Consumers Energy
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40 CFR Part 60 Subpart JJJJ Compliance Test Report

EUEMERGGEN3

Consumers Energy Company
Ray Compressor Station
69333 Omo Road
Armada, Michigan 48005
SRN: B6636

November 1, 2023

Test Date: September 7, 2023

Test Performed by the Consumers Energy Company
Regulatory Compliance Testing Section
Air Emissions Testing Body
Environmental and Laboratory Services Department
Work Order No. 41145900
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EXECUTIVE SUMMARY

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compound (VOC) testing at the exhaust location of EUEMERGGEN3 installed at the Consumers Energy Ray Compressor Station in Armada, Michigan. The engine is a natural gas-fired, four-stroke lean-burn (4SLB), spark ignited (SI), reciprocating internal combustion engine (RICE), ≥130 horsepower, that powers an emergency generator to provide electricity for the site during power outages. EUEMERGGEN3 is an emissions unit identification within Michigan Department of Environment, Great Lakes, and Energy (EGLE) Renewable Operating Permit (ROP) MI-ROP-B6636-2020b and subject to federal air emissions regulations.

The test program was conducted on September 7, 2023, following the Test Protocol submitted June 6, 2023, to EGLE, to satisfy performance testing requirements and evaluate compliance with 40 CFR Part 60, Subpart JJJJ, *Standards of Performance for Stationary Spark Ignition Internal Combustion Engines*, (aka NSPS SI ICE), and the ROP. There were no deviations from the approved stack test protocol, except the proposed test date of July 11, 2023, was postponed to September 7, 2023, due to a plant shutdown.

Three, 60-minute test runs were conducted at the engine exhaust following procedures in United States Environmental Protection Agency (USEPA) Reference Methods (RM) 1, 3A, 4, 7E, 10, 19, and 25A in 40 CFR Part 60, Appendix A. During testing, EUEMERGGEN3 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 EUEMERGGEN3 testing indicate the NO_x, CO, and VOC emissions are compliant with applicable emissions limits and summarized in Table E-1.

Table E-1
Summary of Test Results

Parameter	Units	Average Result of 3 Test Runs EUEMERGGEN3	Emission Limit	
			Subpart JJJJ[1]	ROP
NO_x	g/HP-hr	0.5	2.0	0.5
	ppmvd at 15% O_2	36	160	-
CO	g/HP-hr	2.1	4.0	
	ppmvd at 15% O_2	269	540	
VOC[†]	g/HP-hr	0.55	1.0	0.81
	ppmvd at 15% O_2	44	86	

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
ppmvd at 15% O_2 parts per million by volume, dry basis, at 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 percent O_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 Table 1. 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.

1.0 INTRODUCTION

This report summarizes the results of compliance air emissions testing conducted September 7, 2023, at the Consumers Energy Ray Compressor Station in Armada, 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 of the existing stationary, spark-ignition (SI), reciprocating internal combustion engine (RICE), identified as EUEMERGGEN3 installed at the Ray Compressor Station in Armada, Michigan on September 7, 2023.

A Test Protocol submitted to EGLE on June 6, 2023, was subsequently approved by Andrew Riley, Environmental Quality Analyst with ELGE, in a letter dated June 30, 2023. There were no deviations from the approved stack test protocol, except the proposed test date of July 11, 2023, was postponed to September 7, 2023, due to a plant shutdown.

1.2 Purpose of Testing

The test program was performed to satisfy performance testing requirements and evaluate compliance with 40 CFR Part 60, Subpart JJJJ, *Standards of Performance for Stationary Spark Ignition Internal Combustion Engines*, (aka NSPS SI ICE) and EGLE air permit MI-ROP-B6636-2020b. The applicable emission limits are presented in Table 1-1.

Table 1-1
Applicable Emission Limits

Parameter	Emission Limit	Units	Applicable Requirement
NO_x	0.5	g/HP-hr	MI-ROP-B6636-2020b, EUEMERGGEN3
	2.0	g/HP-hr	40 CFR Part 60, Subpart JJJJ[1]
	160	ppmvd at 15% O_2	40 CFR Part 60, Subpart JJJJ[1]
CO	4.0	g/HP-hr	40 CFR Part 60, Subpart JJJJ[1]
	540	ppmvd at 15% O_2	40 CFR Part 60, Subpart JJJJ[1]
VOC†	0.81	g/HP-hr	MI-ROP-B6636-2020b, EUEMERGGEN3
	1.0	g/HP-hr	40 CFR Part 60, Subpart JJJJ[1]
	86	ppmvd at 15% O_2	40 CFR Part 60, Subpart JJJJ[1]

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
ppmvd at 15% O_2 parts per million by volume, dry basis, at 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 percent O_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.

1.3 Brief Description of Source

EUEMERGGEN3 is a natural gas-fired, four-stroke lean-burn (4SLB), spark ignited (SI), reciprocating internal combustion engine (RICE), ≥130 horsepower that powers an emergency electric generator to provide electricity for the site during power outages. The engine is identified as the emissions unit EUEMERGGEN3 within EGLE air permit MI-ROP-B6636-2020b.

1.4 Contact Information

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

Table 1-2
Contact Information

Program Role	Contact	Address
State Regulatory Administrator	Jeremy Howe Technical Programs Unit Supervisor 231-878-6687 howej@michigan.gov	Michigan Department of Environment, Great Lakes and Energy 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
Regulatory Agency Representative	Andrew Riley Environmental Quality Analyst 586-565-7379 rileya8@michigan.gov	EGLE – Air Quality Division Warren District SE Michigan Office 27700 Donald Court Warren, Michigan 48092
State District Manager	Joyce Zhu Environmental Manager 586-606-2572 zhuj@michigan.gov	EGLE – Air Quality Division Warren District SE Michigan Office 27700 Donald Court Warren, Michigan 48092
State Regulatory Inspector	Noshin Khan Environmental Engineer 586-536-1197 khann5@michigan.gov	EGLE – Air Quality Division Warren District SE Michigan Office 27700 Donald Court Warren, Michigan 48092
Responsible Official	Avelock Robinson Director of Gas Compression 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	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
Field Environmental Coordinator	Thomas Fox Principal Environmental Engineer 989-239-8457 thomas.fox@cmsenergy.com	Consumers Energy Company Bay City Customer Service Center 4141 E. Wilder Road Bay City, Michigan 48706
Test Facility	William F. Harvey Supervisor Gas Compression 586-784-2096 william.f.harvey@cmsenergy.com	Consumers Energy Company Ray Compressor Station 69333 Omo Road Armada, Michigan 48005
Test Team Representative	Thomas Schmelter, QSTI Sr. Engineering Technical Analyst 616-738-3234 thomas.schmelter@cmsenergy.com	Consumers Energy Company 17010 Croswell Road JHC Training Center / 149-10 West Olive Michigan 49460

2.0 SUMMARY OF RESULTS

2.1 OPERATING DATA

During the compliance test, the engine fired natural gas and pursuant to §60.4244(a), the engine was operated at the highest achievable load. The performance testing was conducted with the engine operating at an average load of 93% torque and 93% horsepower, based on the maximum manufacturer's design capacity. Refer to Appendix C for detailed operating data from the facility's data acquisition system.

2.2 APPLICABLE PERMIT INFORMATION

The Ray Compressor Station operates in accordance with MI-ROP-B6636-2020b. EUEMERGGEN3 is the emission unit source identified in the permit. Incorporated within the permit are the applicable federal requirements of 40 CFR Part 60, Subpart JJJJ.

2.3 RESULTS

The results of the EUEMERGGEN3 testing indicate the NO_x, CO, and VOC emissions are compliant with applicable emissions limits. Refer to Table 2-1 for a summary of the test results.

Table 2-1
Summary of Test Results

Parameter	Units	Average Result of 3 Test Runs EUEMERGGEN3	Emission Limit	
			Subpart JJJJ[1]	ROP
NO_x	g/HP-hr	0.5	2.0	0.5
	ppmvd at 15% O_2	36	160	NA
CO	g/HP-hr	2.1	4.0	NA
	ppmvd at 15% O_2	269	540	NA
VOC[†]	g/HP-hr	0.55	1.0	0.81
	ppmvd at 15% O_2	44	86	NA

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
ppmvd at 15% O_2 parts per million by volume, dry basis, at 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 percent O_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 found in Appendix Table 1. A discussion of the results is presented in Section 5.0. Sample calculations and field data sheets are provided in Appendices A and B. Engine operating data and supporting documentation are provided in Appendices C and D.

3.0 SOURCE DESCRIPTION

EUEMERGGEN3 is operated as an emergency SI ICE in the event of a site power outage. A summary of the engine specifications from the manufacturer's gas engine site-specific technical data is presented in Table 3-1.

Table 3-1
Engine Specifications

Parameter[1]	EUEMERGGEN3
Manufactured Date	November 8, 2011
Make	Caterpillar
Model	G3516B
Serial No.	ZBC00239
Output (brake-horsepower)	1,818
Heat Input (mmBtu/hr)	12.25
Exhaust Gas Temp. (°F)	974
Engine Outlet O_2 (Vol-%, dry)	9.3

[1] Engine specifications are based upon vendor data for operation at 100% of rated engine capacity.

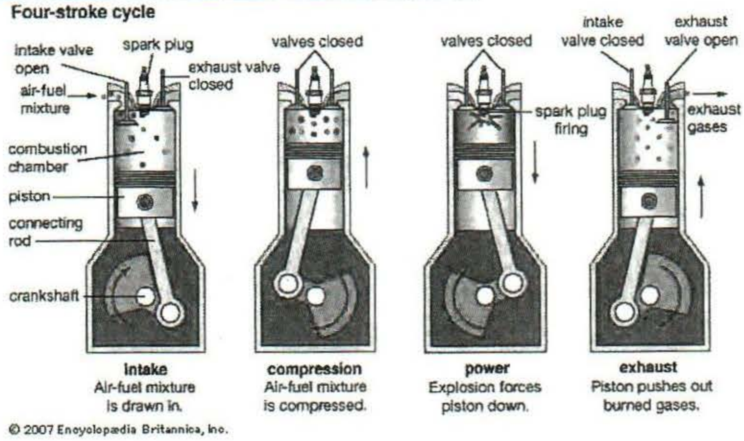
3.1 PROCESS

The Ray Compressor Station is a natural gas transmission and storage facility. The facility operates EUEMERGGEN3 to turn an emergency generator that provides electricity during power outages.

EUEMERGGEN3 is a natural gas-fired 4SLB SI RICE manufactured on November 8, 2011. In a four-stroke engine, air is aspirated into the cylinder during the downward travel of the piston on the intake stroke. Fuel 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 spark 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 open 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 engine provides mechanical shaft power to an electricity-producing generator. 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 is controlled through parametric controls (i.e., timing and air-to-fuel ratio), and lean burn combustion technology to limit air emissions. The Caterpillar engine includes an Advanced Digital Engine Management (ADEM) electronic control system. The ADEM 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 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.

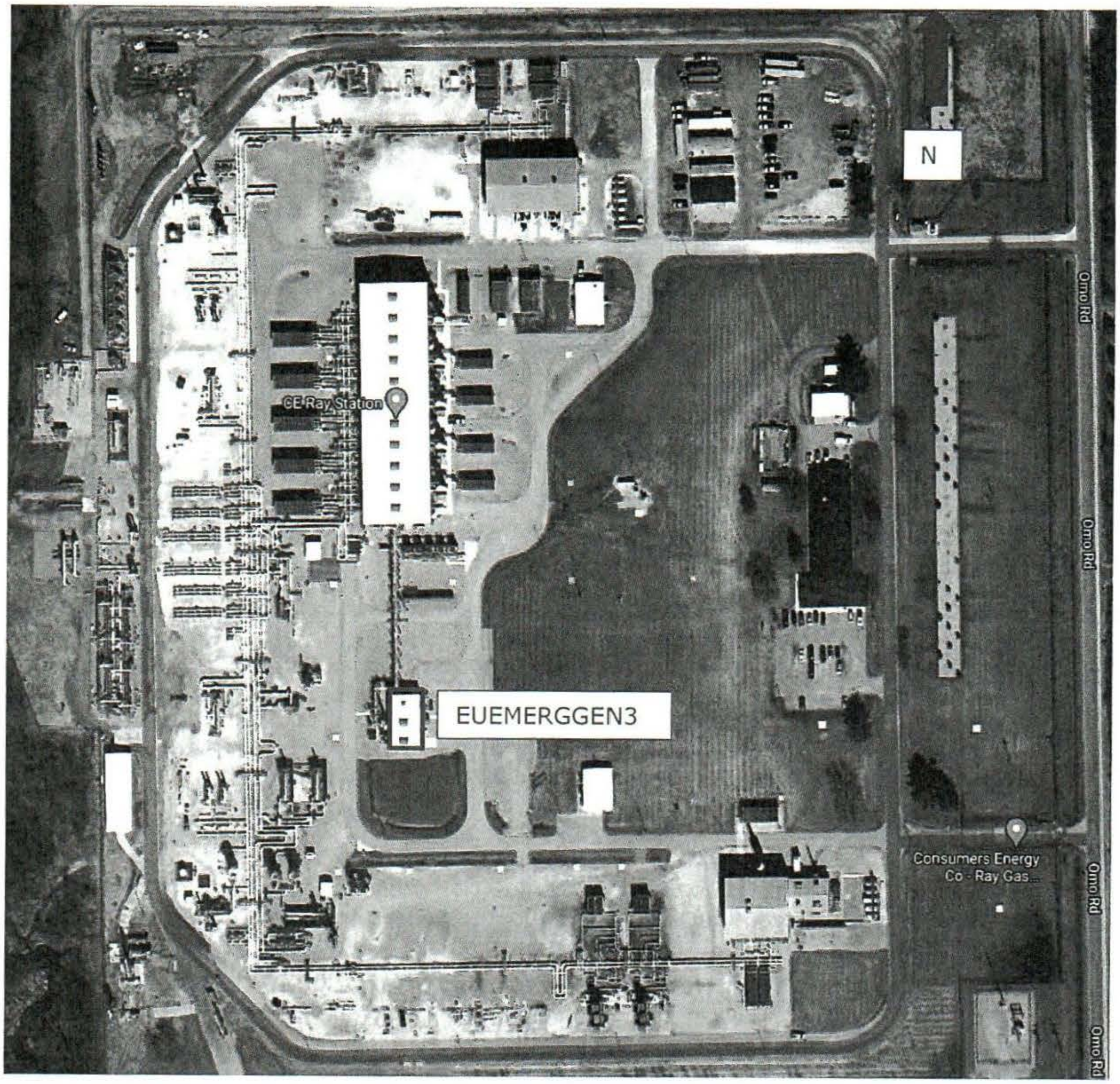
Detailed operating data recorded during testing are provided in Appendix C.

3.2 Process Flow

Located in northern Macomb County, the Ray Compressor Station is a natural gas transmission and storage facility. The site pumps natural gas into and out of underground storage reservoirs and maintains the pressure along the pipeline system. During normal seasonal weather patterns, natural gas is purchased for storage injection in April through October and withdrawn from storage reservoirs in November through March.

EUEMERGGEN3 maintains station electric power during a commercial power outage. The natural gas engine generator set is designed to start and supply power before equipment shutdowns to maintain station flow rate. Refer to Figure 3-2 for the Ray Compressor Station Site Map depicting the EUEMERGGEN3 location.

Figure 3-2. Ray Compressor Station Site Map



3.3 Materials Processed

The fuel utilized in EUEMERGGEN3 is exclusively natural gas, as defined in 40 CFR 72.2. During testing, the natural gas combusted within the engine was comprised of approximately 93% methane and 7% ethane. The daily natural gas chromatograph analysis results are provided in Appendix C. 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

EUEMERGGEN3 has a maximum power output of approximately 1,818 horsepower, and as equipped with the electric generator, a maximum electrical output of 1,318 kilowatts. The engine has a rated heat input of 12.8 million British thermal units per hour (mmBtu/hour).

The engine operating parameters were recorded and averaged for each test run. Refer to Appendix C for operating data recorded during testing.

3.5 PROCESS INSTRUMENTATION

The engine operating parameters were continuously monitored by a distributed control system for the Caterpillar engine, data acquisition systems, the Caterpillar Load Bank operator, and by Consumers Energy personnel during testing. Data were collected during each test for the following parameters: Refer to Appendix C for operating data.

- Total current (RMS Amps)
- Power (Kilowatts)
- Engine speed (rpm)
- Power factor
- Engine Torque (% max)
- Fuel flow (scfm)
- Phase A, B, C, and total current (amps)
- Electric potential (Volts)
- Unit hours

The horsepower of the engine was calculated based on the following:

Engine Torque (% max) X Rated Engine Power at 100% (1818 bhp)

4.0 SAMPLING AND ANALYTICAL PROCEDURES

Consumers Energy RCTS tested for NO_x, CO, VOC, and oxygen (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	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
Nitrogen oxides (NO_x)	7E	Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)
Carbon monoxide (CO)	10	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
Emission rates	19	Sulfur Dioxide Removal and Particulate, Sulfur Dioxide and Nitrogen Oxides from Electric Utility Steam Generators
Volatile organic compounds	25A	Measurement of Gaseous Organic Compound Emissions by Gas Chromatography

4.1 DESCRIPTION OF SAMPLING TRAIN AND FIELD PROCEDURES

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

Table 4-2
Test Matrix

Date (2023)	Run	Sample Type	Start Time (EDT)	Stop Time (EDT)	Test Duration (min)	EPA Test Method	Comment
Sept. 7	1	O_2 NO_x CO VOC	09:00	09:59	60	1 3A 4 7E 10 19 25A	Three-point sample at exhaust stack
	2		11:15	12:14	60		Single-point sample at exhaust stack
	3		13:45	14:44	60		Single-point sample at exhaust stack.

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 2 of 40 CFR Part 60, Subpart JJJJ, and USEPA Method 1, *Sample and Velocity Traverses for Stationary Sources*. The sampling location for EUEMERGGEN3 is described as:

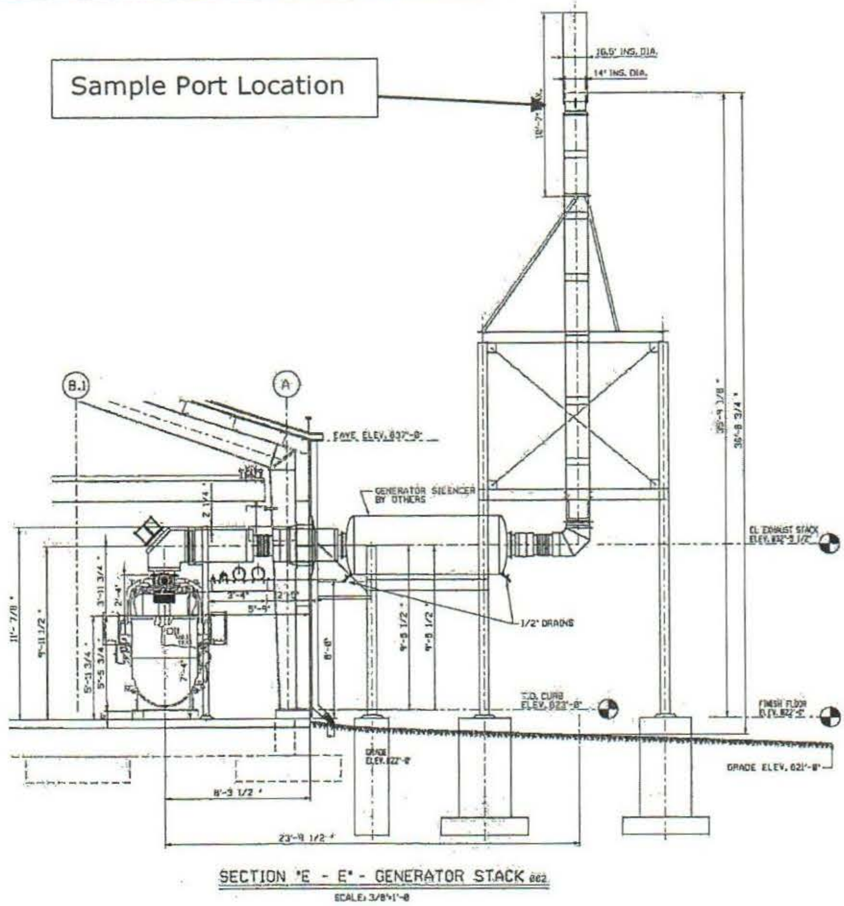
Sample Port in 14-inch diameter duct:

- Approximately 24-feet or 20 duct diameters downstream of a flow disturbance where the engine exhaust makes a 90 degree turn, and
- Approximately 60-inches or 4 duct diameters upstream of the exit to atmosphere.

The sample port is 1-inch in diameter and extends approximately 3 inches beyond the stack wall. 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.

Figure 4-1. EUEMERGGEN3 Sampling Location

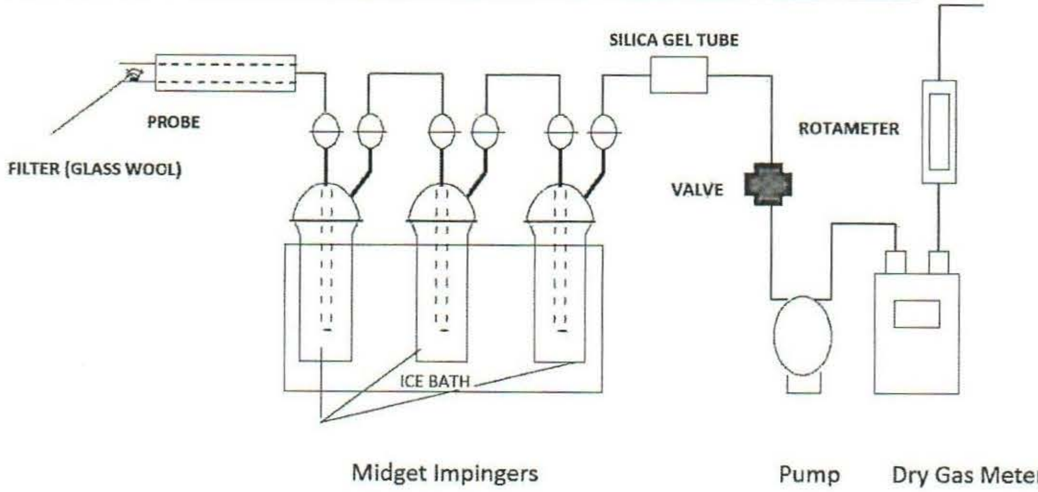


4.3 Moisture Content (USEPA Method 4 / ALT-008)

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 is incorporated into Method 6A of 40 CFR Part 60 and 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 configuration follows the general guidelines contained 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 from the stack at a constant rate through a sample probe, Teflon tubing, four midget impingers, and a metering console with pump. The moisture is removed from the gas stream in the ice-bath chilled impingers and determined gravimetrically. The mass of condensate collected and the volume of flue gas sampled are used to calculate the 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.

4.4 O_2, NO_X, AND CO (USEPA METHODS 3A, 7E, AND 10)

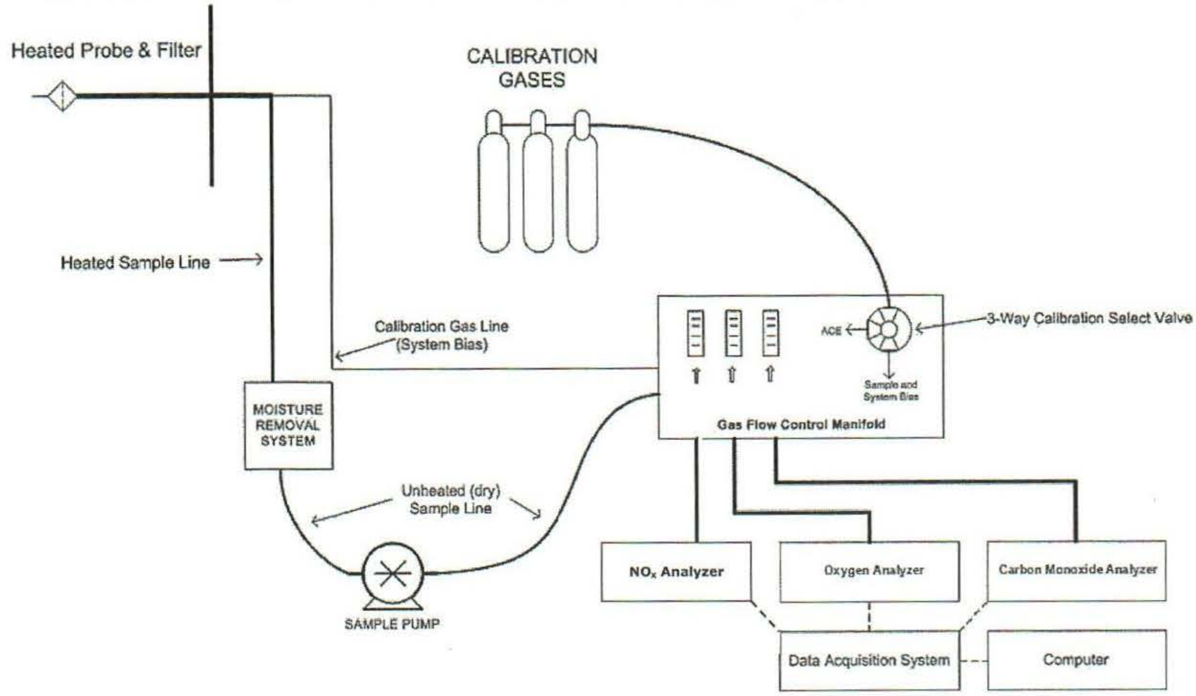
Oxygen, nitrogen oxides, and carbon monoxide concentrations were measured using the following sampling and analytical procedures:

- 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, 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. USEPA Methods 3A, 7E, and 10 Sampling System



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

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

4.5 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_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 Ray Compressor Station is the same gas used for firing EUEMERGGEN3. 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

4.6 Volatile Organic Compounds (USEPA Method 25A)

VOC concentrations were measured from the engine using a Thermo Model 55i Direct Methane and Non-methane Analyzer following the guidelines of USEPA Method 25A, *Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer (FIA)*. The instrument uses a flame ionization detector (FID) to measure the exhaust gas total hydrocarbon concentration in conjunction with a gas chromatography column that separates methane from other organic compounds.

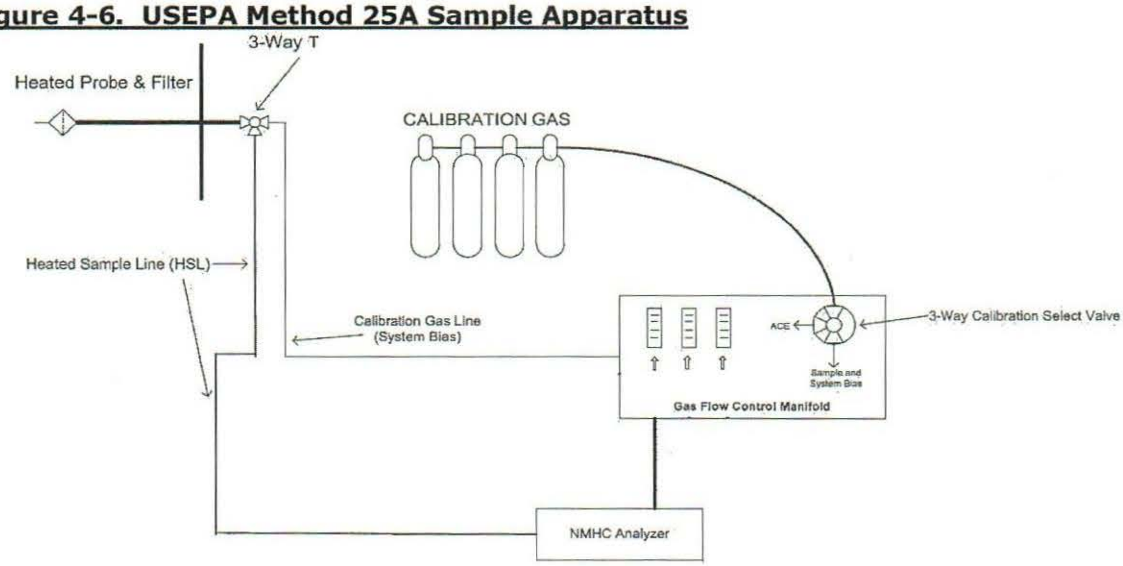
The components of the extractive sample interface apparatus are constructed of stainless steel and Teflon. Flue gas was collected from the stack via a sample probe and heated sample line and into the analyzer, which communicates with the data acquisition handling system (DAHS) via output signal cables. 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). 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.

Please note that 40 CFR 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 analyzer used measures exhaust gas ethane as part of the NMOC measurement. Therefore, the NMOC concentrations measured may reflect a positive NMOC bias.

Figure 4-6. USEPA Method 25A Sample Apparatus



5.0 TEST RESULTS AND DISCUSSION

The test program was conducted September 7, 2023 to satisfy performance testing requirements and evaluate compliance with 40 CFR Part 60, Subpart JJJJ, *Standards of Performance for Stationary Spark Ignition Internal Combustion Engines*, (aka NSPS SI ICE), and MI-ROP-N5792-2018.

Note that the emission rates in this report use calculated fuel flow rates logged by the Caterpillar, Inc. engine generator load bank., rather than as measured by the facility. While a calculated flow rate approach is not necessarily specified by 40 CFR Part 60, Subpart JJJJ, the fuel flow rate used is representative of the maximum, worst-case emission rate scenario.

5.1 Tabulation of Results

The results of the EUEMERGGEN3 testing indicate the NO_x, CO, and VOC emissions are compliant with applicable emissions limits as summarized in Table 2-1. Appendix Table 1 contains detailed tabulation of results, process operating conditions, and exhaust gas conditions for the engine.

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 variations from sampling or operating conditions was encountered during testing.

5.4 Process or Control Equipment Upset Conditions

There were no process or control equipment upset conditions encountered during this test program. The engine was connected to a load bank and operating at the highest achievable load (93% of engine torque, 93% of peak engine horsepower) during testing.

5.5 Air Pollution Control Device Maintenance

No major pollution control device maintenance was performed during the three-month period prior to the test event.

5.6 Re-Test Discussion

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

- Every 8,760 engine-operating hours or 3 years (2026), whichever is first, thereafter to evaluate compliance with NO_x, CO, and VOC emission limits in 40 CFR Part 60, Subpart JJJJ and the ROP. The service meter indicated 353 hours of operation after the conclusion of the compliance test.

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 D 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, 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 operation of analyzers	Calibration gases introduced directly into analyzers	Pre-test	±2.0% of the calibration span or 0.5 ppmv or 0.5% CO_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% CO_2 absolute difference
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
M25A: Calibration Error	Evaluates operation of analyzer and sample system	Calibration gases introduced through sample system	Pre-test	±5.0% of the calibration gas value
M25A: Zero and Calibration Drift	Evaluates analyzer and sample system integrity and accuracy over test duration	Calibration gases introduced through sample system	Pre-test and Post-test	±3.0% of the analyzer calibration 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

The method specific quality assurance and quality control procedures in each method employed during this test program were followed, without deviation.

5.12 QA/QC Blanks

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