FINAL REPORT

GENERAL MOTORS, LLC

WARREN, MICHIGAN

GLOBAL TECHNICAL CENTER THREE BOILER RAA EMISSION TESTING NOX AND O2

RWDI #2302580

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SUBMITTED TO

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EXECUTIVE SUMMARY

RWDI USA LLC (RWDI) was retained by General Motors, LLC (GM) to conduct a Relative Accuracy Audit (RAA) at the Global Technical Center located in Warren, MI. The RAA was completed on August 15th, 2023 on EU-Boiler1-107 (Boiler 1), EU-Boiler2-107 (Boiler 2), and EU-Boiler3-107 (Boiler 3) for Nitrogen Oxides (NO_x) and Oxygen (O_2) for the Predictive Emission Monitoring Systems (PEMS).

RAA is a requirement under the facility permit MI-ROP-B4049-2019 and under United States Environmental Protection Agency (U.S. EPA) Appendix A, 40 CFR, Part 60, subparts Dd. NO_x and O_2 measurements were collected using U.S. EPA Methods 7E and 3A under 40 CFR, Part 60, Appendix A and Performance Specifications (PS) 2, 3, and 16 stipulated in 40 CFR, Part 60, Appendix B.

The PEMS audited during this testing program includes oxides of nitrogen (NO_x) concentration and emission rate and oxygen (O_2) concentration. Data was collected for three (3) 30-minute periods on each of the boilers while each boiler was fired by natural gas.

The table below presents a summary of the results.

Executive Table i: Summary of Results – EU-Boiler1-107 – August 15, 2023

Parameter	Boiler 1	
	Relative Accuracy (RA) (Mean Difference from RM %)	**Relative Accuracy (RA) (Absolute Difference from RM Concentration)**
Oxides of Nitrogen (ppm)	1.1% (Pass – 20% Limit)	0.21 ppm (Pass – 2ppm Limit)
Oxides of Nitrogen (lb/MMBTU)	1.0% (Pass – 20% Limit)	Not Applicable
Oxygen (%)	7.8% (Pass – 20% Limit)	0.31% (Pass – 1% Limit)

Executive Table ii: Summary of Results – EU-Boiler2-107 – August 15, 2023

Parameter	Boiler 2	
	Relative Accuracy (RA) (Mean Difference from RM %)	Relative Accuracy (RA) (Absolute Difference from RM Concentration)
Oxides of Nitrogen (ppm)	4.6% (Pass – 20% Limit)	1.07 ppm (Pass – 2ppm Limit)
Oxides of Nitrogen (lb/MMBTU)	4.9% (Pass – 20% Limit)	Not Applicable
Oxygen (%)	4.7% (Pass – 20% Limit)	0.16% (Pass – 1% Limit)

Executive Table iii: Summary of Results – EU-Boiler3-107 – August 15,2023

Parameter	Boiler 3	
	Relative Accuracy (RA) (Mean Difference from RM %)	Relative Accuracy (RA) (Absolute Difference from RM Concentration)
Oxides of Nitrogen (ppm)	5.3% (Pass – 20% Limit)	1.70 ppm (Pass – 2ppm Limit)
Oxides of Nitrogen (lb/MMBTU)	7.1% (Pass – 20% Limit)	Not Applicable
Oxygen (%)	7.2% (Pass – 20% Limit)	0.26% (Pass – 1% Limit)

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1 INTRODUCTION

RWDI USA LLC (RWDI) was retained by General Motors, LLC (GM) to conduct a Relative Accuracy Audit (RAA) at the Global Technical Center located in Warren, MI. The RAA was completed on August 15th, 2023 on EU-Boiler1-107 (Boiler 1), EU-Boiler2-107 (Boiler 2), EU-Boiler3-107 (Boiler 3) for Nitrogen Oxides (NO_x) and Oxygen (O_2) for the Predictive Emission Monitoring Systems (PEMS). RAA is conducted as a requirement under the facility permit MI-ROP-B4049-2019 and under United States Environmental Protection Agency (U.S. EPA) Appendix A, 40 CFR, Part 60. NO_x and O_2 measurements were collected using U.S. EPA Methods 7E and 3A under 40 CFR, Part 60, Appendix A and Performance Specifications (PS) 2, 3, and 16 stipulated in 40 CFR, Part 60, Appendix B.

The monitors audited during this testing program includes oxides of nitrogen (NO_X) and oxygen (O_2). The relative accuracy requirements are set out in the applicable Performance Specification in 40 CFR 60, Appendix B.

Table 1: Test Personnel

Matt Perko Environmental Engineer	**General Motors – Global Technical Center** 30001 Van Dyke Ave Warren, MI 48093	(586) 242-6763
Steve Smith Project Supervisor	**RWDI USA LLC** 2239 Star Court Rochester Hills, MI 48309	(734) 751-9701
Ben Durham Senior Field Technician		(734) 474-1731
Cade Smith Field Technician		(734) 552-7270

2 PLANT AND SOURCE DESCRIPTION

2.1 Plant Overview

The General Motors Technical Center located in Warren, Michigan has three boilers that are capable of firing natural gas. Each of the boilers has an input capacity of 108 MMBtu/hr while firing NG. The steam from the boilers is utilized as process steam. Low-NOx burners minimize the emissions of nitrogen oxides from the boilers.

2.2 Predictive Emission Monitors Specifications Boilers 1, 2, & 3

The SmartCEMS 60 Predictive Emissions Monitoring System (PEMS) provides continuous data recording and report generation for compliance with 40 CFR Part 60 regulations. The data acquisition system provides a secure and reliable means of collecting and retrieving compliance data. This application has been customized to meet the requirements of gas-fired boiler under 40 CFR Part 60, Subpart Db; and as a PEMS, an alternative to continuous emissions monitoring under 40 CFR Part 60, Performance Specification 16 for Predictive Emissions Monitoring Systems (PS-16)

3 SAMPLING LOCATION

The sampling ports for the RAA testing was located on the top of the boiler house. Each boiler has it's own individual exhaust stack.

4 REFERENCE METHOD SAMPLING

The following section provides an overview of the sampling methodologies employed by the sampling program. The table below summarizes the reference methods used in this study.

Table 2: Summary of Sampling Methodologies

Parameter	Reference Method
RAA Methodology and Calculations	U.S EPA Performance Specifications 2,3, and 16
Oxides of Nitrogen	U.S. EPA Method 7E
Oxygen	U.S. EPA Method 3A
Nitrogen Oxide Emission Rates	U.S. EPA Method 19

4.1 Relative Accuracy Audit

The reference test method procedures outlined above are instrumental test methods. They were conducted in accordance with 40 CFR 60, Appendix B, Performance Specifications 2, 3, and 16. The relative accuracies were calculated according to the appropriate emission standards. To satisfy the RAA requirements of 40 CFR 60, Appendix B, the relative accuracy must not exceed 20.0% of the mean of the reference method since the concentration of NO_x was less than 100ppm. As outlined in Performance Specification 16, Section 13.5 the performance specifications for the RAAs are as follows:

- The average of the three portable analyzer or RM determinations must not differ from the simultaneous PEMS average value by more than 2ppm of the criteria. Therefore, for NO_x, the evaluation of RA was compared to 2ppm of the criteria since the NOx values were less than 20ppm.
- For Oxygen, 20 percent for concentrations was used as the RAA criteria.

The RAA was conducted while the unit operated at a minimum of 50% capacity. The exhaust gas sample was withdrawn from the duct using a stainless-steel probe at a single centroid port along the duct. The sample proceeded through a heated filter where particulate matter was removed. The sample was then transferred via a heated Teflon® line maintained at a temperature of 250°F to a sample conditioner. The sample conditioner removed any moisture from the exhaust gas. The sample was then routed through a manifold system and introduced to the individual CEM's for measurement.

Appendix A, **Appendix C**, **Appendix E** of this report contains detailed information on the Reference Method RAA test runs, including a summary of results, raw PEMs data, corrected CEM data and pre and post-test calibration information for all parameters, respectively for Boilers 1,2, and 3. **Appendix B**, **Appendix D**, **Appendix F** of this report contain 1-minute averages of GM PEMS system, respectively for Boiler 1, Boiler 2, and Boiler 3. **Appendix G** contains calibration gas Certificates of Accuracy. Below is a schematic of the RWDI reference method sampling system.

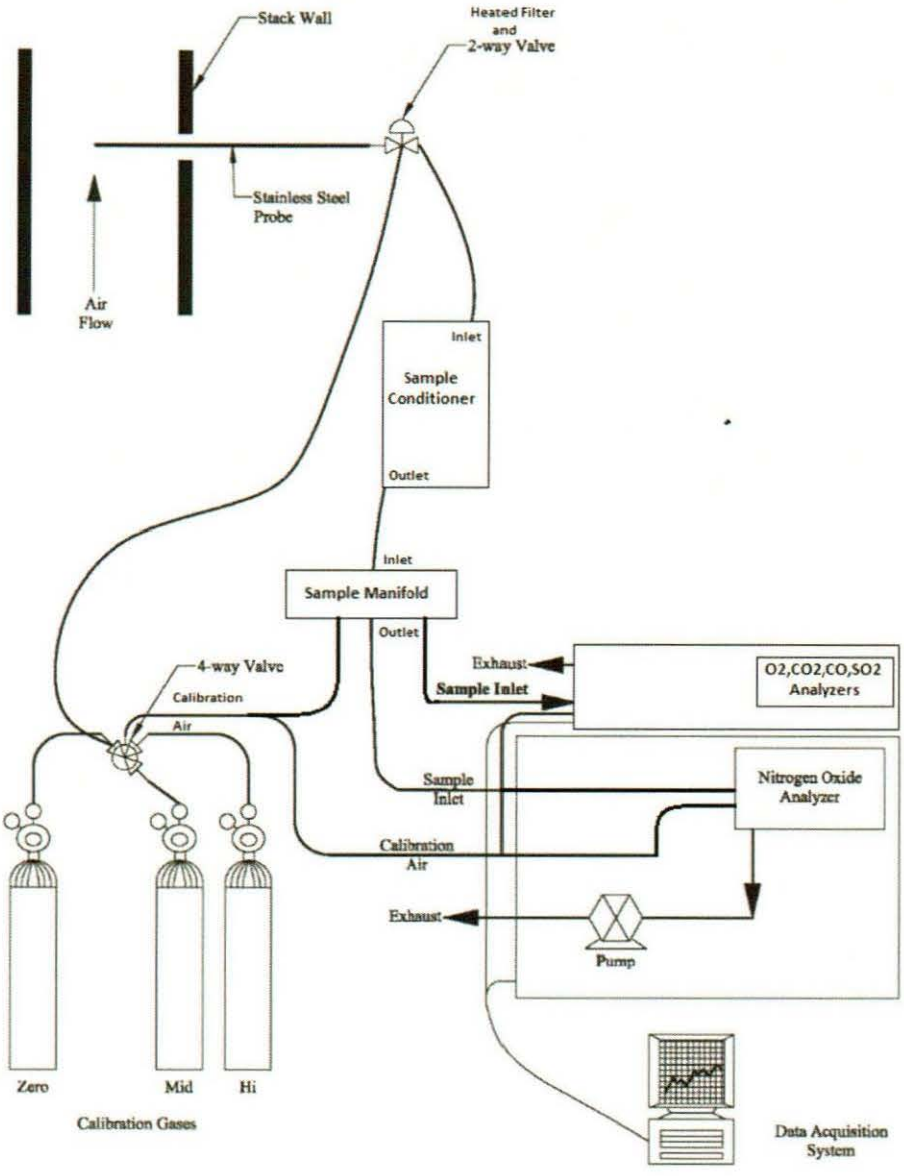

Figure 2: RWDI CEM Sampling System

Table 3: RWDI CEM Analyzers (RM)

RWDI CEM Analyzers					
Parameter	**Unit**	**Location**	**Range**	**Analyzer**	**Serial Number**
O_2	1,2,3	Stack	0 - 25%	Teledyne T200H NOx, O2	851
NOx	1,2,3	Stack	0 – 100 ppm	Teledyne T200H NOx, O2	851

4.2 Oxygen (US EPA method 3A)

US EPA Method 3A, "Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrument Analyzer Procedure)", was used to measure the oxygen concentration of the flue gas. A Teledyne T200H NOx, O_2 paramagnetic analyzer was used for oxygen measurements.

Prior to testing, a 3-point analyzer calibration error check was conducted using US EPA protocol gases. The calibration error check was performed by introducing zero, mid and high-level calibration gases directly into the analyzer. The calibration error check was performed to confirm that the analyzer response was within ±2% of the certified calibration gas introduced. Prior to each test run, a system-bias test was performed where known concentrations of calibration gases were introduced at the probe tip to measure if the analyzers response was within ±5% of the introduced calibration gas concentrations. At the conclusion of each test run a system-bias check was performed to evaluate the percent drift from pre-and post-test system bias checks. The system bias checks confirmed that the analyzer did not drift greater than ±3% throughout a test run.

Data acquisition was provided using a data logger system programmed to collect and record data at one second intervals. Average one-minute concentrations were calculated from the one second measurements.

4.3 Oxides of Nitrogen (US EPA method 7E)

NO_x emissions were measured following USEPA Method 7E, "Determination of Nitrogen Oxides Emissions from Stationary Sources." The NO_x concentration was measured using a Teledyne T200H NOx, O2 Chemiluminescence gas analyzer.

A NO/NO_2 conversion check was performed after testing both sources by introducing NO_2 gas into the NOx analyzer. The analyzers NO_x concentration readout was greater than 90% of the introduced calibration gas; therefore, the conversion met the converter efficiency requirement of section 13.5 of USEPA Method 7E. NO/NO_2 conversion data is outlined in the table below

Table 4: NO/NO_2 Converter Efficiency

Date	Certified Calibration Gas Value (ppmv)	Analyzer Response Peak Value (ppmv)	NO_2 to NO Converter Efficiency (%)	Efficiency: Pass/Fail
8-15-2023 – Boilers 1,2,3	99.0	89.61	**91%**	**PASS**

Note: Converter Efficiency must be >90%

4.4 Nitrogen Oxides Emission Rate Calculation (US EPA Methods 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 NO_x emission factor based on Oxygen concentrations and appropriate F-factors. Equation 19-1 from the method was used. Table 19-1 was used to determine the conversion factor for concentration ($1.194x10^{-7}$) was used for NO_x. Table 19-2 was used for the F-Factor (natural gas 8,710 dscf/10^6 BTU).

$E = (1.194x10^{-7}) \times C_d \times F_d \times ((20.9/(20.9-\%O_{2d}))$

Where:

E = Pollutant Emission Rate (lb/10^6 BTU)

C_d = Pollutant Concentration, Dry Basis (ppm)

F_d = Fuel Factor, Dry Basis (dscf/10^6 BTU)

$\%O_{2d}$ = Oxygen Concentration, Dry Basis (%)

4.5 Quality Assurance and Quality Control Procedures

Quality assurance measures were implemented during the sampling program to ensure the integrity of the results. These measures included detailed documentation of field data, and equipment calibrations for all measured parameters.

Quality control procedures specific to the CEM monitoring included linearity checks, to determine the instrument performance, and reproducibility checks prior to its use in the field. Regular performance checks on the analyzers were also carried out during the testing program by performing 30 minute zero and span calibration checks using EPA Protocol 1 gas standards. Sample system bias checks were also conducted. These checks were used to verify the ongoing precision of the monitor and sampling system over time. Nitrogen was introduced to perform the zero checks, followed by a known calibration (span) gas into the monitor. The response of the monitor to nitrogen and the corresponding sensitivity to the span gas were recorded regularly during the tests. The tables below outline the QA/QC procedures and calibration gas summary.

Table 5: Summary of QA/QC Procedures

Summary of QA/QC Procedures				
Test Method	**QA/QC Procedure**	**QA/QC Objective**	**QA/QC Results**	**Status of QA/QC**
US EPA 3A & 7E	Initial Calibration Error Test	< ±2%	< ±2%	Acceptable
	System Bias Test	< ±5%	< ±5%	Acceptable
	Drift Test	< ±3%	< ±3%	Acceptable
US EPA 7E	NOx Converter Checks	>90% conversion efficiency	>90%	Acceptable

Table 6: Reference Method Calibration Gas Values

Reference Method Calibration Gas Values			
Parameter	**Span Level**	**Calibration Gas Value**	**Calibration Gas Serial Number**
Oxygen	Mid	10.02%	DT0032951
	High	21.05%	EB0001454
Nitrogen Oxides	Mid	24.8ppm	CC350586
	High	51.2ppm	EB010817
Nitrogen Dioxide	Converter Gas	99.0 ppm	SA15110

5 RESULTS

The overall results from the testing are discussed in this section. Detailed results of each individual Reference Method test and individual PEMS tests may be found in **Appendices A & B** for Boiler 1, **Appendices C & D** for Boiler 2, **Appendices E & F** for Boiler 3.

5.1 Summary Relative Accuracy Audit (RAA) Results

A total of three (3), 30-minute tests were completed on the PEMS for NO_X and O_2. **Appendix E** contains the calibration gas certifications and **Appendix F** contains the field notes.

The relative accuracy audit was conducted to determine if the General Motors PEMS will give data that can be compared with data obtained using reference test methods. Below is a summary of the results.

Table 7: Summary of Results – EU-Boiler1-107 – August 15, 2023

Parameter	**Boiler 1**	
	Relative Accuracy (RA) (Mean Difference from RM %)	**Relative Accuracy (RA) (Absolute Difference from RM Concentration)**
Oxides of Nitrogen (ppm)	1.1% (Pass – 20% Limit)	0.21 ppm (Pass – 2ppm Limit)
Oxides of Nitrogen (lb/MMBTU)	1.0% (Pass – 20% Limit)	Not Applicable
Oxygen (%)	7.8% (Pass – 20% Limit)	0.31% (Pass – 1% Limit)

Table 8: Summary of Results – EU-Boiler2-107 – August 15, 2023

Parameter	Boiler 2	
	Relative Accuracy (RA) (Mean Difference from RM %)	Relative Accuracy (RA) (Absolute Difference from RM Concentration)
Oxides of Nitrogen (ppm)	4.6% (Pass – 20% Limit)	1.07 ppm (Pass – 2ppm Limit)
Oxides of Nitrogen (lb/MMBTU)	4.9% (Pass – 20% Limit)	Not Applicable
Oxygen (%)	4.7% (Pass – 20% Limit)	0.16% (Pass – 1% Limit)

Table 9: Summary of Results – EU-Boiler3-107 – August 15,2023

Parameter	Boiler 3	
	Relative Accuracy (RA) (Mean Difference from RM %)	Relative Accuracy (RA) (Absolute Difference from RM Concentration)
Oxides of Nitrogen (ppm)	5.3% (Pass – 20% Limit)	1.70 ppm (Pass – 2ppm Limit)
Oxides of Nitrogen (lb/MMBTU)	7.1% (Pass – 20% Limit)	Not Applicable
Oxygen (%)	7.2% (Pass – 20% Limit)	0.26% (Pass – 1% Limit)

6 BOILER OPERATING CONDITIONS

Operating conditions during the sampling were monitored by General Motors personnel. Testing was performed while Boilers 1, 2, and 3 operated at a greater than 50% load during the RAA. Contact was kept between RWDI and boiler operators to ensure the boiler was running at all times during the testing.

7 CONCLUSIONS

The purpose of the study was to perform the annual RAA for EU-Boiler1, EU-BOILER2, and EU-BOILER3. All analyzers meet the relative accuracy requirements set out in Performance Specification in 40 CFR 60, Appendix B.