MONTROSE
AIR QUALITY SERVICES

Review and Certification

All work, calculations, and other activities and tasks performed and presented in this document were carried out by me or under my direction and supervision. I hereby certify that, to the best of my knowledge, Montrose operated in conformance with the requirements of the Montrose Quality Management System and ASTM D7036-04 during this test project.

Signature: _____ **Date:** November 23, 2023

Name: John Nestor **Title:** District Manager

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1.0 Introduction

1.1 Summary of Test Program

Marquette Board of Light and Power (MBLP) contracted Montrose Air Quality Services, LLC (Montrose) to perform a compliance emissions test program on the dual fuel Reciprocating Internal Combustion Engines (RICE) 1 (EUENGINE01), 2 (EUENGINE02), and 3 (EUENGINE03) at the Marquette Energy Center (State Registration No.: P0668) located in Marquette, Michigan while firing natural gas. The test was conducted on August 24 and 25, 2023, to satisfy the emissions testing requirements pursuant to Michigan Department of Environment, Great Lakes, & Energy (EGLE) renewable operating permit number MI-ROP-P0668-2019 and 40 CFR Part 60, Subpart JJJJ. Testing of the engines while firing light fuel oil (LFO) was not required because the engines operated on fuel oil less than 2% of the time.

The specific objectives were to:

- Verify the emissions of nitrogen oxides (NO_x) (as NO_2), carbon monoxide (CO), formaldehyde, and volatile organic compounds (VOC) from the exhaust serving EUENGINE1, EUENGINE2, and EUENGINE3
- Conduct the test program with a focus on safety

Montrose performed the tests to measure the emission parameters listed in Table 1-1.

Table 1-1
Summary of Test Program

Test Date(s)	Unit ID/ Source Name	Activity/Parameters	Test Methods	No. of Runs	Duration (Minutes)
8/24-25/2023	EUENGINE01, EUENGINE02, EUENGINE03	Velocity/Volumetric Flow Rate	EPA 1 & 2	3	10
8/24-25/2023	EUENGINE01, EUENGINE02, EUENGINE03	O_2, CO_2	EPA 3A	3	60
8/24-25/2023	EUENGINE01, EUENGINE02, EUENGINE03	Moisture	EPA 4 (FTIR)	3	60
8/24-25/2023	EUENGINE01, EUENGINE02, EUENGINE03	NO_x	EPA 7E	3	60
8/24-25/2023	EUENGINE01, EUENGINE02, EUENGINE03	CO	EPA 10	3	60
8/24-25/2023	EUENGINE01, EUENGINE02, EUENGINE03	THC	EPA 25A	3	60
8/24-25/2023	EUENGINE01, EUENGINE02, EUENGINE03	CH_4, C_2H_6, Formaldehdye	EPA 320	3	60

To simplify this report, a list of Units and Abbreviations is included in Appendix C.1. Throughout this report, chemical nomenclature, acronyms, and reporting units are not defined. Please refer to the list for specific details.

This report presents the test results and supporting data, descriptions of the testing procedures, descriptions of the facility and sampling locations, and a summary of the quality assurance procedures used by Montrose. The average emission test results are summarized and compared to their respective permit limits in Tables 1-2 through 1-4. Detailed results for individual test runs can be found in Section 4.0. All supporting data can be found in the appendices.

The testing was conducted by the Montrose personnel listed in Table 1-5. The tests were conducted according to the test plan (protocol) that was submitted to and approved by EGLE on July 24, 2023.

Table 1-2
Summary of Average Compliance Results – EUENGINE01

August 24, 2023

Parameter/Units	Average Results	Emission Limits
Nitrogen Oxides (NO_x)		
lb/hr	1.9	3.3
ppmvd @15%O2	0.6	82
Carbon Monoxide (CO)		
lb/hr	0.2	5.0
ppmvd @15%O2	0.6	270
Formaldehyde		
lb/hr	0.199	0.648
Volatile Organic Compounds (VOC), as propane		
lb/hr	3.0	16.5
ppmvd @15%O2	6.0	60

Table 1-3
Summary of Average Compliance Results – EUENGINE02

August 24, 2023

Parameter/Units	Average Results	Emission Limits
Nitrogen Oxides (NO_x)		
lb/hr	1.5	3.3
ppmvd @15%O2	2.8	82
Carbon Monoxide (CO)		
lb/hr	0.2	5.0
ppmvd @15%O2	0.6	270
Formaldehyde		
lb/hr	0.232	0.648
Volatile Organic Compounds (VOC), as propane		
lb/hr	8.5	16.5
ppmvd @15%O2	16.8	60

Table 1-4
Summary of Average Compliance Results – EUENGINE03

August 25, 2023

Parameter/Units	Average Results	Emission Limits
Nitrogen Oxides (NO_x)		
lb/hr	0.7	3.3
ppmvd @15%O2	1.3	82
Carbon Monoxide (CO)		
lb/hr	0.2	5.0
ppmvd @15%O2	0.8	270
Formaldehyde		
lb/hr	0.167	0.648
Volatile Organic Compounds (VOC), as propane		
lb/hr	9.1	16.5
ppmvd @15%O2	18.2	60

1.2 Key Personnel

A list of project participants is included below:

Facility Information

Source Location: Marquette Board of Light and Power
Marquette Energy Complex
2200 Wright Street
Marquette, MI 49855
Project Contact: Mr. Thomas Skewis
Role: Utility Compliance
Company: MBLP
Email: tskewis@mblp.org

Agency Information

Regulatory Agency: EGLE
Agency Contact: Jeremey Howe
Telephone: 517-335-3122
Email: HoweJ1@michigan.gov

Testing Company Information

Testing Firm: Montrose Air Quality Services, LLC
Contact: John Nestor
Title: District Manager
Telephone: 248-765-5032
Email: jonestor@montrose-env.com

Test personnel and observers are summarized in Table 1-5.

Table 1-5
Test Personnel and Observers

Name	Affiliation	Role/Responsibility
John Nestor	Montrose	District Manager, QI
Joseph Scanlan	EGLE	Observer
Thomas Skewis	MBLP	Test Coordinator

2.0 Plant and Sampling Location Descriptions

2.1 Process Description, Operation, and Control Equipment

The MBLP has installed (3) dual fuel-fired Wärtsilä W18V50DF, four stroke, lean burn, reciprocating internal combustion engines (RICE) nominally rated at 17 MW(173 mmBtu/hr when firing natural gas as primary fuel, 154 mmBtu/hr when firing emergency backup fuel oil).The RICE electric generating units utilize pipeline quality natural gas and is equipped with selective catalytic reduction (SCR) for nitrogen oxides (NOx) control and an oxidation catalyst system for carbon monoxide (CO), volatile organic compound (VOC), and organic hazardous air pollutant (HAP) control. The RICE electric generating units exhaust into individual stacks.

2.2 Flue Gas Sampling Location

Information regarding the sampling location is presented in Table 2-1.

Table 2-1
Sampling Location

Sampling Location	Stack Inside Diameter (in.)	Distance from Nearest Disturbance		Number of Traverse Points
		Downstream EPA "B" (in./dia.)	Upstream EPA "A" (in./dia.)	
EUENGINE01-03 Exhaust	63	>2	>0.5	Flow: 16 (8/port) Gaseous: 3

The sampling location was verified in the field to conform to EPA Method 1. Acceptable cyclonic flow conditions were confirmed prior to testing using EPA Method 1, Section 11.4. See Appendix A.1 for more information.

2.3 Operating Conditions and Process Data

Emission tests were performed while the engines were operating at the conditions required by the permit. The unit was tested when operating normally.

Plant personnel were responsible for establishing the test conditions and collecting all applicable unit-operating data. The process data that was provided is presented in Appendix B. Data collected includes the following parameters:

- Generator Active Power (KW), Engine Load (%)
- Selective catalytic reduction unit (SCR) differential pressure (lbf/ft2)
- SCR inlet and outlet temperature, °F
- Cumulative reagent flow (gallons &gal/hr)
- Natural Gas Fuel Mass Flow (lb/hr) & Cumulative Mass Flow (lb)

3.0 Sampling and Analytical Procedures

3.1 Test Methods

The test methods for this test program have been presented in Table 1-1. Additional information regarding specific applications or modifications to standard procedures is presented below.

3.1.1 EPA Method 1, Sample and Velocity Traverses for Stationary Sources

EPA Method 1 is used to assure that representative samples or measurements of volumetric flow rate are obtained by dividing the cross-section of the stack or duct into equal areas, and then locating a traverse point within each of the equal areas. Acceptable sample locations must be located at least two stack or duct equivalent diameters downstream from a flow disturbance and one-half equivalent diameter upstream from a flow disturbance.

Pertinent information regarding the performance of the method is presented below:

- Method Options:
  - None
- Method Exceptions:
  - None

The sample port and traverse point locations are detailed in Appendix A.

3.1.2 EPA Method 2, Determination of Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

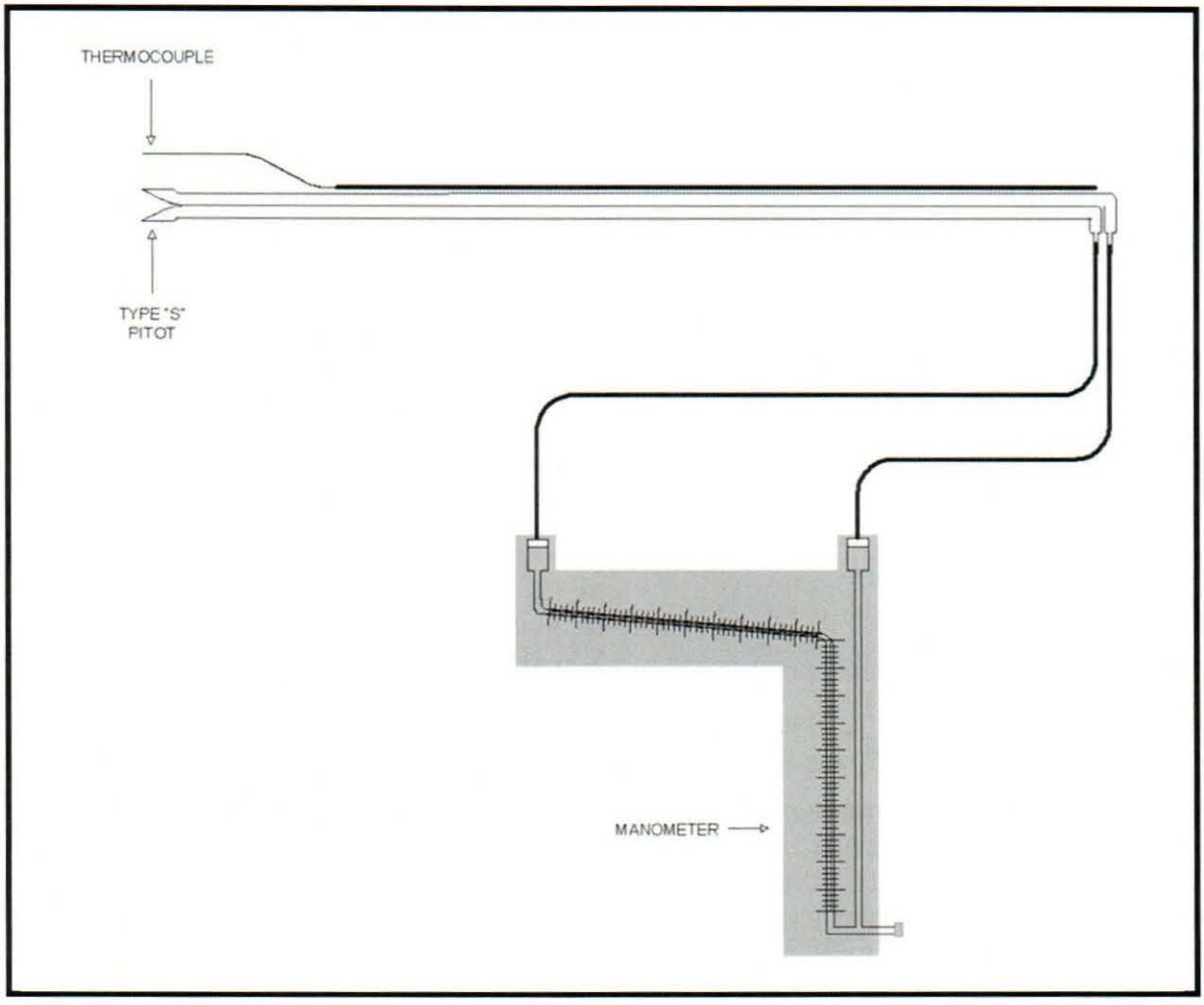
EPA Method 2 is used to measure the gas velocity using an S-type pitot tube connected to a pressure measurement device, and to measure the gas temperature using a calibrated thermocouple connected to a thermocouple indicator. Typically, Type S (Stausscheibe) pitot tubes conforming to the geometric specifications in the test method are used, along with an inclined manometer. The measurements are made at traverse points specified by EPA Method 1.

Pertinent information regarding the performance of the method is presented below:

- Method Options:
  - S-type pitot tube coefficient is 0.84
- Method Exceptions:
  - A flow traverse is conducted once during each test run to represent the flow rate for the entire test run
  - Stack gas temperatures thermocouples are checked using EPA Alternate Method 011 (ALT-011). A single-point calibration is performed using a NIST-traceable thermometer.

The typical sampling system is detailed in Figure 3-1.

Figure 3-1
EPA Method 2 Sampling Train



3.1.3 EPA Method 3A, Determination of Oxygen and Carbon Dioxide in Emissions from Stationary Sources (Instrumental Analyzer Procedure)

EPA Method 3A is an instrumental test method used to measure the concentration of O_2 and CO_2 in stack gas. The effluent gas is continuously or intermittently sampled and conveyed to analyzers that measure the concentrations of O_2 and CO_2. The performance requirements of the method must be met to validate data.

Pertinent information regarding the performance of the method is presented below:

- Method Options:
  - Calibration span values are 20.15% O_2 and 20.13% CO_2
- Method Exceptions:
  - For gaseous emissions sampling, MDL are calculated for each analyzer. The ISDL is equal to the sensitivity of the instrumentation, which is 2% of the span value.
- Target and/or Minimum Required Sample Duration: 60 minutes
- Target Analytes: O_2 and CO_2

The typical sampling system is detailed in Figure 3-2.

3.1.4 EPA Method 7E, Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)

EPA Method 7E is an instrumental test method used to continuously measure emissions of NO_x as NO_2. Conditioned gas is sent to a chemiluminescent analyzer to measure the concentration of NO_x. NO and NO_2 can be measured separately or simultaneously together but, for the purposes of this method, NO_x is the sum of NO and NO_2. The performance requirements of the method must be met to validate the data.

Pertinent information regarding the performance of the method is presented below:

- Method Options:
  - A dry extractive sampling system is used to report emissions on a dry basis
  - Calibration span value is 90.28 ppmvd NO_x
- Method Exceptions:
  - None
- Target and/or Minimum Required Sample Duration: 60 minutes

The typical sampling system is detailed in Figure 3-2.

3.1.5 EPA Method 10, Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)

EPA Method 10 is an instrumental test method used to continuously measure emissions of CO. Conditioned gas is sent to an analyzer to measure the concentration of CO. The performance requirements of the method must be met to validate the data.

Pertinent information regarding the performance of the method is presented below:

- Method Options:
  - A dry extractive sampling system is used to report emissions on a dry basis
  - Calibration span value is 89.52 ppmvd CO
- Method Exceptions:
  - None
- Target and/or Minimum Required Sample Duration: 60 minutes

The typical sampling system is detailed in Figure 3-2.

3.1.6 EPA Method 25A, Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

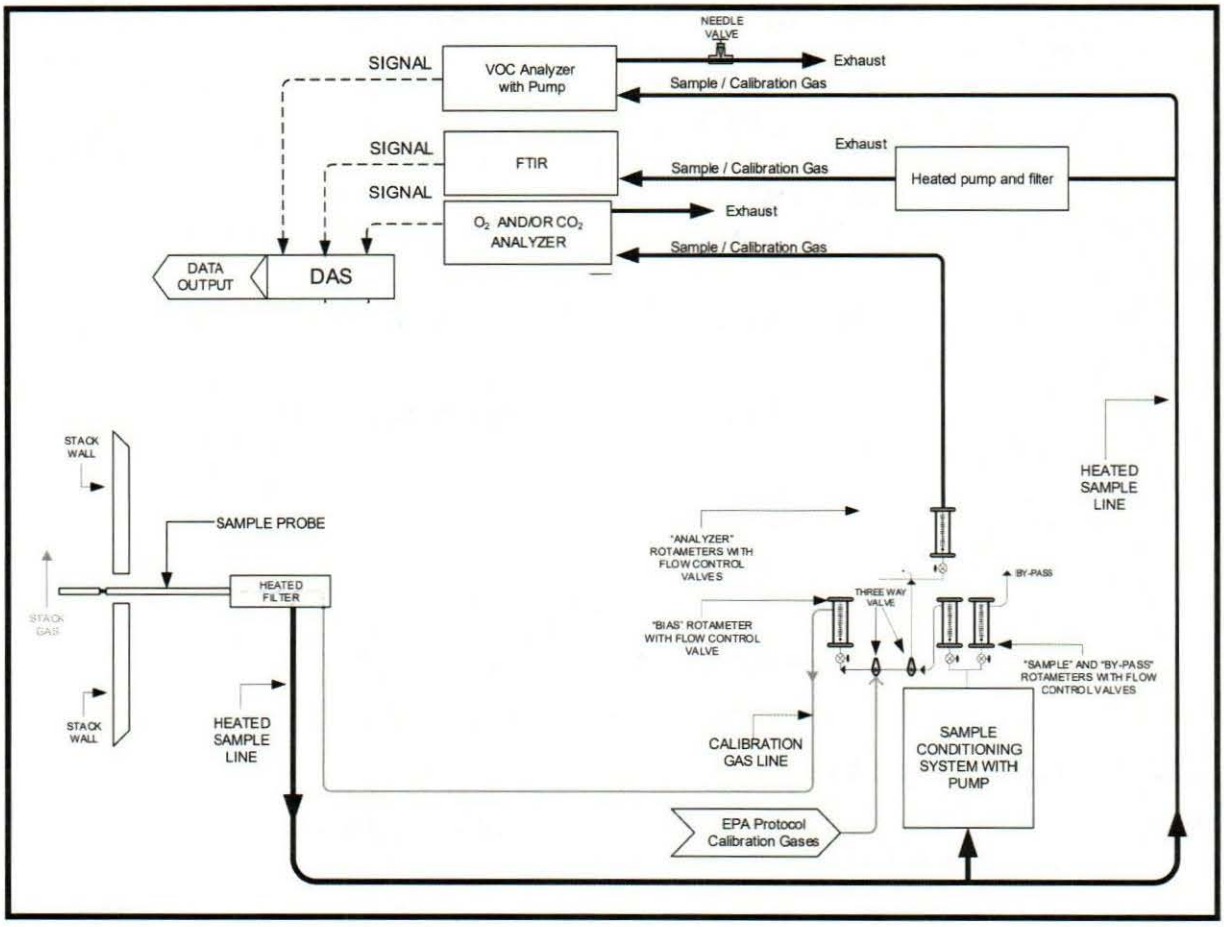
EPA Method 25A is an instrumental test method used for the determination of total gaseous organic concentration of vapors in stack gas. A gas sample is extracted from the source through a heated sample line and glass fiber filter to an FIA. Results are reported as THC as volume concentration equivalents of the calibration gas, typically propane, or as carbon equivalents.

Pertinent information regarding the performance of the method is presented below:

- Method Options:
  - Results are reported in terms of propane
  - Span value for THC is 1,010 ppmvw
  - THC emissions on a C_3H_8 basis are corrected for CH_4 and C_2H_6 and reported as VOC
- Method Exceptions:
- Target and/or Minimum Required Sample Duration: 60 minutes

The typical sampling system is detailed in Figure 3-2.

Figure 3-2
EPA Methods 3A, 7E, 10, 25A, and 320 (FTIR) Sampling Train



3.1.7 EPA Method 320, Measurement of Vapor Phase Organic and Inorganic Emissions by Extractive FTIR Spectroscopy

EPA Method 320 is an instrumental test method used to measure specific analyte concentrations for which EPA reference spectra have been developed or prepared. Extractive emission measurements are performed using FTIR spectroscopy. The FTIR analyzer is composed of a spectrometer and detector, a high optical throughput sampling cell, analysis software, and a quantitative spectral library. The analyzer collects high resolution spectra in the mid infrared spectral region (400 to 4,000 cm^{-1}), which are analyzed using the quantitative spectral library. This provides an accurate, highly sensitive measurement of gases and vapors.

Pertinent information regarding the performance of the method is presented below:

- Method Options:
  - The specific analyte concentrations include H_2O, methane (CH_4), formaldehyde, and ethane (C_2H_6)
  - A dynamic matrix spike is performed using formaldehyde and SF_6 as a tracer gas
- Method Exceptions:
  - None
- Target and/or Minimum Required Sample Duration: 60 minutes

The typical sampling system is detailed in Figure 3-2.

3.2 Process Test Methods

The test plan did not require that process samples be collected during this test program; therefore, no process sample data are presented in this test report.

4.0 Test Discussion and Results

4.1 Field Test Deviations and Exceptions

No field deviations or exceptions from the test plan or test methods occurred during this test program.

4.2 Presentation of Results

The average results are compared to the permit limits in Tables 1-2 through 1-4. The results of individual compliance test runs performed are presented in Table 4-1. Emissions are reported in units consistent with those in the applicable regulations or requirements. Additional information is included in the appendices as presented in the Table of Contents.

Table 4-1
NO_x, CO, Formaldehyde, and VOC Emissions Results - EUENGINE01

Parameter/Units	Run 1	Run 2	Run 3	Average
Date	8/24/2023	8/24/2023	8/24/2023	--
Time	8:20-9:19	10:00-10:59	11:45-12:45	--
Process Data *				
Engine load, BHP	22550.47	22558.53	22555.53	22554.84
Sampling & Flue Gas Parameters				
sample duration, minutes	60	60	60	60
O_2, % volume dry	11.4	11.5	11.5	11.5
CO_2, % volume dry	5.4	5.4	5.4	5.4
moisture content, % volume	10.3	11.4	10.8	10.8
volumetric flow rate, scfm	51,178	50,588	51,610	51,125
volumetric flow rate, dscfm	45,906	44,821	46,036	45,588
Nitrogen Oxides (NO_x)				
ppmvd	4.6	5.6	7.4	5.8
ppmvd @ 15% O2	2.8	3.5	4.6	3.7
lb/hr, as NO_2	1.5	1.8	2.4	1.9
Carbon Monoxide (CO)				
ppmvd	0.8	1.1	1.1	1.0
ppmvd @ 15% O2	0.5	0.7	0.7	0.6
lb/hr	0.2	0.2	0.2	0.2
Formaldehyde				
ppmvw	0.6	1.0	0.9	0.8
lb/hr	0.144	0.237	0.217	0.199
Volatile Organic Compounds (VOC), as propane				
ppmvw	359.7	365.7	397.4	374.3
Methane (CH_4)				
ppmvw	835.8	836.4	904.3	858.8
Ethane (C_2H_6)				
ppmvw	42.0	40.8	42.5	41.8
Non-Methane Non-Ethane Volatile Organic Compounds (NMNEVOC), as propane				
ppmvw	3.0	9.5	13.3	8.6
ppmvd @ 15% O2	2.1	6.7	9.4	6.0
lb/hr	1.0	3.3	4.7	3.0

* Process data was provided by MBLP personnel.

Table 4-2
NO_x, CO, Formaldehyde, and VOC Emissions Results - EUENGINE02

Parameter/Units	Run 1	Run 2	Run 3	Average
Date	8/24/2023	8/24/2023	8/24/2023	--
Time	14:25-15:24	15:50-16:49	17:40-18:39	--
Process Data *				
Engine load, BHP	22595.20	22577.06	22578.64	22583.63
Sampling & Flue Gas Parameters				
sample duration, minutes	60	60	60	60
O_2, % volume dry	11.5	11.4	11.5	11.4
CO_2, % volume dry	5.5	5.5	5.5	5.5
moisture content, % volume	10.6	10.6	10.6	10.6
volumetric flow rate, scfm	51,049	51,164	51,758	51,324
volumetric flow rate, dscfm	45,638	45,741	46,272	45,883
Nitrogen Oxides (NO_x)				
ppmvd	4.0	4.4	5.2	4.6
ppmvd @ 15% O2	2.5	2.8	3.2	2.8
lb/hr, as NO_2	1.3	1.5	1.7	1.5
Carbon Monoxide (CO)				
ppmvd	0.8	1.0	1.1	1.0
ppmvd @ 15% O2	0.5	0.6	0.7	0.6
lb/hr	0.2	0.2	0.2	0.2
Formaldehyde				
ppmvw	0.9	1.0	1.0	1.0
lb/hr	0.215	0.239	0.242	0.232
Volatile Organic Compounds (VOC), as propane				
ppmvw	476.4	482.0	482.1	480.2
Methane (CH_4)				
ppmvw	1063.1	1063.5	1070.7	1065.8
Ethane (C_2H_6)				
ppmvw	55.4	55.1	55.8	55.4
Non-Methane Non-Ethane Volatile Organic Compounds (NMNEVOC), as propane				
ppmvw	21.3	26.9	23.8	24.0
ppmvd @ 15% O2	14.9	18.8	16.6	16.8
lb/hr	7.5	9.4	8.5	8.5

* Process data was provided by MBLP personnel.

Table 4-3
NO_x, CO, Formaldehyde, and VOC Emissions Results - EUENGINE03

Parameter/Units	Run 1	Run 2	Run 3	Average
Date	8/25/2023	8/25/2023	8/25/2023	--
Time	9:05-10:04	10:35-11:34	12:05-13:04	--
Process Data *				
Engine load, BHP	22561.11	22560.54	22565.99	22562.55
Sampling & Flue Gas Parameters				
sample duration, minutes	60	60	60	60
O_2, % volume dry	11.4	11.5	11.5	11.4
CO_2, % volume dry	5.6	5.5	5.5	5.5
moisture content, % volume	11.6	10.9	10.8	11.1
volumetric flow rate, scfm	50,880	51,709	50,767	51,119
volumetric flow rate, dscfm	44,978	46,073	45,285	45,445
Nitrogen Oxides (NO_x)				
ppmvd	2.0	1.9	2.5	2.1
ppmvd @ 15% O2	1.3	1.2	1.5	1.3
lb/hr, as NO_2	0.7	0.6	0.8	0.7
Carbon Monoxide (CO)				
ppmvd	1.3	1.4	1.0	1.2
ppmvd @ 15% O2	0.8	0.9	0.6	0.8
lb/hr	0.3	0.3	0.2	0.2
Formaldehyde				
ppmvw	0.7	0.7	0.7	0.7
lb/hr	0.167	0.169	0.166	0.167
Volatile Organic Compounds (VOC), as propane				
ppmvw	453.2	459.7	466.4	459.8
Methane (CH_4)				
ppmvw	990.7	1014.5	1033.9	1013.0
Ethane (C_2H_6)				
ppmvw	51.3	53.6	54.2	53.0
Non-Methane Non-Ethane Volatile Organic Compounds (NMNEVOC), as propane				
ppmvw	29.3	25.0	23.6	26.0
ppmvd @ 15% O2	20.5	17.5	16.6	18.2
lb/hr	10.2	8.9	8.2	9.1

* Process data was provided by MBLP personnel.

5.0 Internal QA/QC Activities

5.1 QA/QC Audits

EPA Method 3A, 7E, and 10 calibration audits were all within the measurement system performance specifications for the calibration drift checks, system calibration bias checks, and calibration error checks.

EPA Method 25A FIA calibration audits were within the measurement system performance specifications for the calibration drift checks and calibration error checks.

The EPA Method 320 performance parameters measured included signal to noise tests, noise equivalent absorbance (NEA), detector linearity, background spectra, potential interferents, and cell and system leakage. Quality assurance procedures included baseline measurement with ultra-high purity nitrogen, measurement of a calibration transfer standard, direct analyte calibration measurements, and measurements to determine baseline shift. SF_6 was also used as a tracer gas in the calibration gases to verify the sample delivery system integrity. A dynamic matrix spike was performed using SF_6 as a tracer gas. The method QA/QC criteria were met.

5.2 QA/QC Discussion

All QA/QC criteria were met during this test program.

5.3 Quality Statement

Montrose is qualified to conduct this test program and has established a quality management system that led to accreditation with ASTM Standard D7036-04 (Standard Practice for Competence of Air Emission Testing Bodies). Montrose participates in annual functional assessments for conformance with D7036-04 which are conducted by the American Association for Laboratory Accreditation (A2LA). All testing performed by Montrose is supervised on site by at least one Qualified Individual (QI) as defined in D7036-04 Section 8.3.2. Data quality objectives for estimating measurement uncertainty within the documented limits in the test methods are met by using approved test protocols for each project as defined in D7036-04 Sections 7.2.1 and 12.10. Additional quality assurance information is included in the report appendices. The content of this report is modeled after the EPA Emission Measurement Center Guideline Document (GD-043).

Appendix A
Field Data and Calculations

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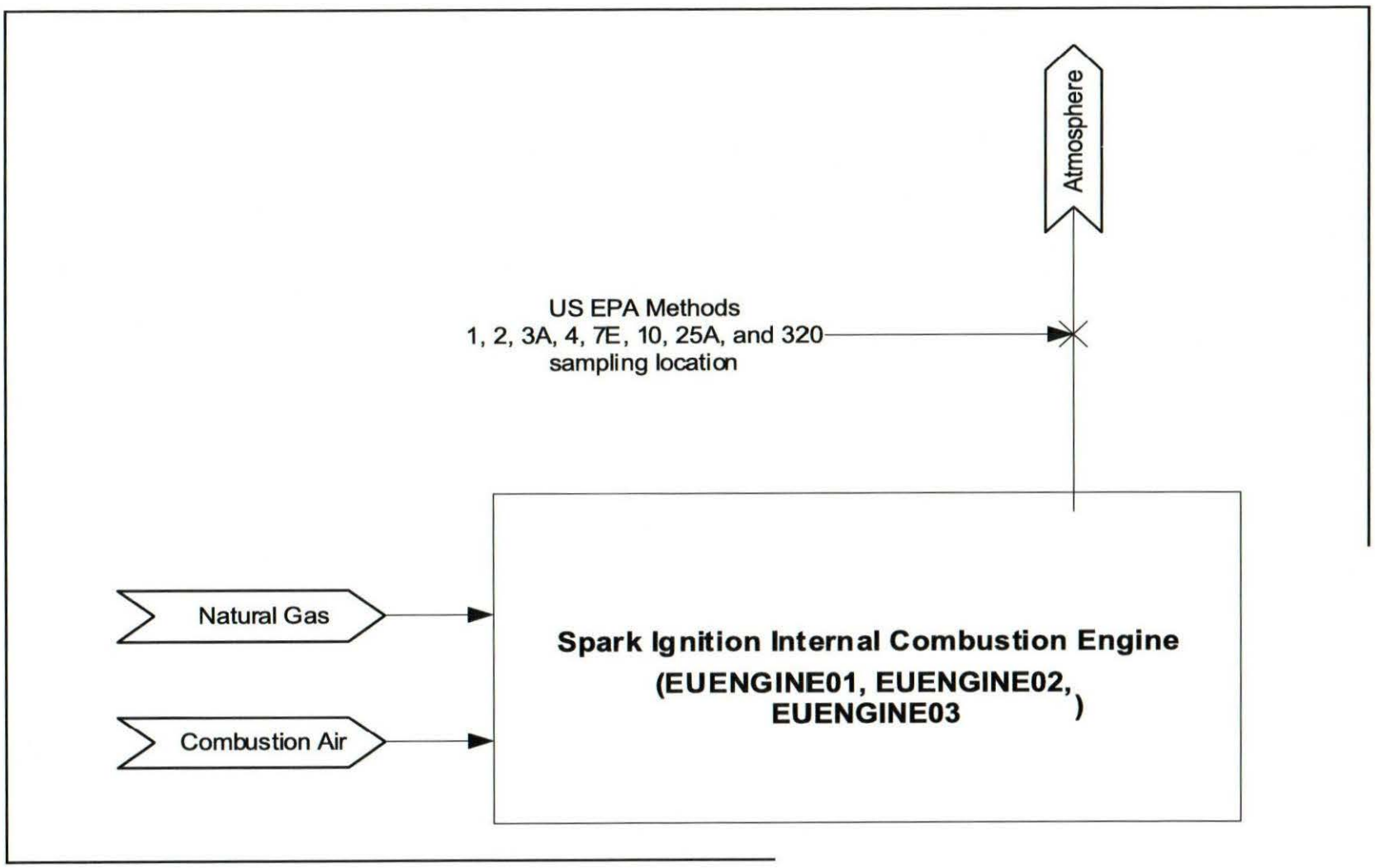
Appendix A.1
Sampling Locations

EUENGINE PROCESS AND SAMPLING LOCATION SCHEMATIC



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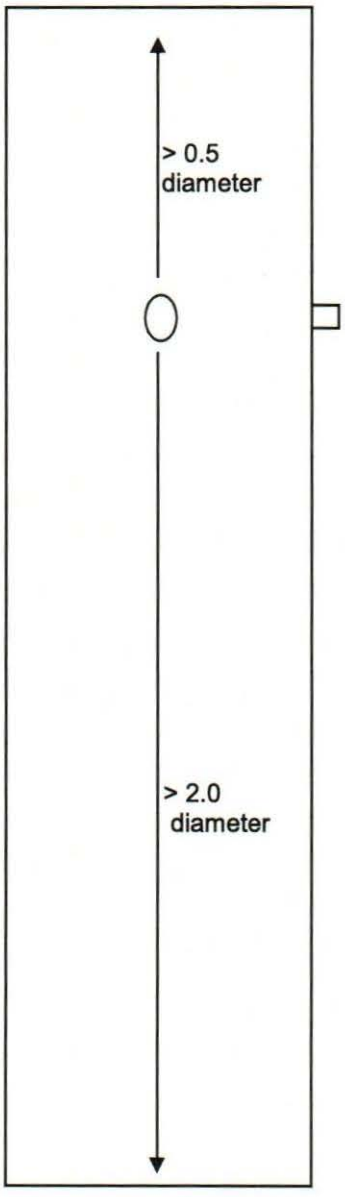
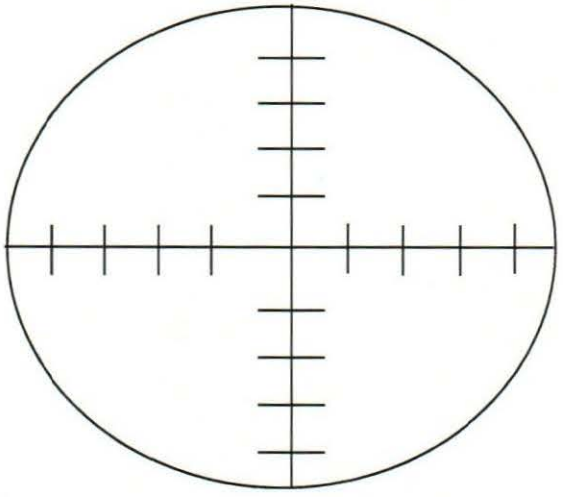
diameter = 63





Not to Scale

Points	Distance "
1	2.0
2	6.6
3	12.2
4	20.3
5	42.7
6	50.8
7	56.4
8	61.0

Site:	Sampling Dates:	Montrose Air Quality Services, LLC
Marquette Energy Center Marquette Board of Light and Power Marquette, MI	8/24/2023-8/24/2023	4949 Fernlee Royal Oak, Michigan

Appendix A.2
EUENGINE Data Sheets