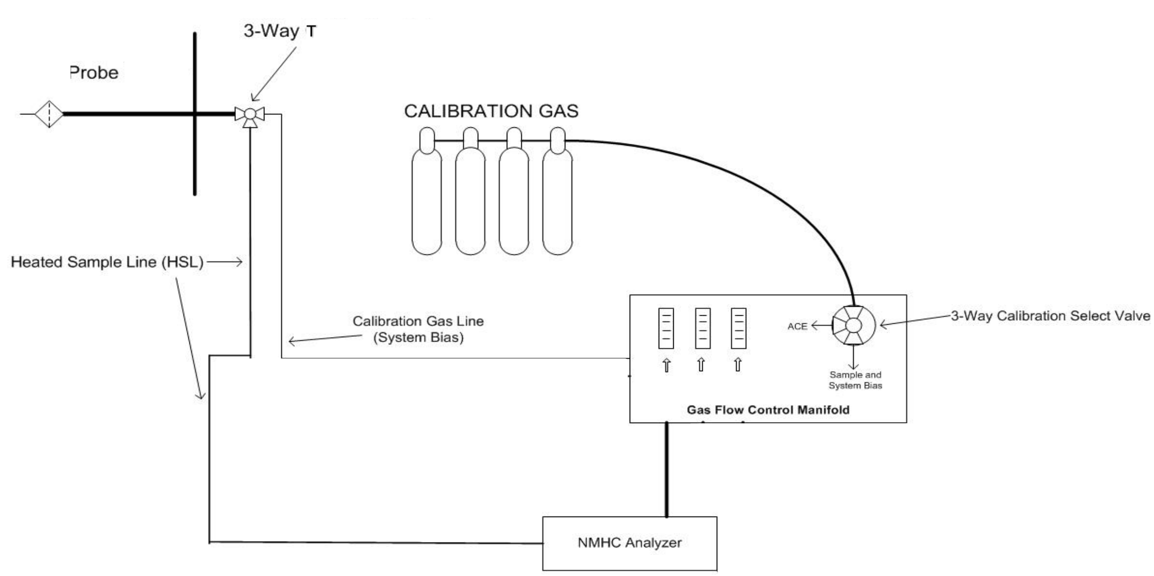
Sample gas is injected into the column and due to methane's low molecular weight and high volatility moves through the column more quickly than other organic compounds that may be present and quantified by the FID. The column is then flushed with inert carrier gas and the remaining non-methane organic 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 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 ±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.

Immediately following each test run, zero and low-level calibration gases are introduced consecutively into the measurement system to ensure analyzer drift is within ±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*.

Since the field VOC instrument measures on a wet basis, exhaust gas moisture content was used to convert the wet VOC concentrations to a dry basis and calculate VOC mass emission rates. The ALT-008 moisture content results were used to convert the VOC concentration to a dry basis and calculate emission rates.

Figure 4-6. USEPA Method 25A NMOC 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 earlier in Table 2-1, the EUEGEN test results indicate the NO_x, CO, and VOC exhaust emissions comply with 40 CFR Part 60, Subpart JJJJ and PTI 202-15A and the EUENGINE3-1 and 3-2 test results indicate the CO reduction measured complies with 40 CFR Part 63, Subpart ZZZZ and PTI 202-15A limits. Appendix Tables 1, 2, and 3 contain detailed tabulation of these results, process operating conditions, and exhaust gas conditions.

5.2 Significance of Results

The test results indicate compliance with 40 CFR Part 60, Subpart JJJJ, 40 CFR Part 63, Subpart ZZZZ and PTI 202-15A.

5.3 Variations from Sampling or Operating Conditions

No operating condition variations were observed during the test program.

5.4 Process or Control Equipment Upset Conditions

The FGENGINES-P3 engine and gas compressor / pump equipment and EUEGEN operated under maximum routine conditions and no upsets were encountered during testing, however EUENGINE3-3, 3-4 and 3-5 were unavailable for testing; thus that performance test was re-scheduled to the week of November 30, 2020.

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 40 CFR Part 60, Subpart JJJJ emission testing for EUEGEN will be performed every 8,760 engine operating hours or 3 years, whichever comes first thereafter to demonstrate compliance. Subsequent 40 CFR Part 63, Subpart ZZZZ emission testing for EUENGINE3-1 and EUENGINE3-2 will be performed annually.

5.7 Results of Audit Samples

Reference method audit samples for this test program are not available from USEPA Stationary Source Audit Sample Program providers. The 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 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 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, 7E, 10, 25A: 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 span, 0.5 ppmv or 0.5% O_2 abs. difference
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- and Post-test	Bias: ±5.0% of span Drift: ±3.0% of span or ≤ 0.5 ppmv or 0.5% O_2 abs. difference
M4 (ALT-008): Field balance calibration	Verify moisture measurement accuracy	Use Class 6 weight to check balance accuracy	Daily before use	Balance must measure weight within ±0.5 gram of certified mass
M7E: NO_2-NO converter efficiency	Evaluates 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/ALT096: Calibration Error	Evaluates operation of analyzer and sample system	Calibration gases introduced through sample system	Pre-test	±5.0% of calibration gas value
M25A/ALT096: Zero and Calibration Drift	Evaluates analyzer and sample system integrity and accuracy over test duration	Calibration gases 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 D.

5.9 Sample Calculations

Sample calculations and formulas used to compute emissions data are presented in Appendix A.

5.10 Field Data Sheets

Field data sheets are presented in Appendix B.

5.11 Laboratory Quality Assurance / Quality Control Procedures

The method specific quality assurance and quality control procedures in each method employed during this test program were followed, without deviation.

5.12 QA / QC Blanks

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