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

EUENGINE3-1

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

July 28, 2022

Test Date: June 22, 2022

Test Performed by the Consumers Energy Company
Regulatory Compliance Testing Section
Air Emissions Testing Body
Laboratory Services Section
Work Orders 30288303
Version No.: 1.0

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EXECUTIVE SUMMARY

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted continuous compliance testing on EUENGINE3-1 at the Freedom Compressor Station in Manchester, Michigan on June 22, 2022.

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 FGENGINES-P3, FGNSPSJJJJ, and FGNESHAPZZZZ flexible groups within Permit to Install (PTI) 202-15A issued by the Michigan Department of Environment, Great Lakes and Energy (EGLE) on November 30, 2017, and subject to federal air emissions regulations.

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), and the PTI.

Three, 60-minute nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOC's), and oxygen (O_2) 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 is postponed until the Fall of 2022 due to delays in the relocation of the engine.

The test results summarized in Tables E-1 and E-2 indicate EUENGINE3-1 is operating in continuous compliance with 40 CFR Part 60, Subpart JJJJ and 40 CFR Part 63, Subpart ZZZZ, as specified in the PTI. 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_x		CO			VOC		
	ppmvd at 15% O_2	g/hp-hr	ppmvd at 15% O_2	g/hp-hr	% Reduction	ppmvd at 15% O_2	g/hp-hr[1]	g/hp-hr[2]
EUENGINE3-1	39	0.4	8	0.05	96.5	3	0.5	0.03
JJJJ[3] Limits	82	1.0	270	2.0		60	0.7	
ZZZZ Limits					≥93			
PTI Limits	82	0.6		0.14	≥93	60		0.2

[1] Non-methane organic compounds (NMOC), as propane
[2] Non-methane, non-ethane organic compounds (NMNEOC), as propane
[3] 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

Parameter	Catalyst Inlet Temp.[1] (°F)	Catalyst Press. Drop (inches)	Initial Catalyst Press. Drop (inches)
EUENGINE3-1 Result	776	2	1.3
ZZZZ Limits	450-1350	±2 (from initial)	
PTI Limits	450-1350	±2 (from initial)	
[1] 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 June 22, 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_x), 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 EUENGINE3-1 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 is postponed until the Fall of 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", and Permit to Install (PTI) 202-15A issued by the Michigan Department of Environment, Great Lakes and Energy (EGLE) on November 30, 2017. EUENGINE3-1 is an associated emissions unit of FGENGINES-P3, FGNSPSJJJJ, and FGNESHAPZZZZ flexible groups within the PTI. The applicable emission limits and associated operating requirements are shown in Table 1-1 and Table 1-2.

Table 1-1
FGENGINES-P3 Subpart JJJJ Requirements

Parameter	Emission Limit	Units	Applicable Requirement[1,2,3]
NO_x	0.6	g/HP-hr	PTI No. 202-15A, Flexible Group Conditions: FGENGINES-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_2	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: FGENGINES-P3
	2.0	g/HP-hr	40 CFR Part 60, Subpart JJJJ, Table 1
	270	ppmvd at 15% O_2	40 CFR Part 60, Subpart JJJJ, Table 1
VOC	0.2 (NMNEOC)	g/HP-hr	PTI No. 202-15A, Flexible Group Conditions: FGENGINES-P3
	0.7 (NMOC)	g/HP-hr	40 CFR Part 60, Subpart JJJJ, Table 1 PTI No. 202-15A, Flexible Group Conditions: FGNSPSJJJJ
	60	ppmvd at 15% O_2	40 CFR Part 60, Subpart JJJJ, Table 1 PTI No. 202-15A, Flexible Group Conditions: FGNSPSJJJJ

NO_x 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

[1] Owners and operators of stationary non-certified SI engines may choose to comply with the emission standards in units of either g/HP-hr or ppmvd at 15 percent O_2
[2] 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.
[3] Emissions limits from PTI No. 202-15A, Flexible Group Conditions: FGENGINES-P3, FGNSPSJJJJ, and FGNESHAPZZZZ.

Table 1-2
FGENGINES-P3 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

† 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_2 or reducing CO emissions by ≥93%. Compliance using the CO reduction efficiency emission limit will be evaluated.

1.3 Brief Description of Source

EUENGINE3-1 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 permit to install No. 202-15A.

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. Jeremy Howe Acting Supervisor 231-878-6687 howej1@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 B. Glick Hwy Jackson, Michigan 49201-1556
State Technical Programs Field Inspector	Ms. Regina Angellotti Environmental Quality Analyst 313-418-0895 angellottir1@michigan.gov	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 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
Field Environmental Coordinator	Mr. Frank Rand Senior Environmental Analyst 734-807-0935 frank.randjr@cmsenergy.com	Consumers Energy Company South Monroe Customer Service Center 7116 Crabb Road Temperance, MI 48182
Facility Leader	Ms. Tara Guenther Principle Technical Analyst Lead 734-482-2042 tara.guenther@cmsenergy.com	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 joseph.gallagher@cmsenergy.com	Consumers Energy Company L&D Training Center 17010 Croswell Street West Olive, Michigan 49460

2.0 SUMMARY OF RESULTS

2.1 Operating Data

During the performance test the engines fired natural gas and 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-N3920-2014b and PTI 202-15A. EUENGINE3-1 is the emission unit source identification and is included in the FGENGINES-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 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_x		CO			VOC[1]		
	ppmvd at 15% O_2	g/hp-hr	ppmvd at 15% O_2	g/hp-hr	% Reduction	ppmvd at 15% O_2	g/hp-hr[1]	g/hp-hr[2]
EUENGINE3-1	39	0.4	8	0.05	96.5	3	0.5	0.03
JJJJ[3] Limits	82	1.0	270	2.0		60	0.7	
ZZZZ Limits					≥93			
PTI Limits	82	0.6		0.14	≥93	60		0.2

[1] Non-methane organic compounds (NMOC), as propane
[2] Non-methane, non-ethane organic compounds (NMNEOC), as propane
[3] 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

Engine/Parameter	Catalyst Inlet Temp.[1] (°F)	Catalyst Press. Drop (inches)	Initial Catalyst Press. Drop (inches)
EUENGINE3-1	776	2	1.3
ZZZZ Limits	450-1350	±2 (from initial)	
PTI Limits	450-1350	±2 (from initial)	

[1] Compliance with the catalyst inlet temperature operating range is based on a 4-hour rolling average

3.0 SOURCE DESCRIPTION

EUENGINE3-1 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

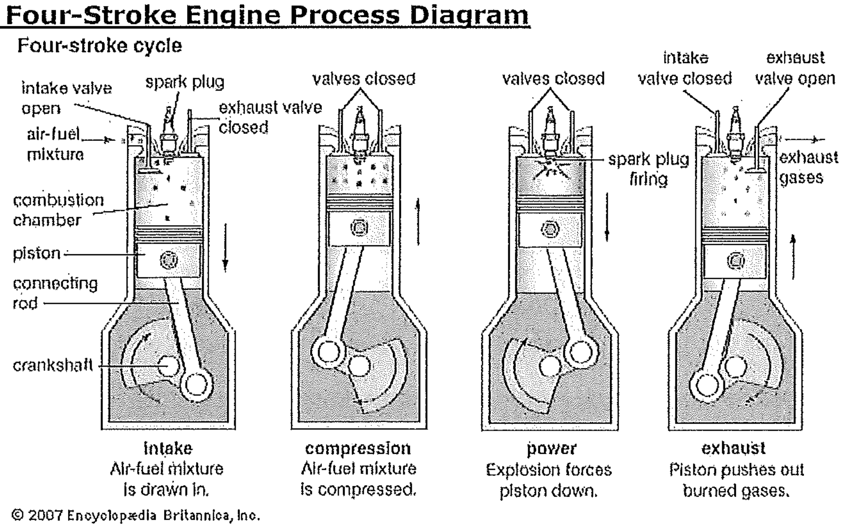
Parameter[1]	EUENGINE3-1
Make	Waukesha
Model	12V275GL
Output (brake-horsepower)	3,750
Heat Input, LHV (mmBtu/hr)	28.96
Exhaust Flow Rate (ACFM, wet)	23,373
Exhaust Gas Temp.	828
[1] Engine specifications are based upon vendor data for operation at 100% of rated engine capacity	

3.1 Process

EUENGINE3-1 is a 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_2 and water, while suppressing the conversion of NO to NO_2.

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 programing and synchronization with the compressor was recently completed.

NO_x 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_x 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.

EUENGINE3-1 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-feet 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

EUENGINE3-1 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 temperature (°F)
- Pressure difference across oxidation catalyst (in. H_2O)

During testing of EUENGINE3-1 the process data was recorded in 15-minute increments using a combination of engine parametric data loggers and manual readings of field instrumentation. Refer to Appendix D for this operating data.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

Triplicate one-hour test runs for NO_x, CO, VOC, and O_2 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_4) & Ethane (C_2H_6)	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
EUENGINE3-1							
June 22	1	O_2 NO_x CO CH_4 C_2H_6 VOC	9:06	10:05	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		10:30	11:29	60		
	3		11:53	12:52	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 bolted blank flange 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:

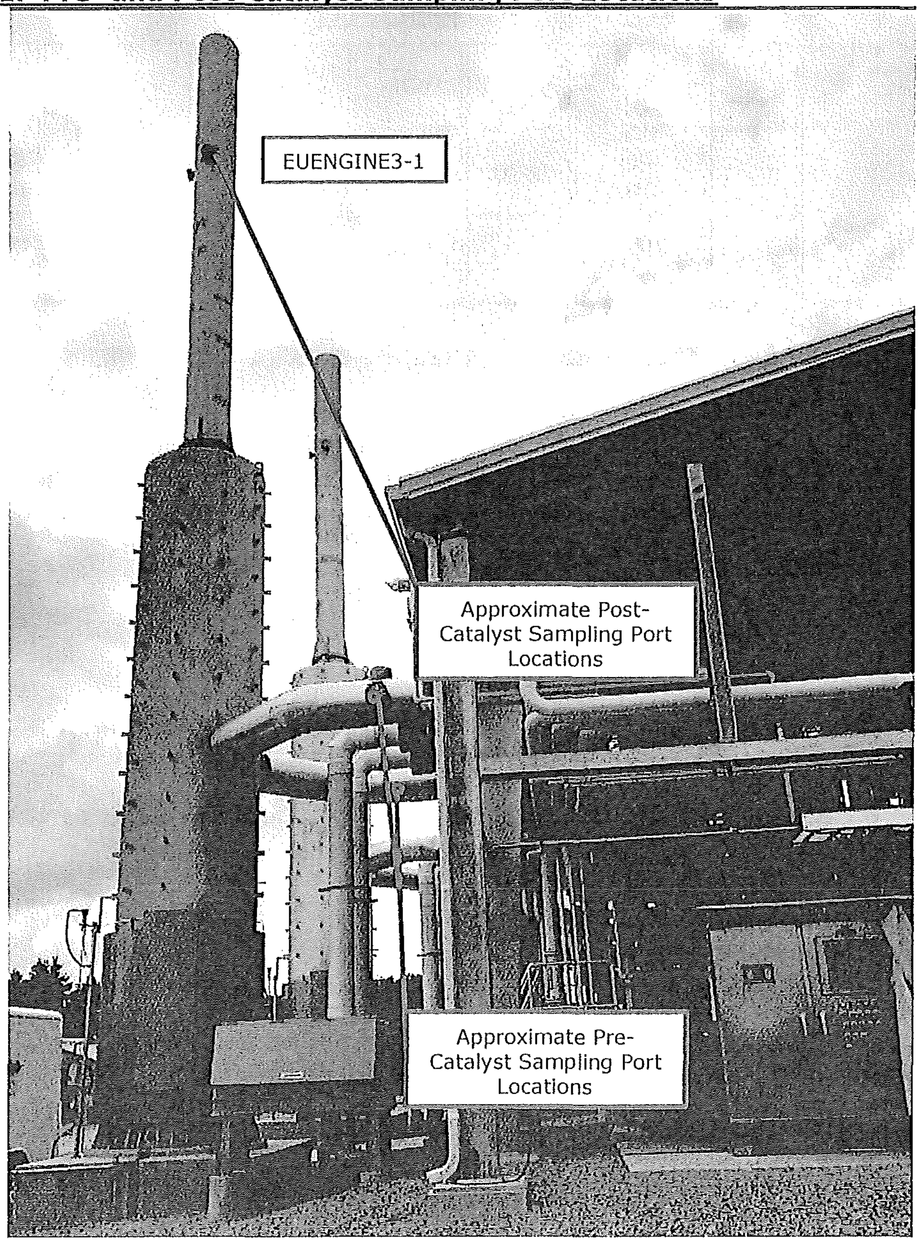
- Approximately 240-inches or 8.0 duct diameters downstream of a duct diameter change flow disturbance, and

- 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 bolted blank flange approximately 4-inches outside the stack wall.

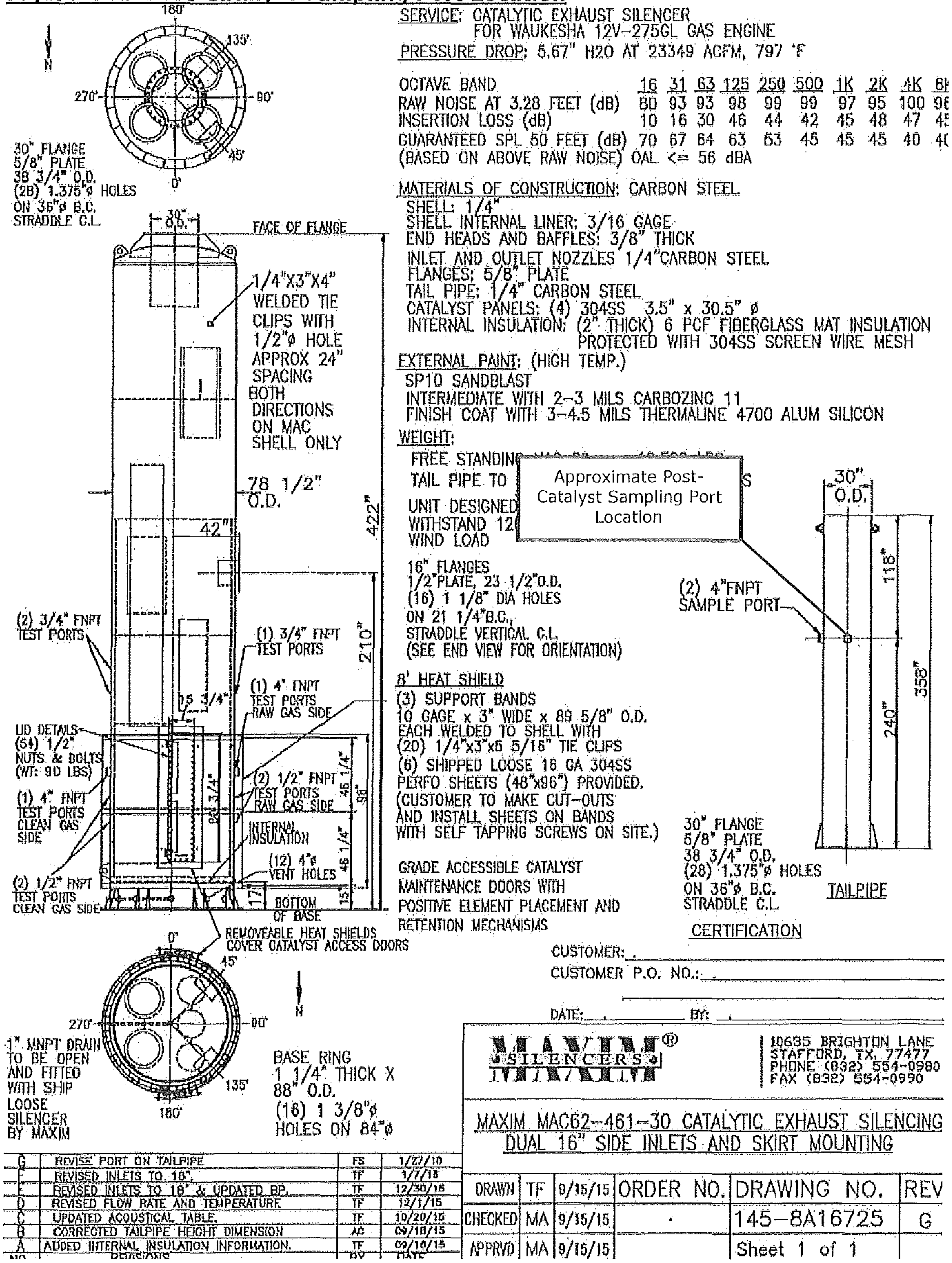
Because the ducts are >12 inches in diameter and the sampling port locations meet the two and half-diameter criterion of Section 11.1.1 of Method 1 of 40 CFR Part 60, Appendix A-1, the duct was sampled at 3 traverse points located at 16.7, 50.0, and 83.3% of the measurement line ('3-point long line').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

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



Photograph of engine prior to relocation to Plant 3

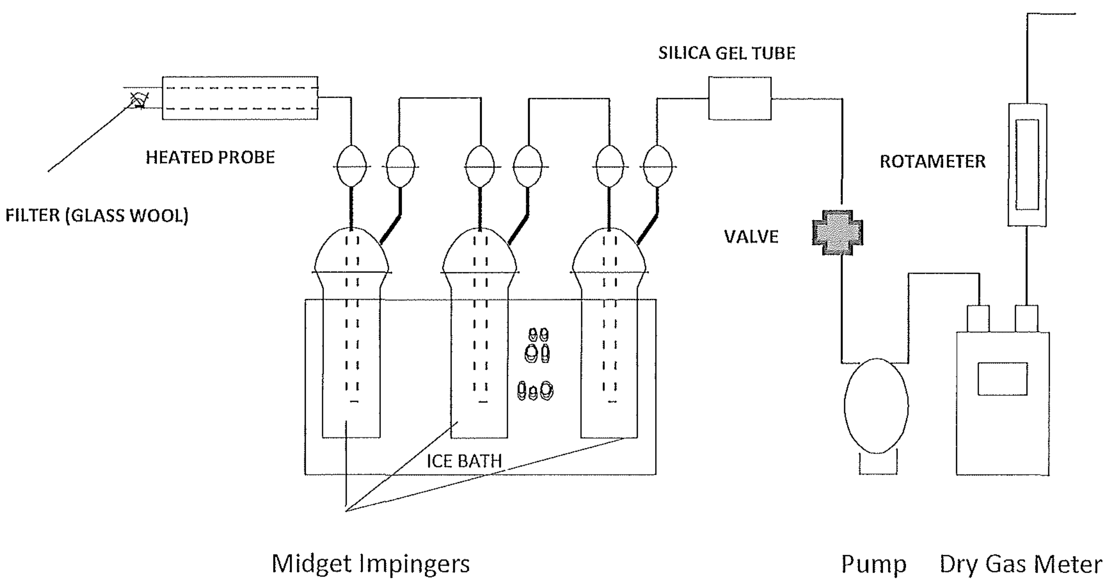
Figure 4-2. Post-Catalyst Sampling Port Location



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_2, NO_X, and CO (USEPA Methods 3A, 7E, and 10)

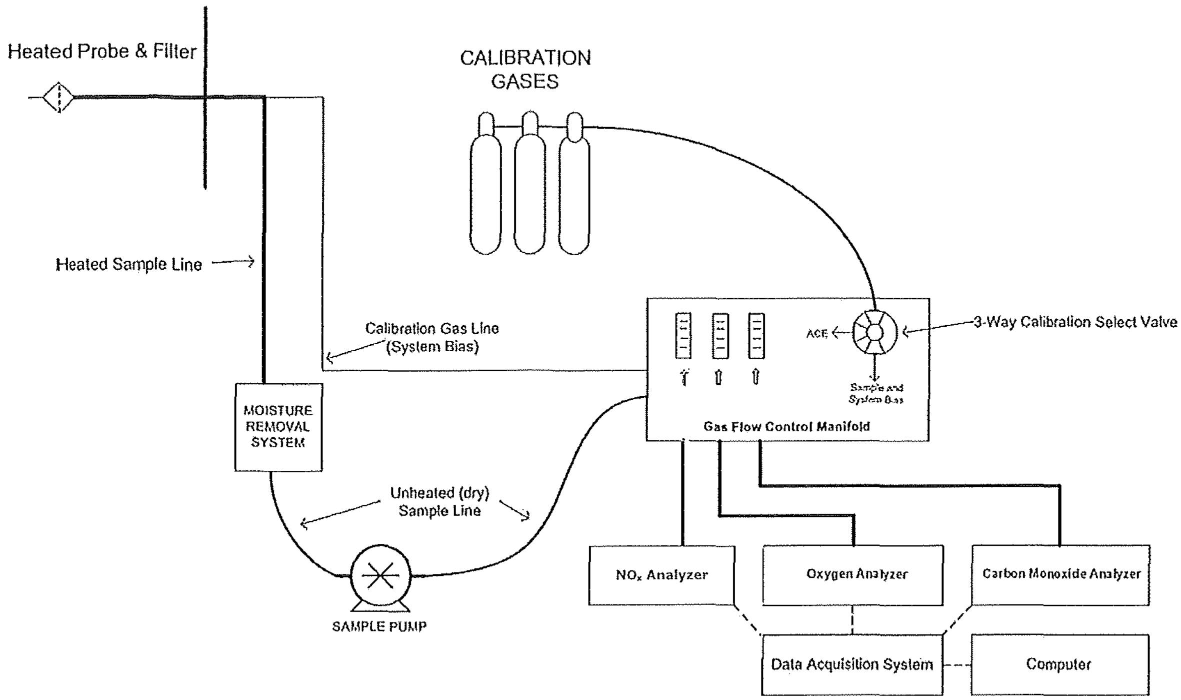
Oxygen, nitrogen oxides, and/or carbon monoxide concentrations were measured using the following sampling and analytical procedures:

- 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 ±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 ±5.0% of span.

A NO_2 to NO conversion efficiency test is 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.

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% 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 ±5.0% of span and drift is within ±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_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 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_w and F_d factors (ratios of combustion gas volumes to heat inputs) using USEPA Method 19 Equations 19-13, 19-14, and 19-15. This F_d factor was then used to calculate the emission flow rate with the corresponding equation presented in Figure 4-5. 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 = 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 (%)

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.

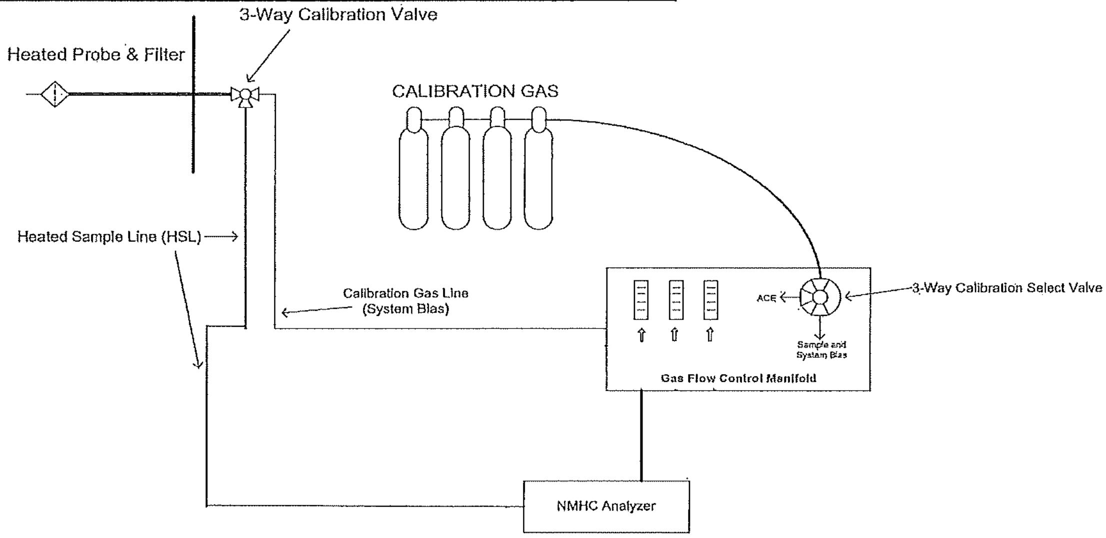
The field VOC instrument was calibrated with zero air and three propane and methane in air calibration gases following USEPA Method 25A procedures at the zero level, low (25 to 35 percent of calibration span), mid (45 to 55 percent of calibration span) and high (equivalent to 80 to 90 percent of instrument 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% $<R<$ 130%. 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 June 22, 2022, 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 EUENGINE3-1 is compliant with the applicable NO_x, CO, and VOC emissions limits and associated operating requirements as summarized in Table 2-1 and Table 2-2. Appendix Table 1 contains detailed tabulation of results, process operating conditions, and exhaust gas conditions.

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 62 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 sample of the exhaust gas was collected during each run. The measured ethane concentration was subtracted from the average 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.

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 PTI
- every 8,760 engine operating hours or 3 years (2025), whichever is first, thereafter, to evaluate compliance with NO_x, CO, and VOC emission limits in 40 CFR Part 60, Subpart JJJJ and the PTI. The engine hours after the conclusion of testing were:
  - EUENGINE3-1: 1064 hours

5.6 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 suitability of sampling location	Measure distance from ports to downstream and upstream flow disturbances	Pre-test	≥2 diameters downstream; ≥0.5 diameter upstream.
M1: Duct diameter/ dimensions	Verifies area of stack is accurately measured	Review as-built drawings and field measurement	Pre-test	Field measurement agreement with as-built drawings
M3A, M7E, M10, M25A: 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 analyzer operation	Calibration gases introduced directly into analyzers	Pre-test	±2.0% of span or ≤0.5 ppmv or ≤0.5 % abs. difference
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: ±5.0% of span Drift: ±3.0% of span or ≤ 0.5 ppmv or 0.5% abs. difference

Table 5-1
QA/QC Procedures

QA/QC Activity	Purpose	Procedure	Frequency	Acceptance Criteria
M7E: NO_2-NO converter efficiency	Evaluates NO_2-NO converter operation	NO_2 gas introduced directly into analyzer	Pre-test or Post-test	NO_x response ≤2% drop from peak value observed
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

5.7 Calibration Sheets

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

5.8 Sample Calculations

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

5.9 Field Data Sheets

Field data sheets are presented in Appendix B.

5.10 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.

5.11 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.

Appendix Table

Table 1
Freedom Compressor Station
EUENGINE3-1 Catalyst Inlet / Outlet Emission Rates and Process Data
June 22, 2022

Parameter	Average Result	
Exhaust Gas Moisture Content, %	10.0	
Diluent Concentrations and Emissions	**Inlet**	**Outlet**
O_2 Concentration, %, dry	11.8	11.7
Carbon Monoxide (CO) Concentrations and Emissions	**Inlet**	**Outlet**
CO Concentration, ppmvd	355.2	12.6
CO Concentration, ppmvd @15% O_2	230.6	8.1
CO Percent Reduction Efficiency, Percent:	96.49	
CO Emission Rate, lb/mmBtu	0.5065	0.0178
CO Emission Rate, lb/hr	12.3	0.4
CO Emission Rate, tpy	53.7	1.9
CO Concentration, g/HP-hr	1.54	0.05
Nitrogen Oxides (NO_x) Concentrations and Emissions	**Outlet**	
NO_x Concentration, ppvmd	61.2	
NO_x Concentration, ppmvd @ 15% O_2	39.3	
NO_x Emission Rate, lb/mmBtu:	0.1416	
NO_x Emission Rate, lb/hr:	3.4	
NO_x Emission Rate, tpy	15.0	
NO_x Emission Rate, g/HP-hr:	0.44	
VOC as Non-Methane Organic Compounds ($VOC_{as\ NMOC}$), Field Analysis	**Outlet**	
$VOC_{as\ NMOC}$ Concentration, ppmvw, as propane:	62.3	
$VOC_{as\ NMOC}$ Concentration, ppmvd, as propane:	69.2	
$VOC_{as\ NMOC}$ Concentration, ppmvd, as propane, @ 15% O_2:	44.4	
$VOC_{as\ NMOC}$ Emission Rate, lb/mmBtu:	0.2	
$VOC_{as\ NMOC}$ Emission Rate, lb/hr:	3.7	
$VOC_{as\ NMOC}$ Emission Rate, tpy:	16.3	
$VOC_{as\ NMOC}$ Emission Rate, g/HP-hr:	0.47	
Ethane Laboratory Analysis	**Outlet**	
Ethane Concentration, ppmvw as ethane:	84.6	
Ethane Concentration, ppmvw as propane:	57.7	
Ethane Concentration, ppmvd as propane:	64.1	
VOC as Non-Methane, Non-Ethane Organic Compounds ($VOC_{as\ NMNEOC}$)	**Outlet**	
$VOC_{as\ NMNEOC}$ Concentration, ppmvw, as propane:	4.6	
$VOC_{as\ NMNEOC}$ Concentration, ppmvd, as propane:	5.1	
$VOC_{as\ NMNEOC}$ Concentration, ppmvd, as propane, @ 15% O_2:	3.3	
$VOC_{as\ NMNEOC}$ Emission Rate, lb/mmBtu:	0.0114	
$VOC_{as\ NMNEOC}$ Emission Rate, lb/hr:	0.3	
$VOC_{as\ NMNEOC}$ Emission Rate, tpy:	1.2	
$VOC_{as\ NMNEOC}$ Emission Rate, g/HP-hr:	0.03	
Engine and Process Data		
Natural Gas Fuel Factor, F_c, scf/mmBtu:	1,012.9	
Natural Gas Fuel Factor, F_d, dscf/mmBtu:	8,527.4	
Engine Fuel Flow Rate, ft^3/min:	398	
Stack gas flow rate, dscfm:	7,616	
Engine Speed, RPM:	1,000	
Engine Torque, %:	93	
Engine Power, BHP:	3,475	

Appendix A
Sample Calculations

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Sample Calculations

Analyzer Calibrations, Drift Corrections (40 CFR 60, Appendix A, Method 7E)

Analyzer Calibration Error

Before beginning the test, a three-point analyzer calibration error (ACE) check is conducted on each analyzer by injecting zero, mid and high-level calibration gases directly into the instrument. The percent response is calculated in the following manner:

$$ACE = \frac{C_{Dir} - C_V}{CS} x100 \qquad [40\ CFR\ 60, App\ A, Method\ 7E, Eq. 7E-1$$

Where:

ACE	=	Analyzer calibration error, percent of calibration span
C_{Dir}	=	Measured concentration of a calibration gas (low, mid, or high) when introduced in direct calibration mode, ppmv or %
C_V	=	Manufacturer certified concentration of calibration gas (low, mid, or high), ppmv or %
CS	=	Calibration span, ppmv

The ACE must be within ±2.0% of the respective span or within 0.5 ppmv absolute difference to be acceptable.

System Bias

An initial system bias is then performed by measuring the instrument response while introducing zero and mid or high-level (upscale) calibration gases at the probe, upstream of all sample conditioning components, and drawing it through the various sample components in the same manner as flue gas. The initial bias is calculated for the low and upscale calibration gases in the following manner:

$$SB = \frac{C_S - C_{Dir}}{CS} \qquad 40\ CFR\ 60, App. A, Method\ 7E, Eq. 7E-2$$

Where:

SB	=	System bias, percent of calibration span
C_s	=	Measured concentration of a calibration gas (low, mid, high) when introduced in system calibration mode, ppmv or %
C_{Dir}	=	Measured concentration of a calibration gas (low, mid, or high) when introduced in direct calibration mode, ppmv or %

The initial system bias check is acceptable if the instrument response at the zero and upscale calibration is within ±5.0% of the calibration span or within 0.5 ppmv absolute difference. After each gaseous run, a final zero and upscale system bias check is performed using the calculation above.

Analyzer Drift

Analyzer drift is quantified and compensated using the following equation:

$$D = |SB_{Final} - SB_i| \qquad 40\ CFR\ 60, App\ A, Method\ 7E, Eq. 7E-4$$

Where:

D = Drift assessment, percent of calibration span
SB_{Final} = Post-run system bias, percent of calibration span
SB_i = Pre-run system bias, percent of calibration span

40 CFR 63, Subpart ZZZZ Calculations

Standardizing Concentration using Oxygen

After completing the final bias, the following calculation is used to determine pollutant concentrations, corrected to 15 percent O_2.

When O_2 is measured as the diluent gas, the pollutant concentration is adjusted to 15 percent O_2 in the following manner:

$$C_{adj} = C_d \frac{5.9}{20.9 - \%O_2}$$

Where:

C_{adj} = Pollutant concentration corrected to 15 percent O_2, ppmvd
C_d = Pollutant concentration measured, ppmd
$\%O_2$ = Measured O_2 concentration, %

Standardizing Concentration using Carbon Dioxide

When CO_2 is measured as the diluent gas, the following equation is used to determine the ratio of O_2 to the measured CO_2:

$$F_o = \frac{0.209 \times F_d}{F_c} \qquad 40\ CFR\ 63, Subpart\ ZZZZ\ Eq. 2$$

Where:

0.209 = Fraction of Air that is oxygen (% by volume)
F_o = Fuel Factor based upon the ratio of oxygen volume to the ultimate CO_2 volume produced by the fuel at 0% excess air (unitless)
F_d = Oxygen based Fuel Factor, dry (dscf/MMBtu)
F_c = Carbon dioxide based Fuel Factor, dry (dscf CO_2/MMBtu)

The CO_2 correction factor is then determined in the following manner:

$$X_{CO2} = \frac{5.9}{F_o} \qquad 40\ CFR\ 63, Subpart\ ZZZZ\ Eq. 3$$

Where:

X_{CO2} = CO_2 correction factor (percent)
5.9 = 20.9 percent O_2 – 15 percent O_2, the defined O_2 correction value (percent)

The CO concentration, corrected to 15 percent O_2 is then expressed in the following manner:

$$C_{adj} = C_d \times \frac{X_{CO_2}}{\%CO_2} \qquad 40\ CFR\ 63, Subpart\ ZZZZ\ Eq. 4$$

Where:

C_{adj} = Pollutant concentration corrected to 15% O_2 ppmvd
C_d = Pollutant concentration at actual O_2 concentration, ppmvd
% CO_2 = Measured CO_2 concentration, dry basis, percent.

CO percent reduction

After correcting the CO concentrations to 15 percent O2, the CO Percent Reduction is calculated using the equation in 40CFR63, Subpart ZZZZ, §63.6620(e)(1).

$$R = \frac{C_i - C_o}{C_i} \qquad 40\ CFR\ 63, Subpart\ ZZZZ\ Eq. 1$$

Where:

R = Percent reduction of CO emissions.
C_i = Concentration of CO at the control device inlet, ppmvd at 15% O2
C_o = Concentration of CO at the control device outlet, ppmvd at 15% O2

40 CFR 63, Subpart JJJJ Calculations

Emission Rate

The NO_x, CO, VOC, O_2, and/or CO_2 concentrations were first bias adjusted per the preceding equations. The g/HP-hr emissions rates would then be determined as follows:

$$ER = \frac{C_d \times K \times Q \times T}{HP - hr} \qquad 40\ CFR\ 63, Subpart\ JJJJ\ Eq. 1$$

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; $K_{NOx} = 1.912 \times 10^{-3}$; $K_{CO} = 1.164 \times 10^{-3}$; $K_{VOC} = 1.833 \times 10^{-3}$ (measured as propane)
Q	=	Stack gas volumetric flow rate, in standard cubic meter per hour, dry basis.
T	=	Time of test run, in hours.
HP-hr	=	Brake work of the engine, horsepower-hour (HP-hr).

Fuel Factors

If Method 19 is used to determine flow in lieu of Method 2, the following equations are employed to calculate test specific fuel factors and flow rates.

The dry oxygen based fuel factor (F_d) is calculated as follows:

$$F_d = \frac{K(K_{hd}\%H + K_G\%C + K_S\%S + K_n\%N - K_O\%O)}{GCV} \qquad 40\ CFR\ 60, App. A, Method\ 19, Eq. 19-13$$

Where:

F_d	=	Oxygen based volume of combustion components per unit of heat content, scf/mmBtu.
K	=	Conversion factor, 10^6 Btu/mmBtu
K_{hd}	=	3.64 scf/lb / %
%H	=	Concentration of hydrogen from the ultimate analysis of the fuel, weight percent
K_c	=	1.53 scf/lb / %
%C	=	Concentration of carbon from the ultimate analysis of the fuel, weight percent
K_s	=	0.57 scf/lb / %
%S	=	Concentration of sulfur from the ultimate analysis of the fuel, weight percent
K_n	=	0.14 scf/lb / %
%N	=	Concentration of nitrogen from the ultimate analysis of the fuel, weight percent
K_o	=	0.46 scf/lb / %
%O	=	Concentration of oxygen from the ultimate analysis of the fuel, weight percent
GCV	=	Gross calorific value of the fuel consistent with the ultimate analysis, Btu/lb

The carbon dioxide based fuel factor (F_c) is calculated as follows:

$$F_C = \frac{K(K_{cc}\%C)}{GCV} \qquad 40\ CFR\ 60, App. A, Method\ 19, Eq. 19-15$$

Where:

F_c	=	CO_2 based volume of combustion components per unit of heat content, scf/mmBtu.
K	=	Conversion factor, 10^6 Btu/mmBtu
K_{cc}	=	0.321 scf/lb / %
%C	=	Concentration of carbon from the ultimate analysis of the fuel, weight percent
GCV	=	Gross calorific value of the fuel consistent with the ultimate analysis, Btu/lb

The wet oxygen based fuel factor (F_w) is calculated as follows:

$$F_W = \frac{K[K_{hw}\%H + K_c\%C + K_s\%S + K_n\%N - K_O\%O + K_w\%H_2O]}{GCV_W} \qquad 40\ CFR\ 60, App. A, Method\ 19, Eq. 19-14$$

Where:

F_d	=	Oxygen based volume of combustion components per unit of heat content, scf/mmBtu.
K	=	Conversion factor, 10^6 Btu/mmBtu
K_{hw}	=	5.57 scf/lb / %
%H	=	Concentration of hydrogen from the ultimate analysis of the fuel, weight percent
K_c	=	1.53 scf/lb / %
%C	=	Concentration of carbon from the ultimate analysis of the fuel, weight percent
K_s	=	0.57 scf/lb / %
%S	=	Concentration of sulfur from the ultimate analysis of the fuel, weight percent
K_n	=	0.14 scf/lb / %
%N	=	Concentration of nitrogen from the ultimate analysis of the fuel, weight percent
K_o	=	0.46 scf/lb / %
%O	=	Concentration of oxygen from the ultimate analysis of the fuel, weight percent
K_w	=	0.21 scf/lb / %
$\%H_2O$	=	Concentration of water from the ultimate analysis of the fuel, weight percent
GCV	=	Gross calorific value of the fuel consistent with the ultimate analysis, Btu/lb

Moisture Content

The exhaust gas moisture content based on Method 4, Section 16.4 is calculated as follows:

$$B_{WS} = B_H + B_A + B_F$$

Where:

B_{WS}	=	Mole fraction of moisture in the stack gas
B_H	=	Mole fraction of moisture from the hydrogen in the fuel
B_A	=	Mole fraction of moisture in the ambient air
B_F	=	Mole fraction of moisture from free water in the fuel

$$B_A = \frac{\%\,RH}{100 P_{bar}\left[10^{\left[6.6912-\left(\frac{3144}{T+390.86}\right)\right]}\right]}$$

Where:

B_A	=	Mole fraction of moisture in the ambient air
P_{bar}	=	Barometric pressure, in. Hg
%RH	=	Percent relative humidity
T	=	Ambient temperature, °F

$$B_F = \left[\frac{0.0036W^2 + 0.075W}{100}\right]\left[\frac{20.9 - O_2}{20.9}\right]$$

Where:

B_F	=	Mole fraction of moisture from free water in the fuel
W	=	Percent free water in the fuel by weight, percent
O_2	=	Percent oxygen in the stack gas, dry basis, percent

$$B_H = \left(1 - \frac{F_d}{F_w}\right)\left(\frac{20.9 - O_2}{20.9}\right)$$

Where:

B_H	=	Mole fraction of moisture from the hydrogen in the fuel
F_d	=	Oxygen based volume of combustion components per unit of heat content, dry scf/mmBtu.
F_w	=	Oxygen based volume of combustion components per unit of heat content, wet scf/mmBtu.
O_2	=	Percent oxygen in the stack gas, dry basis, percent

Volumetric Flow Rate

The flow rate using the dry O_2 concentration and oxygen based fuel factor is as follows:

$$Q_s = F_d \times H \times \left(\frac{20.9}{20.9 - O_2}\right) \qquad \textit{Method 19 FAQ, Eq. 1}$$

Where:

Q_s	=	Stack gas flow rate, dscf/min
F_d	=	Oxygen based volume of combustion components per unit of heat content, scf/mmBtu.
H	=	Fuel heat input rate, as mmBtu/min, measured at the engine fuel feed line (usually calculated as the fuel feed rate in ft^3/min multiplied by the heat content in 10^6 Btu/ft^3
O_2	=	Stack oxygen concentration, dry basis percent by volume

Appendix B
Field Data Sheets

Freedom Compressor Station
EUENGINE3-1 Catalyst Inlet / Outlet Emission Rates and Process Data
Run 1
June 22, 2022

Run Time:	09:06-10:05	
Exhaust Gas Moisture Content, %	8.8	
Diluent Concentrations and Emissions	**Inlet**	**Outlet**
O_2 Concentration, %, dry	11.7	11.6
Carbon Monoxide (CO) Concentrations and Emissions	**Inlet**	**Outlet**
CO Concentration, ppmvd:	354.4	12.5
CO Concentration, ppmvd @15% O_2:	227.0	7.9
CO Percent Reduction Efficiency, Percent:	96.51	
CO Emission Rate, lb/mmBtu:	0.4986	0.0174
CO Emission Rate, lb/hr:	12.0	0.4
CO Emission Rate, tpy:	52.6	1.8
CO Concentration, g/HP-hr:	1.52	0.05
Nitrogen Oxides (NO_x) Concentrations and Emissions	**Outlet**	
NO_x Concentration, ppvmd:	60.6	
NO_x Concentration, ppmvd @ 15% O_2:	38.5	
NO_x Emission Rate, lb/mmBtu:	0.1387	
NO_x Emission Rate, lb/hr:	3.3	
NO_x Emission Rate, tpy:	14.6	
NO_x Emission Rate, g/HP-hr:	0.43	
VOC as Non-Methane Organic Compounds ($VOC_{as\ NMOC}$), Field Analysis	**Outlet**	
$VOC_{as\ NMOC}$ Concentration, ppmvw, as propane:	62.6	
$VOC_{as\ NMOC}$ Concentration, ppmvd, as propane:	68.7	
$VOC_{as\ NMOC}$ Concentration, ppmvd, as propane, @ 15% O_2:	43.6	
$VOC_{as\ NMOC}$ Emission Rate, lb/mmBtu:	0.1507	
$VOC_{as\ NMOC}$ Emission Rate, lb/hr:	3.6	
$VOC_{as\ NMOC}$ Emission Rate, tpy:	15.9	
$VOC_{as\ NMOC}$ Emission Rate, g/HP-hr:	0.46	
Ethane Laboratory Analysis	**Outlet**	
Ethane Concentration, ppmvw as ethane:	83.5	
Ethane Concentration, ppmvw as propane:	56.9	
Ethane Concentration, ppmvd as propane:	62.4	
VOC as Non-Methane, Non-Ethane Organic Compounds ($VOC_{as\ NMNEOC}$)	**Outlet**	
$VOC_{as\ NMNEOC}$ Concentration, ppmvw, as propane:	5.7	
$VOC_{as\ NMNEOC}$ Concentration, ppmvd, as propane:	6.3	
$VOC_{as\ NMNEOC}$ Concentration, ppmvd, as propane, @ 15% O_2:	4.0	
$VOC_{as\ NMNEOC}$ Emission Rate, lb/mmBtu:	0.0138	
$VOC_{as\ NMNEOC}$ Emission Rate, lb/hr:	0.3	
$VOC_{as\ NMNEOC}$ Emission Rate, tpy:	1.5	
$VOC_{as\ NMNEOC}$ Emission Rate, g/HP-hr:	0.04	
Engine and Process Data		
Natural Gas Fuel Factor, F_c, scf/mmBtu:	1,012.9	
Natural Gas Fuel Factor, F_d, dscf/mmBtu:	8,527.4	
Engine Fuel Flow Rate, ft^3/min:	396	
Stack gas flow rate, dscfm:	7,498	
Engine Speed, RPM:	1,000	
Engine Torque, %:	92	
Engine Power, BHP:	3,451	

Freedom Compressor Station
EUENGINE3-1 Catalyst Inlet / Outlet Emission Rates and Process Data
Run 2
June 22, 2022

Run Time:	10:30-11:29	
Exhaust Gas Moisture Content, %	11.1	
Diluent Concentrations and Emissions	**Inlet**	**Outlet**
O_2 Concentration, %, dry	11.8	11.7
Carbon Monoxide (CO) Concentrations and Emissions	**Inlet**	**Outlet**
CO Concentration, ppmvd	356.5	12.6
CO Concentration, ppmvd @15% O_2	232.1	8.1
CO Percent Reduction Efficiency, Percent:	96.50	
CO Emission Rate, lb/mmBtu	0.5097	0.0178
CO Emission Rate, lb/hr	12.3	0.4
CO Emission Rate, tpy	53.9	1.9
CO Concentration, g/HP-hr	1.55	0.05
Nitrogen Oxides (NO_x) Concentrations and Emissions	**Outlet**	
NO_x Concentration, ppvmd	61.2	
NO_x Concentration, ppmvd @ 15% O_2	39.4	
NO_x Emission Rate, lb/mmBtu:	0.1422	
NO_x Emission Rate, lb/hr:	3.4	
NO_x Emission Rate, tpy	15.0	
NO_x Emission Rate, g/HP-hr:	0.44	
VOC as Non-Methane Organic Compounds ($VOC_{as\ NMOC}$), Field Analysis	**Outlet**	
$VOC_{as\ NMOC}$ Concentration, ppmvw, as propane:	63.1	
$VOC_{as\ NMOC}$ Concentration, ppmvd, as propane:	71.0	
$VOC_{as\ NMOC}$ Concentration, ppmvd, as propane, @ 15% O_2:	45.7	
$VOC_{as\ NMOC}$ Emission Rate, lb/mmBtu:	0.1580	
$VOC_{as\ NMOC}$ Emission Rate, lb/hr:	3.8	
$VOC_{as\ NMOC}$ Emission Rate, tpy:	16.7	
$VOC_{as\ NMOC}$ Emission Rate, g/HP-hr:	0.48	
Ethane Laboratory Analysis	**Outlet**	
Ethane Concentration, ppmvw as ethane:	86.0	
Ethane Concentration, ppmvw as propane:	58.6	
Ethane Concentration, ppmvd as propane:	65.9	
VOC as Non-Methane, Non-Ethane Organic Compounds ($VOC_{as\ NMNEOC}$)	**Outlet**	
$VOC_{as\ NMNEOC}$ Concentration, ppmvw, as propane:	4.5	
$VOC_{as\ NMNEOC}$ Concentration, ppmvd, as propane:	5.1	
$VOC_{as\ NMNEOC}$ Concentration, ppmvd, as propane, @ 15% O_2:	3.3	
$VOC_{as\ NMNEOC}$ Emission Rate, lb/mmBtu:	0.0113	
$VOC_{as\ NMNEOC}$ Emission Rate, lb/hr:	0.27	
$VOC_{as\ NMNEOC}$ Emission Rate, tpy:	1.2	
$VOC_{as\ NMNEOC}$ Emission Rate, g/HP-hr:	0.03	
Engine and Process Data		
Natural Gas Fuel Factor, F_c, scf/mmBtu:	1,012.9	
Natural Gas Fuel Factor, F_d, dscf/mmBtu:	8,527.4	
Engine Fuel Flow Rate, ft^3/min:	397	
Stack gas flow rate, dscfm:	7,626	
Engine Speed, RPM:	1,000	
Engine Torque, %:	93	
Engine Power, BHP:	3,478	

Freedom Compressor Station
EUENGINE3-1 Catalyst Inlet / Outlet Emission Rates and Process Data
Run 3
June 22, 2022

Run Time:	11:53-12:52	
Exhaust Gas Moisture Content, %	10.1	
Diluent Concentrations and Emissions	**Inlet**	**Outlet**
O_2 Concentration, %, dry	11.9	11.8
Carbon Monoxide (CO) Concentrations and Emissions	**Inlet**	**Outlet**
CO Concentration, ppmvd	354.7	12.7
CO Concentration, ppmvd @15% O_2	232.7	8.2
CO Percent Reduction Efficiency, Percent:	96.46	
CO Emission Rate, lb/mmBtu	0.5111	0.0181
CO Emission Rate, lb/hr	12.5	0.4
CO Emission Rate, tpy	54.6	1.9
CO Concentration, g/HP-hr	1.55	0.06
Nitrogen Oxides (NO_x) Concentrations and Emissions	**Outlet**	
NO_x Concentration, ppvmd	61.8	
NO_x Concentration, ppmvd @ 15% O_2	39.9	
NO_x Emission Rate, lb/mmBtu:	0.1439	
NO_x Emission Rate, lb/hr:	3.5	
NO_x Emission Rate, tpy	15.4	
NO_x Emission Rate, g/HP-hr:	0.44	
VOC as Non-Methane Organic Compounds ($VOC_{as\ NMOC}$), Field Analysis	**Outlet**	
$VOC_{as\ NMOC}$ Concentration, ppmvw, as propane:	61.1	
$VOC_{as\ NMOC}$ Concentration, ppmvd, as propane:	68.0	
$VOC_{as\ NMOC}$ Concentration, ppmvd, as propane, @ 15% O_2:	43.9	
$VOC_{as\ NMOC}$ Emission Rate, lb/mmBtu:	0.1518	
$VOC_{as\ NMOC}$ Emission Rate, lb/hr:	3.7	
$VOC_{as\ NMOC}$ Emission Rate, tpy:	16.2	
$VOC_{as\ NMOC}$ Emission Rate, g/HP-hr:	0.47	
Ethane Laboratory Analysis	**Outlet**	
Ethane Concentration, ppmvw as ethane:	84.4	
Ethane Concentration, ppmvw as propane:	57.5	
Ethane Concentration, ppmvd as propane:	64.0	
VOC as Non-Methane, Non-Ethane Organic Compounds ($VOC_{as\ NMNEOC}$)	**Outlet**	
$VOC_{as\ NMNEOC}$ Concentration, ppmvw, as propane:	3.6	
$VOC_{as\ NMNEOC}$ Concentration, ppmvd, as propane:	4.0	
$VOC_{as\ NMNEOC}$ Concentration, ppmvd, as propane, @ 15% O_2:	2.6	
$VOC_{as\ NMNEOC}$ Emission Rate, lb/mmBtu:	0.0090	
$VOC_{as\ NMNEOC}$ Emission Rate, lb/hr:	0.2	
$VOC_{as\ NMNEOC}$ Emission Rate, tpy:	1.0	
$VOC_{as\ NMNEOC}$ Emission Rate, g/HP-hr:	0.03	
Engine and Process Data		
Natural Gas Fuel Factor, F_c, scf/mmBtu:	1,012.9	
Natural Gas Fuel Factor, F_d, dscf/mmBtu:	8,527.4	
Engine Fuel Flow Rate, ft^3/min:	401	
Stack gas flow rate, dscfm:	7,724	
Engine Speed, RPM:	1,001	
Engine Torque, %:	93	
Engine Power, BHP:	3,496	

Run 1

Freedom Compressor Station
EUENGINE3-1 Catalyst Inlet

Date: 06/22/22

Reading	Logger Time	O2 %	CO ppm
1	9:06	11.7	347.7
2	9:07	11.7	348.5
3	9:08	11.6	347.2
4	9:09	11.6	347.6
5	9:10	11.7	347.6
6	9:11	11.6	347.5
7	9:12	11.8	347.6
8	9:13	11.6	346.8
9	9:14	11.7	347.0
10	9:15	11.7	347.9
11	9:16	11.7	348.2
12	9:17	11.7	348.8
13	9:18	11.7	348.9
14	9:19	11.7	347.6
15	9:20	11.7	348.1
16	9:21	11.8	347.2
17	9:22	11.7	347.5
18	9:23	11.7	348.5
19	9:24	11.6	348.4
20	9:25	11.7	347.5
21	9:26	11.7	348.4
22	9:27	11.7	349.2
23	9:28	11.7	348.9
24	9:29	11.7	348.9
25	9:30	11.7	349.4
26	9:31	11.7	349.1
27	9:32	11.7	349.7
28	9:33	11.6	348.4
29	9:34	11.7	348.7
30	9:35	11.7	350.0
31	9:36	11.7	350.3
32	9:37	11.3	350.5
33	9:38	11.7	348.9
34	9:39	11.7	350.3
35	9:40	11.7	349.8
36	9:41	11.7	350.0
37	9:42	11.7	349.1
38	9:43	11.7	349.8
39	9:44	11.7	349.6
40	9:45	11.7	348.4
41	9:46	11.5	348.8
42	9:47	11.7	350.1
43	9:48	11.7	349.7
44	9:49	11.7	350.3
45	9:50	11.6	349.5
46	9:51	11.8	349.5
47	9:52	11.8	350.3
48	9:53	11.7	349.2
49	9:54	11.7	349.8
50	9:55	11.6	351.2
51	9:56	11.7	350.4
52	9:57	11.7	350.0
53	9:58	11.7	349.2
54	9:59	11.7	350.7
55	10:00	11.7	349.6
56	10:01	11.7	349.8
57	10:02	11.7	348.8
58	10:03	11.7	349.9
59	10:04	11.7	349.7
60	10:05	11.7	350.1
Uncorrected Average		11.68	349.00
Pre-test Zero	8:25	-0.02	-0.12
Pre-test Upscale	8:37	9.01	454.61
Post-test Zero	10:13	0.02	0.09
Post-test Upscale	10:18	9.01	446.95
C_o		0.00	-0.02
C_m		9.01	450.78
Corrected Average		11.69	354.36

Corrected to Lb/mmBtu			0.4986
Corrected to 15 O2%			227.02
Calibration Gas Used			
	Zero Gas	0.00	0.00
	Upscale Gas	9.015	457.70
Calibration Drift (must be =< 3%)			
	Zero Drift	0.20%	0.02%
	Upscale Drift	-0.04%	-0.85%
Bias (must be < 5.0%)	Initial Bias, Zero	0.77%	0.02%
	Final Bias, Zero	0.57%	0.00%
	Initial Bias, Upscale	0.72%	0.18%
	Final Bias, Upscale	0.76%	1.03%

Freedom Compressor Station
EUENGINE3-1 Catalyst Inlet

Run 2 — Date: 06/22/22

Reading	Logger Time	O2 %	CO ppm
1	10:30	11.8	349.0
2	10:31	11.9	347.6
3	10:32	11.9	349.3
4	10:33	11.8	348.5
5	10:34	11.9	350.0
6	10:35	11.9	348.5
7	10:36	11.8	350.8
8	10:37	11.8	352.2
9	10:38	11.8	350.1
10	10:39	11.8	349.0
11	10:40	11.8	348.5
12	10:41	11.9	349.4
13	10:42	11.8	350.2
14	10:43	11.9	348.8
15	10:44	11.9	348.3
16	10:45	11.8	349.4
17	10:46	11.9	349.7
18	10:47	11.8	350.3
19	10:48	12.0	349.4
20	10:49	11.9	348.8
21	10:50	11.9	348.5
22	10:51	11.9	348.9
23	10:52	11.9	348.4
24	10:53	11.8	348.8
25	10:54	11.9	350.4
26	10:55	11.9	349.0
27	10:56	11.9	349.5
28	10:57	11.9	349.4
29	10:58	11.9	349.9
30	10:59	11.9	350.0
31	11:00	11.9	350.5
32	11:01	11.9	350.4
33	11:02	11.9	349.8
34	11:03	12.0	349.0
35	11:04	11.9	348.9
36	11:05	11.9	348.7
37	11:06	11.9	348.8
38	11:07	11.9	348.9
39	11:08	11.9	347.5
40	11:09	12.0	348.7
41	11:10	11.9	349.6
42	11:11	11.9	348.4
43	11:12	11.9	348.5
44	11:13	12.0	347.9
45	11:14	12.0	349.4
46	11:15	12.0	348.4
47	11:16	12.0	348.6
48	11:17	11.9	348.4
49	11:18	12.0	348.8
50	11:19	12.0	348.5
51	11:20	12.0	349.0
52	11:21	12.0	348.6
53	11:22	12.0	349.1
54	11:23	12.0	348.4
55	11:24	12.0	347.9
56	11:25	12.0	348.5
57	11:26	12.0	348.9
58	11:27	12.0	349.2
59	11:28	12.0	349.4
60	11:29	12.0	348.8
Uncorrected Average		11.91	349.10
Pre-test Zero	10:13	0.02	0.09
Pre-test Upscale	10:18	9.01	446.95
Post-test Zero	11:33	0.39	0.18
Post-test Upscale	11:36	9.24	449.41
C_o		0.20	0.14
C_m		9.12	448.18
Corrected Average		11.84	356.49

Corrected to Lb/mmBtu			0.5097
Corrected to 15 O2%			232.11
Calibration Gas Used			
	Zero Gas	0.00	0.00
	Upscale Gas	9.015	457.70
Calibration Drift (must be =< 3%)			
	Zero Drift	1.82%	0.01%
	Upscale Drift	1.14%	0.27%
Bias (must be < 5.0%)	Initial Bias, Zero	0.57%	0.00%
	Final Bias, Zero	1.25%	0.01%
	Initial Bias, Upscale	0.76%	1.03%
	Final Bias, Upscale	0.38%	0.75%

Run 3

Freedom Compressor Station
EUENGINE3-1 Catalyst Inlet

Date: 06/22/22

Reading	Logger Time	O2 %	CO ppm
1	11:53	12.1	349.9
2	11:54	12.0	351.1
3	11:55	12.0	349.7
4	11:56	12.0	349.6
5	11:57	11.9	350.7
6	11:58	11.8	350.0
7	11:59	12.0	350.6
8	12:00	12.0	349.9
9	12:01	12.1	349.8
10	12:02	12.0	350.5
11	12:03	12.0	351.4
12	12:04	12.1	350.8
13	12:05	11.9	349.8
14	12:06	12.0	349.9
15	12:07	12.0	351.0
16	12:08	12.0	349.3
17	12:09	12.0	348.7
18	12:10	11.9	350.7
19	12:11	12.0	349.8
20	12:12	12.1	348.5
21	12:13	11.9	349.2
22	12:14	12.1	350.6
23	12:15	12.1	350.2
24	12:16	12.0	349.7
25	12:17	12.0	350.1
26	12:18	12.0	349.6
27	12:19	11.9	350.1
28	12:20	12.1	349.3
29	12:21	11.9	350.2
30	12:22	12.0	350.4
31	12:23	12.0	349.3
32	12:24	12.0	350.1
33	12:25	12.1	350.2
34	12:26	12.0	349.0
35	12:27	11.1	350.4
36	12:28	12.0	349.6
37	12:29	12.0	349.1
38	12:30	12.0	350.2
39	12:31	12.0	348.8
40	12:32	12.0	350.4
41	12:33	12.0	349.6
42	12:34	11.9	350.7
43	12:35	12.0	350.2
44	12:36	12.1	350.5
45	12:37	12.0	347.0
46	12:38	12.0	349.3
47	12:39	12.1	349.8
48	12:40	12.0	348.8
49	12:41	12.1	350.8
50	12:42	12.0	349.8
51	12:43	12.0	350.5
52	12:44	12.0	350.3
53	12:45	12.0	349.5
54	12:46	12.0	348.5
55	12:47	12.1	352.4
56	12:48	12.0	349.5
57	12:49	12.0	348.5
58	12:50	12.0	349.4
59	12:51	12.1	350.1
60	12:52	12.1	349.4
Uncorrected Average		11.99	349.88
Pre-test Zero	11:33	0.39	0.18
Pre-test Upscale	11:36	9.24	449.41
Post-test Zero	12:57	0.39	0.07
Post-test Upscale	13:01	9.11	453.42
C_o		0.39	0.13
C_m		9.17	451.42
Corrected Average		11.91	354.72

Corrected to Lb/mmBtu			0.5111
Corrected to 15 O2%			232.74
Calibration Gas Used			
	Zero Gas	0.00	0.00
	Upscale Gas	9.015	457.70
Calibration Drift (must be =< 3%)			
	Zero Drift	0.01%	-0.01%
	Upscale Drift	-0.61%	0.44%
Bias (must be < 5.0%)	Initial Bias, Zero	1.25%	0.01%
	Final Bias, Zero	1.26%	0.00%
	Initial Bias, Upscale	0.38%	0.75%
	Final Bias, Upscale	0.23%	0.31%

Run 1

Freedom Compressor Station
EUENGINE3-1 Catalyst Outlet

Date: 06/22/22

Reading	Logger Time	NOx ppm	O2 %	CO ppm	NMOC ppm
1	9:06	60.9	11.6	12.3	65.7
2	9:07	60.5	11.6	12.3	65.6
3	9:08	59.8	11.7	12.3	65.5
4	9:09	61.1	11.7	12.3	65.2
5	9:10	60.5	11.8	12.2	65.2
6	9:11	60.5	11.8	12.2	65.3
7	9:12	59.9	11.7	12.3	65.5
8	9:13	60.5	11.8	12.3	65.5
9	9:14	60.5	11.7	12.3	65.1
10	9:15	60.7	11.7	12.3	65.5
11	9:16	60.1	11.7	12.2	64.8
12	9:17	60.5	11.7	12.2	65.0
13	9:18	60.8	11.8	12.2	64.9
14	9:19	60.6	11.7	12.2	64.9
15	9:20	61.5	11.7	12.2	65.0
16	9:21	61.6	11.6	12.2	65.1
17	9:22	61.0	11.7	12.2	65.0
18	9:23	61.5	11.6	12.2	65.1
19	9:24	60.7	11.7	12.2	65.2
20	9:25	61.3	11.7	12.2	65.7
21	9:26	60.4	11.6	12.3	65.5
22	9:27	60.8	11.6	12.3	65.0
23	9:28	60.5	11.7	12.2	65.1
24	9:29	60.1	11.8	12.2	62.7
25	9:30	60.3	11.7	12.3	61.8
26	9:31	61.2	11.6	12.3	63.8
27	9:32	60.9	11.7	12.3	64.4
28	9:33	61.6	11.8	12.2	64.3
29	9:34	61.8	11.6	12.3	64.8
30	9:35	60.7	11.7	12.3	65.0
31	9:36	60.8	11.7	12.3	62.7
32	9:37	60.9	11.6	12.3	56.7
33	9:38	60.6	11.8	12.2	52.4
34	9:39	61.2	11.7	12.3	53.9
35	9:40	60.9	11.6	12.3	57.3
36	9:41	61.0	11.7	12.3	59.1
37	9:42	61.4	11.8	12.3	60.0
38	9:43	60.8	11.6	12.3	59.8
39	9:44	60.8	11.6	12.3	60.4
40	9:45	61.7	11.7	12.3	60.5
41	9:46	61.4	11.6	12.4	60.8
42	9:47	60.7	11.8	12.4	60.7
43	9:48	60.9	11.8	12.4	60.8
44	9:49	60.8	11.6	12.5	61.5
45	9:50	60.7	11.7	12.4	61.9
46	9:51	61.1	11.6	12.4	62.5
47	9:52	61.0	11.6	12.4	61.9
48	9:53	60.9	11.6	12.4	62.6
49	9:54	60.1	11.7	12.4	63.2
50	9:55	61.7	11.8	12.5	64.0
51	9:56	61.0	11.7	12.5	65.2
52	9:57	60.9	11.7	12.4	64.9
53	9:58	61.1	11.7	12.4	64.0
54	9:59	61.7	11.7	12.5	64.2
55	10:00	60.9	11.7	12.5	63.7
56	10:01	60.3	11.6	12.5	63.9
57	10:02	61.2	11.7	12.4	63.8
58	10:03	61.6	11.7	12.5	52.4
59	10:04	61.3	11.6	12.5	39.0
60	10:05	60.2	11.8	12.5	46.0
Uncorrected Average		60.87	11.69	12.32	62.28
Pre-test Zero	8:25	0.03	-0.01	0.08	0.45
Pre-test Upscale	8:37	50.41	9.21	24.51	94.82
Post-test Zero	10:13	0.60	0.12	-0.07	0.46
Post-test Upscale	10:18	50.00	8.97	24.12	94.74
C_o		0.32	0.06	0.01	0.46
C_m		50.21	9.09	24.32	94.78
Corrected Average		60.57	11.61	12.47	62.62

		NOx	O2	CO	NMOC
Corrected to Lb/mmBtu		0.1387		0.0174	
Corrected to 15 O2%		38.46		7.92	
Calibration Gas Used					
	Zero Gas	0.00	0.00	0.00	0.00
	Upscale Gas	49.90	9.015	24.61	95.54
Calibration Drift (must be =< 3%)					
	Zero Drift	0.58%	0.65%	-0.30%	0.01%
	Upscale Drift	-0.41%	-1.19%	-0.78%	-0.04%
Bias (must be < 5.0%)	Initial Bias, Zero	0.03%	0.05%	0.16%	0.23%
	Final Bias, Zero	0.61%	0.60%	0.14%	0.23%
	Initial Bias, Upscale	0.56%	1.29%	0.06%	0.00%
	Final Bias, Upscale	0.15%	0.09%	0.72%	0.04%

Freedom Compressor Station
EUENGINE3-1 Catalyst Outlet

Run 2 Date: 06/22/22

Reading	Logger Time	NOx ppm	O2 %	CO ppm	NMOC ppm
1	10:30	60.2	11.6	12.4	64.3
2	10:31	61.5	11.7	12.4	64.5
3	10:32	61.9	11.6	12.3	64.3
4	10:33	60.9	11.6	12.3	64.0
5	10:34	60.8	11.6	12.3	64.0
6	10:35	61.7	11.7	12.3	64.2
7	10:36	62.3	11.7	12.3	64.4
8	10:37	62.5	11.7	12.4	63.8
9	10:38	61.3	11.6	12.3	63.3
10	10:39	60.5	11.7	12.3	64.2
11	10:40	63.0	11.6	12.3	63.2
12	10:41	61.9	11.7	12.3	63.0
13	10:42	61.0	11.7	12.3	63.7
14	10:43	61.6	11.6	12.3	64.3
15	10:44	61.7	11.7	12.4	64.3
16	10:45	61.6	11.6	12.3	64.1
17	10:46	61.5	11.7	12.3	63.8
18	10:47	62.0	11.7	12.3	63.5
19	10:48	62.2	11.6	12.4	63.8
20	10:49	61.7	11.7	12.3	63.8
21	10:50	61.3	11.7	12.3	64.2
22	10:51	61.6	11.7	12.3	64.4
23	10:52	60.9	11.7	12.3	64.0
24	10:53	61.1	11.7	12.3	64.3
25	10:54	60.4	11.7	12.3	58.3
26	10:55	61.0	11.7	12.3	55.2
27	10:56	61.6	11.7	12.3	54.6
28	10:57	62.1	11.7	12.3	56.7
29	10:58	62.3	11.7	12.3	58.4
30	10:59	61.1	11.7	12.3	58.7
31	11:00	61.0	11.7	12.3	59.1
32	11:01	60.5	11.6	12.4	59.8
33	11:02	62.3	11.7	12.5	60.0
34	11:03	60.6	11.7	12.4	60.0
35	11:04	61.4	11.7	12.5	60.5
36	11:05	61.8	11.8	12.5	61.4
37	11:06	61.3	11.7	12.5	61.7
38	11:07	61.2	11.6	12.5	61.6
39	11:08	61.9	11.7	12.4	62.1
40	11:09	61.8	11.7	12.5	63.3
41	11:10	60.3	11.7	12.5	62.5
42	11:11	60.8	11.7	12.5	63.1
43	11:12	61.3	11.8	12.5	63.9
44	11:13	61.3	11.8	12.4	63.2
45	11:14	60.1	11.7	12.5	63.6
46	11:15	61.9	11.7	12.5	63.6
47	11:16	60.8	11.7	12.4	62.8
48	11:17	61.2	11.8	12.5	64.4
49	11:18	61.1	11.6	12.5	64.1
50	11:19	60.6	11.7	12.4	64.2
51	11:20	61.7	11.7	12.4	64.2
52	11:21	61.2	11.8	12.4	62.9
53	11:22	61.4	11.7	12.4	63.3
54	11:23	61.9	11.8	12.3	63.4
55	11:24	61.4	11.8	12.4	53.1
56	11:25	62.7	11.7	12.4	43.6
57	11:26	60.2	11.8	12.4	48.9
58	11:27	60.5	11.7	12.4	52.0
59	11:28	61.7	11.7	12.4	55.6
60	11:29	62.9	11.7	12.4	57.7
Uncorrected Average		61.51	11.67	12.32	62.58
Pre-test Zero	10:13	0.60	0.12	-0.07	0.46
Pre-test Upscale	10:18	50.00	8.97	24.12	94.74
Post-test Zero	11:33	0.78	0.03	-0.12	-0.01
Post-test Upscale	11:36	50.52	8.99	24.12	94.46
C_o		0.69	0.07	-0.10	0.23
C_m		50.26	8.98	24.12	94.60
Corrected Average		61.22	11.74	12.61	63.12

Corrected to Lb/mmBtu		0.1422		0.0178	
Corrected to 15 O2%		39.43		8.13	
Calibration Gas Used					
	Zero Gas	0.00	0.00	0.00	0.00
	Upscale Gas	49.90	9.015	24.61	95.54
Calibration Drift (must be =< 3%)					
	Zero Drift	0.18%	-0.47%	-0.10%	-0.24%
	Upscale Drift	0.53%	0.08%	0.00%	-0.14%
Bias (must be < 5.0%)	Initial Bias, Zero	0.61%	0.60%	0.14%	0.23%
	Final Bias, Zero	0.79%	0.13%	0.24%	0.01%
	Initial Bias, Upscale	0.15%	0.09%	0.72%	0.04%
	Final Bias, Upscale	0.68%	0.18%	0.72%	0.18%

Run 3

Freedom Compressor Station
EUENGINE3-1 Catalyst Outlet

Date: 06/22/22

Reading	Logger Time	NOx ppm	O2 %	CO ppm	NMOC ppm
1	11:53	61.0	11.7	12.5	63.7
2	11:54	61.2	11.6	12.5	63.6
3	11:55	61.3	11.6	12.4	63.7
4	11:56	61.5	11.7	12.3	63.4
5	11:57	61.6	11.6	12.3	63.5
6	11:58	62.1	11.6	12.4	63.6
7	11:59	61.5	11.5	12.3	64.0
8	12:00	62.8	11.6	12.3	63.7
9	12:01	61.8	11.8	12.3	63.8
10	12:02	61.9	11.7	12.4	64.0
11	12:03	61.2	11.7	12.4	63.9
12	12:04	61.9	11.5	12.4	63.6
13	12:05	61.5	11.7	12.4	63.6
14	12:06	62.3	11.7	12.3	63.7
15	12:07	61.1	11.7	12.3	63.5
16	12:08	61.7	11.8	12.3	63.4
17	12:09	62.4	11.7	12.3	63.8
18	12:10	61.7	11.7	12.3	64.0
19	12:11	61.5	11.7	12.3	63.5
20	12:12	62.4	11.6	12.3	63.1
21	12:13	62.1	11.6	12.3	63.6
22	12:14	61.2	11.7	12.4	63.8
23	12:15	62.1	11.6	12.3	63.4
24	12:16	61.6	11.8	12.3	64.0
25	12:17	61.6	11.8	12.3	63.8
26	12:18	61.9	11.7	12.4	63.5
27	12:19	61.9	11.7	12.4	63.2
28	12:20	62.1	11.8	12.3	63.3
29	12:21	61.8	11.8	12.3	64.3
30	12:22	62.1	11.7	12.3	63.9
31	12:23	61.8	11.7	12.3	63.5
32	12:24	61.9	11.7	12.3	63.5
33	12:25	61.8	11.6	12.3	63.9
34	12:26	62.6	11.8	12.5	63.5
35	12:27	61.7	11.7	12.5	63.7
36	12:28	61.6	11.7	12.5	63.5
37	12:29	62.3	11.8	12.5	63.5
38	12:30	61.6	11.7	12.5	63.3
39	12:31	62.0	11.7	12.5	41.9
40	12:32	61.3	11.6	12.5	15.8
41	12:33	61.2	11.7	12.5	29.3
42	12:34	62.2	11.8	12.5	49.5
43	12:35	61.8	11.6	12.5	55.0
44	12:36	61.6	11.7	12.5	57.0
45	12:37	63.6	11.8	12.4	58.1
46	12:38	63.7	11.7	12.5	58.7
47	12:39	63.2	11.7	12.5	59.5
48	12:40	64.1	11.7	12.5	59.8
49	12:41	61.6	11.6	12.5	59.1
50	12:42	61.9	11.8	12.5	58.8
51	12:43	63.1	11.7	12.6	58.9
52	12:44	62.1	11.7	12.6	59.4
53	12:45	62.9	11.8	12.5	60.8
54	12:46	62.5	11.8	12.6	61.0
55	12:47	62.6	11.7	12.6	61.6
56	12:48	61.9	11.7	12.6	60.7
57	12:49	61.3	11.8	12.6	62.8
58	12:50	61.8	11.8	12.6	63.0
59	12:51	61.2	11.7	12.6	62.2
60	12:52	60.8	11.7	12.5	63.4
Uncorrected Average		61.94	11.70	12.42	60.58
Pre-test Zero	11:33	0.78	0.03	-0.12	-0.01
Pre-test Upscale	11:36	50.52	8.99	24.12	94.46
Post-test Zero	12:57	0.74	0.15	-0.07	0.14
Post-test Upscale	13:01	49.88	8.98	24.05	94.81
C_o		0.76	0.09	-0.10	0.07
C_m		50.20	8.98	24.09	94.64
Corrected Average		61.75	11.77	12.74	61.13

		NOx	O2	CO	NMOC
Corrected to Lb/mmBtu		0.1439		0.0181	
Corrected to 15 O2%		39.89		8.23	
Calibration Gas Used					
	Zero Gas	0.00	0.00	0.00	0.00
	Upscale Gas	49.90	9.015	24.61	95.54
Calibration Drift (must be =< 3%)					
	Zero Drift	-0.04%	0.60%	0.11%	0.08%
	Upscale Drift	-0.65%	-0.03%	-0.14%	0.18%
Bias (must be < 5.0%)	Initial Bias, Zero	0.79%	0.13%	0.24%	0.01%
	Final Bias, Zero	0.75%	0.73%	0.14%	0.07%
	Initial Bias, Upscale	0.68%	0.18%	0.72%	0.18%
	Final Bias, Upscale	0.03%	0.14%	0.86%	0.00%

Moisture Determination

Plant:	Freedom Compressor Station
Test Location/Description:	EUEngine3-1

Dry Gas Meter No:	1684-D
Y=	1.005

Moisture Conditions & Start Dates			
Conditions	High	Mid	Low
Start Date	6/23/2022		

Water Vapor in Gas Stream (Percent by Volume)

High Load Tests		Mid Load Tests		Low Load Tests	
Test Run #	Moisture Content	Test Run #	Moisture Content	Test Run #	Moisture Content
1	8.8%				
2	11.1%				
3	10.1%				

Part 75 Moisture Determination Requirements [Section 6.5.7, App. A, 40CFR75]

Flow RATA

1. A minimum of one moisture run is required every flow RATA clock hour or every three test runs (whichever is less restrictive).
2. Alternately, moisture measurements may be made before and after a series of flow runs at a particular load level, if the interval between the two measurements ≤ 3 hours. If this option is selected, average the two measurements and apply them to all RATA runs in the series.

Gas RATA

1. One moisture test shall be conducted in conjunction with each Part 75 gas RATA test run.
2. 21-minute moisture run durations are allowed if performing RM 4 and gas RATA runs concurrently, per 40CFR60 Appendix B, PS No. 2 Section 8.4.3.1,
3. If two 21-minute gas RATA runs can be performed in a 60 minute time period, one RM 4 run may be applied to both gas runs, as long as the sample volume collected during that period was ≥ 21 scf.

Moisture Traverse Points where stratification is not expected:

1. Locate and traverse three (3) points at 16.7, 50.0, and 83.3% of the stack/duct measurement line.
2. If the measurement line is > 7.8 feet (~ 7' 10") you may locate 3 points at 15.75", 47.25", and 78.75" from the stack/duct wall.
3. Alternately, 3 traverse points located at 4.4, 14.6, and 29.6% of the stack/duct diameter may be used.

Moisture Traverse Points where stratification is expected:

1. Locate a minimum of six (6) traverse points in accordance with RM 1 along a diameter in the direction of the expected stratification.
2. Alternately, 3 traverse points may be used if the 12-point stratification test in 40CFR75 Appendix A, Section 6.5.6.1 is performed and passed.

Moisture Determination

Plant: Freedom Compressor Station | Date: 6/23/2022
Location: EUEngine3-1 | Load: High
Dry Gas Mtr: 1684-D | Y Value: 1.005

Run No. 1 | Barometric Pressure (in. Hg): 29.07

Clock Time 24 hour (00:00)	Meter Temp. ° F
09:15	71
09:20	71
09:25	72
09:30	73
09:35	73
09:40	74
09:45	75

Dry Gas Meter	
Finish Reading (L):	59.7290
Start Reading (L):	0.0000
Difference (L):	59.7290
Difference (Ft ³):	2.109

Impinger Assembly	
Finish Weight (gm):	579.90
Start Weight (gm):	575.70
Difference (gm):	4.20

Moisture by Volume: 0.088

Plant: Freedom Compressor Station | Date: 6/23/2022
Location: EUEngine3-1 | Load: High
Dry Gas Mtr: 1684-D | Y Value: 1.005

Run No. 2 | Barometric Pressure (in. Hg): 29.07

Clock Time 24 hour (00:00)	Meter Temp. ° F
10:30	74
10:35	75
10:40	76
10:45	76
10:50	77
10:55	78
11:00	79

Dry Gas Meter	
Finish Reading (L):	59.9450
Start Reading (L):	0.0000
Difference (L):	59.9450
Difference (Ft ³):	2.117

Impinger Assembly	
Finish Weight (gm):	585.30
Start Weight (gm):	579.90
Difference (gm):	5.40

Moisture by Volume: 0.111

Plant: Freedom Compressor Station | Date: 6/23/2022
Location: EUEngine3-1 | Load: High
Dry Gas Mtr: 1684-D | Y Value: 1.005

Run No. 3 | Barometric Pressure (in. Hg): 29.05

Clock Time 24 hour (00:00)	Meter Temp. ° F
11:55	79
12:00	78
12:05	78
12:10	79
12:15	79
12:20	80
12:25	80

Dry Gas Meter	
Finish Reading (L):	60.0220
Start Reading (L):	0.0000
Difference (L):	60.0220
Difference (Ft ³):	2.120

Impinger Assembly	
Finish Weight (gm):	590.10
Start Weight (gm):	585.30
Difference (gm):	4.80

Moisture by Volume: 0.101

Appendix C
Laboratory Data Sheets

CleanAir

CleanAir Engineering
500 W. Wood Street
Palatine, IL 60067-4975
800-627-0033
www.cleanair.com

LABORATORY ANALYSIS FOR ETHANE
Laboratory Services Report No: 64-30120_GC_ ET_ V0

Performed for:
CONSUMERS ENERGY COMPANY
17000 Croswell Street
West Olive, MI 49460

Pertaining to a Field Sampling Project Performed at:
FREEDOM COMPRESSOR STATION

Laboratory Services Project No: 30120
Revision 0: 07/04/2022

To the best of our knowledge, the laboratory report nor the results provided have in any way been reproduced or altered except in full without prior written approval of the lab. The laboratory results presented in this report are accurate, complete, error free, legible and representative of the samples per the analysis described here-in. The lab retains the unaltered final copy for comparison purposes upon request.

Submitted by,

Douglas D. Rhoades
Title: Team Leader – Laboratory Services
Ph: 847-654-4504
Email: drhoades@cleanair.com

REVISION HISTORY

LABORATORY ANALYSIS FOR ETHANE
LABORATORY Services Report No: 64-30120_GC_ ET_ V0

FINAL REPORT REVISION HISTORY

Revision:	Date	Pages	Comments
0	07/04/2022	All	Final version of original document.

REVISION HISTORY

Symbol	Meaning Language
J	The values are considered to be readily quantifiable, therefore these values are believed to be accurate. But the values fall below the Limit of Quantitation (LOQ) value (the lowest point of calibration). These values should probably be used with some discretion.
K	This sample contained a foreign object. The original value is reported, and the corrected value if available is shown with the sample ID suffix 'B'. See narrative for discussion.
L	The reported value is an estimate. The sample matrix interfered with the laboratory's ability to make any accurate termination
M	Off-scale high. Actual value is known to be greater than value given. *To be used when the concentration of the analyte is above the acceptable level for quantitation.*
N	The sample was found to have a negative net weight. Gravimetric analyses are considered to be accurate to +/-0.5mg. See Case narrative for further discussion.
P	Sample held beyond the acceptable holding time.
R	Value reported is less than the laboratory method detection limit. The value is reported for informational purposes only by customer request and shall not be used in statistical analysis
S	Value was found to be below a detectable limit. See Discussion of Analytical Results.
T	The laboratory analysis was from an improperly preserved sample. The data should be used with some discretion.
U	The evaporation steps for the front half acetone rinses, including volume measurements, were not performed by this laboratory. See narrative for discussion
V	Data is associated with a failed verification sample. It is believed not to have affected the data but should be used with some discretion.
W	An associated method blank was found to have analyte present. This may indicate possible blank contamination from laboratory analysis.

CONTENTS

CERTIFICATE OF ANALYSIS

Sample Number	Sample ID	Spike Corrected Concentration of Analyte in Sample (ppmv) Ethane	Concentration of Ethane in Sample (ppmv as Propane) Propane
30120-001	EU Engine 31 - Run 1	83.5	56.9
30120-003	EU Engine 31 - Run 2	86.0	58.6
30120-005	EU Engine 31 - Run 3	84.4	57.5
Limit of Quantitation (LOQ)		1.02	0.70

End of Section 1 – Certificate of Analysis

ANALYTICAL CASE NARRATIVE

INTRODUCTION

Consumers Energy Company contracted Clean Air Engineering Laboratory Services (Laboratory Services) to determine the following:

- Gaseous Organics – non-Methane/non-Ethane Total Hydrocarbons reported as Propane

All analyses were performed on samples received by the Laboratory Services at their facility in Palatine, IL. All analyses were performed in accordance with the applicable EPA Method requirements along with all NELAP quality requirements as outlined and described in Section 3 of this report.

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Key Project Participants

The samples were received at Clean Air Engineering Laboratory Services facility on 06/24/2022. The following is a table of key personnel involved:

Table 2-1:
Pertinent Personnel

Technician	Affiliation	Function
J. Mason	Customer	COC Relinquished
D. Rhoades	Laboratory Services	Sample Receipt
D. Rhoades	Laboratory Services	Analyst
J. Mason	Customer	Project Manager

Accreditation

The Lab performs analyses that are NELAC accredited. Please visit https://lams.nelac-institute.org/LabDetails?id=TNI00173 for a comprehensive list of our accredited services.

ANALYTICAL CASE NARRATIVE

DISCUSSION OF ANALYTICAL RESULTS

Compounds other than Methane/Ethane were not detected during the gas chromatography analyses. Method 18 calls for the sample results to be corrected based on the results of the recovery study. For the bag sampling technique to be considered valid for a compound, the recovery must be between 70% < R < 130%. Table 2-2, below, lists the recovery percentages for each spiked sample.

Table 2-2:
Spike Recovery for Each Spiked Sample

Sample Number	Identification	Ethane Spike Recovery (%)
30120-001	EU Engine 31 - Run 1	103.7%

The as-measured values, not corrected for spike/recovery, are shown in Table 2-3, below. The results shown in the Certificate of Analysis have been corrected for Spike/Recovery.

Table 2-3:
Measured Amount of Analyte in Each Sample – Uncorrected for Spike/Recovery

Sample Number	Sample ID	Concentration of Analyte in Sample (ppmv)[1] Ethane
30120-001	EU Engine 31 - Run 1	86.6
30120-003	EU Engine 31 - Run 2	89.2
30120-005	EU Engine 31 - Run 3	87.5
Method Detection Limit (MDL)		0.36
Limit of Quantitation (LOQ)		1.02

[1] Results have not been corrected for the spike recovery percentage results.

End of Section 2 – Analytical Case Narrative

METHODOLOGY

3-1

Laboratory Services followed procedures as detailed in U.S. EPA Method 18. Table 3-2, below summarizes the methods and their respective sources.

Table 3-2:
List of Analytical Methodology

Title 40 CFR Part 60 Appendix A	
U.S. EPA Method 18	"Measurement of Gaseous Organic Compound Emissions by Gas Chromatography"

These methods appear in detail in Title 40 of the Code of Federal Regulations (CFR) and are located on the internet at http://ecfr.gpoaccess.gov.

Laboratory Services followed specific quality assurance and quality control (QA/QC) procedures as outlined in the individual methods and as prescribed in Laboratory Services' internal Quality Manual. Results of recorded QA/QC activities performed by Laboratory Services are summarized in Appendix III.

Analytical Procedures Common to All Methods

Sample Preparation

- Samples were prepared according to the procedures listed in the EPA Method above. Each sample was analyzed at full strength and a dilution was prepared if necessary to achieve a concentration that was within calibration range limits.

Sample Analysis

- EPA Method 18 is a generic method for measuring gaseous organic compounds. The method is based on separating the major organic components of a gaseous mixture using a gas chromatograph (GC) and measuring them with a suitable detector.
- To identify and quantify the major components, the retention times of each separated component are compared with those of known compounds under identical conditions. The analyst identifies approximate concentrations of the organic emission components beforehand. With this information, standard mixtures are prepared and the GC is calibrated under physical conditions identical to those used for the samples.
- A SRI 8610 GC equipped with a heated ten-port gas sampling valve (VICI two-position) was used to acquire sample onto a continuously purged sample loop. At initiation of each injection (analysis), the valve is actuated to the 'inject' position and sample is flushed onto the column and onto an appropriate detector. The instrument's gas sampling valve is fitted with two sample loops. Table 3-3 lists the sample loops were used for this project:

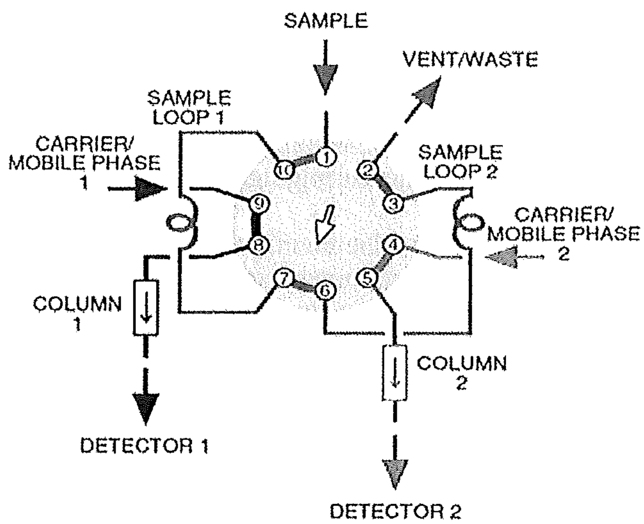
Table 3-3:
List of Sample Loops

Loop	Material	Length (in)	Volume (µL)	Connected to Column	Detector
1	1/16" Sulfinert Coated SS	96	2000	Double Super Q	FID

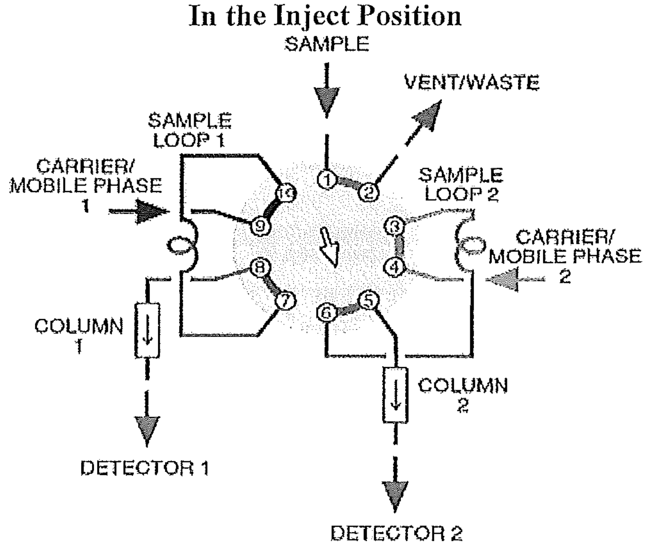
- Sample acquired in Loop 1 is flushed onto two Super Q columns for separation of analytes. Analytes are quantified using an FID detector.
- A schematic of the 10-port sampling valve is shown in Figure 3-4 on the following page.

Figure 3-4:
Schematic Diagram of the 10 Port Sampling Valve

In the Load Position



In the Inject Position



- The list of analytes can be found in Table 3-5. The appropriate sample loop, GC column, and detector are also listed for each analyte.

Table 3-5:
List of Analytes

Compound Order of Elution	Compound	CAS Number	Molecular Weight (g/mole)	Sample Loop	Column	Detector
Compound 1	Ethane	74-84-0	30.07	1	Double Super Q (36")	FID

Detection Limits

- The Method Detection Limit (MDL) was determined in accordance with procedures in 40 CFR 136, Appendix B. Documentation showing the determination of detection limits is included with this report. The Limit of Quantitation (LOQ) is set to be the concentration of the lowest calibration point for each analyte. Values between these limits were quantified, but should be used with discretion as they were below the LOQ. Values that were below the MDL were indicated by a "<" where appropriate

Instrument Calibration

- Instrument calibration followed regulations found in U.S. EPA Method 18.
- Calibration bags were prepared from calibration gas cylinders that are certified to an accuracy of 2% or better and/or from pure compounds diluted in zero nitrogen.
- As per section U.S EPA Method 18, a series of at least 3 standards were prepared and analyzed in triplicate from lowest to highest concentration.
- The average peak area for each calibration point is plotted against the expected concentration.
- In accordance with EPA Performance Specification 9, a least-squares regression with an R^2 value of 0.995 or greater must be produced from the resulting curve.
- In accordance with U.S. EPA Method 18, a full post-test calibration was performed. The pre-test and post-test calibration average peak area for any standard must agree within 5% of any observed area.
- At the beginning and end of each analysis day, a single injection of a calibration point was analyzed to verify instrument calibration.

Quality Control Procedures

Clean Air adheres to QA/QC procedures that both meet and exceed EPA requirements.

- Before the first sample was analyzed and every twenty samples thereafter, a Quality Control (QC) sample was analyzed. The QC sample was prepared from a different traceable gas cylinder than the calibration standards and the CCV. The QC must show a regression concentration within 10 percent of the expected concentration.
- After the first ten samples and every twenty thereafter (and before the post-test calibration) a laboratory blank and a Continuing Calibration Verification (CCV) were analyzed. The CCV was prepared from the same calibration standard as used to create the standards that make up the calibration curve. The laboratory blank must show a regression concentration of zero, and the CCV must show a regression concentration within 10 percent of the expected concentration.
- Every sample was analyzed in triplicate and the average area count used to determine the concentration. Each measured area count must not have a relative difference of more than five percent of the average area count for the three injections. If the relative difference is more than five percent, the sample was reanalyzed until a relative difference of less than five percent is obtained.
- Each point on the calibration curve should be within ± 2 percent of the calibration span of the curve used.
- The observed concentration value of each point on the calibration curve should have a relative percent difference of 10 percent from its expected concentration.

METHODOLOGY

- Paragraph 8.4.2.1 of EPA Method 18 discusses the required procedures for performing a spike and recovery study. The paragraph suggests spiking a bag with a known mixture (gaseous or liquid) of all the target pollutants. The theoretical concentration, in ppm, of each spiked compound in the bag shall be 40% to 60% of the average concentration measured in the three bag samples. If a target compound was not detected in the bag samples, the concentration of that compound to be spiked shall be five times the limit of detection for that compound.
  - For this project, all samples were spiked with pure compound.
  - As the sample volume contained in each spiked bag is not known, an expected spike concentration would be difficult to estimate. Instead, the bags were spiked, mechanically mixed and analyzed within an hour of spiking. The results of this analysis are used to determine the pre-rest concentration for each spiked bag. Each of these spiked bags must then rest the same amount of time as elapsed between sampling and the original analysis. For the bag sampling technique to be considered valid for a compound, the recovery must be between 70% < R < 130%. Table 3-6, below, shows the sampling and analysis dates for all samples.

Table 3-6:
Sampling and Analysis Dates for Each Sample

Sample Number	Identification	Sample Date	Original Analysis Date	No of Days	Spike Origination Date	Spike Final Analysis Date	No of Days
30120-001	EU Engine 31 - Run 1	06/23/22	06/24/22	1	06/24/22	06/25/22	1
30120-002	EU Engine 31 - Run 2	06/23/22	06/24/22	1			
30120-003	EU Engine 31 - Run 3	06/23/22	06/24/22	1			

Standard and Reagent Traceability

- Each calibration standard has been prepared in accordance with U.S. EPA Method 18 and has been designated an original lot number. This number can be used to trace back to the original cylinders or reagents used in the preparation of these standards. These lot numbers are found in the Appendix.
- Method 25A calibration standards are listed in Appendix IV.

Project Archival

- A copy of this report and all associated supporting records will be archived and stored for at least 20 years.
- All samples are archived for a period of one year from the date of receipt in our facility with the following exceptions:
  - Tedlar bag gas chromatography samples are generally discarded within 30 days following the analysis.
- The archival facility is a controlled access storage facility that does not incorporate any environmental controls.

End of Section 3 – Methodology

APPENDIX

4-1

SAMPLE CALCULATIONS

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