EXECUTIVE SUMMARY

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compound (VOC) testing at three, natural gas-fired stationary, spark-ignition (SI) internal combustion engines (ICE), identified as EUENGINE3-1, EUENGINE3-3, and EUENGINE3-4, installed and operating at the St. Clair Compressor Station, in Ira, Michigan. The engines are four-stroke, lean burn (4SLB), 4,835 brake horsepower (BHP) engines which provide mechanical shaft power to compressors to maintain natural gas pipeline pressure for movement in and out of storage reservoirs and along the pipeline system. The engines are grouped as FGENGINES-P3 within Michigan Department of Environment, Great Lakes and Energy (EGLE) Renewable Operating Permit (ROP) No. MI-ROP-B6637-2015a and are subject to state and federal air emission regulations.

The test program was conducted on September 29 and 30, 2020 to evaluate compliance with emission limits in 40 CFR Part 60, Subpart JJJJ, *Standards of Performance for Stationary Spark Ignition Internal Combustion Engines*, (NSPS) and the facility's ROP for the FGENGINE-P3 sources. A test protocol was submitted to EGLE on August 16, 2020 and subsequently approved by Ms. Lindsey Wells, Environmental Quality Analyst, in her letter dated August 28, 2020.

Three, 60-minute test runs were conducted on each engine exhaust following the procedures in United States Environmental Protection Agency (USEPA) Reference Methods (RM) 1, 3A, 4/ALT-008, 7E, 10, 18, 19, and 25A/ALT-096 in 40 CFR 60, Appendix A. Please note that while ALT-096 is not named in 40 CFR 60, Appendix A; ALT-096 incorporates relevant Appendix A, Method 25A procedures and requirements specific to operating a Thermo-Electron Model (TECO) 55I for methane and non-methane organic compounds (NMOC) measurement at 40 CFR 60, Subpart JJJJ sources.

There were no deviations from the approved stack test protocol or associated USEPA Reference Methods. Please note that the protocol included test provisions for four (4) Plant 3 engines within flexible group (FG) FGENGINES-P3; however due to mechanical issues, EUENGINE3-2 was unavailable. An EUENGINE3-2 performance test will be re-scheduled prior to the compliance date of January 10, 2021.

During testing, EUENGINE3-1, EUENGINE3-3, and EUENGINE3-4 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 results of the emissions testing are summarized in Table E-1 on the following page.

Table E-1
Summary of Test Results

Parameter	Units	Average Result of 3 Test Runs	Emission Limit	
			40 CFR 60, Subpart JJJJ[1]	ROP Flexible Group Conditions: FGENGINES-P3
EUENGINE3-1				
NO_x	g/HP-hr	0.47	1.0	0.6
	ppmvd at 15% O_2	39.9	82	
CO	g/HP-hr	0.03	2.0	0.36
	ppmvd at 15% O_2	3.6	270	
VOC[2]	g/HP-hr	0.02	0.7	0.2
	ppmvd at 15% O_2	2.2	60	
EUENGINE3-3				
NO_x	g/HP-hr	0.46	1.0	0.6
	ppmvd at 15% O_2	41.6	82	
CO	g/HP-hr	0.05	2.0	0.36
	ppmvd at 15% O_2	7.1	270	
VOC	g/HP-hr	0.02	0.7	0.2
	ppmvd at 15% O_2	2.2	60	
EUENGINE3-4				
NO_x	g/HP-hr	0.46	1.0	0.6
	ppmvd at 15% O_2	39.5	82	
CO	g/HP-hr	0.03	2.0	0.36
	ppmvd at 15% O_2	4.4	270	
VOC	g/HP-hr	0.01	0.7	0.2
	ppmvd at 15% O_2	1.3	60	

NO_x nitrogen oxides
CO carbon monoxide
VOC volatile organic compounds (non-methane, non-ethane organic compounds), as propane
g/HP-hr grams per horsepower hour

[1] Owners and operators of stationary non-certified SI engines may choose to comply with emission standards in units of either g/HP-hr or ppmvd at 15 percent O_2.
[2] 40 CFR Part 60, Subpart JJJJ refers to volatile organic compounds as defined in 40 CFR, Part 51.100(s)(1) which defines VOC as "*any compound of carbon…other than the following, which have been determined to have negligible photochemical reactivity: methane, ethane…* Therefore, Subpart JJJJ exhaust gas measurements of VOC include only the total non-methane, non-ethane organic compounds.

The EUENGINE3-1, EUENGINE3-3, and EUENGINE3-4 NO_x, CO, and VOC test results indicate compliance with ROP and 40 CFR Part 60, Subpart JJJJ limits.

Detailed results are presented in Appendix Tables 1, 2, and 3. Sample calculations, field data sheets, and laboratory data are presented in Appendices A, B, and C. Engine operating data and supporting documentation are provided in Appendices D and E.

1.0 INTRODUCTION

This report summarizes the results of compliance air emission tests on EUENGINE3-1, EUENGINE3-3, and EUENGINE3-4, installed and operating at the Consumers Energy St. Clair Compressor Station (SCCS) in Ira, Michigan. This document follows the Michigan Department of Environment, Great Lakes and Energy (EGLE) format described in the November 2019, *Format for Submittal of Source Emission Test Plans and Reports*. Reproducing only a portion of this report may omit critical substantiating documentation or cause information to be taken out of context. If any portion of this report is reproduced, please exercise due care in this regard.

1.1 IDENTIFICATION, LOCATION, AND DATES OF TESTS

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compound (VOC) testing on three, stationary, spark-ignition (SI), internal combustion engines (ICE), identified as EUENGINE3-1, EUENGINE3-3, and EUENGINE3-4 installed and operating at SCCS, on September 29 and 30, 2020.

A test protocol was submitted to EGLE on August 16, 2020 and subsequently approved by Ms. Lindsey Wells, Environmental Quality Analyst, in her letter dated August 28, 2020. The protocol detailed the proposed the test program for all four (4) Plant 3 engines within flexible group (FG) FGENGINES-P3; however due to mechanical issues, EUENGINE3-2 was unavailable. (A performance test will be conducted for EUENGINE3-2 prior to the compliance date of January 10, 2021.)

1.2 PURPOSE OF TESTING

The purpose of the test program was to evaluate compliance with emission limits in USEPA 40 CFR Part 60, Subpart JJJJ, *Standards of Performance for Stationary Spark Ignition Internal Combustion Engines* and the facility's Renewable Operating Permit (ROP) for the FGENGINE-P3 sources. The applicable emission limits are presented in Table 1-1.

Table 1-1
FGENGINES-P3 Emission Limits

Parameter	Emission Limit	Units	Applicable Requirement
NO_x	0.6	g/HP-hr	ROP Flexible Group Conditions: FGENGINES-P3
	1.0 or 82	g/HP-hr ppmvd@15% O_2	40 CFR Part 60, Subpart JJJJ, Table 1
CO	0.36	g/HP-hr	ROP Flexible Group Conditions: FGENGINES-P3
	2.0 or 270	g/HP-hr ppmvd@15% O_2	40 CFR Part 60, Subpart JJJJ, Table 1
VOC‡	0.2	g/HP-hr	ROP Flexible Group Conditions: FGENGINES-P3

‡ 40 CFR Part 60 Subpart JJJJ refers to volatile organic compounds as defined in 40 CFR §51.100(s)(1), which specifies a VOC definition including "*any compound of carbon…other than the following, which have been determined to have negligible photochemical reactivity: methane, ethane…*" Therefore, exhaust gas VOC measurements will include the total non-methane organic compounds.

1.3 BRIEF DESCRIPTION OF SOURCE

EUENGINE3-1, EUENGINE3-3, and EUENGINE3-4 are 4,835 brake horsepower, four-stroke lean burn (4SLB), SI ICEs located at an area source of hazardous air pollutant (HAP) emissions. The engines operate as needed to provide mechanical shaft power to compressors to maintain natural gas pipeline pressure for movement in and out of storage reservoirs and along the pipeline system.

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
Regulatory Agency Representative	Ms. Karen Kajiya-Mills Technical Programs Unit Manager 517-335-4874 kajiya-millsk@michigan.gov	EGLE - Technical Programs Unit 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
State Regulatory Inspector	Mr. Sebastian Kallumkal Sr. Environmental Engineer 586-753-3738 kallumkals@michigan.gov	EGLE – Air Quality Division SE Michigan District 27700 Donald Court Warren, Michigan 48092
State Technical Programs Field Inspector	Mr. Matthew Karl Technical Programs Unit 517-282-2126 karlm@michigan.gov	EGLE – Air Quality Division Technical Programs Unit 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
Responsible Official	Mr. Avelock Robinson Director of Gas Compression Operations 586-716-3326 avelock.robinson@cmsenergy.com	Consumers Energy Company St. Clair Compressor Station 10021 Marine City Highway Ira, Michigan 48023
Corporate Air Quality Contact	Ms. Amy Kapuga Senior Engineer 517-788-2201 amy.kapuga@cmsenergy.com	Consumers Energy Company Environmental Services Department 1945 West Parnall Road Jackson, Michigan 49201
Field Environmental Coordinator	Mr. Thomas Fox Senior Engineer 989-667-5153 thomas.fox@cmsenergy.com	Consumers Energy Company Bay City Customer Service Center 4141 E. Wilder Road Bay City, MI 48706
Test Facility	Mr. Nicholas Reed Gas Field Lead III 586-716-3336 nicholas.reed@cmsenergy.com	Consumers Energy Company St. Clair Compressor Station 10021 Marine City Highway Ira, Michigan 48023
Test Team Representative	Mr. Joe Mason, QSTI Sr. Engineering Technical Analyst 616-738-3385 joe.mason@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 test program, pursuant to §60.4244(a), the engines operated within 10% of 100 percent peak (or the highest achievable) load. The average engine load was >91.6% torque and >91.5% horsepower for each test run, based on the maximum manufacturer's design capacity at engine and compressor site conditions. Refer to Attachment D for detailed operating data.

2.2 Applicable Permit Information

SCCS is assigned State of Michigan Registration Number (SRN) B6637 and operates Plant 3 in accordance with MI-ROP-B6637-2015a, with sources EUENGINE3-1, EUENGINE3-2, EUENGINE3-3, and EUENGINE3-4 collectively grouped within the permit as FGENGINES-P3, and associated with the applicable federal requirements of 40 CFR 60, Subpart JJJJ.

2.3 Results

The engine test results indicate the measured NO_x, CO, and VOC emissions comply with ROP and NSPS SI ICE limits. Refer to Table 2-1 for the summary of test results.

Table 2-1
Summary of Test Results

Parameter	Units	AverageResult of 3 Test Runs	Emission Limit	
			40 CFR 60, Subpart JJJJ[1]	ROP Flexible Group Conditions: FGENGINES-P3
EUENGINE3-1				
NO_x	g/HP-hr	0.47	1.0	0.6
	ppmvd at 15% O_2	39.9	82	
CO	g/HP-hr	0.03	2.0	0.36
	ppmvd at 15% O_2	3.6	270	
VOC[2]	g/HP-hr	0.02	0.7	0.2
	ppmvd at 15% O_2	2.2	60	
EUENGINE3-3				
NO_x	g/HP-hr	0.46	1.0	0.6
	ppmvd at 15% O_2	41.6	82	
CO	g/HP-hr	0.05	2.0	0.36
	ppmvd at 15% O_2	7.1	270	
VOC	g/HP-hr	0.02	0.7	0.2
	ppmvd at 15% O_2	2.2	60	
EUENGINE3-4				
NO_x	g/HP-hr	0.46	1.0	0.6
	ppmvd at 15% O_2	39.5	82	
CO	g/HP-hr	0.03	2.0	0.36
	ppmvd at 15% O_2	4.4	270	
VOC	g/HP-hr	0.01	0.7	0.2
	ppmvd at 15% O_2	1.3	60	

[1] Owners and operators of stationary non-certified SI engines may choose to comply with emission standards in units of either g/HP-hr or ppmvd at 15 percent O_2.

[2] 40 CFR Part 60, Subpart JJJJ refers to volatile organic compounds as defined in 40 CFR, Part 51.100(s)(1) which defines VOC as "*any compound of carbon…other than the following, which have been determined to have negligible photochemical reactivity: methane, ethane…* Therefore, Subpart JJJJ exhaust gas measurements of VOC include only the total non-methane, non-ethane organic compounds.

Detailed results are presented in Appendix Tables 1, 2, and 3. A discussion of the results are presented in Section 5.0. Sample calculations, field data sheets, and laboratory results are presented in Appendices A, B, and C. Engine operating data and supporting information are provided in Appendices D and E.

3.0 SOURCE DESCRIPTION

FGENGINES-P3 provide mechanical shaft power to compressors to maintain natural gas pipeline pressure for movement in and out of storage reservoirs and along the pipeline system. Significant maintenance has not been performed on the engines within the past three months. A summary of the engine specifications is provided in Table 3-1.

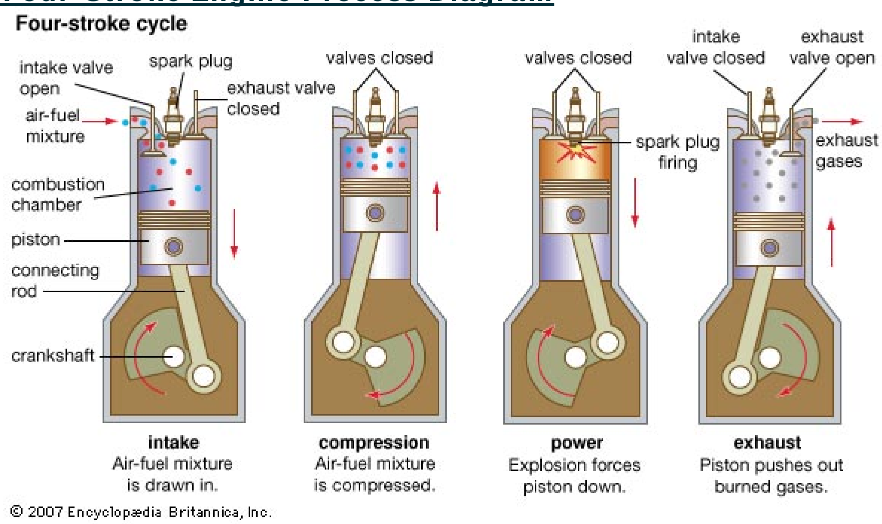
Table 3-1
Engine Specifications

Engine ID	Engine Description		Site-Rated HP	Heat Input, LHV (mmBtu/hr)	Exhaust Gas Temp. (°F)
	Manufacturer	Model			
EUENGINE3-1 EUENGINE3-3 EUENGINE3-4	Waukesha	16V275GL+	4,835	27	828

3.1 PROCESS

The engines utilize the four-stroke engine cycle which starts with the downward air intake piston stroke which aspirates air through intake valves into the combustion chamber (cylinder). When the piston nears the bottom of the cylinder, fuel is injected and the intake valves close. As the piston travels upward, the air/fuel mixture is compressed and ignited, thus forcing the piston downward into the power stroke. At the bottom of the power stroke, exhaust valves open and the piston traveling upward expels the combustion by-products. Refer to Figure 3-1 for a four-stroke engine process diagram.

Figure 3-1. Four-Stroke Engine Process Diagram



The flue gas generated by natural gas combustion is controlled through parametric controls (i.e., timing and air-to-fuel ratio), lean burn combustion technology, and oxidation catalysts. The Waukesha engine includes a control module that monitors and adjusts engine parameters for optimal performance. The NO_x emissions are minimized through the use of lean-burn combustion technology which is defined as 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.

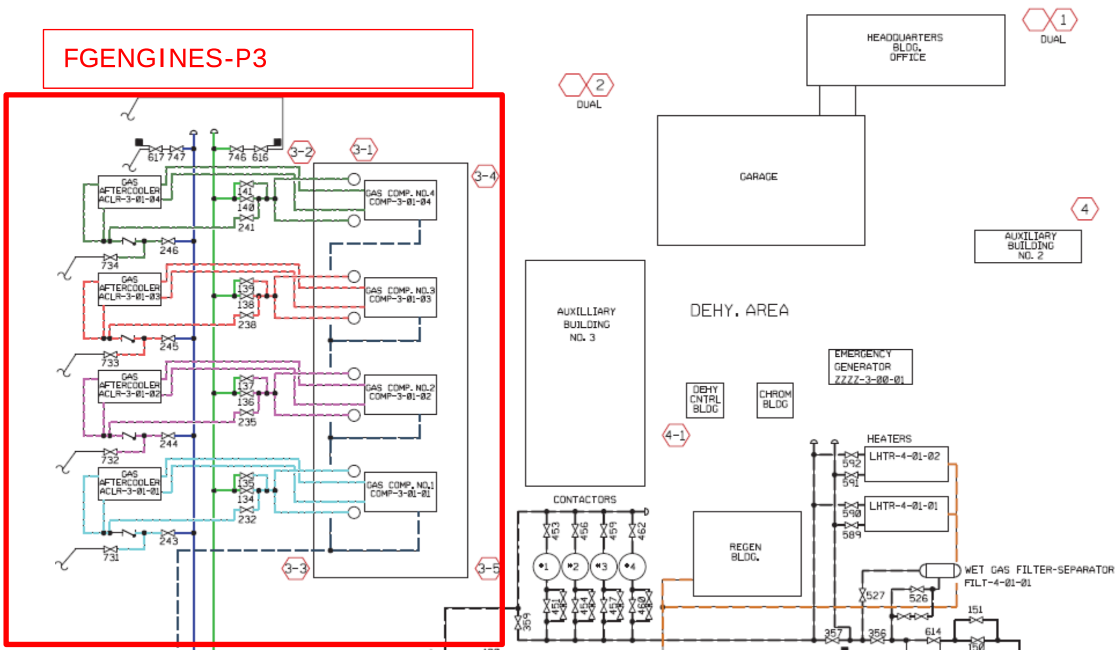
The four catalyst modules installed on each engine use propriety materials to lower the oxidation temperature of CO and other organic compounds within the range of exhaust gas temperatures generated by the engines. The catalyst also provides control of formaldehyde, as well as non-methane and non-ethane hydrocarbons. Detailed operating data recorded during testing are provided in Appendix D.

3.2 Process Flow

Located in southern St. Clair County, the St. Clair Compressor Station helps maintain natural gas pipeline pressures in southeast Michigan. The Hessen, Puttygut, Swan Creek, Four Corners, Ira, and Lenox gas storage fields within the Niagaran geologic formation are used to store approximately 45.6 billion cubic feet of natural gas. The station connects to these six underground storage fields, which provide enough natural gas to serve up to 20 percent of Consumers Energy's 1.7 million gas customers in winter.

The facility is divided into three plants: natural gas reciprocating compressor engines, combustion turbines, and associated equipment for maintaining pressure and moving natural gas in and out of the storage reservoirs. The Plant 3 natural gas compressor engines were the focus of this test program. The green lines in Figure 3-2 represent gas into the engine compression system, while the blue lines represent discharged gas. The gas can be routed through the plant, into underground storage reservoirs, or out to the distribution pipelines.

Figure 3-2. St. Clair Compressor Station Plant 3 Process Flow



3.3 Materials Processed

The fuel utilized in FGENGINES-P3 is exclusively natural gas, as defined in 40 CFR 72.2. During testing the natural gas combusted within the engines was comprised of approximately 92% methane, 7% ethane, 0.4% nitrogen, and 0.2% carbon dioxide. The daily natural gas chromatograph analysis results are provided in Appendix D (St. Clair Line 1500). The gas composition and Btu content were used to calculate site-specific F factors in accordance with United States Environmental Protection Agency (USEPA) Method 19 and used in emission rate calculations.

3.4 Rated Capacity

The maximum engine power output is approximately 4,835 horsepower with a rated heat input of 27 million British thermal units per hour (mmBtu/hour). The normal rated engine capacities are governed by the connected compression equipment operated as a function of facility and gas transmission demand. The engine operating parameters shown in Appendix D were recorded and averaged for each test run.

3.5 Process Instrumentation

Process instrumentation were continuously monitored by GE Power engine controllers for the Waukesha 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:

- Fuel use (cfm)
- Engine speed (rpm)
- Power (BHP)
- Torque (% max)
- Catalyst input temperature (°F)
- Catalyst differential pressure (in. H_2O)
- Engine hours

Refer to Appendix D for operating data.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

Consumers Energy RCTS tested for NO_x, CO, VOC, and oxygen (O_2) concentrations using the 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	Method	USEPA Title
Sample traverses	1	Sample and Velocity Traverses for Stationary Sources
Oxygen	3A	Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)
Moisture content	4 (ALT-008)	Determination of Moisture Content in Stack Gases Alternative Moisture Measurement Method – Midget Impingers
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)
Ethane	18	Measurement of Gaseous Organic Compound Emissions by Gas Chromatography
Emission rates	19	Sulfur Dioxide Removal and Particulate, Sulfur Dioxide and Nitrogen Oxides from Electric Utility Steam Generators
Volatile organic compounds	25A Alt-096	Measurement of Gaseous Organic Compound Emissions by Gas Chromatography and Determination of Total Gaseous Organic Concentration Using A Flame Ionization Analyzer via TECO-55I for NSPS SI ICE

4.1 Description of Sampling Train and Field Procedures

The Table 4-2 test matrix below summarizes the sample parameters and analytical methods employed.

Table 4-2 Test Matrix

Date (2020)	Run	Sample Type	Start Time (EDT)	Stop Time (EDT)	Test Duration (min)	EPA Test Method	Comment
EUENGINE3-1							
September 30	1	O_2 NO_x CO VOC	12:51	13:50	60	1, 4/ALT-008 3A/7E/10 19 25A/18, Alt-096	Flexible bags for ethane analysis collected.
	2		14:16	15:15	60		
	3		15:40	16:39	60		
EUENGINE3-3							
September 29	1	O_2 NO_x CO VOC	09:23	10:22	60	1, 4/ALT-008 3A/7E/10 19 25A/18, Alt-096	Flexible bags for ethane analysis collected.
	2		11:00	11:59	60		
	3		12:23	13:22	60		
EUENGINE3-4							
September 29	1	O_2 NO_x CO VOC	16:22	17:21	60	1, 4/ALT-008 3A/7E/10 19 25A/18, Alt-096	Flexible bags for ethane analysis collected.
September 30	2		08:13	09:12	60		
	3		09:34	10:33	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 USEPA Method 1, *Sample and Velocity Traverses for Stationary Sources.* Two 4-inch diameter test ports protrude approximately 4-inches beyond a 36-inch diameter vertical exhaust stack exiting the engine. The exhaust stacks are designated as SVENGINE3-1, SVENGINE3-3 and SVENGINE3-4 within the ROP. The sampling ports are located:

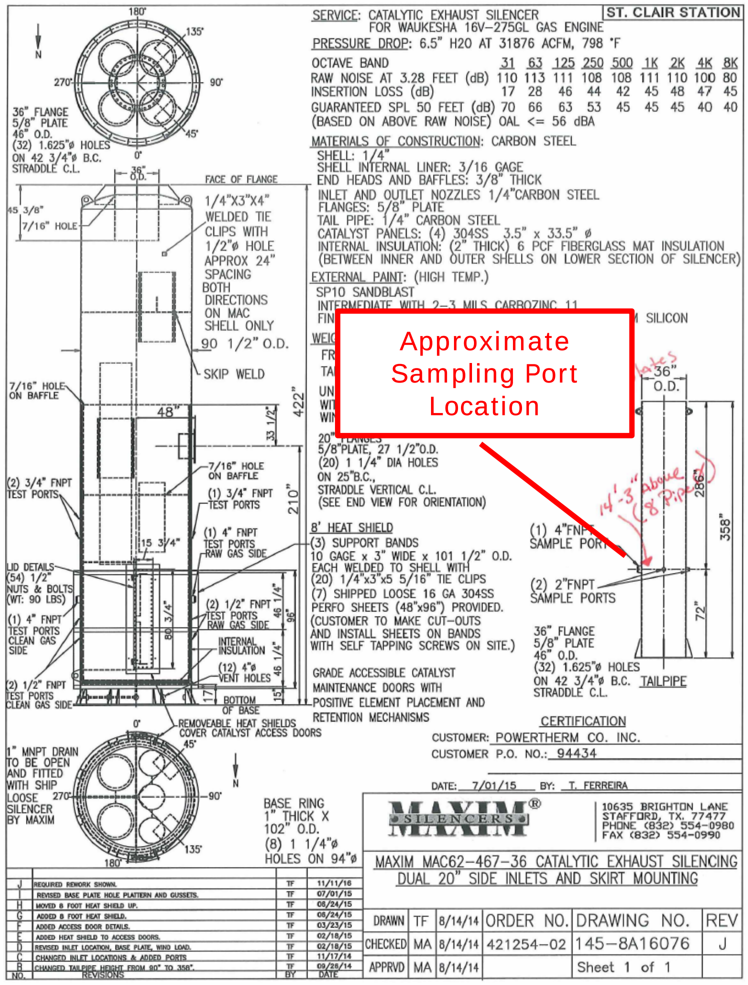
- Approximately 117 inches or 3.25 duct diameters downstream from the oxidation catalyst exhaust confluence to the vertical exhaust stack, and
- Approximately 286 inches or 7.9 duct diameters upstream of the stack exit to atmosphere approximately 65 feet above the ground surface.

Because the duct is >12 inches in diameter and the sampling port location meets 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 duct was sampled at 3 traverse points located at 16.7, 50.0, and 83.3% of the measurement line ('3-point long line'). The exhaust flue gas was sampled from the three traverse points at approximately equal intervals during the test for Run 1.

A three traverse point stratification test was performed using parameter concentrations from Run 1 in accordance with USEPA Method 7E, §8.1.2. The individual point and mean parameter concentrations were calculated and the gas stream was considered unstratified; therefore, parameter concentrations were measured from a single point near the centroid of the stack for Runs 2 and 3.

Gas was sampled during each test from either three traverse points or a single point based on the stratification test results. A representation of an engine exhaust stack sampling location is presented as Figure 4-1.

Figure 4-1. Exhaust Stack Sampling Port Locations

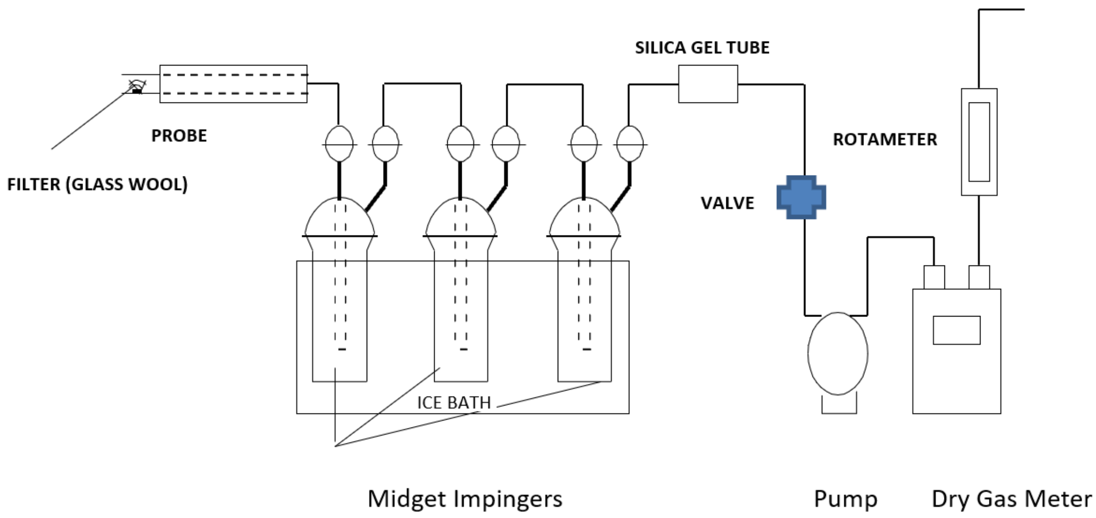


4.1 Moisture Content (USEPA Method 4 / ALT-008)

Exhaust gas moisture content was determined in accordance with USEPA ALT-008, *Alternative Moisture Measurement Method Midget Impingers*, an alternative method for correcting pollutant concentration data to appropriate moisture conditions (e.g. pollutant and/or air flow data on a dry or wet basis) validated May 19, 1993 by the USEPA Emission Measurement Branch. The procedure, incorporated into Method 6A of 40 CFR Part 60, is based on field validation tests described in *An Alternative Method for Stack Gas Moisture Determination* (Jon Stanley, Peter Westlin, 1978, USEPA Emissions Measurement Branch). The sample apparatus follows the general guidelines found in Figure 4-2 and § 8.2 of USEPA Method 4, *Determination of Moisture Content in Stack Gases,* and ALT-008 Figure 1 or 2.

The flue gas is withdrawn at a constant rate from the stack through a sample probe, Teflon tubing, four midget impingers, and a metered pump console. Gas stream moisture is condensed in ice-bath chilled impingers and determined gravimetrically. The condensate mass collected, and moisture sample volume are used to calculate moisture content. Refer to Figure 4-2 for a depiction of the Alternative Method 008 Moisture Sample Apparatus.

Figure 4-2. Alternative Method 008 Moisture Sample Apparatus



*The silica gel tube depicted in the figure above was replaced with a midget impinger (bubbler) with a straight tube insert, as allowed in ALT-008, §1.

4.2 O2, NO_X, AND CO CONCENTRATIONS (USEPA METHODS 3A, 7E, AND 10)

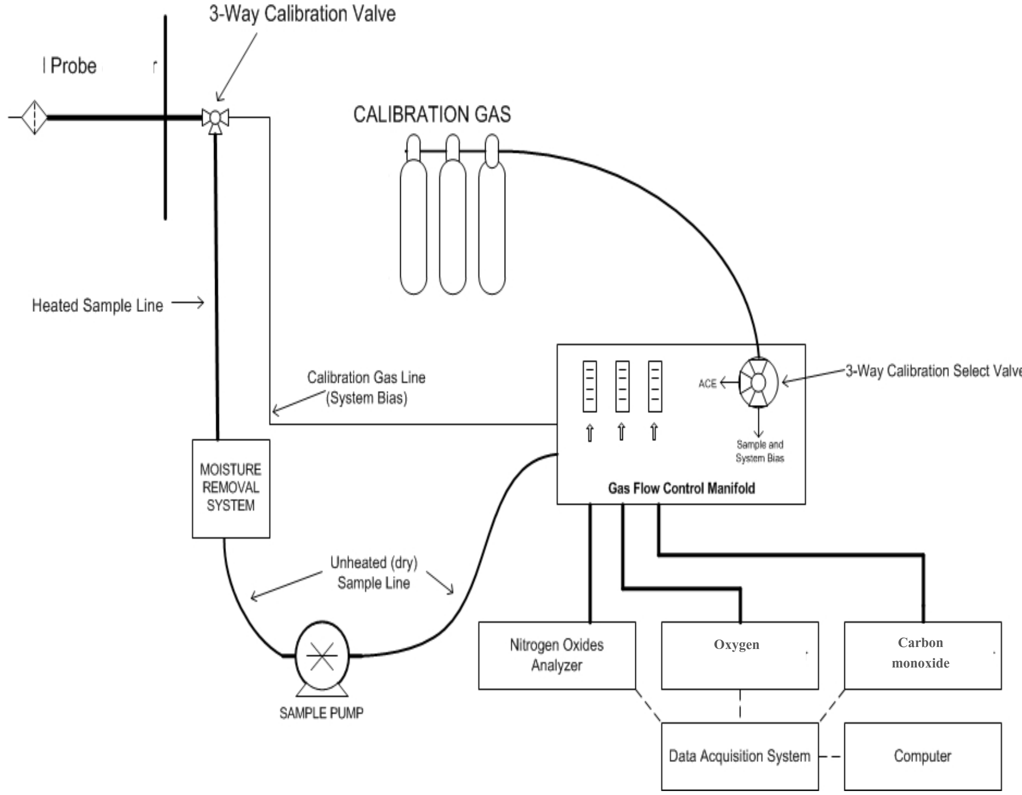
Oxygen, nitrogen oxides, and carbon monoxide concentrations were measured using the following sampling and analytical procedures:

- 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, except for 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 stack 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 4-3 depicts a drawing of the Methods 3A, 7E, and 10 sampling system.

Figure 4-3. 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. The test verified the analyzer response as NO_x was ≥90% of the certified NO_2 calibration gas concentration.

Upon successful completion of the calibration error and initial system bias tests, sample flow rate and component temperatures were verified and the probe was inserted into the duct 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.

4.3 Ethane Concentrations (USEPA Method 18)

USEPA Method 18, *Measurement of Gaseous Organic Compound Emissions by Gas Chromatography*, was used to quantify the ethane component of the measured organic compound emissions. Engine exhaust samples collected in flexible bags were submitted to a laboratory for ethane analysis by gas chromatography with a flame ionization detector. The reported ethane concentrations were converted to propane by the laboratory and subtracted from the measured non-methane hydrocarbon concentrations to derive the non-methane, non-ethane VOC emission rate. Refer to Appendix C for the USEPA Method 18 laboratory results.

4.4 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_c factor and exhaust gas flowrate pursuant to guidance by USEPA to not use default published F factors for such Subpart JJJJ test events.

The natural gas processed by the St. Clair Compressor Station is the same gas used for firing FGENGINE-P3. The facility collects a daily sample of this gas and analyzes it via gas chromatography (GC) for hydrocarbons, non-hydrocarbons, heating value, and other parameters. The test day GC results were obtained to calculate F_w, F_d, and F_c factors (ratios of combustion gas volumes to heat inputs) using USEPA Method 19 Equations 19-13 (F_d), 19-14 (F_w), and 19-15 (F_c). The F_d factor was used to calculate the exhaust gas flow rate using *Equation 19-1* presented in Figure 4-4, which was incorporated into 40 CFR Part 60 Subpart JJJJ *Equations 1, 2, and 3* to calculate g/HP-hr emission rates.

Figure 4-4. USEPA Method 19 Exhaust Flow Rate Equation 19-1

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

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 (%)

Figure 4-5. 40 CFR Part 60 Subpart JJJJ Equation 1, 2, 3

$$ER = \frac{C_d \ x \ K \ x \ Q \ x \ T}{HP - hr}$$

Where:

ER = Emission rate of pollutant in g/HP-hr
C_d = Measured pollutant concentration in parts per million by volume, dry basis (ppmvd)
K = Conversion constant for ppm pollutant to grams per standard cubic meter at 20°C:
KNO_x = 1.912×10^{-3} (Equation 1)
KCO = 1.164×10^{-3} (Equation 2)
KVOC = 1.833×10^{-3} (Equation 3)
Q = Stack gas volumetric flow rate, in cubic meter per hour, dry basis
T = Time of test run, in hours

4.5 Volatile Organic Compounds (ALT-096: USEPA Methods 18/25A)

VOC concentrations were measured from the engine using a Thermo Model 55i Direct Methane and Non-methane Analyzer as approved in alternative test method (ALT)-096 and following the procedures 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 stainless steel and Teflon. Flue gas was collected from the stack via a sample probe and heated sample line and into the analyzer, which communicates with the data acquisition handling system (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 moves through the column more quickly than other organic compounds that may be present and 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.

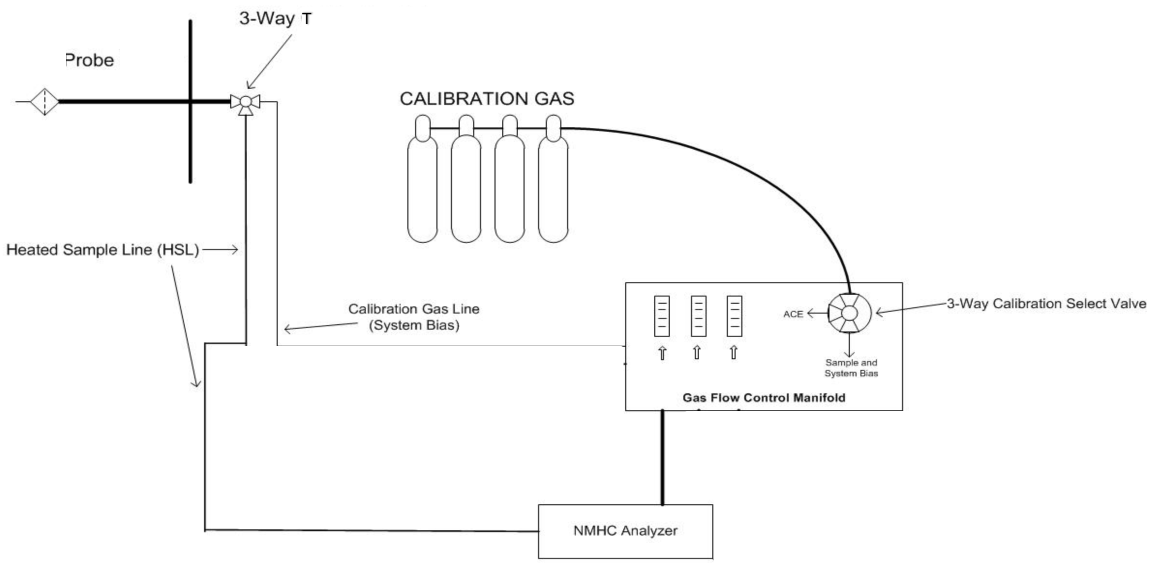
The field VOC instrument was calibrated with a zero air and three propane and methane in air calibration gases following USEPA Method 25A procedures at the zero level, low (25 to 35 percent of calibration span), mid (45 to 55 percent of calibration span) and high (equivalent to 80 to 90 percent of instrument span). Prior to testing, the analyzer was calibrated using hydrocarbon free zero and high-level methane and propane calibration gases, with its signal output adjusted accordingly. A calibration error test was conducted by introducing low- and mid-level calibration gases to the sample system to ensure the analyzer's response was within ±5% of certified concentration. During this procedure, the measurement system response time for each calibration gas introduced to the system, equivalent to 95% of the step change, is observed.

Immediately following each test run, zero and low-level calibration gases are introduced consecutively into the measurement system to ensure analyzer drift is within ±3% of span, thereby validating each test run. As requested by EGLE, the NMOC run concentrations are also corrected for analyzer drift using USEPA Method 7E, *Equation 7E-5b*.

Upon receipt, the laboratory reported ethane is subtracted from the drift corrected NMOC concentration and the wet-basis NMOC concentration is converted to dry-basis using the field measured exhaust gas moisture content. This non-methane, non-ethane organic compound (NMNEOC) concentration, combined with the calculated volumetric flowrate, is the basis for determining mass VOC emission rates and FGENGINES-P3 regulatory compliance.

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 ALT-008 moisture content results were used to convert the VOC concentration to a dry basis and calculate emission rates.

Figure 4-6. USEPA Method 25A NMOC Sample Apparatus



5.0 TEST RESULTS AND DISCUSSION

The test program was performed to evaluate compliance with emission limits in 40 CFR Part 60, Subpart JJJJ and MI-ROP-B6637-2015a.

5.1 Tabulation of Results

The EUENGINE3-1, EUENGINE3-3, and EUENGINE3-4 test results indicate the NO_x, CO, and VOC exhaust emissions comply with 40 CFR Part 60, Subpart JJJJ and MI-ROP-B6637-2015a limits as summarized in Table 2-1. Appendix Tables 1, 2, and 3 contain detailed tabulation of results, process operating conditions, and exhaust gas conditions.

Please note that 40 CFR Part 60, Subpart JJJJ defers to 40 CFR Part 51 VOC definitions, 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…*, and (2), *Where such a method also measures compounds with negligible photochemical reactivity, these…compounds may be excluded as VOC if… accurately quantified, and such exclusion is approved by the enforcement authority.*

Therefore, since the Thermo Scientific 55i NMOC measurement parameter includes ethane, a compound that may be excluded from field measured NMOC results, the CECo test protocol proposed collecting separate exhaust gas ethane samples (if needed) for Method 18 analysis at an outside contracted laboratory. This proposal was accepted by EGLE.

A potential positive ethane bias was first observed at EUENGINE3-4 on September 29 when field measured NMOC results were less than the 0.7 g/HP-hr Subpart JJJJ Limit, but greater than the 0.2 g/HP-hr ROP limit. Therefore, RCTS collected duplicate, representative, "as fired" engine exhaust gas samples for ethane analysis. The duplicate sample was designated for backup analysis due to in-transit shipping damage or if further laboratory quality assurance was needed. Similar NMOC values were observed at EUENGINE3-3 and EUENGINE3-1, so duplicate bag samples were also collected from each.

As noted earlier in this report, the reported ethane laboratory result was converted to propane and subtracted from the field measured NMOC concentrations measured as propane, thus yielding a more accurate, representative NMNEOC (VOC) result.

5.2 Significance of Results

The test results indicate compliance with 40 CFR Part 60, Subpart JJJJ and MI-ROP-B6637-2015a 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 engine and gas compressor / pump equipment were operating under maximum routine conditions and no upsets were encountered during testing, however EUENGINE3-2 was unavailable for testing due to mechanical issues; thus that performance test will be re-scheduled to within 30 calendar days following the first operation of the engine for routine production purposes during the 2020 or 2021 calendar year.

5.5 Air Pollution Control Device Maintenance

Ongoing engine optimization is performed to ensure lean-burn combustion and continuous regulatory emission limit compliance.

5.6 Re-Test Discussion

An engine re-test is not required based on these test program results. Subsequent engine air emissions tests will be performed every 8,760 engine operating hours or 3 years, whichever comes first thereafter to demonstrate compliance. The operating hours at the test conclusion were: 2,686 for EUENGINE3-1, 5,043 for EUENGINE3-3, and 4,099 for EUENGINE3-4.

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 included in this test program are summarized in Table 5-1. 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 if the sampling location is suitable for sampling	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: 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 operation of analyzers	Calibration gases introduced directly into analyzers	Pre-test	±2.0% of the calibration span or 0.5 ppmv or 0.5% O_2 absolute difference
M3A, M7E, 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-test and Post-test	±5.0% of the analyzer calibration span for bias and ±3.0% of analyzer calibration span for drift or ≤ 0.5 ppmv or 0.5% O_2 absolute difference
M4 (ALT-008): Field balance calibration	Verify moisture measurement accuracy	Use Class 6 weight to check balance accuracy	Daily before use	Balance must measure weight within ±0.5 gram of certified mass
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 introduced
M18: Spike Recovery Study	Demonstrate selection of proper sampling/analysis procedures	Compare compound mass collected against spiked media	Once per test for compounds analyzed	Spike recovery within 70≤R≤130% of the spike mass
M25A/ALT096: Calibration Error	Evaluates operation of analyzer and sample system	Calibration gases introduced through sample system	Pre-test	±5.0% of calibration gas value
M25A/ALT096: Zero and Calibration Drift	Evaluates analyzer and sample system integrity and accuracy over test duration	Calibration gases introduced through sample system	Pre and Post-test	±3.0% of analyzer span

5.8 Calibration Sheets

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

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

The method specific quality assurance and quality control procedures in each method employed during this test program were followed, without deviation. Refer to Appendix C for the laboratory data sheets.

5.12 QA / QC Blanks

Other than Method 18 QA/QC and calibration gases used for zero calibrations, no other reagent or media blanks were used. Laboratory QA/QC data is contained in Appendix C.