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Exponent®

Expert Report of Dr. Michael E. Cundy

[redacted] v Ford

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Prepared for:
Joel A. Dewey, Esq.
DLA Piper LLP
The Marbury Building
6225 Smith Ave.
Baltimore, Maryland 21209-3600

Prepared by:
Michael E. Cundy, Ph.D., P.E.

Exponent

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Qualifications and Report Organization

1 My name is Michael Cundy; I am a Senior Engineer at Exponent Inc., a technical and scientific consulting firm. I received a Bachelor of Science degree from The Ohio State University, and Master's and Doctoral degrees in Mechanical Engineering from the University of Michigan. My Curriculum Vitae is included and attached in Appendix A, which includes lists of all publications and presentations authored by me. Currently, Exponent charges $235 per hour for my work in this matter. I have not testified previously in deposition or trial. A list of materials reviewed or relied upon are shown in Appendix B.

2 I am a registered Professional Engineer in the State of Arizona (license #55526). During the course of my employment at Exponent, I have specialized in the application of mechanical engineering principles to the analysis and investigation of thermal, combustion, and fluid processes in various systems, including systems in prototype and production vehicles.

3 My work at the University of Michigan and General Motors was on the development of a direct-injection stratified charge gasoline engine. During the course of this research, I studied air flow, fuel concentration, and temperature fields in engines to better understand combustion performance and stability. This included evaluating engine output and exhaust products under different operating conditions. I utilized a lambda meter to evaluate the fuel-to-air ratio, which affects the composition of exhaust products, including carbon monoxide (CO) concentration.

4 From 2003-2005, I carried out research in the Non-equilibrium Thermodynamics Laboratory at The Ohio State University on a project funded by the U.S. Air Force. I investigated whether a technology called the magneto-hydrodynamic (MHD) force could be used for flow control on supersonic vehicles, such as on the wings of a supersonic jet, to affect how the flow moves around the vehicle. More specifically, I was looking to see if the technology could delay the laminar to turbulent transition point to reduce skin friction, thereby making the vehicle more fuel efficient. I developed laser diagnostics to measure density fluctuations in the boundary layer in this analysis.

5 While in the Quantitative Laser Diagnostics Laboratory at the University of Michigan, I studied fluid flow in internal combustion engine cylinders. I developed and applied particle image velocimetry (PIV) laser diagnostics to measure flow velocity fields (i.e. two dimensional flow maps) at high-speeds in engine cylinders. I applied these diagnostics to test engines at the University of Michigan W. E. Lay Automotive Laboratory, and at the General Motors Research & Development Center. Flow fields were measured at various operating conditions, and the results were made available to develop engine computational models.

6 In other work at the University of Michigan, I developed laser diagnostics to measure fuel concentration at high-speeds in an internal combustion engine cylinder, and utilized this technique along with a spark plug absorption probe which measured fuel concentration and combustion products.

7 My analyses and opinions are based on research I have conducted, case related information I have reviewed as of the date of this report, and my training and experience. My opinions are

established to a reasonable level of engineering certainty. I will consider additional information as appropriate and I may modify or supplement this report based upon any additional work that I may conduct or supervise in review of, analysis of, or response to additional information I receive or review.

8 At this time, I expect to use the tables and figures in this report, all technical references and materials reviewed for this report, inspections and testing results and physical models to illustrate as exhibits at the trial of this matter. Also, I expect to use my Declaration, executed on July 8, 2015, which is attached as Appendix D in this report.

9 I was asked by counsel for Ford Motor Company to perform the following tasks and tests:

A Obtain and document 2011 to 2015 model year Ford Explorers, including vehicles having records of odor complaints ("Complaint Explorers") and vehicles without records of odor complaints ("Non-complaint Explorers").
B Document the condition and performance of the rear seal, and photograph the presence or absence of condensate drain hole valves in the rear hatch.
C Measure CO levels and pressure differences between the cabin interior and outside the rear liftgate, near the latch, of several vehicles while following a consistent route, and with the HVAC systems on max air conditioning (AC), recirculation mode. The vehicles to be tested were 2011 to 2015 model year Complaint and Non-complaint Explorers, and peer contemporaneous mid-size SUVs.
D Measure pressure difference and CO levels at different locations within the interior and exterior of Complaint Explorers under different driving conditions with the HVAC system on max AC, recirculation mode.
E Document the response of the air extractors on stationary Complaint Explorers when the cabin pressure is reduced below ambient.

10 This report is organized into four sections:

A Qualifications and Report Organization

B Case Background

C Peer Vehicle Testing

D Observations, Conclusions, and Opinions

E My CV, including a list of publications and presentations authored by me, is included in Appendix A. The materials reviewed are listed in Appendix B. Additional test data and test observations are provided in Appendix C. My Declaration, executed on July 8, 2015, is attached as Appendix D in this report.

Case Background

A summary of the case background is provided in Mr [redacted] report.

Vehicle Testing

11 All vehicles were tested on the same test route in order to evaluate and compare the pressure difference that develops between the cabin and the outside rear of the vehicle and CO concentrations. The following measurements and features were evaluated:

A Measurement of CO levels inside the occupant compartment, typically in the driver location between the headrest and the seat back and in the rear-most seating row. In vehicles with a dual exhaust, the monitor was placed on the rear-most seating row on the left (driver's) side. On vehicles which only had an exhaust on the right (passenger's) side, the monitor was placed on the rear-most seating row on the right side.

B Measurement of vehicle metrics including speed and accelerator pedal positions.

C Measurement of the pressure differential between the cabin hatch cargo area and the external pressure near the latch on the liftgate.

12 Additional testing was performed with the same measurement instruments, data acquisition systems, video camera, GPS, and gas monitors, and with the same driving characteristics, but on different routes, with additional CO monitors and pressure transmitters, and with different measurement locations.

13 Tests were also performed on select vehicles to evaluate the response of the air extractors when the vehicles were stationary and a vacuum cleaner was used to create a lower pressure inside the cabin compared to ambient (hereafter defined as "negative pressure").

14 Testing from an earlier campaign is described in my Declaration, executed July 8, 2015, which is attached as Appendix D to this document.

<u>Vehicle Selection</u>

15 The peer vehicles were selected based on the criteria described in Mr. [redacted] report. The vehicles tested are shown in Table 1.

Table 1: Vehicles tested.

Note	Model Year	Make	Model	Generation	VIN
Complaint	2014	Ford	Explorer	2011-2015	1FM5K8GT0EG[redacted]
Dixon	2013	Ford	Explorer	2011-2015	1FM5K7D87DG[redacted]
Peer	2015	Dodge	Durango	2011-2016	1C4RDJDG2FC[redacted]
Peer	2015	Nissan	Pathfinder	2013-2016	5N1AR2MN5F[redacted]
Peer	2016	Toyota	4Runner	2010-2016	JTEZU5JR4G5[redacted]
Peer	2015	Jeep	Grand Cherokee	2011-2016	1C4RJEAG4FC[redacted]
Peer	2016	Chevrolet	Traverse	2009-2016	1GNKRHKD9G[redacted]
Peer	2014	Toyota	Highlander	2014-2016	5TDZARFH1ES[redacted]
Peer	2011	Honda	Pilot	2009-2015	5FNYF3H44BB[redacted]
Non-complaint	2015	Ford	Explorer	2011-2015	1FM5K7F82FG[redacted]
Non-complaint	2013	Ford	Explorer	2011-2015	1FM5K8D85DG[redacted]

<u>Pre-Drive Cycle Vehicle Inspections and Vehicle History</u>

16 Test vehicles were inspected and documented to determine their condition, HVAC system controls and venting, and liftgate sealing. Underbody seam sealing was evaluated on Ford Explorers.

17 The 2014 Ford Explorer Sport with VIN 1FM5K8GT0EG[redacted] was a vehicle that was repurchased by Ford because of complaints, and offered to Exponent for testing (Figure 1; hereafter referred to as the Complaint 2014 Ford Explorer). The odometer read 9,557.7 miles at the start of testing. The vehicle was equipped with a twin turbo V6. It appeared to be in good operating condition with no evidence found of current or prior collision damage. The Carfax report was clean. No diagnostic trouble codes (DTCs) were found. Technical Service Bulletin (TSB) 14-0130 had been performed prior to testing. The rubberized undercoating and sealant found on the underbody seams forward of the rear bumper and the condensate drain valves installed in the liftgate can be seen in Figure 3.

18 This vehicle had rear HVAC control and third row seating. A gas monitor was mounted under the driver headrest and on the third row driver side headrest as shown in Figure 4 and Figure 5.

Figure 1. 2014 Ford Explorer Sport VIN 1FM5K8GT0EG[redacted]

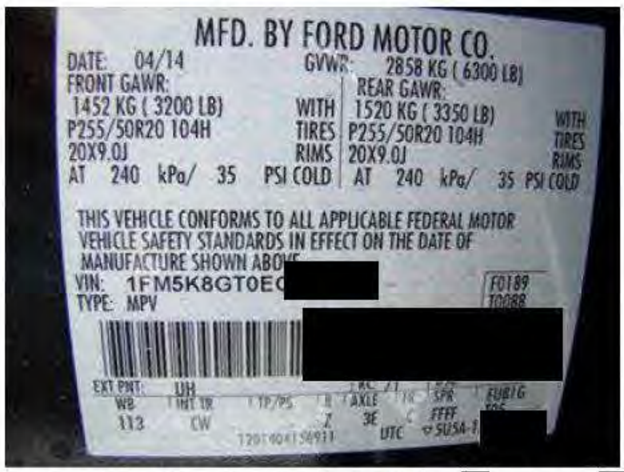

Figure 2. VIN plate for 2014 Ford Expl[redacted]er Sport [redacted].

Figure 3. Underbody seam sealant and liftgate valve applied per TSB 14-0130 to 2014 Ford Explorer 3986.

Figure 4. Gas monitor mounted under driver headrest on 2014 Ford Explorer [redacted]. The calibration check mark is shown at right.

Figure 5. Gas monitor mounted under third row driver side headrest on 2014 Ford Explorer [redacted] The calibration check mark is shown at right.

19 The 2013 Ford Explorer XLT with VIN 1FM5K7D87DG[redacted] was a Complaint Explorer (Figure 6) previously owned by Dixon (hereafter referred to as the [redacted] 2013 Ford Explorer). The odometer read 35,410.1 miles at the start of testing. The vehicle was equipped with a V6. It was visually in good operating condition with no evidence found of current or prior collision damage. The Carfax report was clean. No diagnostic trouble codes (DTCs) were found. Warranty records indicate that TSB 14-0130 had been performed on the vehicle. However, as will be discussed later in the report, there was evidence suggesting that the work was incomplete. For example, there was a lack of sealant on the underbody lap joints forward of the rear bumper (Figure 8).

20 This vehicle had rear HVAC control and third row seating. A gas monitor was mounted under the driver headrest and on the third row driver side headrest as shown in Figure 9 and Figure 10.

Figure 6. Dixon 2013 Ford Explorer XLT VIN 1FM5K7D87DG[redacted].

Figure 7. VIN plate for Dixon 2013 Ford Explorer[redacted].

Figure 8. Lack of underbody seam sealant and liftgate valves on the [redacted] 2013 Ford Explorer 1363. Note the missing liftgate bumper in the right photograph.

Figure 9. Gas monitor mounted under driver headrest on Dixon 2013 Ford Explorer 1363. The calibration check mark is shown at right.

Figure 10. Gas monitor mounted under third row driver side headrest on [redacted] 2013 Ford Explorer [redacted] The calibration check mark is shown at right.

21 The 2015 Dodge Durango Limited with VIN 1C4RDJDG2FC[redacted] had an odometer reading of 2,679 miles at the start of testing (Figure 11). The vehicle was equipped with a V6. It was visually in good operating condition with no evidence found of current or prior collision damage. The Carfax report was clean. No diagnostic trouble codes (DTCs) were found. Some underbody seams were sealed while others were left bare. The liftgate had three drain holes at its lower edge which were not plugged (Figure 13).

22 This vehicle had rear HVAC control and third row seating. A gas monitor was mounted under the driver headrest and on the third row passenger side headrest, due to a passenger side exhaust pipe, as shown in Figure 14 and Figure 15.

Figure 11. 2015 Dodge Durango VIN 1C4RDJDG2FC[redacted].

Figure 12. VIN plate for 2015 Dodge Durango[redacted].

Figure 13. 2015 Dodge Durango [redacted]. Intermittent underbody sealant at left. Open drain holes on the left, middle, and right sides at the latch end of the liftgate (top of photo).

Figure 14. Gas monitor mounted under driver headrest on 2015 Dodge Durango [redacted] The calibration check mark is shown at right.

Figure 15. Gas monitor mounted under third row driver side headrest on 2015 Dodge Durango [redacted]. The calibration check mark is shown at right.

23 The 2015 Nissan Pathfinder with VIN 5N1AR2MN5FC[redacted] had an odometer reading of 16,149 miles at the start of testing (Figure 16). The vehicle was equipped with a V6. It was visually in good operating condition with no evidence found of current or prior collision damage. The Carfax report was clean. No diagnostic trouble codes (DTCs) were found. Some underbody seams were sealed while others were left bare. The liftgate had two drain holes at its lower edge which were not plugged (Figure 18).

24 This vehicle had rear HVAC control and third row seating. A gas monitor was mounted under the driver headrest and on the third row passenger side headrest, due to a passenger side exhaust pipe, as shown in Figure 19 and Figure 20.

Figure 16. 2015 Nissan Pathfinder VIN 5N1AR2MN5FC[redacted].

Figure 17. 2015 Nissan Pathfinder [redacted] VIN plate.

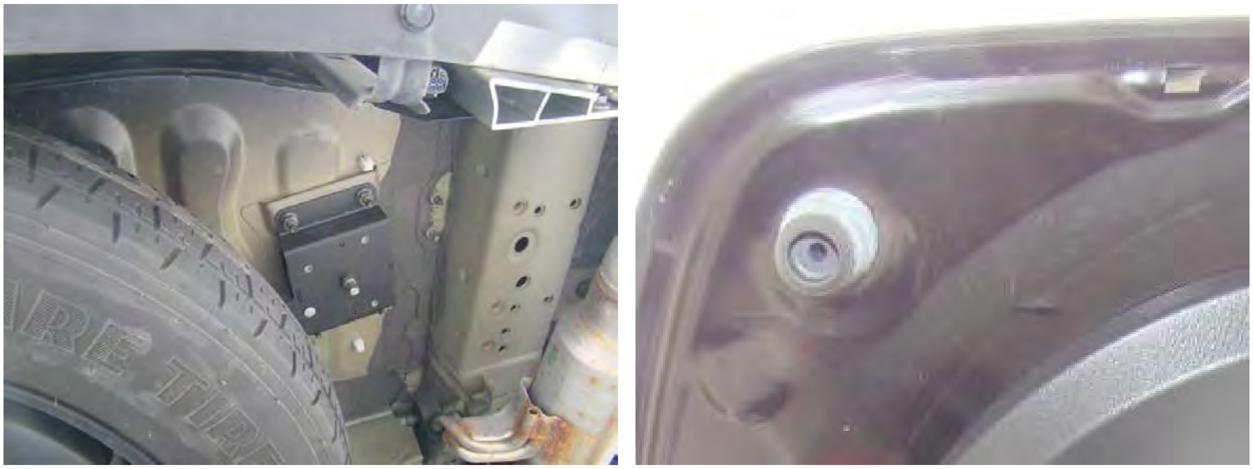

Figure 18. 2015 Nissan Pathfinder 0146. Intermittent underbody sealant at left. Open drain holes at the latch end of the liftgate (right photo, left side drain hole shown).

Figure 19. Gas monitor mounted under driver headrest on 2015 Nissan Pathfinder 0146. The calibration check mark is shown at right.

Figure 20. Gas monitor mounted under third row driver side headrest on 2015 Nissan Pathfinder [redacted]. The calibration check mark is shown at right.

25 The 2016 Toyota 4Runner with VIN JTEZU5JR4G5[redacted] had an odometer reading of 3,621 miles at the start of testing (Figure 21). The vehicle was equipped with a V6. It was visually in good operating condition with no evidence found of current or prior collision damage. The Carfax report was clean. No diagnostic trouble codes (DTCs) were found. The vehicle has a body on frame design and most underbody seams near the rear bumper were not visible, but some appeared to be sealed. The liftgate had three drain holes at its lower edge which were plugged (Figure 23; note that the 2013 model year vehicle in Mr. Robert C. Lange's report did not have plugged drain holes).

26 This vehicle did not have rear HVAC control but did have third row seating. A gas monitor was mounted under the driver headrest and on the third row passenger side headrest, due to a passenger side exhaust pipe, as shown in Figure 24 and Figure 25.

Figure 21. 2016 Toyota 4Runner VIN JTEZU5JR4G5[redacted].

Figure 22. 2016 Toyota 4Runner [redacted] VIN plate.

Figure 23. 2016 Toyota 4Runner [redacted]. Underbody sealant at left. Plugged drain holes on the left, middle, and right sides at the latch end of the liftgate (top of photo).

Figure 24. Gas monitor mounted under driver headrest on 2016 Toyota 4Runner [redacted]. The calibration check mark is shown at right.

Figure 25. Gas monitor mounted under third row driver side headrest on 2016 Toyota 4Runner [redacted]. The calibration check mark is shown at right.

27 The 2015 Jeep Grand Cherokee Laredo with VIN 1C4RJEAG4[redacted] had an odometer reading of 7,602 miles at the start of testing (Figure 26). The vehicle was equipped with a V6. It appeared to be in good operating condition with no evidence found of current or prior collision damage. The Carfax report was clean. No diagnostic trouble codes (DTCs) were found. Some but not all underbody seams near the rear bumper were sealed. The liftgate had three drain holes at its lower edge which were open (Figure 28).

28 This vehicle did not have rear HVAC control, nor did it have third row seating. A gas monitor was mounted under the driver headrest and on the second row passenger side headrest, due to a passenger side exhaust pipe (Figure 29).

Figure 26. 2015 Jeep Grand Cherokee Laredo VIN 1C4RJEAG4F[redacted]

Figure 27. VIN plate for 2015 Jeep Grand Cherokee [redacted]

Figure 28. 2015 Jeep Grand Cherokee[redacted]. Intermittent underbody sealant at left. Open drain holes on the left, middle, and right sides at the latch end of the liftgate (top of photo).

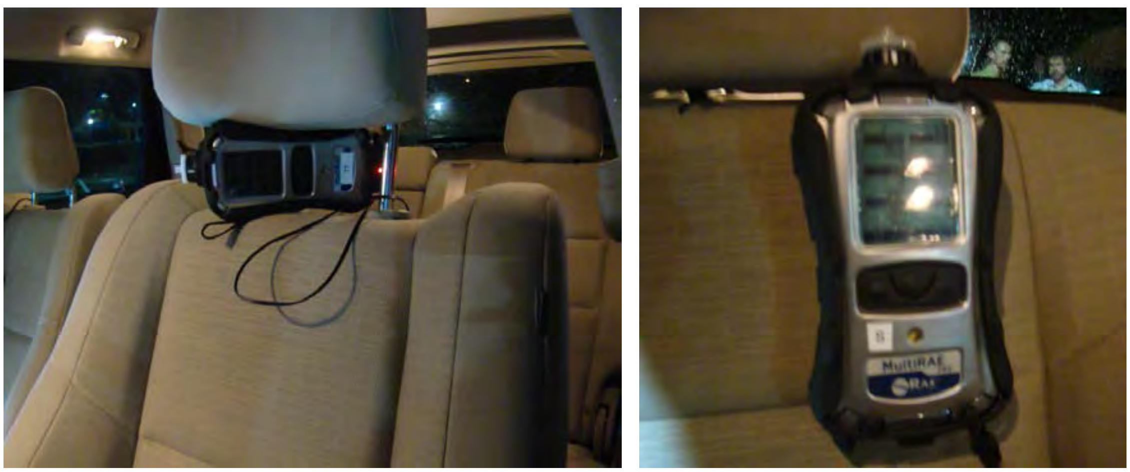

Figure 29: Gas monitor mounted between headrest and seat back in driver's location (left), and second row right side headrest on 2015 Jeep Grand Cherokee [redacted]. The calibration check mark is seen in the image on the right. Calibration logs indicate that the meter on the left is in calibration.

29 The 2016 Chevy Traverse with VIN 1GNKRHKD9GJ1[redacted] had an odometer reading of 9,002 miles at the start of testing (Figure 30). It was equipped with a V6 engine. It was visually in good operating condition with no evidence found of current or prior collision damage. The Carfax report was clean. No diagnostic trouble codes (DTCs) were found. Underbody seams near the rear bumper did not appear to be sealed, but some underbody holes were plugged with a foam sealant. The liftgate had three drain holes at its lower edge. The outer two had check valves, but the central hole was not plugged (Figure 32).

30 This vehicle had rear HVAC control and third row seating. A gas monitor was mounted under the driver headrest and on the third row passenger side headrest, due to a passenger side exhaust pipe.

Figure 30. 2016 Chevy Traverse VIN 1GNKRHKD9GJ[redacted]

Figure 31. 2016 Chevy Traverse 2347 VIN plate.

Figure 32. 2016 Chevy Traverse 2347. Intermittent underbody sealant at left. Plugged drain holes on the left, middle, and right sides at the latch end of the liftgate (top of photo).

31 The 2014 Toyota Highlander with VIN 5TDZARFH1ES[redacted] had an odometer reading of 41,269 miles at the start of testing (Figure 33). The vehicle was equipped with an inline-4

cylinder engine. It was visually in good operating condition. The Carfax report showed a previous sideswipe accident on the passenger side with minor damage (dents and scratches) that appears to have been repaired. No diagnostic trouble codes (DTCs) were found. Underbody seams near the rear bumper appeared to be sealed. The liftgate had three drain holes at its lower edge, the outer two of which were plugged (Figure 35).

32 This vehicle had rear HVAC control and third row seating. A gas monitor was mounted under the driver headrest and on the third row passenger side headrest, due to a passenger side exhaust pipe.

Figure 33. 2014 Toyota Highlander VIN 5TDZARFH1ES[redacted].

Figure 34. 2014 Toyota Highlander [redacted] VIN plate.

Figure 35. 2014 Toyota Highlander 6397. Underbody sealant at left. Outer drain holes are plugged on the left and right sides at the latch end of the liftgate. Middle hole is open (top of photo).

33 The 2011 Honda Pilot with VIN 5FNYF3H44BB[redacted] had an odometer reading of 55,860 miles at the start of testing (Figure 36). The vehicle was equipped with a V6. It was visually in good operating condition with no evidence found of current or prior collision damage. The Carfax report showed two previous rear impact accidents. The damage was reported as "functional" such that the vehicle could be driven away from the accident location. No diagnostic trouble codes (DTCs) were found. Some underbody seams near the rear bumper appeared to be sealed. The liftgate had two drain holes at its lower edge, both of which were plugged with one-way valves (Figure 38).

34 This vehicle had rear HVAC control and third row seating. A gas monitor was mounted under the driver headrest and on the third row driver side headrest.

Figure 36. 2011 Honda Pilot VIN 5FNYF3H44BB[redacted].

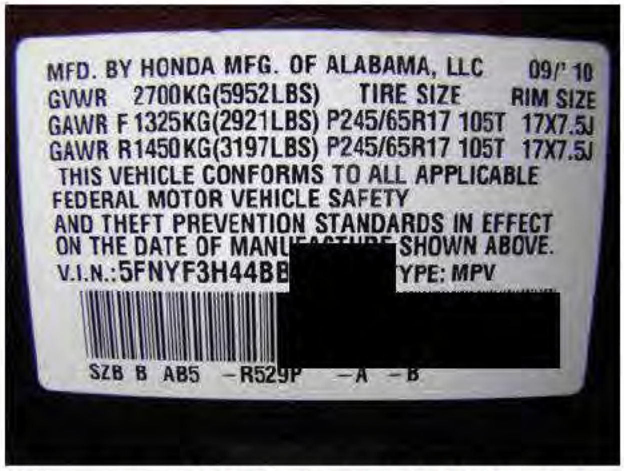

Figure 37. 2011 Honda Pilot 4610 VIN plate.


Figure 38. 2011 Honda Pilo[redacted]. Intermittent underbody sealant at left. Plugged drain holes on the left and right sides at the latch end of the liftgate.

35 The 2015 Ford Explorer Limited with VIN 1FM5K7F82FG[redacted] had an odometer reading of 22,233.2 miles at the start of testing (Figure 39, Figure 40). The vehicle was equipped with a V6. It was visually in good operating condition. The Carfax report showed that the vehicle had been involved in a rear end collision with minor damage. No diagnostic trouble codes (DTCs) were found. There were no warranty records associated with this vehicle. No sealant was observed on the underbody seams forward of the rear bumper (Figure 41).

36 This vehicle had rear HVAC control and third row seating. A gas monitor was mounted under the driver headrest and on the third row driver side headrest.

Figure 39. 2015 Ford Explorer Limited VIN 1FM5K7F82FG[redacted]

Figure 40. 2015 Ford Explorer Limited [redacted] VIN plate.

Figure 41. 2015 Ford Explorer Limited 9474 lack of underbody sealing.

37 The 2013 Ford Explorer XLT with VIN 1FM5K8D85DG[redacted] had an odometer reading of 47,098.9 miles at the start of testing (Figure 42). The vehicle was equipped with a V6. It was visually in good operating condition. The Carfax report showed that the vehicle had been involved in a rear end collision with minor damage. No diagnostic trouble codes (DTCs) were found. There were no warranty records associated with odors or the exhaust system in this vehicle. No sealant was observed on the underbody seams forward of the rear bumper (Figure 44).

38 This vehicle had rear HVAC control and third row seating. A gas monitor was mounted under the driver headrest and on the third row driver side headrest.

Figure 42. 2013 Ford Explorer XLT VIN 1FM5K8D85D[redacted].

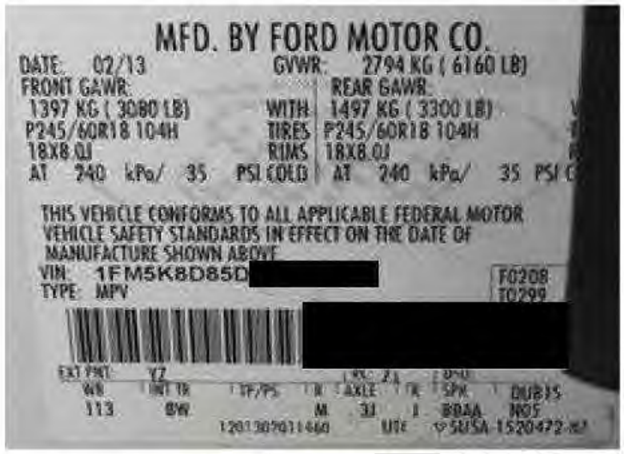

Figure 43. 2013 Ford Explorer [redacted] XLT VIN plate.


Figure 44. 2013 Ford Explorer [redacted] lack of underbody sealing.

Test Drive Cycle and Procedure

39 The driving cycle used for this test series was designed to be representative of Plaintiff [redacted] drive to the fire station at which the CO measurement of 132 ppm in Exhibit A to his Declaration was taken. An overview of the route is shown in Figure 45.

- Because the Plaintiff resides in a gated community, the route started in a retail store parking lot at [redacted]. in Coral Springs, Florida.
- [redacted].

- [redacted]

40 Vehicles were tested with the HVAC on recirculation mode and “Max A/C” selected. On peer vehicles which did not have a “Max A/C” button, the coldest setting with maximum fan speed was used with recirculation mode selected. Rear A/C with maximum fan speed was selected when available. All HVAC vents were opened prior to the test.

41 Vehicles were driven in a responsible fashion with acceleration and braking events necessary for safe traffic flow and generally at legal speeds. However, two opportunities where taken where wide-open throttle (WOT) or full accelerator pedal depression was possible; while merging onto the Sawgrass Expressway and accelerating onto 30th St.

42 Measurements of CO were collected using calibrated RAE Systems MultiRAE Pro, MultiRAE, and MultiRAE Lite gas monitors, sampling and storing data once per second (1 Hz). Each vehicle was instrumented with two gas monitors; one mounted at the front of the occupant compartment between the driver seat headrest and seat back, and one mounted at the rear of the occupant compartment on the third row (2nd row when 3rd row unavailable) headrest on the left side. On vehicles having only one exhaust pipe located on the right side, the monitor was mounted on the right side. At the conclusion of each test, a calibration gas was passed through the gas monitors to demonstrate proper operation.

43 Vehicle performance metrics were measured with an OBDLink MX Bluetooth Diagnostic Scanner. The metrics recorded were vehicle speed, two accelerator pedal position sensor outputs, and barometric pressure.

44 Measurements of the pressure differential between the vehicle occupant compartment and the external pressure behind the rear liftgate near the latch were taken with calibrated Dwyer 677B-15 pressure transmitters, and were recorded at 1 Hz with a calibrated Lascar EL-USB-4 data logger. The pressure transmitter and data logger equipment were mounted in the back of each vehicle on a vertical panel resting on the floor, centered behind the rear-most seat, just forward of the liftgate interior panel. Two sections of PVC tubing, 22.5” long, with an inside diameter of 3/16” were routed under the liftgate, near the hatch latch. Weather stripping was added to the sides of the tubing to seal gaps which may form on each side of the tube as the rear hatch is closed (see Figure 46). One of the tubes was connected to the Dwyer pressure transmitter, and the second tube was connected to a Magnehelic 2302 pressure gage which was used only to verify that the tubes were not pinched prior to the test, when the vehicle was stationary. Using short tube segments of the same lengths in all tests reduced a damping effect and allowed for higher fidelity measurements of turbulence.

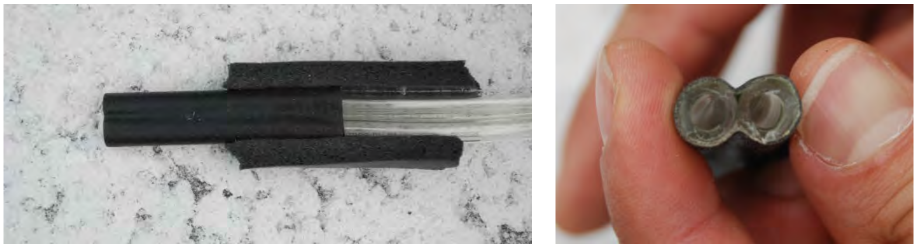

Figure 46: Photographs showing the two 22.5” tubes taped together, and the weather stripping applied to the sides of the tube-bundle to ensure that the hatch seal is not compromised.

45 Test driving was video recorded using Garmin Dash Cam 20 in-car video cameras with GPS loggers. GPS data was collected at 1 Hz.

46 Additional tests were performed on the Complaint 2014 Ford Explorer and the Dixon 2013 Ford Explorer with the same HVAC settings, measurement instruments, data loggers, video cameras, and GPS, but with different routes travelled, multiple CO monitors and pressure transmitters, and with CO monitors and pressure transmitters measuring in different locations.

Test Observations

Comprehensive test data for all of the tests described above can be found in Appendix C. In this section, select observations are presented and discussed.

All Tested Vehicles Developed a Negative Pressure in the Cabin while in Max AC Recirculation or Comparable Modes

The differential pressure transmitters have a positive and a negative pressure port. In this testing, with the pressure transmitter in the hatch cargo area, a tube was connected to the negative port and positioned with the open end outside the vehicle at the back of the lower part of the liftgate, near the latch. Therefore, when the pressure outside the liftgate is lower than the pressure in the cabin, the pressure reading will be positive, and when the pressure outside the liftgate is higher, the pressure reading will be negative. "Negative pressure" is hereafter defined as the case where the interior cabin pressure is lower than the pressure at the outside measurement location.

Dr. Renfroe testified that the exhaust odor problem begins at 30 mph.[1] In his report, he indicates that with the HVAC fan setting on high and in recirculation mode, the negative pressure is -0.1 in H_2O.[2] All of the tested peer vehicles developed a negative pressure of at least -0.1 in H_2O inside the cabin of the vehicle when operated in a max AC, recirculation mode (Table 2) for some periods of time during the testing. The detection of odors in the current testing is noted and described in Appendix C. Briefly, the Chevy Traverse, Toyota Highlander, and Ford Explorers experienced odors, and for two simultaneous Ford Explorer tests, it was unclear if the odors were associated with the Explorers themselves or a heavy duty truck in front of them.

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1 Deposition of David Renfroe, pg. 56.
2 David Renfroe's report, pg. 28.

Table 2: All tests of all vehicles resulted in negative pressures of at least -0.1 in H_2O. Note – pressure was not measured in ID6.

Test ID	Vehicle
1	2015 Nissan Pathfinder SV [redacted]
2	2016 Toyota 4Runner SR5 [redacted]
3	Complaint 2014 Ford Explorer [redacted]
4	Dixon 2013 Ford Explorer XLT [redacted]
5	2015 Dodge Durango Limited [redacted]
7	2015 Nissan Pathfinder SV [redacted]
8	2016 Toyota 4Runner SR5 [redacted]
9	2015 Jeep Grand Cherokee Laredo [redacted]
10	2016 Chevrolet Traverse LT [redacted]
11	2014 Toyota Highlander LE [redacted]
12	2016 Chevrolet Traverse LT [redacted] (non-standard)
13	2011 Honda Pilot [redacted]
14	2015 Ford Explorer Limited [redacted]
15	2013 Ford Explorer XLT [redacted]
16	Complaint 2014 Ford Explorer [redacted] (non-standard)
17	Dixon 2013 Ford Explorer XLT [redacted] (non-standard)

The Negative Pressure and Turbulence Both Become Greater in All of the Tested Vehicles with Increasing Speed

Figure 47 shows a plot of the pressure difference as a function of vehicle speed for the [redacted] 2013 Ford Explorer (test ID4). On average, the negative pressure is shown to become greater with increasing vehicle speed. Additional data for all of the tests illustrating this phenomenon can be seen in Appendix C.

The variability in the measurement, which includes some positive pressure readings indicating that the cabin pressure was higher at times, indicates that the wake region behind the vehicles is highly turbulent. This is true of both Explorers and each of the peer SUVs that were tested. Turbulence is characterized using a mean value and a fluctuating component. Given the highly turbulent nature of the flow behind moving vehicles, it is desirable to electronically measure the flow characteristic of interest (pressure difference, in this case) at a suitable sampling rate in order to understand the mean value and fluctuating component. If an improper pressure gage or measurement method is used, then the pressure outside the liftgate, including whether it is positive or negative, cannot be adequately analyzed. Dr. Renfroe's complete failure to measure negative pressures on any of the peer vehicles he tested is a reflection of an inadequate measurement methodology.

For the [redacted] 2013 Ford Explorer test (ID4) in Figure 47, at 70 mph, the average pressure difference appears to be approximately -0.2 inches of H_2O (in H_2O), and the bulk of the measurements fall between -0.1 and -0.3 in H_2O.

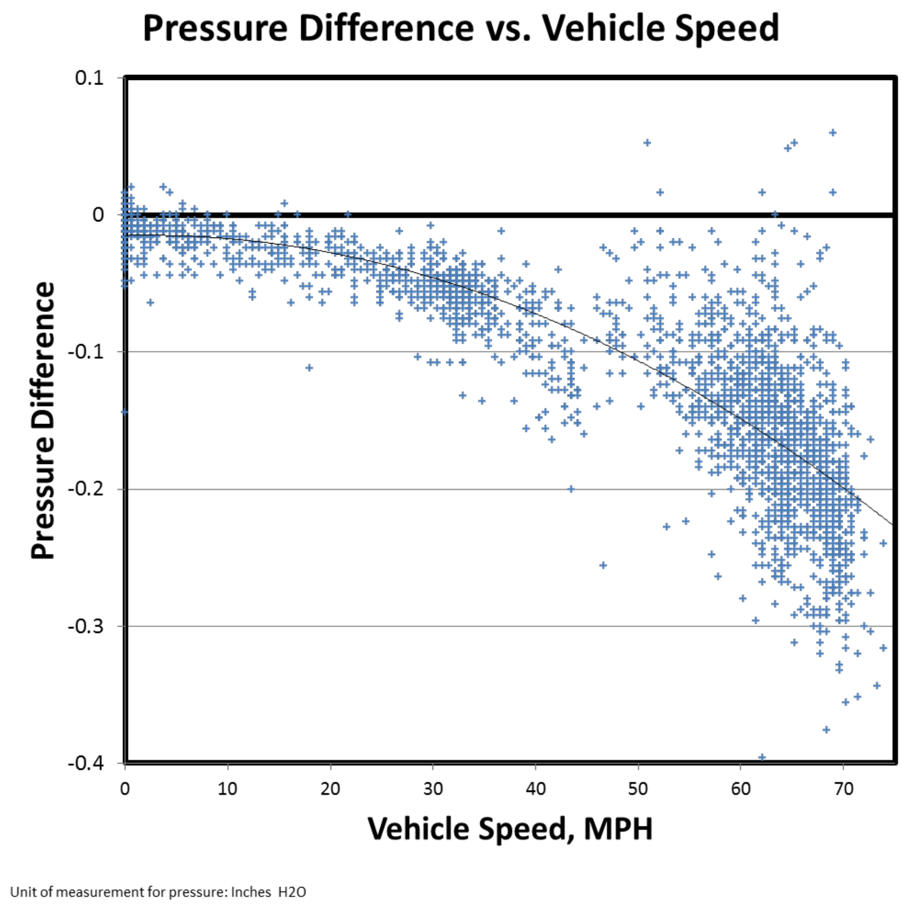

Figure 47: Plot showing the pressure difference between the vehicle cabin and the exterior rear hatch area as a function of vehicle speed in the [redacted] Ford Explorer 1363 (test ID4).

Dr. Renfroe's Differential Pressure Measurements are Problematic

In Dr. Renfroe's report, he indicates that he measured a pressure differential of -0.2 to -0.3 in H_2O for a Ford Explorer. He utilizes a Magnehelic 2302 model pressure gage for his measurements. He indicates that "it's fairly well understood in engineering circles," and it "…is used by everybody in the industry.[3]"

[3] Deposition of David Renfroe, pg. 77

Dr. Renfroe states that the gage was laying down on the floor in the cargo area of the vehicle,[4] which is an improper orientation. A screenshot of the manufacturer's frequently asked questions website is below[5]:

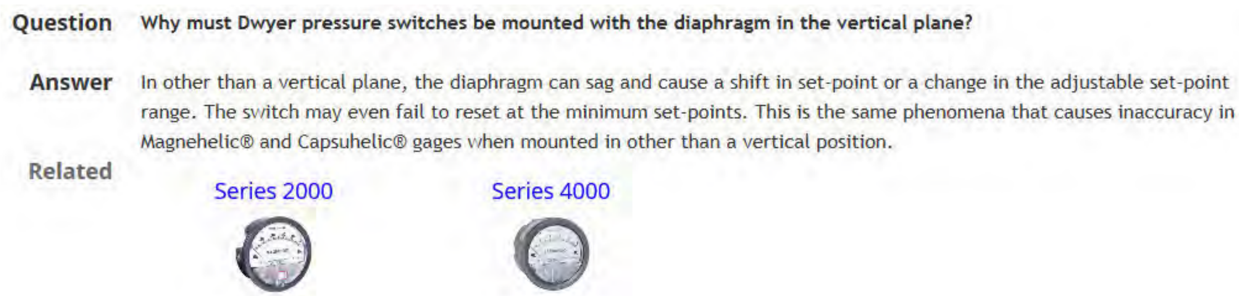

Figure 48: Screenshot of the Magnehelic pressure gage manufacturer's website, which suggests inaccuracy in Dr. Renfroe's pressure measurements because the diaphragm was not in the vertical orientation.

The specifications on the website state that the mounting orientation should be with the diaphragm in the vertical position.[6] If, at the time the gage is ordered, a special "-HC" horizontal calibration option is selected, then the gage can be used in the horizontal orientation. When asked if the gage was calibrated, Dr. Renfroe responded that he merely zero'd the instrument.

Furthermore, this pressure gage is not suitable for use in a moving vehicle, where vibrations, turns, and accelerations are present. In fact, the first sentence in the operators manual in the installation section states "Select a location free from excessive vibration...[7]" In this instrument, vibrations cause the needle to fluctuate, in the absence of any external pressure variations. Driving on the roads, including road roughness, turns, accelerations, and braking, can result in excessive vibrations and forces on the diaphragm that can lead to inaccurate readings.

In summary, this gage was used in an inappropriate application (road testing which can subject the gage to excessive vibrations), and in an inappropriate orientation. Any findings based on the use of such gages for road testing have not been proven to be reliable.

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[4] Deposition of David Renfroe, pg. 77-78
[5] http://www.dwyer-inst.com/Products/Product.cfm?Group_ID=26#questions, accessed 12/11/2015
[6] http://www.dwyer-inst.com/Products/Product.cfm?Group_ID=26#specs, accessed 12/11/2015.
[7] Operators manual for the Magnehelic 2302 differential pressure gage, bulletin A-27

Measurements on a Complaint 2014 Ford Explorer with TSB 14-0130 Completed

In addition to the standard test described earlier, an additional driving test (ID16) was performed on the Complaint 2014 Ford Explorer [redacted]; referred to as the repurchased vehicle in my July 2015 Declaration). This Explorer was driven near Exponent's Miami office to examine whether there is CO infiltration at the left side air extractor. The route followed, using GPS data overlaid on a map, can be seen in

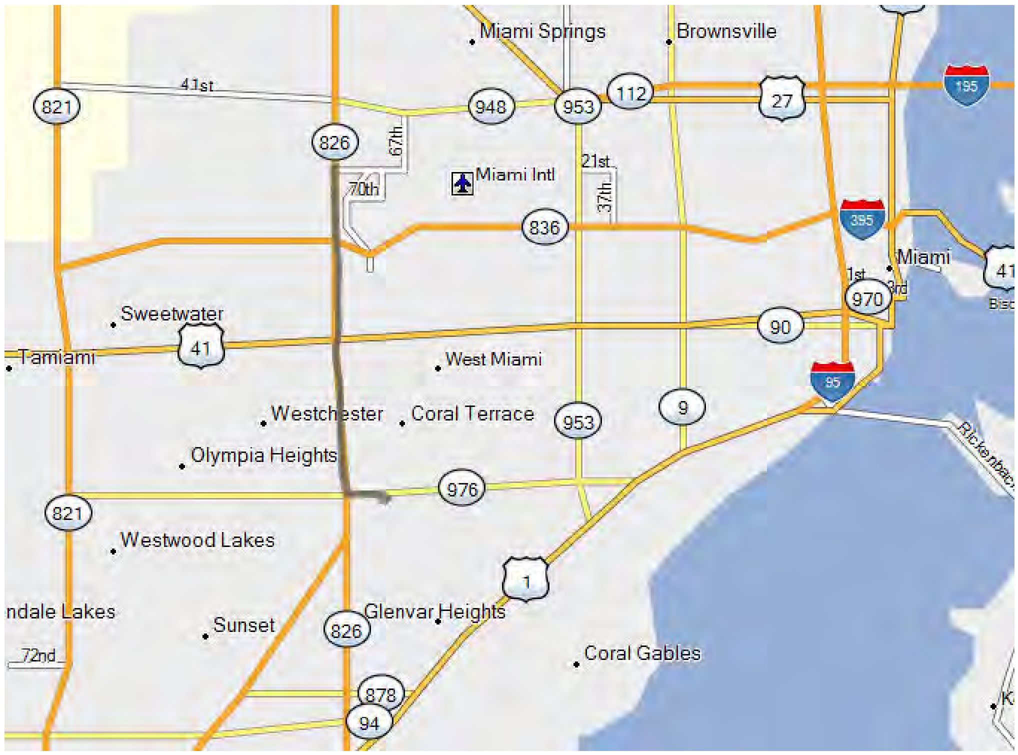

Figure 49: Map with GPS data overlaid on top showing the route taken on test ID16.

As before, the pressure differential between the rear cargo area and the outside lower rear hatch area near the latch was measured. However, in addition, the pressure differential between the cabin (in the rear cargo area) and the area outside of the left side air extractor was also measured. CO concentrations were measured at the rear seat, outside of the left side air extractor (at the same location as the pressure differential measurement), in the cabin at the inside surface of the left side air extractor (which is also the area above lap joints on the underbody which are sealed in both of the TSBs), and outside the vehicle near the seal at the top of the hatch.

A plot showing the vehicle speed and accelerator pedal position D as a function of elapsed time is shown in Figure 50. Three events are identified in the plot where WOT was applied, the latter two of which were while merging onto the freeway.

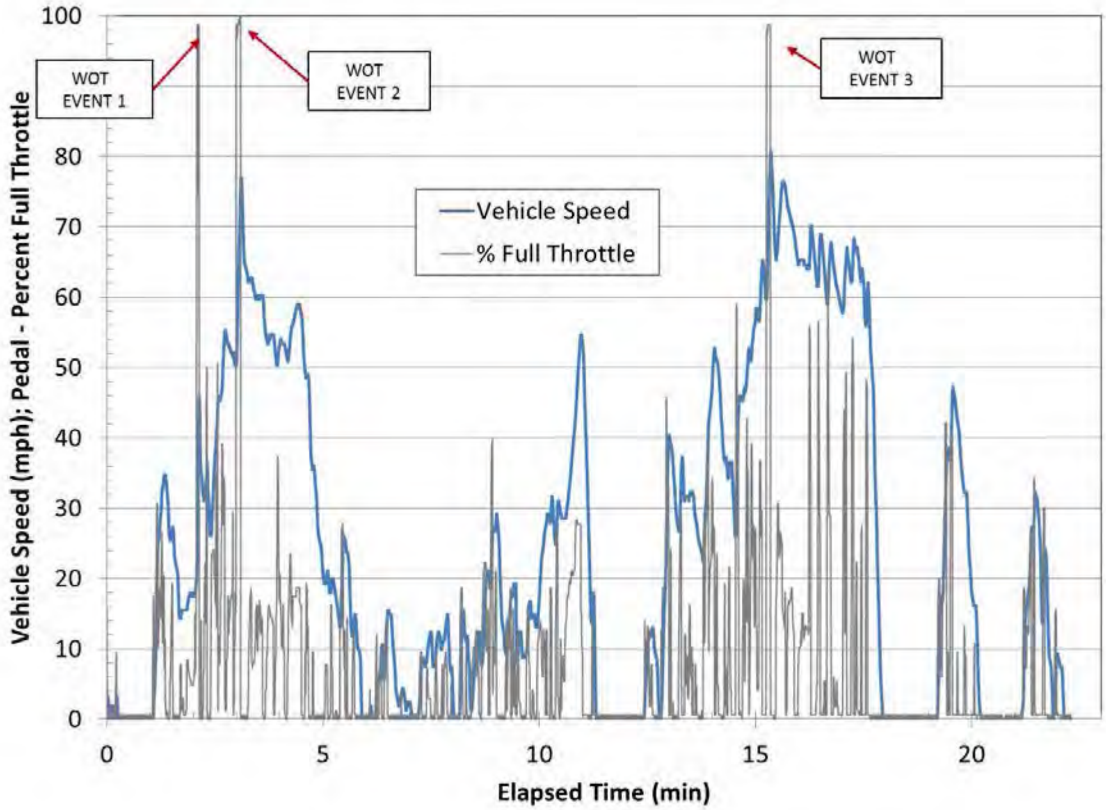

Figure 50: Vehicle speed and accelerator pedal position D for a test with the Complaint 2014 Ford Explorer [redacted] (ID16).

Figure 51 shows a plot with the accelerator pedal position D, along with two CO concentrations measured outside of the vehicle. The CO concentration correlates with the WOT events, although with some time lag. The lag is expected, because it will take time for turbulence to carry exhaust gas to the areas of the sampling tube locations, time for the gas monitor pumps to carry the exhaust gas samples through the sampling tubes, and also time for the sensor to respond.

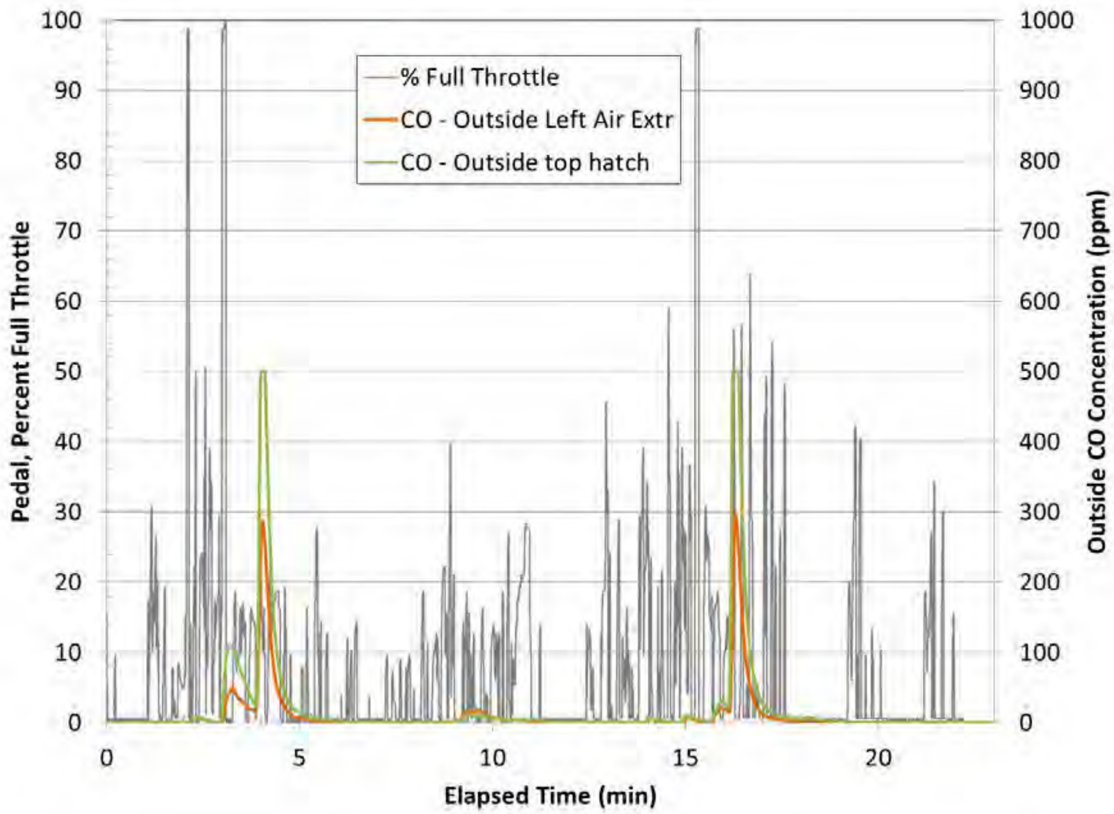

Figure 51: Plot showing the accelerator pedal position with two outside CO concentration measurements for a test with the Complaint 2014 Ford Explorer [redacted].

In the current test, the CO concentration outside the top hatch area briefly reached above the 500 ppm measurement range of the instrument on two WOT events. To the extent that peer vehicles have similar turbulence at the rear hatch and have fuel enrichment on high driver demand, elevated CO levels might also result. As stated in paragraph 18 of my July 8, 2015 Declaration, the rear hatch seal was found to be continuous on this vehicle, with the exception of a very small gap along the bottom of the hatch. However, in my inspection of the Sanchez-Knutson vehicle on January 15, 2015, a fog test revealed inadequate sealing of the top side of the rear hatch in the area where the CO sensors detected elevated CO levels.

The CO concentrations measured from the locations on the outside of the passenger cabin were plotted against the CO concentrations measured on the inside side of the driver's air extractor (which is also in the area above the underbody lap joints that are sealed on this vehicle; see Figure 52). Although the CO concentration reached 286 ppm outside of the air extractor, zero CO was measured inches away on the interior side of the left air extractor.[8]

[8] Note that the gas monitor measuring CO inside the left air extractor and above the underbody lap joints captured the first two WOT events, but stopped recording due to low battery before the last WOT event.

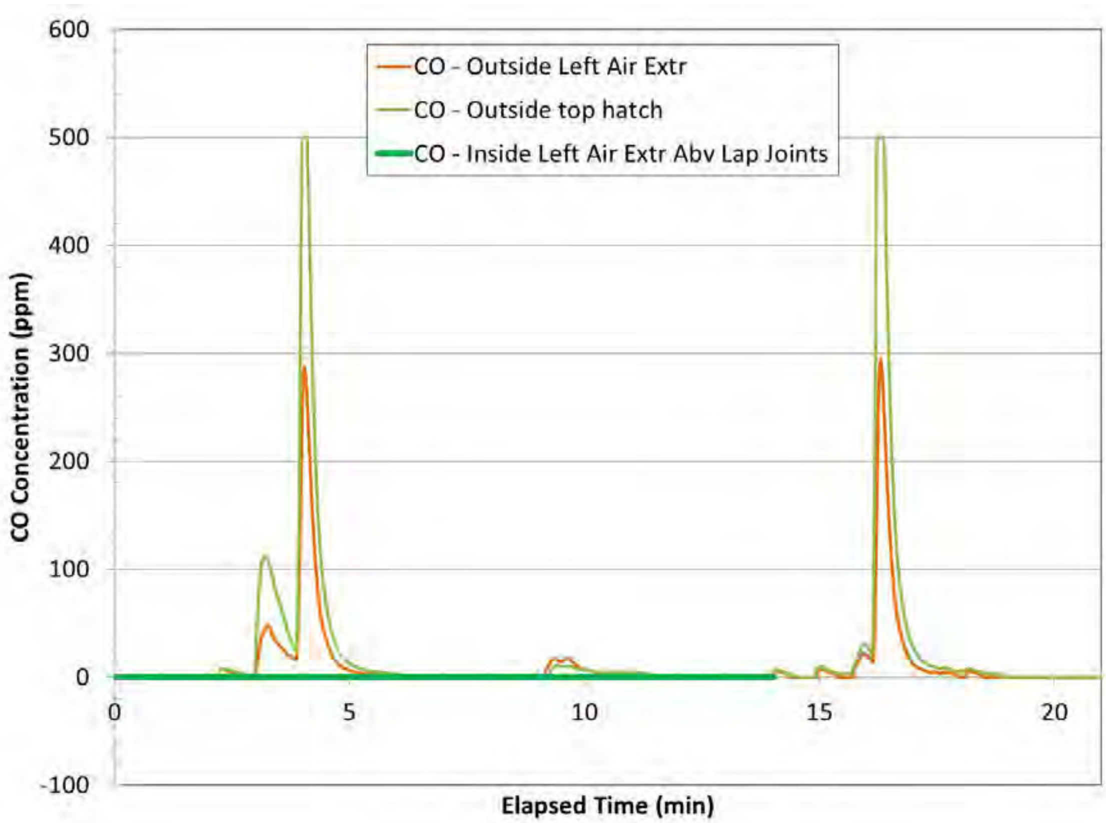

Figure 52: Comparison of CO concentrations measured on the outside of the left air extractor, and on the inside of the same air extractor, which is also the area above the underbody lap joints which are sealed in the TSB. CO levels just inside the driver's side air extractor were below the detection limits. Complaint 2014 Ford Explorer [redacted].

The exterior two CO concentration profiles are then plotted against the CO concentration measured at the left rear seat location (see Figure 53). Again, the CO concentrations at the rear seat was below the level of detection.

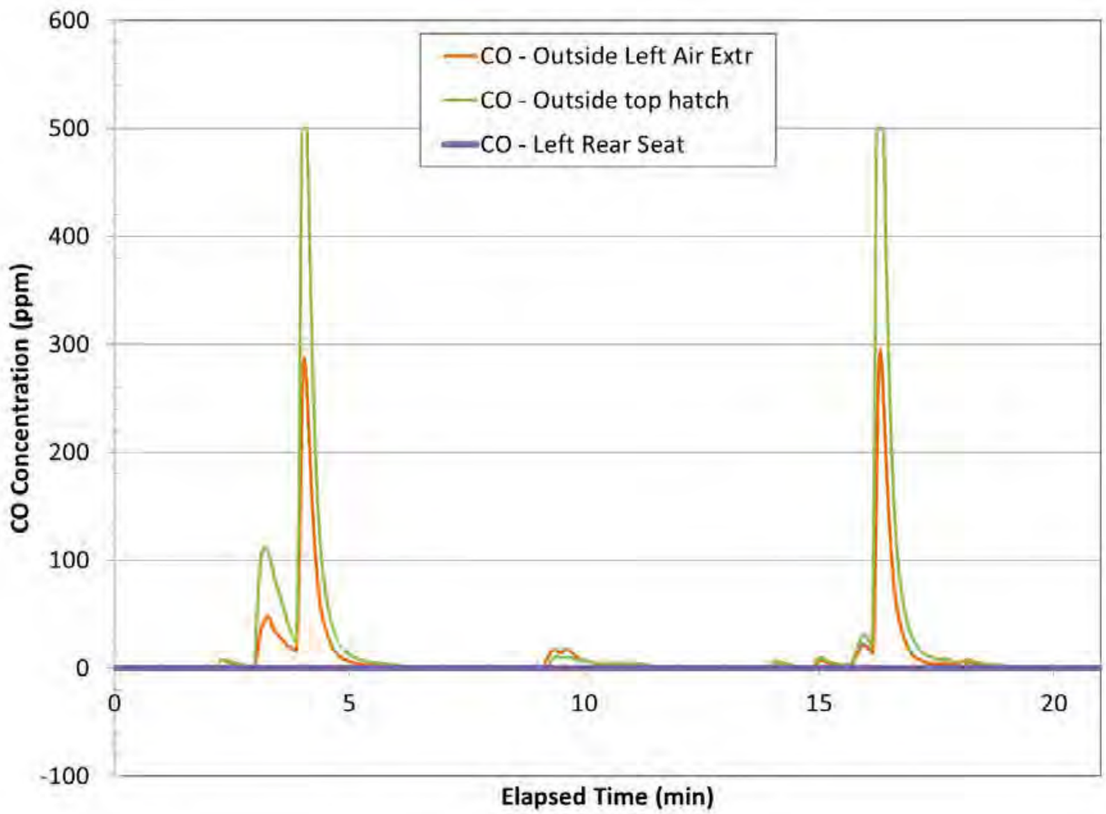

Figure 53: Comparison of CO concentrations measured on the outside of the left air extractor, and in the area of the left rear seat headrest. Zero CO is measured. Complaint 2014 Ford Explorer [redacted].

A plot showing the vehicle speed along with pressure differential between the cabin and the lower center outside of the rear hatch, and pressure differential between the cabin and the outside of the left air extractor is shown in Figure 54. Both pressure traces show positive pressure after the two higher speed WOT events, which is consistent with the reprogrammed HVAC module autonomously switching from recirculation mode to fresh air mode. The pressure difference between the cabin and outside of the left air extractor is less than the pressure difference between the cabin and lower rear hatch area.

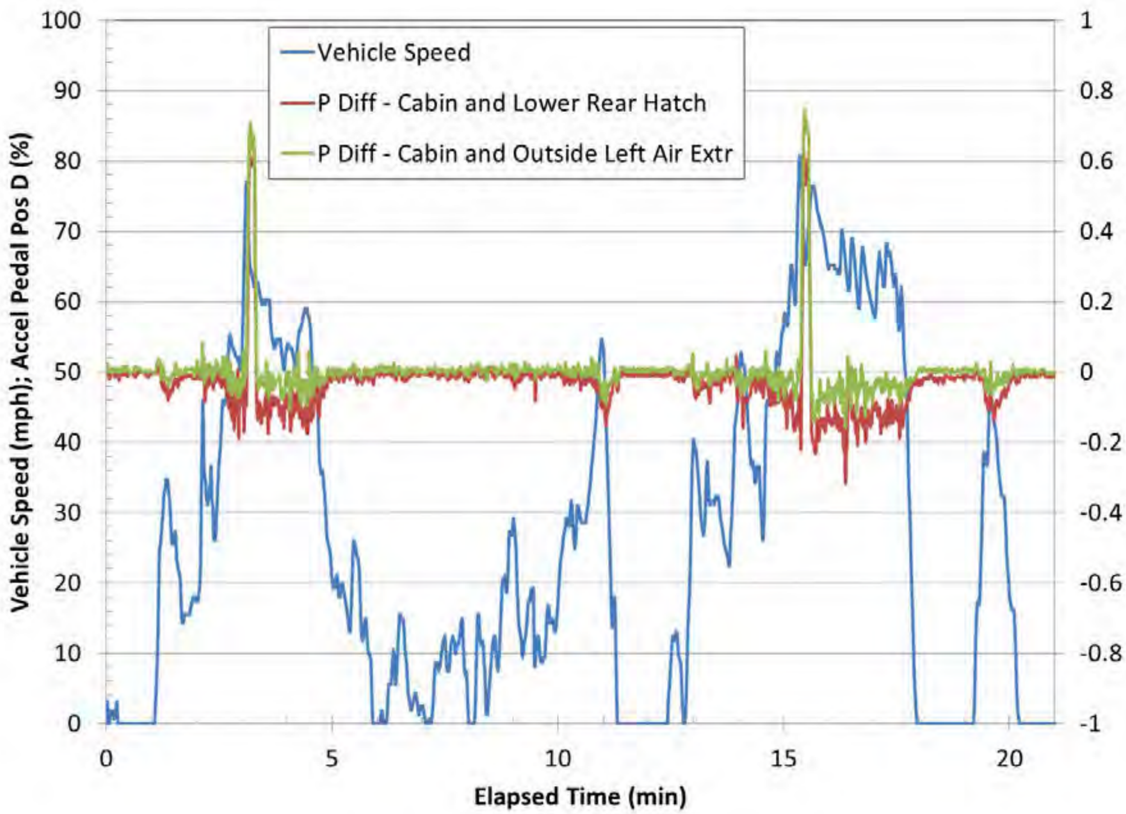

Figure 54: Plot showing the vehicle speed and pressure differential between the cabin and the lower center outside of the rear hatch, and pressure differential between the cabin and the outside of the left air extractor. Complaint 2014 Ford Explorer [redacted].

It is noteworthy to mention again that, in addition to the HVAC reprogramming, valves were placed on the condensate drain holes (see Figure 3), an updated air extractor was installed (p/n BB53 B280B63 AB) on the left and right sides, and the rubberized undercoating and seam sealer was used in all locations specified in the TSB.

In order to test for the functionality of the installed air extractors, the lower part of the bumper cover was pulled back on each side of the Complaint 2014 Ford Explorer. The air extractors were tested by pulling back on the flaps until a gap was created and then applying a negative pressure of approximately -0.25 in H_2O in the cabin using a shop vac. The gap closed due to the negative pressure within half of one second. The testing was captured on video. A Magnehelic 2302 pressure gage mounted in a vertical orientation and in a stationary lab environment with minimal vibrations (proper usage of the instrument) was used. Figure 55 shows a video screenshot of the left side air extractor as found with no apparent gaps (top), a screenshot of the air extractor flap gap that was artificially created (middle), and a screenshot of the same air extractor illustrating that the gap had closed once a negative pressure was applied in the cabin (bottom). Figure 56 shows the results of the same test for the right side.

Left Side Air Extractor Test

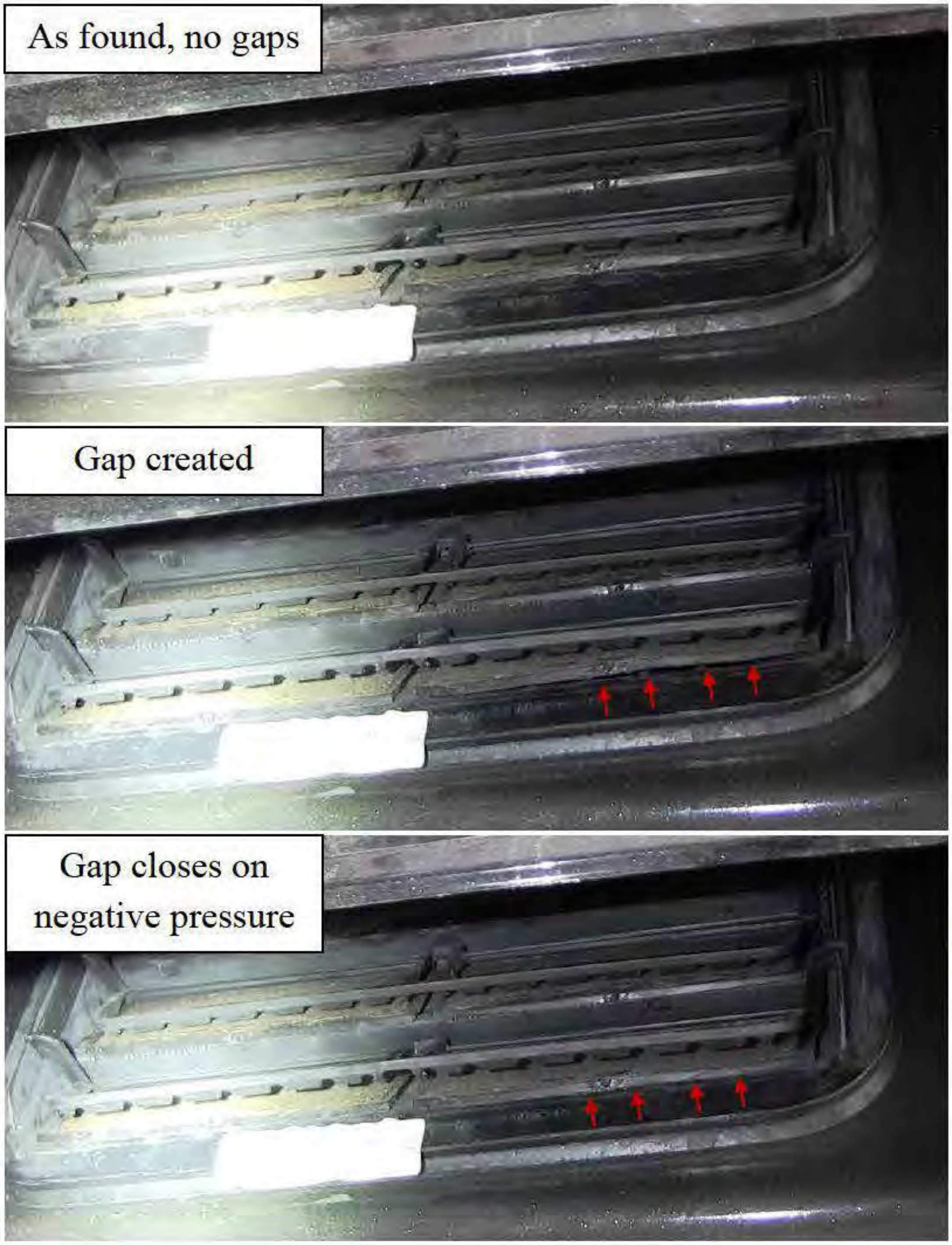

Figure 55: Video screenshot showing no apparent gaps in the left side air extractor as found (Top; 00:01 in video), showing the artificially created gap (Middle; 01:08 in video), and showing the closed gap after a vacuum had been applied (Bottom; 01:12 in video).

Right Side Air Extractor Test

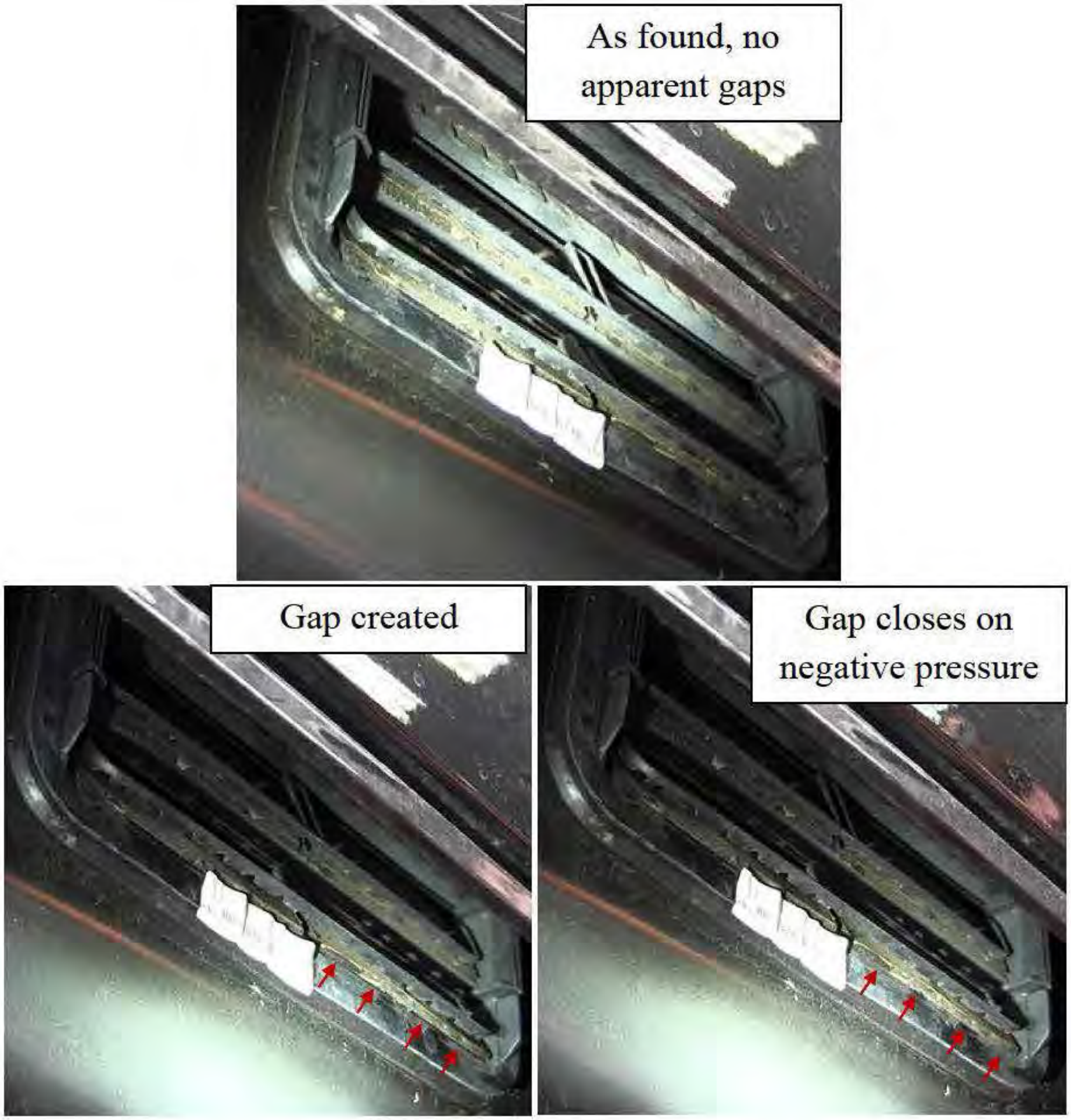

Figure 56: Video screenshot showing no apparent gaps in the left side air extractor as found (top; 00:01 in video), showing the artificially created gap (bottom left; 00:20 in video), and showing the closed gap after a vacuum had been applied (bottom right; 00:22 in video).

Measurements and Observations on the Dixon 2013 Ford Explorer with Inadequate TSB Work

In addition to the standard testing described earlier, an additional driving test (ID17) was performed on the [redacted] 2013 Ford Explorer [redacted]). The vehicle was driven near Exponent's Miami office. The GPS data overlaid on a map can be seen in Figure 57.

Figure 57: Map with GPS data overlaid on top showing the route taken on test ID17.

As before, the pressure differential between the rear cargo area and the outside lower rear hatch area was measured. In addition, the pressure differentials between the rear cargo area and the area outside of the left and right air extractors, and the outside top hatch were also measured. The CO was measured inside of the left and right air extractors and above the respective underbody lap joints, and in the outside top hatch area.

A plot showing the vehicle speed and accelerator pedal position D as a function of elapsed time is shown in Figure 58. Three events are identified in the plot; two of the events were WOT events while merging onto the freeway, and between those was a strong acceleration with about 50% pedal depression.[9]

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[9] The full range of pedal motion must be included in the pedal position sensor range. For this vehicle, 15.7% corresponds to no pedal application, and 78.8% corresponds to WOT. Therefore, 47.1% of the accelerator pedal position D signal corresponds to 49.7%

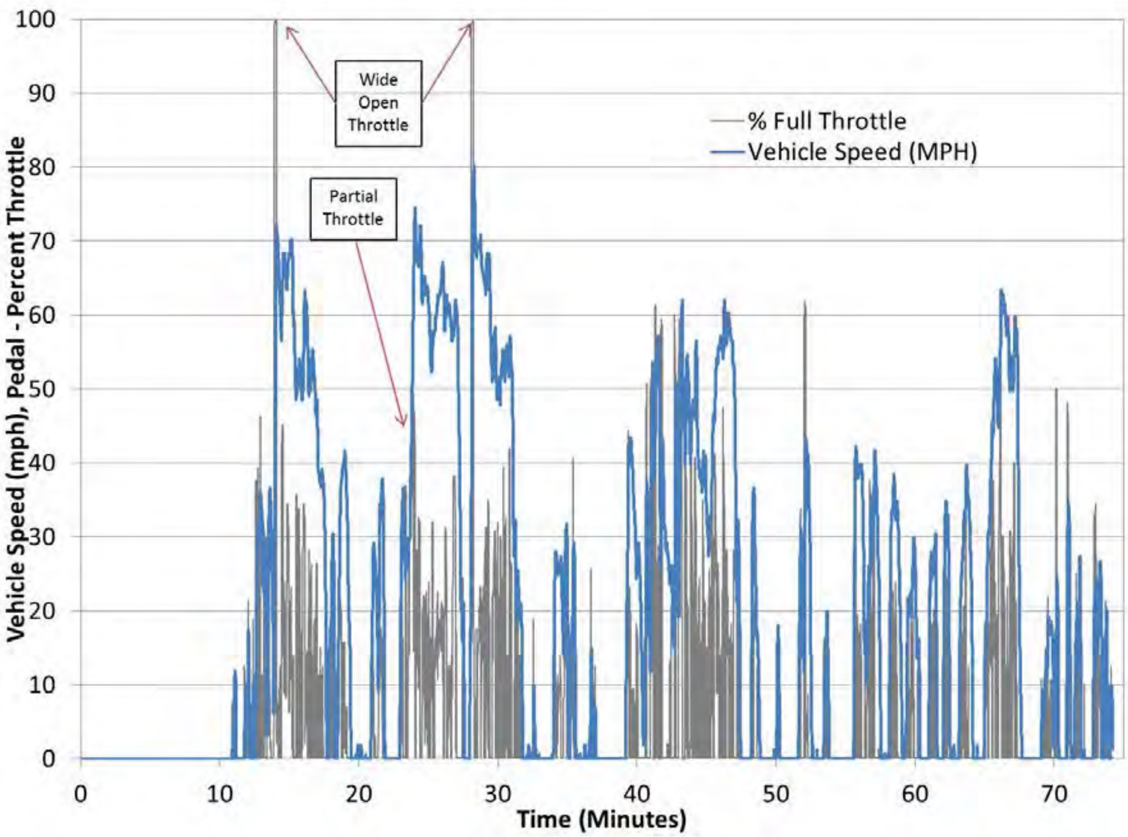

Figure 58: Vehicle speed and accelerator pedal position D for a test with the [redacted] 2013 Ford Explorer (ID17).

Figure 59 shows a plot with the accelerator pedal position D, along with the CO concentration measured outside of the vehicle near the top of the hatch. The elevated CO concentration peaks correlate with WOT events, with some time lag as discussed before. As with the Complaint 2014 Ford Explorer, the CO concentration outside the vehicle at the top hatch reached above the 500 ppm measurement range of the instrument in this area. For the 50% pedal depression event, a CO peak of only 83 ppm was recorded in the outside top hatch region.

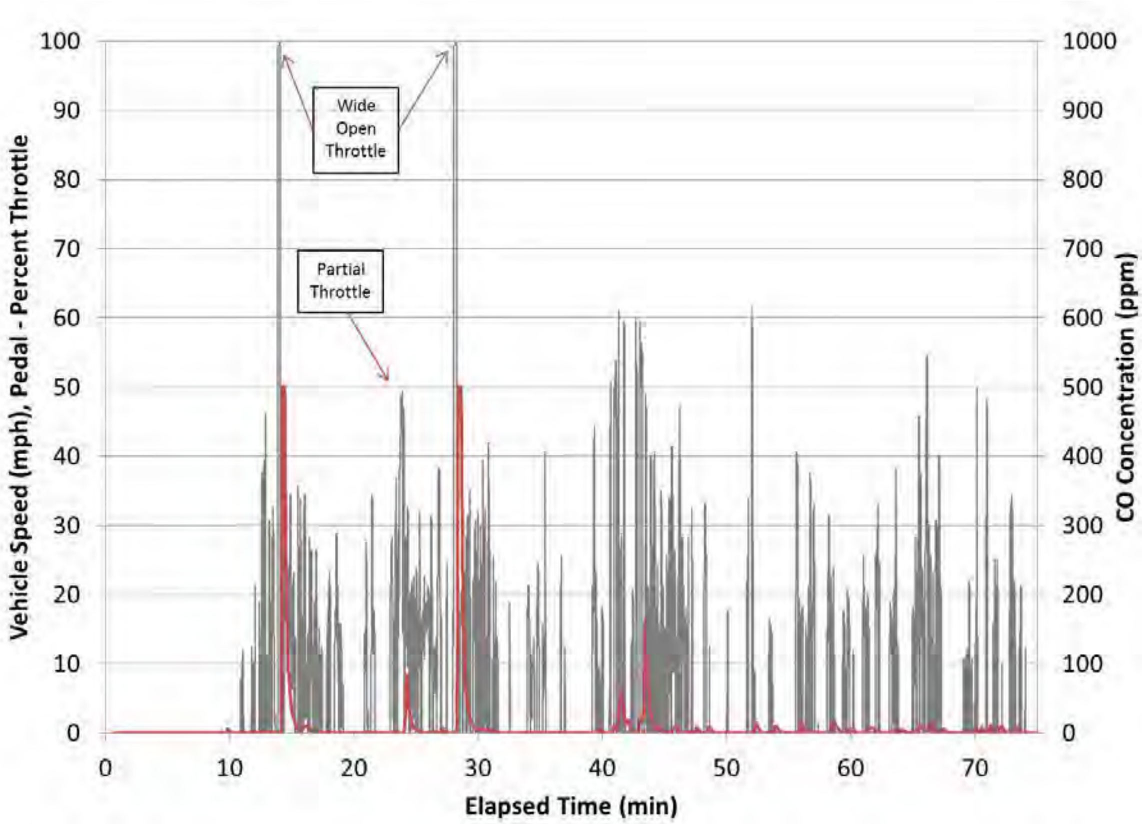

Figure 59: Plot showing the accelerator pedal position with the outside top hatch CO concentration measurements.

The exterior top hatch CO concentration profile is plotted against the CO concentration measured inside the left and right air extractors, above the underbody lap joints (see Figure 60). A small amount of CO is present at these sampling locations, which correlate with the brief relatively high concentration pulses (and accordingly, the WOT events). After entry into the vehicle, it dilutes and the local concentration decays.

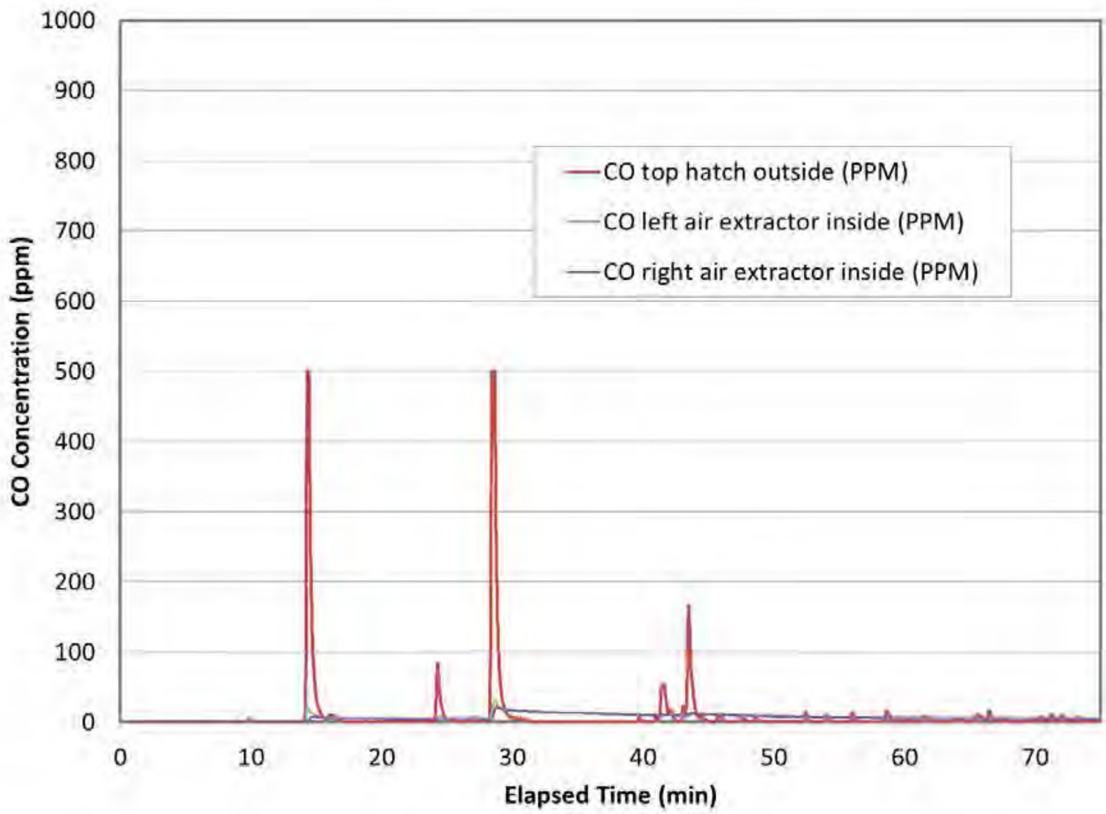

Figure 60: Plot showing the CO concentrations at the outside top hatch location and inside the left and right air extractors, above the underbody lap joints.

The pressure differentials between the hatch cargo area and four different locations were measured, and are shown in Figure 61. The HVAC system on this vehicle does not evidence the blend door opening associated with WOT that is part of TSB 14-0130 actions. This vehicle does not manifest that control logic.

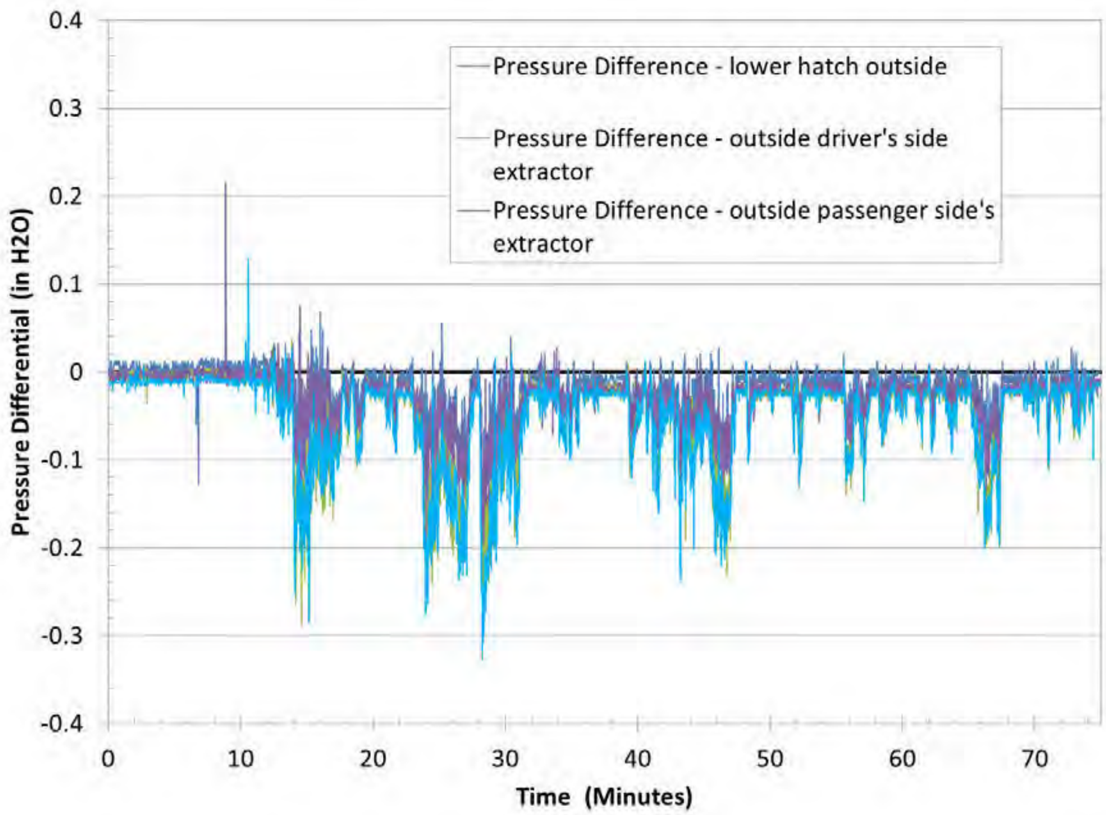

Figure 61: Pressure differential between the rear cargo area and four different locations outside the vehicle; the outside lower hatch, outside top hatch, outside left air extractor, and outside right air extractor.

The hatch seal integrity was investigated with a fog test and a WD40 test. Similar to previous fog tests, a shop vac was connected to a window that was rolled down 1-2 inches, the vacuum nozzle was inserted into the crack, and the remainder of the crack was sealed off. The vacuum was turned on, and a fog machine introduced fog to the rear hatch area. The fog appeared to enter through the condensate drain holes, which were not plugged with drain valves, and the additional hole where the left hatch bumper should have been installed. Some fog entered into the cabin through the grills on the left and right sides of the hatch cargo area, though with the interior plastic panels still attached, the specific entry points could not be identified. The hatch seal was tested by spraying WD40 onto a rag, and wiping a thin film onto the mating surface of the hatch seal. The hatch was then closed and reopened. The areas where the seal had contacted the hatch had a visible sheen where the WD40 had transferred. The hatch seal appeared adequate.

As with the Complaint 2014 Ford Explorer, the functionality of the air extractors were tested on the Dixon 2013 Ford Explorer using the same test methodology described earlier. The left side air extractor was found to be an updated part (p/n BB53 B280B63 AB). The flaps all appeared to rest on the frame prior to the start of the test, with the exception of the lower right flap which had a very small gap. A more visible gap was created, and the response to a negative pressure in the cabin was observed and video recorded. As with the Complaint 2014 Ford Explorer, the air extractor flap quickly closed due to the negative pressure. Figure 62 shows a screenshot of the gap that was artificially created (left), and the closure of the same gap once a negative pressure was applied in the cabin (right).

Left Side Air Extractor Test

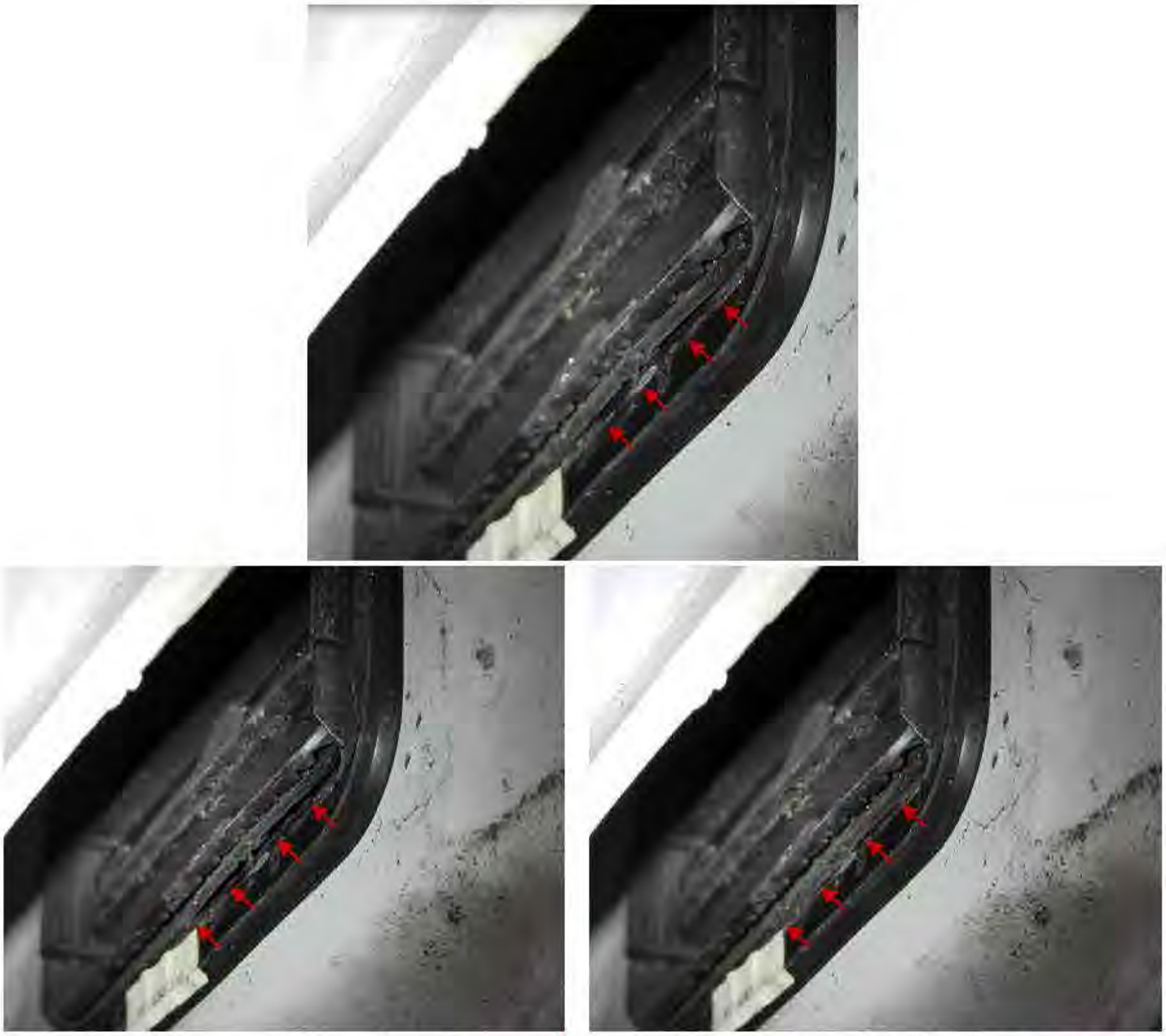

Figure 62: Video screenshots showing a small gap in the lower right left side air extractor prior to the test (top; 00:01 in video), showing the artificially created gap (bottom left; 00:15 in video), and showing the closed gap after a vacuum had been applied (bottom right; 00:16 in video).

The passenger side of the [redacted] vehicle had the original air extractor design and did not visually have gaps. The thin rubber flaps appeared to rest against the frame. Attempts were made to manually create an air gap and the vacuum was applied. To illustrate the effects of the negative pressure, one corner of one of the flaps was lifted during vacuum application, and the flap was observed to move to close the gap. The results of the testing are shown in Figure 63.

Right Side Air Extractor Test

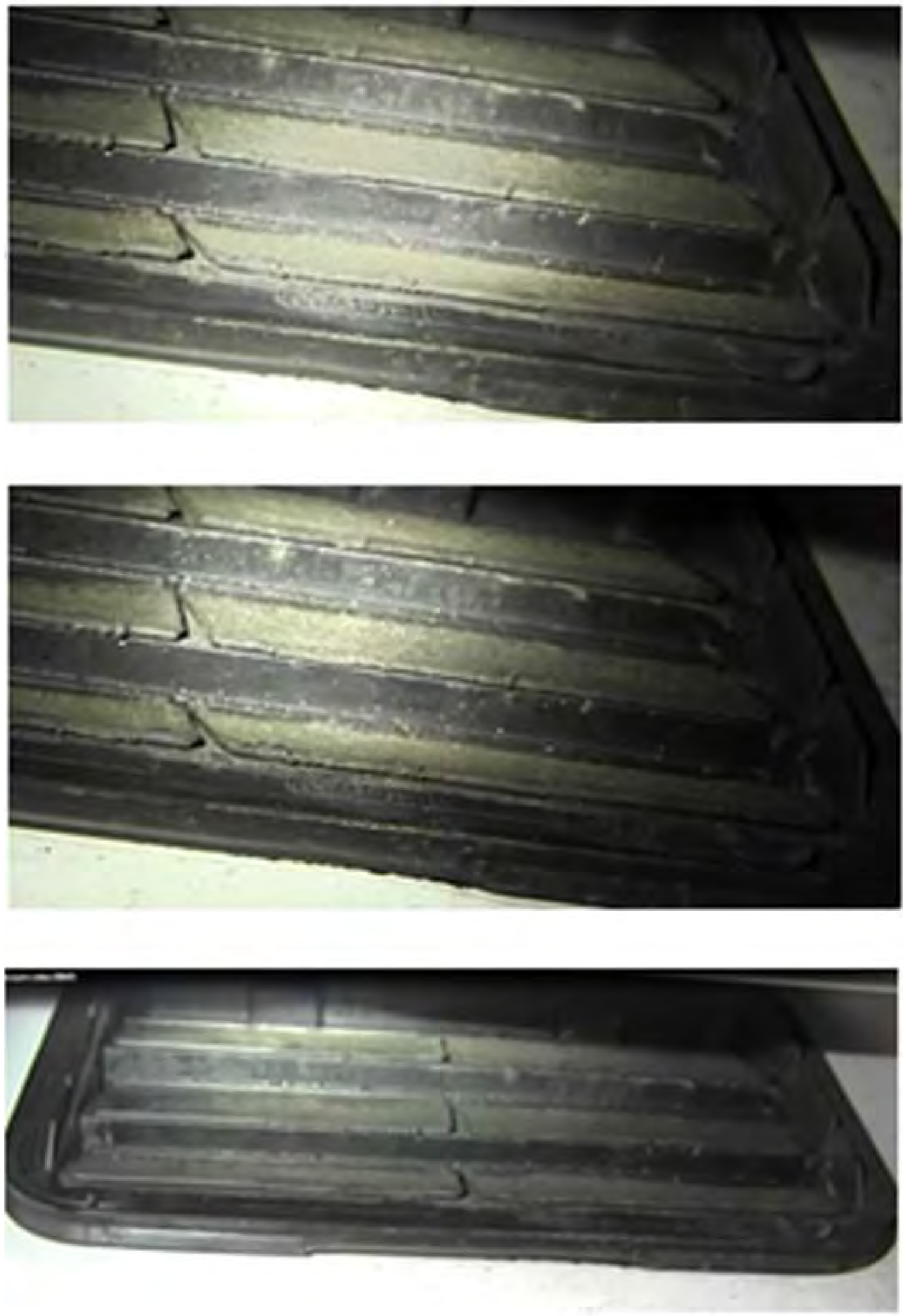

Figure 63: Video screenshots showing an artificially created gap in the lower right left side air extractor prior to the test (top; 00:35 in video), showing the closed gap after a vacuum had been applied (middle; 00:39 in video), and showing all of the flaps after the testing concluded (bottom; 01:28 in video).

Although the air extractors appeared to be functional, the underbody lap joints were not sealed according to the TSB (see Figure 64).

Figure 64: Photographs showing the underbody of the [redacted] vehicle. The sealer was not applied to all locations specified in the TSB.

Furthermore, the condensate drain valves were not installed on the [redacted] vehicle hatch according to the TSB, and the left side rubber bumper was missing from the hatch, as seen in Figure 65.

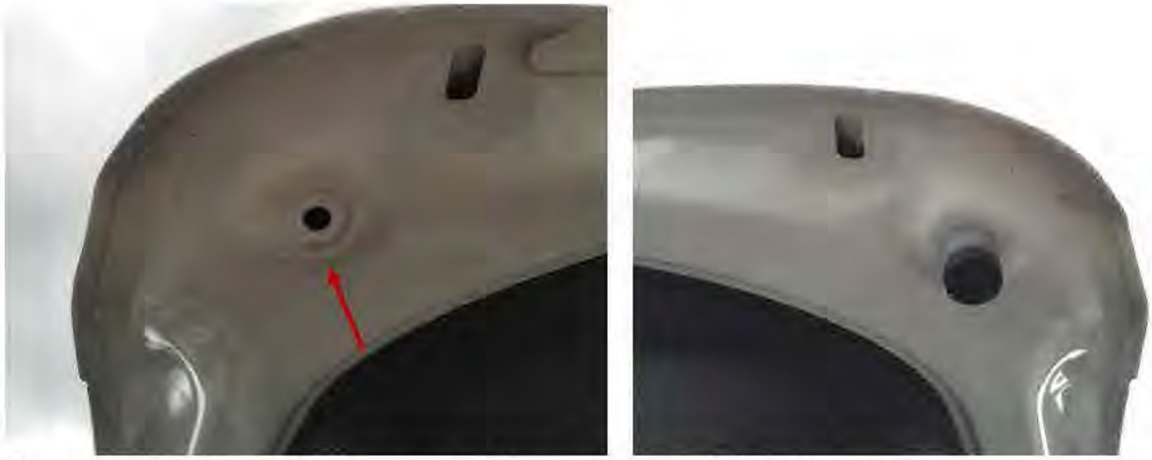

Figure 65: Photographs showing that the condensate drain valves were not installed on the left or right sides (left and right photographs, respectively) of the [redacted] vehicle. Additionally, the rubber bumper was missing from the left side of the hatch (left photograph, red arrow), creating an additional entry path.

The Dixon vehicle recorded CO levels slightly above the detection limit near the end of the test drive from the Sanchez-Knutson residence to the fire station when monitors were placed at the driver's location and in a rear seat location. The test engineer detected an odor at the conclusion of a WOT on the onramp to the freeway, and a more faint odor at the conclusion of a WOT on 30th Ave. The test engineer also detected an odor in heavy traffic on the freeway at the same time that a nearby test engineer in a Dodge Durango detected an odor, suggesting that the odor may be associated with another vehicle on the road.

During a second test (ID17), the gas monitors were configured to draw air samples from the area inside of the air extractors and above the lap joints on the underbody. Small CO concentrations were detected in this area. The TSB actions were incomplete for this vehicle. Pressure differential measurements did not show any positive pressure around times of accelerations, suggesting that the HVAC module had not been reprogrammed.

Summary of Max CO Concentrations in the Ford Explorers

Model Yr	VIN (last 5 digits)	Test ID	# of WOTs	Test Duration (Minutes)	CO Sensor Position	CO Min *	CO Max	CO Average **
2014	[redacted] Buyback	ID 3	3	42	Driver	<1	<1	<1
					Rear	<1	<1	<1
2013	[redacted]	ID 4	2	45	Driver	<1	7	<1
					Rear	<1	7	<1
2015	[redacted]	ID 14	3	41	Driver	<1	6	<1
					Rear	<1	7	<1
2013	[redacted]	ID 15	5	43	Driver	<1	15	4.5
					Rear	<1	16	4.4
2014	[redacted] Buyback	ID 16	3	21	Rear	<1	<1	<1

Note:
All tests conducted with the HVAC system on Max A/C, in recirculation mode, and with the rear A/C on.
* Detection limit is 1 PPM for CO
** The average is calculated as the sum of the CO concentrations, which were collected every one second, divided by the length of the test (in seconds). For the CO average calculation, the test duration was from start of drive until final stop. However, if sensors detected CO in the cabin at the final destination, the test duration was extended until CO concentrations dropped below the detection limit.

Figure 66: Summary of Max CO Concentrations in the Ford Explorers.

Observations, Conclusions, and Opinions

A Several peer vehicles were tested and various parameters were measured, including CO concentration, pressure differential, vehicle speed, and accelerator pedal positions.

B When the HVACs were operated in recirculation mode at max fan speed, all peer vehicles tested developed a negative pressure inside the cabin with respect to the outside rear area, just above the center of the rear bumper.

C Small gaps were artificially created in the [redacted] 2013 Ford Explorer 1363 and Complaint 2014 Ford Explorer [redacted] air extractors. These gaps closed up in less than 0.5 seconds when a negative pressure of 0.25 in H_2O was created inside the vehicle.

D The Dixon 2013 Ford Explorer [redacted] was missing a rubber bumper on the left side of the rear hatch, which is a point of exhaust gas ingress. This vehicle also did not have all of the changes associated with TSB 12-12-04 or TSB 14-0130 made, including the condensate drain valves and the reprogramming of the HVAC system.

E Dr. Renfroe utilized a differential pressure gage which is not suitable for environments with excessive vibration (such as driving tests) and he used it in an incorrect orientation. The readings from the gages were not documented in any fashion that could be reproduced, and indeed his peer vehicle readings were inconsistent with measurements made using appropriate, scientific, calibrated instrumentation. He has not demonstrated that the gage readings he obtained, particularly for the peer vehicles, are reliable.

Appendix A

CV of Michael E. Cundy, Ph.D., P.E.

Michael E. Cundy, Ph.D., P.E.

Senior Engineer

Professional Profile

Dr. Cundy is a licensed Mechanical Engineer with expertise in the fields of combustion, heat transfer, thermodynamics, fluid mechanics, and measurement systems. He has utilized these skills extensively in the analysis and investigation of mechanical and electrical vehicle systems, in both prototype and production versions. He has coordinated and participated in testing which has involved automotive refrigerant flammability, mechanical stress due to thermal expansion, electrical fault energy dissipation, exhaust system temperature testing, insulation flammability, circuit resistive fault testing, systems response to induced failures, burst testing of tubes, fire propagation, module-to-module communication via controller area networks, smoke detector operation, and more. He also has considerable experience with instrumentation and measurement systems. Additional work has included evaluation of the condition of a powder coating operation post-fire, heat transfer testing of winter jackets, and the determination of air conditioner capacity needed for a mobile laboratory to be used in specific geographical locations. Dr. Cundy also has extensive experience in fire cause and origin investigations involving vehicles, houses, and larger structures. He has worked in areas of product development, third-party validation, and product safety.

Prior to joining Exponent, he was a member of the Quantitative Laser Diagnostics Laboratory in the Walter E. Lay Automotive Laboratory at the University of Michigan in Ann Arbor, Michigan, where he developed and applied various laser diagnostic tools to study combustion in internal combustion engines. His work included developing and applying temperature field diagnostics to evaluate heat transfer from hot gases to the engine block, utilizing particle-image velocimetry to study flow patterns in engines, and developing and applying fuel concentration diagnostics to study combustion stability, including misfires and partial burns, in an advanced internal combustion engine.

While at the University of Michigan, Dr. Cundy was an instructor for a laboratory course which focused on experimental data collection, analysis, and data presentation, with an emphasis on error analysis.

Dr. Cundy also performed fluid mechanics research in the Non-equilibrium Thermodynamics Laboratory at The Ohio State University in Columbus, Ohio. He worked on a project funded by the U.S. Air Force where he developed a laser diagnostic tool to measure density fluctuations in the boundary layer of a supersonic flow.

Academic Credentials and Professional Honors

Ph.D., Mechanical Engineering, University of Michigan, Ann Arbor, 2012
M.S.E., Mechanical Engineering, University of Michigan, Ann Arbor, 2008
B.S., Mechanical Engineering, The Ohio State University (*with distinction, with honors*), 2005

Alternate – National Fire Protection Association (NFPA) Technical Committee on Recreational Vehicles, 2012–2014

Licenses and Certifications

Licensed Professional Mechanical Engineer, Arizona, #55526

Fire Investigation 1A: Fire Origin and Cause Determination; accredited by the California State Fire Marshal

Fire Investigation 1B: Techniques of Fire Investigation; accredited by the California State Fire Marshal

Publications

Colwell JD, Cundy M, Full-scale burn test of a 1992 compact pickup truck. SAE Paper 2013-01-0209, 2013.

Cundy ME. Development of high-speed laser diagnostics for the investigation of scalar heterogeneities in engines. Ph.D. dissertation, University of Michigan, 2012.
Cundy ME, Trunk P, Dreizler A, Sick V. Gas-phase toluene LIF temperature imaging near surfaces at 10 kHz. Experiments in Fluids 2011, DOI 10.1007/s00348-011-1137-8.

Cundy ME, Sick V. Hydroxyl radical imaging at kHz rates using a frequency quadrupled Nd:YLF laser. Applied Physics B 2009; 96(2):241–244.

Cundy ME, Schucht T, Thiele O, Sick V. High-speed laser-induced fluorescence and spark plug absorption sensor diagnostics for mixing and combustion studies in engines. Applied Optics 2009; 48(4):B94-B104.

Cundy ME. Detection and measurement of density fluctuations induced by a magnetohydrodynamic force in a supersonic boundary layer. Undergraduate Honors Thesis, The Ohio State University, 2005.

Meyer R, Nishihara M, Hicks A, Chintala M, Cundy M, Lempert WR, Adamovich IV, Gogineni S. Measurements of flow conductivity and density fluctuations in supersonic nonequilibrium MHD flows. AIAA Journal 2005; 43(9):1923.

Conference Presentations

Cundy M, Schucht T, Thiele O, Sick V. Novel optical diagnostics for mixing and combustion studies in engines. Poster presented at the University of Michigan Graduate Student Symposium, Ann Arbor, MI, November 2008.

Cundy M, Sick V. Misfire analysis techniques in a direct injection engine. Presented at the Gordon Conference on Laser Diagnostics in Combustion, Oxford, UK, August 2007.

Cundy M, Lempert W. Study of the effect of electromagnetic fields on density fluctuations in a supersonic boundary layer. Presented at the Denman Undergraduate Honors Research Forum, Columbus, OH, May 2004.

Cundy M, Sick V. Hydroxyl radical imaging at kHz rates using a frequency quadrupled Nd:YLF laser. Presented at the University of Michigan Graduate Student Symposium, Ann Arbor, MI, November 2009.

Drake MC, Fansler TD, Cundy M, Sick V. High-repetition-rate Mie scattering and particle-image-velocimetry for flow and combustion diagnostics in a direct-injection gasoline engine. Presented at the 6th U. S. National Combustion Meeting, Ann Arbor, MI, May 2009.

Cundy M, Schucht T, Thiele O, Sick V. Novel optical diagnostics for mixing and combustion studies in engines. Presented at the University of Michigan Graduate Student Symposium, Ann Arbor, MI, November 2008.

Appendix B

List of Materials Reviewed

Pleadings

Class Action Complaint, [redacted] *v. Ford Motor Company*, U.S.D.C. Southern District of California, June 9, 2014.

Plaintiff's Motion for Class Certification and Incorporated Supporting Memorandum, [redacted], *individually and on behalf of all those similarly situated v. Ford Motor Company*, Case No. [redacted], U.S.D.C. Southern District of Florida, June 25, 2014.

Second Amended Class Action Complaint, [redacted], *individually and on behalf of all those similarly situated v. Ford Motor Company*, Case No. [redacted], U.S.D.C. Southern District of Florida, March 30, 2015.

Plaintiff's Renewed Motion for Class Certification and Incorporated Supporting Memorandum, [redacted], *individually and on behalf of all those similarly*[redacted] *v. Ford Motor Company*, Case No. [redacted]4 WPD, U.S.D.C. Southern District of Florida, June 8, 2015.

[redacted]

Reports

David Renfroe, November 13, 2015

Appendix C

ID1 Test Results: 2015 Nissan Pathfinder 0146

The data captured for test ID1 can be seen in Figure 67. This test was run simultaneous with test ID2. Zero CO was measured at both the driver and rear seat locations.

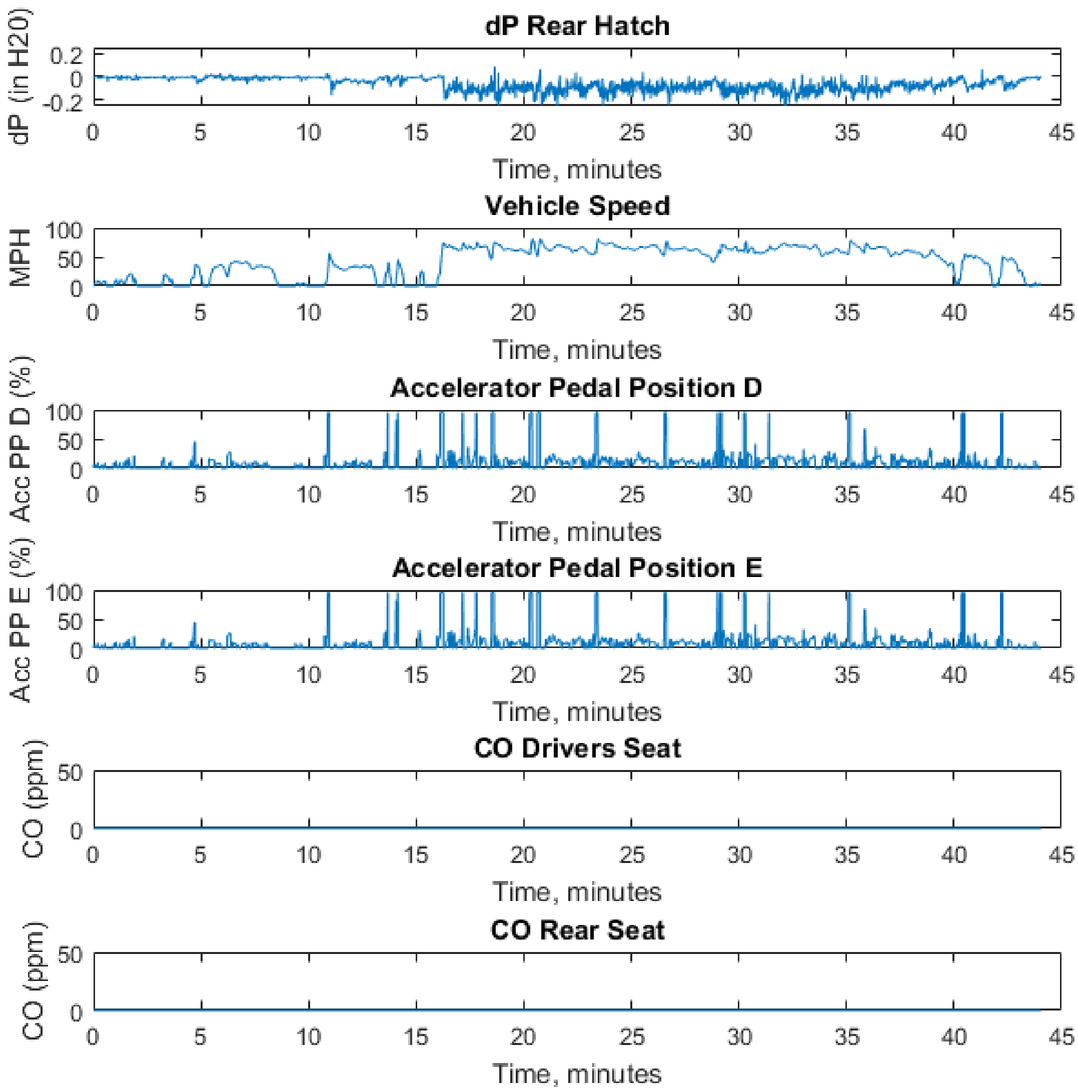

Figure 67: 2015 Nissan Pathfinder 0146 ID1 test data.

ID2 Test Results: 2016 Toyota 4Runner 3514

The data captured for test ID2 can be seen in Figure 68. This test was run simultaneously with ID1.

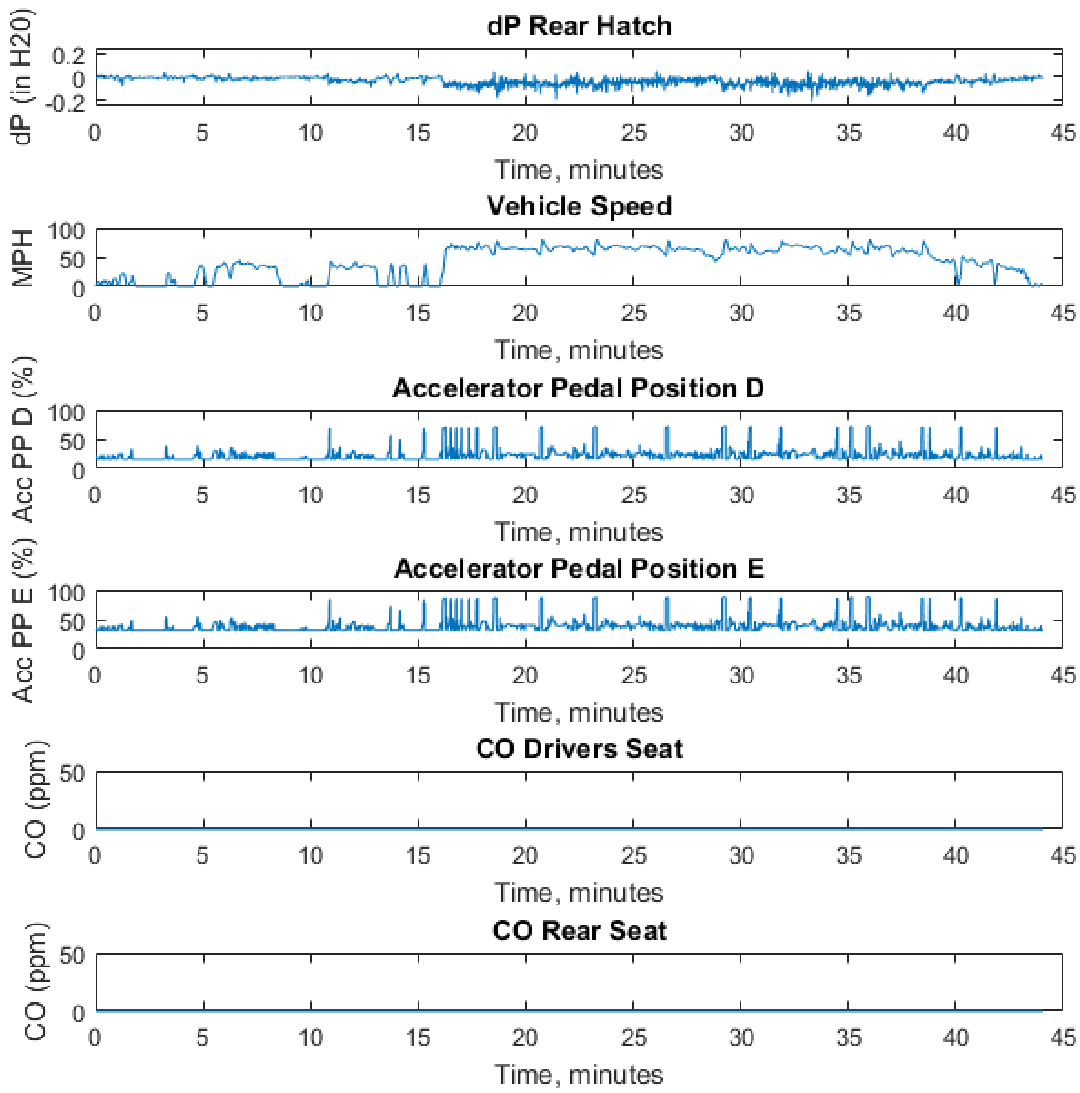

Figure 68: 2016 Toyota 4Runner 3514 test ID2 data.

ID3 Test Results: Complaint 2014 Ford Explorer 3986

The data captured for test ID3 can be seen in Figure 69. This data was captured simultaneously with test ID4. An odor was detected after WOT on-ramp application. Odor dissipated after approximately 7 seconds.

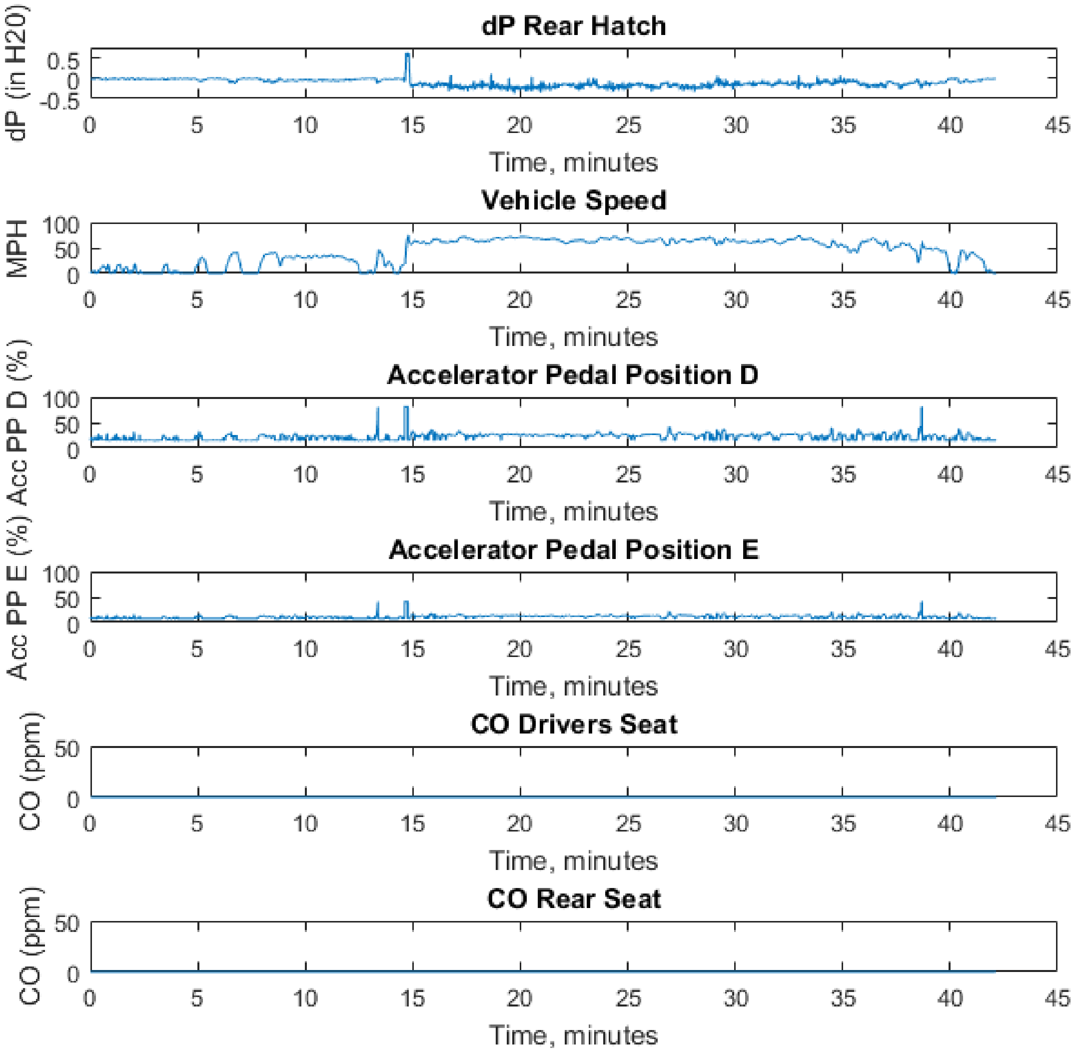

Figure 69: Complaint 2014 Ford Explorer 3986 test ID3 data.

ID4 Test Results: Dixon 2013 Ford Explorer 1363

The data captured for test ID4 can be seen in Figure 70. This data was captured simultaneously with test ID3. An odor was detected on three occasions during the test drive. The first odor was detected after the WOT on the onramp to the freeway, and it dissipated after a few minutes. The second odor was experienced in heavy traffic on the freeway. An odor was simultaneously detected by another test engineer nearby on the route, suggesting that the odor could have been associated with other vehicles. An odor was also detected after a WOT on 30th Ave., which was faint compared to the first detected odor.

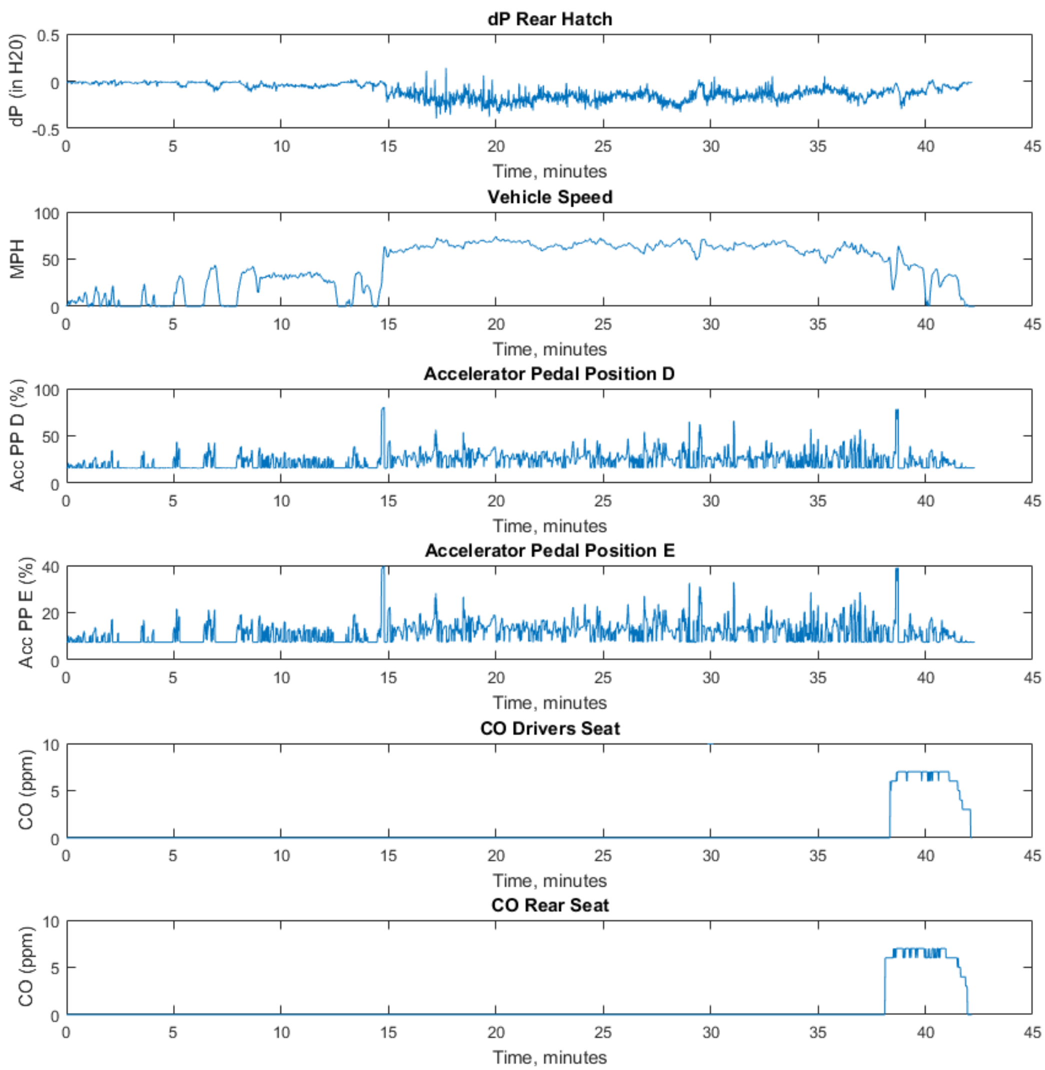

Figure 70: Dixon 2013 Ford Explorer 1363 test ID4 data.

ID5 Test Results: 2015 Dodge Durango 6788

The data captured for test ID5 can be seen in Figure 71. This data was not captured simultaneously with another test.

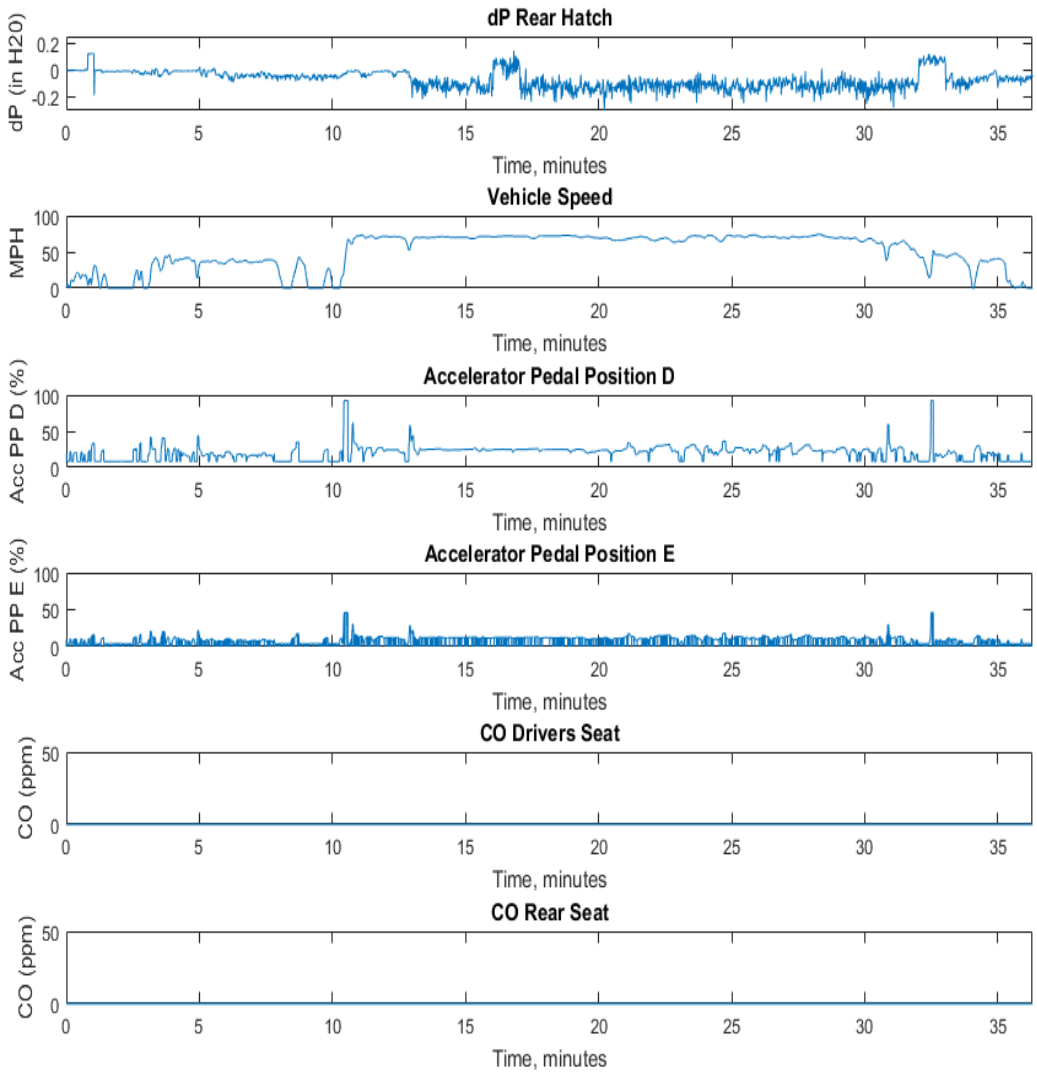

Figure 71. 2015 Dodge Durango [redacted] test ID5 data.

ID6 Test Results: 2016 Toyota 4Runner 3514

The data acquisition system malfunctioned and no pressure data was recorded for this test. Zero CO was recorded during this test. This data was captured simultaneously with test ID7.

ID7 Test Results: 2015 Nissan Pathfinder 0146

The data captured for test ID7 can be seen in Figure 72. This data was captured simultaneously with test ID6.

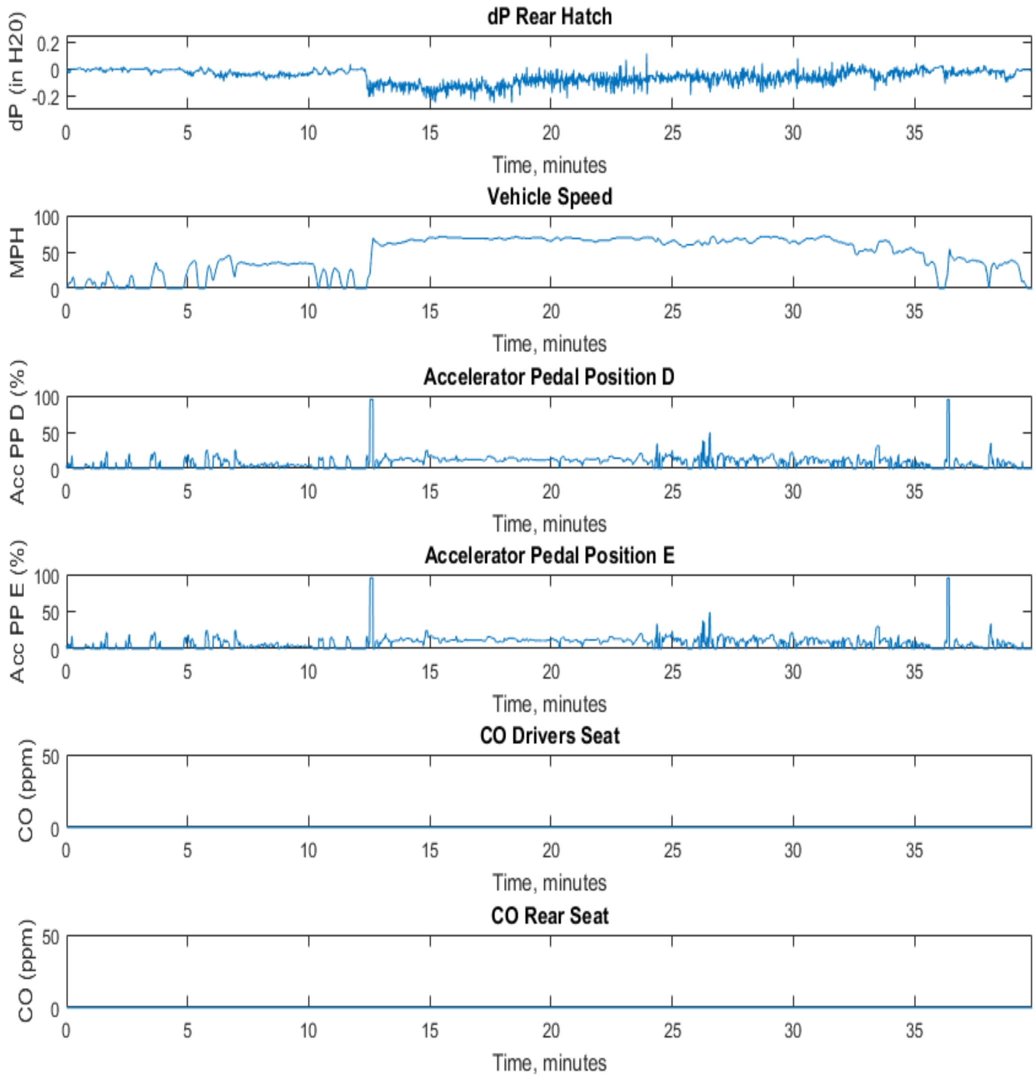

Figure 72: 2015 Nissan Pathfinder 0146 test ID7 data

ID8 Test Results: 2016 Toyota 4Runner 3514

The data captured for test ID8 can be seen in Figure 73. This test is a repeat of test ID6. There were no vehicles tested simultaneously.

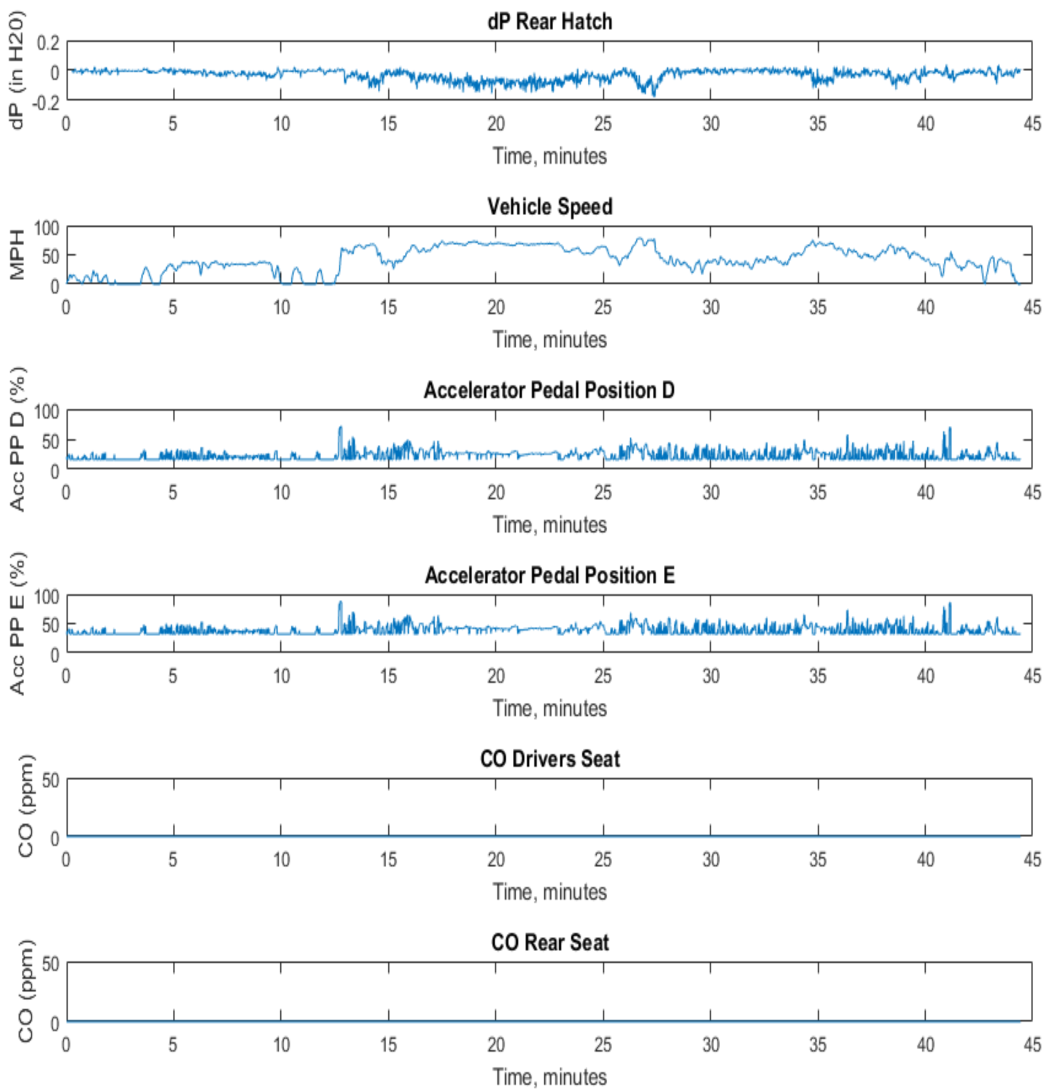

Figure 73: 2016 Toyota 4Runner 3514 test ID8 data.

ID9 Test Results: 2015 Jeep Grand Cherokee 6213

The data captured for test ID9 can be seen in Figure 74. Test ID10 and ID11 were tested simultaneously. CO was registered on the gas monitors prior to the test drive with vehicles idleing.

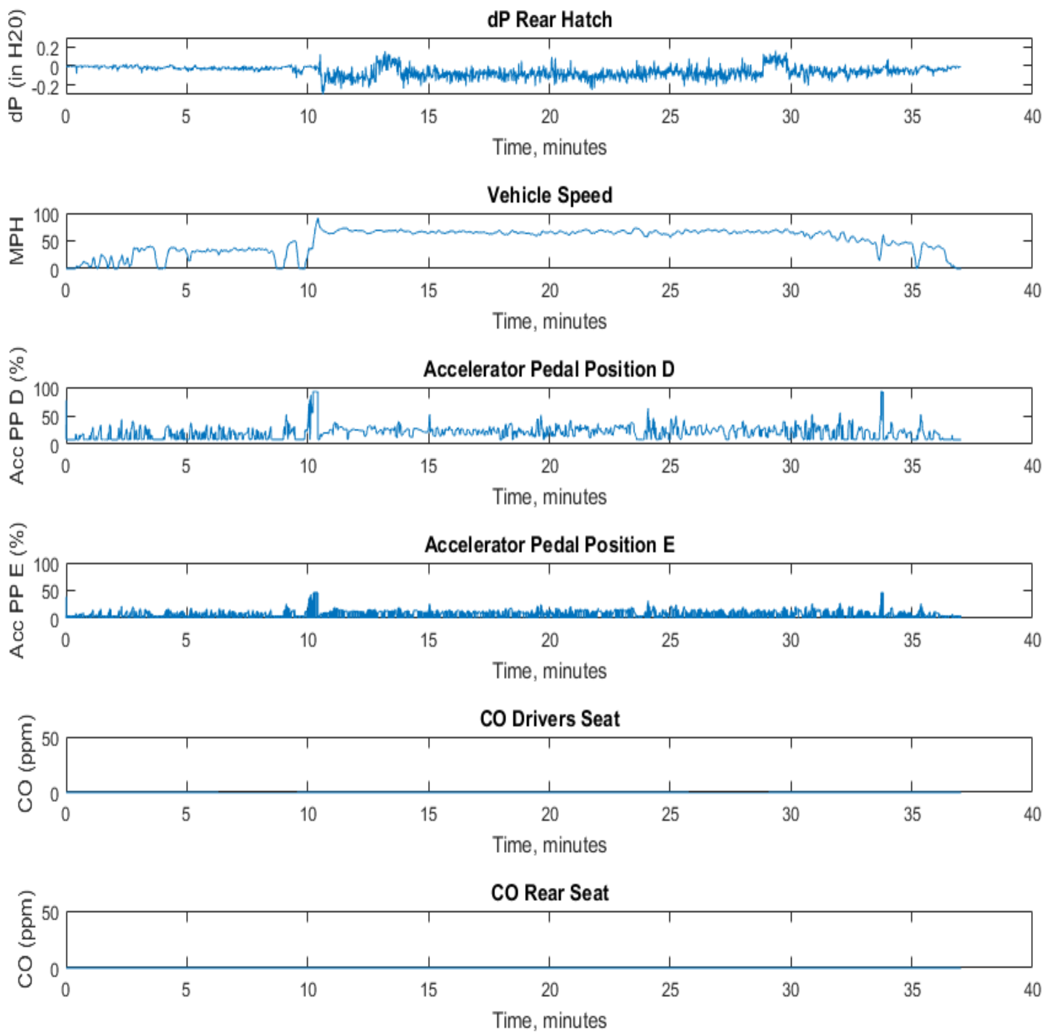

Figure 74: 2015 Jeep Grand Cherokee 6213 test ID9 data.

ID10 Test Results: 2016 Chevrolet Traverse 2347

The data captured for test ID10 can be seen in Figure 75. Test ID9 and ID11 were tested simultaneously. An exhaust odor was observed at the conclusion of a WOT on the onramp to the freeway for approximately 10-15 seconds, at which point it dissipated.

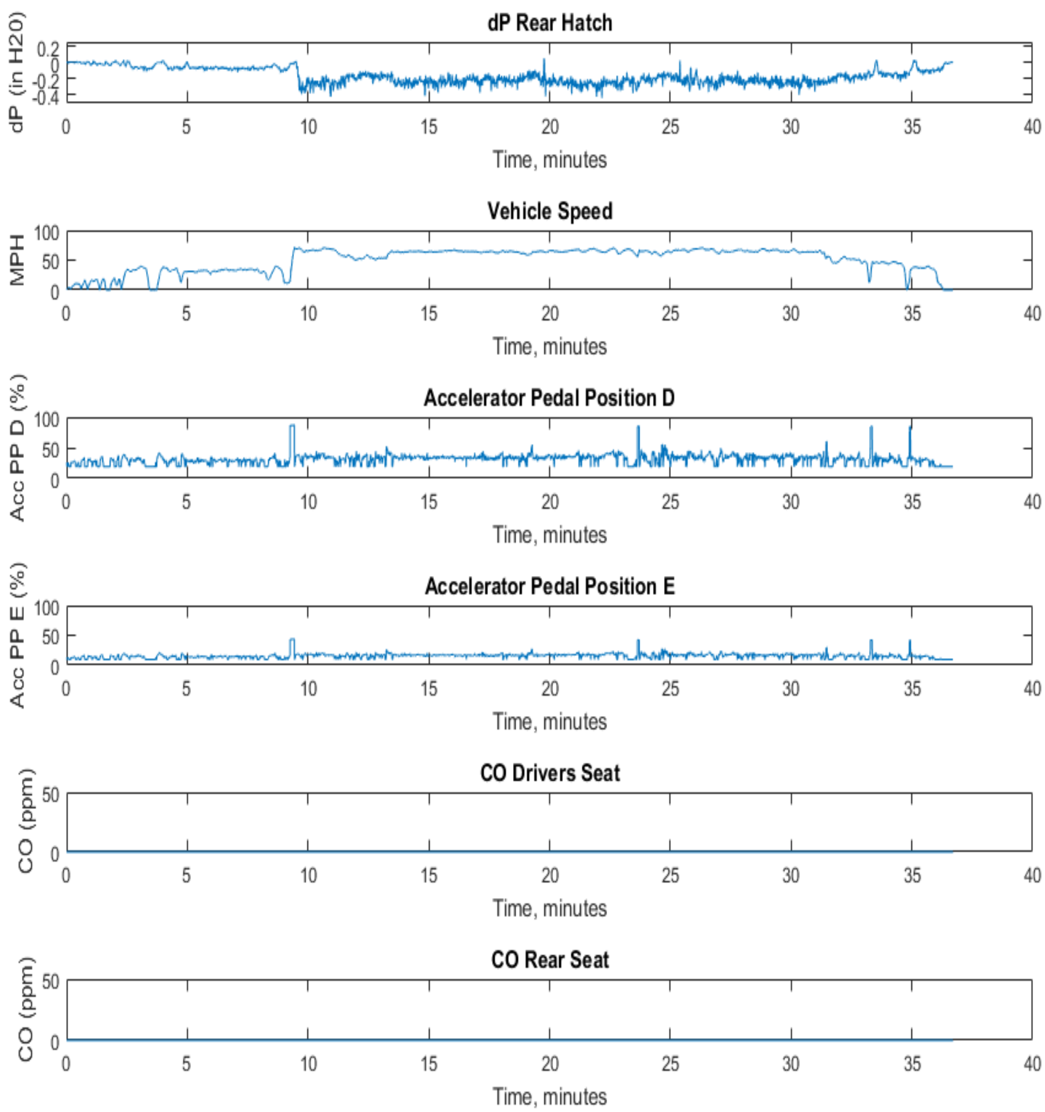

Figure 75: 2016 Chevrolet Traverse 2347 test ID10 data.

ID11 Test Results: 2014 Toyota Highlander 6397

The data captured for test ID11 can be seen in Figure 76. Test ID9 and ID11 were tested simultaneously. An exhaust odor was observed at the conclusion of a WOT on the onramp to the freeway. Also, CO was detected just outside of the left rear door prior to the start of the test, while the vehicle was idleing.

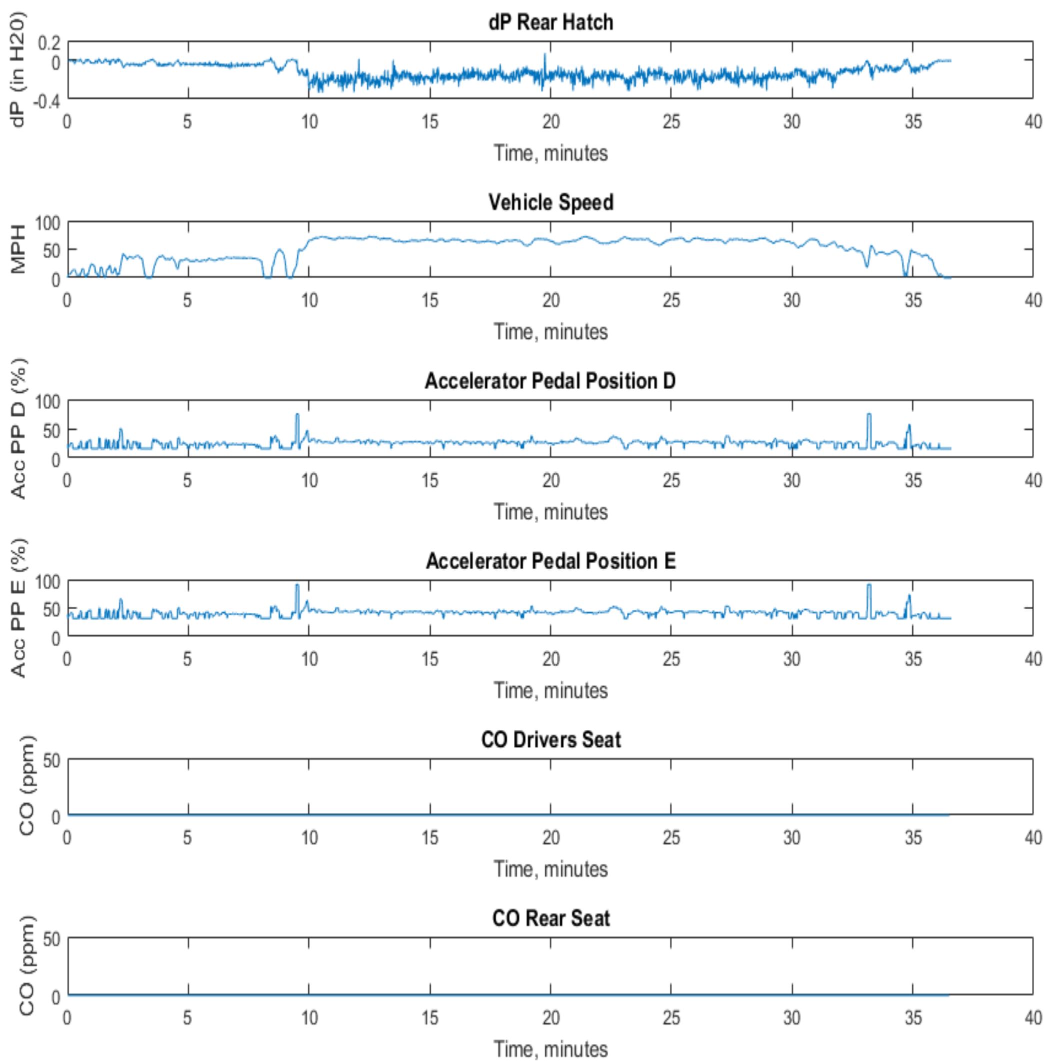

Figure 76: 2014 Toyota Highlander 6397 test ID11 data.

ID12 Test Results: 2016 Chevrolet Traverse

The objective of this test was to determine the effect of rear HVAC fan speed on the pressure differential between the hatch cargo area and the exterior lower hatch near latch area. Therefore, no CO data was collected, and the route travelled was different than Timothy Knutson's route from his residence to the fire state. The data are shown in

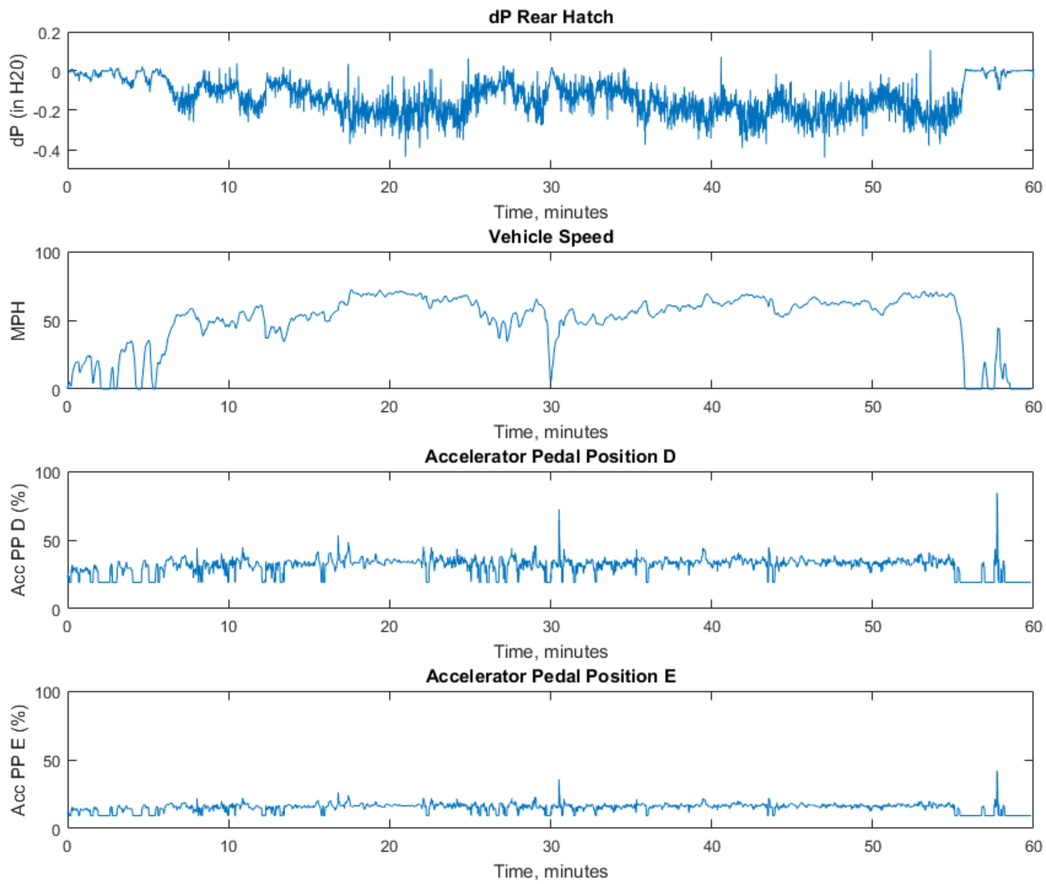

Figure 77: 2016 Chevrolet Traverse test ID12 data.

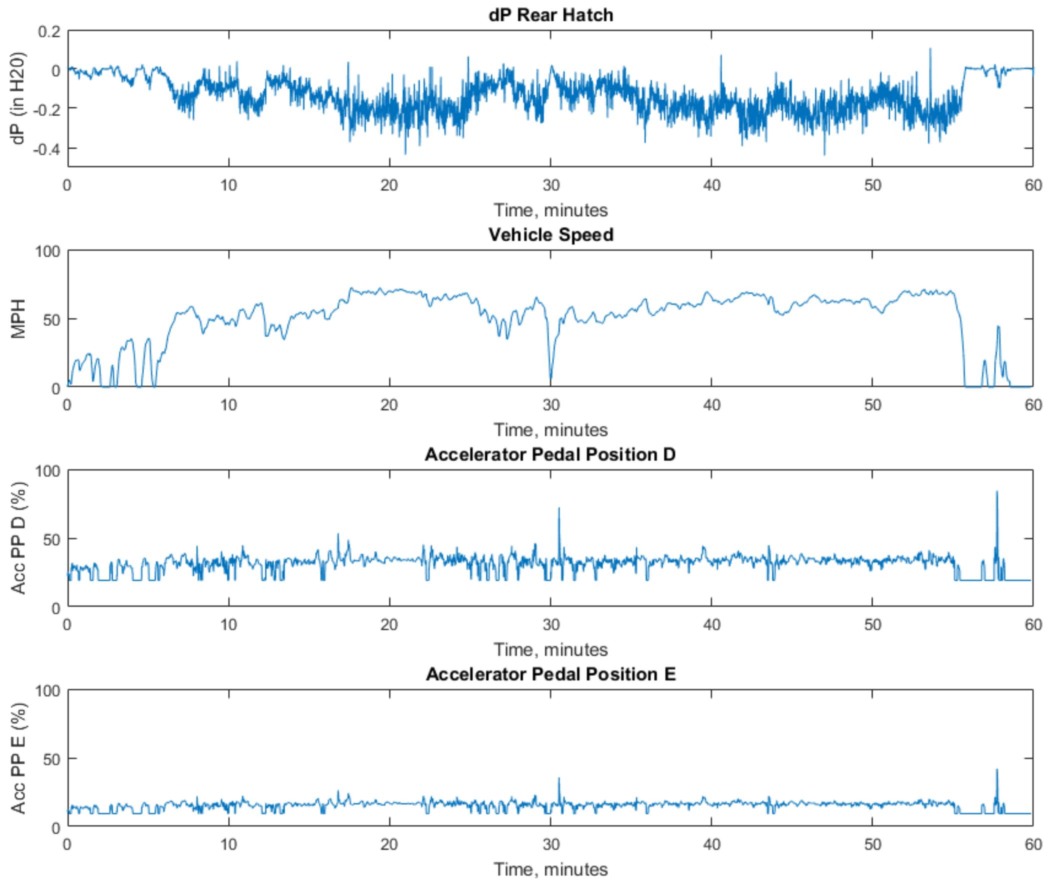

Figure 77: 2016 Chevrolet Traverse test ID12 data.

ID13 Test Results: 2011 Honda Pilot 4610

The data captured for test ID11 can be seen in Figure 76. The vehicle was not tested simultaneously with another vehicle.

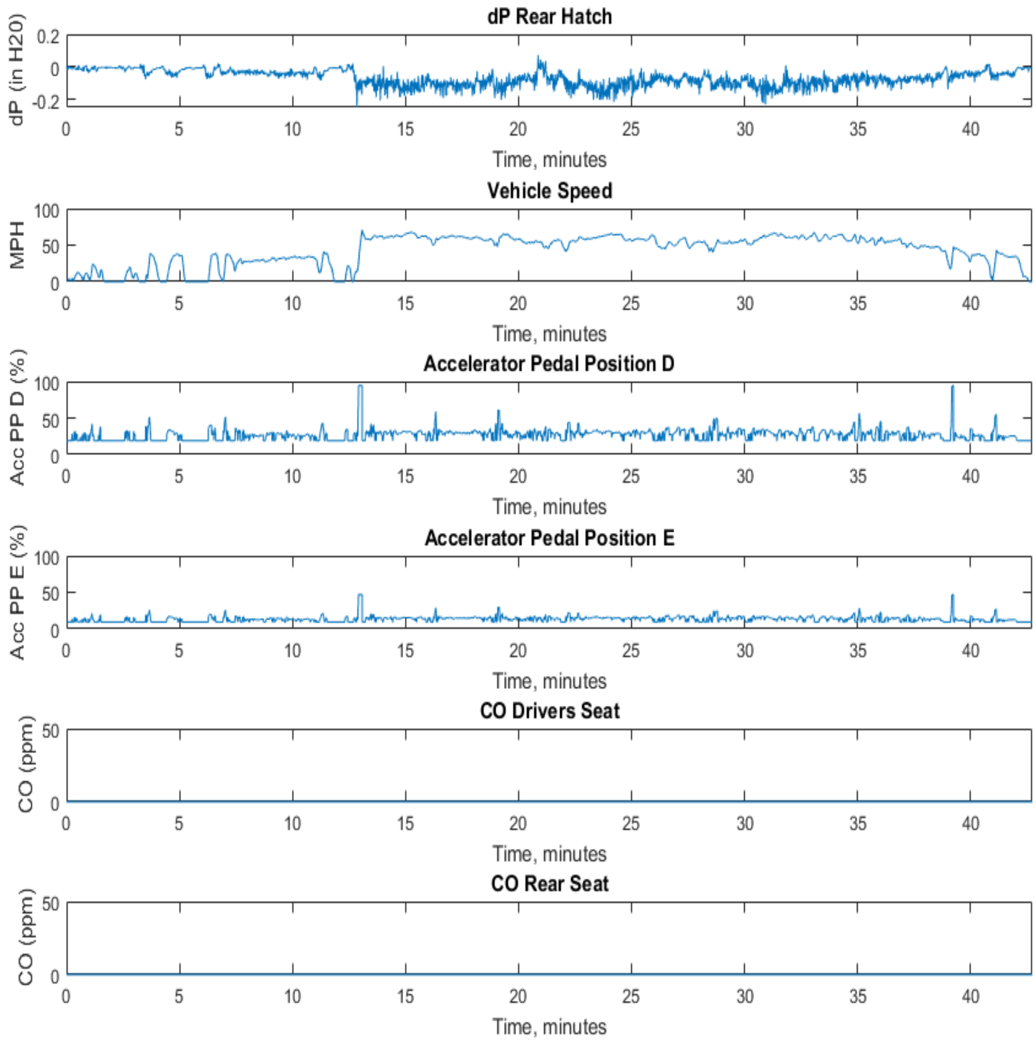

Figure 78: 2011 Honda Pilot 4610 test ID13 data.

ID14 Test Results: 2015 Ford Explorer 9474

The data captured for test ID14 can be seen in Figure 79. Test ID15 was tested simultaneously. An exhaust odor was observed at the conclusion of a WOT on the onramp to the freeway, which was detected at approximately the same time by the ID15 test engineer. A Diesel truck was ahead of both test vehicles, so it was possible that the exhaust from that vehicle is what the test engineers had smelled (see Figure 80). Even when vehicles are set to "Max AC" mode, with recirculation, some systems are designed to allow outside air into the vehicle.[10] A fog test was performed on an Explorer to confirm that these vehicles do let fresh air in when in recirculation mode. A test was run with windows rolled up, the vehicle in Max AC mode, and fog was directed towards the fresh air inlets at the base of the front windshield, and fog entered the cabin through the vents.

Note that the pressure sensor did not appear to function properly during this test.

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[10] Schnubel, Mark, Today's Technician: Automotive Heating & Air Conditioning Classroom Manual and Shop Manual, 5th edition, 2013, pg. 285.

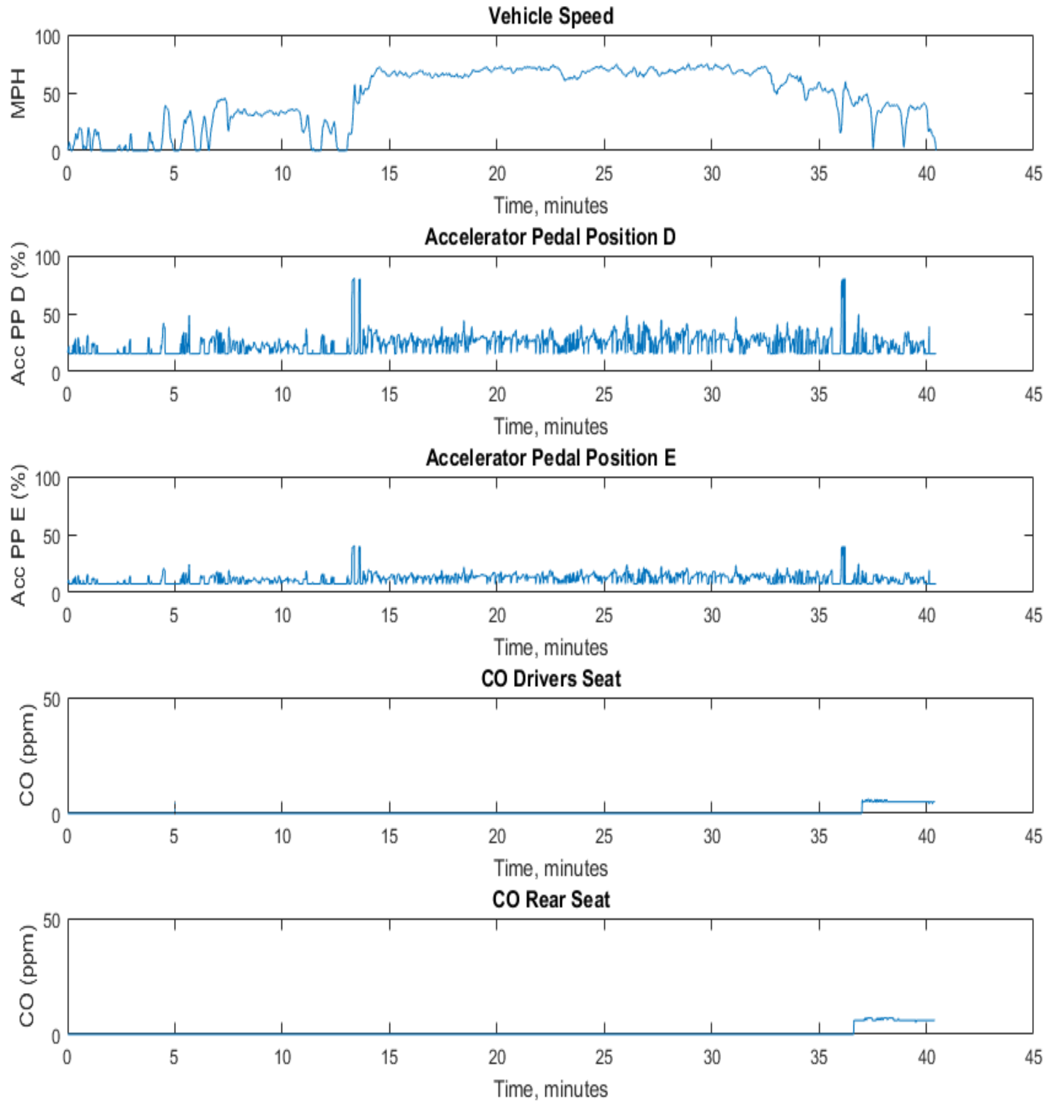

Figure 79: 2015 Ford Explorer 9474 test ID14 data.

Figure 80: Video screenshot showing the truck on the onramp ahead of the ID14 test vehicle after the WOT.

ID15 Test Results: 2013 Ford Explorer 5462

The data captured for test ID15 can be seen in Figure 81. Test ID14 was tested simultaneously. An exhaust odor was observed at the conclusion of a WOT on the onramp to the freeway, which was detected simultaneously by the ID14 test engineer as described before. A Diesel truck was nearby, so it was unclear if the exhaust from that vehicle is what the test engineers had smelled. Alternatively, it is possible that the ID15 test engineer had smelled the exhaust of the ID14 vehicle.

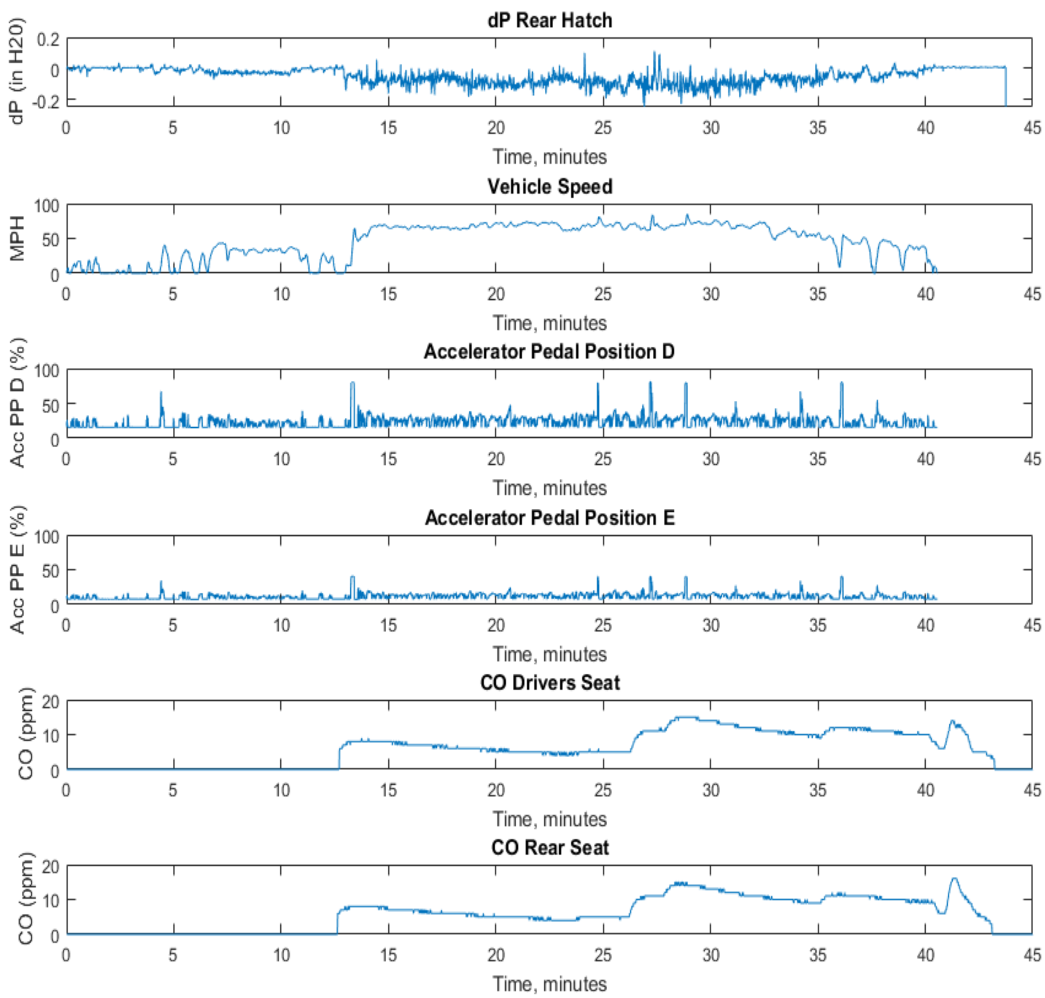

Figure 81: 2013 Ford Explorer [redacted] test ID15 data.

ID16 Test Results: Complaint 2014 Ford Explorer [redacted]

The OBD-II and pressure differential data captured for test ID16 can be seen in Figure 82, and the CO data can be seen in Figure 83. Note that the left air extractor inside, above underbody lap joints CO monitor's battery discharged approximately 14 minutes into the test.

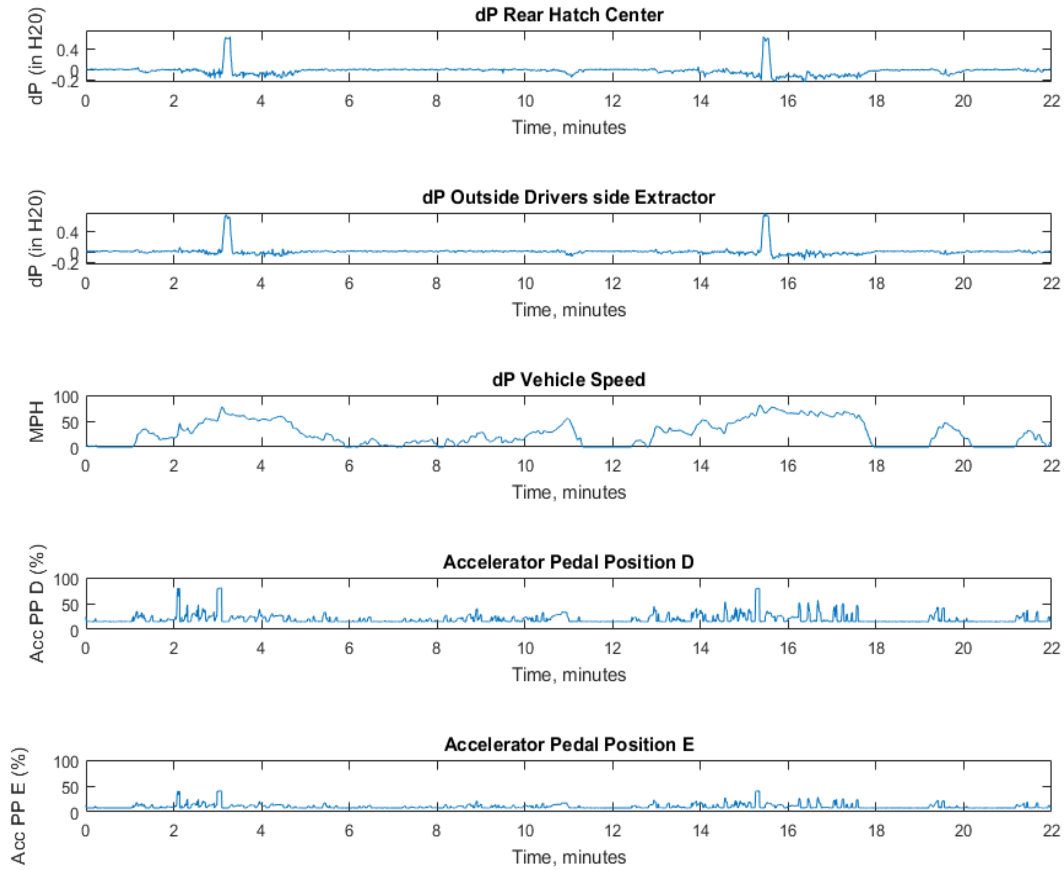

Figure 82: Complaint 2014 Ford Explorer 3986 test ID16 OBD and pressure differential data.

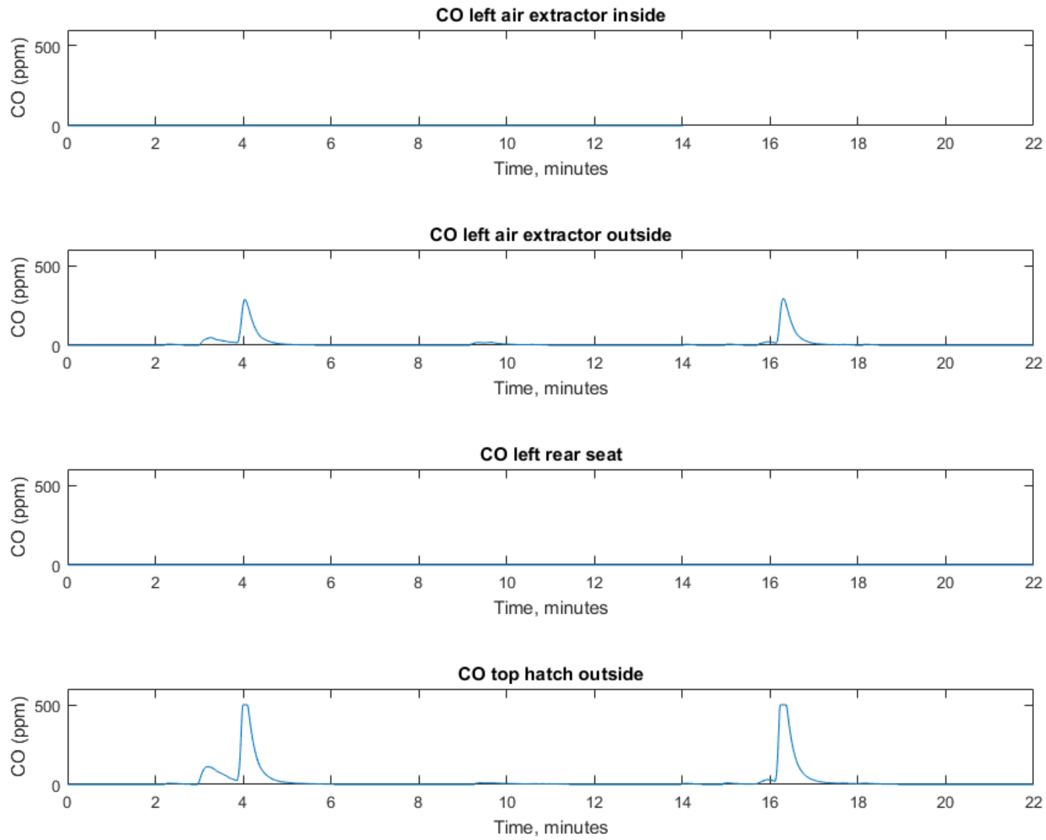

Figure 83: Complaint 2014 Ford Explorer 3986 test ID16 CO data.

ID17 Test Results: Dixon 2013 Ford Explorer [redacted]

The OBD-II and pressure differential data captured for test ID16 can be seen in Figure 84, and the CO data can be seen in Figure 85.

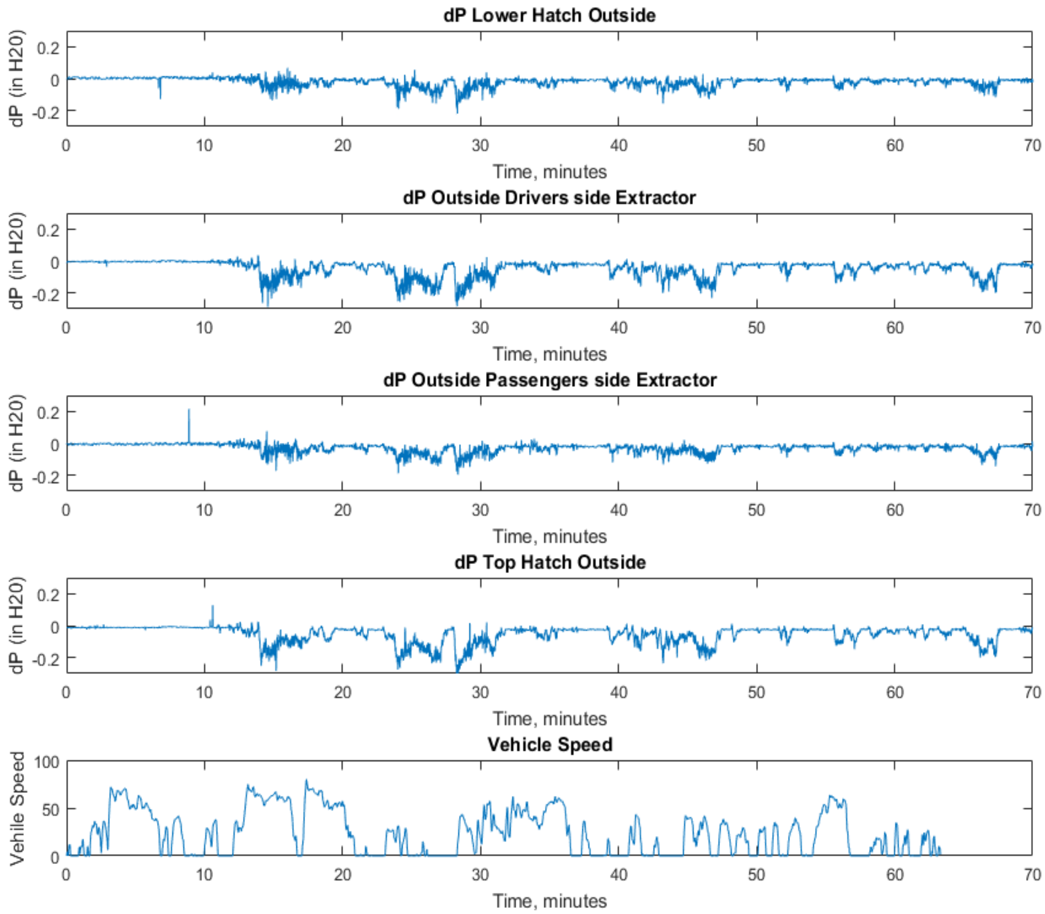

Figure 84: Dixon 2013 Ford Explorer 1363 test ID17 OBD-II and pressure differential data.

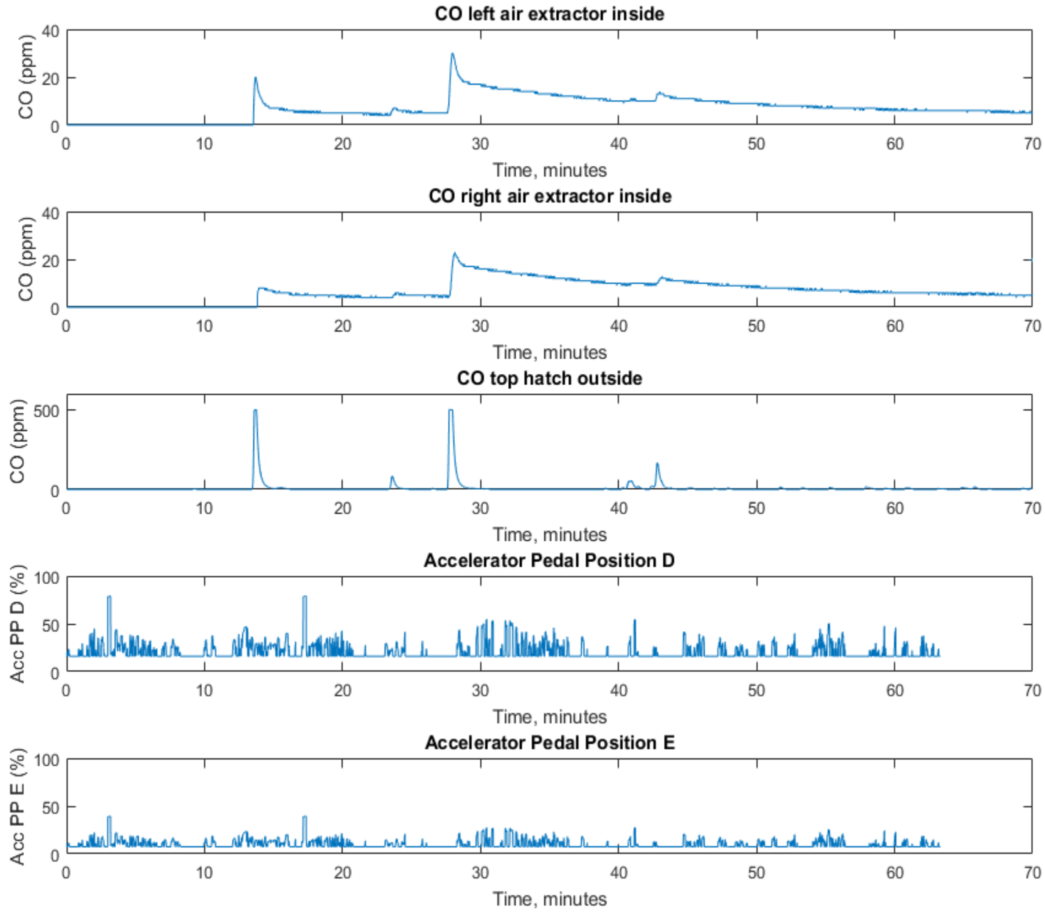

Figure 85: Dixon 2013 Ford Explorer [redacted] test ID17 OBD and CO data.

IN THE UNITED STATES DISTRICT COURT
FOR THE SOUTHERN DISTRICT OF FLORIDA

[redacted],
Individually, and on behalf of all those similarly situated,

Plaintiff

vs.

FORD MOTOR COMPANY

Defendant.

CASE [redacted]

Expert Declaration of Michael E. Cundy, Ph.D., P.E.

I, Dr. Michael Cundy, hereby declare:

1. I am a Senior Engineer employed by Exponent, an engineering and scientific consulting firm, and am located in Phoenix, Arizona. I received a Bachelor's degree in Mechanical Engineering from The Ohio State University in 2005, and Master's and Doctoral degrees in Mechanical Engineering from the University of Michigan in 2008 and 2012, respectively. While at the University of Michigan, I worked in the General Motors Research and Development Center in Warren, Michigan. I am a registered Professional Engineer in the State of Arizona (license #55526). During the course of my employment at Exponent, I have specialized in the application of mechanical engineering principles to the analysis and investigation of thermal, combustion, and fluid processes in various systems, including systems in prototype and production vehicles.

2. My work at the University of Michigan and General Motors was on the development of a direct-injection stratified charge gasoline engine. During the course of this research, I studied air flow, fuel concentration, and temperature fields in engines to better understand combustion performance and stability. This included evaluating engine output and exhaust products under different operating conditions. I utilized a lambda meter to

evaluate the fuel-to-air ratio, which affects the composition of exhaust products, including carbon monoxide (CO) concentration.

3. From 2003-2005, I carried out research in the Non-equilibrium Thermodynamics Laboratory at The Ohio State University on a project funded by the U.S. Air Force. I investigated whether a technology called the magneto-hydrodynamic (MHD) force could be used for flow control on supersonic vehicles, such as on the wings of a supersonic jet, to affect how the flow moves around the vehicle. More specifically, I was looking to see if the technology could delay the laminar to turbulent transition point to reduce skin friction, thereby making the vehicle more fuel efficient. I developed laser diagnostics to measure density fluctuations in the boundary layer in this analysis.

4. While in the Quantitative Laser Diagnostics Laboratory at the University of Michigan, I studied fluid flow in internal combustion engine cylinders. I developed and applied particle image velocimetry (PIV) laser diagnostics to measure flow velocity fields (i.e. two dimensional flow maps) at high-speeds in engine cylinders. I applied these diagnostics to test engines at the University of Michigan W. E. Lay Automotive Laboratory, and at the General Motors Research & Development Center. Flow fields were measured at various operating conditions, and the results were made available to develop engine computational models.

5. In other work at the University of Michigan, I developed laser diagnostics to measure fuel concentration at high-speeds in an internal combustion engine cylinder, and utilized this technique along with a spark plug absorption probe which measured fuel concentration and combustion products.

6. A copy of my curriculum vitae (CV) is attached and marked as Exhibit A, which includes lists of all publications and presentations authored by me. Currently, Exponent charges $235 per hour for my work in this matter. I have not testified previously in deposition or trial. A list of materials reviewed or relied upon are shown in Exhibit B.

7. The opinions in this declaration are provided to a reasonable degree of engineering certainty. I reserve the right to supplement this declaration and to expand or modify opinions based on review of additional material as it becomes available, review of work performed by others, and/or subsequent analysis or testing done by me. I am offering this declaration in support of Ford Motor Company's opposition to Plaintiffs' Renewed Motion for Class Certification.

8. I was asked by counsel for Ford Motor Company to evaluate the claims relating to carbon monoxide (CO) infiltration made by [redacted] regarding their 2013 Ford Explorer ("Subject Vehicle").

9. As part of my analysis, I tested the Subject Vehicle, three exemplar Ford Explorers rented from car rental companies, and a Ford Explorer that was repurchased from a customer due to complaints of exhaust odor.

10. Based on my knowledge and testing of engines and vehicle performance, when drivers request maximum engine performance by commanding wide open throttle ('pedal to the metal'), better engine performance can be attained by temporarily running the engine with a richer-than-ideal fuel-to-air mixture, which will markedly increase tailpipe emissions of CO. When driver demand for power decreases, the engine reverts to running in a manner that maintains minimal tailpipe emissions. Thus, to increase the probability that measurable CO would enter the vehicle, I had to intentionally find opportunities to run the engine wide-open-throttle while driving.

11. I inspected the Subject Vehicle on January 15, 2015. I drove the Subject Vehicle with several wide-open throttle accelerations from the Sanchez-Knutson residence to the Fire Station in Broward County, with the windows rolled up, the air conditioner set to "Max AC" mode (recirculation on), and with the rear climate setting at its coldest and highest fan speed. The drive was approximately 30 minutes in duration. A Ford engineer, James Engle, sat in the passenger seat and took CO readings with a calibrated RAE Systems MultiRAE Pro gas monitor. The highest momentarily recorded CO concentration was 61

ppm. Approximately 10 minutes later, the CO concentration had fallen to 27 ppm. At the conclusion of the trip, the CO concentration had fallen to 18 ppm. This is in contrast to the 132 ppm shown in Exhibit A to Timothy Knutson's Declaration, which is a photograph taken at the conclusion of his trip on the same route.

12. Exhibit A to [redacted] Declaration shows a photograph of the RAE Systems MultiRAE Pro gas monitor used in the testing described in his deposition. The screen does not show a check mark at the top, which is present only when "all sensors tested and calibrated according to policy."[1] During all Exponent testing, a check mark was present (see Figure 1).

Figure 1 Photograph from Exhibit A to [redacted] Declaration (left) which does not show a check mark, and a photograph taken at the conclusion of an Exponent test with the Subject Vehicle showing a check mark.

13. I rented three exemplar Ford Explorers[2] and tested them on the same (or very similar route; road construction was in progress during the subject vehicle test drive) in Florida. These vehicles were driven in a similar fashion as the Subject Vehicle, with several wide-open throttle accelerations, "Max AC" on (recirculation on), windows rolled up, and with the rear climate setting at its coldest and highest fan speed. CO concentrations were measured in the center dash area (same location as the monitor in Exhibit A to Timothy Knutson's Declaration), and were periodically measured in the passenger and driver side

[1] RAE Systems MultiRAE Pro gas monitor manual, revision C, March 2014, pg. 10.

[2] VIN: 1FM5K7F81FG[redacted] (2015 Ford Explorer with 3.5L V6), VIN: 1FM5K7F85FGB[redacted] (2015 Ford Explorer with 3.5L V6), VIN: 1FM5K7F89EG[redacted] (2014 Ford Explorer with 3.5L V6)

areas. Measurements in the various front seat locations were essentially the same. Out of all three exemplar vehicles, the highest momentarily recorded CO concentration was 18 ppm. During that same test, the CO concentration had fallen to 11 ppm approximately 9 minutes later. When these vehicles were driven as I normally drive my personal vehicle, in a manner consistent with current traffic patterns and safe driving habits, 0 ppm was recorded at the locations described above.

14. I tested a Ford Explorer Sport[3] which was repurchased from a customer who had complained of exhaust odor. I tested this vehicle on Phoenix, Arizona roads with several wide-open throttle accelerations, with "Max AC" on (recirculation on), windows rolled up, and with the rear climate setting at its coldest and highest fan speed. As before, the CO concentration was measured at various locations in the front seat area, which yielded the same or similar results. The highest momentarily recorded CO concentration was 10 ppm. The CO concentration had fallen to 5 ppm approximately 5 minutes later. When this vehicle was driven as I normally drive my personal vehicle, in a manner consistent with current traffic patterns and safe driving habits, 0 ppm was recorded at the locations described above.

15. I acquired two additional calibrated RAE Systems MultiRAE Pro gas monitors and installed them in the middle row, left seat, and in the rear row, left seat, of the repurchased Explorer, and measured CO concentrations simultaneously with the original meter that was positioned in the front center location. The middle and rear row sensor inlets were positioned a few inches below where the seat back meets the headrest. I tested the repurchased Explorer on Phoenix, Arizona roads with several wide-open throttle accelerations, with "Max AC" on (recirculation on), windows rolled up, and with the rear climate setting at its coldest and highest fan speed. The highest CO concentrations recorded were 11, 13, and 14 ppm in the front center, middle row left seat, and rear row left seat, respectively. Figure 2 shows a plot of the vehicle speed, accelerator pedal position sensor D signal, and the CO concentrations measured at each location. Note that the accelerator pedal position sensor D signal is at idle at

[3] VIN: 1FM5K8GT0EGC[redacted] (2014 Ford Explorer Sport with 3.5L V6 twin-turbo)

approximately 15% of full scale, and wide-open throttle is approximately 80% of full scale. I repeated the test on the same roads in the opposite direction as I normally drive my personal vehicle, in a manner consistent with current traffic patterns and safe driving habits, and recorded 0 ppm at all three locations for the duration of the test. At the conclusion of each of these two tests, I ran calibration gases through the CO meters to verify their proper operation and calibration, which are the three peaks shown between 27 and 32 minutes.[4]

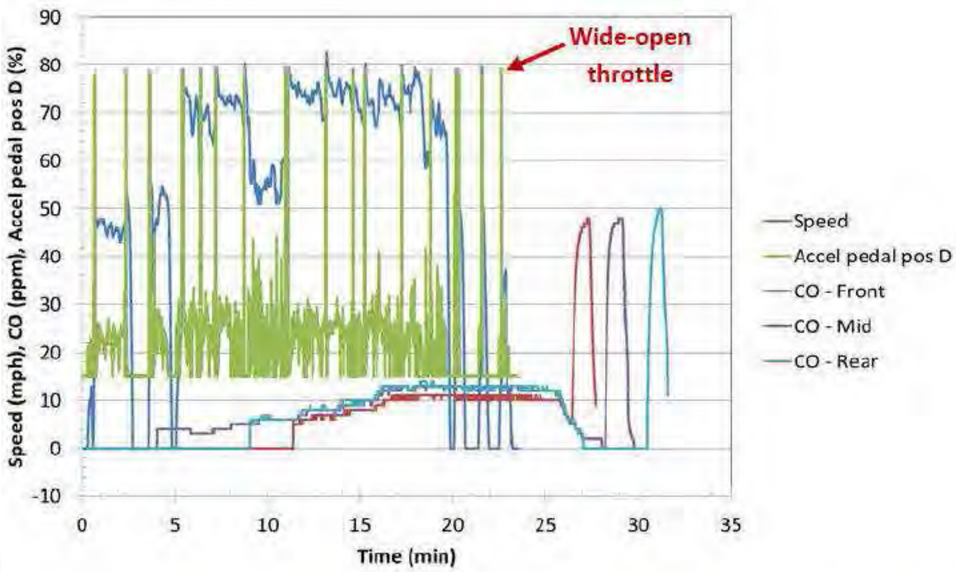

Figure 2 **Plot showing the vehicle speed, accelerator pedal position sensor D, and CO concentration in the front, near the AC vents, in the middle left seat, and in the rear left seat.**

16. I drove the repurchased vehicle as I normally drive my personal vehicle in a manner consistent with current traffic patterns and safe driving habits for approximately 150 miles over the course of eight different trips. These trips included different front air conditioner settings, adjusted to comfort with recirculation mode on, the rear fan set to its maximum speed and coldest setting, different cargo loads, and with the windows rolled up. The middle and rear row seats were folded down during three trips to accommodate different cargo loads. During all trips, 0 ppm CO was recorded in the front central location.

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[4] The calibration gas I used was RAE Systems, lot 1829253, cylinder 70 containing CO at 50 ppm.

17. The CO concentration measured in the Plaintiff's vehicle by the Plaintiff is not typical of the four other Explorers that I tested, and did not represent the CO levels measured using a CO monitor that was in calibration. The higher values of CO that I measured in the Subject Vehicle relative to the tested Explorers are likely the result of an inadequate repair of the lift gate sealing system after the Subject Vehicle had been involved in a rear collision on or around June 5, 2013. During the rear collision, a 2003 Jeep Liberty crashed into the rear of the Subject Vehicle,[5] causing substantial damage and requiring replacement of the rear bumper, lift gate, rear body panels, rear floor pan, muffler, and sill plates, among other components.[6] Photographs of the exterior damage to both vehicles can be seen in Figure 3. Additional photographs of damage to the bumper impact bar and the body at the hatch perimeter can be seen in Figure 4, and a photograph of the buckled rear floor pan can be seen in Figure 5.

Figure 3 **Photographs showing the external damage to the Ford Explorer (left; SKZ3-000802) and Jeep Liberty (right; SKZ3-000848) which occurred during the collision on or around June 5, 2013.**

[5] Florida Traffic Crash Report, SZK3 000228-236

[6] Sawgrass Ford Collision Center repair estimate, pp. SZK3 000139-SZK3 000148

Figure 4 **Photograph (SKZ3-000759) showing damage to the impact bar and the body at the hatch perimeter.**

Figure 5 **Photograph (SKZ3-000784) showing buckling of the rear floor pan area, where the spare tire resides.**

18. During the inspection of the Subject Vehicle on January 15, 2015, I created a slight vacuum in the vehicle using a Ridgid brand 6-gallon shop vacuum cleaner. A fog machine was held outside the vehicle and directed towards different areas of the vehicle rear. Fog entered the cabin quickly through areas around the perimeter of the rear hatch, particularly near the top. Upon inspection of the sealing area, witness marks on the lift gate surface indicated that the seal was not touching all the way around the perimeter (see Figure 6). This is consistent with poor repair. The repurchased vehicle rear hatch had witness marks from the rear hatch seal all around the perimeter, with the exception of a small (0.1"-0.2") gap (see Figure 7 for a photograph of the witness marks in the repurchased vehicle).

Figure 6 Witness marks from the seal on the top side of the rear hatch on the Subject Vehicle. Gaps are present.

Figure 7 Photograph showing the witness marks on the repurchased vehicle. The witness marks appeared to be continuous along the perimeter of the hatch, with the exception of a small 0.1"-0.2" gap near the bottom.

19. A fog test was performed on the repurchased Ford Explorer using the same fog machine and a Ridgid brand 6-gallon shop vacuum with the highest water lift available (model WD06701, 53" H_2O). Screen-captures from the videos of the Subject Vehicle and repurchased vehicle tests taken approximately 25 seconds into each test are shown in Figure 8. The significant fog intrusion on the Subject Vehicle is consistent with a poorly adjusted rear hatch and/or seal.

Figure 8 Screen captures taken approximately 30 seconds after the test was started in the Subject Vehicle (top) and in the repurchased vehicle (bottom).

20. Technical service bulletin (TSB) actions were either incomplete or done inadequately on the Subject Vehicle, thereby limiting the repair effectiveness.
    a. In certain areas, the applied Motorcraft Seam Sealer did not close the gaps in body panels, and the 3M Rubberized Undercoating did not cover the region indicated by the TSB. Figure 9 shows pictures from TSB 12-12-4 indicating proper coverage of the 3M Rubberized Undercoating spray (left picture) and the areas where the Motorcraft Seam Sealer should be applied (right picture) on the driver's side of the vehicle, near the muffler. Incomplete or inadequate application of the spray and seam sealer on the Subject Vehicle are shown in Figure 10. This is in contrast to the repurchased Explorer, which can be seen in Figure 11.
    b. The auxiliary climate control drain should have been covered prior to spraying the 3M Rubberized Undercoating, but it appears that this step was skipped (see Figure 12).

Figure 9 Photographs from TSB 12-12-4 illustrating areas on the driver's side which are to be covered with a "generous" amount of 3M Rubberized Undercoating (left picture) and seams to seal with the Motorcraft Seam Sealer (right picture). The yellow box in the right picture shows the field of view for the picture of the Subject Vehicle in Figure 10 and repurchased Explorer in Figure 11.

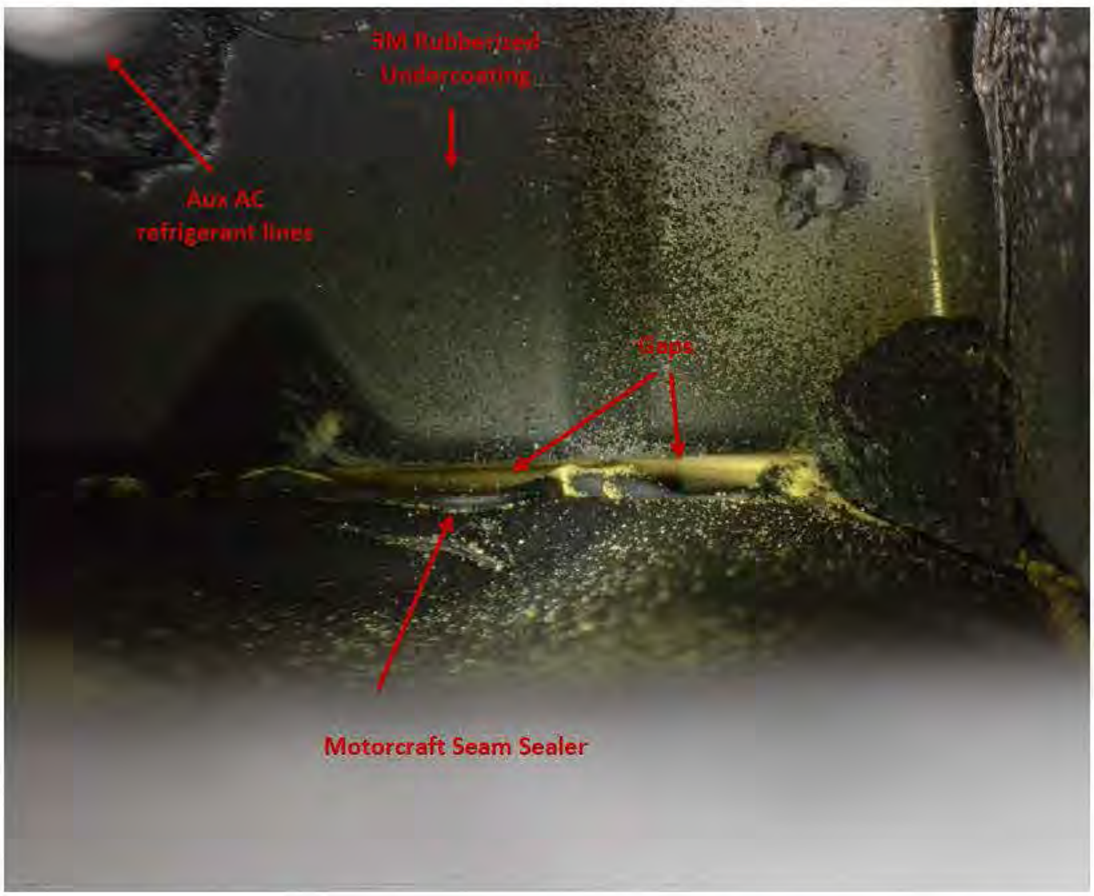

Figure 10 Photograph of the underbody of the Subject Vehicle near the auxiliary air conditioner refrigerant inlet showing gaps that the seam sealer was intended to seal, and incomplete coverage of the 3M Rubberized Undercoating.

Figure 11 Photograph of the repurchased Explorer with the same field of view as in Figure 10 showing adequate application and coverage of the Motorcraft Seam Sealer and 3M Rubberized Undercoating.

Figure 12 Photograph of the underbody of the Subject Vehicle showing the auxiliary climate control drain with 3M Rubberized Undercoating on it.

21. Vehicles are designed to prevent water intrusion into the cabin, but are not hermetically sealed to prevent air exchange. Even if such a production vehicle could be designed, it would not be advisable to do so since air exchange is needed so passengers do not deplete the oxygen in the vehicle. In the case of air conditioning systems, even when they are set to "Max AC" mode, with recirculation, some systems are designed to allow 20% fresh air into the vehicle.[7]

I declare under penalty of perjury that the foregoing is true and correct.

Executed on July 8, 2015

Michael E. Cundy, Ph.D., P.E.

[7] Schnubel, Mark, *Today's Technician: Automotive Heating & Air Conditioning Classroom Manual and Shop Manual*, 5th edition, 2013, pg. 285.

Exhibit A

CV of Michael E. Cundy, Ph.D., P.E.

Michael E. Cundy, Ph.D., P.E.

Senior Engineer

Professional Profile

Dr. Cundy is a licensed Mechanical Engineer with expertise in the fields of combustion, heat transfer, thermodynamics, fluid mechanics, and measurement systems. He has utilized these skills extensively in the analysis and investigation of mechanical and electrical vehicle systems, in both prototype and production versions. He has coordinated and participated in testing which has involved automotive refrigerant flammability, mechanical stress due to thermal expansion, electrical fault energy dissipation, exhaust system temperature testing, insulation flammability, circuit resistive fault testing, systems response to induced failures, burst testing of tubes, fire propagation, module-to-module communication via controller area networks, smoke detector operation, and more. He also has considerable experience with instrumentation and measurement systems. Additional work has included evaluation of the condition of a powder coating operation post-fire, heat transfer testing of winter jackets, and the determination of air conditioner capacity needed for a mobile laboratory to be used in specific geographical locations. Dr. Cundy also has extensive experience in fire cause and origin investigations involving vehicles, houses, and larger structures. He has worked in areas of product development, third-party validation, and product safety.

Prior to joining Exponent, he was a member of the Quantitative Laser Diagnostics Laboratory in the Walter E. Lay Automotive Laboratory at the University of Michigan in Ann Arbor, Michigan, where he developed and applied various laser diagnostic tools to study combustion in internal combustion engines. His work included developing and applying temperature field diagnostics to evaluate heat transfer from hot gases to the engine block, utilizing particle-image velocimetry to study flow patterns in engines, and developing and applying fuel concentration diagnostics to study combustion stability, including misfires and partial burns, in an advanced internal combustion engine.

While at the University of Michigan, Dr. Cundy was an instructor for a laboratory course which focused on experimental data collection, analysis, and data presentation, with an emphasis on error analysis.

Dr. Cundy also performed fluid mechanics research in the Non-equilibrium Thermodynamics Laboratory at The Ohio State University in Columbus, Ohio. He worked on a project funded by the U.S. Air Force where he developed a laser diagnostic tool to measure density fluctuations in the boundary layer of a supersonic flow.

Academic Credentials and Professional Honors

Ph.D., Mechanical Engineering, University of Michigan, Ann Arbor, 2012
M.S.E., Mechanical Engineering, University of Michigan, Ann Arbor, 2008
B.S., Mechanical Engineering, The Ohio State University (*with distinction, with honors*), 2005

Alternate – National Fire Protection Association (NFPA) Technical Committee on Recreational Vehicles, 2012–2014

Licenses and Certifications

Licensed Professional Mechanical Engineer, Arizona, #55526

Fire Investigation 1A: Fire Origin and Cause Determination; accredited by the California State Fire Marshal

Fire Investigation 1B: Techniques of Fire Investigation; accredited by the California State Fire Marshal

Publications

Colwell JD, Cundy M, Full-scale burn test of a 1992 compact pickup truck. SAE Paper 2013-01-0209, 2013.

Cundy ME. Development of high-speed laser diagnostics for the investigation of scalar heterogeneities in engines. Ph.D. dissertation, University of Michigan, 2012.
Cundy ME, Trunk P, Dreizler A, Sick V. Gas-phase toluene LIF temperature imaging near surfaces at 10 kHz. Experiments in Fluids 2011, DOI 10.1007/s00348-011-1137-8.

Cundy ME, Sick V. Hydroxyl radical imaging at kHz rates using a frequency quadrupled Nd:YLF laser. Applied Physics B 2009; 96(2):241–244.

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Conference Presentations

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Drake MC, Fansler TD, Cundy M, Sick V. High-repetition-rate Mie scattering and particle-image-velocimetry for flow and combustion diagnostics in a direct-injection gasoline engine. Presented at the 6th U. S. National Combustion Meeting, Ann Arbor, MI, May 2009.

Cundy M, Schucht T, Thiele O, Sick V. Novel optical diagnostics for mixing and combustion studies in engines. Presented at the University of Michigan Graduate Student Symposium, Ann Arbor, MI, November 2008.

Exhibit B

List of Materials Reviewed

Pleadings

Class Action Complaint, [redacted] *v. Ford Motor Company*, U.S.D.C. Southern District of California, June 9, 2014.

Plaintiff's Motion for Class Certification and Incorporated Supporting Memorandum, [redacted] *individually and on behalf of all those similarly situated v. Ford Motor Company*, Case No [redacted] WPD, U.S.D.C. Southern District of Florida, June 25, 2014.

Second Amended Class Action Complaint, [redacted], *individually and on behalf of all those similarly situated v. Ford Motor Company*, Case No. [redacted] U.S.D.C. Southern District of Florida, March 30, 2015.

Plaintiff's Renewed Motion for Class Certification and Incorporated Supporting Memorandum, [redacted], *individually and on behalf of all those similarly situated v. Ford Motor Company*, Case No [redacted], U.S.D.C. Southern District of Florida, June 8, 2015.

[redacted]

TSBs, Recalls and ONPs

TSB 12-12-04	Explorer exhaust odor in vehicle, superseded by TSB 14-0130
TSB 14-0130	Exhaust odor in vehicle

Additional Documents

Allstate file including any and all records associated with car accident on June 5, 2013. [redacted])

Progressive file including any and all records associated with car accident on June 5, 2013. [redacted])

Progressive file including only photos associated with car accident on June 5, 2013. [redacted]

Allstate file including only photos associated with car accident on June 5, 2013. ([redacted]-[redacted])

Allstate file including only photos associated with car accident on June 5, 2013. ([redacted]-[redacted])

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