FINAL REPORT

AVL POWERTRAIN ENGINEERING, INC.

ANN ARBOR, MICHIGAN

SOURCE TESTING REPORT: EUTESTCELLS NOX AND CO EMISSIONS

RWDI #2506709

December 18, 2024

SUBMITTED TO

Jeremy Howe
Air Quality Division Technical Programs Unit (TPU)
Constitution Hall
2nd Floor, South
525 W Allegan Street
Lansing, Michigan 48909-7760

Stephen Plewa
AVL Powertrain
EHS & Facilities Manager
Steve.Plewa@avl.com

AVL Powertrain
1801 E Ellsworth Rd
Ann Arbor, MI 48108

SUBMITTED BY

Brad Bergeron, A.Sc.T., d.E.T.
Technical Director | Principal
Brad.Bergeron@rwdi.com

Steve Smith, QSTI
Project Manager | Associate
Steve.Smith@rwdi.com

RWDI USA LLC
Consulting Engineers & Scientists
24445 Forterra Drive
Warren, MI 48089
T: 248.841.8442
F: 519.823.1316

CANADA'S BEST MANAGED COMPANIES Platinum member

rwdi.com

© 2024 RWDI USA LLC ("RWDI") ALL RIGHTS RESERVED
This document is intended for the sole use of the party to whom it is addressed and may contain information that is privileged and/or confidential. If you have received this in error, please notify us immediately. Accessible document formats provided upon request. ® RWDI name and logo are registered trademarks in Canada and the United States of America.

EXECUTIVE SUMMARY

RWDI was retained by AVL Powertrain Engineering, Inc. (AVL) to perform compliance stack emissions testing at their facility located at 1801 E Ellsworth Rd, Ann Arbor, MI 48108. The objective of the testing was to demonstrate compliance with total oxides of nitrogen (NOx) and carbon monoxide (CO) on one (1) of the EUTESTCELLS. The testing was conducted in order to determine compliance with the requirements listed in Michigan Department of Environment, Great Lakes, and Energy (EGLE) ROP No. MI-ROP-N6989-2020, FGTESTCELLS. To determine compliance, testing included three (3) completed tests while an engine was running on gasoline fuel in the designated test cell.

Executive Table i: EUTESTCELL Average NO_x and CO Emission Rates

Unit	Pollutant	Unit	Average Results	Permit Limit (tpy)
EUTESTCELLS	NO_x	lb/hr lb/gal. of fuel lb/lb of fuel lb/MMBTU	1.06 1.03 0.16 8.55	91.2
	CO	lb/hr lb/gal. of fuel lb/lb of fuel lb/MMBTU	1.11 1.11 0.17 8.95	127.5

Notes: The average data is based on 3 test runs. An emission rate of pounds of pollutant per pounds of fuel is determined, and therefore an emission limit for testing does not apply.

TABLE OF CONTENTS

LIST OF TABLES 4

1 INTRODUCTION 1

1.1 Location and Dates of Testing 1

1.2 Purpose of Testing 1

1.3 Description of Source 1

1.4 Personnel Involved in Testing 2

2 SUMMARY OF RESULTS 2

2.1 Operating Data 2

2.2 Applicable Permit Number 2

3 SOURCE DESCRIPTION 3

3.1 Description of Process and Emission Control Equipment 3

3.2 Process Flow Sheet or Diagram (if applicable) 3

3.3 Type and Quantity of Raw and Finished Materials 3

3.4 Normal Rated Capacity of Process 3

3.5 Process Instrumentation Monitored During the Test 3

4 SAMPLING AND ANALYTICAL PROCEDURES 3

4.1 Description of Sampling Train and Field Procedures ..... **Error! Bookmark not defined.**

4.1.1 Oxygen, Oxides of Nitrogen, and Carbon Monoxide 3

4.1.2 USEPA Method 19 4

4.1.3 USEPA Method 205 5

4.2 Description of Recovery and Analytical Procedures 5

4.3 Sampling Port Description 5

5 SAMPLING RESULTS 6

5.1 Discussion of Results 6

5.2 Variations in Testing Procedures 6

5.3 Process Upset Conditions During Testing 6
5.4 Maintenance Performed in Last Three Months 6
5.5 Re-Test 6
5.6 Audit Samples 6
5.7 Field Data Sheets 7
5.8 Calibration Data 7
5.9 Example Calculations 7
5.10 Laboratory Data 7
5.11 Test Plan and EGLE Correspondence 7

LIST OF TABLES (Found Within the Report Text)

Table 1.4: List of Testing Personnel 2
Table 4.4: EUTESTCELLS Average NOx and CO Emission Rates 5

LIST OF TABLES

Table 1: Summary of Sampling Parameters and Methodology
Table 2: EUTESTCELLS Sampling Summary
Table 3: EUTESTCELLS – NO_x Testing Summary
Table 4: EUTESTCELLS – CO Testing Summary

LIST OF FIGURES

Figure 1: Sampling Location Characteristics
Figure 2: USEPA Method 3A, 7E,10 Schematic

LIST OF APPENDICES

Appendix A: Process Data
Appendix B: CEMS Data
Appendix C: Field Notes
Appendix D: Calibration Data
Appendix E: Example Calculations
Appendix F: Analytical Data
Appendix G: Test Plan and EGLE Correspondence

1 INTRODUCTION

RWDI was retained by AVL Powertrain Engineering, Inc. (AVL) to perform compliance stack emissions testing at their facility located at 1801 E Ellsworth Rd, Ann Arbor, MI 48108. The objective of the testing was to demonstrate compliance with total oxides of nitrogen (NOx) and carbon monoxide (CO) on one (1) of the EUTESTCELLS. The testing was conducted in order to determine compliance with the requirements listed in Michigan Department of Environment, Great Lakes, and Energy (EGLE) ROP No. MI-ROP-N6989-2020, FGTESTCELLS. To determine compliance, testing included three (3) completed tests while an engine was running on gasoline fuel in the designated test cell. A 3.6L V6 engine was used for the testing.

1.1 Location and Dates of Testing

The test program took place at the AVL Powertrain facility located at 1801 E Ellsworth Rd, Ann Arbor, MI on October 29th.

1.2 Purpose of Testing

This testing was conducted to show compliance with Michigan Department of Environment, Great Lakes, and Energy (EGLE) ROP No. MI-ROP-N6989-2020, FGTESTCELLS.

1.3 Description of Source

AVL operates twenty (20) dynamometer test cells under Flexible Group FGTESTCELLS using gasoline, diesel, and/or natural gas fuels.

1.4 Personnel Involved in Testing

Table 1.4: Testing Personnel

Personnel	Company	Contact Number
Steve Plewa Steve.Plewa@avi.com	**AVL Powertrain, Inc.** 1801 Ellsworth Rd. Ann Arbor, MI 48108	(734) 368-4087
Jeremy Howe	**State of Michigan Department of Environment, Great Lakes and Energy**	N/A
Steve Smith Project Manager Steve.Smith@rwdi.com	**RWDI USA LLC** 24445 Forterra Dr. Warren, MI 48089	(734) 751-9701
Brad Bergeron Technical Director Brad.Bergeron@rwdi.com		(248) 234-3885
Mason Sakshaug Supervisor, Source Mason.Sakshaug@rwdi.com		(989) 323-0355
David Trahan Senior Field Technician Dave.Trahan@rwdi.com		(248) 841-8442
Roy Zimmer Field Technician Roy.Zimmer@rwdi.com		(810) 956-7478

2 SUMMARY OF RESULTS

2.1 Operating Data

Production data included the following:

- Fuel type;
- Fuel flow rate;
- Cell(s) tested; and
- Engine Size.

Production data can be found in **Appendix A**.

2.2 Applicable Permit Number

MI-ROP-N6989-2020, FGTESTCELLS

3 SOURCE DESCRIPTION

3.1 Description of Process and Emission Control Equipment

AVL operates twenty (20) dynamometer test cells under Flexible Group FGTESTCELLS using gasoline, diesel, and/or natural gas fuels. If fuel usage is greater than 34,500 gallons, catalytic converters are used to control emissions.

3.2 Process Flow Sheet or Diagram (if applicable)

A process flow diagram is available upon request.

3.3 Type and Quantity of Raw and Finished Materials

Testing was completed on a 3.6L V6 Gasoline Engine. Gasoline was used as the raw material.

3.4 Normal Rated Capacity of Process

The dynamometers use a variety of engines and testing was completed on a 3.6 L Gasoline Engine.

3.5 Process Instrumentation Monitored During the Test

No process instrumentation was being monitored for this testing.

4 SAMPLING AND ANALYTICAL PROCEDURES

4.1 Oxygen, Oxides of Nitrogen, and Carbon Monoxide

O_2, NO_x, and CO concentrations were determined utilizing RWDI's continuous emissions monitoring (CEM) system in accordance with USEPA Methods 3A, 7E, and 10, respectively. Prior to testing, a 3-point analyzer calibration error check was conducted using USEPA 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 were used to confirm that the analyzer did not drift greater than ±3% throughout each test run.

Zero and upscale calibration checks were conducted both before and after each test run to quantify measurement system calibration drift and sampling system bias. Upscale is either the mid- or high-range gas, whichever most closely approximates the flue gas level. During these checks, the calibration gases were introduced into the sampling system at the probe outlet so that the calibration gases were analyzed in the same manner as the flue gas samples.

A gas sample was continuously extracted from the stack and delivered to a series of gas analyzers, which measure the pollutant or diluent concentrations in the gas. The analyzers were calibrated on-site using EPA Protocol No. 1 certified calibration mixtures. The end of the probe was connected to a heated Teflon sample line, which delivered the sample gases from the stack to the CEM system. The heated sample line was designed to maintain the gas temperature above 250°F to prevent condensation of stack gas moisture within the line.

Before entering the analyzers, the gas sample passed directly into a refrigerated condenser, which cools the gas to approximately 35°F to remove the stack gas moisture. After passing through the condenser, the dry gas entered a Teflon-head diaphragm pump and a flow control panel, which delivered the gas in series to the NO_x, CO, and O_2 analyzers. Each of these analyzers measure the respective gas concentrations on a dry volumetric basis.

4.2 USEPA Method 19

USEPA Method 19, "Determination of Sulfur Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide and Nitrogen Oxide Emission Rates," was used to calculate a NO_x and CO 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. 1.197×10^{-7} was used for NO_x and 7.27×10^{-8} was used for CO. A fuel analysis was completed to determine the F_d factor.

$$E = (1.194 \times 10^{-7}) \times C_d \times F_d \times ((20.9/(20.9-\%O_{2d}))$$

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 (%)

4.3 USEPA Method 205

Calibration gases were mixed using an Environics 4040 Gas Dilution System. The mass flow controllers are factory calibrated using a primary flow standard traceable to the United States National Institute of Standards and Technology (NIST). Each flow controller utilizes an 11-point calibration table with linear interpolation, to increase accuracy and reduce flow controller nonlinearity. The calibration is done yearly, and the records are included in the appendix. A multi-point EPA Method 205 check was executed in the field prior to testing to ensure accurate gas-mixtures. The gas dilution system consists of calibrated orifices or mass flow controllers and dilutes a high-level calibration gas to within ±2% of predicted values. The gas divider is capable of diluting gases at set increments and was evaluated for accuracy in the field in accordance with US EPA Method 205 "*Verification of Gas Dilution Systems for Field Instrument Calibrations*". The gas divider dilutions were measured to evaluate that the responses were within ±2% of predicted values. In addition, a certified mid-level calibration gas within ±10% of one of the tested dilution gases was introduced into the analyzer to ensure the response of the gas calibration is within ±2% of gas divider dilution concentration.

4.4 Description of Recovery and Analytical Procedures

There were no samples to recover during this test program, as all testing used real time data from the analyzers.

4.5 Sampling Port Description

A figure of the testing location is provided in the **Figures** section.

5 SAMPLING RESULTS

The following table give the averages for each permit requirement. The **Tables** section and **Appendix B** provides a detailed breakdown of each test.

Table 4.4: EUTESTCELL Average NO_x and CO Emission Rates

Unit	Pollutant	Unit	Average Results	Permit Limit (tpy)
EUTESTCELLS	NO_x	lb/hr lb/gal. of fuel lb/lb of fuel lb/MMBTU	1.06 1.03 0.16 8.55	91.2
	CO	lb/hr lb/gal. of fuel lb/lb of fuel lb/MMBTU	1.11 1.11 0.17 8.95	127.5

Notes: The average data is based on 3 test runs. An emission rate of pounds of pollutant per pounds of fuel is determined, and therefore an emission limit for testing does not apply.

5.1 Discussion of Results

The emission rate (lb of pollutant/lb of fuel) is used as an emission factor. Emission rate in lb per hour, lb per gallon of fuel and lb per MMBTU are also provided.

5.2 Variations in Testing Procedures

All testing was completed as per the respective USEPA method.

5.3 Process Upset Conditions During Testing

During Test 1, the engine used for the testing experienced a shutdown. Testing was briefly paused and re-started once the engine was back online.

5.4 Maintenance Performed in Last Three Months

Regular maintenance is performed monthly.

5.5 Re-Test

This was not a re-test.

5.6 Audit Samples

No audit sample were required.

5.7 Field Data Sheets

Field data sheets can be found in **Appendix C**.

5.8 Calibration Data

Calibration data can be found in **Appendix D**.

5.9 Example Calculations

Example calculations can be found in **Appendix E**.

5.10 Laboratory Data

A sample of the fuel used in the engine during testing was collected and sent for analysis, these results can be found in **Appendix F.**

5.11 Test Plan and EGLE Correspondence

The test plan and all EGLE correspondence can be found in **Appendix G**.

TABLES

Table 1: Summary of Sampling Parameters and Methodology

Source Location	No. of Tests	Sampling Parameter	Sampling Method
EUTESTCELLS	3	Oxygen	U.S. EPA [1] Method 3A
		Nitrogen Oxides	U.S. EPA [1] Method 7E
		Carbon Monoxide	U.S. EPA [1] Method 10
		Emissions Calculations	U.S. EPA [1] Method 19

Notes:

[1] U.S. EPA - United States Environmental Protection Agency

Table 2: EUTESTCELLS Sampling Summary

Source	Test #	Sampling Date	Start Time	End Time
EUTESTCELLS	Test #1	29-Oct-24	8:15 AM	9:38 AM
	Test #2	29-Oct-24	10:05 AM	11:04 AM
	Test #3	29-Oct-24	11:20 AM	12:19 PM

Test 1 was briefly paused during its run

Table 3: EUTESTCELLS - NO_x Testing Summary

RWDI Project #2506709

Durability				O_2	NO_x	NO_x Emission Rate				Gas Used					NO_x Emission Rate
Test ID	Date	Start	End	%	ppm	lb/dscf	lb/hr	lb / gal. fuel	lb/lb fuel	lb/hr	Density of Fuel	Fuel Used (gal./test)	MMBTU/hr	Gross Calorie Value (BTU/lb)	lb/MMBTU
1	2024-10-29	8:15	9:38	20.00	309.4	3.68E-05	0.984	0.952	0.154	6.4	6.2	1.0	0.124	19469	7.92
2	2024-10-29	10:05	11:04	20.11	303.9	3.61E-05	1.102	1.066	0.173	6.4	6.2	1.0	0.124	19469	8.87
3	2024-10-29	11:20	12:19	20.10	306.7	3.65E-05	1.100	1.064	0.172	6.4	6.2	1.0	0.124	19469	8.85
		Average		20.07	306.7	3.65E-05	1.062	1.028	0.166	6.4	6.2	1.0	0.124	19,469	8.55

Caloric value for natural gas used 19469 btu/ft^3

Conversion for ppm to lbs/scf (U.S. EPA Method 19) 1.197E-07

Fd - 9192 $dscf/10^6$ BTU

$E = (1.194 \times 10^{-7}) \times C_{rf} \times F_{rf} \times ((20.9/(20.9-\%O_{2rf}))$

Where:

E = Pollutant Emission Rate ($lb/10^6$ BTU)
C_d = Pollutant Concentration, Dry Basis (ppm)
F_{rf} = Fuel Factor, Dry Basis ($dscf/10^6$ BTU)
$\%O_{2d}$ = Oxygen Concentration, Dry Basis (%)

Table 4: EUTESTCELLS - CO Testing Summary

RWDI Project #2506709

Durability				O_2	CO	CO Emission Rate				Fuel Used					CO Emission Rate
Test ID	Date	Start	End	%	ppm	lb/dscf	lb/hr	lb/ gal. fuel	lb/lb of fuel	lb/hr	Density of Fuel (lb/gal.)	Fuel Used (gal./test)	MMBTU/hr	Gross Calorie Value (BTU/lb)	lb/MMBTU
1	2024-10-29	8:15	9:38	20.00	602.85	4.36E-05	1.16	1.13	0.182	6.4	6.2	1.0	0.124	19469	9.37
2	2024-10-29	10:05	11:04	20.11	495.34	3.58E-05	1.09	1.06	0.171	6.4	6.2	1.0	0.124	19469	8.78
3	2024-10-29	11:20	12:19	20.10	496.55	3.59E-05	1.08	1.05	0.170	6.4	6.2	1.0	0.124	19469	8.71
		Average		20.07	531.58	3.85E-05	1.11	1.08	0.174	6.4	6.2	1.0	0.124	19469	8.95

Caloric value for natural gas used 19469 btu/ft^3

Conversion for ppm to lbs/scf (U.S. EPA Method 19) 7.270E-08

Fd - 9192 $dscf/10^o$ BTU

$E = (7.27x10^{-8}) \times C_d \times F_d \times ((20.9/(20.9-\%O_{2d}))$

Where:

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

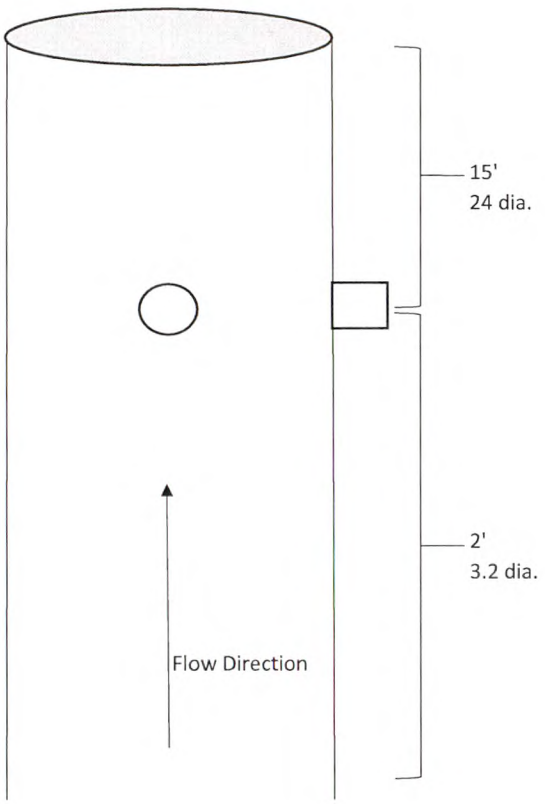
C_d = Pollutant Concentration, Dry Basis (ppm)

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

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

FIGURES

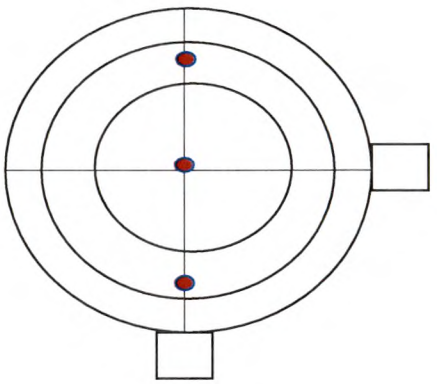
Figure No. #1 - Sampling Location Characterstics



Diameter: 7.5

Sampling Points (in.)	
1	1.30
2	3.80
3	6.20

For strat check



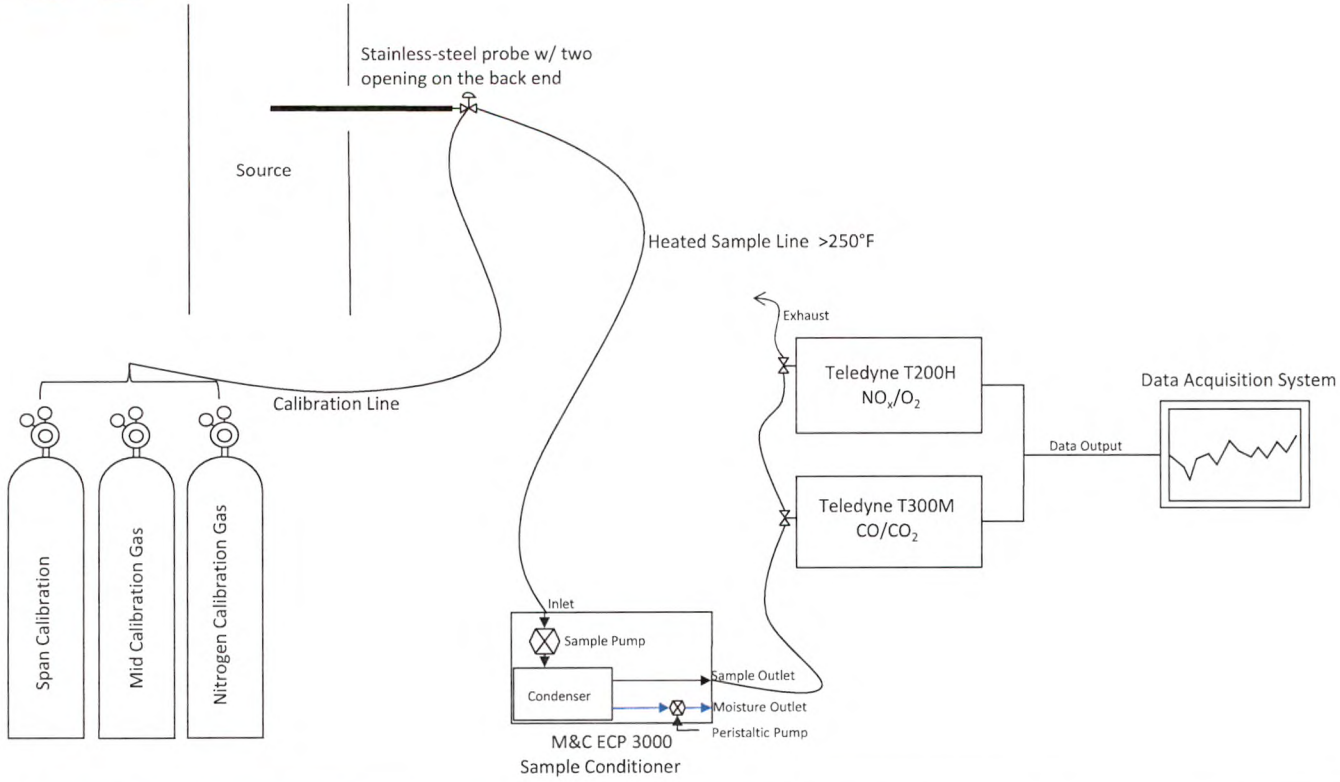
Not to scale

Source
AVL Powertrain
1801 Ellsworth Rd
Ann Arbor, MI 48108

Date:
10/29/2024

RWDI USA LLC
24445 Forterra Drive
Warren, MI 48089

Figure No. 2: USEPA Method 3A, 7E, 10 Schematic



USEPA Method 3A,6C,7E,10

AVL Powertrain

Ann Arbor, MI

Project# 2506709

Date: October 29, 2024