EXECUTIVE SUMMARY

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted continuous compliance testing on three (3) 4-stroke lean burn (4SLB) natural gas-fired, spark-ignition, reciprocating internal combustion engines (RICE) identified as EUENGINE1, EUENGINE3, and EUENGINE4 at the Consumers Energy White Pigeon Compressor Station in White Pigeon, Michigan.

The facility is classified as a major source of hazardous air pollutants (HAP). The engines are natural gas-fired, four-stroke lean-burn (4SLB), spark ignited (SI), reciprocating internal combustion engines (RICE), >500 horsepower that power compressors used to maintain pressure in pipelines transporting natural gas from main lines to storage facilities located in Michigan or local distribution companies. The engines are collectively grouped as FGENGINES within Michigan Department of Environment, Great Lakes and Energy (EGLE) Renewable Operating Permit (ROP) MI-ROP-N5573-2018 and subject to federal air emissions regulations.

The test program was conducted April 6 through 8, 2021 to satisfy performance testing requirements and evaluate compliance with 40 CFR Part 60, Subpart JJJJ, "Standards of Performance for Stationary Spark Ignition Internal Combustion Engines," (aka NSPS SI ICE), 40 CFR Part 63, Subpart ZZZZ, "National Emission Standards for Hazardous Air Pollutants (NESHAP) for Reciprocating Internal Combustion Engines," and the ROP.

Three, 60-minute test runs for nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs) and oxygen (O_2) were conducted at each RICE 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 using 40 CFR Part 63, § 63.6620, Equation 1. There were no deviations from the approved stack test protocol or associated USEPA RM with the exception that EUENGINE2 was not able to be tested during this test program. A fire occurred on April 7, 2021 and EUENGINE2 was taken out of service for repairs and investigation. EUENGINE2 will be tested prior to returning to service. During testing, the engines were operated at horsepower and torque conditions within plus or minus (±) 10 percent of 100 percent peak (or the highest achievable) load, as specified in 40 CFR 60.4244(a).

The Subpart ZZZZ test results summarized in Table E-1 indicate EUENGINE1, EUENGINE3 and EUENGINE4 are operating in continuous compliance with the 40 CFR Part 63 Subpart ZZZZ RICE NESHAP, and as specified in the facility ROP.

Detailed results are presented in Appendix Tables 1, 2, and 3. Sample calculations and field data sheets are presented in Appendices A and B. Engine operating data and supporting documentation are provided in Appendices C and D. Data from a voided run on EUENGINE4 is presented in Appendix E.

Table E-1
Summary of Test Results

Engine	NO_x (g/hp-hr)	CO (g/hp-hr)	CO (% Reduction)	VOC[1] (g/hp-hr)	Catalyst Inlet Temperature[2] (°F)	Catalyst Pressure Drop (inches)	Initial Catalyst Pressure Drop (inches)
Engine 1	0.3	0.01	99.2	0.64	738	4.1	3.5
Engine 3	0.3	0.01	98.5	0.76	754	2.8	2.9
Engine 4	0.4	0.01	99.2	0.54	759	3.2	3.0
JJJJ Limits	**2.0**	**4.0**		**1.0**			
ZZZZ Limits			**≥93**		**450-1350**	**±2 (from initial)**	
ROP Limits	**0.5**	**0.2**	**≥93**	**1.0**	**450-1350**	**±2 (from initial)**	

[1]Non-methane organic compounds (NMOC), as propane
[2]Compliance with the catalyst inlet temperature operating range is based on a 4-hour rolling average

1.0 INTRODUCTION

This report summarizes the results of compliance air emissions testing conducted April 6 through 8, 2021 at the Consumers Energy White Pigeon Compressor Station (WPCS) in White Pigeon, 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), volatile organic compounds (VOCs) and oxygen (O_2) at the oxidation catalyst inlet and/or outlet of three, stationary, spark-ignition (SI), reciprocating internal combustion engines (RICE), identified as EUENGINE1, EUENGINE3 and EUENGINE4 installed and operating at WPCS in White Pigeon, Michigan on April 6 through 8, 2021.

A test protocol, submitted to EGLE on January 27, 2021, was subsequently approved by Mr. Matt Karl, EGLE Environmental Quality Analyst, in a letter dated March 17, 2021. There were no deviations from the approved stack test protocol or associated USEPA RM, with the exception that EUENGINE2 was not able to be tested during this test program. A fire occurred on April 7th, 2021 and EUENGINE2 was taken out of service for repairs and investigation. EUENGINE2 will be tested prior to returning to service.

1.2 Purpose of Testing

The test program was conducted April 6 through 8, 2021 to satisfy performance testing requirements and evaluate compliance with 40 CFR Part 60, Subpart JJJJ, "Standards of Performance for Stationary Spark Ignition Internal Combustion Engines," (aka NSPS SI ICE), 40 CFR Part 63, Subpart ZZZZ, "National Emission Standards for Hazardous Air Pollutants (NESHAP) for Reciprocating Internal Combustion Engines," and MI-ROP-N5573-2018. The applicable emission limits are presented in Table 1-1.

Table 1-1
Applicable Emission Limits

Parameter	Emission Limit			Units
	40 CFR Part 60, Subpart JJJJ[1, 2]	40 CFR Part 63, Subpart ZZZZ	MI-ROP-5573-2018	
NO_x	2.0		0.5	g/HP-hr
CO[1]	4.0		0.2	g/HP-hr
		93	93	% reduction across oxidation catalyst
VOC	1.0		1.0	g/HP-hr

[1] 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.

1.3 Brief Description of Source

WPCS operates one Caterpillar Model 3608 4SLB engine (EUENGINE1) and three Caterpillar Model 3616 4SLB engines (EUENGINE2 – 4) installed at Plant 3 to maintain pressure in the pipeline transporting natural gas from a main line to storage facilities or local distribution companies in Michigan. The engines are collectively grouped as FGENGINES within MI-ROP-N5573-2018.

1.4 Contact Information

Table 1-2 presents the names, addresses, and telephone numbers of the contacts for information regarding the test and the test report, and names and affiliation of personnel involved in conducting the testing.

Table 1-2
Contact Information

Program Role	Contact	Address
State Regulatory Administrator	Ms. Karen Kajiya-Mills Technical Programs Unit Manager 517-335-4874 kajiya-millsk@michigan.gov	Michigan Department of Environment, Great Lakes and Energy Technical Programs Unit 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
State Technical Programs Field Inspector	Ms. Matt Karl Technical Programs Unit Field Operations Section 517-282-2126 karlm@michigan.gov	Michigan Department of Environment, Great Lakes and Energy Technical Programs Unit 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
State Regulatory Inspector	Mr. Chance Collins Environmental Quality Analyst 269-254-7119 collinsc21@michigan.gov/air	Michigan Department of Environment, Great Lakes and Energy Kalamazoo District Office 7953 Adobe Road Kalamazoo, Michigan 49009-5025
Responsible Official	Mr. Avelock Robinson, Director 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. Gerald (Frank) Rand Jr. Senior Environmental Analyst 734-850-4209 frank.randjr@cmsenergy.com	Consumers Energy Company So. Monroe Service Center 7116 Crabb Road Temperance, Michigan 48182
Test Facility	Mr. Timothy Wolf Gas Field Leader III 269-483-2902 timothy.wolf@cmsenergy.com	Consumers Energy Company White Pigeon Compressor Station 68536 A Road, Route 1 White Pigeon, Michigan 49099
Test Team Representative	Mr. Dillon King, QSTI Sr. Engineering Technical Analyst II 989-895-0107 dillon.king@cmsenergy.com	Consumers Energy Company D.E. Karn Generating Complex 2742 N. Weadock Hwy, ESD Trailer #4 Essexville, Michigan 48732

2.0 SUMMARY OF RESULTS

2.1 Operating Data

During the performance test, the engines fired natural gas and, pursuant to §60.4244(a), were operated within 10% of 100 percent peak (or the highest achievable) load. The performance test was conducted with the engines operating at a 3-run average load of 96.8% horsepower or greater, based on the maximum manufacturer's design capacity at engine and compressor site conditions. Refer to Appendix C for detailed operating data.

2.2 Applicable Permit Information

The White Pigeon Compressor Station operates in accordance with MI-ROP-N5573-2018. EUENGINE1, EUENGINE2, EUENGINE3, and EUENGINE4 are the emission unit sources identified in the permit. Collectively they are included within the FGENGINES flexible group. Incorporated within the permit are the applicable federal requirements of 40 CFR Part 60, Subpart JJJJ and 40 CFR Part 63, Subpart ZZZZ.

2.3 Results

The CO reduction efficiency across the exhaust catalysts, when combined with engine parameter data, indicate the NO_x, CO, and VOC emissions are compliant with applicable emissions limits. Refer to Table 2-1 for the summary of test results.

Table 2-1
Summary of Test Results

Engine	NO_x (g/hp-hr)	CO (g/hp-hr)	CO (% Reduction)	VOC[1] (g/hp-hr)	Catalyst Inlet Temperature[2] (°F)	Catalyst Pressure Drop (inches)	Initial Catalyst Pressure Drop (inches)
Engine 1	0.3	0.01	99.2	0.64	738	4.1	3.5
Engine 3	0.3	0.01	98.5	0.76	754	2.8	2.9
Engine 4	0.4	0.01	99.2	0.54	759	3.2	3.0
JJJJ Limits	**2.0**	**4.0**		**1.0**			
ZZZZ Limits			**≥93**		**450-1350**	**±2 (from initial)**	
ROP Limits	**0.5**	**0.2**	**≥93**	**1.0**	**450-1350**	**±2 (from initial)**	

[1]Non-methane organic compounds (NMOC), as propane
[2]Compliance with the catalyst inlet temperature operating range is based on a 4-hour rolling average

Detailed results are presented in Appendix Tables 1 - 4. A discussion of the results is presented in Section 5.0. Sample calculations and field data sheets are presented in Appendices A and B. Engine operating data and supporting documentation are provided in Appendices C and D.

3.0 SOURCE DESCRIPTION

EUENGINE1, EUENGINE3, and EUENGINE4 are operated as needed to maintain natural gas pressure along the natural gas pipeline system. A summary of the engine specifications is presented in Table 3-1.

Table 3-1
Engine Specifications

Parameter[1]	EUENGINE1	EUENGINE3, and EUENGINE4
Purchase Year	2008	2008
Installation Date	June 15, 2010	June 15, 2010
Make	Caterpillar	Caterpillar
Model	G3608	G3616
Cylinders	8	16
Output (brake-horsepower)	2,370	4,735
Heat Input (mmBtu/hr)	16.1	32.0
Exhaust Flow Rate (acfm, wet)	16,144	32,100
Exhaust Gas Temp. (°F)	857	856
Engine Outlet O_2 (Vol-%, dry)	12.00	12.00
Engine Outlet CO_2 (Vol-%, dry)	5.81	5.81
CO, uncontrolled (ppmvd)	570.0	572.0
CO, controlled[2] (ppmvd)	39.9	40.0

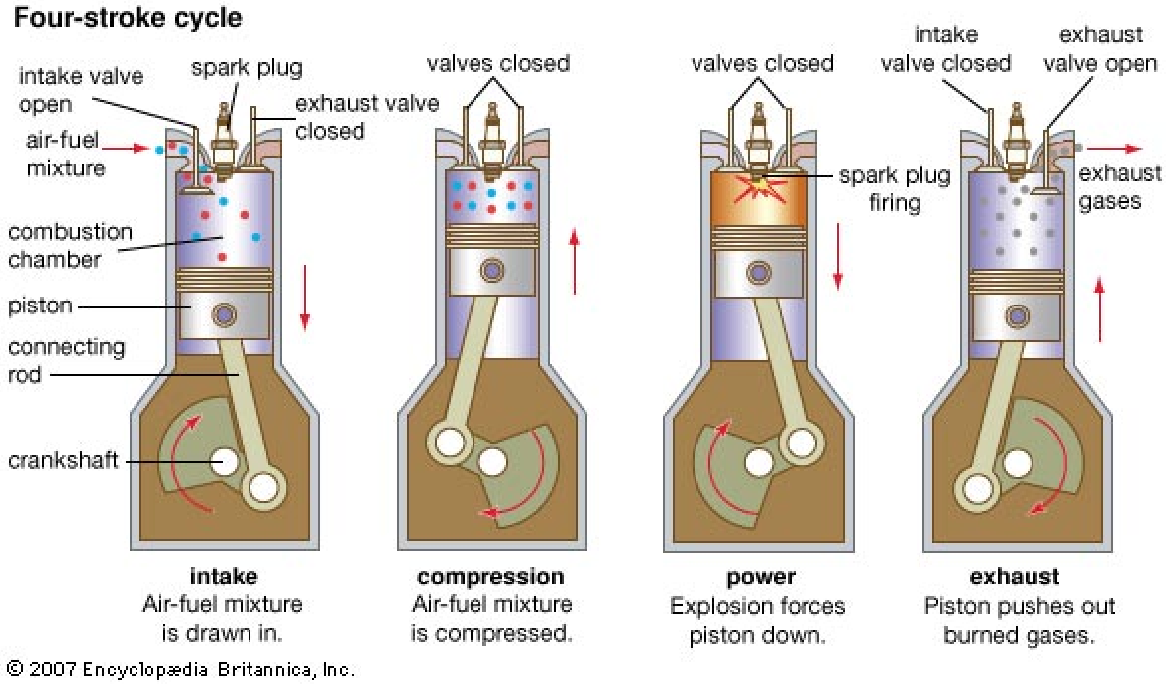
[1] All engine specifications are based upon vendor data for operation at 100% of rated engine capacity.
[2] The controlled CO concentrations are based upon the vendor not to exceed CO concentrations at 100% load, and a reduction of 93% by volume for the associated oxidation catalysts.

3.1 PROCESS

EUENGINE1, EUENGINE3, and EUENGINE4 are natural gas-fired 4SLB SI RICEs constructed in 2010. In a 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 when the piston is near the bottom of the intake stroke; the intake ports close as the piston moves to the top of the cylinder, compressing the air/fuel mixture. The ignition and combustion of the air/fuel charge begins the downward movement of the piston called the power stroke. As the piston reaches the bottom of the power stroke, valves are opened, and combustion products are expelled from the cylinder as the piston travels upward. A new air-to-fuel charge is injected as the piston moves downward with a new intake stroke.

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

Figure 3-1. Four-Stroke Engine Process Diagram



The natural gas-fired engine flue gas is controlled through parametric controls (i.e., timing and air-to-fuel ratio), lean burn combustion technology, and oxidation catalysts. The Caterpillar engines includes an Advanced Digital Engine Management (ADEM) III electronic control system. The ADEM III electronic controls integrate governing (engine sensing and monitoring, air/fuel ratio control, ignition timing, and detonation control) into one comprehensive engine control system for optimum performance and reliability.

The NO_x emissions from each of the engines 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 and resulting in lower NO_x emissions.

The engines are also equipped with oxidation catalysts. Pollution Control Associates, Inc. (PCA) manufacturers the model ADCAT CO catalysts (part number 28283.5-300CO) that are installed on each engine exhaust stack. The catalysts are designed in a modular manner where each Caterpillar Model G3616 engine is equipped with four catalyst modules, while the Caterpillar Model 3608 engine is equipped with two catalyst modules. The catalyst uses proprietary materials to lower the oxidation temperature of CO and other organic compounds, thus maximizing the catalyst efficiency specific to the exhaust gas temperatures generated by the engines. The catalyst vendor has guaranteed a CO removal efficiency of 93%. The catalysts also provide control of formaldehyde, as well as non-methane and non-ethane hydrocarbons with the estimated destruction efficiency of 85% and 75%, respectively.

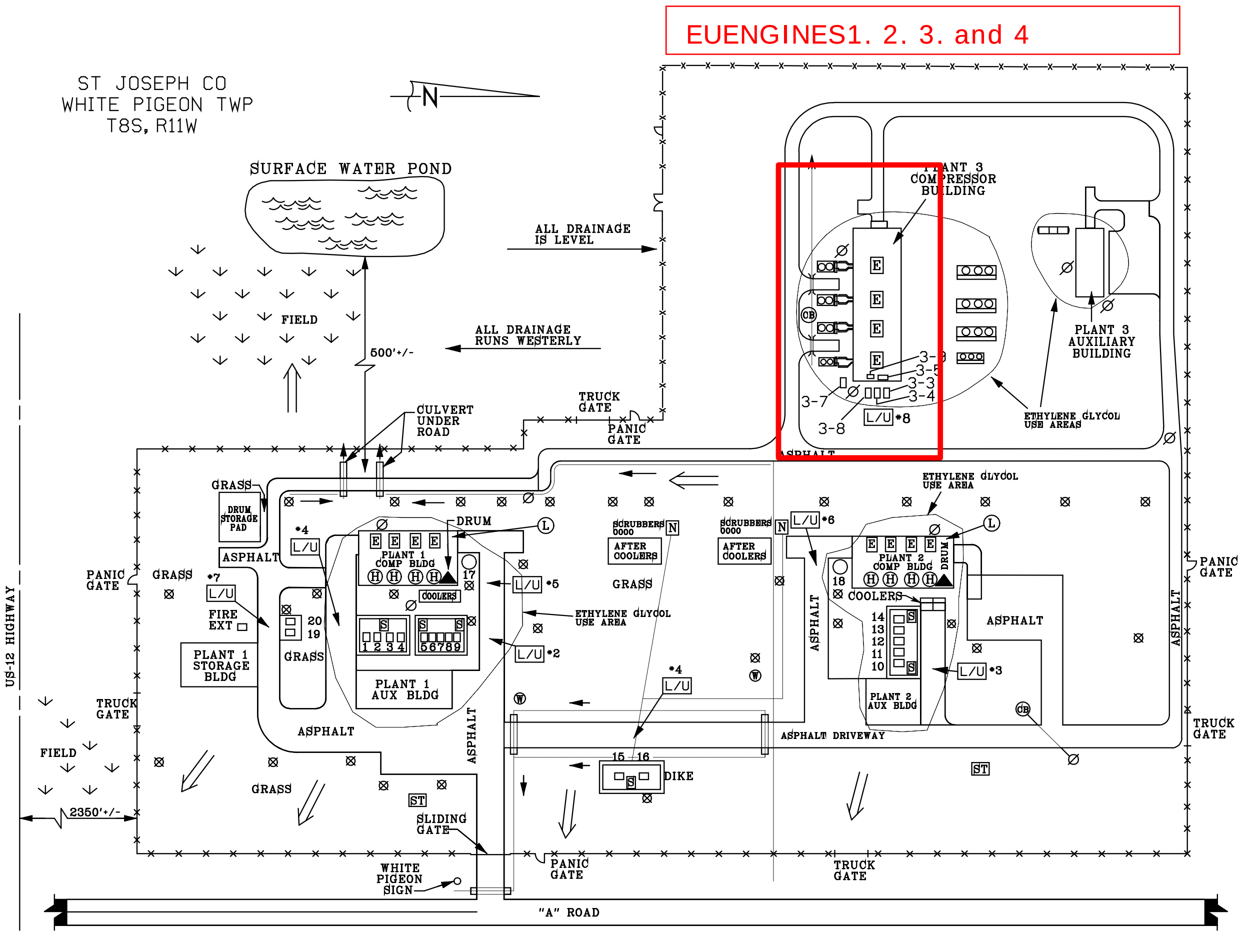
Detailed operating data recorded during testing are provided in Appendix C.

3.2 Process Flow

Located in southwestern St. Joseph County, the White Pigeon Compressor Station helps maintain natural gas pressures in the natural gas pipeline transmission system. The station receives natural gas from the ANR and Trunk Line interstate pipeline sources and provides adequate system pressure to support customer load and injection operations at other compressor stations. The Plant 3 compressor engines have the capacity to pump 800 million cubic feet of natural gas a day.

The facility is divided into three plants comprising natural gas reciprocating compressor engines, emergency generators, and associated equipment to maintain pressure in natural gas transmission system. The Plant 3 natural gas compressor engines were the focus of this test program. Refer to Figure 3-2 for the White Pigeon Compressor Station Plant 3 Site Map.

Figure 3-2. White Pigeon Compressor Station Plant 3 Site Map



3.3 Materials Processed

The fuel utilized in EUENGINE1, EUENGINE3 and EUENGINE4 is exclusively natural gas, as defined in 40 CFR 72.2. During testing, the natural gas combusted within the engines was comprised of approximately 93% methane, 6% ethane, 1% nitrogen, and 0.2% carbon dioxide.

3.4 Rated Capacity

EUENGINE1 has a maximum power output of approximately 2,370 horsepower while EUENGINE3 and EUENGINE4 are rated at 4,735 horsepower. The engines have a rated heat input of 16.1 and 32.0 million British thermal units per hour (mmBtu/hour), respectively. The normal rated capacities of the engines are a function of facility and gas transmission demand. The engine operating parameters were recorded and averaged for each test run. Refer to Appendix C for operating data recorded during testing.

3.5 Process Instrumentation

The engine operating parameters were continuously monitored by a distributed control system for the Caterpillar engines, data acquisition systems, and by Consumers Energy operations personnel during testing. Data were collected at 1-minute intervals during each test for the following parameters:

- Discharge pressure (psi)
- Suction pressure (psi)
- Catalyst differential pressure (in. H_2O)
- Catalyst inlet temperature (°F)
- Catalyst exhaust temperature (°F)
- Power (BHP)
- Engine speed (rpm)
- Compressor Torque (% max)
- Compressor Load Step (unit less)
- Fuel use (1,000 scf/hr)

Refer to Appendix C for operating data.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

Consumers Energy RCTS tested for NO_x, CO, VOCs, and O_2 concentrations using the United States Environmental Protection Agency (USEPA) test methods presented in Table 4-1. The sampling and analytical procedures associated with each parameter are described in the following sections.

Table 4-1
Test Methods

Parameter	USEPA	
	Method	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	Determination of Moisture Content in Stack Gases
Nitrogen oxides (NO_x)	7E	Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)
Carbon monoxide (CO)	10	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
Emission rates	19	Sulfur Dioxide Removal and Particulate, Sulfur Dioxide and Nitrogen Oxides from Electric Utility Steam Generators
Volatile organic compounds	25A	Measurement of Gaseous Organic Compound Emissions by Gas Chromatography

4.1 DESCRIPTION OF SAMPLING TRAIN AND FIELD PROCEDURES

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

Table 4-2
Test Matrix

Date (2021)	Run	Sample Type	Start Time (EDT)	Stop Time (EDT)	Test Duration (min)	EPA Test Method	Comment
EUENGINE4							
April 6	1*	O_2 NO_x CO VOC	9:00	9:59	60	1 3A 4 7E 10 19 25A	Void run – equipment issue
	1		12:00	12:59	60		Sampling performed at three traverse points
	2		13:30	14:29	60		
	3		15:01	16:00	60		
EUENGINE3							
April 7	1	O_2 NO_x CO VOC	12:00	12:59	60	1 3A 4 7E 10 19 25A	Sampling performed at three traverse points
	2		13:30	14:29	60		
	3		15:03	16:02	60		
EUENGINE1							
April 8	1	O_2 NO_x CO VOC	8:15	9:14	60	1 3A 4 7E 10 19 25A	Sampling performed at three traverse points
	2		9:40	10:39	60		
	3		11:05	12:04	60		

*: First attempt at Run 1 was voided when a broken fitting was discovered on the VOC probe

4.2 Sample Location and Traverse Points (USEPA Method 1)

The number and location of traverse points was evaluated according to the requirements in Table 4 of 40 CFR Part 63, Subpart ZZZZ and USEPA Method 1, *Sample and Velocity Traverses for Stationary Sources*. The engine sampling locations are presented in the following section. Pre-catalyst and post-catalyst sampling port location drawings are presented as Figures 4-1 (EUENGINE1) and 4-2 (EUENGINE3 and EUENGINE4).

EUENGINE1

Sample Port Location Upstream of Oxidation Catalyst in 26-inch diameter duct:

- Approximately 60-inches or 2.3 duct diameters downstream of a flow disturbance where the engine exhaust enters the exhaust stack, and
- Approximately 85-inches or 3.3 duct diameters upstream of the catalysts.

Sample Port Location Downstream of Oxidation Catalyst in 26-inch diameter duct:

- Approximately 52-inches or 2 duct diameters downstream of a flow disturbance, and
- Approximately 573-inches or 22 duct diameters upstream of the stack exit.

EUENGINE3 and EUENGINE4

Sample Port Location Upstream of Oxidation Catalyst in 34.5-inch equivalent diameter duct (note sample port is within the duct annulus):

- Approximately 127-inches or 3.7 duct diameters downstream of a flow disturbance where the engine exhaust enters the exhaust stack, and
- Approximately 41-inches or 1.2 duct diameters upstream of the catalysts.

Sample Port Location Downstream of Oxidation Catalyst in 36-inch diameter duct:

- Approximately 72-inches or 2 duct diameters downstream of a flow disturbance, and
- Approximately 679-inches or 18.9 duct diameters upstream of the stack exit.

The sample ports are 0.5 to 1-inch in diameter and extend 3 inches beyond the stack wall. Because the ducts are >12 inches in diameter and the port locations meet the two and one-half diameter criterion of Section 11.1.1 of Method 1 of 40 CFR Part 60, Appendix A-1, the exhaust ducts were sampled at approximately equal intervals at 3 traverse points located at 16.7, 50.0, and 83.3% of the measurement line. The sample port upstream of the oxidation catalyst was not traversed at EUENGINE3and EUENGINE4 and flue gas concentrations were measured at a single sample location due to duct configuration.

Figure 4-1. EUENGINE1 Sampling Locations

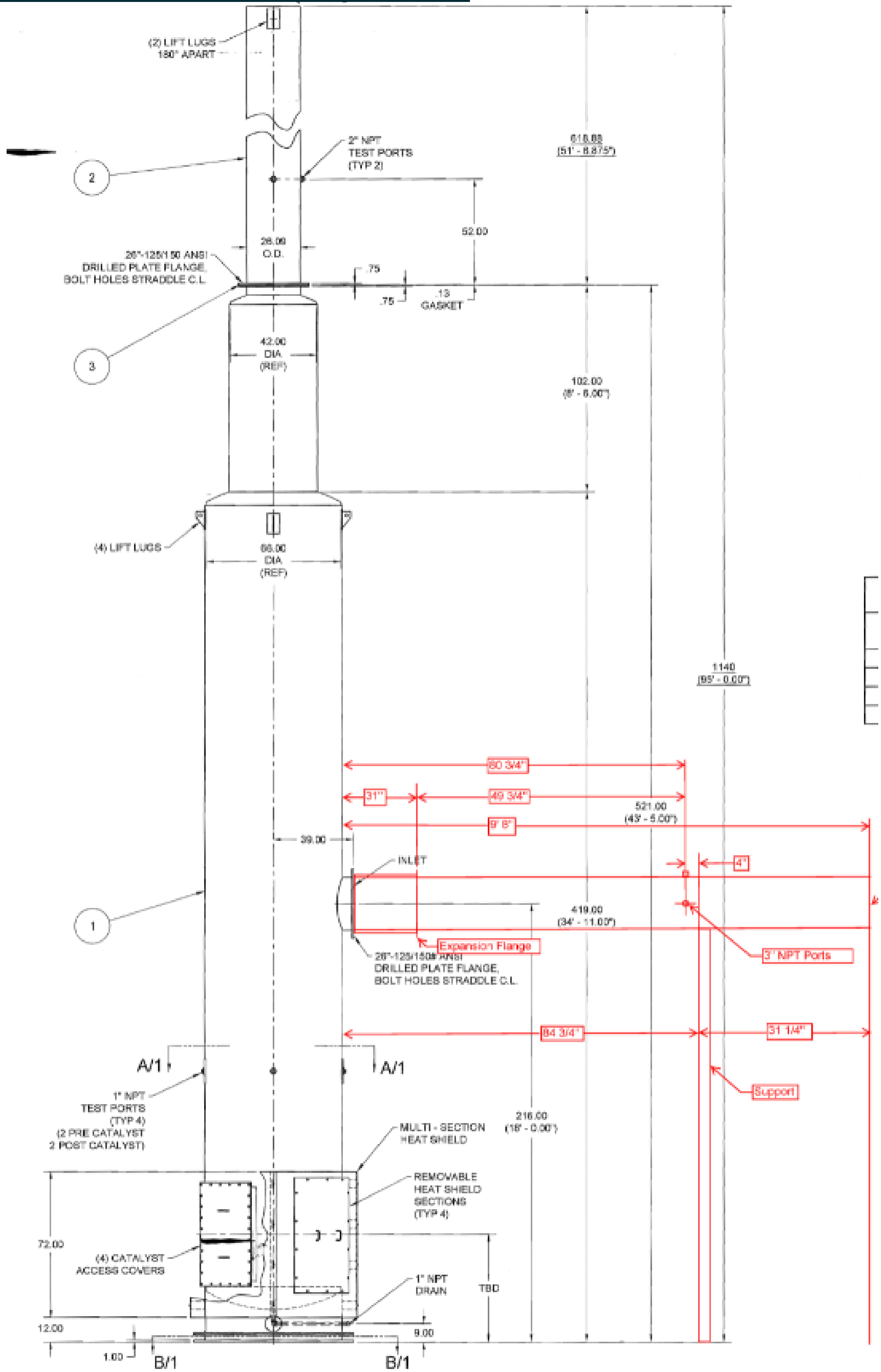
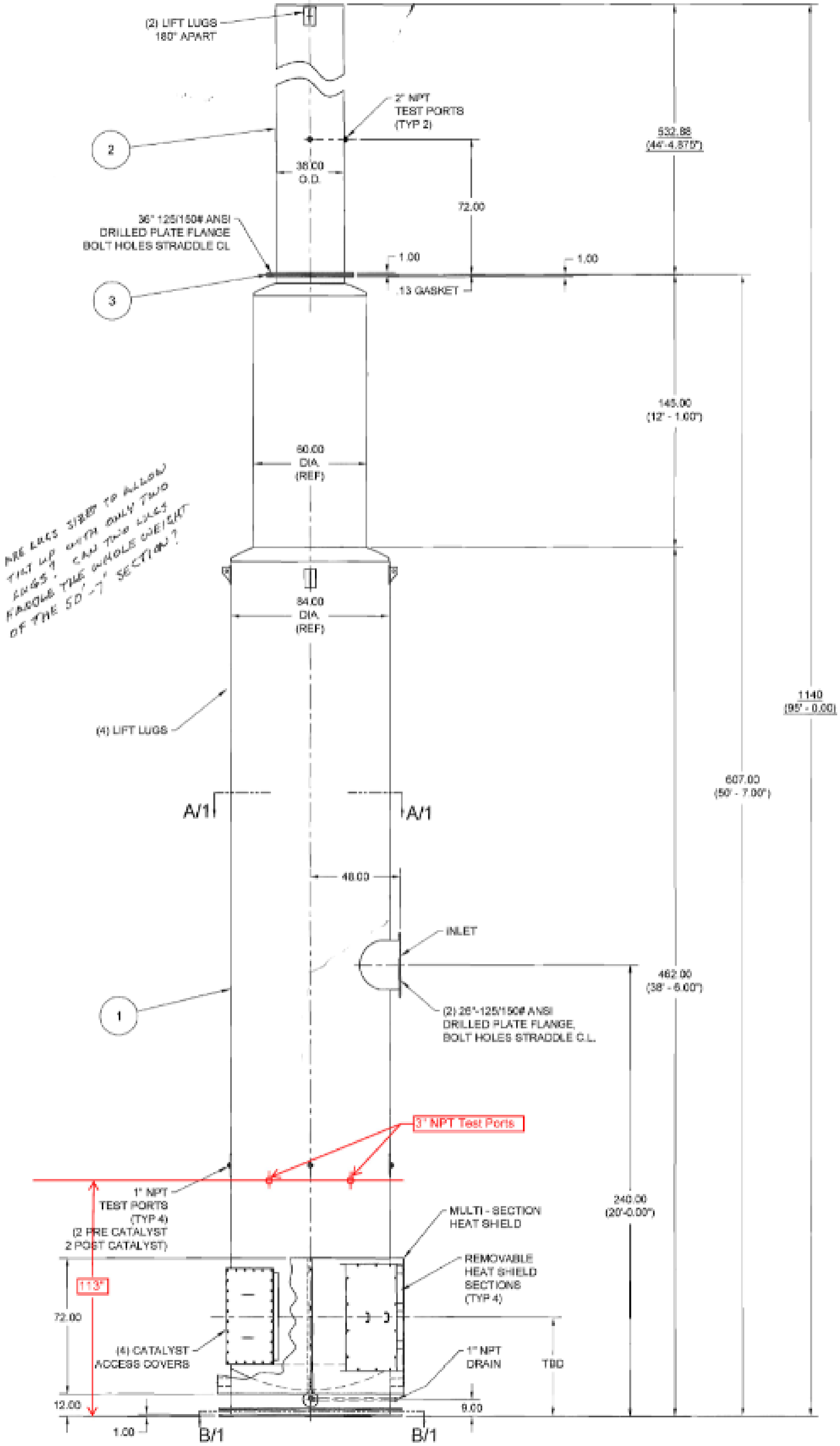


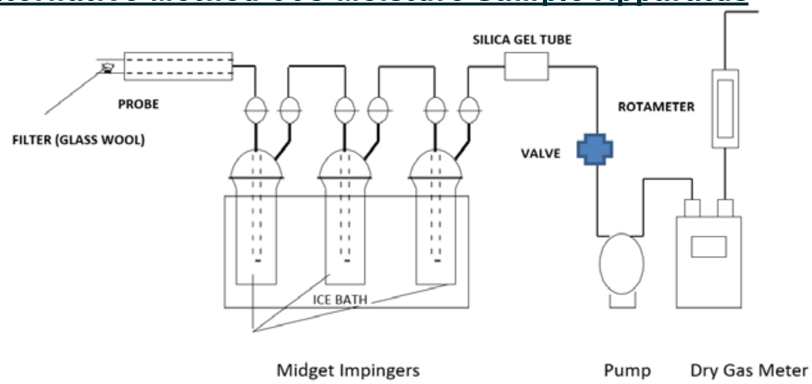
Figure 4-2. EUENGINE3 and EUENGINE4 Sampling Locations



4.3 MOISTURE CONTENT (USEPA ALT-008)

Exhaust gas moisture content was determined at each engine following specifications in USEPA Method 4, *Determination of Moisture Content in Stack Gases*, or equivalent alternate moisture methodology, such as ALT - 008, to convert wet-basis volatile organic compound measurements to a dry basis. Exhaust gas is drawn from the stack into impingers immersed in an ice-bath, condensing any water therein, after which the condensed water is measured gravimetrically to calculate the percent moisture content (Figure 4-3).

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)

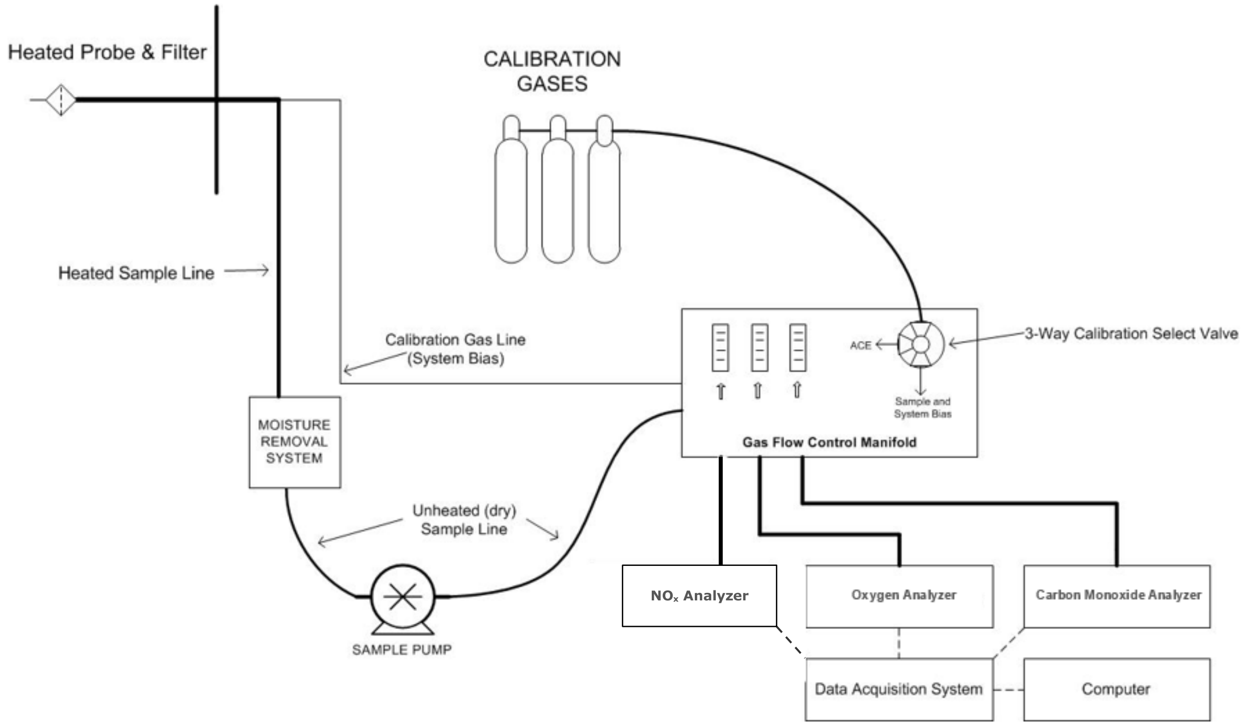
Oxygen, nitrogen oxides, and/or carbon monoxide concentrations were measured using the following sampling and analytical procedures:

- 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).*

The sampling procedures of the methods are similar with the exception of the analyzers and analytical technique used to quantify the parameters of interest. The measured oxygen concentrations were used to adjust the pollutant concentrations to 15% O_2 and calculate pollutant emission rates.

Engine exhaust gas was extracted from the 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 were calibrated by performing a calibration error test where zero-, mid-, and high-level calibration gases were introduced directly to the back of the analyzers. The calibration error check was performed to evaluate if the analyzers response was within ±2.0% of the calibration gas span or high calibration gas concentration. An initial system-bias test was performed where the zero- and mid- or high- calibration gases were introduced at the sample probe to measure the ability of the system to respond accurately to within ±5.0% of span.

A NO_2 to NO conversion efficiency test was performed on the NO_X analyzer prior to beginning the test program to evaluate the ability of the instrument to convert NO_2 to NO before analyzing for NO_x.

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

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

For the analyzer calibration error tests, bias tests and drift checks, these evaluations are also passed if the standard criteria are not achieved, but the absolute difference between the analyzer responses and calibration gas is less than or equal to 0.5 ppmv for NO_x and CO or 0.5% for O_2.

4.5 Emission Rates (USEPA Method 19)

USEPA Method 19, *Determination of Sulfur Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide, and Nitrogen Oxide Emission Rates*, was used to calculate a fuel specific F 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 4-4. 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 Method 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.

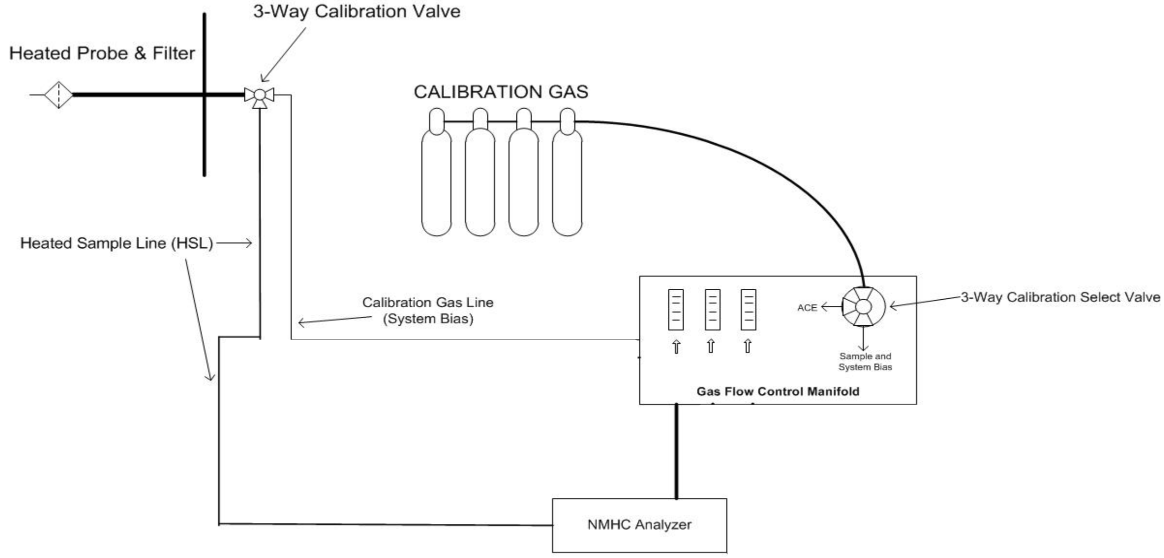
The components of the extractive sample interface apparatus are constructed of Type 316 stainless steel and Teflon. Flue gas was sampled from the stack via a sample probe and heated sample line and into the analyzer, which communicates with data acquisition handling systems (DAHS) via output signal cables. 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 4-5 for a drawing of the USEPA Method 5 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). Please note that since the field VOC instrument measures on a wet basis, exhaust gas moisture content was used to convert the wet VOC concentrations to a dry basis and calculate VOC mass emission rates. The moisture content results from natural gas fuel samples collected during the test program were used to calculate the final VOC concentrations and emission rates.

Please note that 40 CFR Part 63, 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 analyzers used measure exhaust gas ethane as part of the NMOC measurement. Therefore, if the RICE are firing natural gas containing elevated ethane concentrations, such as that obtained from shale sources, the NMOC concentrations measured may reflect a positive NMOC bias or non-compliance.

Figure 4-6. USEPA Method 25A Sample Apparatus



4.7 Test Results and Discussion

The test program was conducted April 6 through 8, 2021 to satisfy performance testing requirements and evaluate compliance with 40 CFR Part 60, Subpart JJJJ, "Standards of Performance for Stationary Spark Ignition Internal Combustion Engines," (aka NSPS SI ICE), 40 CFR Part 63, Subpart ZZZZ, "National Emission Standards for Hazardous Air Pollutants (NESHAP) for Reciprocating Internal Combustion Engines," and MI-ROP-N5573-2018.

4.8 Tabulation of Results

The EUENGINE1, EUENGINE3 and EUENGINE4 test results indicate the NO_x, CO, and VOC emissions are compliant with applicable emissions limits as summarized in Table 2-1. Appendix Tables 1 - 3 contain detailed tabulation of results, process operating conditions, and exhaust gas conditions for each respective RICE.

4.9 Significance of Results

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

4.10 Variations from Sampling or Operating Conditions

No operating condition variations were observed during the test program. Following the first test run on EUENGINE4, RCTS noticed the VOC calibration gases weren't responding as expected. Upon investigation of the probe it was discovered that a fitting had broken near the junction of the sample probe and calibration gas line (likely prior to the beginning of the run while the probe was being positioned in the stack). Very low VOC concentrations during that run indicate that ambient air was sampled so the run was voided. Three runs were completed after the repairs to the sample probe were made. Void test data is included in Appendix E.

4.11 Process or Control Equipment Upset Conditions

The engines and gas compressors were operating under maximum routine conditions and no upsets were encountered during testing.

4.12 Air Pollution Control Device Maintenance

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

4.13 Re-Test Discussion

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

- annually to evaluate the reduction of CO emissions across the oxidation catalyst in accordance with 40 CFR Part 63 Subpart ZZZZ and the ROP
- every 8,760 engine operating hours or 3 years (2022), whichever is first, to evaluate compliance with NO_x, CO, and VOC emission limits in 40 CFR Part 60, Subpart JJJJ and the ROP

Due to a fire that occurred on EUENGINE2, it was not tested during this test program. Repairs are in progress and it is expected it will be tested in late June or early July prior to being declared operable.

4.14 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 sample 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, M10: Calibration gas standards	Ensures accurate calibration standards	Traceability protocol of calibration gases	Pre-test	Calibration gas uncertainty ≤2.0%
M3A, M10: Calibration Error	Evaluates operation of analyzers	Calibration gases introduced directly into analyzers	Pre-test	±2.0% of the calibration span
M3A, M10: System Bias and Analyzer Drift	Evaluates analyzer and sample system integrity and accuracy over test duration	Calibration gases introduced at sample probe tip, heated sample line, and into analyzers	Pre and Post-test	±5.0% of the analyzer calibration span for bias and ±3.0% of analyzer calibration span for drift
M7E: NO_2-NO Converter efficiency	Evaluates operation of NO_2-NO converter	NO_2 calibration gas introduced directly into analyzer	Pre-test or Post-test	NO_x response ≥90% of certified NO_2 calibration gas

4.15 Calibration Sheets

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

4.16 Sample Calculations

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

4.17 Field Data Sheets

Field data sheets are presented in Appendix B.

4.18 Laboratory Quality Assurance / Quality Control Procedures

Laboratory analysis was not required for this compliance demonstration.

4.19 QA/QC Blanks

Other than Method 3A and 10 QA/QC and calibration gases used for zero calibrations, no other reagent or media blanks were used. QA/QC data are presented in Appendix D.