IMPACT COMPLIANCE & TESTING

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AIR QUALITY DIVISION

Executive Summary

AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF SULFUR DIOXIDE EMISSIONS FROM
LANDFILL GAS FUELED ENGINES

ENERGY DEVELOPMENTS MICHIGAN, LLC
BRENT RUN RENEWABLE ENERGY FACILITY

Energy Developments Michigan, LLC (EDL) contracted Impact Compliance & Testing, Inc. (ICT) to perform emission testing for sulfur dioxide (SO_2) emission rate for three (3) Caterpillar (CAT®) landfill gas-fired reciprocating internal combustion engines (RICE) operated at the EDL renewable energy facility at the Brent Run Landfill in Montrose, Genesee County, Michigan. A summary of measured pollutants and comparison to the emission limits of Permit to Install (PTI) No. 176-18 are presented below.

Emission Unit	Measured Pollutant	Average Test Value	Permit Limit	Pass / Fail
EUENGINE3	SO_2 emissions, lb/hr	2.46	3.56	Pass
EUENGINE4	SO_2 emissions, lb/hr	2.26	3.56	Pass
EUENGINE6	SO_2 emissions, lb/hr	2.42	3.56	Pass
FGENGINES	Fuel H_2S content, ppmv	534	--	--
FGENGINES	Fuel TRS content, ppmv	569	--	--

The test results indicate that the emission units operated in compliance with the permitted air pollutant emission rates.

IMPACT COMPLIANCE & TESTING

AIR EMISSION TEST REPORT

Title:	AIR EMISSION TEST REPORT FOR THE VERIFICATION OF SULFUR DIOXIDE EMISSIONS FROM LANDFILL GAS FUELED ENGINES
Report Date:	September 3, 2020
Test Dates:	July 30-31, 2020

Facility Information	
Name:	Energy Developments Michigan, LLC Brent Run Renewable Energy Facility
Street Address:	8247 Vienna Road (M-57)
City, County:	Montrose, Genesee
SRN:	N5987

Facility Permit Information	
Permit to Install No.	176-18
Operating Permit	MI-ROP-N5987-2015a
Emission Units:	EUENGINE3, EUENGINE4, EUENGINE6

Testing Contractor	
Company:	Impact Compliance & Testing, Inc.
Mailing Address:	4180 Keller Rd, Ste B Holt, MI 48842
Phone:	(517) 268-0043
Project No.:	2000141

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AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF SULFUR DIOXIDE EMISSIONS
FROM
LANDFILL GAS FUELED INTERNAL COMBUSTION ENGINES

ENERGY DEVELOPMENTS MICHIGAN, LLC
BRENT RUN RENEWABLE ENERGY FACILITY

1.0 INTRODUCTION

Energy Developments Michigan, LLC (EDL) owns and operates a renewable energy facility located at the Brent Run Landfill in Montrose, Genesee County, Michigan. The EDL facility primarily consists of five (5) Caterpillar (CAT®) gas fueled reciprocating internal combustion engines and electricity generator sets (RICE gensets) that are identified as emission units EUENGINE3, EUENGINE4, EUENGINE5, EUENGINE6, and EUENGINE7 and flexible group FGICEENGINES in Permit to Install (PTI) No. 176-18.

The facility has been issued Renewable Operating Permit (ROP) MI-ROP-N5987-2015a. However, the conditions of PTI 176-18 have not yet been incorporated into the ROP.

In December 2019 emission testing for all five engines was performed as required by the conditions of PTI 176-18. The measured sulfur dioxide (SO_2) emission rate exceeded the permitted emission rate for three engines; EUENGINE3, EUENGINE4, and EUENGINE6.

This test report presents the results of follow-up SO_2 emission rate testing performed for emission units EUENGINE3, EUENGINE4, and EUENGINE6. The compliance testing was performed by Impact Compliance & Testing, Inc. (ICT) representatives Robert Harvey and Clay Gaffey on July 30-31, 2020. Dan Zimmerman, EDL Senior Compliance Manager, managed the test event.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Protocol dated July 16, 2020 that was reviewed and approved by the Michigan Department of Environment, Great Lakes and Energy (EGLE) Air Quality Divisions (AQD). EGLE representatives Michelle Luplow and Regina Angellotti were on-site to witness the emission test event.

Questions regarding this emission test report should be directed to:

Emission Test Procedures	Robert Harvey, P.E. Services Director Impact Compliance & Testing, Inc. 4180 Keller Rd, Ste B Holt, MI 48842 (517) 481-3170 Rob.Harvey@ImpactCandT.com
Responsible Official	Dan Zimmerman Senior Compliance Manager EDL PO Box 15217 Lansing, MI 48901 (517) 896-4417 Dan.Zimmerman@edlenergy.com

Report Certification

This test report was prepared by ICT based on field sampling data collected by ICT. Facility process data were collected and provided by EDL employees or representatives. This test report has been reviewed by EDL representatives and approved for submittal to the EGLE-AQD.

A Report Certification signed by the facility's Responsible Official accompanies this report.

I certify that the testing was conducted in accordance with the specified test methods and submitted test plan unless otherwise specified in this report. I believe the information provided in this report and its attachments are true, accurate, and complete.

Report Prepared By:

Robert L. Harvey, P.E.
Services Director
Impact Compliance & Testing, Inc.

2.0 TEST RESULTS SUMMARY

2.1 Purpose and Objective of the Tests

Emission testing performed in December 2019 failed to demonstrate compliance with the allowable SO_2 emission rate specified in PTI 176-18 for emission units EUENGINE3, EUENGINE4, and EUENGINE6. A retest of these engines was performed in July 2020.

Attachment 1 provides a copy of the EGLE test plan approval letter.

2.2 Summary of Air Pollutant and Gas Sampling Measurements

The gases exhausted from each LFG fueled RICE were sampled for three (3) one-hour test periods during the compliance testing performed July 30-31, 2020. The treated LFG that is used as fuel was evaluated for hydrogen sulfide (H_2S) content during each test period using a Draeger stain tube. Additionally, a sample of the treated LFG fuel for each test day was sent to a laboratory for sulfur content analysis.

The testing was performed while the RICE generator sets were operated at maximum operating conditions or at least within 10% of rated electricity generation rate, which is 1,600 kW. EDL representatives recorded the generator electricity output (kW) at 15-minute intervals for each test period.

Fuel flowrate (pounds per hour (lb/hr or pph) and fuel methane content (%) were also recorded by EDL representatives every 15 minutes for each test period.

Attachment 2 provides operating records provided by EDL representatives for the test periods.

Table 2.1 presents the average measured emission rates and operating conditions for the landfill gas engines (average of the three test periods for each engine).

Data for each one-hour sampling period are presented in Section 6.0 of this report.

Table 2.1 Average measured emission rates and operating conditions for the landfill gas fired engines (three-test average)

Emission Unit / Parameter	Average Test Value	Permit Limit	Pass / Fail
EUENGINE3			
SO_2 emissions (lb/hr)	2.46	3.56	Pass
Generator output (kW)	1,564	--	--
Fuel use (lb/hr)	2,415	--	--
EUENGINE4			
SO_2 emissions (lb/hr)	2.26	3.56	Pass
Generator output (kW)	1,548	--	--
Fuel use (lb/hr)	2,339	--	--
EUENGINE6			
SO_2 emissions (lb/hr)	2.42	3.56	Pass
Generator output (kW)	1,547	--	--
Fuel use (lb/hr)	2,405	--	--
FGICENGINES			
Fuel sulfur content[1], ppmv H_2S	534	--	Note 3
Fuel sulfur content[2], ppmv TRS	569	--	Note 3

Notes
1. Average of nine (9) Draeger chemical stain tubes
2. Total reduced sulfur, average of two laboratory analyses.
3. The SO_2 emission limits are based on a sulfur content of 640 ppmv. However, there is no specific permit limit for LFG sulfur content.

3.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

3.1 General Process Description

Landfill gas (LFG) containing methane is generated in the Brent Run Landfill from the anaerobic decomposition of disposed waste materials. The LFG is collected from both active and capped landfill cells using a system of wells (gas collection system). The collected LFG is transferred to the EDL renewable energy facility where it is treated and used as fuel for the RICE. Each RICE is connected to an electricity generator that produces electricity that is transferred to the local utility.

3.2 Rated Capacities and Air Emission Controls

The CAT® Model No. G3520C RICE has a rated output of 2,242 brake-horsepower (bhp) and the connected generators have a rated electricity output of 1,600 kilowatts (kW). The engines are designed to fire low-pressure, lean fuel mixtures (e.g., LFG) and are equipped with an air-to-fuel ratio controller that monitors engine performance parameters and automatically adjusts the air-to-fuel ratio and ignition timing to maintain efficient fuel combustion.

The RICE generator sets are not equipped with an add-on emission control device. Air pollutant emissions are minimized through the proper operation of the gas treatment system and efficient fuel combustion in the engines.

Sulfur contained in the LFG is oxidized and converted to SO_2 during combustion and is formed irrespective of the type of combustion device. Therefore, the engines potentially produce the same amount of SO_2 per unit of fuel as do the landfill flares.

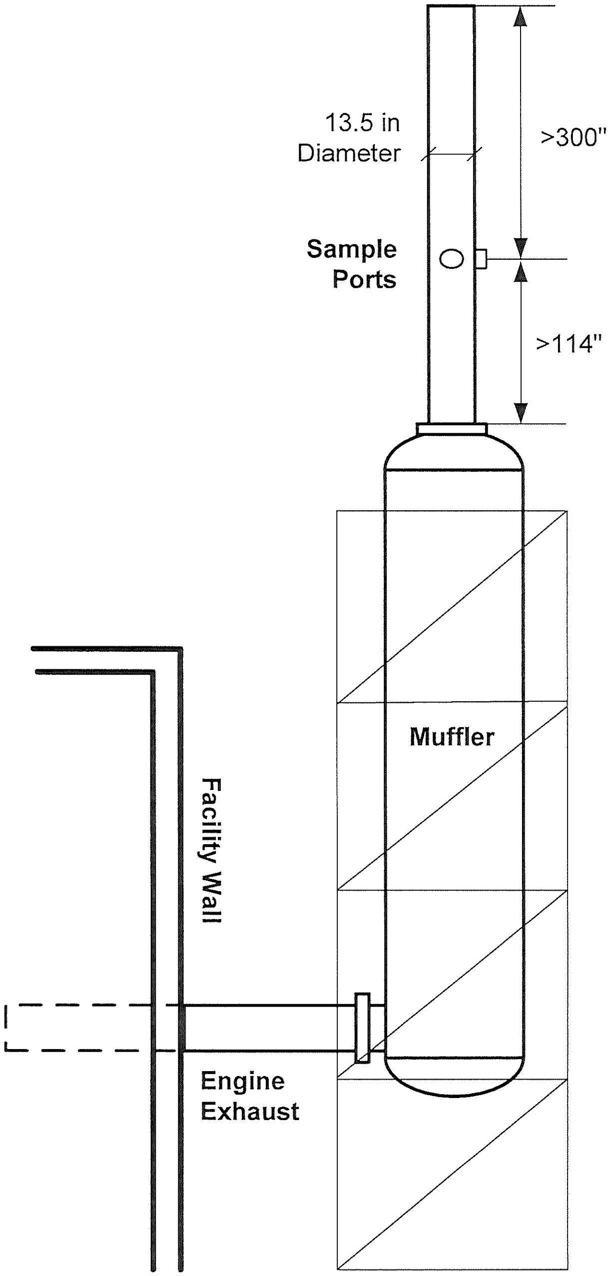
3.3 Sampling Locations

For each RICE, exhaust gas is directed through a muffler and is released to the atmosphere through a dedicated vertical exhaust stack with a vertical release point.

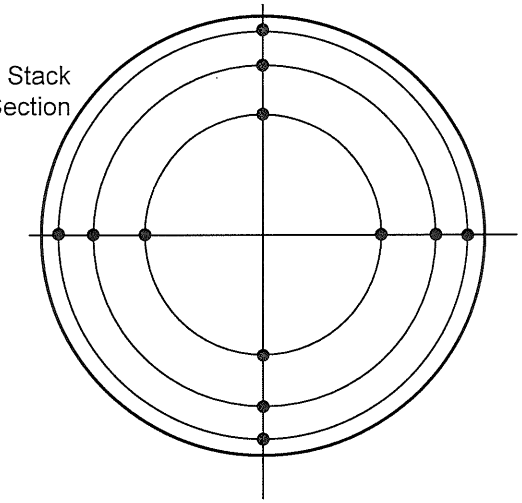
The exhaust stack sampling ports for EUENGINE3, EUENGINE4, and EUENGINE6 are located in the exhaust stack with an inner diameter of 13.5 inches. Each stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location greater than 300 inches (>22 duct diameters) upstream and greater than 114 inches (>8 duct diameters) downstream from any flow disturbance and satisfies the USEPA Method 1 criteria for a representative sample location.

Traverse points were determined in accordance with USEPA Method 1.

A diagram of the emission test sampling location is presented on the following page.



Exhaust Stack
Cross-Section



Velocity sample locations as
measured from stack wall

Pt. #	in.
1	0.6
2	2.0
3	4.0
4	9.5
5	11.5
6	12.9

8-17-20	**Energy Developments – Brent Run** **Exhaust Sample Location, CAT 3520C RICE**		
	Scale None	Sheet 1 of 1	IMPACT COMPLIANCE & TESTING

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A test protocol for the air emission testing was reviewed and approved by the EGLE-AQD. This section provides a summary of the sampling and analytical procedures that were used during the test periods.

4.1 Summary of Sampling Methods

USEPA Method 1	Exhaust gas velocity measurement locations were determined based on the physical stack arrangement and requirements in USEPA Method 1.
USEPA Method 2	Exhaust gas velocity pressure was determined using a Type-S Pitot tube connected to a red oil incline manometer; temperature was measured using a K-type thermocouple connected to the Pitot tube.
USEPA Method 3A	Exhaust gas O_2 and CO_2 content was determined using zirconia ion/paramagnetic and infrared instrumental analyzers, respectively.
USEPA Method 4	Exhaust gas moisture was determined based on the water weight gain in chilled impingers.
USEPA Method 6C	SO_2 emissions by pulsed ultraviolet fluorescence instrumental analyzer
ASTM D4810	On-site fuel sulfur content using chemical stain tube
ASTM D5504	Laboratory fuel sulfur content by gas chromatography

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

The RICE exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 once during each sampling period. An S-type Pitot tube connected to a red-oil manometer was used to determine velocity pressure at each traverse point across the stack cross section. Gas temperature was measured using a K-type thermocouple mounted to the Pitot tube.

Attachment 3 provides exhaust gas flowrate calculations and field data sheets.

4.3 Exhaust Gas Molecular Weight Determination (USEPA Method 3A)

CO_2 and O_2 content in each RICE exhaust gas stream were measured continuously throughout each test period in accordance with USEPA Method 3A. The CO_2 content of the exhaust was monitored using a Servomex 1440D single beam single wavelength (SBSW) infrared gas analyzer. The O_2 content of the exhaust was monitored using a Servomex 1440D gas analyzer that uses a paramagnetic sensor.

During each sampling period, a continuous sample of the RICE exhaust gas stream was extracted from the stack using a stainless steel probe connected to a Teflon® heated sample line. The sampled gas was conditioned by removing moisture prior to being introduced to the analyzers; therefore, measurement of O_2 and CO_2 concentrations correspond to standard dry gas conditions. Instrument response data were recorded using an ESC Model 8816 data acquisition system that monitored the analog output of the instrumental analyzers continuously and logged data as one-minute averages.

Prior to, and at the conclusion of each test, the instruments were calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias (described in Section 5.0 of this document). Sampling times were recorded on field data sheets.

Attachment 4 provides O_2 and CO_2 calculation sheets. Instrument on-minute data data are provided in Attachment 5.

4.4 Exhaust Gas Moisture Content (USEPA Method 4)

Moisture content of the RICE exhaust gas stream was determined in accordance with USEPA Method 4. The moisture sampling was performed concurrently with the instrumental analyzer sampling. During each sampling period, a gas sample was extracted at a constant rate from the source where moisture was removed from the sampled gas stream using impingers that were submersed in an ice bath. At the conclusion of each sampling period, the moisture gain in the impingers was determined gravimetrically by weighing each impinger to determine net weight gain.

Attachment 3 provides exhaust gas moisture gain field data sheets.

4.5 Measurement of SO2 Concentration (USEPA Method 6C)

RICE exhaust gas SO_2 concentration measurements were performed using a Thermo Environmental Instruments, Inc. (TEI) Model 43c that uses pulsed ultraviolet fluorescence technology in accordance with USEPA Method 6C for the measurement of SO_2 concentration.

The exhaust sample was extracted from the stack and transported to the instrumental analyzer using the same system described in Section 4.3.

Prior to, and at the conclusion of each test, the instrument was calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias (described in Section 5.0 of this document).

Attachment 4 provides SO_2 calculation sheets. Instrument on-minute data are provided in Attachment 5.

4.6 Fuel Gas Sulfur Content Analyses

The treated LFG that is used as fuel was evaluated for H_2S content during each test period using a Draeger stain tube (nine total). Additionally, a sample of the treated LFG fuel was collected for each day of testing (two total) and sent to a laboratory for analysis.

The fuel gas samples were collected using an evacuated, inert (silonite-coated) stainless steel canister that was connected to the on-line gas analyzer within the EDL facility. Sample canister vacuum was recorded before and after sampling and verified by the laboratory upon receipt.

The gas samples were analyzed by ALS Analytical (Simi Valley, CA) for sulfur bearing compounds by ASTM D5504.

Attachment 6 provides a copy of the laboratory analytical report and photos of the Draeger stain tubes for each test period.

5.0 QA/QC ACTIVITIES

5.1 Exhaust Gas Flow

Prior to arriving onsite, or onsite prior to beginning compliance testing, the instruments used during the source test to measure exhaust gas properties and velocity (barometer, pyrometer, scale, and Pitot tube) were calibrated to specifications outlined in the sampling methods.

The Pitot tube and connective tubing were leak-checked periodically throughout the test event to verify the integrity of the measurement system.

The absence of significant cyclonic flow for the exhaust configurations were verified using an S-type Pitot tube and oil manometer. The Pitot tube was positioned at each velocity traverse point with the planes of the face openings of the Pitot tube perpendicular to the stack cross-sectional plane. The Pitot tube was then rotated to determine the null angle (rotational angle as measured from the perpendicular, or reference, position at which the differential pressure is equal to zero).

5.2 Gas Divider Certification (USEPA Method 205)

A STEC Model SGD-710C 10-step gas divider was used to obtain appropriate calibration span gases. The ten-step STEC gas divider was NIST certified (within the last 12 months) with a primary flow standard in accordance with Method 205. When cut with an appropriate zero gas, the ten-step STEC gas divider delivered calibration gas values ranging from 0% to 100% (in 10% step increments) of the USEPA Protocol 1 calibration gas that was introduced into the system. The field evaluation procedures presented in Section 3.2 of Method 205 were followed prior to use of gas divider. The field evaluation yielded no errors greater than 2% of the triplicate measured average and no errors greater than 2% from the expected values.

5.3 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure SO_2, O_2, and CO_2 have had an interference response test preformed prior to their use in the field pursuant to the interference response test procedures specified in USEPA Method 7E. The appropriate interference test gases (i.e., gases that would be encountered in the exhaust gas stream) were introduced into each analyzer, separately and as a mixture with the analyte that each analyzer is designed to measure. All of analyzers exhibited a composite deviation of less than 2.5% of the span for all measured interferent gases. No major analytical components of the analyzers have been replaced since performing the original interference tests.

5.4 Instrument Calibration and System Bias Checks

At the beginning of each day of the testing program, initial three-point instrument calibrations were performed for the SO_2, O_2, and CO_2 analyzers by injecting calibration gas directly into the inlet sample port for each instrument. System bias checks were performed prior to and at the conclusion of each sampling period by introducing the upscale calibration gas and zero gas into the sampling system (at the base of the stainless steel sampling probe prior to the particulate filter and Teflon® heated sample line) and determining the instrument response against the initial instrument calibration readings.

The instruments were calibrated with USEPA Protocol 1 certified concentrations of SO_2 (in air) and blend gas of O_2 and CO_2 (in nitrogen). The instruments were zeroed using nitrogen or air as appropriate. A STEC Model SGD-710C ten-step gas divider was used to obtain intermediate calibration gas concentrations as needed.

5.5 Determination of Exhaust Gas Stratification

Several stratification checks have been performed on the engine exhausts that have demonstrated the RICE exhaust gas stream is not stratified. An initial check was performed on Engine 4 on the first test day. The stainless steel sample probe was positioned at sample points correlating to 16.7, 50.0 (centroid) and 83.3% of each stack diameter. Pollutant concentration data were recorded at each sample point for a minimum of twice the maximum system response time.

The recorded concentration data indicates that the measured CO_2, O_2, and SO_2 concentrations did not vary by more than 5% of the mean across each stack diameter. Previous stratification checks for Engines 3 and 6 are submitted with this report as requested by EGLE.

Based on these data, the exhaust gas is not stratified and the compliance test sampling was performed at a single sampling location within the RICE exhaust stack.

5.6 Meter Box Calibrations

The Nutech Model 2010 sampling console, which was used for the exhaust gas moisture content sampling, was calibrated prior to and after the testing program. This calibration uses the critical orifice calibration technique presented in USEPA Method 5. The metering console calibration exhibited no data outside the acceptable ranges presented in USEPA Method 5.

The digital pyrometer in the Nutech metering consoles were calibrated using a NIST traceable Omega® Model CL 23A temperature calibrator.

Attachment 7 presents test equipment quality assurance data (instrument calibration and system bias check records; calibration gas and gas divider certifications; interference test results; meter box, Pitot tube and scale calibration records; stratification checks).

6.0 RESULTS

6.1 Test Results and Allowable Emission Limits

Engine operating data and air pollutant emission measurement results for each one-hour test period are presented in Tables 6.1 through 6.3.

The measured SO_2 emission rates for each LFG-fueled RICE genset are less than the allowable limit specified in PTI No. 176-18.

A summary of on-site and laboratory fuel sulfur content analyses is presented in Table 6.4.

The SO_2 emission limits are based on a fuel sulfur content of 640 ppmv, which is specified in the permit as the level that triggers more frequent fuel monitoring. However, there is no specific permit limit for fuel sulfur content.

6.2 Variations from Normal Sampling Procedures or Operating Conditions

Each RICE generator set was operated within 10% of maximum output during the test periods. The testing for all pollutants was performed in accordance with USEPA methods and the approved test plan.

Table 6.1 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 3 (EUENGINE3)

Test No. Test date Test period (24-hr clock)	1 7/30/20 13:25-14:25	2 7/30/20 15:10-16:10	3 7/30/20 16:53-17:53	Three Test Average
Fuel flowrate (lb/hr)	2,425	2,415	2,405	2,415
Generator output (kW)	1,563	1,565	1,565	1,564
Engine output (bhp)	2,191	2,192	2,193	2,192
LFG methane content (%)	50.7	50.7	50.8	50.7
Exhaust gas temperature (°F)	822	815	822	820
Exhaust gas flowrate (dscfm)	4,339	4,379	4,398	4,372
Exhaust gas flowrate (scfm)	4,953	4,997	4,995	4,982
<u>Exhaust Gas Composition</u>				
CO_2 content (% vol)	11.6	11.6	11.6	11.6
O_2 content (% vol)	8.57	8.58	8.65	8.60
Moisture (% vol)	12.4	12.4	12.0	12.2
<u>Sulfur Dioxide</u>				
SO_2 conc. (ppmvd)	56.7	56.3	56.2	56.4
SO_2 emissions (lb/hr)	2.46	2.46	2.47	2.46
Permitted emissions (lb/hr)	-	-	-	*3.56*

Table 6.2 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 4 (EUENGINE4)

Test No. Test date Test period (24-hr clock)	1 7/30/20 8:20-9:20	2 7/30/20 10:00-11:00	3 7/30/20 11:45-12:45	Three Test Average
Fuel flowrate (lb/hr)	2,340	2,338	2,339	2,339
Generator output (kW)	1,544	1,546	1,554	1,548
Engine output (bhp)	2,164	2,166	2,177	2,169
LFG methane content (%)	50.6	50.6	50.6	50.6
Exhaust gas temperature (°F)	804	808	794	802
Exhaust gas flowrate (dscfm)	4,188	4,030	3,927	4,048
Exhaust gas flowrate (scfm)	4,816	4,597	4,478	4,631
Exhaust Gas Composition				
CO_2 content (% vol)	11.6	11.2	11.6	11.5
O_2 content (% vol)	8.49	9.10	8.67	8.75
Moisture (% vol)	13.0	12.3	12.3	12.6
Sulfur Dioxide				
SO_2 conc. (ppmvd)	57.8	55.1	54.6	55.9
SO_2 emissions (lb/hr)	2.42	2.22	2.14	2.26
Permitted emissions (lb/hr)	-	-	-	*3.56*

Table 6.3 Measured exhaust gas conditions and air pollutant emission rates for Engine No. 6 (EUENGINE6)

Test No. Test date Test period (24-hr clock)	1 7/31/20 8:20-9:20	2 7/31/20 10:05-11:05	3 7/31/20 11:47-12:47	Three Test Average
Fuel flowrate (lb/hr)	2,409	2,404	2,402	2,405
Generator output (kW)	1,555	1,555	1,532	1,547
Engine output (bhp)	2,180	2,178	2,146	2,168
LFG methane content (%)	50.4	50.4	50.4	50.4
Exhaust gas temperature (°F)	830	828	826	828
Exhaust gas flowrate (dscfm)	4,640	4,523	4,354	4,506
Exhaust gas flowrate (scfm)	5,311	5,161	4,941	5,138
<u>Exhaust Gas Composition</u>				
CO_2 content (% vol)	11.6	11.6	11.5	11.6
O_2 content (% vol)	8.59	8.68	8.68	8.65
Moisture (% vol)	12.6	12.4	11.9	12.3
<u>Sulfur Dioxide</u>				
SO_2 conc. (ppmvd)	52.5	54.3	54.9	53.9
SO_2 emissions (lb/hr)	2.43	2.45	2.38	2.42
Permitted emissions (lb/hr)	-	-	-	*3.56*

Table 6.4 Summary of LFG fuel sulfur content analysis

Result / Parameter	Test Value	Note
Draeger tube, H_2S content (ppmv)	534	[1]
Laboratory, H_2S content (ppmv)	555	[2]
Laboratory, TRS content (ppmv)	569	[2,3]
Laboratory, TRS content ($\mu g/m^3$)	743,163	[2.3]
Calculated SO_2 emission rate (lb/hr)	2.93	[4]
Calculated SO_2 emission factor (lb/MMcf)	94.6	[4]

1. Estimated from observation of nine (9) Draeger® tubes. Photos are provided in Attachment 6.
2. Average of two laboratory samples.
3. TRS concentration based on the total of all sulfur-bearing compounds detected in the sample. See laboratory report in Attachment 6.
4. Theoretical SO_2 emission rate calculated using the fuel use rate and emission factor derived from the laboratory analysis. Assumes 100% conversion of all sulfur bearing compounds to SO_2.