EXECUTIVE SUMMARY

Montrose Air Quality Services, LLC (Montrose) was retained by Western Michigan University (WMU) to measure total volatile organic compounds (VOC) emissions at the exhausts of two natural gas-fired reciprocating internal combustion engines (RICE) (EU-ENGINE9 and EU-ENGINE10) located at WMU's Robert M. Beam Power Plant in Kalamazoo, Michigan. The facility operates under Michigan Department of Environment, Great Lakes, and Energy (EGLE) Renewable Operating Permit No. MI-ROP-K2131-2021.

The emissions testing is required by the permit's SC V.2 requires the following:

- VOC emission (with CH_2O) must be ≤ 6.4 lb/hr.

The emissions test program was conducted on July 8, 2021, and August 10, 2021. The results of the emissions test program are summarized in the following tables.

SUMMARY OF AVERAGE COMPLIANCE RESULTS -
EU-ENGINE9
JULY 8, 2021

Parameter/Units	Average Results	Emission Limits
Formaldehyde (CH_2O)		
lb/hr	0.154	--
Formaldehyde (CH_2O), as Propane		
lb/hr	0.075	--
Volatile Organic Compounds (VOC), as Propane †		
lb/hr	0.084	--
Total VOC, (With CH_2O), as Propane ‡		
lb/hr	0.160	6.4

† Volatile Organic Compounds (VOC), as propane emissions exclude methane, ethane, and formaldehyde concentrations .

‡ Total VOC(With CH_2O) as propane emissions exclude methane and ethane concentrations .

SUMMARY OF AVERAGE COMPLIANCE RESULTS - EU-ENGINE10 AUGUST 10, 2021

Parameter/Units	Average Results	Emission Limits
Formaldehyde (CH_2O)		
lb/hr	0.254	--
Formaldehyde (CH_2O), as Propane		
lb/hr	0.124	--
Volatile Organic Compounds (VOC), as Propane †		
lb/hr	0.143	--
Total VOC (With CH_2O), as Propane ‡		
lb/hr	0.268	6.4

† Volatile Organic Compounds (VOC), as propane emissions exclude methane, ethane, and formaldehyde concentrations .

‡ Total VOC(With CH_2O) as propane emissions exclude methane and ethane concentrations .

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: Todd Wessel Date: 09 / 03 / 2021

Name: Todd Wessel Title: Client Project Manager

I have reviewed, technically and editorially, details, calculations, results, conclusions, and other appropriate written materials contained herein. I hereby certify that, to the best of my knowledge, the presented material is authentic, accurate, and conforms to the requirements of the Montrose Quality Management System and ASTM D7036-04.

Signature: Date: 09 / 03 / 2021

Name: Matthew Young Title: District Manager

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1.0 INTRODUCTION

1.1 SUMMARY OF TEST PROGRAM

Western Michigan University (State Registration No.: K2131) contracted Montrose Air Quality Services, LLC (Montrose) to perform a compliance test program on the RICE Engines 1 (EU-ENGINE9) and 2 (EU-ENGINE10) at the Western Michigan University-Robert M. Beam Power Plant facility located in Kalamazoo, Michigan. Testing was performed on July 8, 2021, and August 10, 2021, for the purpose of satisfying the emission testing requirements pursuant to Michigan Department of Environment, Great Lakes, and Energy (EGLE) Renewable Operation Permit No. MI-ROP-K2131-2021.

The specific objectives were to:

- Verify the emissions of CH_2O and VOC (including CH_2O) at the exhaust stack serving EU-ENGINE9 and EU-ENGINE10 in accordance with Permit MI-ROP-K2131-2021 SC V.2
- Conduct the test program with a focus on safety

Montrose performed the tests to measure the emission parameters listed in Tables 1-1 through 1-3.

TABLE 1-1
SUMMARY OF JULY TEST PROGRAM - EU-ENGINE9

Test Date(s)	Unit ID/ Source Name	Activity/ Parameters	Test Methods	No. of Runs	Duration (Minutes)
7/8/2021	EU-ENGINE9	Velocity/Volumetric Flow Rate	EPA 1 & 2	4	5-8
7/8/2021	EU-ENGINE9	O_2	EPA 3A	3	60
7/8/2021	EU-ENGINE9	Moisture, CO_2, VOC, CH_2O	EPA 320	3	60

TABLE 1-2
SUMMARY OF AUGUST TEST PROGRAM - EU-ENGINE10

Test Date(s)	Unit ID/ Source Name	Activity/ Parameters	Test Methods	No. of Runs	Duration (Minutes)
8/10/2021	EU-ENGINE10	Velocity/Volumetric Flow Rate	EPA 1 & 2	4	5-8
8/10/2021	EU-ENGINE10	O_2	EPA 3A	3	60
8/10/2021	EU-ENGINE10	Moisture, CO_2, VOC, CH_2O	EPA 320	3	60

To simplify this report, a list of Units and Abbreviations is included in Appendix D.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 1-3 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 Intent-to-Test notification dated May 21, 2021, that was submitted to the EGLE.

TABLE 1-3
SUMMARY OF AVERAGE COMPLIANCE RESULTS -
EU-ENGINE9
JULY 8, 2021

Parameter/Units	Average Results	Emission Limits
Formaldehyde (CH_2O)		
lb/hr	0.154	--
Formaldehyde (CH_2O), as Propane		
lb/hr	0.075	--
Volatile Organic Compounds (VOC), as Propane †		
lb/hr	0.084	--
Total VOC (With CH_2O), as Propane ‡		
lb/hr	0.160	6.4

† Volatile Organic Compounds (VOC), as propane emissions exclude methane, ethane, and formaldehyde concentrations .

‡ Total VOC(With CH_2O) as propane emissions exclude methane and ethane concentrations .

TABLE 1-4
SUMMARY OF AVERAGE COMPLIANCE RESULTS -
EU-ENGINE10
AUGUST 10, 2021

Parameter/Units	Average Results	Emission Limits
Formaldehyde (CH_2O)		
lb/hr	0.254	--
Formaldehyde (CH_2O), as Propane		
lb/hr	0.124	--
Volatile Organic Compounds (VOC), as Propane †		
lb/hr	0.143	--
Total VOC (With CH_2O), as Propane ‡		
lb/hr	0.268	6.4

† Volatile Organic Compounds (VOC), as propane emissions exclude methane, ethane, and formaldehyde concentrations .

‡ Total VOC(With CH_2O) as propane emissions exclude methane and ethane concentrations .

1.2 KEY PERSONNEL

A list of project participants is included below:

Facility Information

Source Location:	Western Michigan University Robert M. Beam Power Plant 1903 West Michigan Avenue Kalamazoo, MI 49008	
Project Contact:	George Jarvis	Mark Weiss
Role:	Power Plant Director	Director of EHS
Company:	Western Michigan University	Western Michigan University
Telephone:	269-387-8548	269-387-5588
Email:	george.jarvis@wmich.edu	mark.weiss@wmich.edu

Agency Information

Regulatory Agency:	EGLE
Agency Contact:	Karen Kajiya-Mills
Telephone:	517-335-3122
Email:	kajiya-millk@michigan.gov

Testing Company Information

Testing Firm:	Montrose Air Quality Services, LLC	
Contact:	Matthew Young	Todd Wessel
Title:	District Manager	Client Project Manager
Telephone:	248-548-8070	248-548-8070
Email:	myoung@montrose-env.com	twessell@montrose-env.com

Laboratory Information

Laboratory:	Prism Analytical Technologies
City, State:	Mount Pleasant, MI 48858
Method:	EPA Method 320

Subcontractor (or Consultant) Information

Company:	NTH Consultants, Ltd.
Contact:	Abbie Welch
Telephone:	616-450-6436
Email:	awelch@nthconsultants.com

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

TABLE 1-5
TEST PERSONNEL AND OBSERVERS

Name	Affiliation	Role/Responsibility
Todd Wessel	Montrose	Client Project Manager, QI
Steve Smith	Montrose	Client Project Manager, QI
Shane Rabideau	Montrose	Field Technician
Phil Kauppi	Montrose	Client Project Manager, QI
George Jarvis	Western Michigan University	Observer/Client Liaison/Test Coordinator
Lindsey Wells	EGLE	Observer
Monica Brothers	EGLE	Observer
Trevon Drost	EGLE	Observer

2.0 PLANT AND SAMPLING LOCATION DESCRIPTIONS

2.1 PROCESS DESCRIPTION, OPERATION, AND CONTROL EQUIPMENT

Western Michigan University's Robert M. Beam Power Plant operates two 3,500 HP natural gas-fired reciprocating internal combustion engines (RICE) manufactured by Caterpillar. Each RICE is rated at 3,448 brake horsepower (HP) (2.5 megawatts (MW)) with a maximum heat input of 22 MMBtu/hr. Engine 1 (EU-ENGINE9) and Engine 2 (EU-ENGINE10) use lean-burn technology and are each equipped with oxidation catalysts for control of CO and VOC emissions. EU-ENGINE9 and EU-ENGINE10 were commissioned to provide electricity during on-peak hours to the WMU Kalamazoo campus. The EU-ENGINE9 was in operation for the July test event while EU-ENGINE10 was in operation for the August test event.

2.2 FLUE GAS SAMPLING LOCATIONS

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

TABLE 2-1
SAMPLING LOCATIONS

Sampling Location	Stack Inside Diameter (in.)	Distance from Nearest Disturbance		Number of Traverse Points
		Downstream EPA "B" (in./dia.)	Upstream EPA "A" (in./dia.)	
EU-ENGINE9 Exhaust Stack	19.5	72.0 / 3.7	36.0 / 1.9	Flow: 16 (8/port); Gaseous: 3
EU-ENGINE10 Exhaust Stack	19.5	72.0 / 3.7	36.0 / 1.9	Flow: 16 (8/port); Gaseous: 3

Sampling locations were 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 greater than 90% capacity.

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:

- Engine Output, kW
- Engine Fuel Use, acfh
- Catalyst Inlet Temperature, °F
- Average Pressure Drop Across Catalyst, in H_2O

3.0 SAMPLING AND ANALYTICAL PROCEDURES

3.1 TEST METHODS

The test methods for this test program were presented previously 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 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.

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

3.1.2 EPA Method 2, Determination of Stack 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.

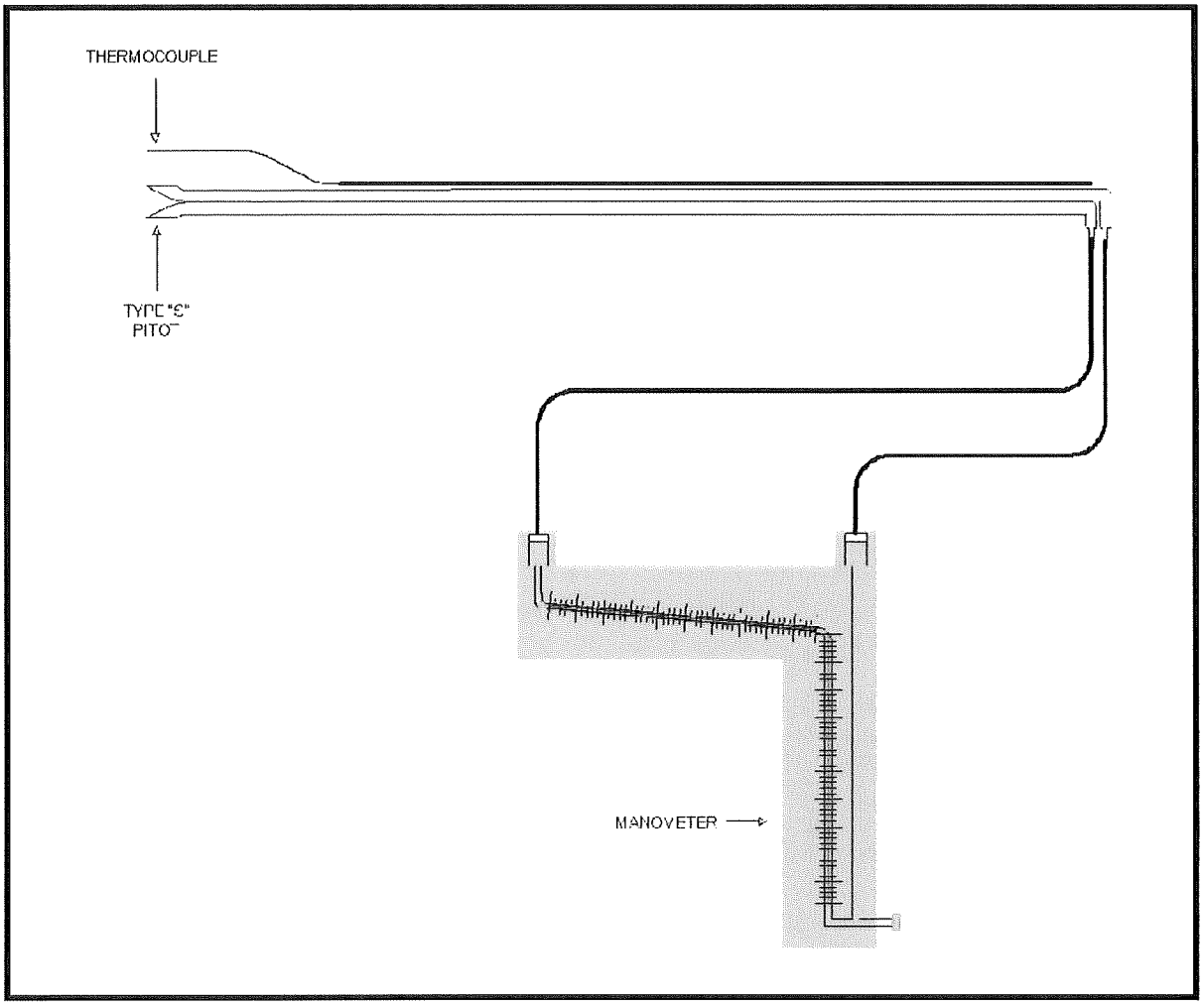
The typical sampling system is detailed in Figure 3-1.

3.1.3 EPA Method 3A, Determination of Oxygen and Carbon Dioxide Concentrations 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 concentration of O_2 and CO_2. The performance requirements of the method must be met to validate data.

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

FIGURE 3-1
EPA METHOD 2 SAMPLING TRAIN

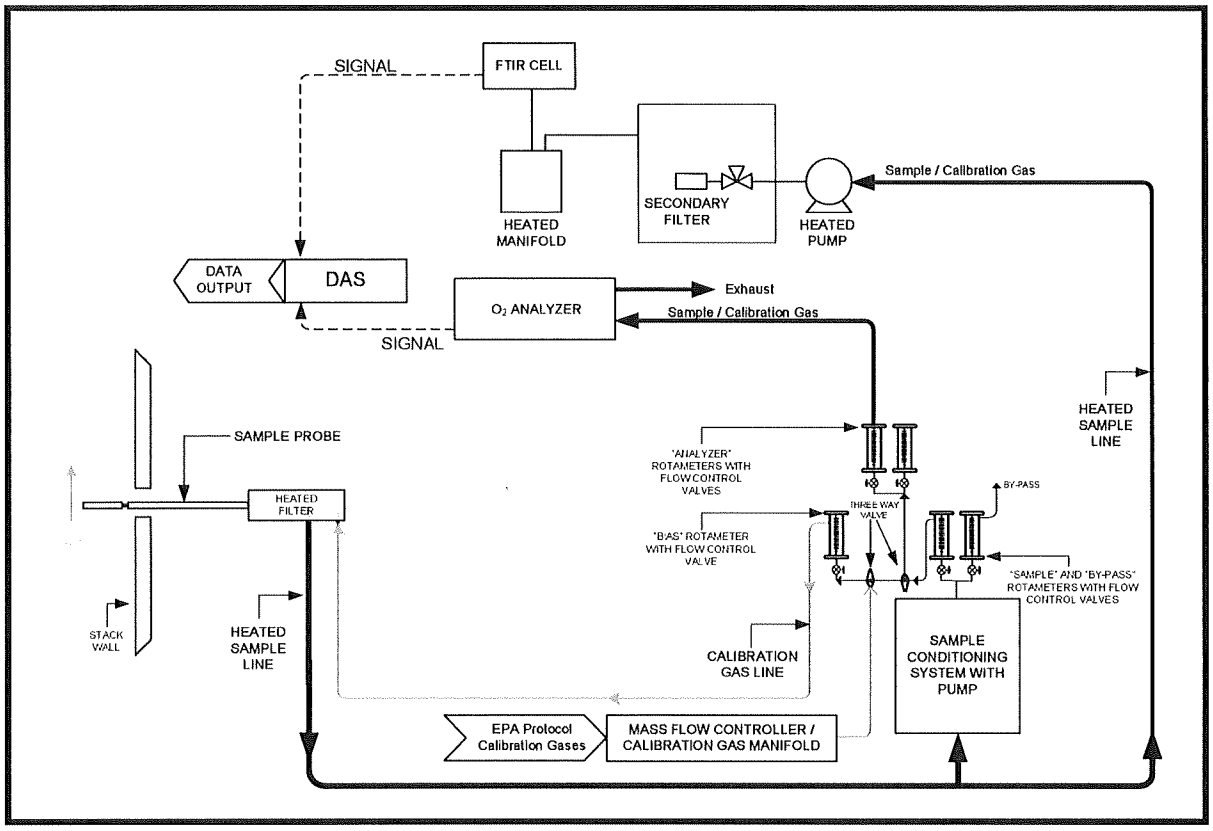


3.1.4 EPA Method 320, Measurement of Vapor Phase Organic and Inorganic Emissions by Extractive FTIR Spectroscopy

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.

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

FIGURE 3-2
EPA METHOD 3A (O_2), 320 SAMPLING TRAIN



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 1-3 through 1-4. The results of individual compliance test runs performed are presented in Tables 4-1 through 4-2. 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
CH_2O AND VOC EMISSIONS RESULTS - EU-ENGINE9

Run Number	1	2	3	Average
Date	7/8/2021	7/8/2021	7/8/2021	--
Time	8:40-9:40	10:00-11:00	11:20-12:20	--
Process Data				
Engine Output, kW	2,503	2,500	2,491	2,498
Flue Gas Parameters				
O_2, % volume dry	9.34	9.36	9.39	9.36
CO_2, % volume dry	6.48	6.48	6.47	6.47
flue gas temperature, °F	732.2	737.3	733.0	734.1
moisture content, % volume	12.90	12.90	12.80	12.87
volumetric flow rate, dscfm	5,955	6,031	6,139	6,042
Formaldehyde (CH_2O)				
ppmvd	5.28	5.40	5.62	5.43
lb/hr	0.147	0.152	0.161	0.154
Formaldehyde (CH_2O), as Propane				
lb/hr	0.072	0.074	0.079	0.075
Volatile Organic Compounds (VOC), as Propane †				
ppmvd	2.10	2.00	2.00	2.03
lb/hr	0.086	0.083	0.084	0.084
Total VOC (With CH_2O), as Propane ‡				
lb/hr	0.158	0.157	0.163	0.160

† Volatile Organic Compounds (VOC), as propane emissions exclude methane, ethane, and formaldehyde concentrations .

‡ Total VOC(With CH_2O) as propane emissions exclude methane and ethane concentrations .

TABLE 4-2
CH_2O AND VOC EMISSIONS RESULTS - EU-ENGINE10

Run Number	1	2	3	Average
Date	8/10/2021	8/10/2021	8/10/2021	--
Time	8:55-9:55	10:07-11:07	11:19-12:19	--
Process Data				
Engine Output, kW	2,492	2,492	2,486	2,490
Flue Gas Parameters				
O_2, % volume dry	9.36	9.37	9.37	9.37
CO_2, % volume dry	6.59	6.58	6.57	6.58
flue gas temperature, °F	700.4	716.4	726.5	714.5
moisture content, % volume	13.50	13.50	13.50	13.50
volumetric flow rate, dscfm	5,974	6,005	5,994	5,991
Formaldehyde (CH_2O)				
ppmvd	8.90	9.13	9.36	9.13
lb/hr	0.247	0.255	0.261	0.254
Formaldehyde (CH_2O), as Propane				
lb/hr	0.121	0.125	0.128	0.124
Volatile Organic Compounds (VOC), as Propane †				
ppmvd	3.30	3.50	3.70	3.50
lb/hr	0.135	0.143	0.151	0.143
Total VOC, (With CH_2O) as Propane ‡				
lb/hr	0.256	0.268	0.279	0.268

† Volatile Organic Compounds (VOC), as propane emissions exclude methane, ethane, and formaldehyde concentrations .

‡ Total VOC(With CH_2O) as propane emissions exclude methane and ethane concentrations .

5.0 INTERNAL QA/QC ACTIVITIES

5.1 QA/QC AUDITS

EPA Method 3A calibration audits were all within the measurement system performance specifications for the calibration drift checks, system calibration bias 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 (~100 ppm ethylene), direct analyte calibration measurements, and measurements to determine baseline shift. SF_6 was also used as a tracer gas in the calibration gases to evaluate dilution ratios and 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.

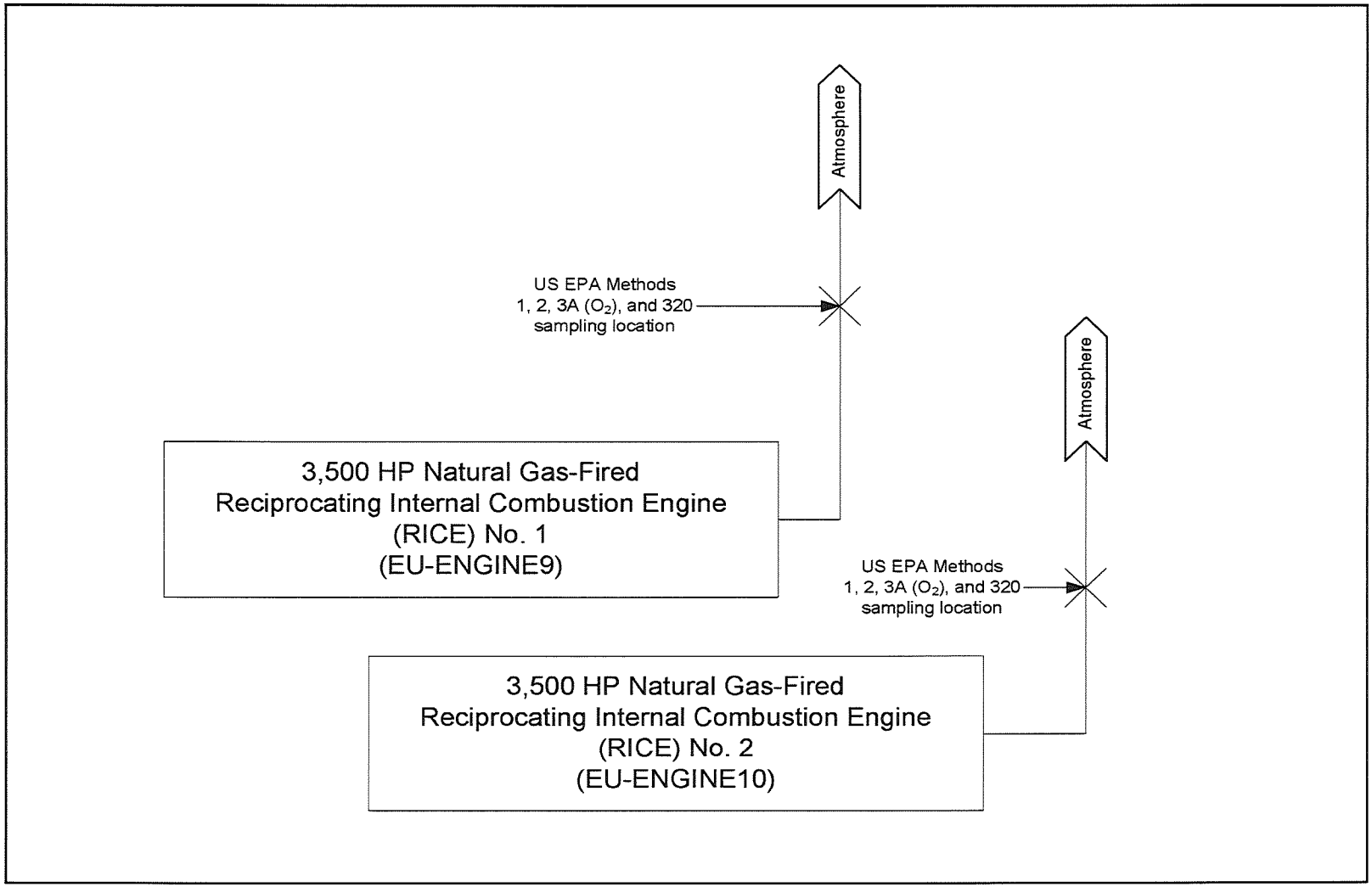
5.3 QUALITY STATEMENT

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).

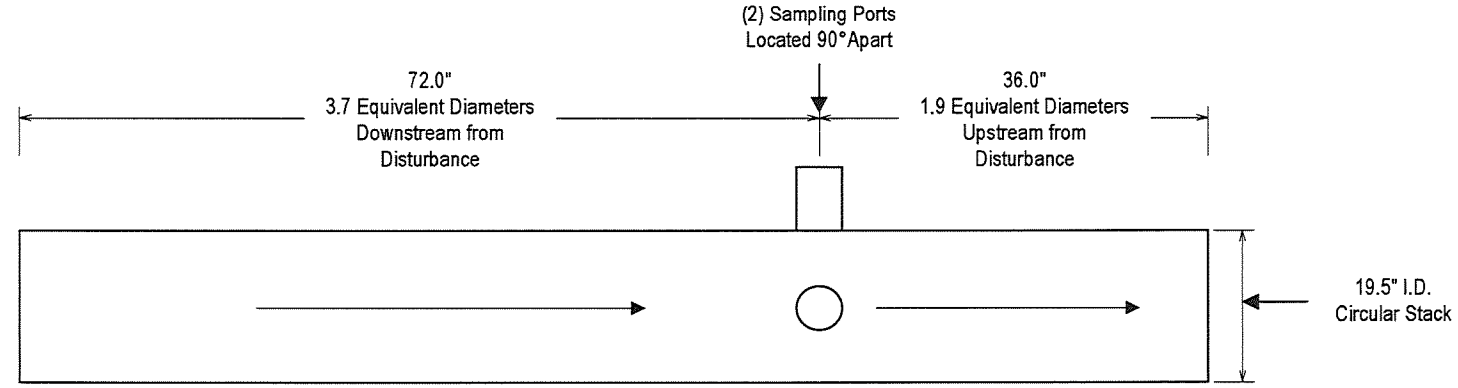
APPENDIX A
FIELD DATA AND CALCULATIONS

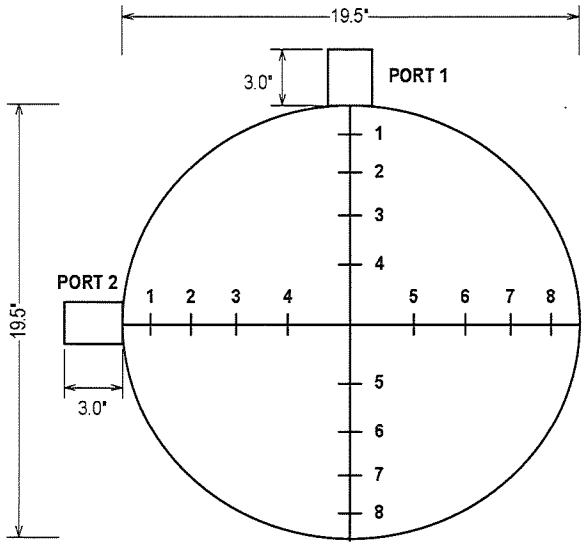
Appendix A.1
Sampling Locations

EU-ENGINE9 AND EU-ENGINE10 SAMPLING LOCATION SCHEMATIC



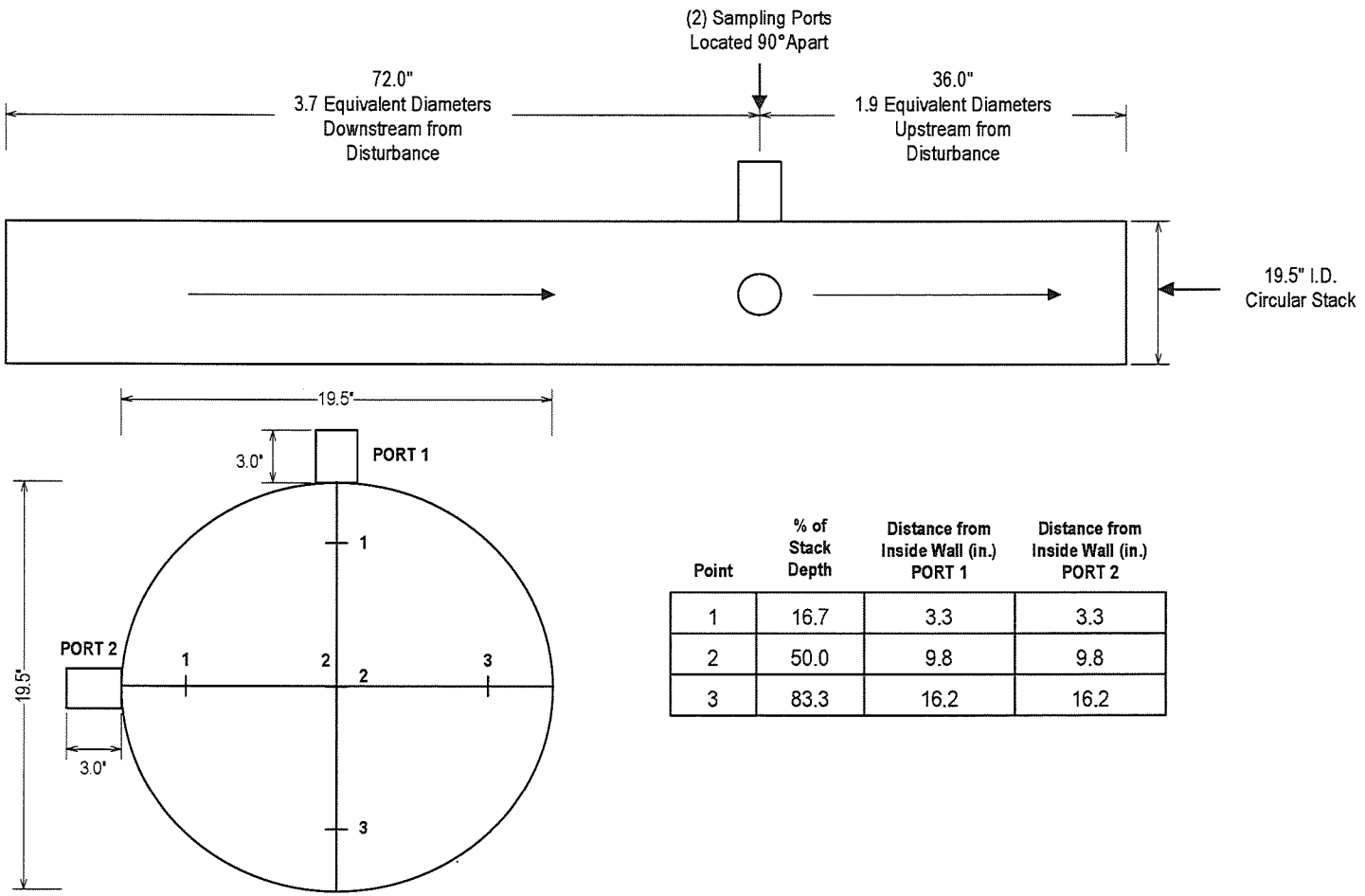
EU-ENGINE9 EXHAUST STACK FLOW TRAVERSE POINT LOCATION DRAWING





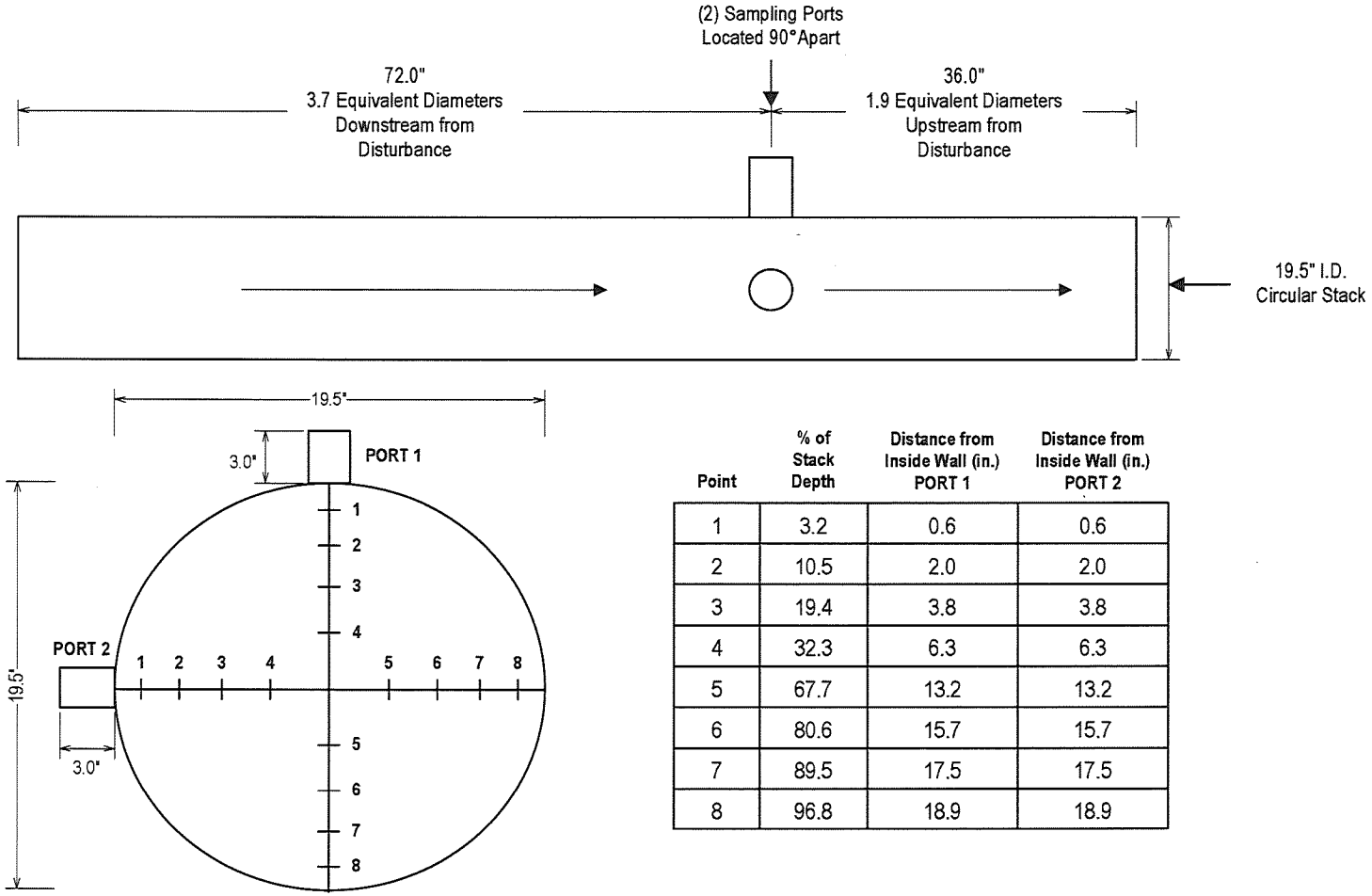
Point	% of Stack Depth	Distance from Inside Wall (in.) PORT 1	Distance from Inside Wall (in.) PORT 2
1	3.2	0.6	0.6
2	10.5	2.0	2.0
3	19.4	3.8	3.8
4	32.3	6.3	6.3
5	67.7	13.2	13.2
6	80.6	15.7	15.7
7	89.5	17.5	17.5
8	96.8	18.9	18.9

EU-ENGINE9 EXHAUST STACK CEMS TRAVERSE POINT LOCATION DRAWING



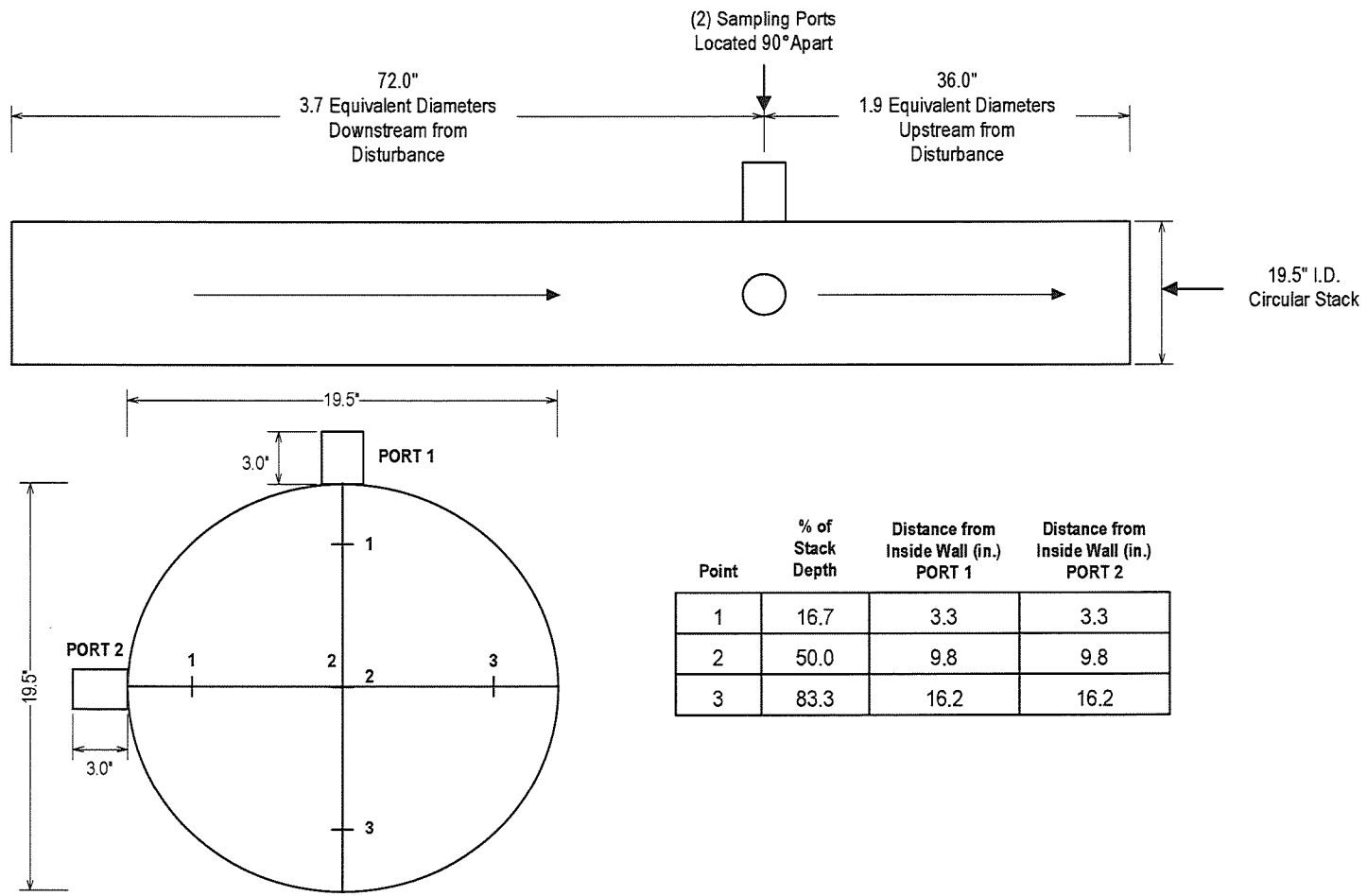
Point	% of Stack Depth	Distance from Inside Wall (in.) PORT 1	Distance from Inside Wall (in.) PORT 2
1	16.7	3.3	3.3
2	50.0	9.8	9.8
3	83.3	16.2	16.2

EU-ENGINE10 EXHAUST STACK FLOW TRAVERSE POINT LOCATION DRAWING



Point	% of Stack Depth	Distance from Inside Wall (in.) PORT 1	Distance from Inside Wall (in.) PORT 2
1	3.2	0.6	0.6
2	10.5	2.0	2.0
3	19.4	3.8	3.8
4	32.3	6.3	6.3
5	67.7	13.2	13.2
6	80.6	15.7	15.7
7	89.5	17.5	17.5
8	96.8	18.9	18.9

EU-ENGINE10 EXHAUST STACK CEMS TRAVERSE POINT LOCATION DRAWING



Point	% of Stack Depth	Distance from Inside Wall (in.) PORT 1	Distance from Inside Wall (in.) PORT 2
1	16.7	3.3	3.3
2	50.0	9.8	9.8
3	83.3	16.2	16.2