



**Consumers Energy**

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

**EUENGINE3-1 & EUENGINE3-2**

Consumers Energy Company  
Freedom Compressor Station  
12201 Pleasant Lake Rd,  
Manchester, Michigan 48158  
SRN: N3920

December 11, 2019

**Test Dates: October 30 and 31, 2019**

Test Performed by the Consumers Energy Company  
Regulatory Compliance Testing Section  
Air Emissions Testing Body  
Laboratory Services Section  
Work Orders 34845296 & 34845297  
Version No.: 1.0

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## EXECUTIVE SUMMARY

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), and volatile organic compound (VOC) testing on two (2) natural gas-fired, 4-stroke lean burn (4SLB), Waukesha Model 12V275GL reciprocating internal combustion engines (RICE) (designated as EUENGINE3-1 and EUENGINE3-2) at the Freedom Compressor Station in Manchester, Michigan.

The test program was conducted on October 30 and 31, 2019 to satisfy performance test requirements and evaluate compliance with United States Environmental Protection Agency (USEPA) 40 CFR Part 60, Subpart JJJJ, *Standards of Performance for Stationary Spark Ignition Internal Combustion Engines*, 40 CFR Part 63, Subpart ZZZZ, *National Emission Standards for Hazardous Air Pollutants (NESHAP) for Stationary Reciprocating Internal Combustion Engines* (aka RICE MACT), and Michigan Department of Environment, Great Lakes, and Energy (EGLE) Permit to Install (PTI) No. 202-15A, issued November 30, 2017. EUENGINE3-1 and EUENGINE3-2 are associated emissions units of FGENGINE3-P3, FGNSPSJJJJ, and FGNESHAPZZZZ flexible groups within the PTI. A test protocol outlining the proposed testing and data quality objectives was submitted to EGLE on July 31, 2019 and subsequently approved by Mr. David Patterson, Environmental Quality Analyst, in a letter dated August 19, 2019.

**Table E-1**  
**Summary of Average EUENGINE3-1 and EUENGINE3-2 Test Results**

Parameter	Units	EUENGINE		Emission Limits		
		3-1	3-2	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	0.5	0.5	1.0		0.6
	ppmvd at 15% O <sub>2</sub>	38	39	82		82
CO	g/HP-hr	0.06	0.07	2.0		0.14
	ppmvd at 15% O <sub>2</sub>	8	11	270		
	% reduction	96	95		≥93 <sup>†</sup>	≥93
VOC (as NMNEOC)	g/HP-hr	0.04	0.03	0.7		0.2
	ppmvd C <sub>3</sub> H <sub>8</sub> at 15% O <sub>2</sub>	3	3	60		60
Catalyst Inlet Temperature	°F	805	788		≥450 & ≤1350	
Catalyst Pressure Drop	pressure (in H <sub>2</sub> O)	1.1	1.6		0-3.3 (EUENGINE3-1) 0-3.8 (EUENGINE3-2)	

NO<sub>x</sub>= nitrogen oxides  
CO = carbon monoxide  
VOC = volatile organic compounds (non-methane, non-ethane organic compounds (NMNEOC)), as propane  
g/HP-hr = grams per horsepower hour  
<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>1</sup> 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<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: FGENGINE3-P3, FGNSPSJJJJ, and FGNESHAPZZZZ.

The test program consisted of triplicate 60-minute test runs conducted at each engine following procedures in USEPA Reference Methods (RM) 1, 3A, 4 (Alt-008), 7E, 10, 18, 19, and 25A contained in 40 CFR Part 60, Appendix A. During testing, the engines operated within  $\pm 10$  percent of 100 percent peak (or the highest achievable) load, as specified in 40 CFR 60.4244(a) and 40 CFR 63.6620(b). There were no test protocol or RM deviations during the event. The NO<sub>x</sub>, CO, and VOC test results summarized in Table E-1 indicate the engines comply with the applicable NESHAP, RICE MACT, and EGLE PTI 202-15A emissions limits.

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

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## 1.0 INTRODUCTION

This report summarizes compliance air emission results from tests conducted at the Consumers Energy Freedom Compressor Station (FCS) in Manchester, Michigan.

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

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), and volatile organic compound (VOC) testing of two natural gas-fired 4-stroke lean burn (4SLB), Waukesha Model 12V275GL reciprocating internal combustion engines (RICE) designated as EUENGINE3-1 and EUENGINE3-2 (i.e., FGENGINE3-P3) at the Freedom Compressor Station in Manchester, Michigan.

A test protocol outlining the proposed testing and data quality objectives was submitted to EGLE on July 31, 2019 and subsequently approved by Mr. David Patterson, Environmental Quality Analyst, in a letter dated August 19, 2019. The test program was conducted on October 30 and 31, 2019. There were no deviations from the approved stack test protocol or associated United States Environmental Protection Agency (USEPA) Reference Methods (RM).

### 1.2 PURPOSE OF TESTING

The purpose of the test program was to satisfy performance test requirements and evaluate compliance with United States Environmental Protection Agency (USEPA) 40 CFR Part 60, Subpart JJJJ, *Standards of Performance for Stationary Spark Ignition Internal Combustion Engines*, 40 CFR Part 63, Subpart ZZZZ, *National Emission Standards for Hazardous Air Pollutants (NESHAP) for Stationary Reciprocating Internal Combustion Engines* (aka RICE MACT), and Michigan Department of Environment, Great Lakes, and Energy (EGLE) Permit to Install (PTI) No. 202-15A, issued November 30, 2017. EUENGINE3-1 and EUENGINE3-2 are associated emissions units of FGENGINE3-P3, FGNSPSJJJJ, and FGNESHAPZZZZ flexible groups within the PTI. The applicable emission limits are shown in Table 1-1.

**Table 1-1  
EUENGINE3-1 and EUENGINE3-2 Emission Limits**

Parameter	Emission Limit	Units	Applicable Requirement <sup>1,2,3</sup>
NO <sub>x</sub>	0.6	g/HP-hr	PTI No. 202-15A, Flexible Group Conditions: FGENGINE3-P3
	1.0	g/HP-hr	40 CFR Part 60, Subpart JJJJ, Table 1 PTI No. 202-15A, Flexible Group Conditions: FGNSPSJJJJ
	82	ppmvd at 15% O <sub>2</sub>	40 CFR Part 60, Subpart JJJJ, Table 1 PTI No. 202-15A, Flexible Group Conditions: FGNSPSJJJJ
CO	0.14	g/HP-hr	PTI No. 202-15A, Flexible Group Conditions: FGENGINE3-P3
	2.0	g/HP-hr	40 CFR Part 60, Subpart JJJJ, Table 1
	270	ppmvd at 15% O <sub>2</sub>	40 CFR Part 60, Subpart JJJJ, Table 1
	93 <sup>†</sup>	% Reduction across oxidation catalyst	PTI No. 202-15A, Flexible Group Conditions: FGNESHAPZZZZ 40 CFR §63.6300(b) – 40 CFR Part 63, Subpart ZZZZ, Table 2a

**Table 1-1  
EUENGINE3-1 and EUENGINE3-2 Emission Limits**

Parameter	Emission Limit	Units	Applicable Requirement <sup>1,2,3</sup>
VOC <sup>†</sup>	0.2	g/HP-hr	PTI No. 202-15A, Flexible Group Conditions: FGENGINES-P3
	0.7	g/HP-hr	40 CFR Part 60, Subpart JJJJ, Table 1 PTI No. 202-15A, Flexible Group Conditions: FGNSPSJJJJ
	60	ppmvd at 15% O <sub>2</sub>	40 CFR Part 60, Subpart JJJJ, Table 1 PTI No. 202-15A, Flexible Group Conditions: FGNSPSJJJJ
NO <sub>x</sub>	nitrogen oxides		
CO	carbon monoxide		
VOC	volatile organic compounds (non-methane, non-ethane organic compounds (NMNEOC)), as propane		
g/HP-hr	grams per horsepower hour		
<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>1</sup> 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 <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. 202-15, Flexible Group Conditions: FGENGINES-P3, FGNSPSJJJJ, and FGNESHAPZZZZ.			

### 1.3 BRIEF DESCRIPTION OF SOURCE

EUENGINE3-1 and EUENGINE3-2 are classified as new (installed 2016) four stroke lean burn (4SLB) spark-ignited 3,750 brake horsepower (BHP) engines located at a major source of hazardous air pollutant (HAP) emissions. The engines are used to maintain pressure of natural gas along the pipeline system. Initial startup of the engines occurred in October 2016. Initial compliance testing was performed on March 21 and 22, 2017 that established the acceptable pressure drop range across the oxidation catalysts. Additional performance testing was performed September 12-13, 2017, October 10, 2018 and December 14, 2018. This continuous compliance demonstration emissions testing was performed on October 30 and 31, 2019.

### 1.4 CONTACT INFORMATION

Table 1-2 presents contact information of personnel involved in the test program.

**Table 1-2  
Contact Information**

Program Role	Contact	Address
State Regulatory Administrator	Ms. Karen Kajiya-Mills Technical Programs Unit Manager 517-335-4874 <a href="mailto:kajiya-millsk@michigan.gov">kajiya-millsk@michigan.gov</a>	Michigan Department of Environment, Great Lakes and Energy 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
State Technical Programs Field Inspector	Mr. David Patterson Technical Programs Unit 517-284-6782 <a href="mailto:pattersond2@michigan.gov">pattersond2@michigan.gov</a>	
State Regulatory Inspector	Mr. Mike Kovalchick Environmental Quality Analyst 517-416-5025 <a href="mailto:kovalchickm@michigan.gov">kovalchickm@michigan.gov</a>	Michigan Department of Environment, Great Lakes and Energy Jackson District 301 East Louis B. Glick Hwy Jackson, Michigan 49201-1556

**Table 1-2  
Contact Information**

Program Role	Contact	Address
Responsible Official	Mr. Gregory Baustian Executive Director Natural Gas Compression 616-237-4009 <a href="mailto:gregory.baustian@cmsenergy.com">gregory.baustian@cmsenergy.com</a>	Consumers Energy Company Zeeland Generation 425 N. Fairview Road Zeeland, Michigan 49464
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. Frank Rand Senior Environmental Analyst 734-850-4209 <a href="mailto:frank.randjr@cmsenergy.com">frank.randjr@cmsenergy.com</a>	Consumers Energy Company South Monroe Customer Service Center 7216 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 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) and §63.6620(b), operated within 10% of 100 percent peak (or the highest achievable) load. Based on pipeline pressures and site conditions, the highest achievable load for EUENGINE3-1 and EUENGINE3-2 was 82% and 86%, respectively. Refer to Appendix D for detailed operating data.

### 2.2 APPLICABLE PERMIT INFORMATION

The Freedom Compressor Station operates in accordance with air permit MI-ROP-N3920-2014b and PTI 202-15A. EUENGINE3-1 and EUENGINE3-2 are the emission unit source identifications and are included in the FGENGINE3-P3 flexible group in PTI 202-15A. Incorporated within the permit are the applicable requirements of 40 CFR Part 60, Subpart JJJJ - Standards of Performance for Stationary Spark Ignition Internal Combustion Engines and 40 CFR Part 63, Subpart ZZZZ - National Emission Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines.

### 2.3 RESULTS

The test results in Table 2-1 indicate each engine and oxidation catalyst complies with the applicable NO<sub>x</sub>, CO and VOC emission and percent CO reduction limits.



**Table 2-1  
Summary of Average EUENGINE3-1 and EUENGINE3-2 Test Results**

Parameter	Units	EUENGINE		Emission Limits		
		3-1	3-2	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	0.5	0.5	1.0		0.6
	ppmvd at 15% O <sub>2</sub>	38	39	82		82
CO	g/HP-hr	0.06	0.07	2.0		0.14
	ppmvd at 15% O <sub>2</sub>	8	11	270		
	% reduction	96	95		≥93 <sup>†</sup>	≥93
VOC (as NMNEOC)	g/HP-hr	0.04	0.03	0.7		0.2
	ppmvd C <sub>3</sub> H <sub>8</sub> at 15% O <sub>2</sub>	3	3	60		60
Catalyst Inlet Temperature	°F	805	788		≥450 & ≤1350	
Catalyst Pressure Drop	pressure (in H <sub>2</sub> O)	1.1	1.6		0-3.27 (engine3-1) 1.26-5.36 (engine3-2)	

NO<sub>x</sub> = nitrogen oxides  
CO = carbon monoxide  
VOC = volatile organic compounds (non-methane, non-ethane organic compounds (NMNEOC)), as propane  
g/HP-hr = grams per horsepower hour  
<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>1</sup> 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<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: FGENGINE3-P3, FGNPSJJJJ, and FGNESHAPZZZZ.

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

### 3.0 SOURCE DESCRIPTION

EUENGINE3-1 and EUENGINE3-2 are natural gas fired RICE used to maintain pressure of natural gas along the pipeline system. A summary of the engine specifications from vendor data are provided in Table 3-1.

**Table 3-1  
Summary of Engine Specifications**

Parameter <sup>1</sup>	EUENGINE3-1 and EUENGINE3-2
Make	Waukesha
Model	12V275GL
Output (brake-horsepower)	3,750
Heat Input, LHV (mmBtu/hr)	28.96
Exhaust Flow Rate (ACFM, wet)	23,373
Exhaust Gas Temp.	828

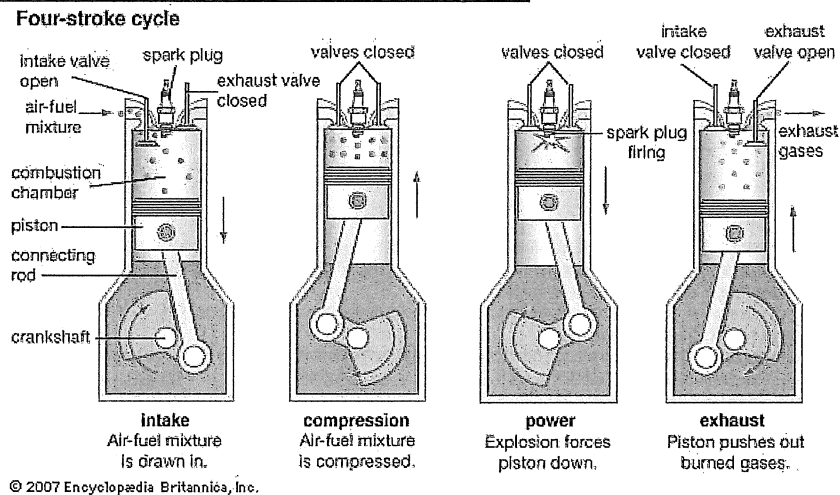
<sup>1</sup> Engine specifications are based upon vendor data for operation at 100% of rated engine capacity

### 3.1 PROCESS

EUENGINE3-1 and EUENGINE3-2 are natural gas-fired, spark ignited, 4SLB RICE installed in 2016 with initial startup on October 24, 2016. In the 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 with the piston near the bottom of the intake stroke and the intake valves close as the piston moves to the top of the cylinder, compressing the air/fuel mixture. A spark plug at the top of the cylinder ignites the air/fuel charge causing the charge to expand and initiate the downward movement of the piston, called the power stroke. As the piston reaches the bottom of the power stroke, valves open to exhaust combustion products from the cylinder as the piston travels upward. A new air-to-fuel charge is injected as the piston moves downward in a new intake stroke.

The engine provides mechanical shaft power for a gas compressor. The compressor is used to maintain pressure within the natural gas pipeline transmission and distribution system to consumers. Refer to Figure 3-1 for a four-stroke engine process diagram.

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



Natural gas combustion by-products are controlled through parametric controls (i.e., timing and operating at a lean air-to-fuel ratio) and by post-combustion oxidizing catalysts installed on the engine exhaust system. The RICE oxidation catalysts are manufactured by Advanced Catalyst Systems, Inc. Four catalyst modules are installed on each engine exhaust stack use proprietary materials to lower the oxidation temperature of CO and other organic compounds to engine exhaust gas temperatures, thus maximizing the catalyst efficiency specific to the exhaust gas temperatures of engines. As carbon monoxide passes through the catalytic oxidation system, CO and volatile organic compounds are oxidized to CO<sub>2</sub> and water, while suppressing the conversion of NO to NO<sub>2</sub>.

The catalyst vendor has guaranteed a CO destruction efficiency of 93%. Although Consumers Energy has chosen to comply with the CO reduction emission limit requirement, the catalyst also provides control of formaldehyde and non-methane and non-ethane hydrocarbons (NMNEHC). The estimated destruction efficiency for formaldehyde and NMNEHC is 80%. Although optimization of the engine programming and synchronization with the compressor was completed, no other significant maintenance was performed on the engine or oxidation catalysts within three months of the scheduled test.

Nitrogen oxides (NO<sub>x</sub>) emissions from the engine is minimized using lean-burn combustion technology. Lean-burn combustion refers to a high level of excess air (generally 50% to 100% relative to the stoichiometric amount) in the combustion chamber. The excess air

absorbs heat during the combustion process, thereby reducing the combustion temperature and pressure resulting in lower NO<sub>x</sub> emissions.

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

### **3.2 PROCESS FLOW**

Located in 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 primarily 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.

EUENGINE3-1 and EUENGINE3-2 are natural gas reciprocating engines used to drive a two-stage compressor to maintain pressure and move natural gas through the pipeline system. The exhaust stack is of non-typical design. Specifically, the bottom portion of the stack incorporates an annulus, where an outer stack surrounds an inner circular stack (the shape is like a doughnut as 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 are discharged unobstructed vertically upwards through the 65-foot high stack to atmosphere.

### **3.3 MATERIALS PROCESSED**

The engine fuel is exclusively natural gas, as defined in 40 CFR §72.2. Recent natural gas sample analyses indicate a fuel composition of approximately 92% methane, 5% ethane, 2% nitrogen, and 0.5% carbon dioxide.

### **3.4 RATED CAPACITY**

EUENGINE3-1 and EUENGINE3-2 have maximum outputs of approximately 3,750 horsepower. At this achievable output, the heat input rating is approximately 28.96 mmBtu/hr. However, the maximum achievable operating condition of the engine is constrained by site and pipeline specific conditions.

### **3.5 PROCESS INSTRUMENTATION**

During testing, the following engine operating parameters were monitored and collected:

- Engine brake horsepower (HP)
- Engine speed (RPM)
- Engine Load as Torque (% max)
- Fuel gas flow (scfm)
- Suction pressure (psi)
- Discharge pressure (psi)
- Catalyst inlet temperature (°F)
- Pressure differential across Oxidation catalyst (in H<sub>2</sub>O)

During testing of EUENGINE3-1 the process data was recorded in 1-minute increments using a combination of engine parametric data loggers and manual readings of field instrumentation. Based on the difficulty of collecting the process data at such frequency, process instrumentation data was logged at approximate 15-minute increments during testing of EUENGINE3-2. Refer to Appendix D for this operating data.

## 4.0 SAMPLING AND ANALYTICAL PROCEDURES

Triplicate one-hour test runs for NO<sub>x</sub>, CO, VOC, and oxygen (O<sub>2</sub>) concentrations were conducted using the USEPA test methods in Table 4-1. The sampling and analytical procedures associated with each parameter are described further 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/Alt-008	Determination of Moisture Content in Stack Gases
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)
Methane (CH <sub>4</sub> ) & Ethane (C <sub>2</sub> H <sub>6</sub> )	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	Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

### 4.1 DESCRIPTION OF SAMPLING TRAIN AND FIELD PROCEDURES

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

**Table 4-2  
Test Matrix**

Date (2019)	Run	Sample Type	Start Time (EST)	Stop Time (EST)	Test Duration (min)	EPA Test Method	Comment
<b>EUENGINE3-1</b>							
October 30	1	O <sub>2</sub> NO <sub>x</sub> CO CH <sub>4</sub> C <sub>2</sub> H <sub>6</sub> VOC	9:10	10:09	60	1 3A 4(alt-008) 7E 10 18 19 25A	3-points located in each duct at 16.7, 50.0 & 83.3 % of the measurement line were traversed at each sample location
	2		10:40	11:39	60		
	3		12:53	13:52	60		
<b>EUENGINE3-2</b>							
October 31	1	O <sub>2</sub> NO <sub>x</sub> CO CH <sub>4</sub> C <sub>2</sub> H <sub>6</sub> VOC	8:55	9:54	60	1 3A 4(alt-008) 7E 10 18 19 25A	3-points located in each duct at 16.7, 50.0 & 83.3 % of the measurement line were traversed at each sample location
	2		10:18	11:17	60		
	3		11:37	12:36	60		

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

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

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

##### **Pre-catalyst Sampling Ports**

Two test ports are located in each of two 16-inch diameter horizontal exhaust ducts exiting the engine. The pre-catalyst sampling ports are situated:

- 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 flow disturbance caused by a change in duct diameter and flow direction as it enters exhaust stack and oxidation catalyst.

The pre-catalyst sample ports are 4-inches in diameter and sealed by a bolted blank flange approximately 4-inches outside the duct wall.

## Post-catalyst Sampling Ports

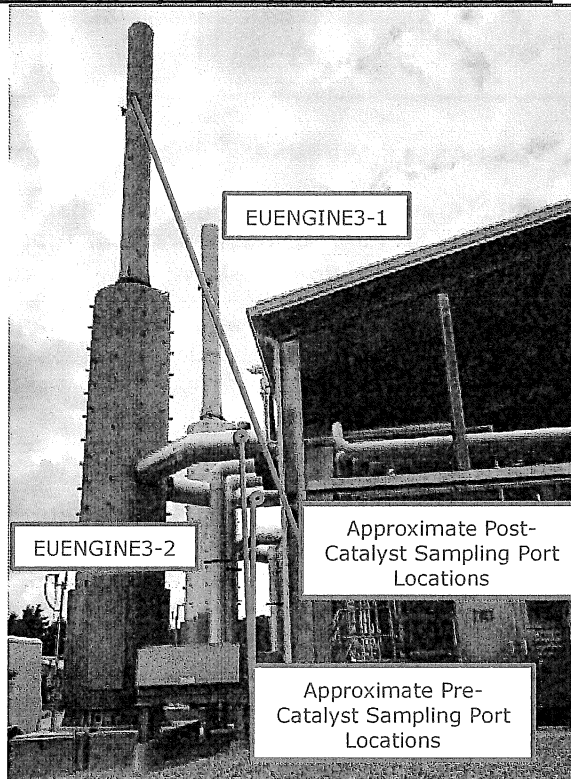
Two test ports are located in a 30-inch vertical exhaust stack exiting the engine and oxidation catalyst. The post-catalyst sampling ports are situated:

- 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.

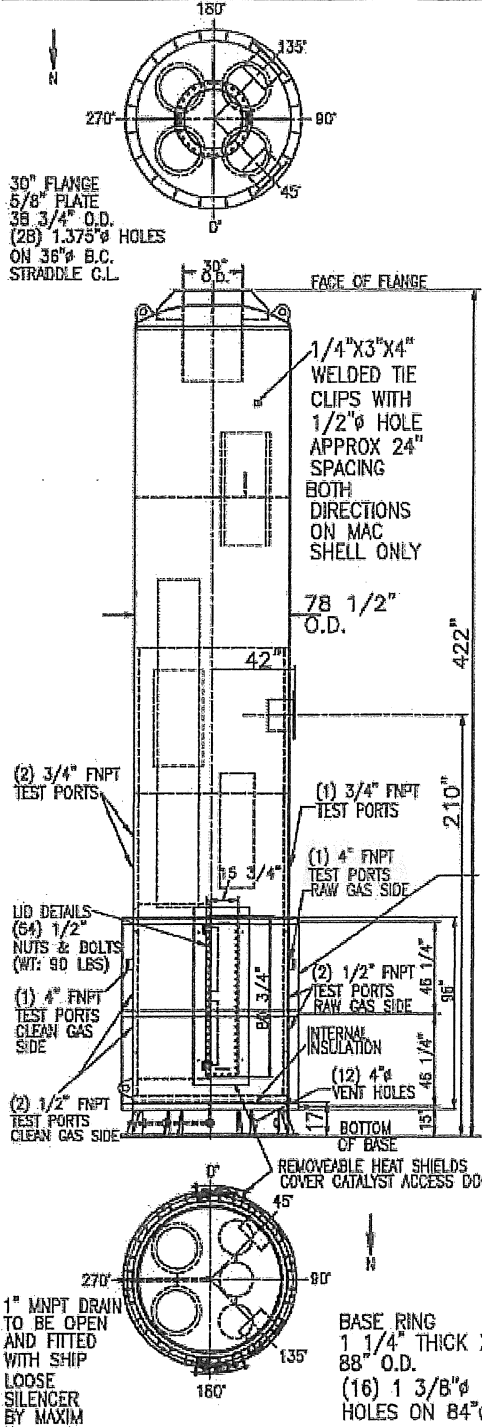
The post-catalyst sample ports are 4-inches in diameter and sealed by a bolted blank flange approximately 4-inches outside the stack wall.

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 flue gas was sampled from the three traverse points at approximately equal intervals during the tests. Pre-catalyst and post-catalyst sampling port location drawings are presented as Figures 4-1 and 4-2.

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



**Figure 4-2. Post-Catalyst Sampling Port Location**



SERVICE: CATALYTIC EXHAUST SILENCER  
FOR WAUKESHA 12V-275GL GAS ENGINE  
PRESSURE DROP: 5.67" H2O AT 23349 ACFM, 797 °F

OCTAVE BAND	16	31	63	125	250	500	1K	2K	4K	8K
RAW NOISE AT 3.28 FEET (dB)	80	93	93	98	99	99	97	95	100	9E
INSERTION LOSS (dB)	10	16	30	46	44	42	45	48	47	4E
GUARANTEED SPL 50 FEET (dB)	70	67	64	63	53	45	45	45	40	4C

(BASED ON ABOVE RAW NOISE) OAL <= 56 dBA

MATERIALS OF CONSTRUCTION: CARBON STEEL  
SHELL: 1/4"  
SHELL INTERNAL LINER: 3/16 GAGE  
END HEADS AND BAFFLES: 3/8" THICK  
INLET AND OUTLET NOZZLES 1/4" CARBON STEEL  
FLANGES: 5/8" PLATE  
TAIL PIPE: 1/4" CARBON STEEL  
CATALYST PANELS: (4) 304SS 3.5" x 30.5" Ø  
INTERNAL INSULATION: (2" THICK) 6 PCF FIBERGLASS MAT INSULATION PROTECTED WITH 304SS SCREEN WIRE MESH

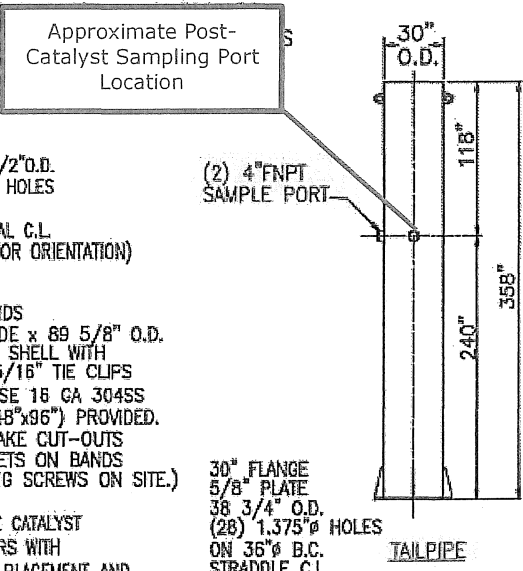
EXTERNAL PAINT: (HIGH TEMP.)  
SP10 SANDBLAST  
INTERMEDIATE WITH 2-3 MILS CARBOZINC 11  
FINISH COAT WITH 3-4.5 MILS THERMALINE 4700 ALUM SILICON

WEIGHT:  
FREE STANDING TAIL PIPE TO WITHSTAND 120 WIND LOAD

16" FLANGES  
1/2" PLATE, 23 1/2" O.D.  
(16) 1 1/8" DIA HOLES  
ON 21 1/4" B.C.,  
STRADDLE VERTICAL C.L.  
(SEE END VIEW FOR ORIENTATION)

8' HEAT SHIELD  
(3) SUPPORT BANDS  
10 GAGE x 3" WIDE x 89 5/8" O.D.  
EACH WELDED TO SHELL WITH  
(20) 1/4"x3"x5 5/16" TIE CLIPS  
(6) SHIPPED LOOSE 16 GA 304SS PERFO SHEETS (48"x96") PROVIDED.  
(CUSTOMER TO MAKE CUT-OUTS AND INSTALL SHEETS ON BANDS WITH SELF TAPPING SCREWS ON SITE.)

GRADE ACCESSIBLE CATALYST MAINTENANCE DOORS WITH POSITIVE ELEMENT PLACEMENT AND RETENTION MECHANISMS



30" FLANGE  
5/8" PLATE  
38 3/4" O.D.  
(28) 1.375" Ø HOLES  
ON 36" Ø B.C.  
STRADDLE C.L.

**CERTIFICATION**

CUSTOMER: \_\_\_\_\_  
CUSTOMER P.O. NO.: \_\_\_\_\_  
DATE: \_\_\_\_\_ BY: \_\_\_\_\_

**MAXIM SILENCERS**  
10635 BRIGHTON LANE  
STAFFORD, TX, 77477  
PHONE (832) 554-0980  
FAX (832) 554-0990

**MAXIM MAC62-461-30 CATALYTIC EXHAUST SILENCING  
DUAL 16" SIDE INLETS AND SKIRT MOUNTING**

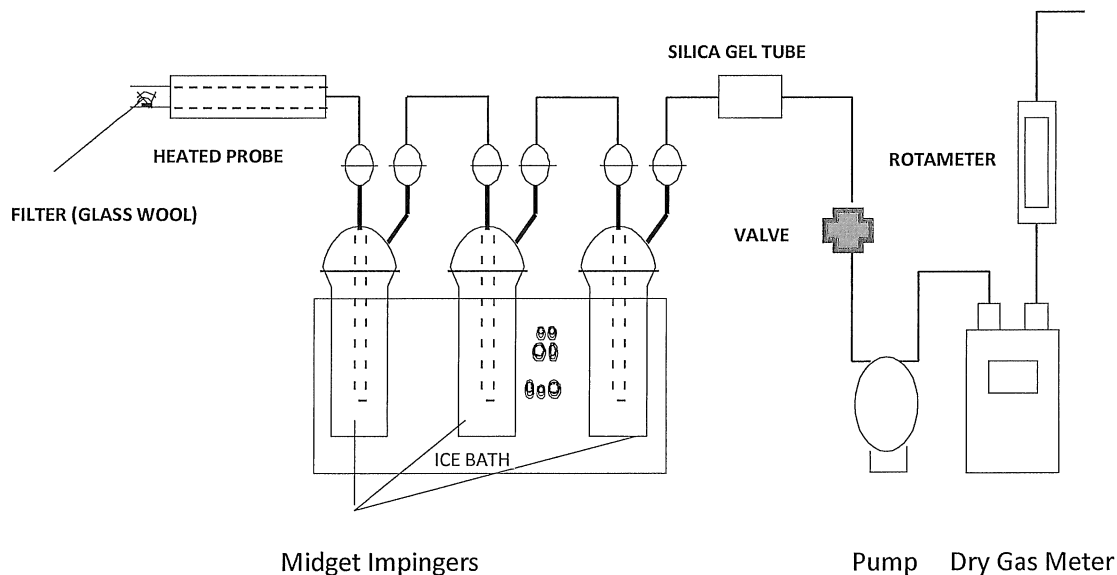
G	REVISE PORT ON TAILPIPE	FB	1/27/16
F	REVISED INLETS TO 16"	TF	1/7/16
E	REVISED INLETS TO 16" & UPDATED BP.	TF	12/30/15
D	REVISED FLOW RATE AND TEMPERATURE	TF	12/1/15
C	UPDATED ACOUSTICAL TABLE.	TF	10/20/15
B	CORRECTED TAILPIPE HEIGHT DIMENSION	AC	09/16/15
A	ADDED INTERNAL INSULATION INFORMATION.	TF	09/16/15

DRAWN	TF	9/15/15	ORDER NO.	DRAWING NO.	REV
CHECKED	MA	9/15/15		145-8A16725	G
APPRVD	MA	9/15/15		Sheet 1 of 1	

### 4.3 MOISTURE CONTENT (USEPA ALT-008)

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

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



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

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

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

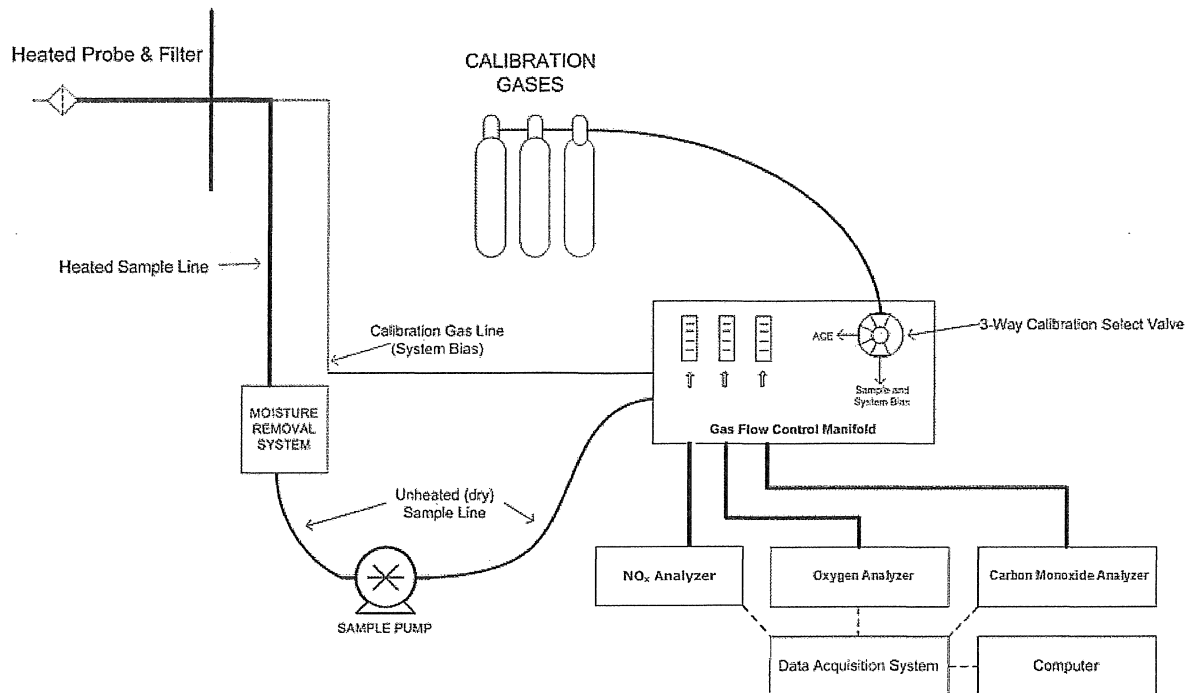
- USEPA Method 3A, *Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)*,
- USEPA Method 7E, *Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)*, and
- USEPA Method 10, *Determination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



Each cited method sampling is procedurally similar with the exception of the analyzer and analytical technique used. Engine exhaust gas was extracted from the stacks or ducts through a stainless-steel probe, heated Teflon® sample line, and through a gas conditioning system to remove water and dry the sample before entering a sample pump, flow control manifold, and gas analyzers.

Figure 4-4 depicts a drawing of the Methods 3A, 7E, and 10 sampling system.

**Figure 4-4. USEPA Methods 3A, 7E, and 10 Sampling System**



Prior to sampling engine exhaust gas, the analyzers are calibrated by performing a calibration error test where zero-, mid-, and high-level calibration gases are introduced directly to the back of the analyzers. The calibration error check is performed to evaluate if the analyzers response was within  $\pm 2.0\%$  of the calibration gas span or high calibration gas concentration. An initial system-bias test is then performed where the zero- and mid- or high- calibration gases are introduced at the sample probe to measure the ability of the system to respond accurately to within  $\pm 5.0\%$  of span.

A  $\text{NO}_2$  to  $\text{NO}$  conversion efficiency test is 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  $\text{NO}_x$ .

Upon successful completion of the calibration error and initial system bias tests, sample flow rate and component temperatures are verified and the probes inserted into the ducts at the appropriate traverse point. After confirming the engine is operating at established conditions, the test run is initiated. Gas concentrations are recorded at 1-minute intervals throughout each 60-minute test run. Oxygen concentrations are measured to adjust the pollutant concentrations to 15%  $\text{O}_2$  and calculate pollutant emission rates.

At the conclusion of each test run, a post-test system bias check is performed to compare analyzer bias and drift relative to pre-test system bias checks, ensuring analyzer bias is within  $\pm 5.0\%$  of span and drift is within  $\pm 3.0\%$ . The analyzer response is also used to correct measured gas concentrations for analyzer drift.

#### 4.5 EMISSION RATES (USEPA METHOD 19)

USEPA Method 19, *Determination of Sulfur Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide, and Nitrogen Oxide Emission Rates*, was used to calculate exhaust gas flowrate.

The default natural gas fuel factor in Method 19 is then used to calculate the emission flow rate with the corresponding equation presented in Figure 4-5. The flow rate was used in calculations to present emissions in units of g/HP-hr.

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

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

Where:

$Q_s$  = stack flow rate (dscf/min)

$F_d$  = Volumes of combustion components per unit of heat content (scf/mmBtu)

$H$  = fuel heat input rate, (mmBtu/min), at the higher heating value (HHV) measured at engine fuel feed line, calculated as (fuel feed rate in ft<sup>3</sup>/min) x (fuel heat content in mmBtu/ft<sup>3</sup>)

$O_2$  = stack oxygen concentration, dry basis (%)

#### 4.6 VOLATILE ORGANIC COMPOUNDS (USEPA METHODS 18 AND 25A)

VOC concentrations were measured from each engine using a Thermo Model 55i Direct Methane and Non-methane Analyzer following the guidelines of USEPA Method 25A, *Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer (FIA)*. The instrument uses a flame ionization detector (FID) to measure the exhaust gas total hydrocarbon concentration in conjunction with a gas chromatography column that separates methane from other organic compounds.

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

Sample gas is injected into the column and due to methane's low molecular weight and high volatility, the compound moves through the column more quickly than other organic compounds that may be present and is quantified by the FID. The column is then flushed with inert carrier gas and the remaining non-methane organic compounds are analyzed in the FID. This analytical technique allows separate measurements for methane and non-methane organic compounds via the use of a single FID. Refer to Figure 4-6 for a drawing of the USEPA Method 25A sampling apparatus.

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

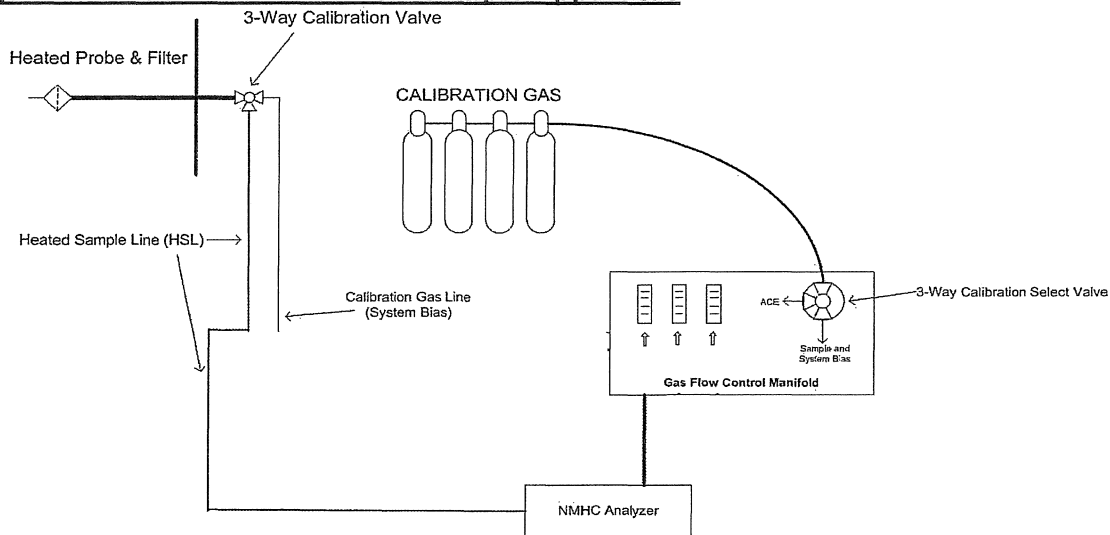
Please note that 40 CFR Part 60, Subpart JJJJ refers to the definition of VOC found in 40 CFR, Part 51 and does not include methane or ethane. Specifically, §51.100(s)(1) defines VOC as "any compound of carbon...other than the following, which have been determined to

have negligible photochemical reactivity: methane, ethane..." The Thermo 55i analyzer used measured exhaust gas ethane as part of the NMOC measurement. Therefore, Tedlar bag samples were collected to quantify the ethane fraction of the NMOC concentration using USEPA Method 18, *Measurement of Gaseous Organic Compound Emissions by Gas Chromatography*.

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

Method 18 requires the sample results to be corrected based on results obtained from a spike recovery study. For the bag sampling technique to be considered valid for a compound, the recovery must be between 70% <math>R < 130\%</math>. The recovery study performed on the Freedom Compressor engine Tedlar bag samples successfully achieved the R value requirement and that value was applied to correct the reported methane and ethane concentrations as propane. It should be noted, the laboratory report provides the concentration of analyte in sample as ppmv as well as ppmv as propane. Consumers Energy has converted the ppmv concentration to ppmv as propane using the calculation and data analysis procedures consistent with USEPA Method 25A, Section 12.0, which provides a more conservative estimate of NMNEVOC emissions. The USEPA Method 18 laboratory report is presented in Appendix E.

**Figure 4-6. USEPA Method 25A Sample Apparatus**



## **5.0 TEST RESULTS AND DISCUSSION**

The test program conducted October 30 and 31, 2019, satisfies the performance testing and compliance evaluation requirements in 40 CFR Part 60, Subpart JJJJ, *Standards of Performance for Stationary Spark Ignition Internal Combustion Engines*, 40 CFR Part 63, Subpart ZZZZ, *National Emission Standards for Hazardous Air Pollutants for Reciprocating Internal Combustion Engines* and PTI 202-15A.

### **5.1 TABULATION OF RESULTS**

The results of the testing indicate the NO<sub>x</sub>, CO, and VOC engine emissions are compliant with the applicable emissions limits summarized in Table 2-1. Appendix Tables 1 through 2 contain detailed tabulation of results, process operating conditions, and exhaust gas conditions for each respective RICE.

### **5.2 SIGNIFICANCE OF RESULTS**

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

### **5.3 VARIATIONS FROM SAMPLING OR OPERATING CONDITIONS**

During testing non-methane VOC concentrations were measured at concentrations of approximately 70 ppmv as propane where compliance could not be determined without quantifying ethane concentrations through the collection of Tedlar bag samples and USEPA Method 18 analysis. One Tedlar bag was collected from the exhaust of each engine and this ethane concentration was subtracted from the non-methane VOC concentration for each test run to estimate non-methane, non-ethane VOC emissions and evaluate compliance with permit limits. This approach was outlined within the approved test protocol and discussed with EGLE representatives onsite during testing.

On October 30, 2019 Run 3 was initiated at EUENGINE3-1 at 12:07; however, a data logging error caused the test to be restarted at 12:43. The flue gas moisture concentration measured from 12:07 to 12:37 was voided in the field and not used in emissions calculations. A moisture measurement from 13:10 to 13:40 and concurrent with the Run 3 gaseous concentrations was used to calculate Run 3 emissions results.

### **5.4 PROCESS OR CONTROL EQUIPMENT UPSET CONDITIONS**

The engine and gas compressor were operating under maximum routine conditions and no upsets were encountered during testing. However, due to seasonal demands and pipeline conditions, engine load was limited to a 3-run average of 82% of maximum torque for EUENGINE3-1 and 86% for EUENGINE3-2.

### **5.5 AIR POLLUTION CONTROL DEVICE MAINTENANCE**

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

## 5.6 RE-TEST DISCUSSION

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

- annually to evaluate the reduction of CO emissions across the oxidation catalyst in accordance with 40 CFR Part 60 Subpart JJJJ and the PTI
- every 8,760 engine operating hours or 3 years (2022), whichever is first, thereafter to evaluate compliance with NO<sub>x</sub>, CO, and VOC emission limits in 40 CFR Part 63, Subpart ZZZZ and the PTI. The engine hours after the conclusion of testing were:
  - EUENGINE3-1: 3186 hours
  - EUENGINE3-2: 3510 hours

Because the engine operating load was limited during test, and an operating load restriction has been self-imposed by the facility, subsequent testing may occur in order to evaluate the engine emissions when operated within  $\pm 10$  percent of 100 percent load.

## 5.7 RESULTS OF AUDIT SAMPLES

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

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

QA/QC Activity	Purpose	Procedure	Frequency	Acceptance Criteria
M1: Sampling Location	Evaluates sampling location suitability for sampling	Measure distance from ports to downstream and upstream flow disturbances	Pre-test	$\geq 2$ diameters downstream; $\geq 0.5$ diameter upstream.
M1: Duct diameter/ dimensions	Verifies area of stack is accurately measured	Review as-built drawings and field measurement	Pre-test	Field measurement agreement with as-built drawings
M3A, M7E, M10, M25A: Calibration gas standards	Ensures accurate calibration standards	Traceability protocol of calibration gases	Pre-test	Calibration gas uncertainty $\leq 2.0\%$
M3A, M7E, M10: Calibration Error	Evaluates analyzer operation	Calibration gases introduced directly into analyzers	Pre-test	$\pm 2.0\%$ of calibration span
M3A, M7E, M10: System Bias and Analyzer Drift	Evaluates analyzer/sample system integrity and accuracy over test duration	Calibration gas introduced at sample probe tip, HSL, and into analyzers	Pre-test and Post-test	Bias: $\pm 5.0\%$ of calibration span Drift: $\pm 3.0\%$ of calibration span
M7E: NO <sub>2</sub> -NO converter efficiency	Evaluates NO <sub>2</sub> -NO converter operation	NO <sub>2</sub> calibration gas introduced directly into analyzer	Pre-test or Post-test	NO <sub>x</sub> response $\geq 90\%$ of certified NO <sub>2</sub> calibration gas

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

<b>QA/QC Activity</b>	<b>Purpose</b>	<b>Procedure</b>	<b>Frequency</b>	<b>Acceptance Criteria</b>
M25A: Calibration Error	Evaluates analyzer and sample system operation	Calibration gases introduced through sample system	Pre-test	±5.0% of the calibration gas value
M25A: Zero and Calibration Drift	Evaluates analyzer/sample system integrity and accuracy over test duration	Calibration gases introduced through sample system	Pre-test and Post-test	±3.0% of the analyzer calibration span

## **5.8 CALIBRATION SHEETS**

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

## **5.9 SAMPLE CALCULATIONS**

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

## **5.10 FIELD DATA SHEETS**

Field data sheets are presented in Appendix B.

## **5.11 LABORATORY QUALITY ASSURANCE / QUALITY CONTROL PROCEDURES**

The method specific quality assurance and quality control procedures in each method employed during this test program were followed, without deviation. Refer to Appendix C for the laboratory data sheets associated with the natural gas fuel samples collected during the test program.

## **5.12 QA/QC BLANKS**

The Method 3A, 7E, 10, and 25A calibration gases described in Table 5-1 above were the only QA/QC media employed during the test event. QA/QC data are shown in Appendix E.