



**Consumers Energy**

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

**EUENGINE3-2**

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

October 31, 2022

**Test Date: September 13, 2022**

Test Performed by the Consumers Energy Company  
Regulatory Compliance Testing Section  
Air Emissions Testing Body  
Laboratory Services Section  
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## EXECUTIVE SUMMARY

On September 13, 2022, Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted continuous compliance testing on EUENGINE3-2 at the Freedom Compressor Station in Manchester, Michigan.

The facility is classified as a major source of hazardous air pollutants (HAP) and the engine is a natural gas-fired, 4-stroke lean-burn (4SLB), spark-ignited (SI), reciprocating internal combustion engine (RICE), >500 horsepower that powers a compressor used to maintain pressure in pipelines transporting natural gas along the pipeline system. The engine is one of five (5) associated emissions units of FGENGINE3-P3, FGNSPSJJJJ, and FGNESHAPZZZZ flexible groups within Michigan Department of Environment, Great Lakes and Energy (EGLE), Renewable Operating Permit (ROP) MI-ROP-N3920-2022.

The test program was conducted to satisfy performance test requirements and evaluate compliance with 40 CFR Part 60, Subpart JJJJ, "Standards of Performance for Stationary Spark Ignition Internal Combustion Engines," (aka NSPS SI ICE), 40 CFR Part 63, Subpart ZZZZ, "National Emission Standards for Hazardous Air Pollutants (NESHAP) for Stationary Reciprocating Internal Combustion Engines as incorporated in Michigan Department of Environment, Great Lakes and Energy (EGLE), Renewable Operating Permit (ROP) MI-ROP-N3920-2022.

Three, 60-minute nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), and volatile organic compounds (VOC's), and oxygen (O<sub>2</sub>) test runs were conducted at the oxidation catalyst outlet following the procedures in United States Environmental Protection Agency (USEPA) Reference Methods (RM) 1, 3A, 4, 7E, 10, 19, and 25A in 40 CFR Part 60, Appendix A. CO was also measured at the oxidation catalyst inlet to calculate percent CO reduction efficiency. There were no deviations from the approved stack test protocol submitted on April 20, 2022, or associated USEPA RM, except the test date for EUENGINE3-2 was postponed until the September 13, 2022 due to delays in the relocation of the engine.

The test results summarized in Tables E-1 and E-2 indicate EUENGINE3-2 is operating in continuous compliance with 40 CFR Part 60, Subpart JJJJ and 40 CFR Part 63, Subpart ZZZZ, as specified in in Michigan Department of Environment, Great Lakes and Energy (EGLE), Renewable Operating Permit (ROP) MI-ROP-N3920-2022.

Detailed results are presented in Appendix Table 1. 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.

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

Engine/ Parameter	NO <sub>x</sub>		CO			VOC		
	ppmvd at 15% O <sub>2</sub>	g/hp- hr	ppmvd at 15% O <sub>2</sub>	g/hp-hr	% Reduction	ppmvd at 15% O <sub>2</sub>	g/hp-hr <sup>1</sup>	g/hp-hr <sup>2</sup>
EUENGINE3-2	41	0.5	10	0.07	95	4	0.4	0.04
JJJJ <sup>3</sup> Limits	82	1.0	270	2.0		60	0.7	
ZZZZ Limits					≥93			
ROP Limits		0.6		0.14				0.2

<sup>1</sup> Non-methane organic compounds (NMOC), as propane

<sup>2</sup> Non-methane, non-ethane organic compounds (NMNEOC), as propane

<sup>3</sup> Requirements for non-emergency engines greater than 500 brake HP, commencing construction after June 12, 2006 and manufactured on or after July 1, 2010

**Table E-2**  
**Summary of Operating Results**

Engine/Parameter	Catalyst Inlet Temp. <sup>1</sup> (°F)	Catalyst Press. Drop (inches)	Initial Catalyst Press. Drop (inches)
EUENGINE3-2	754	1.8	1.8
ZZZZ Limits	450-1350	±2 (from initial)	
ROP Limits	450-1350	±2 (from initial)	
<sup>1</sup> Compliance with the catalyst inlet temperature operating range is based on a 4-hour rolling average			

## 1.0 INTRODUCTION

This report summarizes compliance air emission results from tests conducted September 13, 2022, at the Consumers Energy 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 nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), and volatile organic compound (VOC) testing of a natural gas-fired 4-stroke lean-burn (4SLB), Waukesha Model 12V275GL reciprocating internal combustion engine (RICE) designated as EUENGINE3-2 at the Freedom Compressor Station in Manchester, Michigan.

A test protocol outlining the proposed testing and data quality objectives was submitted to EGLE on April 20, 2022, and subsequently approved by Ms. Regina Angellotti, Environmental Quality Analyst, in a letter dated May 5, 2022. There were no deviations from the approved stack test protocol or associated USEPA RM, except the test date for EUENGINE3-2 was postponed until the September 13, 2022 due to delays in the relocation of the engine.

### 1.2 PURPOSE OF TESTING

The purpose of the test program was to satisfy performance test requirements and evaluate compliance with 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", as incorporated in State of Michigan, ROP MI-ROP-N3920-2022. During testing, the engines operated within  $\pm 10$  percent of 100 percent peak (or highest achievable) load, as specified in 40 CFR §60.4244(a). EUENGINE3-2 is an associated emission unit of FGENGINE3-P3, FGNSPSJJJJ, and FGNESHAPZZZZ flexible groups within the Michigan Department of Environment, Great Lakes and Energy (EGLE), Renewable Operating Permit (ROP) MI-ROP-N3920-2022. The applicable emission limits and associated operating requirements are shown in Table 1-1 and Table 1-2.

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

Parameter	Emission Limit	Units	Applicable Requirement <sup>1,2,3</sup>
NO <sub>x</sub>	0.6	g/HP-hr	MI-ROP-N3920-2022, Flexible Group Conditions: FGENGINES-P3
	1.0	g/HP-hr	40 CFR Part 60, Subpart JJJJ, Table 1 MI-ROP-N3920-2022, Flexible Group Conditions: FGNSPSJJJJ
	82	ppmvd at 15% O <sub>2</sub>	40 CFR Part 60, Subpart JJJJ, Table 1 MI-ROP-N3920-2022, Flexible Group Conditions: FGNSPSJJJJ
CO	0.14	g/HP-hr	MI-ROP-N3920-2022, Flexible Group Conditions: FGENGINES-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	MI-ROP-N3920-2022, Flexible Group Conditions: FGNESHAPZZZZ 40 CFR §63.6300(b) – 40 CFR Part 63, Subpart ZZZZ, Table 2a
VOC	0.2	g/HP-hr	MI-ROP-N3920-2022, Flexible Group Conditions: FGENGINES-P3
	0.7	g/HP-hr	40 CFR Part 60, Subpart JJJJ, Table 1 MI-ROP-N3920-2022, Flexible Group Conditions: FGNSPSJJJJ
	60	ppmvd at 15% O <sub>2</sub>	40 CFR Part 60, Subpart JJJJ, Table 1 MI-ROP-N3920-2022, 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 MI-ROP-N3920-2022, Flexible Group Conditions: FGENGINES-P3, FGNSPSJJJJ, and FGNESHAPZZZZ.			

**Table 1-2  
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 <sup>†</sup>	≥450°F and ≤1350°F	±2" from Initial Performance Test	MI-ROP-N3920-2022, 40 CFR §63.6300(b) and Table 2a

<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 will be evaluated.

### 1.3 BRIEF DESCRIPTION OF SOURCE

EUENGINE3-2 is classified as a four-stroke lean-burn natural gas-fired, spark-ignition reciprocating internal combustion engine, which is located and operating at the Freedom Compressor Station in Manchester, Michigan. The engine is part of the flexible group FGENGINES-P3 as found in the FCS Michigan Department of Environment, Great Lakes and Energy (EGLE), Renewable Operating Permit (ROP) MI-ROP-N3920-2022.

### 1.4 CONTACT INFORMATION

Table 1-3 presents contact information of personnel involved in the test program.

**Table 1-3  
Contact Information**

Program Role	Contact	Address
Regulatory Agency Representative	Mr. Jeremiah Brown Unit Supervisor (Acting) 517-599-7825 <a href="mailto:BrownJ9@michigan.gov">BrownJ9@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 B. Glick Hwy Jackson, Michigan 49201-1556
State Technical Programs Field Inspector	Ms. Regina Angellotti Environmental Quality Analyst 313-418-0895 <a href="mailto:angellottir1@michigan.gov">angellottir1@michigan.gov</a>	EGLE – Detroit District Cadillac Place, Suite 2-300 3048 West Grand Blvd. Detroit, MI 48202-6058
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. Frank Rand Senior Environmental Analyst 734-807-0935 <a href="mailto:frank.randjr@cmsenergy.com">frank.randjr@cmsenergy.com</a>	Consumers Energy Company South Monroe Customer Service Center 7116 Crabb Road Temperance, MI 48182
Facility Representative	Ms. Tara Guenther Principle Technical Analyst Lead 734-482-2042 <a href="mailto:tara.guenther@cmsenergy.com">tara.guenther@cmsenergy.com</a>	Consumers Energy Company Freedom Compressor Station 12201 Pleasant Lake Road Manchester, Michigan 48158
Test Team Representative	Mr. Joe Gallagher Engineering Technical Analyst 231-720-4856 <a href="mailto:joseph.gallagher@cmsenergy.com">joseph.gallagher@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 operated within 10% of 100 percent peak (or the highest achievable) load. The performance testing was conducted with the engine operating at an average load >93% torque and >92% horsepower, based on the maximum manufacturer's design capacity at engine and compressor site conditions. Refer to Appendix D for detailed operating data.

### 2.2 APPLICABLE PERMIT INFORMATION

The Freedom Compressor Station operates in accordance with air permit MI-ROP-N3920-2022. EUENGINE3-2 is the emission unit source identification and is included in the FGENGINE3-P3 flexible group in Michigan Department of Environment, Great Lakes and Energy (EGLE), Renewable Operating Permit (ROP) MI-ROP-N3920-2022. 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 Tables 2-1 and 2-2 indicate the engine complies with the applicable emission limits and associated operating requirements.

Detailed results are presented in Appendix Table 1. 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.

**Table 2-1  
Summary of Test Results**

Engine/ Parameter	NO <sub>x</sub>		CO			VOC		
	ppmvd at 15% O <sub>2</sub>	g/hp-hr	ppmvd at 15% O <sub>2</sub>	g/hp-hr	% Reduction	ppmvd at 15% O <sub>2</sub>	g/hp-hr <sup>1</sup>	g/hp-hr <sup>2</sup>
EUENGINE3-2	41	0.5	10	0.07	95	4	0.4	0.04
JJJJ <sup>3</sup> Limits	82	1.0	270	2.0		60	0.7	
ZZZZ Limits					≥93			
ROP Limits		0.6		0.14				0.2

<sup>1</sup> Non-methane organic compounds (NMOC), as propane

<sup>2</sup> Non-methane, non-ethane organic compounds (NMNEOC), as propane

<sup>3</sup> Requirements for non-emergency engines greater than 500 brake HP, commencing construction after June 12, 2006 and manufactured on or after July 1, 2010

**Table 2-2  
Summary of Operating Results**

Parameter	Catalyst Inlet Temp. <sup>1</sup> (°F)	Catalyst Press. Drop (inches)	Initial Catalyst Press. Drop (inches)
EUENGINE3-2 Result	754	1.8	1.8
ZZZZ Limits	450-1350	±2 (from initial)	
ROP Limits	450-1350	±2 (from initial)	

<sup>1</sup> Compliance with the catalyst inlet temperature operating range is based on a 4-hour rolling average

## 3.0 SOURCE DESCRIPTION

EUENGINE3-2 is a 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>	EUENGINE3-2
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

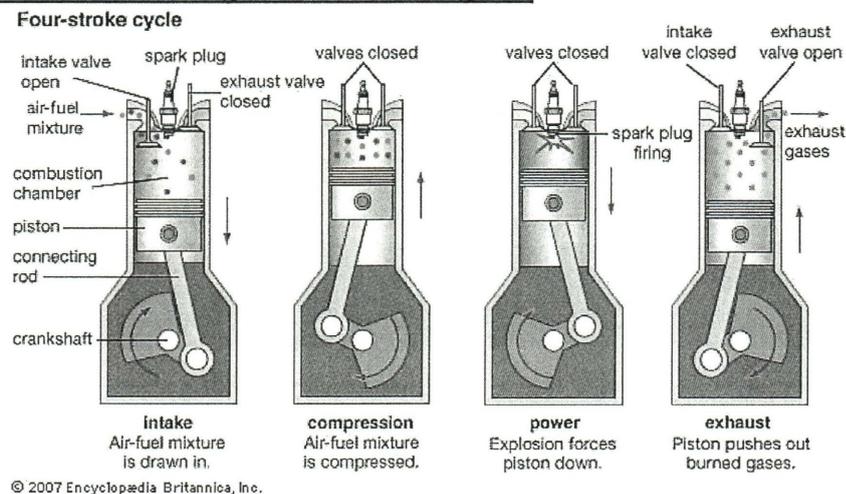
<sup>1</sup>Engine specifications are based upon vendor data for operation at 100% of rated engine capacity

### 3.1 PROCESS

EUENGINE3-2 is a natural gas-fired, spark ignited, 4SLB RICE installed in 2016 with initial startup on October 26, 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 using proprietary materials are installed on each engine exhaust stack 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 the engines. As the flue gas 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%. Optimization of the engine programming and synchronization with the compressor was recently completed.

NO<sub>x</sub> emissions from the engine are 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 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.

EUENGINE3-2 is a natural gas reciprocating engine 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, 7% ethane, 0.4% nitrogen, and 0.2% carbon dioxide.

### 3.4 RATED CAPACITY

EUENGINE3-2 has a maximum output 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 Compressor Torque (% max)
- Fuel gas flow (scfm)
- Suction pressure (psi)
- Discharge pressure (psi)
- Catalyst inlet temperature (°F)
- Pressure difference across oxidation catalyst (in. H<sub>2</sub>O)

During testing of EUENGINE3-2 the process data was recorded in 15-minute increments using a combination of engine parametric data loggers and manual readings of field instrumentation. The only exception is during the time period of 9 am to 10 am where increased granularity of the data was needed to calculate the engine torque during this time period. 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 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	7E	Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)
Carbon monoxide	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 (2022)	Run	Sample Type	Start Time (EST)	Stop Time (EST)	Test Duration (min)	EPA Test Method	Comment
<b>EUENGINE3-2</b>							
September 13	1	O <sub>2</sub> NO <sub>x</sub> CO CH <sub>4</sub> C <sub>2</sub> H <sub>6</sub> VOC	9:00	9:59	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		10:35	11:34	60		
	3		12:20	13:19	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*.

The 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 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 stainless steel gate valve approximately 4-inches outside the duct wall.

### Post-catalyst Sampling Ports

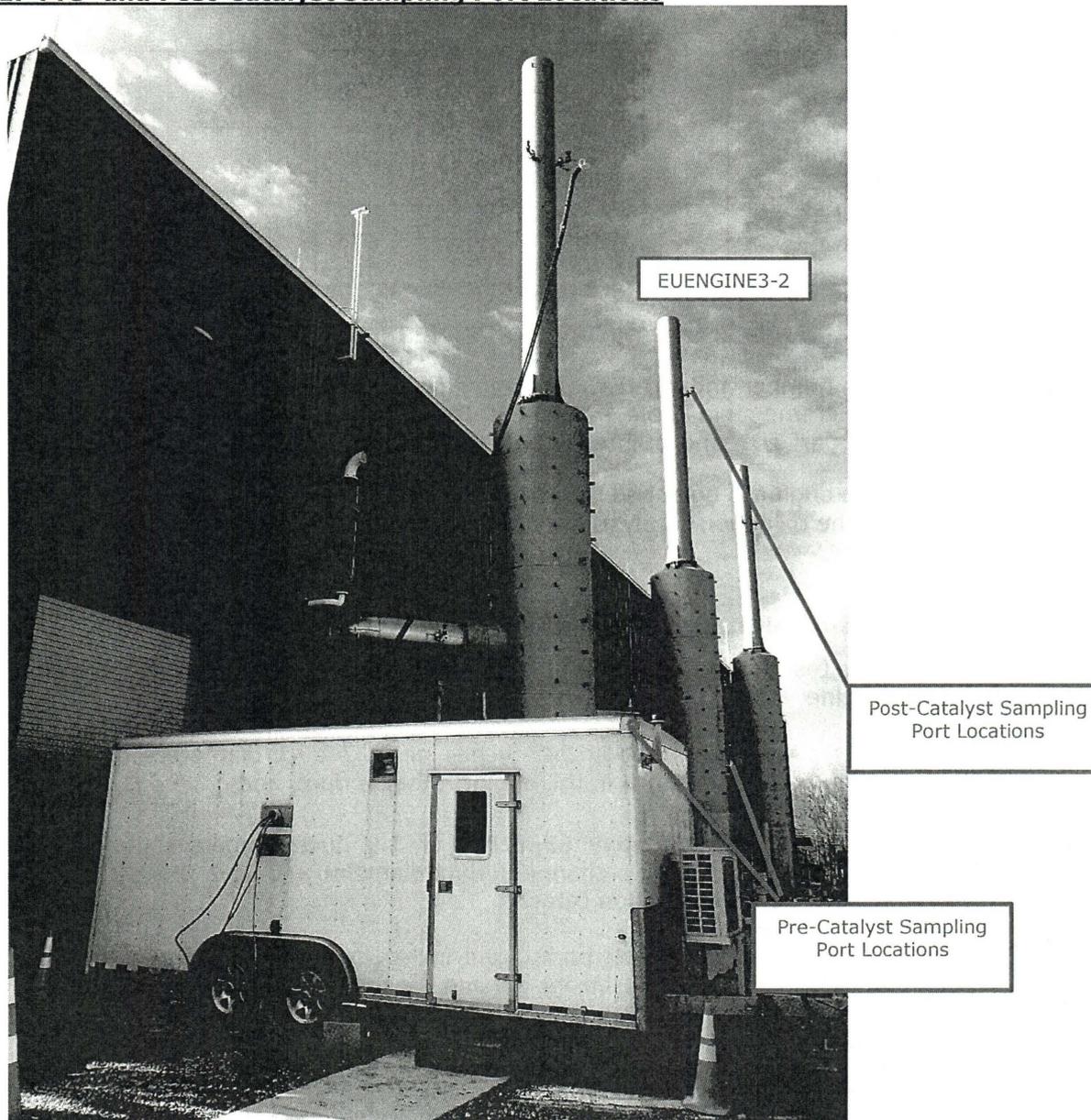
Two test ports are in a 30-inch vertical exhaust stack exiting the engine and oxidation catalyst. The post-catalyst sampling ports are situated:

- 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 stainless steel gate valve approximately 4-inches outside the stack wall.

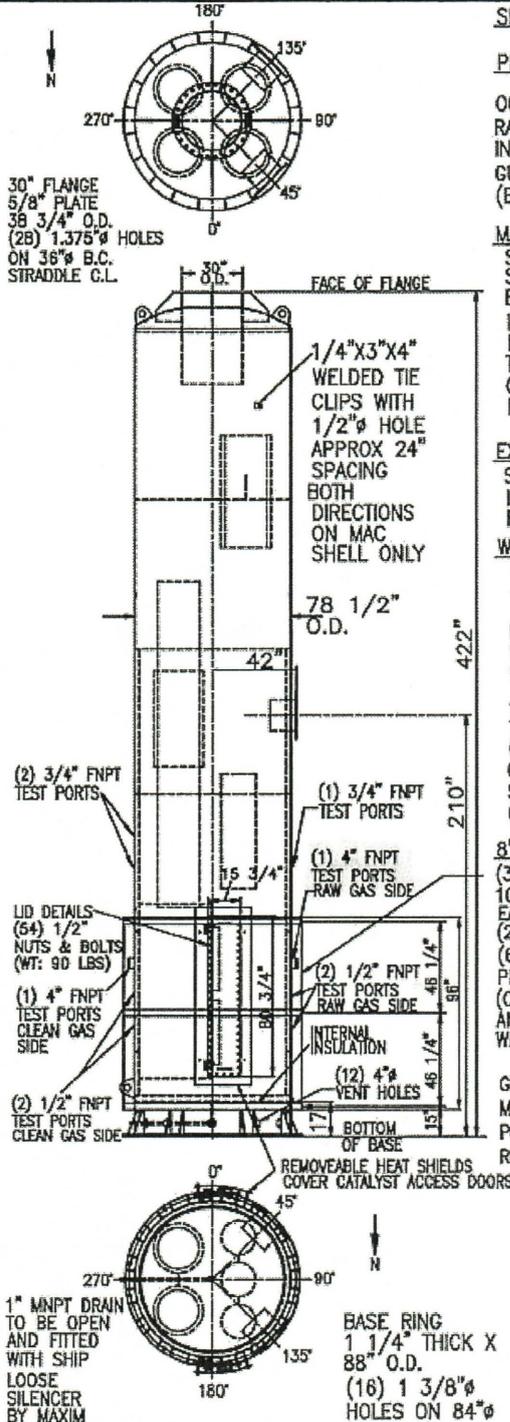
Because the ducts are >12 inches in diameter and the sampling port locations meet the two and half-diameter criterion of Section 11.1.1 of Method 1 of 40 CFR Part 60, Appendix A-1, the duct was sampled at 3 traverse points located at 16.7, 50.0, and 83.3% of the measurement line ('3-point long line'). 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 images are presented as Figures 4-1 and 4-2.

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



Photograph of engine location at Plant 3 Compressor

**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" φ  
 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:**

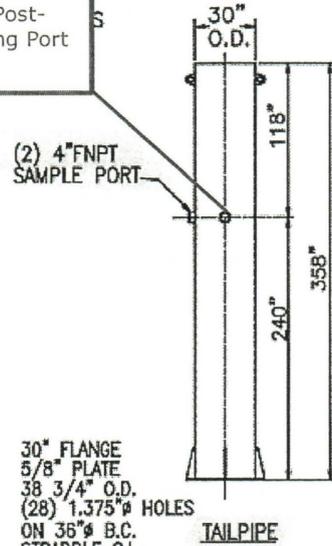
FREE STANDING  
 TAIL PIPE TO  
 UNIT DESIGNED  
 WITHSTAND 120  
 WIND LOAD

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

Approximate Post-Catalyst Sampling Port Location



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

**CERTIFICATION**

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



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**

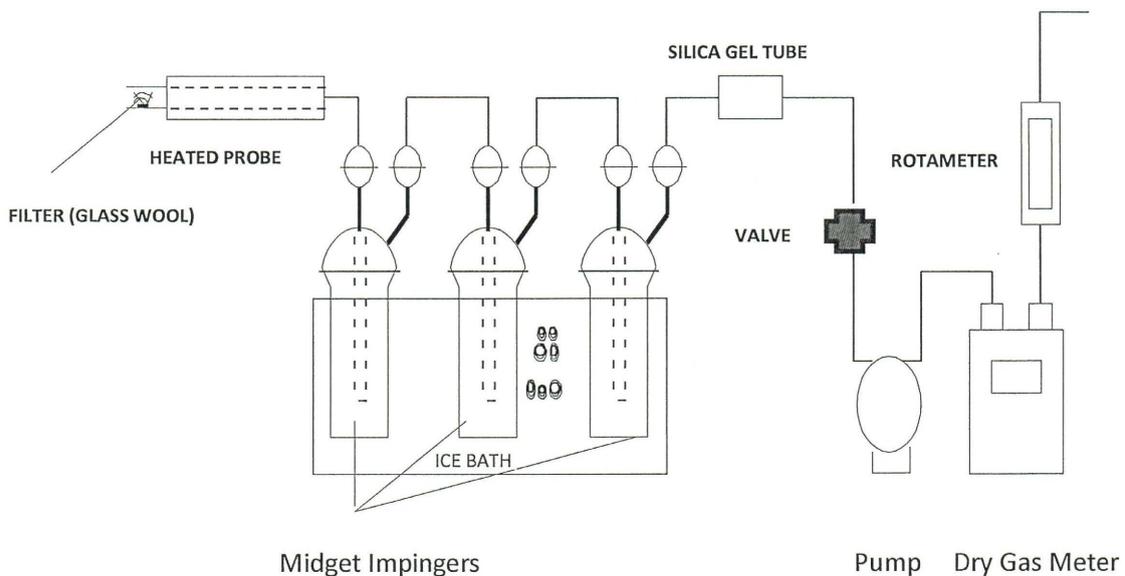
G	REVISE PORT ON TAILPIPE	FS	1/27/15
F	REVISED INLETS TO 16"	TF	1/7/16
E	REVISED INLETS TO 18" & UPDATED BP.	TF	12/30/15
D	REVISED FLOW RATE AND TEMPERATURE	TF	12/1/15
C	UPDATED ACOUSTICAL TABLE	TF	10/20/15
B	CORRECTED TAILPIPE HEIGHT DIMENSION	AC	09/18/15
A	ADDED INTERNAL INSULATION INFORMATION.	TF	09/18/15

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)

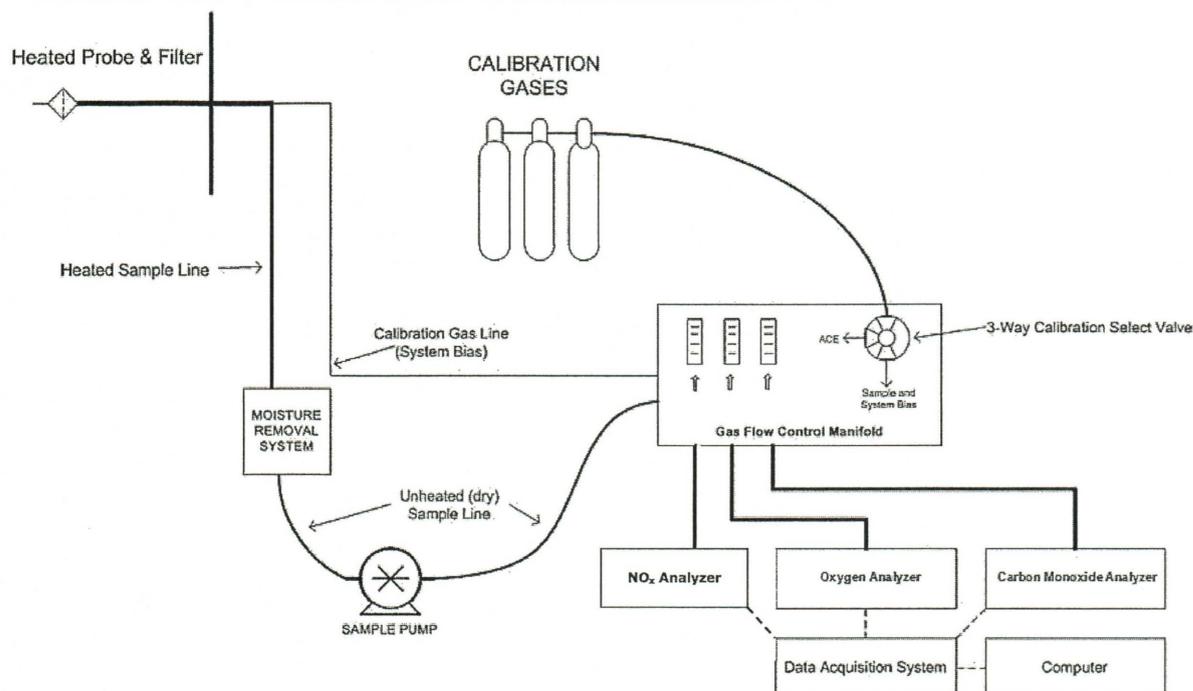
Oxygen, nitrogen oxides, and/or carbon monoxide concentrations were measured using the following sampling and analytical procedures:

- 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 except for 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.

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<sub>x</sub> and CO or 0.5% for O<sub>2</sub>.

#### 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 factor and exhaust gas flowrate.

A fuel sample was collected during testing and analyzed by gas chromatography, ultraviolet fluorescence, and electronic sensing cells to obtain hydrocarbons, non-hydrocarbons, heating value, and other parameters of the natural gas samples. The results were used to calculate F<sub>w</sub> and F<sub>d</sub> factors (ratios of combustion gas volumes to heat inputs) using USEPA Method 19 Equations 19-13, 19-14, and 19-15. This F<sub>d</sub> factor was 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<sub>s</sub> = stack flow rate (dscf/min)

F<sub>d</sub> = 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<sub>2</sub> = 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 the engine exhaust. The 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.

## 5.4 AIR POLLUTION CONTROL DEVICE MAINTENANCE

Other than routine 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.

## 5.5 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 63 Subpart ZZZZ and the ROP MI-ROP-N3920-2022
- every 8,760 engine operating hours or 3 years (2025), whichever is first, thereafter, to evaluate compliance with NO<sub>x</sub>, CO, and VOC emission limits in 40 CFR Part 60, Subpart JJJJ and ROP MI-ROP-N3920-2022. The engine hours after the conclusion of testing