REPORT

FCA US LLC

DETROIT, MICHIGAN

MACK ENGINE PLANT:
2018 FG-DYNOS TESTING

RWDI #1701780

August 27, 2018

SUBMITTED TO

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EXECUTIVE SUMMARY

RWDI AIR Inc. (RWDI) was retained by Fiat Chrysler Automobiles (FCA) US LLC (FCA) to complete the emission sampling program at their Mack Avenue Engine Plant (MAEP) located at 11570 Warren Avenue East, Detroit, Michigan. MAEP operates an engine manufacturing plant that produces 3.0-liter, 3.2-liter and 3.6-liter Pentastar V-6 engines for Chrysler, Dodge, Jeep vehicles and other related vehicles. MEAP operates up to three (3) dynamometer test cells (EU-DYNO1, EU-DYNO2, and EU-DYNO3) to complete engine performance testing on engines using unleaded gasoline.

The test program included measurements of carbon monoxide (CO), nitrogen oxides (NOx), VOCs (as propane), benzene, 1,3-butadiene and formaldehyde concentrations and emission rates from one (1) of the three (3) engine dynamometer test cells under FG-DYNOS as required in the Renewable Operating Permit issued by the State of Michigan Department of Environmental Quality (MDEQ) (Permit Number MI-ROP-M4085-2015a). Testing was successfully completed on June 14th, 15th, and 28th, 2018.

The tables below present a summary of the results from each parameter.

Table 1: Nitrogen Oxides Results - EU-DYNO1

Test #	NOx (ppm)	NOx (lb/test)	Fuel Per Test (gal)	lb of NOx/gal Fuel
T1	721.4	1.51	3.3	0.46
T2	644.7	1.42	3.4	0.42
T3	730.7	1.57	3.3	0.47
Average	**698.9**	**1.50**	**3.3**	**0.45**

Table 2: Carbon Monoxide Results - EU-DYNO1

Test #	CO (ppm)	CO (lb/test)	Fuel Per Test (gal)	lb of CO/gal fuel
T1	2551	2.28	3.3	0.68
T2	3611	4.23	3.5	1.20
T3	4300	4.59	3.6	1.28
Average	**3488**	**3.70**	**3.5**	**1.05**

Table 3: VOC's (THC as Propane) Results - EU-DYNO1

Test #	THC (ppm)	THC (lb/test)	Fuel Per Test (gal)	lb of THC/gal Fuel
T1	70.7	0.10	3.3	0.030
T2	67.2	0.12	3.5	0.035
T3	92.3	0.16	3.6	0.043
Average	**76.8**	**0.13**	**3.5**	**0.036**

Table 4: Formaldehyde Results - EU-DYNO1

Test #	Form. (mg/m^3)	Form. (lb/test)	Fuel Per Test (gal)	lb of Form/gal fuel
T1	1.7	0.0020	3.6	0.00056
T2	13	0.0131	3.5	0.0038
T3	3.1	0.0034	3.3	0.00102
Average	**5.9**	**0.0062**	**3.5**	**0.0018**

Table 5: Benzene Results - EU-DYNO1

Test #	Benzene (mg/m^3)	Benzene (lb/test)	Fuel Per Test (gal)	lb of Benzene/gal fuel
T1	6.0	0.015	7.0	0.0022
T2	7.1	0.016	7.1	0.0022
T3	7.1	0.016	6.8	0.0023
Average	**6.7**	**0.016**	**6.9**	**0.0022**

Table 6: 1,3-Butadiene Results - EU-DYNO1

Test #	1,3-Butadiene (mg/m^3)	1,3 Butadiene (lb/test)	Fuel Per Test (gal)	lb of 1,3-Butadiene/gal fuel
T1	0.16	0.00064	10.4	0.000061
T2	0.16	0.00053	10.5	0.000050
T3	0.17	0.00055	10.2	0.000054
Average	**0.16**	**0.00057**	**10.4**	**0.000055**

1 INTRODUCTION

RWDI AIR Inc. (RWDI) has been retained by Fiat Chrysler Automobiles (FCA) US LLC (FCA) to complete the emission sampling program at their Mack Avenue Engine Plant (MAEP) located at 11570 Warren Avenue East, Detroit, Michigan. The emission sampling program completed on June 14th, 15th, and 28th, 2018 included measurements of carbon monoxide (CO), nitrogen oxides (NOx), VOCs (as propane), benzene, 1,3-butadiene and formaldehyde concentrations and emission rates from one (1) of the three (3) engine dynamometer test cells under FG-DYNOS as noted in the Renewable Operating Permit issued by the State of Michigan Department of Environmental Quality (MDEQ) (Permit Number MI-ROP-M4085-2015a). RWDI also completed flue gas velocity measurements and moisture content measurements for each set of tests completed. RWDI utilized the methods outlined by the United States Environmental Protection Agency (U.S. EPA) Methods 1, 2, 3, 4, 3A, 7E, 10, 25A, CARB Method 430 and SW-846 Method 0030.

Table 7: Test Personnel

Company	Position	Individual
RWDI	Project Supervisor	Brad Bergeron
RWDI	Senior Technician	Kirk Easto
RWDI	Field Technician	Matthew Lantz
RWDI	Field Technician	Steve Sanderson
FCA Mack Engine	Environmental Specialist	Keith Jones
FCA Corporate Office	Air Compliance Manager	Rohit Patel

2 PLANT AND SOURCE DESCRIPTION

2.1 Plant Overview

MAEP operates an engine manufacturing plant that produces 3.0-liter, 3.2-liter and 3.6-liter Pentastar V-6 engines for Chrysler, Dodge, Jeep vehicles and other related vehicles. MAEP operates up to three (3) dynamometer test cells (EU-DYNO1, EU-DYNO2, and EU-DYNO3) to completing engine performance testing on engines using unleaded gasoline. The dynamometer test cells fall under FG-DYNOS Flexibility Group Condition. There are no controls associated with these dynamometer test cells.

Table 8: Emission Unit Description

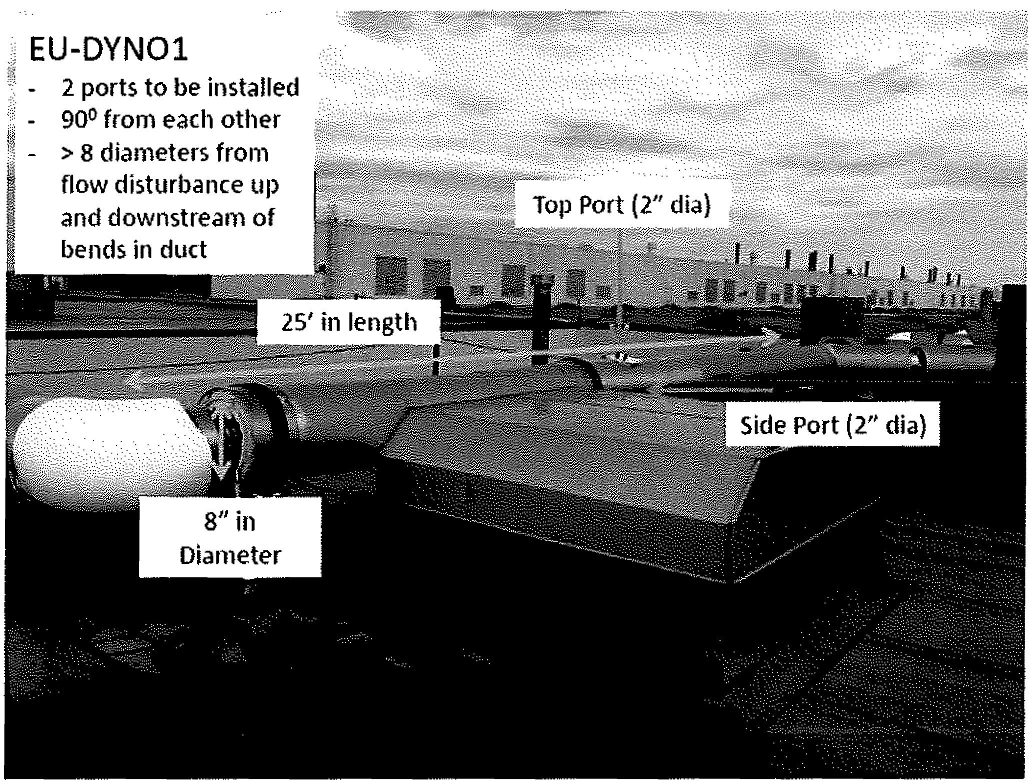
Units	Capacity
FG-DYNOS	Three (3) dynamometer engine test cells for engines burning unleaded gasoline. No controls are in place for the dynamometer test cells.

3 SAMPLING LOCATION

The outlet sampling locations of the three (3) dynamometer engine test cells under FG-DYNOS are located on the roof level that discharge to exhaust stacks that were not suitable for collection of the stack gas. Therefore, RWDI completed the sampling from the duct runs that are between the Dyno cells and the exhaust stack. EU-DYNO1 had the longest duct run with the most ideal sampling locations for testing and was selected as the Dyno for the testing campaign. All Dynos duct diameter were 9" and had two (2) sampling ports, 90 degrees apart and 2 inches in diameter installed on the duct runs. The sampling ports were located more than 8 duct diameters up and downstream of any flow disturbances for EU-DYNO1.

The photo below outlines the sampling location

Figure 1: Sampling Location



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4 REFERENCE METHOD SAMPLING

The following table outlines the test parameters, methods and applicable analytical methods for this source testing program. Testing was conducted on one (1) dynamometer at MAEP (EU-DYNO1). The testing consisted of three (3) 43-minute tests for each of volatile organic compounds (VOCs), formaldehyde, carbon monoxide (CO) and nitrogen oxide (NOx) at the outlet of the source. In discussion with MDEQ, the 43-minute test was deemed to be acceptable since the test duration was equal to one (1) test cycle time for the engine performance test.

For Benzene and 1,3-Butadiene, longer test durations (approximately 2-hours) were required as per SW-846 – Method 0031. Since the SW-846 Method 0031 requires the media (tubes) to be changed out every 40 minutes, it was agreed to complete the Benzene and 1-3-Butadiene testing over three (3) engine performance cycles per test. Therefore, in order to complete three (3) 2-hour tests for Benzene and 1-3-Butadiene, a total of nine (9) engine performance tests were tested.

In addition, RWDI also completed exhaust flow determination for each source (consistent with U.S.EPA Methods 1 to 4). Note that Oxygen and Carbon Dioxide also consisted of real-time measurements as per U.S. EPA Method 3A.

Table 9: Summary of Sampling Methodologies

Parameter	Method	Analytical Method
Exhaust Gas Flow Rates	USEPA Methods 1 & 2	Field data analysis and reduction.
Molecular Weight	USEPA Method 3	Field data analysis by electrochemical cell procedure.
Moisture Content	USEPA Method 4	Field data analysis by impingers.
Oxygen / Carbon Dioxide	USEPA Method 3A	Paramagnetic Analyzer
Carbon Monoxide	USEPA Method 10	Non- Dispersive Infrared Detector
Nitrogen Oxide (NOx)	USEPA Method 7E	Gas Phase Chemiluminescence
Volatile Organic Compounds (VOCs)	USEPA Method 25A	Flame Ionization Detection
Formaldehyde	CARB Method 430	High Performance Liquid Chromatography
Benzene and 1,3-Butadiene	SW-846 - Method 0031	Gas Chromatography

Notes: USEPA Method 1, "Sample and Velocity Traverses for Stationary Sources" and Method 2, "Determination of Stack Velocity and Flowrate (Type-S Pitot Tube)" will be used to measure exhaust gas flowrates.

USEPA Method 3, "Gas Analysis for Carbon Dioxide, Oxygen, Excess Air, and Dry Molecular Weight," will be used to measure exhaust gas molecular weight (electrochemical cell procedure).

USEPA Method 4, "Determination of Moisture Content in Stack Gases," (1 trial for each source at a minimum of 21 ft3).

USEPA Method 3A, "Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrument Analyzer Procedure)", will be used to determine Oxygen.

USEPA Method 10, "Determination of Carbon Monoxide Concentrations in Emissions from Stationary Sources (Instrument Analyzer Procedure)", will be used to Carbon Monoxide.

USEPA Method 7E, "Determination of Nitrogen Oxides Emissions from Stationary Sources", will be used to determine NOx.

USEPA Method 25A, "Determination of Total Gaseous Organics using a Flame Ionization Detector", will be used to determine VOCs.

CARB Method 430 "Determination of Formaldehyde and Acetaldehyde in Emissions from Stationary Sources: will be used to determine Formaldehyde.

SW-846 Method 0031 "Sampling Method for Volatile Organic Compounds" will be used to determine Benzene and 1,3-Butadiene.

4.1 Stack Velocity, Temperature, and Volumetric Flow Rate Determination

The exhaust velocities and flow rates were determined following the US EPA Method 2, "Determination of Stack Gas Velocity and Flow Rate (Type S Pitot Tube)". Velocity measurements were taken with a pre-calibrated S-Type pitot tube and incline manometer. Volumetric flow rates were determined following the equal area method as outlined in US EPA Method 2. Temperature measurements were made simultaneously with the velocity measurements and were conducted using a chromel-alumel type "k" thermocouple in conjunction with a digital temperature indicator.

The dry molecular weight of the stack gas was determined following calculations outlined in US EPA Method 3, "Determination of Molecular Weight of Dry Stack Gas". Stack moisture content was determined through direct condensation and according to US EPA Method 4, "Determination of Moisture Content of Stack Gas". Moisture was collected at a single point during each test. Sampling for Nitrogen Oxides (NO_x), Carbon Monoxide (CO), Oxygen (O_2) and Carbon Dioxide (CO_2).

4.2 Sampling for Nitrogen Oxides, Carbon Monoxide, Oxygen and Carbon Dioxide

Carbon Monoxide, nitrogen oxides, oxygen and carbon dioxide concentrations were determined utilizing RWDI's continuous emissions monitoring (CEM) system.

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 is 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 a test run.

Zero and upscale calibration checks were conducted both before and after each test run in order 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 probe tip was equipped with a sintered stainless-steel filter for particulate removal. The sample was withdrawn from a single point at the center of the stack. The stainless-steel filter is 6 inches in length. Due to the small duct size (9 inches) testing with the 6-inch filter allowed sample to be drawn evenly across the centroid of the stack. 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 is designed to maintain the gas temperature above 250°F in order to prevent condensation of stack gas moisture within the line.

Before entering the analyzers, the gas sample passed directly into a refrigerated condenser, which cooled 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 CO, O_2, CO_2, and NO_x analyzers. Each of these analyzers measured the respective gas concentrations on a dry volumetric basis. NO_x sampling was completed on June 15th, 2018 and CO sampling was completed on June 28th, 2018. As per discussions with MDEQ a final CO calibration check was completed with a high range calibration gas (8.88%) the analyzer response was within the acceptable criteria.

4.3 Sampling for Volatile Organic Compounds (VOC) (EPA Method 25A)

VOC testing was performed on the outlet of EU-DYNO1. The measurements were taken continuously following the USEPA Method 25A on the outlet for total hydrocarbons (as propane).

Testing consisted of three (3) 43-minute tests on FG-DYNO1. Regular performance checks on the CEM were carried out by zero and span calibration checks using USEPA Protocol calibration gases. These checks verified the ongoing precision of the monitor with time by introducing pollutant-free (zero) air followed by known calibration gas (span) into the monitor. The response of the monitor to pollutant-free air and the corresponding sensitivity to the span gases were reviewed frequently as an ongoing indication of analyser performance. Total Hydrocarbon (THC) (as propane) testing was completed on June 28th, 2018.

4.4 Sampling for Formaldehyde

Sampling for formaldehyde was conducted following procedures outlined in CARB Method 430. Gaseous emissions were drawn through a Teflon sample line and two impingers in series, each impinger containing an aqueous acidic solution of 2,4-dinitrophenyl-hydrazine (DNPH). The sample line was rinsed with another aliquot of the same solution. An aldehyde reacts with DNPH by nucleophilic addition on the carbonyl followed by 1,2-elimination of water and the formation of a 2,4-dinitrophenylhydrazone. Acid is required to promote protonation of the carbonyl because DNPH is a weak nucleophile.

After organic solvent extraction, the sample was analyzed using reverse phase High Pressure Liquid Chromatography (HPLC) with an ultraviolet (UV) absorption detector operated at 360 nm. Impingers were analyzed separately.

Triplicate samples were collected at a sampling rate of 0.3 L/min. Stack gas was collected for one engine cycle or 43 minutes. During Test 3 a train spiked with 25 ug of formaldehyde was run in parallel with the Test 3 normal train (duplicate). The duplicate train had an emission rate of 0.58 mg/s and the spiked train had an emission rate of 0.92 mg/s. Both trains sampled stack gas at the same time.

4.5 Sampling for Benzene and 1,3-Butadiene

Sampling for Benzene and 1,3-Butadiene was conducted using a volatile organic sampling train (SMVOC) following U.S. EPA SW846 Method 0031. Sample gas was collected on a set of adsorbent tubes, the first two (2) containing Tenax®-GC, and the third containing Anasorb®-747. No visible condensate was built up in the knock out flask located after the first tube therefore the knock out flask was not recovered for analysis.

Sampling was conducted following the SLO-SMVOC suggested by the method for compounds with lower boiling points. Each set of tubes were sampled over a 43-minute period at 0.5 L/min (coincidentally corresponding to the approximate cycle times). Three sets made up a single test covering three (3) process cycles. A total of nine (9) process cycles were tested during this test period.

4.5.1 Modification

For the Benzene results, the laboratory ran the first set of tubes in each of the tests and noted that the sample concentration was over-ranged for Benzene. As a result, the 2nd and 3rd tubes for each test were run with a higher dilution. Based on the results for the 1st set of tubes for Benzene, this set was excluded from each of the overall test results. Therefore, concentration and emission rate estimates were based on the 2nd and 3rd set of tubes only. With the exclusion of the 1st set of tubes from each test for Benzene, the total sample volume and total amount of fuel used was adjusted according. 1,3-Butadiene was not detected in the samples and therefore all three (3) sets of tubes were used in the concentration and emission rate calculations are originally proposed.

5 QUALITY ASSURANCE/QUALITY CONTROL ACTIVITIES

Applicable quality assurance measures were implemented during the sampling program to ensure the integrity of the results. These measures included detailed documentation of field data, equipment calibrations for all measured parameters, completion of Chain of Custody forms when submitting laboratory samples, and submission of field blank samples to the laboratories.

All samplers are bench tested and calibrated in RWDI's office prior to field deployment and, in many cases, calibrated again in the field before use. For the Benzene, 1,3-Butadiene and Formaldehyde sampling trains, both pre- and post- leak checks were conducted by plugging the inlet and drawing a vacuum of 380 mm of water for at least one minute. Dry gas meter reading leakage rates greater than 4 percent of the average sampling rate or 0.00057 m^3/min (0.02 cfm), whichever is less, are unacceptable. Similar leak check procedures for the Pitot tube and pressure lines were conducted. A set of blanks for each parameter were submitted for analyses as well.

Chain of custody forms were completed and submitted along with the samples to the laboratory. All sampling media was provided or prepared by the laboratory responsible for its subsequent analysis.

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 a test run.

6 RESULTS

The average emission results for this study are presented in the tables below. Detailed information regarding each test run can be found in Appendix B-E.

Table 1: Nitrogen Oxides Results - EU-DYNO1

Test #	NOx (ppm)	NOx (lb/test)	Fuel Per Test (gal)	lb of NOx/gal Fuel
T1	721.4	1.51	3.3	0.46
T2	644.7	1.42	3.4	0.42
T3	730.7	1.57	3.3	0.47
Average	**698.9**	**1.50**	**3.3**	**0.45**

Table 2: Carbon Monoxide Results - EU-DYNO1

Test #	CO (ppm)	CO (lb/test)	Fuel Per Test (gal)	lb of CO/gal fuel
T1	2551	2.28	3.3	0.68
T2	3611	4.23	3.5	1.20
T3	4300	4.59	3.6	1.28
Average	**3488**	**3.70**	**3.5**	**1.05**

Table 3: VOC's (THC as Propane) Results - EU-DYNO1

Test #	THC (ppm)	THC (lb/test)	Fuel Per Test (gal)	lb of THC/gal Fuel
T1	70.7	0.10	3.3	0.030
T2	67.2	0.12	3.5	0.035
T3	92.3	0.16	3.6	0.043
Average	**76.8**	**0.13**	**3.5**	**0.036**

Table 4: Formaldehyde Results - EU-DYNO1

Test #	Form. (mg/m^3)	Form. (lb/test)	Fuel Per Test (gal)	lb of Form/gal fuel
T1	1.7	0.0020	3.6	0.00056
T2	13	0.013	3.5	0.0038
T3	3.1	0.0034	3.3	0.00102
Average	**5.9**	**0.0062**	**3.5**	**0.0018**

Table 5: Benzene Results - EU-DYNO1

Test #	Benzene (mg/m^3)	Benzene (lb/test)	Fuel Per Test (gal)	lb of Benzene/gal fuel
T1	6.0	0.015	7.0	0.0022
T2	7.1	0.016	7.1	0.0022
T3	7.1	0.016	6.8	0.0023
T1	**6.7**	**0.016**	**6.9**	**0.0022**

Table 6: 1,3-Butadiene Results - EU-DYNO1

Test #	1,3-Butadiene (mg/m^3)	1,3 Butadiene (lb/test)	Fuel Per Test (gal)	lb of 1,3-Butadiene/gal fuel
T1	0.16	0.00064	10.4	0.000061
T2	0.16	0.00053	10.5	0.000050
T3	0.17	0.00055	10.2	0.000054
Average	**0.16**	**0.00057**	**10.4**	**0.000055**

7 CONCLUSIONS

The purpose of the study was to perform the emission sampling program on EU-DYNO1per FCA Mack Avenue Engine Plant Renewable Operating Permit (ROP) MI-ROP-M4085-2015a. The sampling program included measurements of carbon monoxide (CO), nitrogen oxides (NO_x), VOCs (as propane), benzene, 1,3-butadiene and formaldehyde concentrations and emission rates. All contaminants were successfully sampled on June 14th, 15th and 28th, 2018 while the EU-DYNO1 was operating at standard operating procedures. All parameters were sampled in accordance with US EPA referenced methodologies.