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

EUENGINE1, EUENGINE2, EUENGINE3, and EUENGINE4

Consumers Energy Company
White Pigeon Compressor Station
68536 A Road, Route 1
White Pigeon, Michigan 49099
SRN: N5573

April 19, 2024

Test Dates: March 25 – 27, 2024

Test Performed by the Consumers Energy Company
Regulatory Compliance Testing Section
Air Emissions Testing Body
Laboratory Services Section
Work Order No. 42330222

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EXECUTIVE SUMMARY

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted continuous compliance testing on four reciprocating internal combustion engines (RICE) identified as EUENGINE1, EUENGINE2, 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) 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 are subject to federal air emissions regulations.

The test program was conducted May 25 through 27, 2024, 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," 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, ALT-008, 7E, 10, 19, and 25A in 40 CFR Part 60, Appendix A. CO and O_2 were also measured at the oxidation catalyst inlet to calculate percent CO reduction efficiency using 40 CFR 63, § 63.6620, Equation 1. There were no deviations from the approved stack test protocol or associated USEPA RM. During testing, the engines were operated at horsepower and torque conditions within ±10% of 100% load, as specified in 40 CFR 63.6620(b).

The test results summarized in Table E-1 indicate EUENGINE1, EUENGINE2, EUENGINE3 and EUENGINE4 are operating in continuous compliance with the emission limits in 40 CFR Part 60, Subpart JJJJ, 40 CFR Part 63, Subpart ZZZZ, and the facility ROP.

Detailed results are presented in Appendix Tables 1 through 4. 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

Parameter	Units	Average Result EUENGINE				Emission Limit		
		1	2	3	4	40 CFR Part 60, Subpart JJJJ[1, 2]	40 CFR Part 63, Subpart ZZZZ	MI-ROP-5573-2018
NO_x	g/HP-hr	0.3	0.4	0.3	0.3	2.0		0.5
	ppmvd at 15% O_2	25	33	28	25	160		
CO	g/HP-hr	0.01	0.03	0.03	0.01	4.0		0.2
	ppmvd at 15% O_2	2	5	4	1	540		
	% reduction	99	98	99	99		>93	>93
VOC	g/HP-hr	0.4	0.4	0.5	0.4	1.0		1.0
	ppmvd at 15% O_2	34	39	43	34	86		

g/HP-hr: grams per horsepower hour
ppmvd at 15% O_2: parts per million by volume, dry basis, corrected to 15% oxygen

[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% 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.

1.0 INTRODUCTION

This report summarizes the results of compliance air emissions testing conducted March 25 through 27, 2024 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) testing at the oxidation catalyst outlet of four stationary, spark-ignition (SI), reciprocating internal combustion engines (RICE), identified as EUENGINE1, EUENGINE2, EUENGINE3 and EUENGINE4, installed and operating at WPCS in White Pigeon, Michigan, from March 25 through 27, 2024.

A test protocol was submitted to EGLE on January 22, 2024, and subsequently approved by Jeremy Howe, Technical Programs Unit Supervisor, in a letter dated February 23, 2024. There were no deviations from the approved stack test protocol or associated United States Environmental Protection Agency (USEPA) Reference Methods (RM).

1.2 Purpose of Testing

The test program was conducted 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," 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 Tables 1-1 and 1-2.

Table 1-1
Applicable Emission Limits

Parameter	Emission Limit	Units	Applicable Requirement[1,2,3]
NO_x	0.5	g/HP-hr	MI-ROP- N5573-2018, FGENGINES
	2.0	g/HP-hr	40 CFR Part 60, Subpart JJJJ, Table 1
	160	ppmvd at 15% O_2	40 CFR Part 60, Subpart JJJJ, Table 1
CO	0.2	g/HP-hr	MI-ROP-N5573-2018, FGENGINES
	4.0	g/HP-hr	40 CFR Part 60, Subpart JJJJ, Table 1
	540	ppmvd at 15% O_2	40 CFR Part 60, Subpart JJJJ, Table 1
VOC	1.0	g/HP-hr	MI-ROP- N5573-2018, FGENGINES
	1.0	g/HP-hr	40 CFR Part 60, Subpart JJJJ, Table 1
	86	ppmvd at 15% O_2	40 CFR Part 60, Subpart JJJJ, Table 1

g/HP-hr: grams per horsepower hour
ppmvd at 15% O_2: parts per million by volume, dry basis, corrected to 15% oxygen
[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% 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.

Table 1-2
40 CFR Part 63, Subpart ZZZZ Requirements

CO Reduction Efficiency (%)	Oxidation Catalyst Inlet Temperature (°F)	Oxidation Catalyst Pressure Drop (in H_2O)	Applicable Requirement
≥93†	≥450°F and ≤1350°F (based on 4-hour rolling)	±2" from Initial Performance Test	MI-ROP-N5573-2018, 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%O_2 or reducing CO emissions by ≥93%. Compliance using the CO reduction efficiency emission limit was evaluated.

1.3 Brief Description of Source

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

1.4 Contact Information

Table 1-3 presents the names, addresses, and telephone numbers of the contacts for information regarding the test and the test report, and names and affiliation of personnel involved in conducting the testing.

Table 1-3
Contact Information

Program Role	Contact	Address
Statewide Regulatory Oversite	Jeremy Howe Technical Programs Unit Supervisor 231-878-6687 howej1@michigan.gov	EGLE Technical Programs Unit Constitution Hall, 2nd Floor S 525 W. Allegan Street Lansing, Michigan 48933
District Regulatory Oversight	Monica Brothers District Supervisor 269-312-2535 brothersm@michigan.gov	EGLE Air Quality Division Kalamazoo District Office 7953 Adobe Road Kalamazoo, Michigan 49009
State Regulatory Inspector	Jared Edgerton Environmental Quality Analyst 269-312-1540 edgertonj1@michigan.gov	EGLE Air Quality Division Kalamazoo District Office 7953 Adobe Road Kalamazoo, Michigan 49009
Responsible Official	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
Station Supervisor	Timothy Wolf Supervisor Compression Operations 269-483-2902 timothy.wolf@cmsenergy.com	Consumers Energy Company White Pigeon Compressor Station 68536 A Road, Route 1 White Pigeon, Michigan 49099
Field Environmental Coordinator	Frank Rand Principal Environmental Analyst 734-807-0935 frank.randjr@cmsenergy.com	Consumers Energy Company South Monroe Customer Service Center 7216 Crabb Road Temperance, MI 48182
Corporate Air Quality Contact	Amy Kapuga Principal Environmental Engineer 517-788-2201 amy.kapuga@cmsenergy.com	Consumers Energy Company Environmental Services Department 1945 West Parnall Road Jackson, Michigan 49201
Test Team Representative	Thomas Schmelter, QSTI Principal Lab Technical Analyst 248-388-1525 thomas.schmelter@cmsenergy.com	Consumers Energy Company L&D Training Center 17010 Croswell Street West Olive, Michigan 49460

2.0 SUMMARY OF RESULTS

2.1 Operating Data

During the performance test, the engines fired natural gas and, pursuant to §63.6620(b), were operated within 10% of 100% load. The performance test was conducted with each engine operating at a 3-run average load of 93.3% 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 test results in Tables 2-1 and 2-2 indicate the engines comply with the applicable emission limits and associated operating requirements.

Table 2-1
Summary of Test Results

Parameter	Units	Average Result EUENGINE				Emission Limit		
		1	2	3	4	40 CFR Part 60, Subpart JJJJ[1, 2]	40 CFR Part 63, Subpart ZZZZ	MI-ROP-5573-2018
NO_x	g/HP-hr	0.3	0.4	0.3	0.3	2.0		0.5
	ppmvd at 15% O_2	25	33	28	25	160		
CO	g/HP-hr	0.01	0.03	0.03	0.01	4.0		0.2
	ppmvd at 15% O_2	2	5	4	1	540		
	% reduction	99	98	99	99		>93	>93
VOC	g/HP-hr	0.4	0.4	0.5	0.4	1.0		1.0
	ppmvd at 15% O_2	34	39	43	34	86		

g/HP-hr: grams per horsepower hour
ppmvd at 15% O_2: parts per million by volume, dry basis, corrected to 15% oxygen
[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% 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.

Table 2-2
Summary of Operating Results

Parameter	Catalyst Inlet Temperature[1] (°F)	Catalyst Pressure Drop (in H_2O)	Initial Catalyst Pressure Drop (in H_2O)
EUENGINE1	743	3.9	3.5
EUENGINE2	720	2.8	3.2
EUENGINE3	702	2.7	2.9
EUENGINE4	771	3.2	3.0
ZZZZ Limit	450-1350	±2 from initial	

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

Detailed results are presented in Appendix Tables 1 through 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

FGENGINES 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	EUENGINE2, 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

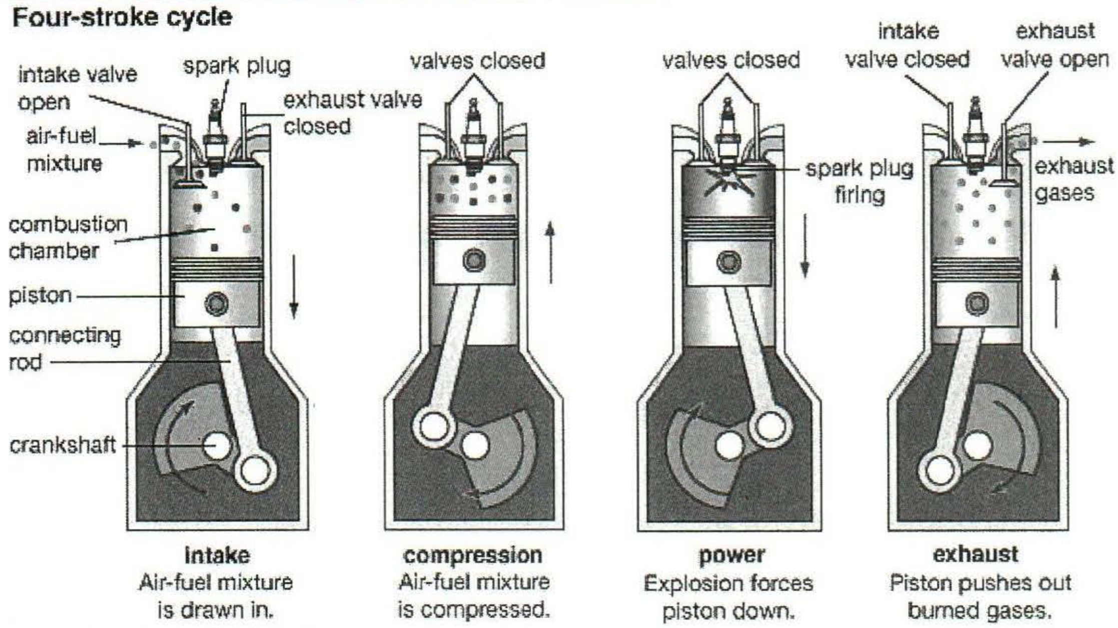
1 All engine specifications are based upon vendor data for operation at 100% of rated engine capacity.
2 The controlled CO concentrations are based upon the vendor not to exceed CO concentrations at 100% load, and a reduction of 93% by volume for the associated oxidation catalysts.

3.1 PROCESS

EUENGINE1, EUENGINE2, EUENGINE3, and EUENGINE4 are natural gas-fired 4SLB SI RICE 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 include 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.

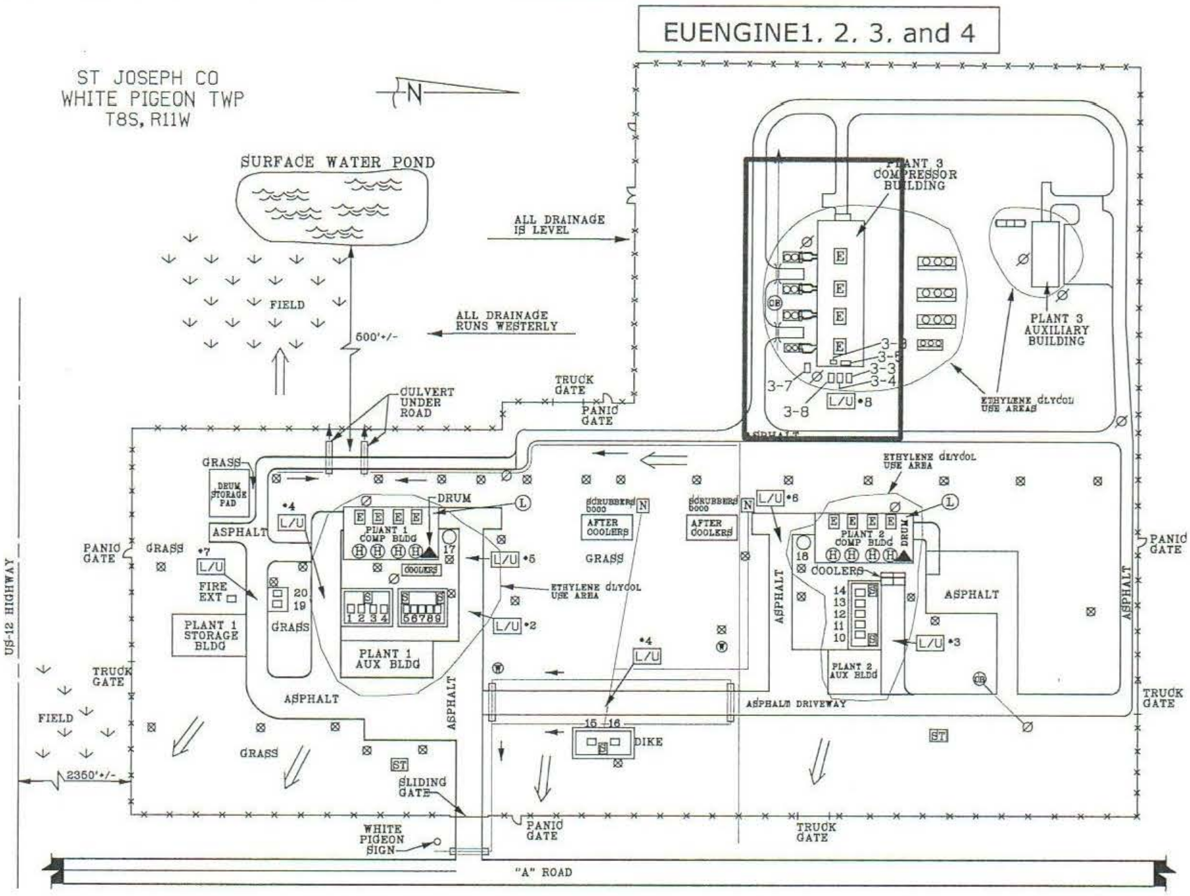
Detailed operating data recorded during testing are provided in Appendix C.

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 per day.

The facility is divided into three plants comprising of 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, EUENGINE2, 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, 0.5% nitrogen, and 0.5% carbon dioxide.

3.4 Rated Capacity

EUENGINE1 has a maximum power output of approximately 2,370 horsepower while EUENGINE2 through 4 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/hr), 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

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 12-second 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)
- Horsepower (HP)
- Engine speed (rpm)
- Compressor Torque (% max)
- Compressor Load Step (unitless)
- Fuel use (scfm)

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 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	ALT-008	Alternative Moisture Measurement Method Midget Impingers
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)
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 (2024)	Run	Sample Type	Start Time (EDT)	Stop Time (EDT)	Test Duration (min)	EPA Test Method	Comment
EUENGINE4							
March 26	1	O_2, NO_x, CO, VOC	08:30	09:29	60	1, 3A, ALT-008, 7E, 10, 19, 25A	
	2		10:00	10:59	60		
	3		11:25	12:24	60		
EUENGINE3							
March 26	1	O_2, NO_x, CO, VOC	13:15	14:14	60	1, 3A, ALT-008, 7E, 10, 19, 25A	
	2		14:35	15:34	60		
	3		16:20	17:1A9	60		
EUENGINE2							
March 27	1	O_2, NO_x, CO, VOC	07:45	08:44	60	1, 3A, ALT-008, 7E, 10, 19, 25A	
	2		09:05	10:04	60		
	3		10:20	11:19	60		
EUENGINE1							
March 27	1	O_2, NO_x, CO, VOC	13:00	13:59	60	1, 3A, ALT-008, 7E, 10, 19, 25A	
	2		14:15	15:14	60		
	3		15:30	16:29	60		

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 (EUENGINE2, 3, and 4).

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.

EUENGINE2, 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 equal intervals at 3 traverse points located at 16.7, 50.0, and 83.3% of the measurement line.

Figure 4-1. EUENGINE1 Sampling Locations

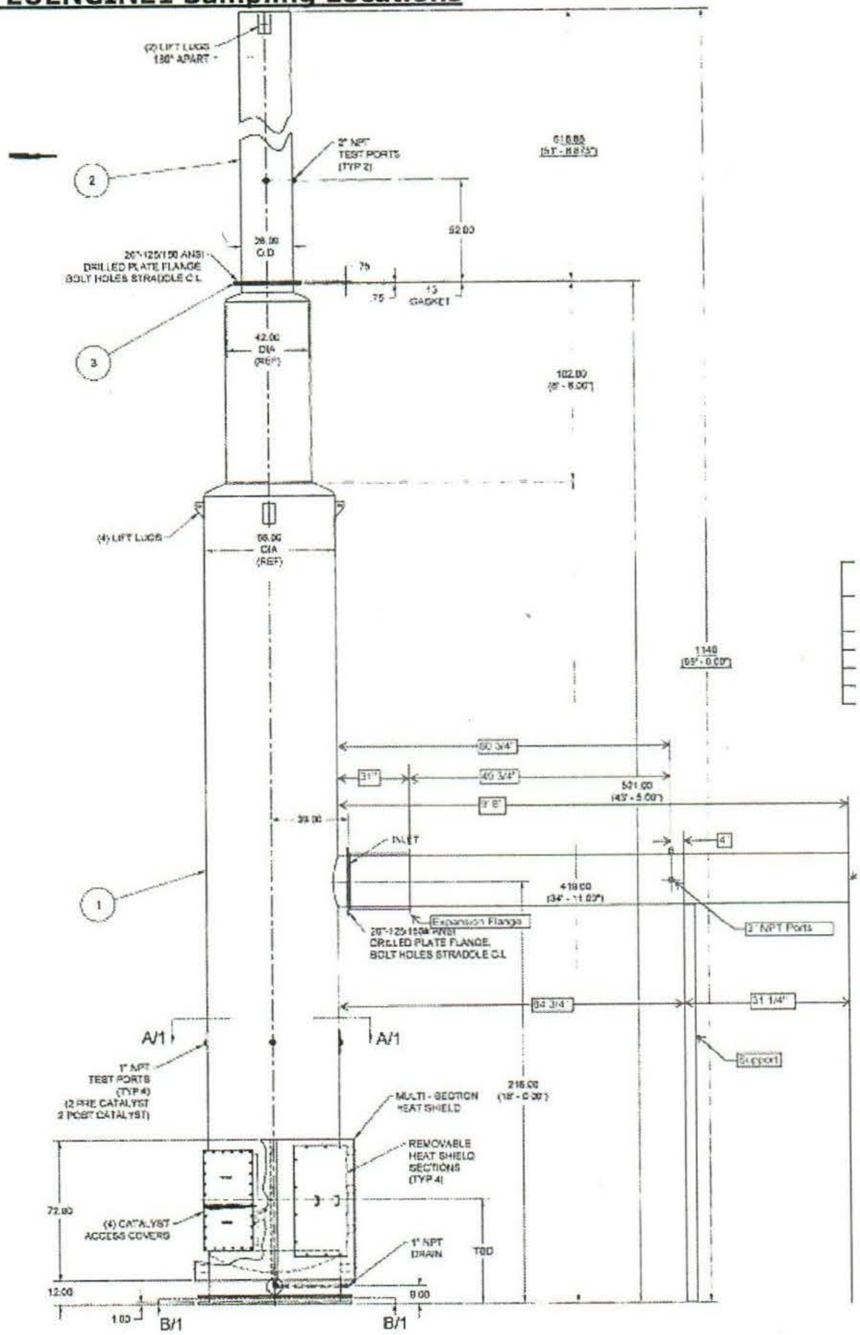
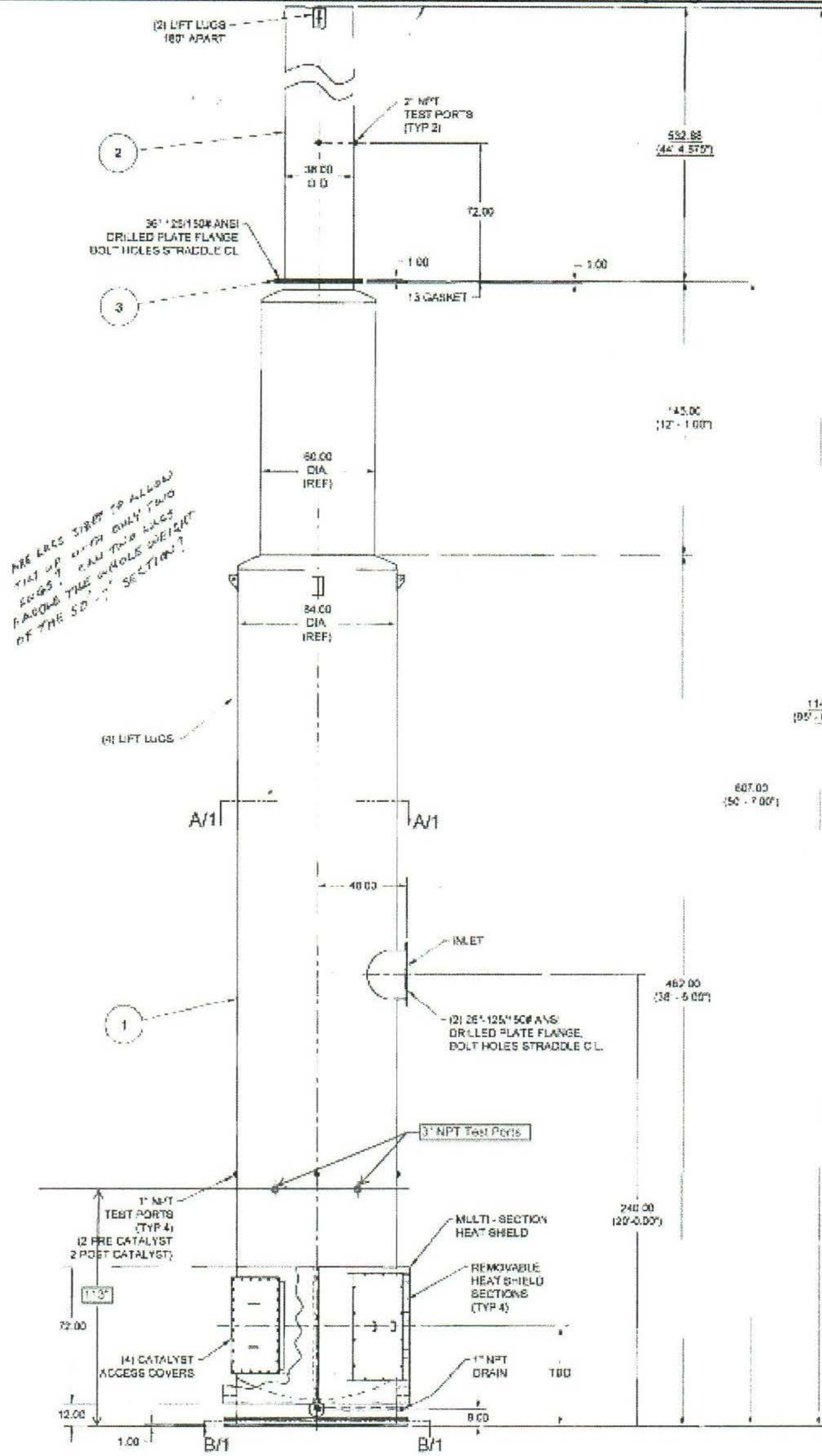


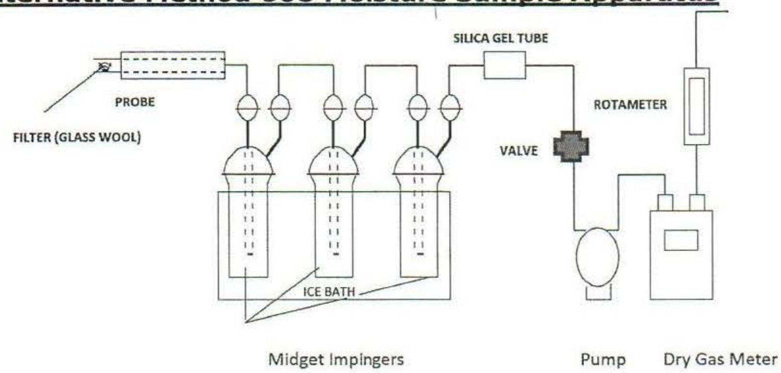
Figure 4-2. EUENGINE2, EUENGINE3, and EUENGINE4 Sampling Locations



4.3 Moisture Content (USEPA ALT-008)

Exhaust gas moisture content was determined at each engine following specifications in USEPA Method ALT-008, *Alternative Moisture Measurement Method Midget Impingers*, to convert wet-basis volatile organic compound measurements to 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)

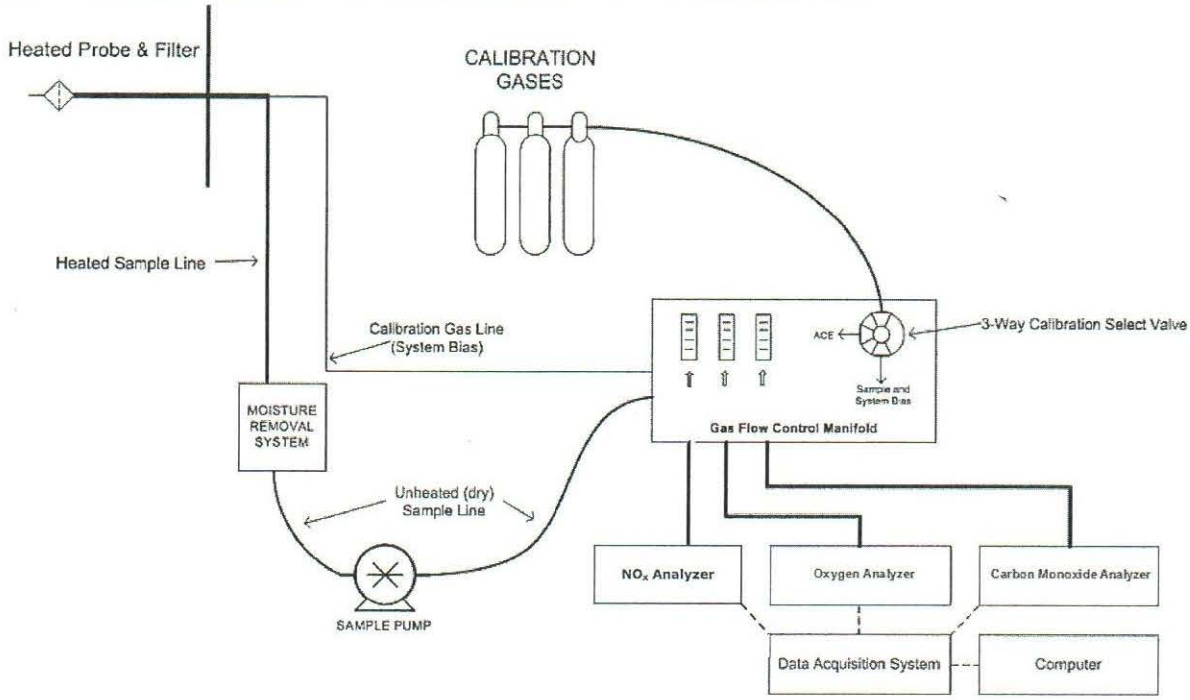
Oxygen, nitrogen oxides, and carbon monoxide concentrations were measured using the following sampling and analytical procedures:

- 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 (i.e., high calibration gas concentration). An initial system bias test was performed where the zero- and mid-calibration gases were introduced at the sample probe to measure the ability of the system to respond accurately to within ±5.0% of span.

An 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 between 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 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

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

Where:

Q_s = stack flow rate (dscf/min)
F_d = fuel-specific oxygen-based F factor, dry basis, from Method 19 (dscf/MMBtu)
H = fuel heat input rate, (MMBtu/min), at the higher heating value (HHV) measured at engine fuel feed line, calculated as (fuel feed rate in ft^3/min) x (fuel heat content in MMBtu/ft^3)
O_2 = stack oxygen concentration, dry basis (%)

4.6 Volatile Organic Compounds (USEPA Method 25A)

VOC concentrations were measured 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.

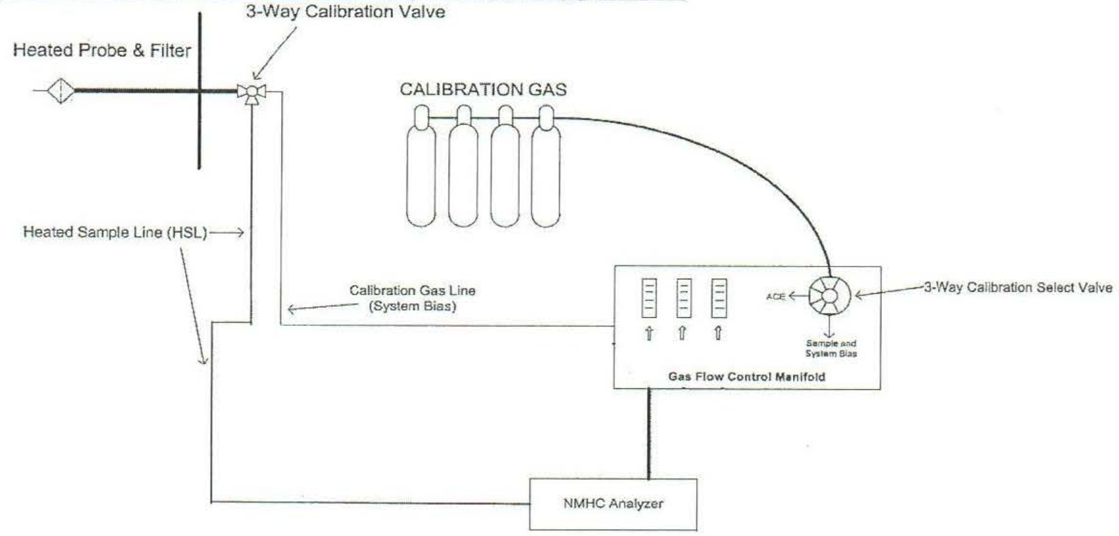
The components of the extractive sample interface apparatus are constructed of Type 316 stainless steel and Teflon. Flue gas was sampled from the stack via a sample probe and heated sample line and into the analyzer, which communicates with data acquisition handling systems (DAHS) via output signal cables. 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, where methane's low molecular weight and high volatility allow it to move more quickly through the column than other organic compounds 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 calibration gases following USEPA Method 25A procedures at the zero, low (25 to 35% of calibration span), mid (45 to 55% of calibration span) and high (80 to 90% of calibration span) levels. Since the instrument measures on a wet basis, gas moisture content was used to convert the wet VOC concentrations to a dry basis and calculate VOC mass 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 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



5.0 TEST RESULTS AND DISCUSSION

The test program was conducted March 25 through 27, 2024, 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," 40 CFR Part 63, Subpart ZZZZ, "National Emission Standards for Hazardous Air Pollutants (NESHAP) for Reciprocating Internal Combustion Engines," and MI-ROP-N5573-2018.

5.1 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 Tables 2-1 and 2-2. Appendix Tables 1 through 4 contain detailed tabulation of results, process operating conditions, and exhaust gas conditions for each respective RICE.

5.2 Significance of Results

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

5.3 Variations from Sampling or Operating Conditions

No operating condition variations were observed during the test program.

5.4 Process or Control Equipment Upset Conditions

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

5.5 Air Pollution Control Device Maintenance

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

5.6 Re-Test Discussion

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

- Annually to evaluate the reduction of CO emissions across the oxidation catalyst in accordance with 40 CFR 60 Subpart JJJJ and the ROP
- Every 8,760 engine operating hours or 3 years (2027), whichever is first, thereafter to evaluate compliance with NO_x, CO, and VOC emission limits in 40 CFR Part 63, Subpart ZZZZ and the ROP

5.7 Results of Audit Samples

Audit samples for the reference methods utilized during this test program are not available from USEPA Stationary Source Audit Sample Program providers.

The USEPA reference methods performed state reliable results are obtained by persons equipped with a thorough knowledge of the techniques associated with each method. Factors with the potential to cause measurement errors are minimized by implementing quality control (QC) and assurance (QA) programs into the applicable components of field testing. QA/QC components were included in this test program. Table 5-1 summarizes the primary field quality assurance and quality control activities that were performed. Refer to Appendix E for supporting documentation.

Table 5-1
QA/QC Procedures

QA/QC Activity	Purpose	Procedure	Frequency	Acceptance Criteria
M1: Sampling Location	Evaluates 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
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
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 ≥90% of NO_2 concentration

Table 5-1
QA/QC Procedures

QA/QC Activity	Purpose	Procedure	Frequency	Acceptance Criteria
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 span

5.8 Calibration Sheets

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

5.9 Sample Calculations

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

5.10 Field Data Sheets

Field data sheets are presented in Appendix B.

5.11 Laboratory Quality Assurance / Quality Control Procedures

Laboratory analysis was not required for this compliance demonstration.

5.12 QA/QC Blanks

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