

**Air Emissions Testing
of
Natural Gas Emergency
Generator**

**Lansing Board of Water & Light
REO Town Cogeneration Plant
1201 South Washington Avenue
Lansing, Michigan**

Prepared for
**Lansing Board of Water & Light
Lansing, Michigan**

Bureau Veritas Project No. 11013-000213.00
October 11, 2013



**BUREAU
VERITAS**

Move Forward with Confidence

Bureau Veritas North America, Inc.
22345 Roethel Drive
Novi, Michigan 48375
248.344.1770
www.us.bureauveritas.com/hse



Executive Summary

Lansing Board of Water & Light (BWL) retained Bureau Veritas North America, Inc. (Bureau Veritas) to test air emissions at the REO Town Cogeneration Plant in Lansing, Michigan. Lansing BWL operates a natural-gas-fired spark ignition internal combustion emergency engine installed to provide power to the facility during power outages. The purpose of the testing was to satisfy certain requirements of the Michigan Department of Environmental Quality (MDEQ) Permit to Install 149-10B, dated April 12, 2013 and evaluate compliance with permit limits. The relevant permit emission limits are presented below:

Permit Emission Limits

Pollutant	Emission Limit	Time Period / Operating Scenario	Equipment	USEPA Testing Method	Underlying Applicable Requirements
NO _x	0.5 g/bhp-hr	Test Protocol	EUNGENGINE	7E	R 336.1205(1)(a) and (1)(b), R 336.2802(4), R 336.2803, R 336.2804, 40 CFR 52.21(a)(2), (c), and (d), 40 CFR 60.4233(e)
CO	2.5 g/bhp-hr	Test Protocol	EUNGENGINE	10	R 336.1205(1)(a) and (1)(b), R 336.2802(4), R 336.2804, 40 CFR 52.21(a)(2) and (d), 40 CFR 60.4233(e)
PM	0.12 lb/hr	Test Protocol	EUNGENGINE	5/202	R 336.1205(1)(a) and (1)(b), R 336.1224, R 336.1331(1)(c)
PM ₁₀	0.13 lb/hr	Test Protocol	EUNGENGINE	5/202	R 336.1205(1)(a) and (1)(b), R 336.2802(4), R 336.2803, R 336.2804, 40 CFR 52.21(a)(2), (c), and (d)
PM _{2.5}	0.13 lb/hr	Test Protocol	EUNGENGINE	5/202	R 336.1205(1)(a) and (1)(b), R 336.2802(4), R 336.2803, R 336.2804, 40 CFR 52.21(a)(2), (c),



					and (d)
VOC	0.81 g/bhp-hr	Test Protocol	EUNGENGINE	25A	R 336.1702, 40 CFR 60.4233(e)

g/bhp-hr: gram per brake horsepower-hour
lb/hr: pound per hour

Emission testing was performed following United States Environmental Protection Agency (USEPA) Methods 1, 2, 3, 3A, 4, 5, 7E, 10, 25A, 202, and 205 on September 10, 2013. Three 60-minute test runs were conducted to measure NO_x, CO, and VOC and four, 120-minute test runs were conducted to measure PM, PM_{2.5}, and PM₁₀ at the EUNGENGINE source. The sum of the Method 5 (PM) and 202 (CPM) mass collected represent particulate matter with a nominal aerodynamic diameter less than 10 microns (PM₁₀) and 2.5 microns (PM_{2.5}). The engine was operated within 10 percent of 100 percent peak load during testing.

The first particulate matter test run was voided as it appears to be performed during start-up and is not-considered representative or normal operating emissions.

The following table summarizes the results of the testing in comparison to permit limits. Detailed results are presented in Tables 1 and 2 in the appendix of this report.

EUNGENGINE Emissions Results

Parameter	Units	Run 1 [†]	Run 2	Run 3	Run 4	Average [†]	Limit
PM	lb/hr	0.10	0.03	0.02	0.03	0.02	0.12
PM _{2.5}	lb/hr	0.35	0.11	0.06	0.10	0.09	0.13
PM ₁₀	lb/hr	0.35	0.11	0.06	0.10	0.09	0.13
NO _x	g/bhp-hr	0.29	0.44	0.42	-	0.38	0.5
CO	g/bhp-hr	0.66	0.99	0.93	-	0.86	2.5
VOC	g/bhp-hr	0.18	0.18	0.01	-	0.12	0.81

PM₁₀ emissions include all sample fractions less than 10 and greater than 2.5 micrometers in aerodynamic diameter

PM_{2.5} emissions include all sample fractions less than 2.5 micrometers in aerodynamic diameter

g/bhp-hr: gram per brake horsepower-hour

lb/hr = pound per hour

[†]: Run 1 excluded from the particulate matter run averages

The average natural gas emergency generator emission results indicate compliance with the permit limits.



1.0 Introduction

Lansing Board of Water & Light (BWL) retained Bureau Veritas North America, Inc. (Bureau Veritas) to test air emissions at the REO Town Cogeneration Plant in Lansing, Michigan. Lansing BWL operates a natural-gas-fired spark ignition internal combustion emergency engine installed to provide power to the facility during power outages. The purpose of the September 10, 2013 emissions testing was to satisfy certain requirements of the Michigan Department of Environmental Quality (MDEQ) Permit to Install 149-10B, dated April 12, 2013 and evaluate compliance with permit limits.

1.1 Summary of Test Program

Lansing Board of Water & Light's (BWLs) REO Town Cogeneration Plant operates a natural-gas-fired spark ignition internal combustion emergency engine installed to provide power to the facility during power outages. The exhaust of the EUNGENGINE source is directed to atmosphere via a 13.5-inch-diameter duct that is approximately 50 feet high without post combustion controls. An oxidation catalyst or catalytic reduction device is not installed.

Bureau Veritas measured emissions as summarized in Table 1-1 below:

**Table 1-1
Source, Parameters, Permit Limits, and Test Date**

Source Identification	Parameter	Permit Limit	Test Date
EUNGENGINE	PM	0.12 lb/hr	September 10, 2013
	PM _{2.5}	0.13 lb/hr	September 10, 2013
	PM ₁₀	0.13 lb/hr	September 10, 2013
	NO _x	0.5 g/bhp-hr	September 10, 2013
	CO	2.5 g/bhp-hr	September 10, 2013
	VOC	0.81 g/bhp-hr	September 10, 2013

g/bhp-hr: gram per brake horsepower-hour
lb/hr = pound per hour



Bureau Veritas tested for the emission test parameters presented in Table 1-2 to evaluate compliance with the emission limits.

**Table 1-2
Emissions Test Parameters**

Parameter	Source	Reference Method	
	EU- NGENGINE	Method	Title
Sampling ports and traverse points	●	1	Sample and Velocity Traverses for Stationary Sources
Velocity and flowrate	●	2	Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)
Molecular weight	●	3	Gas Analysis for the Determination of Dry Molecular Weight
Molecular weight	●	3A	Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrument Analyzer Procedure)
Moisture content	●	4	Determination of Moisture Content in Stack Gases (approximation method)
PM	●	5	Determination of Particulate Matter Emissions from Stationary Sources
Oxides of nitrogen	●	7E	Determination of Nitrogen Oxides Emissions from Stationary Sources
Carbon monoxide	●	10	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
VOCs	●	25A	Determination of Total Gaseous Organic Concentrations using a Flame Ionization Analyzer
Condensable PM	●	202	Dry Impinger Method for Determining Condensable Particulate Emissions from Stationary Sources
Gas dilution	●	205	Verification of Gas Dilution Systems for Field Instrument Calibrations; this method is for calibration gases.

The testing was conducted in accordance with the USEPA sampling methods listed above with the following exceptions:

- USEPA Method 3A, 7E, and 10 stratification tests were not conducted and the sample was collected from a single point near the centroid of the duct. The stratification test requirements in Method 7E do not lend themselves well to the small-diameter stacks of



stationary combustion engines and the emissions are generally too temporally variable to render a stratification test meaningful. In addition, the engine exhaust is over 100 feet below the sampling location stack and the emissions should be should be well mixed.

1.2 Purpose of Testing

The purpose of the testing was to satisfy certain requirements of the Michigan Department of Environmental Quality (MDEQ) Permit to Install 149-10B, dated April 12, 2013 and evaluate compliance with permit limits.

1.3 Contact Information

Mr. Thomas Schmelter, Senior Project Manager with Bureau Veritas, directed the compliance testing program. Ms. Angie Goodman, Environmental Compliance Specialist, with Lansing Board of Water & Light, provided process coordination and arranged for facility operating parameters to be recorded. Messrs. Nathan Hude and David Patterson with Michigan Department of Environmental Quality (MDEQ) witnessed the testing. Contact information for these individuals is listed in Table 1-3.



**Table 1-3
Key Personnel**

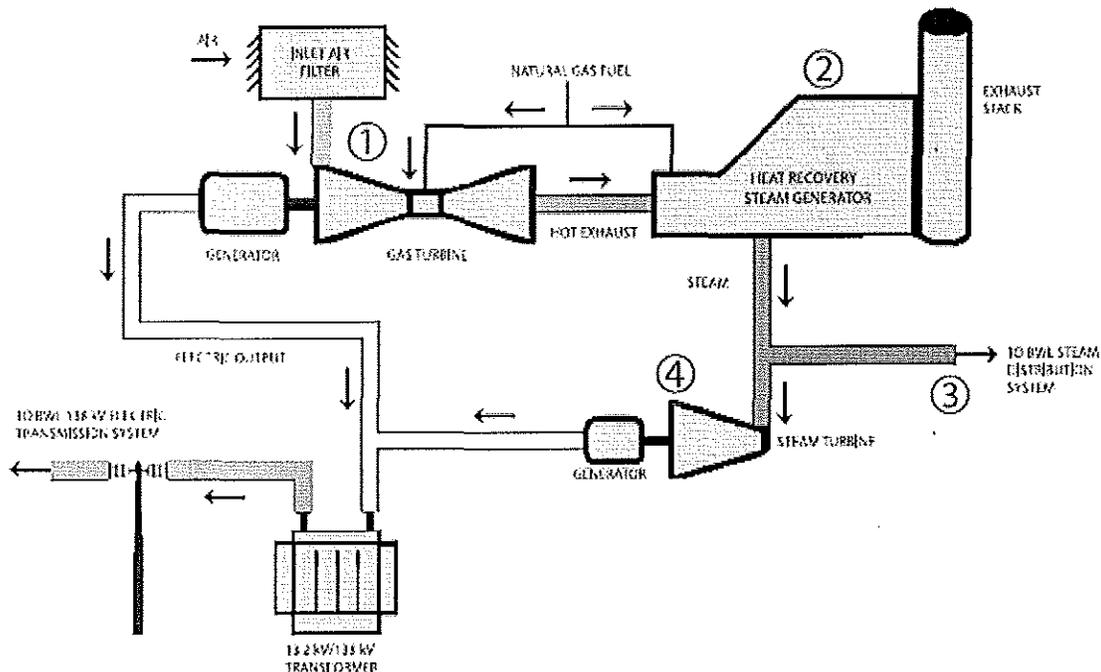
Permittee	Emission Testing Company
Lansing Board of Water & Light 1201 South Washington Avenue Lansing, Michigan 48910 Telephone 517.702.6000	Bureau Veritas North America, Inc. 22345 Roethel Drive Novi, Michigan 48375 Telephone 248.344.1770 Facsimile 248.344.2656
Angie Goodman Environmental Compliance Specialist Telephone 517.702.7059 amel@LBWL.com	Thomas Schmelter, QSTI Senior Project Manager Telephone 248.344.3003 thomas.schmelter@us.bureauveritas.com
Michigan Department of Environmental Quality	
MDEQ – Air Quality Division Technical Programs Unit 525 W. Allegan Street Lansing, Michigan 48909-7760 Telephone 517.335.3082 Facsimile 517.241.3571	MDEQ – Air Quality Division Technical Programs Unit 525 W. Allegan Street Lansing, Michigan 48909-7760 Telephone 517.335.3082 Facsimile 517.241.3571
Nathan Hude Environmental Quality Analyst Telephone 517.335.3082 huden@michigan.gov	David Patterson Environmental Quality Analyst Telephone 517.241.7469 pattersond2@michigan.gov

2.0 Source and Sampling Locations

2.1 Process Description

REO Town Cogeneration Plant is a combined-cycle cogeneration facility. A combined-cycle cogeneration facility uses natural gas to generate steam and electricity in a two-step process. First, a gas turbine burns natural gas to directly turn an electric generator. It then captures the hot exhaust to produce steam, which can be delivered to steam heating customers or used to turn a second electric generator. Refer to Figure 2-1

Cogeneration Diagram



1. Combustion Turbine-Generator - air & fuel are mixed to fire a turbine which turns a generator to produce electricity and hot exhaust.
2. Hot exhaust passes through a Heat Recovery Steam Generator (HRSG) to produce steam. The steam goes to one of two places:
 3. The Steam can go to downtown steam customers or;
 4. Steam can be used to turn a steam turbine-generator set to produce additional electricity.

Figure 2-1. Cogeneration Diagram

Source: Lansing Board of Water & Light. (2013) Going Commercial. Available at: <http://www.lbwl.com/uploadedFiles/REOTownBrochure.pdf>



The facility operates two natural-gas-fired turbines (EUTURBINE1 and EUTURBINE2), two heat recovery steam generators (HRSGs) with duct burners (EUHRSG1 and EUHRSG2), a steam turbine, a natural-gas-fired auxiliary boiler (EUAUXBOILER), a four-cell mechanical draft cooling tower (EUCOOLTWR), an emergency engine (EUNGENGINE), and other miscellaneous ancillary equipment.

The turbines are equipped with HRSGs to produce steam from the turbine exhaust gas for use as process steam or to power a steam turbine generator to produce electric power. The HRSGs are equipped with duct burners to provide supplemental heat for steam production and power output. The auxiliary boiler serves as backup when a combustion turbine/HRSG is out of service and/or during periods of peak demand. The emergency engine is used to power the facility during power outages and was the focus of this test program. A photograph of the emergency engine is provided in Figure 2-2.

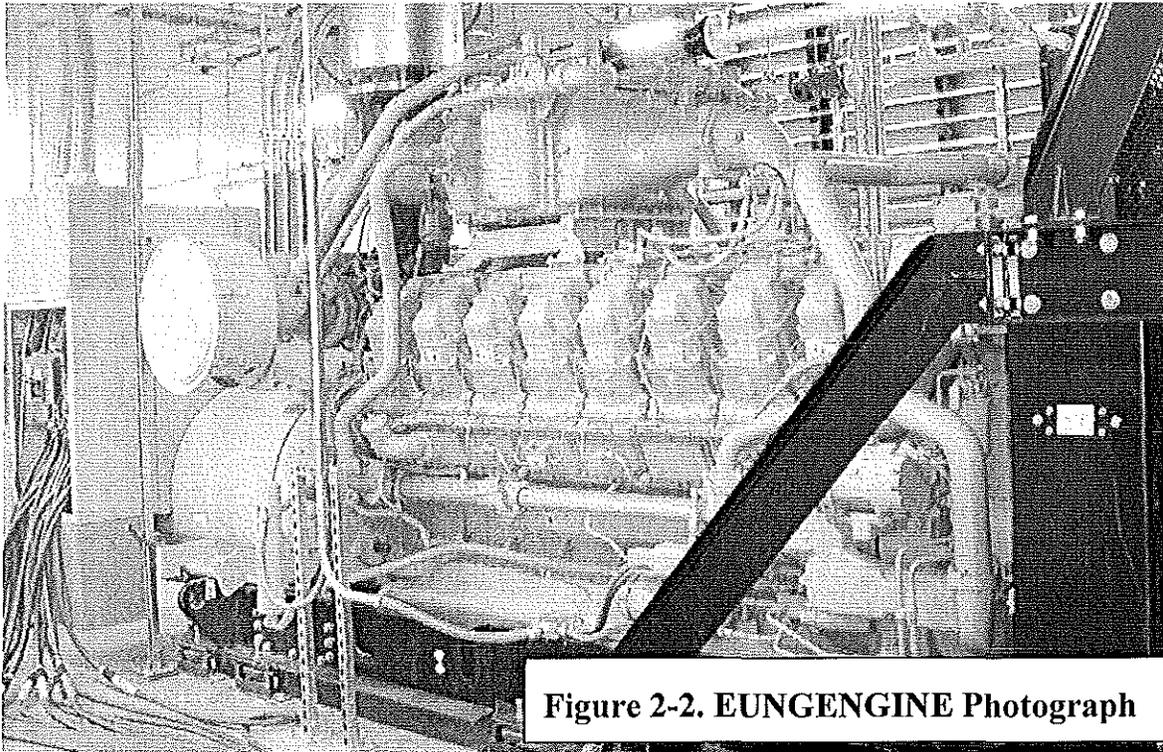


Figure 2-2. EUNGENGINE Photograph

The emergency generator engine is a Caterpillar Model G3516B LE fueled by natural gas. The engine serial number is ZBC00252. The engine was connected to an Avtron load bank to dissipate power during testing. The engine operated within 10 percent of 100 percent load.

Operating parameters recorded during testing are included in Appendix E. Tables 2-1 and 2-2 summarize the natural-gas-fired spark ignition internal combustion emergency engine operating parameters during the 1-hour gaseous emissions tests and 2-hour particulate matter tests.



**Table 2-1
Natural Gas Emergency Generator Operating Parameters 1-hour Tests**

Parameter	Units	Run 1	Run 2	Run 3	Run 4	Average
Power Output	kilowatts	1,320.75	1,318.51	1,318.79	-	1,319.35
Fuel Use	lb/hr	600.30	598.86	597.99	-	599.05
lb/hr: pound per hour						

**Table 2-2
Natural Gas Emergency Generator Operating Parameters 2-hour Tests**

Parameter	Units	Run 1	Run 2	Run 3	Run 4	Average
Power Output	kilowatts	1320.08	1318.46	1318.88	1319.73	1319.29
Fuel Use	lb/hr	599.78	598.95	598.16	598.52	598.76
lb/hr: pound per hour						

2.2 Control Equipment

The exhaust of the EUNGENGINE source is directed to atmosphere without post combustion controls. An oxidation catalyst or catalytic reduction device is not installed.

2.3 Flue Gas Sampling Locations

Two 4-inch-internal-diameter sampling ports oriented at 90° to one another are located in a straight section of the exhaust stack accessed via the roof. The west and north ports were used for sampling during this test program. The sampling ports extend 5-inches outward from the stack interior wall. The ports are located at the following locations relative to the nearest flow disturbances:

- Approximately 10 feet downstream (~9 duct diameters) of any flow disruptions
- Approximately 50 feet upstream (~44 duct diameters) of the stack exit to the atmosphere

Refer to Figure 1 in the Appendix for a drawing of the natural gas emergency generator source showing the sampling ports and traverse point locations. A photograph of the sampling location is provided in Figure 2-3.



Figure 2-3. EUNGENINE Sampling Location

2.4 Process Sampling Locations

Process sampling was not required during this test program. A process sample is a sample that is analyzed for operational parameters, such as calorific value of a fuel (e.g., natural gas, coal), organic compound content (e.g., paint coatings), or composition (e.g., polymers).

3.0 Summary and Discussion of Results

3.1 Objectives and Test Matrix

The purpose of the emission test program is to satisfy certain requirements of the Michigan Department of Environmental Quality (MDEQ) Permit to Install 149-10B, dated April 12, 2013 and to evaluate compliance with permit limits. Table 3-1 presents the sampling and analytical matrix.

**Table 3-1
Lansing Board of Water & Light Test Matrix**

Sampling Location	No. of Runs	Sample/Type of Pollutant	USEPASA Sampling Method	Sampling Organization	Test Time (min)	Analytical Method	Analytical Laboratory
Generator Exhaust	4†	Flowrate, PM, PM _{2.5} , PM ₁₀ ,	1, 2, 3, 4, 5, 202	Bureau Veritas	120	Chemical absorption, gravimetric	Bureau Veritas
Generator Exhaust	3	NO _x , CO, VOC	3A, 7E, 10, 25A, 205	Bureau Veritas	60	paramagnetic, chemiluminescence, gas filter wheel infrared, gas dilution	Not applicable

† Run 1 was excluded from the three-run average

3.2 Applicable Permit or Source Designation

The applicable permit is MDEQ Permit to Install No. 149-10B. The air emission source that was tested was EUNGENGINE. The cover page of the Permit is presented as Figure 3-1.



**MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR QUALITY DIVISION**

April 12, 2013

**PERMIT TO INSTALL
149-10B**

ISSUED TO
Lansing Board of Water and Light

LOCATED AT
1232 Haco Drive
Lansing, Michigan

IN THE COUNTY OF
Ingham

STATE REGISTRATION NUMBER
B2647

The Air Quality Division has approved this Permit to Install, pursuant to the delegation of authority from the Michigan Department of Environmental Quality. This permit is hereby issued in accordance with and subject to Section 5505(1) of Article II, Chapter I, Part 55, Air Pollution Control, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. Pursuant to Air Pollution Control Rule 336.1201(1), this permit constitutes the permittee's authority to install the identified emission unit(s) in accordance with all administrative rules of the Department and the attached conditions. Operation of the emission unit(s) identified in this Permit to Install is allowed pursuant to Rule 336.1201(6).

DATE OF RECEIPT OF ALL INFORMATION REQUIRED BY RULE 203: March 22, 2013	
DATE PERMIT TO INSTALL APPROVED: April 12, 2013	SIGNATURE:
DATE PERMIT VOICED:	SIGNATURE:
DATE PERMIT REVOKED:	SIGNATURE:

Figure 3-1. PTI 149-10B Cover Page



3.3 Field Test Changes and Issues

Field test changes were communicated between Lansing Board of Water & Light, Bureau Veritas, and Michigan Department of Environmental Quality personnel onsite. The following sections summarize the field test changes and issues.

3.3.1 Isokinetic Sampling

Bureau Veritas calculated the ideal nozzle size for Run 1 using historical testing data. However, a high sample train vacuum was encountered at the start of testing and it became difficult to obtain isokinetic sampling rate. Therefore, the test was paused, the sampling train was removed from the stack, leak-checked, and a new nozzle was installed and used for the remainder of the run. In order to calculate the run isokinetic sampling rate the average nozzle size used during the test was used. The isokinetic sampling rate for Run 1 was 96% and within EPA Method 5 criterion of $\pm 10\%$ of 100%.

3.3.2 Exclusion of PM Run 1

Based on visual evaluation of the Method 5 quartz filters, historical test data, and operating the engine within its break-in period, Run 1 was excluded from the three-run average used to evaluate compliance for the particulate matter emissions limit. The filter from Run 1 was analyzed by scanning electron microscope. The results of this analysis are provided in Appendix F. A photograph of the particulate matter filters collected during testing is presented in Figure 3-2 below:

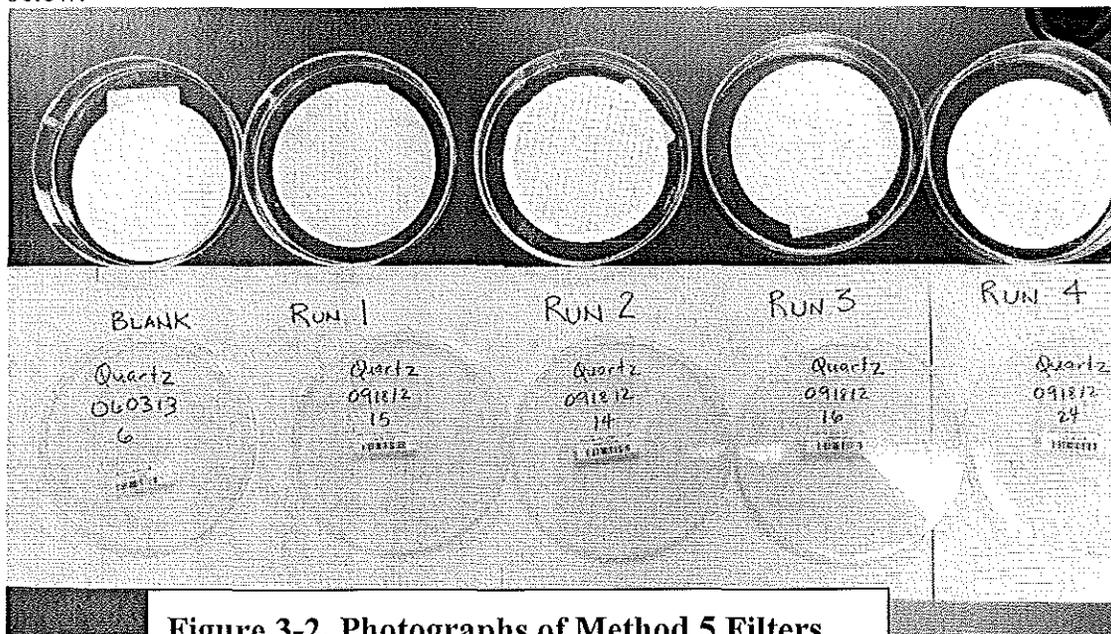


Figure 3-2. Photographs of Method 5 Filters



3.3.3 Method 5 Probe Temperature

Section 6.1.1.2 of USEPA Method 5 requires the glass lined sampling probe to be maintained at a temperature of $248 \pm 25^\circ \text{F}$ during sampling. However, because the flue gas temperature average 780°F during the tests, the sample probe could not be maintained within the EPA Method 5 criterion. Since, both filterable and condensable particulate matter concentrations were measured the high probe temperature is unlikely to have an effect on the results.

3.3.4 PM Run 3 Method 5 Acetone Rinse

During recovery of particulate matter within the sampling probe and nozzle, the nozzle was broken. Some of the glass from the nozzle was collected in the sample bottle. With the glass present the desiccated weight of the acetone rinse was 46 mg. With the glass removed the weight was 2.9 mg. The desiccated weight of the rinse with the glass removed was used to evaluate compliance with permit limits.

3.4 Summary of Results

The purpose of the testing was to satisfy certain requirements of the Michigan Department of Environmental Quality (MDEQ) Permit to Install 149-10B, dated April 12, 2013 and evaluate compliance with permit limits.

Detailed results are presented in Tables 1 and 2 after the Table tab of this report. Calibration and inspection sheets are presented in Appendix A. Sample calculations are presented in Appendix B. Field data sheets and computer-generated data sheets are behind Appendix D. Facility operating parameters and laboratory data are presented in Appendix E and F.

The results in comparison to permit limits are summarized in Table 3-2.



**Table 3-2
EUNGINE Emissions Results**

Parameter	Units	Run 1 [†]	Run 2	Run 3	Run 4	Average [†]	Limit
PM	lb/hr	0.10	0.03	0.02	0.03	0.02	0.12
PM _{2.5}	lb/hr	0.35	0.11	0.06	0.10	0.09	0.13
PM ₁₀	lb/hr	0.35	0.11	0.06	0.10	0.09	0.13
NO _x	g/bhp-hr	0.29	0.44	0.42	-	0.38	0.5
CO	g/bhp-hr	0.66	0.99	0.93	-	0.86	2.5
VOC	g/bhp-hr	0.18	0.18	0.01	-	0.12	0.81

PM₁₀ emissions include all sample fractions less than 10 and greater than 2.5 micrometers in aerodynamic diameter
 PM_{2.5} emissions include all sample fractions less than 2.5 micrometers in aerodynamic diameter
 g/bhp-hr: gram per brake horsepower-hour
 lb/hr = pound per hour
[†]: Run 1 excluded from the particulate matter run averages

The average natural gas emergency generator emission results indicate compliance with the permit limits.

4.0 Sampling and Analytical Procedures

Bureau Veritas measured emissions in accordance with the procedures specified in the USEPA Standards of Performance for New Stationary Sources and State of Michigan Part 10 Rules Intermittent Testing and Sampling. The sampling and analytical methods used are indicated in the following table:

**Table 4-1
Emissions Test Parameters**

Parameter	Source	USEPA Reference	
	EU- NGENGINE	Method	Title
Sampling ports and traverse points	●	1	Sample and Velocity Traverses for Stationary Sources
Velocity and flowrate	●	2	Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)
Molecular weight	●	3	Gas Analysis for the Determination of Dry Molecular Weight
Molecular weight	●	3A	Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrument Analyzer Procedure)
Moisture content	●	4	Determination of Moisture Content in Stack Gases (approximation method)
PM	●	5	Determination of Particulate Matter Emissions from Stationary Sources
Oxides of nitrogen	●	7E	Determination of Nitrogen Oxides Emissions from Stationary Sources
Carbon monoxide	●	10	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
VOCs	●	25A	Determination of Total Gaseous Organic Concentrations using a Flame Ionization Analyzer
Condensable PM	●	202	Dry Impinger Method for Determining Condensable Particulate Emissions from Stationary Sources
Gas dilution	●	205	Verification of Gas Dilution Systems for Field Instrument Calibrations; this method is for calibration gases.



4.1 Sampling Train and Procedures

The following sections describe the USEPA source sampling methods used during this test program.

4.1.1 Volumetric Flowrate (USEPA Methods 1 and 2)

Method 1, "Sample and Velocity Traverses for Stationary Sources," from 40 CFR 60, Appendix A, was used to evaluate the sampling location and the number of traverse points for sampling and the measurement of velocity profiles. Details of the sampling location and number of velocity traverse points are presented in the Table 4-2.

Table 4-2
Sampling Location and Number of Traverse Points

Duct Sampling Location	Diameter (inches)	Distance from Ports to Upstream Flow Disturbance (diameters)	Distance from Ports to Downstream Flow Disturbances (diameters)	Number of Ports	Traverse Points per Port	Total Points [†]	Cyclonic Flow Check Average Null Angle
EUNGENGINE	13.5	~9	~44	2	6	12	0.4

Figure 1 in the Appendix depicts the EUNGENGINE exhaust source sampling locations and traverse points.

Method 2, "Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)," was used to measure flue gas velocity and calculate volumetric flowrate. An S-type Pitot tube and thermocouple assembly calibrated in accordance with Method 2, Section 10.0, connected to an oil-filled manometer was used during testing. Because the dimensions of the Pitot tube met the requirements outlined in Method 2, Section 10.1, and were within the specified limits, the baseline Pitot tube coefficient of 0.84 (dimensionless) was assigned. Refer to Appendix A for the calibration and inspection sheets. Refer to Appendix B for sample calculations of flue gas velocity and volumetric flow rate.

Cyclonic Flow Check. Bureau Veritas evaluated whether cyclonic flow was present at the sampling location. Cyclonic flow is defined as a flow condition with an average null angle greater than 20°. The direction of flow can be determined by aligning the Pitot tube to obtain zero (null) velocity head reading—the direction would be parallel to the Pitot tube face openings or perpendicular to the null position. By measuring the angle of the Pitot tube face openings in relation to the stack walls when a null angle is obtained, the direction of flow is measured. If the



absolute average of the flow direction angles is greater than 20 degrees, the flue gas is considered to be cyclonic at that sampling location and an alternative location should be found.

The measurements indicate the absence of cyclonic flow at the sampling location. Field data sheets are included in Appendix C. Computer-generated field data sheets are included in Appendix D.

4.1.2 Molecular Weight (USEPA Method 3)

The carbon dioxide contribution to stack gas molecular weight was measured using Method 3, "Gas Analysis for the Determination of Dry Molecular Weight." Flue gas was extracted from the stack through a probe positioned near the centroid of the duct and directed into a Fyrite® gas analyzer. The concentrations of carbon dioxide (CO₂) were measured by chemical absorption with a Fyrite® gas analyzer to within ±0.5%. The average CO₂ result of the grab samples were used to calculate molecular weight.

4.1.3 Moisture Content (USEPA Method 4)

The moisture of the flue gas was measured following the procedures in USEPA Method 4, "Determination of Moisture Content in Stack Gases," in conjunction with USEPA Method 202. Prior to testing, Bureau Veritas estimated the moisture content using previous stack test data.

4.1.4 Filterable and Condensable Particulate Matter (USEPA Methods 5 and 202)

USEPA Methods 5, "Determination of Particulate Matter Emissions from Stationary Sources" and 202, "Dry Impinger Method for Determining Condensable Particulate Emissions from Stationary Sources," was used to measure particulate matter emissions at the EUNGENGINE source. USEPA Method 5 measures filterable particulate matter (PM), while the Method 202 train collects condensable material (CPM).

CPM is defined as material that is in vapor phase at stack conditions, but that condenses and/or reacts upon cooling and dilution in the ambient air to form solid or liquid FPM immediately after discharge from the stack. Method 202 collects CPM within a water-dropout impinger, modified Greenburg-Smith impinger, and a Teflon filter.

The sum of the Method 5 (PM) and Method 202 (CPM) mass collected represent particulate matter with a nominal aerodynamic diameter less than 10 microns (PM₁₀) and 2.5 microns (PM_{2.5}).

Bureau Veritas' modular Methods 5 and 202 isokinetic stack sampling system consists of the following (in order from the stack to the control case):



- A borosilicate glass button-hook nozzle.
- A heated (248±25°F) quartz glass-lined probe.
- A desiccated and pre-weighed 110-millimeter-diameter quartz fiber filter (manufactured to at least 99.95% efficiency (<0.05 % penetration) for 0.3-micron dioctyl phthalate smoke particles) in a heated (248±25°F) filter box.
- An EPA Method 23-type stack gas condenser with water recirculation pump.
- A set of four GS impingers with the configuration shown in Table 4-3.
- A second (back-half) CPM Teflon filter inserted between the second and third impingers and maintained at a temperature <85°F.
- A sampling line.
- An Environmental Supply® control case equipped with a pump, dry-gas meter, and calibrated orifice.

Table 4-3
Method 202 Impinger Configuration

Impinger Order (Upstream to Downstream)	Impinger Type	Impinger Contents	Amount of Contents
1	Modified – dropout	Empty	0 milliliter
2	Modified	Empty	0 milliliter
CPM Filter			
3	Modified	HPLC water	100 milliliter
4	Modified	Silica gel desiccant	~200-300 grams

Bureau Veritas selected a pre-cleaned quartz glass nozzle with an inner diameter that approximated the calculated ideal value from historical data. The nozzle was measured with calipers across three cross-sectional chords. The nozzle was rinsed and brushed with acetone and connected to the quartz glass-lined sample probe. The impact and static pressure openings of the Pitot tube were leak-checked at or above a velocity head of 3 inches of water for more than 15 seconds. The sampling train was leak-checked by capping the nozzle tip and applying a vacuum of approximately 15 inches of mercury to the sampling train. The dry-gas meter was monitored to measure the sample train leakage rate was less than 0.02 cubic feet per minute. The sample probe then was inserted into the sampling port to begin sampling.



Ice was placed around Impingers 3 and 4. The Method 5 probe and filter temperatures were allowed to stabilize at 248 ± 25 °F before each sample run. After the desired operating conditions were coordinated with the facility, testing was initiated. Stack parameters (e.g., flue velocity, temperature) were monitored to establish the isokinetic sampling rate within ± 10 % for the duration of the test.

At the conclusion of a test run and the post-test leak check, the sampling train was disassembled and the impingers and filter were transported to the recovery area. The filter was recovered using Teflon-lined tweezers and placed in a Petri dish, sealed with Teflon tape, and labeled as FPM Container 1. The nozzle, probe, and the front half of the filter holder assembly was brushed and, at a minimum, triple-rinsed with acetone to recover particulate matter. The acetone rinses were collected in pre-cleaned sample containers, sealed with Teflon tape, and labeled as FPM Container 2.

The mass of liquid collected in each impinger was measured using an electronic scale accurate to ± 0.5 gram. These data was used to calculate the moisture content of the sampled flue gas.

After weighing the impinger but prior to the recovery of the Method 202 train and immediately after the conclusion of the test, the impinger train was purged with filtered 99.9% pure nitrogen gas to remove dissolved sulfur gases from the impingers. The nitrogen purge was conducted because water condensed in the first two impingers.

The contents of the first two impingers were collected in a glass sample container labeled as "CPM Container 1, aqueous liquid impinger contents." The back of the filter-holder, glass-lined probe, condenser, Impingers 1 and 2, front-half of the CPM filter holder, and all connecting glassware was rinsed twice with HPLC water and the recovery rinsate was added to CPM Container 1. Following the HPLC water rinse, the back of the filter-holder, probe extension, condenser, Impingers 1 and 2, front-half of the CPM filter holder, and connecting glassware were rinsed with acetone and then rinsed twice with hexane. The acetone and hexane rinses were collected in a glass sample container labeled as "CPM Container 2, organic rinses."

The CPM filter was recovered using Teflon-lined tweezers and placed in a Petri dish or glass sample container; the container was sealed with Teflon tape, and labeled as "CPM Container 3, CPM filter sample."

The mass of condensate collected in Impingers 3 and 4 was measured to calculate the moisture content of the flue gas; the contents of these impingers were not be recovered.

The Method 5 and 202 sample containers, including a field train blank, field train proof blank, acetone, HPLC water, and hexane blanks were transported to the laboratory for analysis.



4.1.5 O₂, NO_x, and CO (USEPA Method 3A, 7E, and 10)

Oxygen concentrations were measured following USEPA Method 3A, "Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (instrumental analyzer procedure). Oxides of nitrogen concentrations were measured using Method 7E, "Determination of Nitrogen Oxides Emissions from Stationary Sources (instrument analyzer procedure)." Carbon monoxide concentrations were measured using USEPA Method 10, "Determination of Carbon Monoxide Emissions from Stationary Sources (instrument analyzer procedure)." These sampling methods are similar with the exception of the analyzer specifications. Sampling for O₂, NO_x, and CO consisted of extracting flue gas from the exhaust duct through:

- A stainless-steel probe.
- Heated Teflon sample line to prevent condensation.
- A chilled Teflon impinger train with peristaltic pump to remove moisture from the sampled gas stream prior to entering the analyzer.
- Paramagnetic analyzer to measure O₂ concentrations, chemiluminescence gas analyzer to measure NO_x concentrations, and a gas filter wheel infrared analyzer to measure CO concentrations.

Data was recorded at 1-second intervals with data acquisition software (DAS). Recorded pollutant concentrations were averaged over the duration of each test run and reported in 1-minute averages. Refer to Appendix C for the field data sheets.

The stratification test requirement of Section 8.1.1 of Method 7E is difficult to implement because emissions from engines in general are too temporally variable to render a stratification test meaningful; Bureau Veritas measured pollutant concentrations from a single sampling location near the centroid of the duct.

An NO/NO₂ conversion was performed prior to testing using an NO₂ calibration gas.

A calibration error check was performed by introducing zero-, mid-, and high-level calibration gases directly into each analyzer. The calibration error check was performed to evaluate the analyzers response within the acceptable $\pm 2\%$ of the calibration span.

Prior to each test run, a system-bias test was performed; in this test, known concentrations of calibration gases were introduced at the sampling probe tip to measure if the analyzer's response was within $\pm 5\%$ of the calibration span. At the conclusion of the each test run, an additional system-bias check was performed to evaluate the drift from pre- and post-test system-bias checks. Since the analyzer's drift were less than 3.0% of calibration span, the tests were considered valid.



Calibration data and USEPA Protocol 1 certification sheets for the calibration gases used are included behind Appendix A.

4.1.6 Volatile Organic Compounds (USEPA Method 25A)

VOC concentrations were measured following USEPA Method 25A, "Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer." Flue gas samples were collected through a stainless steel probe and heated Teflon sample line into the analyzer. Bureau Veritas used a J.U.M. 109A flame-ionization-detector-based hydrocarbon analyzer during the testing.

A flame ionization detector (FID) determines the average hydrocarbon concentration in part per million by volume (ppmv) of VOC as the calibration gas (propane or methane). The FIDs are fueled by 100% hydrogen, which generates a flame with a negligible number of ions. Flue gas is introduced into the FID and enters the flame chamber. The combustion of flue gas generates electrically charged ions. The analyzer applies a polarizing voltage between two electrodes around the flame, producing an electrostatic field. Negatively charged ions, anions, migrate to a collector electrode, while positive charged ions, cations, migrate to a high-voltage electrode. The current between the electrodes is directly proportional to the hydrocarbon concentration in the sample. The flame chamber is depicted below.

Using the voltage analog signal, measured by the FID, the concentration of volatile organic compounds is recorded by the data acquisition system (DAS). The average concentration of VOC is reported as the calibration gas (i.e., propane or methane) in equivalent units. To obtain the concentration as a different calibration gas, a response factor (RF) is measured.

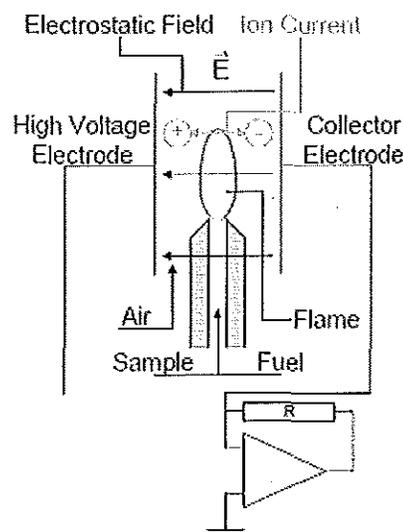


Figure 4-1. FID Flame Chamber

For this testing, the outlet VOC concentrations were measured with a FID calibrated using propane calibration gases and non-regulated methane concentrations were measured with a FID equipped with a nonmethane cutter calibrated using methane calibration gases. The use of a non-methane cutter to measure methane concentrations is listed in 40 CFR 1065.265. The VOC and methane concentrations were measured at 1-second intervals.

A response factor for the FID calibrated in methane was obtained to report the concentration results as propane and subtract them from the mass VOC emissions as. This response factor was obtained by introducing a known concentration of methane gas into the analyzer calibrated in



propane. The analyzers response was divided by the concentration of the calibration gas to obtain the response factor. For example, the FID calibrated using propane gases reported a concentration of 621.1 ppmv when a 1,407-ppmv methane gas was introduced. The response factor was calculated as:

$$RF = \frac{1,407 \text{ ppmv Methane}}{621.1 \text{ ppmv Propane}} = 2.3$$

Before testing, the FID analyzers were calibrated by introducing zero (<1% of span value) and high (80-90% span value) calibration range gases to the tip of the sampling probe. The span value was set to 1.5 to 2.5 times the expected concentration (e.g., 0-1,000 ppmv). Low-range (25-35% of span value) and mid-range (45-55% of span value) calibration gases were then introduced. The analyzers were considered to be calibrated when the analyzer's response was $\pm 5\%$ of the calibration gas value.

At the conclusion of each test a calibration drift test was performed by introducing the zero- and mid-range calibration gas to the tip of the sampling probe. The test run data were considered valid because the calibration drift test demonstrated the analyzers were responding within $\pm 3\%$ of calibration span from pre-test to post-test calibrations.

4.1.7 Gas Dilution (USEPA Method 205)

A gas dilution system was used to introduce known values of calibration gases into the VOC and CO analyzers. The gas dilution system consisted of calibrated orifices. The system diluted a high-level calibration gas to within $\pm 2\%$ of predicted values. This gas divider was capable of diluting gases at 80, 60, 50, 30, and 25% increments.

Before the start of testing, the gas divider dilutions were measured to be within 2% of predicted values. Three sets of dilutions at 80, 60, 50, 30, and 25% of the high level (844.8 ppmv propane) calibration gas were performed. In addition, a certified mid-level calibration gas (482 ppmv propane) was introduced into the analyzer; this calibration gas concentration was within $\pm 10\%$ of the 60% gas divider dilution concentration. Refer to Appendix A for the certified calibration gas certificates and the gas dilution field calibration results.

4.2 Procedures for Obtaining Process Data

Process data was recorded by Lansing Board of Water & Light personnel. Recorded process data were provided to Bureau Veritas at the conclusion of the testing. The process data are summarized in Section 2.0 and included in Appendix E.



4.3 Sampling Identification and Custody

USEPA Methods 5 and 202 recovery and analytical procedures were applicable to this test program. Applicable Chain of Custody procedures followed guidelines outlined within ASTM D4840-99(2004), "Standard Guide for Sampling Chain-of-Custody Procedures." Detailed sampling and recovery procedures are described in Section 4.0. For each sample collected (i.e. filter, probe rinse) sample identification and custody procedures were completed as follows:

- Containers were sealed with Teflon tape to prevent contamination
- Containers were labeled with test number, location, and test date
- The level of fluid was marked on the outside of the sample containers to identify if leakage occurred prior to receipt of the samples by the laboratory
- Containers were placed in a cooler for storage
- Samples were logged using guidelines outlined in ASTM D4840-99(2004), "Standard Guide for Sampling Chain-of-Custody Procedures"
- Samples were transported to the laboratory under chain of custody.

Chains of custody and laboratory analytical results are included in Appendix F.



5.0 QA/QC Activities

Equipment used in this emissions test program passed quality assurance/quality control (QA/QC) procedures. Refer to Appendix A for equipment inspection and calibration documents.

5.1 Pretest QA/QC Activities

Before testing, the sampling equipment was cleaned, inspected, and calibrated according to procedures outlined in the applicable USEPA sampling method and USEPA's "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume and Principles: Volume III, Stationary Source Specific Methods." Refer to Appendix A for pre-test inspection and calibration sheets.

5.2 QA/QC Audits

The results of select sampling and equipment QA/QC audits and the acceptable USEPA tolerance are presented in the following sections (also see Appendix A).

5.2.1 Method 5 QA/QC Audits

The sampling trains described in Section 4.1 were audited for measurement accuracy and data reliability. The following table summarizes the QA/QC audits conducted on each sampling train.



**Table 5-1
Method 5 Sampling Train QA/QC Audits**

Parameter	Run 1	Run 2	Run 3	Run 4	Method Requirement	Comment
EUNGENGINE						
Average velocity pressure head (in H ₂ O)	3.9	4.0	4.0	3.9	>0.05 in H ₂ O [†]	Valid
Sampling train leak check Post-test	0.000 ft ³ for 1 min at 21 in Hg	0.000 ft ³ for 1 min at 7 in Hg	0.010 ft ³ for 1 min at 14 in Hg	0.010 ft ³ for 1 min at 8 in Hg	<0.020 ft ³ for 1 minute at ≥ recorded during test	Valid
Sampling vacuum (in Hg)	12 to 18	4 to 6	5 to 7	5		
† Manometer capable of reading 0 to 10 in H ₂ O acceptable for measuring differential pressure head above 0.05 in H ₂ O						

5.2.2 Dry-Gas Meter QA/QC Audits

The following table summarizes the dry-gas meter calibration checks in comparison to the acceptable USEPA tolerance. Meter Box 2 was used during this testing to measure particulate matter and moisture content at the generator exhaust. Refer to Appendix A for DGM calibrations.

**Table 5-2
Dry-Gas Meter Calibration QA/QC Audit**

Test Method	Meter Box	Pre-test DGM Calibration Factor (Y) (dimensionless)	Post-Test DGM Calibration Check Value (Y _{qa}) (dimensionless)	Absolute Difference Between Pre- and Post-test DGM Calibrations	Acceptable Tolerance	Calibration Result
EUNGENGINE						
Method 5/202	2	0.999 (August 22, 2013)	1.004 (September 20, 2013)	0.005	≤0.05	Valid

5.2.3 Thermocouple QA/QC Audits

Temperature measurements using thermocouples and digital pyrometers were compared to a reference temperature (i.e., ice water bath, boiling water) prior to testing to evaluate accuracy of



the equipment. The thermocouples and pyrometers measured temperature within $\pm 1.5\%$ of reference temperatures and were within USEPA acceptance criteria. Thermocouple calibration sheets are presented in Appendix A.

5.3 QA/QC Blanks

Reagent and field blanks were analyzed for the constituent of interest. The results of the blanks are presented in Table 5-3. The blank results do not indicate significant contamination occurred in the field. Blank corrections were not applied.

**Table 5-3
QA/QC Blanks**

Sample Identification	Result (mg)	Comment
M5 Acetone Blank	2.2	210 mL sample, blank corrections were not applied.
M5 Filter Blank	0.72	Blank corrections were not applied. Method detection limit is 0.5 mg
M202 Water Field Reagent Blank	1.0	Performed to ensure residual mass is not contributing to CPM measurements.
M202 Acetone Field Reagent Blank	>0.5	Performed to ensure residual mass is not contributing to CPM measurements.
M202 Hexane Field Reagent Blank	>0.5	Performed to ensure residual mass is not contributing to CPM measurements.
M202 Field Train Proof Blank	2.8	Sample collected prior to Run 1, to demonstrate cleanliness of glassware.
M202 Field Train Recovery Blank	1.6	Sample collected after Run 2 to evaluate contamination in the field. Blank corrections were not applied. Maximum blank correction is 2.0 mg.

5.4 QA/QC Issues

QA/QC issues were not encountered; the audits demonstrate sample collection accuracy for the test runs.



Limitations

The information and opinions rendered in this report are exclusively for use by Lansing Board of Water & Light. Bureau Veritas North America, Inc. will not distribute or publish this report without Lansing Board of Water & Light's consent except as required by law or court order. The information and opinions are given in response to a limited assignment and should be implemented only in light of that assignment. Bureau Veritas North America, Inc. accepts responsibility for the competent performance of its duties in executing the assignment and preparing reports in accordance with the normal standards of the profession, but disclaims any responsibility for consequential damages.

This report prepared by: *Thomas R. Schmelter*
Thomas Schmelter, QSTI
Senior Project Manager
Health, Safety, and Environmental Services

This report reviewed by: *Derek R. Wong*
Derek R. Wong, Ph.D., P.E.
Director and Vice President
Health, Safety, and Environmental Services



Tables



Table 1
EUNGENINE Emergency Generator Gaseous Emissions Results
Lansing Board of Water & Light - REO Town Cogeneration Plant
Lansing, Michigan

Sample Date: September 10, 2013
 Bureau Veritas Project Number 11013-000213.00

Parameter	Run 1	Run 2	Run 3	Average
Start Time	9:55	13:15	15:40	
End Time	10:55	14:15	16:40	
Run Duration (hour)	1	1	1	1
Volumetric Flowrate (dscfm)	3,768	3,862	3,859	3,830
Volumetric Flowrate (dscmh)	6,403	6,562	6,557	6,508
Power Output (kW)	1,321	1,319	1,319	1,319
Power Output (HP)	1,770	1,767	1,768	1,769
Fuel Flowrate (lb/hr)	600.30	598.86	597.99	599.05
Average Outlet O ₂ Concentration (%)	17.1	15.3	15.6	16.0
Pre-test system calibration, zero gas (Co)	-0.03	0.6	0.1	0.22
Post-test system calibration, zero gas (Co)	0.6	0.1	0.2	0.3
Certified low bracket gas concentration (Cma)	11.0	11.0	11.0	11.0
Pre-test system calibration, low bracket gas (Cm)	11.0	10.9	10.9	10.9
Post-test system calibration, low bracket gas (Cm)	10.9	10.9	10.9	10.9
Average Corrected O ₂ Concentration ¹ (%)	17.4	15.6	15.8	16.3
Average Outlet NO _x Concentration (ppmvd NO ₂)	42	62	59	54
Pre-test system calibration, zero gas (Co)	0.9	3.0	1.3	1.7
Post-test system calibration, zero gas (Co)	3.0	1.3	1.7	2.0
Certified low bracket gas concentration (Cma)	116	116	116	116
Pre-test system calibration, low bracket gas (Cm)	115	115	113	114
Post-test system calibration, low bracket gas (Cm)	115	113	114	114
Average Corrected NO _x Concentration ¹ (ppmvd NO ₂)	42	62	60	54
NO _x Emission Rate (g/BHP-hr)	0.29	0.44	0.42	0.38
Average Outlet CO Concentration (ppmvd CO)	156.1	230.0	218.0	201.3
Pre-test system calibration, zero gas (Co)	-0.6	0.2	1.0	0.2
Post-test system calibration, zero gas (Co)	0.2	1.0	1.1	0.8
Certified low bracket gas concentration (Cma)	473.0	473.0	473.0	473.0
Pre-test system calibration, low bracket gas (Cm)	471.0	471.0	476.0	472.7
Post-test system calibration, low bracket gas (Cm)	471.0	476.0	475.0	474.0
Average Corrected CO Concentration ¹ (ppmvd CO)	156.9	229.4	216.3	200.8
CO Emission Rate (g/BHP-hr)	0.66	0.99	0.93	0.86
Average Outlet Methane Concentration (ppmv CH ₄)	874.1	749.4	894.7	839.4
Pre-test system calibration, zero gas (Co)	0.0	2.0	2.4	1.5
Post-test system calibration, zero gas (Co)	2.0	2.4	-1.0	1.1
Certified low bracket gas concentration (Cma)	844.2	844.2	844.2	844.2
Pre-test system calibration, low bracket gas (Cm)	830.0	823.0	848.0	833.7
Post-test system calibration, low bracket gas (Cm)	823.0	848.0	873.0	848.0
Average Corrected Methane Concentration ¹ (ppmv CH ₄)	892.8	757.0	877.7	842.5
Average Corrected Methane Concentration ¹ (ppmv C ₃ H ₈)	383.2	324.9	376.7	361.6
Average Outlet VOC Concentration (ppmv C ₃ H ₆)	405.4	341.1	364.6	370.4
Pre-test system calibration, zero gas (Co)	0.0	3.5	-4.0	-0.2
Post-test system calibration, zero gas (Co)	3.5	-4.0	-0.4	-0.3
Certified low bracket gas concentration (Cma)	482.0	482.0	482.0	482.0
Pre-test system calibration, low bracket gas (Cm)	484.0	468.0	468.0	473.3
Post-test system calibration, low bracket gas (Cm)	468.0	468.0	462.0	466.0
Average Corrected VOC Concentration ¹ (ppmv C ₃ H ₆)	410.3	351.4	378.4	380.0
Average Corrected NMVOC Concentration ¹ (ppmv C ₃ H ₆)	27.1	26.5	1.7	18.4
VOC Emission Rate (g/BHP-hr)	0.18	0.18	0.01	0.12

2.33 Methane to propane response factor

0.746 kilowatt (kW) = 1 horsepower (HP)

¹ corrected for analyzer drift

dscfm: dry standard cubic feet per minute

dscmh: dry standard cubic meter per hour

ppmv(d): parts per million volume (dry)

NO_x: nitrogen dioxide

lb/hour: pounds per hour

g/BHP-hr: grams per brake horsepower-hour



Table 2 - EUNGENINE Emergency Generator Particulate Matter Results

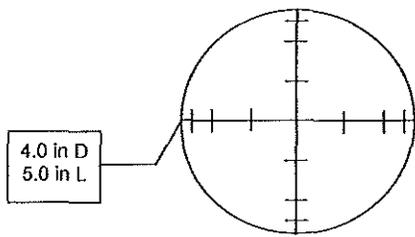
Facility		Lansing Board of Water and Light - REO Town Cogeneration Plant				
Source Designation		EUNGENINE Emergency Generator Exhaust				
Test Date		Sep 10, 2013	Sep 10, 2013	Sep 10, 2013	Sep 10, 2013	
Meter/Nozzle Information		Run 1	Run 2	Run 3	Run 4	Average
Meter Temperature, T _m	°F	85	99	100	97	99
Meter Pressure, P _m	in Hg	30.14	30.11	30.11	30.10	30.10
Measured Sample Volume, V _m	ft ³	96.22	93.69	94.36	92.20	93.41
Sample Volume, V _m	std ft ³	93.79	89.00	89.36	87.81	88.72
Sample Volume, V _m	std m ³	2.66	2.52	2.53	2.49	2.51
Condensate Volume, V _w	std ft ³	14.14	13.28	12.67	13.03	12.99
Gas Density, ρ _g	std lb/ft ³	0.0733	0.0733	0.0735	0.0732	0.0733
Total weight of sampled gas	lb	7.916	7.496	6.750	6.611	6.952
Nozzle Size, A _n	ft ²	0.0002138	0.0001928	0.0001928	0.0001928	0.0001928
Isokinetic Variation, I	%	96	99	100	102	100
Stack Data						
Average Stack Temperature, T _s	°F	783	781	781	781	781
Molecular Weight Stack Gas-dry, M _d	lb/lb-mole	29.80	29.76	29.76	29.72	29.75
Molecular Weight Stack Gas-wet, M _w	lb/lb-mole	28.25	28.23	28.30	29.72	28.75
Stack Gas Specific Gravity, G _s		0.98	0.97	0.98	1.03	0.99
Percent Moisture, B _{as}	%	13.10	12.99	12.42	12.92	12.78
Water Vapor Volume (fraction)		0.131	0.130	0.124	0.129	0.128
Pressure, P _s	in Hg	30.00	30.00	30.00	30.00	30.00
Average Stack Velocity, V _s	ft/sec	170.75	174.43	173.20	167.11	171.58
Area of Stack	ft ²	0.99	0.99	0.99	0.99	0.99
Exhaust Gas Flowrate						
Flowrate	ft ³ /min, actual	10,184	10,403	10,330	9,967	10,233
Flowrate	ft ³ /min, standard wet	4,337	4,438	4,406	4,251	4,365
Flowrate	ft ³ /min, standard dry	3,768	3,862	3,859	3,702	3,808
Flowrate	m ³ /min, standard dry	107	109	109	105	108
Collected Mass						
Particulate Matter Acetone Wash	mg	12	3.9	2.9	4.6	3.8
Particulate Matter Filter	mg	6.3	<0.5	<0.5	<0.5	<0.5
Total Filterable Particulate Matter (FPM)	mg	18.3	4.4	3.4	5.1	4.3
Inorganic CPM	mg	19	12	5.4	9.0	8.8
Organic CPM	mg	29	3.0	1.3	3.0	2.4
Total Condensable Particulate Matter (CPM)	mg	48	15	6.7	12.0	11.2
Total FPM and CPM	mg	66.3	19.4	10.1	17.1	15.5
Concentration						
Particulate Matter (FPM)	mg/dscf	0.20	0.05	0.04	0.06	0.05
Particulate Matter (FPM)	grain/dscf	0.003	0.001	0.001	0.001	0.001
Total Condensable Particulate Matter (CPM)	mg/dscf	0.51	0.17	0.07	0.13	0.13
Total Condensable Particulate Matter (CPM)	grain/dscf	0.0079	0.0026	0.0012	0.0021	0.0019
Total FPM and CPM	mg/dscf	0.71	0.22	0.11	0.19	0.17
Total FPM and CPM	grain/dscf	0.0109	0.003	0.002	0.003	0.0027
Mass Emission Rate						
Particulate Matter (FPM)	lb/hr	0.10	0.03	0.02	0.03	0.02
Total Condensable Particulate Matter (CPM)	lb/hr	0.26	0.09	0.04	0.07	0.06
Total FPM and CPM (PM ₁₀ & PM _{2.5})	lb/hr	0.35	0.11	0.06	0.10	0.09

Run 1 omitted from average; Average of Runs 2, 3, and 4 presented



Figures

13.5 in INTERNAL DIAMETER



TRAVERSE POINT	DISTANCE FROM STACK WALL (INCHES)
6	12.9
5	11.5
4	9.5
3	4.0
2	2.0
1	0.6

	DISTANCE FROM PORTS TO NEAREST UPSTREAM BEND/DISTURBANCE	DISTANCE FROM PORTS TO NEAREST DOWNSTREAM BEND/DISTURBANCE
Engine Exhaust Stack	~120 INCHES (~9 DIAMETERS)	~600 INCHES (~44 DIAMETERS)

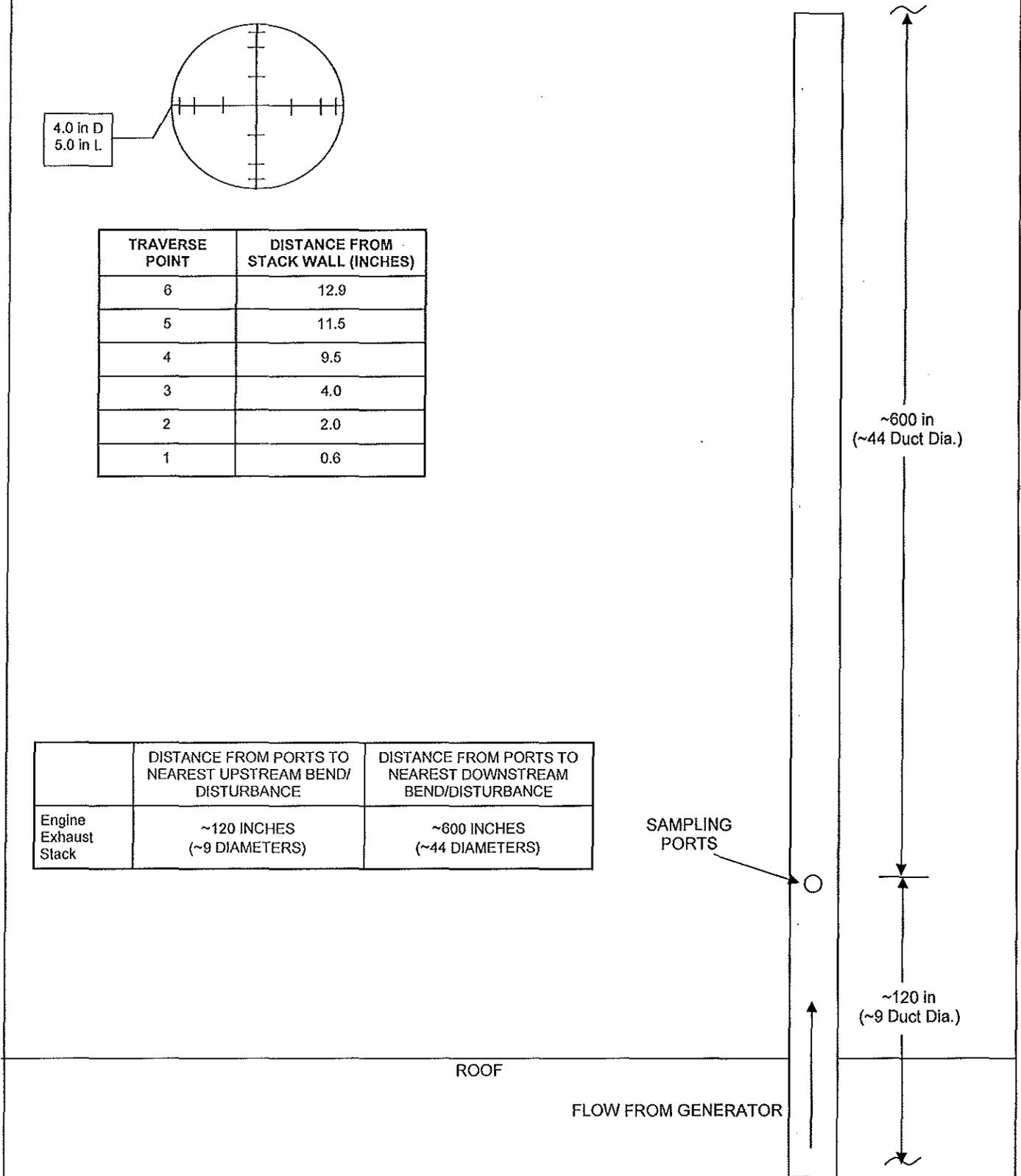


Figure 1
EUNGENINE Exhaust Sampling
Ports and Traverse Point Locations



Lansing Board of Water & Light
1201 South Washington Avenue
Lansing, Michigan

Project No. 11013-000213.00

Last Revision: 9/20/2013

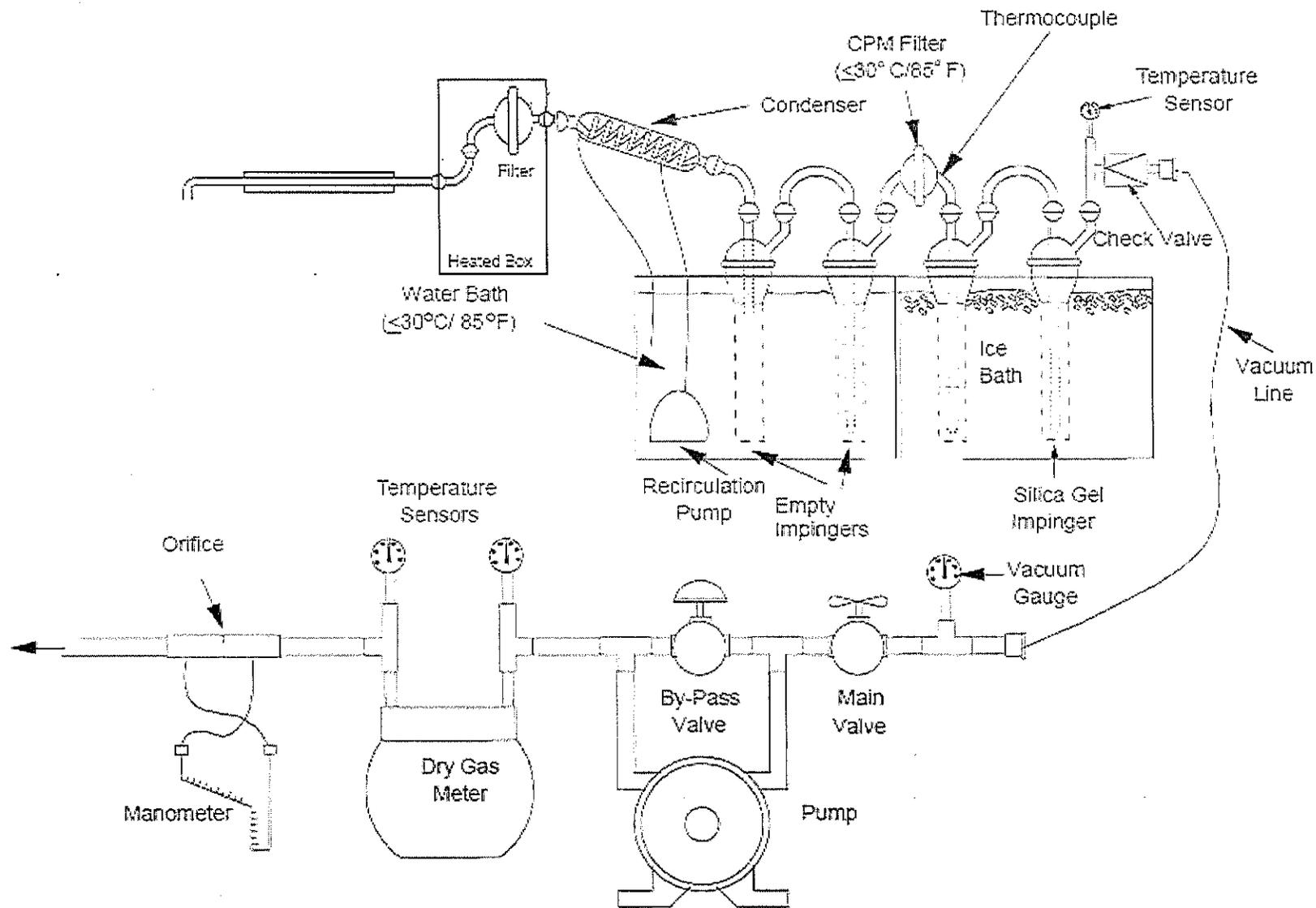


Figure 2
 USEPA Method 5/202 Sampling
 Train



Lansing Board of Water & Light
 1201 South Washington Avenue
 Lansing, Michigan

Project No. 11013-000213.00

Last Revision: 9/20/2013

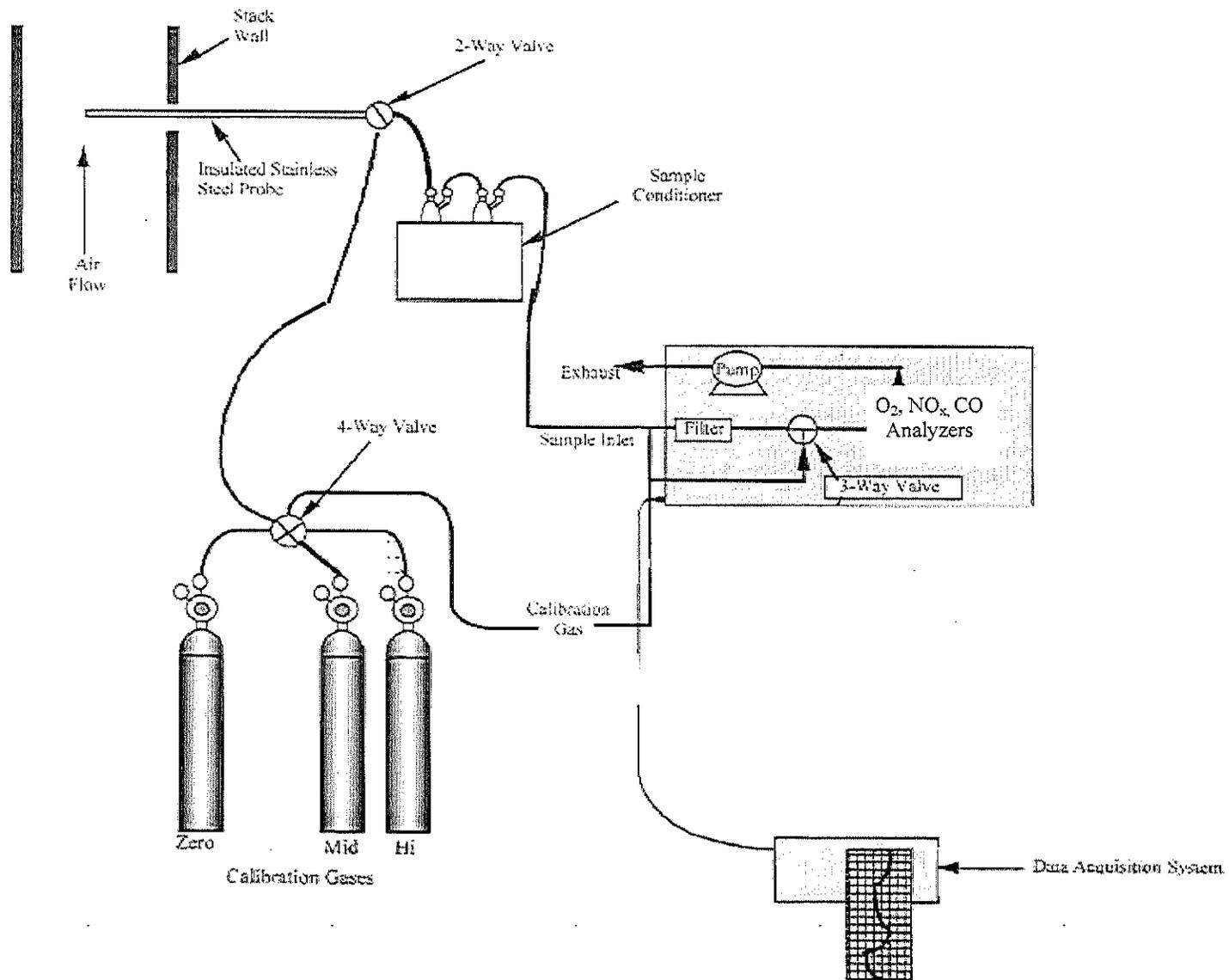


Figure 3
 USEPA Method 3A, 7E, and 10
 Sampling Train



Lansing Board of Water & Light
 1201 South Washington Avenue
 Lansing, Michigan

Project No. 11013-000213.00

Last Revision: 9/20/2013

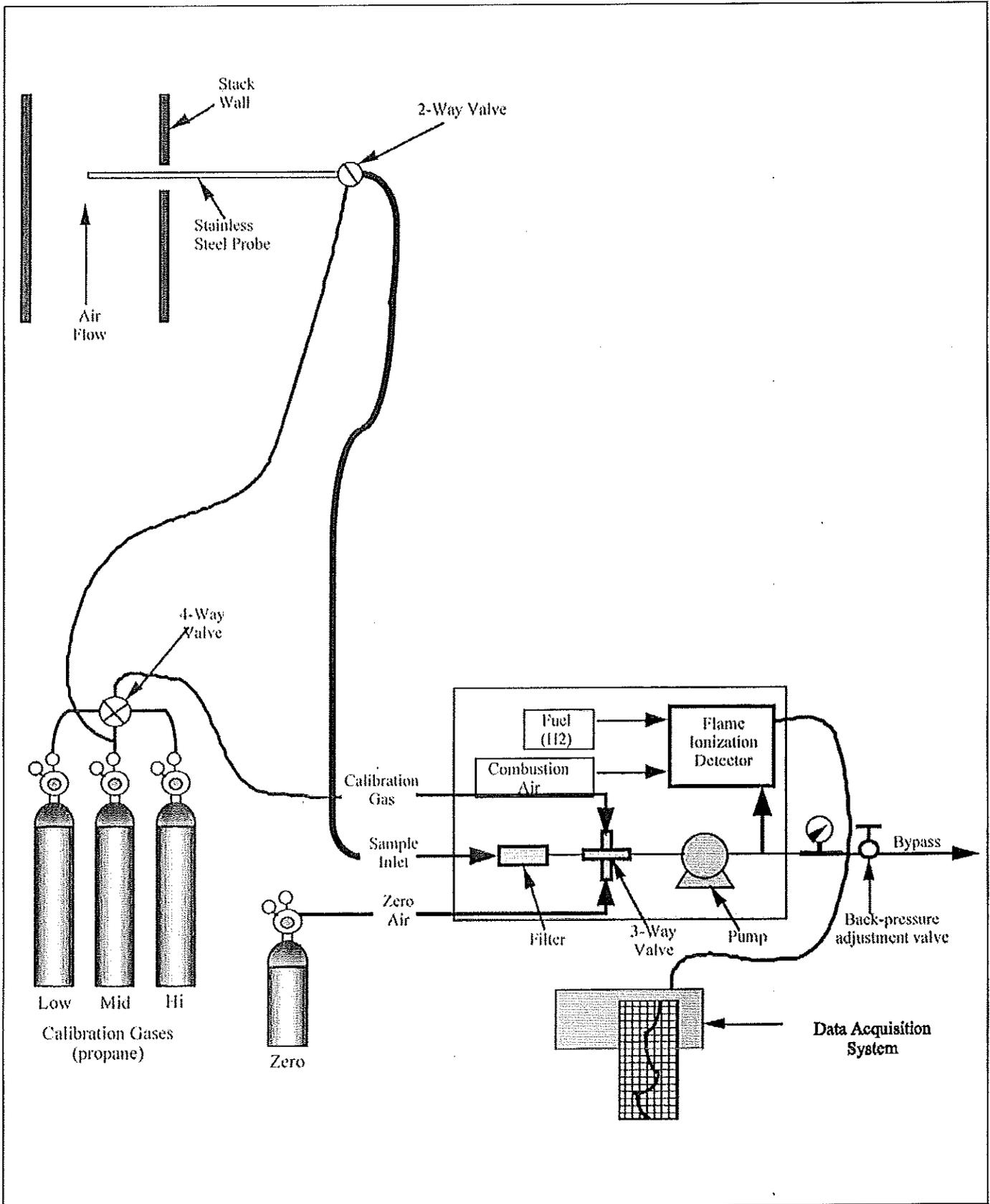


Figure 4
USEPA Method 25A Sampling
Train



Lansing Board of Water & Light
1201 South Washington Avenue
Lansing, Michigan

Project No. 11013-000213.00

Last Revision: 9/20/2013

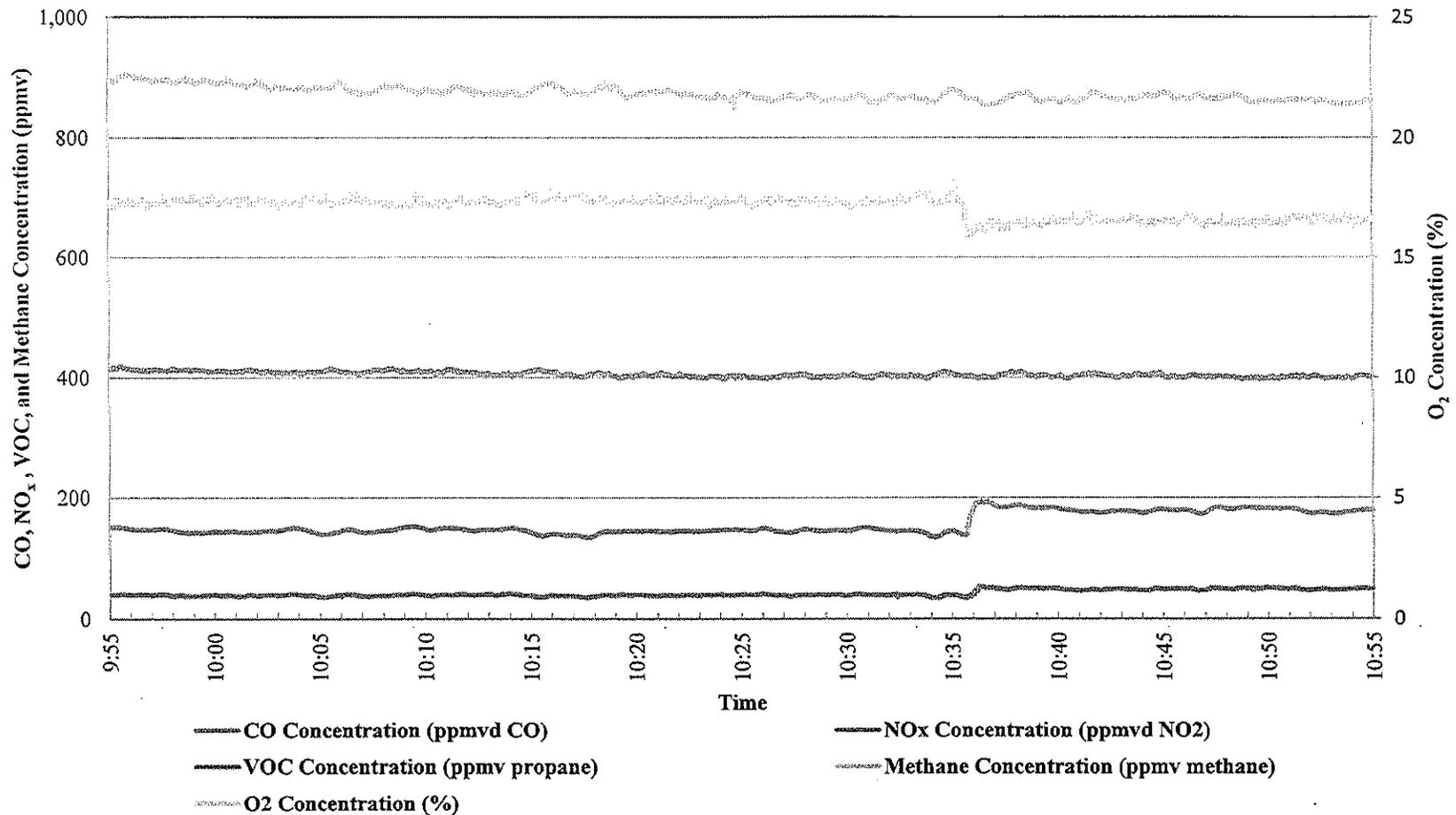


Graphs

CO, NO_x, VOC, Methane, and O₂ Concentrations - Run 1
Lansing Board of Water & Light - REO Cogeneration Plant



Lansing, Michigan
Bureau Veritas Project No. 11013-000213.00
Sampling Date: September 10, 2013

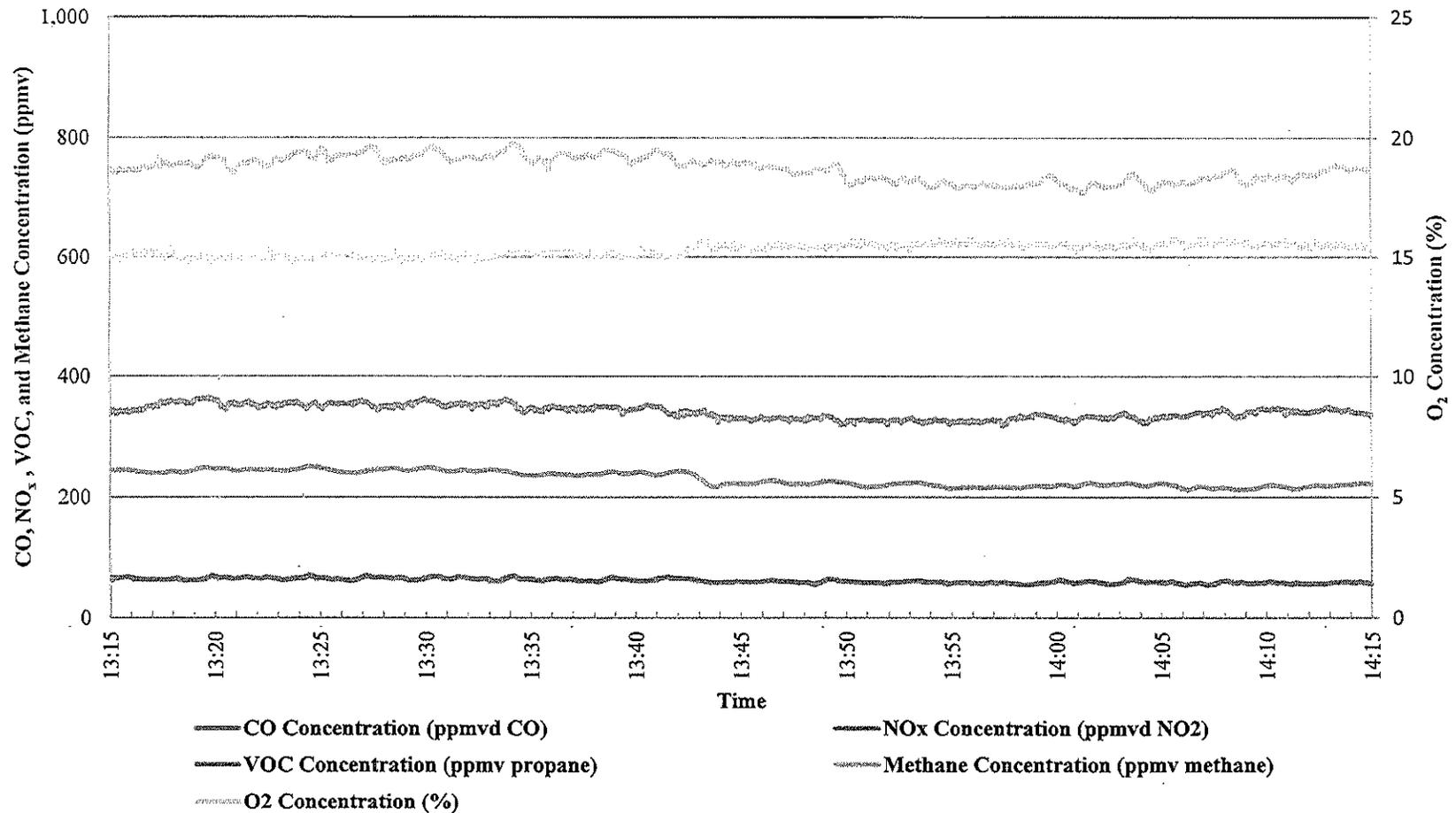


CO, NO_x, VOC, Methane, and O₂ Concentrations - Run 2
Lansing Board of Water & Light - REO Cogeneration Plant

Lansing, Michigan

Bureau Veritas Project No. 11013-000213.00

Sampling Date: September 10, 2013



CO, NO_x, VOC, Methane, and O₂ Concentrations - Run 3
Lansing Board of Water & Light - REO Cogeneration Plant
Lansing, Michigan
Bureau Veritas Project No. 11013-000213.00
Sampling Date: September 10, 2013

