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BIODIESEL AND RENEWABLE DIESEL CHARACTERIZATION AND TESTING IN MODERN LD DIESEL PASSENGER CARS AND TRUCKS

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COORDINATING RESEARCH COUNCIL, INC.
5755 NORTH POINT PARKWAY SUITE 265·ALPHARETTA, GA 30022

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Final Report

CRC Project No. AVFL – 17b: Biodiesel and Renewable Diesel Characterization and Testing in Modern LD Diesel Passenger Cars and Trucks

Prepared for:

Mr. Brent Bailey
Coordinating Research Council Inc.
3650 Mansell Road, Suite 140
Alpharetta, GA 30022
(678) 795-0506

November 2014

Submitted by:

Georgios Karavalakis, Ph.D.
Thomas D. Durbin, Ph.D.
Robert L. Russell, Ph.D.

University of California
CE-CERT
Riverside, CA 92521
951-781-5799
951-781-5790 (fax)

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Executive Summary

In recent years, government agencies around the world have implemented legislation that targets growing the use of renewable fuels in the transportation sector. In the U.S., the Energy Independence and Security Act of 2007 mandates the use of 36 billion gallons of biofuels in the transportation fuel market by 2022. The European Union (EU) has implemented several government mandates, such as the EU Renewable Energy Directive (2009/28/EC), which requires at least 10% (energy basis) of each Member State's transport fuel use to come from renewable sources (including biofuels). In California, the low carbon fuel standard (LCFS) was implemented in 2011 to promote the reduction of greenhouse gas emissions by targeting a 10% reduction in the carbon intensity of transportation fuels by 2020 (Farrell and Sperling, 2007). With the expectation that the diesel light-duty vehicle population will continue to increase in the U.S. market in the near future and the substantial increase in the U.S. production of biodiesel over the past three years (US EIA), the primary objective of this program is to characterize the impact of biodiesel blends from different feedstocks and a renewable diesel blend with different types of petroleum diesel fuels on the exhaust emissions from modern technology light-duty passenger cars and light-duty trucks.

A total of seven fuels were used in this study, including two reference fuels: a Federal Ultra Low Sulfur Diesel (ULSD) and a CARB ULSD. Three different fatty acid methyl esters (FAME) were selected: a methyl ester produced from soybean oil (SME), a waste cooking oil methyl ester (WCO), and a methyl ester produced from animal fat (AFME). A hydrogenated vegetable oil (HVO) renewable diesel was also used. The three FAME and one renewable diesel blendstocks were used to prepare four 20 vol% blends with the Federal ULSD. Only the WCO biodiesel was used to prepare a 20 vol% blend in the CARB ULSD.

This study evaluated five light-duty diesel cars and three trucks equipped with direct injection, common-rail diesel engines. These vehicles were all equipped with diesel particle filter (DPF) and selective catalytic reduction (SCR) aftertreatment systems.

Every vehicle/fuel combination was tested at least twice over the Federal Test Procedure (FTP) driving cycle. The test vehicles were preconditioned using a procedure that included multiple fuel drain and fills (to 40% of the fuel tank volume), a catalyst sulfur purge cycle, four coast downs (70 to 30 miles per hour), and finally an LA4 cycle. Emissions measurements were made for THC, NMHC, NO_x, CO, CO_2, CH_4, PM mass, and fuel economy. Measurements of unregulated emissions were also made for elemental carbon (EC) and organic carbon (OC) fracrions, real-time ammonia (NH_3) emissions, particle number (PN) emissions, real-time particle size distributions, polycyclic aromatic hydrocarbons (PAHs), and nitro-PAHs. Nitrogen oxide (NO), nitrogen dioxide (NO_2), and nitrous oxide (N_2O) were also measured for Vehicle #4 through Vehicle #8.

An ancillary investigation was performed on two of the test vehicles (Vehicle #1 and Vehicle #3) fueled with the Federal ULSD and Fed/SME-20 blend to evaluate emissions generated during a DPF regeneration event. The regeneration testing protocol included driving each vehicle on-road for approximately 160 miles (20 LA4-equivalents) to build up soot in the DPF. Regulated and unregulated emissions measurements were conducted over a double EPA Highway Fuel Economy Test (HWFET) cycle. A baseline double HWFET was also conducted on the Federal ULSD for each vehicle for comparison purposes.

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The regulated emissions, carbon balance fuel economy, PM mass and PN emissions, and formaldehyde and acetaldehyde emissions were subjected to statistical analysis using the Mixed procedure in PC/SAS (Statistical Analysis System for Personal Computers) from SAS Institute, Inc. For pollutants where the Mixed model showed that there were statistically significant differences between test fuels for FTP weighted composite or individual cycle phases, additional pairwise comparisons were performed using a least significant difference test to determine the specific fuel pairs that were statistically different. Results were classified as statistically significant for p ” 0.05 and marginally statistically significant for $0.05 < p$ ” 0.1. A summary of the FTP weighted composite results for which fuel pairs were found to be different at a statistically significant level is provided in Table ES-1. While each pairwise difference in Table ES-1 is statistically significant at the 95% or 90% level, it should be noted that this does not mean that there is a 95 or even 90% probability of all the listed differences being true simultaneously. Results reported here are for the test conditions used in this study (i.e., test fuels, vehicles, driving cycles). Other trends may be observed under different conditions.

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Table ES-1: Summary of statistical comparisons for different fuels

NO_x LSM (g/mile)							THC LSM (g/mile)							NMHC LSM (g/mile)						
A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
0.066	0.075	0.071	0.070	0.074	0.073	0.071	0.040	0.032	0.039	0.034	0.038	0.035	0.033	0.018	0.013	0.019	0.014	0.019	0.013	0.014
NS							**B 18% lower than A** **G 16% lower than A** **C 19% higher than B** **E 17% higher than B** G 14% lower than C							**B 28% lower than A** **F 24% lower than A** G 20% lower than A **C 48% higher than B** **E 49% higher than B** **D 24% lower than C** **F 29% lower than C** **G 26% lower than C** **E 32% higher than C** **E 32% higher than D** **F 29% lower than E** **G 26% lower than E**						
CH_4 LSM (g/mile)							CO LSM (g/mile)							CO_2 LSM (g/mile)						
A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
0.021	0.021	0.021	0.021	0.020	0.023	0.020	0.164	0.114	0.172	0.139	0.159	0.144	0.134	460	462	469	463	470	459	462
F 15% higher than E							**B 31% lower than A** G 18% lower than A **C 52% higher than B** **D 22% higher than B** **E 40% higher than B** **F 26% higher than B** **D 19% lower than C** F 17% lower than C **G 22% lower than C**							**C 1.9% higher than A** **E 1.7% higher than A** **E 2.3% higher than B** **F 2.1% lower than C** **E 1.7% higher than D** **F 2.5% lower than E** **G 1.7% lower than E**						
FE LSM (miles/gallon)							Formaldehyde LSM (µg/mile)							Acetaldehyde (µg/mile)						
A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
0.039	0.040	0.040	0.040	0.041	0.040	0.041	4744	3227	5780	4986	5639	4384	4202	1543	943	1684	1440	1622	1509	1408
B 3.7% lower than A **C 4.2% lower than A** **D 4.2% lower than A** **E 4.6% lower than A** **F 2.8 % lower than A** **G 5.7% lower than A** **G 2.1% lower than B** **F 2.1% higher than E** **G 3.0% lower than F**							**B 32% lower than A** **C 79% higher than B** **D 54% higher than B** **E 75% higher than B**							**B 39% lower than A** **C 79% higher than B** **E 72% higher than B** **F 60% higher than B** D 53% higher than B						

Where: A= Fed ULSD; B=CARB ULSD; C=Fed/SME-20; D=Fed/AFME-20; E=Fed/WCO-20; F=Fed/HVO-20; and G=CARB/WCO-20
Bold values are statistically significant p ” 0.05; *Underlined values are marginally statistically significant* $0.05 < p \leq 0.1$

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The emissions from the eight modern technology light-duty diesel vehicles tested in this program showed fuel effects for some pollutants, but not for others. For the weighted THC emissions, the CARB ULSD showed statistically significant reductions compared to the Federal ULSD, while the biodiesel blends with Federal ULSD showed statistically significant increases compared to CARB ULSD. Although some general trends towards lower THC emissions were seen with the biodiesel blends, these results indicate that diesel fuels with lower aromatics and higher cetane number (like CARB ULSD) produce lower THC emissions than 20 vol% biodiesel blends with ULSD having higher aromatics and lower cetane number.

Analogous to THC, weighted NMHC emissions showed statistically significant reductions for CARB ULSD compared to Federal ULSD. The 20 vol% renewable diesel blend also showed statistically significantly lower NMHC emissions compared to Federal ULSD. Some FAME blends in Federal ULSD showed statistically significant increases in NMHC emissions compared to CARB ULSD. Statistically significant differences were also observed between biofuel pairs.

For weighted CO emissions, both the CARB ULSD and the CARB/WCO blend showed statistically significant reductions compared to Federal ULSD. The FAME and renewable diesel blends in Federal ULSD showed statistically significantly higher CO emissions compared to CARB ULSD.

CO_2 emissions showed a slight upward trend for the biodiesel blends. Statistically significant increases in CO_2 emissions were seen for the SME and WCO blends with Federal ULSD compared to both reference diesel fuels. Statistically significant trends were also seen between different fuel pairs for weighted CO_2 emissions, as well as for the cold-start, hot-running, and hot-start CO_2 emissions. Fuel economy, measured on a carbon balance basis, showed, in most cases, statistically significant decreases with CARB ULSD and with biofuel blends compared to Federal ULSD for all three FTP phases and for the weighted values.

NO_x emissions did not show any statistically significant fuel effect for the entire FTP cycle or the individual phases. NO, NO_2, and N_2O emissions were measured for Vehicles #4 through Vehicle #8 and no statistically significant fuel effects were observed. NO_2 was the predominant NO_x species for each of these vehicles with the exception of Vehicles #5 and #6. In these two vehicles, NO emissions were generally higher than the other test vehicles, and their NO levels followed a trend similar to their NO_x emission levels.

Similar to NO_x emissions, PM mass and PN emissions did not show any statistically significant differences between all seven test fuels. It should be noted that PM mass emissions for all eight vehicles were below 3 mg/mile. No statistically significant differences were observed in the EC/OC fractions, with EC being at zero or near zero levels for most vehicles and OC being the majority of the carbonaceous fraction of the PM. The absence of fuel trends for the nitrogen oxides and PM, OC, and EC was largely due to the presence of the SCR for reducing NO_x emissions and the DPF for reducing PM emissions, which which minimized the effect of fuel composition on these emissions.

Formaldehyde and acetaldehyde were the dominant aldehydes in the exhaust for all eight vehicles, with heavier aldehydes, aromatic aldehydes, and ketones being detected for some vehicles but in lesser amounts. For formaldehyde emissions, CARB ULSD showed statistically significant reductions compared to Federal ULSD, while the biodiesel blends exhibited statistically significant increases relative to CARB ULSD. Similar to formaldehyde, acetaldehyde emissions showed statistically significant reductions for CARB ULSD relative to

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Federal diesel, while the biodiesel and the renewable diesel blends led to statistically significant increases in acetaldehyde emissions compared to CARB ULSD. In general, the increases in lower-molecular weight aldehydes with biodiesel can be ascribed to the higher oxygen content in the methyl ester molecule.

PAHs in the vehicle exhaust were dominated by lower and medium molecular weight compounds for all vehicle/fuel combinations, suggesting that these compounds were pyrolyzed from incomplete combustion of the fuel. Heavier PAHs also were found in the exhaust but in lesser amounts. Total gas-phase PAH emissions were found in significantly higher concentrations than their corresponding particle-phase PAHs. The largest contributors to the gas-phase PAHs were mainly the two-membered ring compounds and their ethyl- and methyl-substituted derivatives. The total PAH results for the biodiesel and renewable diesel blend did not show clear trends, with some increases and some decreases in total PAH emissions compared to the reference Federal and CARB ULSDs. The gas-phase nitro-PAHs were more abundant than particle-phase nitro-PAHs, with lighter compounds, such as 1-nitronaphthalene and methyl-substituted nitronaphthalenes, being the dominant nitrated compounds. The predominant species for the particle-phase nitro-PAHs were the nitronaphthalenes, nitrophenanthrenes, and 1-nitropyrene. The biodiesel and renewable diesel blends showed both increases and decreases in gas- and particle-phase nitro-PAH emissions.

For all eight vehicles, NH_3 emissions showed measurable concentrations especially for Vehicle #1 and Vehicle #2. NH_3 emission levels for Vehicle #1 were higher than those of all vehicles tested during the course of this program. For the majority of vehicles, NH_3 emissions were found to be at or near zero levels. In general, NH_3 emissions for all eight vehicles did not present any consistent fuel trends between the baseline ULSDs and the biofuel blends.

Emissions measured on Vehicle #1 and Vehicle #3 during DPF regeneration showed increases compared to the highway driving cycle without DPF regeneration. This tendency was seen on both vehicles for the Fed/SME-20 blend and to a lesser extent for the Federal ULSD. Increases in emissions for some pollutants were seen for the biodiesel blend compared to the Federal ULSD, including THC, CH_4, PN, black carbon, and formaldehyde for Vehicle #1, and THC, NMHC, CO, NO_x, CO_2, and formaldehyde for Vehicle #3. For Vehicle #3, the increase in total carbonyl emissions for the biodiesel blend during DPF regeneration was statistically significant. Particle size distributions during DPF regeneration for both vehicles were dominated by the production of nucleation mode particles with peaks at around 10 nm in diameter. For other pollutants, the biodiesel blends showed reductions in emissions relative to the Federal ULSD, including PAHs and gas-phase nitro-PAHs for Vehicle #1, and PM mass for Vehicle #3. Further analysis of the PAH results showed that the biodiesel blends increased the formation of 2-ring PAH species during regeneration testing relative to Federal ULSD. Certain nitrated species, which were nearly below detection limits during baseline testing, increased with biodiesel relative to Federal ULSD during tests that included DPF regeneration, suggesting that these species formed in the DPF. Ammonia emissions exhibited higher concentrations (NH_3 slip) with subsequent reductions in NO_x emission levels during DPF regenerations, suggesting that the SCR system enabled significant NO_x conversion over the course of these events. The NH_3 emissions exhibited similar behavior for both the Federal ULSD and Fed/SME-20 blend during DPF regeneration, indicating that emissions during regeneration were primarily a function of vehicle operation, and did not show strong sensitivity to fuel composition.

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Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
ANOVA	Analysis of Variance
CARB	California Air Resources Board
CE-CERT	College of Engineering-Center for Environmental Research and Technology (University of California, Riverside)
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CRC	Coordinating Research Council
CPC	Condensation Particle Counter
DNPH	2,4-Dinitrophenylhydrazine
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
ECU	Engine Control Unit
EC	Elemental Carbon
EEPS	Engine Exhaust Particle Sizer
EPA	Environmental Protection Agency
FAME	Fatty Acid Methyl Ester
FTP	Federal Test Procedure
GC	Gas Chromatograph
GHG	Greenhouse Gas
HPLC	High Performance Liquid Chromatograph
HWFET	Highway Fuel Economy Test
g/mile	Grams per mile
LDV	Light-Duty Vehicle
LDT	Light-Duty Truck
LNT	Lean NO_x Trap

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Lpm……..	Liters per minute
MAAP……..	Multi-Angle Absorption Photometer
MPG……..	Miles per gallon
MPH……..	Miles per hour
ng/mile……...	Nano grams per mile
NH_3……...	Ammonia
nitro-PAHs……	Nitrated Polycyclic Aromatic Hydrocarbons
NMHC……..	Non-Methane Hydrocarbons
NO_x ……..	Nitrogen Oxides
NO……	Nitric Oxide
NO_2…….	Nitrogen Dioxide
N_2O…….	Nitrous Oxide
OBD……..	On-board Diagnostics
OC…….	Organic Carbon
PAHs…….	Polycyclic Aromatic Hydrocarbons
PC……..	Passenger Car
PDP-CVS……..	Positive Displacement Pump-Constant Volume Sampling
PM…….	Particulate Matter
PN……..	Particle Number
SCR……...	Selective Catalytic Reduction
SVOC……	Semi-Volatile Organic Compound
TDL……..	Tunable Diode Laser
THC……..	Total Hydrocarbons
TIGF…….	Teflon-Impregnated Glass Fiber
ULSD……	Ultra-low sulfur diesel
VERL……	Vehicle Emissions Research Laboratory

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1. Introduction

The global energy map is changing, with potentially far-reaching consequences for energy markets and trade. Global energy demand is expected to grow by more than one-third over the period from 2010 to 2035 with China, India and the Middle East accounting for 60% of the increase (IEA, 2012). Although energy demand is not expected to rise significantly in Organization for Economic Co-operation and Development (OECD) countries, there is a pronounced shift in these countries away from oil, coal, and, in some countries, nuclear towards natural gas and renewable fuels (IEA, 2012). In the United States (U.S.), there is considerable interest in biodiesel because of its domestic and renewable origin, as well as its potential to reduce life-cycle emissions of greenhouse gases (GHG) (Shrake et al., 2010). Biodiesel, collectively known as fatty acid methyl esters (FAME), is a renewable transportation fuel consisting of long-chain alkyl esters, which contain two oxygen atoms per molecule. Biodiesel is generally produced by the transesterification process from vegetable oils, used cooking oils, and animal fats. Biodiesel has similar properties to middle distillate petroleum diesel, is free of sulfur and aromatic compounds, non-toxic, and readily biodegradable (Hoekman et al., 2011; Lapuerta et al., 2008a).

Regulations are a main driver for biofuels development. The European Union (EU) directive on renewable energy (2009/28/EC) stipulates that each member state has to ensure that 10% of the fuel for the transport sector is biofuel or renewable electricity in 2020. Furthermore, the EU fuels quality directive already allows an increase of biodiesel content in diesel to 7% (B7) by volume. In the U.S., the EPA Renewable Fuel Standard version 2 (EPA-RFS2) and the California Low Carbon Fuel Standard (CA-LCFS), a state-enacted policy to reduce GHG emissions from motor vehicles, are driving the U.S. biofuels market. The EPA-RFS2 requires that 36 billion gallons of renewable fuel be available in the U.S. market by 2022. Although over the next several years ethanol is expected to make up the majority of this requirement, biodiesel and renewable diesel formulations are expected to have the largest penetration into the diesel fuel market. Unlike most European countries where diesel vehicle sales make up more than half of the new automobile market, the penetration rate for light-duty diesel vehicles in the U.S. is much lower due to lower gasoline prices and more stringent regulatory standards that reduce the attractiveness of diesel vehicles. However, because of their greater efficiency compared to conventional gasoline vehicles, light-duty diesel vehicles could become an important component of automaker strategies to meet rising U.S. Corporate Average Fuel Economy (CAFE) requirements. Some automotive manufacturers are currently offering diesel versions of some existing models in the U.S. market. These modern light-duty diesel vehicles incorporate a combination of engine design optimization and exhaust aftertreatment devices, including diesel particle filters (DPFs) for particulate matter (PM) and selective catalytic reduction (SCR) for nitrogen oxide (NO_x), to achieve the significant reductions needed to meet the current and upcoming U.S. standards (Wallington et al., 2013).

The effects of biodiesel usage on vehicle emissions have been investigated by various groups within the academic, commercial and regulatory communities. Many studies have reported that emissions of carbon monoxide (CO) total hydrocarbons (THC), and PM can be reduced with the addition of biodiesel, although an increase in NO_x emissions is usually acknowledged (Durbin et al., 2007; Lapuerta et al., 2008a; Giakoumis et al., 2012; Hoekman and Robbins, 2012). The majority of these studies have been conducted on heavy-duty and, generally, older technology engines (McCormick et al., 2001). Only a few studies are available on modern light-duty (LD) diesel vehicles, employing common-rail engine systems and aftertreatment technologies (Martini et al., 2007; Bannister et al., 2010; Rose et al., 2010; Karavalakis et al., 2010a; Macor et al.,

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2011; Nikanjam et al., 2011). There also is a gap in the literature regarding the effect of biodiesel on unregulated pollutants. Several studies have reported an increase in carbonyl emissions (aldehydes and ketones) with the use of biodiesel blends, as a consequence of the oxygen content in the methyl ester molecule (Correa and Arbilla, 2008; Fontaras et al., 2009; Fontaras et al., 2010a Cahill and Okamoto, 2012). In addition, most authors have observed some decreases in emissions of polycyclic aromatic hydrocarbons (PAH) and their nitrated derivatives (nitro-PAH) when using biodiesel (Bagley et al., 1998; Yang et al., 2007; Macor et al., 2011; Surawski et al., 2011). However, the effect of biodiesel source material on PAH and nitro-PAH emissions is less clear, since there are a number of vehicle studies showing some increase in light molecular-weight PAH compounds with biodiesel (Karavalakis et al., 2010a; Karavalakis et., 2010b). Similar to toxic PAH compounds, information in the literature on particle number (PN) emissions and particle size distributions (PSDs) from biodiesel vehicles is limited and inconsistent. Increased PN emissions and lower size particles are generally but not always observed, and the reasons for such inconsistencies are not properly understood (Fontaras et al., 2009; Fontaras et al., 2010b).

The available literature, including CRC AVFL-17 (Hoekman et al., 2009) and CRC AVFL-17a (Hoekman et al., 2011) studies, have shown that the emissions results from late model vehicles/engines equipped with NO_x emission control catalysts, such as SCR or lean NO_x traps (LNT) are limited. With the diesel vehicle fleet turning over to much lower emitting vehicles, the University of California, Riverside's College of Engineering-Center for Environmental Research and Technology (CE-CERT) and the Coordinating Research Council (CRC) have undertaken a comprehensive study, which aims specifically at understanding the effects of different biodiesel blends and renewable diesel blends on regulated and selected unregulated exhaust emissions from modern technology light-duty passenger cars and light-duty trucks. The resulting study was termed the 'CRC AVFL – 17b' program. This study included emissions testing on eight light-duty diesel vehicles with seven different fuels, including both Federal and California ultra-low sulfur diesel, and five 20% biodiesel and renewable diesel blends. This report presents the results of this study and its implications in terms of the broader literature.

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2. Experimental Procedures

2.1 Test Fuels

A total of seven fuels were used in this study. A Federal Ultra Low Sulfur Diesel (ULSD) and a CARB ULSD were used as the baseline fuels. The Federal ULSD was supplied from Chevron's Refinery in Pascagoula, MS, and had properties typical of those found in most automotive diesel fuels across the country. The CARB ULSD was supplied from BP's Vinvale Terminal in Southgate, CA, and had properties typical of diesel fuels used in California, which has specifications more stringent than those of Federal ULSD.

Three fatty acid methyl esters were used as blendstocks with the baseline diesel fuels. A methyl ester produced from soybean oil (SME), a waste cooking oil methyl ester (WCO), and a methyl ester produced from animal fat (AFME). The soy-based biodiesel was selected because soybean oil is the dominant oil produced in the U.S., and the development of biodiesel in the U.S. has focused around this type of feedstock. Both the waste cooking oil and the animal fat feedstocks are considered to be low-cost and low environmental impact feedstocks, and are characterized as CO_2 neutral. In addition, the animal fat biodiesel was selected since it is comprised of more saturated molecules and has less tendency to increase NO_x emissions compared to other feedstocks (Knothe, 2008). The soy-based biodiesel was supplied by Community Fuels, CA, the waste cooking oil biodiesel was supplied by Imperial Western Products, CA, and the animal fat biodiesel was donated by Renewable Energy Group, TX. All three producers were BQ9000 accredited certified. All neat biodiesel fuels were treated with commercial synthetic antioxidant additives to delay the onset of oxidation in the fuel and prevent degradation products that could cause engine and injector problems. The treat rate for the soy-based biodiesel was 1000 ppm of Nalco EC 5300 A additive. For the waste cooking oil biodiesel, the treat rate was 500 ppm of Albermarle Ethanox 4760r additive. For the animal fat biodiesel, the treat rate was 60 ppm of Eastman BioExtend™ 30 Antioxidant Solution. The main physicochemical parameters of the neat biodiesels are listed in Table 2.1.

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Table 2-1: Properties of the neat methyl esters

Property	Method	SME	AFME	WCO
Sulfur (ppm)	D5453	0.6	5.4	13.55
Cloud Point (°F)	D5773	32.9	58.3	37.7
Cetane Number	D613	49.19	67.06	58.05
Derived Cetane Number (IQT)	D6890	49.45	65.37	61.56
Ignition delay (ms)		4.148	3.105	3.267
CFPP (°C)	D6371	-4	10	-2
CHNS by combustion (wt%)	D529			
C (wt%)		77.38	75.02	76.74
H (wt%)		11.66	11.54	11.75
N (wt%)		<0.15	< 0.75	<0.15
S (wt%)		<0.40		<0.40
Density by Digital Density Meter (API Gravity) at 60 °F	D4052			
API Gravity		28.23	30.26	28.18
Density (g/ml)		0.8850	0.8739	0.8852
Flash Point by Pensky-Martins Closed Cup (°F)	D93	>300	302	>300
Viscosity by Capillary Viscometer (mm^2/s at 40°C)	D445	4.068	4.662	4.765
Lubricity by HFRR @ 60 °C (microns)	D6079	178	211	179.5
Iodine Number (g Iodine/100 g)	EN1411	128	51	100
Oxygen by Atomic Emission Detection w/ extraction prep	GC-AED-O w/ prep	14.17	14.96	14.37
Ester Content (wt%)	EN14103	98.9	99.2	94.0
Linolenic acid methyl ester (wt%)	EN14103	7.8	<1.0	3.2
Free glycerin (wt%)	D6584	< 0.005	< 0.005	< 0.005
Monoglycerides (wt%)	D6584	0.274	0.263	0.55
Diglycerides (wt%)	D6584	0.130	< 0.050	0.139
Triglycerides (wt%)	D6584	0.089	< 0.050	< 0.050
Total glycerin (wt%)	D6584	0.100	0.077	0.165
Water by Karl Fischer Titration (ppm)	D6304	277	832	444
Oxidation Stability (hours)	EN14112	7.9	5.5	3.0
Total Acid Number (mg KOH/g)	D664	0.21	0.44	0.41
BTU Gross and Net by Bomb Calorimeter (Btu/lb)	D240			
BTU Gross (Btu/lb)		17,158	17,165	17,102
BTU Net (Btu/lb)		16,094	16,050	16,030
Na+K (wt ppm)	ICP-AES	<1, <1.7	<1.0	1.6, <1.7
Ca+Mg (wt ppm)		<0.7, <0.7	<0.7, <0.7	<0.7, <0.7
P (wt ppm)		<0.7	<1.1	<0.7

In addition to the methyl ester fuels, a renewable diesel fuel was also employed in this study. This fuel, supplied from Neste Oil, Espoo, Finland, is an HVO (hydrogenated vegetable oil)-type fuel that is paraffinic in nature. HVO is characterized by a higher cetane number compared to regular diesel fuel, its free of sulfur and aromatic compounds, and can be produced with a cloud point close to -40 °C. However, it has poorer lubrication properties and lower volumetric energy content than regular diesel fuel (Hartikka et al., 2012). Although HVO is a renewable biofuel, it differs from methyl esters because the fatty acid feedstocks are hydrotreated to remove oxygen and to eventually produce a pure hydrocarbon fuel. The main properties of the renewable diesel are shown in Table 2.2. Additional analysis has been performed to determine the metals content in the renewable diesel.

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Table 2-2: Properties of the renewable diesel fuel

Property	Method	Renewable Diesel
Hydrocarbon Types by Fluorescent Indicator Absorption (FIA)	D1319	
Aromatics (vol%)		< 5.0
Olefins (vol%)		0.8
Saturates (vol%)		> 95.0
Aromatics by Supercritical Fluid Chromatography (SFC) (area% equiv to wt%)	D5186	
1 Ring Aromatics (area% equiv to wt%)		0.00
2 Ring Aromatics (area% equiv to wt%)		0.00
3+ Ring Aromatics (area% equiv to wt%)		0.00
Non-Aromatics (area% equiv to wt%)		100.00
Total Aromatics (area% equiv to wt%)		0.00
Sulfur in HC by Oxidative Combustion and Ultraviolet Fluorescence (UVF)	D5453	
ppm		0.4
Oxygen by Atomic Emission Detection w/ extraction prep	GC-AED-O w/ prep	0.01
FAME content (wt%)		< 0.05
Range		A
Water by Karl Fischer Titration (ppm)	D6304	14
Metals by Inductively Coupled Plasma Mass Spectrometry (ppm)	ICP-MS	
V 51 (wtppm)		0.010
Cr 52 (wtppm)		0.005
Fe 56 (wtppm)		0.216
Co 59 (wtppm)		< 0.005
Ni 60 (wtppm)		< 0.005
Cu 63 (wtppm)		0.016
Zn 66 (wtppm)		0.226
As 75 (wtppm)		<0.005
Se 78 (wtppm)		<0.005
Ag 107 (wtppm)		< 0.005
Cd 111 (wtppm)		< 0.005
Sn 118 (wtppm)		0.153
Sb 121 (wtppm)		< 0.005
Ba 138 (wtppm)		< 0.005
Metals by Inductively Coupled Plasma Atomic Emission Spect (ppm)	ICP-AES	
Al (wtppm)		< 0.6
Ba (wtppm)		< 1.1
Ca (wtppm)		< 0.7
Cd (wtppm)		< 0.6
Cr (wtppm)		< 0.9
Cu (wtppm)		< 1.1
Fe (wtppm)		< 1.1
Mg (wtppm)		< 0.7
Mn (wtppm)		< 0.6
Mo (wtppm)		< 0.9
Na (wtppm)		< 1.0
Ni (wtppm)		< 1.1
P (wtppm)		< 1.1
S (wtppm)		< 100
Si (wtppm)		< 0.6
Ti (wtppm)		< 0.9
V (wtppm)		< 1.1
Zn (wtppm)		< 0.7
Distillation	D86	
IBP (F)		334.8
T05 (F)		401.2
T10 (F)		441.5

Table 2-2: Properties of the renewable diesel fuel (Continued)		
Property	**Method**	**Renewable Diesel**
T20 (F)		479.1
T30 (F)		503.1
T40 (F)		516.4
T50 (F)		524.1
T60 (F)		529.7
T70 (F)		535.5
T80 (F)		541.9
T90 (F)		550.9
T95 (F)		558.1
FBP (F)		574.2
Recovery (%)		97.6
Residue (%)		1.5
Loss (%)		0.9
E200 (ml)		0.0
E300 (ml)		0.0
Flash Point by Pensky-Martins Closed Cup	D93	149
CHNS by combustion (wt%)	D5291	
C (wt%)		85.07
H (wt%)		14.87
N (wt%)		< 0.15
S (wt%)		< 0.40
Total (wt%)		99.94
BTU Gross and Net by Bomb Calorimeter (Btu/lb)	D240	
BTU Gross (Btu/lb)		20,320
BTU Net (Btu/lb)		18,964
Cetane Number by Engine	D613	76.15
Derived Cetane Number by IQT	D6890	
Derived Cetane Number		72.86
Ignition Delay (ms)		2.851
Density by Digital Density Meter (API Gravity) at 60F	D4052	
API Gravity		50.97
Density (g/ml)		0.7747
Viscosity by Capillary Viscometer (mm^2/s at 40°C)	D445	2.483
Lubricity by HFRR at 60°C (microns)	D6079	422.0
Cloud Point by Constant Cooling Rate (°C)	D5773	-24.0
Cold Filter Plugging Point (CFPP), (°C)	D6371	-26.0

All three methyl esters and the renewable diesel were used to create blends with the Federal ULSD at a proportion of 20% by volume. For the CARB ULSD, only the waste cooking oil biodiesel was used to prepare blends at 20% by volume. Blends are labeled with diesel fuel, followed by the biodiesel and biodiesel concentration. For example, Fed/SME-20 denotes Federal ULSD containing soy-based biodiesel at 20 volume percent. The main properties of the reference ULSD fuels and associated test methods are provided in Table 2.3. Additional analyses were conducted to evaluate the metals content in the ULSD fuels. Table 2.3 also shows the basic properties of the biodiesel and the renewable diesel blends.

The drums used to store the neat biodiesels and their blends with the diesel fuels were nitrogen-purged, blanketed, and stored in an area protected from sunlight and rain at CE-CERT.

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Table 2-3: Properties of the reference ULSD fuels, the biodiesel, and the renewable diesel blends

Property	Method	Federal ULSD	Fed/ SME-20	Fed/ AFME-20	Fed/ WCO-20	Fed/ HVO-20	CARB ULSD	CARB/ WCO-20
Sulfur in HC by Oxidative Combustion and Ultraviolet Fluorescence (UVF), ppm	D5453	7.9	6	6.63	6.14	5.75	9.9	9.8
Cloud Point (°F)	D5773	3.7	10.9	27	11.5	1.3	19.9	21.6
Cetane Number	D613	44.21	45.89	49.32	46.99	51.85	57.54	56.85
Derived Cetane Number by IQT	D6890							
Derived Cetane Number		45.36	45.67	49.76	47.88	50.86	54.85	54.80
Ignition Delay (ms)		4.562	4.528	4.119	4.298	4.083	3.703	3.707
Cold Filter Plugging Point (CFPP), (°C)	D6371	-15.7	-15	-11	-15	-19	-6.7	-7
CHNS by combustion (wt%)	D5291							
C (wt%)		86.75	84.97	84.72	84.98	86.55	86.55	84.84
H (wt%)		12.66	12.57	12.65	12.66	13.14	13.14	13.15
N (wt%)		<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	< 0.15
S (wt%)		<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	< 0.40
Density by Digital Density Meter (API Gravity) at 60°F	D4052							
API Gravity		34.98	33.64	34.06	33.64	37.95	39.04	36.95
Density (g/ml)		0.8491	0.8560	0.8538	0.8560	0.8342	0.8289	0.8392
Distillation	D86							
IBP (°F)		331.3	344.7	344.3	341.6	333.3	345.4	349.5
T05 (°F)		378.7	389.7	389.1	389.5	383.0	380.1	388.6
T10 (°F)		397.8	412.0	410.9	412.2	406.0	399.2	411.1
T20 (°F)		428.9	448.9	448.7	449.1	437.7	425.5	445.3
T30 (°F)		456.3	484.7	484.0	483.6	466.3	450.5	476.1
T40 (°F)		483.4	517.6	516.0	516.0	491.4	477.1	508.8
T50 (°F)		509.0	546.3	543.0	545.0	511.7	502.3	538.5
T60 (°F)		531.7	572.2	568.0	570.9	530.1	528.6	568.4
T70 (°F)		554.9	594.9	589.8	593.4	548.2	556.3	594.1
T80 (°F)		579.6	614.3	608.7	613.9	568.2	586.3	616.3
T90 (°F)		610.7	631.6	627.1	632.5	597.6	622.9	636.6
T95 (°F)		635.4	644.5	640.2	648.1	625.3	649.9	653.7
FBP (°F)		659.7	661.8	658.0	664.2	652.8	675.3	674.2
Recovery (%)		98.0	98.3	98.3	98.1	98.4	99	99.4
Residue (%)		1.4	1.4	1.4	1.4	1.4	1.0	0.6
Loss (%)		0.6	0.3	0.3	0.5	0.2	0.0	0.0
Flash Point by Pensky-Martins Closed Cup (°F)	D93	139	147	147	156	165	153	164
Lubricity by HFRR at 60°C (microns)	D6079	315.5	180.5	186	172.5	386	415.0	156.5
Total Acid Number (mg KOH/g)	D664		<0.05	<0.05	0.07	<0.05		0.10
BTU Gross and Net by Bomb Calorimeter (Btu/lb)	D240							
BTU Gross (Btu/lb)		19,572	19,108	19,092	19,058	19,731	19,813	19,322
BTU Net (Btu/lb)		18,417	17,961	17,938	17,903	18,532	18,590	18,122
Viscosity by Capillary Viscometer (mm^2/s at 40°C)	D445	2.654	2.809	2.896	2.898	2.543	2.536	2.907
Water by Karl Fischer Titration (ppm)	D6304	20	93	92	108	14	19	64

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Table 2-3: Properties of the reference ULSD fuels, the biodiesel, and the renewable diesel blends (Continued)								
Property	**Method**	**Federal ULSD**	**Fed/ SME-20**	**Fed/ AFME-20**	**Fed/ WCO-20**	**Fed/ HVO-20**	**CARB ULSD**	**CARB/ WCO-20**
FAME in Diesel by FTIR-ATR-PLS (wt%)	EN14078							
FAME content (wt%)		<0.05	16.7	17.0	16.9	<0.05	<0.05	16.4
Range		A					A	B
Oxygen by Atomic Emission Detection w/ extraction prep	GC-AED-O w/ prep	0.03	3.14	3.13	2.98	0.02	0.02	2.47
Hydrocarbon Types by Fluorescent Indicator Absorption (FIA)	D1319							
Aromatics (vol%)		34.2	41.6	41.6	40.0	23.4	20.0	30.0
Olefins (vol%)		1.9	2.4	2.3	2.0	2.0	2.1	2.5
Saturates (vol%)		63.9	56.0	56.1	58.0	74.6	77.9	67.5
Aromatics by Supercritical Fluid Chromatography (SFC) (area% equiv to wt%)	D5186							
1 Ring Aromatics (area% equiv to wt%)		28.83	22.27	27.56	16.62	21.66	19.61	16.27
2 Ring Aromatics (area% equiv to wt%)		3.63	4.63	4.56	3.46	4.81	1.48	1.51
3+ Ring Aromatics (area% equiv to wt%)		0.14	0.44	0.29	0.29	0.43	0.00	0.00
Non-Aromatics (area% equiv to wt%)		67.40	57.07	53.77	69.44	70.10	78.91	68.89
Total Aromatics (area% equiv to wt%)		32.60	27.34	32.41	20.37	26.90	21.09	17.78
Oxidation Stability (hr)	EN15751	-	18.9	18.1	16.7	21.9	-	13.3
Metals by Inductively Coupled Plasma Mass Spectrometry (ppm)	ICP-MS							
V 51 (wtppm)	0.009							0.016
Cr 52 (wtppm)	0.010							0.008
Fe 56 (wtppm)	0.347							0.351
Co 59 (wtppm)	< 0.005							< 0.005
Ni 60 (wtppm)	< 0.005							< 0.005
Cu 63 (wtppm)	0.014							0.022
Zn 66 (wtppm)	0.151							0.226
As 75 (wtppm)	<0.005							<0.005
Se 78 (wtppm)	0.010							0.008
Ag 107 (wtppm)	< 0.005							< 0.005
Cd 111 (wtppm)	< 0.005							< 0.005
Sn 118 (wtppm)	0.165							0.221
Sb 121 (wtppm)	0.008							< 0.005
Ba 138 (wtppm)	< 0.005							0.005
Metals by Inductively Coupled Plasma Atomic Emission Spect (ppm)								
Al (wtppm)	< 0.6							< 0.6
Ba (wtppm)	< 1.1							< 1.1
Ca (wtppm)	< 0.7							< 0.7
Cd (wtppm)	< 0.6							< 0.6
Cr (wtppm)	< 0.9							< 0.9

Table 2-3: Properties of the reference ULSD fuels, the biodiesel, and the renewable diesel blends (Continued)								
Property	**Method**	**Federal ULSD**	**Fed/ SME-20**	**Fed/ AFME-20**	**Fed/ WCO-20**	**Fed/ HVO-20**	**CARB ULSD**	**CARB/ WCO-20**
Cu (wtppm)	< 1.1							< 1.1
Fe (wtppm)	< 1.1							< 1.1
Mg (wtppm)	< 0.7							< 0.7
Mn (wtppm)	< 0.7							< 0.7
Mo (wtppm)	< 0.9							< 0.9
Na (wtppm)	< 1.0							< 1.0
Ni (wtppm)	< 1.1							< 1.2
P (wtppm)	< 1.1							< 1.1
S (wtppm)	< 101							< 102
Si (wtppm)	< 0.6							< 0.6
Ti (wtppm)	< 0.9							< 0.9
V (wtppm)	< 1.1							< 1.1
Zn (wtppm)	< 0.7							< 0.7

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Neat biodiesels and their blends with petroleum diesel undergo oxidation during prolonged storage periods. For this reason, the deterioration of the biodiesel blends (oxygenated blends) employed in this program was monitored after a period of approximately 12 months following the initial fuel quality check. Properties of interest included the oxidation stability of the blends, density, kinematic viscosity, acid number, and cetane number, as shown in Table 2.4. It is interesting to note that the oxidation stability for all biodiesel blends was found to be well above the ASTM minimum standard of 6 hours. However, all blends experienced a drop in oxidation stability in terms of their induction time over the 12 months when compared to the first samples from the 'freshly blended' blends, with the exception of CARB/WCO-20 blend. The effect of storage stability degradation was generally noticeable for some properties for most biodiesel blends, with the exception of CARB/WCO-20 blend. Increases in density, viscosity, and acid number were seen for the blends with the Federal ULSD, which is an indication of peroxides, acids, and polymeric compounds formation. The formation, to some extent, of peroxides and hydroperoxides of the methyl ester component in the blend may also positively affect the cetane number, since these species can act as cetane improvers.

Table 2-4: Key properties of biodiesel blends after a time period of 12 months

Property	Fed/SME-20		Fed/AFME-20		Fed/WCO-20		CARB/WCO-20	
	Fresh	12 mo.	Fresh	12 mo.	Fresh	12 mo.	Fresh	12 mo.
Derived Cetane Number by IQT	45.67	46.01	49.76	50.18	47.88	48.31	54.80	55.24
Ignition Delay (ms)	4.578	4.490	4.119	4.082	4.298	4.256	3.707	3.675
API gravity at 60°F	33.64	33.61	34.06	34.05	33.64	33.62	36.95	37.27
Density (g/ml)	0.8560	0.8562	0.8533	0.8539	0.8560	0.8561	0.8392	0.8376
Viscosity (mm^2/s)	2.809	2.814	2.896	2.902	2.898	3.033	2.907	2.728
Oxidation Stability (hr)	18.9	12.3	18.1	13.6	16.7	10.8	13.3	14.8
Acid number (mg KOH/g)	<0.05	0.05	<0.05	0.07	0.07	0.08	0.10	0.07

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2.2 Test Vehicles

Eight test vehicles were chosen with the intent of representing the latest light-duty diesel technologies sold in the U.S. The test matrix included a mix of different manufacturers (both domestic and European) and passenger cars/trucks. The vehicles employed in this program, presented in a random order, were a 2012 model year (MY) Mercedes Benz ML 350, a 2012 MY Chevrolet Silverado 2500HD, 2012 MY Volkswagen Passat, a 2013 MY Ford F250 Super Duty, a 2013 MY Dodge Ram 2500, a 2013 MY BMW X5 35d, a 2014 MY Chevy Cruze, and a 2014 Jeep Grand Cherokee. The vehicles were all equipped with a DPF to reduce PM emissions, SCR technology to reduce NO_x emissions to comply with standards in California and other states, and a diesel oxidation catalyst (DOC) to control primarily CO and THC emissions and partly PM emissions. The recommended fuel for domestic vehicles was up to 20 vol% biodiesel (B20) according to the owner's manual, as opposed to the European vehicles where the recommended fuel was up to 5 vol% biodiesel (B5) in diesel fuel. The Mercedes Benz ML 350, Volkswagen Passat, and BMW X5 35d vehicles were provided in-kind by Mercedes-Benz, USA, Volkswagen of America, and BMW USA, respectively, while the remaining vehicles were purchased from private dealerships. For all eight vehicles, the aftertreatment system was assumed to be 'de-greened' as they had each accumulated more than 4,000 miles, and no reduction in catalytic activity due to aging was expected since all test vehicles had relatively low total mileage.

The 2012 Volkswagen Passat is a front-wheel drive vehicle that has a 2.0 liter, four-cylinder, in-line, turbocharged, direct injection, common-rail engine with a six-speed automatic transmission. The engine can deliver 140 horsepower at 4,000 rpm and 236 lb-ft torque at 1,750 rpm and has a compression ratio of 16.5:1. The vehicle was certified to Tier 2 Bin5/LEVII emissions standards and had 17,205 miles at the start of the test campaign.

The 2014 Chevrolet Cruze is a passenger car equipped with a 2.0 liter, four-cylinder, in-line, turbocharged, direct injection, common-rail engine. The engine can deliver 151 horsepower at 4000 rpm and 264 lb-ft at 2600 rpm and has a compression ratio of 16.5:1. The vehicle was certified to Tier 2 Bin5/LEVII emissions standards and had 6,433 miles at the start of the test campaign.

The 2013 BMW X5 35d is an all-wheel drive vehicle that has a 3.0 liter, six-cylinder, in-line, turbocharged, direct injection, common-rail engine. The engine can deliver 255 horsepower at 4000 rpm and 413 lb-ft at 1500-3000 rpm and has a compression ratio of 16.5:1. The vehicle was certified to Tier 2 Bin5/LEVII emissions standards and had 4,401 miles at the start of the test campaign.

The 2012 Mercedes Benz ML 350 is an all-wheel drive vehicle that has a 3.0 liter, six-cylinder turbocharged, direct injection, common-rail engine with a seven-speed automatic transmission. The engine can deliver 240 horsepower at 3,600 rpm and 455 lb-ft torque at 1,600-2,400 rpm, and has a compression ratio of 15.5:1. The vehicle was certified to Tier 2 Bin5/ULEVII emissions standards and had 8,228 miles at the start of the test campaign.

The 2014 Grand Jeep Cherokee is an all-wheel drive vehicle that has a 3.0 liter, six-cylinder, direct injection, common-rail engine. The engine can deliver 240 horsepower at 3600 rpm and 260 lb-ft at 4800 rpm and has a compression ratio of 15.5:1. The vehicle was certified to Tier 2 Bin5/LEVII emissions standards and had 4,262 miles at the start of the test campaign.

The 2013 Dodge Ram 2500 is a pickup truck fitted with a 6.7 liter, six-cylinder, in-line, turbocharged, direct injection, common-rail Cummins engine. The engine can deliver 370

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horsepower at 2800 rpm and 800 lb-ft at 1700 rpm and has a compression ratio of 17.3:1. The vehicle was certified to Tier 2 Bin5/LEVII emissions standards and had 16,654 miles at the start of the test campaign.

The 2013 Ford F250 Super Duty pickup truck is a high volume sale product in the U.S. market. This vehicle has a 6.7 liter, eight-cylinder turbocharged, direct injection, common-rail engine. The engine can deliver 440 horsepower at 2800 rpm and 860 lb-ft torque at 1600 rpm and has a compression ratio of 16.2:1. The vehicle was certified to Tier 2 Bin5/LEVII emissions standards and had 10,017 miles at the start of the test campaign.

The 2012 Chevrolet Silverado 2500HD Duramax is a pickup truck that is widely available in the U.S. market. It is considered to be a light-duty diesel vehicle. This vehicle has rear-wheel drive and a 6.6-liter, eight-cylinder, turbocharged, direct injection, common-rail engine with a six-speed automatic transmission. The engine can deliver 397 horsepower at 3,000 rpm and 765 lb-ft torque at 1,600 rpm and has a compression ratio of 16.8:1. The vehicle was certified to Tier 2 Bin5/LEVII emissions standards and had 21,078 miles at the start of the test campaign.

Prior to the start of testing, the engine lubricating oil and oil filters on each vehicle were replaced at a local dealership according to manufacturer's recommendations. For the Mercedes Benz ML 350, fresh Mobil 1 SAE 5W-40, ESP Formula M low-ash motor oil was used. For the Chevrolet Silverado, fresh Mobil 1 SAE 5W-30 was used. For the Volkswagen Passat, aged lubricant oil in the engine was replaced with fresh full synthetic motor oil (Castrol EDGE, SAE 5W-30). For the BMW X5 35d, the fully synthetic BMW Longlife-04 SAE 5W-30 oil was used. For the Ford F250, Motorcraft SAE 10W-30 super duty diesel motor oil was used. For the Dodge Ram 2500, synthetic Mopar SAE 5W40 oil was used. For the Chevrolet Cruze, full synthetic Mobil 1 SAE 5W-30 motor oil was used. Finally, for the Grand Jeep Cherokee, synthetic blend Pennzoil SAE 5W-30 motor oil was used.

The main technical characteristics of the test vehicles are summarized in Table 2.5. Note that the vehicles are not listed in the table in the same order that they are shown in the figures such that the results are blind with respect to any of the specific test vehicles.

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Table 2-5: Technical specification of the test vehicles used in this program

Engine	2.0L Turbo-diesel inline 4 cylinder	2.0L, 4 cylinder, inline, turbocharged	3.0L inline 6 cylinder	3.0L Turbo-diesel V6	3.0L, V6 cylinder	6.7L, 6 cylinder, inline, turbocharged	6.7L, V8 cylinder turbocharged	6.6L Turbo-diesel V8
Power	140 hp at 4,000 rpm	151 hp at 4000 rpm	255 hp at 4000 rpm	240 hp at 3,600 rpm	240 hp at 3600 rpm	370 hp at 2800 rpm	440 hp at 2800 rpm	397 hp at 3,000 rpm
Fuel injection	Common-rail direct fuel injection	Common-rail direct fuel injection	Common-rail direct fuel injection	Common-rail direct fuel injection	Common-rail direct fuel injection	Common-rail direct fuel injection	Common-rail direct fuel injection	Common-rail direct fuel injection
Torque	236 lb-ft at 1,750 rpm	264 lb-ft at 2600 rpm	413 lb-ft at 1500-3000 rpm	455 lb-ft at 1,600-2,400 rpm	260 lb-ft at 4800 rpm	800 lb-ft at 1700 rpm	860 lb-ft torque at 1600 rpm	765 lb-ft at 1,600 rpm
Compression ratio	16.5:1	16.5:1	16.5:1	15.5:1	15.5:1	17.3:1	16.2:1	16.8:1
Aftertreatment	DOC/DPF/SCR	DOC/DPF/SCR	DOC/DPF/SCR	DOC/DPF/SCR	DOC/DPF/SCR	DOC/DPF/SCR	DOC/DPF/SCR	DOC/DPF/SCR
Miles at start of testing	17,205	6,433	4,401	8,228	4,262	16,654	10,017	21,078
Emissions Standards	Tier 2 Bin5/LEVII	Tier 2 Bin5/LEVII	Tier 2 Bin5/LEVII	Tier 2 Bin5/ULEVII	Tier 2 Bin5/LEVII	Tier 2 Bin5/LEVII	Tier 2 Bin5/LEVII	Tier 2 Bin5/LEVII

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2.3 Test Sequence, Randomization, and Fuel Conditioning

Each vehicle/fuel combination was tested at least twice using the Federal Test Procedure (FTP) test cycle, which is used for emission certification and fuel economy testing of light-duty vehicles in the U.S. Additional tests were conducted on some vehicles to evaluate emissions during operation that included particulate filter regeneration, as discussed in section 2.5. The FTP test cycle is shown in Figure 2.1.

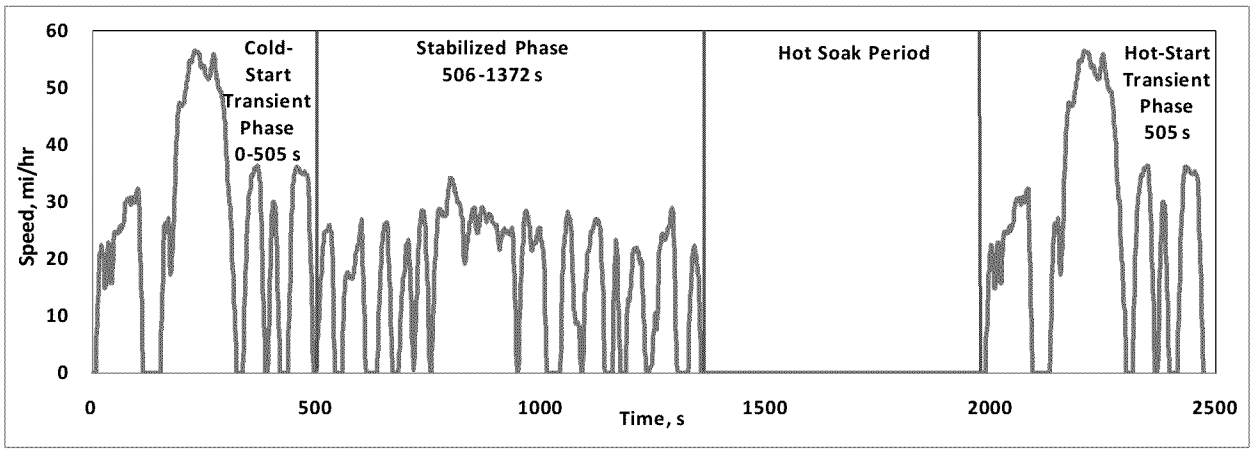

Figure 2-1: FTP Driving Cycle

The fuel testing sequence for each vehicle is provided in Table 2.6. The testing order of the fuels for each vehicle was randomized, subject to logistic considerations. The test vehicles are also presented in random order labelled as Vehicle #1 through Vehicle #8.

Table 2-6: Randomization Sequence for Each Vehicle

Vehicle #	Test Sequence
1	AEDFCBG
2	GACBEFD
3	GEFCBDA
4	CBEGFAD
5	DCEAFGB
6	GECBADF
7	FEDGABC
8	EGDABCF

Where: A= Fed ULSD; B=CARB ULSD; C=Fed/SME-20; D=Fed/AFME-20; E=Fed/WCO-20; F=Fed/HVO-20; and G=CARB/WCO-20

After completing the initial duplicate FTP tests on each vehicle/fuel combination, the data were evaluated to determine whether additional testing was required. A third test was performed if differences in FTP regulated emissions exceeded a predefined limit. This limit was defined using the same criteria as used in previous CRC studies, such as the E-60, E-67, E-83, and other older programs (Durbin et al., 2004; Painter and Rutherford 1992). Specifically, a third test was performed if the difference in the measurements exceeded the following: THC 33%, NO_x 29%, CO 70%, provided the absolute difference in the measurements was greater than 5 mg/mi. The emissions measurements for the third test also included the carbonyl compounds, PM mass, EC/OC fractions, real-time ammonia, PAHs/nitro-PAHs, and particle number emissions and particle size distributions.

Before each test on a specific vehicle, the engine oil was changed, as discussed above. Following the oil change, the vehicle was conditioned on the oil for a period approximately equivalent to two US06 cycles, followed by an LA4 and a US06 cycle sequence repeated twice (i.e., a total of 4 US06 cycles and 2 LA4s). The preconditioning for the oil was done with either the fuel in the tank or with the first fuel in the fuel randomization sequence for each vehicle. More specifically, the oil preconditioning procedure for Vehicle #1, Vehicle #2, Vehicle #3, Vehicle #5, Vehicle #6, and Vehicle #7 was done with the retail fuel in the tank (regular CARB diesel), while preconditioning for Vehicle #4 and Vehicle #8, the oil preconditioning was done with Fed/SME-20 and Fed/WCO-20, respectively.

Before each test on a specific vehicle/fuel combination, the vehicle was preconditioned with a procedure that included a fuel drain and fill (40%), followed by a catalyst sulfur purge cycle, four coast downs (70-30 mph), two additional drain and fills, and preconditioning driving over an LA4 on the dynamometer. In cases where back-to-back tests were conducted on the same vehicle/fuel combination, no additional preconditioning was performed, unless the time between tests exceeded the FTP time limit of 36 hours for soak time, such as for breaks in testing due to weekends. In these cases, the vehicle was operated over an additional FTP cycle prior to the official FTP test. Vehicles under active test were stored indoors in a temperature-controlled soak area adjacent to the test cell. Figure 2.2 summarizes the fuel and oil conditioning procedure in a flow chart. This sequence was used for all vehicles and fuels, including passenger cars and light-duty trucks.

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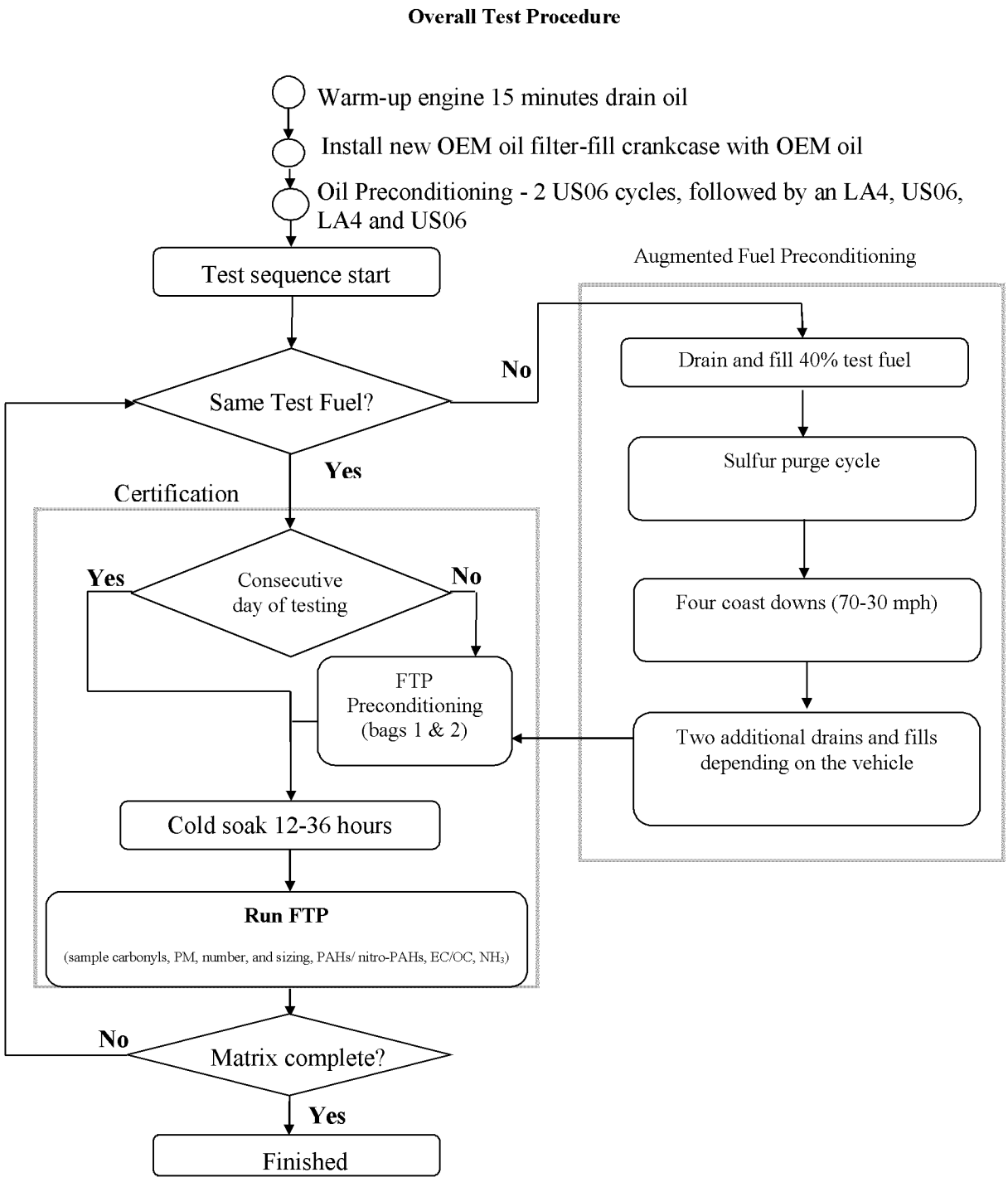

Figure 2-2: Test sequence for fuel change procedure and oil conditioning

2.4 Emissions Testing

Vehicle emissions measurements were conducted in CE-CERT's Vehicle Emissions Research Laboratory (VERL). The centerpiece of the VERL is a 48-inch Burke E. Porter single-roll electric chassis dynamometer, capable of testing vehicles weighing up to 12,000 lbs. A Pierburg Positive Displacement Pump-Constant Volume Sampling (PDP-CVS) system was used to obtain certification-quality emissions measurements.

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For each FTP test, standard bag and modal tailpipe measurements were made for THC, non-methane hydrocarbons (NMHC), methane (CH_4), NO_x, CO, CO_2, and fuel economy. The VERL configuration utilizes a Pierburg/AVL AMA-4000 emissions bench for the measurement of both the bag emissions and the second-by-second post-catalyst measurements. The Pierburg AMA-4000 includes a flame ionization detector (FID) for THC and NMHC emissions, a chemiluminescence analyzer for NO_x emissions and a non-dispersive infrared (NDIR) analyzer for CO and CO_2. Fuel economy was determined using CO_2 and the other emissions using the carbon balance method, as discussed below. The detection limits of the AMA-4000 are 0.2 ppm, 0.05 ppm, and 0.5 ppm, respectively, for THC, NO_x, and CO. All gaseous emissions were determined according to EPA protocols for light-duty emission testing as given in the Code of Federal Regulations, Title 40, Part 86, and within the accuracy limitations established therein.

PM Mass and Number Measurements

PM measurements were made on both a mass and number basis. Because of the very low levels of PM emissions expected from the modern technology, DPF-equipped diesel vehicles to be tested, PM mass samples were collected cumulatively over the entire FTP cycle, with one sample collected for each test. PM mass samples were collected at a filter face velocity of 100 cm/s, consistent with Code of Federal Regulations, Title 40, Part 1065, although other provisions of Part 1065, such as control of the temperature at the filter face to 47±5 °C and meeting requirements on residence time, were not incorporated into the PM sampling protocol. Tunnel blank samples were collected throughout the program for a total of 15 background samples for the PM sampling. Total PM mass determinations were collected using 47 mm Teflon® filters and measured with a 1065-compliant microbalance in a temperature- and humidity-controlled clean chamber.

Total particle number (PN) was also measured using a TSI 3776 ultrafine-Condensation Particle Counter (CPC). This is a butanol-based CPC able to count particles down to 2.5 nm. This instrument can sample about 300,000 particles per second, making the ultrafine CPC ideal for an accurate total PN measurement.

Real-time particle size distributions were also obtained using an Engine Exhaust Particle Sizer (EEPS) spectrometer. The EEPS was used to obtain real-time, second-by-second size distributions from 5.6 to 560 nm. Particles were sampled at a flow rate of 10 lpm, which is sufficiently high to minimize diffusional losses. They were then charged with a corona charger and sized based on their electrical mobility in an electrical field. Concentrations were determined through the use of multiple electrometers.

Since regeneration of the DPF produced exhaust particle concentrations that were higher than the maximum limit of 300,000 particles per second for the CPCs, a portable secondary dilution system was implemented to reduce the concentration of particles entering the ultrafine CPC for this element of the test program (discussed below). This system took diluted exhaust from the CVS and further diluted it with clean compressed air in a well-mixed chamber. Three of these systems were employed during the regeneration testing. The SMPS utilized one of the secondary dilution systems with a dilution ratio of 12:1. The EEPS and ultrafine CPC used two secondary dilution systems in series with a total dilution ratio of 600:1.

Elemental Carbon and Organic Carbon Analysis

Elemental and organic carbon samples (EC/OC) were collected in parallel on pre-cleaned QAT Tissuquartz quartz-fiber filters (Pall-Gelman, Ann Arbor, MI, USA). Quartz fiber filters were

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pre-cleaned to remove carbonaceous contaminants by firing for 4 hours at 600 ºC. These filters were stored in dark sealed petri dishes at 0 ºC until use.

A Thermal/Optical Carbon Aerosol Analyzer (Sunset Laboratory, Forest Grove, OR) operating on the NIOSH (National Institute of Occupational Safety and Health) Method 5040 was used to analyze OC and EC. This analytical method has two stages. In the first stage, organic and carbonate carbon (if present) are volatilized from the sample in a pure helium atmosphere as the temperature is stepped to about 820 ºC. Evolved carbon is catalytically oxidized to CO_2 in a bed of granular MnO_2, reduced to CH_4 in a nickel-firebrick methanator and quantified as CH_4 by a flame ionization detector (FID). During the second stage of the analysis, measurements to correct for the pyrolysis of OC and EC measurements are made. The oven temperature is lowered to 60ºC, a 1:9 oxygen–helium mix is introduced and the oven temperature is then raised to about 860ºC. As oxygen enters the oven, pyrolytically generated EC from OC is oxidized and a concurrent increase in filter transmittance occurs. Correction for the char contribution to EC is made by measuring the amount of char oxidation required to return the filter to its initial transmittance value. More details on the analysis can be found elsewhere (Birch and Cary, 1996). The detection limit is 0.2 mg C.

Carbonyl Compounds Sampling and Analysis

Samples for carbonyl analysis were collected through a heated line onto 2,4-dinitrophenylhydrazine (DNPH) coated silica cartridges (Waters Corp., Milford, MA). Sampled cartridges were extracted using 5 mL of acetonitrile and injected into an Agilent 1200 series high performance liquid chromatograph (HPLC) equipped with a variable wavelength detector. The column used was a 5 µm Deltabond AK resolution (200cm x 4.6mm ID). The HPLC sample injection and operating conditions were set up according to the specifications of the SAE 930142HP protocol (Siegl et al., 1993).

Ammonia Measurements

Measurements of ammonia (NH_3) were also obtained on a real-time basis using a tunable diode laser near infrared absorption spectrometer (TDL). The TDL system was used because it provided significant advantages for the measurement of exhaust NH_3 in sensitivity, response time, and the ability to measure in situ in raw exhaust.

PAH and nitro-PAH Sampling and Analysis

PAH and nitro-PAH samples were collected on Teflon®-impregnated glass fiber (TIGF) filters (100 mm). Prior to the sample collection, TIGF filters were cleaned by sonication for 10 minutes in dichloromethane (CH_2Cl_2) twice, with the solvent replaced and drained, and sonicated for 10 minutes in methanol twice with the solvent replaced. Filters are then dried in a vacuum oven at 50°C for minimum of 24 hours, placed in foil packages that have been fired at 500 °C for 4 hours, placed in Uline metallic ZipTop static shielding bags, and stored at room temperature. Amberlite XAD-4 polyaromatic absorbent resin (Aldrich Chemical Company, Inc.) was washed with Liquinox soap and rinsed with hot water, followed with deionized (DI) water and technical grade methanol (3-4 times). The XAD-4 was then extracted using a Dionex Accelerated Solvent Extractor (Dionex Corporation, Sunnyvale, CA) for 15 min/cell with dichloromethane (CH_2Cl_2) at 1500 psi and 80°C, followed by acetone. It was then dried in a vacuum oven at 50°C. Cleaned XAD-4 was packed into a glass cartridge and placed in Uline ZipTop metallic static-shielding bags and stored in clean room at room temperature. Sample preparation was done in part at the Desert Research Institute (DRI) and in part in CE-CERT's internal chemical laboratories.

Cartridges prepared at DRI were packed in plastic tubes with field data sheets with the same unique PMI number and shipped in coolers on blue ice priority mail overnight to CE-CERT.

The SVOC collected on each filter-XAD sampling train were extracted separately with high-purity, HPLC-grade dichloromethane (DCM) followed by acetone by accelerated solvent extraction (ASE). The ASE method pressurized and heated the media for 15 min/cell at 1500 psi and 80°C. The following deuterated internal standards were added to the media (XAD and filters) prior to extraction: naphthalene-d_8, acenaphthylene-d_8, phenanthrene-d_{10}, anthracene-d_{10}, chrysene-d_{12}, pyrene-d_{10}, benz[a]anthracene-d_{12}, benzo[a]pyrene-d_{12}, benzo[e]pyrene-d_{12}, benzo[k]fluoranthene-d-$_{12}$, benzo[g,h,i]perylene-d_{12}, coronene-d_{12}, 1-nitronaphthalene-d_7, 2-nitrobiphenyl-d_9, 1-nitrofluorene-d_9, 9-nitroanthracene-d_9, 3-nitrofluoranthene-d_9, 1-nitropyrene-d_9, 9-nitrochrysene-d_{11}, 6-nitrobenzo[a]pyrene-d_{11}. Extracts were concentrated to ~1mL by rotary evaporation at 35-45°C under gentle vacuum, and filtered through a 0.2 µm PTFE disposable filter (Whatman Pura disc TM 25TF). Filtrate was collected in a 4 mL amber glass vial for a total volume of ~4 mL (including flask rinse with solvent). Approximately 500 µl of hexane was added at this time, and the extracts were reduced in volume under a gentle stream of ultra high purity (UHP) nitrogen (with a Chrompack CP-Gas-Clean moisture filter) to ~250 µL.

The sample extracts were extremely complex and required extensive clean-up prior to PAH and nitro-PAH analysis to remove interferences, which reduce peak resolution and increase baseline noise. Isolation of the PAH and nitro-PAH-rich fraction was achieved with the use of a solid-phase extraction (SPE) aminopropyl Sep-Pak cartridge (Waters, Milford, MA). Sep-Pak cartridges (3 mL, 500 mg) were first pre-conditioned with 3 mL DCM followed by 3 mL hexane. The sample extract was then transferred onto the cartridge and eluted with 5 mL 2% DCM in hexane, followed by 5 mL of 20% DCM in hexane. Approximately 100 µl of toluene was added at this time, and the extracts were reduced in volume under a gentle stream of UHP nitrogen (with a Chrompack CP-Gas-Clean moisture filter) to ~100 µL. The final extract volume was adjusted to 100 µL with toluene and analyzed for non-polar analytes without further alteration.

The analysis of the PAH and nitro-PAH extracts were both performed at the Desert Research Institute, Reno, NV. The XAD cartridge extracts were analyzed separately by electron impact (EI) GC/MS for PAHs using a Varian 4000 GC/MS system equipped with a CP-8400 autosampler. A 1 µL injection onto a 30-m 5% phenylmethylsilicone fused-silica capillary column (DB-5MS+DG, J&W Scientific, Folsom CA) was performed. Compounds and corresponding deuterated internal standards were quantified by selective ion monitoring (SIM). Additional analyses were performed for filter PAH and nitro-PAH on a Scion 456 GC interfaced with a Scion TQ triple quadrupole MS/MS and equipped with CP-8400 autosampler, due to the superior sensitivity of this instrument. The PAH method utilized the same capillary column mentioned previously, while the nitro-PAH method required a 30-m DB-17MS column (J&W Scientific, Folsom CA). Negative ion chemical ionization (NICI) with methane as a reagent gas was utilized for nitro-PAH analysis to enhance detection sensitivity.

A 6-level calibration was performed for each compound of interest, and a mid-level check standard was run at least once every ten samples. If the relative accuracy of measurement (defined as a percentage difference from the standard value) was greater than 20%, then the instrument underwent routine injector/column/detector cleanup (or replacement) followed by recalibration. Nitro-PAH analysis is particularly sensitive to column age, due to the chemical affinity of target compounds to active sites.

2.5 Regeneration Emissions Testing Protocol

A protocol was developed and implemented to evaluate emissions during a period of vehicle operation that included regeneration of the particulate filter. This protocol was included in the emissions testing performed on Vehicle #1 and Vehicle #3 during their respective operation on Federal ULSD and Fed/SME-20. The regeneration testing was incorporated into the test matrix at the same point where these two fuels were otherwise being tested. Within the test matrix, the regeneration testing was done immediately after the main test sequence of either two or three tests was done on the fuel being evaluated. Prior to the first FTP on the Federal ULSD and Fed/SME-20 fuels, the vehicle was forced to regenerate to establish a baseline and remove potential impacts and carryover effects from the DPF from other fuels tested on the particular vehicle. The regeneration testing was conducted following the regular two or three FTPs that were being conducted as part of the test matrix.

For Vehicle 1, the regeneration event was triggered externally in the laboratory. After the vehicle was driven on-road to build up soot, technical personnel from the manufacturer instrumented the vehicle and manually triggered a DPF regeneration mode over the HWFET cycle. For vehicle 3, the manufacturer programmed the vehicle's ECM to regenerate every 170 miles.

The regeneration testing protocol included driving each vehicle on-road on a route designed to simulate the LA4 portion of the FTP cycle in terms of typical speeds as well as number of stops, for approximately 160 miles (20 LA4s) to build up soot in the DPF. Regulated emissions, PM mass, particle number emissions and particle size distributions, carbonyls, PAHs/nitro-PAHs, EC/OC, and NH_3 emissions were measured during a regeneration event for each vehicle/fuel combination over the EPA Highway Fuel Economy Cycle (HWFET). The HWFET (Figure 2.3) is a chassis dynamometer driving schedule, developed by the U.S. EPA for the determination of highway fuel economy of light-duty vehicles. The duration of the cycle is 765 seconds, the total distance is 10.26 miles, and the average speed is 48.3 miles/hour.

A double HWFET was conducted for each vehicle/fuel combination to provide ample time for the regeneration to be completed. The same protocol was repeated for each test fuel to collect a second set of samples of every emission component. To provide a baseline for comparison, a baseline double HWFET emissions test was conducted after the FTP testing was completed on the Federal fuel, but prior to any of the on-road HWFET conditioning. This baseline double HWFET was only conducted on the Federal ULSD.

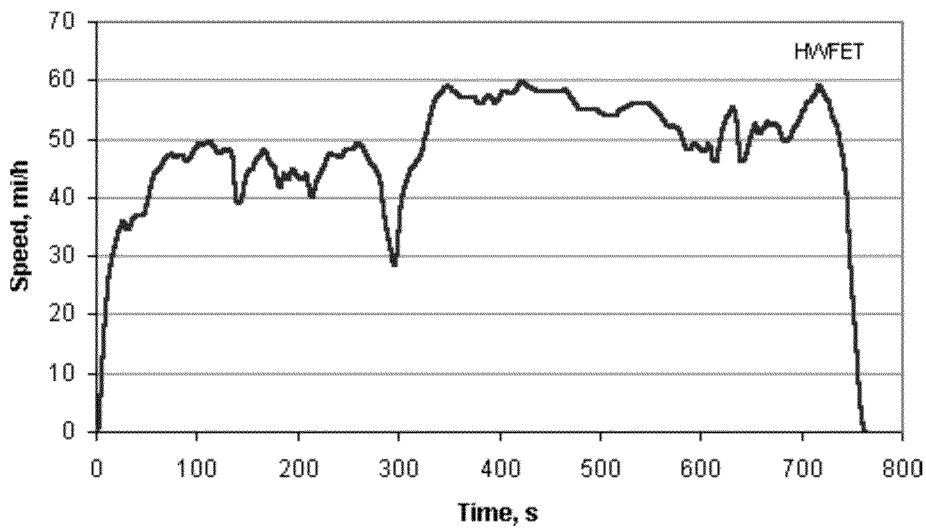

Figure 2-3: U.S. EPA HWFET Cycle

2.6 Statistical Analysis

Statistical analyses for selected emission pollutants were run using the Mixed procedure in PC/SAS from SAS Institute, Inc. Mixed models include both fixed and random factors. The fuel type was treated in the model as a fixed factor, that is, the levels of this factor were the specific fuel types of interest. Vehicles were included as a random factor. Although the vehicles were recruited for testing based on criteria for specific vehicle manufacturers or aftertreatment technologies, the vehicles were still selected at random from the larger population of vehicles of that specific manufacturer/technology within the in-use fleet. This was done to allow extrapolation of the results of the fuel effects onto a larger population of vehicle types, not just those that were used in the experiment. The mixed models were performed for each pollutant to determine the statistical significance of any fuels effects. The fixed effect included in the model was the fuel type and the random effect was vehicle.

The normality of residuals was checked in the models for all regulated and toxic emissions to determine if a transformation was necessary. Analyses using the logarithmic transform of the data in similar previous studies have shown that the emissions standard deviation is relatively constant as a percentage of the emission level. For example, vehicles with higher emission levels will tend to have a higher variability on an absolute basis than those with lower emissions levels. Examination of the current data revealed that this relationship between the emissions level and variability held true even for the very low-emitting vehicles. All the emissions were analyzed on the natural logarithm scale. Fuel economy was analyzed in the inverse scale (i.e., gallons/mile). For emissions components that included zeros for individual bags or weighted emissions, a small constant was added prior to taking the logarithm to allow the analyses to be done in the logarithm scale. Any added constants were selected to be as small as possible, and in all cases did not exceed the background levels.

For pollutants where the Mixed model showed a statistically significant for a particular driving cycle phase, pairwise comparisons were made using a least significant difference test to determine the fuel pairs for which statistically significant differences were found. Statistical analysis results were considered to be statistically significant for p " 0.05, although there are also cases noted where 0.05 < p " 0.1 as marginally statistically significant in the text. The results from the ln or inverse models were "back transformed" to provide least square means for all pollutants on each fuel. This provided an arithmetic measure to evaluate the magnitude of any statistically significant effects. Any constants added to facilitate the analysis in logarithm scale were subsequently subtracted from the least square means after the back transformation to the arithmetic scale was made. This analysis only treats individual pairwise comparisons. Basis probability theory clearly shows that the likelihood of multiple comparisons being significant simultaneously will be at a lower level of probability. This analysis was not conducted in a way that validates multiple, simultaneous, comparisons.

The regeneration testing results were not included in the main statistical analyses using the Mixed model, since the regeneration testing was done ancillary to the main test matrix. For the regeneration emissions testing, results were separately analyzed using a simple equal variance, two-tailed t-test to evaluate the statistical significance between the two fuels employed in the regeneration testing.

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3. Emissions Testing Results

This section presents and discusses figures which show the weighted FTP regulated and unregulated emission results for the eight diesel vehicles tested. The results for each test vehicle/fuel combination represent the average of all test runs done on that particular combination. The error bars represent one standard deviation on the average values for the individual vehicles. It should be noted that the error bars for some pollutants were below zero for some vehicle/fuel combinations, which suggests that the measurements were close to the CVS tunnel background measurement levels. Detailed results for the statistical analyses and the results for individual vehicles are provided in Appendix A, Appendix B, Appendix C, and Appendix D, respectively.

3.1 THC, NMHC, and CH_4 Emissions

The weighted FTP THC, NMHC, and CH_4 emissions results are presented in Figures 3.1, 3.2, and 3.3, respectively. Emissions of THC were generally found in very low concentrations for all vehicle/fuel combinations ranging from 0.012 to 0.083 g/mile, as shown in Figure 3.1. Overall, THC emissions showed some trends of lower emissions with the use of some biodiesel blends and CARB ULSD compared to Federal ULSD. The weighted THC emissions showed statistically significant differences between fuels, with CARB ULSD and CARB/WCO-20 blend showing decreases of 18% and 16%, respectively, compared to Federal ULSD. Statistically significant increases in weighted THC emissions of 19% and 17%, respectively, were also found for Fed/SME-20 and Fed/WCO-20 blends compared to CARB ULSD.

The cold-start phase of the FTP dominated the THC emissions as a result of the cold engine and the DOC being below its light-off temperature. For most vehicles, hot-running and hot-start THC emissions were found to be substantially lower than cold-start THC emissions, as shown in Table 3.1. Hot-start THC emissions for Vehicle #7 and Vehicle #8 were generally higher than hot-running THC emissions, whereas the light-duty truck Vehicle #6 showed comparable cold-start THC emissions to the passenger car Vehicle #3 and approximately three times lower cold-start THC emissions than the passenger car Vehicle #7. For Vehicle #7, it is assumed that this phenomenon in terms of less efficient THC oxidation in the aftertreatment systems is related to the lower catalyst size or different catalyst type. Statistically significant differences between fuels in THC emissions were also seen during the cold-start phase of the FTP cycle. Similar to weighted THC emissions, CARB ULSD showed a statistically significant decrease of 20% relative to Federal ULSD, while CARB/WCO-20 showed a marginally statistically significant decrease of 14% relative to Federal ULSD. Statistically significant increases in THC emissions on the order of 31% and 24%, respectively, were seen for Fed/SME-20 and Fed/WCO-20 blends compared to CARB ULSD. The blends of Fed/AFME-20, Fed/WCO-20, and CARB/WCO-20 also showed statistically significant reductions in THC emissions of 17%, 15%, and 18%, respectively, compared to Fed/SME-20 blend. Statistically significant effects in THC emissions were also observed during the hot-running phase of the FTP, but not for the hot-start phase. For the hot-running phase, CARB ULSD showed marginally statistically significant lower THC emissions (18%) and CARB/WCO-20 showed statistically significant lower THC emissions (23%) both compared to Federal ULSD. Statistically significant lower THC emissions (20%) were also seen for CARB/WCO-20 compared to Fed/SME-20.

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Table 3-1: Cold-start, hot-running, and hot-start THC emissions, expressed in g/mile, for all vehicle/fuel combinations over the FTP cycle

	Vehicle #1			**Vehicle #2**		
	Cold-start	Hot-running	Hot-start	Cold-start	Hot-running	Hot-start
Federal ULSD	0.099	0.017	0.008	0.166	0.032	0.035
CARB ULSD	0.074	0.011	0.005	0.133	0.037	0.030
Fed/SME-20	0.109	0.013	0.006	0.175	0.037	0.031
Fed/AFME-20	0.084	0.013	0.007	0.149	0.042	0.038
Fed/WCO-20	0.099	0.015	0.005	0.146	0.031	0.032
Fed/HVO-20	0.087	0.012	0.007	0.139	0.039	0.037
CARB/WCO-20	0.082	0.010	0.007	0.147	0.039	0.038
	Vehicle #3			**Vehicle #4**		
	Cold-start	Hot-running	Hot-start	Cold-start	Hot-running	Hot-start
Federal ULSD	0.049	0.012	0.008	0.126	0.036	0.022
CARB ULSD	0.038	0.011	0.009	0.106	0.029	0.015
Fed/SME-20	0.062	0.011	0.007	0.138	0.029	0.018
Fed/AFME-20	0.044	0.011	0.008	0.116	0.024	0.016
Fed/WCO-20	0.069	0.011	0.007	0.121	0.030	0.017
Fed/HVO-20	0.047	0.012	0.010	0.128	0.026	0.016
CARB/WCO-20	0.046	0.011	0.009	0.108	0.021	0.013
	Vehicle #5			**Vehicle #6**		
	Cold-start	Hot-running	Hot-start	Cold-start	Hot-running	Hot-start
Federal ULSD	0.320	0.024	0.018	0.037	0.015	0.010
CARB ULSD	0.217	0.013	0.012	0.024	0.013	0.008
Fed/SME-20	0.244	0.022	0.017	0.034	0.010	0.006
Fed/AFME-20	0.303	0.023	0.017	0.024	0.011	0.007
Fed/WCO-20	0.222	0.019	0.016	0.047	0.020	0.013
Fed/HVO-20	0.264	0.015	0.012	0.024	0.012	0.007
CARB/WCO-20	0.274	0.015	0.014	0.024	0.011	0.006
	Vehicle #7			**Vehicle #8**		
	Cold-start	Hot-running	Hot-start	Cold-start	Hot-running	Hot-start
Federal ULSD	0.134	0.011	0.023	0.137	0.012	0.090
CARB ULSD	0.104	0.008	0.023	0.162	0.012	0.082
Fed/SME-20	0.160	0.016	0.030	0.143	0.012	0.069
Fed/AFME-20	0.107	0.008	0.022	0.120	0.012	0.073
Fed/WCO-20	0.114	0.008	0.021	0.130	0.011	0.076
Fed/HVO-20	0.103	0.008	0.025	0.162	0.013	0.098
CARB/WCO-20	0.098	0.007	0.024	0.164	0.013	0.092

The CARB ULSD showed lower THC emissions relative to Federal ULSD for seven out of the eight vehicles. The CARB ULSD's lower aromatics and higher cetane number relative to the Federal ULSD were probably the main contributors to the lower THC emissions. Most studies of biodiesel in uncontrolled engines have shown reduced THC emissions relative to petroleum diesel. The higher oxygen concentration of biodiesel is one of the main factors contributing to lower THC emissions, although the absence of aromatic content as well as the advanced injection and combustion timing also promote more complete combustion. Moreover, the higher cetane number of biodiesel contributes to the reduction of the ignition delay, where a large

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amount of HC is formed (Lapuerta et al., 2008a; Giakoumis et al., 2012). Overall, studies conducted on modern technology vehicles where the cold-start phase dominates THC emissions show that the biodiesel benefit for THC has somewhat faced. Many authors in related studies have reported either insignificant changes or even increases in THC emissions for biodiesel relative to ULSD (Martini et al., 2007; Bannister et al., 2010; Fontaras et al., 2010b; Rose et al., 2010; Bakeas et al., 2011b). These results also showed some consistent increases in THC emissions for the unsaturated Fed/SME-20 compared to the other biodiesel blends. This phenomenon could be ascribed to the lower cetane number of soy-based biodiesel compared to the other biodiesel fuels used in this study. The results reported here also showed consistent cold-start and weighted THC increases for the biodiesel blends compared to CARB ULSD. It is possible that the lower volatility of biodiesel compared to petroleum diesel combined with biodiesel's lower heating value may lead to higher levels of HC with high molecular weights which are difficult to vaporize and burn. This lower volatility may also cause higher fuel consumption that could form localized regions with higher fuel-to-air ratios resulting in increased THC emissions.

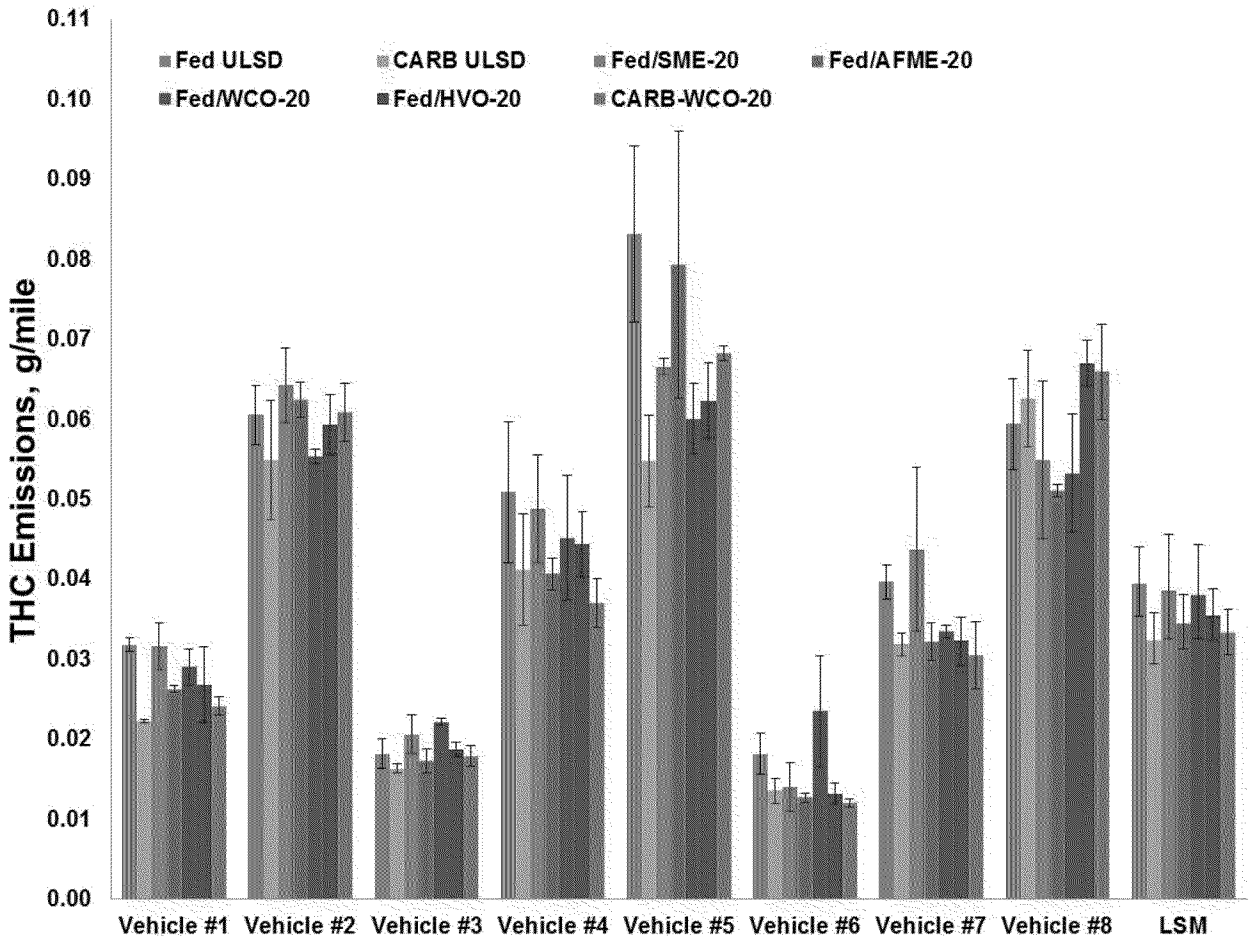

Figure 3-1: Weighted THC emissions over the FTP

Emissions of NMHC were found at very low concentrations for all vehicle/fuel combinations, as shown in Figure 3.2. For the weighted NMHC emissions, CARB ULSD and Fed/HVO-20 showed statistically significant reductions of 28% and 24%, respectively, compared to Federal ULSD. Compared to CARB ULSD, the blends of Fed/SME-20 and Fed/WCO-20 also showed statistically significant increases in NMHC emissions of 48% and 49%, respectively. Similar to THC emissions, the blends of Fed/AFME-20, Fed/WCO-20, and CARB/WCO-20 showed statistically significant reductions compared to Fed/SME-20. In addition, Fed/WCO-20 showed a statistically significant increase in weighted NMHC emissions of 32% relative to Fed/AFME-20,

whereas Fed/HVO-20 and CARB/WCO-20 showed statistically significant reductions of 29% and 26%, respectively, relative to Fed/WCO-20 blend.
For the cold-start phase of the FTP, CARB ULSD, Fed/HVO-20 and CARB/WCO-20 exhibited statistically significant reductions in NMHC emissions of 29%, 18% and 18%, respectively, compared to Federal ULSD. The blends of Fed/SME-20 and Fed/WCO-20 showed statistically significant increases in NMHC emissions of 60% and 50%, respectively, and the Fed/AFME-20 a marginally statistically significant 20% increase compared to CARB ULSD. Statistically significant reductions of 25%, 28%, and 29% were also seen for Fed/AFME-20, Fed/HVO-20, and CARB/WCO-20, respectively, compared to Fed/SME-20. Similar to weighted NMHC emissions, Fed/WCO-20 showed a statistically significant increase of 24% compared to Fed/AFME-20, whereas Fed/HVO-20 and CARB/WCO-20 showed statistically significant reductions of 23% and 24%, respectively, relative to Fed/WCO-20 blend. For the hot-running phase, there were no statistically significant effects between the fuels, while for the hot-start phase Fed/HVO-20 showed a statistically significant reduction in NMHC emissions of 47% compared to both Federal ULSD and Fed/WCO-20.

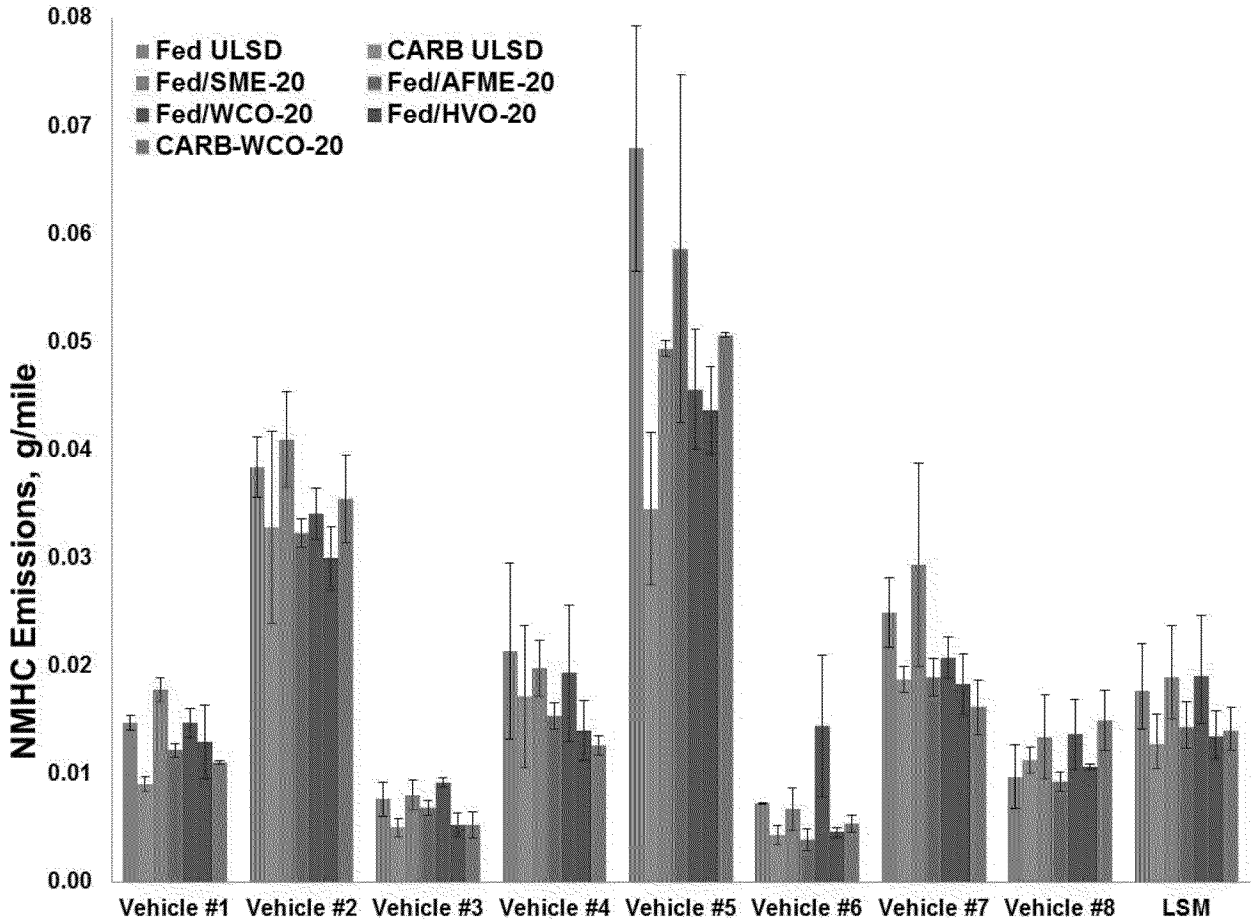

Figure 3-2: Weighted NMHC emissions over the FTP

Methane (CH_4) emissions are presented in Figure 3.3. While CH_4 is not toxic and not relevant to ozone-forming potential, CH_4 emissions are a strong greenhouse gas that must be accounted for. A fairly large body of data reporting CH_4 emissions from gasoline-fueled light-duty vehicles exists. However, there is limited information concerning the magnitude of CH_4 emissions from modern technology light-duty diesel vehicles operated with alternative fuel formulations and their contribution to the global and regional CH_4 inventory. For this program, CH_4 emissions were at very low levels for most vehicle/fuel combinations over the FTP cycle, ranging from 0.008 to 0.065 g/mile. For the weighted CH_4 emissions, Fed/HVO-20 showed a statistically

significant increase of 15% compared to Fed/WCO-20, while the test fuels had the same effect on CH_4 emissions during the cold-start phase. For the hot-running phase, CARB/WCO-20 showed a marginally statistically significant decrease of 13% compared to federal ULSD and Fed/HVO-20 showed a marginally statistically significant increase of 14% compared to CARB ULSD. Reductions in CH_4 emissions for CARB/WCO-20 on the order of 13% at a marginally statistically significant level and 15% at a statistically significant level were also seen compared to Fed/AFME-20 and Fed/HVO-20, respectively. For the hot-start phase, the results showed statistically significant increases in CH_4 emissions of 22%, 21%, and 27%, respectively, for Fed/HVO-20 compared to CARB ULSD, Fed/SME-20, and Fed/WCO-20, while CARB/WCO-20 showed a marginally statistically significant reduction of 17% compared to Fed/HVO-20.

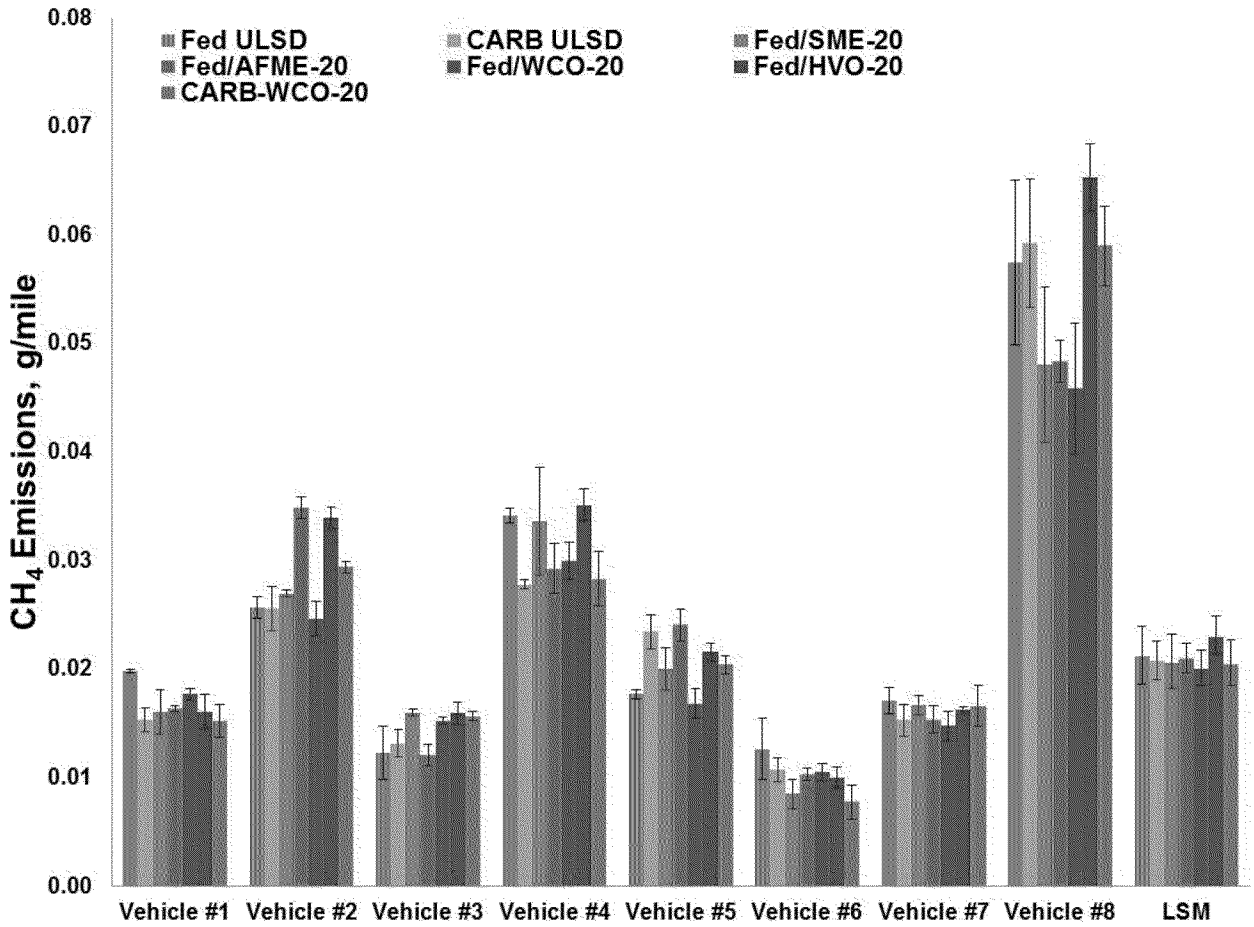

Figure 3-3: Weighted CH_4 emissions over the FTP

3.2 CO Emissions

CO emissions are shown in Figure 3.4. For the weighted CO emissions, the results revealed a statistically significant decrease of 31% and a marginally statistically significant decrease of 18% for CARB ULSD and CARB/WCO-20, respectively, compared to Federal ULSD. Compared to CARB ULSD, the blends of Fed/SME-20, Fed/AFME-20, Fed/WCO-20, and Fed/HVO-20 showed statistically significant increases in CO emissions on the order of 52%, 22%, 40%, and 26%, respectively. The blends of Fed/AFME-20 and CARB/WCO-20 showed statistically significant decreases in CO emissions on the order of 19% and 22%, respectively, compared to Fed/SME-20, while a 17% decrease was also seen for Fed/HVO-20 compared to Fed/SME-20 at a marginally statistically significant level.

For the cold-start phase of the FTP, the results showed statistically significant decreases in CO emissions of 31% and 18%, respectively, for CARB ULSD and CARB/WCO-20 relative to Federal ULSD. For the blends of Fed/SME-20, Fed/AFME-20, Fed/WCO-20, and Fed/HVO-20, cold-start CO emissions showed statistically significant increases of 53%, 23%, 41%, and 24%, respectively, compared to CARB ULSD. Emissions of CO also showed statistically significant reductions on the order of 19%, 19%, and 23% for Fed/AFME-20, Fed/HVO-20, and CARB/WCO-20, respectively, compared to Fed/SME-20. CO emissions did not show any strong fuel effects for the hot-running and hot-start phases of the FTP cycle.

CO emissions tend to be relatively low in diesel engine combustion due to the lean operation diesel engines. The use of biodiesel in diesel engines can reduce CO emissions because of its higher oxygen content, which favors more complete combustion. In addition, the higher cetane number of some saturated biodiesel fuels and the hydrogenated vegetable oil contribute to lower (engine-out) CO. Several studies reported reductions in CO emissions with biodiesel blends (Di et al., 2009; Bakeas et al., 2011a; Nikanjam et al., 2011) and with HVO blends (Murtonen et al., 2009; Pflaum et al., 2010) relative to regular ULSD. In contrast, several chassis dynamometer studies have shown trends of increasing CO emissions with increasing biodiesel percentage in the fuel blend (Durbin et al., 2000; Rose et al., 2010; Fontaras et al., 2009; Fontaras et al., 2010; Bannister et al. 2010). This study's results showed stronger differences between the CARB ULSD and the Federal ULSD compared to the addition of biodiesel. Most biodiesel blends with Federal ULSD showed increased CO emissions relative to the CARB ULSD, but a greater tendency for reduced CO emissions relative to the Federal ULSD. In addition, similar to THC emissions, the more unsaturated Fed/SME-20 blend systematically led to higher CO emissions than the other biodiesel blends.

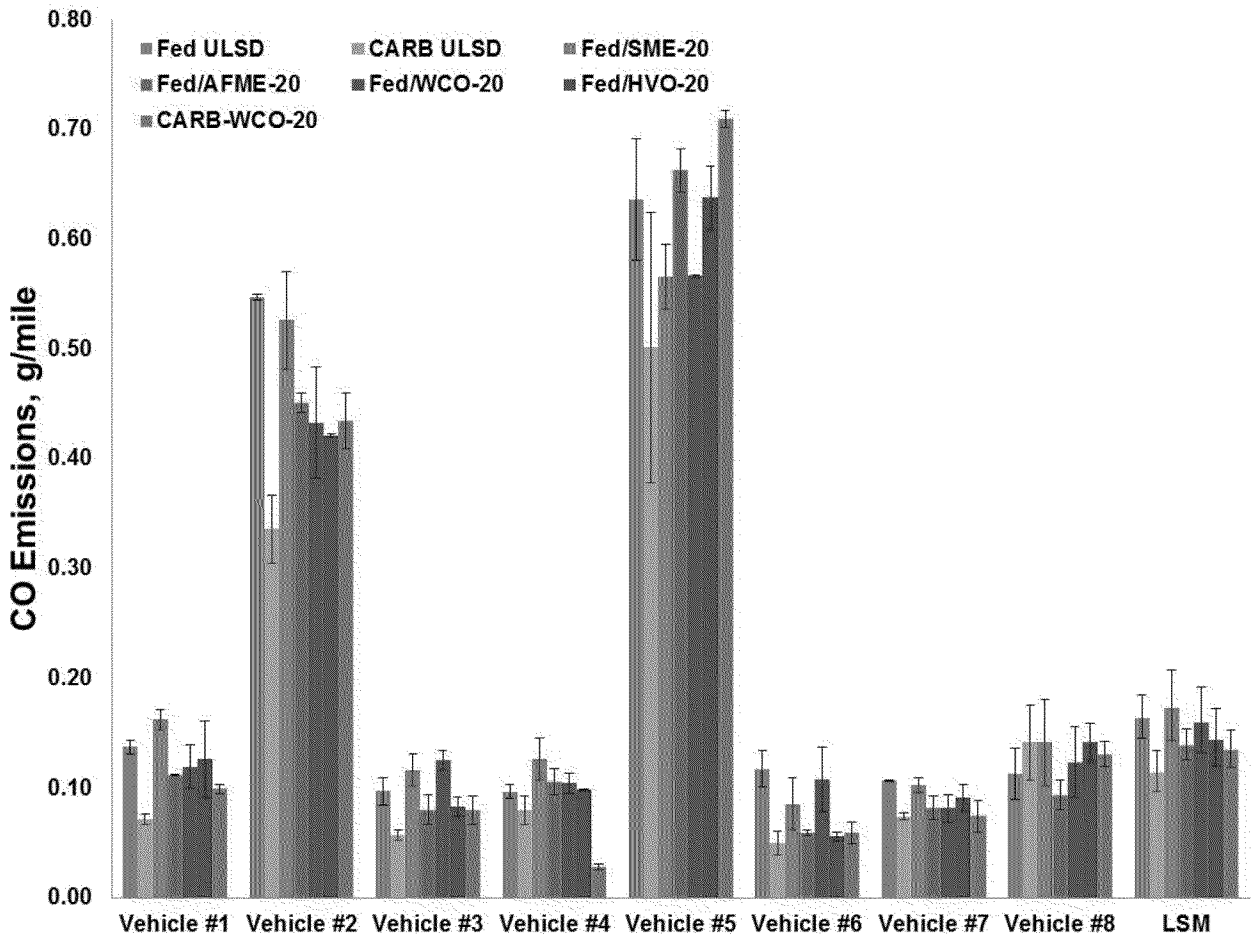

Figure 3-4: Weighted CO emissions over the FTP

3.3 NO_x Emissions

Nitrogen oxides (NO_x) are one of the toughest pollutants to control in a diesel engine. They consist mostly of nitric oxide (NO) and nitrogen dioxide (NO_2), and play an important role in the ground-level atmospheric ozone formation. Formation of NO_x is strongly dependent on temperature (thermal NO_x), residence time of the mixture at high temperatures, and local concentration of oxygen. Other contributing factors are injection timing, fuel type, and fuel properties. Average NO_x emissions over the FTP are shown in Figure 3.5. Statistical analysis of the results showed that neither the weighted NO_x nor NO_x from any individual phase of the FTP were influenced by the test fuels.

Over the years, numerous studies have focused on the impact of biodiesel on NO_x emissions, with most studies showing either increases in NO_x with biodiesel or no change in NO_x emissions. Most of the studies in this area have focused on heavy-duty engines where NO_x increases with biodiesel have been attributed to a variety of factors including, but not limited to, the stoichiometry during combustion, higher adiabatic flame temperatures, the impact of lower energy biodiesel on the engine control system, or reduced radiative heat losses (Giakoumis et al., 2012; Hoekman and Robbins, 2012). Studies of light-duty diesel vehicles/engines have shown less consistent NO_x impacts with biodiesel. Some studies of light-duty vehicles have shown lower NO_x emissions with biodiesel over the more lightly-loaded FTP and NEDC which could be attributed to lower engine loads than are usually seen for test cell engines (Staat and Gateau, 1995; Fontaras et al., 2010b; Bakeas et al., 2011b). In the present study, the vehicles were equipped with SCR aftertreatment, which is currently the most prevalent technology for reducing NO_x emissions. Any combustion process-related impacts on NO_x emissions were likely overshadowed by the significant reductions from the advanced NO_x aftertreatment controls leading to a lack of any significant differences in NO_x emissions between fuels. Differences in engine-out NO_x emissions may produce differences in urea Diesel Exhaust Fluid (DEF) consumption rate. However, there was no attempt to measure DEF consumption rate in this study. While reductions in NO_x emissions for some biodiesel blends and vehicle combinations relative to both ULSDs were observed, as well as some NO_x increases for the unsaturated biodiesel blend relative to the other biofuel blends and ULSDs, these phenomena were not consistent throughout the fleet and the differences were not statistically significant.

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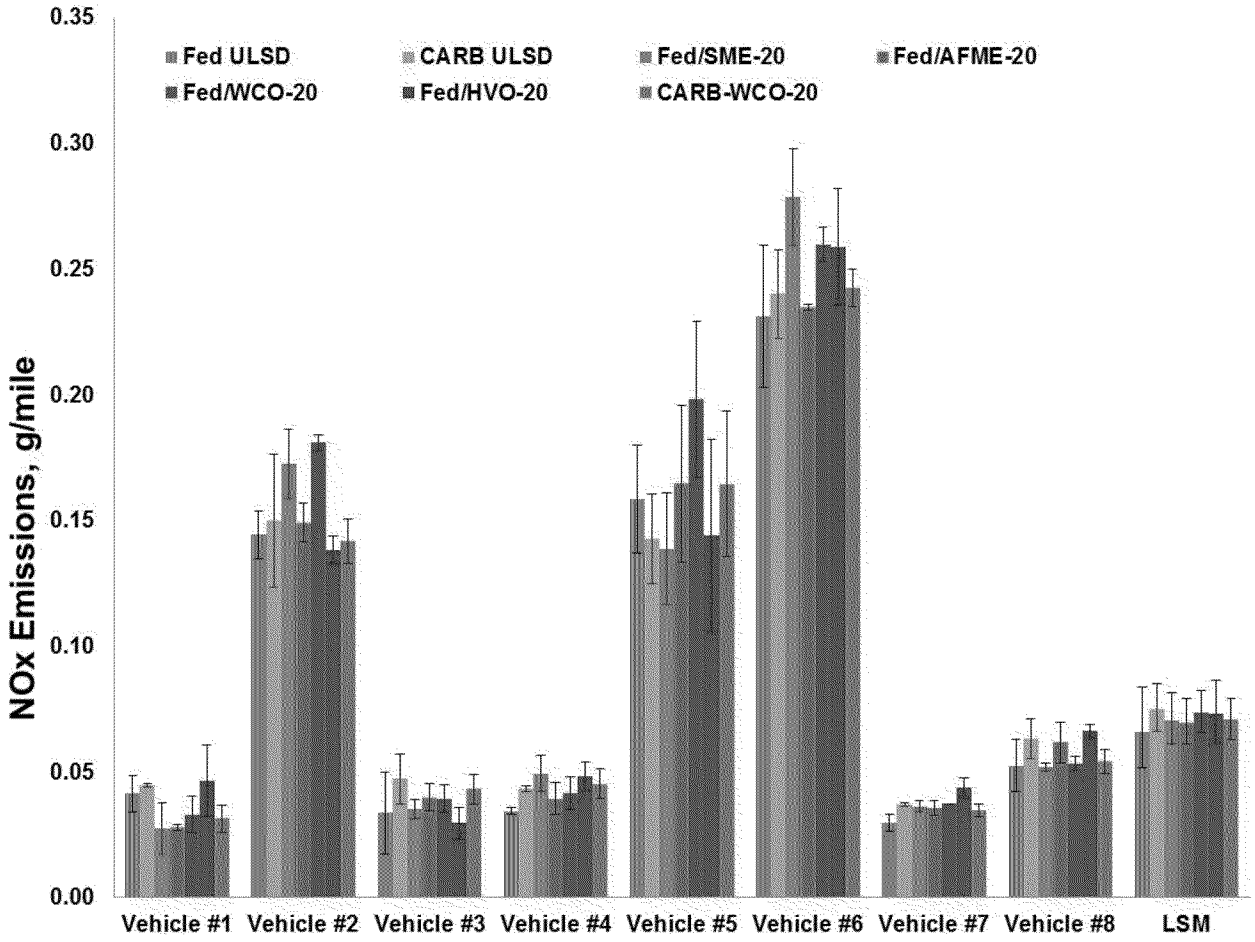

Figure 3-5: Weighted NO_x emissions over the FTP

3.4 CO_2 Emissions and Fuel Economy

CO_2 emissions are shown in Figure 3.6. An increasing trend in CO_2 emissions was observed with most of the biodiesel blends compared to the baseline Federal and CARB fuels. For the weighted CO_2 emissions, the results showed statistically significant increases of 1.9% for Fed/SME-20 and 2.3% for Fed/WCO-20 compared to Federal ULSD and of 1.7% for Fed/WCO-20 compared to CARB ULSD. The blend of Fed/WCO-20 showed a statistically significant increase in CO_2 emissions of 1.7% compared to Fed/AFME-20, whereas the blends of Fed/HVO-20 and CARB/WCO-20 showed statistically significant decreases of 2.5% and 1.7%, respectively, compared to Fed/WCO-20.

For the cold-start phase, statistically significant decreases in CO_2 emissions were seen for Fed/HVO-20 (2.8%) and CARB/WCO-20 (2.4%) compared to Fed/Fed/WCO-20. For the hot-running phase of the FTP, statistically significant increases in CO_2 emissions of 2.3% for Fed/SME-20 and 2.6% for Fed/WCO-20 compared to Federal ULSD and 1.8% for Fed/WCO-20 compared to CARB ULSD were observed. The Fed/HVO-20 blend was also lower at a statistically significant level on the order of 2.1% and 2.4%, respectively, compared to Fed/SME-20 and Fed/WCO-20. For the hot-start CO_2 emissions, the results showed marginally statistically significant increases of 2.3% for Fed/SME-20 and 2.4% for Fed/WCO-20 compared to Federal ULSD, while Fed/HVO-20 showed a statistically significant decrease of 2.4% for both Fed/SME-20 and Fed/WCO-20.

Available studies in the literature report both increases and decreases in CO_2 emissions with the application of biodiesel fuels. Previous studies conducted on Euro 3 and Euro 4 light-duty vehicles running on different biodiesel blends showed some increases in CO_2 emissions or insignificant differences when compared to regular ULSD (Rose et al., 2010; Karavalakis et al., 2011a; Kousoulidou et al., 2012). According to the authors, a contributing factor for the higher CO_2 emissions could be due to difference in H:C ratios for biodiesel compared to that of petroleum diesel, as the presence of a carbonyl group in the methyl ester interrupts the H to C sequence in the fuel. As a result, more carbon is injected into the cylinder for the same energy content. Taking into account a typical methyl ester speciation, a neat biodiesel delivers approximately 1.8% more carbon into the cylinder for the same energy as petroleum diesel fuel. The increase in carbon per unit of energy leads to a proportional increase of CO_2 emissions. In addition, the lower energy content of biodiesel and its blends compared to petroleum diesel forces the engine to operate at a higher 'apparent' load, i.e., requiring more fuel to be injected per stroke. This higher apparent load may lead the engine to operate at a different point in the engine map, resulting to a different thermodynamic efficiency.

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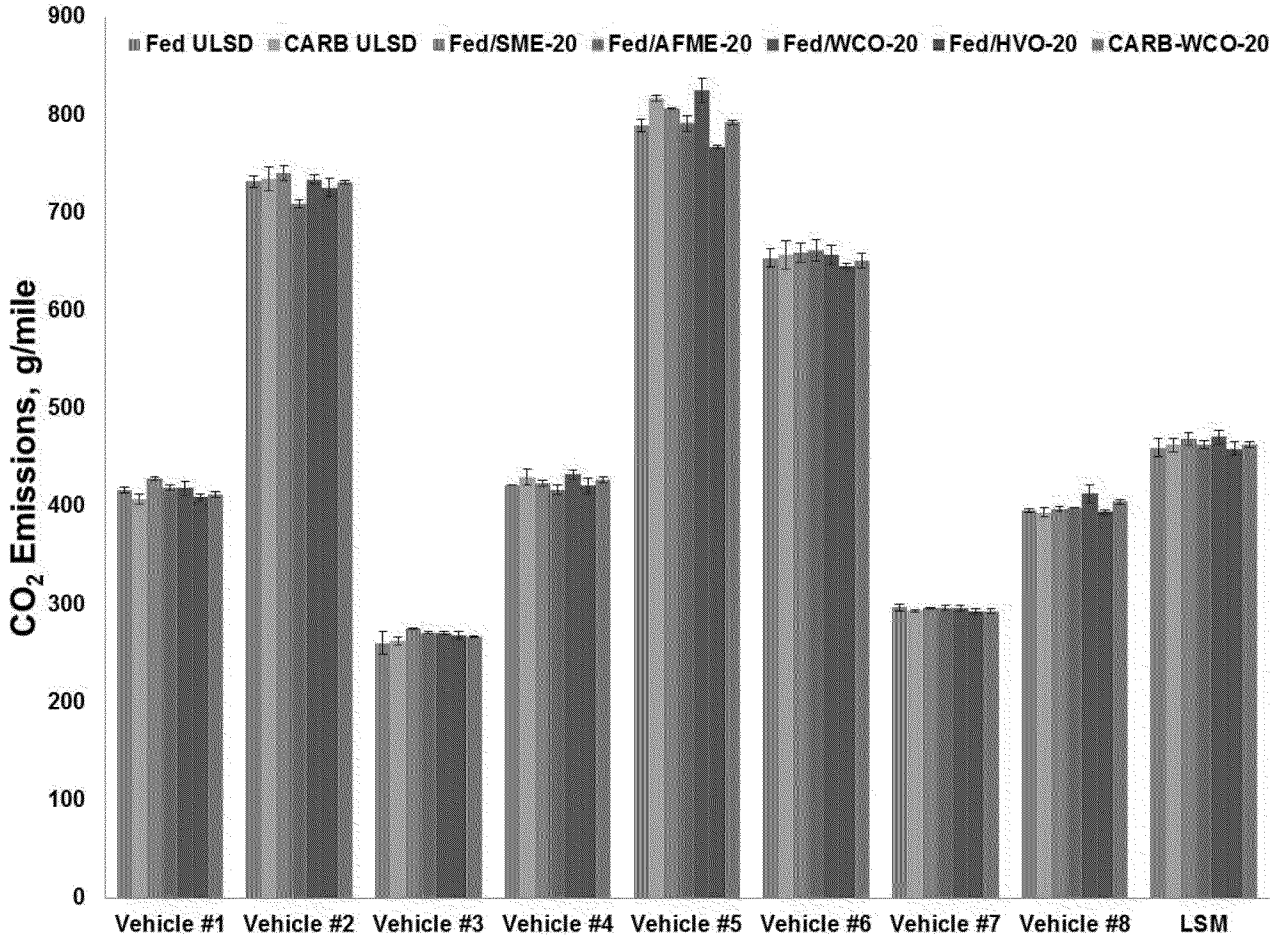

Figure 3-6: Weighted CO_2 emissions over the FTP

The fuel economy results for the different test vehicles are presented in Figure 3.7. For this study, fuel economy was calculated based on the carbon balance method and the unique properties for each different test fuel, rather than the standard EPA equation. The carbon balance equation (shown below) more directly accounts for the differences in energy content between different fuels, which are somewhat normalized out in the standard EPA equation.

$$\frac{\text{[illegible]} \times \text{[illegible]} \times 3781.8}{(\text{[illegible]} \times \text{[illegible]}) + (0.429 \times \text{[illegible]}) + (0.273 \times \text{[illegible]})}$$

Where:

3781.8: Density of water at 60 ˚F in g/gals

THC: THC emission rate (g/mile)

CO: CO emission rate (g/mile)

CO_2: CO_2 emission (g/mile)

CWF: Carbon weight fraction of the test fuel

sp.gr: Specific gravity of the test fuel

For the weighted fuel economy, the results showed some strong effects for the Federal ULSD compared to CARB ULSD and the biofuel blends, but CARB ULSD did not show strong effects compared to biodiesel blends. Compared to Federal ULSD, weighted fuel economy showed

statistically significant decreases of 3.7%, 4.2%, 4.2%, 4.8%, 2.8%, and 5.7% for CARB ULSD, Fed/SME-20, Fed/AFME-20, Fed/WCO-20, Fed/HVO-20, and CARB/WCO-20. As expected, the CARB ULSD and the HVO blend showed smaller differences in fuel economy compared to the Federal ULSD. It is interesting to note that comparing the gross heating values for the test fuels, their energy contents are lower by 2.4% for Fed/SME-20, 2.5% for Fed/AFME-20, 2.6% for Fed/WCO-20, and 1.3% for CARB/WCO-20 compared to Federal ULSD. On the other hand, CARB ULSD and Fed/HVO-20 blend showed higher gross heating values by 1.2% and 0.8%, respectively, compared to Federal ULSD. For CARB ULSD, the only statistically significant effect in weighted fuel economy was observed for CARB/WCO-20 blend, which showed a reduction of 2.1%. The blend of Fed/HVO-20 showed a statistically significant increase of 2.1% compared to Fed/WCO-20, while CARB/WCO-20 showed a statistically significant decrease of 3.0% compared to Fed/HVO-20.

For the cold-start phase, fuel economy results showed statistically significant decreases of 3.4%, 3.3%, 3.8%, 4.3%, and 4.6% for CARB ULSD, Fed/SME-20, Fed/AFME-20, Fed/WCO-20, and CARB/WCO-20 compared to Federal ULSD, while the non-oxygenated Fed/HVO-20 showed a marginally statistically significant decrease of 2.1% compared to Federal ULSD. The blend of Fed/HVO-20 showed a marginally statistically significant increase in fuel economy of 2.3% compared to Fed/WCO-20 and CARB/WCO-20 showed a statistically significant decrease of 2.5% compared to Fed/HVO-20. Similar to the weighted and cold-start fuel economy results, for the hot-running phase, fuel economy showed statistically significant decreases of 3.9%, 4.5%, 4.5%, 5.2%, 3.2%, and 6.4%, respectively, for CARB ULSD, Fed/SME-20, Fed/AFME-20, Fed/WCO-20, Fed/HVO-20, and CARB/WCO-20 compared to Federal ULSD. Compared to CARB ULSD, the only statistically significant decrease was seen for CARB/WCO-20 (2.7%). A marginally statistically significant increase on the order of 2.1% and a statistically significant decrease of 3.4% was seen for the Fed/HVO-20 compared to Fed/WCO-20 and CARB/WCO-20, respectively. For the hot-start phase of the FTP, fuel economy results showed statistically significant decreases of 3.6%, 4.7%, 3.9%, 4.6%, and 5.6%, respectively, for CARB ULSD, Fed/SME-20, Fed/AFME-20, Fed/WCO-20, and CARB/WCO-20 compared to Federal ULSD, while the non-oxygenated Fed/HVO-20 showed a marginally statistically significant decrease of 2.8% compared to Federal ULSD. A marginally statistically significant decrease of 2.9% was also seen for CARB/WCO-20 compared to Fed/HVO-20.

The reductions in fuel economy with the biodiesel blends are in line with previous studies (Rose et al., 2010; Karavalakis et al. 2010a; Bakeas et al., 2011a) and can be attributed to the lower energy content of biodiesel compared to petroleum diesel. This trend is consistent when comparing the biodiesel blends with the Federal ULSD, i.e., the fuel with the highest energy content, but this trend less consistent when comparing the biodiesel blends with federal diesel to CARB ULSD, due to the lower energy content of the CARB ULSD compared to the Federal ULSD.

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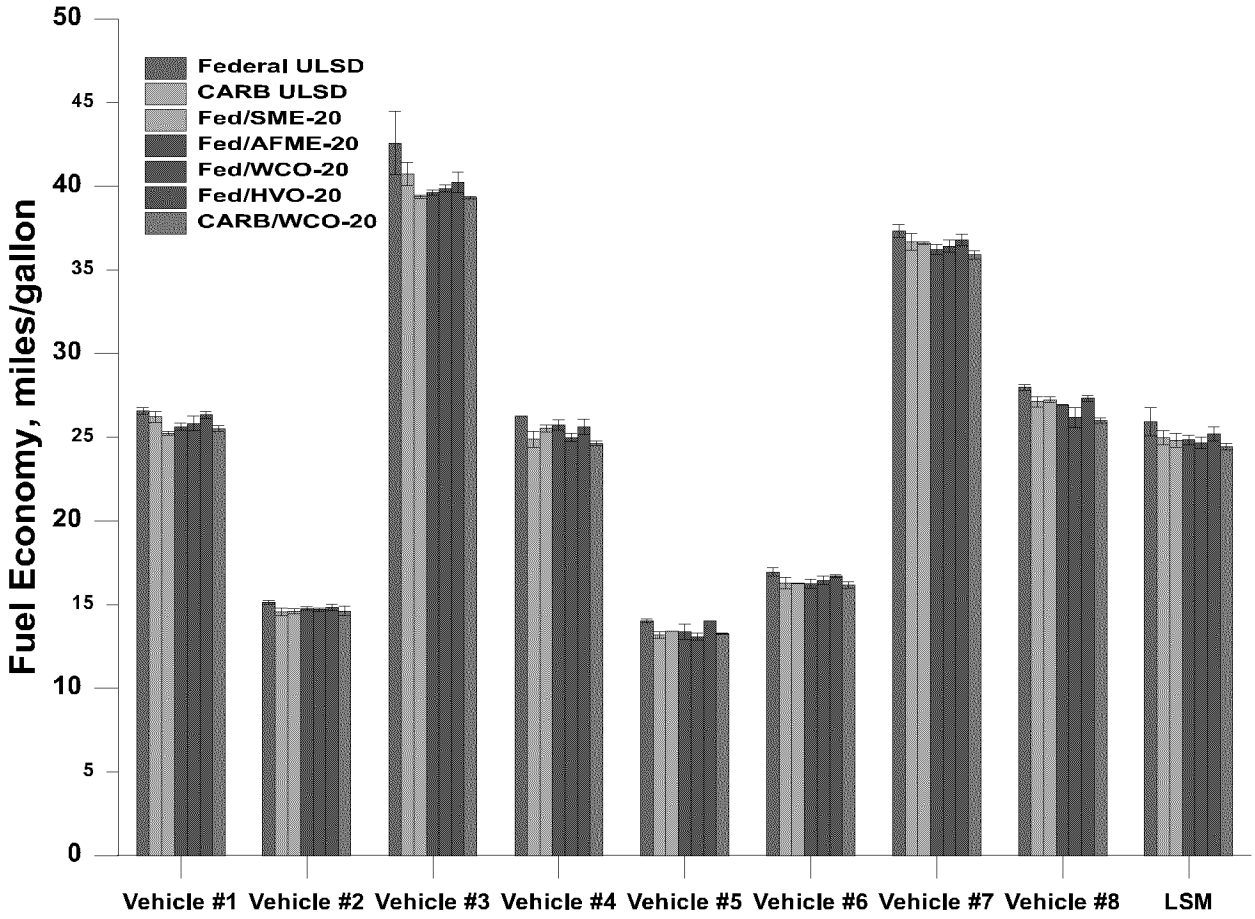

Figure 3-7: Average fuel economy results based on the carbon balance method

3.5 PM Emissions

PM mass emissions are shown in Figure 3.8. PM emission rates ranged from approximately 0.18 to 2.65 mg/mi, consistent with the lower PM emission rates that are typically seen for light-duty diesel vehicles equipped with DPF aftertreatment (Fontaras et al., 2014; May et al., 2014). The PM emission rates for the cumulative samples were, in most cases, well above the tunnel background level, which is provided as the rightmost bar in the figure. The PM emissions rates for the vehicles are shown without subtraction for the tunnel background. The larger error bars for some vehicle/fuel combinations can be attributed to test-to-test variability, as the typical accuracy of the PM measurement itself is approximately ±5-15%. For this study, PM mass emissions did not show any statistically significant differences between the test fuels. The results showed both increases and decreases in PM mass emissions with the biofuel blends compared to both ULSD fuels, with these differences not being consistent or statistically significant between fuels for the fleet as a whole.

In understanding the PM emission results, it is important to note that many of the biodiesel emissions studies to date have been conducted on vehicles/engines without extensive aftertreatment systems for PM reductions. In general, most of these studies with light-duty or heavy-duty engines have found decreasing PM mass emissions during transient operations for biodiesel blends (McCormick et al., 2001; Lapuerta 2008b; Kousoulidou et al., 2010), although there are several chassis dynamometer studies conducted on light-duty vehicles fueled with various biodiesel blends that have shown increases in PM emissions relative to regular ULSD fuels (Peterson and Reece, 1996; Durbin et al., 2000; Martini et al., 2007; Fontaras et al., 2009; Karavalakis et al., 2009; Bakeas et al., 2011). Various reasons have been documented to explain

the reductions in PM emissions with the use of biodiesel fuels, with the primary contributing factor for the PM decrease being the presence of oxygen in the methyl ester molecule. Oxygenated fuels, such as biodiesel blends, possess the ability to reduce locally fuel-rich regions and limit soot nucleation early in the formation process, thus reducing PM emissions. In addition, the absence of aromatic compounds in biodiesel fuels, which are generally considered to act as soot precursors, may also be a reason for the reductions in PM emissions compared to the baseline diesel fuels (Lapuerta et al., 2008a). For studies that have shown increases in PM emissions for light-duty vehicles, where cold-start emissions are a significant portion of the overall PM emissions, it is possible that certain physical properties of biodiesel can prevail over its increased oxygen content (Fontaras et al. 2009; Bakeas et al. 2011; Karavalakis et al. 2009; Martini et al. 2007). For example, the higher initial boiling point of biodiesel compared to regular petroleum ULSD, which leads to more difficult fuel evaporation at low temperatures, and the higher viscosity of biodiesel, which reduces the rate of spray atomization, could both contribute to increased PM emissions.

Biodiesel emissions studies for vehicles/engines equipped with advanced aftertreatment controls, and particularly DPFs, are more limited. Studies of heavy-duty engines and vehicles equipped with DPFs have generally shown that biodiesel does not have a strong influence on PM emissions given the already significant reductions in PM emissions that are obtained from the DPF (Lammert et al. 2012; Williams et al. 2011a; Olatunj et al. 2010; Gsyel et al. 2014; Hajbabaei et al. 2013). For a retrofit DPF equipped heavy-duty engine, however, Williams et al. (2006) showed that PM reductions of 27% for biodiesel blend compared to ULSD could still be obtained along with a significant lowering of balance point temperature and an increase in regeneration rate. Williams et al. (2010) also found that the presence of oxygen can promote faster regenerations and greater soot reactivity for a catalyzed DPF. Studies of light-duty vehicles with more advanced aftertreatment systems are more limited. There have also been a number of studies that have looked at the potential impact of impurities in biodiesel on longer term durability of DPFs and lube oil dilution, but these issues are not relevant for comparison with the current study, which was of short duration (Williams et al. 2011; Williams et al. 2013; He et al. 2011).

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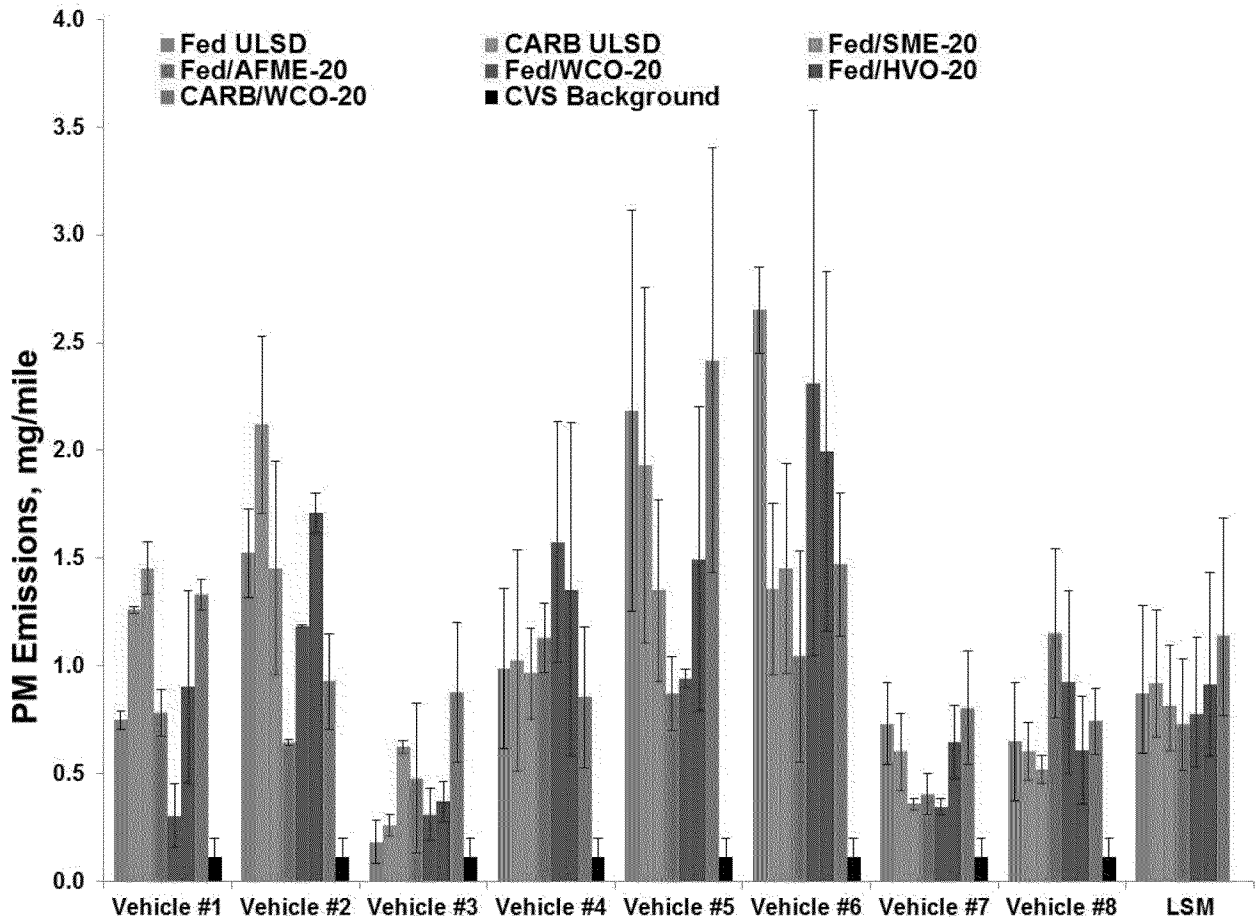


Figure 3-8: PM mass emissions over the FTP

3.6 Particle Number Emissions

Total particle number emissions, expressed in particles/mile, are shown in Figure 3.9. Statistical analysis was conducted on both the cold-start and the weighted particle number emissions for the fleet as a whole. The results did not reveal any statistically significant different between the test fuels for either the cold-start or the weighted particle number emissions. It should be noted that particle number emissions for Vehicle #5 and Vehicle #7 were found to be lower than the other test vehicles. In general, some reductions were seen in particle number emissions with the use of biofuel blends for Vehicle #1 and Vehicle #2, but not for the other test vehicles. Particle number emissions showed both increases and decreases with the biofuel blends and largely a lack of fuel trends throughout the fleet. This phenomenon could be ascribed to the presence of the DPF control, which appeared to eliminate any potential engine fuel effect. Similar results, where biodiesel fuel effects have been negligible for DPF equipped engines, have been reported in other studies (Lammert et al., 2012; Williams et al., 2011a), although other studies have seen reductions for biodiesel fuels even at these relatively low particle number levels (Li et al. 2012; Fontaras et al., 2014).

Figure 3.10 (a-h) shows the particle number emissions for each vehicle/fuel combination for each individual phase of the FTP cycle. With the exception of Vehicle #2, particle number emissions were dominated by the cold-start phase of the FTP cycle, where the majority of particle number emissions were produced during the first 200-300 seconds of the cycle. This phenomenon was due to the fact that the engine was cold and the DOC was below its light-off temperature. It is assumed that these elevated particle number emissions during the cold-start might be semi-

volatile materials escaping oxidation as the catalytic converters have not reached the light-off temperature. For the hot-running and hot-start phases of the FTP, particle number emissions for most vehicles were substantially lower than those emitted during cold-start conditions, suggesting higher filtration efficiency of the DPF. It should be noted that during cold-start operation the particle number measurement variability was increased compared to phases 2 and 3 of the FTP. It was also observed that the use of biodiesel blends increased the variability of the particle number emissions during the cold-start phase when compared to both ULSD fuels. Although there is no clear explanation for this phenomenon, it is theorized that the overall absence of fuel effects were related to changes in the filtration efficiency as the DPF heated up and to the increase of soluble organic fraction (SOF) particles of biodiesel, which somehow affected the measurement variability during cold-start operation.

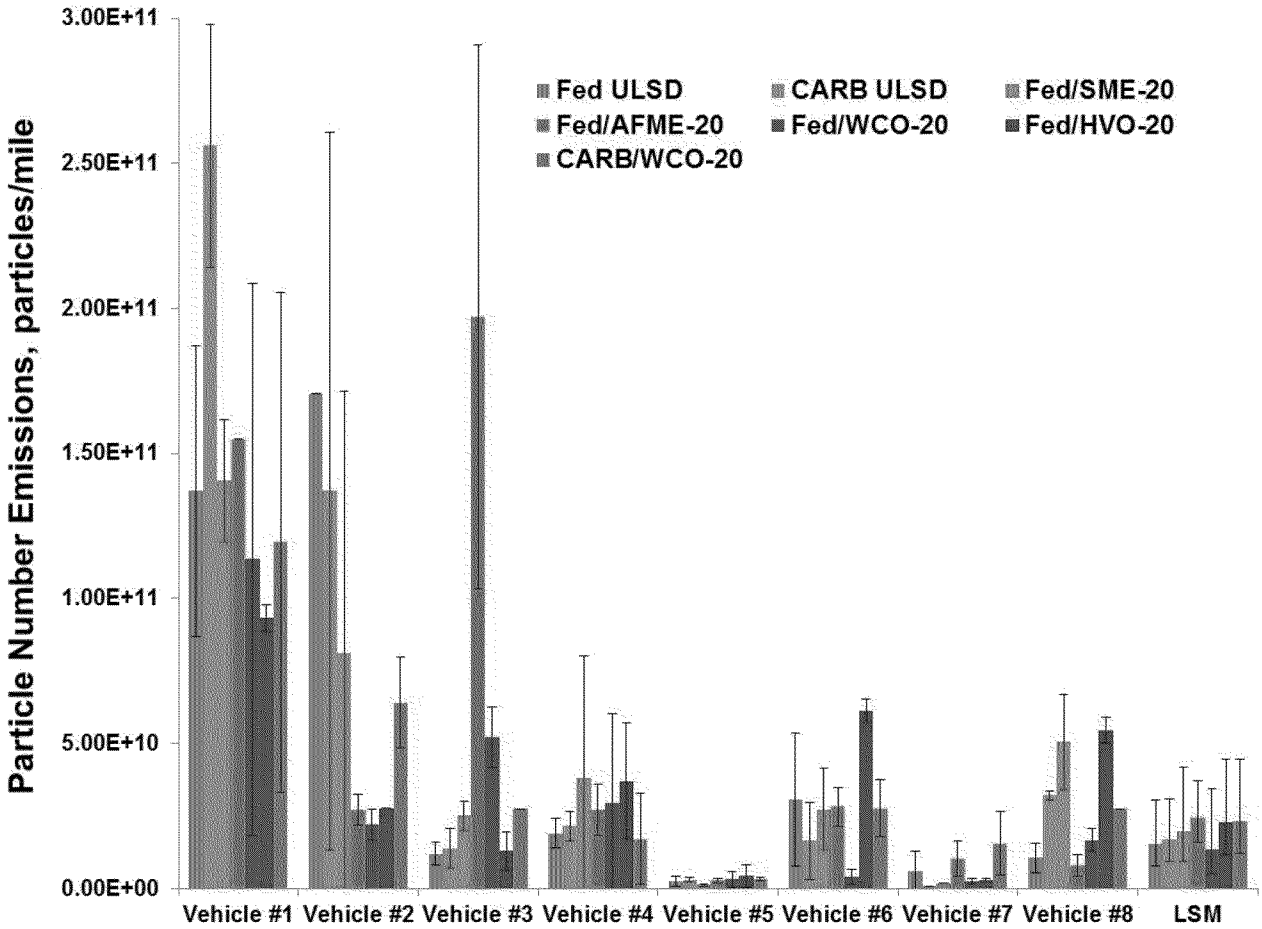
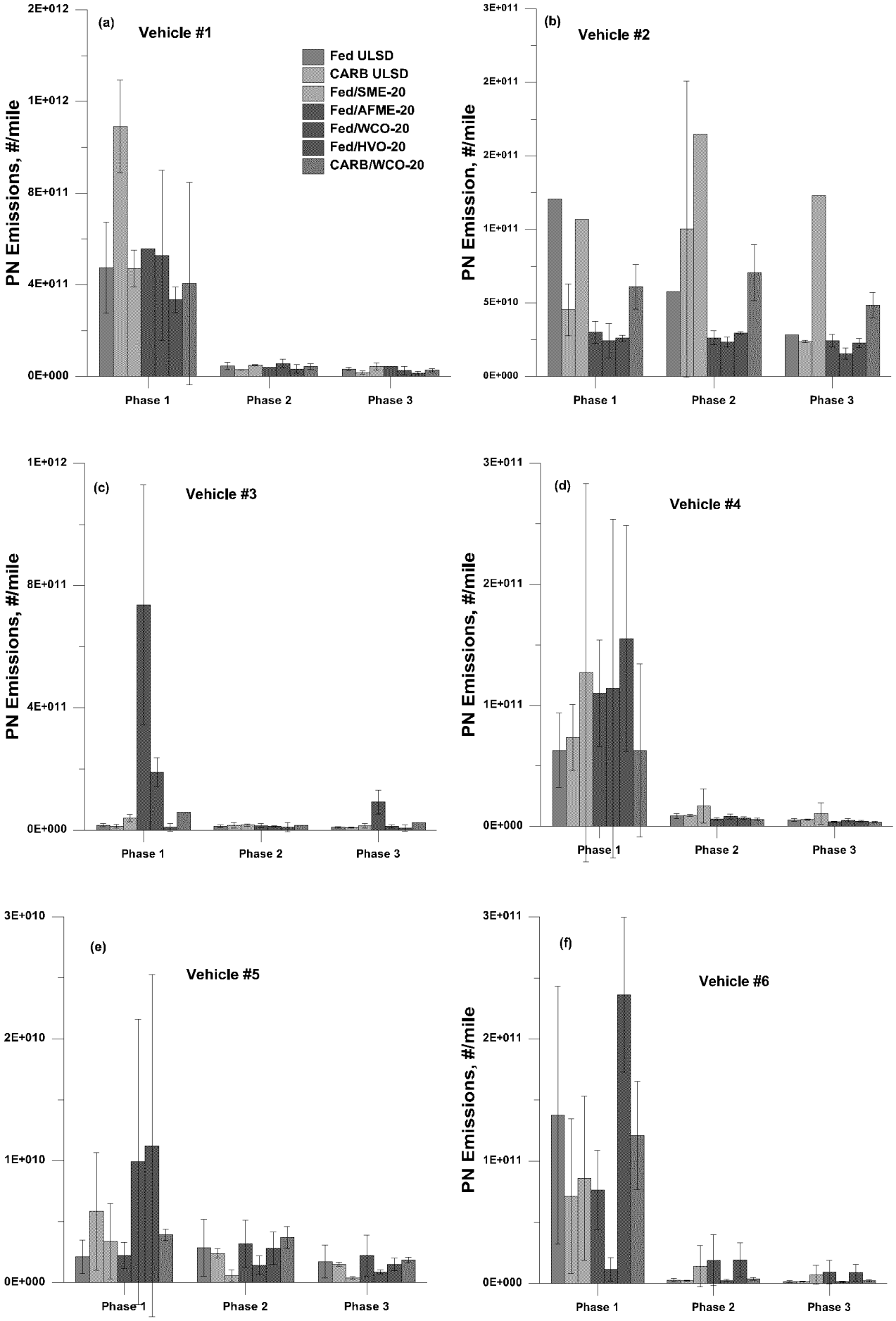


Figure 3-9: Particle number emissions over the FTP


(a)
Vehicle #1
Fed ULSD
CARB ULSD
Fed/SME-20
Fed/AFME-20
Fed/WCO-20
Fed/HVO-20
CARB/WCO-20
PN Emissions, #/mile
2E+012
1E+012
8E+011
4E+011
0E+000
Phase 1
Phase 2
Phase 3
(b)
Vehicle #2
PN Emission, #/mile
3E+011
2E+011
2E+011
1E+011
5E+010
0E+000
Phase 1
Phase 2
Phase 3
(c)
Vehicle #3
PN Emissions, #/mile
1E+012
8E+011
4E+011
0E+000
Phase 1
Phase 2
Phase 3
(d)
Vehicle #4
PN Emissions, #/mile
3E+011
2E+011
1E+011
0E+000
Phase 1
Phase 2
Phase 3
(e)
Vehicle #5
3E+010
2E+010
1E+010
0E+000
Phase 1
Phase 2
Phase 3
(f)
Vehicle #6
PN Emissions, #/mile
3E+011
2E+011
1E+011
0E+000
Phase 1
Phase 2
Phase 3

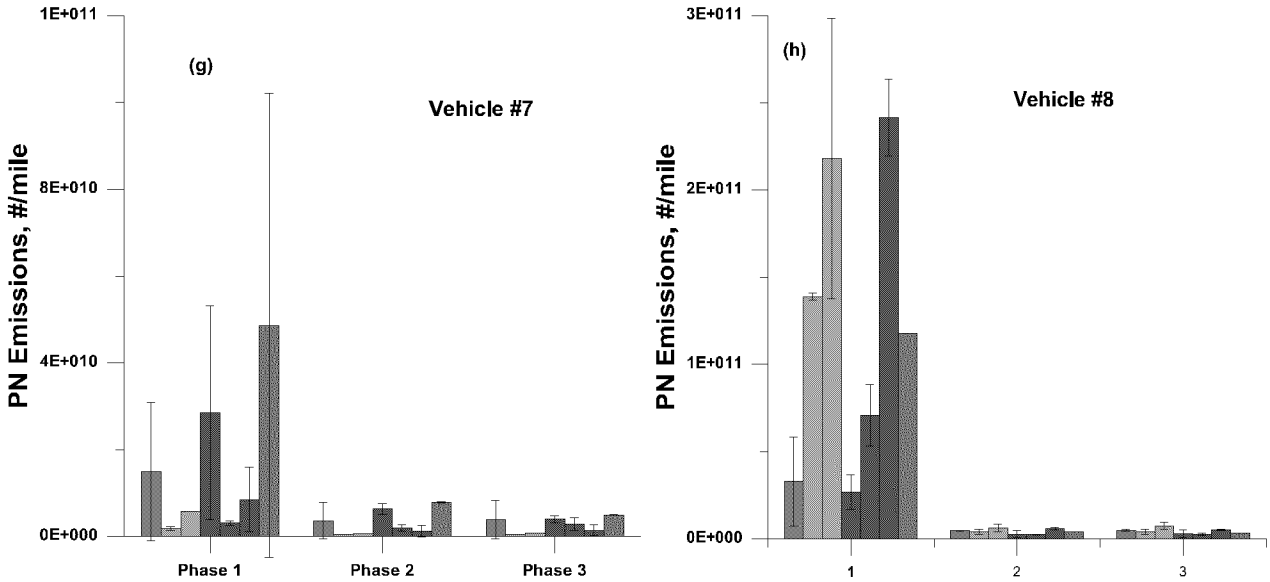


Figure 3-10 (a-h): Particle number emissions for each individual phase of the FTP

3.7 Particle Size Distributions

Average EEPS particle size distributions (PSDs) for Vehicle #1 through Vehicle #8 are shown in Figures 3.11 through 3.18, respectively. It should be noted the EEPS was not available for testing Fed ULSD, Fed/AFME-20, and Fed/WCO-20 for Vehicle #1 and for the Fed/HVO-20 blend for Vehicle #2. For Vehicle #1, all fuels produced size distributions with peaks at 30-50 nm in diameter. The CARB ULSD was found to produce the highest accumulation mode particle concentrations at around 50 nm followed by the CARB/WCO-20 blend. This is somewhat consistent with the higher particle number emissions for the CARB ULSD compared to the biodiesel blends and the renewable diesel blend, as shown in Figure 3.9, and the generally higher PM masses for these two fuels, as shown in Figure 3.8. For Vehicle #2, the differences in PSDs between the test fuels were not as strong, with all fuels showing accumulation mode particles with mobility diameters at ~ 30-40 nm. Similar to Vehicle #1, CARB ULSD and its blend with WCO produced higher accumulation mode particle concentrations than Federal ULSD and the other biofuel blends. The PSDs for Vehicle #3 showed that all fuels produced accumulation mode particles with peaks at around 50 nm in diameter. The Fed/AFME-20 blend exhibited more accumulation mode particles than the other biodiesel blends, the HVO blend, and the reference ULSDs. This is consistent with the higher total particle number emissions for the animal fat biodiesel compared to all other fuels, as shown in Figure 3.9. Vehicle #4 displayed a unimodal distribution with the accumulation mode dominating the PSD for all fuels. The biofuel blends showed higher accumulation mode particle counts than both ULSD fuels, with the non-oxygenated Fed/HVO-20 blend producing higher accumulation mode particles than the biodiesel blends. All fuels showed accumulation mode particles ranging between 45 to 53 nm in diameter.

For Vehicle #5, the PSDs were largely unimodal, with a peak around 90 nm. The PSD profile for the Fed/SME-20 blend showed a bimodal distribution, with the accumulation mode particles peaking at about 107 nm and a smaller number of nucleation mode particles peaking at 14 nm. However, the overall particle counts for this blend were found to be significantly lower compared to all other test fuels for this vehicle and close to the CVS tunnel background limits. In addition, the PSD profile for the Fed/AFME-20 was quite unstable, with nucleation mode

particles peaking at around 9 nm and accumulation mode particles peaking at around 60 nm. It was also found that a second nucleation mode at around 26 nm was formed for this particular blend. Analogous to Vehicle #4, the blends of Fed/HVO-20, Fed/WCO-20 and CARB/WCO-20 showed higher accumulation mode particle concentrations compared to both ULSD fuels. The non-oxygenated HVO blend showed the highest accumulation mode particle counts followed by the Fed/WCO-20 and the CARB/WCO-20 blends. For the biofuel blends, the accumulation mode particles ranged from 94-107 nm in diameter, whereas for the ULSD fuels particle size ranged from 70-93 nm in diameter. Vehicle #6 displayed unimodal distributions with accumulation mode particles ranging from 60 to 80 nm in diameter. The non-oxygenated fuels, namely the ULSD fuels and the HVO blend, produced higher accumulation mode particle concentrations compared to the biodiesel blends. These results are somewhat consistent with the higher PM mass and number emissions for the Fed/HVO-20 compared to the biodiesel blends.

Unlike the other the test vehicles, Vehicle #7 displayed a decidedly bimodal distribution profile for all fuels, with the accumulation mode particles dominating the particle size distribution. The nucleation mode particles ranged from 9-11 nm, while the accumulation mode particles ranged from 40-53 nm in diameter. The biodiesel blends of CARB/WCO-20, Fed/AFME-20, and Fed/SME-20 showed higher accumulation mode particle counts than both reference ULSD fuels, while the HVO blend and Fed/WCO-20 blend showed very low particle counts close to the CVS background levels, consistent with the PM mass emissions for this vehicle as seen in Figure 3.9. Similar to Vehicle #7, Vehicle #8 displayed bimodal distribution profile for all fuels, with the exception of the Fed/SME-20 blend that showed a unimodal distribution with no decidedly accumulation mode peak. Vehicle #8, however, showed much higher concentrations in the nucleation mode range, in contrast to the PSDs for Vehicle #7. The nucleation mode geometric mean particle diameter ranged from 9-20 nm and the accumulation mode mean particle diameter ranged from 52-70 nm. The Fed/SME-20 blend showed the highest nucleation mode particle concentrations followed by the HVO blend, CARB ULSD, and CARB/WCO-20. This result is also consistent with the higher particle number emissions for these fuels. For the accumulation mode particles, the CARB ULSD and HVO blend showed the highest concentrations, followed by the Fed/WCO-20 blend and Federal ULSD.

Although not consistent, the results showed that the soy-based biodiesel blend led to increases for some test vehicles in both nucleation and accumulation mode particle concentrations compared to the other biodiesel blends. Soy-based biodiesel, in particular, contains unsaturated fatty esters, which have been shown to increase nucleation mode particles, possibly because of the emission of organic species with high boiling points, which tend to be more condensable than hydrocarbon components (Schönborn et al., 2009). In addition, the double bonds in the ester molecules are likely to provide a direct path to the formation of carbonaceous soot via the formation of ethene and ethyne during the thermal decomposition of the molecule. Both of these species are known precursor molecules to carbonaceous soot. In general, the particle size distribution results did not show a trend for the fleet as a whole. For some vehicles, biodiesel blends resulted in decreases in accumulation mode particles compared to ULSD fuels. This could be due to the reactivity of surface oxygen groups bonded at edge sites in the methyl ester providing higher rates of oxidation of particulates and to the absence of polyaromatic compounds in the methyl ester, since aromatics are considered precursors for the soot formation process. It is interesting to note that the renewable diesel blend showed higher concentrations of accumulation mode particles for Vehicle #4, Vehicle #5, and Vehicle #6 compared to both baseline ULSDs and the biodiesel blends. Although the renewable diesel contained a negligible amount of aromatics and sulfur, it appears that the absence of oxygen necessary to suppress soot formation played some role in the higher accumulation mode particles.

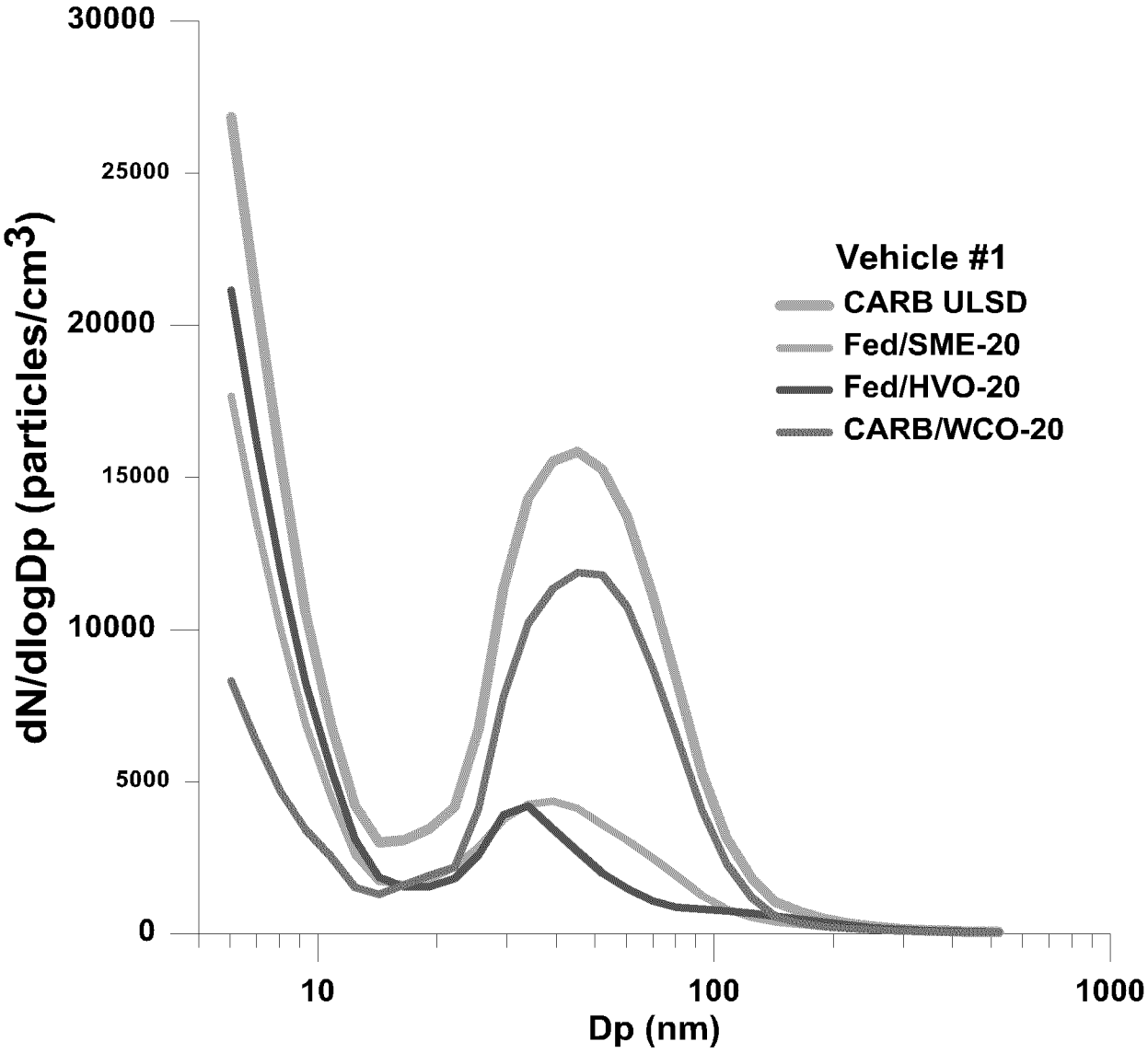


Figure 3-11: Particle size distributions for Vehicle #1 over the FTP

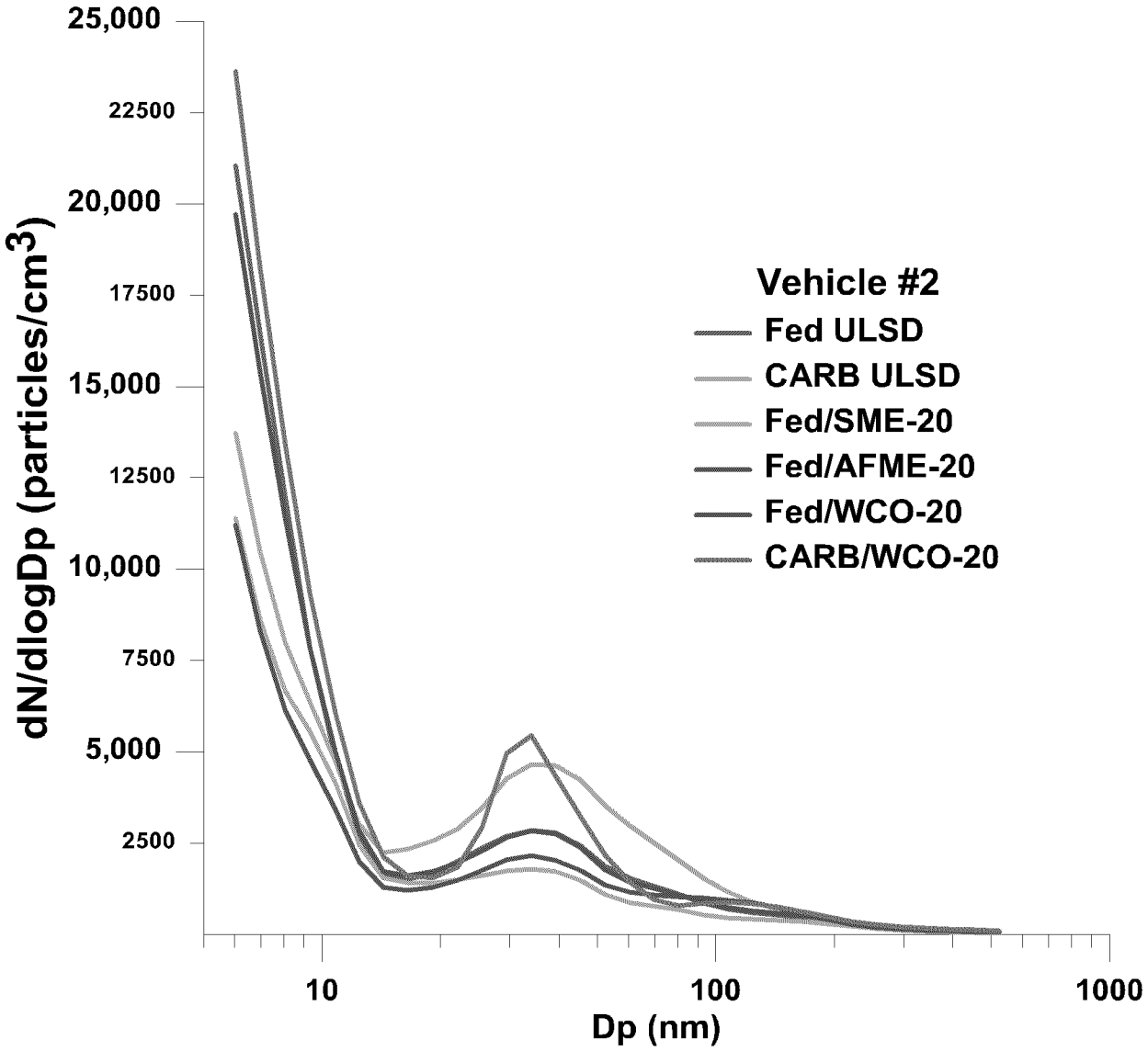


Figure 3-12: Particle size distributions for Vehicle #2 over the FTP

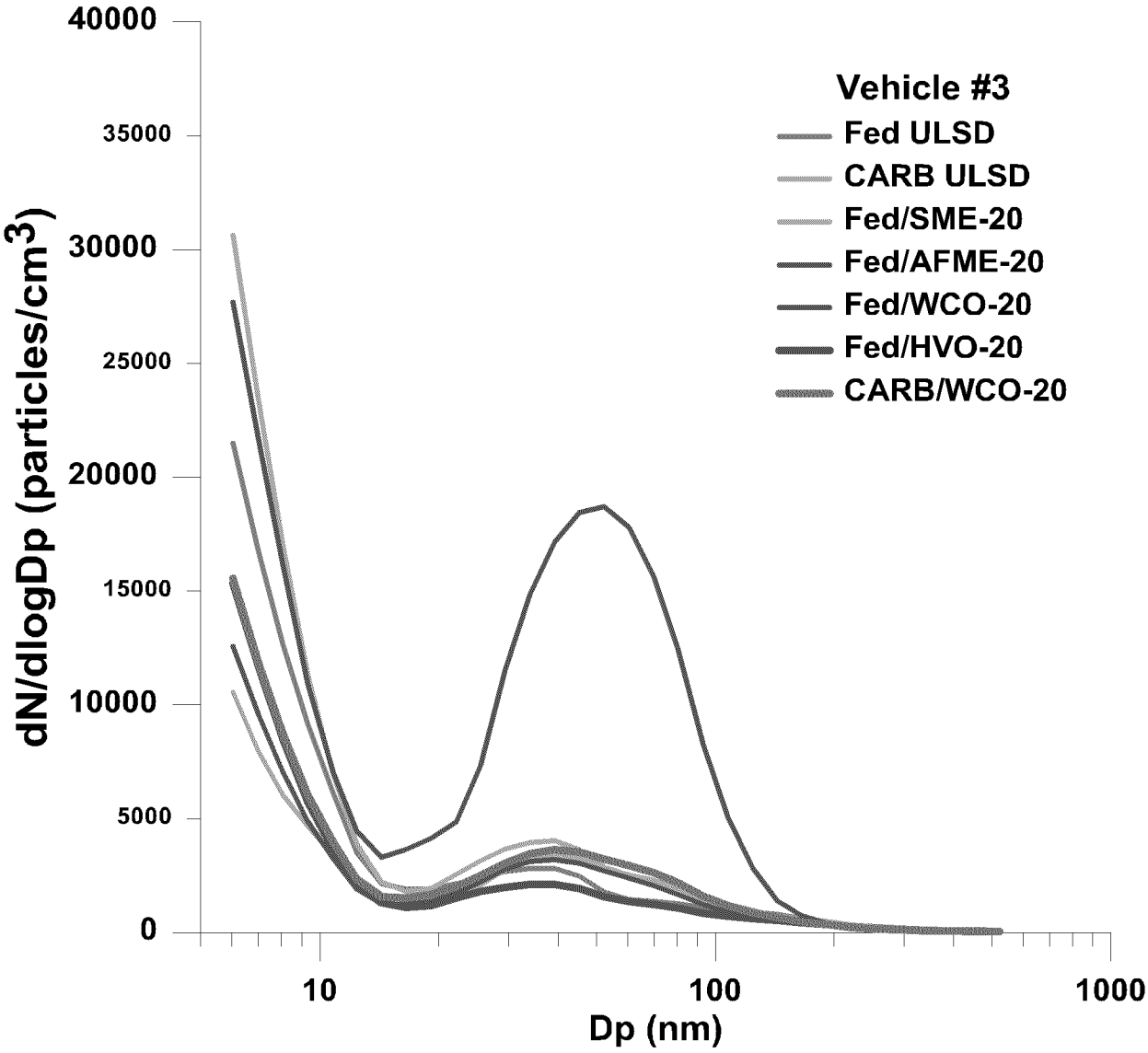


Figure 3-13: Particle size distributions for Vehicle #3 over the FTP

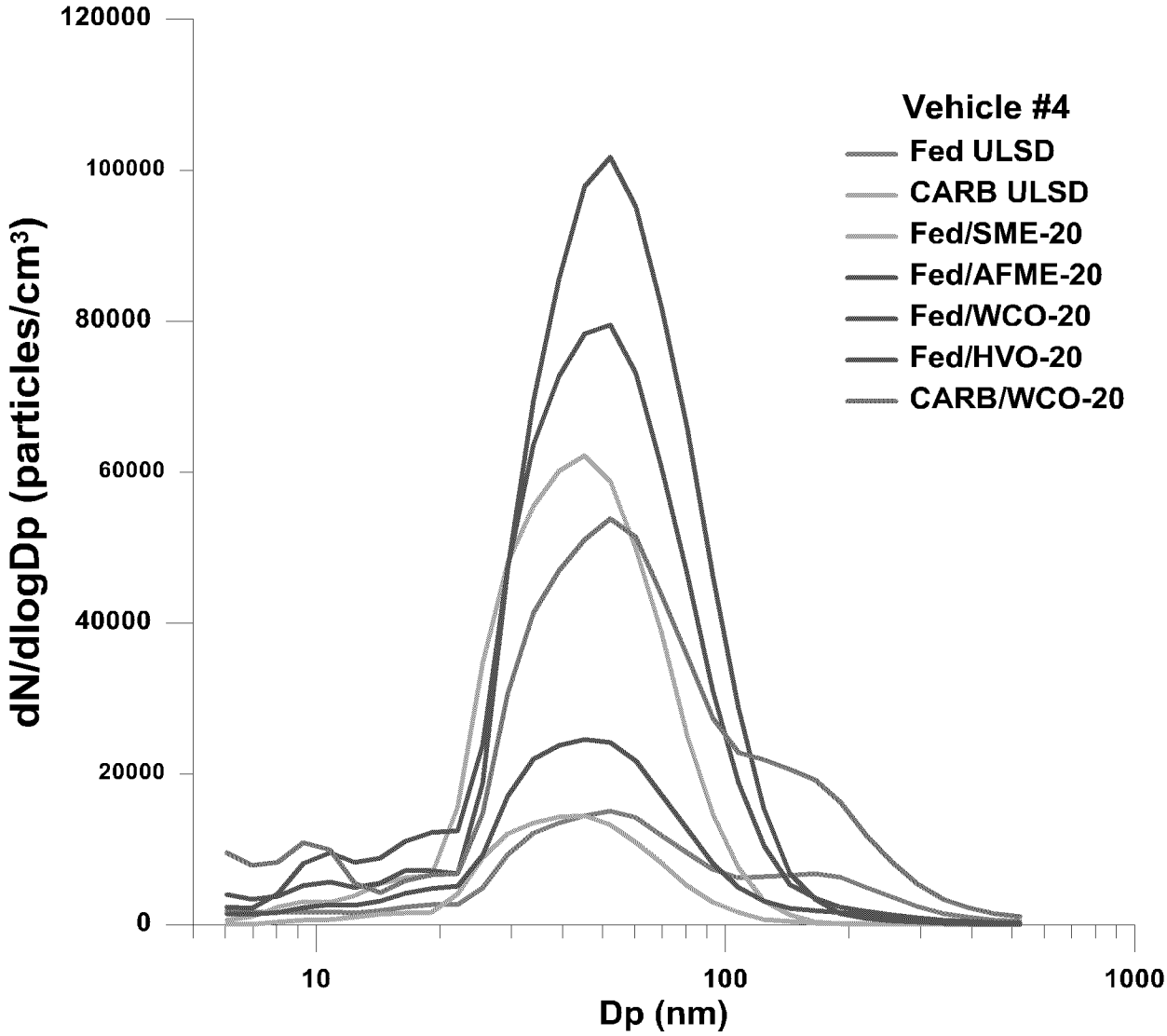


Figure 3-14: Particle size distributions for Vehicle #4 over the FTP

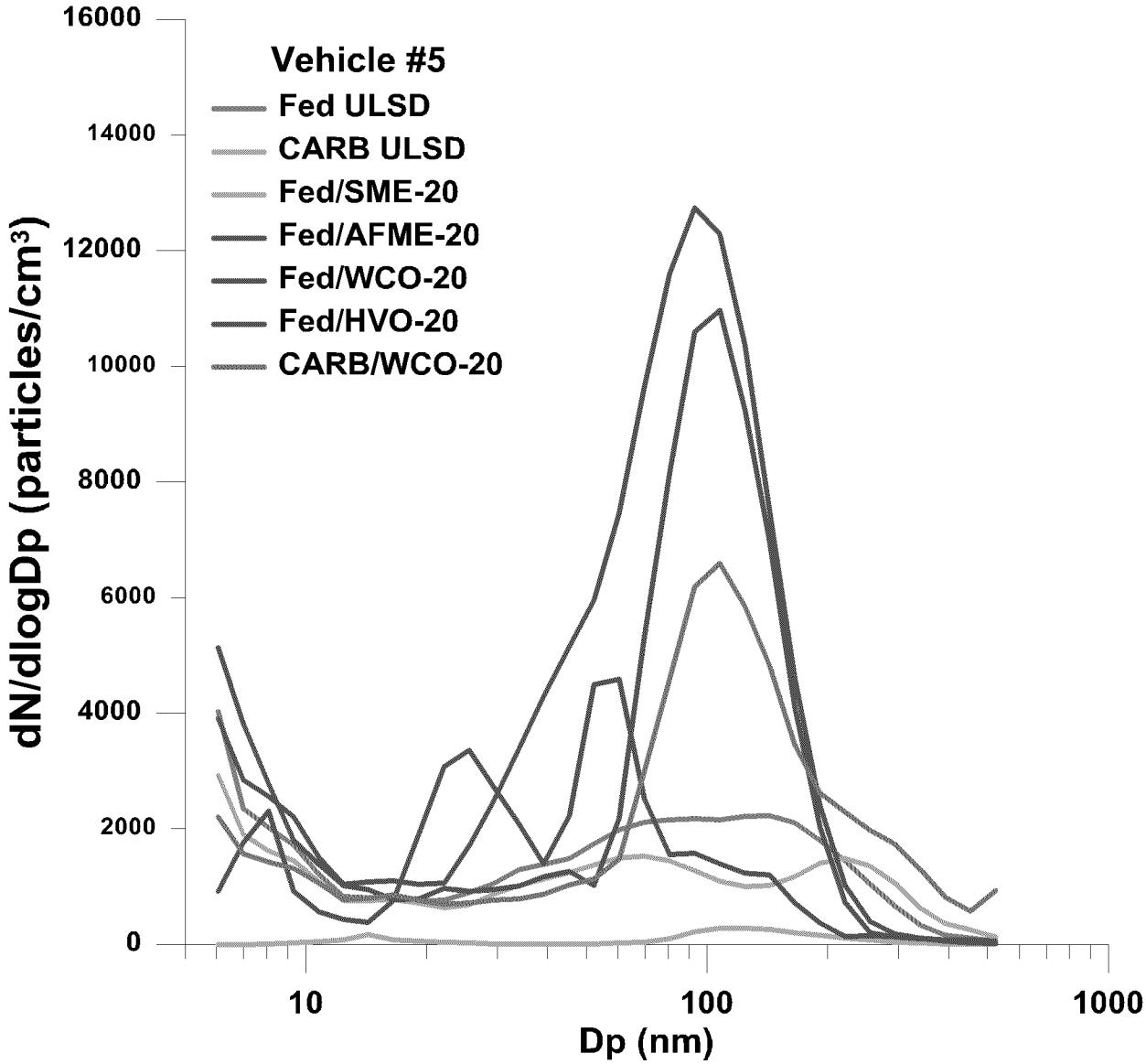


Figure 3-15: Particle size distributions for Vehicle #5 over the FTP

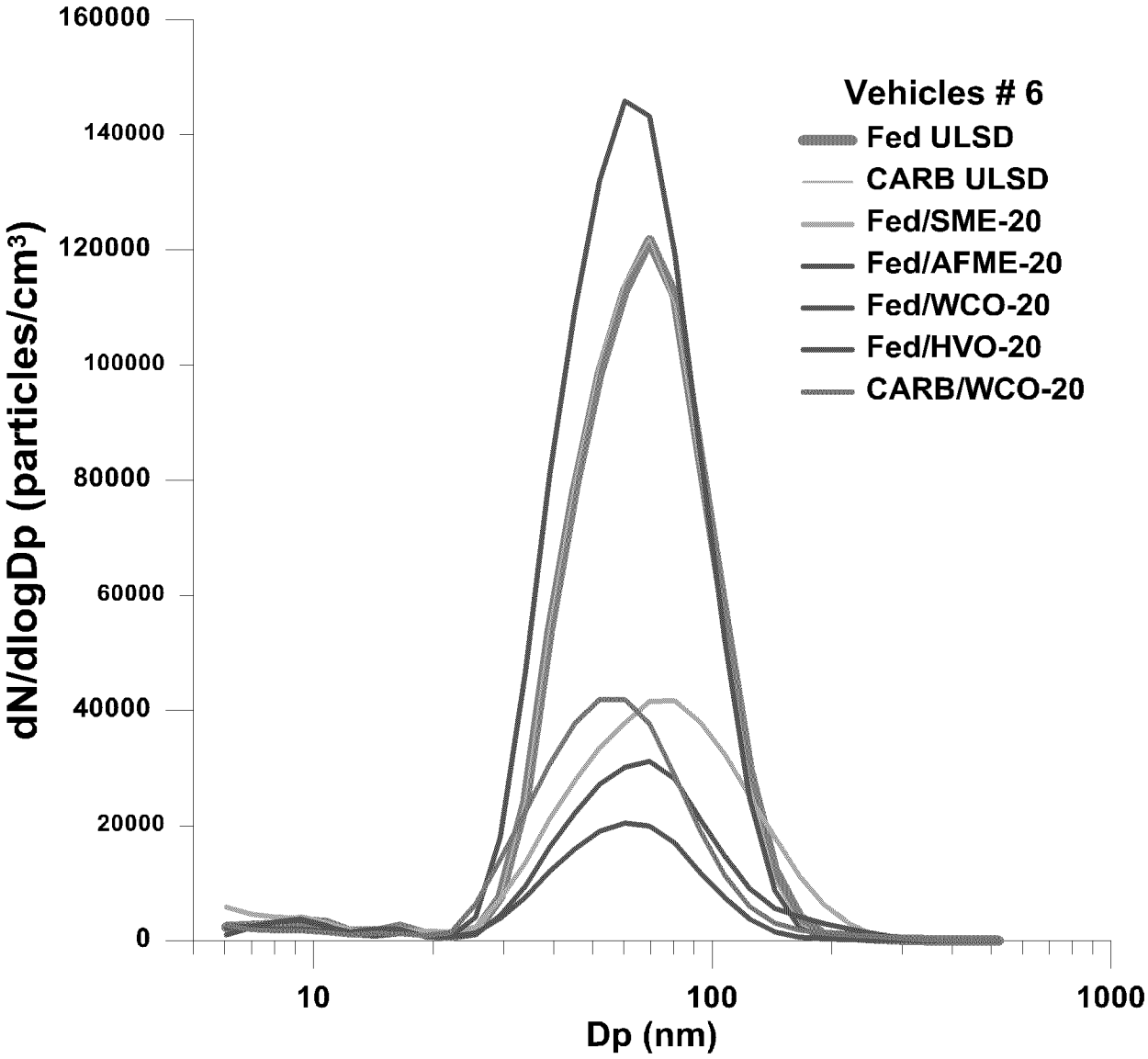


Figure 3-16: Particle size distributions for Vehicle #6 over the FTP

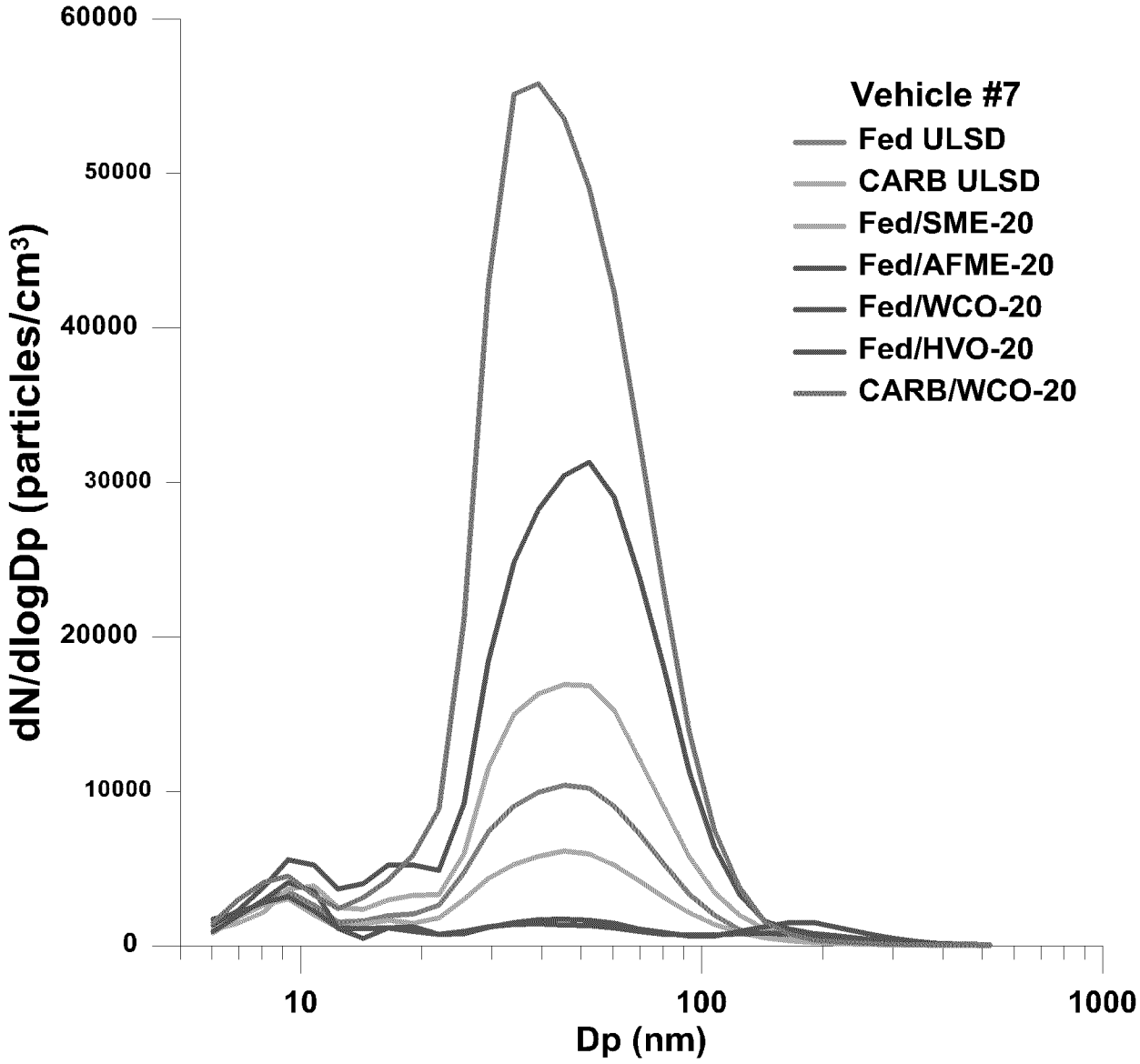


Figure 3-17: Particle size distributions for Vehicle #7 over the FTP

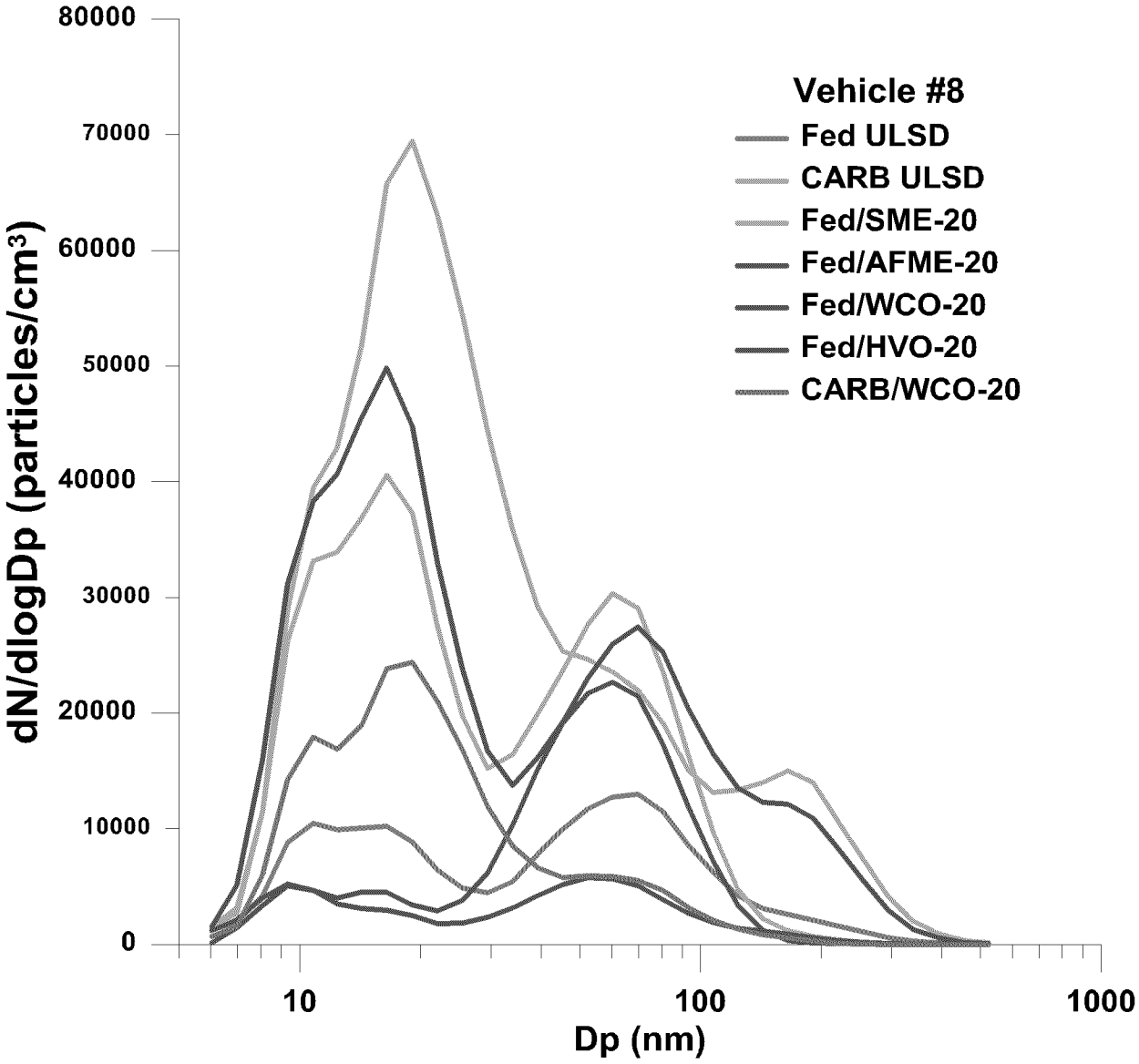


Figure 3-18: Particle size distributions for Vehicle #8 over the FTP

3.8 Carbonyl Emissions

Carbonyl compounds play an important role in atmospheric chemistry and urban air quality because they are precursors to free radicals, ozone, and peroxyacyl nitrates (PAN). Aldehydes such as formaldehyde, acetaldehyde, and acrolein are characterized as motor vehicle air toxics and are known human carcinogens or irritants. Five carbonyl compounds (formaldehyde, acetaldehyde, acrolein, propionaldehyde, and methyl ethyl ketone (MEK)) are listed as hazardous air pollutants (HAP) by the US EPA. Some aldehydes, such as formaldehyde, acetaldehyde, acrolein, and some di-aldehydes also have high incremental reactivity for ozone formation, which may result in increased ground level ozone (a regulated air pollutant) and pose air quality problems for areas that are already in ozone non-attainment or are on the borderline of attainment.

This study identified formaldehyde and acetaldehyde as the predominant aldehyde compounds in the exhaust, with some of the heavier carbonyl compounds either being detected in lesser amounts for some of the test vehicles or below the CVS tunnel background levels for the other vehicles. These results are consistent with those of Fontaras et al. (2010), Karavalakis et al. (2011), Macor et al. (2011), and He et al. (2009), showing the predominance of low molecular-weight carbonyls in emissions from biodiesel-fueled vehicles/engines. These results also indicate that high molecular-weight carbonyl compounds, such as aromatic aldehydes and heavier saturated aliphatic aldehydes, were effectively oxidized in the DOC/DPF system for most test vehicles, suggesting that the vehicle aftertreatment control technology greatly exceeds the fuel effect for heavier carbonyl emission rates. Figures 3.19 and 3.20 show the formaldehyde and acetaldehyde emissions, respectively, for all vehicle/fuel combinations measured over the FTP. There were statistically significant differences in formaldehyde emissions between the test fuels for the vehicle fleet as a whole. More specifically, CARB ULSD showed a statistically significant decrease in formaldehyde emissions of 32% compared to Federal ULSD. Compared to CARB ULSD, the blends of Fed/SME-20, Fed/AFME-20, and Fed/WCO-20 showed statistically significant increases in formaldehyde emissions of 79%, 54%, and 75%, respectively. For acetaldehyde emissions, CARB ULSD showed a statistically significant decrease of 39% compared to Federal ULSD, whereas Fed/SME-20, Fed/WCO-20, and Fed/HVO-20 blends showed statistically significant increases of 79%, 72%, and 60%, respectively, compared to CARB ULSD. A marginally statistically significant increase of 53% for Fed/AFME-20 blend relative to CARB ULSD was also observed. Higher formaldehyde and acetaldehyde emissions with biodiesel fuels compared to petroleum diesels have also seen in previous studies (Fontaras et al., 2010a; Karavalakis et al., 2011b; Macor et al., 2011; Martini et al., 2007). In general, the higher carbonyl emissions for the biodiesel blends could be attributed to the oxygenated ester group. Previous studies have also reported that the use of paraffinic fuels can reduce carbonyl emissions compared to oxygenated fuels such as methyl esters (Heikkila et al., 2012), although this phenomenon has not been observed under the present test conditions.

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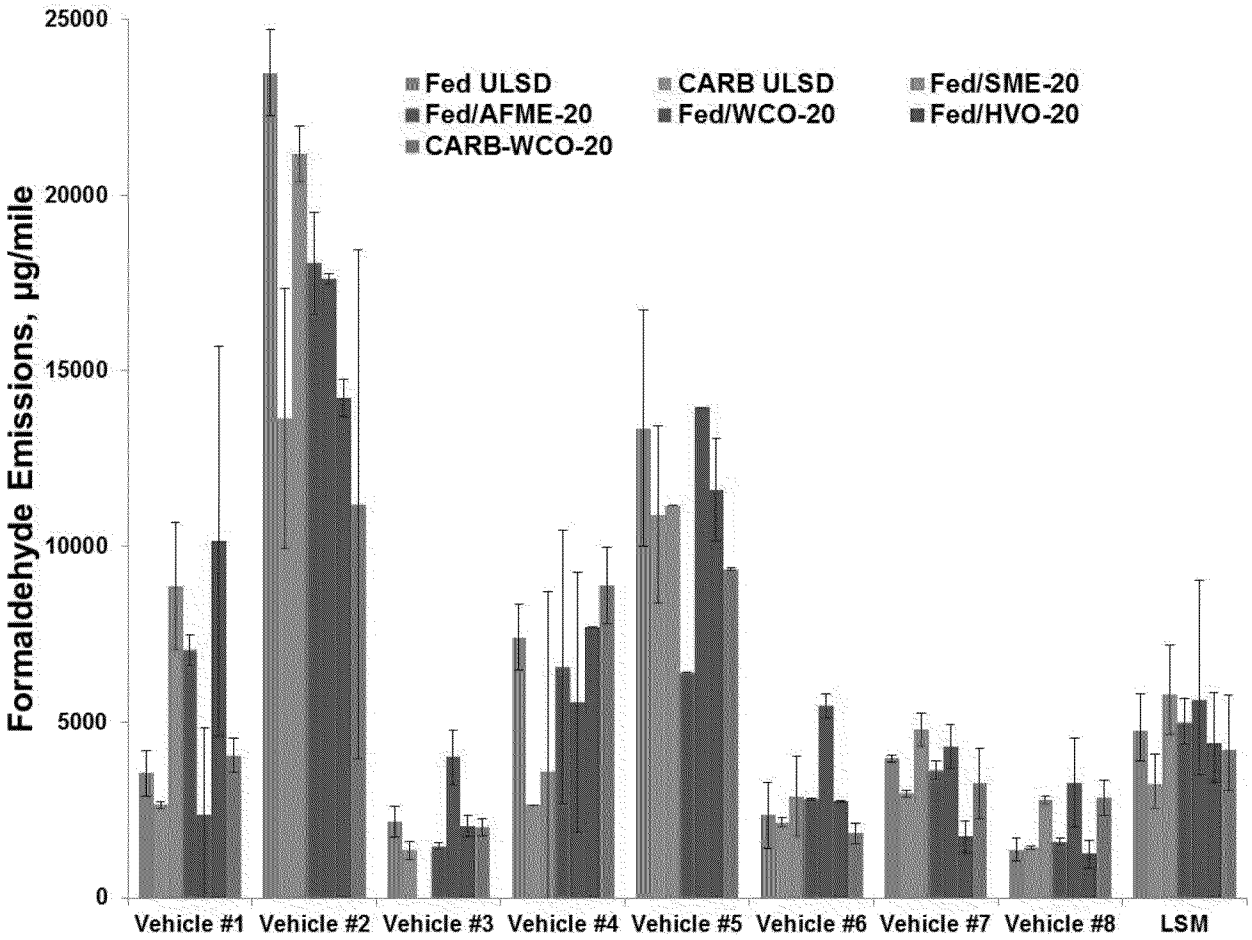


Figure 3-19: Formaldehyde emissions for all vehicle/fuel combination over the FTP

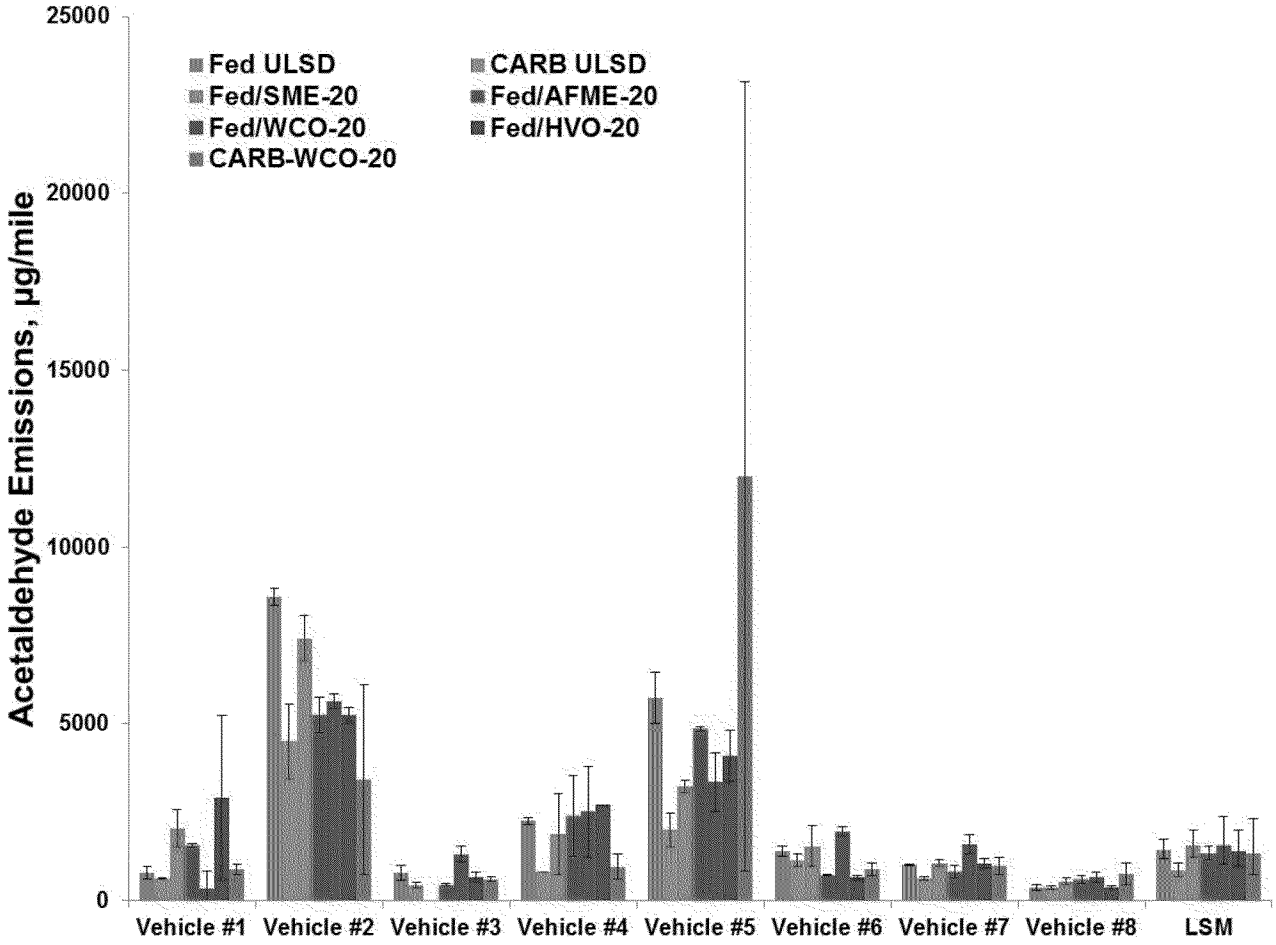
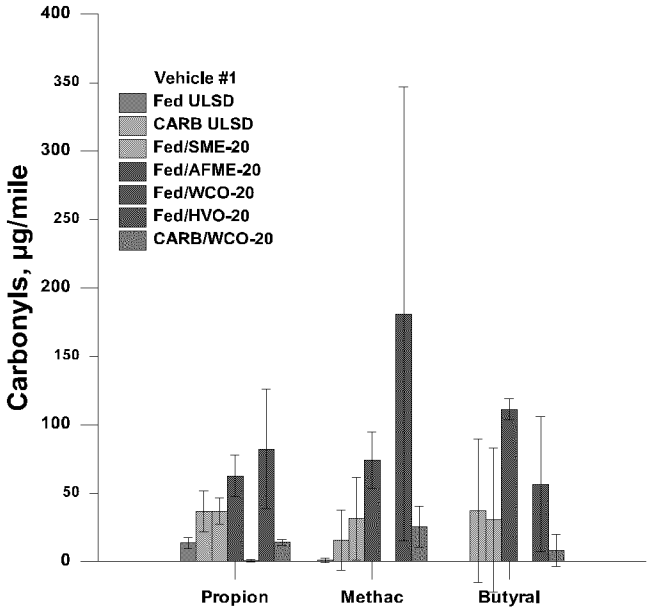
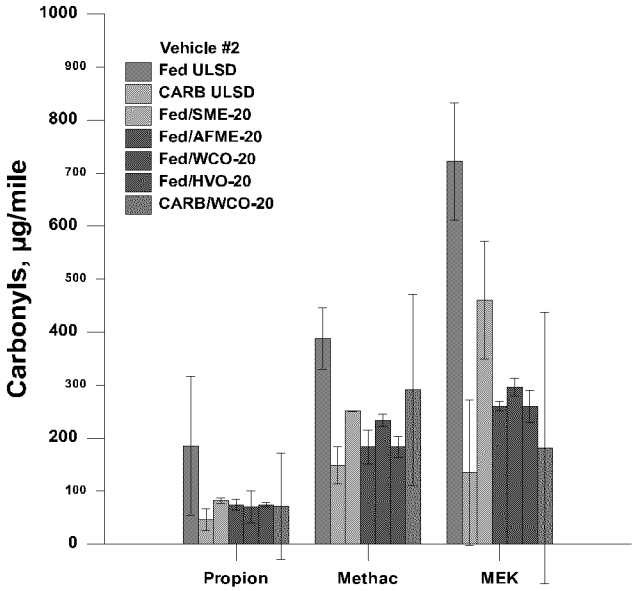
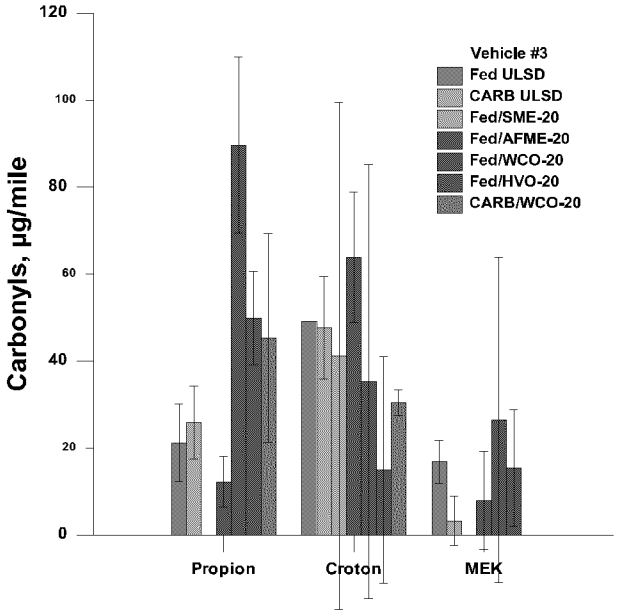


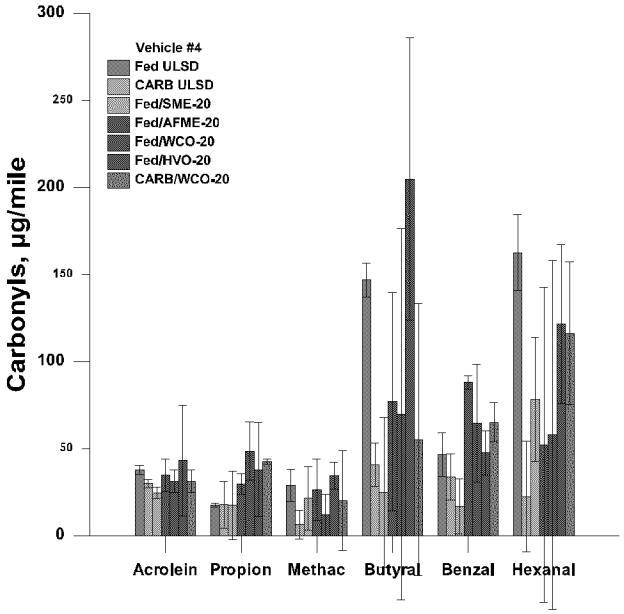
Figure 3-20: Acetaldehyde emissions for all vehicle/fuel combination over the FTP

Figure 3.21 (a-g) shows the main higher molecular weight aldehydes and ketones identified in each vehicle's exhaust. For most of the test vehicles, propionaldehyde, methacrolein, and methyl ethyl ketone (MEK) were the dominant higher molecular weight carbonyls in the exhaust. Data for Vehicle #7 is not included because the majority of heavier aldehydes and ketones were close to or below the CVS background levels. While the concentrations of these compounds were substantially lower compared to those of formaldehyde and acetaldehyde, and characterized by large measurement variability, fuel trends were observed for some vehicles but not for others. For Vehicle #2 and Vehicle #5, for example, the biofuel blends generally showed a decreasing trend in most carbonyl compounds relative to Federal ULSD. There was also a trend for higher higher carbonyl emissions for Fed/AFME-20 for Vehicle #1.


Vehicle #1
Fed ULSD
CARB ULSD
Fed/SME-20
Fed/AFME-20
Fed/WCO-20
Fed/HVO-20
CARB/WCO-20
Carbonyls, µg/mile
0
50
100
150
200
250
300
350
400
Propion
Methac
Butyral


Vehicle #2
Fed ULSD
CARB ULSD
Fed/SME-20
Fed/AFME-20
Fed/WCO-20
Fed/HVO-20
CARB/WCO-20
Carbonyls, µg/mile
0
100
200
300
400
500
600
700
800
900
1000
Propion
Methac
MEK


Vehicle #3
Fed ULSD
CARB ULSD
Fed/SME-20
Fed/AFME-20
Fed/WCO-20
Fed/HVO-20
CARB/WCO-20
Carbonyls, µg/mile
0
20
40
60
80
100
120
Propion
Croton
MEK


Vehicle #4
Fed ULSD
CARB ULSD
Fed/SME-20
Fed/AFME-20
Fed/WCO-20
Fed/HVO-20
CARB/WCO-20
Carbonyls, µg/mile
0
50
100
150
200
250
300
Acrolein
Propion
Methac
Butyral
Benzal
Hexanal

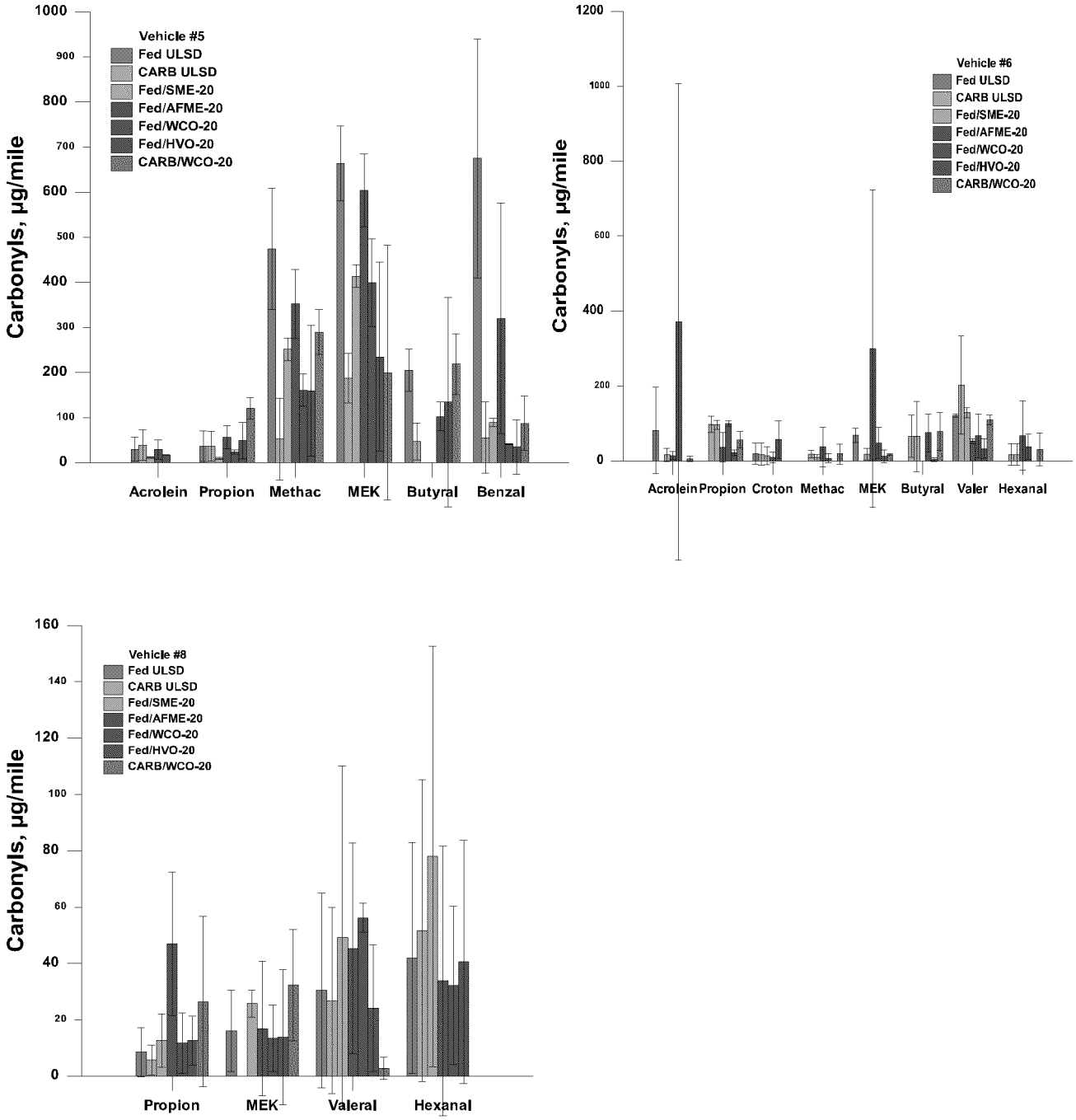


Figure 3-21 (a-g): Higher molecular weight carbonyl compounds for the test vehicles

3.9 PAH and nitro-PAH Emissions

Polycyclic aromatic hydrocarbons (PAHs) are a class of complex organic molecules, which include carbon and hydrogen with a fused ring structure containing at least 2 benzene rings. PAH emissions mainly originate from fuel combustion (pyrosynthesis of aromatic compounds), unburned fuel (pyrolysis of fuel fragments), and unburned lubricating oil. PAH compounds are widely distributed in the atmosphere, and they are well known for their mutagenic and carcinogenic properties. A total of 16 PAHs, ranging in size, from naphthalene (2-rings) to benzo[g,h,i]perylene and indeno[1,2,3-c,d]pyrene (6-rings) have been identified as priority pollutants by the US EPA.

For this program, more than 100 gas- and particle-phase PAH compounds were identified and quantified in the exhaust of each vehicle/fuel combination, including non-substituted PAHs, methyl- and ethyl-substituted PAHs, and oxygenated PAHs. Tables D1 through D16 summarize the PAH emission results (see Appendix D), while Figure 3.22 (a-b) shows the total gas- and particle-phase PAH emissions. In addition, Figures 3.23 (a-b) through 3.25 (a-b) present the total PAH emissions for each vehicle/fuel combination categorized by family compound, including total non-substituted PAHs, total methyl- and ethyl-substituted PAHs, and total oxygenated PAHs.

Overall, the results showed that lower and medium molecular-weight PAHs were the dominant compounds in the exhaust for all vehicle/fuel combinations (see Appendix D). The higher levels of light PAHs suggest that these compounds were pyrolyzed from incomplete combustion of the fuel (Lea-Langton et al., 2008). Previous vehicle and engine studies have also reported the dominant profile of light PAHs in biodiesel exhaust (Martini et al., 2007; Karavalakis et al., 2010b; Karavalakis et al., 2011b; Macor et al., 2011). Some heavier PAHs were also found in the exhaust of all eight vehicles, but in lesser amounts than those of light PAHs. The formation of these species might be due to pyrosynthesis of lower molecular-weight aromatic compounds to larger PAHs and to the contribution of the lubricant oil (Lim McKenzie et al., 2007). Higher molecular-weight compounds, such as those of benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(ah)anthracene, dibenzo(a,j)anthracene, benzo(b)chrysene, coronene, dibenzo(a,e)pyrene, dibenzo(a,i)pyrene, dibenzo(a,h)pyrene, dibenzo(ah+ac)anthracene, and dibenzo(b,k)fluoranthene were found to be almost undetectable for most vehicle/fuel combinations. This phenomenon was more pronounced for the gas-phase PAHs, where the majority of medium and heavier PAHs were at very low concentrations or undetectable for most fuels compared to the particle-phase PAHs. Additionally, the results indicated that with increasing ring-number, PAHs were retained more efficiently in the DPF/DOC system.

The results for the biodiesel and the renewable diesel blends did not show clear fuel trends, with both increases and decreases in PAH emissions compared to the reference Federal ULSD and CARB ULSD. For this study, statistical analyses were run on some selected PAH species that were found in relatively high concentrations for all vehicle/fuel combinations. For the particle-phase PAHs, statistical analysis was performed on phenanthrene, 2-methylphenanthrene, 3-methylphenanthrene, fluoranthene, and pyrene. For the gas-phase PAHs, statistical analysis was performed on the predominant naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, fluorene, phenanthrene, fluoranthene, and pyrene. Fluorene was selected because it was a dominant PAH compound for all vehicle/fuel combinations in the gas-phase but not in the particle-phase. Statistical analysis did not show any strong fuel effects for most PAH compounds except for fluorene. For fluorene emissions, the only statistically significant difference was found with Fed/SME-20, which showed a 238% increase compared to CARB ULSD.

Total particle-phase PAH emissions, as shown in Figure 3.22a, revealed that the biodiesel blends and renewable diesel blend led to increases compared to Federal ULSD and CARB ULSD for some vehicles and decreases for some others. The higher total particle-phase PAH emissions for some vehicles/fuel combinations were due to the presence of higher concentrations of light, semi-volatile PAH compounds, including naphthalene, 2-methylnaphthalene, 1-methylnaphthalene, 2,6+2,7-dimethylnaphthalene, 1,4+1,5+2,3-dimethylnaphthalene, and phenanthrene, which were abundant in the particle-phase, as well as in the gas-phase.

Total gas-phase PAH emissions were found in significantly higher concentrations than their corresponded particle-phase PAHs (Figure 3.22b). The highest contributors to the gas-phase PAHs were mainly the two-membered ring compounds and their ethyl- and methyl-substitutes. These were naphthalene, 2-methylnaphthalene, 1-methylnaphthalene, 2,6+2,7-

dimethylnaphthalene, 1,3+1,6+1,7dimethylnaphthalene, acenaphthene, 1+2 ethylnaphthalene, and trimethylnaphthalenes. The next major contributors to the gas-phase PAHs were three-membered ring PAH compounds, including fluorene, phenanthrene, and methylphenanthrenes. It should be noted that some heavier compounds, such as fluoranthene and pyrene, were detected in significantly higher concentrations relative to the particle-phase. These results indicate that fluoranthene, pyrene, and phenanthrene are typical semi-volatile compounds that should be accounted for in both the gas-phase and particle-phase. Heavier molecular-weight PAHs were almost absent in the gas-phase, indicating that these compounds made a negligible contribution to the total gas-phase PAHs. Some exceptions were observed for Vehicle #2, such as indeno[1,2,3-cd]pyrene, which is a six-membered ring compound and a probable human carcinogen. For Vehicle #5, the very high total gas-phase PAH concentration for Federal ULSD was primarily due to the high levels of naphthalene compared to the other fuels. The high levels of naphthalene for Vehicle #5 on the Federal ULSD fuel were found in both tests conducted for that test matrix point.

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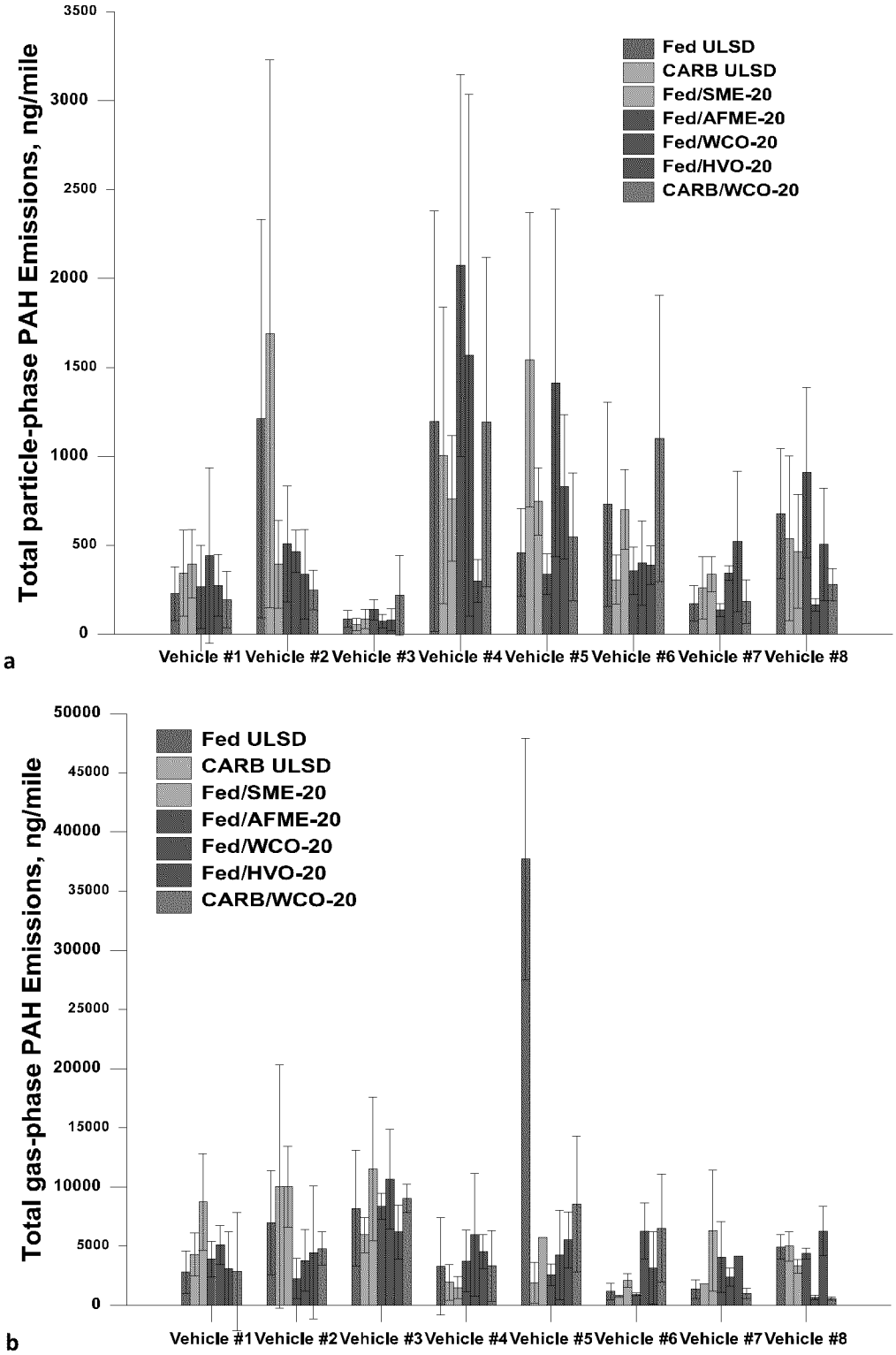


Figure 3-22 (a-b): Total particle-phase (a) and gas-phase (b) PAH emissions for all vehicle/fuel combinations over the FTP

Figure 3.23 (a-b) presents the total gas- and particle-phase non-substitute PAH emissions for all vehicle/fuel combinations. As expected, the emission levels of the total non-substitute PAHs were found to be much lower than those of total PAHs. The emission profile for the particle-phase non-substituted PAHs followed patterns similar to the total particle-phase PAHs for all eight vehicles. Similar results were observed for the total non-substituted gas-phase PAHs, which followed the same trends as the total gas-phase PAHs.

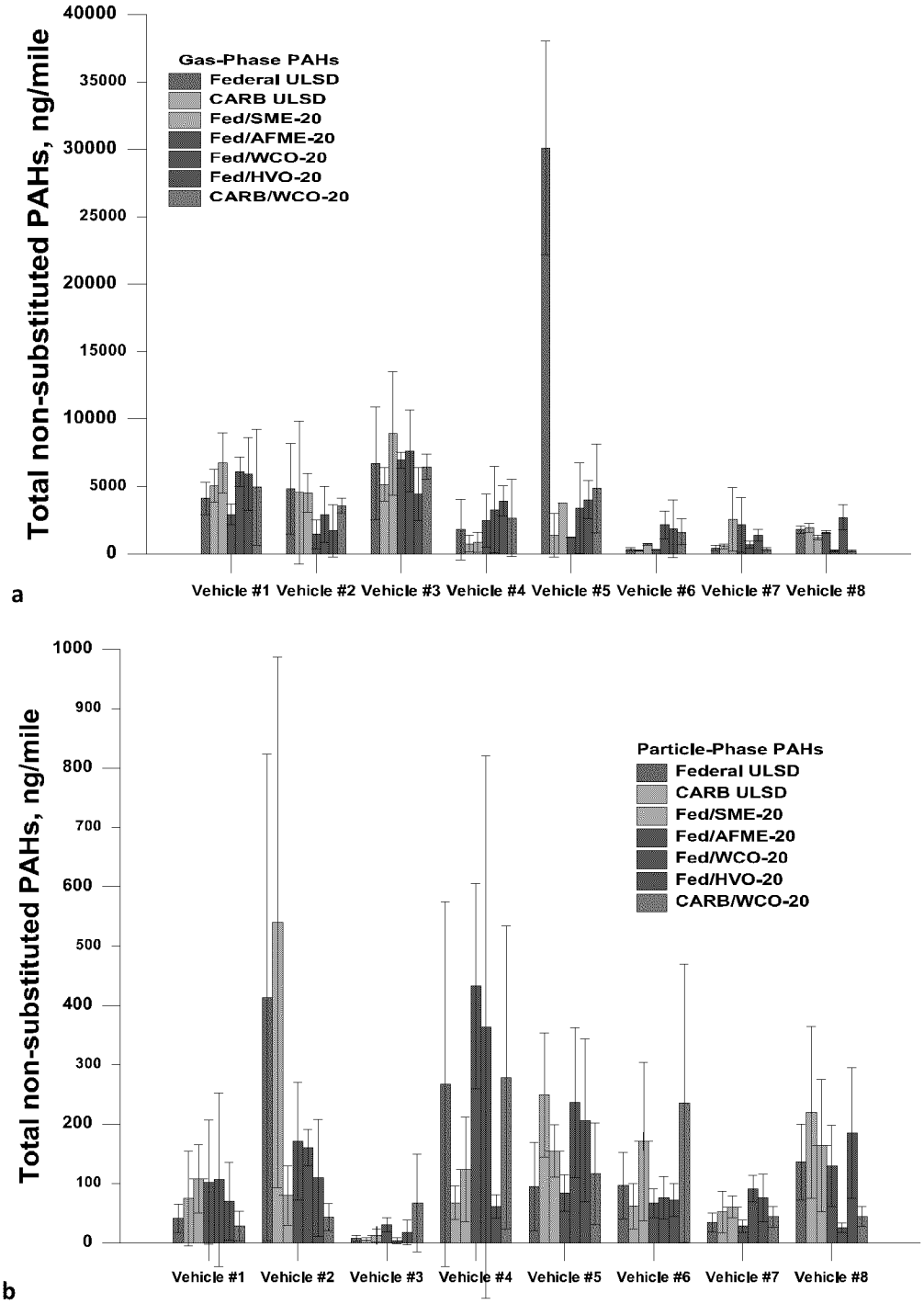
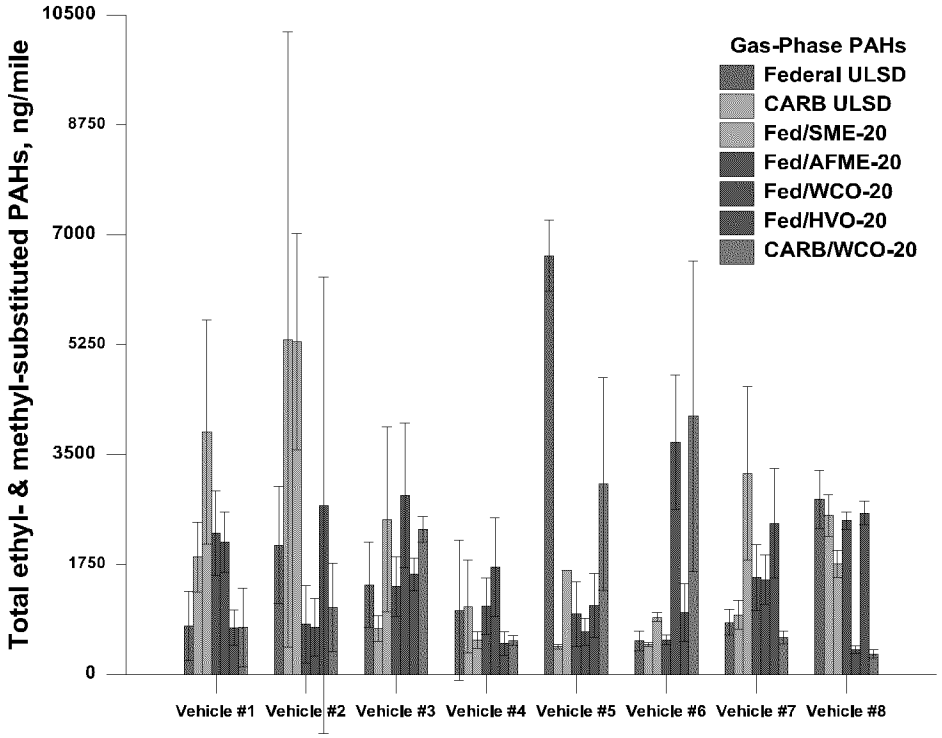
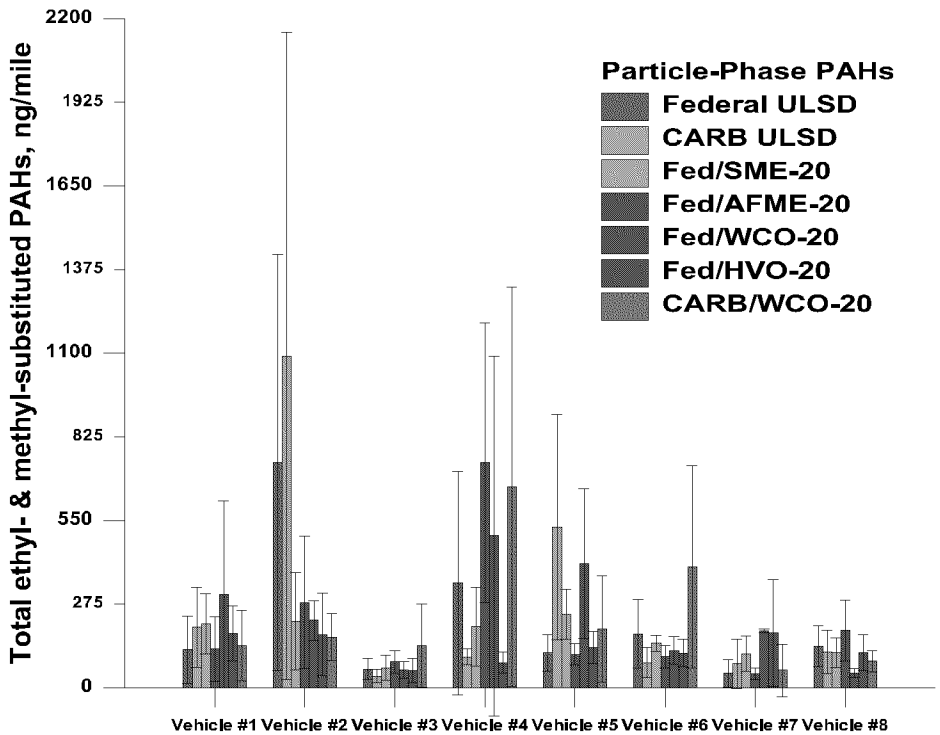


Figure 3-23 (a-b): Total gas- (a) and particle-phase (b) non-substituted PAH emissions for all vehicle/fuel combinations over the FTP

Figure 3.24 (a-b) shows the total gas- and particle-phase ethyl- and methyl-substituted PAH emissions. For the gas-phase total ethyl- and methyl-substituted PAHs, it was observed that the application of the unsaturated soy-based biodiesel blend (Fed/SME-20) led to higher emissions than the Federal ULSD for Vehicle #1, Vehicle #2, Vehicle #3, Vehicle #6, and Vehicle #7. For Vehicle #6, some increases in gas-phase total ethyl- and methyl-substituted PAHs were seen for Fed/WCO-20 and CARB/WCO-20 compared to both ULSD fuels, whereas the opposite phenomenon was observed for Vehicle #8. Particle-phase total ethyl- and methyl-substituted PAH were found in considerably lower concentrations than their corresponded gas-phase components, indicating that both light and heavier ethyl- and methyl-substituted PAHs were either absent from that phase or detected in very low levels.



a



b

Figure 3-24 (a-b): Total gas- (a) and particle-phase (b) ethyl- and methyl-substituted PAH emissions for all vehicle/fuel combinations over the FTP

Oxygenated PAHs (oxy-PAHs) such as polycyclic aromatic quinones have been found to generate reactive oxygen species resulting in oxidative stress that can lead to allergic diseases, and polycyclic aromatic ketones, quinones and anhydrides are well known mutagenic compounds (Knecht et al., 2013). Similar to PAHs, oxy-PAH compounds are emitted mainly from combustion processes, and they can also originate from heterogeneous reactions between PAHs and ozone. In contrast to their parent PAHs, most of the oxy-PAHs found in diesel

particulate matter are directly toxic and mutagenic (Durant et al., 1996). Figure 3.25 (a-b) presents the total gas- and particle-phase oxygenated PAH emissions from all vehicle/fuel combinations. The most abundant oxy-PAH compounds in the exhaust for both phases were xanthone, 9-fluorenone, perinaphthenone, and anthraquinone. The compounds of 1,4-naphthoquinone and anthrone were found at higher concentrations in gas-phase than in particle-phase. Other oxy-PAH compounds, such as 9,10-dihydrobenzo(a)pyrene-7(8H)-one were undetectable for both phases, or found at very low levels, such as those of benz(a)anthracene-7,12-dione, 9-anthraaldehyde, and acenaphthenequinone. It is noteworthy that although acenaphthenequinone was undetectable for the gas-phase, it was found in the particle-phase for some fuels for some vehicles, but not for others. Generally, total oxy-PAH emissions were seen in higher concentrations in the gas-phase than the particle-phase, suggesting that most of these compounds, which were light molecular-weight, three-membered ring PAHs, existed in the gas-phase.

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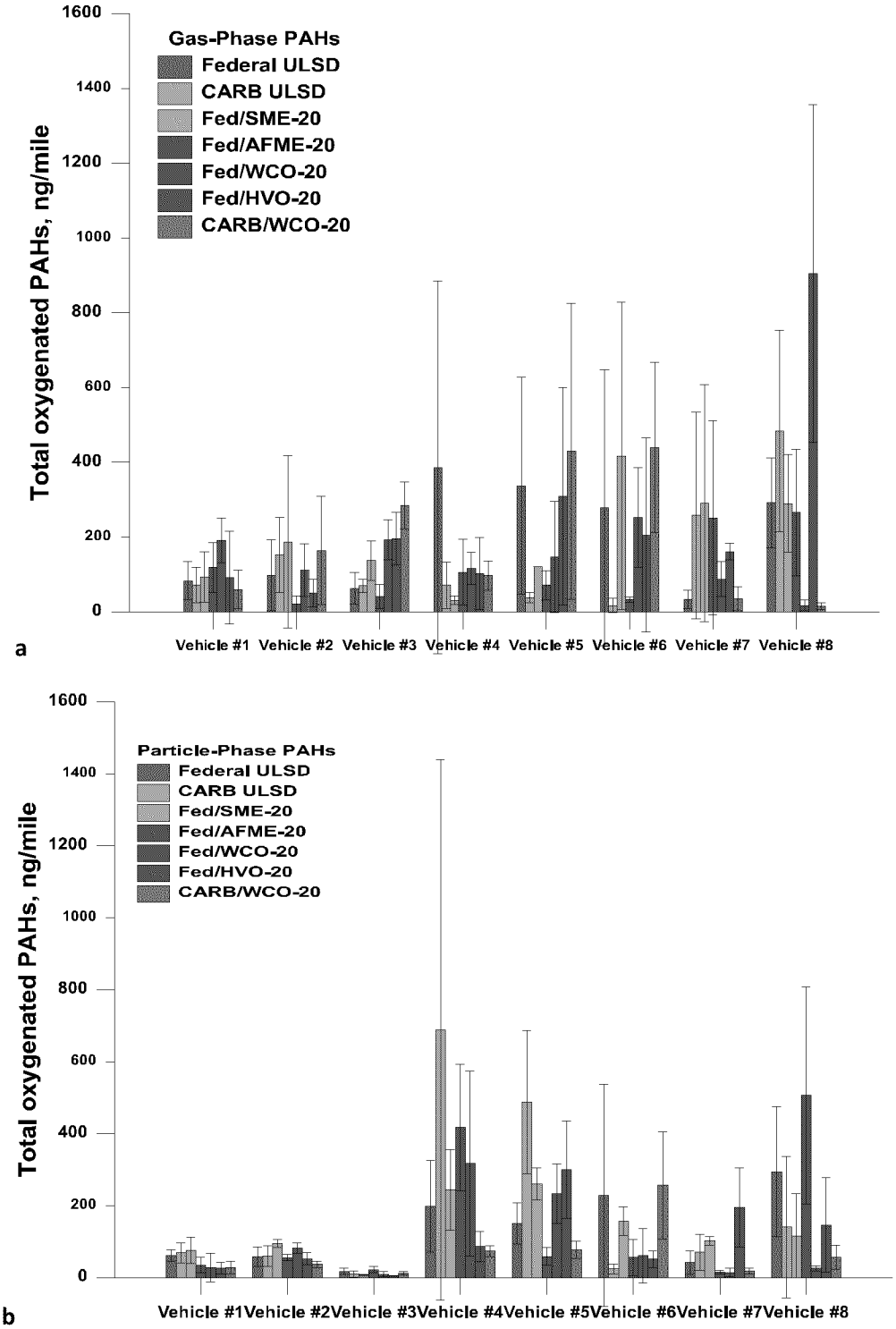

Figure 3-25 (a-b): Total gas- (a) and particle-phase (b) oxygenated PAH emissions for all vehicle/fuel combinations over the FTP

The influence of biodiesel type and source material on individual PAH compounds were not particularly strong. Although some trends were seen for higher emissions for certain light- and heavier PAH species with the use of biodiesel, these phenomena were not consistent throughout the fleet. It is interesting to note that some biodiesel blends showed upward trends in some oxygenated PAH species when compared, specifically, to CARB ULSD. Chrysene, a PAH compound known for its carcinogenic and teratogenic properties, was found at higher concentrations for the soy-based blend (Fed/SME-20) compared to both ULSDs for Vehicle #1, Vehicle #7, and Vehicle #8, and higher than CARB ULSD for Vehicle #4. The concentrations of

7,12-dimethylbenz(a)anthracene, a probable human carcinogen, were also found at relatively higher levels than other heavier particle-phase PAHs for some vehicles, with the unsaturated Fed/SME-20 blend leading to higher emissions of 7,12-dimethylbenz(a)anthracene compared to both ULSDs, but not necessarily to the other biodiesel blends. Higher emissions for the Fed/SME-20 blend compared to the baseline ULSDs were also seen for benzo(b)fluoranthene, benzo(k)fluoranthene, and benzo(a)pyrene for almost all vehicles tested. The first two PAH compounds are probable carcinogens, while the latter is considered to be mutagenic and highly carcinogenic. The use of some biodiesel blends also showed some increases in benzo(ghi)perylene for some vehicles, which is toxic and a suspected carcinogen PAH compound. It should be noted that particle-phase benzo(ghi)perylene was found in relative high concentrations among the heavier particle-phase PAH compounds, while it was almost undetectable in the gas-phase. It should also be noted that some methyl-substituted PAHs (methylnapthalenes) found in the gas-phase showed increases for some biodiesel blends when compared to both baseline diesel fuels. It appeared that the soy-based biodiesel blend and the Fed/WCO-20 blend showed some of the most consistent increases in gas-phase methyl-substituted PAH emissions compared to both ULSDs.

The results of this program indicate that the higher PAH levels seen for some biodiesel blends were no doubt due to the combustion process, as there were essentially no aromatics in the biodiesel portion of the unburned fuel blend. Previous studies have shown that the use of unsaturated biodiesel fuels, especially methyl esters obtained from soybean oil, are susceptible to PAH formation and can even led to comparable or higher PAH emissions than regular ULSD (Karavalakis et al. 2010b; Karavalakis et al., 2011a; Ratcliff et al., 2010). Unsaturated compounds react thermally, above 250 – 300 ºC, via the Diels-Alder reaction to dimerize or trimerize to form six-member rings (cyclohexanes). The dehydrogenation of these cyclohexanes produces single ring aromatic compounds, which react further, leading to PAH formation. Alternatively, gaseous olefinic fragments (e.g., acetylene, propargyl, and 1,3-butadiene) from pyrolysis of unsaturated methyl esters may react further to form aromatics. Therefore, it seems reasonable to speculate that pyrolysis of the unsaturated soy-based blend occurring within the diffusion flame of the diesel engine may have produced these aromatic structures. In the case of the renewable diesel blend, the lower or small differentiations in both total gas- and particle-phase PAH emissions could be a consequence of the absence of aromatics compounds in the HVO fuel compared to both reference ULSDs.

Nitrated polycyclic aromatic hydrocarbons (nitro-PAHs) can be either directly produced from combustion sources by electrophilic aromatic substitution reactions between nitrating agents, such as nitrogen dioxide (NO_2), and the parent PAHs, or formed from their parent PAHs by atmospheric OH or NO_3 radical initiated reactions (Miet et al., 2009). Nitration of PAHs also occurs during the catalytic reactions of the exhaust gas in the DPF, and during sampling and cleanup. The latter two would be considered as unwanted artifacts. In the DPF, PAH nitration reactions with NO_2, nitrous acid (HNO_2), and nitric acid (HNO_3) can occur as declining temperatures lead to aerosol formation and adsorption onto PM (Heeb et al., 2008). Most studies have reported that emissions of nitro-PAH compounds from diesel engines/vehicles are typically at least an order of magnitude lower than rates for PAH emissions (Bagley et al., 1998; Ratcliff et al., 2010; Karavalakis et al., 2011b; Hu et al., 2013). However, many nitro-PAHs are highly mutagenic, genotoxic, and carcinogenic (Durant et al., 1996). A total of thirty six nitro-PAH compounds in both gas- and particle-phase were analyzed from 1-nitronaphthalene through 3-nitrobenzo[e]pyrene. Gas-phase and particle-phase nitro-PAH values for all vehicle/fuel combinations along with their standard deviations are presented in Table D17 through Table D32 (see Appendix D). Figures 3.26 and 3.27 show the total gas- and particle-phase nitro-PAH emissions, expressed in ng/mile, for all vehicle/fuel combinations.

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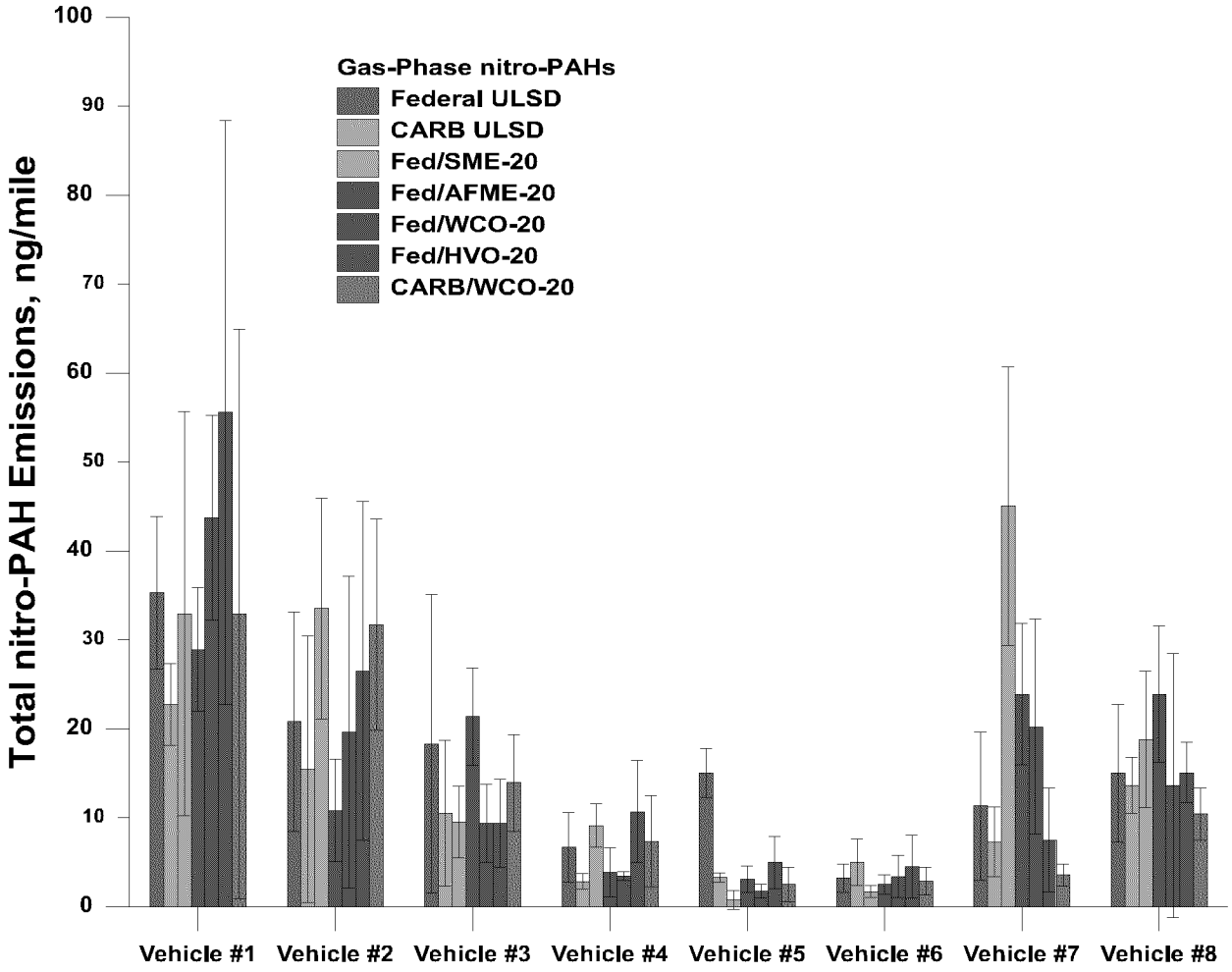

Figure 3-26: Total gas-phase nitro-PAH emissions for all vehicle/fuel combinations over the FTP

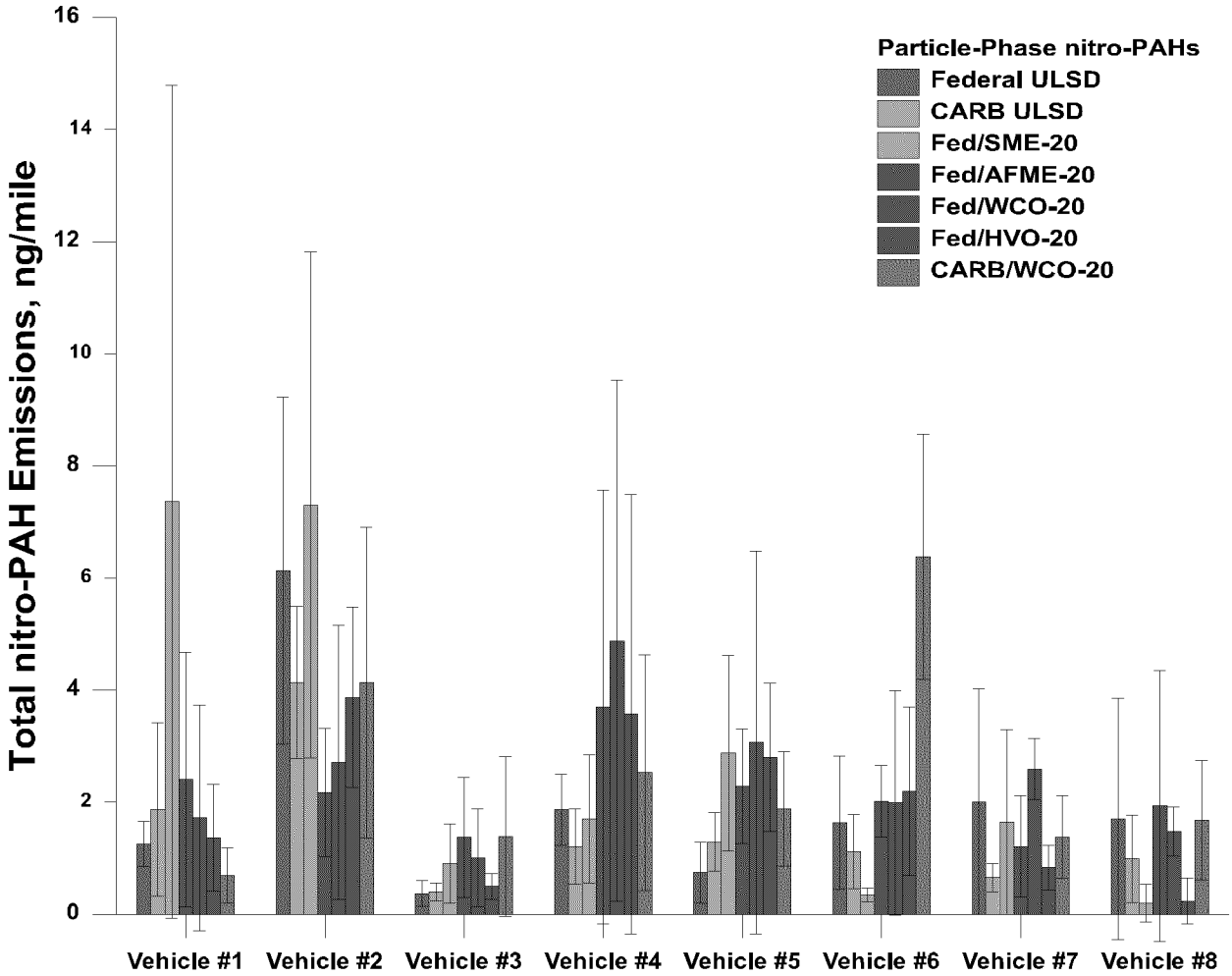

Figure 3-27: Total particle-phase nitro-PAH emissions for all vehicle/fuel combinations over the FTP

The results show that the gas-phase nitro-PAHs are more abundant than particle-phase nitro-PAHs, with light weight molecular compounds, such as 1-nitronaphthalene and methyl-substituted nitronaphthalenes, being dominant in the exhaust. Specifically, the predominant species in the gas-phase for all eight vehicles were 1-nitronaphthalene, 2-nitronaphthalene, 1-methyl-5-nitronaphthalene, 2-methyl-4-nitronaphthalene, 1-methyl-4-nitronaphthalene, 1-methyl-6-nitronaphthalene, 9-nitroanthracene, 1,3-dinitronaphthalene, 9-nitrophenanthrene, and 3-nitrophenanthrene. Higher molecular-weight nitro-PAHs, such as dinitropyrenes, 7-nitrobenz(a)anthracene, and 1-nitrobenzo[e]pyrene, were below the detection limit of the method. In addition to the above species, 1-nitropyrene, a compound that usually partitions exclusively in the particle-phase, was detected in the gas-phase for Vehicle #4, Vehicle #5, Vehicle #6 and Vehicle #7, but not for the other test vehicles. The relatively high concentrations of 3-nitrophenanthrene that were observed for Vehicle #1, Vehicle #2, and Vehicle#3 could be attributed to the selective nitration of phenanthene.

The most abundant nitro-PAH compounds in the particle-phase were 1,3-dinitronaphthalene, 1,8-dinitronaphthalene, 9-nitrophenanthrene, 3-nitrophenanthrene, 1-nitropyrene, 1,6-dinitropyrene, and 4-nitrobiphenyl. Light molecular weight nitro-PAHs, including 1-nitronaphthalene, 2-nitronaphthalene, and 9-nitroanthracene, were also found in the exhaust, which indicates that these compounds partitioned in both the vapor and particle phases. The 1-nitropyrene has been used as marker of diesel exhaust and it is a precursor for 1,3-, 1,6- and 1,8-dinitropyrenes. However, the dinitropyrenes were not detected for most of the test vehicles in this program, with

the exception of 1,6-dinitropyrene, which was present for Vehicle #6 and Vehicle #7. Analogous to the gas-phase nitro-PAHs, heavier particle-phase nitro-PAH species were found to be below the detection limits.

The use of biodiesel blends and the renewable diesel blend produced discordant results for gas- and particle-phase nitro-PAH emissions, with both increases and decreases. Comparing the reference ULSDs, the CARB ULSD showed a trend towards lower total gas- and particle-phase nitro-PAH emissions compared to Federal ULSD. For this study, statistical analysis was performed on some selected nitro-PAH species that were found in relatively high concentrations for all vehicle/fuel combinations. For the gas-phase, statistical analysis was run on 1-nitronaphthalene, 2-nitronaphthalene, and 2-methyl-4-nitronaphthalene. For the particle-phase, statistical analysis was run on 1,3-dinitronaphthalene and 1-nitropyrene. Statistical analysis did not show any strong fuel effects for most nitro-PAH compounds except for the gas-phase 1-nitronaphthalene. For 1-nitronaphthalene emissions, CARB ULSD and CARB/WCO-20 blend showed marginally statistically significant decreases of 87% and 89%, respectively, compared to Federal ULSD.

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3.10 Organic and Elemental Carbon Emissions

Organic carbon (OC) emissions are shown in Figure 3.28 for the main FTP portion of the testing program. Although elemental carbon (EC) emissions were also measured for these tests, the EC emissions were near zero for the FTP testing, so the EC results are not included in the figure. The observation that the carbonaceous portion of the PM contains very little EC is consistent with other studies of vehicles equipped with DPFs. Cheung et al. (2009) tested diesel passenger cars with different exhaust configurations, including a DOC and DPF on regular ULSD and on soy-based biodiesel over the NEDC and the Artemis cycles. They found that a DPF-fitted vehicle significantly reduced EC/OC emissions, while a biodiesel-fueled vehicle emitted predominantly OC emissions. Similar trends were reported from Kooter et al. (2011), showing approximately a 90% reduction in the EC fraction of pure biodiesel compared to regular ULSD. They also reported that with the application of a DPF, EC fraction was near zero compared to regular ULSD. The results reported here for the OC emissions did not show any statistically significant fuel effects for the vehicle fleet as a whole.

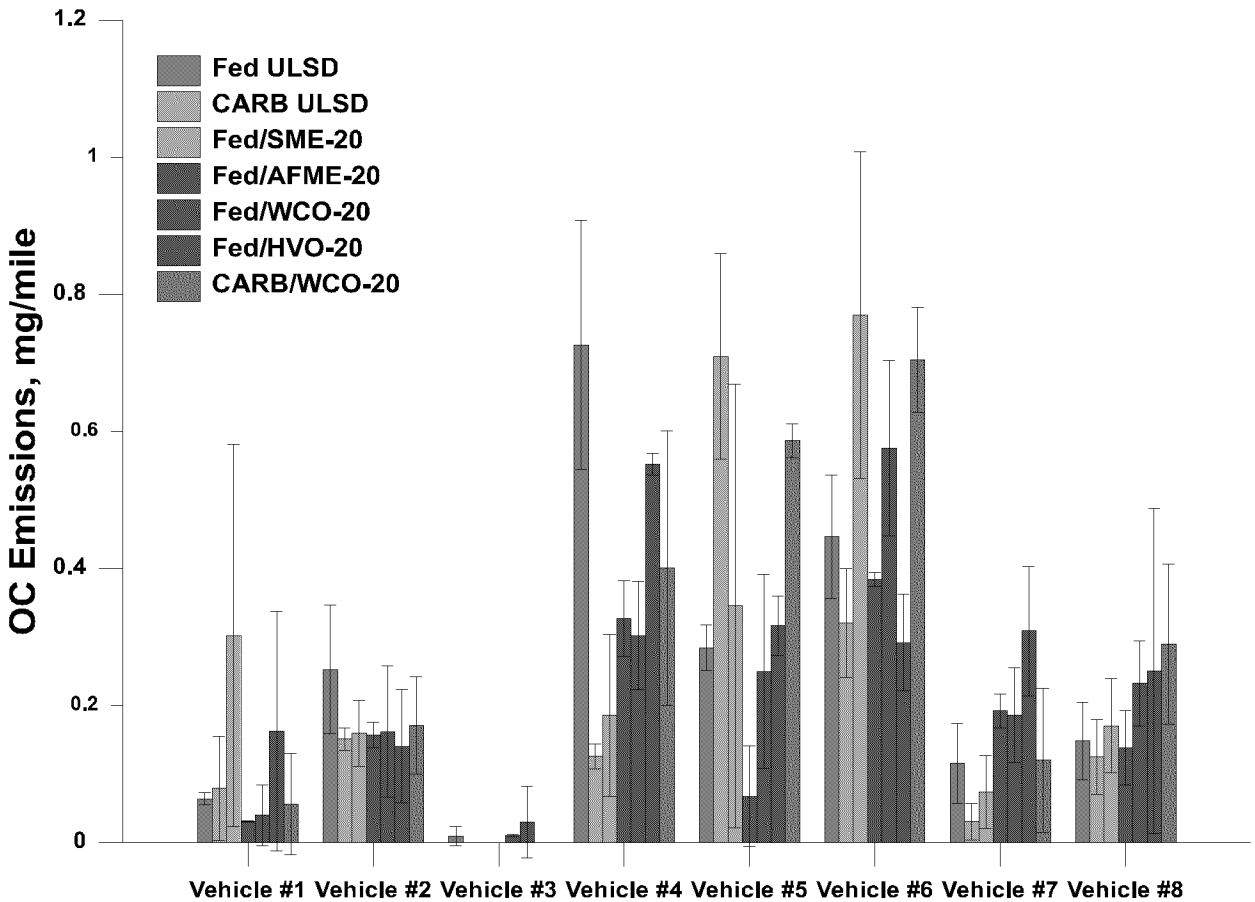

Figure 3-28: Organic Carbon (OC) emissions over the FTP

3.11 Ammonia Emissions

Ammonia (NH_3) emissions for the test vehicles are provided in Figure 3.29. Measureable NH_3 emissions were predominantly seen for Vehicle #1, which had average emissions ranging from 5.5 to 17.5 mg/mi, and Vehicle #2, which had average emissions ranging from 5.1 to 7.8 mg/mi. The NH_3 measurement variability for Vehicle #1 appeared to be due to operational differences from test to test with respect to the SCR system. Specifically, in some tests NH_3 emissions were readily apparent and showed distinct trends, as shown below, while for other tests the NH_3 emissions were near the background levels. Vehicle #3 showed lower, but generally measureable NH_3 emissions ranging from 0.9 to 2.5 mg/mi. The NH_3 emissions for Vehicles #4 through #8 were near the background levels for most of the test matrix points; their average NH_3 emissions were less than 1 mg/mi. Overall, there were no consistent trends in NH_3 emissions between the reference ULSDs and the biodiesel fuels for the fleet of eight vehicles. NH_3 spikes were observed for a few tests even for vehicles where the NH_3 emissions were near zero, namely for Vehicle #5 with the Fed/AFME-20, Vehicle #7 with the Fed/SME-20, and Vehicle #8 with the Fed/SME-20. These spikes appear to be isolated instances of NH_3 slip, predominantly in bag 3, as opposed to actual fuel effects. It should be noted that data are not available for some test matrix points for Vehicle #4 and Vehicle #5, and one point for Vehicle #6, but it is assumed that these data points would be similarly near the background levels for these vehicles.

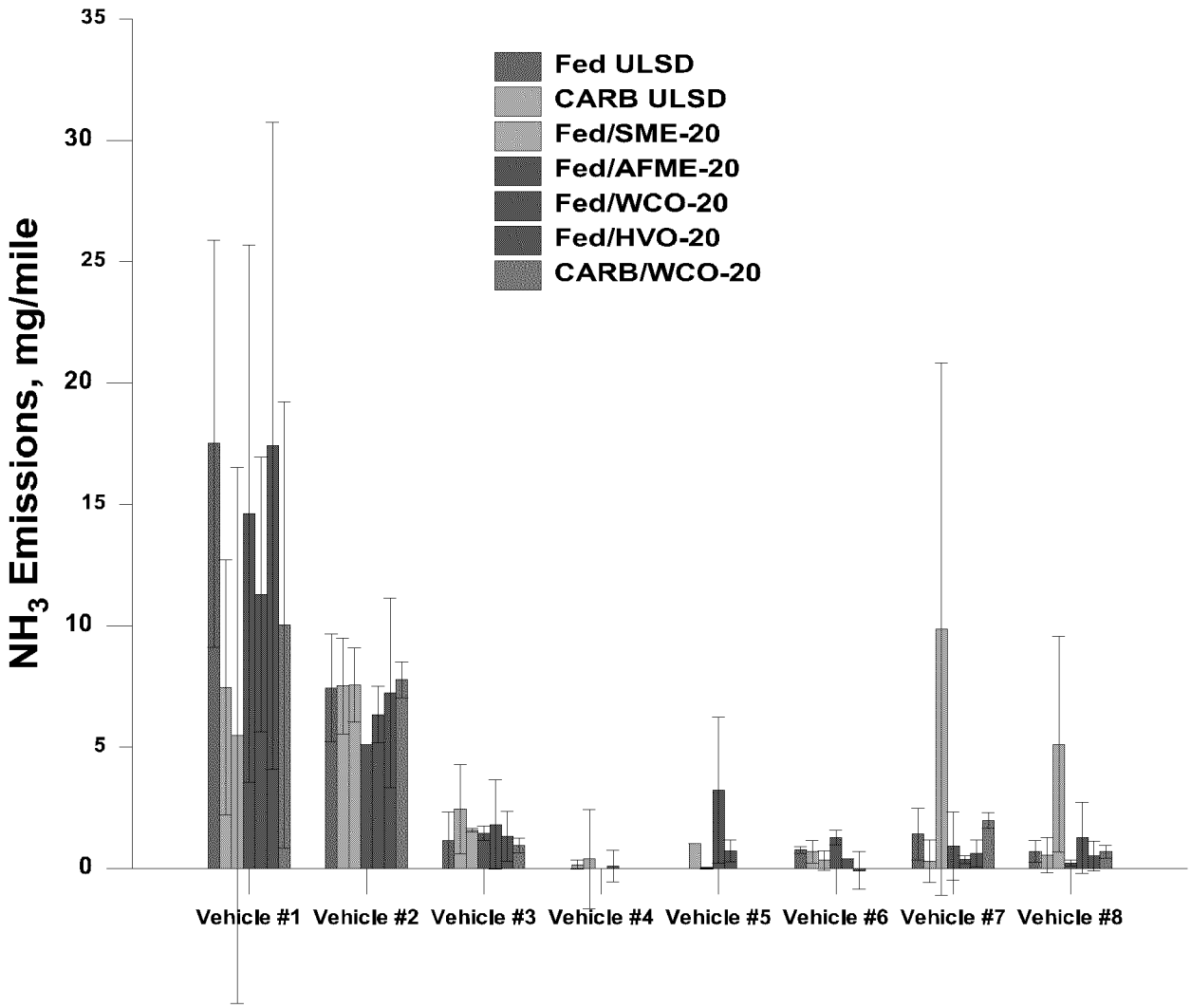

Figure 3-29: NH_3 emissions over the FTP

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The real-time traces of NH_3 versus NO_x emissions over the FTP cycle give some insight into their formation mechanisms. For comparison purposes, real-time NH_3 versus NO_x emissions are provided for two fuels, namely Federal ULSD and Fed/WCO-20 blend, on Vehicles #1 and #2, which showed the greatest NH_3 emissions. These fuels were selected as representative of the fuels tested during the course of this program. Figure 3.30 (a-b) through Figure 3.31 (a-b) presents the real-time NH_3 versus NO_x emissions, expressed in ppm, over the FTP cycle for Vehicle #1 and Vehicle #2. It is clear that for Vehicle #1, NO_x concentrations were highest during the cold-start, with almost negligible NH_3 concentrations at the same time. A substantial reduction in NO_x emissions was seen after approximately the first 300 seconds of the cycle, along with a subsequent increase in NH_3 emissions. This phenomenon was observed for both the Federal ULSD and the biodiesel blend. While the tests shown in the real-time plots for Vehicle #1 showed higher levels of NH_3, there were also tests for Vehicle #1 where the NH_3 emissions were near the background level, as noted above. For Vehicle #2, elevated NO_x emissions were also seen for both fuels during the cold-start phase of the FTP, with NO_x emissions declining significantly after the first 300 seconds of the cycle. Emissions of NH_3 for Vehicle #2, however, were at very low concentrations throughout the entire cycle, and were very close to the background level.

The functioning of an SCR depends on the catalyst material, urea dosing strategy, temperature, and physical system layout. A certain minimum exhaust temperature is required for SCR to promote hydrolysis of urea into NH_3, which then reduces NO_x into elemental nitrogen (N_2) and water (H_2O). As a result, SCR function depends on driving conditions to the extent that they affect exhaust temperature and urea dosing strategy. Under the present test conditions, the higher NO_x emissions under cold-start could be attributed to the insufficient exhaust temperature for urea hydrolysis and optimum catalyst activity, as the SCR catalyst was below its light-off temperature. During phase 2 and phase 3 of the FTP, NO_x emissions were reduced to very low concentrations, showing that SCR was effective in controlling NO_x when the exhaust temperatures were sufficiently high. Other chassis dynamometer studies have also reported elevated NO_x emissions during cold-starts, with the bulk of these studies being carried out in heavy-duty diesel vehicles equipped with SCR control technology (Williams et al., 2010; Misra et al., 2013).

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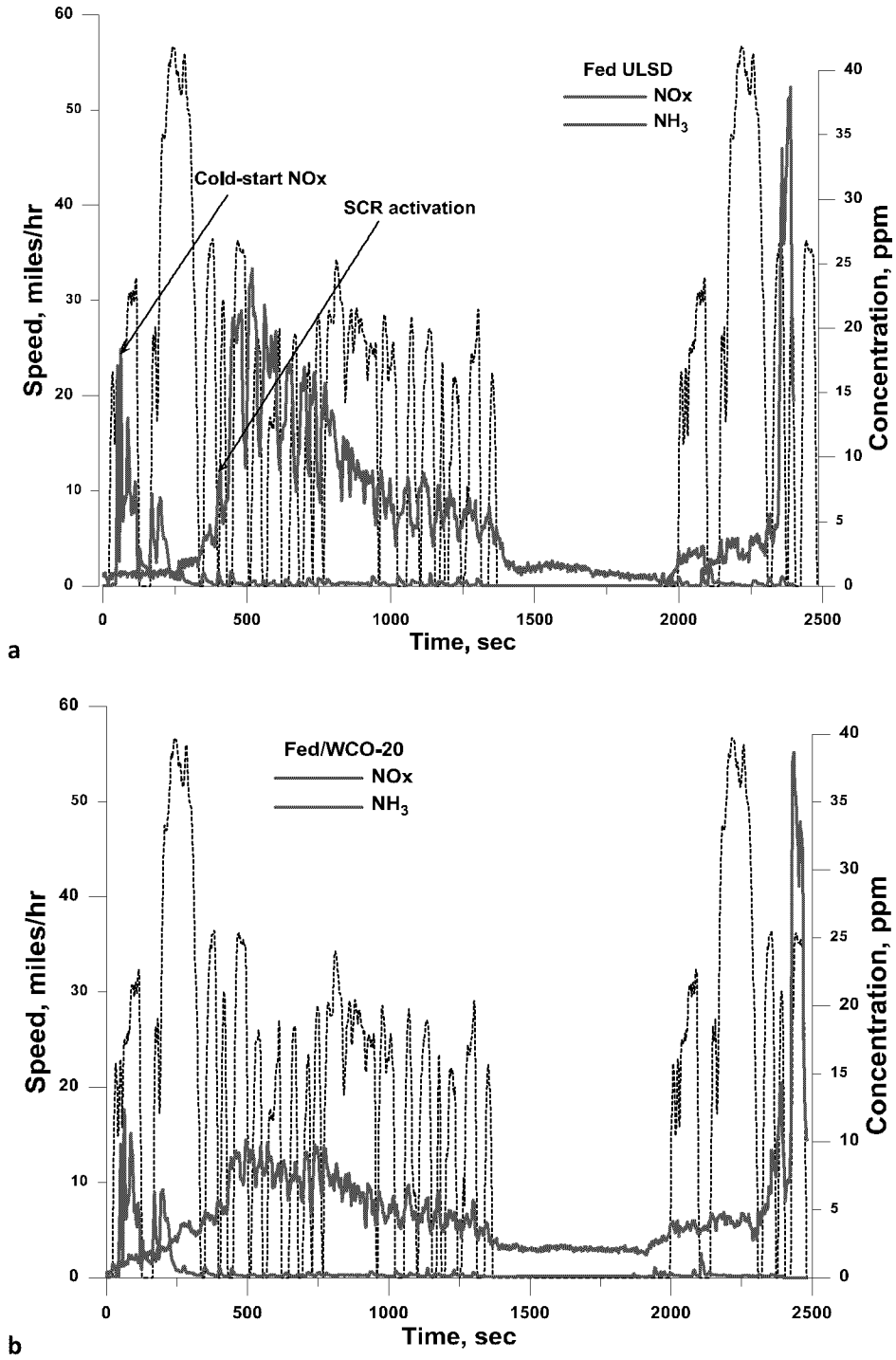

Figure 3-30 (a-b): Real-time NH_3 versus NO_x emissions for Federal ULSD (a) and Fed/WCO-20 blend (b) over the FTP for Vehicle #1

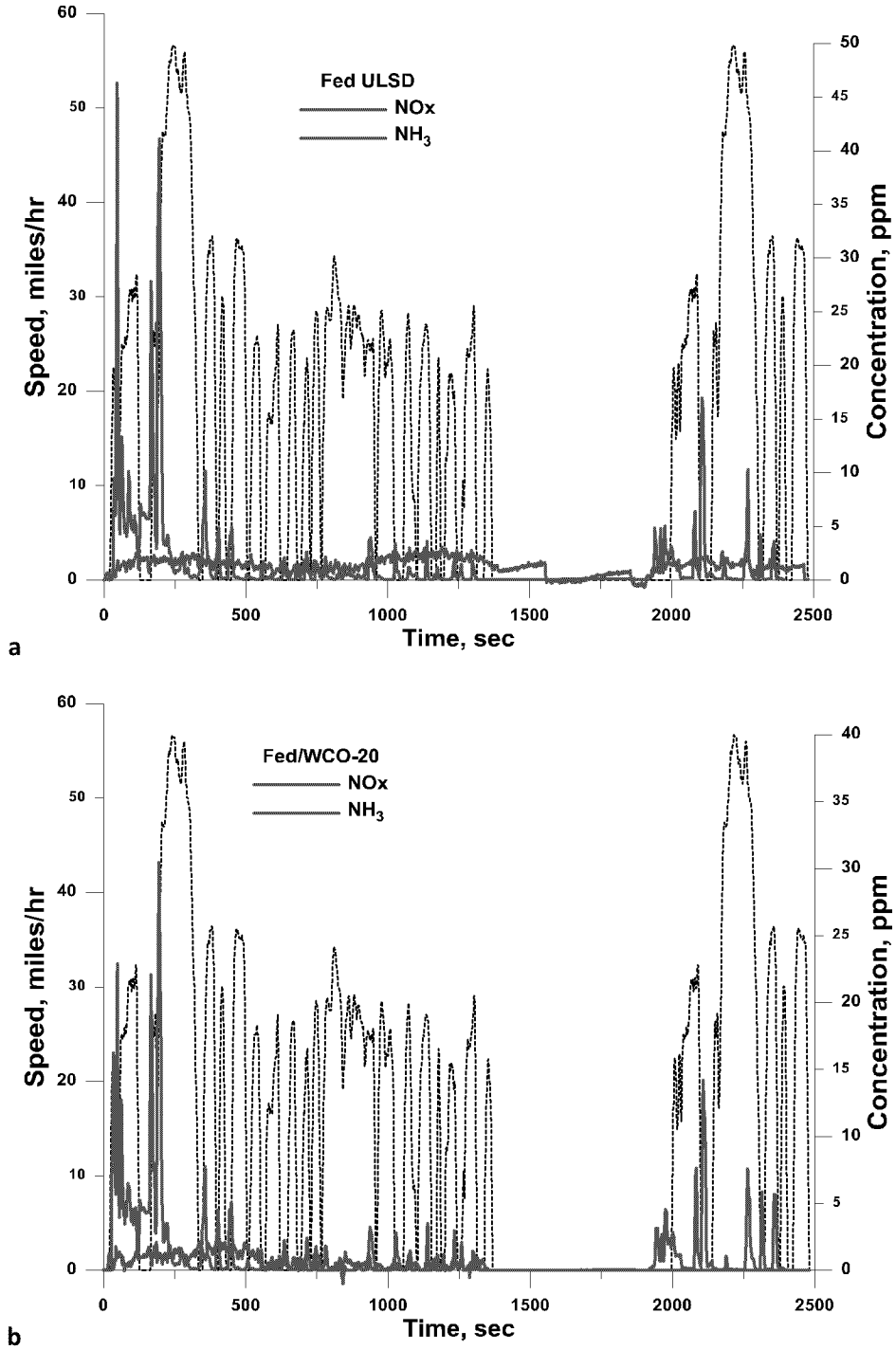

Figure 3-31 (a-b): Real-time NH_3 versus NO_x emissions for Federal ULSD (a) and Fed/WCO-20 blend (b) over the FTP for Vehicle #2

3.12 Nitrogenous Compounds

Nitrogenous compounds, including nitric oxide (NO), nitrogen dioxide (NO_2), and nitrous oxide (N_2O), were only measured during the second phase of the AVFL-17b program and limited to Vehicle #4 through Vehicle #8. NO, NO_2, and N_2O emissions, as well as the NO:NO_2 ratio are shown in Figures 3.32, 3.33, 3.34, and 3.35, respectively. For NO emissions, no statistically significant fuel effects were seen for the five vehicles tested. The light-duty diesel trucks, Vehicle #5 and Vehicle #6, generally showed higher NO emissions than the other test vehicles, and their NO levels followed a trend similar to their NO_x emission levels. NO_2 is a highly

reactive gas contributing to the formation of ground-level ozone and fine particle pollution, and is linked to adverse health effects. NO_2 emissions were higher than those of NO for Vehicle #4, Vehicle #7, and Vehicle #8, as seen in Figure 3.31 and in comparing Figure 3.30 and Figure 3.31. Similar to NO, NO_2 emissions did not show statistically significant fuel effects for the five vehicles tested. However, some trends towards lower NO_2 emissions for the biofuel blends were seen for Vehicle #6 and Vehicle #7. There were also no statistically significant fuel effects for the NO:NO_2 ratio.

N_2O is considered an important GHG emission component, as it is considerably more potent than CO_2. N_2O emissions varied from 0.01 to 0.02 g/mile for Vehicle #4 and Vehicle #6 through Vehicle #8, while Vehicle #5 showed higher N_2O emissions ranging from 0.03 to 0.07 g/mile. N_2O emissions did not show consistent fuel trends over Vehicle #4 through Vehicle #8. This observation is also supported by the statistical analyses, which showed a lack of significant effects among the test fuels. Lower N_2O emissons were found for the Fed/SME-20 and Fed/AFME-20 fuels for Vehicle #5. The Fed/HVO-20 showed higher emissions for Vehicle #7 and lower emissions for Vehicle #8. Vehicle #6 showed higher emissions for Federal ULSD compared to the other fuels.

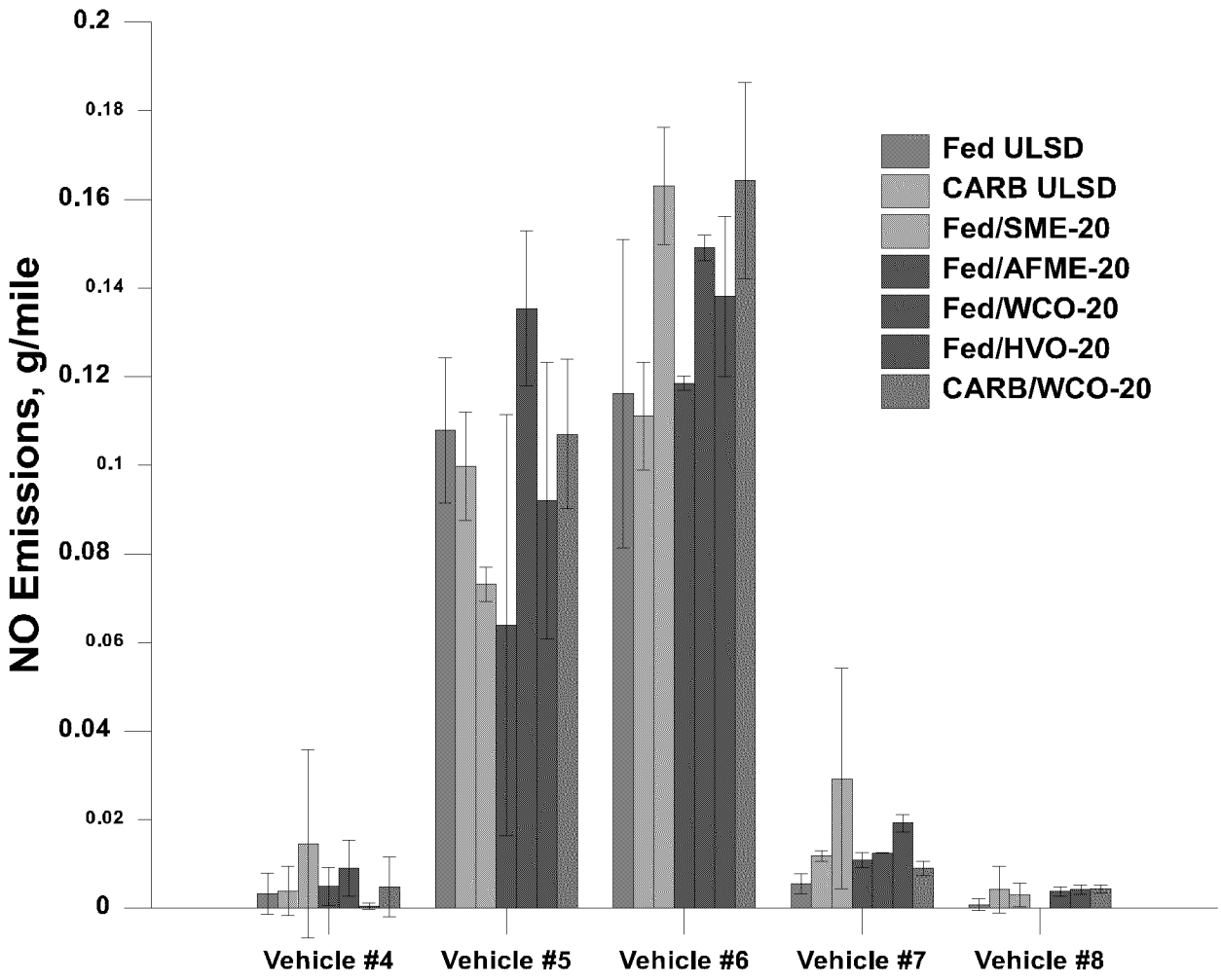

Figure 3-32: NO emissions for Vehicle #4-Vehicle #8 over the FTP

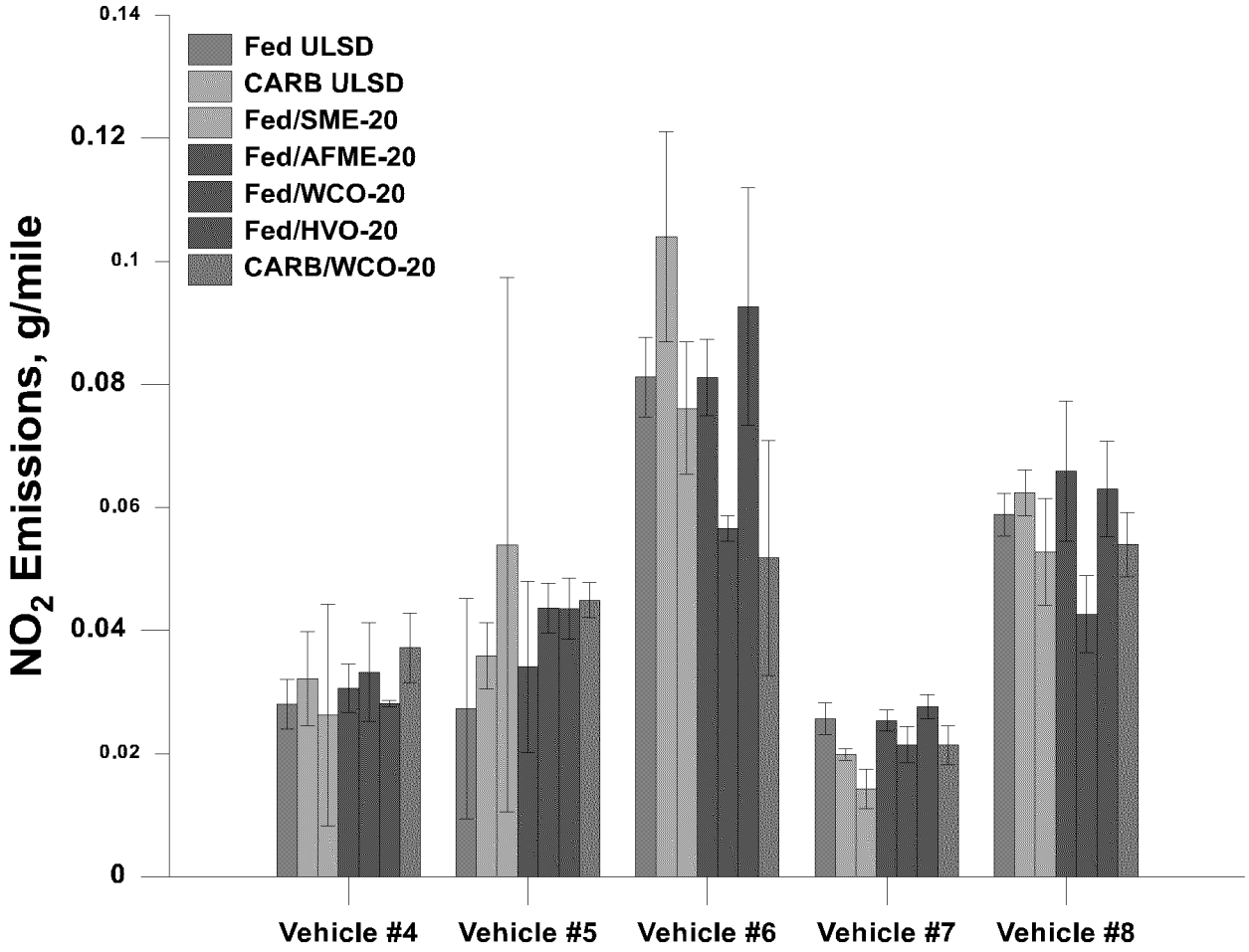

Figure 3-33: NO_2 emissions for Vehicle #4-Vehicle #8 over the FTP

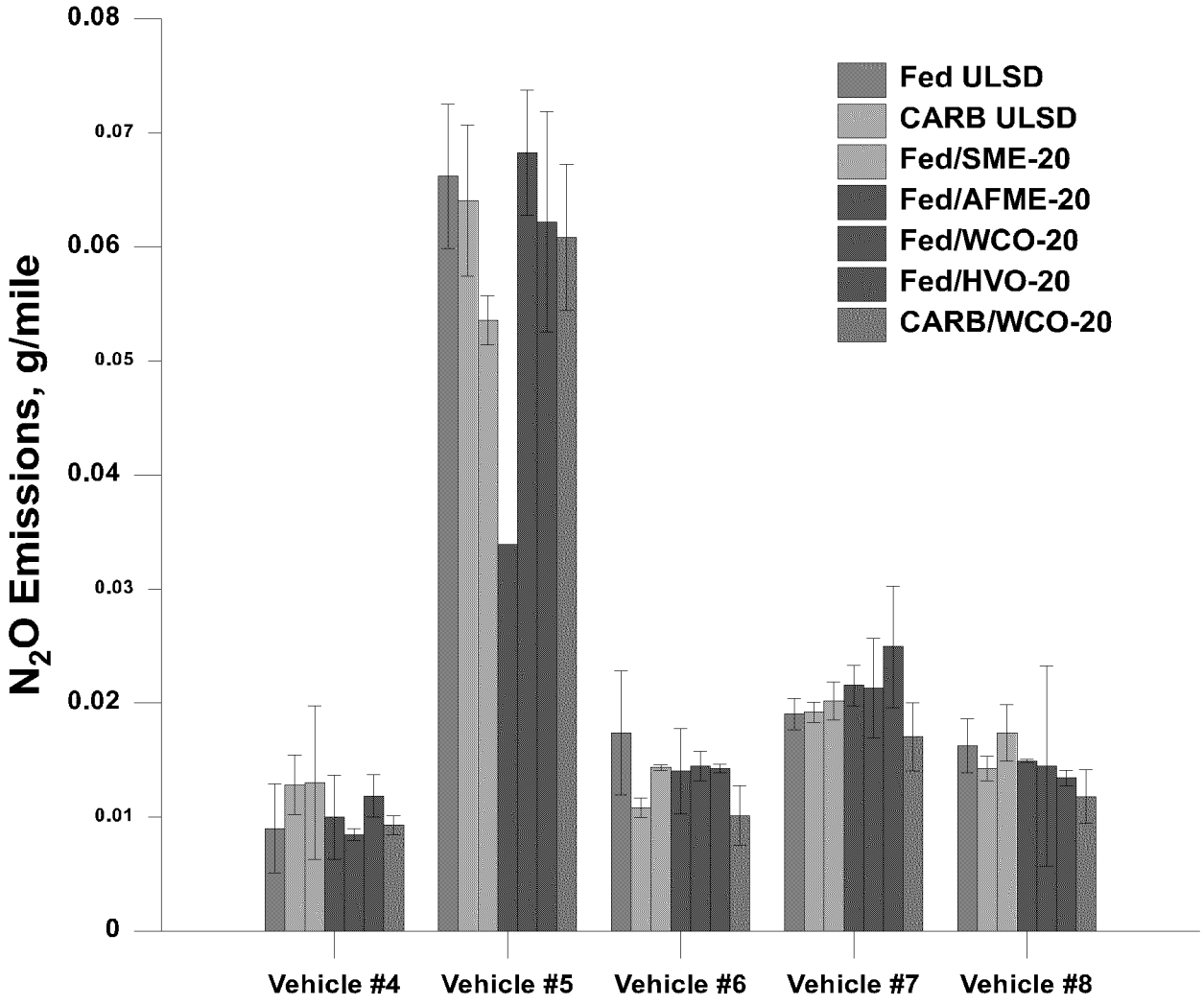

Figure 3-34: N_2O emissions for Vehicle #4-Vehicle #8 over the FTP

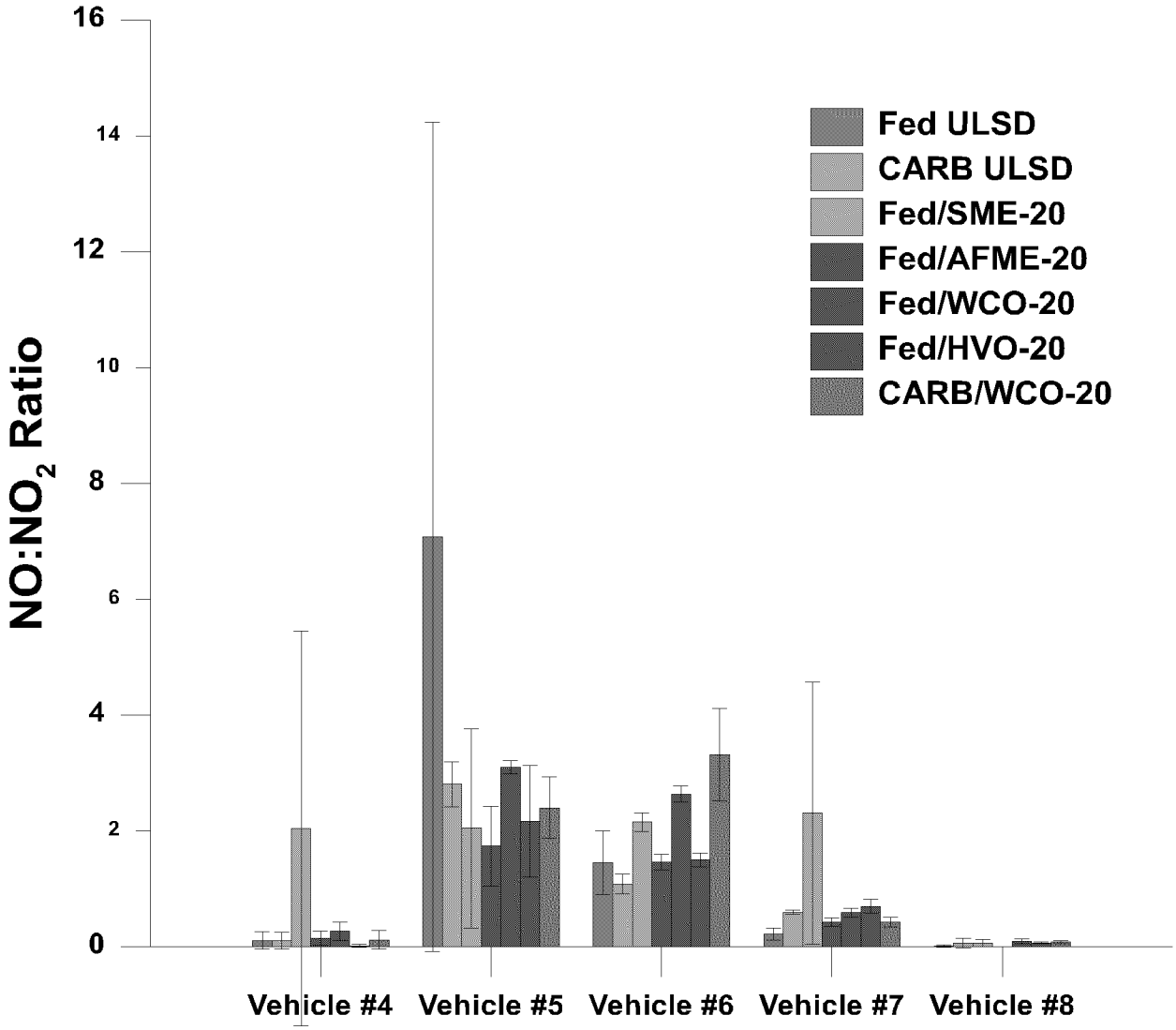

Figure 3-35: $NO:NO_2$ ratio for Vehicle #4-Vehicle #8 over the FTP

3.13 Regeneration Testing Results

The regeneration of the DPF is of particular interest because it requires a diesel engine to operate in very different regimes with different control requirements than normal operation. The regeneration event typically requires temperatures greater than 550ºC across the DPF. The need for regeneration is triggered by an increased pressure drop across the DPF, which is indicative of soot loading, but the timing of the actual regeneration event is a strong function of the vehicle's driving pattern. Generally, the regeneration is initiated under high speed driving conditions, since temperatures are already higher. The high exhaust temperatures required for the regeneration are created by retarding the main fuel injection and introducing a post-injection of fuel in the exhaust manifold before to the DPF. The combination of main injection retard and post-injection can be used to increase exhaust temperatures without introducing additional torque. Changing the injection parameters leads to increased DOC inlet temperatures directly which may cause a significant increase in HC, which reacts over the DOC to provide additional heat to the DPF (Campbell et al., 2006; Beatrice et al., 2012).

Regeneration emissions testing was conducted on Vehicle #1 and Vehicle #3 on the Federal ULSD and the Fed/SME-20 blend over the HWFET cycle. For each fuel/vehicle combination, two DPF regeneration emission tests were performed over the HWFET, while a single run was

performed on each vehicle on Federal ULSD over the HWFET to provide baseline measurements for comparison purposes. It should be noted that no DPF regeneration occurred during the baseline testing over the HWFET for any vehicle. For Vehicle #1, three DPF regeneration emissions measurements were made on the Fed/SME-20 blend as a result of CPC malfunctions during the first DPF regeneration test. All the DPF regeneration events had different characteristics; much of this variability was due to the duration of the DPF regeneration events, since the same protocol was used for all vehicles/fuels combinations. For Vehicle #1, the first regeneration event on the Federal ULSD lasted approximately 17 minutes and the second event lasted 11 minutes. For Vehicle #1 on the biodiesel blend, the first regeneration event lasted about 16 minutes, the second event lasted 22 minutes, and the third event lasted 16 minutes. For Vehicle #3, the first regeneration event on the Federal ULSD lasted 12 minutes and the second event lasted 9 minutes; For Vehicle #3 on the biodiesel blend, the first regeneration event lasted about 11 minutes and the second event lasted 7 minutes.

Figure 3.36 (a-b) and Figure 3.37 (a-b) show the regulated emissions and CO_2 emissions and fuel economy for Vehicle #1 and Vehicle #3, respectively, during the DPF regeneration events over the HWFET. For Vehicle #1, the regulated emissions for both fuels during the DPF regeneration events were significantly higher than for the baseline HWFET measurement. The use of biodiesel resulted in marked increases in THC, CH_4, and NMHC emissions compared to Federal ULSD. CO, NO_x and CO_2 emissions during DPF regenerations were comparable between fuels within the experimental variability. As expected, fuel economy was lower for both fuels during DPF regeneration; the biodiesel blend exhibited slightly higher fuel economy compared to Federal ULSD. For Vehicle #3, the application of biodiesel blends led to marked increases in THC, NMHC, CO, NO_x, and CO_2 emissions compared to Federal ULSD. It should be emphasized that NO_x emissions for Vehicle #3 were approximately three times higher than those seen for Vehicle #1. This result was unexpected since NO_x emissions were at the same levels for both vehicles during normal FTP operation. Similarly, fuel economy was lower for both fuels during the regeneration testing; the biodiesel blend showed lower fuel economy compared to Federal ULSD. It is worth noting that the higher CH_4 emissions for both vehicles could be explained by the higher temperatures of the exhaust gas during the DPF regeneration, thus increasing oxidation of higher hydrocarbons on the oxidation catalyst. This could lead to an increased percentage of CH_4, which is more difficult to oxidize. For Vehicle #1, most of the THC was found to be CH_4. Also, the higher tailpipe CO emissions during DPF regenerations for both vehicles are associated with partial oxidation of carbon to CO rather than to CO_2. The higher THC and CO emissions for the biodiesel blend during the regeneration process might indicate poorer combustion efficiency relative to Federal ULSD.

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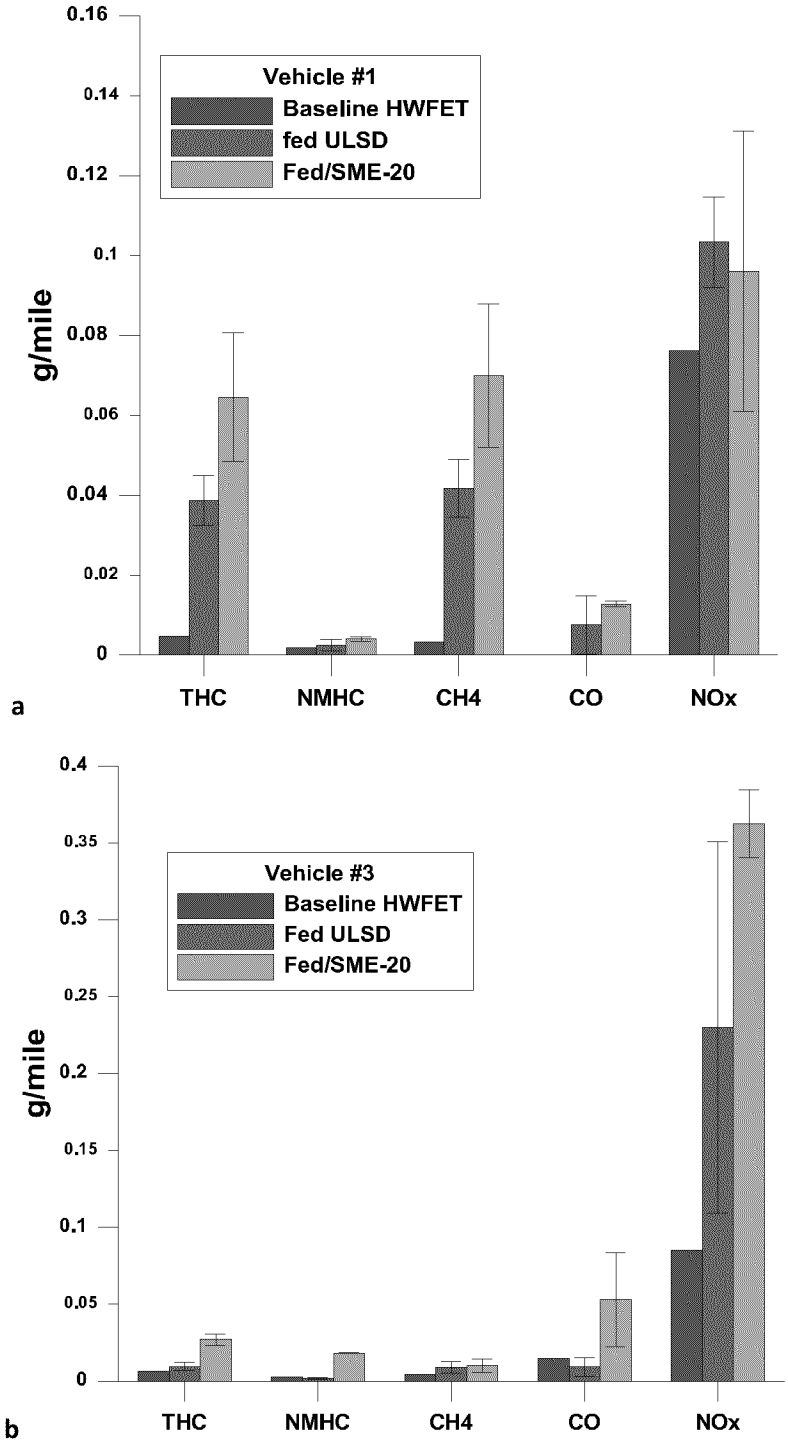


Figure 3-36 (a-b): Regulated emissions for Vehicle #1 (a) and Vehicle #3 (b) during regeneration emissions testing over the HWFET

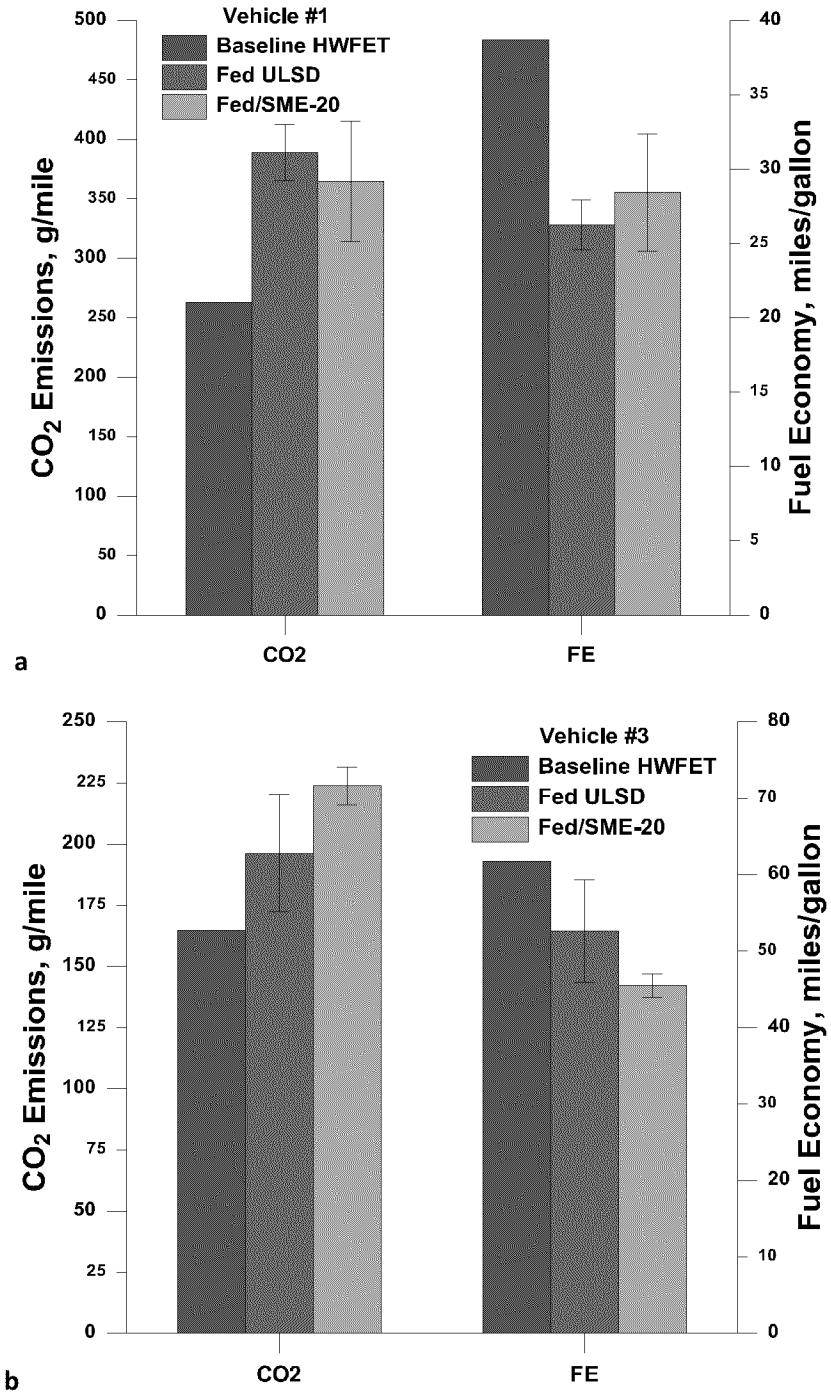


Figure 3-37 (a-b): CO_2 emissions and fuel economy for Vehicle #1 (a) and Vehicle #3 (b) during regeneration emissions testing over the HWFET

Figure 3.38 presents the PM mass emissions for both vehicles during the DPF regeneration events. For comparison, the baseline HWFET measurement on Federal ULSD is included. No Teflon® filters were collected during the baseline HWFET cycle for Vehicle #1. Based on the PM mass results obtained from Vehicle #3 testing, both fuels led to significant increases in PM emissions compared to the baseline test. Also, PM mass emissions were considerably higher for both fuels during the regeneration emissions testing compared to the FTP PM mass emissions for both vehicles. The use of soy-based biodiesel blend for Vehicle #3 resulted in a statistically significant 40% PM mass reduction compared to Federal ULSD. The reductions in PM mass emissions for the biodiesel blend could be due to the presence of oxygen content and the absence of aromatics compounds in the methyl ester.

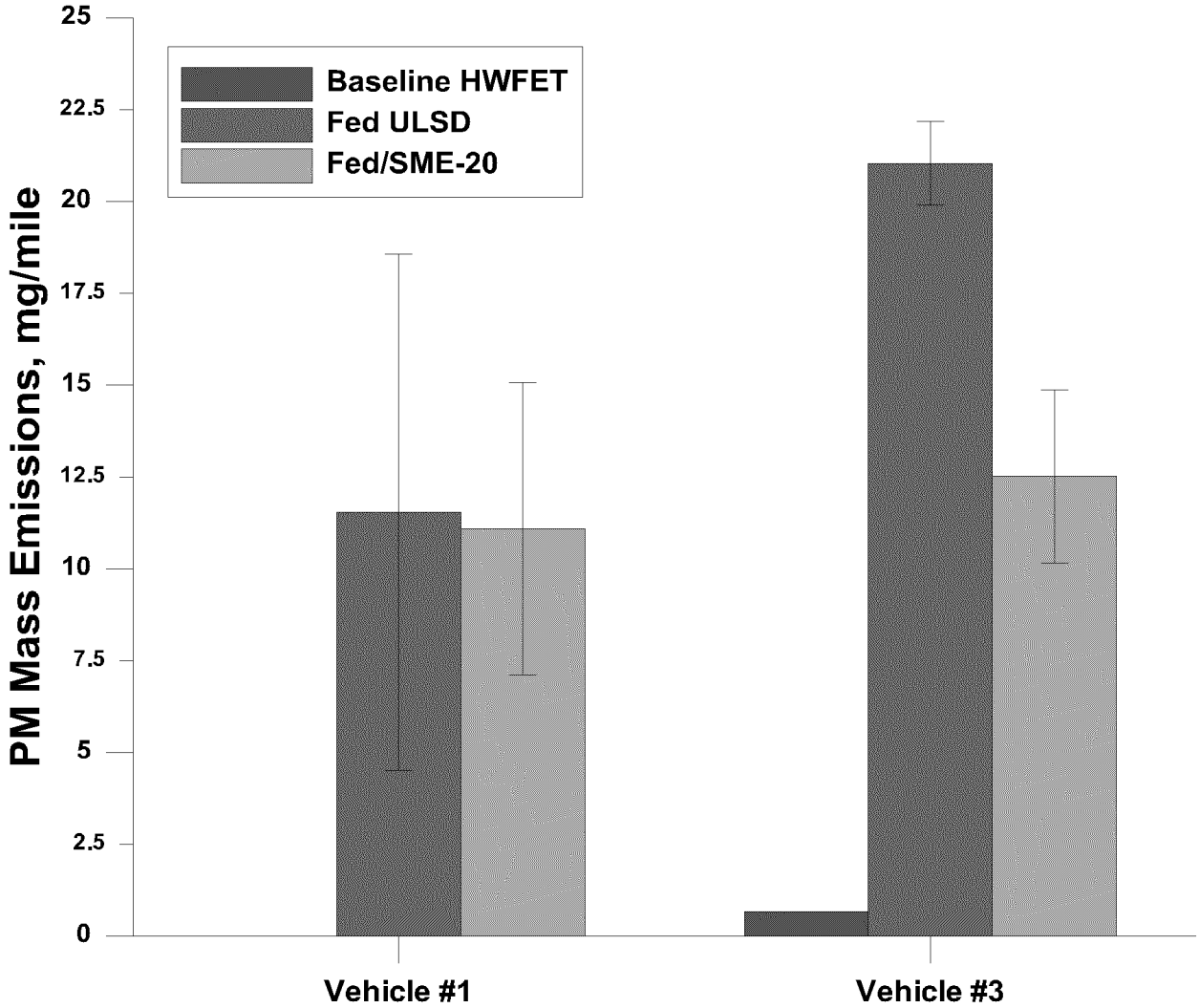


Figure 3-38: PM mass emissions during regeneration emissions testing over the HWFET

Total particle number emissions are shown in Figure 3.39. Overall, particle number emissions were significantly higher for both fuels during the regeneration events than the baseline HWFET testing, with particle number emissions for the biodiesel blend for Vehicle #1 being higher than those of Vehicle #3. For Vehicle #1, the use of biodiesel resulted in a marked increase in particle number emissions compared to Federal ULSD. This increase was on the order of 390% and was also statistically significant. For Vehicle #2, a decrease of 28% in particle number emissions was observed for the biodiesel blend compared to Federal ULSD. Overall, total particle number emissions during regeneration testing were several orders of magnitude higher compared to those emitted during standard FTP operation. This observation is in qualitative agreement with the findings from Giechaskiel et al. (2007), Bikas and Zervas (2007), Dwyer et al., (2010), and Mamakos et al. (2013). The elevated total particle population could be attributed to the formation of volatile nanoparticles during DPF regeneration. These volatile particles were generally found to peak at approximately 10 nm (mobility diameter) and have been associated to the formation of sulfates (Bergmann et al., 2009). Another factor that may have contributed to the increased particle number emissions during regeneration testing is treduced efficiency of DPF filtration caused by oxidation (and thus removal) of accumulated soot, which also filters airborne particles (Konstantopoulos et al., 2007).

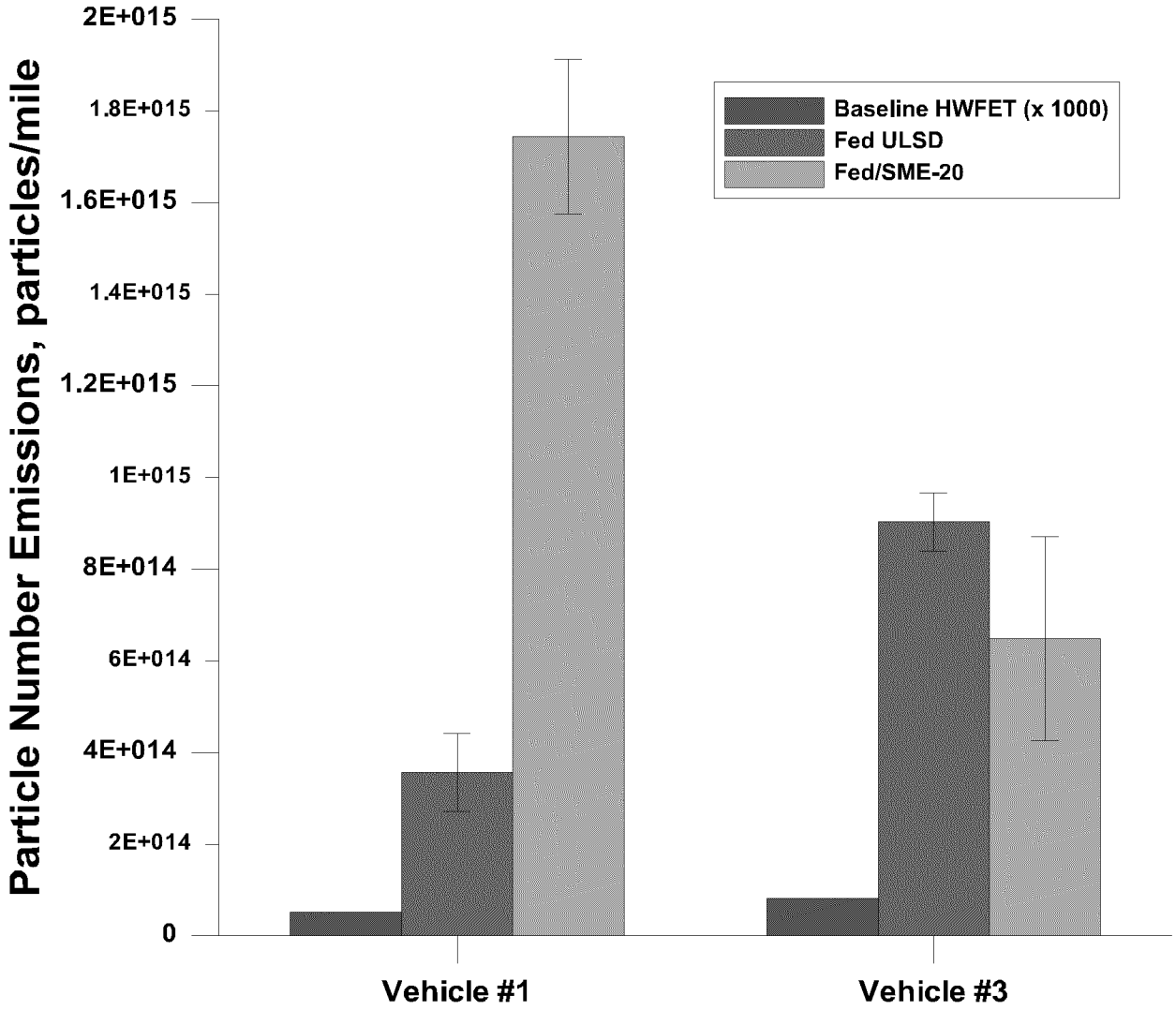
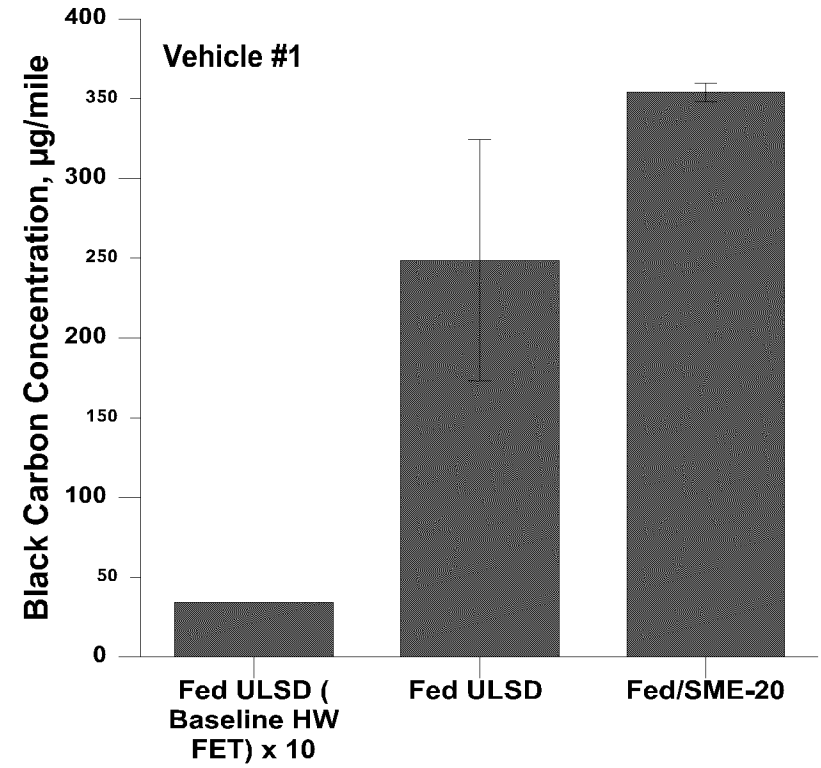
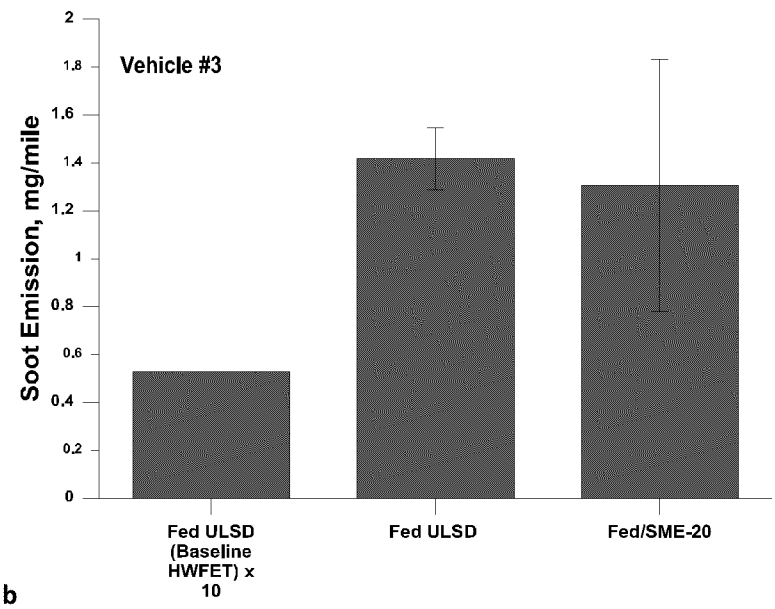


Figure 3-39: Particle number emissions during regeneration emissions testing over the HWFET

Figure 3.40 (a-b) shows the black carbon concentrations for Vehicle #1 during the DPF regeneration event. It should be mentioned that the MAAP instrument wasn't functional during the regeneration emissions testing for Vehicle #3, so no black carbon emissions are available for this vehicle. However, real-time soot emission measurements were made for Vehicle #3 using an AVL MSS instrument. For Vehicle #1, black carbon concentrations were found to be significantly higher during the regeneration emissions testing, with the biodiesel blend showing an increase in black carbon emissions of 42% compared to Federal ULSD. This increase in black carbon emissions for the biodiesel blend was in line with the increase observed for the total particle number emissions compared to Federal ULSD. For Vehicle #3, real-time soot emissions were higher for both fuels during the regeneration testing compared to the baseline testing. No significant differences were seen between the fuels during regeneration. In addition, comparing the two instruments together, it was seen that soot and black carbon emission factors correlated well. However, a closer analysis of real-time soot and black carbon results showed the opposite phenomenon, which could be ascribed to the different techniques used by the AVL MSS and the MAAP instruments.



a



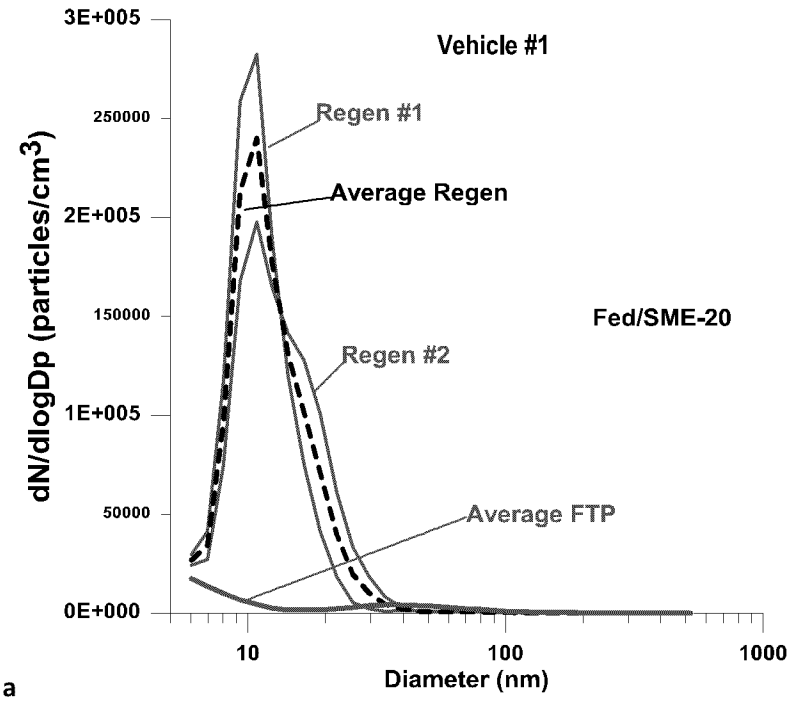
b

Figure 3-40 (a-b): Black carbon concentrations for Vehicle #1 (a) and real-time soot emissions for Vehicle #3 (b) during regeneration emissions testing over the HWFET

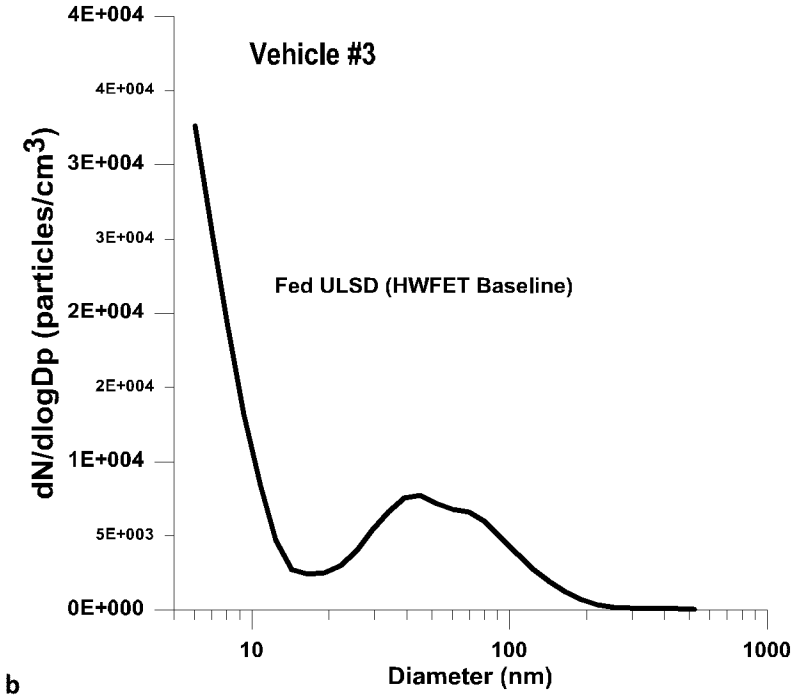
Particle size distributions are shown in Figure 3.41 (a-c). It should be mentioned that particle size distributions measurements were not made for Vehicle #1 on Federal ULSD during regeneration testing, as the EEPS was not available at that time. The displayed data show that during regeneration events, a substantial nucleation mode was apparent. Diesel engine nucleation mode particles likely consist of water, sulfate, and/or volatile hydrocarbons, and it is well known that dilution ratio, temperature and residence time have profound effects upon the rate of nucleation of these species and hence upon the size and concentration of nucleation mode particles

(Campbell et al., 2006). For this study, these particles may have formed from sulfate nuclei with condensed hydrocarbons. Probable sources of sulfates are sulfur adsorbed on the soot, sulfur trapped in the DPF, and sulfur in the aftertreatment devices. More specifically, a possible explanation for nucleation mode particles found in the tailpipe might be the ability of the DPF to store sulfur compounds that can be released and oxidized to SO_3/H_2SO_4 during regeneration due to the increased temperature (Bergmann et al., 2009). Moreover, sulfur from the fuel (mainly from Federal ULSD) that is injected into the catalyst to heat the DPF may play an important role.

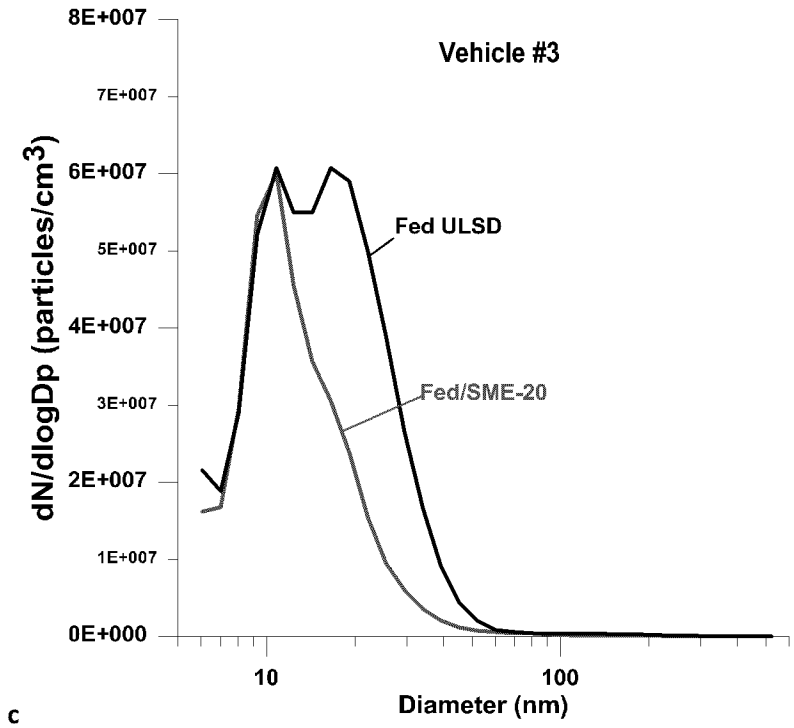
For Vehicle #3, nucleation mode particle concentrations were found to be many orders of magnitude higher than those of Vehicle #1, a result inconsistent with the lower particle number emissions observed for the Vehicle #3 relative to Vehicle #1. It is possible that DPF loading for Vehicle #3 tests was higher, although the regeneration event for the Vehicle #3 was shorter in duration than for Vehicle #1. For a higher DPF loading more sulfur (e.g., from lubricant oil) is accumulated, which in turn leads to a formation of nucleation particles during regeneration. It should be also emphasized that the use of biodiesel had no effect on particle size distributions for Vehicle #3.



a



b



c

Figure 3-41 (a-c): Particle size distributions for Vehicle #1 (a) and Vehicle #3 (b, c) during regeneration emissions testing over the HWFET

Emissions of carbonyl compounds for both vehicles during regeneration emissions testing over the HWFET are shown in Figure 3.42 (a-c). For both vehicles, the most abundant carbonyl compound in the exhaust during the regeneration event was formaldehyde, followed by acetaldehyde. For Vehicle #1, heavier carbonyls were also present in the exhaust, but in lesser amounts, with propionaldehyde, butyraldehyde, benzaldehyde, and hexanaldehyde being detected mainly during regeneration events, but not in the baseline HWFET testing. The application of biodiesel showed increases of 92% and 372%, respectively, for formaldehyde and acetaldehyde emissions compared to Federal ULSD, although these differences were not statistically significant. For Vehicle #3, some heavier carbonyl compounds, including those of

propionaldehyde, crotonaldehyde, butyraldehyde, and benzaldehyde, were detected in the exhaust during regeneration testing, but in very low concentrations. It is worth noting that heavier carbonyls for the Vehicle #3 were found at considerably higher levels than those of Vehicle #1, while formaldehyde and acetaldehyde were at comparable levels. Similar to Vehicle #1 regeneration emissions testing, the use of biodiesel resulted in marked increases in formaldehyde (389%) and acetaldehyde (767%) emissions compared to Federal ULSD, with the increase in formaldehyde emissions being statistically significant. The increases in carbonyl emissions with biodiesel relative to Federal ULSD during regeneration testing can be confirmed by the total carbonyl emissions results, as shown in Figure 3.40c. Total carbonyls appeared in higher concentrations during regeneration testing compared to baseline testing for both vehicles, with the soy-based biodiesel resulting in marked increases in total carbonyl emissions. For Vehicle #3, the biodiesel blend showed a statistically significant increase of 313% in total carbonyl emissions compared to Federal ULSD.

In general, the increase in carbonyl emissions with the biodiesel blend could be due to the oxygen content in the ester molecule, which can promote the formation of aldehydes during combustion (Correa and Arbilla, 2008). During DPF regeneration, the DPF effectively oxidized most carbonyl compounds with the notable exception of formaldehyde. During the regeneration events, there was a significant increase in THC in the exhaust due to the fuel injection, which promotes reactions over the DOC to provide additional heat to the DPF. It is reasonable to assume that some THC escaped from the DOC/DPF system, as the aftertreatment may not have sufficient capacity to fully oxidize the additional THC during the regeneration event. This observation is also in line with the THC results shown in Figure 3.34 (a-b). It is therefore possible that some heavier hydrocarbon species, including higher molecular-weight aldehydes, were related to hydrocarbons that did not fully oxidize in the aftertreatment system. In the case of formaldehyde, it is possible that the higher formaldehyde emission concentrations were due to different formation pathways, since formaldehyde is an intermediate oxidation product from other aldehydes and hydrocarbons within the DPF. In addition, formaldehyde is an intermediate step in the oxidation of methane under high temperature conditions and across the DOC; thus, the high concentrations observed for methane emissions during the DPF regeneration events for both vehicles may have contributed to the formation of formaldehyde emissions.

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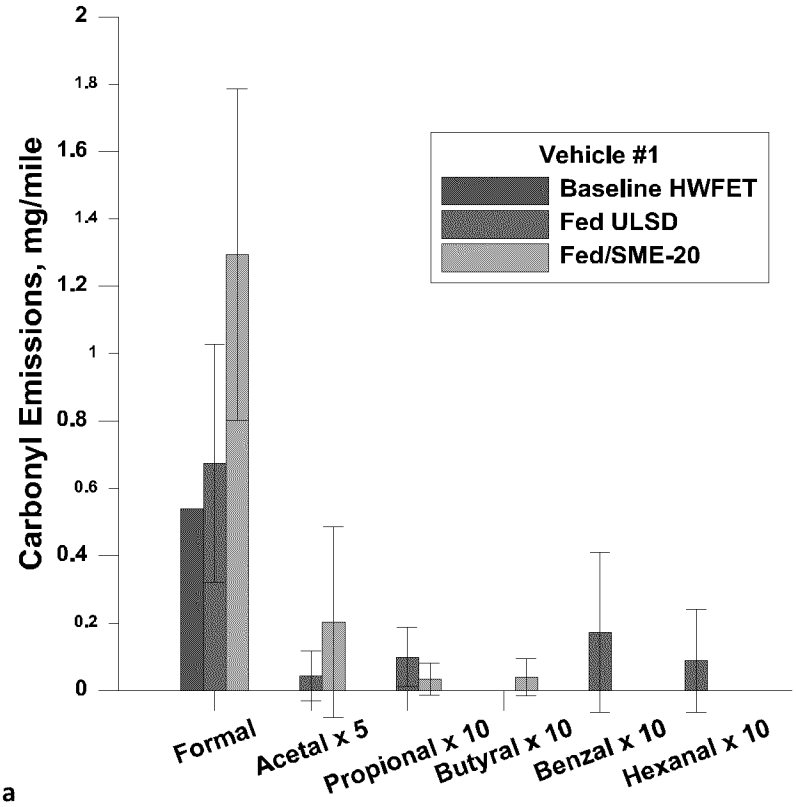
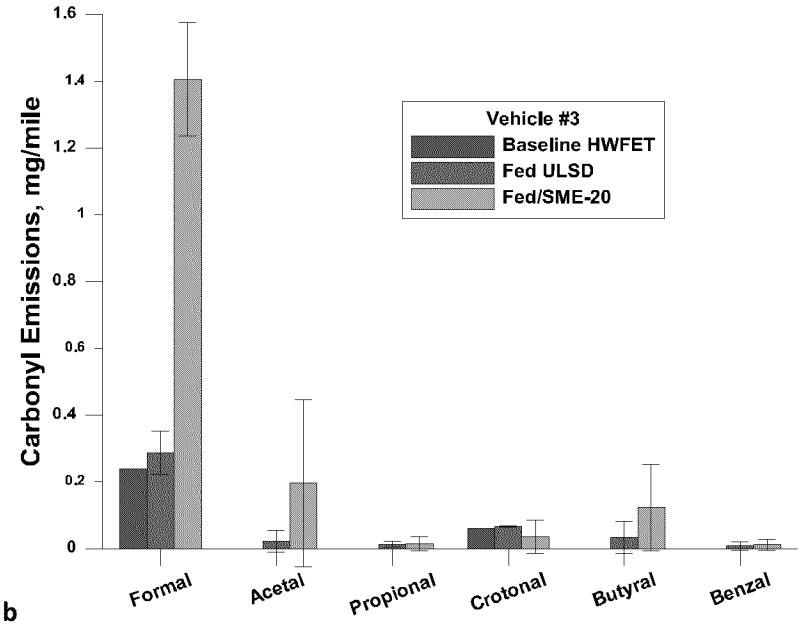

Carbonyl Emissions, mg/mile
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Vehicle #1
Baseline HWFET
Fed ULSD
Fed/SME-20
Formal
Acetal x 5
Propional x 10
Butyral x 10
Benzal x 10
Hexanal x 10

a


Carbonyl Emissions, mg/mile
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Vehicle #3
Baseline HWFET
Fed ULSD
Fed/SME-20
Formal
Acetal
Propional
Crotonal
Butyral
Benzal

b

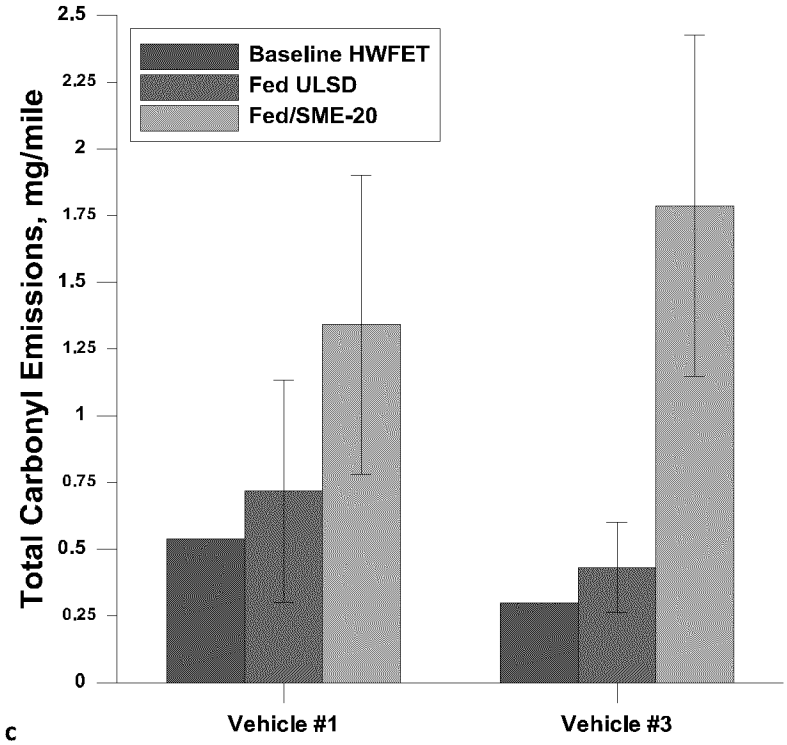


Figure 3-42 (a-c): Individual carbonyl emissions for Vehicle #1 (a) and Vehicle #3 (b) and total carbonyl emissions for both vehicles (c) during regeneration emissions testing over the HWFET

Figure 3.43 shows the total gas-phase PAH emissions for the two vehicles during the DPF regeneration events. Table D33 (see Appendix D) lists the individual gas-phase PAH compounds for both vehicles/fuels combinations over the HWFET. For both vehicles, the aromatic compounds, C_{12} biphenyls and the C_{13} methylbiphenyls (2-methylbiphenyl, 3-methylbiphenyl, and 4-methylbiphenyl) were by far the most predominant species in the gas-phase followed by naphthalene, methyl- and ethylnaphthalenes, fluorene, 9-fluorenone, phenanthrene, xanthone, fluoranthene, and pyrene. Compounds with higher molecular weights were found at very low levels, or were below the detection limits. Total gas-phase PAH emissions for Federal ULSD were comparable between the regeneration and baseline testing. The use of biodiesel resulted in an increase of 55% in total gas-phase PAH emissions compared to Federal ULSD for Vehicle #3, although these differences were not statistically significant. For Vehicle #1, the gas-phase PAHs were comparable within the experimental variability for the Federal ULSD and the soy-based biodiesel.

The use of soy-based biodiesel blend led to sharp increases in most gas-phase PAH species during regeneration emissions testing compared to Federal ULSD. Although this observation holds true for both vehicles, this trend isn't reflected in the total gas-phase PAH emissions for Vehicle #1. This was because, while lighter gas-phase PAHs were dominant for the biodiesel blend, the biphenyls and methylbiphenyl compounds were the dominant gas-phase PAHs for the Federal ULSD, and they dictated the total gas-phase PAH distribution for the Federal ULSD. Specifically, the use of biodiesel led to marked increases in gas-phase naphthalene, methyl- and ethylnaphthalenes, acenaphthene, fluorene, and methylfluorenes. In most cases, these compounds were found in significantly higher concentrations during the regeneration emissions testing compared to the baseline HWFET testing. For Vehicle #1, the emissions for the biodiesel blend were higher in phenanthrene, methylphenanthrenes, anthracene, anthraquinone, and fluoranthene. This phenomenon was not observed for Vehicle #3, where levels of these

compounds were lower with the biodiesel blend than Federal ULSD during regeneration emissions testing.

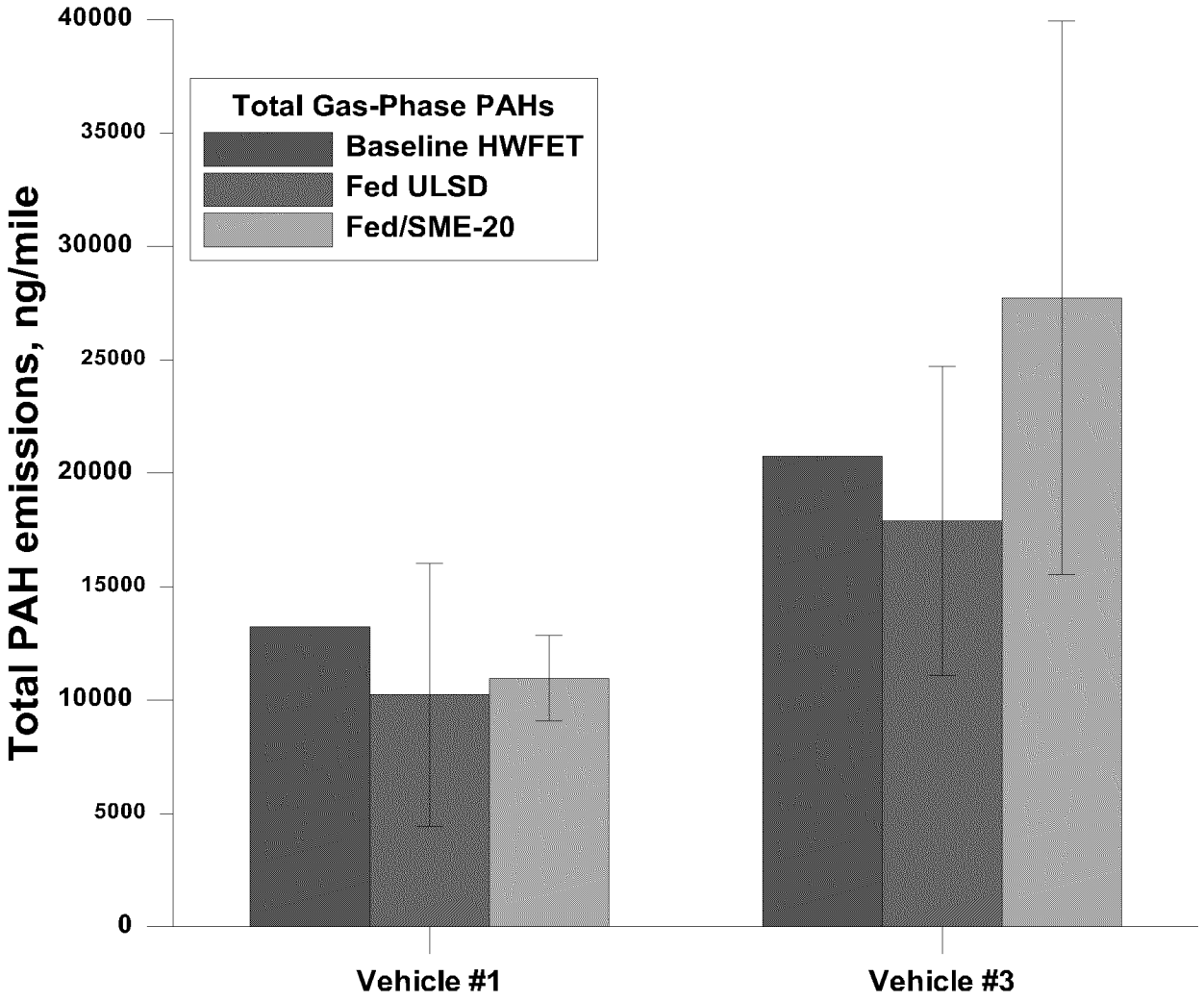


Figure 3-43: Total gas-phase PAH emissions during regeneration emissions testing over the HWFET cycle

Although the gas-phase PAHs dominate the overall emissions of PAHs, the particle-phase PAHs include most of the probable human carcinogenic compounds (Armstrong et al., 2004). Figure 3.44 shows the total particle-phase PAH emissions for both vehicles during regeneration emissions testing over the HWFET. Table D34 (see Appendix D) lists the individual gas-phase PAHs during the regeneration emissions testing and baseline testing for both vehicles on the Federal ULSD and Fed/SME-20. The PAHs with three or four rings were the predominant species in the particle-phase for both vehicles during regeneration testing, including phenanthrene, methylphenanthrenes, dimethylphenanthrenes, fluoranthene, pyrene, and 4-methylpyrene. Some oxygenated PAHs were also found in the exhaust in relatively high concentrations, including 9-fluorenone, xanthone, and anthraquinone. Lighter PAHs with two rings were also detected in the particle-phase in considerable concentrations. Naphthalene, methyl- and ethylnaphthalenes, dimethylnaphthalenes, and trimethylnaphthalenes dominated the low molecular-weight particle-phase PAH distribution. The contribution of PAHs with five or more rings from the vehicles during the regeneration emissions testing in the particle-phase distribution was also notable, with benzo(ghi)fluoranthene, benz(a)anthracene, chrysene, 7,12-

dimethylbenz(a)anthracene, benzo(b)fluoranthene, and benzo(e)pyrene showing highest concentrations for both Federal ULSD and Fed/SME-20 blend.

As shown in Figure 3.44, total particle-phase PAHs for both vehicles exhibited increases compared to the baseline testing, in contrast to the gas-phase PAH results. For Vehicle #1, total particle-phase PAHs showed a 53% reduction for the biodiesel blend compared to the federal ULSD, with this difference not being statistically significant. For Vehicle #3, the fuel differences were within the experimental variability of the data. Unlike the gas-phase PAHs, the particle-phase species demonstrated lower oxidation rates in the DOC/DPF system for both vehicles during regeneration testing compared to baseline testing.

The individual particle-phase PAH distribution for Vehicle #1 showed that phenanthrene, methylphenanthrenes, benzo(ghi)fluoranthene, benz(a)anthracene, chrysene, benzo(b)fluoranthene, and benzo(e)pyrene were the PAH species found at higher levels for the biodiesel blend than Federal ULSD during regeneration testing. For Vehicle #3, most PAH species with 3-4 rings showed higher concentrations with biodiesel compared to Federal ULSD, including phenanthrene, anthracene, fluoranthene, pyrene, methylpyrenes, and methylphenanthrenes. Heavier PAHs and some oxygenated compounds showed increases with the use of biodiesel blend during regeneration testing, including benzonaphthothiophene, benzo(ghi)fluoranthene, benz(a)anthracene, chrysene, benzanthrone, benz(a)anthracene-7,12-dione, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, benzo(e)pyrene, benzo(a)pyrene, indeno[123-cd]pyrene, benzo(ghi)perylene, triphenylene, and coronene. Interestingly, these high molecular-weight PAHs were also found in higher concentrations than in the baseline testing for Vehicle #3. For Vehicle #3, the use of biodiesel also increased the light 2-ring PAH species, such as naphthalene and methylnaphthalenes, relative to Federal ULSD. For Vehicle #3, it is possible that the oxygenate fraction in the fuel and the absence of aromatics did not play a significant role in reducing PAH emissions. It is also possible that the influence of biodiesel source material (degree of unsaturation) under high combustion temperatures contributed to PAH formation during regeneration testing. Overall, these results indicate that part of the PAHs found may not have come from the engine. They may instead have originated from excess fuel or hydrocarbons injected prior to the DPF during regeneration, via either combustion of excess hydrocarbons or incomplete oxidation in the DOC/DPF, even at the higher temperature condition. Therefore, it is reasonable to hypothesize that the PAHs produced under regeneration conditions are different from those produced from combustion in the engine, thus changing the PAH emission profile.

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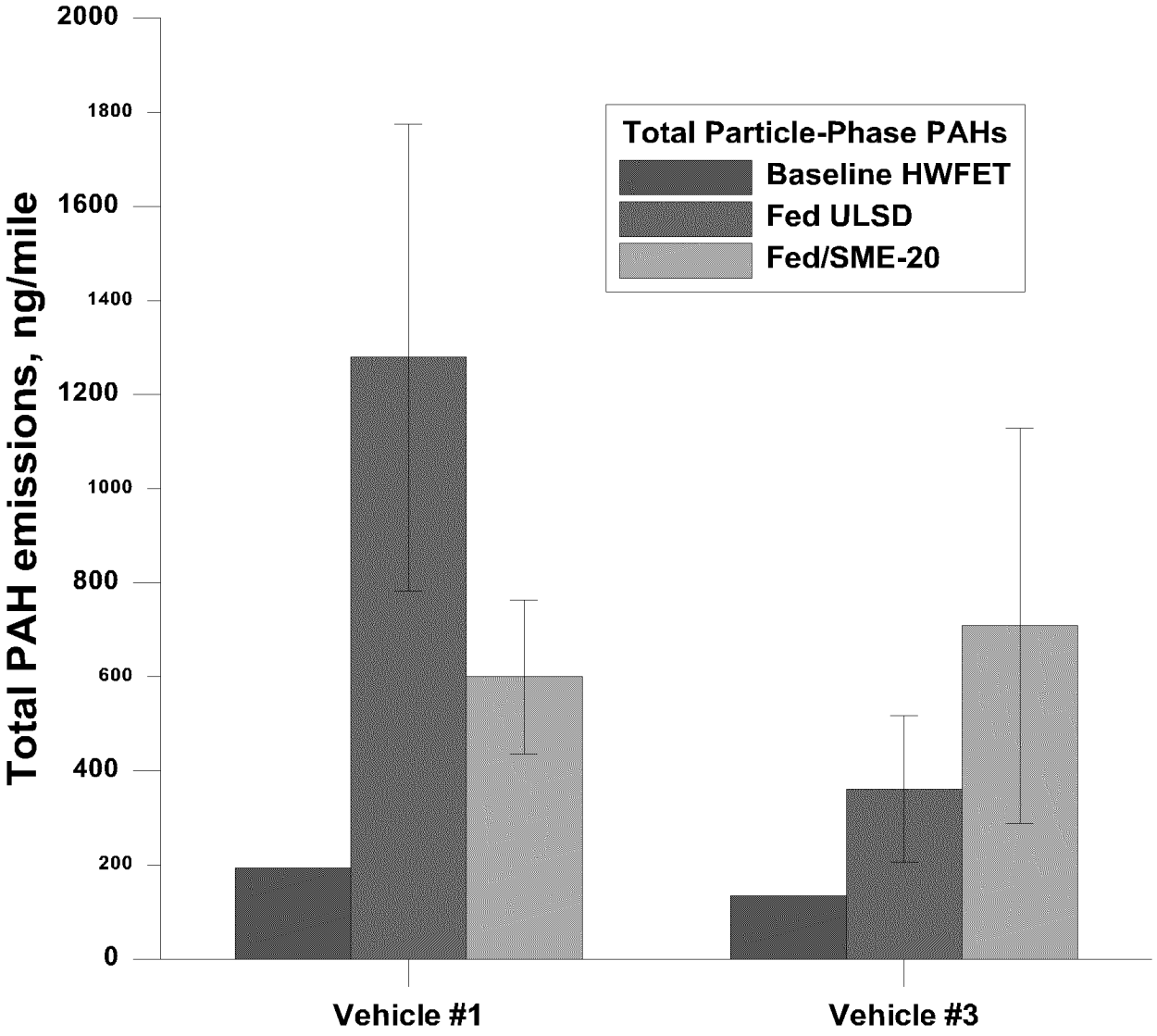

Figure 3-44: Total particle-phase PAH emissions during regeneration emissions testing over the HWFET cycle

Figure 3.45 shows the total gas-phase nitro-PAH emissions for both vehicles during DPF regeneration and baseline testing over the HWFET. Table D35 (see Appendix D) lists the individual gas-phase nitro-PAH species along with their corresponding standard deviations. Similar to normal FTP testing, a total of 36 species of nitro-PAHs in gas-phase were analyzed during regeneration emissions testing. The most abundant species in the gas-phase for both vehicles were 1-nitronaphthalene, 2-nitronaphthalene, 1-methyl-6-nitronaphthalene, and 3-nitrophenanthrene. Heavier nitro-PAH species, including 1-nitropyrene, were nearly below the detection limit in the gas-phase. For Vehicle #1, total gas-phase nitro-PAHs trended lower for both fuels during regeneration testing compared to the baseline testing. This result generally indicates higher conversion efficiencies of these species in the DPF during regeneration testing. The use of biodiesel showed a 54% reduction in total gas-phase nitro-PAH emissions compared to Federal ULSD, but this difference was not statistically significant. For Vehicle #3, total gas-phase nitro-PAHs during DPF regeneration trended higher than those of the baseline testing, but not at a statistically significant level, while the large variability for the biodiesel blend made comparisons with the Federal ULSD difficult.

A more detailed analysis on the individual gas-phase nitro-PAHs suggests that the majority of these species exhibited enhanced emissions during regeneration testing for both vehicles. In particular, there were cases where certain species, such as 1-methyl-6-nitronaphthalene, 4-nitrobiphenyl, and 9-nitroanthracene, were undetectable for the baseline testing but not for the regeneration testing. Most notably, these species showed an increase with the use of biodiesel blend relative to Federal ULSD for both vehicles. DPFs can support nitration reactions, but they can also catalyze nitro-PAH degradation through oxidation (Heeb et al., 2008; Carrara and Niessner, 2011). During regeneration events, where typical temperatures across the DPF can exceed 500°C, even larger PAHs may volatilize, leading to gas-phase reactions not observed at ambient conditions. Vapor pressures of nitro-PAHs are two to three orders of magnitude lower than those of their parent PAHs, and their reactivities are assumed to be higher. Therefore, longer residence times and higher conversion efficiencies are expected, unless nitro-PAHs do form de novo in the DPF (Heeb et al., 2008; Heeb et al., 2010). Under the present test conditions, the results indicated that most nitro-PAH species formed de novo in the DPFs during regeneration testing.

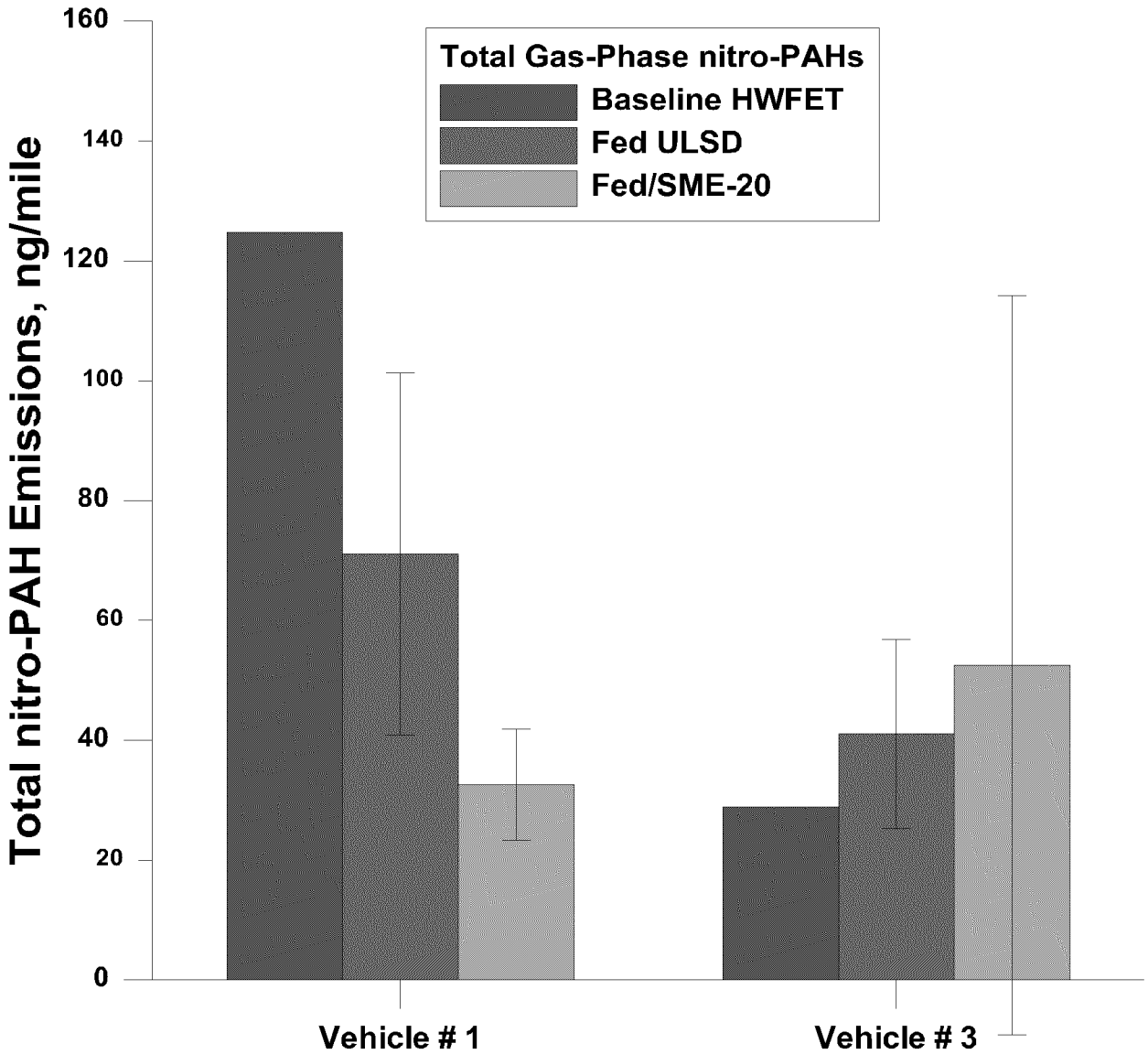

Figure 3-45: Total gas-phase nitro-PAH emissions during regeneration emissions testing over the HWFET cycle

Figure 3.46 displays the total particle-phase nitro-PAH emissions for both vehicles during DPF regeneration and baseline testing over the HWFET. Table D36 (see Appendix D) lists the individual particle-phase nitro-PAH species. Total particle-phase nitro-PAHs were found in considerably lower concentrations than the particle-phase compounds; the emission levels of Vehicle #3 were lower than those from Vehicle #1. The predominant species for both vehicles in the particle-phase were 3-nitrophenanthrene, 4-nitrophenanthrene, 1,8-dinitronaphthalene, and 1-nitropyrene. For both vehicles, particle-phase nitro-PAHs increased during regeneration testing compared to baseline testing. The particle-phase nitro-PAHs were lower for the biodiesel than Federal ULSD, but not at a statistically significant level given the experimental variability. Federal ULSD and biodiesel showed comparable emissions, within the experimental variability, for Vehicle #3.

Similar to gas-phase nitro-PAHs, formation of particle-phase species increased during regeneration testing, suggesting that several of these compounds can be formed de novo in the DPF via nitration reactions. Specifically, the compounds of 4-nitrophenanthrene, 3-nitrophenanthrene, and 9-nitrophenanthrene, detected at very low levels in baseline testing but at higher concentrations in regeneration testing, may have formed from a selective nitration of phenanthrene in the DPF. In addition, the relatively high concentration of 1-nitropyrene for both vehicles during regeneration testing could be due to the high NO_x emissions seen during the regeneration events that would cause nitration of some of the available pyrene, forming 1-nitropyrene.

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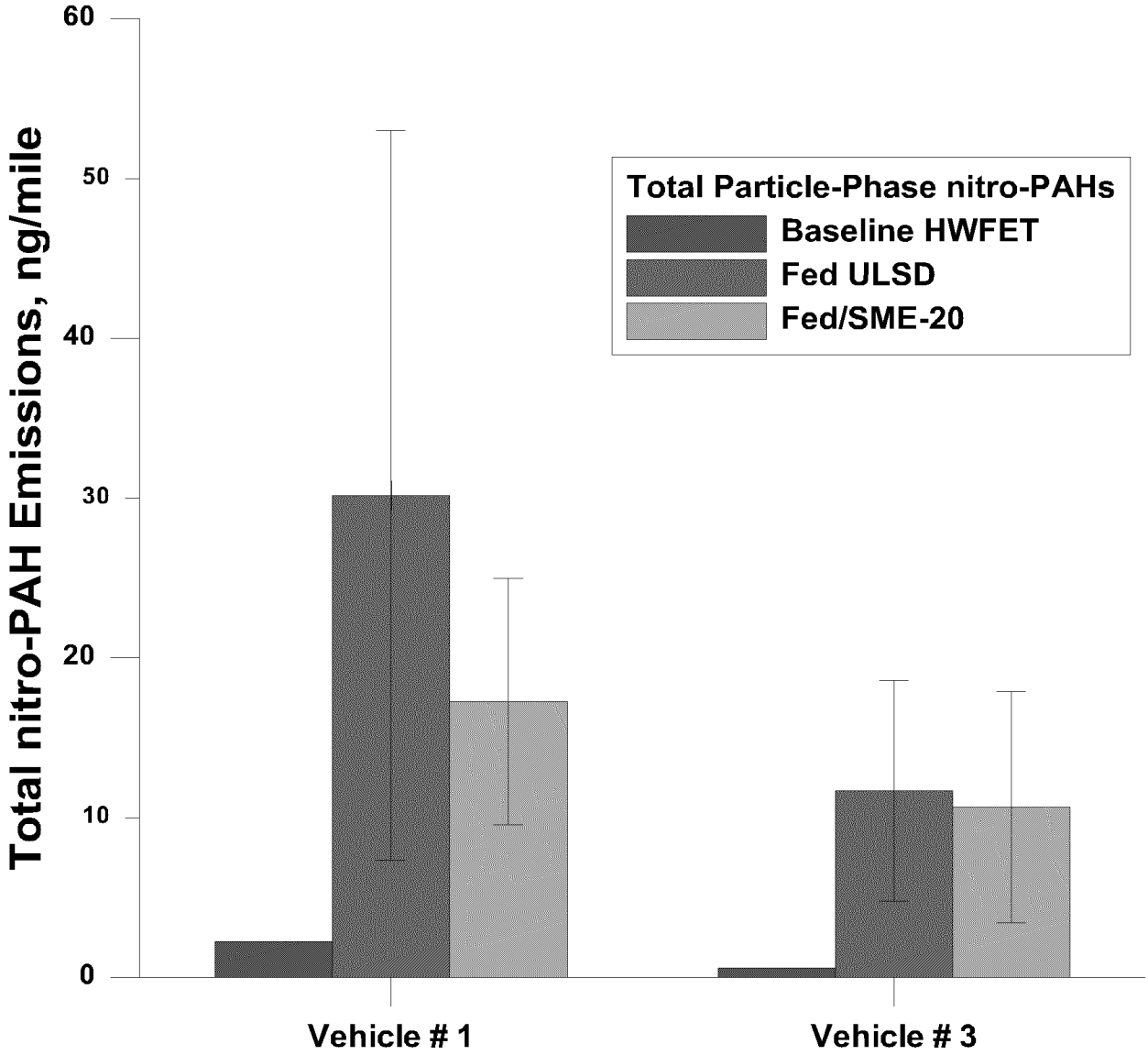

Figure 3-46: Total particle-phase nitro-PAH emissions during regeneration emissions testing over the HWFET cycle

EC and OC emissions for regeneration testing are shown in Figure 3.47 (a-b). For Vehicle #3, OC emissions increased by two to four times during DPF regeneration testing compared to baseline testing. Baseline testing on Vehicle #3 showed very low EC emissions, similar to FTP results. The DPF regeneration results show that much higher levels of EC are formed during DPF regeneration than during typical operation. The EC emissions rates were roughly twice those of corresponding OC emission rates for most combinations in the regeneration testing. The EC and OC emissions did not show strong fuel trends for the regeneration testing for either vehicle. Emissions for the Federal ULSD and the Fed/SME-20 were comparable in most cases within the experimental variability. Generally, for combustion, it is expected that the use of biodiesel would decrease the EC fraction due to the oxygen content in the methyl ester atoms, which inhibits the in-cylinder soot production both by disrupting the carbon chain development and by promoting oxidation. OC emissions depend on the physicochemical properties of the fuel. Unburned biodiesel is less volatile and hence more liable to nucleate and condense on smaller particles when the exhaust gas sample is cooled down in the tailpipe, resulting in increased OC emissions for biodiesel. As the vehicles do not show strong and consistent trends with respect to decreasing

EC and increasing OC with biodiesel, it appears the OC/EC trends with the aftertreatment are more complex than those related to basic combustion. Data from additional vehicles could provide more insight in this area.

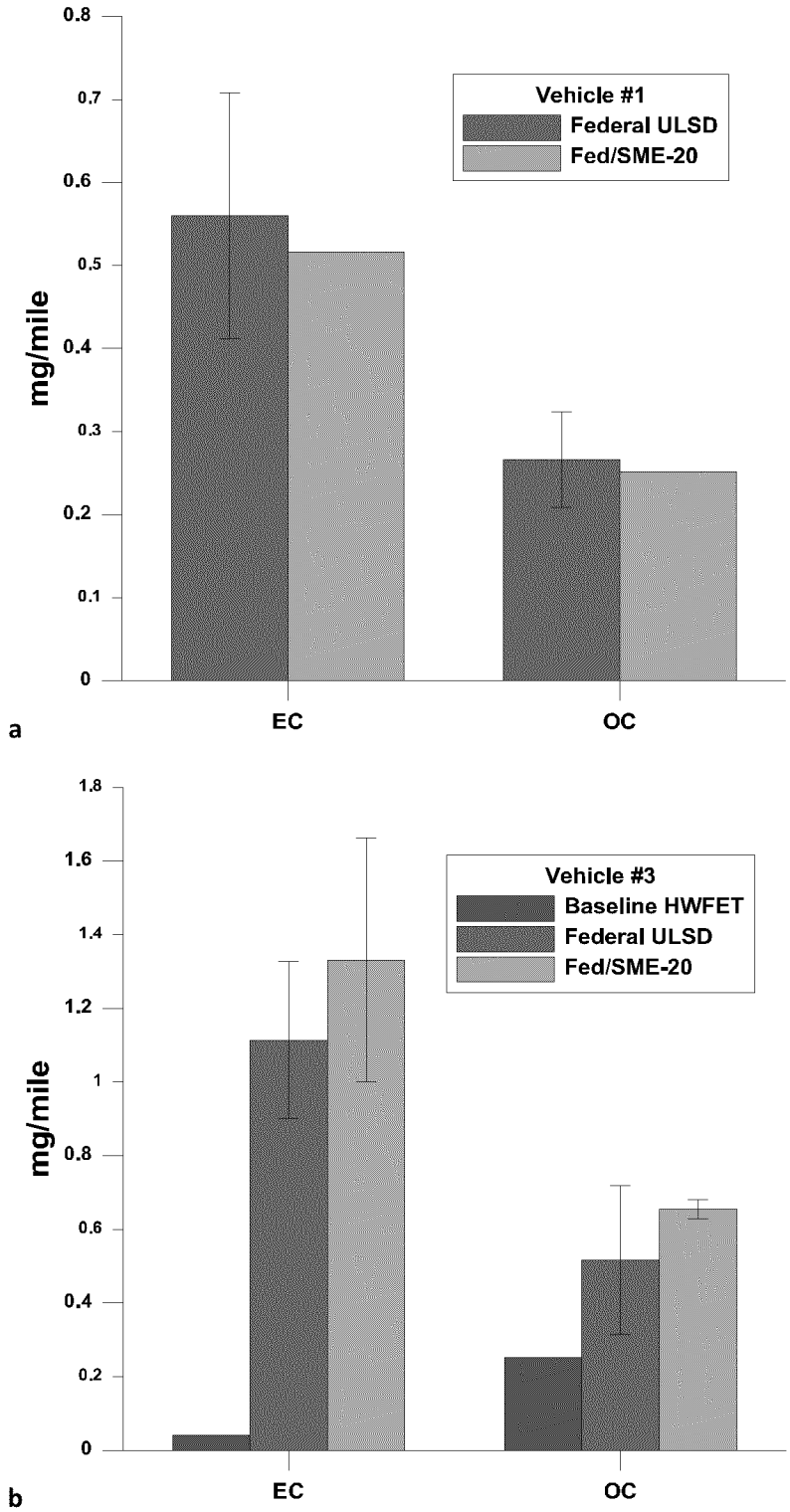

Figure 3-47 (a-b): EC/OC emissions for Vehicle #1 (a) and Vehicle #3 (b) during regeneration emission testing over the HWFET

Emissions of NH_3 are presented for Vehicle #1 during the baseline HWFET testing on Federal ULSD and the DPF regeneration testing on Federal ULSD and Fed/SME-20. For better representation of the results, the real-time traces of NH_3 and NO_x emissions over the HWFET

cycle are given to provide some insight on their formation mechanisms during the DPF regeneration event. Figure 3.48 (a-c) and Figure 3.49 (a-b) show the real-time NH_3 versus NO_x emissions, expressed in ppm, over the HWFET cycle for Vehicle #1. For the baseline HWFET testing, NH_3 emissions remained at very low concentrations throughout the entire cycle, while NO_x emissions showed some sharp peaks during the first 300 seconds of the cycle. Testing on the HWFET cycle was always done as a 'hot-start'; the vehicle was warmed up for 10-15 minutes at a steady state speed of 35-40 miles/hour followed by a soak period of approximately 15 minute prior to testing.

Figure 3.48 (b-c) presents the real-time NH_3 versus NO_x emissions during two regeneration emissions tests with the vehicle operated on Federal ULSD. For both tests, it can be observed that the DPF regeneration event started at approximately the same time, although the duration of the regeneration was somewhat different. Similar to the baseline HWFET testing, NO_x emissions appeared to peak during the first 150-200 seconds of the cycle, while NH_3 emissions were at very low levels prior to the start of the regeneration. During DPF regeneration, the opposite trend was observed with elevated NH_3 concentrations and low levels of NO_x emissions, suggesting that the SCR system enabled significant NO_x conversion during DPF regeneration. This result probably suggests that the operation of SCR is highly dependent on engine operating conditions when they affect the temperature of the aftertreatment system temperature and the exhaust, and the urea dosing strategy. It is interesting to note that elevated NH_3 concentrations (NH_3 slip) were seen during DPF regeneration, although it was expected that most of the NH_3 formed in excess of the amount needed to suppress NO_x emissions during regeneration would be combusted due to the high temperature in the DPF (greater than 550°C). Figure 3.49 (a-b) shows the real-time NH_3 versus NO_x emissions during the regeneration emissions testing when the vehicle was operated on Fed/SME-20 blend. The NH_3 and NO_x emissions show similar behavior for the Fed/SME-20 blend to that seen for the Federal ULSD during regeneration, indicating that emissions during regeneration are primarily a function of the operation of the vehicle, and don't show strong fuel trends.

It is noteworthy that for both fuels, NH_3 concentrations were seen at elevated levels during the first stages of the DPF regeneration event, while NO_x emissions during this same period were at almost negligible levels. It appeared that as the regeneration evolved, NH_3 concentrations decreased somewhat along with corresponding increase in NO_x emissions. Spikes in NO_x emissions were also seen at various points throughout the regeneration, in some cases during accelerations but in other cases during decelerations, indicating that NO_x emissions during regeneration were likely to be related to a combination of factors in the operation of the engine and the aftertreatment system.

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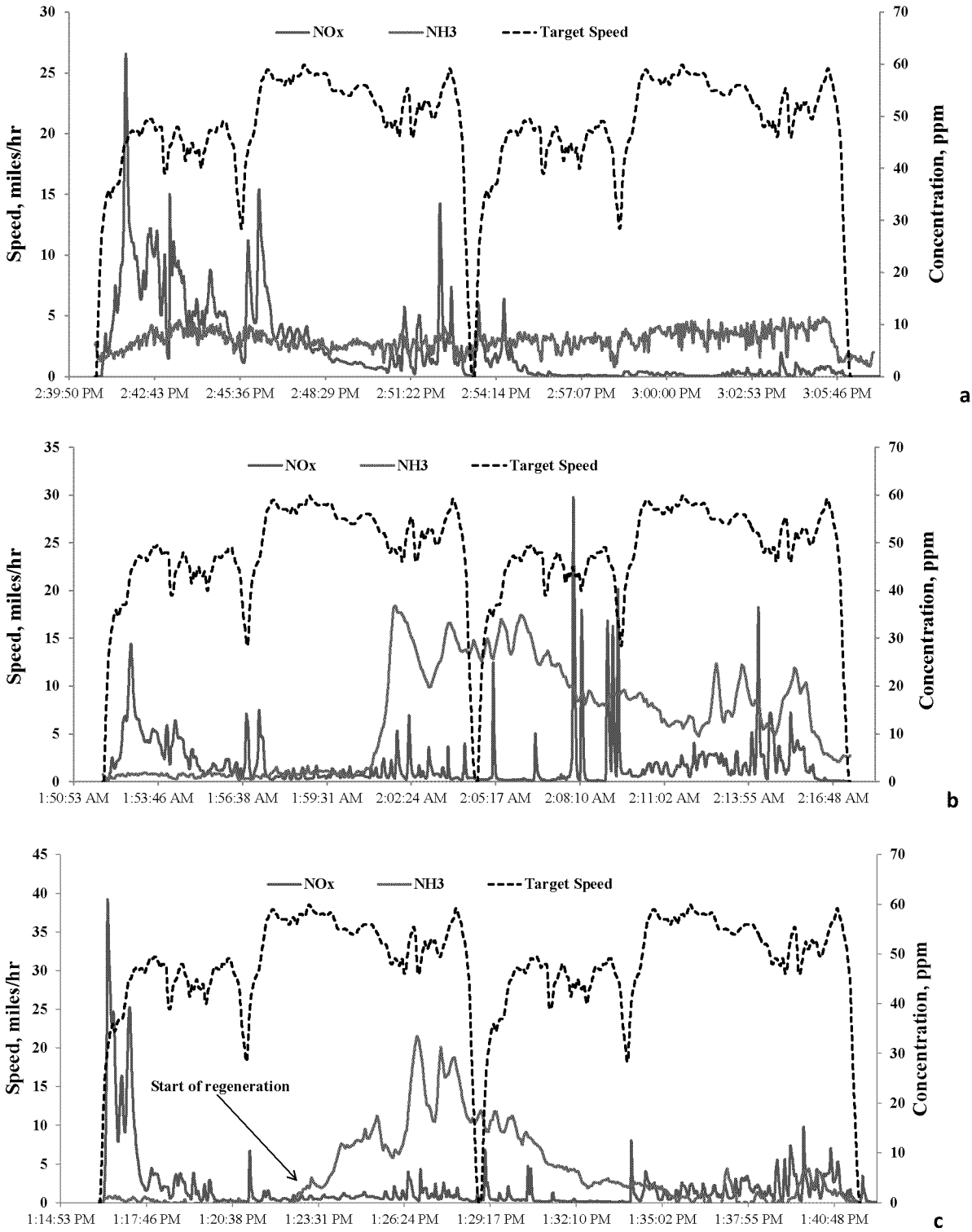

Figure 3-48 (a-c): Real-time NH_3 versus NO_x emissions for Vehicle #1 on Federal ULSD for the baseline HWFET testing (a), during regeneration emissions testing #1 (b) and regeneration emissions testing #2 (c)

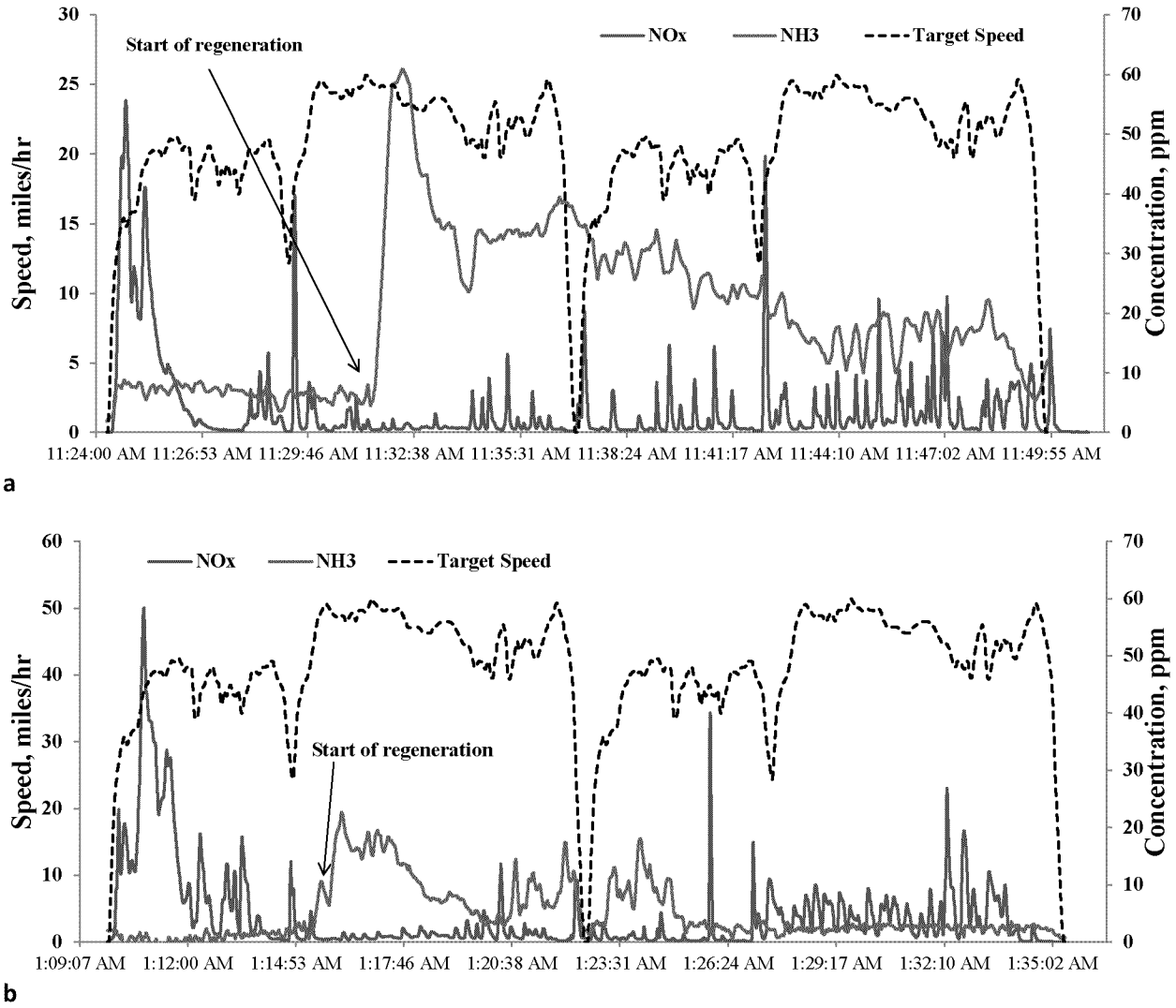

Figure 3-49 (a-b): Real-time NH_3 versus NO_x emissions for Vehicle #1 on Fed/SME-20 during regeneration emissions testing #1 (a) and regeneration emissions testing #2 (b) over the HWFET cycle

4. Summary

Currently, there is limited data on the emissions impacts of biofuels on light-duty diesel vehicles equipped with NO_x and PM emission control catalysts such as SCR and DPFs. The University of California, Riverside's College of Engineering-Center for Environmental Research and Technology (CE-CERT) and the Coordinating Research Council (CRC) have undertaken a comprehensive study, aimed specifically at understanding the effects of different biodiesel blends and renewable diesel blends on regulated and selected unregulated exhaust emissions from modern technology light-duty passenger cars and light-duty trucks. The resulting study was termed the 'CRC AVFL – 17b' program. This program was conducted in two phases. This report describes the analysis of the dataset collected in both phases of the AVFL-17b program. The effort encompassed emissions testing on eight light-duty diesel vehicles with seven different fuels over the Federal Test Procedure (FTP), including a Federal and California diesel, and five 20 vol% biodiesel and renewable diesel blends.

Test results for the fleet of eight vehicles are summarized below. They were tested for regulated emissions, fuel economy, particles, and toxic compounds. Statistical analyses on selected emission pollutants were performed using the Mixed procedure in PC/SAS from SAS Institute, Inc. For pollutants where the Mixed model showed that there were statistically significant differences between test fuels for FTP weighted composite or individual cycle phases, additional pairwise comparisons were performed using a least significant difference test to determine the specific fuel pairs that were statistically different. Results were classified as statistically significant for p " 0.05 and marginally statistically significant for $0.05 < p$ " 0.1.

- Overall, THC emissions showed trends of lower emissions with the use of some biodiesel blends and CARB ULSD compared to Federal ULSD. The weighted THC emissions showed statistically significant differences between fuels, with CARB ULSD and CARB/WCO-20 blend showing decreases of 18% and 16%, respectively, compared to Federal ULSD. Statistically significant increases in weighted THC emissions of 19% and 17%, respectively, were found for Fed/SME-20 and Fed/WCO-20 blends compared to CARB ULSD.
- For the weighted NMHC emissions, CARB ULSD and Fed/HVO-20 showed statistically significant reductions of 28% and 24%, respectively, compared to Federal ULSD. Compared to CARB ULSD, the blends of Fed/SME-20 and Fed/WCO-20 also showed statistically significant increases in NMHC emissions of 48% and 49%, respectively. Similar to THC emissions, the blends of Fed/AFME-20, Fed/WCO-20, and CARB/WCO-20 showed statistically significant reductions compared to Fed/SME-20.
- For the weighted CO emissions, the results revealed a statistically significant decrease of 31% and a marginally statistically significant decrease of 18% for CARB ULSD and CARB/WCO-20, respectively, compared to Federal ULSD. Compared to CARB ULSD, the blends of Fed/SME-20, Fed/AFME-20, Fed/WCO-20, and Fed/HVO-20 showed statistically significant increases in CO emissions on the order of 52%, 22%, 40%, and 26%, respectively. The blends of Fed/AFME-20 and CARB/WCO-20 showed statistically significant decreases in CO emissions on the order of 19% and 22%, respectively, compared to Fed/SME-20, while a 17% decrease was also seen for Fed/HVO-20 compared to Fed/SME-20 at a marginally statistically significant level.
- No statistically significant fuel effects were seen neither for weighted NO_x nor NO_x from any individual phase of the FTP. For the subset of vehicles where NO and NO_2 were measured, NO_2 emissions were the predominant nitrogen oxide species of three vehicles, while NO was the predominant species for the other two vehicles. NO, NO_2, and the NO/NO_2 ratio did not show any statistically significant fuel effects. The lack of fuel

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trends for the nitrogen oxides is largely a result of the presence of the SCR, which provides significant reductions that would likely negate any biodiesel fuel effects on these emissions. N_2O emissions did not show any statistically significant fuel effects for the same subset of vehicles.

- PM emission rates were below 3 mg/mi for all vehicles, ranging from approximately 0.18 to 2.65 mg/mi. PM mass emissions did not show any statistically significant differences between the test fuels. OC represented the predominant portion of the carbonaceous PM, with EC being at zero or near zero levels for most vehicles. The lack of fuel trends for the PM, OC, and EC is largely a result of the presence of the DPF, which provides significant reductions that would likely negate any biodiesel fuel effects on these emissions.
- An increasing trend in CO_2 emissions was observed with most of the biodiesel blends compared to the baseline Federal and CARB fuels. For the weighted CO_2 emissions, the results showed statistically significant increases of 1.9% for Fed/SME-20 and 2.3% for Fed/WCO-20 compared to Federal ULSD and of 1.7% for Fed/WCO-20 compared to CARB ULSD. The blend of Fed/WCO-20 showed a statistically significant increase in CO_2 emissions of 1.7% compared to Fed/AFME-20, whereas the blends of Fed/HVO-20 and CARB/WCO-20 showed statistically significant decreases of 2.5% and 1.7%, respectively, compared to Fed/WCO-20.
- For the weighted fuel economy, the results showed some strong effects for the Federal ULSD compared to CARB ULSD and the biofuel blends, but the CARB ULSD did not show strong effects compared to biodiesel blends. Compared to Federal ULSD, weighted fuel economy showed statistically significant decreases of 3.7%, 4.2%, 4.2%, 4.8%, 2.8%, and 5.7% for CARB ULSD, Fed/SME-20, Fed/AFME-20, Fed/WCO-20, Fed/HVO-20, and CARB/WCO-20. As expected, the CARB ULSD and the HVO blend showed smaller differences in fuel economy compared to the Federal ULSD. Compared to Federal ULSD, the heating values for Fed/SME-20, Fed/AFME-20, Fed/WCO-20, and CARB/WCO-20 were lower by 2.4%, 2.5%, 2.6%, and 1.3%, respectively, while the heating values for CARB ULSD and Fed/HVO-20 were higher by 1.2% and 0.8%, respectively. For CARB ULSD, the only statistically significant effect in weighted fuel economy was observed for CARB/WCO-20 blend, which showed a reduction of 2.1%. The blend of Fed/HVO-20 showed a statistically significant increase of 2.1% compared to Fed/WCO-20, while CARB/WCO-20 showed a statistically significant decrease of 3.0% compared to Fed/HVO-20.
- Particle number did not show any statistically significant fuel differences. The majority of particle number emissions were produced during cold start, during the first 200-300 seconds of the cycle.
- Particle size distributions were bimodal for most of the vehicles, showing particles in both the nucleation and accumulation modes, but some only showed unimodal distributions. Differences in particle size distributions between fuels were variable and not consistent from vehicle to vehicle.
- Formaldehyde and acetaldehyde were the predominant carbonyl compounds, although heavier carbonyl compounds were also identified. CARB ULSD showed a statistically significant decrease in formaldehyde emissions of 32% compared to Federal ULSD. Compared to CARB ULSD, the blends of Fed/SME-20, Fed/AFME-20, and Fed/WCO-20 showed statistically significant increases in formaldehyde emissions of 79%, 54%, and 75%, respectively. For acetaldehyde emissions, CARB ULSD showed a statistically significant decrease of 39% compared to Federal ULSD, whereas Fed/SME-20, Fed/WCO-20, and Fed/HVO-20 blends showed statistically significant increases of 79%, 72%, and 60%, respectively, compared to CARB ULSD. A marginally statistically significant increase of 53% for Fed/AFME-20 blend relative to CARB ULSD was also observed.

- Lower and medium molecular-weight compounds dominated the PAHs measured in the exhaust for all vehicle/fuel combinations, suggesting that these molecules were pyrolyzed from incomplete combustion of the fuel. Heavier PAHs were also found in the exhaust but in lesser amounts, suggesting that with increasing ring-number, PAHs were retained more efficiently in the DPF/DOC system. Total gas-phase PAH emissions were found in significantly higher concentrations than their corresponded particle-phase PAHs. The highest contributors to the gas-phase PAHs were mainly the two-membered ring compounds and their ethyl- and methyl-substitutes. The total PAH results for the biodiesel and the renewable diesel blends did not show clear trends, with some increases and some decreases in total PAH emissions compared to the baseline Federal and CARB ULSDs.
- The gas-phase nitro-PAHs were more abundant than particle-phase nitro-PAHs, with light weight compounds, such as nitronaphthalenes and methyl-substituted nitronaphthalenes, being dominant. The predominant species for the particle-phase nitro-PAHs were the nitrophenanthrenes and 1-nitropyrene. The biodiesel and the renewable diesel blends showed mixed results for gas- and particle-phase nitro-PAH emissions, with both increases and decreases. Statistically significant differences were only seen for gas-phase 1-nitronaphthalene emissions, with CARB ULSD and CARB/WCO-20 showing marginally statistically significant reductions of 87% and 89%, respectively, compared to Federal ULSD.
- Measureable NH_3 emissions were predominantly seen for Vehicle #1, which had average emissions ranging from 5.5 to 17.5 mg/mi, and Vehicle #2, which had average emissions ranging from 5.1 to 7.8 mg/mi. The NH_3 emissions for Vehicles #4 through #8 were near the background levels for most of the test matrix points, and generally had average NH_3 emissions of less than 1 mg/mi. In general, NH_3 emissions did not show any strong trends between the reference ULSDs and the biofuel blends for the fleet of eight vehicles.
- Emissions during regeneration showed increases compared to the baseline highway driving without regeneration. This tendency was seen for Vehicle #1 and for Vehicle #3 for the Fed/SME-20 blend but not as much for the Federal ULSD. Increases in emissions for some pollutants were seen for the biodiesel blend compared to the Federal ULSD, including THC, CH_4, particle number, black carbon, and formaldehyde for Vehicle #1, and THC, NMHC, CO, NO_x, CO_2, and formaldehyde for Vehicle #3. It was noteworthy that the use of biodiesel led to higher THC and CO emissions during the regeneration process, which could be an indication of poorer combustion efficiency relative to Federal ULSD. Particle size distributions during regeneration testing for both vehicles were dominated by the production of nucleation mode particles with peaks at around 10 nm in diameter. For other pollutants, biodiesel showed reductions in emissions relative to the Federal ULSD, including PAHs and gas-phase nitro-PAHs for Vehicle #1, and PM mass for Vehicle #3. Further analysis on the PAH results showed that biodiesel negatively influenced the formation of 2-ring PAH species during regeneration testing relative to Federal ULSD. It was also observed that certain nitrated species, which were practically below detection limits during baseline testing, increased with biodiesel relative to Federal ULSD during regeneration testing, suggesting that these species formed de novo in the DPF. The EC and OC emissions did not show strong fuel trends for the regeneration testing for either of the two vehicles tested, with the emissions for the Federal ULSD and the Fed/SME-20 being comparable in most cases within the experimental variability. During DPF regeneration, the concentrations of NH_3 were found at high levels (NH_3 slip) for both the Federal ULSD and the Fed/SME-20, while NO_x emissions were found at low concentrations, suggesting that the SCR system enabled significant NO_x conversion during DPF regeneration.

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Appendix A

Table A-1: Summary of statistical comparisons for different fuels

	Bag 1							Bag 2							Bag 3							Weighted						
NO_x	**LSM (g/mile)**																											
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
	0.193	0.219	0.217	0.211	0.219	0.210	0.206	0.016	0.019	0.015	0.016	0.014	0.022	0.017	0.045	0.049	0.041	0.044	0.055	0.047	0.049	0.066	0.075	0.071	0.070	0.074	0.073	0.071
	Statistical Analysis																											
	NS							NS							NS							NS						
THC	**LSM (g/mile)**																											
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
	0.109	0.087	0.115	0.095	0.108	0.097	0.094	0.018	0.015	0.017	0.015	0.016	0.015	0.014	0.019	0.016	0.016	0.017	0.016	0.018	0.017	0.040	0.032	0.039	0.034	0.038	0.035	0.033
	Statistical Analysis																											
	B 20% lower than A G 14% lower than A **C 31% higher than B** **E 24 % higher than B** **D 17% lower than C** **F 15% lower than C** **G 18% lower than C**							B 18% lower than A **G 23% lower than A** **G 20% lower than C**							NS							**B 18% lower than A** **G 16% lower than A** **C 19% higher than B** **E 17% higher than B** G 14% lower than C						
NMHC	**LSM (g/mile)**																											
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
	0.067	0.048	0.077	0.058	0.071	0.055	0.055	0.004	0.002	0.002	0.002	0.002	0.001	0.002	0.004	0.003	0.003	0.003	0.004	0.002	0.003	0.018	0.013	0.019	0.014	0.019	0.013	0.014
	Statistical Analysis																											
	B 29% lower than A **F 18% lower than A** **G 18% lower than A** **C 60% higher than B** D 20% higher than B **E 50% higher than B** **D 25% lower than C** **F 28% lower than C** **G 29% lower than C** **E 24% higher than D** **F 23% lower than E** **G 24% lower than E**							NS							**F 47% lower than A**							**B 28% lower than A** **F 24% lower than A** G 20% lower than A **C 48% higher than B** **E 49% higher than B** **D 24% lower than C** **F 29% lower than C** **G 26% lower than C** **E 32% higher than C** **E 32% higher than D** **F 29% lower than E** **G 26% lower than E**						
CH_4	**LSM (g/mile)**																											
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
	0.037	0.038	0.036	0.036	0.035	0.041	0.037	0.015	0.013	0.014	0.015	0.014	0.015	0.013	0.014	0.013	0.013	0.014	0.012	0.016	0.013	0.021	0.021	0.021	0.021	0.020	0.023	0.020
	Statistical Analysis																											

	Bag 1							Bag 2							Bag 3							Weighted						
	NS							G 13% lower than A F 14% higher than B G 13% lower than D **G 15% lower than F**							**F 22% higher than B** **F 21% higher than C** **F 27% higher than E** G 17% lower than F							**F 15% higher than E**						
CO	**LSM (g/mile)**																											
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
	0.772	0.534	0.815	0.657	0.753	0.662	0.631	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.003	0.002	0.002	0.002	0.002	0.003	0.002	0.164	0.114	0.172	0.139	0.159	0.144	0.134
	Statistical Analysis																											
	B 31% lower than A **G 18% lower than A** **C 53% higher than B** **D 23% higher than B** **E 41% higher than B** **F 24% higher than B** **D 19% lower than C** **F 19% lower than C** **G 23% lower than C**							NS							NS							**B 31% lower than A** G 18% lower than A **C 52% higher than B** **D 22% higher than B** **E 40% higher than B** **F 26% higher than B** **D 19% lower than C** F 17% lower than C **G 22% lower than C**						
CO_2	**LSM (g/mile)**																											
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
	529	531	533	528	538	523	525	452	456	462	457	464	453	458	421	422	430	423	431	420	423	460	462	469	463	470	459	462
	Statistical Analysis																											
	F 2.8% lower than E **G 2.4% lower than E**							**C 2.3% higher than A** **E 2.6% higher than A** **E 1.8% higher than B** **F 2.1% lower than C** **F 2.4% lower than E**							C 2.3% higher than A E 2.4% higher than A **F 2.4% lower than C** **F 2.4% lower than E**							**C 1.9% higher than A** **E 1.7% higher than A** **E 2.3% higher than B** **F 2.1% lower than C** **E 1.7% higher than D** **F 2.5% lower than E** **G 1.7% lower than E**						
FE	**LSM (miles/gallon)**																											
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
	0.044	0.046	0.046	0.046	0.046	0.045	0.047	0.038	0.040	0.040	0.040	0.040	0.039	0.041	0.035	0.036	0.037	0.037	0.037	0.036	0.037	0.039	0.040	0.040	0.040	0.041	0.040	0.041
	Statistical Analysis																											
	B 3.4% lower than A **C 3.3% lower than A** **D 3.8% lower than A** **E 4.3% lower than A** F 2.1% lower than A **G 4.6% lower than A** F 2.3% higher than E G 2.5% lower than F							**B 3.9% lower than A** **C 4.5% lower than A** **D 4.5% lower than A** **E 5.2% lower than A** **F 3.2% lower than A** **G 6.4% lower than A** **G 2.7 lower than B** F 2.1% higher than E **G 3.4% lower than F**							**B 3.6% lower than A** **C 4.7% lower than A** **D 3.9% lower than A** **E 4.6% lower than A** F 2.8 % lower than A **G 5.6% lower than A** G 2.9% lower than F							**B 3.7% lower than A** **C 4.2% lower than A** **D 4.2% lower than A** **E 4.6% lower than A** **F 2.8 % lower than A** **G 5.7% lower than A** **G 2.1% lower than B** **F 2.1% higher than E** **G 3.0% lower than F**						
PN	**LSM (particles/mile)**																											
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G

	Bag 1							Bag 2							Bag 3							Weighted						
	3.27E+10	3.83E+10	4.79E+10	5.91E+10	3.20E+10	5.26E+10	5.21E+10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.52E+10	1.69E+10	1.95E+10	2.44E+10	1.33E+10	2.27E+10	2.31E+10
	Statistical Analysis																											
	NS							NA							NA							NS						
PM	**LSM (mg/mile)**																											
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
																						0.871	0.917	0.815	0.731	0.776	0.913	1.139
	Statistical Analysis																											
																						NS						
Formaldehyde	**LSM (µg/mile)**																											
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
																						4744	3227	5780	4986	5639	4384	4202
	Statistical Analysis																											
																						B 32% lower than A **C 79% higher than B** **D 54% higher than B** **E 75% higher than B**						
Acetaldehyde	**LSM (µg/mile)**																											
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
																						1543	943	1684	1440	1622	1509	1408
	Statistical Analysis																											
																						B 39% lower than A **C 79% higher than B** **E 72% higher than B** **F 60% higher than B** D 53% higher than B						
EC	**LSM (mg/mile)**																											
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
																						0.028	0.027	0.051	0.027	0.024	0.020	0.024
	Statistical Analysis																											
																						NS						
OC	**LSM (mg/mile)**																											
	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
																						0.255	0.374	0.409	0.363	0.334	0.349	0.351
	Statistical Analysis																											
																						NS						

Where: A= Fed ULSD; B=CARB ULSD; C=Fed/SME-20; D=Fed/AFME-20; E=Fed/WCO-20; F=Fed/HVO-20; and G=CARB/WCO-20
Bold values are statistically significant p ” 0.05; *Underlined values are marginally statistically significant 0.05 < p ≤ 0.1*

Appendix B

Table B1: Least square means for cold-start THC emissions

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	-2.2122	0.10946
fuel2	B	-2.4376	0.08737
fuel2	C	-2.1662	0.114612
fuel2	D	-2.3570	0.094704
fuel2	E	-2.2243	0.108143
fuel2	F	-2.3295	0.097344
fuel2	G	-2.3680	0.093668

Table B2: Multiple comparisons and p values for cold-start THC emissions

Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.2254	0.05236	124	4.30	<.0001	Tukey-Kramer	0.0007
fuel2	A	C	-0.04600	0.05307	124	-0.87	0.3878	Tukey-Kramer	0.9768
fuel2	A	D	0.1447	0.05433	124	2.66	0.0088	Tukey-Kramer	0.1165
fuel2	A	E	0.01208	0.05368	124	0.22	0.8224	Tukey-Kramer	1.0000
fuel2	A	F	0.1172	0.05352	124	2.19	0.0304	Tukey-Kramer	0.3084
fuel2	A	G	0.1558	0.05588	124	2.79	0.0062	Tukey-Kramer	0.0864
fuel2	B	C	-0.2714	0.05111	124	-5.31	<.0001	Tukey-Kramer	<.0001
fuel2	B	D	-0.08068	0.05243	124	-1.54	0.1264	Tukey-Kramer	0.7209
fuel2	B	E	-0.2133	0.05178	124	-4.12	<.0001	Tukey-Kramer	0.0013
fuel2	B	F	-0.1082	0.05171	124	-2.09	0.0385	Tukey-Kramer	0.3638
fuel2	B	G	-0.06964	0.05398	124	-1.29	0.1995	Tukey-Kramer	0.8554
fuel2	C	D	0.1907	0.05299	124	3.60	0.0005	Tukey-Kramer	0.0082
fuel2	C	E	0.05808	0.05219	124	1.11	0.2680	Tukey-Kramer	0.9232
fuel2	C	F	0.1632	0.05234	124	3.12	0.0023	Tukey-Kramer	0.0357
fuel2	C	G	0.2018	0.05454	124	3.70	0.0003	Tukey-Kramer	0.0058
fuel2	D	E	-0.1326	0.05367	124	-2.47	0.0148	Tukey-Kramer	0.1790

Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	D	F	-0.02750	0.05368	124	-0.51	0.6093	Tukey-Kramer	0.9986
fuel2	D	G	0.01105	0.05580	124	0.20	0.8434	Tukey-Kramer	1.0000
fuel2	E	F	0.1051	0.05295	124	1.99	0.0493	Tukey-Kramer	0.4290
fuel2	E	G	0.1437	0.05523	124	2.60	0.0104	Tukey-Kramer	0.1345
fuel2	F	G	0.03855	0.05523	124	0.70	0.4865	Tukey-Kramer	0.9925

Table B3: Least square means for hot-running THC emissions

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	-4.0333	0.017716
fuel2	B	-4.2296	0.014558
fuel2	C	-4.0797	0.016913
fuel2	D	-4.1733	0.015401
fuel2	E	-4.1166	0.0163
fuel2	F	-4.1999	0.014997
fuel2	G	-4.2989	0.013583

Table B4: Multiple comparisons and p values for hot-running THC emissions

Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.1963	0.06600	124	2.97	0.0035	Tukey-Kramer	0.0532
fuel2	A	C	0.04638	0.06690	124	0.69	0.4894	Tukey-Kramer	0.9928
fuel2	A	D	0.1400	0.06848	124	2.04	0.0430	Tukey-Kramer	0.3925
fuel2	A	E	0.08328	0.06766	124	1.23	0.2207	Tukey-Kramer	0.8808
fuel2	A	F	0.1666	0.06746	124	2.47	0.0149	Tukey-Kramer	0.1794
fuel2	A	G	0.2656	0.07044	124	3.77	0.0003	Tukey-Kramer	0.0046
fuel2	B	C	-0.1499	0.06442	124	-2.33	0.0216	Tukey-Kramer	0.2394
fuel2	B	D	-0.05633	0.06610	124	-0.85	0.3957	Tukey-Kramer	0.9787
fuel2	B	E	-0.1131	0.06527	124	-1.73	0.0858	Tukey-Kramer	0.5961
fuel2	B	F	-0.02968	0.06518	124	-0.46	0.6496	Tukey-Kramer	0.9993

Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	B	G	0.06924	0.06805	124	1.02	0.3109	Tukey-Kramer	0.9491
fuel2	C	D	0.09362	0.06680	124	1.40	0.1635	Tukey-Kramer	0.8001
fuel2	C	E	0.03690	0.06579	124	0.56	0.5759	Tukey-Kramer	0.9977
fuel2	C	F	0.1203	0.06598	124	1.82	0.0707	Tukey-Kramer	0.5354
fuel2	C	G	0.2192	0.06876	124	3.19	0.0018	Tukey-Kramer	0.0292
fuel2	D	E	-0.05672	0.06766	124	-0.84	0.4034	Tukey-Kramer	0.9804
fuel2	D	F	0.02665	0.06766	124	0.39	0.6944	Tukey-Kramer	0.9997
fuel2	D	G	0.1256	0.07034	124	1.79	0.0767	Tukey-Kramer	0.5605
fuel2	E	F	0.08337	0.06674	124	1.25	0.2140	Tukey-Kramer	0.8732
fuel2	E	G	0.1823	0.06962	124	2.62	0.0099	Tukey-Kramer	0.1294
fuel2	F	G	0.09892	0.06962	124	1.42	0.1579	Tukey-Kramer	0.7896

Table B5: Least squares means for weighted THC emissions

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	-3.2314	0.03950216
fuel2	B	-3.4285	0.03243556
fuel2	C	-3.2542	0.0386117
fuel2	D	-3.3670	0.03449296
fuel2	E	-3.2706	0.03798363
fuel2	F	-3.3386	0.0354866
fuel2	G	-3.3999	0.03337661

Table B6: Multiple comparisons and p values for weighted THC emissions

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.1971	0.04821	124	4.09	<.0001	Tukey-Kramer	0.0015
fuel2	A	C	0.02274	0.04886	124	0.47	0.6425	Tukey-Kramer	0.9992
fuel2	A	D	0.1355	0.05002	124	2.71	0.0077	Tukey-Kramer	0.1046

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	E	0.03911	0.04942	124	0.79	0.4302	Tukey-Kramer	0.9854
fuel2	A	F	0.1071	0.04927	124	2.17	0.0316	Tukey-Kramer	0.3169
fuel2	A	G	0.1684	0.05145	124	3.27	0.0014	Tukey-Kramer	0.0227
fuel2	B	C	-0.1744	0.04705	124	-3.71	0.0003	Tukey-Kramer	0.0057
fuel2	B	D	-0.06158	0.04828	124	-1.28	0.2045	Tukey-Kramer	0.8618
fuel2	B	E	-0.1580	0.04767	124	-3.31	0.0012	Tukey-Kramer	0.0201
fuel2	B	F	-0.08995	0.04761	124	-1.89	0.0612	Tukey-Kramer	0.4913
fuel2	B	G	-0.02864	0.04970	124	-0.58	0.5654	Tukey-Kramer	0.9974
fuel2	C	D	0.1128	0.04879	124	2.31	0.0225	Tukey-Kramer	0.2470
fuel2	C	E	0.01637	0.04805	124	0.34	0.7339	Tukey-Kramer	0.9999
fuel2	C	F	0.08441	0.04819	124	1.75	0.0823	Tukey-Kramer	0.5830
fuel2	C	G	0.1457	0.05022	124	2.90	0.0044	Tukey-Kramer	0.0646
fuel2	D	E	-0.09640	0.04941	124	-1.95	0.0533	Tukey-Kramer	0.4512
fuel2	D	F	-0.02836	0.04942	124	-0.57	0.5671	Tukey-Kramer	0.9974
fuel2	D	G	0.03294	0.05137	124	0.64	0.5226	Tukey-Kramer	0.9953
fuel2	E	F	0.06803	0.04875	124	1.40	0.1653	Tukey-Kramer	0.8032
fuel2	E	G	0.1293	0.05085	124	2.54	0.0122	Tukey-Kramer	0.1531
fuel2	F	G	0.06130	0.05085	124	1.21	0.2303	Tukey-Kramer	0.8908

Table B7: Least square means for cold-start NMHC emissions

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	-2.7037	0.06695731
fuel2	B	-3.0413	0.04777274
fuel2	C	-2.5701	0.07652789
fuel2	D	-2.8553	0.05753856
fuel2	E	-2.6386	0.07146125
fuel2	F	-2.9041	0.05479809

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	G	-2.9079	0.05459025

Table B8: Multiple comparisons and p values for cold-start NMHC emissions

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.3376	0.06281	124	5.37	<.0001	Tukey-Kramer	<.0001
fuel2	A	C	-0.1336	0.06366	124	-2.10	0.0379	Tukey-Kramer	0.3601
fuel2	A	D	0.1516	0.06517	124	2.33	0.0216	Tukey-Kramer	0.2399
fuel2	A	E	-0.06506	0.06439	124	-1.01	0.3143	Tukey-Kramer	0.9508
fuel2	A	F	0.2004	0.06420	124	3.12	0.0022	Tukey-Kramer	0.0354
fuel2	A	G	0.2042	0.06703	124	3.05	0.0028	Tukey-Kramer	0.0438
fuel2	B	C	-0.4712	0.06130	124	-7.69	<.0001	Tukey-Kramer	<.0001
fuel2	B	D	-0.1860	0.06290	124	-2.96	0.0037	Tukey-Kramer	0.0558
fuel2	B	E	-0.4026	0.06211	124	-6.48	<.0001	Tukey-Kramer	<.0001
fuel2	B	F	-0.1372	0.06203	124	-2.21	0.0288	Tukey-Kramer	0.2970
fuel2	B	G	-0.1334	0.06475	124	-2.06	0.0415	Tukey-Kramer	0.3829
fuel2	C	D	0.2852	0.06356	124	4.49	<.0001	Tukey-Kramer	0.0003
fuel2	C	E	0.06853	0.06261	124	1.09	0.2758	Tukey-Kramer	0.9286
fuel2	C	F	0.3340	0.06278	124	5.32	<.0001	Tukey-Kramer	<.0001
fuel2	C	G	0.3378	0.06543	124	5.16	<.0001	Tukey-Kramer	<.0001
fuel2	D	E	-0.2167	0.06438	124	-3.37	0.0010	Tukey-Kramer	0.0172
fuel2	D	F	0.04880	0.06438	124	0.76	0.4499	Tukey-Kramer	0.9884
fuel2	D	G	0.05258	0.06693	124	0.79	0.4336	Tukey-Kramer	0.9860
fuel2	E	F	0.2655	0.06351	124	4.18	<.0001	Tukey-Kramer	0.0011
fuel2	E	G	0.2692	0.06625	124	4.06	<.0001	Tukey-Kramer	0.0016
fuel2	F	G	0.003772	0.06625	124	0.06	0.9547	Tukey-Kramer	1.0000

Table B9: Least square means for hot-start NMHC emissions

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	-5.4478	0.00400577

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	B	-5.6448	0.00323586
fuel2	C	-5.6486	0.00322244
fuel2	D	-5.5824	0.00346352
fuel2	E	-5.4501	0.00399588
fuel2	F	-6.0286	0.00210886
fuel2	G	-5.6050	0.00337942

Table B10: Multiple comparisons and p values for hot-start NMHC emissions

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.1970	0.1862	124	1.06	0.2923	Tukey-Kramer	0.9390
fuel2	A	C	0.2008	0.1888	124	1.06	0.2896	Tukey-Kramer	0.9375
fuel2	A	D	0.1346	0.1932	124	0.70	0.4875	Tukey-Kramer	0.9926
fuel2	A	E	0.002269	0.1909	124	0.01	0.9905	Tukey-Kramer	1.0000
fuel2	A	F	0.5808	0.1904	124	3.05	0.0028	Tukey-Kramer	0.0431
fuel2	A	G	0.1571	0.1988	124	0.79	0.4308	Tukey-Kramer	0.9855
fuel2	B	C	0.003790	0.1818	124	0.02	0.9834	Tukey-Kramer	1.0000
fuel2	B	D	-0.06240	0.1865	124	-0.33	0.7385	Tukey-Kramer	0.9999
fuel2	B	E	-0.1947	0.1842	124	-1.06	0.2925	Tukey-Kramer	0.9392
fuel2	B	F	0.3839	0.1839	124	2.09	0.0389	Tukey-Kramer	0.3669
fuel2	B	G	-0.03984	0.1920	124	-0.21	0.8360	Tukey-Kramer	1.0000
fuel2	C	D	-0.06619	0.1885	124	-0.35	0.7261	Tukey-Kramer	0.9998
fuel2	C	E	-0.1985	0.1856	124	-1.07	0.2871	Tukey-Kramer	0.9359
fuel2	C	F	0.3801	0.1862	124	2.04	0.0433	Tukey-Kramer	0.3943
fuel2	C	G	-0.04363	0.1940	124	-0.22	0.8224	Tukey-Kramer	1.0000
fuel2	D	E	-0.1323	0.1909	124	-0.69	0.4896	Tukey-Kramer	0.9928
fuel2	D	F	0.4463	0.1909	124	2.34	0.0210	Tukey-Kramer	0.2349
fuel2	D	G	0.02256	0.1985	124	0.11	0.9097	Tukey-Kramer	1.0000
fuel2	E	F	0.5785	0.1883	124	3.07	0.0026	Tukey-Kramer	0.0407

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	E	G	0.1549	0.1965	124	0.79	0.4321	Tukey-Kramer	0.9857
fuel2	F	G	-0.4237	0.1964	124	-2.16	0.0330	Tukey-Kramer	0.3267

Table B11: Least squares means for weighted NMHC emissions

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	-4.0379	0.01763447
fuel2	B	-4.3600	0.01277839
fuel2	C	-3.9681	0.01890933
fuel2	D	-4.2437	0.01435438
fuel2	E	-3.9641	0.01898512
fuel2	F	-4.3111	0.01341878
fuel2	G	-4.2659	0.01403923

Table B12: Multiple comparisons and p values for weighted NMHC emissions

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.3221	0.07551	124	4.27	<.0001	Tukey-Kramer	0.0008
fuel2	A	C	-0.06984	0.07653	124	-0.91	0.3632	Tukey-Kramer	0.9699
fuel2	A	D	0.2058	0.07835	124	2.63	0.0097	Tukey-Kramer	0.1269
fuel2	A	E	-0.07376	0.07741	124	-0.95	0.3425	Tukey-Kramer	0.9628
fuel2	A	F	0.2732	0.07718	124	3.54	0.0006	Tukey-Kramer	0.0099
fuel2	A	G	0.2280	0.08059	124	2.83	0.0055	Tukey-Kramer	0.0778
fuel2	B	C	-0.3919	0.07370	124	-5.32	<.0001	Tukey-Kramer	<.0001
fuel2	B	D	-0.1163	0.07562	124	-1.54	0.1268	Tukey-Kramer	0.7218
fuel2	B	E	-0.3958	0.07468	124	-5.30	<.0001	Tukey-Kramer	<.0001
fuel2	B	F	-0.04888	0.07457	124	-0.66	0.5133	Tukey-Kramer	0.9947
fuel2	B	G	-0.09408	0.07785	124	-1.21	0.2291	Tukey-Kramer	0.8897

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	C	D	0.2757	0.07642	124	3.61	0.0004	Tukey-Kramer	0.0079
fuel2	C	E	-0.00392	0.07527	124	-0.05	0.9585	Tukey-Kramer	1.0000
fuel2	C	F	0.3430	0.07548	124	4.54	<.0001	Tukey-Kramer	0.0003
fuel2	C	G	0.2978	0.07866	124	3.79	0.0002	Tukey-Kramer	0.0043
fuel2	D	E	-0.2796	0.07740	124	-3.61	0.0004	Tukey-Kramer	0.0078
fuel2	D	F	0.06737	0.07741	124	0.87	0.3858	Tukey-Kramer	0.9763
fuel2	D	G	0.02217	0.08047	124	0.28	0.7834	Tukey-Kramer	1.0000
fuel2	E	F	0.3469	0.07636	124	4.54	<.0001	Tukey-Kramer	0.0003
fuel2	E	G	0.3017	0.07965	124	3.79	0.0002	Tukey-Kramer	0.0043
fuel2	F	G	-0.04520	0.07965	124	-0.57	0.5714	Tukey-Kramer	0.9976

Table B13: Least square means for hot-running CH_4 emissions

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	-4.2269	0.01459757
fuel2	B	-4.3245	0.01324017
fuel2	C	-4.2367	0.01445522
fuel2	D	-4.2247	0.01462972
fuel2	E	-4.2783	0.01386621
fuel2	F	-4.1976	0.01503161
fuel2	G	-4.3623	0.01274903

Table B14: Multiple comparisons and p values for hot-running CH_4 emissions

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.09762	0.04481	124	2.18	0.0313	Tukey-Kramer	0.3147
fuel2	A	C	0.009819	0.04542	124	0.22	0.8292	Tukey-Kramer	1.0000
fuel2	A	D	-0.00222	0.04649	124	-0.05	0.9620	Tukey-Kramer	1.0000

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	E	0.05143	0.04594	124	1.12	0.2651	Tukey-Kramer	0.9210
fuel2	A	F	-0.02937	0.04580	124	-0.64	0.5226	Tukey-Kramer	0.9953
fuel2	A	G	0.1354	0.04783	124	2.83	0.0054	Tukey-Kramer	0.0774
fuel2	B	C	-0.08781	0.04374	124	-2.01	0.0469	Tukey-Kramer	0.4152
fuel2	B	D	-0.09984	0.04487	124	-2.22	0.0279	Tukey-Kramer	0.2899
fuel2	B	E	-0.04620	0.04432	124	-1.04	0.2992	Tukey-Kramer	0.9430
fuel2	B	F	-0.1270	0.04425	124	-2.87	0.0048	Tukey-Kramer	0.0701
fuel2	B	G	0.03777	0.04620	124	0.82	0.4152	Tukey-Kramer	0.9828
fuel2	C	D	-0.01204	0.04535	124	-0.27	0.7911	Tukey-Kramer	1.0000
fuel2	C	E	0.04161	0.04467	124	0.93	0.3534	Tukey-Kramer	0.9667
fuel2	C	F	-0.03919	0.04479	124	-0.87	0.3834	Tukey-Kramer	0.9757
fuel2	C	G	0.1256	0.04668	124	2.69	0.0081	Tukey-Kramer	0.1094
fuel2	D	E	0.05365	0.04593	124	1.17	0.2451	Tukey-Kramer	0.9048
fuel2	D	F	-0.02715	0.04594	124	-0.59	0.5556	Tukey-Kramer	0.9970
fuel2	D	G	0.1376	0.04775	124	2.88	0.0047	Tukey-Kramer	0.0679
fuel2	E	F	-0.08080	0.04531	124	-1.78	0.0770	Tukey-Kramer	0.5620
fuel2	E	G	0.08397	0.04727	124	1.78	0.0781	Tukey-Kramer	0.5664
fuel2	F	G	0.1648	0.04727	124	3.49	0.0007	Tukey-Kramer	0.0118

Table B15: Least square means for hot-start CH_4 emissions

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	-4.2663	0.01403361
fuel2	B	-4.3516	0.01288618
fuel2	C	-4.3429	0.01299878
fuel2	D	-4.2711	0.01396641
fuel2	E	-4.3909	0.01238957
fuel2	F	-4.1553	0.01568109

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	G	-4.3387	0.01305349

Table B16: Multiple comparisons and p values for hot-start CH_4 emissions

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.08532	0.06041	124	1.41	0.1603	Tukey-Kramer	0.7942
fuel2	A	C	0.07657	0.06123	124	1.25	0.2134	Tukey-Kramer	0.8726
fuel2	A	D	0.004795	0.06267	124	0.08	0.9391	Tukey-Kramer	1.0000
fuel2	A	E	0.1246	0.06193	124	2.01	0.0464	Tukey-Kramer	0.4127
fuel2	A	F	-0.1110	0.06174	124	-1.80	0.0747	Tukey-Kramer	0.5523
fuel2	A	G	0.07235	0.06447	124	1.12	0.2639	Tukey-Kramer	0.9202
fuel2	B	C	-0.00875	0.05896	124	-0.15	0.8822	Tukey-Kramer	1.0000
fuel2	B	D	-0.08053	0.06049	124	-1.33	0.1856	Tukey-Kramer	0.8360
fuel2	B	E	0.03925	0.05974	124	0.66	0.5124	Tukey-Kramer	0.9946
fuel2	B	F	-0.1963	0.05966	124	-3.29	0.0013	Tukey-Kramer	0.0216
fuel2	B	G	-0.01297	0.06228	124	-0.21	0.8353	Tukey-Kramer	1.0000
fuel2	C	D	-0.07178	0.06113	124	-1.17	0.2426	Tukey-Kramer	0.9026
fuel2	C	E	0.04800	0.06021	124	0.80	0.4268	Tukey-Kramer	0.9849
fuel2	C	F	-0.1876	0.06038	124	-3.11	0.0024	Tukey-Kramer	0.0370
fuel2	C	G	-0.00422	0.06293	124	-0.07	0.9466	Tukey-Kramer	1.0000
fuel2	D	E	0.1198	0.06192	124	1.93	0.0553	Tukey-Kramer	0.4618
fuel2	D	F	-0.1158	0.06192	124	-1.87	0.0639	Tukey-Kramer	0.5042
fuel2	D	G	0.06756	0.06437	124	1.05	0.2960	Tukey-Kramer	0.9412
fuel2	E	F	-0.2356	0.06108	124	-3.86	0.0002	Tukey-Kramer	0.0034
fuel2	E	G	-0.05222	0.06372	124	-0.82	0.4140	Tukey-Kramer	0.9825
fuel2	F	G	0.1833	0.06372	124	2.88	0.0047	Tukey-Kramer	0.0687

Table B17: Least squares means for weighted CH_4 emissions

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	-3.8583	0.02110385

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	B	-3.8767	0.02071909
fuel2	C	-3.8863	0.02052113
fuel2	D	-3.8664	0.02093359
fuel2	E	-3.9115	0.02001046
fuel2	F	-3.7730	0.02298301
fuel2	G	-3.8898	0.02044944

Table B18: Multiple comparisons and p values for weighted CH_4 emissions

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.01843	0.04258	124	0.43	0.6659	Tukey-Kramer	0.9995
fuel2	A	C	0.02804	0.04316	124	0.65	0.5172	Tukey-Kramer	0.9949
fuel2	A	D	0.008050	0.04418	124	0.18	0.8557	Tukey-Kramer	1.0000
fuel2	A	E	0.05319	0.04366	124	1.22	0.2254	Tukey-Kramer	0.8858
fuel2	A	F	-0.08532	0.04353	124	-1.96	0.0522	Tukey-Kramer	0.4452
fuel2	A	G	0.03149	0.04545	124	0.69	0.4897	Tukey-Kramer	0.9928
fuel2	B	C	0.009606	0.04156	124	0.23	0.8176	Tukey-Kramer	1.0000
fuel2	B	D	-0.01038	0.04265	124	-0.24	0.8081	Tukey-Kramer	1.0000
fuel2	B	E	0.03476	0.04211	124	0.83	0.4108	Tukey-Kramer	0.9819
fuel2	B	F	-0.1038	0.04206	124	-2.47	0.0150	Tukey-Kramer	0.1806
fuel2	B	G	0.01306	0.04390	124	0.30	0.7666	Tukey-Kramer	0.9999
fuel2	C	D	-0.01999	0.04310	124	-0.46	0.6436	Tukey-Kramer	0.9992
fuel2	C	E	0.02515	0.04245	124	0.59	0.5546	Tukey-Kramer	0.9969
fuel2	C	F	-0.1134	0.04257	124	-2.66	0.0088	Tukey-Kramer	0.1167
fuel2	C	G	0.003454	0.04436	124	0.08	0.9381	Tukey-Kramer	1.0000
fuel2	D	E	0.04514	0.04365	124	1.03	0.3031	Tukey-Kramer	0.9451

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	D	F	-0.09337	0.04365	124	-2.14	0.0344	Tukey-Kramer	0.3368
fuel2	D	G	0.02344	0.04538	124	0.52	0.6064	Tukey-Kramer	0.9986
fuel2	E	F	-0.1385	0.04306	124	-3.22	0.0017	Tukey-Kramer	0.0269
fuel2	E	G	-0.02170	0.04492	124	-0.48	0.6299	Tukey-Kramer	0.9990
fuel2	F	G	0.1168	0.04492	124	2.60	0.0104	Tukey-Kramer	0.1348

Table B19: Least squares means for cold-start CO emissions

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	-0.2589	0.77190021
fuel2	B	-0.6270	0.53419198
fuel2	C	-0.2050	0.81464732
fuel2	D	-0.4198	0.65717824
fuel2	E	-0.2835	0.75314312
fuel2	F	-0.4125	0.6619932
fuel2	G	-0.4601	0.63122052

Table B20: Multiple comparisons and p values for cold-start CO emissions

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.3681	0.06208	124	5.93	<.0001	Tukey-Kramer	<.0001
fuel2	A	C	-0.05392	0.06292	124	-0.86	0.3931	Tukey-Kramer	0.9781
fuel2	A	D	0.1609	0.06441	124	2.50	0.0138	Tukey-Kramer	0.1692
fuel2	A	E	0.02465	0.06364	124	0.39	0.6991	Tukey-Kramer	0.9997
fuel2	A	F	0.1536	0.06345	124	2.42	0.0169	Tukey-Kramer	0.1989
fuel2	A	G	0.2013	0.06625	124	3.04	0.0029	Tukey-Kramer	0.0448
fuel2	B	C	-0.4221	0.06059	124	-6.97	<.0001	Tukey-Kramer	<.0001
fuel2	B	D	-0.2073	0.06216	124	-3.33	0.0011	Tukey-Kramer	0.0189

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	B	E	-0.3435	0.06139	124	-5.60	<.0001	Tukey-Kramer	<.0001
fuel2	B	F	-0.2146	0.06131	124	-3.50	0.0006	Tukey-Kramer	0.0113
fuel2	B	G	-0.1669	0.06400	124	-2.61	0.0102	Tukey-Kramer	0.1326
fuel2	C	D	0.2148	0.06282	124	3.42	0.0009	Tukey-Kramer	0.0146
fuel2	C	E	0.07857	0.06188	124	1.27	0.2065	Tukey-Kramer	0.8644
fuel2	C	F	0.2075	0.06205	124	3.34	0.0011	Tukey-Kramer	0.0183
fuel2	C	G	0.2552	0.06467	124	3.95	0.0001	Tukey-Kramer	0.0025
fuel2	D	E	-0.1362	0.06363	124	-2.14	0.0343	Tukey-Kramer	0.3358
fuel2	D	F	-0.00728	0.06363	124	-0.11	0.9091	Tukey-Kramer	1.0000
fuel2	D	G	0.04039	0.06615	124	0.61	0.5426	Tukey-Kramer	0.9964
fuel2	E	F	0.1289	0.06277	124	2.05	0.0421	Tukey-Kramer	0.3867
fuel2	E	G	0.1766	0.06548	124	2.70	0.0080	Tukey-Kramer	0.1077
fuel2	F	G	0.04767	0.06548	124	0.73	0.4680	Tukey-Kramer	0.9906

Table B21: Least squares means for weighted CO emissions

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	-1.8096	0.16371961
fuel2	B	-2.1754	0.11356272
fuel2	C	-1.7589	0.17223422
fuel2	D	-1.9731	0.13902521
fuel2	E	-1.8403	0.15876979
fuel2	F	-1.9405	0.14363212
fuel2	G	-2.0068	0.13441813

Table B22: Multiple comparisons and p values for weighted CO emissions

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.3658	0.06173	124	5.93	<.0001	Tukey-Kramer	<.0001
fuel2	A	C	-0.05072	0.06257	124	-0.81	0.4192	Tukey-Kramer	0.9835
fuel2	A	D	0.1635	0.06405	124	2.55	0.0119	Tukey-Kramer	0.1498
fuel2	A	E	0.03072	0.06328	124	0.49	0.6282	Tukey-Kramer	0.9990
fuel2	A	F	0.1309	0.06309	124	2.08	0.0401	Tukey-Kramer	0.3740
fuel2	A	G	0.1972	0.06588	124	2.99	0.0033	Tukey-Kramer	0.0505
fuel2	B	C	-0.4165	0.06025	124	-6.91	<.0001	Tukey-Kramer	<.0001
fuel2	B	D	-0.2022	0.06182	124	-3.27	0.0014	Tukey-Kramer	0.0228
fuel2	B	E	-0.3350	0.06105	124	-5.49	<.0001	Tukey-Kramer	<.0001
fuel2	B	F	-0.2348	0.06096	124	-3.85	0.0002	Tukey-Kramer	0.0034
fuel2	B	G	-0.1685	0.06364	124	-2.65	0.0091	Tukey-Kramer	0.1208
fuel2	C	D	0.2142	0.06247	124	3.43	0.0008	Tukey-Kramer	0.0141
fuel2	C	E	0.08144	0.06153	124	1.32	0.1881	Tukey-Kramer	0.8397
fuel2	C	F	0.1816	0.06171	124	2.94	0.0039	Tukey-Kramer	0.0578
fuel2	C	G	0.2479	0.06430	124	3.86	0.0002	Tukey-Kramer	0.0034
fuel2	D	E	-0.1328	0.06328	124	-2.10	0.0379	Tukey-Kramer	0.3598
fuel2	D	F	-0.03261	0.06328	124	-0.52	0.6072	Tukey-Kramer	0.9986
fuel2	D	G	0.03370	0.06578	124	0.51	0.6093	Tukey-Kramer	0.9986
fuel2	E	F	0.1002	0.06242	124	1.61	0.1110	Tukey-Kramer	0.6792
fuel2	E	G	0.1665	0.06511	124	2.56	0.0118	Tukey-Kramer	0.1485
fuel2	F	G	0.06631	0.06511	124	1.02	0.3105	Tukey-Kramer	0.9489

Table B23: Least squares means for cold-start CO_2 emissions

Least Squares Means			
Effect	fuel2	Estimate	Standard Error
fuel2	A	6.2713	529.164845
fuel2	B	6.2741	530.648583
fuel2	C	6.2785	532.988581
fuel2	D	6.2683	527.57973
fuel2	E	6.2879	538.022295

Least Squares Means			
Effect	fuel2	Estimate	Standard Error
fuel2	F	6.2593	522.852815
fuel2	G	6.2633	524.948415

Table B24: Multiple comparisons and p values for cold-start CO_2 emissions

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	-0.00278	0.007498	124	-0.37	0.7119	Tukey-Kramer	0.9998
fuel2	A	C	-0.00718	0.007600	124	-0.94	0.3468	Tukey-Kramer	0.9644
fuel2	A	D	0.003013	0.007780	124	0.39	0.6992	Tukey-Kramer	0.9997
fuel2	A	E	-0.01662	0.007687	124	-2.16	0.0326	Tukey-Kramer	0.3241
fuel2	A	F	0.01200	0.007664	124	1.57	0.1200	Tukey-Kramer	0.7042
fuel2	A	G	0.008029	0.008002	124	1.00	0.3177	Tukey-Kramer	0.9524
fuel2	B	C	-0.00440	0.007318	124	-0.60	0.5486	Tukey-Kramer	0.9967
fuel2	B	D	0.005788	0.007509	124	0.77	0.4423	Tukey-Kramer	0.9873
fuel2	B	E	-0.01384	0.007415	124	-1.87	0.0643	Tukey-Kramer	0.5064
fuel2	B	F	0.01477	0.007405	124	2.00	0.0482	Tukey-Kramer	0.4229
fuel2	B	G	0.01080	0.007730	124	1.40	0.1647	Tukey-Kramer	0.8021
fuel2	C	D	0.01019	0.007588	124	1.34	0.1818	Tukey-Kramer	0.8303
fuel2	C	E	-0.00944	0.007474	124	-1.26	0.2090	Tukey-Kramer	0.8674
fuel2	C	F	0.01918	0.007495	124	2.56	0.0117	Tukey-Kramer	0.1481
fuel2	C	G	0.01521	0.007811	124	1.95	0.0538	Tukey-Kramer	0.4538
fuel2	D	E	-0.01963	0.007686	124	-2.55	0.0119	Tukey-Kramer	0.1497
fuel2	D	F	0.008987	0.007686	124	1.17	0.2446	Tukey-Kramer	0.9043
fuel2	D	G	0.005016	0.007990	124	0.63	0.5313	Tukey-Kramer	0.9958
fuel2	E	F	0.02861	0.007582	124	3.77	0.0002	Tukey-Kramer	0.0045
fuel2	E	G	0.02464	0.007909	124	3.12	0.0023	Tukey-Kramer	0.0360
fuel2	F	G	-0.00397	0.007909	124	-0.50	0.6166	Tukey-Kramer	0.9988

Table B25: Least squares means for hot-running CO_2 emissions

Least Squares Means			
Effect	fuel2	Estimate	Standard Error

Least Squares Means			
Effect	fuel2	Estimate	Standard Error
fuel2	A	6.1136	451.962856
fuel2	B	6.1217	455.638622
fuel2	C	6.1365	462.432222
fuel2	D	6.1254	457.327608
fuel2	E	6.1395	463.821602
fuel2	F	6.1149	452.55079
fuel2	G	6.1262	457.693616

Table B26: Multiple comparisons and p values for hot-running CO_2 emissions

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	-0.00809	0.005618	124	-1.44	0.1521	Tukey-Kramer	0.7785
fuel2	A	C	-0.02287	0.005694	124	-4.02	0.0001	Tukey-Kramer	0.0019
fuel2	A	D	-0.01180	0.005829	124	-2.02	0.0451	Tukey-Kramer	0.4052
fuel2	A	E	-0.02591	0.005759	124	-4.50	<.0001	Tukey-Kramer	0.0003
fuel2	A	F	-0.00131	0.005742	124	-0.23	0.8199	Tukey-Kramer	1.0000
fuel2	A	G	-0.01258	0.005996	124	-2.10	0.0380	Tukey-Kramer	0.3605
fuel2	B	C	-0.01478	0.005483	124	-2.70	0.0080	Tukey-Kramer	0.1081
fuel2	B	D	-0.00370	0.005626	124	-0.66	0.5118	Tukey-Kramer	0.9945
fuel2	B	E	-0.01782	0.005556	124	-3.21	0.0017	Tukey-Kramer	0.0276
fuel2	B	F	0.006784	0.005548	124	1.22	0.2237	Tukey-Kramer	0.8840
fuel2	B	G	-0.00448	0.005792	124	-0.77	0.4404	Tukey-Kramer	0.9870
fuel2	C	D	0.01108	0.005685	124	1.95	0.0536	Tukey-Kramer	0.4528
fuel2	C	E	-0.00304	0.005600	124	-0.54	0.5881	Tukey-Kramer	0.9981
fuel2	C	F	0.02156	0.005616	124	3.84	0.0002	Tukey-Kramer	0.0036
fuel2	C	G	0.01030	0.005852	124	1.76	0.0810	Tukey-Kramer	0.5779
fuel2	D	E	-0.01412	0.005758	124	-2.45	0.0156	Tukey-Kramer	0.1865
fuel2	D	F	0.01049	0.005759	124	1.82	0.0710	Tukey-Kramer	0.5367

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	D	G	-0.00078	0.005986	124	-0.13	0.8963	Tukey-Kramer	1.0000
fuel2	E	F	0.02460	0.005681	124	4.33	<.0001	Tukey-Kramer	0.0006
fuel2	E	G	0.01334	0.005926	124	2.25	0.0262	Tukey-Kramer	0.2768
fuel2	F	G	-0.01127	0.005926	124	-1.90	0.0596	Tukey-Kramer	0.4833

Table B27: Least squares means for hot-start CO_2 emissions

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	6.0420	420.733661
fuel2	B	6.0454	422.16659
fuel2	C	6.0649	430.479628
fuel2	D	6.0476	423.096379
fuel2	E	6.0653	430.651854
fuel2	F	6.0406	420.145046
fuel2	G	6.0484	423.434992

Table B28: Multiple comparisons and p values for hot-start CO_2 emissions

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	-0.00339	0.007635	124	-0.44	0.6581	Tukey-Kramer	0.9994
fuel2	A	C	-0.02294	0.007739	124	-2.96	0.0036	Tukey-Kramer	0.0546
fuel2	A	D	-0.00556	0.007922	124	-0.70	0.4841	Tukey-Kramer	0.9923
fuel2	A	E	-0.02329	0.007827	124	-2.98	0.0035	Tukey-Kramer	0.0530
fuel2	A	F	0.001449	0.007804	124	0.19	0.8530	Tukey-Kramer	1.0000
fuel2	A	G	-0.00641	0.008149	124	-0.79	0.4328	Tukey-Kramer	0.9858
fuel2	B	C	-0.01955	0.007452	124	-2.62	0.0098	Tukey-Kramer	0.1278
fuel2	B	D	-0.00217	0.007646	124	-0.28	0.7767	Tukey-Kramer	1.0000
fuel2	B	E	-0.01991	0.007551	124	-2.64	0.0094	Tukey-Kramer	0.1241

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	B	F	0.004836	0.007540	124	0.64	0.5225	Tukey-Kramer	0.9953
fuel2	B	G	-0.00303	0.007872	124	-0.38	0.7013	Tukey-Kramer	0.9997
fuel2	C	D	0.01738	0.007727	124	2.25	0.0263	Tukey-Kramer	0.2774
fuel2	C	E	-0.00035	0.007611	124	-0.05	0.9630	Tukey-Kramer	1.0000
fuel2	C	F	0.02439	0.007632	124	3.20	0.0018	Tukey-Kramer	0.0286
fuel2	C	G	0.01653	0.007954	124	2.08	0.0398	Tukey-Kramer	0.3722
fuel2	D	E	-0.01773	0.007826	124	-2.27	0.0252	Tukey-Kramer	0.2690
fuel2	D	F	0.007009	0.007827	124	0.90	0.3722	Tukey-Kramer	0.9726
fuel2	D	G	-0.00085	0.008136	124	-0.10	0.9167	Tukey-Kramer	1.0000
fuel2	E	F	0.02474	0.007721	124	3.20	0.0017	Tukey-Kramer	0.0278
fuel2	E	G	0.01688	0.008054	124	2.10	0.0381	Tukey-Kramer	0.3615
fuel2	F	G	-0.00786	0.008054	124	-0.98	0.3308	Tukey-Kramer	0.9582

Table B29: Least squares means for weighted CO_2 emissions

Least Squares Means			
Effect	fuel2	Estimate	Standard Error
fuel2	A	6.1308	459.803857
fuel2	B	6.1364	462.385981
fuel2	C	6.1497	468.576793
fuel2	D	6.1371	462.709765
fuel2	E	6.1537	470.454853
fuel2	F	6.1280	458.518207
fuel2	G	6.1365	462.432222

Table B30: Multiple comparisons and p values for weighted CO_2 emissions

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	-0.00568	0.005135	124	-1.11	0.2710	Tukey-Kramer	0.9253

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	C	-0.01897	0.005205	124	-3.64	0.0004	Tukey-Kramer	0.0070
fuel2	A	D	-0.00633	0.005328	124	-1.19	0.2369	Tukey-Kramer	0.8973
fuel2	A	E	-0.02291	0.005264	124	-4.35	<.0001	Tukey-Kramer	0.0005
fuel2	A	F	0.002734	0.005249	124	0.52	0.6034	Tukey-Kramer	0.9985
fuel2	A	G	-0.00575	0.005481	124	-1.05	0.2959	Tukey-Kramer	0.9411
fuel2	B	C	-0.01329	0.005012	124	-2.65	0.0091	Tukey-Kramer	0.1200
fuel2	B	D	-0.00065	0.005142	124	-0.13	0.8989	Tukey-Kramer	1.0000
fuel2	B	E	-0.01723	0.005078	124	-3.39	0.0009	Tukey-Kramer	0.0157
fuel2	B	F	0.008411	0.005071	124	1.66	0.0997	Tukey-Kramer	0.6446
fuel2	B	G	-0.00008	0.005294	124	-0.01	0.9887	Tukey-Kramer	1.0000
fuel2	C	D	0.01263	0.005197	124	2.43	0.0165	Tukey-Kramer	0.1947
fuel2	C	E	-0.00395	0.005119	124	-0.77	0.4422	Tukey-Kramer	0.9873
fuel2	C	F	0.02170	0.005133	124	4.23	<.0001	Tukey-Kramer	0.0009
fuel2	C	G	0.01321	0.005349	124	2.47	0.0149	Tukey-Kramer	0.1795
fuel2	D	E	-0.01658	0.005264	124	-3.15	0.0020	Tukey-Kramer	0.0327
fuel2	D	F	0.009066	0.005264	124	1.72	0.0875	Tukey-Kramer	0.6026
fuel2	D	G	0.000579	0.005472	124	0.11	0.9159	Tukey-Kramer	1.0000
fuel2	E	F	0.02565	0.005193	124	4.94	<.0001	Tukey-Kramer	<.0001
fuel2	E	G	0.01716	0.005417	124	3.17	0.0019	Tukey-Kramer	0.0310
fuel2	F	G	-0.00849	0.005417	124	-1.57	0.1197	Tukey-Kramer	0.7036

Table B31: Least squares means for cold-start fuel economy

Least Squares Means		
Effect	fuel2	Estimate
fuel2	A	22.5265
fuel2	B	21.7664
fuel2	C	21.7912
fuel2	D	21.6802
fuel2	E	21.5562
fuel2	F	22.0430
fuel2	G	21.4915

Table B32: Multiple comparisons and p values for cold-start fuel economy

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.7601	0.1648	124	4.61	<.0001	Tukey-Kramer	0.0002
fuel2	A	C	0.7353	0.1671	124	4.40	<.0001	Tukey-Kramer	0.0004
fuel2	A	D	0.8463	0.1710	124	4.95	<.0001	Tukey-Kramer	<.0001
fuel2	A	E	0.9703	0.1690	124	5.74	<.0001	Tukey-Kramer	<.0001
fuel2	A	F	0.4836	0.1685	124	2.87	0.0048	Tukey-Kramer	0.0700
fuel2	A	G	1.0350	0.1759	124	5.88	<.0001	Tukey-Kramer	<.0001
fuel2	B	C	-0.02476	0.1609	124	-0.15	0.8779	Tukey-Kramer	1.0000
fuel2	B	D	0.08621	0.1651	124	0.52	0.6024	Tukey-Kramer	0.9985
fuel2	B	E	0.2102	0.1630	124	1.29	0.1996	Tukey-Kramer	0.8555
fuel2	B	F	-0.2765	0.1628	124	-1.70	0.0919	Tukey-Kramer	0.6181
fuel2	B	G	0.2749	0.1699	124	1.62	0.1082	Tukey-Kramer	0.6712
fuel2	C	D	0.1110	0.1668	124	0.67	0.5071	Tukey-Kramer	0.9942
fuel2	C	E	0.2350	0.1643	124	1.43	0.1552	Tukey-Kramer	0.7845
fuel2	C	F	-0.2518	0.1648	124	-1.53	0.1290	Tukey-Kramer	0.7275
fuel2	C	G	0.2997	0.1717	124	1.75	0.0834	Tukey-Kramer	0.5871
fuel2	D	E	0.1240	0.1689	124	0.73	0.4644	Tukey-Kramer	0.9902
fuel2	D	F	-0.3627	0.1690	124	-2.15	0.0337	Tukey-Kramer	0.3323
fuel2	D	G	0.1887	0.1756	124	1.07	0.2848	Tukey-Kramer	0.9345
fuel2	E	F	-0.4867	0.1667	124	-2.92	0.0042	Tukey-Kramer	0.0614
fuel2	E	G	0.06470	0.1739	124	0.37	0.7104	Tukey-Kramer	0.9998
fuel2	F	G	0.5514	0.1739	124	3.17	0.0019	Tukey-Kramer	0.0306

Table B33: Least squares means for hot-running fuel economy

Least Squares Means		
Effect	fuel2	Estimate
fuel2	A	26.3148
fuel2	B	25.2998
fuel2	C	25.1340
fuel2	D	25.1191
fuel2	E	24.9499
fuel2	F	25.4745

Least Squares Means		
Effect	fuel2	Estimate
fuel2	G	24.6283

Table B34: Multiple comparisons and p values for hot-running fuel economy

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	1.0150	0.1785	124	5.69	<.0001	Tukey-Kramer	<.0001
fuel2	A	C	1.1808	0.1810	124	6.53	<.0001	Tukey-Kramer	<.0001
fuel2	A	D	1.1957	0.1852	124	6.46	<.0001	Tukey-Kramer	<.0001
fuel2	A	E	1.3649	0.1830	124	7.46	<.0001	Tukey-Kramer	<.0001
fuel2	A	F	0.8403	0.1825	124	4.60	<.0001	Tukey-Kramer	0.0002
fuel2	A	G	1.6865	0.1905	124	8.85	<.0001	Tukey-Kramer	<.0001
fuel2	B	C	0.1658	0.1743	124	0.95	0.3431	Tukey-Kramer	0.9631
fuel2	B	D	0.1808	0.1788	124	1.01	0.3139	Tukey-Kramer	0.9506
fuel2	B	E	0.3499	0.1766	124	1.98	0.0497	Tukey-Kramer	0.4314
fuel2	B	F	-0.1747	0.1763	124	-0.99	0.3238	Tukey-Kramer	0.9552
fuel2	B	G	0.6716	0.1841	124	3.65	0.0004	Tukey-Kramer	0.0069
fuel2	C	D	0.01493	0.1807	124	0.08	0.9343	Tukey-Kramer	1.0000
fuel2	C	E	0.1841	0.1780	124	1.03	0.3030	Tukey-Kramer	0.9450
fuel2	C	F	-0.3405	0.1785	124	-1.91	0.0587	Tukey-Kramer	0.4790
fuel2	C	G	0.5057	0.1860	124	2.72	0.0075	Tukey-Kramer	0.1021
fuel2	D	E	0.1691	0.1830	124	0.92	0.3572	Tukey-Kramer	0.9680
fuel2	D	F	-0.3554	0.1830	124	-1.94	0.0544	Tukey-Kramer	0.4568
fuel2	D	G	0.4908	0.1902	124	2.58	0.0111	Tukey-Kramer	0.1413
fuel2	E	F	-0.5246	0.1805	124	-2.91	0.0043	Tukey-Kramer	0.0638
fuel2	E	G	0.3217	0.1883	124	1.71	0.0901	Tukey-Kramer	0.6120
fuel2	F	G	0.8462	0.1883	124	4.49	<.0001	Tukey-Kramer	0.0003

Table B35: Least squares means for hot-start fuel economy

Least Squares Means		
Effect	fuel2	Estimate
fuel2	A	28.4521
fuel2	B	27.4355
fuel2	C	27.1274

Least Squares Means		
Effect	fuel2	Estimate
fuel2	D	27.3353
fuel2	E	27.1310
fuel2	F	27.6558
fuel2	G	26.8505

Table B36: Multiple comparisons and p values for hot-start fuel economy

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	1.0166	0.2609	124	3.90	0.0002	Tukey-Kramer	0.0030
fuel2	A	C	1.3247	0.2644	124	5.01	<.0001	Tukey-Kramer	<.0001
fuel2	A	D	1.1168	0.2707	124	4.13	<.0001	Tukey-Kramer	0.0013
fuel2	A	E	1.3211	0.2675	124	4.94	<.0001	Tukey-Kramer	<.0001
fuel2	A	F	0.7963	0.2667	124	2.99	0.0034	Tukey-Kramer	0.0515
fuel2	A	G	1.6016	0.2785	124	5.75	<.0001	Tukey-Kramer	<.0001
fuel2	B	C	0.3081	0.2547	124	1.21	0.2286	Tukey-Kramer	0.8891
fuel2	B	D	0.1001	0.2613	124	0.38	0.7022	Tukey-Kramer	0.9997
fuel2	B	E	0.3045	0.2580	124	1.18	0.2402	Tukey-Kramer	0.9004
fuel2	B	F	-0.2203	0.2577	124	-0.85	0.3943	Tukey-Kramer	0.9783
fuel2	B	G	0.5850	0.2690	124	2.17	0.0315	Tukey-Kramer	0.3168
fuel2	C	D	-0.2080	0.2640	124	-0.79	0.4324	Tukey-Kramer	0.9858
fuel2	C	E	-0.00363	0.2601	124	-0.01	0.9889	Tukey-Kramer	1.0000
fuel2	C	F	-0.5284	0.2608	124	-2.03	0.0449	Tukey-Kramer	0.4038
fuel2	C	G	0.2769	0.2718	124	1.02	0.3103	Tukey-Kramer	0.9488
fuel2	D	E	0.2044	0.2674	124	0.76	0.4463	Tukey-Kramer	0.9879
fuel2	D	F	-0.3204	0.2675	124	-1.20	0.2332	Tukey-Kramer	0.8937
fuel2	D	G	0.4848	0.2780	124	1.74	0.0837	Tukey-Kramer	0.5882
fuel2	E	F	-0.5248	0.2638	124	-1.99	0.0489	Tukey-Kramer	0.4269
fuel2	E	G	0.2805	0.2752	124	1.02	0.3101	Tukey-Kramer	0.9487
fuel2	F	G	0.8053	0.2752	124	2.93	0.0041	Tukey-Kramer	0.0605

Table B37: Least squares means for weighted fuel economy

Least Squares Means		
Effect	fuel2	Estimate

Least Squares Means		
Effect	fuel2	Estimate
fuel2	A	25.9131
fuel2	B	24.9616
fuel2	C	24.8159
fuel2	D	24.8355
fuel2	E	24.6606
fuel2	F	25.1813
fuel2	G	24.4256

Table B38: Multiple comparisons and p values for weighted fuel economy

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.9515	0.1661	124	5.73	<.0001	Tukey-Kramer	<.0001
fuel2	A	C	1.0972	0.1683	124	6.52	<.0001	Tukey-Kramer	<.0001
fuel2	A	D	1.0775	0.1723	124	6.25	<.0001	Tukey-Kramer	<.0001
fuel2	A	E	1.2525	0.1703	124	7.36	<.0001	Tukey-Kramer	<.0001
fuel2	A	F	0.7318	0.1698	124	4.31	<.0001	Tukey-Kramer	0.0006
fuel2	A	G	1.4875	0.1773	124	8.39	<.0001	Tukey-Kramer	<.0001
fuel2	B	C	0.1457	0.1621	124	0.90	0.3704	Tukey-Kramer	0.9721
fuel2	B	D	0.1261	0.1663	124	0.76	0.4499	Tukey-Kramer	0.9884
fuel2	B	E	0.3010	0.1643	124	1.83	0.0693	Tukey-Kramer	0.5290
fuel2	B	F	-0.2197	0.1640	124	-1.34	0.1829	Tukey-Kramer	0.8320
fuel2	B	G	0.5360	0.1712	124	3.13	0.0022	Tukey-Kramer	0.0345
fuel2	C	D	-0.01967	0.1681	124	-0.12	0.9070	Tukey-Kramer	1.0000
fuel2	C	E	0.1552	0.1656	124	0.94	0.3502	Tukey-Kramer	0.9656
fuel2	C	F	-0.3654	0.1660	124	-2.20	0.0296	Tukey-Kramer	0.3026
fuel2	C	G	0.3903	0.1730	124	2.26	0.0258	Tukey-Kramer	0.2740
fuel2	D	E	0.1749	0.1702	124	1.03	0.3062	Tukey-Kramer	0.9467
fuel2	D	F	-0.3457	0.1703	124	-2.03	0.0444	Tukey-Kramer	0.4008
fuel2	D	G	0.4100	0.1770	124	2.32	0.0222	Tukey-Kramer	0.2446
fuel2	E	F	-0.5207	0.1679	124	-3.10	0.0024	Tukey-Kramer	0.0376
fuel2	E	G	0.2351	0.1752	124	1.34	0.1821	Tukey-Kramer	0.8308
fuel2	F	G	0.7557	0.1752	124	4.31	<.0001	Tukey-Kramer	0.0006

Table B39: Least squares means for cumulative PM mass

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
fuel2	6	121	1.60	0.1534
Least Squares Means				
Effect	fuel2	Estimate	Back transformed	
fuel2	A	-0.1377	0.87136006	
fuel2	B	-0.08711	0.91657627	
fuel2	C	-0.2047	0.81489175	
fuel2	D	-0.3127	0.73146932	
fuel2	E	-0.2533	0.77623498	
fuel2	F	-0.09146	0.91259782	
fuel2	G	0.1301	1.13894227	

Table B40: Least squares means for cold-start PN

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
fuel2	6	111	0.90	0.4955
Least Squares Means				
Effect	fuel2	Estimate	Back transformed	
fuel2	A	24.2108	3.2705E+10	
fuel2	B	24.3699	3.8345E+10	
fuel2	C	24.5932	4.7939E+10	
fuel2	D	24.8017	5.9053E+10	
fuel2	E	24.1882	3.1974E+10	
fuel2	F	24.6866	5.2633E+10	

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
fuel2	G	24.6772	5.214E+10	

Table B41: Least squares means for weighted PN

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
fuel2	6	110	1.25	0.2870
Least Squares Means				
Effect	fuel2	Estimate	Back transformed	
fuel2	A	23.4463	1.5226E+10	
fuel2	B	23.5476	1.685E+10	
fuel2	C	23.6962	1.9549E+10	
fuel2	D	23.9185	2.4416E+10	
fuel2	E	23.3128	1.3324E+10	
fuel2	F	23.8463	2.2715E+10	
fuel2	G	23.8649	2.3142E+10	

Table B42: Least squares means for formaldehyde

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	8.4646	4743.8295
fuel2	B	8.0793	3226.97356
fuel2	C	8.6621	5779.65921
fuel2	D	8.5143	4985.55495
fuel2	E	8.6375	5639.21415

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	F	8.3857	4383.92622
fuel2	G	8.3434	4202.35348

Table B43: Multiple comparisons and p values for formaldehyde

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.3853	0.1271	119	3.03	0.0030	Tukey-Kramer	0.0459
fuel2	A	C	-0.1975	0.1324	119	-1.49	0.1384	Tukey-Kramer	0.7492
fuel2	A	D	-0.04967	0.1317	119	-0.38	0.7066	Tukey-Kramer	0.9998
fuel2	A	E	-0.1729	0.1317	119	-1.31	0.1917	Tukey-Kramer	0.8446
fuel2	A	F	0.07896	0.1299	119	0.61	0.5445	Tukey-Kramer	0.9965
fuel2	A	G	0.1212	0.1376	119	0.88	0.3803	Tukey-Kramer	0.9748
fuel2	B	C	-0.5828	0.1264	119	-4.61	<.0001	Tukey-Kramer	0.0002
fuel2	B	D	-0.4350	0.1255	119	-3.47	0.0007	Tukey-Kramer	0.0126
fuel2	B	E	-0.5582	0.1255	119	-4.45	<.0001	Tukey-Kramer	0.0004
fuel2	B	F	-0.3064	0.1237	119	-2.48	0.0147	Tukey-Kramer	0.1775
fuel2	B	G	-0.2641	0.1314	119	-2.01	0.0467	Tukey-Kramer	0.4141
fuel2	C	D	0.1478	0.1305	119	1.13	0.2596	Tukey-Kramer	0.9167
fuel2	C	E	0.02455	0.1303	119	0.19	0.8509	Tukey-Kramer	1.0000
fuel2	C	F	0.2764	0.1294	119	2.14	0.0347	Tukey-Kramer	0.3388
fuel2	C	G	0.3187	0.1367	119	2.33	0.0214	Tukey-Kramer	0.2380
fuel2	D	E	-0.1232	0.1300	119	-0.95	0.3450	Tukey-Kramer	0.9637
fuel2	D	F	0.1286	0.1284	119	1.00	0.3186	Tukey-Kramer	0.9527
fuel2	D	G	0.1709	0.1360	119	1.26	0.2114	Tukey-Kramer	0.8700
fuel2	E	F	0.2519	0.1285	119	1.96	0.0522	Tukey-Kramer	0.4450
fuel2	E	G	0.2941	0.1362	119	2.16	0.0328	Tukey-Kramer	0.3256
fuel2	F	G	0.04225	0.1344	119	0.31	0.7538	Tukey-Kramer	0.9999

Table B44: Least squares means for acetaldehyde

Least Squares Means			
Effect	fuel2	Estimate	Back transformed

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	7.3413	1542.71634
fuel2	B	6.8486	942.560398
fuel2	C	7.4289	1683.9542
fuel2	D	7.2722	1439.71434
fuel2	E	7.3912	1621.65093
fuel2	F	7.3190	1508.69452
fuel2	G	7.2500	1408.10485

Table B45: Multiple comparisons and p values for acetaldehyde

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	A	B	0.4927	0.1438	119	3.43	0.0008	Tukey-Kramer	0.0143
fuel2	A	C	-0.08756	0.1497	119	-0.58	0.5597	Tukey-Kramer	0.9971
fuel2	A	D	0.06915	0.1489	119	0.46	0.6433	Tukey-Kramer	0.9992
fuel2	A	E	-0.04990	0.1489	119	-0.34	0.7382	Tukey-Kramer	0.9999
fuel2	A	F	0.02233	0.1470	119	0.15	0.8795	Tukey-Kramer	1.0000
fuel2	A	G	0.09137	0.1557	119	0.59	0.5584	Tukey-Kramer	0.9971
fuel2	B	C	-0.5803	0.1430	119	-4.06	<.0001	Tukey-Kramer	0.0017
fuel2	B	D	-0.4236	0.1419	119	-2.98	0.0034	Tukey-Kramer	0.0520
fuel2	B	E	-0.5426	0.1419	119	-3.82	0.0002	Tukey-Kramer	0.0039
fuel2	B	F	-0.4704	0.1399	119	-3.36	0.0010	Tukey-Kramer	0.0175
fuel2	B	G	-0.4014	0.1486	119	-2.70	0.0079	Tukey-Kramer	0.1072
fuel2	C	D	0.1567	0.1476	119	1.06	0.2904	Tukey-Kramer	0.9378
fuel2	C	E	0.03767	0.1473	119	0.26	0.7987	Tukey-Kramer	1.0000
fuel2	C	F	0.1099	0.1464	119	0.75	0.4543	Tukey-Kramer	0.9889
fuel2	C	G	0.1789	0.1546	119	1.16	0.2494	Tukey-Kramer	0.9084
fuel2	D	E	-0.1190	0.1470	119	-0.81	0.4197	Tukey-Kramer	0.9836
fuel2	D	F	-0.04682	0.1453	119	-0.32	0.7478	Tukey-Kramer	0.9999

Differences of Least Squares Means									
Effect	fuel2	fuel2	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
fuel2	D	G	0.02222	0.1538	119	0.14	0.8854	Tukey-Kramer	1.0000
fuel2	E	F	0.07223	0.1453	119	0.50	0.6200	Tukey-Kramer	0.9989
fuel2	E	G	0.1413	0.1541	119	0.92	0.3610	Tukey-Kramer	0.9692
fuel2	F	G	0.06904	0.1520	119	0.45	0.6506	Tukey-Kramer	0.9993

Table B46: Least squares means for gas-phase naphthalene

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
fuel2	6	100	1.03	0.4080

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	6.8599	952.2717356
fuel2	B	6.2028	493.1306718
fuel2	C	7.2063	1346.895815
fuel2	D	6.7023	813.276509
fuel2	E	6.9322	1023.745943
fuel2	F	6.7925	890.1386259
fuel2	G	6.3229	556.1864926

Table B47: Least squares means for gas-phase 2-methylnaphthalene

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
fuel2	6	99	1.75	0.1164

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	5.7016	299.3459716

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**B**	5.5272	251.4388956
fuel2	**C**	5.9529	384.867839
fuel2	**D**	5.5579	259.2777809
fuel2	**E**	5.3993	221.2514859
fuel2	**F**	5.4299	228.1264316
fuel2	**G**	4.9351	139.0870505

Table B48: Least squares means for gas-phase 1-methylnaphthalene

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
fuel2	6	99	1.68	0.1344

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**A**	5.1376	169.3065417
fuel2	**B**	4.9172	135.6195424
fuel2	**C**	5.4790	238.6069806
fuel2	**D**	5.0175	150.0332483
fuel2	**E**	4.9341	137.948033
fuel2	**F**	4.6860	107.4186368
fuel2	**G**	4.3478	76.30819767

Table B49: Least squares means for gas-phase fluorene

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
fuel2	6	100	2.00	0.0723

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Standard Error**
fuel2	**A**	4.2573	69.61905437
fuel2	**B**	3.6145	36.1327749

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Standard Error**
fuel2	**C**	4.8142	122.2481743
fuel2	**D**	4.0731	57.73877083
fuel2	**E**	4.4854	87.71242869
fuel2	**F**	4.2278	67.56622044
fuel2	**G**	4.2104	66.38348782

Table B50: Multiple comparisons and p values for gas-phase fluorene

Differences of Least Squares Means									
Effect	**fuel2**	**fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
fuel2	**A**	**B**	0.6428	0.3605	100	1.78	0.0776	Tukey-Kramer	0.5626
fuel2	**A**	**C**	-0.5570	0.3664	100	-1.52	0.1317	Tukey-Kramer	0.7322
fuel2	**A**	**D**	0.1841	0.3663	100	0.50	0.6164	Tukey-Kramer	0.9988
fuel2	**A**	**E**	-0.2281	0.3728	100	-0.61	0.5421	Tukey-Kramer	0.9963
fuel2	**A**	**F**	0.02947	0.3605	100	0.08	0.9350	Tukey-Kramer	1.0000
fuel2	**A**	**G**	0.04683	0.3663	100	0.13	0.8985	Tukey-Kramer	1.0000
fuel2	**B**	**C**	-1.1998	0.3664	100	-3.27	0.0015	Tukey-Kramer	0.0238
fuel2	**B**	**D**	-0.4587	0.3663	100	-1.25	0.2135	Tukey-Kramer	0.8717
fuel2	**B**	**E**	-0.8709	0.3728	100	-2.34	0.0215	Tukey-Kramer	0.2377
fuel2	**B**	**F**	-0.6133	0.3605	100	-1.70	0.0920	Tukey-Kramer	0.6169
fuel2	**B**	**G**	-0.5960	0.3663	100	-1.63	0.1069	Tukey-Kramer	0.6655
fuel2	**C**	**D**	0.7411	0.3723	100	1.99	0.0492	Tukey-Kramer	0.4269
fuel2	**C**	**E**	0.3289	0.3788	100	0.87	0.3873	Tukey-Kramer	0.9764
fuel2	**C**	**F**	0.5865	0.3664	100	1.60	0.1127	Tukey-Kramer	0.6823
fuel2	**C**	**G**	0.6038	0.3723	100	1.62	0.1079	Tukey-Kramer	0.6685
fuel2	**D**	**E**	-0.4122	0.3781	100	-1.09	0.2782	Tukey-Kramer	0.9296
fuel2	**D**	**F**	-0.1546	0.3663	100	-0.42	0.6738	Tukey-Kramer	0.9995
fuel2	**D**	**G**	-0.1373	0.3716	100	-0.37	0.7126	Tukey-Kramer	0.9998
fuel2	**E**	**F**	0.2576	0.3728	100	0.69	0.4913	Tukey-Kramer	0.9928
fuel2	**E**	**G**	0.2749	0.3781	100	0.73	0.4689	Tukey-Kramer	0.9906
fuel2	**F**	**G**	0.01735	0.3663	100	0.05	0.9623	Tukey-Kramer	1.0000

Table B51: Least squares means for gas-phase fluoranthene

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
fuel2	6	101	0.92	0.4834

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	2.3721	9.719880412
fuel2	B	2.1689	7.748655225
fuel2	C	2.7204	14.18639559
fuel2	D	2.1354	7.460430002
fuel2	E	2.5249	11.48964624
fuel2	F	2.5897	12.32577327
fuel2	G	2.6933	13.78037075

Table B52: Least squares means for gas-phase pyrene

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
fuel2	6	101	0.75	0.6100

Least Squares Means			
Effect	fuel2	Estimate	Back transformed
fuel2	A	2.6183	12.71239269
fuel2	B	2.3317	9.295428894
fuel2	C	2.7817	15.14644659
fuel2	D	2.3152	9.126948106
fuel2	E	2.4798	10.9388764
fuel2	F	2.9511	18.12698184
fuel2	G	2.6917	13.75674107

Table B53: Least squares means for gas-phase phenanthrene

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
fuel2	6	100	0.81	0.5619

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Standard Error**
fuel2	**A**	4.8690	130.1906611
fuel2	**B**	4.7352	113.8862337
fuel2	**C**	5.0784	160.5170231
fuel2	**D**	4.5919	98.68174747
fuel2	**E**	4.9238	137.5242135
fuel2	**F**	4.9823	145.8093578
fuel2	**G**	5.0373	154.0535085

Table B54: Least squares means for particle-phase phenanthrene

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
fuel2	6	99	1.34	0.2479

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**A**	1.8830	5.573194897
fuel2	**B**	2.3158	9.133026098
fuel2	**C**	2.1479	7.566849111
fuel2	**D**	2.6542	13.21361062
fuel2	**E**	2.6340	12.92937612
fuel2	**F**	2.3215	9.190949271
fuel2	**G**	2.0221	6.55417205

Table B55: Least squares means for particle-phase 3-methylphenanthrene

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
fuel2	6	100	1.74	0.1199

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**A**	0.9896	2.590158194

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**B**	1.1434	3.037417471
fuel2	**C**	1.3407	3.721717772
fuel2	**D**	1.3024	3.578113556
fuel2	**E**	0.8641	2.272869542
fuel2	**F**	0.3226	1.280712955
fuel2	**G**	0.3770	1.357904309

Table B56: Least squares means for particle-phase 2-methylphenanthrene

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
fuel2	6	100	1.10	0.3707

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**A**	0.3987	1.389886586
fuel2	**B**	0.3197	1.276714688
fuel2	**C**	0.4563	1.478223741
fuel2	**D**	1.2434	3.367382547
fuel2	**E**	0.7705	2.060846407
fuel2	**F**	-0.07740	0.825519572
fuel2	**G**	0.5718	1.671452798

Table B57: Least squares means for particle-phase fluoranthene

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
fuel2	6	100	0.84	0.5449

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**A**	0.4891	1.530847796
fuel2	**B**	0.6819	1.877631665

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**C**	0.6995	1.912746083
fuel2	**D**	0.8250	2.181880765
fuel2	**E**	0.3833	1.367118099
fuel2	**F**	0.4533	1.473496165
fuel2	**G**	-0.04210	0.858773898

Table B58: Least squares means for particle-phase pyrene

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
fuel2	6	100	1.72	0.1237

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**A**	0.5544	1.640896134
fuel2	**B**	0.9281	2.429698182
fuel2	**C**	0.9067	2.376137781
fuel2	**D**	1.2364	3.343195622
fuel2	**E**	1.0384	2.724693887
fuel2	**F**	0.9135	2.393032896
fuel2	**G**	-0.1667	0.746453509

Table B59: Least squares means for gas-phase 1-nitronaphthalene

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**A**	1.1303	3.086585336
fuel2	**B**	-0.9057	0.394258805
fuel2	**C**	-0.4680	0.616253524
fuel2	**D**	0.7700	2.149766254
fuel2	**E**	-0.3990	0.660990701
fuel2	**F**	-0.6104	0.533133572
fuel2	**G**	-1.0882	0.326822228

Table B60: Multiple comparisons and p values for gas-phase 1-nitronaphthalene

Differences of Least Squares Means									
Effect	**fuel2**	**fuel2**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**
fuel2	**A**	**B**	2.0359	0.7001	90	2.91	0.0046	Tukey-Kramer	0.0663
fuel2	**A**	**C**	1.5983	0.6908	90	2.31	0.0230	Tukey-Kramer	0.2491
fuel2	**A**	**D**	0.3603	0.7018	90	0.51	0.6089	Tukey-Kramer	0.9986
fuel2	**A**	**E**	1.5293	0.7121	90	2.15	0.0344	Tukey-Kramer	0.3345
fuel2	**A**	**F**	1.7407	0.7389	90	2.36	0.0207	Tukey-Kramer	0.2298
fuel2	**A**	**G**	2.2185	0.7607	90	2.92	0.0045	Tukey-Kramer	0.0648
fuel2	**B**	**C**	-0.4377	0.6786	90	-0.64	0.5206	Tukey-Kramer	0.9950
fuel2	**B**	**D**	-1.6756	0.6895	90	-2.43	0.0171	Tukey-Kramer	0.1983
fuel2	**B**	**E**	-0.5066	0.6998	90	-0.72	0.4710	Tukey-Kramer	0.9908
fuel2	**B**	**F**	-0.2952	0.7287	90	-0.41	0.6863	Tukey-Kramer	0.9996
fuel2	**B**	**G**	0.1826	0.7504	90	0.24	0.8083	Tukey-Kramer	1.0000
fuel2	**C**	**D**	-1.2380	0.6782	90	-1.83	0.0713	Tukey-Kramer	0.5347
fuel2	**C**	**E**	-0.06896	0.6905	90	-0.10	0.9207	Tukey-Kramer	1.0000
fuel2	**C**	**F**	0.1424	0.7194	90	0.20	0.8435	Tukey-Kramer	1.0000
fuel2	**C**	**G**	0.6203	0.7388	90	0.84	0.4034	Tukey-Kramer	0.9800
fuel2	**D**	**E**	1.1690	0.7002	90	1.67	0.0985	Tukey-Kramer	0.6379
fuel2	**D**	**F**	1.3804	0.7305	90	1.89	0.0620	Tukey-Kramer	0.4924
fuel2	**D**	**G**	1.8582	0.7484	90	2.48	0.0149	Tukey-Kramer	0.1780
fuel2	**E**	**F**	0.2114	0.7407	90	0.29	0.7760	Tukey-Kramer	1.0000
fuel2	**E**	**G**	0.6892	0.7611	90	0.91	0.3676	Tukey-Kramer	0.9708
fuel2	**F**	**G**	0.4778	0.7873	90	0.61	0.5454	Tukey-Kramer	0.9964

Table B61: Least squares means for gas-phase 2-nitronaphthalene

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
fuel2	6	93	1.13	0.3522

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**A**	-0.6674	0.503040751
fuel2	**B**	-0.08942	0.904461419

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**C**	0.2022	1.214092802
fuel2	**D**	-0.6478	0.513195542
fuel2	**E**	-0.5972	0.540350462
fuel2	**F**	-0.07154	0.920959038
fuel2	**G**	-0.2417	0.77529173

Table B62: Least squares means for gas-phase 2-methyl-4-nitronaphthalene

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
fuel2	6	100	1.01	0.4244

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**A**	-1.8268	0.150927713
fuel2	**B**	-1.8930	0.140619273
fuel2	**C**	-1.0468	0.341059344
fuel2	**D**	-2.1480	0.106717359
fuel2	**E**	-1.9331	0.134698936
fuel2	**F**	-1.1700	0.300366941
fuel2	**G**	-1.4963	0.213957271

Table B63: Least squares means for particle-phase 1,3-dinitronaphthalene

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
fuel2	6	100	2.05	0.0662

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**A**	-3.7599	0.022286069
fuel2	**B**	-2.5050	0.080675598
fuel2	**C**	-3.2339	0.038403525
fuel2	**D**	-2.3478	0.094579205
fuel2	**E**	-2.1225	0.118731924

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**F**	-3.5670	0.027240448
fuel2	**G**	-3.4738	0.02999901

Table B64: Least squares means for particle-phase 1-nitropyrene

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
fuel2	6	98	1.06	0.3940

Least Squares Means			
Effect	**fuel2**	**Estimate**	**Back transformed**
fuel2	**A**	-2.0425	0.128704045
fuel2	**B**	-1.9542	0.140677774
fuel2	**C**	-2.6446	0.070033762
fuel2	**D**	-2.1115	0.120056246
fuel2	**E**	-1.9338	0.143597682
fuel2	**F**	-2.6201	0.071795583
fuel2	**G**	-1.7396	0.174590623

Table B65: Least squares means for OC

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
fuel2	6	122	1.59	0.1569
Least Squares Means				
Effect	**fuel2**	**Estimate**	**Back transformed**	
fuel2	A	-1.3648	0.25543176	
fuel2	B	-0.9836	0.37396241	
fuel2	C	-0.8934	0.40926189	
fuel2	D	-1.0143	0.3626562	
fuel2	E	-1.0963	0.33410499	

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
fuel2	F	-1.0538		0.34861051
fuel2	G	-1.0473		0.35088386

Appendix C

Table C1: Average weighted emissions (g/mile) and carbon balance fuel economy (miles/gallons) for the test vehicle/fuel combinations

	THCw Average						
	Federal ULSD	CARB Diesel	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
Vehicle #1	0.032	0.022	0.032	0.026	0.029	0.027	0.024
Vehicle #2	0.061	0.055	0.064	0.062	0.055	0.059	0.061
Vehicle #3	0.018	0.016	0.021	0.017	0.022	0.019	0.018
Vehicle #4	0.051	0.041	0.049	0.041	0.045	0.044	0.037
Vehicle #5	0.083	0.055	0.067	0.079	0.060	0.062	0.068
Vehicle #6	0.018	0.014	0.014	0.013	0.024	0.013	0.012
Vehicle #7	0.040	0.032	0.044	0.032	0.034	0.032	0.031
Vehicle #8	0.059	0.063	0.055	0.051	0.053	0.067	0.066
	NMHCw Average						
Vehicle #1	0.015	0.009	0.018	0.012	0.015	0.013	0.011
Vehicle #2	0.038	0.033	0.041	0.032	0.034	0.030	0.035
Vehicle #3	0.008	0.005	0.008	0.007	0.009	0.005	0.005
Vehicle #4	0.021	0.017	0.020	0.015	0.019	0.014	0.013
Vehicle #5	0.068	0.035	0.049	0.059	0.046	0.044	0.051
Vehicle #6	0.007	0.004	0.007	0.004	0.014	0.005	0.005
Vehicle #7	0.025	0.019	0.029	0.019	0.021	0.018	0.016
Vehicle #8	0.010	0.011	0.013	0.009	0.014	0.011	0.015
	CH_4w Average						
Vehicle #1	0.020	0.015	0.016	0.016	0.018	0.016	0.015
Vehicle #2	0.026	0.026	0.027	0.035	0.025	0.034	0.029
Vehicle #3	0.012	0.013	0.016	0.012	0.015	0.016	0.016
Vehicle #4	0.034	0.028	0.034	0.029	0.030	0.035	0.028
Vehicle #5	0.018	0.023	0.020	0.024	0.017	0.022	0.020
Vehicle #6	0.013	0.011	0.008	0.010	0.011	0.010	0.008
Vehicle #7	0.017	0.015	0.017	0.015	0.015	0.016	0.017

Vehicle #8	0.057	0.059	0.048	0.048	0.046	0.065	0.059
	COw Average						
Vehicle #1	0.137	0.072	0.162	0.111	0.119	0.126	0.099
Vehicle #2	0.547	0.336	0.526	0.451	0.432	0.421	0.434
Vehicle #3	0.097	0.057	0.116	0.080	0.125	0.083	0.080
Vehicle #4	0.097	0.080	0.126	0.105	0.104	0.098	0.028
Vehicle #5	0.636	0.501	0.566	0.663	0.566	0.638	0.709
Vehicle #6	0.117	0.049	0.085	0.059	0.108	0.055	0.059
Vehicle #7	0.107	0.074	0.103	0.082	0.081	0.091	0.074
Vehicle #8	0.112	0.141	0.141	0.093	0.123	0.141	0.131
	NOxw Average						
Vehicle #1	0.041	0.045	0.028	0.028	0.033	0.046	0.031
Vehicle #2	0.144	0.150	0.173	0.149	0.181	0.138	0.142
Vehicle #3	0.034	0.047	0.035	0.040	0.039	0.030	0.043
Vehicle #4	0.035	0.043	0.049	0.039	0.041	0.048	0.045
Vehicle #5	0.159	0.143	0.139	0.165	0.198	0.144	0.165
Vehicle #6	0.231	0.240	0.279	0.235	0.260	0.259	0.243
Vehicle #7	0.030	0.037	0.036	0.036	0.037	0.044	0.035
Vehicle #8	0.053	0.063	0.052	0.062	0.053	0.066	0.054
	CO_2w Average						
Vehicle #1	417	408	429	419	418	409	412
Vehicle #2	731	734	740	709	734	726	731
Vehicle #3	260	262	275	271	271	268	267
Vehicle #4	421	429	424	417	432	421	427
Vehicle #5	789	817	807	791	825	767	792
Vehicle #6	654	656	659	661	657	645	651
Vehicle #7	296	293	295	296	296	293	293
Vehicle #8	396	394	397	398	413	394	404
	Carbon Balance FEw Average						
Vehicle #1	26.6	26.2	25.2	25.6	25.8	26.3	25.5
Vehicle #2	15.1	14.5	14.6	14.8	14.7	14.8	14.6
Vehicle #3	42.6	40.7	39.4	39.6	39.9	40.2	39.3
Vehicle #4	26.3	24.9	25.5	25.7	25.0	25.6	24.6
Vehicle #5	14.0	13.2	13.4	13.4	13.1	14.0	13.3
Vehicle #6	16.9	16.3	16.3	16.2	16.4	16.7	16.2
Vehicle #7	37.3	36.7	36.6	36.2	36.4	36.8	35.9
Vehicle #8	28.0	27.1	27.2	26.9	26.2	27.3	26.0

Table C2: Cycle-based PM mass emissions (mg/mile)

	Vehicle #1	Vehicle #2	Vehicle #3	Vehicle #4	Vehicle #5	Vehicle #6	Vehicle #7	Vehicle #8
Federal ULSD	0.75	1.52	0.18	0.99	2.18	2.65	0.73	0.68
CARB Diesel	1.26	2.12	0.26	1.02	1.93	1.36	0.60	0.60
Fed/SME-20	1.45	1.45	0.62	0.96	1.35	1.45	0.36	0.52
Fed/AFME-20	0.78	0.64	0.48	1.13	0.87	1.04	0.40	1.22
Fed/WCO-20	0.30	1.18	0.31	1.57	0.94	2.31	0.35	0.96
Fed/HVO-20	0.90	1.71	0.37	1.35	1.50	2.00	0.65	0.68
CARB/WCO-20	1.33	0.93	0.88	0.85	2.42	1.47	0.80	0.74

Table C3: Average weighted particle number emissions (particles/mile)

	Federal ULSD	CARB ULSD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
Vehicle #1	1.3699E+11	2.5606E+11	1.4055E+11	1.5478E+11	1.1357E+11	9.3367E+10	1.1938E+11
Vehicle #2	1.7060E+11	1.3703E+11	8.0970E+10	2.7200E+10	2.1994E+10	2.7623E+10	6.4027E+10
Vehicle #3	1.1868E+10	1.3765E+10	2.4971E+10	1.9704E+11	5.2160E+10	1.2932E+10	2.7491E+10
Vehicle #4	1.8989E+10	2.1574E+10	3.8112E+10	2.7090E+10	2.9433E+10	3.7038E+10	1.7124E+10
Vehicle #5	2.4069E+09	2.8700E+09	1.1178E+09	2.7282E+09	3.0456E+09	4.2168E+09	3.2468E+09
Vehicle #6	3.0608E+10	1.6467E+10	2.7156E+10	2.8242E+10	4.0827E+09	6.1371E+10	2.7636E+10
Vehicle #7	6.0422E+09	7.4305E+08	1.7559E+09	1.0301E+10	2.4375E+09	2.7754E+09	1.5522E+10
Vehicle #8	1.0599E+10	3.2045E+10	5.0502E+10	7.8220E+09	1.6707E+10	5.4498E+10	2.7432E+10

Table C4: Average weighted formaldehyde and acetaldehyde emissions (µg/mile)

	Formaldehyde						
	Federal ULSD	CARB ULSD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
Vehicle #1	3543.11	2640.01	8862.72	7045.30	2363.63	10156.08	4054.39
Vehicle #2	23470.97	13640.84	21170.88	18063.27	17604.70	14219.30	11198.73
Vehicle #3	2160.38	1343.24	0.00	1468.99	3996.21	2037.56	2008.66
Vehicle #4	7415.22	2637.97	3581.87	6565.03	5571.03	7699.53	8901.01
Vehicle #5	13364.28	10907.81	11163.07	6406.56	13961.16	11608.09	9346.51
Vehicle #6	2350.20	2150.73	2893.87	2807.90	5465.21	2741.87	1835.22
Vehicle #7	3968.16	2962.77	4786.39	3632.91	4300.29	1731.71	3253.83
Vehicle #8	1371.32	1438.90	2779.58	1598.66	3281.07	1251.14	2841.68
	Acetaldehyde						
Vehicle #1	797.10	632.37	2047.58	1565.77	353.18	2925.94	885.13
Vehicle #2	8585.19	4503.52	7414.71	5258.81	5640.61	5258.81	3431.55
Vehicle #3	780.78	445.87	0.00	447.34	1317.33	673.09	609.87
Vehicle #4	2256.81	811.39	1889.00	2391.74	2515.08	2702.30	962.67
Vehicle #5	5731.96	2002.23	3234.01	4860.36	3349.48	4102.87	12000.85
Vehicle #6	1405.08	1149.30	1535.58	728.95	1957.58	653.29	877.32
Vehicle #7	1015.40	623.52	1056.51	815.26	1600.72	1060.88	971.40
Vehicle #8	367.85	378.34	542.94	598.47	655.71	381.20	762.92

Table C5: Average nitrogenous emissions for Vehicle #4 to Vehicle #8 (g/mile)

	NO Average						
	Federal ULSD	CARB Diesel	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
Vehicle #4	0.0033	0.0039	0.0145	0.0049	0.0090	0.0005	0.0048
Vehicle #5	0.1078	0.0997	0.0731	0.0639	0.1354	0.0920	0.1070
Vehicle #6	0.1161	0.1111	0.1631	0.1185	0.1491	0.1381	0.1643
Vehicle #7	0.0055	0.0119	0.0292	0.0109	0.0124	0.0192	0.0090
Vehicle #8	0.0008	0.0042	0.0030	0.0000	0.0038	0.0042	0.0043
	NO2 Average						
Vehicle #4	0.028	0.032	0.026	0.031	0.033	0.028	0.037
Vehicle #5	0.027	0.036	0.054	0.034	0.044	0.044	0.045
Vehicle #6	0.081	0.104	0.076	0.081	0.057	0.093	0.052
Vehicle #7	0.026	0.020	0.014	0.025	0.021	0.028	0.021
Vehicle #8	0.059	0.062	0.053	0.066	0.043	0.063	0.054
	N2O Average						
Vehicle #4	0.009	0.013	0.013	0.010	0.008	0.012	0.009
Vehicle #5	0.066	0.064	0.054	0.034	0.068	0.062	0.061
Vehicle #6	0.017	0.011	0.014	0.014	0.014	0.014	0.010
Vehicle #7	0.019	0.019	0.020	0.022	0.021	0.025	0.017
Vehicle #8	0.016	0.014	0.017	0.015	0.014	0.013	0.012
	NO:NO2 Ratio						
Vehicle #4	0.106	0.103	2.040	0.149	0.270	0.017	0.116
Vehicle #5	7.074	2.802	2.048	1.734	3.096	2.168	2.399
Vehicle #6	1.451	1.084	2.155	1.465	2.637	1.502	3.318
Vehicle #7	0.220	0.595	2.306	0.429	0.586	0.700	0.425
Vehicle #8	0.013	0.067	0.064	0.000	0.092	0.067	0.082

Table C6: Average OC emissions (mg/mile)

	Federal ULSD	CARB ULSD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
Vehicle #1	0.064	0.080	0.302	0.031	0.040	0.163	0.057
Vehicle #2	0.253	0.152	0.160	0.157	0.162	0.141	0.171
Vehicle #3	0.010	0.000	0.000	0.000	0.011	0.030	0.000
Vehicle #4	0.727	0.126	0.186	0.327	0.302	0.552	0.401
Vehicle #5	0.285	0.710	0.346	0.068	0.250	0.317	0.587
Vehicle #6	0.447	0.320	0.770	0.384	0.576	0.292	0.705
Vehicle #7	0.116	0.031	0.074	0.193	0.186	0.309	0.121
Vehicle #8	0.148	0.125	0.171	0.139	0.233	0.250	0.290

Table C7: Average NH_3 emissions (mg/mile)

	Federal ULSD	CARB Diesel	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
Vehicle #1	17.5	7.5	5.5	14.6	11.3	17.4	10.0
Vehicle #2	7.4	7.5	7.6	5.1	6.3	7.2	7.8
Vehicle #3	1.2	2.5	1.6	1.4	1.8	1.3	0.9
Vehicle #4	NA	0.2	0.4	NA	0.1	NA	NA
Vehicle #5	NA	1.0	0.0	3.2	0.7	NA	NA
Vehicle #6	0.8	0.7	0.3	1.3	0.4	-0.1	NA
Vehicle #7	1.4	0.3	9.9	0.9	0.4	0.6	2.0
Vehicle #8	0.7	0.5	5.1	0.2	1.3	0.5	0.7

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Table C8: Average emissions during regeneration emissions testing for Vehicle #1 and Vehicle #3

	Vehicle #1		
	Baseline HWFET	**Federal ULSD**	**Fed/SME-20**
THC, g/mi	0.0047	0.039	0.065
NMHC, g/mi	0.0018	0.003	0.004
CH4, g/mi	0.0033	0.042	0.070
CO, g/mi	0.0000	0.008	0.013
NOx, g/mi	0.0761	0.103	0.096
CO2, g/mi	263	389	365
FE, mi/gallon	38.7	26.2	28.4
PM mass, mg/mi	NA	11.54	11.10
PN, #/mi	5.21E+03	3.56E+14	1.74E+15
BC, µg/mi	34.11 (x10)	248.62	353.94
EC, mg/mi	NA	0.560	0.516
OC, mg/mi	NA	0.266	0.252
Formal, µg/mi	0.539	0.674	1.293
Acetal x 5, µg/mi	0.000	0.043	0.203
Propional x 10, µg/mi	0.000	0.100	0.033
Butyral x 10, µg/mi	0.000	0.000	0.040
Benzal x 10, µg/mi	0.000	0.172	0.000
Hexanal x 10, µg/mi	0.000	0.088	0.000
	Vehicle #3		
THC, g/mi	0.007	0.010	0.027
NMHC, g/mi	0.003	0.002	0.018
CH4, g/mi	0.005	0.009	0.010
CO, g/mi	0.015	0.009	0.053
NOx, g/mi	0.085	0.230	0.362
CO2, g/mi	165	196	224
FE, mi/gallon	61.7	52.7	45.5
PM mass, mg/mi	0.66	21.04	12.52
PN, #/mi	8.20E+13	9.03E+14	6.48E+14
Soot Mass, mg/mi	0.52 (x10)	1.417	1.306
EC, mg/mi	0.040	1.114	1.331
OC, mg/mi	0.252	0.517	0.655
Formal, µg/mi	0.238	0.287	1.405
Acetal, µg/mi	0.000	0.023	0.196
Propional, µg/mi	0.000	0.013	0.015
Crotonal, µg/mi	0.060	0.067	0.036
Butyral, µg/mi	0.000	0.034	0.123
Benzal, µg/mi	0.000	0.008	0.012

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Appendix D

Table D1: Gas-phase PAH emissions for Vehicle #1

Component (ng/mile)	Fed ULSD	CARB USLD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
Naphthalene	253.91 ± 195.88	473.53 ± 221.80	2272.57 ± 822.60	815.15 ± 357.26	2014.97 ± 68.10	441.20 ± 559.90	50.22 ± 71.01
Quinoline	0.00 ± 0.00	0.00 ± 0.00	2.08 ± 2.95	2.06 ± 2.92	42.81 ± 46.02	5.13 ± 7.26	0.00 ± 0.00
2-methylnaphthalene	197.27 ± 95.12	436.48 ± 134.89	804.52 ± 425.48	420.13 ± 103.08	764.95 ± 69.05	230.86 ± 64.31	46.69 ± 60.50
1-methylnaphthalene	90.33 ± 41.32	240.58 ± 26.31	509.03 ± 325.65	234.23 ± 78.60	423.32 ± 9.65	151.98 ± 0.28	25.51 ± 34.50
Biphenyl	32.68 ± 16.56	78.88 ± 25.27	122.11 ± 58.81	76.74 ± 4.41	77.64 ± 28.64	26.74 ± 9.15	41.09 ± 58.10
2-methylbiphenyl	2230.79 ± 477.44	2694.35 ± 137.01	2054.23 ± 588.42	1495.97 ± 283.48	3392.02 ± 551.37	3709.07 ± 903.28	2949.50 ± 2776.74
2,6+2,7-dimethylnaphthalene	19.83 ± 28.04	173.64 ± 83.67	318.07 ± 153.76	154.58 ± 53.79	87.85 ± 24.28	0.00 ± 0.00	12.71 ± 3.34
1,3+1,6+1,7dimethylnaphth	48.70 ± 29.05	316.29 ± 26.86	624.39 ± 343.51	293.26 ± 74.25	171.51 ± 48.61	47.96 ± 36.22	92.63 ± 56.12
1,4+1,5+2,3-dimethylnaphth	33.81 ± 29.18	79.93 ± 11.87	131.69 ± 51.16	86.73 ± 28.96	90.79 ± 32.70	15.79 ± 12.08	29.33 ± 31.15
Acenaphthylene	5.99 ± 8.47	8.80 ± 12.44	20.23 ± 5.06	11.78 ± 16.66	26.70 ± 37.76	5.92 ± 0.17	0.00 ± 0.00
1,2-dimethylnaphthalene	0.00 ± 0.00	19.64 ± 27.78	30.21 ± 13.67	15.93 ± 8.30	10.12 ± 8.34	4.92 ± 6.96	0.00 ± 0.00
1,8-dimethylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Acenaphthene	5.03 ± 7.11	10.75 ± 15.20	56.80 ± 43.42	39.56 ± 8.47	66.87 ± 28.78	0.00 ± 0.00	0.00 ± 0.00
3-methylbiphenyl	850.00 ± 337.86	851.05 ± 537.93	1159.69 ± 77.26	0.00 ± 0.00	0.00 ± 0.00	1038.10 ± 784.90	1234.89 ± 851.19
4-methylbiphenyl	461.53 ± 16.64	779.86 ± 182.50	410.05 ± 85.14	0.00 ± 0.00	93.64 ± 132.43	467.87 ± 354.23	471.94 ± 374.76
1+2ethylnaphthalene	140.72 ± 91.40	182.03 ± 27.72	313.10 ± 68.19	192.96 ± 41.16	192.65 ± 18.70	155.30 ± 25.46	124.33 ± 28.18
1-ethyl-2-methylnaphthalene	2.07 ± 2.93	4.98 ± 7.05	53.43 ± 22.94	33.63 ± 8.25	5.04 ± 7.13	2.11 ± 2.99	15.25 ± 15.54
2,3,5+I-trimethylnaphthalene	13.91 ± 19.67	21.55 ± 16.37	156.78 ± 19.89	95.62 ± 3.88	25.81 ± 36.50	0.00 ± 0.00	15.91 ± 22.50

B-trimethylnaphthalene	23.67 ± 33.48	70.16 ± 33.47	182.71 ± 69.92	126.93 ± 12.91	23.95 ± 0.31	14.73 ± 3.75	25.12 ± 35.53
A-trimethylnaphthalene	28.11 ± 39.75	102.31 ± 50.19	239.94 ± 60.54	180.08 ± 25.59	50.57 ± 50.15	5.98 ± 4.36	73.97 ± 104.61
C-trimethylnaphthalene	38.58 ± 29.14	58.37 ± 0.38	192.24 ± 106.95	100.27 ± 49.78	26.70 ± 37.76	14.48 ± 20.48	64.20 ± 90.80
2-ethyl-1-methylnaphthalene	0.00 ± 0.00	2.05 ± 2.90	4.03 ± 0.20	10.02 ± 8.32	16.06 ± 16.73	0.00 ± 0.00	2.13 ± 3.01
E-trimethylnaphthalene	4.44 ± 6.28	26.22 ± 16.34	100.67 ± 4.94	76.73 ± 3.94	7.42 ± 10.49	0.00 ± 0.00	8.75 ± 0.53
2,4,5-trimethylnaphthalene	0.00 ± 0.00	2.03 ± 2.88	0.00 ± 0.00	7.99 ± 11.29	0.00 ± 0.00	0.00 ± 0.00	5.17 ± 7.32
F-trimethylnaphthalene	12.43 ± 17.58	18.63 ± 16.39	84.27 ± 8.05	27.74 ± 4.09	10.10 ± 12.57	0.00 ± 0.00	14.52 ± 20.53
Fluorene	134.86 ± 70.40	0.00 ± 0.00	366.41 ± 367.40	198.90 ± 20.27	171.91 ± 14.90	86.41 ± 35.10	55.95 ± 77.54
1,4,5-trimethylnaphthalene	11.84 ± 16.74	0.00 ± 0.00	2.78 ± 3.93	2.96 ± 4.18	0.00 ± 0.00	0.00 ± 0.00	5.83 ± 0.36
J-trimethylnaphthalene	11.84 ± 16.74	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
A-Methylfluorene	4.17 ± 0.04	2.03 ± 2.88	15.33 ± 7.37	21.85 ± 8.41	7.16 ± 4.14	0.00 ± 0.00	15.91 ± 22.50
B-Methylfluorene	2.98 ± 0.03	1.47 ± 2.07	5.65 ± 3.79	0.00 ± 0.00	2.99 ± 0.04	2.96 ± 0.09	4.19 ± 5.92
1-Methylfluorene	3.59 ± 5.08	0.59 ± 0.83	0.00 ± 0.00	10.04 ± 4.20	0.59 ± 0.84	0.58 ± 0.82	3.35 ± 4.74
9-fluorenone	19.15 ± 21.22	4.98 ± 7.05	13.99 ± 19.78	74.99 ± 16.92	49.12 ± 4.86	23.25 ± 32.88	23.43 ± 33.14
Dibenzothiophene	3.59 ± 5.08	0.00 ± 0.00	1.15 ± 0.06	1.18 ± 0.00	0.59 ± 0.84	1.18 ± 0.03	0.61 ± 0.86
Phenanthrene	92.33 ± 9.22	131.18 ± 48.69	152.45 ± 7.49	200.66 ± 28.61	152.08 ± 91.19	77.09 ± 14.81	115.04 ± 48.20
Anthracene	6.51 ± 9.21	3.52 ± 4.98	21.39 ± 5.11	10.05 ± 12.55	3.56 ± 5.03	1.18 ± 0.03	4.21 ± 4.38
Xanthone	2.98 ± 0.03	11.66 ± 4.05	2.88 ± 0.14	20.64 ± 16.63	59.79 ± 11.94	5.98 ± 4.36	2.92 ± 0.18
1,4-Naphthoquinone	11.91 ± 0.10	5.84 ± 0.04	11.51 ± 0.56	5.89 ± 8.33	5.93 ± 8.39	0.00 ± 0.00	2.79 ± 3.95
Acenaphthenequinone	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylphenanthrene	8.97 ± 8.50	20.40 ± 8.12	11.41 ± 3.50	17.73 ± 12.58	5.96 ± 4.16	1.45 ± 2.05	22.96 ± 10.95
2-methylphenanthrene	19.05 ± 0.17	24.52 ± 0.16	4.13 ± 4.27	21.87 ± 20.94	0.60 ± 0.85	4.20 ± 4.30	50.38 ± 9.28

Perinaphthenone	22.07 ± 8.61	16.71 ± 23.63	42.12 ± 30.51	5.03 ± 7.11	43.14 ± 4.78	44.38 ± 62.77	7.13 ± 4.55
2-methylanthracene	2.98 ± 0.03	2.92 ± 0.02	4.16 ± 5.89	1.48 ± 2.09	2.99 ± 0.04	5.85 ± 4.01	0.00 ± 0.00
4,5-methylenephenanthrene	5.95 ± 0.05	2.93 ± 4.15	2.98 ± 4.21	8.85 ± 4.15	3.02 ± 4.27	3.02 ± 4.27	2.79 ± 3.95
9-methylphenanthrene	4.15 ± 4.17	15.75 ± 4.03	0.00 ± 0.00	12.99 ± 0.04	12.46 ± 17.62	4.20 ± 4.30	9.79 ± 3.52
1-methylphenanthrene	0.00 ± 0.00	2.03 ± 2.88	1.94 ± 2.75	10.04 ± 0.03	0.00 ± 0.00	2.11 ± 2.99	7.54 ± 10.66
Anthrone	14.87 ± 4.08	32.07 ± 12.18	11.11 ± 15.71	5.92 ± 8.37	14.83 ± 20.98	12.08 ± 17.08	23.59 ± 9.68
9-methylanthracene	4.17 ± 0.04	2.05 ± 2.90	1.94 ± 2.75	4.13 ± 0.01	0.00 ± 0.00	2.11 ± 2.99	4.08 ± 0.25
Anthraquinone	2.96 ± 4.18	0.00 ± 0.00	11.51 ± 0.56	2.96 ± 4.18	11.92 ± 8.31	3.02 ± 4.27	0.00 ± 0.00
A-dimethylphenanthrene	7.99 ± 11.30	4.09 ± 0.03	39.54 ± 42.57	2.07 ± 2.93	2.08 ± 2.94	9.93 ± 8.07	47.22 ± 17.71
B-dimethylphenanthrene	0.59 ± 0.84	12.79 ± 16.43	6.55 ± 9.26	0.59 ± 0.84	0.00 ± 0.00	6.64 ± 9.39	0.61 ± 0.86
1,7-dimethylphenanthrene	7.16 ± 4.27	2.05 ± 2.90	7.00 ± 4.41	2.06 ± 2.92	2.08 ± 2.94	0.00 ± 0.00	4.75 ± 6.71
3,6-dimethylphenanthrene	0.00 ± 0.00	5.86 ± 8.29	2.78 ± 3.93	2.96 ± 4.18	5.99 ± 0.08	5.92 ± 0.17	2.79 ± 3.95
D-dimethylphenanthrene	1.50 ± 2.12	1.47 ± 2.07	0.00 ± 0.00	1.48 ± 2.09	2.99 ± 0.04	2.96 ± 0.09	2.92 ± 0.18
E-dimethylphenanthrene	2.96 ± 4.18	2.93 ± 4.15	2.78 ± 3.93	0.00 ± 0.00	14.89 ± 12.51	3.02 ± 4.27	0.00 ± 0.00
C-dimethylphenanthrene	4.15 ± 4.17	4.07 ± 4.10	4.13 ± 4.27	7.08 ± 0.02	55.24 ± 26.11	4.20 ± 4.30	3.96 ± 3.88
Fluoranthene	1.48 ± 2.09	0.00 ± 0.00	11.41 ± 3.50	11.80 ± 4.14	10.38 ± 14.68	0.00 ± 0.00	7.61 ± 10.76
Pyrene	47.53 ± 24.85	11.65 ± 8.18	97.18 ± 137.43	64.89 ± 24.85	14.89 ± 12.51	32.35 ± 11.59	21.30 ± 30.13
9-Anthraaldehyde	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Retene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
benzo(a)fluorene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.90 ± 4.10	3.04 ± 4.30
benzo(b)fluorene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
5-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

B-MePy/MeFl	0.00 ± 0.00	0.00 ± 0.00	1.94 ± 2.75	2.07 ± 2.93	0.00 ± 0.00	4.92 ± 6.96	0.00 ± 0.00
1-MeFl+C-MeFl/Py	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1+3-methylfluoranthene	2.10 ± 2.97	0.00 ± 0.00	0.00 ± 0.00	2.07 ± 2.93	0.00 ± 0.00	2.03 ± 2.87	2.13 ± 3.01
4-methylpyrene	2.07 ± 2.93	2.05 ± 2.90	0.00 ± 0.00	4.13 ± 0.01	2.08 ± 2.94	0.00 ± 0.00	1.95 ± 2.76
C-MePy/MeFl	0.00 ± 0.00	2.05 ± 2.90	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	4.14 ± 0.12	0.00 ± 0.00
D-MePy/MeFl	2.07 ± 2.93	0.00 ± 0.00	1.94 ± 2.75	0.00 ± 0.00	2.11 ± 2.99	2.03 ± 2.87	0.00 ± 0.00
1-methylpyrene	5.97 ± 4.26	0.00 ± 0.00	1.49 ± 2.10	0.00 ± 0.00	0.00 ± 0.00	1.51 ± 2.13	0.00 ± 0.00
Benzonaphthothiophene	0.60 ± 0.85	0.00 ± 0.00	1.15 ± 0.06	0.00 ± 0.00	1.20 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
benzo(c)phenanthrene	2.98 ± 0.03	0.00 ± 0.00	2.88 ± 0.14	2.95 ± 0.01	4.53 ± 6.41	1.45 ± 2.05	0.00 ± 0.00
Benzo(ghi)fluoranthene	2.98 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	1.47 ± 2.08	2.99 ± 0.04	1.51 ± 2.13	2.92 ± 0.18
9-phenylanthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	9.01 ± 4.35	5.92 ± 0.17	0.00 ± 0.00
6-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Cyclopenta(c,d)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.03 ± 2.87	0.00 ± 0.00
Benz(a)anthracene	2.07 ± 2.93	0.00 ± 0.00	0.00 ± 0.00	2.07 ± 2.93	0.00 ± 0.00	4.14 ± 0.12	0.00 ± 0.00
Chrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzanthrone	2.96 ± 4.18	0.00 ± 0.00	0.00 ± 0.00	2.96 ± 4.18	5.99 ± 0.08	0.00 ± 0.00	0.00 ± 0.00
Benz(a)anthracene-7,12-dione	5.99 ± 8.47	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7-methylbenz(a)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7,12-dimethylbenz(a)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	29.45 ± 41.65	71.90 ± 9.39	33.21 ± 46.97	0.00 ± 0.00
Benzo(b)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(j)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Benzo(k)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(a)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BeP	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.11 ± 2.99	0.00 ± 0.00	2.13 ± 3.01
BaP	0.00 ± 0.00	1.47 ± 2.07	1.49 ± 2.10	0.00 ± 0.00	1.48 ± 2.10	4.34 ± 6.14	0.00 ± 0.00
Perylene	0.00 ± 0.00	0.00 ± 0.00	1.49 ± 2.10	0.00 ± 0.00	14.86 ± 16.74	1.51 ± 2.13	1.52 ± 2.15
3-methylcholanthrene	1.19 ± 0.01	1.17 ± 0.01	1.15 ± 0.06	4.14 ± 4.19	4.22 ± 4.29	1.18 ± 0.03	0.56 ± 0.79
7-methylbenzo(a)pyrene	0.60 ± 0.85	0.00 ± 0.00	0.00 ± 0.00	24.25 ± 34.30	0.00 ± 0.00	0.60 ± 0.85	0.00 ± 0.00
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.03 ± 2.87	0.00 ± 0.00
Indeno[123-cd]fluoranthene	3.00 ± 4.24	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Indeno[123-cd]pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ac)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ah+ac)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.97 ± 4.20	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ah)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,j)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(b)chrysene	0.00 ± 0.00	7.92 ± 11.20	0.00 ± 0.00	0.00 ± 0.00	8.01 ± 11.33	0.00 ± 0.00	0.00 ± 0.00
Picene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.07 ± 2.93	5.14 ± 7.26	0.00 ± 0.00	0.00 ± 0.00
Benzo(ghi)perylene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	4.13 ± 0.01	2.11 ± 2.99	2.11 ± 2.99	0.00 ± 0.00
Anthanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Triphenylene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,l)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Coronene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Dibenzo(a,e)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,i)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,h)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(b,k)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Table D2: Gas-phase PAH emissions for the Vehicle #2

Component (ng/mile)	Fed ULSD	CARB USLD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
Naphthalene	2916.37 ± 1603.86	1484.05 ± 1873.24	1652.05 ± 157.42	400.22 ± 409.71	1385.78 ± 1021.02	895.99 ± 1261.71	1029.47 ± 310.54
Quinoline	20.09 ± 0.37	2.65 ± 3.75	5.22 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	32.04 ± 37.73	17.16 ± 16.45
2-methylnaphthalene	641.91 ± 335.48	1215.31 ± 861.75	672.78 ± 26.70	262.56 ± 207.48	178.33 ± 59.28	817.60 ± 1051.22	290.61 ± 202.03
1-methylnaphthalene	327.04 ± 193.93	691.85 ± 556.77	400.52 ± 57.82	156.77 ± 136.14	132.23 ± 32.23	534.54 ± 755.95	224.26 ± 147.30
Biphenyl	77.74 ± 40.67	180.83 ± 114.13	130.53 ± 10.61	13.34 ± 18.86	13.49 ± 19.07	135.35 ± 191.42	121.73 ± 34.57
2-methylbiphenyl	374.57 ± 529.72	1068.87 ± 1511.61	0.00 ± 0.00	162.34 ± 229.58	402.89 ± 569.77	0.00 ± 0.00	1740.94 ± 29.78
2,6+2,7-dimethylnaphthalene	128.02 ± 7.59	420.71 ± 398.83	292.37 ± 57.87	27.99 ± 21.85	29.55 ± 41.78	223.81 ± 316.51	29.96 ± 42.37
1,3+1,6+1,7dimethylnaphth	235.76 ± 6.23	734.65 ± 758.90	553.38 ± 226.51	68.94 ± 3.73	59.17 ± 32.45	425.88 ± 602.28	6.72 ± 9.50
1,4+1,5+2,3-dimethylnaphth	12.70 ± 5.49	235.60 ± 215.71	165.57 ± 63.21	35.19 ± 4.50	16.90 ± 10.83	115.14 ± 162.84	36.71 ± 27.33
Acenaphthylene	11.02 ± 15.58	87.01 ± 102.08	7.46 ± 10.55	7.62 ± 10.78	7.69 ± 0.02	68.63 ± 97.06	11.73 ± 5.42
1,2-dimethylnaphthalene	2.64 ± 3.73	61.86 ± 48.67	2.61 ± 3.69	0.00 ± 0.00	2.70 ± 3.81	36.98 ± 52.30	6.61 ± 9.35
1,8-dimethylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	11.85 ± 16.76
Acenaphthene	56.91 ± 41.05	65.16 ± 9.60	117.10 ± 10.49	0.00 ± 0.00	21.87 ± 30.93	29.36 ± 41.52	25.00 ± 16.37
3-methylbiphenyl	436.99 ± 618.00	788.39 ± 1114.95	700.87 ± 991.18	248.29 ± 254.12	453.49 ± 161.78	0.00 ± 0.00	0.00 ± 0.00
4-methylbiphenyl	96.15 ± 61.37	253.95 ± 359.14	78.32 ± 36.96	315.01 ± 7.20	200.10 ± 98.48	149.20 ± 135.52	0.00 ± 0.00

1+2ethylnaphthalene	149.77 ± 55.14	299.50 ± 237.90	228.97 ± 52.63	62.29 ± 70.35	63.13 ± 49.13	181.87 ± 257.20	107.37 ± 9.94
1-ethyl-2-methylnaphthalene	19.90 ± 20.68	63.30 ± 89.52	132.00 ± 73.77	0.00 ± 0.00	0.00 ± 0.00	21.73 ± 30.73	0.00 ± 0.00
2,3,5+I-trimethylnaphthalene	23.95 ± 16.22	150.48 ± 212.80	385.57 ± 158.03	13.65 ± 19.31	25.71 ± 36.36	29.36 ± 41.52	0.00 ± 0.00
B-trimethylnaphthalene	33.91 ± 47.96	298.62 ± 317.42	413.90 ± 216.03	0.00 ± 0.00	0.00 ± 0.00	45.75 ± 64.70	0.00 ± 0.00
A-trimethylnaphthalene	111.36 ± 24.27	366.39 ± 355.58	477.29 ± 279.29	16.60 ± 23.48	44.13 ± 62.40	74.35 ± 105.14	1.98 ± 2.79
C-trimethylnaphthalene	63.67 ± 48.50	250.00 ± 332.57	350.54 ± 84.21	56.80 ± 49.02	3.84 ± 5.43	0.00 ± 0.00	0.00 ± 0.00
2-ethyl-1-methylnaphthalene	2.64 ± 3.73	10.01 ± 14.16	20.14 ± 0.01	0.00 ± 0.00	5.38 ± 0.02	0.00 ± 0.00	2.77 ± 3.91
E-trimethylnaphthalene	33.48 ± 0.61	117.46 ± 160.87	197.63 ± 94.84	0.00 ± 0.00	0.00 ± 0.00	24.78 ± 35.05	0.00 ± 0.00
2,4,5-trimethylnaphthalene	5.21 ± 0.09	24.20 ± 26.88	6.34 ± 8.96	0.00 ± 0.00	13.07 ± 0.04	2.67 ± 3.77	0.00 ± 0.00
F-trimethylnaphthalene	64.78 ± 6.44	115.05 ± 139.62	199.13 ± 57.92	0.00 ± 0.00	4.60 ± 6.51	4.58 ± 6.47	0.00 ± 0.00
Fluorene	474.79 ± 306.97	231.32 ± 146.72	1127.73 ± 73.29	114.49 ± 45.03	193.86 ± 44.08	135.10 ± 102.26	263.94 ± 58.16
1,4,5-trimethylnaphthalene	14.78 ± 10.25	15.16 ± 21.44	29.84 ± 31.66	0.00 ± 0.00	0.00 ± 0.00	3.81 ± 5.39	0.00 ± 0.00
J-trimethylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	14.92 ± 21.10	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
A-Methylfluorene	16.42 ± 5.56	39.03 ± 5.90	113.39 ± 68.62	23.82 ± 15.36	2.70 ± 3.81	6.48 ± 9.17	13.27 ± 10.95
B-Methylfluorene	1.88 ± 2.66	14.96 ± 5.07	22.38 ± 5.28	1.91 ± 2.69	3.85 ± 0.01	1.91 ± 2.70	19.72 ± 22.39
1-Methylfluorene	24.10 ± 32.00	20.45 ± 26.82	124.56 ± 15.88	9.00 ± 0.21	0.77 ± 1.09	0.77 ± 1.08	0.78 ± 1.10
9-fluorenone	0.00 ± 0.00	13.72 ± 19.40	28.73 ± 40.62	8.94 ± 5.10	40.01 ± 16.43	2.68 ± 3.79	44.94 ± 44.84
Dibenzothiophene	1.49 ± 0.03	0.74 ± 1.05	4.47 ± 6.33	0.00 ± 0.00	0.00 ± 0.00	0.77 ± 1.08	0.79 ± 1.12
Phenanthrene	220.44 ± 109.22	262.66 ± 30.57	533.28 ± 52.48	71.62 ± 33.45	130.84 ± 71.08	137.53 ± 5.00	184.46 ± 35.25
Anthracene	16.46 ± 10.82	16.42 ± 10.35	27.59 ± 26.36	0.00 ± 0.00	0.77 ± 1.09	5.34 ± 5.39	0.00 ± 0.00
Xanthone	1.84 ± 2.60	33.74 ± 0.52	26.10 ± 31.63	1.84 ± 2.61	3.85 ± 0.01	3.82 ± 0.01	11.82 ± 11.22
1,4-Naphthoquinone	0.00 ± 0.00	30.08 ± 11.07	3.73 ± 5.27	3.81 ± 5.39	7.69 ± 0.02	0.00 ± 0.00	3.89 ± 5.50

Acenaphthenequinone	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylphenanthrene	37.25 ± 5.94	29.95 ± 4.84	100.69 ± 21.05	18.51 ± 20.79	19.23 ± 0.06	15.31 ± 16.25	17.78 ± 25.14
2-methylphenanthrene	24.00 ± 21.48	35.12 ± 15.36	143.21 ± 10.62	8.12 ± 11.48	36.15 ± 5.55	39.77 ± 21.73	44.91 ± 39.29
Perinaphthenone	53.98 ± 76.34	50.57 ± 43.20	53.72 ± 58.04	2.58 ± 3.65	47.61 ± 48.80	24.49 ± 27.09	64.09 ± 38.12
2-methylanthracene	9.42 ± 13.32	3.75 ± 0.06	11.19 ± 0.01	0.00 ± 0.00	5.78 ± 8.17	7.63 ± 5.38	1.95 ± 2.75
4,5-methylenephenanthrene	3.77 ± 5.33	11.21 ± 5.13	7.46 ± 0.00	0.00 ± 0.00	3.85 ± 5.45	3.81 ± 5.39	3.95 ± 5.59
9-methylphenanthrene	8.08 ± 11.43	27.70 ± 4.87	57.43 ± 5.25	0.76 ± 1.08	13.07 ± 5.40	1.53 ± 0.00	21.26 ± 16.86
1-methylphenanthrene	6.24 ± 8.83	21.14 ± 29.89	35.05 ± 10.53	5.25 ± 0.12	6.55 ± 9.26	2.68 ± 3.79	18.57 ± 26.26
Anthrone	33.62 ± 16.39	11.13 ± 15.73	52.23 ± 63.31	0.00 ± 0.00	0.00 ± 0.00	11.47 ± 5.44	11.85 ± 16.76
9-methylanthracene	6.24 ± 8.83	5.25 ± 0.08	5.22 ± 0.00	0.00 ± 0.00	2.69 ± 3.80	2.67 ± 3.77	0.00 ± 0.00
Anthraquinone	0.00 ± 0.00	3.71 ± 5.24	18.64 ± 26.36	0.00 ± 0.00	7.69 ± 0.02	0.00 ± 0.00	15.80 ± 22.35
A-dimethylphenanthrene	23.95 ± 16.22	9.04 ± 5.44	20.14 ± 0.01	12.87 ± 10.90	16.89 ± 16.26	2.68 ± 3.79	0.00 ± 0.00
B-dimethylphenanthrene	5.16 ± 5.17	0.00 ± 0.00	35.06 ± 36.94	0.76 ± 1.08	16.95 ± 21.80	46.51 ± 65.78	1.57 ± 0.02
1,7-dimethylphenanthrene	5.21 ± 0.09	9.04 ± 5.44	12.68 ± 10.54	2.58 ± 3.65	5.38 ± 0.02	5.35 ± 0.02	2.77 ± 3.91
3,6-dimethylphenanthrene	0.00 ± 0.00	3.79 ± 5.36	14.92 ± 0.01	3.69 ± 5.22	7.69 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
D-dimethylphenanthrene	0.00 ± 0.00	3.75 ± 0.06	3.73 ± 0.00	0.00 ± 0.00	3.85 ± 0.01	1.91 ± 2.71	1.98 ± 2.79
E-dimethylphenanthrene	0.00 ± 0.00	3.79 ± 5.36	11.19 ± 5.28	0.00 ± 0.00	0.00 ± 0.00	7.64 ± 0.02	3.95 ± 5.59
C-dimethylphenanthrene	5.26 ± 5.36	20.45 ± 26.82	27.59 ± 15.81	0.74 ± 1.04	5.39 ± 5.45	0.77 ± 1.08	68.07 ± 26.99
Fluoranthene	7.39 ± 5.13	7.46 ± 5.19	16.79 ± 23.74	1.84 ± 2.61	3.85 ± 0.01	3.82 ± 0.01	11.82 ± 11.22
Pyrene	41.06 ± 16.53	22.50 ± 0.35	55.95 ± 26.40	22.26 ± 20.70	15.41 ± 21.80	15.28 ± 0.04	54.89 ± 0.59
9-Anthraaldehyde	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Retene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

benzo(a)fluorene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	3.89 ± 5.50
benzo(b)fluorene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	3.81 ± 5.39	0.00 ± 0.00
5-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
B-MePy/MeFl	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.72 ± 3.85
1-MeFl+C-MeFl/Py	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.58 ± 3.65	0.00 ± 0.00	2.67 ± 3.77	2.72 ± 3.85
1+3-methylfluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.72 ± 3.85
4-methylpyrene	5.21 ± 0.09	0.00 ± 0.00	5.22 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.72 ± 3.85
C-MePy/MeFl	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.67 ± 3.77	0.00 ± 0.00
D-MePy/MeFl	0.00 ± 0.00	0.00 ± 0.00	2.61 ± 3.69	2.67 ± 3.77	2.70 ± 3.81	0.00 ± 0.00	2.77 ± 3.91
1-methylpyrene	1.84 ± 2.60	0.00 ± 0.00	0.00 ± 0.00	1.84 ± 2.61	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzonaphthothiophene	0.73 ± 1.04	0.74 ± 1.05	0.00 ± 0.00	0.74 ± 1.04	0.00 ± 0.00	1.53 ± 0.00	0.00 ± 0.00
benzo(c)phenanthrene	0.00 ± 0.00	1.90 ± 2.68	5.59 ± 7.91	1.84 ± 2.61	5.78 ± 8.17	5.72 ± 8.09	0.00 ± 0.00
Benzo(ghi)fluoranthene	1.88 ± 2.66	3.75 ± 0.06	1.86 ± 2.64	0.00 ± 0.00	3.85 ± 0.01	3.82 ± 0.01	11.82 ± 11.22
9-phenylanthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	3.69 ± 5.22	3.85 ± 5.45	0.00 ± 0.00	0.00 ± 0.00
6-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Cyclopenta(c,d)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.58 ± 3.65	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benz(a)anthracene	5.21 ± 0.09	0.00 ± 0.00	0.00 ± 0.00	2.67 ± 3.77	0.00 ± 0.00	17.92 ± 25.34	17.28 ± 5.73
Chrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzanthrone	7.44 ± 0.14	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	11.73 ± 5.42
Benz(a)anthracene-7,12-dione	0.00 ± 0.00	3.79 ± 5.36	3.73 ± 5.28	3.69 ± 5.22	3.84 ± 5.43	7.64 ± 0.02	0.00 ± 0.00
3-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7-methylbenz(a)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

7,12-dimethylbenz(a)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	19.27 ± 27.25	0.00 ± 0.00	97.99 ± 4.49
Benzo(b)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(j)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(k)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(a)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BeP	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.58 ± 3.65	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BaP	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.84 ± 2.61	0.00 ± 0.00	1.91 ± 2.70	0.00 ± 0.00
Perylene	0.00 ± 0.00	5.56 ± 7.87	0.00 ± 0.00	0.00 ± 0.00	7.68 ± 5.41	0.00 ± 0.00	1.98 ± 2.79
3-methylcholanthrene	0.00 ± 0.00	1.50 ± 0.02	5.22 ± 5.27	0.74 ± 1.04	1.54 ± 0.00	0.76 ± 1.08	1.57 ± 0.02
7-methylbenzo(a)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	20.54 ± 29.05
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00 ± 0.00	5.25 ± 0.08	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Indeno[123-cd]fluoranthene	0.00 ± 0.00	0.00 ± 0.00	3.73 ± 5.27	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Indeno[123-cd]pyrene	74.40 ± 1.35	74.99 ± 1.16	74.59 ± 0.04	75.00 ± 1.72	76.90 ± 0.23	76.41 ± 0.22	78.42 ± 0.84
Dibenzo(ac)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ah+ac)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ah)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	3.84 ± 5.43	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,j)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(b)chrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Picene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	10.36 ± 14.65	0.00 ± 0.00	0.00 ± 0.00
Benzo(ghi)perylene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.67 ± 3.77	0.00 ± 0.00	2.67 ± 3.77	0.00 ± 0.00
Anthanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.67 ± 3.77	0.00 ± 0.00

Triphenylene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,l)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Coronene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,e)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,i)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,h)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(b,k)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Table D3: Gas-phase PAH emission for Vehicle #3

Component (ng/mile)	Fed ULSD	CARB USLD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
Naphthalene	823.96 ± 419.22	387.93 ± 121.85	3488.89 ± 3193.02	1039.17 ± 409.74	3292.82 ± 2589.81	875.97 ± 54.04	1426.98 ± 116.00
Quinoline	9.55 ± 5.33	6.01 ± 5.18	74.58 ± 47.30	11.24 ± 7.28	23.18 ± 4.68	7.97 ± 2.38	14.52 ± 2.55
2-methylnaphthalene	235.73 ± 71.40	181.54 ± 21.05	564.60 ± 368.44	269.55 ± 79.76	494.72 ± 120.29	301.71 ± 10.90	464.64 ± 1.30
1-methylnaphthalene	141.39 ± 74.98	103.67 ± 14.83	721.23 ± 721.68	202.09 ± 113.54	619.41 ± 491.39	167.09 ± 16.64	245.21 ± 17.65
Biphenyl	83.80 ± 80.06	41.42 ± 7.90	102.01 ± 34.88	65.21 ± 16.23	81.43 ± 8.11	78.42 ± 19.85	102.00 ± 22.77
2-methylbiphenyl	3056.73 ± 1887.21	2056.89 ± 460.17	2232.53 ± 837.08	3096.34 ± 22.20	1392.21 ± 175.59	1296.70 ± 1041.10	2144.47 ± 502.68
2,6+2,7-dimethylnaphthalene	94.89 ± 23.64	44.89 ± 7.74	100.23 ± 2.42	104.43 ± 19.50	161.32 ± 57.83	133.05 ± 26.27	174.51 ± 13.56
1,3+1,6+1,7dimethylnaphth	159.49 ± 70.77	83.54 ± 15.76	269.79 ± 112.09	173.74 ± 11.64	335.09 ± 34.96	190.00 ± 14.76	271.80 ± 19.88
1,4+1,5+2,3-dimethylnaphth	46.65 ± 24.15	28.40 ± 1.14	122.08 ± 104.53	64.25 ± 6.26	127.05 ± 13.51	57.23 ± 11.63	90.47 ± 11.51
Acenaphthylene	14.35 ± 17.89	5.09 ± 4.67	8.79 ± 4.97	10.58 ± 2.29	12.08 ± 9.68	9.03 ± 4.93	19.06 ± 14.80
1,2-dimethylnaphthalene	7.00 ± 0.28	3.36 ± 4.75	22.86 ± 12.45	5.23 ± 7.40	15.64 ± 12.39	12.70 ± 2.27	20.73 ± 0.16
1,8-dimethylnaphthalene	1.70 ± 2.40	0.00 ± 0.00	1.76 ± 2.49	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

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Acenaphthene	5.95 ± 0.24	30.08 ± 3.52	30.60 ± 0.02	3.05 ± 4.31	47.50 ± 10.24	31.65 ± 0.74	45.57 ± 6.98
3-methylbiphenyl	1647.34 ± 1016.44	1655.34 ± 412.23	1859.53 ± 247.44	1859.82 ± 45.84	1678.24 ± 114.15	1182.64 ± 619.27	1351.92 ± 127.70
4-methylbiphenyl	743.27 ± 440.66	776.16 ± 204.96	838.86 ± 152.26	765.28 ± 27.24	685.53 ± 52.38	612.63 ± 142.99	832.84 ± 74.83
1+2ethylnaphthalene	38.05 ± 31.22	16.20 ± 4.16	41.15 ± 9.97	32.39 ± 11.87	35.39 ± 12.58	37.01 ± 6.84	56.03 ± 17.53
1-ethyl-2-methylnaphthalene	125.14 ± 49.59	73.51 ± 30.36	102.00 ± 17.48	127.40 ± 19.95	119.54 ± 10.91	72.90 ± 14.57	127.87 ± 13.20
2,3,5+I-trimethylnaphthalene	49.25 ± 14.37	10.24 ± 6.88	56.27 ± 17.37	42.63 ± 23.31	117.89 ± 28.04	76.42 ± 4.37	79.49 ± 7.94
B-trimethylnaphthalene	66.00 ± 29.88	22.63 ± 25.92	69.28 ± 7.41	71.83 ± 46.36	125.66 ± 59.95	80.94 ± 17.33	104.31 ± 4.08
A-trimethylnaphthalene	87.09 ± 35.68	24.88 ± 3.76	67.52 ± 9.90	78.94 ± 51.49	149.91 ± 60.18	86.18 ± 0.54	133.71 ± 3.48
C-trimethylnaphthalene	69.50 ± 30.02	24.88 ± 3.76	62.25 ± 7.50	66.26 ± 18.77	108.25 ± 40.20	88.21 ± 17.50	107.80 ± 5.72
2-ethyl-1-methylnaphthalene	0.70 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.44 ± 2.47	2.52 ± 2.51	0.00 ± 0.00
E-trimethylnaphthalene	37.15 ± 21.29	17.18 ± 6.56	52.76 ± 2.52	47.86 ± 15.91	83.19 ± 13.02	49.17 ± 6.30	63.93 ± 5.38
2,4,5-trimethylnaphthalene	4.25 ± 2.65	4.84 ± 6.84	10.03 ± 14.18	11.38 ± 7.72	30.16 ± 5.18	19.01 ± 8.16	45.59 ± 2.09
F-trimethylnaphthalene	39.45 ± 13.97	10.94 ± 6.85	46.42 ± 2.46	37.96 ± 15.72	63.12 ± 17.73	48.05 ± 3.70	61.19 ± 10.24
Fluorene	80.05 ± 67.54	105.86 ± 4.88	121.33 ± 9.87	40.93 ± 30.77	180.15 ± 9.03	124.07 ± 36.35	179.67 ± 8.72
1,4,5-trimethylnaphthalene	5.90 ± 2.23	0.69 ± 0.03	2.46 ± 2.49	4.24 ± 0.08	37.30 ± 51.78	8.00 ± 0.19	12.81 ± 7.43
J-trimethylnaphthalene	70.10 ± 59.72	4.16 ± 0.19	9.50 ± 2.49	7.78 ± 0.15	45.99 ± 59.21	8.06 ± 5.33	11.05 ± 0.09
A-Methylfluorene	5.40 ± 7.64	0.00 ± 0.00	17.58 ± 9.94	3.53 ± 0.07	19.08 ± 7.53	23.61 ± 2.02	22.43 ± 7.15
B-Methylfluorene	2.45 ± 0.10	9.60 ± 10.25	2.46 ± 0.00	0.00 ± 0.00	2.42 ± 0.02	4.40 ± 2.67	7.57 ± 7.27
1-Methylfluorene	3.50 ± 0.14	0.00 ± 0.00	1.76 ± 2.49	0.00 ± 0.00	5.18 ± 2.40	3.58 ± 5.06	6.91 ± 0.05
9-fluorenone	49.70 ± 36.64	46.91 ± 4.62	66.83 ± 19.94	12.54 ± 17.73	95.22 ± 6.46	118.62 ± 36.22	140.00 ± 23.07
Dibenzothiophene	1.75 ± 0.07	2.52 ± 3.56	7.03 ± 2.48	1.77 ± 0.03	12.15 ± 5.01	16.49 ± 10.67	13.83 ± 2.55
Phenanthrene	190.10 ± 200.59	67.87 ± 18.93	123.80 ± 4.89	50.38 ± 20.96	154.86 ± 8.79	139.14 ± 18.70	237.40 ± 18.93

Anthracene	8.80 ± 2.83	1.79 ± 2.53	1.76 ± 2.49	1.79 ± 2.53	10.39 ± 0.10	9.18 ± 7.93	25.94 ± 7.53
Xanthone	1.75 ± 0.07	5.88 ± 8.31	22.86 ± 4.96	4.48 ± 6.33	41.58 ± 2.84	21.92 ± 8.23	86.38 ± 3.11
1,4-Naphthoquinone	1.19 ± 1.68	9.37 ± 0.43	13.02 ± 9.96	11.29 ± 2.28	11.07 ± 2.35	11.73 ± 7.99	7.57 ± 7.27
Acenaphthenequinone	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylphenanthrene	19.60 ± 18.10	8.39 ± 11.87	12.31 ± 2.50	5.28 ± 2.40	20.76 ± 4.70	18.25 ± 5.57	29.36 ± 2.22
2-methylphenanthrene	31.80 ± 16.13	10.30 ± 4.43	24.62 ± 0.02	14.19 ± 5.27	34.64 ± 0.32	10.73 ± 15.18	34.55 ± 0.27
Perinaphthenone	9.50 ± 2.86	0.00 ± 0.00	2.11 ± 2.98	2.09 ± 2.96	14.55 ± 0.14	9.85 ± 2.80	14.57 ± 14.77
2-methylanthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.72 ± 2.43
4,5-methylenephenanthrene	6.66 ± 9.42	1.18 ± 1.66	2.99 ± 4.23	0.00 ± 0.00	4.17 ± 2.49	7.91 ± 7.53	11.05 ± 2.36
9-methylphenanthrene	12.50 ± 12.87	10.30 ± 4.43	8.79 ± 2.48	0.00 ± 0.00	13.81 ± 9.67	10.79 ± 10.03	22.46 ± 2.62
1-methylphenanthrene	19.65 ± 20.58	5.21 ± 0.24	14.07 ± 2.48	0.87 ± 1.23	8.61 ± 9.72	9.03 ± 4.93	15.51 ± 9.65
Anthrone	0.70 ± 0.03	2.37 ± 2.34	11.25 ± 9.94	9.52 ± 2.32	2.41 ± 2.43	4.37 ± 0.10	7.60 ± 0.06
9-methylanthracene	1.26 ± 1.78	2.43 ± 0.11	2.46 ± 0.00	1.22 ± 1.73	4.14 ± 2.41	2.55 ± 0.06	0.00 ± 0.00
Anthraquinone	0.00 ± 0.00	0.00 ± 0.00	7.03 ± 0.00	0.00 ± 0.00	3.44 ± 4.87	19.98 ± 2.10	6.93 ± 4.94
A-dimethylphenanthrene	0.90 ± 1.27	0.00 ± 0.00	0.88 ± 1.24	0.90 ± 1.27	0.00 ± 0.00	4.62 ± 6.54	5.16 ± 4.85
B-dimethylphenanthrene	12.35 ± 5.45	10.24 ± 6.88	15.82 ± 9.94	10.58 ± 2.29	15.59 ± 0.15	18.28 ± 8.14	20.70 ± 7.17
1,7-dimethylphenanthrene	7.80 ± 5.26	0.69 ± 0.03	7.74 ± 4.97	2.50 ± 2.55	4.13 ± 4.86	4.37 ± 0.10	9.34 ± 2.51
3,6-dimethylphenanthrene	1.75 ± 0.07	0.84 ± 1.19	1.76 ± 0.00	0.90 ± 1.27	1.73 ± 0.02	3.67 ± 2.66	3.45 ± 2.42
D-dimethylphenanthrene	3.55 ± 2.62	1.74 ± 0.08	1.76 ± 0.00	1.77 ± 0.03	2.58 ± 3.65	5.52 ± 5.27	5.18 ± 0.04
E-dimethylphenanthrene	0.36 ± 0.51	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.34 ± 0.49	0.37 ± 0.52	2.41 ± 2.42
C-dimethylphenanthrene	11.30 ± 5.40	4.16 ± 0.19	7.74 ± 4.97	5.98 ± 2.38	9.32 ± 7.26	6.27 ± 7.86	12.77 ± 2.34
Fluoranthene	16.80 ± 17.99	10.99 ± 4.40	13.01 ± 2.48	2.50 ± 2.55	19.73 ± 2.27	13.43 ± 2.26	33.50 ± 2.18

Pyrene	15.66 ± 22.15	5.79 ± 4.64	21.80 ± 2.47	1.25 ± 1.77	31.83 ± 7.05	17.10 ± 0.40	35.27 ± 7.60
9-Anthraaldehyde	0.00 ± 0.00	5.15 ± 2.21	14.07 ± 4.96	0.00 ± 0.00	24.41 ± 34.51	8.94 ± 12.65	20.69 ± 9.61
Retene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
benzo(a)fluorene	0.00 ± 0.00	1.79 ± 2.53	0.00 ± 0.00	0.00 ± 0.00	1.72 ± 2.43	3.64 ± 0.09	1.72 ± 2.43
benzo(b)fluorene	0.00 ± 0.00	0.00 ± 0.00	1.76 ± 2.49	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
5-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
B-MePy/MeFl	0.00 ± 0.00	0.00 ± 0.00	1.76 ± 2.49	0.00 ± 0.00	1.72 ± 2.43	3.64 ± 0.09	0.00 ± 0.00
1-MeFl+C-MeFl/Py	0.00 ± 0.00	0.00 ± 0.00	1.76 ± 2.49	0.00 ± 0.00	1.72 ± 2.43	3.64 ± 0.09	1.72 ± 2.43
1+3-methylfluoranthene	0.85 ± 1.20	1.74 ± 0.08	0.88 ± 1.24	0.00 ± 0.00	1.73 ± 0.02	0.89 ± 1.26	0.00 ± 0.00
4-methylpyrene	2.45 ± 0.10	0.00 ± 0.00	1.23 ± 1.74	1.22 ± 1.73	2.42 ± 0.02	2.55 ± 0.06	1.20 ± 1.70
C-MePy/MeFl	1.26 ± 1.78	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.22 ± 1.73	2.55 ± 0.06	1.20 ± 1.70
D-MePy/MeFl	1.26 ± 1.78	1.25 ± 1.77	0.00 ± 0.00	0.00 ± 0.00	1.22 ± 1.73	2.55 ± 0.06	2.42 ± 0.02
1-methylpyrene	1.80 ± 2.55	0.00 ± 0.00	1.76 ± 2.49	0.00 ± 0.00	3.46 ± 0.03	1.85 ± 2.61	1.72 ± 2.43
Benzonaphthothiophene	0.00 ± 0.00	0.69 ± 0.03	0.70 ± 0.00	0.71 ± 0.01	2.41 ± 2.43	0.73 ± 0.02	0.35 ± 0.49
benzo(c)phenanthrene	0.90 ± 1.27	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.73 ± 0.02	0.92 ± 1.31	0.00 ± 0.00
Benzo(ghi)fluoranthene	1.19 ± 1.68	1.18 ± 1.66	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
9-phenylanthracene	1.80 ± 2.55	0.00 ± 0.00	0.00 ± 0.00	1.79 ± 2.53	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
6-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Cyclopenta(c,d)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benz(a)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Chrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzanthrone	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.36 ± 0.51	0.00 ± 0.00	0.36 ± 0.51	0.69 ± 0.01

Benz(a)anthracene-7,12-dione	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7-methylbenz(a)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7,12-dimethylbenz(a)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(b)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(j)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(k)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(a)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BeP	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BaP	1.26 ± 1.78	2.43 ± 0.11	1.23 ± 1.74	2.47 ± 0.05	4.17 ± 2.49	0.00 ± 0.00	0.00 ± 0.00
Perylene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.74 ± 2.47	0.00 ± 0.00	0.00 ± 0.00
3-methylcholanthrene	1.80 ± 2.55	3.47 ± 0.16	1.76 ± 2.49	1.74 ± 2.47	1.72 ± 2.43	3.64 ± 0.09	3.45 ± 0.03
7-methylbenzo(a)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Indeno[123-cd]fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Indeno[123-cd]pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ac)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ah+ac)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ah)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,j)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(b)chrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Picene	0.70 ± 0.03	0.69 ± 0.03	0.70 ± 0.00	0.35 ± 0.49	0.69 ± 0.01	0.00 ± 0.00	0.69 ± 0.01
Benzo(ghi)perylene	0.00 ± 0.00	0.00 ± 0.00	0.35 ± 0.50	0.00 ± 0.00	4.16 ± 0.04	0.73 ± 0.02	0.69 ± 0.01
Anthanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Triphenylene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,l)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Coronene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,e)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,i)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,h)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(b,k)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Table D4: Gas-phase PAH emission for Vehicle #4

Component (ng/mile)	Fed ULSD	CARB ULSD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
naphthalene	1447.17±1866.22	334.08±195.24	675.83±678.01	2136.79±1725.48	2635.87±2925.23	3803.23±1059.94	2460.21±2823.80
quinoline	1.32±1.11	1.05±0.73	2.63±2.98	2.83±3.27	31.47±43.01	2.59±2.92	0.26±0.37
2-methylnaphthalene	83.93±62.04	113.32±58.37	76.05±19.05	185.64±31.36	134.60±0.00	36.53±2.56	74.53±1.85
1-methylnaphthalene	46.04±36.04	50.91±22.55	38.15±10.08	96.54±22.05	67.04±0.00	20.61±1.62	38.71±4.84
Biphenyl	93.88±122.33	33.61±10.07	25.78±2.26	76.87±44.78	817.20±1107.18	35.45±8.48	28.71±12.29
2,6+2,7-dimethylnaphthalene	37.35±39.40	65.28±42.11	36.84±10.45	72.77±36.76	67.04±0.00	14.08±3.54	30.29±3.36
1,3+1,6+1,7dimethylnaphth	50.50±51.30	98.83±63.35	54.47±13.82	115.51±57.06	103.46±0.00	21.65±3.09	44.77±4.47
1,4+1,5+2,3-dimethylnaphth	18.41±19.33	35.39±23.07	18.68±4.86	36.79±17.09	41.17±0.00	9.15±1.94	19.23±0.37
Acenaphthylene	5.26±3.71	6.04±1.80	2.89±0.37	8.34±2.33	50.12±56.69	1.04±0.01	7.11±3.35
1,2-dimethylnaphthalene	9.73±10.78	16.77±11.73	8.68±0.38	15.04±5.65	17.95±0.00	3.13±0.03	8.16±1.86
1,8-dimethylnaphthalene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Acenaphthene	87.04±118.62	23.84±17.98	15.52±4.11	23.69±4.41	40.12±0.00	5.21±1.42	21.33±0.37
1+2ethylnaphthalene	259.28±358.47	25.97±14.24	18.42±4.48	42.05±8.92	47.51±0.00	7.04±1.03	42.40±8.56
1-ethyl-2-methylnaphthalene	11.57±12.64	13.11±8.05	7.10±2.61	13.75±3.83	13.72±0.00	7.07±4.88	7.37±0.74

2,3,5+I-trimethylnaphthalene	39.45±50.57	60.49±51.83	26.58±9.33	33.18±11.99	50.67±0.00	8.87±0.64	24.49±0.38
B-trimethylnaphthalene	21.83±24.16	56.59±44.06	23.95±11.56	38.87±17.05	48.03±0.00	9.65±1.00	19.23±3.35
A-trimethylnaphthalene	29.72±33.83	58.96±42.92	30.52±9.70	52.31±27.14	62.81±0.00	13.31±0.96	29.76±7.07
C-trimethylnaphthalene	22.09±26.03	58.42±45.90	24.47±7.09	36.55±14.52	47.51±0.00	8.08±1.76	17.65±4.10
2-ethyl-1-methylnaphthalene	0.79±1.12	1.31±1.10	0.53±0.00	1.30±0.35	11.02±14.83	0.26±0.37	0.53±0.74
E-trimethylnaphthalene	36.03±46.48	37.99±29.74	19.74±5.60	23.85±9.19	35.37±0.00	5.74±0.06	14.75±2.24
2,4,5-trimethylnaphthalene	122.02±162.87	99.50±86.77	23.15±3.00	61.51±13.40	93.43±0.00	20.82±11.59	25.02±1.86
F-trimethylnaphthalene	27.35±34.95	39.81±32.33	16.84±5.97	20.74±7.77	32.73±0.00	5.74±0.68	13.17±2.24
Fluorene	46.81±55.77	91.34±88.72	48.15±15.30	50.12±6.95	87.62±0.00	13.57±1.33	30.81±4.10
1,4,5-trimethylnaphthalene	12.88±18.22	17.04±11.36	4.74±2.98	1.30±0.35	91.56±112.31	3.37±4.02	2.11±0.75
J-trimethylnaphthalene	9.20±12.27	10.73±11.42	8.42±5.96	4.92±2.50	20.59±0.00	2.62±1.50	3.42±0.37
A-Methylfluorene	22.09±25.28	32.73±29.05	19.73±4.86	25.35±16.52	35.37±0.00	4.19±2.26	11.59±7.45
B-Methylfluorene	3.94±5.58	6.03±4.77	7.36±5.20	20.09±23.96	118.54±159.44	42.28±1.02	1.84±1.86
1-Methylfluorene	10.26±11.52	14.68±10.27	8.42±2.24	44.56±54.10	24.17±14.77	66.02±2.61	11.85±6.33
9-fluorenone	173.83±216.02	31.17±24.61	13.95±4.85	46.51±36.79	27.98±0.00	13.10±9.00	18.96±2.23
Dibenzothiophene	9.73±10.04	14.64±17.71	5.00±3.35	3.37±1.05	3.69±0.00	4.72±4.48	7.90±0.75
Phenanthrene	163.09±154.61	247.33±240.38	112.63±38.06	179.10±138.81	245.97±0.00	42.60±9.69	110.35±8.58
Anthracene	5.00±5.58	8.12±6.24	4.74±0.75	8.30±2.81	6.33±0.00	2.61±0.77	3.95±0.37
Xanthone	7.10±6.32	5.23±5.15	2.89±0.37	6.98±4.67	6.86±0.00	3.67±3.73	3.42±1.86
1,4-Naphthoquinone	41.29±56.15	1.85±1.13	1.84±1.86	11.76±8.64	33.73±25.45	15.25±20.10	38.45±28.30
Acenaphthenequinone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3-methylphenanthrene	26.30±29.74	29.58±26.85	12.89±3.36	25.38±12.11	38.53±0.00	17.56±13.11	30.81±1.87
2-methylphenanthrene	17.89±19.33	29.81±33.92	12.10±2.99	19.10±18.09	35.37±0.00	12.60±12.69	15.80±0.00
Perinaphthenone	2.89±3.35	2.89±1.09	0.53±0.74	3.09±4.36	5.28±0.00	25.49±30.91	2.11±1.49
2-methylanthracene	13.94±19.71	14.89±20.31	10.52±2.97	8.62±4.91	26.39±0.00	4.97±1.16	3.69±2.98
4,5-methylenephenanthrene	7.89±8.92	5.50±4.78	3.68±0.75	4.40±2.51	8.45±0.00	5.75±1.54	2.63±0.00
9-methylphenanthrene	10.78±10.78	15.69±16.95	7.10±0.38	13.68±13.39	17.42±0.00	17.34±20.12	10.80±4.84
1-methylphenanthrene	7.10±6.32	11.24±12.90	5.00±1.87	8.52±7.59	14.25±0.00	10.50±11.19	5.27±2.24
Anthrone	124.12±171.80	11.51±11.79	2.37±0.37	6.50±0.47	8.45±0.00	21.26±22.01	17.38±2.24
9-methylanthracene	14.20±20.08	0.52±0.74	0.26±0.37	0.00±0.00	29.11±40.42	0.52±0.01	0.79±0.37

Anthraquinone	23.41±28.63	15.96±15.83	7.10±1.12	28.11±30.09	33.63±17.70	13.85±2.73	14.48±1.86
A-dimethylphenanthrene	2.89±3.35	6.02±6.26	2.10±0.00	11.58±15.63	45.13±52.62	18.01±0.17	1.84±0.37
B-dimethylphenanthrene	2.89±3.35	5.23±5.90	2.89±1.86	12.87±16.72	55.61±69.69	9.99±12.66	1.32±0.37
1,7-dimethylphenanthrene	3.16±3.72	5.23±5.90	3.68±2.23	11.85±14.53	29.65±32.23	20.37±1.70	2.63±0.00
3,6-dimethylphenanthrene	3.68±4.46	5.23±6.64	1.05±0.75	4.93±1.03	59.54±78.97	4.99±6.33	5.79±4.47
D-dimethylphenanthrene	14.73±18.59	19.37±17.66	5.53±4.10	8.31±0.61	63.77±66.30	20.99±20.16	3.69±0.00
E-dimethylphenanthrene	0.53±0.74	2.09±2.21	1.05±0.00	1.81±1.81	53.78±67.09	8.41±10.43	3.16±0.74
C-dimethylphenanthrene	9.73±12.27	9.94±11.06	4.47±0.37	8.53±6.86	67.18±74.85	21.29±27.92	6.58±0.37
Fluoranthene	16.58±9.28	22.76±24.69	11.05±2.99	26.58±25.70	127.26±143.40	14.68±11.97	11.85±0.37
Pyrene	17.88±20.82	24.05±29.51	8.42±0.75	14.45±14.49	79.80±74.04	10.50±11.19	12.90±0.37
9-Anthraaldehyde	4.21±5.21	0.78±1.11	1.05±1.49	1.30±0.35	0.00±0.00	6.01±1.91	1.84±1.12
Retene	0.00±0.00	0.26±0.37	0.00±0.00	0.26±0.36	0.26±0.37	0.79±1.12	0.00±0.00
benzo(a)fluorene	0.53±0.74	0.26±0.37	0.00±0.00	0.51±0.73	0.00±0.00	0.52±0.01	0.26±0.37
benzo(b)fluorene	1.58±2.23	0.00±0.00	0.26±0.37	1.29±1.08	0.00±0.00	0.78±0.36	0.79±1.12
5-methylchrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
B-MePy/MeFl	1.05±0.74	0.26±0.37	0.26±0.37	1.55±1.45	0.26±0.37	1.31±0.38	0.26±0.37
1-MeFl+C-MeFl/Py	0.53±0.00	0.79±0.36	0.26±0.37	13.37±18.91	0.00±0.00	4.94±4.01	1.84±0.37
1+3-methylfluoranthene	1.84±1.86	0.26±0.37	0.26±0.37	1.55±1.45	0.26±0.37	1.04±0.01	1.05±0.74
4-methylpyrene	1.31±1.86	0.78±1.11	0.26±0.37	1.03±0.72	1.06±1.49	1.84±2.60	1.05±0.00
C-MePy/MeFl	3.16±4.46	0.26±0.37	0.26±0.37	2.06±2.17	0.00±0.00	2.08±0.72	1.58±1.49
D-MePy/MeFl	2.37±2.60	2.10±1.47	1.58±2.23	8.24±10.17	1.06±1.49	17.47±2.39	2.90±1.12
1-methylpyrene	1.84±1.86	0.52±0.74	0.26±0.37	1.03±0.72	0.53±0.75	5.98±4.00	0.53±0.00
Benzonaphthothiophene	1.58±1.49	0.52±0.74	0.00±0.00	9.28±10.89	1.06±1.49	5.73±2.15	0.00±0.00
benzo(c)phenanthrene	0.26±0.37	0.00±0.00	0.00±0.00	0.26±0.37	0.26±0.37	0.26±0.37	0.00±0.00
Benzo(ghi)fluoranthene	5.79±7.44	0.78±1.11	2.63±2.23	1.03±0.72	0.00±0.00	8.14±9.32	0.26±0.37
9-phenylanthracene	0.26±0.37	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.26±0.37	0.00±0.00
6-methylchrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Cyclopenta(c,d)pyrene	0.79±1.12	0.00±0.00	0.26±0.37	0.78±0.36	0.00±0.00	0.00±0.00	0.00±0.00
Benz(a)anthracene	0.79±1.12	0.00±0.00	0.00±0.00	0.26±0.36	0.00±0.00	0.00±0.00	0.00±0.00
Chrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Benzanthrone	1.58±1.49	0.78±1.11	0.26±0.37	1.54±2.18	0.00±0.00	1.58±2.23	0.26±0.37
Benz(a)anthracene-7,12-dione	7.10±9.30	0.26±0.37	0.53±0.00	0.26±0.37	0.00±0.00	2.37±3.35	0.00±0.00
3-methylchrysene	0.26±0.37	0.26±0.37	0.00±0.00	0.26±0.36	0.00±0.00	0.00±0.00	0.00±0.00
7-methylbenz(a)anthracene	1.58±2.23	0.00±0.00	0.00±0.00	0.51±0.73	0.26±0.37	0.00±0.00	0.00±0.00
7,12-dimethylbenz(a)anthracene	1.58±2.23	0.26±0.37	0.26±0.37	0.51±0.73	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(b)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(j)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(k)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(a)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.26±0.37
BeP	0.00±0.00	0.00±0.00	0.00±0.00	0.52±0.01	0.00±0.00	0.00±0.00	0.00±0.00
BaP	0.26±0.37	0.00±0.00	0.26±0.37	0.26±0.37	0.00±0.00	0.52±0.73	1.05±1.49
Perylene	0.26±0.37	0.00±0.00	#DIV/0!	0.00±0.00	0.00±0.00	0.52±0.73	0.26±0.37
3-methylcholanthrene	0.00±0.00	0.52±0.74	0.26±0.37	0.00±0.00	0.00±0.00	0.26±0.37	0.00±0.00
7-methylbenzo(a)pyrene	0.00±0.00	0.26±0.37	0.26±0.37	0.00±0.00	0.26±0.37	0.00±0.00	0.26±0.37
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00±0.00	0.00±0.00	0.26±0.37	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Indeno[123-cd]fluoranthene	0.00±0.00	0.00±0.00	0.53±0.74	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Indeno[123-cd]pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(ac)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(ah+ac)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(ah)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,j)anthracene	0.00±0.00	0.26±0.37	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(b)chrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.53±0.74
Picene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(ghi)perylene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Anthanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Triphenylene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,l)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Coronene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,e)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Dibenzo(a,i)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,h)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(b,k)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table D5: Gas-phase PAH emission for Vehicle #5

Component (ng/mile)	Fed ULSD	CARB ULSD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
naphthalene	29596.39±7676.97	1279.59±1588.50	3271.05±0.00	1048.78±0.00	3133.46±3294.43	3557.51±1185.15	3752.19±2570.61
quinoline	206.38±8.00	7.12±7.23	24.50±0.00	120.51±146.61	3.05±1.44	20.80±3.86	30.48±32.53
2-methylnaphthalene	2477.30±688.41	84.54±29.27	327.00±0.00	108.49±0.00	85.04±14.05	131.93±42.61	461.19±145.60
1-methylnaphthalene	2054.22±662.96	51.10±25.34	236.15±0.00	75.80±0.00	59.66±16.19	75.44±24.94	244.46±65.29
Biphenyl	378.91±46.46	27.03±0.16	92.89±0.00	173.38±198.95	39.09±10.03	100.57±69.16	175.73±92.97
2,6+2,7-dimethylnaphthalene	235.03±19.05	31.97±2.55	89.22±0.00	90.88±73.17	31.22±4.68	55.36±14.63	178.52±102.62
1,3+1,6+1,7dimethylnaphth	405.42±36.05	49.57±3.27	139.13±0.00	176.52±160.66	49.25±7.21	97.32±32.72	279.89±123.96
1,4+1,5+2,3-dimethylnaphth	118.02±8.08	15.86±1.80	47.14±0.00	58.03±51.94	17.52±1.80	32.52±10.54	89.65±44.72
Acenaphthylene	5.10±2.13	1.49±0.03	5.81±0.00	3.45±0.73	5.08±3.59	4.49±0.16	39.04±31.67
1,2-dimethylnaphthalene	45.46±1.05	5.95±0.59	22.07±0.00	25.70±24.44	14.47±9.70	12.54±4.72	35.20±21.24
1,8-dimethylnaphthalene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Acenaphthene	104.32±32.54	7.94±0.85	29.34±0.00	19.66±3.28	31.72±19.73	84.26±94.56	133.19±131.98
1+2ethylnaphthalene	498.37±30.72	15.60±2.16	63.47±0.00	93.68±102.36	24.12±7.55	252.17±313.94	329.74±369.28
1-ethyl-2-methylnaphthalene	35.30±16.15	5.95±0.59	13.42±0.00	14.70±10.98	7.11±1.44	10.54±1.74	37.69±29.05
2,3,5+I-trimethylnaphthalene	65.29±45.62	17.12±0.67	69.76±0.00	29.50±3.18	27.92±1.45	35.04±5.42	135.13±99.77
B-trimethylnaphthalene	73.48±50.74	16.83±3.19	61.86±0.00	32.91±9.41	25.38±4.32	35.57±5.45	120.17±65.77
A-trimethylnaphthalene	123.59±64.83	23.06±0.62	65.37±0.00	41.73±16.28	26.65±6.12	44.10±8.10	142.54±93.83
C-trimethylnaphthalene	66.59±53.22	18.85±0.36	61.63±0.00	28.50±5.28	25.64±4.68	33.91±2.38	115.80±67.43
2-ethyl-1-methylnaphthalene	1.02±0.01	0.50±0.01	0.76±0.00	0.98±0.69	0.51±0.72	1.31±0.31	3.41±1.97
E-trimethylnaphthalene	47.62±32.13	11.91±0.23	41.33±0.00	21.12±5.35	17.01±3.24	26.09±7.24	80.00±55.34
2,4,5-trimethylnaphthalene	55.10±51.33	9.96±4.40	68.62±0.00	22.47±17.27	5.58±0.00	8.53±2.65	19.35±7.39
F-trimethylnaphthalene	44.04±29.94	11.41±0.22	47.45±0.00	18.68±1.90	20.31±2.14	23.10±3.73	78.99±56.77
Fluorene	75.05±60.14	19.30±4.55	108.51±0.00	49.41±4.72	44.93±6.13	48.26±5.31	181.40±116.68
1,4,5-trimethylnaphthalene	14.36±15.27	2.22±1.71	19.77±0.00	7.88±1.47	5.84±0.36	24.17±15.37	41.14±32.49

J-trimethylnaphthalene	28.16±18.99	5.92±3.40	28.17±0.00	10.33±0.59	13.20±2.16	15.94±3.01	53.19±38.11
A-Methylfluorene	36.32±15.43	12.65±0.59	39.26±0.00	20.89±2.92	15.99±12.57	19.39±3.55	80.80±69.32
B-Methylfluorene	6.65±2.22	1.99±0.74	7.08±0.00	3.69±0.38	31.46±39.47	2.06±2.14	16.23±7.26
1-Methylfluorene	21.49±10.27	7.44±0.14	18.99±0.00	8.86±0.78	45.93±46.28	7.85±3.36	17.91±12.49
9-fluorenone	98.48±42.25	13.15±0.60	33.73±0.00	16.70±4.70	15.99±1.80	212.37±231.61	258.05±250.05
Dibenzothiophene	11.75±1.53	4.23±1.13	10.66±0.00	2.71±1.77	5.33±0.36	3.72±0.93	34.18±34.77
Phenanthrene	265.05±129.06	70.52±9.05	310.25±0.00	107.44±6.92	128.70±6.89	247.92±103.91	607.36±380.86
Anthracene	8.19±5.84	2.24±0.39	11.17±0.00	4.42±0.65	6.09±4.31	9.07±3.43	21.25±11.50
Xanthone	11.00±4.05	2.48±0.05	8.62±0.00	3.44±0.03	3.81±1.07	8.25±2.27	24.57±9.07
1,4-Naphthoquinone	31.34±21.08	2.73±0.40	6.69±0.00	32.09±26.46	0.00±0.00	3.33±4.70	7.98±9.86
Acenaphthenequinone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3-methylphenanthrene	107.82±13.07	8.93±0.17	37.56±0.00	15.97±3.67	20.82±3.60	35.16±21.51	122.58±120.55
2-methylphenanthrene	23.04±15.34	7.70±1.20	45.22±0.00	13.03±0.22	17.26±1.45	21.38±9.25	66.79±56.64
Perinaphthenone	3.85±5.45	0.75±0.36	6.32±0.00	3.20±1.08	2.28±1.08	8.38±7.51	7.17±8.00
2-methylanthracene	3.32±0.34	1.71±2.42	7.40±0.00	5.37±7.60	12.44±6.83	22.55±13.80	43.67±29.65
4,5-methylenephenanthrene	8.71±7.29	2.73±0.40	5.31±0.00	3.69±0.31	7.61±2.15	5.00±0.88	27.97±23.15
9-methylphenanthrene	14.32±5.16	4.96±0.09	21.85±0.00	7.12±1.67	14.47±9.68	12.78±3.61	36.27±22.75
1-methylphenanthrene	11.01±7.66	3.47±0.07	15.98±0.00	5.66±0.40	5.84±1.79	9.86±3.09	28.66±18.40
Anthrone	61.52±62.57	2.26±2.50	9.43±0.00	4.16±5.18	7.11±5.74	11.38±0.17	50.80±61.13
9-methylanthracene	1.03±1.45	0.25±0.36	0.76±0.00	0.74±0.34	0.76±0.36	1.06±0.05	2.91±2.69
Anthraquinone	129.02±152.99	15.79±8.82	54.18±0.00	10.33±0.80	115.53±137.55	63.76±42.94	77.69±56.35
A-dimethylphenanthrene	7.41±1.14	1.24±0.37	7.62±0.00	2.70±1.02	3.55±0.72	6.26±3.44	13.39±7.51
B-dimethylphenanthrene	3.07±2.19	0.99±0.02	5.85±0.00	1.23±0.36	8.37±8.25	2.14±0.85	9.51±8.46
1,7-dimethylphenanthrene	3.33±1.83	1.24±0.33	6.60±0.00	1.97±0.02	2.79±1.08	2.15±1.60	10.82±8.88
3,6-dimethylphenanthrene	3.84±1.83	1.24±0.37	5.59±0.00	1.48±0.01	2.03±0.72	2.41±1.24	12.61±7.85
D-dimethylphenanthrene	10.23±4.41	4.48±2.19	11.16±0.00	3.21±1.77	15.48±17.58	3.18±0.15	14.42±7.56
E-dimethylphenanthrene	4.09±0.03	0.24±0.35	4.07±0.00	3.67±3.79	6.35±0.36	16.85±7.92	53.50±53.54
C-dimethylphenanthrene	12.00±0.45	2.73±0.40	14.48±0.00	4.91±1.34	7.11±1.44	6.63±0.69	26.93±23.11
Fluoranthene	35.81±13.99	6.71±1.18	34.06±0.00	9.59±0.95	12.18±1.43	36.68±7.75	75.49±11.86
Pyrene	14.83±5.16	3.98±0.78	38.43±0.00	7.13±0.97	11.67±5.74	15.67±2.62	40.04±16.66

9-Anthraaldehyde	0.25±0.36	0.25±0.36	2.03±0.00	0.74±0.34	0.76±0.36	1.30±1.06	2.06±0.65
Retene	0.00±0.00	0.00±0.00	0.26±0.00	0.00±0.00	0.00±0.00	1.10±1.55	1.31±0.42
benzo(a)fluorene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	1.31±0.42
benzo(b)fluorene	0.51±0.00	0.00±0.00	0.26±0.00	0.00±0.00	1.02±0.72	0.51±0.72	0.53±0.76
5-methylchrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
B-MePy/MeFl	1.03±1.45	0.00±0.00	0.00±0.00	0.00±0.00	0.25±0.36	0.00±0.00	2.36±1.20
1-MeFl+C-MeFl/Py	0.00±0.00	0.00±0.00	0.00±0.00	0.24±0.35	2.79±3.95	0.00±0.00	1.01±1.43
1+3-methylfluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.24±0.35	0.25±0.36	0.55±0.77	0.00±0.00
4-methylpyrene	1.54±1.46	0.00±0.00	2.03±0.00	0.25±0.35	0.25±0.36	0.53±0.03	2.11±1.55
C-MePy/MeFl	0.77±0.37	0.00±0.00	0.51±0.00	0.00±0.00	1.27±1.79	0.51±0.72	0.53±0.76
D-MePy/MeFl	1.28±0.37	0.00±0.00	1.27±0.00	0.25±0.35	8.88±12.56	0.77±1.09	0.00±0.00
1-methylpyrene	0.77±0.37	0.00±0.00	1.27±0.00	0.25±0.35	1.01±1.44	0.53±0.03	1.84±1.18
Benzonaphthothiophene	2.03±2.87	0.73±1.04	3.80±0.00	0.99±1.40	2.79±3.23	0.82±1.16	0.00±0.00
benzo(c)phenanthrene	0.77±0.37	0.00±0.00	0.00±0.00	0.00±0.00	0.51±0.72	1.10±1.55	0.00±0.00
Benzo(ghi)fluoranthene	3.85±5.45	0.75±0.36	0.74±0.00	0.74±1.05	2.28±1.08	4.65±6.58	1.77±2.50
9-phenylanthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6-methylchrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Cyclopenta(c,d)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.25±0.36	0.00±0.00	0.00±0.00
Benz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Chrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzanthrone	0.25±0.36	0.00±0.00	0.00±0.00	0.24±0.35	0.76±1.08	0.55±0.77	0.50±0.71
Benz(a)anthracene-7,12-dione	0.77±1.09	0.00±0.00	0.00±0.00	0.24±0.35	0.00±0.00	0.00±0.00	0.00±0.00
3-methylchrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.24±0.35	0.25±0.36	0.00±0.00	0.00±0.00
7-methylbenz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7,12-dimethylbenz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.25±0.36	0.00±0.00	0.00±0.00
Benzo(b)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(j)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(k)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(a)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
BeP	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

BaP	0.25±0.36	0.00±0.00	0.00±0.00	0.24±0.35	0.51±0.00	0.00±0.00	0.00±0.00
Perylene	0.00±0.00	0.00±0.00	0.25±0.00	0.74±0.34	0.00±0.00	0.27±0.39	0.00±0.00
3-methylcholanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7-methylbenzo(a)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.24±0.35	0.00±0.00	0.00±0.00	0.25±0.36
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Indeno[123-cd]fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Indeno[123-cd]pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(ac)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(ah+ac)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.24±0.35	0.25±0.36	0.00±0.00	0.00±0.00
Dibenzo(ah)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,j)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(b)chrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Picene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.26±0.36	0.00±0.00
Benzo(ghi)perylene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Anthanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Triphenylene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,l)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Coronene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,e)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,i)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,h)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(b,k)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table D6: Gas-phase PAH emission for Vehicle #6

Component (ng/mile)	Fed ULSD	CARB ULSD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
naphthalene	208.81±79.54	146.94±28.88	507.56±43.64	215.29±10.88	824.16±702.48	1622.44±1986.07	440.10±0.00
quinoline	4.47±3.47	2.76±1.75	6.04±3.54	4.27±1.00	1.75±1.05	2.07±0.74	1.48±2.10
2-methylnaphthalene	80.90±8.67	75.84±2.69	143.17±2.70	106.76±4.54	348.19±62.84	123.22±57.16	517.86±398.46
1-methylnaphthalene	39.45±4.35	38.55±0.82	78.39±0.66	53.62±1.21	154.66±36.35	74.16±43.78	249.37±202.48
Biphenyl	30.65±11.20	26.71±1.74	54.70±4.14	25.91±2.08	166.69±34.84	93.10±85.11	317.57±299.63

2-methylbiphenyl	149.00±91.40	164.26±45.07	217.45±36.58	74.69±8.43	127.67±86.51	13225.80±18617.55	19446.11±27030.14
2,6+2,7-dimethylnaphthalene	41.13±13.16	32.75±1.10	66.55±4.54	41.54±1.73	268.61±42.91	57.31±12.68	307.68±224.16
1,3+1,6+1,7dimethylnaphth	67.32±20.19	56.19±1.74	111.92±5.43	66.73±3.55	410.68±97.78	93.46±23.08	451.68±316.05
1,4+1,5+2,3-dimethylnaphth	21.19±7.10	16.88±0.15	36.30±2.99	19.64±1.02	136.91±29.05	32.28±10.01	149.05±106.01
Acenaphthylene	1.25±0.37	1.51±0.69	8.06±0.68	2.26±1.03	13.25±8.05	3.35±1.81	12.59±11.52
1,2-dimethylnaphthalene	7.98±2.71	7.30±0.27	15.63±2.91	6.80±0.46	57.04±17.98	10.84±2.97	51.40±32.18
1,8-dimethylnaphthalene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Acenaphthene	11.70±6.54	11.08±0.13	22.69±2.94	9.82±0.51	79.58±19.22	86.96±106.98	272.44±323.12
3-methylbiphenyl	118.39±74.55	101.84±11.91	182.75±3.21	67.19±1.43	571.73±297.04	4038.13±5593.67	12214.09±16818.59
4-methylbiphenyl	44.78±26.18	44.40±11.22	75.61±6.12	27.68±0.27	256.58±109.25	1372.18±1896.19	5091.85±7032.61
1+2ethylnaphthalene	22.68±8.49	19.15±0.94	40.83±0.55	21.13±1.09	99.10±24.03	254.18±324.55	426.59±504.80
1-ethyl-2-methylnaphthalene	6.72±3.08	5.54±0.07	14.62±1.48	6.29±0.26	51.04±14.48	9.81±0.05	54.02±37.28
2,3,5+I-trimethylnaphthalene	23.89±13.07	18.63±1.20	43.86±2.31	21.44±5.68	229.37±86.43	33.31±7.82	191.37±124.64
B-trimethylnaphthalene	28.38±13.71	21.91±1.52	48.91±5.18	25.72±6.10	245.60±99.42	32.25±0.21	203.04±126.47
A-trimethylnaphthalene	35.11±16.08	27.71±0.38	57.23±6.28	33.28±7.65	274.72±83.60	43.88±3.86	282.35±207.91
C-trimethylnaphthalene	28.39±13.00	22.91±1.51	48.66±6.25	26.23±6.82	254.12±98.64	34.84±2.72	213.54±134.35
2-ethyl-1-methylnaphthalene	0.00±0.00	0.50±0.71	1.26±0.36	0.76±0.37	6.75±4.55	1.03±0.00	7.69±5.99
E-trimethylnaphthalene	17.43±8.93	13.60±0.55	30.50±2.61	15.89±4.17	154.54±69.65	23.49±4.86	136.21±80.17
2,4,5-trimethylnaphthalene	3.00±0.05	3.78±0.31	8.57±0.68	3.78±0.42	48.76±21.94	5.68±0.76	87.54±88.87
F-trimethylnaphthalene	16.18±8.59	12.34±0.92	28.74±0.83	14.63±4.50	160.84±57.92	21.17±3.75	128.31±76.68
Fluorene	32.36±17.18	26.44±2.18	63.77±1.32	24.18±1.81	329.65±65.82	33.81±1.26	255.06±150.44
1,4,5-trimethylnaphthalene	4.76±1.13	6.78±3.13	9.82±3.17	6.30±1.17	54.57±9.50	18.61±13.23	30.75±7.85
J-trimethylnaphthalene	11.70±5.83	9.06±1.32	19.16±1.50	10.09±3.01	120.57±42.99	15.23±2.63	56.03±7.29
A-Methylfluorene	10.98±1.95	12.83±3.05	14.37±1.84	11.86±3.39	113.39±41.97	12.64±0.30	109.17±96.41
B-Methylfluorene	2.49±0.67	2.02±0.02	2.27±1.77	2.02±0.74	21.32±7.60	2.84±0.38	15.78±5.55
1-Methylfluorene	8.72±3.76	8.07±0.81	11.35±1.83	9.33±2.64	23.20±23.56	12.39±3.71	59.86±38.55
9-fluorenone	9.96±4.80	11.99±16.24	7.84±11.08	14.37±3.43	86.76±86.75	169.80±219.77	98.41±88.17
Dibenzothiophene	1.25±0.33	0.75±0.35	2.77±0.35	0.75±1.06	18.84±13.96	1.81±1.10	18.35±7.79
Phenanthrene	64.06±22.00	67.72±6.67	90.51±12.12	60.74±10.57	774.82±205.09	113.67±54.56	547.99±385.19
Anthracene	3.49±1.36	2.52±0.03	4.54±0.02	2.52±0.04	20.06±6.53	2.32±1.08	12.04±8.64

Xanthone	2.24±1.03	1.76±0.34	2.52±0.72	2.53±1.46	15.31±8.27	3.62±1.48	21.66±23.64
1,4-Naphthoquinone	0.25±0.36	0.75±1.06	5.81±8.22	0.00±0.00	3.25±1.75	2.83±4.00	23.53±15.12
Acenaphthenequinone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3-methylphenanthrene	11.22±3.01	15.84±4.44	12.86±3.26	17.22±13.80	96.85±41.13	25.59±16.55	65.79±30.17
2-methylphenanthrene	6.22±3.09	6.05±0.07	10.08±0.75	6.05±1.52	89.27±23.36	10.33±4.43	58.81±36.37
Perinaphthenone	0.50±0.01	0.76±0.37	0.00±0.00	1.76±0.38	7.97±11.27	5.70±8.06	17.30±20.27
2-methylanthracene	10.73±2.31	13.11±1.58	15.13±2.91	4.79±1.14	44.99±38.25	7.48±3.25	21.46±2.48
4,5-methylenephenanthrene	2.00±0.03	3.28±0.40	1.51±0.01	1.77±1.10	13.02±2.02	4.40±4.77	14.27±6.21
9-methylphenanthrene	3.74±1.71	4.03±0.66	5.29±0.38	3.03±0.76	48.64±11.71	6.46±1.86	32.47±20.08
1-methylphenanthrene	2.24±1.03	2.51±0.68	3.53±1.44	2.52±0.75	34.62±13.02	1.54±1.45	22.03±15.78
Anthrone	1.99±0.68	1.01±0.72	5.05±2.87	2.01±0.03	2.77±3.92	3.62±5.13	32.00±36.88
9-methylanthracene	0.50±0.01	0.25±0.36	0.50±0.00	0.25±0.36	1.25±0.36	1.55±2.20	2.84±3.32
Anthraquinone	262.91±361.09	0.25±0.36	394.48±387.96	11.32±0.89	133.69±19.51	18.88±19.43	237.60±32.85
A-dimethylphenanthrene	1.25±0.33	1.26±0.37	2.27±0.37	0.76±0.37	12.27±0.26	1.55±0.74	8.42±4.22
B-dimethylphenanthrene	0.99±0.69	1.01±0.72	1.26±0.36	0.76±0.37	12.54±2.93	1.29±1.10	18.27±18.16
1,7-dimethylphenanthrene	0.99±0.69	1.01±0.01	1.77±0.36	1.26±0.38	16.29±3.31	1.81±1.10	23.72±25.86
3,6-dimethylphenanthrene	1.00±0.02	1.01±0.01	1.26±0.36	0.76±0.37	13.27±0.96	1.29±0.37	35.89±42.38
D-dimethylphenanthrene	1.25±0.33	1.52±1.44	1.26±0.36	0.76±0.37	11.03±2.92	1.03±0.73	7.66±3.84
E-dimethylphenanthrene	9.48±1.98	11.60±2.28	15.89±5.41	4.03±0.78	38.51±48.12	6.19±2.89	25.02±1.64
C-dimethylphenanthrene	2.24±1.03	2.27±0.38	4.54±1.44	2.52±0.75	31.09±7.33	3.62±1.48	25.61±18.05
Fluoranthene	3.98±2.77	3.54±1.47	9.33±1.82	3.78±0.42	71.13±3.70	7.75±5.15	41.72±28.27
Pyrene	3.48±2.77	3.02±0.04	8.32±3.24	3.28±1.12	42.03±12.43	3.88±2.57	21.45±11.47
9-Anthraaldehyde	0.25±0.35	0.25±0.36	0.50±0.71	0.25±0.35	2.01±1.43	0.52±0.73	2.26±1.00
Retene	0.25±0.35	0.00±0.00	0.00±0.00	0.00±0.00	1.00±0.01	0.00±0.00	0.51±0.02
benzo(a)fluorene	0.00±0.00	0.00±0.00	0.75±1.07	0.00±0.00	0.50±0.00	0.00±0.00	1.02±0.75
benzo(b)fluorene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	1.04±1.47
5-methylchrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
B-MePy/MeFl	0.25±0.35	0.00±0.00	1.26±1.78	0.00±0.00	0.00±0.00	0.00±0.00	1.30±1.83
1-MeFl+C-MeFl/Py	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	5.69±7.35
1+3-methylfluoranthene	0.25±0.35	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	9.33±13.20

4-methylpyrene	0.00±0.00	0.25±0.35	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	4.15±5.87
C-MePy/MeFl	0.25±0.35	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	1.81±2.57
D-MePy/MeFl	0.25±0.35	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	5.44±7.70
1-methylpyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	1.30±1.83
Benzonaphthothiophene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.26±0.37	6.74±9.53
benzo(c)phenanthrene	0.25±0.35	0.00±0.00	0.25±0.36	0.00±0.00	0.00±0.00	0.00±0.00	3.09±2.97
Benzo(ghi)fluoranthene	1.24±1.04	0.75±1.06	0.76±1.07	0.76±0.37	0.00±0.00	0.00±0.00	7.00±9.90
9-phenylanthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.25±0.35	0.00±0.00	0.26±0.37
6-methylchrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Cyclopenta(c,d)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.25±0.35	0.00±0.00	1.04±1.47
Benz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.78±1.10
Chrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzanthrone	0.25±0.35	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.52±0.73	4.41±6.23
Benz(a)anthracene-7,12-dione	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	2.07±2.93
3-methylchrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.52±0.73
7-methylbenz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.26±0.37
7,12-dimethylbenz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	1.30±1.83
Benzo(b)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(j)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(k)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(a)fluoranthene	0.00±0.00	0.00±0.00	0.25±0.36	0.00±0.00	0.00±0.00	0.00±0.00	0.25±0.35
BeP	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
BaP	0.00±0.00	0.76±0.37	0.00±0.00	0.00±0.00	0.25±0.35	0.00±0.00	0.00±0.00
Perylene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.25±0.36	0.00±0.00	0.00±0.00
3-methylcholanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7-methylbenzo(a)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.26±0.37	0.26±0.37
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.26±0.37
Indeno[123-cd]fluoranthene	0.00±0.00	0.00±0.00	0.75±1.07	0.00±0.00	0.00±0.00	0.00±0.00	0.26±0.37
Indeno[123-cd]pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Dibenzo(ac)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(ah+ac)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(ah)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,j)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(b)chrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Picene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(ghi)perylene	0.00±0.00	0.25±0.35	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Anthanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Triphenylene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,l)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Coronene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,e)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,i)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,h)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(b,k)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table D7: Gas-phase PAH emission for Vehicle #7

Component (ng/mile)	Fed ULSD	CARB ULSD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
naphthalene	367.21±177.17	473.93±135.27	2319.15±2159.42	1979.09±1859.93	515.67±62.01	1019.03±162.07	252.78±101.81
quinoline	50.11±37.65	16.76±0.90	97.93±70.51	30.08±3.04	42.23±21.26	58.55±2.27	7.22±8.50
2-methylnaphthalene	265.53±205.53	309.15±82.02	946.77±494.35	413.45±56.00	411.78±24.43	535.39±28.07	114.49±86.24
1-methylnaphthalene	164.23±116.20	164.82±47.17	574.24±350.95	254.39±34.48	240.61±12.70	330.20±13.68	65.46±51.53
Biphenyl	29.48±16.67	33.92±6.32	161.99±134.91	115.80±103.04	57.65±21.33	108.00±51.43	29.51±10.95
2,6+2,7-dimethylnaphthalene	51.48±31.82	52.28±15.62	229.57±177.28	92.69±30.86	111.49±18.65	186.65±90.36	42.34±14.13
1,3+1,6+1,7dimethylnaphth	107.24±67.10	95.78±30.66	403.31±304.31	152.28±19.59	189.66±13.55	296.98±133.82	74.29±25.97
1,4+1,5+2,3-dimethylnaphth	31.77±19.48	27.89±7.43	133.43±105.08	47.48±8.96	59.04±6.40	93.34±42.82	22.62±7.62
Acenaphthylene	2.29±1.95	1.31±1.86	3.11±0.59	1.99±0.16	1.68±1.08	7.75±1.60	2.75±0.90
1,2-dimethylnaphthalene	10.69±6.06	10.45±4.25	10.43±11.43	7.70±7.79	22.33±6.02	34.92±19.95	8.86±1.41
1,8-dimethylnaphthalene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Acenaphthene	5.65±1.52	7.55±2.78	85.42±108.98	76.83±99.31	15.90±14.25	32.33±22.34	10.99±1.87
1+2ethylnaphthalene	31.93±20.56	33.21±10.57	373.48±418.80	312.29±370.30	61.48±5.96	103.41±33.25	22.33±9.35
1-ethyl-2-methylnaphthalene	7.48±2.39	5.76±1.13	17.71±11.11	11.50±0.55	14.07±6.90	25.25±13.20	8.55±1.40
2,3,5+I-trimethylnaphthalene	12.06±2.39	16.09±7.41	30.10±19.34	23.88±9.14	34.24±28.93	82.76±60.76	21.23±3.94
B-trimethylnaphthalene	16.49±3.91	21.02±6.93	46.04±29.21	28.72±4.52	44.95±28.92	95.79±64.03	27.64±4.45
A-trimethylnaphthalene	23.83±9.97	24.72±8.65	72.44±48.39	38.87±7.41	56.88±32.79	119.51±78.97	33.73±3.24
C-trimethylnaphthalene	16.34±4.56	19.75±6.88	42.80±25.90	28.56±3.86	43.42±30.22	91.69±64.29	27.33±3.59
2-ethyl-1-methylnaphthalene	0.46±0.22	0.32±0.01	1.47±1.24	0.78±0.67	1.38±0.65	2.58±0.18	0.76±0.21
E-trimethylnaphthalene	10.54±3.69	11.72±4.30	29.36±19.98	19.08±5.75	25.99±20.73	62.23±43.85	17.56±2.60
2,4,5-trimethylnaphthalene	2.90±1.08	3.04±0.80	6.79±4.53	4.61±1.00	6.73±5.61	17.67±13.30	4.43±1.14
F-trimethylnaphthalene	7.94±2.17	10.27±3.57	20.35±15.27	14.49±6.05	24.00±19.22	57.68±43.48	15.42±2.14
Fluorene	15.27±4.34	21.06±8.73	33.07±17.63	21.66±3.88	53.49±56.16	111.55±91.08	28.99±1.23
1,4,5-trimethylnaphthalene	1.22±0.00	2.25±0.99	16.05±16.78	13.82±12.32	7.80±7.56	18.43±12.21	5.19±0.93
J-trimethylnaphthalene	5.35±1.09	6.25±1.83	12.83±8.86	9.54±2.44	16.66±13.60	41.51±33.60	10.98±0.29
A-Methylfluorene	6.11±0.44	18.19±15.05	31.34±35.46	5.52±0.16	17.73±16.85	31.01±14.85	11.29±0.29
B-Methylfluorene	1.37±0.65	6.57±1.84	9.03±0.11	0.76±0.63	3.21±2.37	7.10±4.85	2.29±0.25
1-Methylfluorene	6.11±3.90	59.41±74.28	122.67±96.20	6.44±0.62	12.23±9.93	22.36±14.74	6.71±0.52

9-fluorenone	10.84±2.82	211.01±273.83	205.65±269.29	175.52±247.79	18.80±13.60	8.87±11.70	10.23±1.64
Dibenzothiophene	0.31±0.43	0.80±0.26	4.28±2.67	0.78±0.67	1.22±0.86	2.41±2.12	0.15±0.22
Phenanthrene	38.18±9.99	57.77±26.88	96.15±70.95	64.27±36.54	108.06±110.80	199.28±134.18	55.85±4.17
Anthracene	1.83±0.87	4.49±1.08	4.43±2.46	1.23±0.47	3.82±4.54	10.71±9.95	1.82±0.84
Xanthone	1.83±0.87	1.77±0.75	3.84±1.63	2.47±1.37	2.75±2.16	5.15±1.65	1.98±0.24
1,4-Naphthoquinone	3.21±2.81	2.90±1.47	22.84±20.47	6.11±1.12	9.02±0.23	0.00±0.00	6.62±9.36
Acenaphthenequinone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3-methylphenanthrene	8.55±0.44	9.06±6.67	20.37±11.91	20.66±8.83	21.39±25.93	18.02±5.57	17.15±11.00
2-methylphenanthrene	5.19±1.74	5.80±2.94	8.56±4.51	6.18±3.21	11.46±11.88	17.53±10.51	5.95±0.72
Perinaphthenone	0.15±0.22	0.96±0.04	4.56±5.18	3.58±3.79	0.00±0.00	1.07±1.52	0.15±0.21
2-methylanthracene	5.04±1.52	7.30±6.38	6.21±1.19	3.02±2.95	14.21±16.20	34.92±3.44	3.83±1.99
4,5-methylenephenanthrene	1.38±1.08	2.73±0.79	3.68±4.36	3.75±5.31	5.20±5.62	6.18±5.72	2.59±0.25
9-methylphenanthrene	3.67±2.16	3.86±1.51	5.46±2.66	3.86±2.06	6.72±6.91	9.83±5.24	3.51±0.69
1-methylphenanthrene	2.29±0.65	2.25±0.99	2.36±2.07	1.99±0.16	6.11±6.91	8.30±6.55	2.29±0.19
Anthrone	0.46±0.65	0.80±0.26	1.19±0.43	1.24±0.90	1.83±2.16	3.47±3.18	0.76±0.64
9-methylanthracene	0.31±0.43	0.16±0.22	1.92±1.44	1.72±2.43	0.61±0.43	0.45±0.21	0.31±0.00
Anthraquinone	15.59±16.87	39.37±0.00	51.35±18.60	61.81±4.18	53.97±28.25	139.60±0.00	14.00±19.38
A-dimethylphenanthrene	1.68±1.08	1.29±0.50	1.63±0.19	1.08±0.25	2.14±2.16	3.64±0.38	1.53±0.45
B-dimethylphenanthrene	1.68±1.08	0.97±0.49	1.04±0.64	1.39±0.69	1.83±1.73	1.66±0.62	0.92±0.01
1,7-dimethylphenanthrene	1.99±1.51	1.13±0.72	1.48±0.02	1.23±0.47	2.29±1.94	4.39±1.88	1.37±0.20
3,6-dimethylphenanthrene	1.22±0.87	2.52±1.70	6.97±1.13	1.08±0.68	1.68±1.94	1.97±1.05	0.61±0.01
D-dimethylphenanthrene	1.99±1.95	1.13±0.72	1.03±0.62	0.77±0.24	1.38±1.51	26.78±35.71	2.77±3.06
E-dimethylphenanthrene	2.75±0.44	4.69±3.57	5.18±0.15	3.50±1.85	20.17±27.22	9.42±2.69	0.76±0.21
C-dimethylphenanthrene	3.97±3.03	2.26±1.44	3.41±0.25	2.62±1.16	4.74±4.54	5.27±5.73	2.29±0.25
Fluoranthene	3.82±1.09	9.04±2.57	17.61±1.68	5.41±3.41	7.95±7.78	16.47±10.31	3.97±0.05
Pyrene	4.43±2.81	5.47±2.47	5.18±0.99	2.77±0.95	6.42±6.48	11.36±2.22	2.90±0.25
9-Anthraaldehyde	0.61±0.43	0.32±0.01	0.45±0.21	0.00±0.00	0.61±0.43	2.76±3.90	0.15±0.22
Retene	0.15±0.22	0.00±0.00	0.15±0.21	0.00±0.00	0.15±0.22	0.15±0.21	0.00±0.00
benzo(a)fluorene	0.00±0.00	0.00±0.00	0.15±0.21	0.00±0.00	0.00±0.00	0.15±0.21	0.00±0.00
benzo(b)fluorene	0.15±0.22	0.00±0.00	0.15±0.21	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

5-methylchrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
B-MePy/MeFl	0.15±0.22	0.00±0.00	0.00±0.00	0.31±0.44	0.00±0.00	0.30±0.43	0.00±0.00
1-MeFl+C-MeFl/Py	0.00±0.00	0.00±0.00	0.44±0.62	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1+3-methylfluoranthene	0.00±0.00	0.00±0.00	0.29±0.42	0.16±0.22	0.00±0.00	0.00±0.00	0.15±0.21
4-methylpyrene	1.38±1.51	0.00±0.00	0.45±0.63	0.47±0.66	0.31±0.43	0.30±0.43	0.15±0.22
C-MePy/MeFl	0.15±0.22	0.00±0.00	0.00±0.00	0.16±0.22	0.15±0.22	0.00±0.00	0.00±0.00
D-MePy/MeFl	1.22±1.30	0.00±0.00	0.30±0.42	0.16±0.22	0.00±0.00	0.15±0.22	0.00±0.00
1-methylpyrene	1.22±1.30	0.00±0.00	0.30±0.42	0.31±0.44	0.31±0.43	0.45±0.64	0.15±0.22
Benzonaphthothiophene	0.00±0.00	0.00±0.00	0.00±0.00	0.31±0.44	0.00±0.00	0.00±0.00	0.00±0.00
benzo(c)phenanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.15±0.22	0.15±0.21	0.00±0.00
Benzo(ghi)fluoranthene	1.07±0.65	0.33±0.46	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.46±0.21
9-phenylanthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6-methylchrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Cyclopenta(c,d)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Chrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzanthrone	0.00±0.00	0.16±0.23	0.59±0.83	0.16±0.22	0.00±0.00	0.00±0.00	0.00±0.00
Benz(a)anthracene-7,12-dione	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.30±0.43
3-methylchrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.15±0.22	0.15±0.21	0.00±0.00
7-methylbenz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7,12-dimethylbenz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(b)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(j)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(k)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(a)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.15±0.21	0.00±0.00
BeP	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
BaP	0.00±0.00	0.16±0.23	0.15±0.21	0.15±0.21	0.15±0.22	0.00±0.00	0.31±0.00
Perylene	0.00±0.00	0.16±0.23	0.00±0.00	0.15±0.21	0.15±0.22	0.31±0.43	0.15±0.22
3-methylcholanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7-methylbenzo(a)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Indeno[123-cd]fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Indeno[123-cd]pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(ac)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(ah+ac)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(ah)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,j)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(b)chrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Picene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(ghi)perylene	0.00±0.00	0.00±0.00	0.15±0.21	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Anthanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Triphenylene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,l)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Coronene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,e)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,i)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,h)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(b,k)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table D8: Gas-phase PAH emission for Vehicle #8

Component (ng/mile)	Fed ULSD	CARB ULSD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
naphthalene	1122.68±97.27	1403.07±242.14	791.07±97.04	1109.76±53.24	164.54±59.91	1678.90±435.37	136.40±28.55
quinoline	40.43±17.13	41.74±13.39	41.70±6.83	45.37±3.15	1.26±1.19	67.91±21.95	0.41±0.00
2-methylnaphthalene	644.80±102.11	702.50±178.35	457.78±3.82	620.58±32.34	67.57±28.73	745.00±311.19	45.81±10.79
1-methylnaphthalene	353.38±35.64	378.15±97.45	244.97±14.06	326.99±9.57	34.21±13.47	394.35±160.70	22.18±4.37
Biphenyl	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	19.03±2.83	0.00±0.00	17.41±5.25
2,6+2,7-dimethylnaphthalene	185.48±8.95	150.11±29.05	113.57±16.34	155.67±11.99	28.76±3.34	141.51±17.18	22.60±3.78
1,3+1,6+1,7dimethylnaphth	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	48.83±8.25	0.00±0.00	38.14±5.81
1,4+1,5+2,3-dimethylnaphth	98.41±6.32	80.42±17.22	59.29±12.05	88.29±1.61	14.38±0.47	74.00±11.44	12.02±2.33
Acenaphthylene	9.22±6.85	39.51±21.73	9.73±15.83	24.69±4.11	0.63±0.29	31.01±31.42	1.04±0.29

1,2-dimethylnaphthalene	35.47±33.84	37.60±38.38	28.19±12.10	14.79±1.65	5.92±1.74	65.17±1.87	4.56±0.58
1,8-dimethylnaphthalene	38.64±15.94	48.12±8.60	28.10±6.09	55.14±3.45	0.00±0.00	50.58±3.01	0.00±0.00
Acenaphthene	74.09±3.83	55.65±16.33	63.79±14.80	51.61±0.28	10.58±1.29	74.56±17.04	12.02±5.26
1+2ethylnaphthalene	55.23±8.98	48.62±8.25	36.31±7.57	47.00±0.20	9.90±9.79	50.05±10.66	2.07±1.76
1-ethyl-2-methylnaphthalene	264.94±57.38	257.21±14.80	176.97±22.09	292.63±26.03	4.02±0.26	277.20±3.30	3.73±0.01
2,3,5+I-trimethylnaphthalene	107.22±24.64	56.09±7.68	55.02±16.88	85.57±18.52	19.06±3.76	44.56±19.11	17.20±5.55
B-trimethylnaphthalene	121.02±34.04	81.19±10.99	60.58±11.46	106.71±15.10	20.94±0.72	59.20±6.34	17.21±2.03
A-trimethylnaphthalene	32.35±10.90	31.48±4.27	19.20±4.96	31.09±1.13	24.54±0.98	29.46±0.41	21.35±3.78
C-trimethylnaphthalene	168.34±33.40	130.71±20.20	92.23±12.90	133.98±11.02	21.79±0.49	102.77±9.01	18.03±3.20
2-ethyl-1-methylnaphthalene	7.89±2.10	4.41±3.00	1.12±0.92	5.12±2.38	0.85±0.01	0.97±0.85	0.62±0.29
E-trimethylnaphthalene	61.96±22.61	56.96±16.45	37.94±17.20	59.75±0.49	13.54±0.72	44.08±14.29	10.99±2.62
2,4,5-trimethylnaphthalene	35.89±8.67	26.62±4.93	24.08±4.97	27.05±0.45	3.17±0.27	21.76±3.16	3.52±1.46
F-trimethylnaphthalene	178.15±47.08	135.89±37.58	89.92±8.59	146.22±10.47	12.49±2.20	99.81±12.94	10.99±2.62
Fluorene	153.49±28.68	122.52±19.82	118.62±7.46	122.42±2.01	15.24±0.73	136.62±15.28	15.55±4.38
1,4,5-trimethylnaphthalene	4.09±2.25	1.63±2.19	1.43±1.48	0.59±0.83	2.32±1.48	8.62±7.54	1.24±0.58
J-trimethylnaphthalene	24.39±8.25	17.43±3.47	13.90±4.80	16.78±0.45	10.79±0.99	11.14±8.84	9.54±2.33
A-Methylfluorene	46.89±15.41	40.73±9.44	32.79±14.85	35.97±5.00	6.99±0.96	42.92±1.50	6.84±4.98
B-Methylfluorene	33.16±4.76	22.85±14.49	19.28±5.34	23.52±1.26	7.64±6.65	16.76±3.68	9.13±8.81
1-Methylfluorene	66.60±20.69	66.71±21.92	57.33±2.84	37.44±10.49	4.44±0.26	70.23±5.47	4.15±0.58
9-fluorenone	101.07±32.16	82.26±12.97	64.96±10.36	89.47±5.23	5.53±7.23	266.15±168.91	1.24±0.00
Dibenzothiophene	18.80±6.12	16.57±2.23	14.26±2.65	10.65±0.19	0.21±0.30	19.00±0.60	0.21±0.29
Phenanthrene	348.84±112.52	220.16±18.46	176.90±15.44	243.12±22.72	38.73±3.63	526.04±266.20	42.29±8.15
Anthracene	10.28±1.96	7.83±3.89	5.80±5.22	7.68±1.70	0.63±0.29	25.63±11.87	0.42±0.59
Xanthone	5.18±1.10	7.86±0.97	4.84±2.03	6.29±0.64	1.27±0.01	16.61±9.21	1.24±0.00
1,4-Naphthoquinone	100.70±48.49	292.33±168.73	157.25±87.98	113.62±155.48	1.27±0.61	470.32±100.90	0.42±0.59
Acenaphthenequinone	26.97±2.98	21.83±1.04	16.43±1.91	17.98±3.15	0.00±0.00	17.83±2.68	0.00±0.00
3-methylphenanthrene	47.40±17.52	28.19±7.58	23.13±4.60	30.02±4.72	6.35±1.25	41.87±1.34	6.22±1.75
2-methylphenanthrene	48.97±17.50	31.94±3.63	22.85±4.31	30.59±0.24	3.39±1.23	37.28±4.21	4.15±1.17
Perinaphthenone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.43±0.60	0.00±0.00	0.41±0.00
2-methylanthracene	10.23±2.16	6.95±0.91	5.21±0.57	6.98±0.16	6.34±0.54	7.45±0.91	6.01±2.63

4,5-methylenephenanthrene	13.13±7.89	11.80±2.03	7.29±0.80	11.38±0.36	1.06±1.51	13.19±2.50	1.87±0.88
9-methylphenanthrene	26.39±9.71	17.19±1.74	12.04±2.04	15.74±0.29	2.54±0.62	18.49±3.36	2.69±0.88
1-methylphenanthrene	25.63±6.89	16.10±1.17	14.70±5.14	21.47±1.62	1.69±0.58	23.30±4.41	2.07±0.00
Anthrone	4.49±7.77	6.87±11.89	14.08±24.38	0.00±0.00	1.48±0.29	91.98±159.31	1.24±0.00
9-methylanthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.21±0.30	0.00±0.00	0.21±0.29
Anthraquinone	5.90±3.71	12.56±6.83	5.42±1.18	9.93±3.55	5.95±5.44	9.56±8.29	10.15±7.32
A-dimethylphenanthrene	9.35±4.77	7.06±0.56	3.62±2.11	6.02±1.25	0.64±0.30	10.96±2.25	1.24±0.58
B-dimethylphenanthrene	4.96±1.50	1.14±0.99	2.58±2.15	2.63±0.90	0.64±0.30	2.84±0.74	1.04±0.88
1,7-dimethylphenanthrene	10.95±3.13	6.85±6.01	5.02±4.35	3.48±4.93	1.27±0.01	4.99±8.64	1.04±1.46
3,6-dimethylphenanthrene	5.46±1.12	2.13±0.95	3.06±1.68	2.53±1.23	1.06±0.91	4.25±0.99	1.87±0.30
D-dimethylphenanthrene	9.27±3.64	4.21±0.60	4.57±1.47	4.88±0.17	3.19±4.52	6.17±0.94	6.22±0.01
E-dimethylphenanthrene	0.93±1.60	0.68±0.79	0.94±0.82	1.88±0.30	2.77±3.91	1.65±0.14	3.11±0.88
C-dimethylphenanthrene	8.11±14.05	14.79±25.61	0.00±0.00	0.00±0.00	1.70±0.61	42.18±6.07	2.28±0.88
Fluoranthene	53.57±15.08	48.23±7.48	33.39±12.61	39.08±2.60	4.24±2.43	128.98±88.60	8.08±2.63
Pyrene	26.64±10.07	30.72±11.55	18.36±14.05	20.99±2.75	2.12±0.62	109.07±79.37	2.90±1.17
9-Anthraaldehyde	43.27±17.41	26.51±9.11	26.30±3.74	28.19±1.90	0.42±0.59	31.57±2.36	0.62±0.88
Retene	0.71±0.12	1.08±0.05	0.69±0.27	0.84±0.03	0.00±0.00	0.87±0.42	0.00±0.00
benzo(a)fluorene	0.82±1.43	0.52±0.90	0.66±1.13	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
benzo(b)fluorene	0.19±0.33	0.30±0.33	0.42±0.47	0.83±0.10	0.00±0.00	1.19±2.06	0.00±0.00
5-methylchrysene	1.45±2.51	0.33±0.58	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
B-MePy/MeFl	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1-MeFl+C-MeFl/Py	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1+3-methylfluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	1.87±3.24	0.00±0.00
4-methylpyrene	2.02±2.97	1.63±1.33	2.45±3.42	1.71±0.62	0.21±0.30	3.56±2.47	0.21±0.29
C-MePy/MeFl	0.49±0.55	0.28±0.48	0.60±1.04	0.39±0.55	0.00±0.00	0.00±0.00	0.00±0.00
D-MePy/MeFl	2.23±3.18	0.28±0.32	2.68±3.62	0.98±0.10	0.21±0.30	2.59±0.81	0.00±0.00
1-methylpyrene	0.50±0.87	0.94±1.47	1.37±2.30	0.20±0.28	0.00±0.00	0.16±0.19	0.00±0.00
Benzonaphthothiophene	0.00±0.00	0.07±0.12	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
benzo(c)phenanthrene	0.20±0.34	0.25±0.44	0.27±0.47	0.00±0.00	0.21±0.30	0.38±0.66	0.21±0.29
Benzo(ghi)fluoranthene	1.57±1.27	1.22±1.43	1.20±1.52	0.35±0.50	1.28±1.81	2.46±2.04	0.62±0.29

9-phenylanthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	1.38±1.49	0.00±0.00
6-methylchrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.26±0.37	0.00±0.00	0.00±0.00	0.00±0.00
Cyclopenta(c,d)pyrene	0.64±0.56	1.09±1.31	0.00±0.00	0.30±0.43	0.00±0.00	0.28±0.48	0.00±0.00
Benz(a)anthracene	0.07±0.12	0.72±1.25	0.00±0.00	0.11±0.15	0.00±0.00	0.00±0.00	0.00±0.00
Chrysene	0.23±0.39	0.29±0.51	0.28±0.25	1.51±0.36	0.00±0.00	0.00±0.00	0.00±0.00
Benzanthrone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benz(a)anthracene-7,12-dione	4.01±6.95	33.36±57.78	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3-methylchrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7-methylbenz(a)anthracene	0.00±0.00	0.27±0.46	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7,12-dimethylbenz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.21±0.29
Benzo(b)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.23±0.32	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(j)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(k)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(a)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
BeP	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
BaP	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.42±0.00	0.00±0.00	0.21±0.29
Perylene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.42±0.00	0.00±0.00	0.41±0.00
3-methylcholanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7-methylbenzo(a)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.42±0.59	0.00±0.00	0.21±0.29
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Indeno[123-cd]fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.21±0.30	0.00±0.00	0.21±0.29
Indeno[123-cd]pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(ac)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(ah+ac)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.21±0.29
Dibenzo(ah)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,j)anthracene	0.05±0.09	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(b)chrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Picene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Benzo(ghi)perylene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Anthanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.36±0.51	0.00±0.00	0.00±0.00	0.00±0.00
Triphenylene	0.03±0.05	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,l)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Coronene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,e)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,i)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(a,h)pyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Dibenzo(b,k)fluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table D9: Particle-phase PAH emissions for Vehicle #1

Component (ng/mile)	Fed ULSD	CARB USLD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
Naphthalene	0.41 ± 0.58	3.72 ± 5.26	0.00 ± 0.00	0.00 ± 0.00	71.45 ± 101.04	10.87 ± 15.37	5.39 ± 7.62
Quinoline	0.00 ± 0.00	7.69 ± 10.87	0.00 ± 0.00	1.75 ± 2.48	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
2-methylnaphthalene	16.49 ± 17.85	14.81 ± 20.94	0.00 ± 0.00	13.25 ± 12.18	57.14 ± 67.95	15.51 ± 21.93	20.29 ± 28.69
1-methylnaphthalene	7.03 ± 9.94	6.13 ± 5.72	4.69 ± 3.65	6.16 ± 6.98	31.27 ± 44.23	13.35 ± 18.88	11.45 ± 16.20
Biphenyl	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.53 ± 0.75	1.39 ± 1.96	1.31 ± 1.85	0.00 ± 0.00
2-methylbiphenyl	11.87 ± 1.93	14.44 ± 10.12	11.54 ± 1.12	15.20 ± 3.24	7.73 ± 10.93	8.50 ± 4.63	7.39 ± 0.19
2,6+2,7-dimethylnaphthalene	2.61 ± 3.70	5.01 ± 2.81	3.61 ± 2.15	1.11 ± 1.19	4.64 ± 2.40	4.66 ± 6.59	1.76 ± 2.49
1,3+1,6+1,7dimethylnaphth	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1,4+1,5+2,3-dimethylnaphth	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	7.14 ± 10.09	34.77 ± 38.52	24.34 ± 1.92	0.00 ± 0.00
Acenaphthylene	1.39 ± 1.96	1.64 ± 2.32	1.98 ± 2.79	1.43 ± 2.02	1.55 ± 2.20	0.00 ± 0.00	0.00 ± 0.00
1,2-dimethylnaphthalene	7.01 ± 0.28	4.02 ± 0.36	0.80 ± 1.13	5.71 ± 5.55	0.00 ± 0.00	2.40 ± 2.33	6.99 ± 1.34
1,8-dimethylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Acenaphthene	3.93 ± 0.22	1.90 ± 2.68	2.55 ± 3.61	3.79 ± 5.36	1.86 ± 2.64	4.93 ± 1.83	1.79 ± 2.53

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3-methylbiphenyl	1.74 ± 2.46	4.78 ± 6.76	0.00 ± 0.00	14.77 ± 18.90	3.43 ± 4.85	5.37 ± 7.60	0.00 ± 0.00
4-methylbiphenyl	2.11 ± 2.94	4.07 ± 5.75	1.27 ± 1.80	13.10 ± 14.98	0.19 ± 0.26	7.29 ± 4.77	0.00 ± 0.00
1+2ethylnaphthalene	3.77 ± 5.34	79.64 ± 39.00	89.35 ± 8.53	32.94 ± 25.70	77.23 ± 40.08	60.44 ± 6.94	12.52 ± 17.70
1-ethyl-2-methylnaphthalene	20.53 ± 29.03	3.46 ± 0.20	1.60 ± 2.26	0.00 ± 0.00	13.47 ± 19.05	0.00 ± 0.00	1.32 ± 1.87
2,3,5+I-trimethylnaphthalene	2.40 ± 0.63	5.66 ± 0.37	3.93 ± 1.76	5.16 ± 1.73	12.22 ± 11.63	5.05 ± 0.33	3.08 ± 1.62
B-trimethylnaphthalene	14.39 ± 17.13	17.60 ± 23.07	19.30 ± 26.11	2.98 ± 0.02	7.19 ± 7.67	2.60 ± 0.76	27.24 ± 3.71
A-trimethylnaphthalene	0.00 ± 0.00	0.83 ± 1.18	0.00 ± 0.00	0.00 ± 0.00	10.53 ± 14.90	0.00 ± 0.00	1.35 ± 1.91
C-trimethylnaphthalene	0.00 ± 0.00	0.11 ± 0.16	0.38 ± 0.53	0.00 ± 0.00	5.03 ± 7.12	0.00 ± 0.00	0.00 ± 0.00
2-ethyl-1-methylnaphthalene	0.00 ± 0.00	0.85 ± 0.50	0.77 ± 1.10	0.00 ± 0.00	0.00 ± 0.00	0.50 ± 0.70	0.00 ± 0.00
E-trimethylnaphthalene	0.76 ± 0.67	2.94 ± 4.15	0.00 ± 0.00	0.59 ± 0.84	4.98 ± 6.95	0.00 ± 0.00	0.00 ± 0.00
2,4,5-trimethylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
F-trimethylnaphthalene	1.66 ± 2.09	1.24 ± 1.75	0.00 ± 0.00	0.41 ± 0.58	2.15 ± 2.95	0.90 ± 1.27	0.00 ± 0.00
Fluorene	1.63 ± 1.32	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1,4,5-trimethylnaphthalene	0.00 ± 0.00	2.66 ± 3.76	16.94 ± 23.95	4.68 ± 6.62	0.00 ± 0.00	3.08 ± 1.91	0.00 ± 0.00
J-trimethylnaphthalene	2.80 ± 3.95	3.07 ± 1.46	3.26 ± 0.99	4.33 ± 1.95	1.77 ± 2.51	2.94 ± 4.15	2.79 ± 0.18
A-Methylfluorene	2.67 ± 1.91	3.26 ± 4.39	3.57 ± 0.60	1.93 ± 1.00	8.37 ± 10.04	0.00 ± 0.00	6.96 ± 8.22
B-Methylfluorene	0.00 ± 0.00	2.23 ± 3.15	3.19 ± 0.28	0.00 ± 0.00	0.00 ± 0.00	2.38 ± 3.36	2.70 ± 3.83
1-Methylfluorene	3.74 ± 0.59	4.78 ± 0.71	5.40 ± 0.96	1.93 ± 2.73	10.75 ± 10.30	7.22 ± 2.89	5.16 ± 0.20
9-fluorenone	6.85 ± 1.61	6.54 ± 1.23	4.59 ± 3.48	3.46 ± 4.90	0.00 ± 0.00	2.90 ± 4.10	5.72 ± 0.64
Dibenzothiophene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.11 ± 1.57	0.00 ± 0.00	0.82 ± 1.16	0.00 ± 0.00
Phenanthrene	0.00 ± 0.00	5.66 ± 5.23	9.89 ± 2.07	14.31 ± 20.23	7.13 ± 5.95	12.09 ± 13.16	0.00 ± 0.00
Anthracene	1.24 ± 1.75	1.40 ± 1.98	0.39 ± 0.55	0.81 ± 1.15	2.55 ± 3.61	0.64 ± 0.90	1.20 ± 1.70

Xanthone	14.58 ± 4.72	25.06 ± 10.55	18.25 ± 0.11	14.75 ± 1.01	18.48 ± 26.14	4.72 ± 1.37	6.45 ± 5.17
1,4-Naphthoquinone	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Acenaphthenequinone	5.39 ± 7.62	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	3.41 ± 4.83	1.78 ± 2.52
3-methylphenanthrene	0.62 ± 0.88	4.31 ± 0.64	7.90 ± 1.29	1.44 ± 2.04	0.94 ± 1.33	3.10 ± 0.83	2.97 ± 4.19
2-methylphenanthrene	0.00 ± 0.00	0.49 ± 0.70	4.26 ± 2.26	1.39 ± 1.96	8.00 ± 11.32	2.90 ± 0.16	5.67 ± 8.02
Perinaphthenone	23.63 ± 1.02	24.81 ± 9.21	32.79 ± 25.25	10.46 ± 14.79	7.56 ± 10.70	11.18 ± 0.27	4.87 ± 6.89
2-methylanthracene	0.98 ± 1.39	0.43 ± 0.61	0.00 ± 0.00	1.10 ± 1.55	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
4,5-methylenephenanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.31 ± 0.44	0.00 ± 0.00	0.24 ± 0.34	0.00 ± 0.00
9-methylphenanthrene	2.30 ± 3.25	2.95 ± 4.17	4.58 ± 0.94	6.38 ± 3.30	0.00 ± 0.00	3.15 ± 0.81	1.86 ± 2.63
1-methylphenanthrene	6.62 ± 0.82	7.07 ± 0.35	6.80 ± 2.63	8.59 ± 2.46	0.00 ± 0.00	7.08 ± 0.96	1.87 ± 2.64
Anthrone	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
9-methylanthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Anthraquinone	10.55 ± 0.74	10.64 ± 4.56	17.36 ± 3.85	6.10 ± 0.82	2.18 ± 3.08	3.83 ± 5.42	9.13 ± 2.62
A-dimethylphenanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
B-dimethylphenanthrene	3.36 ± 4.76	6.39 ± 0.29	6.60 ± 1.92	3.16 ± 4.46	2.12 ± 3.00	3.76 ± 0.62	5.65 ± 1.21
1,7-dimethylphenanthrene	0.00 ± 0.00	0.00 ± 0.00	0.96 ± 1.35	1.56 ± 2.20	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3,6-dimethylphenanthrene	9.93 ± 0.26	3.18 ± 4.49	0.27 ± 0.39	0.23 ± 0.32	0.00 ± 0.00	1.91 ± 2.69	4.78 ± 1.91
D-dimethylphenanthrene	2.67 ± 1.37	4.29 ± 1.06	2.59 ± 3.66	2.73 ± 1.95	0.00 ± 0.00	2.20 ± 3.11	2.74 ± 3.87
E-dimethylphenanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
C-dimethylphenanthrene	2.23 ± 3.15	2.33 ± 3.30	2.84 ± 4.01	2.21 ± 3.12	0.00 ± 0.00	2.11 ± 2.99	0.00 ± 0.00
Fluoranthene	0.00 ± 0.00	2.18 ± 3.08	4.74 ± 0.86	0.59 ± 0.84	0.00 ± 0.00	0.31 ± 0.43	0.29 ± 0.41
Pyrene	0.00 ± 0.00	4.02 ± 5.69	9.98 ± 0.01	3.20 ± 3.20	3.21 ± 4.54	0.90 ± 1.27	0.00 ± 0.00

9-Anthraaldehyde	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Retene	0.00 ± 0.00	0.00 ± 0.00	0.24 ± 0.35	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
benzo(a)fluorene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
benzo(b)fluorene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
5-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
B-MePy/MeFl	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1-MeFl+C-MeFl/Py	0.00 ± 0.00	1.20 ± 1.70	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	3.13 ± 1.76
1+3-methylfluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
4-methylpyrene	3.50 ± 1.39	3.70 ± 1.36	8.55 ± 6.25	3.55 ± 2.87	1.32 ± 1.87	2.29 ± 0.99	3.71 ± 0.35
C-MePy/MeFl	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
D-MePy/MeFl	1.07 ± 1.51	1.95 ± 2.76	1.35 ± 1.91	0.00 ± 0.00	0.00 ± 0.00	0.91 ± 1.29	2.32 ± 3.28
1-methylpyrene	4.06 ± 0.65	1.36 ± 1.92	3.22 ± 0.61	1.30 ± 1.83	0.00 ± 0.00	2.35 ± 0.54	2.70 ± 0.93
Benzonaphthothiophene	0.00 ± 0.00	0.74 ± 1.05	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.65 ± 0.92	0.00 ± 0.00
benzo(c)phenanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(ghi)fluoranthene	2.27 ± 0.14	6.10 ± 2.95	9.35 ± 0.00	6.47 ± 0.63	1.24 ± 1.75	2.94 ± 1.39	2.82 ± 1.14
9-phenylanthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
6-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Cyclopenta(c,d)pyrene	0.00 ± 0.00	0.41 ± 0.58	0.35 ± 0.50	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benz(a)anthracene	0.00 ± 0.00	0.22 ± 0.31	1.32 ± 1.86	0.23 ± 0.33	0.00 ± 0.00	0.26 ± 0.17	0.09 ± 0.12
Chrysene	1.33 ± 0.38	0.78 ± 0.67	3.97 ± 2.79	1.04 ± 0.66	0.80 ± 1.13	1.09 ± 0.25	0.67 ± 0.95
Benzanthrone	0.00 ± 0.00	1.46 ± 2.07	2.88 ± 4.07	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benz(a)anthracene-7,12-	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

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3-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7-methylbenz(a)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7,12-dimethylbenz(a)anthracene	3.33 ± 0.28	4.12 ± 1.36	5.21 ± 0.21	5.19 ± 2.76	13.17 ± 3.80	2.52 ± 3.28	2.41 ± 3.41
Benzo(b)fluoranthene	0.53 ± 0.61	0.11 ± 0.05	4.04 ± 2.65	0.17 ± 0.24	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(j)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	2.45 ± 0.20	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(k)fluoranthene	1.03 ± 0.79	0.72 ± 1.01	1.01 ± 0.72	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(a)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BeP	0.39 ± 0.55	0.63 ± 0.47	2.43 ± 0.21	0.70 ± 0.06	0.22 ± 0.31	0.06 ± 0.08	0.02 ± 0.03
BaP	0.56 ± 0.79	1.46 ± 1.15	2.38 ± 0.55	0.00 ± 0.00	0.00 ± 0.00	0.31 ± 0.44	0.47 ± 0.26
Perylene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylcholanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7-methylbenzo(a)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Indeno[123-cd]fluoranthene	0.77 ± 1.09	0.00 ± 0.00	1.10 ± 1.55	0.00 ± 0.00	0.00 ± 0.00	1.42 ± 0.23	0.00 ± 0.00
Indeno[123-cd]pyrene	1.02 ± 0.48	1.00 ± 1.42	2.77 ± 1.69	0.54 ± 0.76	0.00 ± 0.00	1.01 ± 0.28	0.00 ± 0.00
Dibenzo(ac)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ah+ac)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ah)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,j)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(b)chrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Picene	4.85 ± 3.77	2.47 ± 3.49	7.95 ± 2.59	5.08 ± 7.18	1.39 ± 1.97	5.24 ± 7.41	1.76 ± 2.49
Benzo(ghi)perylene	3.46 ± 0.82	5.84 ± 2.57	8.22 ± 3.09	3.73 ± 0.17	2.34 ± 3.31	3.33 ± 0.11	1.63 ± 2.31
Anthanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Triphenylene	0.00 ± 0.00	0.00 ± 0.00	14.36 ± 20.30	14.06 ± 19.89	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,l)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Coronene	0.00 ± 0.00	0.00 ± 0.00	2.61 ± 3.69	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,e)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,i)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,h)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(b,k)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Table D10: Particle-phase PAH emissions for Vehicle #2

Component (ng/mile)	Fed ULSD	CARB USLD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
Naphthalene	222.88 ± 249.37	303.88 ± 347.67	0.00 ± 0.00	24.63 ± 34.83	0.00 ± 0.00	4.14 ± 5.86	0.00 ± 0.00
Quinoline	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
2-methylnaphthalene	183.19 ± 192.93	298.53 ± 329.43	8.38 ± 11.85	22.85 ± 32.31	10.74 ± 8.38	4.75 ± 2.02	4.61 ± 6.52
1-methylnaphthalene	101.66 ± 100.01	149.81 ± 168.68	2.75 ± 3.89	11.90 ± 16.82	11.48 ± 11.12	3.65 ± 5.16	7.45 ± 10.54
Biphenyl	15.99 ± 22.62	17.74 ± 22.23	0.00 ± 0.00	1.17 ± 1.65	0.00 ± 0.00	5.34 ± 0.25	9.15 ± 12.94
2-methylbiphenyl	24.83 ± 12.97	24.20 ± 11.41	13.78 ± 3.31	13.54 ± 2.38	16.69 ± 1.57	14.71 ± 1.61	12.43 ± 0.59
2,6+2,7-dimethylnaphthalene	44.12 ± 37.48	62.25 ± 58.75	4.76 ± 6.74	10.56 ± 14.93	5.66 ± 2.46	3.73 ± 3.17	4.14 ± 5.85
1,3+1,6+1,7dimethylnaphth	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1,4+1,5+2,3-dimethylnaphth	35.66 ± 50.43	64.68 ± 91.47	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.27 ± 1.80

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Acenaphthylene	0.00 ± 0.00	3.36 ± 4.75	7.50 ± 10.61	1.59 ± 2.25	1.97 ± 2.78	5.41 ± 3.19	1.65 ± 2.33
1,2-dimethylnaphthalene	20.14 ± 14.96	21.03 ± 11.37	7.10 ± 3.61	8.37 ± 0.16	3.00 ± 0.72	0.28 ± 0.39	2.09 ± 2.72
1,8-dimethylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Acenaphthene	1.87 ± 2.65	3.85 ± 5.45	6.91 ± 3.06	3.55 ± 5.02	7.83 ± 0.05	6.35 ± 1.88	3.61 ± 0.34
3-methylbiphenyl	49.33 ± 41.99	51.89 ± 20.73	1.69 ± 2.39	37.38 ± 23.14	25.20 ± 1.22	13.71 ± 19.39	0.00 ± 0.00
4-methylbiphenyl	20.44 ± 17.47	39.31 ± 7.75	1.20 ± 1.70	25.85 ± 6.94	24.67 ± 2.14	12.82 ± 18.13	0.00 ± 0.00
1+2ethylnaphthalene	89.91 ± 50.32	197.85 ± 172.71	71.55 ± 58.57	61.88 ± 30.79	69.11 ± 3.69	31.65 ± 44.76	76.96 ± 5.97
1-ethyl-2-methylnaphthalene	2.77 ± 3.92	2.25 ± 3.18	4.04 ± 1.46	4.07 ± 1.79	3.96 ± 1.07	1.82 ± 2.58	0.00 ± 0.00
2,3,5+I-trimethylnaphthalene	11.86 ± 5.47	16.12 ± 3.74	7.79 ± 0.10	10.35 ± 3.14	9.59 ± 0.41	6.75 ± 0.73	4.53 ± 1.30
B-trimethylnaphthalene	18.35 ± 15.59	19.37 ± 13.20	24.55 ± 27.27	32.18 ± 35.29	6.59 ± 1.31	42.59 ± 6.67	1.26 ± 1.78
A-trimethylnaphthalene	9.27 ± 11.21	10.30 ± 14.57	0.14 ± 0.20	0.50 ± 0.71	0.59 ± 0.84	0.00 ± 0.00	0.00 ± 0.00
C-trimethylnaphthalene	10.25 ± 14.47	15.72 ± 20.49	0.00 ± 0.00	2.20 ± 1.52	0.20 ± 0.28	0.00 ± 0.00	0.00 ± 0.00
2-ethyl-1-methylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	1.00 ± 1.42	1.11 ± 1.57	1.64 ± 2.32	2.79 ± 0.49	0.00 ± 0.00
E-trimethylnaphthalene	16.48 ± 15.38	24.24 ± 23.38	0.00 ± 0.00	5.07 ± 5.07	1.24 ± 1.75	0.00 ± 0.00	0.00 ± 0.00
2,4,5-trimethylnaphthalene	3.49 ± 4.94	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
F-trimethylnaphthalene	16.73 ± 12.10	14.79 ± 14.70	1.01 ± 1.43	0.15 ± 0.22	2.53 ± 1.63	4.94 ± 5.02	0.04 ± 0.06
Fluorene	7.81 ± 10.08	5.45 ± 7.71	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1,4,5-trimethylnaphthalene	77.37 ± 78.93	85.51 ± 72.13	10.44 ± 10.09	19.68 ± 10.76	11.26 ± 0.33	3.83 ± 5.41	0.00 ± 0.00
J-trimethylnaphthalene	7.48 ± 4.15	0.00 ± 0.00	4.91 ± 0.31	9.04 ± 1.65	4.82 ± 0.62	3.99 ± 0.39	3.99 ± 1.47
A-Methylfluorene	4.11 ± 1.68	11.97 ± 13.31	2.07 ± 2.93	16.12 ± 22.79	6.10 ± 4.03	3.80 ± 5.38	1.64 ± 2.32
B-Methylfluorene	6.74 ± 9.53	0.00 ± 0.00	7.74 ± 2.63	3.76 ± 5.32	0.00 ± 0.00	3.72 ± 5.26	2.46 ± 3.48
1-Methylfluorene	14.79 ± 11.16	8.46 ± 11.96	4.36 ± 4.52	7.63 ± 10.36	0.10 ± 0.14	7.55 ± 6.27	9.51 ± 5.52

9-fluorenone	12.85 ± 0.10	9.19 ± 3.54	9.67 ± 0.57	0.00 ± 0.00	8.19 ± 0.85	6.53 ± 3.94	2.88 ± 4.07
Dibenzothiophene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Phenanthrene	20.22 ± 18.46	35.82 ± 0.85	9.77 ± 4.62	35.20 ± 10.74	37.44 ± 2.96	17.57 ± 24.85	0.00 ± 0.00
Anthracene	5.17 ± 4.11	4.45 ± 2.36	1.26 ± 0.34	3.20 ± 0.93	0.83 ± 1.17	3.22 ± 1.41	0.51 ± 0.72
Xanthone	14.98 ± 3.80	13.94 ± 9.25	20.98 ± 2.99	12.63 ± 0.70	12.86 ± 2.55	12.18 ± 1.74	5.45 ± 1.95
1,4-Naphthoquinone	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Acenaphthenequinone	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylphenanthrene	14.40 ± 10.24	13.90 ± 3.72	5.56 ± 1.90	9.39 ± 0.96	9.27 ± 1.73	5.51 ± 1.92	1.16 ± 1.63
2-methylphenanthrene	6.76 ± 6.26	10.37 ± 8.96	5.55 ± 7.84	5.72 ± 5.78	4.93 ± 0.03	4.54 ± 6.42	4.58 ± 6.45
Perinaphthenone	13.42 ± 18.98	24.38 ± 8.36	36.79 ± 2.39	24.86 ± 5.55	42.16 ± 3.28	26.34 ± 0.59	27.05 ± 1.69
2-methylanthracene	0.63 ± 0.89	0.00 ± 0.00	0.84 ± 1.19	0.00 ± 0.00	3.12 ± 1.02	1.88 ± 2.66	4.07 ± 1.43
4,5-methylenephenanthrene	0.00 ± 0.00	0.08 ± 0.12	0.00 ± 0.00	0.00 ± 0.00	0.36 ± 0.51	0.00 ± 0.00	0.00 ± 0.00
9-methylphenanthrene	3.38 ± 1.53	0.00 ± 0.00	4.62 ± 0.92	6.10 ± 2.27	4.62 ± 0.22	4.98 ± 7.05	1.26 ± 1.78
1-methylphenanthrene	12.15 ± 5.43	17.12 ± 0.56	9.46 ± 1.32	15.94 ± 1.82	14.05 ± 3.45	5.58 ± 7.89	3.14 ± 4.44
Anthrone	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
9-methylanthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Anthraquinone	13.89 ± 0.68	12.12 ± 6.88	10.69 ± 4.75	17.92 ± 3.08	12.62 ± 5.16	7.25 ± 10.26	0.00 ± 0.00
A-dimethylphenanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
B-dimethylphenanthrene	5.54 ± 7.83	11.35 ± 2.41	8.44 ± 4.39	7.82 ± 0.36	8.02 ± 2.90	6.54 ± 0.65	9.55 ± 4.16
1,7-dimethylphenanthrene	0.00 ± 0.00	4.13 ± 5.84	0.00 ± 0.00	0.00 ± 0.00	2.11 ± 2.99	1.75 ± 2.48	0.00 ± 0.00
3,6-dimethylphenanthrene	4.10 ± 5.80	2.15 ± 3.05	1.80 ± 2.54	0.38 ± 0.54	0.00 ± 0.00	3.20 ± 4.53	2.95 ± 2.48
D-dimethylphenanthrene	7.14 ± 4.55	5.01 ± 7.08	4.55 ± 1.01	1.69 ± 2.39	5.36 ± 0.96	0.71 ± 1.00	0.00 ± 0.00

E-dimethylphenanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
C-dimethylphenanthrene	0.00 ± 0.00	5.87 ± 8.31	0.00 ± 0.00	0.00 ± 0.00	4.39 ± 0.28	2.54 ± 3.59	0.00 ± 0.00
Fluoranthene	4.93 ± 4.18	4.60 ± 3.41	3.48 ± 3.74	1.56 ± 1.28	1.43 ± 0.96	1.10 ± 1.56	0.00 ± 0.00
Pyrene	8.08 ± 9.42	12.18 ± 6.25	5.01 ± 7.09	5.69 ± 2.92	6.46 ± 2.49	2.63 ± 3.72	0.00 ± 0.00
9-Anthraaldehyde	0.00 ± 0.00	0.00 ± 0.00	16.68 ± 23.58	0.00 ± 0.00	4.95 ± 6.99	0.00 ± 0.00	0.00 ± 0.00
Retene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.19 ± 0.27	0.20 ± 0.28	0.11 ± 0.15	0.00 ± 0.00
benzo(a)fluorene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
benzo(b)fluorene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
5-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
B-MePy/MeFl	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1-MeFl+C-MeFl/Py	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.42 ± 3.42	0.00 ± 0.00	0.00 ± 0.00
1+3-methylfluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
4-methylpyrene	4.17 ± 2.43	6.27 ± 0.18	4.12 ± 0.88	2.01 ± 2.84	5.44 ± 2.34	5.72 ± 0.51	4.88 ± 4.00
C-MePy/MeFl	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
D-MePy/MeFl	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1-methylpyrene	5.17 ± 1.74	4.13 ± 0.83	4.62 ± 0.80	0.00 ± 0.00	2.56 ± 1.45	0.00 ± 0.00	1.56 ± 2.21
Benzonaphthothiophene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
benzo(c)phenanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(ghi)fluoranthene	9.45 ± 4.88	7.88 ± 0.06	7.37 ± 0.82	6.31 ± 3.10	4.56 ± 0.28	7.86 ± 4.82	4.23 ± 1.37
9-phenylanthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
6-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Cyclopenta(c,d)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Benz(a)anthracene	0.00 ± 0.00	1.03 ± 1.45	0.00 ± 0.00	0.02 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.05 ± 0.07
Chrysene	1.35 ± 1.91	1.59 ± 0.19	1.36 ± 0.03	0.00 ± 0.00	0.59 ± 0.83	0.52 ± 0.74	1.12 ± 0.20
Benzanthrone	2.54 ± 3.59	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.66 ± 2.34	0.00 ± 0.00	1.04 ± 1.46
Benz(a)anthracene-7,12-dione	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7-methylbenz(a)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7,12-dimethylbenz(a)anthracene	2.75 ± 3.88	7.64 ± 1.67	6.50 ± 0.63	3.96 ± 5.60	8.86 ± 7.75	6.05 ± 2.97	13.86 ± 1.42
Benzo(b)fluoranthene	0.67 ± 0.69	1.06 ± 0.75	1.45 ± 0.37	0.33 ± 0.47	0.00 ± 0.00	0.28 ± 0.39	0.00 ± 0.00
Benzo(j)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(k)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.51 ± 0.72	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(a)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BeP	2.08 ± 0.95	1.48 ± 0.11	0.87 ± 0.64	0.89 ± 0.05	0.33 ± 0.24	0.66 ± 0.24	0.03 ± 0.04
BaP	0.66 ± 0.94	0.00 ± 0.00	1.12 ± 0.81	0.00 ± 0.00	0.57 ± 0.26	0.78 ± 0.05	0.51 ± 0.72
Perylene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylcholanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7-methylbenzo(a)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Indeno[123-cd]fluoranthene	0.63 ± 0.89	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.60 ± 0.02	1.77 ± 0.56	1.24 ± 0.67
Indeno[123-cd]pyrene	0.18 ± 0.15	0.07 ± 0.00	0.07 ± 0.00	0.08 ± 0.00	0.58 ± 0.01	0.39 ± 0.12	0.28 ± 0.15
Dibenzo(ac)anthracene	1.41 ± 2.00	0.00 ± 0.00	0.70 ± 0.99	0.00 ± 0.00	1.43 ± 0.18	0.41 ± 0.58	0.50 ± 0.70
Dibenzo(ah+ac)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Dibenzo(ah)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,j)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(b)chrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Picene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(ghi)perylene	9.31 ± 3.64	13.63 ± 1.79	10.18 ± 8.20	4.53 ± 2.46	19.07 ± 6.83	5.72 ± 8.09	4.51 ± 1.94
Anthanthrene	6.27 ± 0.04	6.61 ± 1.66	5.34 ± 0.78	5.63 ± 0.31	5.40 ± 3.00	3.93 ± 1.00	3.75 ± 0.26
Triphenylene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,l)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Coronene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,e)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,i)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,h)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(b,k)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Table D11: Particle-phase PAH emissions for Vehicle #3

Component (ng/mile)	Fed ULSD	CARB USLD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
Naphthalene	0.25 ± 0.35	1.02 ± 1.44	7.84 ± 6.25	2.23 ± 3.15	0.00 ± 0.00	6.22 ± 8.79	38.16 ± 46.80
Quinoline	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
2-methylnaphthalene	5.52 ± 4.45	3.75 ± 5.30	13.80 ± 13.80	9.40 ± 11.60	0.67 ± 0.40	10.02 ± 14.18	35.93 ± 42.24
1-methylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	2.11 ± 2.99	0.22 ± 0.31	0.00 ± 0.00	5.45 ± 7.70	20.02 ± 28.31
Biphenyl	0.00 ± 0.00	0.00 ± 0.00	0.91 ± 1.29	0.22 ± 0.31	0.46 ± 0.65	3.38 ± 4.77	14.39 ± 20.00
2-methylbiphenyl	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.34 ± 0.48

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2,6+2,7-dimethylnaphthalene	2.03 ± 0.07	1.05 ± 0.51	2.69 ± 2.57	1.53 ± 1.49	0.72 ± 0.84	2.46 ± 2.35	11.10 ± 12.12
1,3+1,6+1,7dimethylnaphth	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1,4+1,5+2,3-dimethylnaphth	10.01 ± 8.51	16.22 ± 4.28	23.24 ± 6.95	19.82 ± 0.46	43.69 ± 12.83	22.01 ± 0.90	33.21 ± 18.95
Acenaphthylene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.34 ± 0.48	0.00 ± 0.00
1,2-dimethylnaphthalene	2.58 ± 1.46	2.35 ± 0.86	2.89 ± 1.08	3.30 ± 0.16	1.49 ± 2.11	2.21 ± 3.12	11.61 ± 11.99
1,8-dimethylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.42 ± 2.00	1.33 ± 1.87	0.00 ± 0.00	0.00 ± 0.00
Acenaphthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylbiphenyl	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.66 ± 0.93	4.05 ± 5.72
4-methylbiphenyl	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.04	0.34 ± 0.49	0.93 ± 1.31
1+2ethylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1-ethyl-2-methylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
2,3,5+I-trimethylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
B-trimethylnaphthalene	0.26 ± 0.37	0.00 ± 0.00	0.00 ± 0.00	0.22 ± 0.26	0.66 ± 0.01	0.24 ± 0.33	0.30 ± 0.43
A-trimethylnaphthalene	1.40 ± 1.98	0.66 ± 0.84	0.00 ± 0.00	0.95 ± 1.35	0.45 ± 0.30	0.00 ± 0.00	0.00 ± 0.00
C-trimethylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.06 ± 1.49	1.13 ± 1.60	0.00 ± 0.00
2-ethyl-1-methylnaphthalene	0.11 ± 0.15	0.00 ± 0.00	0.03 ± 0.04	0.41 ± 0.58	1.27 ± 0.18	0.90 ± 1.28	0.00 ± 0.00
E-trimethylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
2,4,5-trimethylnaphthalene	0.60 ± 0.11	0.13 ± 0.18	0.34 ± 0.44	0.60 ± 0.84	0.10 ± 0.15	0.00 ± 0.00	0.60 ± 0.32
F-trimethylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Fluorene	0.58 ± 0.39	0.00 ± 0.00	0.30 ± 0.29	0.75 ± 0.84	0.59 ± 0.23	0.27 ± 0.03	0.00 ± 0.00
1,4,5-trimethylnaphthalene	19.04 ± 4.91	8.40 ± 5.25	7.59 ± 0.08	11.39 ± 3.77	0.03 ± 0.05	0.66 ± 0.93	6.95 ± 3.83
J-trimethylnaphthalene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

A-Methylfluorene	1.69 ± 1.07	0.38 ± 0.54	0.00 ± 0.00	0.66 ± 0.94	0.44 ± 0.62	1.12 ± 0.72	0.50 ± 0.42
B-Methylfluorene	2.04 ± 2.88	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.10 ± 0.14	0.70 ± 0.99	2.74 ± 2.54
1-Methylfluorene	0.92 ± 0.13	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.06	0.00 ± 0.00	1.16 ± 1.64	1.17 ± 1.24
9-fluorenone	1.01 ± 0.60	0.00 ± 0.00	1.08 ± 1.35	2.59 ± 1.27	1.76 ± 1.17	2.00 ± 0.07	2.45 ± 0.17
Dibenzothiophene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Phenanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.13 ± 0.63	0.00 ± 0.00	0.30 ± 0.42	1.25 ± 0.64
Anthracene	0.13 ± 0.18	0.27 ± 0.38	0.86 ± 0.39	0.55 ± 0.16	0.08 ± 0.12	0.43 ± 0.60	0.96 ± 0.64
Xanthone	3.48 ± 0.72	5.64 ± 2.48	4.85 ± 0.38	7.44 ± 3.39	4.98 ± 2.38	2.98 ± 0.13	4.88 ± 0.03
1,4-Naphthoquinone	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Acenaphthenequinone	0.28 ± 0.09	0.00 ± 0.00	0.65 ± 0.92	2.98 ± 4.21	2.34 ± 3.31	0.34 ± 0.48	2.88 ± 1.84
3-methylphenanthrene	1.50 ± 0.96	1.12 ± 0.57	0.95 ± 0.74	3.09 ± 0.70	2.47 ± 2.40	1.45 ± 0.86	0.58 ± 0.43
2-methylphenanthrene	0.90 ± 1.27	0.00 ± 0.00	0.53 ± 0.19	3.71 ± 0.66	0.00 ± 0.00	0.21 ± 0.30	0.95 ± 0.53
Perinaphthenone	3.44 ± 4.86	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.39 ± 0.55
2-methylanthracene	0.00 ± 0.00	0.00 ± 0.00	2.15 ± 3.05	1.99 ± 2.81	0.00 ± 0.00	0.00 ± 0.00	4.29 ± 6.07
4,5-methylenephenanthrene	3.16 ± 0.41	2.26 ± 0.36	0.83 ± 0.12	3.38 ± 0.96	0.68 ± 0.97	2.59 ± 0.22	1.15 ± 0.41
9-methylphenanthrene	0.15 ± 0.21	0.01 ± 0.02	0.00 ± 0.00	1.22 ± 0.76	0.57 ± 0.80	0.31 ± 0.44	0.19 ± 0.26
1-methylphenanthrene	0.49 ± 0.64	0.18 ± 0.25	0.25 ± 0.35	1.53 ± 0.53	0.00 ± 0.00	0.80 ± 1.12	1.06 ± 0.84
Anthrone	7.82 ± 1.51	4.38 ± 6.19	0.00 ± 0.00	8.62 ± 0.07	0.00 ± 0.00	0.00 ± 0.00	1.46 ± 2.06
9-methylanthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Anthraquinone	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
A-dimethylphenanthrene	1.18 ± 0.03	1.38 ± 1.95	0.27 ± 0.38	2.95 ± 1.47	0.00 ± 0.00	0.90 ± 1.28	0.90 ± 1.27
B-dimethylphenanthrene	1.07 ± 0.24	0.00 ± 0.00	0.00 ± 0.00	1.60 ± 0.52	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

1,7-dimethylphenanthrene	1.16 ± 0.58	0.00 ± 0.00	1.24 ± 1.75	0.69 ± 0.12	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3,6-dimethylphenanthrene	0.65 ± 0.88	0.08 ± 0.12	0.62 ± 0.87	1.30 ± 0.72	0.00 ± 0.00	0.00 ± 0.00	1.50 ± 1.01
D-dimethylphenanthrene	1.40 ± 1.99	0.00 ± 0.00	0.00 ± 0.00	2.10 ± 1.37	0.00 ± 0.00	0.00 ± 0.00	1.28 ± 1.03
E-dimethylphenanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
C-dimethylphenanthrene	2.71 ± 0.15	0.00 ± 0.00	5.19 ± 3.34	8.01 ± 2.71	2.42 ± 0.90	1.21 ± 0.05	1.00 ± 1.41
Fluoranthene	0.28 ± 0.39	0.00 ± 0.00	0.00 ± 0.00	4.60 ± 0.02	0.49 ± 0.69	0.00 ± 0.00	0.13 ± 0.18
Pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	7.54 ± 0.80	0.58 ± 0.82	0.00 ± 0.00	0.27 ± 0.39
9-Anthraaldehyde	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Retene	0.00 ± 0.00	0.01 ± 0.02	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
benzo(a)fluorene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
benzo(b)fluorene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
5-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
B-MePy/MeFl	0.49 ± 0.69	0.00 ± 0.00	0.00 ± 0.00	0.66 ± 0.93	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1-MeFl+C-MeFl/Py	0.28 ± 0.39	0.62 ± 0.88	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1+3-methylfluoranthene	0.27 ± 0.38	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
4-methylpyrene	0.15 ± 0.21	0.11 ± 0.15	0.31 ± 0.44	2.36 ± 0.01	0.00 ± 0.00	0.05 ± 0.07	0.00 ± 0.00
C-MePy/MeFl	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
D-MePy/MeFl	1.43 ± 0.37	0.00 ± 0.00	0.63 ± 0.89	4.03 ± 0.36	0.00 ± 0.00	0.95 ± 1.35	1.27 ± 0.23
1-methylpyrene	0.08 ± 0.12	0.00 ± 0.00	0.05 ± 0.07	1.42 ± 0.29	0.00 ± 0.00	0.20 ± 0.28	0.00 ± 0.00
Benzonaphthothiophene	0.37 ± 0.25	0.25 ± 0.35	0.14 ± 0.20	0.96 ± 0.77	0.78 ± 1.10	1.29 ± 0.60	0.47 ± 0.53
benzo(c)phenanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(ghi)fluoranthene	0.07 ± 0.10	0.00 ± 0.00	0.04 ± 0.06	2.32 ± 1.95	0.08 ± 0.11	0.14 ± 0.04	1.09 ± 1.00

9-phenylanthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
6-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Cyclopenta(c,d)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.08 ± 0.11	0.44 ± 0.17	0.00 ± 0.00	0.27 ± 0.38	0.04 ± 0.06
Benz(a)anthracene	0.94 ± 0.17	0.00 ± 0.00	0.57 ± 0.29	0.67 ± 0.13	0.00 ± 0.00	0.35 ± 0.49	0.47 ± 0.66
Chrysene	1.41 ± 0.42	0.34 ± 0.15	0.83 ± 0.82	1.75 ± 0.12	0.00 ± 0.00	1.14 ± 0.28	0.92 ± 1.31
Benzanthrone	0.71 ± 1.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benz(a)anthracene-7,12-dione	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylchrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.28 ± 0.40	0.00 ± 0.00	0.39 ± 0.15	0.00 ± 0.00
7-methylbenz(a)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7,12-dimethylbenz(a)anthracene	0.00 ± 0.00	0.88 ± 0.63	0.91 ± 1.28	0.00 ± 0.00	1.09 ± 1.54	0.81 ± 0.17	0.85 ± 1.17
Benzo(b)fluoranthene	0.50 ± 0.24	0.18 ± 0.14	0.18 ± 0.20	0.30 ± 0.43	0.26 ± 0.36	0.23 ± 0.01	0.28 ± 0.03
Benzo(j)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.78 ± 1.10
Benzo(k)fluoranthene	0.00 ± 0.00	0.04 ± 0.05	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(a)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BeP	0.09 ± 0.12	0.02 ± 0.02	0.17 ± 0.02	0.12 ± 0.07	0.02 ± 0.03	0.23 ± 0.27	0.13 ± 0.02
BaP	0.09 ± 0.13	0.17 ± 0.24	0.18 ± 0.05	0.10 ± 0.15	0.00 ± 0.00	0.24 ± 0.09	0.21 ± 0.03
Perylene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylcholanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
7-methylbenzo(a)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Indeno[123-cd]fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Indeno[123-cd]pyrene	0.00 ± 0.00	0.17 ± 0.24	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ac)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ah+ac)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ah)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,j)anthracene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(b)chrysene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Picene	0.48 ± 0.20	1.00 ± 0.27	0.00 ± 0.00	0.00 ± 0.00	0.20 ± 0.28	0.54 ± 0.76	0.00 ± 0.00
Benzo(ghi)perylene	0.29 ± 0.42	0.35 ± 0.49	0.26 ± 0.30	0.47 ± 0.46	0.12 ± 0.17	0.62 ± 0.11	0.32 ± 0.02
Anthanthrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Triphenylene	0.22 ± 0.32	0.00 ± 0.00	0.00 ± 0.00	0.53 ± 0.14	0.28 ± 0.39	0.00 ± 0.00	0.97 ± 1.37
Dibenzo(a,l)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Coronene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,e)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,i)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,h)pyrene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(b,k)fluoranthene	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Table D12: Particle-phase PAH emissions for Vehicle #4

Component (ng/mile)	Fed ULSD	CARB ULSD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
naphthalene	80.10± 93.20	18.99± 10.61	36.56± 21.92	113.79± 57.62	66.49± 85.13	7.31± 0.82	98.24± 95.73
quinoline	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	13.45± 16.06	0.00± 0.00	0.00± 0.00
2-methylnaphthalene	58.75± 62.26	16.06± 4.25	33.14± 17.08	118.41± 84.53	57.25± 74.30	12.57± 6.78	112.72± 107.28
1-methylnaphthalene	33.72± 37.28	8.17± 2.69	17.62± 9.28	57.22± 37.27	34.56± 45.17	4.97± 1.16	72.17± 79.71
Biphenyl	49.53± 49.96	19.24± 8.75	23.68± 7.42	77.04± 44.93	40.60± 38.88	7.04± 1.77	22.65± 0.00

2-methylbiphenyl	137.79± 140.57	51.88± 14.29	58.67± 5.64	132.80± 61.96	122.41± 35.16	22.92± 9.35	57.94± 0.00
2,6+2,7-dimethylnaphthalene	19.23± 18.27	6.85± 1.56	15.78± 11.15	57.22± 38.01	31.93± 42.19	5.23± 1.53	62.42± 65.19
1,3+1,6+1,7dimethylnaphth	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,4+1,5+2,3-dimethylnaphth	24.76± 24.61	9.48± 1.58	15.26± 8.17	55.87± 30.27	38.74± 30.31	5.74± 0.06	81.91± 93.49
Acenaphthylene	21.60± 21.63	7.10± 0.44	10.79± 0.38	19.26± 3.24	21.33± 8.65	4.16± 2.17	42.93± 46.56
1,2-dimethylnaphthalene	10.27± 9.32	2.38± 3.37	4.47± 6.32	46.24± 29.75	21.37± 25.77	2.88± 1.88	20.81± 8.57
1,8-dimethylnaphthalene	5.01± 5.59	0.78± 1.11	1.31± 1.86	23.28± 15.82	3.69± 2.25	1.04± 0.01	12.38± 12.29
Acenaphthene	4.22± 4.47	0.79± 0.38	6.05± 7.06	29.24± 16.62	20.06± 28.37	2.10± 1.50	1.32± 1.86
3-methylbiphenyl	129.35± 122.68	49.72± 3.11	72.09± 6.63	174.95± 100.47	134.26± 41.53	25.53± 8.58	63.20± 0.00
4-methylbiphenyl	63.75± 59.66	24.47± 2.11	35.52± 3.31	83.85± 51.65	66.61± 22.25	12.51± 4.29	32.13± 0.00
1+2ethylnaphthalene	28.98± 30.57	9.48± 2.33	14.21± 4.45	42.07± 27.48	27.41± 23.94	5.22± 0.06	75.85± 84.93
1-ethyl-2-methylnaphthalene	3.94± 5.58	7.36± 0.07	9.73± 3.34	34.86± 36.93	28.22± 29.52	4.21± 5.95	34.50± 45.07
2,3,5+I-trimethylnaphthalene	6.85± 5.97	2.63± 0.77	7.63± 7.06	25.58± 13.63	16.88± 20.91	3.14± 1.51	16.33± 9.69
B-trimethylnaphthalene	9.75± 7.83	3.94± 0.33	11.31± 11.52	40.27± 30.03	27.18± 38.44	4.19± 2.26	5.00± 7.08
A-trimethylnaphthalene	6.06± 7.08	1.32± 0.39	3.42± 2.60	16.14± 2.45	8.70± 9.34	1.31± 0.38	20.54± 24.58
C-trimethylnaphthalene	15.81± 14.92	5.00± 0.42	13.41± 11.52	44.69± 30.46	26.12± 33.23	4.44± 1.16	48.99± 50.66
2-ethyl-1-methylnaphthalene	0.00± 0.00	0.26± 0.37	0.53± 0.74	2.09± 0.77	0.79± 1.12	0.26± 0.37	0.00± 0.00
E-trimethylnaphthalene	3.69± 2.98	1.32± 0.39	3.42± 4.83	10.72± 7.88	33.25± 46.28	2.62± 2.24	6.85± 2.98
2,4,5-trimethylnaphthalene	0.79± 1.12	1.32± 0.39	3.68± 3.72	10.72± 7.88	8.70± 8.60	2.36± 1.87	19.49± 18.62
F-trimethylnaphthalene	17.12± 15.29	4.47± 0.42	14.73± 8.17	47.49± 23.52	34.57± 45.92	4.45± 1.89	44.51± 46.56
Fluorene	20.29± 20.51	7.64± 2.68	17.62± 16.73	72.34± 43.39	49.87± 66.82	7.32± 1.56	86.12± 103.18
1,4,5-trimethylnaphthalene	0.53± 0.74	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
J-trimethylnaphthalene	0.00± 0.00	0.26± 0.37	2.10± 2.23	6.04± 8.55	5.81± 8.21	1.57± 0.02	1.05± 0.00
A-Methylfluorene	26.08± 28.71	7.10± 0.44	9.47± 0.73	27.39± 12.55	22.39± 12.38	3.91± 0.33	9.48± 0.00
B-Methylfluorene	0.26± 0.37	0.00± 0.00	1.05± 1.49	2.10± 2.97	0.52± 0.74	0.00± 0.00	0.00± 0.00
1-Methylfluorene	10.54± 11.18	2.10± 0.02	3.95± 2.60	16.98± 10.19	13.45± 16.80	2.35± 0.39	4.21± 0.00
9-fluorenone	10.01± 10.44	2.90± 1.15	6.84± 2.23	22.97± 12.12	10.81± 12.33	1.57± 0.02	2.63± 0.00
Dibenzothiophene	7.38± 7.46	2.37± 0.40	3.16± 1.49	15.13± 6.11	10.54± 6.74	2.09± 0.02	4.21± 0.00
Phenanthrene	88.53± 105.87	16.87± 6.87	28.14± 23.41	143.68± 23.52	117.94± 154.93	22.99± 3.20	26.33± 0.00
Anthracene	26.09± 32.43	5.28± 3.03	6.31± 1.48	21.64± 8.79	52.25± 71.67	4.18± 1.52	11.59± 0.00

Xanthone	2.37± 1.12	1.06± 0.75	6.05± 3.35	3.64± 0.06	111.90± 156.76	6.31± 8.19	0.53± 0.00
1,4-Naphthoquinone	26.87± 18.66	14.72± 2.08	16.31± 0.02	9.00± 12.73	14.21± 0.81	15.66± 0.57	7.90± 11.17
Acenaphthenequinone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-methylphenanthrene	10.28± 12.30	2.11± 1.51	2.63± 2.23	12.22± 0.55	12.14± 15.68	2.35± 0.34	2.11± 0.00
2-methylphenanthrene	12.65± 14.91	2.37± 1.14	4.47± 1.86	16.90± 0.63	19.79± 25.76	1.81± 2.56	3.69± 0.00
Perinaphthenone	152.87± 91.71	667.08± 746.93	208.59± 103.60	338.46± 98.19	172.22± 76.68	59.17± 33.12	59.52± 0.00
2-methylanthracene	0.00± 0.00	0.00± 0.00	0.26± 0.37	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
4,5-methylenephenanthrene	2.90± 3.36	0.53± 0.01	1.05± 0.74	4.16± 0.06	3.96± 4.85	0.52± 0.01	1.05± 0.00
9-methylphenanthrene	5.27± 5.96	0.79± 0.38	1.58± 1.49	6.50± 0.27	7.65± 10.08	1.04± 0.01	2.11± 0.00
1-methylphenanthrene	5.53± 6.34	1.06± 0.75	1.31± 1.11	7.03± 1.21	6.07± 7.84	1.04± 0.01	1.05± 0.00
Anthrone	0.00± 0.00	0.00± 0.00	0.00± 0.00	11.83± 16.73	4.46± 6.30	0.00± 0.00	0.00± 0.00
9-methylanthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Anthraquinone	4.48± 2.61	1.31± 0.36	2.63± 0.75	17.28± 15.71	2.64± 2.99	0.26± 0.37	2.63± 3.72
A-dimethylphenanthrene	0.00± 0.00	0.53± 0.01	0.53± 0.74	3.63± 0.68	2.64± 3.73	0.79± 0.38	0.00± 0.00
B-dimethylphenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.53± 0.75	0.26± 0.37	0.00± 0.00
1,7-dimethylphenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	1.84± 2.60	0.00± 0.00	0.00± 0.00
3,6-dimethylphenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.26± 0.37	0.00± 0.00
D-dimethylphenanthrene	20.82± 29.44	1.84± 0.39	0.00± 0.00	0.00± 0.00	1.84± 2.60	0.00± 0.00	0.00± 0.00
E-dimethylphenanthrene	2.90± 3.36	0.53± 0.01	0.53± 0.00	1.54± 2.18	0.26± 0.37	0.52± 0.01	0.00± 0.00
C-dimethylphenanthrene	0.26± 0.37	0.26± 0.37	0.00± 0.00	1.54± 2.18	0.00± 0.00	0.00± 0.00	1.05± 0.00
Fluoranthene	8.96± 8.95	2.11± 0.77	2.89± 1.86	11.43± 1.30	11.08± 12.70	2.61± 0.03	2.63± 0.00
Pyrene	11.33± 13.79	2.63± 0.77	2.89± 1.11	11.13± 6.08	13.72± 16.43	3.13± 0.70	2.63± 0.00
9-Anthraaldehyde	1.58± 2.23	1.58± 0.02	2.89± 1.11	6.57± 9.29	0.79± 1.11	2.61± 0.03	0.00± 0.00
Retene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.26± 0.36	0.00± 0.00	0.00± 0.00	0.00± 0.00
benzo(a)fluorene	0.00± 0.00	0.00± 0.00	0.26± 0.37	0.00± 0.00	0.00± 0.00	0.26± 0.37	0.00± 0.00
benzo(b)fluorene	0.79± 1.12	0.26± 0.37	0.00± 0.00	0.00± 0.00	0.53± 0.75	0.00± 0.00	0.00± 0.00
5-methylchrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
B-MePy/MeFl	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-MeFl+C-MeFl/Py	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1+3-methylfluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

4-methylpyrene	1.32± 1.12	0.53± 0.01	1.58± 0.75	1.03± 1.45	0.79± 1.12	0.78± 0.36	#DIV/0!
C-MePy/MeFl	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	#DIV/0!
D-MePy/MeFl	0.00± 0.00	0.00± 0.00	1.05± 1.49	0.00± 0.00	0.53± 0.75	0.26± 0.37	#DIV/0!
1-methylpyrene	0.53± 0.75	0.00± 0.00	0.79± 1.12	0.00± 0.00	0.79± 1.12	0.26± 0.37	#DIV/0!
Benzonaphthothiophene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
benzo(c)phenanthrene	0.00± 0.00	0.00± 0.00	0.26± 0.37	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benzo(ghi)fluoranthene	1.05± 0.75	0.53± 0.01	1.32± 1.86	0.00± 0.00	0.26± 0.37	2.10± 2.24	0.00± 0.00
9-phenylanthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6-methylchrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Cyclopenta(c,d)pyrene	0.00± 0.00	0.00± 0.00	0.26± 0.37	0.51± 0.73	0.26± 0.37	0.00± 0.00	0.00± 0.00
Benz(a)anthracene	1.32± 1.12	0.00± 0.00	0.79± 0.37	0.00± 0.00	0.53± 0.75	0.00± 0.00	0.00± 0.00
Chrysene	1.58± 1.49	0.53± 0.01	1.05± 0.75	0.77± 1.09	1.32± 1.12	0.52± 0.01	0.53± 0.00
Benzanthrone	0.00± 0.00	0.00± 0.00	0.53± 0.74	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benz(a)anthracene-7,12-dione	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-methylchrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7-methylbenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7,12-dimethylbenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benzo(b)fluoranthene	0.26± 0.37	0.53± 0.01	0.79± 1.12	0.51± 0.73	0.79± 1.12	0.53± 0.74	0.26± 0.37
Benzo(j)fluoranthene	0.00± 0.00	0.26± 0.37	0.53± 0.74	1.03± 1.45	0.26± 0.37	0.53± 0.74	0.53± 0.74
Benzo(k)fluoranthene	0.00± 0.00	0.26± 0.37	0.53± 0.74	0.00± 0.00	0.00± 0.00	0.79± 1.12	0.26± 0.37
Benzo(a)fluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
BeP	0.26± 0.37	0.79± 0.38	1.32± 1.12	1.05± 1.49	0.00± 0.00	0.53± 0.74	0.26± 0.37
BaP	0.26± 0.37	0.79± 0.38	0.79± 1.12	1.58± 2.23	0.26± 0.37	0.26± 0.37	0.00± 0.00
Perylene	0.00± 0.00	0.26± 0.37	0.26± 0.37	0.00± 0.00	0.00± 0.00	0.26± 0.37	0.00± 0.00
3-methylcholanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7-methylbenzo(a)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00± 0.00	0.00± 0.00	0.00± 0.00	7.62± 10.78	0.00± 0.00	0.00± 0.00	0.00± 0.00
Indeno[123-cd]fluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	1.31± 1.86	0.53± 0.75	0.00± 0.00	0.00± 0.00
Indeno[123-cd]pyrene	0.00± 0.00	0.53± 0.01	0.79± 0.37	0.51± 0.73	1.32± 1.12	0.26± 0.37	1.58± 1.49

Dibenzo(ac)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(ah+ac)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(ah)anthracene	0.00± 0.00	0.53± 0.01	0.53± 0.74	0.00± 0.00	1.32± 1.87	0.26± 0.37	0.26± 0.37
Dibenzo(a,j)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.79± 1.12	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benzo(b)chrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Picene	0.00± 0.00	0.26± 0.37	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benzo(ghi)perylene	0.26± 0.37	0.79± 0.38	1.84± 1.86	1.56± 0.02	2.37± 2.62	0.79± 0.38	3.42± 4.10
Anthanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Triphenylene	0.26± 0.37	0.00± 0.00	0.26± 0.37	0.51± 0.73	0.53± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(a,l)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Coronene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.26± 0.37	0.00± 0.00
Dibenzo(a,e)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(a,i)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(a,h)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(b,k)fluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Table D13: Particle-phase PAH emissions for Vehicle #5

Component (ng/mile)	Fed ULSD	CARB ULSD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
naphthalene	18.84± 15.75	98.40± 85.12	19.43± 8.71	23.08± 6.72	52.82± 0.00	67.50± 35.41	25.55± 19.52
quinoline	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	1.01± 1.44	0.51± 0.72	0.00± 0.00
2-methylnaphthalene	17.85± 6.37	136.95± 125.43	19.67± 2.49	13.04± 1.87	67.50± 56.68	14.48± 2.67	26.27± 22.79
1-methylnaphthalene	9.95± 3.90	70.37± 59.00	11.24± 2.14	8.37± 2.17	44.92± 40.54	7.41± 0.36	14.02± 12.28
Biphenyl	13.51± 6.04	73.36± 58.24	19.68± 3.29	7.87± 0.77	66.24± 24.02	19.23± 3.19	19.99± 12.40
2-methylbiphenyl	29.04± 19.29	107.47± 95.82	21.47± 5.10	27.60± 10.71	174.59± 195.19	60.98± 28.36	45.63± 14.67
2,6+2,7-dimethylnaphthalene	7.91± 1.03	69.12± 60.07	10.73± 0.02	6.89± 0.07	21.83± 5.73	6.63± 0.69	14.99± 15.91
1,3+1,6+1,7dimethylnaphth	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,4+1,5+2,3-dimethylnaphth	10.70± 6.42	57.09± 47.32	13.29± 0.69	7.38± 0.77	23.35± 2.86	10.63± 2.01	15.09± 10.77
Acenaphthylene	5.35± 3.21	7.04± 0.00	4.60± 0.73	4.93± 1.44	7.36± 2.52	8.38± 3.34	9.01± 3.67
1,2-dimethylnaphthalene	6.36± 6.09	3.27± 4.62	13.80± 3.64	4.44± 3.52	10.92± 1.80	5.40± 4.75	4.85± 3.84
1,8-dimethylnaphthalene	0.26± 0.36	6.16± 3.74	10.47± 1.78	2.22± 1.07	13.71± 5.03	3.23± 2.40	2.05± 1.39

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Acenaphthene	5.10± 2.13	14.08± 0.00	7.15± 0.02	3.19± 1.71	17.01± 1.09	1.57± 0.67	5.57± 7.11
3-methylbiphenyl	35.68± 19.97	62.84± 0.00	26.83± 2.59	29.56± 8.64	190.07± 198.41	66.79± 27.89	61.39± 30.91
4-methylbiphenyl	17.59± 8.90	30.67± 0.00	14.82± 2.20	15.02± 3.98	97.70± 102.26	35.84± 16.68	29.80± 14.94
1+2ethylnaphthalene	8.92± 5.35	17.09± 0.00	9.96± 2.51	7.14± 1.81	20.05± 11.84	9.02± 1.18	13.56± 9.36
1-ethyl-2-methylnaphthalene	1.54± 2.18	0.00± 0.00	6.12± 8.66	4.21± 5.96	7.61± 10.77	6.28± 2.69	3.74± 5.29
2,3,5+I-trimethylnaphthalene	4.08± 1.41	12.07± 0.00	9.45± 0.34	4.93± 1.44	13.20± 3.58	4.82± 2.48	8.38± 8.84
B-trimethylnaphthalene	4.85± 0.33	16.09± 0.00	9.97± 0.38	5.41± 0.64	16.24± 5.02	3.98± 0.57	11.17± 12.03
A-trimethylnaphthalene	2.80± 1.79	5.03± 0.00	4.09± 1.45	1.72± 0.37	6.35± 2.51	3.20± 0.90	3.81± 3.88
C-trimethylnaphthalene	6.63± 2.12	20.61± 0.00	15.58± 6.83	6.89± 0.76	21.32± 7.17	5.61± 2.14	12.97± 13.05
2-ethyl-1-methylnaphthalene	0.26± 0.36	0.25± 0.36	0.00± 0.00	0.49± 0.00	0.76± 0.36	0.00± 0.00	0.27± 0.38
E-trimethylnaphthalene	3.07± 0.74	5.53± 0.00	4.09± 0.71	2.46± 0.72	7.87± 3.94	2.15± 1.60	5.61± 4.91
2,4,5-trimethylnaphthalene	2.04± 0.71	6.03± 0.00	9.72± 6.53	4.44± 3.52	15.48± 0.37	5.15± 5.11	3.78± 5.35
F-trimethylnaphthalene	6.12± 1.40	18.10± 0.00	10.47± 1.78	5.66± 0.40	18.02± 8.25	5.04± 0.62	12.70± 13.43
Fluorene	11.47± 5.33	35.19± 0.00	17.38± 0.04	13.03± 1.61	33.76± 15.42	10.03± 1.01	16.26± 16.96
1,4,5-trimethylnaphthalene	0.00± 0.00	1.96± 2.77	0.00± 0.00	0.00± 0.00	1.52± 0.00	0.00± 0.00	0.00± 0.00
J-trimethylnaphthalene	0.26± 0.36	5.39± 6.91	4.35± 1.09	0.98± 0.01	5.84± 0.36	1.90± 1.96	1.01± 1.43
A-Methylfluorene	5.60± 4.29	9.55± 0.00	9.45± 0.34	6.90± 2.16	36.03± 36.60	9.33± 3.07	10.00± 5.83
B-Methylfluorene	1.03± 1.45	1.01± 0.00	3.06± 2.16	0.25± 0.35	0.76± 1.08	1.35± 1.19	7.87± 8.86
1-Methylfluorene	3.57± 2.14	7.54± 0.00	8.43± 3.96	3.44± 0.03	11.93± 6.10	3.20± 0.90	6.63± 5.60
9-fluorenone	3.31± 2.50	5.53± 0.00	6.39± 0.35	3.44± 0.03	21.06± 22.60	5.53± 0.86	4.10± 2.77
Dibenzothiophene	2.80± 1.79	4.02± 0.00	4.35± 1.09	3.20± 1.08	6.09± 0.71	2.89± 0.98	4.10± 2.77
Phenanthrene	29.03± 22.90	57.31± 0.00	53.14± 5.67	26.60± 7.22	85.02± 70.67	30.68± 10.87	34.25± 25.77
Anthracene	9.68± 6.43	14.08± 0.00	14.57± 4.01	7.41± 7.03	6.85± 5.39	8.97± 1.07	9.54± 2.92
Xanthone	4.61± 3.65	2.47± 0.65	2.30± 0.36	1.98± 2.11	25.88± 33.01	2.06± 2.14	1.29± 0.31
1,4-Naphthoquinone	15.07± 0.47	0.00± 0.00	11.75± 3.59	14.27± 1.53	9.65± 13.65	15.61± 0.38	0.80± 1.13
Acenaphthenequinone	0.00± 0.00	0.00± 0.00	1.79± 2.53	0.00± 0.00	0.76± 1.08	0.00± 0.00	0.00± 0.00
3-methylphenanthrene	2.80± 2.51	15.48± 15.49	10.47± 2.51	2.95± 0.73	8.63± 5.02	2.90± 0.23	3.59± 2.06
2-methylphenanthrene	3.56± 2.86	19.39± 21.03	13.28± 5.75	3.70± 1.78	13.45± 11.12	4.75± 0.52	4.11± 2.04
Perinaphthenone	118.35± 40.31	434.52± 155.93	201.57± 0.00	35.99± 16.36	159.35± 0.00	270.47± 124.65	61.90± 6.90
2-methylanthracene	0.00± 0.00	0.49± 0.69	2.55± 2.89	0.25± 0.35	0.00± 0.00	1.04± 0.70	0.00± 0.00

4,5-methylenephenanthrene	0.76± 1.08	3.69± 3.09	2.81± 1.08	0.74± 0.36	3.55± 2.87	1.57± 0.67	1.02± 0.69
9-methylphenanthrene	1.53± 1.43	8.35± 8.26	5.11± 2.16	1.23± 0.36	5.33± 4.66	1.84± 0.29	2.05± 1.39
1-methylphenanthrene	1.02± 0.71	7.62± 7.22	4.60± 2.16	1.48± 0.71	5.08± 4.30	1.57± 0.67	1.80± 1.03
Anthrone	4.62± 6.53	0.00± 0.00	4.35± 6.15	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
9-methylanthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Anthraquinone	2.04± 0.71	32.94± 30.94	5.11± 3.60	1.22± 1.73	2.79± 3.95	1.83± 1.03	7.82± 11.06
A-dimethylphenanthrene	1.02± 1.44	1.47± 2.08	3.06± 2.16	0.49± 0.00	1.02± 1.44	1.04± 0.70	0.76± 1.07
B-dimethylphenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.76± 1.08	0.00± 0.00	0.00± 0.00
1,7-dimethylphenanthrene	0.00± 0.00	0.50± 0.71	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.26± 0.36	0.00± 0.00
3,6-dimethylphenanthrene	0.00± 0.00	0.00± 0.00	1.53± 0.72	0.24± 0.35	1.78± 2.51	0.00± 0.00	0.00± 0.00
D-dimethylphenanthrene	0.00± 0.00	0.00± 0.00	2.04± 2.89	0.00± 0.00	0.00± 0.00	0.26± 0.36	0.00± 0.00
E-dimethylphenanthrene	0.25± 0.36	1.72± 1.72	3.06± 2.16	0.25± 0.35	0.25± 0.36	0.79± 0.34	0.27± 0.38
C-dimethylphenanthrene	0.00± 0.00	0.00± 0.00	2.81± 3.97	0.49± 0.69	1.02± 1.44	0.51± 0.72	0.00± 0.00
Fluoranthene	3.05± 2.87	11.32± 8.91	9.71± 4.32	2.22± 1.07	11.93± 11.84	13.90± 15.79	3.86± 1.68
Pyrene	3.82± 3.95	7.63± 6.52	15.32± 9.36	2.72± 2.46	16.24± 13.63	13.72± 12.43	3.62± 0.59
9-Anthraaldehyde	2.03± 2.87	12.30± 10.99	20.17± 18.39	1.98± 2.80	12.94± 8.97	2.56± 3.62	0.80± 1.13
Retene	0.00± 0.00	0.00± 0.00	0.51± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
benzo(a)fluorene	1.02± 1.44	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	#DIV/0!	0.00± 0.00
benzo(b)fluorene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	#DIV/0!	0.00± 0.00
5-methylchrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
B-MePy/MeFl	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-MeFl+C-MeFl/Py	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1+3-methylfluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.49± 0.69	0.00± 0.00	2.30± 3.26	0.00± 0.00
4-methylpyrene	0.25± 0.36	0.00± 0.00	2.55± 1.44	0.49± 0.00	1.78± 0.36	2.58± 2.87	0.52± 0.02
C-MePy/MeFl	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	#DIV/0!	0.00± 0.00
D-MePy/MeFl	0.00± 0.00	0.00± 0.00	1.79± 2.53	0.00± 0.00	0.00± 0.00	1.28± 1.81	0.00± 0.00
1-methylpyrene	0.00± 0.00	0.00± 0.00	1.53± 2.16	0.00± 0.00	0.51± 0.72	2.30± 3.26	0.27± 0.38
Benzonaphthothiophene	0.00± 0.00	0.00± 0.00	2.55± 3.61	0.00± 0.00	0.00± 0.00	2.45± 2.74	0.00± 0.00
benzo(c)phenanthrene	0.00± 0.00	0.00± 0.00	2.55± 3.61	0.00± 0.00	0.00± 0.00	2.30± 3.26	0.00± 0.00
Benzo(ghi)fluoranthene	0.25± 0.36	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	#DIV/0!	0.00± 0.00

9-phenylanthracene	0.00± 0.00	0.00± 0.00	1.02± 0.00	0.00± 0.00	0.76± 1.08	0.00± 0.00	0.00± 0.00
6-methylchrysene	0.25± 0.36	0.00± 0.00	0.26± 0.36	0.25± 0.35	0.00± 0.00	0.26± 0.36	0.00± 0.00
Cyclopenta(c,d)pyrene	0.25± 0.36	0.00± 0.00	0.26± 0.36	0.25± 0.35	0.51± 0.72	#DIV/0!	0.00± 0.00
Benz(a)anthracene	0.25± 0.36	0.25± 0.36	0.51± 0.72	0.00± 0.00	0.00± 0.00	#DIV/0!	0.00± 0.00
Chrysene	1.02± 0.71	1.48± 0.67	0.51± 0.72	0.25± 0.35	0.25± 0.36	#DIV/0!	0.77± 0.34
Benzanthrone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	#DIV/0!	0.00± 0.00
Benz(a)anthracene-7,12-dione	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	1.92± 2.71	0.00± 0.00
3-methylchrysene	0.00± 0.00	0.00± 0.00	2.04± 2.89	0.00± 0.00	0.00± 0.00	0.26± 0.36	0.00± 0.00
7-methylbenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7,12-dimethylbenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benzo(b)fluoranthene	0.51± 0.72	0.25± 0.36	0.77± 0.36	0.00± 0.00	0.51± 0.00	6.14± 8.68	2.79± 3.19
Benzo(j)fluoranthene	1.78± 2.52	0.75± 1.07	0.77± 0.36	0.00± 0.00	0.00± 0.00	26.69± 21.10	2.80± 2.46
Benzo(k)fluoranthene	0.00± 0.00	0.00± 0.00	0.26± 0.36	0.00± 0.00	1.27± 1.79	4.09± 5.79	0.00± 0.00
Benzo(a)fluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	1.28± 1.81	0.00± 0.00
BeP	0.76± 1.08	0.00± 0.00	1.28± 1.08	0.25± 0.35	0.25± 0.36	#DIV/0!	0.27± 0.38
BaP	0.51± 0.72	0.00± 0.00	1.53± 0.00	0.00± 0.00	0.51± 0.72	#DIV/0!	0.27± 0.38
Perylene	0.00± 0.00	0.00± 0.00	0.26± 0.36	0.00± 0.00	0.25± 0.36	2.05± 2.89	0.00± 0.00
3-methylcholanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7-methylbenzo(a)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00± 0.00	0.00± 0.00	6.63± 9.38	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Indeno[123-cd]fluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.51± 0.72	0.00± 0.00
Indeno[123-cd]pyrene	0.51± 0.72	0.00± 0.00	0.51± 0.00	0.00± 0.00	0.51± 0.00	#DIV/0!	0.52± 0.02
Dibenzo(ac)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.26± 0.36	0.00± 0.00
Dibenzo(ah+ac)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(ah)anthracene	0.51± 0.72	0.00± 0.00	0.26± 0.36	0.00± 0.00	0.00± 0.00	2.05± 2.89	0.27± 0.38
Dibenzo(a,j)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.51± 0.72	0.00± 0.00
Benzo(b)chrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.77± 1.09	0.00± 0.00
Picene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.25± 0.35	0.00± 0.00	1.02± 1.45	0.00± 0.00
Benzo(ghi)perylene	0.76± 1.08	0.99± 0.68	0.77± 0.36	0.25± 0.35	0.76± 0.36	#DIV/0!	0.77± 0.34

Anthanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	#DIV/0!	0.00± 0.00
Triphenylene	0.25± 0.36	0.50± 0.71	0.00± 0.00	0.00± 0.00	0.00± 0.00	2.05± 2.89	0.52± 0.02
Dibenzo(a,l)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Coronene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	#DIV/0!	0.00± 0.00
Dibenzo(a,e)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.77± 1.09	0.00± 0.00
Dibenzo(a,i)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(a,h)pyrene	0.25± 0.36	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(b,k)fluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Table D14: Particle-phase PAH emissions for Vehicle #6

Component (ng/mile)	Fed ULSD	CARB ULSD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
naphthalene	13.44± 7.57	6.02± 3.49	22.94± 2.59	8.28± 3.07	14.00± 6.98	6.70± 2.16	50.13± 46.44
quinoline	0.76± 1.07	1.00± 0.70	1.01± 1.42	0.75± 0.34	0.25± 0.36	1.03± 0.00	0.00± 0.00
2-methylnaphthalene	13.72± 3.68	7.03± 3.48	20.42± 1.15	10.04± 3.40	15.26± 5.90	8.51± 3.97	65.09± 63.41
1-methylnaphthalene	7.72± 3.06	3.77± 1.74	11.34± 0.40	4.52± 1.35	7.75± 3.84	4.38± 2.53	32.44± 32.60
Biphenyl	18.95± 6.07	10.81± 3.79	22.44± 1.87	11.81± 3.02	15.75± 8.03	11.87± 0.67	41.78± 17.18
2-methylbiphenyl	78.19± 36.28	45.78± 10.85	74.12± 8.13	43.99± 6.78	42.98± 27.30	48.01± 6.80	48.27± 11.68
2,6+2,7-dimethylnaphthalene	8.73± 2.34	4.01± 2.80	8.07± 0.03	7.03± 2.74	9.01± 1.35	5.67± 2.89	33.32± 25.47
1,3+1,6+1,7dimethylnaphth	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,4+1,5+2,3-dimethylnaphth	15.71± 5.06	8.54± 3.46	17.90± 1.14	8.80± 1.64	11.01± 4.17	11.35± 1.40	34.55± 8.34
Acenaphthylene	13.95± 6.15	8.05± 2.04	14.87± 1.13	7.29± 0.95	7.49± 5.61	8.52± 1.14	9.37± 0.68
1,2-dimethylnaphthalene	9.42± 9.75	1.00± 1.41	8.82± 0.39	6.01± 3.46	5.52± 3.59	1.55± 0.72	17.05± 5.95
1,8-dimethylnaphthalene	3.98± 2.06	1.25± 1.05	4.03± 0.73	3.02± 0.66	2.50± 0.69	2.06± 0.01	4.79± 0.91
Acenaphthene	1.00± 0.02	0.75± 0.35	67.48± 94.01	1.26± 0.34	0.75± 0.36	0.77± 1.09	15.04± 21.27
3-methylbiphenyl	84.20± 34.77	50.31± 12.22	82.69± 7.45	47.76± 8.50	51.49± 29.36	57.03± 2.83	73.00± 37.57
4-methylbiphenyl	42.11± 16.68	25.65± 6.82	41.09± 3.37	24.13± 3.89	25.24± 14.33	28.38± 0.14	41.28± 17.16
1+2ethylnaphthalene	11.95± 5.47	6.79± 2.41	14.37± 0.30	9.28± 3.77	9.25± 3.83	7.48± 0.33	32.21± 5.04
1-ethyl-2-methylnaphthalene	4.20± 5.94	3.25± 4.59	6.81± 1.10	3.48± 4.93	5.25± 1.73	7.48± 1.79	12.19± 17.23
2,3,5+I-trimethylnaphthalene	4.49± 1.35	2.51± 1.39	4.79± 0.34	4.77± 0.99	5.02± 1.46	3.86± 2.54	14.12± 12.29
B-trimethylnaphthalene	3.98± 2.06	7.08± 5.07	2.51± 3.55	4.52± 1.35	4.27± 1.80	2.83± 4.00	24.68± 23.03

A-trimethylnaphthalene	2.49± 0.67	1.51± 0.69	1.26± 1.06	1.75± 1.75	2.26± 0.37	1.55± 0.72	6.68± 5.95
C-trimethylnaphthalene	7.24± 0.95	4.02± 1.38	7.06± 0.69	6.03± 1.33	7.01± 0.05	6.18± 4.35	24.01± 28.37
2-ethyl-1-methylnaphthalene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.25± 0.36	0.26± 0.36	0.78± 1.10
E-trimethylnaphthalene	1.50± 0.02	1.51± 0.69	3.02± 0.70	2.01± 0.68	2.50± 0.69	2.06± 1.45	5.96± 8.43
2,4,5-trimethylnaphthalene	6.69± 7.32	1.25± 1.05	1.01± 1.42	3.03± 0.76	1.75± 0.37	1.80± 1.09	6.72± 8.10
F-trimethylnaphthalene	4.76± 1.13	3.52± 1.38	5.04± 1.41	5.02± 1.34	6.02± 1.46	4.89± 3.99	23.59± 33.37
Fluorene	8.26± 1.89	5.78± 3.14	6.30± 3.18	9.03± 4.13	8.28± 2.54	8.24± 7.26	39.02± 47.49
1,4,5-trimethylnaphthalene	0.25± 0.36	0.25± 0.35	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.51± 0.73	0.00± 0.00
J-trimethylnaphthalene	1.24± 1.04	0.50± 0.01	0.00± 0.00	0.25± 0.35	1.01± 1.42	0.77± 1.09	3.37± 4.77
A-Methylfluorene	11.49± 1.24	7.54± 2.76	11.85± 0.40	7.30± 0.24	8.25± 3.12	7.48± 0.33	13.46± 2.97
B-Methylfluorene	1.24± 1.04	0.00± 0.00	4.78± 5.33	0.25± 0.35	1.25± 1.05	0.77± 1.09	1.30± 1.83
1-Methylfluorene	4.01± 1.47	3.26± 1.74	6.55± 0.03	3.27± 0.30	4.26± 0.32	2.84± 0.35	12.00± 6.49
9-fluorenone	3.51± 2.17	2.76± 1.75	3.52± 2.12	1.76± 0.33	2.51± 0.02	4.38± 1.07	8.74± 8.17
Dibenzothiophene	4.25± 0.42	3.01± 1.39	3.53± 0.73	2.27± 0.39	2.51± 0.02	3.87± 0.35	6.68± 5.95
Phenanthrene	21.59± 13.76	17.32± 10.84	17.37± 12.41	21.33± 8.56	18.06± 5.81	21.66± 7.92	70.24± 83.27
Anthracene	9.49± 1.27	5.52± 3.50	22.93± 4.54	6.28± 0.97	11.00± 6.29	3.87± 1.11	23.33± 11.72
Xanthone	1.25± 0.37	0.75± 0.35	1.76± 0.35	0.50± 0.01	2.25± 1.75	0.52± 0.00	1.56± 2.20
1,4-Naphthoquinone	7.58± 10.72	11.11± 3.70	1.01± 1.42	13.36± 1.99	8.31± 11.75	13.67± 1.03	14.08± 19.91
Acenaphthenequinone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.52± 0.73
3-methylphenanthrene	3.26± 1.82	2.51± 2.11	2.52± 1.42	2.26± 1.03	2.76± 1.08	5.16± 0.75	6.43± 6.30
2-methylphenanthrene	4.27± 2.54	3.26± 2.45	2.52± 2.13	3.01± 1.38	3.51± 0.74	6.45± 1.13	8.30± 11.73
Perinaphthenone	206.75± 286.67	2.76± 1.75	139.71± 34.06	2.77± 0.31	37.13± 48.95	6.72± 5.14	198.01± 69.77
2-methylanthracene	3.71± 4.54	0.25± 0.35	0.00± 0.00	0.25± 0.35	0.00± 0.00	0.52± 0.00	0.00± 0.00
4,5-methylenephenanthrene	0.75± 0.36	0.75± 0.35	0.50± 0.71	0.50± 0.01	0.75± 0.36	1.03± 0.00	1.56± 2.20
9-methylphenanthrene	1.26± 1.08	1.50± 1.41	0.50± 0.71	1.26± 0.34	1.00± 0.72	2.32± 0.38	3.63± 5.13
1-methylphenanthrene	1.76± 1.09	1.25± 1.05	0.75± 1.07	1.26± 0.34	1.25± 0.36	2.32± 0.38	2.83± 2.60
Anthrone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	2.77± 3.92	11.64± 11.37	14.52± 20.53
9-methylanthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Anthraquinone	4.48± 2.76	2.51± 1.39	10.84± 1.74	34.37± 45.73	4.24± 3.86	2.84± 0.35	13.48± 19.07
A-dimethylphenanthrene	1.01± 1.43	0.75± 1.06	0.00± 0.00	0.75± 0.34	0.50± 0.71	2.84± 1.11	0.00± 0.00

B-dimethylphenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,7-dimethylphenanthrene	0.00± 0.00	0.50± 0.71	0.00± 0.00	0.25± 0.35	0.25± 0.36	0.52± 0.73	0.00± 0.00
3,6-dimethylphenanthrene	0.25± 0.36	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.25± 0.36	0.78± 0.37	0.26± 0.37
D-dimethylphenanthrene	0.51± 0.71	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.25± 0.36	0.52± 0.73	0.00± 0.00
E-dimethylphenanthrene	0.76± 1.07	0.75± 1.06	0.00± 0.00	0.75± 0.34	0.50± 0.71	1.81± 0.37	1.04± 1.47
C-dimethylphenanthrene	30.44± 38.77	1.00± 1.41	0.00± 0.00	0.75± 0.34	0.76± 1.07	1.29± 1.83	2.59± 3.67
Fluoranthene	4.78± 3.96	4.51± 4.22	2.27± 1.77	3.00± 2.09	4.26± 0.39	4.64± 0.02	7.67± 4.56
Pyrene	6.53± 4.34	4.51± 4.22	2.77± 1.06	3.00± 2.09	6.51± 1.37	7.75± 2.23	7.15± 3.82
9-Anthraaldehyde	4.55± 6.43	4.26± 4.58	0.00± 0.00	3.51± 2.08	3.78± 5.34	10.59± 4.07	5.96± 8.43
Retene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
benzo(a)fluorene	0.25± 0.36	0.25± 0.35	0.00± 0.00	0.00± 0.00	0.25± 0.35	0.52± 0.00	0.26± 0.37
benzo(b)fluorene	0.25± 0.36	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.26± 0.37
5-methylchrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
B-MePy/MeFl	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-MeFl+C-MeFl/Py	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1+3-methylfluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
4-methylpyrene	2.26± 1.80	1.00± 0.70	0.25± 0.36	0.75± 0.34	1.25± 0.36	2.58± 1.47	1.56± 2.20
C-MePy/MeFl	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
D-MePy/MeFl	1.76± 1.79	0.75± 1.06	0.00± 0.00	0.25± 0.35	0.76± 1.07	2.84± 1.84	1.04± 1.47
1-methylpyrene	1.51± 1.44	0.50± 0.71	0.00± 0.00	0.25± 0.35	0.50± 0.71	1.55± 0.74	0.78± 1.10
Benzonaphthothiophene	0.00± 0.00	0.00± 0.00	0.25± 0.36	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.25± 0.35
benzo(c)phenanthrene	0.25± 0.36	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.25± 0.36	0.26± 0.37	0.26± 0.37
Benzo(ghi)fluoranthene	1.75± 0.33	0.75± 0.35	4.30± 6.08	0.50± 0.01	0.25± 0.36	1.29± 0.37	1.54± 1.48
9-phenylanthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.26± 0.37
6-methylchrysene	0.50± 0.01	0.00± 0.00	1.01± 1.43	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Cyclopenta(c,d)pyrene	0.25± 0.36	0.25± 0.35	0.00± 0.00	0.00± 0.00	0.25± 0.36	0.78± 0.37	0.52± 0.73
Benz(a)anthracene	0.51± 0.71	0.25± 0.35	0.25± 0.36	0.25± 0.35	0.50± 0.00	0.78± 0.37	1.02± 0.75
Chrysene	1.26± 1.08	1.00± 0.70	0.51± 0.71	1.01± 0.02	0.50± 0.00	0.78± 0.37	1.27± 0.40
Benzanthrone	0.25± 0.36	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.78± 0.37	0.00± 0.00
Benz(a)anthracene-7,12-dione	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

3-methylchrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7-methylbenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7,12-dimethylbenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benzo(b)fluoranthene	1.26± 1.08	1.00± 0.70	1.01± 0.00	1.01± 0.02	0.50± 0.70	0.26± 0.37	0.78± 1.10
Benzo(j)fluoranthene	0.75± 0.36	0.25± 0.35	1.52± 2.14	0.00± 0.00	0.25± 0.35	0.52± 0.00	0.00± 0.00
Benzo(k)fluoranthene	0.51± 0.71	0.75± 0.35	1.01± 1.42	0.75± 0.34	0.25± 0.35	0.00± 0.00	0.00± 0.00
Benzo(a)fluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
BeP	2.01± 1.44	1.26± 0.34	3.78± 0.37	1.26± 0.34	1.00± 0.70	0.78± 0.37	1.30± 1.83
BaP	0.51± 0.71	0.25± 0.36	0.00± 0.00	0.25± 0.35	0.25± 0.36	0.52± 0.00	2.07± 2.93
Perylene	0.51± 0.71	0.50± 0.01	0.00± 0.00	0.50± 0.01	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-methylcholanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7-methylbenzo(a)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Indeno[123-cd]fluoranthene	0.25± 0.36	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.26± 0.37
Indeno[123-cd]pyrene	0.75± 0.36	0.50± 0.01	0.25± 0.36	0.50± 0.01	0.25± 0.35	0.00± 0.00	0.52± 0.73
Dibenzo(ac)anthracene	0.25± 0.36	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(ah+ac)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(ah)anthracene	0.51± 0.71	0.25± 0.36	0.25± 0.36	0.50± 0.01	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(a,j)anthracene	0.99± 1.40	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benzo(b)chrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Picene	1.73± 2.45	0.25± 0.36	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.26± 0.36	0.00± 0.00
Benzo(ghi)perylene	1.25± 0.37	1.01± 0.01	0.76± 0.35	1.01± 0.02	0.50± 0.70	0.52± 0.00	1.54± 1.48
Anthanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Triphenylene	0.25± 0.36	0.25± 0.35	0.25± 0.36	0.00± 0.00	0.25± 0.36	0.26± 0.37	0.77± 0.38
Dibenzo(a,l)pyrene	0.25± 0.36	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Coronene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(a,e)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(a,i)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(a,h)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Dibenzo(b,k)fluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Table D15: Particle-phase PAH emissions for Vehicle #7

Component (ng/mile)	Fed ULSD	CARB ULSD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
naphthalene	3.66± 3.02	16.08± 8.83	11.02± 11.44	3.07± 0.52	46.76± 62.23	5.92± 1.15	3.37± 2.63
quinoline	0.15± 0.22	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.15± 0.22	1.22± 1.73	0.00± 0.00
2-methylnaphthalene	2.90± 1.94	4.20± 2.87	3.72± 2.35	3.84± 0.76	2.45± 0.00	28.26± 31.46	4.45± 3.72
1-methylnaphthalene	1.98± 1.08	2.42± 1.68	2.53± 1.91	2.15± 0.06	1.53± 0.00	7.79± 7.61	2.30± 1.97
Biphenyl	6.87± 4.96	9.43± 1.05	13.41± 13.56	5.35± 0.93	4.29± 0.00	11.25± 3.57	6.27± 2.88
2-methylbiphenyl	14.51± 0.24	17.08± 9.25	17.18± 0.62	13.58± 3.72	13.78± 0.00	18.33± 4.28	18.78± 2.61
2,6+2,7-dimethylnaphthalene	2.59± 1.94	3.22± 1.48	2.83± 2.34	3.37± 0.10	2.45± 0.00	9.45± 7.41	3.99± 3.93
1,3+1,6+1,7dimethylnaphth	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,4+1,5+2,3-dimethylnaphth	3.82± 1.51	5.64± 3.16	4.60± 2.36	4.13± 0.53	3.98± 0.00	16.16± 12.22	5.66± 3.31
Acenaphthylene	2.60± 0.21	3.07± 2.15	2.96± 0.45	2.59± 1.01	3.06± 0.00	3.49± 0.60	3.82± 0.70
1,2-dimethylnaphthalene	0.92± 0.43	1.12± 0.27	2.37± 0.86	1.39± 0.69	98.09± 0.00	43.30± 58.26	1.38± 0.66
1,8-dimethylnaphthalene	0.76± 0.21	0.97± 0.49	0.44± 0.20	1.23± 0.47	48.74± 0.00	13.44± 14.76	1.38± 0.66
Acenaphthene	0.31± 0.43	0.96± 0.04	0.75± 1.06	0.46± 0.23	0.31± 0.00	3.06± 4.33	1.69± 2.39
3-methylbiphenyl	17.10± 2.13	20.80± 11.88	19.71± 2.53	16.04± 3.65	20.52± 0.00	25.64± 0.54	24.30± 8.29
4-methylbiphenyl	8.70± 1.50	10.96± 5.85	10.23± 1.16	8.55± 1.92	10.11± 0.00	14.42± 0.39	12.54± 4.47
1+2ethylnaphthalene	2.75± 0.86	3.54± 1.49	4.61± 3.19	3.37± 0.34	2.76± 0.00	7.46± 4.60	3.98± 1.78
1-ethyl-2-methylnaphthalene	4.89± 0.86	5.56± 0.90	2.06± 2.91	2.25± 3.18	4.59± 0.00	16.23± 22.95	3.08± 4.35
2,3,5+I-trimethylnaphthalene	1.83± 1.29	2.26± 1.44	1.93± 1.49	2.15± 0.50	2.14± 0.00	3.50± 2.40	2.46± 2.62
B-trimethylnaphthalene	1.83± 1.29	2.10± 1.21	1.34± 1.90	2.00± 0.27	1.53± 0.00	0.00± 0.00	2.62± 3.70
A-trimethylnaphthalene	0.76± 0.21	0.64± 0.03	0.74± 0.64	0.61± 0.02	1.23± 0.00	2.75± 3.47	0.92± 1.31
C-trimethylnaphthalene	2.44± 1.72	2.73± 1.24	2.97± 2.13	3.07± 0.09	2.76± 0.00	1.35± 1.91	3.99± 3.93
2-ethyl-1-methylnaphthalene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.16± 0.22	0.00± 0.00	0.15± 0.21	0.00± 0.00
E-trimethylnaphthalene	0.76± 0.65	1.13± 0.72	1.04± 1.06	0.92± 0.03	0.92± 0.00	0.00± 0.00	1.23± 1.74
2,4,5-trimethylnaphthalene	0.61± 0.43	0.82± 1.16	0.73± 1.04	0.92± 0.03	0.92± 0.00	0.00± 0.00	1.38± 1.53
F-trimethylnaphthalene	2.29± 1.94	2.42± 1.68	1.78± 1.28	2.45± 0.07	2.76± 0.00	3.21± 3.26	3.54± 4.58
Fluorene	4.27± 3.88	5.94± 2.27	6.24± 3.84	4.44± 0.09	4.29± 0.00	15.59± 19.08	6.76± 8.28

1,4,5-trimethylnaphthalene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.61± 0.00	0.00± 0.00	0.31± 0.44
J-trimethylnaphthalene	0.46± 0.65	0.00± 0.00	0.15± 0.21	0.47± 0.66	0.31± 0.00	9.18± 12.99	0.62± 0.87
A-Methylfluorene	4.27± 1.29	7.59± 3.30	16.58± 1.07	3.82± 0.97	3.68± 0.00	1.65± 2.34	3.82± 1.56
B-Methylfluorene	0.00± 0.00	0.16± 0.23	0.00± 0.00	0.00± 0.00	0.31± 0.00	0.00± 0.00	0.31± 0.44
1-Methylfluorene	2.29± 1.94	12.49± 13.03	44.09± 7.04	2.59± 1.01	1.53± 0.00	0.90± 1.28	2.61± 2.84
9-fluorenone	2.29± 1.51	13.80± 11.62	41.37± 9.48	2.15± 0.06	3.37± 0.00	0.45± 0.64	1.84± 1.75
Dibenzothiophene	1.37± 0.65	1.46± 1.19	1.18± 0.01	1.37± 0.61	1.84± 0.00	0.30± 0.43	1.69± 1.53
Phenanthrene	9.16± 7.76	10.52± 7.86	9.37± 6.18	9.46± 2.76	8.58± 0.00	33.65± 42.90	15.84± 19.83
Anthracene	3.81± 3.67	3.37± 1.26	5.20± 3.62	3.65± 1.63	1.23± 0.00	6.05± 2.93	3.06± 1.33
Xanthone	2.75± 3.45	0.65± 0.48	0.59± 0.43	0.15± 0.21	0.31± 0.00	0.00± 0.00	0.46± 0.22
1,4-Naphthoquinone	12.67± 3.65	8.71± 3.03	4.85± 6.86	7.53± 1.74	4.44± 6.28	0.00± 0.00	3.69± 5.22
Acenaphthenequinone	0.00± 0.00	0.00± 0.00	0.15± 0.21	0.00± 0.00	0.15± 0.22	0.00± 0.00	0.00± 0.00
3-methylphenanthrene	1.07± 1.08	1.46± 1.19	0.89± 0.43	1.22± 0.40	1.23± 0.00	0.00± 0.00	1.84± 1.75
2-methylphenanthrene	1.53± 1.29	2.87± 0.11	3.71± 1.93	1.38± 0.18	1.23± 0.00	0.00± 0.00	2.30± 2.40
Perinaphthenone	10.98± 14.24	18.92± 18.41	51.26± 3.52	1.53± 0.39	0.92± 0.00	171.52± 109.85	2.14± 1.32
2-methylanthracene	0.31± 0.43	1.15± 1.62	0.45± 0.63	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
4,5-methylenephenanthrene	0.46± 0.22	0.48± 0.24	0.00± 0.00	0.31± 0.01	0.31± 0.00	0.00± 0.00	0.46± 0.65
9-methylphenanthrene	0.76± 0.65	1.26± 0.85	0.73± 1.04	0.61± 0.02	0.61± 0.00	0.00± 0.00	0.92± 1.31
1-methylphenanthrene	0.46± 0.22	0.49± 0.70	0.89± 0.43	0.61± 0.42	0.61± 0.00	0.00± 0.00	0.77± 1.09
Anthrone	10.07± 14.24	18.37± 25.98	0.00± 0.00	1.41± 1.99	0.00± 0.00	0.00± 0.00	0.00± 0.00
9-methylanthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Anthraquinone	1.07± 0.21	6.00± 4.97	1.76± 2.49	1.53± 0.39	3.37± 0.00	22.48± 28.39	8.93± 10.02
A-dimethylphenanthrene	0.76± 0.65	5.12± 7.24	0.00± 0.00	0.31± 0.01	0.00± 0.00	0.00± 0.00	0.00± 0.00
B-dimethylphenanthrene	0.46± 0.65	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,7-dimethylphenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3,6-dimethylphenanthrene	0.61± 0.86	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
D-dimethylphenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
E-dimethylphenanthrene	0.00± 0.00	0.33± 0.46	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.15± 0.22
C-dimethylphenanthrene	2.44± 3.45	5.61± 6.54	6.32± 8.93	0.16± 0.22	0.00± 0.00	0.00± 0.00	0.77± 0.66
Fluoranthene	1.07± 0.65	1.94± 1.43	1.19± 0.85	1.07± 0.19	0.92± 0.00	0.30± 0.43	1.69± 1.53

Pyrene	1.07± 0.65	1.94± 1.43	0.89± 0.43	0.76± 0.19	0.61± 0.00	1.22± 0.87	1.53± 0.88
9-Anthraaldehyde	0.15± 0.22	1.64± 2.32	0.00± 0.00	1.22± 0.40	1.23± 0.00	0.00± 0.00	0.92± 1.31
Retene	0.00± 0.00	0.16± 0.23	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
benzo(a)fluorene	1.68± 2.37	0.33± 0.46	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.15± 0.22
benzo(b)fluorene	2.14± 3.02	0.00± 0.00	0.44± 0.20	0.00± 0.00	0.00± 0.00	0.31± 0.43	0.00± 0.00
5-methylchrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	3.21± 4.55	0.00± 0.00
B-MePy/MeFl	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-MeFl+C-MeFl/Py	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1+3-methylfluoranthene	0.00± 0.00	0.78± 1.10	2.52± 0.66	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
4-methylpyrene	0.61± 0.86	0.47± 0.21	1.19± 0.43	0.31± 0.01	0.00± 0.00	0.00± 0.00	0.15± 0.22
C-MePy/MeFl	0.00± 0.00	0.31± 0.44	0.89± 0.01	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
D-MePy/MeFl	0.46± 0.65	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-methylpyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benzonaphthothiophene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
benzo(c)phenanthrene	0.00± 0.00	1.09± 1.53	3.41± 0.25	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benzo(ghi)fluoranthene	0.15± 0.22	0.63± 0.43	1.33± 0.22	0.15± 0.21	0.00± 0.00	0.00± 0.00	0.31± 0.44
9-phenylanthracene	0.00± 0.00	0.62± 0.88	1.93± 0.23	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6-methylchrysene	0.15± 0.22	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Cyclopenta(c,d)pyrene	0.00± 0.00	0.94± 0.86	2.37± 0.45	0.00± 0.00	1.38± 1.94	0.00± 0.00	0.15± 0.22
Benz(a)anthracene	1.22± 1.29	0.00± 0.00	0.00± 0.00	0.00± 0.00	1.68± 2.38	0.00± 0.00	0.00± 0.00
Chrysene	0.76± 1.08	0.79± 0.19	1.19± 1.69	0.30± 0.42	2.90± 4.11	3.98± 5.63	0.61± 0.01
Benzanthrone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benz(a)anthracene-7,12-dione	1.37± 1.51	2.48± 3.51	2.50± 3.53	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-methylchrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	12.40± 17.53	0.00± 0.00
7-methylbenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7,12-dimethylbenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benzo(b)fluoranthene	0.46± 0.22	0.48± 0.24	0.59± 0.43	0.30± 0.42	1.53± 2.16	0.00± 0.00	0.76± 0.23
Benzo(j)fluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.92± 1.30	0.00± 0.00	0.15± 0.21
Benzo(k)fluoranthene	0.15± 0.22	0.33± 0.46	0.15± 0.21	0.30± 0.42	1.68± 2.38	0.00± 0.00	0.46± 0.22

Benzo(a)fluoranthene	0.00± 0.00	0.00± 0.00	0.15± 0.21	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
BeP	0.31± 0.43	0.65± 0.48	0.59± 0.43	0.30± 0.42	2.75± 3.89	0.00± 0.00	1.07± 0.23
BaP	0.31± 0.43	0.32± 0.01	0.45± 0.21	0.15± 0.21	1.53± 2.16	0.00± 0.00	0.31± 0.00
Perylene	0.15± 0.22	0.16± 0.23	0.15± 0.21	0.15± 0.21	1.83± 2.59	0.00± 0.00	0.31± 0.00
3-methylcholanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7-methylbenzo(a)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Indeno[123-cd]fluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.92± 1.30	0.00± 0.00	0.00± 0.00
Indeno[123-cd]pyrene	0.15± 0.22	0.33± 0.46	0.30± 0.42	0.30± 0.42	2.29± 3.24	0.00± 0.00	0.61± 0.01
Dibenzo(ac)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(ah+ac)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(ah)anthracene	0.31± 0.43	0.33± 0.46	0.30± 0.42	0.30± 0.42	1.68± 2.38	0.00± 0.00	0.31± 0.00
Dibenzo(a,j)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benzo(b)chrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Picene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	2.26± 3.19	0.00± 0.00
Benzo(ghi)perylene	0.61± 0.43	0.81± 0.71	0.75± 1.06	0.45± 0.64	2.90± 4.11	0.15± 0.21	1.22± 0.02
Anthanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Triphenylene	0.00± 0.00	0.47± 0.21	8.00± 0.51	0.15± 0.21	1.83± 2.59	0.00± 0.00	0.15± 0.22
Dibenzo(a,l)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Coronene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(a,e)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(a,i)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(a,h)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(b,k)fluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Table D16: Particle-phase PAH emissions for Vehicle #8

Component (ng/mile)	Fed ULSD	CARB ULSD	Fed/SME-20	Fed/AFME-20	Fed/WCO-20	Fed/HVO-20	CARB/WCO-20
naphthalene	75.17± 10.81	112.07± 15.87	84.91± 27.73	57.73± 26.85	3.60± 0.93	50.19± 34.70	5.39± 2.92

quinoline	3.35± 2.91	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.64± 0.30	0.00± 0.00	0.21± 0.29
2-methylnaphthalene	18.13± 1.38	17.75± 2.61	15.08± 5.81	12.18± 5.18	3.81± 0.63	20.54± 3.05	5.80± 2.92
1-methylnaphthalene	9.50± 2.35	11.83± 3.42	12.06± 3.14	7.14± 10.10	1.91± 0.91	12.27± 2.87	3.11± 1.46
Biphenyl	17.24± 3.84	15.72± 8.28	12.12± 5.06	9.85± 3.81	6.14± 0.95	16.63± 3.12	8.29± 0.58
2-methylbiphenyl	35.70± 20.92	14.21± 15.47	16.77± 15.17	29.36± 0.77	20.72± 2.81	8.29± 4.71	26.33± 2.09
2,6+2,7-dimethylnaphthalene	2.28± 0.36	5.74± 1.45	4.71± 1.30	1.79± 1.46	3.82± 1.83	2.56± 0.66	4.77± 2.05
1,3+1,6+1,7dimethylnaphth	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,4+1,5+2,3-dimethylnaphth	1.51± 1.44	3.36± 2.43	5.17± 3.07	2.94± 2.32	4.87± 0.94	2.55± 2.56	7.26± 0.87
Acenaphthylene	0.37± 0.64	6.98± 6.15	3.13± 4.13	0.00± 0.00	4.02± 0.26	0.00± 0.00	5.18± 0.30
1,2-dimethylnaphthalene	0.01± 0.02	0.00± 0.00	0.00± 0.00	0.94± 1.33	2.54± 0.62	0.00± 0.00	2.49± 1.17
1,8-dimethylnaphthalene	2.48± 4.30	11.05± 19.13	3.94± 3.42	0.00± 0.00	1.48± 0.29	6.40± 0.46	1.66± 0.58
Acenaphthene	2.07± 3.59	4.10± 6.39	4.38± 7.59	6.64± 9.13	0.42± 0.00	0.00± 0.00	0.62± 0.29
3-methylbiphenyl	34.33± 15.42	20.91± 16.57	25.91± 15.18	28.16± 1.96	23.90± 0.69	19.08± 6.44	34.21± 1.51
4-methylbiphenyl	14.03± 7.92	7.90± 7.86	11.27± 6.47	11.47± 0.03	12.90± 0.19	9.64± 1.00	17.42± 0.61
1+2ethylnaphthalene	0.00± 0.00	0.00± 0.00	0.97± 1.69	0.00± 0.00	3.81± 0.03	1.06± 1.84	5.18± 0.87
1-ethyl-2-methylnaphthalene	5.45± 1.65	6.48± 0.83	4.10± 3.55	3.92± 4.22	0.00± 0.00	1.01± 1.75	3.32± 4.70
2,3,5+I-trimethylnaphthalene	1.17± 1.44	2.47± 0.84	1.52± 1.39	1.58± 0.02	2.12± 0.62	1.03± 0.90	3.73± 1.75
B-trimethylnaphthalene	10.72± 9.26	0.76± 0.20	0.51± 0.44	9.36± 13.24	1.91± 0.91	0.46± 0.47	3.52± 0.87
A-trimethylnaphthalene	0.00± 0.00	0.74± 1.28	0.00± 0.00	0.00± 0.00	0.85± 0.61	0.00± 0.00	1.45± 0.29
C-trimethylnaphthalene	4.87± 1.96	8.77± 3.73	12.58± 2.34	0.00± 0.00	2.75± 0.92	10.53± 0.57	4.97± 1.75
2-ethyl-1-methylnaphthalene	1.30± 2.26	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.21± 0.30	0.21± 0.37	0.21± 0.29
E-trimethylnaphthalene	7.72± 6.74	2.05± 1.78	1.98± 1.24	3.66± 0.36	0.64± 0.30	2.67± 1.36	1.45± 0.88
2,4,5-trimethylnaphthalene	10.36± 7.94	0.00± 0.00	0.00± 0.00	23.27± 0.20	0.42± 0.59	0.00± 0.00	2.70± 0.88
F-trimethylnaphthalene	0.70± 1.20	0.27± 0.46	0.00± 0.00	8.63± 12.17	2.33± 0.92	0.00± 0.00	4.56± 1.75
Fluorene	1.34± 0.84	1.08± 0.98	1.51± 1.37	0.73± 0.79	3.82± 1.83	1.60± 1.43	8.29± 2.33
1,4,5-trimethylnaphthalene	4.43± 1.37	4.16± 0.86	5.50± 1.57	3.30± 0.67	0.00± 0.00	3.68± 1.46	0.00± 0.00
J-trimethylnaphthalene	9.46± 6.24	0.00± 0.00	0.00± 0.00	25.66± 0.92	0.42± 0.00	0.00± 0.00	0.62± 0.29
A-Methylfluorene	11.98± 3.93	6.66± 1.86	8.19± 2.32	11.94± 3.86	4.87± 0.34	6.97± 1.93	7.46± 1.16
B-Methylfluorene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-Methylfluorene	0.00± 0.00	0.00± 0.00	1.23± 1.59	0.00± 0.00	3.18± 1.52	0.48± 0.83	7.46± 2.92

9-fluorenone	3.93± 1.79	5.35± 2.61	5.43± 1.69	15.96± 12.33	4.45± 2.13	7.53± 1.77	10.57± 5.56
Dibenzothiophene	3.27± 1.10	0.93± 0.50	2.10± 0.61	3.82± 0.87	1.27± 0.01	1.70± 0.23	2.28± 0.29
Phenanthrene	2.51± 2.24	5.86± 7.49	1.18± 1.32	2.36± 1.22	6.57± 2.75	6.99± 7.93	15.34± 4.67
Anthracene	0.76± 1.32	0.00± 0.00	0.00± 0.00	2.94± 4.16	2.75± 0.32	0.00± 0.00	2.28± 2.05
Xanthone	10.81± 0.33	9.48± 1.64	14.34± 1.80	10.73± 1.60	0.21± 0.30	11.36± 4.10	0.41± 0.00
1,4-Naphthoquinone	34.82± 32.68	9.09± 15.75	20.68± 29.38	15.05± 21.29	12.27± 0.11	44.44± 29.39	13.89± 2.03
Acenaphthenequinone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	7.04± 9.96
3-methylphenanthrene	11.13± 2.77	10.00± 10.21	13.80± 5.36	20.07± 8.86	0.85± 0.01	1.13± 1.95	1.66± 0.00
2-methylphenanthrene	2.61± 2.29	0.82± 1.42	0.00± 0.00	10.14± 5.78	1.48± 0.31	2.94± 5.09	2.69± 0.88
Perinaphthenone	132.10± 48.83	47.23± 64.69	49.52± 46.13	75.49± 42.37	8.27± 3.96	41.98± 36.80	14.09± 4.67
2-methylanthracene	1.42± 1.27	0.84± 0.29	1.49± 0.96	2.95± 4.17	0.00± 0.00	1.71± 0.85	0.83± 0.00
4,5-methylenephenanthrene	2.75± 0.22	3.06± 0.96	2.16± 0.30	2.90± 0.52	0.21± 0.30	1.96± 0.79	0.41± 0.00
9-methylphenanthrene	1.65± 1.73	0.70± 0.94	0.00± 0.00	12.09± 9.98	0.42± 0.00	0.79± 1.14	1.45± 0.29
1-methylphenanthrene	1.14± 0.31	2.74± 2.52	2.53± 0.68	0.63± 0.90	0.64± 0.30	2.49± 1.96	1.04± 0.29
Anthrone	103.56± 91.48	59.05± 102.28	17.22± 29.83	368.99± 215.18	0.00± 0.00	25.19± 43.64	6.23± 8.80
9-methylanthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Anthraquinone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.64± 0.30	0.96± 1.62	2.07± 1.17
A-dimethylphenanthrene	0.00± 0.00	0.18± 0.31	0.18± 0.31	0.00± 0.00	0.00± 0.00	0.36± 0.63	2.69± 0.29
B-dimethylphenanthrene	0.43± 0.74	0.00± 0.00	0.20± 0.34	0.66± 0.94	0.00± 0.00	0.59± 1.02	0.00± 0.00
1,7-dimethylphenanthrene	0.25± 0.43	1.12± 0.09	0.17± 0.30	1.24± 1.75	0.00± 0.00	0.00± 0.00	0.21± 0.29
3,6-dimethylphenanthrene	0.16± 0.27	0.38± 0.35	0.00± 0.00	0.36± 0.51	0.00± 0.00	0.64± 1.11	0.00± 0.00
D-dimethylphenanthrene	0.44± 0.42	0.28± 0.49	0.23± 0.41	1.90± 2.69	0.00± 0.00	0.69± 1.19	0.00± 0.00
E-dimethylphenanthrene	1.08± 0.98	0.70± 0.78	0.00± 0.00	5.00± 3.32	0.00± 0.00	0.14± 0.24	0.21± 0.29
C-dimethylphenanthrene	0.00± 0.00	2.64± 2.86	0.00± 0.00	0.68± 0.96	1.26± 1.78	2.27± 3.93	4.15± 5.87
Fluoranthene	7.10± 3.99	15.98± 23.33	6.36± 6.14	13.75± 6.32	0.85± 0.01	26.46± 15.34	1.45± 0.29
Pyrene	13.12± 5.34	22.16± 26.91	13.83± 9.74	14.58± 6.04	1.27± 0.01	42.83± 19.28	1.24± 0.00
9-Anthraaldehyde	1.24± 2.15	4.53± 6.60	5.13± 4.52	8.67± 9.06	0.00± 0.00	11.39± 10.94	0.62± 0.88
Retene	0.94± 0.29	0.83± 0.55	1.21± 0.56	1.28± 0.60	0.00± 0.00	1.39± 0.08	0.00± 0.00
benzo(a)fluorene	0.59± 1.03	0.54± 0.94	0.85± 1.48	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
benzo(b)fluorene	1.54± 1.35	1.09± 0.39	0.72± 1.25	0.00± 0.00	0.00± 0.00	1.09± 0.97	0.00± 0.00

5-methylchrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
B-MePy/MeFl	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-MeFl+C-MeFl/Py	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1+3-methylfluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
4-methylpyrene	7.09± 1.38	6.30± 5.21	10.34± 2.81	6.97± 0.55	0.42± 0.00	16.27± 10.13	0.41± 0.00
C-MePy/MeFl	2.82± 4.88	2.64± 4.58	0.92± 1.60	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
D-MePy/MeFl	3.32± 3.45	3.80± 4.33	5.16± 2.94	3.74± 0.11	0.21± 0.30	10.44± 7.76	0.00± 0.00
1-methylpyrene	2.82± 0.82	3.58± 3.43	4.10± 2.72	2.96± 0.34	0.42± 0.00	7.20± 4.12	0.00± 0.00
Benzonaphthothiophene	1.31± 0.53	0.75± 0.97	0.53± 0.92	0.68± 0.96	0.00± 0.00	1.81± 0.32	0.00± 0.00
benzo(c)phenanthrene	0.52± 0.54	1.05± 0.65	0.50± 0.86	0.79± 0.43	0.21± 0.30	1.16± 0.18	0.41± 0.59
Benzo(ghi)fluoranthene	5.44± 4.75	9.29± 8.12	7.10± 6.66	5.12± 1.77	0.42± 0.00	11.86± 2.95	0.62± 0.29
9-phenylanthracene	4.20± 2.94	3.36± 0.74	5.51± 4.91	1.35± 1.91	0.00± 0.00	10.48± 0.98	0.21± 0.29
6-methylchrysene	0.42± 0.73	0.37± 0.63	0.00± 0.00	0.37± 0.53	0.00± 0.00	0.31± 0.53	0.00± 0.00
Cyclopenta(c,d)pyrene	1.53± 1.78	3.21± 4.28	2.35± 2.75	1.09± 0.65	0.42± 0.00	2.98± 3.47	0.41± 0.00
Benz(a)anthracene	0.75± 1.10	0.57± 0.62	1.64± 2.06	0.27± 0.24	0.00± 0.00	1.39± 0.34	0.00± 0.00
Chrysene	0.60± 0.68	1.35± 0.97	1.87± 2.85	2.66± 1.48	0.21± 0.30	1.68± 0.39	0.41± 0.00
Benzanthrone	7.66± 3.12	4.54± 2.24	3.46± 3.91	11.02± 0.17	0.00± 0.00	3.82± 2.91	0.00± 0.00
Benz(a)anthracene-7,12-dione	0.00± 0.00	0.93± 1.61	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	1.66± 0.00
3-methylchrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.76± 1.31	0.00± 0.00
7-methylbenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7,12-dimethylbenz(a)anthracene	1.16± 0.49	2.50± 0.87	3.30± 0.79	3.56± 2.42	0.00± 0.00	2.53± 2.22	0.00± 0.00
Benzo(b)fluoranthene	1.11± 1.40	1.67± 1.62	2.32± 3.42	1.01± 0.45	0.00± 0.00	1.19± 1.67	0.21± 0.29
Benzo(j)fluoranthene	0.53± 0.76	0.78± 0.71	1.43± 1.90	0.64± 0.47	0.00± 0.00	0.79± 0.86	0.00± 0.00
Benzo(k)fluoranthene	0.51± 0.88	0.68± 1.18	1.32± 2.00	0.48± 0.68	0.00± 0.00	0.69± 1.19	0.00± 0.00
Benzo(a)fluoranthene	0.00± 0.00	0.00± 0.00	0.32± 0.55	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
BeP	1.51± 1.09	2.10± 1.72	2.34± 2.10	1.14± 0.21	0.21± 0.30	2.05± 1.25	0.21± 0.29
BaP	1.24± 1.18	1.12± 1.54	1.90± 2.56	0.65± 0.11	0.00± 0.00	1.20± 1.10	0.00± 0.00
Perylene	0.00± 0.00	6.45± 11.18	0.56± 0.96	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-methylcholanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

7-methylbenzo(a)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00± 0.00	0.00± 0.00	0.02± 0.03	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Indeno[123-cd]fluoranthene	0.55± 0.50	0.74± 0.67	0.26± 0.44	1.15± 0.18	0.00± 0.00	0.30± 0.26	0.00± 0.00
Indeno[123-cd]pyrene	0.71± 0.88	0.62± 1.08	1.35± 1.71	0.74± 0.37	0.00± 0.00	0.61± 0.84	0.21± 0.29
Dibenzo(ac)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(ah+ac)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(ah)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.21± 0.29
Dibenzo(a,j)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Benzo(b)chrysene	0.31± 0.54	0.70± 1.22	1.27± 0.13	2.03± 0.62	0.00± 0.00	0.69± 0.25	0.00± 0.00
Picene	1.10± 0.95	0.75± 1.30	0.00± 0.00	3.00± 1.19	0.21± 0.30	0.00± 0.00	0.42± 0.59
Benzo(ghi)perylene	1.32± 2.29	3.20± 4.96	3.10± 5.22	0.86± 0.72	0.00± 0.00	2.65± 4.15	0.21± 0.29
Anthanthrene	0.34± 0.59	0.55± 0.94	0.87± 1.23	0.33± 0.46	0.00± 0.00	0.60± 0.85	0.00± 0.00
Triphenylene	2.34± 0.51	3.01± 0.95	2.61± 0.96	2.45± 0.81	0.64± 0.30	2.54± 0.32	1.24± 0.58
Dibenzo(a,l)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Coronene	0.42± 0.73	1.66± 1.92	1.51± 2.61	0.16± 0.23	0.00± 0.00	1.33± 1.87	0.00± 0.00
Dibenzo(a,e)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(a,i)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(a,h)pyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
Dibenzo(b,k)fluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Table D17: Gas-phase nitro-PAH emissions for Vehicle #1

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	30.32± 7.21	0.00± 0.00	13.72± 6.63	14.49± 1.46	16.64± 5.85	19.22± 0.00	17.92± 25.34
1-methyl-5-nitronaphthalene	0.00± 0.00	0.05± 0.08	0.75± 0.52	0.00± 0.00	0.00± 0.00	13.64± 0.00	0.00± 0.00
2-nitronaphthalene	0.00± 0.00	3.83± 0.06	1.62± 0.42	0.49± 0.64	0.29± 0.21	7.59± 6.68	0.86± 0.68
2-nitrobiphenyl	0.16± 0.05	0.57± 0.41	0.30± 0.31	0.23± 0.04	0.13± 0.17	0.31± 0.00	0.34± 0.37
2-methyl-4-nitronaphthalene	0.00± 0.00	0.26± 0.10	0.16± 0.23	0.02± 0.02	0.03± 0.04	9.90± 7.31	0.00± 0.00
1-methyl-4-nitronaphthalene	0.00± 0.00	0.61± 0.06	0.48± 0.18	0.09± 0.12	0.00± 0.00	7.89± 7.73	0.28± 0.40
1-methyl-6-nitronaphthalene	0.00± 0.00	5.40± 1.26	1.71± 0.43	1.17± 1.65	2.11± 0.82	0.00± 0.00	3.67± 2.25
3-nitrobiphenyl	0.05± 0.01	0.16± 0.02	0.15± 0.05	0.20± 0.09	0.11± 0.02	0.10± 0.02	0.10± 0.08

4-nitrobiphenyl	0.00± 0.00	0.64± 0.90	0.13± 0.19	0.41± 0.58	0.00± 0.00	0.14± 0.20	0.28± 0.40
1,3-dinitronaphthalene	0.02± 0.02	1.57± 1.31	0.90± 1.24	0.21± 0.30	0.06± 0.08	0.78± 0.14	0.73± 0.63
1,5-dinitronaphthalene	0.06± 0.03	0.00± 0.00	0.15± 0.10	0.13± 0.03	0.54± 0.42	0.08± 0.12	0.00± 0.00
5-nitroacenaphthene	0.04± 0.06	0.00± 0.00	0.00± 0.00	0.04± 0.06	0.00± 0.00	0.19± 0.27	0.00± 0.00
2-nitrofluorene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
4-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
9-nitroanthracene	0.00± 0.00	0.05± 0.07	0.00± 0.00	0.24± 0.20	0.29± 0.11	0.35± 0.06	0.33± 0.47
9-nitrophenanthrene	0.00± 0.00	0.15± 0.21	0.54± 0.54	0.09± 0.04	0.15± 0.21	0.71± 0.26	0.28± 0.40
1,8-dinitronaphthalene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-nitrophenanthrene	4.65± 1.19	9.46± 0.12	12.34± 11.89	10.91± 1.49	23.39± 3.59	8.33± 6.73	8.04± 0.82
2-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.18± 0.25	0.00± 0.00	0.00± 0.00	0.05± 0.07
2-nitroanthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2-nitrofluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-nitrofluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.07± 0.10
4-nitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-nitropyrene	0.00± 0.00	0.01± 0.01	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2-nitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2,7-dinitrofluorene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2,7-dinitrofluoren-9-one	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7-nitrobenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6-nitrochrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-nitrobenzanthrone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,3-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,6-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,8-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6a+1e-nitrobenzpyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-nitrobenzo[e]pryene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-nitrobenzo[e]pryene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Table D18: Gas-phase nitro-PAH emissions for Vehicle #2

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	3.28± 4.63	3.12± 4.41	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-methyl-5-nitronaphthalene	2.46± 0.53	0.12± 0.17	1.22± 0.29	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2-nitronaphthalene	1.19± 0.07	1.12± 0.25	5.45± 1.22	0.47± 0.27	0.99± 0.51	1.39± 0.19	9.51± 0.00
2-nitrobiphenyl	0.27± 0.37	0.44± 0.13	0.22± 0.11	0.63± 0.15	0.53± 0.08	0.49± 0.21	0.95± 0.25
2-methyl-4-nitronaphthalene	0.25± 0.18	0.20± 0.29	1.00± 0.04	0.04± 0.06	0.07± 0.09	0.00± 0.00	0.00± 0.00
1-methyl-4-nitronaphthalene	0.49± 0.31	0.38± 0.54	1.36± 0.08	0.57± 0.05	0.83± 0.08	0.66± 0.07	0.00± 0.00
1-methyl-6-nitronaphthalene	3.32± 3.08	4.09± 1.66	9.98± 5.83	4.39± 3.11	3.09± 4.37	1.49± 0.58	4.89± 1.92
3-nitrobiphenyl	0.27± 0.09	0.22± 0.09	0.50± 0.15	0.13± 0.01	0.33± 0.20	0.20± 0.10	0.42± 0.15
4-nitrobiphenyl	0.54± 0.54	0.34± 0.43	0.32± 0.46	0.18± 0.00	0.13± 0.19	0.12± 0.17	0.00± 0.00
1,3-dinitronaphthalene	0.39± 0.55	0.68± 0.96	0.15± 0.21	0.26± 0.24	0.57± 0.81	0.04± 0.06	0.00± 0.00
1,5-dinitronaphthalene	0.07± 0.10	0.00± 0.00	0.03± 0.04	0.04± 0.05	0.05± 0.06	0.00± 0.00	0.18± 0.18
5-nitroacenaphthene	0.60± 0.12	0.00± 0.00	0.30± 0.22	0.11± 0.16	0.00± 0.00	0.00± 0.00	0.11± 0.16
2-nitrofluorene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.03± 0.04	0.00± 0.00	0.00± 0.00
4-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
9-nitroanthracene	0.97± 0.94	0.47± 0.67	0.26± 0.04	0.27± 0.38	0.35± 0.49	0.33± 0.29	0.81± 0.12
9-nitrophenanthrene	0.58± 0.10	0.69± 0.29	1.07± 0.37	0.31± 0.44	0.65± 0.39	0.85± 0.01	0.38± 0.23
1,8-dinitronaphthalene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.10± 0.13	0.00± 0.00	0.00± 0.00
3-nitrophenanthrene	6.15± 0.71	3.59± 5.08	11.69± 3.33	3.45± 0.85	11.50± 9.50	20.91± 17.34	14.50± 7.62
2-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.40± 0.57	0.02± 0.03	0.00± 0.00
2-nitroanthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2-nitrofluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-nitrofluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
4-nitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-nitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2-nitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2,7-dinitrofluorene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2,7-dinitrofluoren-9-one	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7-nitrobenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6-nitrochrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

3-nitrobenzanthrone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,3-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,6-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,8-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6a+1e-nitrobenzpyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-nitrobenzo[e]pryene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-nitrobenzo[e]pryene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Table D19: Gas-phase nitro-PAH emissions for Vehicle #3

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	14.19± 11.97	0.00± 0.00	0.00± 0.00	17.33± 2.33	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-methyl-5-nitronaphthalene	0.47± 0.44	0.14± 0.02	0.54± 0.25	1.24± 0.73	0.45± 0.18	0.22± 0.01	0.73± 0.07
2-nitronaphthalene	1.83± 2.59	1.23± 0.30	2.81± 0.38	0.51± 0.30	3.16± 0.06	1.99± 0.06	2.91± 0.38
2-nitrobiphenyl	0.30± 0.22	0.43± 0.09	0.64± 0.01	0.27± 0.11	0.70± 0.09	0.55± 0.05	0.88± 0.22
2-methyl-4-nitronaphthalene	0.04± 0.05	0.28± 0.01	0.62± 0.14	0.00± 0.00	0.52± 0.09	0.63± 0.04	0.69± 0.12
1-methyl-4-nitronaphthalene	0.07± 0.10	0.25± 0.00	0.93± 0.16	0.14± 0.20	0.71± 0.11	0.55± 0.02	0.92± 0.22
1-methyl-6-nitronaphthalene	0.53± 0.74	3.73± 1.75	1.35± 0.07	0.54± 0.76	0.05± 0.07	1.57± 2.21	2.87± 0.97
3-nitrobiphenyl	0.08± 0.08	0.09± 0.08	0.07± 0.01	0.00± 0.00	0.13± 0.05	0.07± 0.01	0.10± 0.02
4-nitrobiphenyl	0.00± 0.00	0.17± 0.14	0.00± 0.00	0.00± 0.00	0.03± 0.04	0.00± 0.00	0.00± 0.00
1,3-dinitronaphthalene	0.00± 0.00	0.00± 0.00	0.15± 0.05	0.00± 0.00	0.05± 0.08	0.32± 0.07	0.13± 0.08
1,5-dinitronaphthalene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.02± 0.02	0.01± 0.01
5-nitroacenaphthene	0.00± 0.00	0.00± 0.00	0.04± 0.02	0.00± 0.00	0.05± 0.05	0.25± 0.35	0.00± 0.00
2-nitrofluorene	0.00± 0.00	0.00± 0.00	0.08± 0.05	0.00± 0.00	0.04± 0.01	0.11± 0.04	0.07± 0.10
4-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.08± 0.12	0.00± 0.00	0.18± 0.25	0.34± 0.04	0.21± 0.29
9-nitroanthracene	0.02± 0.03	1.40± 1.98	0.00± 0.00	0.00± 0.00	0.42± 0.31	0.63± 0.89	1.02± 1.44
9-nitrophenanthrene	0.00± 0.00	0.06± 0.08	1.62± 1.93	0.00± 0.00	0.93± 0.39	1.64± 0.43	3.35± 1.45
1,8-dinitronaphthalene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.01± 0.01	0.00± 0.00
3-nitrophenanthrene	0.81± 0.57	2.73± 3.75	0.60± 0.85	1.36± 1.04	1.66± 2.35	0.35± 0.49	0.00± 0.00
2-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2-nitroanthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

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2-nitrofluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.18± 0.09	0.16± 0.23	0.05± 0.07
3-nitrofluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
4-nitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-nitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.12± 0.17	0.00± 0.00	0.00± 0.00
2-nitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2,7-dinitrofluorene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2,7-dinitrofluoren-9-one	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7-nitrobenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6-nitrochrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-nitrobenzanthrone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,3-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,6-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,8-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6a+1e-nitrobenzpyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-nitrobenzo[e]pryene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-nitrobenzo[e]pryene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Table D20: Gas-phase nitro-PAH emissions for Vehicle #4

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	2.87± 1.40	1.34±N/A	6.55± 1.62	1.96± 1.23	2.26±N/A	6.22±N/A	3.06± 1.86
1-methyl-5-nitronaphthalene	0.18± 0.19	0.03± 0.02	0.23± 0.01	0.09± 0.07	0.03± 0.05	0.18± 0.22	0.12± 0.03
2-nitronaphthalene	1.40± 0.19	0.20± 0.02	0.66± 0.24	0.29± 0.11	0.22± 0.03	0.07±N/A	0.70± 0.19
2-nitrobiphenyl	0.13± 0.08	0.04± 0.00	0.05± 0.01	0.03± 0.00	0.03± 0.00	0.19± 0.24	0.08± 0.03
2-methyl-4-nitronaphthalene	0.34± 0.21	0.08± 0.00	0.22± 0.09	0.09± 0.05	0.08± 0.01	0.24± 0.30	0.13± 0.06
1-methyl-4-nitronaphthalene	0.27± 0.28	0.07± 0.02	0.14± 0.07	0.09± 0.05	0.07± 0.02	0.04±N/A	0.16± 0.07
1-methyl-6-nitronaphthalene	0.12± 0.12	0.04± 0.00	0.03± 0.00	0.03± 0.02	0.02± 0.01	0.01±N/A	0.09± 0.01
3-nitrobiphenyl	0.23± 0.20	0.09± 0.04	0.11± 0.04	0.08± 0.02	0.07± 0.00	0.20± 0.26	0.21± 0.13
4-nitrobiphenyl	0.14± 0.19	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.12± 0.17	0.00±N/A	0.14± 0.19
1,3-dinitronaphthalene	0.22± 0.12	0.12± 0.02	0.20± 0.01	0.17± 0.01	0.17± 0.01	0.06± 0.09	0.25± 0.06
1,5-dinitronaphthalene	0.00± 0.00	0.03± 0.02	0.02± 0.01	0.06± 0.06	0.00± 0.00	0.00±N/A	0.00±N/A

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5-nitroacenaphthene	0.08± 0.11	0.04± 0.01	0.05± 0.02	0.04± 0.02	0.04± 0.02	0.09± 0.12	0.12± 0.12
2-nitrofluorene	0.01± 0.01	0.01± 0.02	0.01± 0.01	0.01± 0.01	0.00± 0.00	0.04± 0.06	0.12± 0.12
4-nitrophenanthrene	0.00±N/A	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
9-nitroanthracene	0.25± 0.26	0.07± 0.04	0.12± 0.04	0.11± 0.07	0.10± 0.08	0.03±N/A	0.17± 0.11
9-nitrophenanthrene	0.01± 0.01	0.02± 0.03	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.29± 0.41	0.08± 0.12
1,8-dinitronaphthalene	0.02± 0.01	0.08± 0.10	0.04± 0.01	0.02± 0.00	0.02± 0.00	0.02± 0.02	0.46± 0.63
3-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2-nitrophenanthrene	0.00± 0.00	0.15± 0.21	0.44± 0.05	0.24± 0.33	0.00± 0.00	0.09±N/A	0.11± 0.15
2-nitroanthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.32± 0.46	0.00± 0.00	0.00±N/A	0.04± 0.06
2-nitrofluoranthene	0.03± 0.05	0.13± 0.08	0.11± 0.01	0.08± 0.02	0.10± 0.03	0.00±N/A	0.17± 0.23
3-nitrofluoranthene	0.00± 0.00	0.03± 0.05	0.01± 0.02	0.01± 0.01	0.00± 0.00	0.40± 0.57	0.11± 0.15
4-nitropyrene	0.00± 0.00	0.03± 0.04	0.01± 0.01	0.01± 0.01	0.00± 0.00	0.34± 0.48	0.09± 0.13
1-nitropyrene	0.39± 0.46	0.15± 0.04	0.08± 0.03	0.05± 0.03	0.11± 0.06	0.42±N/A	0.23± 0.18
2-nitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2,7-dinitrofluorene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00±N/A	0.00± 0.00	0.59± 0.34	0.26±N/A
2,7-dinitrofluoren-9-one	0.00± 0.00	0.00± 0.00	0.04± 0.06	0.11± 0.16	0.00± 0.00	0.22±N/A	0.00± 0.00
7-nitrobenz(a)anthracene	0.00± 0.00	0.06± 0.08	0.03± 0.04	0.00± 0.00	0.02± 0.03	0.00±N/A	0.22± 0.15
6-nitrochrysene	0.00± 0.00	0.03± 0.04	0.01± 0.01	0.00± 0.00	0.00± 0.00	0.11± 0.15	0.14± 0.20
3-nitrobenzanthrone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.10± 0.14
1,3-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,6-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,8-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6a+1e-nitrobenzpyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-nitrobenzo[e]pryene	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 1.23	N/A± 0.00
3-nitrobenzo[e]pryene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.87± 1.23	0.00± 0.00

Table D21: Gas-phase nitro-PAH emissions for Vehicle #5

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	5.09±N/A	0.84± 0.02	0.12± 0.17	0.93± 0.49	0.39± 0.20	0.60±N/A	0.18±N/A
1-methyl-5-nitronaphthalene	0.55± 0.12	0.12± 0.02	0.00± 0.00	0.14± 0.11	0.05± 0.01	0.29± 0.22	0.11± 0.10

2-nitronaphthalene	3.94±N/A	0.59± 0.04	0.09± 0.13	0.74± 0.44	0.28± 0.10	0.45±N/A	0.15±N/A
2-nitrobiphenyl	0.26± 0.19	0.14± 0.02	0.00± 0.00	0.09± 0.05	0.04± 0.01	0.14± 0.06	0.07± 0.10
2-methyl-4-nitronaphthalene	0.38± 0.24	0.16± 0.01	0.05± 0.07	0.13± 0.02	0.07± 0.02	0.16±N/A	0.27± 0.33
1-methyl-4-nitronaphthalene	0.42± 0.24	0.18± 0.03	0.05± 0.08	0.13± 0.03	0.06± 0.01	0.14± 0.05	0.17± 0.13
1-methyl-6-nitronaphthalene	0.17± 0.07	0.05± 0.02	0.02± 0.03	0.05± 0.02	0.04± 0.03	0.09±N/A	0.07± 0.07
3-nitrobiphenyl	0.49± 0.32	0.16± 0.02	0.06± 0.08	0.14± 0.02	0.07± 0.02	0.23± 0.10	0.18± 0.21
4-nitrobiphenyl	0.35±N/A	0.03± 0.04	0.03± 0.04	0.07± 0.03	0.03± 0.00	0.11±N/A	0.14± 0.20
1,3-dinitronaphthalene	0.25± 0.07	0.05± 0.07	0.06± 0.08	0.14± 0.02	0.13± 0.03	0.03± 0.04	0.13± 0.09
1,5-dinitronaphthalene	0.19± 0.03	0.08± 0.02	0.03± 0.04	0.05± 0.01	0.06± 0.01	0.08±N/A	0.05± 0.02
5-nitroacenaphthene	0.28± 0.11	0.12± 0.05	0.05± 0.07	0.09± 0.00	0.07± 0.02	0.07± 0.10	0.15± 0.22
2-nitrofluorene	0.12± 0.03	0.03± 0.00	0.02± 0.02	0.01± 0.00	0.02± 0.00	0.14± 0.12	0.11± 0.06
4-nitrophenanthrene	0.34± 0.45	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
9-nitroanthracene	0.44±N/A	0.27± 0.03	0.03± 0.05	0.22± 0.09	0.11± 0.07	0.30± 0.08	0.29± 0.21
9-nitrophenanthrene	0.11± 0.03	0.03± 0.00	0.01± 0.02	0.01± 0.02	0.02± 0.00	0.24± 0.27	0.02± 0.03
1,8-dinitronaphthalene	0.27± 0.04	0.09± 0.03	0.03± 0.04	0.03± 0.01	0.04± 0.01	0.24± 0.11	0.04± 0.05
3-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2-nitrophenanthrene	0.11± 0.16	0.00± 0.00	0.01± 0.02	0.00± 0.00	0.00± 0.00	0.05± 0.07	0.06± 0.08
2-nitroanthracene	0.17± 0.14	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.32± 0.45	0.00± 0.00
2-nitrofluoranthene	0.17± 0.02	0.04± 0.01	0.01± 0.02	0.03± 0.01	0.06± 0.01	0.05± 0.07	0.06± 0.00
3-nitrofluoranthene	0.24± 0.20	0.02± 0.01	0.01± 0.01	0.01± 0.01	0.02± 0.03	0.03± 0.04	0.07± 0.05
4-nitropyrene	0.08± 0.01	0.03± 0.00	0.01± 0.01	0.00± 0.01	0.02± 0.02	0.05± 0.07	0.01± 0.02
1-nitropyrene	0.19± 0.03	0.12± 0.01	0.04± 0.06	0.04± 0.00	0.09± 0.01	0.38± 0.35	0.17±N/A
2-nitropyrene	0.12± 0.02	0.00± 0.00	0.00± 0.00	0.03± 0.04	0.09± 0.12	0.00± 0.00	0.00± 0.00
2,7-dinitrofluorene	0.12± 0.17	0.07± 0.05	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.16± 0.15	0.00± 0.00
2,7-dinitrofluoren-9-one	0.03± 0.04	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.23± 0.32	0.01± 0.01
7-nitrobenz(a)anthracene	0.09± 0.00	0.03± 0.01	0.00± 0.00	0.01± 0.01	0.02± 0.03	0.23± 0.17	0.00± 0.00
6-nitrochrysene	0.08± 0.03	0.03± 0.01	0.01± 0.01	0.00± 0.00	0.03± 0.04	0.13± 0.07	0.00± 0.00
3-nitrobenzanthrone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.02± 0.03	0.00± 0.00
1,3-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,6-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

1,8-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6a+1e-nitrobenzpyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-nitrobenzo[e]pryene	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00
3-nitrobenzo[e]pryene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Table D22: Gas-phase nitro-PAH emissions for Vehicle #6

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	0.91± 0.20	2.11± 1.02	0.40± 0.14	0.86± 0.07	0.73± 0.50	0.87±N/A	0.65±N/A
1-methyl-5-nitronaphthalene	0.18± 0.05	0.15±N/A	0.10± 0.05	0.38± 0.08	0.13± 0.03	0.55± 0.42	0.23± 0.13
2-nitronaphthalene	0.37± 0.03	0.40± 0.23	0.24± 0.09	0.24± 0.12	0.26±N/A	0.22±N/A	0.36± 0.15
2-nitrobiphenyl	0.11± 0.04	0.12± 0.11	0.03± 0.01	0.08± 0.08	0.16± 0.16	0.22± 0.22	0.06± 0.02
2-methyl-4-nitronaphthalene	0.08± 0.02	0.15± 0.21	0.08± 0.02	0.12± 0.03	0.23± 0.16	0.12±N/A	0.15± 0.09
1-methyl-4-nitronaphthalene	0.12± 0.04	0.20± 0.18	0.09± 0.03	0.13± 0.02	0.25± 0.10	0.07± 0.09	0.19± 0.07
1-methyl-6-nitronaphthalene	0.03± 0.02	0.01± 0.02	0.03± 0.03	0.00± 0.01	0.06± 0.02	0.03±N/A	0.02± 0.01
3-nitrobiphenyl	0.07± 0.01	0.08± 0.05	0.07± 0.03	0.06± 0.00	0.22± 0.21	0.48± 0.55	0.08± 0.01
4-nitrobiphenyl	0.00± 0.00	0.00± 0.00	0.03± 0.05	0.00± 0.00	0.04± 0.06	0.04±N/A	0.13± 0.18
1,3-dinitronaphthalene	0.10± 0.05	0.07± 0.01	0.10± 0.01	0.06± 0.03	0.16± 0.06	0.02± 0.03	0.16± 0.05
1,5-dinitronaphthalene	0.03± 0.04	0.01± 0.02	0.04± 0.01	0.02± 0.01	0.02± 0.02	0.03±N/A	0.02± 0.02
5-nitroacenaphthene	0.03± 0.04	0.00± 0.00	0.06± 0.00	0.02± 0.02	0.19± 0.07	0.03± 0.04	0.09± 0.06
2-nitrofluorene	0.14± 0.06	0.16± 0.03	0.02± 0.01	0.10± 0.12	0.18± 0.24	0.40± 0.53	0.01± 0.01
4-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.11± 0.15
9-nitroanthracene	0.12± 0.03	0.09± 0.01	0.10± 0.04	0.10± 0.06	0.44± 0.32	0.13± 0.03	0.28± 0.14
9-nitrophenanthrene	0.08± 0.04	0.18± 0.01	0.01± 0.01	0.03± 0.04	0.09± 0.13	0.00± 0.00	0.01± 0.01
1,8-dinitronaphthalene	0.04± 0.03	0.03± 0.01	0.04± 0.01	0.03± 0.01	0.04± 0.02	0.18± 0.23	0.02± 0.01
3-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2-nitrophenanthrene	0.16± 0.15	0.05± 0.07	0.00± 0.00	0.09± 0.13	0.00± 0.00	0.00± 0.00	0.11± 0.15
2-nitroanthracene	0.35± 0.49	0.84± 0.52	0.00± 0.00	0.06± 0.09	0.00±N/A	0.00± 0.00	0.07± 0.09
2-nitrofluoranthene	0.02± 0.02	0.02± 0.03	0.05± 0.02	0.05± 0.07	0.02± 0.02	0.39± 0.53	0.05± 0.01
3-nitrofluoranthene	0.00± 0.00	0.00± 0.00	0.01± 0.01	0.01± 0.02	0.00± 0.00	0.34± 0.48	0.00± 0.00
4-nitropyrene	0.00± 0.00	0.00± 0.00	0.06± 0.01	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

1-nitropyrene	0.28± 0.25	0.36± 0.10	0.13±N/A	0.06± 0.09	0.20± 0.21	0.30± 0.25	0.04± 0.06
2-nitropyrene	0.00± 0.00	0.00± 0.00	0.06± 0.08	0.00± 0.00	0.00± 0.00	0.00±N/A	0.00± 0.00
2,7-dinitrofluorene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2,7-dinitrofluoren-9-one	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00±N/A	0.08± 0.11
7-nitrobenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6-nitrochrysene	0.00± 0.00	0.00± 0.00	0.01± 0.01	0.00± 0.00	0.00± 0.00	0.09± 0.12	0.01± 0.01
3-nitrobenzanthrone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,3-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,6-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,8-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6a+1e-nitrobenzpyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-nitrobenzo[e]pryene	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00
3-nitrobenzo[e]pryene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Table D23: Gas-phase nitro-PAH emissions for Vehicle #7

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	3.35± 1.80	1.97± 0.55	18.83± 4.12	10.84± 2.27	10.17± 7.11	2.59± 2.14	1.51± 0.27
1-methyl-5-nitronaphthalene	5.39± 4.72	2.27± 1.33	9.73±N/A	7.68± 0.83	7.14± 3.78	3.39± 2.76	0.82± 0.59
2-nitronaphthalene	0.66± 0.39	0.58± 0.04	6.98± 6.44	0.61±N/A	0.46±N/A	0.21± 0.08	0.41± 0.09
2-nitrobiphenyl	0.06± 0.00	0.05± 0.01	0.23± 0.15	0.14± 0.12	0.07± 0.03	0.03± 0.02	0.04± 0.02
2-methyl-4-nitronaphthalene	0.77± 0.59	0.32± 0.12	6.79± 2.88	4.20± 4.19	1.16± 0.60	0.49± 0.38	0.18± 0.07
1-methyl-4-nitronaphthalene	0.46± 0.29	0.18± 0.06	0.54±N/A	0.00±N/A	0.54±N/A	0.44± 0.34	0.12± 0.04
1-methyl-6-nitronaphthalene	0.00± 0.01	0.00± 0.00	0.00±N/A	0.00±N/A	0.01± 0.01	0.01± 0.00	0.01± 0.00
3-nitrobiphenyl	0.06± 0.00	0.04± 0.02	0.10±N/A	0.07±N/A	0.08± 0.01	0.04± 0.00	0.06± 0.01
4-nitrobiphenyl	0.01± 0.01	0.00± 0.00	0.00±N/A	0.00± 0.00	0.00± 0.00	0.02± 0.01	0.04± 0.00
1,3-dinitronaphthalene	0.03± 0.03	0.09± 0.06	0.03± 0.04	0.01± 0.01	0.04± 0.01	0.03± 0.00	0.03± 0.00
1,5-dinitronaphthalene	0.01± 0.01	0.02± 0.02	0.00±N/A	0.01±N/A	0.02± 0.02	0.02± 0.00	0.01± 0.00
5-nitroacenaphthene	0.01± 0.02	0.02± 0.03	0.00± 0.00	0.01± 0.02	0.04± 0.05	0.04± 0.01	0.05± 0.01
2-nitrofluorene	0.04± 0.05	0.16± 0.10	0.27± 0.16	0.18± 0.23	0.04± 0.02	0.01± 0.00	0.01± 0.00
4-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

9-nitroanthracene	0.10± 0.00	0.10± 0.05	0.04± 0.06	0.03± 0.04	0.13± 0.06	0.07± 0.01	0.10± 0.01
9-nitrophenanthrene	0.04± 0.04	0.06± 0.09	0.22± 0.16	0.00± 0.01	0.03± 0.00	0.02± 0.01	0.00± 0.00
1,8-dinitronaphthalene	0.01± 0.00	0.04± 0.02	0.14± 0.17	0.12± 0.16	0.04± 0.06	0.02± 0.01	0.01± 0.00
3-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2-nitrophenanthrene	0.05± 0.07	0.28± 0.05	0.05± 0.07	0.00± 0.00	0.03± 0.04	0.00± 0.00	0.00± 0.00
2-nitroanthracene	0.20± 0.28	0.36± 0.51	0.17± 0.23	0.00± 0.00	0.03± 0.04	0.00± 0.00	0.00± 0.00
2-nitrofluoranthene	0.01± 0.01	0.04± 0.05	0.00± 0.00	0.01± 0.01	0.03± 0.04	0.01± 0.01	0.00± 0.01
3-nitrofluoranthene	0.00± 0.00	0.20± 0.22	0.37± 0.52	0.00± 0.00	0.02± 0.03	0.00± 0.00	0.00± 0.00
4-nitropyrene	0.00± 0.00	0.05± 0.05	0.20± 0.28	0.00± 0.00	0.03± 0.04	0.01± 0.01	0.00± 0.00
1-nitropyrene	0.07± 0.02	0.28± 0.30	0.22± 0.13	0.02± 0.03	0.09± 0.01	0.03± 0.01	0.15± 0.14
2-nitropyrene	0.00± 0.00	0.10± 0.15	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2,7-dinitrofluorene	0.00± 0.00	0.02± 0.02	0.00± 0.00	0.00± 0.00	0.02± 0.03	0.01± 0.01	0.00± 0.00
2,7-dinitrofluoren-9-one	0.00± 0.00	0.00± 0.00	0.00±N/A	0.00±N/A	0.00± 0.00	0.00± 0.00	0.00± 0.00
7-nitrobenz(a)anthracene	0.00± 0.00	0.04± 0.06	0.00± 0.00	0.00± 0.00	0.03± 0.04	0.01± 0.01	0.00± 0.00
6-nitrochrysene	0.00± 0.00	0.02± 0.03	0.15± 0.22	0.00± 0.00	0.03± 0.04	0.00± 0.00	0.00± 0.00
3-nitrobenzanthrone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,3-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,6-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,8-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6a+1e-nitrobenzpyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-nitrobenzo[e]pryene	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00	N/A± 0.00
3-nitrobenzo[e]pryene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Table D24: Gas-phase nitro-PAH emissions for Vehicle #8

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	5.92± 3.46	5.00± 1.28	6.85± 3.39	13.76± 5.72	7.92± 8.19	5.13± 1.18	5.38± 0.52
1-methyl-5-nitronaphthalene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.65± 0.78	0.00± 0.00	0.24± 0.00
2-nitronaphthalene	4.01± 0.80	3.13± 0.33	5.13± 0.83	5.11± 1.13	2.31± 2.63	4.08± 0.44	0.69± 0.04
2-nitrobiphenyl	0.54± 0.15	0.89± 0.26	0.86± 0.70	0.86± 0.19	0.12± 0.12	1.34± 0.30	0.11± 0.04
2-methyl-4-nitronaphthalene	0.79± 0.42	0.75± 0.65	1.38± 0.83	1.11± 0.05	0.37± 0.44	0.82± 0.41	0.09± 0.00

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1-methyl-4-nitronaphthalene	0.54± 0.43	1.04± 0.13	1.10± 0.76	1.07± 0.05	0.37± 0.43	0.73± 0.21	0.21± 0.05
1-methyl-6-nitronaphthalene	0.31± 0.38	0.93± 0.28	1.05± 0.90	0.72± 0.05	0.61± 0.87	0.77± 0.37	1.08± 0.22
3-nitrobiphenyl	0.37± 0.12	0.29± 0.06	0.26± 0.03	0.21± 0.08	0.07± 0.07	0.28± 0.05	0.08± 0.03
4-nitrobiphenyl	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.29± 0.41	0.00± 0.00	0.39± 0.02
1,3-dinitronaphthalene	1.33± 0.25	1.45± 0.08	1.93± 0.11	0.92± 0.25	0.08± 0.04	1.75± 0.23	0.22± 0.17
1,5-dinitronaphthalene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.06± 0.08	0.00± 0.00	0.09± 0.02
5-nitroacenaphthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2-nitrofluorene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.07± 0.09	0.06± 0.11	0.16± 0.02
4-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
9-nitroanthracene	0.35± 0.20	0.17± 0.09	0.23± 0.11	0.11± 0.16	0.12± 0.07	0.12± 0.10	0.15± 0.02
9-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.04± 0.06	0.00± 0.00	0.08± 0.00
1,8-dinitronaphthalene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.03± 0.00	0.00± 0.00	0.03± 0.00
3-nitrophenanthrene	0.87± 1.51	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2-nitrophenanthrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
2-nitroanthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.30± 0.43	0.00± 0.00	0.18± 0.25
2-nitrofluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-nitrofluoranthene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
4-nitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-nitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.18± 0.12	0.00± 0.00	0.26± 0.14
2-nitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.97± 1.36
2,7-dinitrofluorene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.01± 0.01	0.00± 0.00	0.01± 0.01
2,7-dinitrofluoren-9-one	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
7-nitrobenz(a)anthracene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6-nitrochrysene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
3-nitrobenzanthrone	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,3-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,6-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1,8-dinitropyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
6a+1e-nitrobenzpyrene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00
1-nitrobenzo[e]pryene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	N/A±N/A	0.00± 0.00	N/A±N/A

3-nitrobenzo[e]pryene	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00	0.00± 0.00

Table D25: Particle-phase nitro-PAH emissions for Vehicle #1

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	0.00±0.00	0.03±0.02	0.08±0.05	0.01±0.01	0.00±0.00	0.12±0.07	0.01±0.02
1-methyl-5-nitronaphthalene	0.01±0.02	0.07±0.08	0.00±0.00	0.00±0.00	0.02±0.03	0.07±0.07	0.00±0.00
2-nitronaphthalene	0.01±0.01	0.05±0.01	0.04±0.02	0.02±0.01	0.00±0.00	0.02±0.00	0.02±0.00
2-nitrobiphenyl	0.03±0.00	0.03±0.04	0.03±0.03	0.02±0.01	0.00±0.00	0.02±0.02	0.03±0.00
2-methyl-4-nitronaphthalene	0.01±0.02	0.04±0.02	0.01±0.01	0.01±0.01	0.00±0.00	0.04±0.02	0.02±0.02
1-methyl-4-nitronaphthalene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1-methyl-6-nitronaphthalene	0.00±0.00	0.03±0.05	0.10±0.15	0.00±0.00	0.00±0.00	0.05±0.08	0.07±0.09
3-nitrobiphenyl	0.00±0.00	0.00±0.01	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.01	0.00±0.00
4-nitrobiphenyl	0.21±0.13	0.38±0.45	0.81±0.08	0.24±0.20	0.52±0.73	0.10±0.14	0.27±0.15
1,3-dinitronaphthalene	0.00±0.00	0.15±0.21	0.47±0.32	0.10±0.14	0.06±0.09	0.13±0.18	0.00±0.00
1,5-dinitronaphthalene	0.03±0.04	0.04±0.06	0.10±0.15	0.00±0.00	0.12±0.17	0.03±0.04	0.00±0.00
5-nitroacenaphthene	0.00±0.00	0.07±0.10	0.09±0.13	0.04±0.06	0.00±0.00	0.00±0.00	0.00±0.01
2-nitrofluorene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
4-nitrophenanthrene	0.21±0.02	0.07±0.00	0.12±0.06	0.14±0.07	0.16±0.06	0.09±0.01	0.06±0.07
9-nitroanthracene	0.00±0.00	0.00±0.00	0.06±0.03	0.00±0.00	0.03±0.04	0.00±0.00	0.00±0.00
9-nitrophenanthrene	0.00±0.00	0.30±0.42	4.16±5.88	1.15±1.62	0.23±0.33	0.00±0.00	0.01±0.02
1,8-dinitronaphthalene	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.06±0.02	0.02±0.03	0.00±0.00
3-nitrophenanthrene	0.53±0.04	0.38±0.08	0.60±0.21	0.58±0.09	0.29±0.41	0.46±0.08	0.13±0.09
2-nitrophenanthrene	0.05±0.07	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2-nitroanthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2-nitrofluoranthene	0.04±0.00	0.00±0.00	0.07±0.05	0.01±0.01	0.05±0.02	0.03±0.05	0.00±0.00
3-nitrofluoranthene	0.00±0.00	0.00±0.00	0.07±0.10	0.00±0.00	0.00±0.00	0.04±0.06	0.00±0.00
4-nitropyrene	0.00±0.00	0.06±0.00	0.12±0.03	0.00±0.00	0.03±0.05	0.00±0.00	0.00±0.00
1-nitropyrene	0.10±0.04	0.13±0.00	0.41±0.13	0.10±0.04	0.15±0.07	0.13±0.09	0.07±0.02
2-nitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2,7-dinitrofluorene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

2,7-dinitrofluoren-9-one	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7-nitrobenz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6-nitrochrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3-nitrobenzanthrone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,3-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,6-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,8-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6a+1e-nitrobenzpyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1-nitrobenzo[e]pryene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3-nitrobenzo[e]pryene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table D26: Particle-phase nitro-PAH emissions for Vehicle #2

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	0.04±0.06	0.03±0.00	0.03±0.05	0.00±0.00	0.04±0.00	0.04±0.01	0.11±0.00
1-methyl-5-nitronaphthalene	0.01±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.01	0.07±0.01
2-nitronaphthalene	0.02±0.03	0.02±0.03	0.10±0.01	0.03±0.01	0.03±0.01	0.03±0.02	0.02±0.01
2-nitrobiphenyl	0.00±0.00	0.05±0.02	0.09±0.02	0.02±0.03	0.04±0.01	0.02±0.02	0.02±0.02
2-methyl-4-nitronaphthalene	0.03±0.05	0.03±0.04	0.07±0.01	0.02±0.00	0.06±0.03	0.03±0.01	0.10±0.00
1-methyl-4-nitronaphthalene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1-methyl-6-nitronaphthalene	0.00±0.00	0.11±0.16	0.15±0.21	0.00±0.00	0.05±0.06	0.09±0.13	0.07±0.11
3-nitrobiphenyl	0.02±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00
4-nitrobiphenyl	0.85±0.28	0.28±0.40	2.33±0.04	0.09±0.12	0.12±0.17	0.22±0.31	0.35±0.22
1,3-dinitronaphthalene	0.23±0.33	0.62±0.03	0.24±0.35	0.53±0.46	0.24±0.04	0.18±0.25	0.01±0.01
1,5-dinitronaphthalene	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
5-nitroacenaphthene	0.11±0.05	0.04±0.00	0.34±0.48	0.00±0.00	0.02±0.03	0.10±0.02	0.00±0.01
2-nitrofluorene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.03	0.00±0.00
4-nitrophenanthrene	0.30±0.22	0.10±0.06	0.18±0.07	0.11±0.04	0.11±0.03	0.07±0.02	0.12±0.03
9-nitroanthracene	0.10±0.05	0.00±0.00	0.03±0.05	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
9-nitrophenanthrene	1.51±0.13	1.60±0.16	1.90±2.69	0.12±0.17	1.15±1.63	1.45±0.04	1.33±1.28
1,8-dinitronaphthalene	0.14±0.02	0.07±0.10	0.07±0.03	0.01±0.02	0.03±0.05	0.02±0.03	0.02±0.03

3-nitrophenanthrene	1.38±0.64	0.78±0.19	0.88±0.10	0.69±0.05	0.52±0.11	0.96±0.35	1.35±0.82
2-nitrophenanthrene	0.00±0.00	0.06±0.08	0.04±0.06	0.00±0.00	0.06±0.09	0.03±0.04	0.04±0.06
2-nitroanthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2-nitrofluoranthene	0.16±0.16	0.00±0.00	0.07±0.05	0.02±0.03	0.00±0.00	0.14±0.04	0.15±0.11
3-nitrofluoranthene	0.03±0.04	0.00±0.00	0.02±0.03	0.00±0.00	0.00±0.00	0.08±0.09	0.00±0.00
4-nitropyrene	0.16±0.04	0.04±0.06	0.09±0.02	0.05±0.08	0.03±0.04	0.03±0.05	0.00±0.00
1-nitropyrene	1.04±0.95	0.29±0.01	0.65±0.25	0.45±0.12	0.19±0.14	0.36±0.12	0.37±0.05
2-nitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2,7-dinitrofluorene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2,7-dinitrofluoren-9-one	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7-nitrobenz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6-nitrochrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3-nitrobenzanthrone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,3-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,6-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,8-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6a+1e-nitrobenzpyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1-nitrobenzo[e]pryene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3-nitrobenzo[e]pryene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table D27: Particle-phase nitro-PAH emissions for Vehicle #3

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	0.01±0.02	0.01±0.00	0.01±0.00	0.12±0.05	0.03±0.01	0.01±0.01	0.03±0.01
1-methyl-5-nitronaphthalene	0.01±0.01	0.00±0.00	0.00±0.00	0.03±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2-nitronaphthalene	0.03±0.03	0.01±0.01	0.02±0.00	0.11±0.02	0.03±0.01	0.03±0.00	0.04±0.01
2-nitrobiphenyl	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2-methyl-4-nitronaphthalene	0.02±0.03	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.01±0.01	0.00±0.00
1-methyl-4-nitronaphthalene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.08±0.12	0.05±0.08	0.00±0.00
1-methyl-6-nitronaphthalene	0.01±0.02	0.00±0.00	0.02±0.03	0.14±0.20	0.02±0.03	0.00±0.00	0.06±0.04
3-nitrobiphenyl	0.00±0.01	0.00±0.00	0.00±0.00	0.01±0.01	0.01±0.00	0.00±0.00	0.00±0.00

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4-nitrobiphenyl	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.01	0.18±0.25	0.00±0.00	0.00±0.00
1,3-dinitronaphthalene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.05±0.07	0.00±0.00	0.00±0.00
1,5-dinitronaphthalene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.05±0.07	0.00±0.00	0.00±0.00
5-nitroacenaphthene	0.00±0.01	0.03±0.02	0.00±0.00	0.02±0.03	0.01±0.02	0.00±0.00	0.00±0.00
2-nitrofluorene	0.00±0.00	0.00±0.00	0.00±0.01	0.08±0.11	0.00±0.00	0.00±0.00	0.00±0.00
4-nitrophenanthrene	0.03±0.00	0.01±0.01	0.02±0.00	0.14±0.06	0.04±0.02	0.05±0.01	0.04±0.04
9-nitroanthracene	0.03±0.01	0.00±0.00	0.02±0.03	0.10±0.00	0.02±0.02	0.00±0.01	0.05±0.05
9-nitrophenanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,8-dinitronaphthalene	0.02±0.01	0.05±0.02	0.02±0.00	0.02±0.01	0.01±0.01	0.01±0.01	0.01±0.01
3-nitrophenanthrene	0.10±0.03	0.15±0.01	0.65±0.60	0.54±0.57	0.20±0.07	0.23±0.07	0.97±1.10
2-nitrophenanthrene	0.02±0.03	0.03±0.01	0.07±0.02	0.00±0.00	0.08±0.04	0.01±0.01	0.03±0.04
2-nitroanthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2-nitrofluoranthene	0.00±0.00	0.05±0.04	0.00±0.00	0.00±0.00	0.01±0.02	0.00±0.00	0.03±0.04
3-nitrofluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
4-nitropyrene	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.02±0.02	0.02±0.02
1-nitropyrene	0.04±0.01	0.06±0.04	0.05±0.01	0.06±0.01	0.16±0.10	0.10±0.00	0.09±0.02
2-nitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2,7-dinitrofluorene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.04
2,7-dinitrofluoren-9-one	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7-nitrobenz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6-nitrochrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3-nitrobenzanthrone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,3-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,6-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,8-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6a+1e-nitrobenzpyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1-nitrobenzo[e]pryene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3-nitrobenzo[e]pryene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table D28: Particle-phase nitro-PAH emissions for Vehicle #4

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	0.06±0.04	0.09±0.00	0.28±0.13	0.33±0.36	0.31±0.21	0.09±N/A	0.11±0.09
1-methyl-5-nitronaphthalene	0.02±0.01	0.01±0.00	0.02±0.02	0.07±0.06	0.00±N/A	0.08±0.11	0.01±0.02
2-nitronaphthalene	0.06±0.04	0.07±0.02	0.08±0.09	0.29±0.29	0.21±0.06	0.28±0.33	0.08±0.04
2-nitrobiphenyl	0.02±0.01	0.02±0.00	0.02±0.01	0.09±0.12	0.05±0.07	0.14±0.20	0.06±0.06
2-methyl-4-nitronaphthalene	0.03±0.01	0.02±0.01	0.02±0.03	0.10±0.10	0.06±0.02	0.09±0.12	0.02±0.01
1-methyl-4-nitronaphthalene	0.03±0.01	0.03±0.00	0.04±0.02	0.12±0.13	0.44±0.54	0.20±0.19	0.07±0.05
1-methyl-6-nitronaphthalene	0.01±0.00	0.01±0.00	0.01±0.00	0.06±0.07	0.19±0.27	0.27±0.38	0.02±0.03
3-nitrobiphenyl	0.06±0.01	0.04±0.01	0.05±0.02	0.20±0.21	0.17±0.16	0.13±0.12	0.06±0.01
4-nitrobiphenyl	0.00±0.00	0.00±0.00	0.00±0.00	0.05±0.07	0.00±0.00	0.00±0.00	0.00±0.00
1,3-dinitronaphthalene	0.13±0.05	0.20±0.02	0.16±0.01	0.33±0.27	0.20±N/A	0.33±N/A	0.22±0.10
1,5-dinitronaphthalene	0.03±0.00	0.02±0.00	0.03±0.01	0.33±0.44	0.20±0.28	0.24±0.32	0.10±0.12
5-nitroacenaphthene	0.05±0.01	0.03±0.00	0.05±0.03	0.14±0.13	0.13±0.12	0.06±0.03	0.05±0.01
2-nitrofluorene	0.07±0.00	0.03±0.00	0.02±0.02	0.36±0.51	0.16±0.22	0.17±0.25	0.25±0.34
4-nitrophenanthrene	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
9-nitroanthracene	0.09±0.08	0.09±0.05	0.11±0.03	0.39±0.47	0.23±0.31	0.28±0.34	0.16±0.19
9-nitrophenanthrene	0.10±0.05	0.02±0.03	0.11±0.07	0.00±0.00	0.06±0.09	0.00±0.00	0.00±0.00
1,8-dinitronaphthalene	0.09±0.00	0.06±0.01	0.04±0.00	0.04±N/A	0.43±0.61	0.33±0.42	0.21±0.23
3-nitrophenanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2-nitrophenanthrene	0.06±0.08	0.03±0.04	0.03±0.05	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2-nitroanthracene	0.00±0.00	0.00±0.00	0.12±0.16	0.00±0.00	0.11±0.16	0.00±0.00	0.16±0.22
2-nitrofluoranthene	0.07±0.01	0.05±0.07	0.05±0.01	0.00±0.00	0.23±0.33	0.22±0.31	0.15±0.13
3-nitrofluoranthene	0.08±0.00	0.02±0.03	0.07±0.06	0.00±0.00	0.15±0.21	0.23±0.32	0.13±0.19
4-nitropyrene	0.04±0.01	0.01±0.01	0.05±0.05	0.00±0.00	0.16±0.22	0.11±0.16	0.08±0.08
1-nitropyrene	0.26±0.14	0.16±0.16	0.13±N/A	0.28±N/A	0.09±N/A	0.11±N/A	0.29±0.05
2-nitropyrene	0.00±0.00	0.00±N/A	0.00±0.00	0.00±N/A	0.00±N/A	0.00±N/A	0.00±0.00
2,7-dinitrofluorene	0.07±0.00	0.00±0.00	0.00±0.00	0.00±N/A	0.00±N/A	0.00±N/A	0.00±N/A
2,7-dinitrofluoren-9-one	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7-nitrobenz(a)anthracene	0.09±0.00	0.05±0.02	0.00±0.00	0.06±N/A	0.25±0.36	0.15±0.22	0.22±0.07
6-nitrochrysene	0.04±0.00	0.03±0.00	0.00±0.00	0.00±N/A	0.12±0.17	0.07±0.10	0.06±0.08

3-nitrobenzanthrone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±N/A	0.00±0.00	0.00±0.00	0.00±0.00
1,3-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,6-dinitropyrene	0.33±0.03	0.11±0.16	0.22±0.30	0.12±0.17	0.86±0.13	0.00±0.00	0.00±0.00
1,8-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6a+1e-nitrobenzpyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.33±0.47	0.08±0.11	0.00±0.00	0.00±0.00
1-nitrobenzo[e]pryene	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A
3-nitrobenzo[e]pryene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table D29: Particle-phase nitro-PAH emissions for Vehicle #5

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	0.06±0.04	0.14±0.07	0.22±0.10	0.23±0.00	0.31±0.33	0.13±0.03	0.11±0.09
1-methyl-5-nitronaphthalene	0.01±0.00	0.01±0.01	0.01±0.02	0.03±0.02	0.00±0.00	0.08±0.01	0.02±0.00
2-nitronaphthalene	0.05±0.02	0.12±0.08	0.16±0.02	0.17±0.03	0.34±0.37	0.13±0.02	0.11±0.10
2-nitrobiphenyl	0.02±0.01	0.02±0.01	0.05±0.02	0.06±0.05	0.03±0.04	0.02±0.03	0.03±0.01
2-methyl-4-nitronaphthalene	0.02±0.02	0.04±0.03	0.08±0.01	0.03±0.04	0.05±0.07	0.00±0.00	0.04±0.03
1-methyl-4-nitronaphthalene	0.03±0.01	0.05±0.02	0.12±0.02	0.09±0.04	0.08±0.05	0.11±0.04	0.04±0.02
1-methyl-6-nitronaphthalene	0.00±0.00	0.00±0.00	0.03±0.03	0.01±0.01	0.01±0.01	0.03±0.05	0.01±0.00
3-nitrobiphenyl	0.03±0.01	0.04±0.03	0.11±0.01	0.07±0.01	0.09±0.09	0.09±0.03	0.06±0.03
4-nitrobiphenyl	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,3-dinitronaphthalene	0.17±0.01	0.18±0.00	0.51±0.26	0.35±0.23	0.46±0.32	0.68±0.04	0.32±0.02
1,5-dinitronaphthalene	0.02±0.01	0.01±0.00	0.11±0.16	0.08±0.11	0.00±0.00	0.00±0.00	0.02±0.01
5-nitroacenaphthene	0.01±0.01	0.02±0.01	0.07±0.04	0.01±0.02	0.03±0.04	0.05±0.03	0.03±0.00
2-nitrofluorene	0.01±0.01	0.00±0.00	0.15±0.21	0.09±0.12	0.00±0.00	0.09±0.13	0.02±0.02
4-nitrophenanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.04±0.06	0.00±0.00	0.00±0.00	0.00±0.00
9-nitroanthracene	0.05±0.03	0.07±0.02	0.30±0.14	0.08±0.01	0.10±0.04	0.29±0.19	0.09±0.03
9-nitrophenanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.02
1,8-dinitronaphthalene	0.02±0.00	0.02±0.01	0.20±0.22	0.07±0.07	0.00±0.00	0.11±0.16	0.06±0.04
3-nitrophenanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2-nitrophenanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.04±0.06
2-nitroanthracene	0.00±0.00	0.00±0.00	0.00±N/A	0.00±0.00	0.00±0.00	0.00±0.00	0.13±0.19

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2-nitrofluoranthene	0.02±0.03	0.03±0.05	0.00±N/A	0.18±0.04	0.00±0.00	0.00±0.00	0.00±0.00
3-nitrofluoranthene	0.00±0.00	0.00±0.00	0.09±0.13	0.00±0.00	0.00±0.00	0.08±0.12	0.06±0.09
4-nitropyrene	0.00±0.00	0.00±0.00	0.07±0.10	0.00±0.00	0.00±0.00	0.00±0.00	0.04±0.06
1-nitropyrene	0.08±0.12	0.09±0.04	0.41±N/A	0.17±0.11	0.74±0.89	0.61±0.04	0.21±0.04
2-nitropyrene	0.00±0.00	0.00±0.00	0.00±N/A	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2,7-dinitrofluorene	0.00±0.00	0.00±0.00	0.00±N/A	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.02
2,7-dinitrofluoren-9-one	0.00±0.00	0.00±0.00	0.03±0.04	0.00±0.00	0.00±0.00	0.02±0.03	0.00±0.00
7-nitrobenz(a)anthracene	0.02±0.02	0.02±0.02	0.10±0.14	0.03±0.05	0.04±0.05	0.12±0.16	0.03±0.05
6-nitrochrysene	0.01±0.01	0.00±0.00	0.05±0.07	0.00±0.00	0.00±0.00	0.02±0.03	0.01±0.02
3-nitrobenzanthrone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,3-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,6-dinitropyrene	0.12±0.17	0.42±0.13	0.00±0.00	0.49±0.02	0.00±0.00	0.00±0.00	0.36±0.09
1,8-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6a+1e-nitrobenzpyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1-nitrobenzo[e]pryene	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A
3-nitrobenzo[e]pryene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.78±1.10	0.13±0.19	0.00±0.00

Table D30: Particle-phase nitro-PAH emissions for Vehicle #6

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	0.07±0.00	0.07±0.01	0.02±0.03	0.15±0.01	0.10±0.10	0.18±0.11	0.22±0.23
1-methyl-5-nitronaphthalene	0.01±0.02	0.01±0.02	0.01±0.01	0.02±0.00	0.02±0.01	0.01±0.01	0.03±0.01
2-nitronaphthalene	0.07±0.04	0.06±0.05	0.02±0.02	0.09±0.02	0.08±0.08	0.18±0.09	0.13±0.12
2-nitrobiphenyl	0.01±0.01	0.01±0.01	0.01±0.01	0.11±0.02	0.05±0.07	0.05±0.07	0.04±0.01
2-methyl-4-nitronaphthalene	0.02±0.03	0.02±0.02	0.00±0.00	0.05±0.00	0.02±0.03	0.04±0.06	0.04±0.06
1-methyl-4-nitronaphthalene	0.05±0.01	0.04±0.01	0.00±0.00	0.09±0.02	0.05±0.07	0.06±0.03	0.08±0.02
1-methyl-6-nitronaphthalene	0.00±0.00	0.01±0.00	0.00±0.00	0.01±0.01	0.01±0.01	0.02±0.01	0.04±0.01
3-nitrobiphenyl	0.04±0.03	0.05±0.01	0.01±0.01	0.06±0.03	0.04±0.05	0.10±0.03	0.10±0.02
4-nitrobiphenyl	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.12±0.01
1,3-dinitronaphthalene	0.32±0.10	0.25±0.04	0.21±0.01	0.31±0.01	0.33±0.16	0.30±0.03	0.22±0.11
1,5-dinitronaphthalene	0.04±0.04	0.00±0.01	0.00±0.00	0.07±0.01	0.05±0.07	0.00±0.00	0.13±0.04

5-nitroacenaphthene	0.01±0.02	0.02±0.02	0.00±0.00	0.02±0.01	0.02±0.02	0.04±0.02	0.17±0.06
2-nitrofluorene	0.05±0.07	0.00±0.00	0.00±0.00	0.11±0.02	0.08±0.11	0.00±0.00	0.29±0.09
4-nitrophenanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.08±0.11	0.00±0.00
9-nitroanthracene	0.10±0.03	0.12±0.03	0.00±0.00	0.23±0.05	0.19±0.24	0.27±0.15	0.24±0.00
9-nitrophenanthrene	0.17±0.20	0.03±0.00	0.00±0.00	0.01±0.02	0.00±0.00	0.02±0.03	0.21±0.12
1,8-dinitronaphthalene	0.06±0.05	0.02±0.00	0.00±0.00	0.09±0.02	0.04±0.05	0.01±0.01	0.40±0.13
3-nitrophenanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2-nitrophenanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.28±0.07
2-nitroanthracene	0.00±0.00	0.00±0.00	0.00±N/A	0.00±0.00	0.17±0.24	0.23±0.33	0.12±0.17
2-nitrofluoranthene	0.11±0.10	0.03±0.00	0.00±0.00	0.07±0.05	0.05±0.07	0.00±0.00	0.39±0.05
3-nitrofluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.03	0.00±0.00	0.00±0.00	0.61±0.04
4-nitropyrene	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.01	0.00±0.00	0.00±0.00	0.39±0.09
1-nitropyrene	0.22±0.06	0.11±0.02	0.08±0.02	0.28±0.01	0.42±0.50	0.42±0.12	0.71±0.14
2-nitropyrene	0.00±0.00	0.10±0.14	0.00±0.00	0.07±0.10	0.00±0.00	0.00±0.00	0.00±0.00
2,7-dinitrofluorene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.36±0.01
2,7-dinitrofluoren-9-one	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.04
7-nitrobenz(a)anthracene	0.00±0.00	0.03±0.05	0.00±0.00	0.00±0.00	0.02±0.02	0.00±0.00	0.65±0.29
6-nitrochrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.28±0.12
3-nitrobenzanthrone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,3-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,6-dinitropyrene	0.27±0.38	0.13±0.19	0.00±0.00	0.14±0.19	0.28±0.08	0.20±0.29	0.00±0.00
1,8-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6a+1e-nitrobenzpyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.10±0.14
1-nitrobenzo[e]pryene	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A
3-nitrobenzo[e]pryene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table D31: Particle-phase nitro-PAH emissions for Vehicle #7

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	0.06±0.00	0.05±0.02	0.06±0.02	0.13±0.04	0.16±N/A	0.05±0.06	0.06±0.04
1-methyl-5-nitronaphthalene	0.02±0.01	0.01±0.00	0.03±0.01	0.05±0.04	0.06±0.04	0.01±0.01	0.01±0.00

2-nitronaphthalene	0.05±0.01	0.04±0.02	0.04±0.00	0.08±0.04	0.10±N/A	0.04±0.06	0.06±0.05
2-nitrobiphenyl	0.02±0.00	0.02±0.01	0.03±0.02	0.04±0.04	0.04±N/A	0.01±0.01	0.02±0.01
2-methyl-4-nitronaphthalene	0.02±0.00	0.01±0.01	0.03±0.01	0.05±0.02	0.08±N/A	0.01±0.02	0.02±0.02
1-methyl-4-nitronaphthalene	0.02±0.00	0.02±0.01	0.03±0.00	0.05±0.02	0.07±N/A	0.02±0.02	0.03±0.02
1-methyl-6-nitronaphthalene	0.01±0.00	0.00±0.00	0.01±0.00	0.01±0.01	0.05±0.07	0.00±0.00	0.01±0.00
3-nitrobiphenyl	0.03±0.01	0.02±0.01	0.02±0.00	0.03±0.01	0.05±N/A	0.01±0.01	0.04±0.03
4-nitrobiphenyl	0.02±0.03	0.00±0.00	0.00±0.00	0.02±0.02	0.00±0.00	0.00±0.00	0.10±0.14
1,3-dinitronaphthalene	0.07±0.00	0.11±0.04	0.19±0.09	0.10±0.03	0.13±0.02	0.14±0.07	0.08±0.03
1,5-dinitronaphthalene	0.01±0.00	0.00±0.00	0.02±0.02	0.01±0.02	0.02±0.00	0.01±0.00	0.02±0.01
5-nitroacenaphthene	0.02±0.01	0.01±0.01	0.02±0.03	0.03±0.03	0.02±N/A	0.00±0.01	0.02±0.00
2-nitrofluorene	0.00±0.00	0.00±0.00	0.06±0.09	0.05±0.08	0.00±0.00	0.00±0.00	0.01±0.01
4-nitrophenanthrene	0.00±0.00	0.00±0.00	0.03±0.04	0.00±0.00	0.00±0.00	0.00±0.00	0.07±0.03
9-nitroanthracene	0.05±0.02	0.03±0.05	0.09±0.06	0.09±0.05	1.04±N/A	0.12±0.01	0.07±0.04
9-nitrophenanthrene	0.03±0.05	0.00±0.00	0.08±0.02	0.08±0.02	0.09±0.07	0.05±0.04	0.04±0.01
1,8-dinitronaphthalene	0.03±0.04	0.01±0.00	0.05±0.07	0.02±0.03	0.02±0.01	0.00±0.00	0.05±0.03
3-nitrophenanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2-nitrophenanthrene	0.00±0.00	0.00±0.00	0.02±0.03	0.00±0.00	0.00±0.00	0.00±0.00	0.04±0.05
2-nitroanthracene	0.07±0.10	0.00±0.00	0.00±0.00	0.04±0.06	0.10±0.14	0.00±0.00	0.00±0.00
2-nitrofluoranthene	0.00±0.00	0.02±0.00	0.04±0.06	0.00±0.00	0.09±0.09	0.00±0.00	0.06±0.02
3-nitrofluoranthene	0.04±0.06	0.00±0.00	0.06±0.09	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.02
4-nitropyrene	0.01±0.02	0.00±0.00	0.05±0.07	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.01
1-nitropyrene	0.11±0.01	0.07±0.02	0.15±0.15	0.13±0.11	0.04±0.01	0.02±0.00	0.08±0.01
2-nitropyrene	1.05±1.49	0.00±0.00	0.26±0.37	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2,7-dinitrofluorene	0.00±N/A	0.00±0.00	0.02±0.04	0.01±0.02	0.00±0.00	0.00±0.00	0.06±0.08
2,7-dinitrofluoren-9-one	0.00±0.00	0.00±0.00	0.02±0.03	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
7-nitrobenz(a)anthracene	0.09±0.12	0.00±0.00	0.08±0.11	0.03±0.04	0.04±0.06	0.00±0.00	0.03±0.02
6-nitrochrysene	0.00±0.00	0.00±0.00	0.03±0.05	0.01±0.02	0.00±0.00	0.00±0.00	0.02±0.01
3-nitrobenzanthrone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,3-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.04	0.00±0.00	0.00±0.00	0.00±0.00
1,6-dinitropyrene	0.16±0.03	0.21±0.05	0.12±0.17	0.11±0.15	0.39±0.04	0.33±0.08	0.35±0.01

1,8-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
6a+1e-nitrobenzpyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1-nitrobenzo[e]pryene	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A	N/A±N/A
3-nitrobenzo[e]pryene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table D32: Particle-phase nitro-PAH emissions for Vehicle #8

Component (ng/mile)	A	B	C	D	E	F	G
1-nitronaphthalene	0.26±0.34	0.00±0.00	0.00±0.00	0.29±0.41	0.10±0.03	0.00±0.00	0.10±0.01
1-methyl-5-nitronaphthalene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.01±0.01
2-nitronaphthalene	0.05±0.10	0.00±0.00	0.00±0.00	0.13±0.18	0.07±0.05	0.00±0.00	0.09±0.00
2-nitrobiphenyl	0.23±0.40	0.00±0.00	0.00±0.00	0.00±0.00	0.04±0.00	0.00±0.00	0.05±0.01
2-methyl-4-nitronaphthalene	0.05±0.09	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.01	0.00±0.00	0.03±0.00
1-methyl-4-nitronaphthalene	0.00±0.00	0.00±0.00	0.05±0.09	0.00±0.00	0.05±0.01	0.00±0.00	0.04±0.01
1-methyl-6-nitronaphthalene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.01±0.00
3-nitrobiphenyl	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.00	0.00±0.00	0.04±0.01
4-nitrobiphenyl	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.13±0.18
1,3-dinitronaphthalene	0.24±0.42	0.14±0.11	0.00±0.00	0.52±0.43	0.30±0.07	0.00±0.00	0.22±0.06
1,5-dinitronaphthalene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.00	0.00±0.00	0.01±0.01
5-nitroacenaphthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.04±0.01	0.00±0.00	0.04±0.03
2-nitrofluorene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.12±0.02	0.00±0.00	0.04±0.06
4-nitrophenanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.06±0.08
9-nitroanthracene	0.09±0.16	0.15±0.14	0.00±0.00	0.00±0.00	0.10±0.01	0.11±0.18	0.13±0.02
9-nitrophenanthrene	0.04±0.06	0.04±0.08	0.00±0.00	0.00±0.00	0.04±0.01	0.00±0.00	0.02±0.03
1,8-dinitronaphthalene	0.30±0.22	0.22±0.31	0.08±0.13	0.61±0.86	0.08±0.02	0.13±0.22	0.03±0.01
3-nitrophenanthrene	0.00±0.00	0.17±0.05	0.06±0.11	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2-nitrophenanthrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.05±0.07
2-nitroanthracene	0.19±0.32	0.00±0.00	0.00±0.00	0.26±0.37	0.00±0.00	0.00±0.00	0.00±0.00
2-nitrofluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.07±0.02	0.00±0.00	0.08±0.00
3-nitrofluoranthene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.04±0.06	0.00±0.00	0.03±0.03
4-nitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.04±0.01	0.00±0.00	0.00±0.01

1-nitropyrene	0.24±0.03	0.27±0.09	0.00±0.00	0.12±0.17	0.22±0.05	0.00±0.00	0.17±0.04
2-nitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2,7-dinitrofluorene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2,7-dinitrofluoren-9-one	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01
7-nitrobenz(a)anthracene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.04±0.06	0.00±0.00	0.02±0.01
6-nitrochrysene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3-nitrobenzanthrone	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,3-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1,6-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.20±0.28
1,8-dinitropyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.06±0.09
6a+1e-nitrobenzpyrene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1-nitrobenzo[e]pryene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	N/A±N/A	0.00±0.00	N/A±N/A
3-nitrobenzo[e]pryene	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table D33: Gas-phase PAH emissions during regeneration emissions testing for Vehicle #1 and Vehicle #3 over the HWFET

Component (ng/mile)	**Vehicle #1**			**Vehicle #3**		
	Baseline HWFET	Federal ULSD	Fed/SME-20	Baseline HWFET	Federal ULSD	Fed/SME-20
Naphthalene	160.83	141.29 ± 199.82	796.09 ± 118.76	1148.59	709.91 ± 110.93	2201.62 ± 423.07
Quinoline	0.00	2.98 ± 4.22	2.20 ± 0.08	0.00	12.03 ± 11.92	4.41 ± 6.23
2-methylnaphthalene	55.10	131.07 ± 21.65	280.08 ± 7.55	213.19	178.93 ± 118.41	437.46 ± 279.80
1-methylnaphthalene	45.31	77.09 ± 21.04	138.49 ± 12.92	115.81	76.26 ± 64.19	240.79 ± 180.21
Biphenyl	12.59	137.23 ± 31.80	196.52 ± 111.16	110.54	386.43 ± 102.57	401.33 ± 305.22

2-methylbiphenyl	9048.16	4946.48 ± 1990.22	3837.52 ± 47.35	9989.33	8845.36 ± 3338.79	12814.00 ± 5523.52
2,6+2,7-dimethylnaphthalene	0.00	0.00 ± 0.00	114.63 ± 31.51	115.81	94.66 ± 53.81	144.98 ± 103.01
1,3+1,6+1,7dimethylnaphth	0.00	11.98 ± 16.95	189.92 ± 33.32	201.08	161.70 ± 132.61	259.93 ± 183.95
1,4+1,5+2,3-dimethylnaphth	6.15	14.39 ± 20.35	65.95 ± 33.21	51.06	55.31 ± 36.74	76.11 ± 51.52
Acenaphthylene	0.00	2.55 ± 3.61	3.22 ± 4.55	7.90	4.15 ± 5.86	3.89 ± 5.50
1,2-dimethylnaphthalene	0.00	4.74 ± 6.70	12.92 ± 15.08	15.79	10.87 ± 8.09	10.37 ± 14.67
1,8-dimethylnaphthalene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Acenaphthene	0.00	11.79 ± 11.62	20.89 ± 8.15	0.00	4.70 ± 6.65	30.34 ± 42.91
3-methylbiphenyl	2195.61	702.07 ± 992.88	1218.04 ± 70.68	5375.51	3802.33 ± 1348.48	6321.97 ± 2873.64
4-methylbiphenyl	1149.55	396.53 ± 243.45	634.69 ± 137.64	2279.27	1844.64 ± 622.45	3073.37 ± 1089.95
1+2ethylnaphthalene	192.15	174.62 ± 54.39	242.55 ± 15.12	30.00	36.34 ± 24.46	19.97 ± 28.24
1-ethyl-2-methylnaphthalene	4.75	6.49 ± 9.18	36.20 ± 29.81	260.56	249.82 ± 28.77	338.41 ± 86.19
2,3,5+I-trimethylnaphthalene	0.00	0.00 ± 0.00	140.66 ± 68.33	50.01	26.98 ± 12.68	62.14 ± 47.80
B-trimethylnaphthalene	0.00	0.00 ± 0.00	120.61 ± 102.31	101.07	69.23 ± 60.06	76.12 ± 55.18
A-trimethylnaphthalene	1.40	0.00 ± 0.00	148.99 ± 94.66	106.33	66.46 ± 56.15	114.96 ± 88.25
C-trimethylnaphthalene	2.80	0.00 ± 0.00	130.65 ± 66.46	95.80	79.52 ± 45.51	81.29 ± 55.20
2-ethyl-1-methylnaphthalene	0.00	0.00 ± 0.00	7.02 ± 6.90	6.32	44.79 ± 63.34	0.00 ± 0.00
E-trimethylnaphthalene	0.00	2.63 ± 3.72	68.35 ± 39.78	44.74	29.74 ± 16.59	56.96 ± 40.47
2,4,5-trimethylnaphthalene	7.55	2.98 ± 4.22	3.73 ± 2.09	0.00	17.56 ± 19.74	32.14 ± 40.36
F-trimethylnaphthalene	0.00	0.00 ± 0.00	65.64 ± 50.97	45.80	33.38 ± 13.00	52.82 ± 40.45
Fluorene	70.48	38.97 ± 55.11	216.84 ± 19.06	55.27	81.31 ± 53.14	207.14 ± 158.12
1,4,5-trimethylnaphthalene	0.00	1.76 ± 2.48	6.20 ± 4.22	6.32	6.21 ± 7.22	14.00 ± 18.34
J-trimethylnaphthalene	0.00	0.00 ± 0.00	14.17 ± 2.71	1.05	6.41 ± 0.33	1.03 ± 0.00
A-Methylfluorene	10.35	8.25 ± 11.67	46.92 ± 44.97	0.00	2.76 ± 3.91	5.19 ± 7.33
B-Methylfluorene	0.00	5.66 ± 4.40	7.93 ± 4.71	3.68	0.00 ± 0.00	4.41 ± 6.23
1-Methylfluorene	0.00	0.86 ± 0.22	22.30 ± 16.98	5.26	2.76 ± 3.91	2.59 ± 3.67
9-fluorenone	55.10	193.63 ± 131.76	4.34 ± 6.14	52.64	305.59 ± 68.30	282.21 ± 209.64
Dibenzothiophene	0.00	0.35 ± 0.50	2.24 ± 2.30	0.00	5.43 ± 4.05	3.89 ± 5.50
Phenanthrene	46.15	204.23 ± 76.06	388.59 ± 33.04	74.75	175.98 ± 65.49	166.64 ± 81.18
Anthracene	0.00	4.37 ± 4.74	21.00 ± 1.49	5.26	5.53 ± 7.82	0.00 ± 0.00

Xanthone	51.74	2411.82 ± 1481.61	1210.37 ± 479.41	7.90	70.06 ± 29.95	42.79 ± 60.51
1,4-Naphthoquinone	2.80	1.76 ± 2.48	7.73 ± 6.39	8.95	11.84 ± 4.37	3.62 ± 0.02
Acenaphthenequinone	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylphenanthrene	1.40	10.93 ± 11.85	74.94 ± 21.80	15.79	26.88 ± 8.90	12.93 ± 3.71
2-methylphenanthrene	0.56	11.39 ± 14.67	88.17 ± 19.12	31.58	40.51 ± 20.91	15.53 ± 7.38
Perinaphthenone	41.12	81.17 ± 37.62	13.15 ± 1.76	0.00	6.08 ± 8.60	6.20 ± 0.03
2-methylanthracene	0.00	2.15 ± 0.56	9.38 ± 1.89	0.00	2.76 ± 3.91	0.00 ± 0.00
4,5-methylenephenanthrene	0.00	7.02 ± 9.93	9.34 ± 4.11	8.95	4.70 ± 6.65	1.82 ± 2.57
9-methylphenanthrene	0.00	15.70 ± 13.54	44.51 ± 2.89	5.26	27.07 ± 16.45	12.95 ± 11.03
1-methylphenanthrene	1.96	13.54 ± 14.11	24.49 ± 18.61	7.90	40.61 ± 24.68	18.11 ± 7.39
Anthrone	5.59	8.78 ± 12.41	7.81 ± 1.95	22.11	3.83 ± 3.96	8.80 ± 3.70
9-methylanthracene	1.96	3.01 ± 0.79	3.81 ± 2.35	3.68	3.74 ± 0.19	1.82 ± 2.57
Anthraquinone	5.59	21.86 ± 23.70	39.22 ± 0.85	0.00	24.31 ± 12.54	2.59 ± 3.67
A-dimethylphenanthrene	1.96	1.23 ± 1.74	8.48 ± 0.30	0.00	1.38 ± 1.95	0.00 ± 0.00
B-dimethylphenanthrene	0.56	2.11 ± 2.98	8.36 ± 6.37	18.42	21.45 ± 4.86	25.82 ± 10.85
1,7-dimethylphenanthrene	1.96	3.01 ± 0.79	11.70 ± 4.85	6.32	14.70 ± 12.06	1.03 ± 0.00
3,6-dimethylphenanthrene	2.80	1.76 ± 2.48	3.14 ± 0.11	0.00	2.67 ± 0.14	1.30 ± 1.83
D-dimethylphenanthrene	0.00	5.66 ± 4.40	12.52 ± 1.78	0.00	4.15 ± 5.86	1.30 ± 1.83
E-dimethylphenanthrene	0.00	9.57 ± 6.32	3.14 ± 0.11	1.05	1.07 ± 0.05	0.52 ± 0.73
C-dimethylphenanthrene	0.56	59.25 ± 46.28	29.12 ± 14.33	6.32	11.93 ± 8.15	6.20 ± 0.03
Fluoranthene	9.79	42.36 ± 41.87	48.83 ± 10.58	16.84	55.02 ± 25.41	5.70 ± 8.07
Pyrene	25.17	149.38 ± 77.22	78.74 ± 16.06	3.68	32.35 ± 45.75	4.41 ± 6.23
9-Anthraaldehyde	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	21.35 ± 1.09	5.19 ± 7.33
Retene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
benzo(a)fluorene	0.00	0.00 ± 0.00	1.61 ± 2.28	0.00	2.76 ± 3.91	0.00 ± 0.00
benzo(b)fluorene	0.00	1.76 ± 2.48	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
5-methylchrysene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
B-MePy/MeFl	0.00	0.00 ± 0.00	1.13 ± 1.59	0.00	0.00 ± 0.00	0.00 ± 0.00
1-MeFl+C-MeFl/Py	0.00	1.23 ± 1.74	0.00 ± 0.00	0.00	5.34 ± 0.27	2.59 ± 3.67
1+3-methylfluoranthene	0.00	1.23 ± 1.74	1.13 ± 1.59	2.63	1.38 ± 1.95	0.00 ± 0.00

4-methylpyrene	0.00	1.23 ± 1.74	3.73 ± 2.09	3.68	0.00 ± 0.00	0.00 ± 0.00
C-MePy/MeFl	0.00	2.98 ± 4.22	1.07 ± 1.52	0.00	1.80 ± 2.55	0.00 ± 0.00
D-MePy/MeFl	0.00	1.23 ± 1.74	1.13 ± 1.59	0.00	1.94 ± 2.74	0.00 ± 0.00
1-methylpyrene	1.40	1.27 ± 1.80	3.10 ± 2.11	0.00	5.34 ± 0.27	0.00 ± 0.00
Benzonaphthothiophene	0.00	0.86 ± 0.22	0.32 ± 0.46	1.05	0.00 ± 0.00	0.00 ± 0.00
benzo(c)phenanthrene	1.40	0.00 ± 0.00	2.30 ± 3.25	0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(ghi)fluoranthene	0.00	2.15 ± 0.56	0.77 ± 1.08	3.68	4.37 ± 6.19	0.00 ± 0.00
9-phenylanthracene	0.00	4.31 ± 1.12	0.00 ± 0.00	0.00	2.76 ± 3.91	0.00 ± 0.00
6-methylchrysene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Cyclopenta(c,d)pyrene	0.00	3.01 ± 0.79	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Benz(a)anthracene	0.00	1.23 ± 1.74	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Chrysene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Benzanthrone	0.00	4.31 ± 1.12	1.61 ± 2.28	0.00	0.55 ± 0.78	0.52 ± 0.73
Benz(a)anthracene-7,12-dione	2.80	6.06 ± 1.36	1.61 ± 2.28	0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylchrysene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
7-methylbenz(a)anthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
7,12-dimethylbenz(a)anthracene	0.00	57.55 ± 26.79	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(b)fluoranthene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(j)fluoranthene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(k)fluoranthene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(a)fluoranthene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
BeP	0.00	1.78 ± 2.52	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
BaP	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Perylene	1.40	1.27 ± 1.80	0.80 ± 1.14	0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylcholanthrene	0.56	5.96 ± 7.44	0.63 ± 0.02	5.26	5.15 ± 7.28	2.58 ± 3.64
7-methylbenzo(a)pyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	2.57 ± 3.64	0.00 ± 0.00
9,10-dihydrobenzo(a)pyrene-7(8H)-one	1.96	4.77 ± 1.70	1.13 ± 1.59	0.00	2.57 ± 3.64	0.00 ± 0.00
Indeno[123-cd]fluoranthene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Indeno[123-cd]pyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ac)anthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00

Dibenzo(ah+ac)anthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ah)anthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,j)anthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(b)chrysene	0.00	33.94 ± 14.74	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Picene	0.00	0.00 ± 0.00	0.00 ± 0.00	1.05	0.51 ± 0.73	0.52 ± 0.73
Benzo(ghi)perylene	0.00	1.78 ± 2.52	1.07 ± 1.52	1.05	0.55 ± 0.78	0.52 ± 0.73
Anthanthrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Triphenylene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,l)pyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Coronene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,e)pyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,i)pyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,h)pyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(b,k)fluoranthene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00

Table D34: Particle-phase PAH emissions during regeneration emissions testing for Vehicle #1 and Vehicle #3 over the HWFET

Component (ng/mile)	**Vehicle #1**			**Vehicle #3**		
	Baseline HWFET	Federal ULSD	Fed/SME-20	Baseline HWFET	Federal ULSD	Fed/SME-20
Naphthalene	27.13	20.24 ± 0.40	0.00 ± 0.00	0.00	5.76 ± 1.75	39.85 ± 17.16
Quinoline	0.00	7.79 ± 11.01	7.14 ± 1.52	0.00	3.00 ± 4.24	7.06 ± 9.20
2-methylnaphthalene	42.75	29.55 ± 10.84	0.00 ± 0.00	0.00	13.95 ± 0.58	22.01 ± 14.10
1-methylnaphthalene	18.76	17.83 ± 3.18	4.62 ± 3.85	0.00	0.10 ± 0.14	9.81 ± 5.90
Biphenyl	2.02	1.85 ± 2.62	0.74 ± 0.60	0.00	0.36 ± 0.51	5.00 ± 5.74
2-methylbiphenyl	3.23	9.46 ± 11.47	12.20 ± 5.60	0.00	0.00 ± 0.00	0.00 ± 0.00
2,6+2,7-dimethylnaphthalene	9.10	4.76 ± 5.21	1.54 ± 0.14	0.00	4.56 ± 0.16	4.75 ± 2.03
1,3+1,6+1,7dimethylnaphth	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
1,4+1,5+2,3-dimethylnaphth	0.00	2.39 ± 3.39	0.00 ± 0.00	18.58	13.88 ± 19.63	34.68 ± 3.60
Acenaphthylene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
1,2-dimethylnaphthalene	3.36	2.20 ± 1.27	0.66 ± 0.94	0.00	7.37 ± 3.79	3.45 ± 1.33

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1,8-dimethylnaphthalene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	2.20 ± 3.12	0.98 ± 1.38
Acenaphthene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylbiphenyl	0.00	0.00 ± 0.00	4.75 ± 4.04	0.00	35.13 ± 0.91	12.74 ± 18.02
4-methylbiphenyl	0.00	1.44 ± 2.03	1.85 ± 1.93	0.00	20.40 ± 1.44	4.49 ± 6.34
1+2ethylnaphthalene	41.37	19.17 ± 27.12	52.68 ± 5.13	0.00	0.00 ± 0.00	0.00 ± 0.00
1-ethyl-2-methylnaphthalene	0.00	0.00 ± 0.00	2.36 ± 0.41	0.00	0.00 ± 0.00	0.00 ± 0.00
2,3,5+I-trimethylnaphthalene	0.00	3.13 ± 4.43	2.88 ± 0.38	0.00	0.00 ± 0.00	0.00 ± 0.00
B-trimethylnaphthalene	5.98	10.51 ± 8.55	5.81 ± 0.88	0.90	5.59 ± 2.92	1.95 ± 0.25
A-trimethylnaphthalene	0.00	0.00 ± 0.00	0.75 ± 0.24	0.00	4.75 ± 1.05	0.48 ± 0.26
C-trimethylnaphthalene	0.94	0.70 ± 0.99	0.18 ± 0.25	0.00	0.00 ± 0.00	0.00 ± 0.00
2-ethyl-1-methylnaphthalene	0.00	0.00 ± 0.00	6.10 ± 7.35	2.08	0.72 ± 1.02	0.00 ± 0.00
E-trimethylnaphthalene	0.00	0.00 ± 0.00	4.09 ± 2.57	0.00	0.00 ± 0.00	0.00 ± 0.00
2,4,5-trimethylnaphthalene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	4.24 ± 0.45	0.45 ± 0.36
F-trimethylnaphthalene	2.92	1.77 ± 2.51	1.04 ± 1.47	0.00	0.00 ± 0.00	0.00 ± 0.00
Fluorene	0.00	0.00 ± 0.00	0.00 ± 0.00	2.75	0.79 ± 0.85	1.21 ± 1.04
1,4,5-trimethylnaphthalene	2.10	0.00 ± 0.00	8.15 ± 2.94	5.96	29.32 ± 7.11	7.88 ± 7.55
J-trimethylnaphthalene	0.00	0.00 ± 0.00	1.58 ± 2.23	0.00	0.00 ± 0.00	0.00 ± 0.00
A-Methylfluorene	0.00	1.80 ± 2.55	0.90 ± 0.68	4.73	3.31 ± 2.48	4.54 ± 1.06
B-Methylfluorene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.98 ± 1.39
1-Methylfluorene	0.00	0.00 ± 0.00	1.92 ± 2.17	1.46	3.58 ± 0.63	0.00 ± 0.00
9-fluorenone	0.00	17.40 ± 3.13	10.13 ± 0.51	1.19	5.72 ± 1.38	28.20 ± 1.39
Dibenzothiophene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Phenanthrene	0.72	11.28 ± 3.43	14.27 ± 2.27	0.12	9.30 ± 0.64	27.08 ± 16.71
Anthracene	0.00	0.00 ± 0.00	0.93 ± 0.60	1.19	1.18 ± 1.56	4.92 ± 3.53
Xanthone	13.28	985.26 ± 337.47	209.50 ± 13.43	8.40	9.30 ± 2.93	8.95 ± 0.27
1,4-Naphthoquinone	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Acenaphthenequinone	0.00	0.00 ± 0.00	0.00 ± 0.00	8.60	1.92 ± 1.71	6.18 ± 3.56
3-methylphenanthrene	0.00	0.13 ± 0.19	3.85 ± 0.19	2.69	3.31 ± 0.27	7.92 ± 3.15
2-methylphenanthrene	0.53	2.55 ± 3.61	11.07 ± 4.89	3.19	4.82 ± 0.78	9.96 ± 4.24
Perinaphthenone	8.43	0.00 ± 0.00	17.71 ± 0.79	0.00	40.47 ± 24.62	0.00 ± 0.00

2-methylanthracene	0.00	0.00 ± 0.00	0.13 ± 0.19	0.00	0.00 ± 0.00	5.27 ± 6.90
4,5-methylenephenanthrene	0.00	0.00 ± 0.00	0.00 ± 0.00	5.40	4.74 ± 0.74	3.64 ± 1.04
9-methylphenanthrene	0.00	0.00 ± 0.00	3.94 ± 0.68	0.61	2.85 ± 1.94	3.87 ± 1.71
1-methylphenanthrene	0.00	3.24 ± 4.59	6.12 ± 2.15	1.01	2.49 ± 1.83	4.86 ± 1.29
Anthrone	0.00	0.00 ± 0.00	0.00 ± 0.00	12.93	9.28 ± 13.13	0.00 ± 0.00
9-methylanthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Anthraquinone	2.33	31.45 ± 0.02	20.21 ± 0.98	0.00	0.00 ± 0.00	10.76 ± 9.82
A-dimethylphenanthrene	0.00	0.00 ± 0.00	0.00 ± 0.00	3.78	3.30 ± 2.06	7.42 ± 2.27
B-dimethylphenanthrene	0.00	0.00 ± 0.00	5.59 ± 1.02	2.38	1.56 ± 0.60	3.63 ± 1.04
1,7-dimethylphenanthrene	0.00	0.00 ± 0.00	1.47 ± 2.08	1.00	3.49 ± 0.20	6.61 ± 1.23
3,6-dimethylphenanthrene	0.00	0.00 ± 0.00	0.68 ± 0.45	2.08	0.30 ± 0.42	4.91 ± 0.30
D-dimethylphenanthrene	3.26	0.00 ± 0.00	4.71 ± 0.97	2.22	6.21 ± 0.70	7.70 ± 1.39
E-dimethylphenanthrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.46 ± 0.64
C-dimethylphenanthrene	0.00	0.00 ± 0.00	4.94 ± 0.77	5.75	6.59 ± 0.86	7.09 ± 10.03
Fluoranthene	0.00	17.58 ± 5.74	6.86 ± 4.24	1.96	10.04 ± 0.55	38.14 ± 9.17
Pyrene	0.00	27.89 ± 12.16	15.99 ± 6.63	0.00	3.15 ± 4.46	54.73 ± 18.86
9-Anthraaldehyde	0.00	0.00 ± 0.00	2.41 ± 3.41	0.00	0.00 ± 0.00	0.00 ± 0.00
Retene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.08 ± 0.11	0.00 ± 0.00
benzo(a)fluorene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.27 ± 0.38	0.88 ± 1.25
benzo(b)fluorene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.41 ± 0.58	0.79 ± 0.36
5-methylchrysene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
B-MePy/MeFl	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	2.84 ± 1.93	1.21 ± 1.71
1-MeFl+C-MeFl/Py	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	1.08 ± 1.53
1+3-methylfluoranthene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	2.17 ± 3.07
4-methylpyrene	0.00	7.80 ± 3.44	6.92 ± 2.58	1.04	1.15 ± 1.62	4.03 ± 0.63
C-MePy/MeFl	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
D-MePy/MeFl	0.00	0.00 ± 0.00	5.38 ± 0.44	2.51	3.28 ± 2.32	5.69 ± 1.02
1-methylpyrene	0.00	1.13 ± 1.60	4.22 ± 0.41	0.62	0.23 ± 0.33	3.41 ± 0.98
Benzonaphthothiophene	0.00	0.00 ± 0.00	0.00 ± 0.00	1.88	0.58 ± 0.27	4.29 ± 0.96
benzo(c)phenanthrene	0.00	0.00 ± 0.00	0.90 ± 1.28	0.00	2.27 ± 1.46	2.13 ± 3.01

Benzo(ghi)fluoranthene	0.00	23.56 ± 12.17	30.24 ± 15.65	3.30	17.68 ± 6.71	41.38 ± 27.84
9-phenylanthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	1.39 ± 1.97
6-methylchrysene	0.00	0.00 ± 0.00	0.74 ± 1.04	0.00	0.40 ± 0.56	0.00 ± 0.00
Cyclopenta(c,d)pyrene	0.00	0.00 ± 0.00	2.03 ± 0.29	0.00	0.85 ± 0.04	1.13 ± 0.57
Benz(a)anthracene	0.00	0.00 ± 0.00	4.15 ± 1.46	1.71	1.61 ± 1.85	13.42 ± 10.06
Chrysene	0.00	3.00 ± 4.24	11.46 ± 5.61	3.60	8.64 ± 3.39	21.42 ± 13.46
Benzanthrone	0.00	0.00 ± 0.00	21.45 ± 12.86	3.61	8.29 ± 3.53	22.99 ± 17.52
Benz(a)anthracene-7,12-dione	0.00	0.00 ± 0.00	7.29 ± 5.01	0.00	2.88 ± 4.08	9.80 ± 6.18
3-methylchrysene	0.00	0.00 ± 0.00	0.95 ± 1.34	0.00	0.00 ± 0.00	1.68 ± 1.32
7-methylbenz(a)anthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.49 ± 0.69	0.00 ± 0.00
7,12-dimethylbenz(a)anthracene	4.49	6.70 ± 2.95	3.43 ± 0.23	1.16	3.61 ± 0.80	2.68 ± 3.79
Benzo(b)fluoranthene	0.00	1.98 ± 0.26	11.43 ± 8.04	2.52	5.83 ± 2.41	30.20 ± 24.34
Benzo(j)fluoranthene	0.00	0.00 ± 0.00	3.83 ± 2.74	0.62	1.46 ± 1.48	11.70 ± 9.91
Benzo(k)fluoranthene	0.00	0.00 ± 0.00	2.44 ± 1.35	0.21	0.55 ± 0.70	8.23 ± 7.62
Benzo(a)fluoranthene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.90 ± 0.77
BeP	0.49	0.99 ± 0.30	6.32 ± 4.20	1.49	2.75 ± 2.27	17.60 ± 14.00
BaP	0.00	0.00 ± 0.00	0.12 ± 0.17	0.53	0.00 ± 0.00	4.27 ± 4.25
Perylene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
3-methylcholanthrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
7-methylbenzo(a)pyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
9,10-dihydrobenzo(a)pyrene-7(8H)-one	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Indeno[123-cd]fluoranthene	0.00	0.00 ± 0.00	1.38 ± 0.51	0.00	0.00 ± 0.00	1.13 ± 1.60
Indeno[123-cd]pyrene	0.00	0.00 ± 0.00	1.53 ± 0.70	1.36	0.36 ± 0.50	9.85 ± 8.52
Dibenzo(ac)anthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ah+ac)anthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(ah)anthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,j)anthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Benzo(b)chrysene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Picene	0.00	0.00 ± 0.00	4.33 ± 1.24	0.18	0.95 ± 1.35	0.00 ± 0.00
Benzo(ghi)perylene	0.00	0.00 ± 0.00	4.77 ± 2.38	2.83	1.03 ± 1.45	32.74 ± 27.84

Anthanthrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Triphenylene	0.00	2.45 ± 3.47	2.11 ± 2.98	0.99	4.00 ± 0.75	5.05 ± 2.09
Dibenzo(a,l)pyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Coronene	0.00	0.00 ± 0.00	0.00 ± 0.00	2.92	0.00 ± 0.00	30.43 ± 27.09
Dibenzo(a,e)pyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,i)pyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(a,h)pyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
Dibenzo(b,k)fluoranthene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00

Table D35: Gas-phase nitro-PAH emissions during regeneration emissions testing for Vehicle #1 and Vehicle #3 over the HWFET

Compound (ng/mile)	**Vehicle #1**			**Vehicle #3**		
	Baseline HWFET	Federal ULSD	Fed/SME-20	Baseline HWFET	Federal ULSD	Fed/SME-20
1-nitronaphthalene	14.56	13.90 ± 2.52	0.00 ± 0.00	25.35	25.55 ± 1.74	24.13 ± 34.12
1-methyl-5-nitronaphthalene	0.04	0.00 ± 0.00	0.72 ± 0.20	0.08	0.13 ± 0.04	0.47 ± 0.31
2-nitronaphthalene	0.14	2.22 ± 0.37	6.05 ± 0.10	0.45	1.21 ± 0.59	3.21 ± 2.15
2-nitrobiphenyl	0.27	0.63 ± 0.07	0.60 ± 0.05	0.61	0.88 ± 0.01	0.94 ± 0.37
2-methyl-4-nitronaphthalene	0.00	0.05 ± 0.07	0.84 ± 0.32	0.00	0.00 ± 0.00	0.64 ± 0.90
1-methyl-4-nitronaphthalene	0.06	0.07 ± 0.10	0.87 ± 0.22	0.00	0.00 ± 0.00	0.68 ± 0.79
1-methyl-6-nitronaphthalene	0.00	2.29 ± 1.71	3.60 ± 0.02	1.10	0.71 ± 1.01	6.67 ± 9.43
3-nitrobiphenyl	0.05	0.32 ± 0.18	0.52 ± 0.14	0.10	0.46 ± 0.07	0.47 ± 0.14
4-nitrobiphenyl	0.00	0.33 ± 0.46	0.54 ± 0.09	0.00	3.10 ± 0.77	2.99 ± 1.11
1,3-dinitronaphthalene	0.00	3.49 ± 3.30	3.33 ± 1.41	0.00	0.00 ± 0.00	0.54 ± 0.77
1,5-dinitronaphthalene	0.06	5.13 ± 5.00	2.73 ± 1.34	0.00	0.00 ± 0.00	0.10 ± 0.14
5-nitroacenaphthene	0.09	0.16 ± 0.03	0.04 ± 0.06	0.06	0.13 ± 0.18	0.03 ± 0.04
2-nitrofluorene	0.00	0.02 ± 0.03	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
4-nitrophenanthrene	38.82	2.07 ± 2.93	0.82 ± 1.01	0.00	0.00 ± 0.00	1.06 ± 1.49
9-nitroanthracene	0.00	0.90 ± 1.28	1.93 ± 0.04	0.00	0.81 ± 0.00	3.10 ± 4.39
9-nitrophenanthrene	0.19	1.08 ± 1.28	1.88 ± 0.75	0.00	0.12 ± 0.08	1.68 ± 1.35
1,8-dinitronaphthalene	0.00	0.02 ± 0.03	0.05 ± 0.08	0.00	0.00 ± 0.00	0.00 ± 0.00

3-nitrophenanthrene	70.49	37.98 ± 10.51	8.07 ± 3.46	1.10	7.98 ± 11.28	5.83 ± 4.17
2-nitrophenanthrene	0.00	0.44 ± 0.35	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
2-nitroanthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
2-nitrofluoranthene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
3-nitrofluoranthene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
4-nitropyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
1-nitropyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
2-nitropyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
2,7-dinitrofluorene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
2,7-dinitrofluoren-9-one	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
7-nitrobenz(a)anthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
6-nitrochrysene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
3-nitrobenzanthrone	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
1,3-dinitropyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
1,6-dinitropyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
1,8-dinitropyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
6a+1e-nitrobenzpyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
1-nitrobenzo[e]pryene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
3-nitrobenzo[e]pryene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00

Table D36: Particle-phase nitro-PAH emissions during regeneration emissions testing for Vehicle #1 and Vehicle #3 over the HWFET

Compound (ng/mile)	**Vehicle #1**			**Vehicle #3**		
	Baseline HWFET	Federal ULSD	Fed/SME-20	Baseline HWFET	Federal ULSD	Fed/SME-20
1-nitronaphthalene	0.00	0.06 ± 0.02	0.04 ± 0.01	0.00	0.03 ± 0.00	0.06 ± 0.02
1-methyl-5-nitronaphthalene	0.00	0.00 ± 0.00	0.01 ± 0.00	0.00	0.00 ± 0.00	0.01 ± 0.01
2-nitronaphthalene	0.01	0.11 ± 0.01	0.10 ± 0.00	0.02	0.05 ± 0.03	0.11 ± 0.03
2-nitrobiphenyl	0.00	0.02 ± 0.01	0.03 ± 0.02	0.00	0.02 ± 0.02	0.02 ± 0.02
2-methyl-4-nitronaphthalene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.01	0.06 ± 0.06	0.00 ± 0.00
1-methyl-4-nitronaphthalene	0.00	0.10 ± 0.13	0.05 ± 0.07	0.00	0.00 ± 0.00	0.10 ± 0.09

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1-methyl-6-nitronaphthalene	0.08	0.00 ± 0.00	0.00 ± 0.00	0.04	0.00 ± 0.00	0.00 ± 0.00
3-nitrobiphenyl	0.00	0.03 ± 0.00	0.02 ± 0.00	0.01	0.01 ± 0.01	0.05 ± 0.00
4-nitrobiphenyl	0.00	0.93 ± 0.58	0.82 ± 0.01	0.00	0.03 ± 0.04	0.27 ± 0.15
1,3-dinitronaphthalene	0.19	3.13 ± 1.59	0.88 ± 0.22	0.00	0.00 ± 0.00	0.00 ± 0.00
1,5-dinitronaphthalene	0.00	1.30 ± 0.86	0.46 ± 0.17	0.00	0.00 ± 0.00	0.01 ± 0.02
5-nitroacenaphthene	0.10	0.00 ± 0.00	0.02 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
2-nitrofluorene	0.00	1.06 ± 1.49	0.76 ± 0.19	0.00	0.00 ± 0.00	0.00 ± 0.00
4-nitrophenanthrene	0.11	2.57 ± 1.02	0.88 ± 0.28	0.04	0.16 ± 0.01	0.28 ± 0.15
9-nitroanthracene	0.01	0.27 ± 0.12	0.07 ± 0.02	0.05	0.23 ± 0.07	0.55 ± 0.05
9-nitrophenanthrene	1.04	7.99 ± 7.09	4.80 ± 2.42	0.00	0.00 ± 0.00	0.00 ± 0.00
1,8-dinitronaphthalene	0.03	1.25 ± 0.52	0.53 ± 0.28	0.03	0.16 ± 0.05	0.24 ± 0.03
3-nitrophenanthrene	0.51	7.74 ± 6.71	4.27 ± 1.94	0.15	1.58 ± 0.72	2.03 ± 0.90
2-nitrophenanthrene	0.00	1.01 ± 0.47	0.75 ± 0.13	0.10	0.42 ± 0.30	0.39 ± 0.00
2-nitroanthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
2-nitrofluoranthene	0.04	0.39 ± 0.24	0.27 ± 0.17	0.00	0.03 ± 0.02	0.02 ± 0.01
3-nitrofluoranthene	0.00	0.04 ± 0.05	0.19 ± 0.26	0.00	0.06 ± 0.01	0.00 ± 0.00
4-nitropyrene	0.01	0.24 ± 0.11	0.37 ± 0.34	0.00	0.07 ± 0.00	0.20 ± 0.28
1-nitropyrene	0.12	1.96 ± 1.81	1.99 ± 1.17	0.12	8.32 ± 5.28	1.91 ± 0.17
2-nitropyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.04 ± 0.06	2.59 ± 2.74
2,7-dinitrofluorene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.03 ± 0.05	0.00 ± 0.00
2,7-dinitrofluoren-9-one	0.00	0.00 ± 0.00	0.00 ± 0.00	0.02	0.00 ± 0.00	0.00 ± 0.00
7-nitrobenz(a)anthracene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.32 ± 0.07	0.00 ± 0.00
6-nitrochrysene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.06 ± 0.09	0.00 ± 0.00
3-nitrobenzanthrone	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
1,3-dinitropyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
1,6-dinitropyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
1,8-dinitropyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	1.81 ± 2.56
6a+1e-nitrobenzpyrene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
1-nitrobenzo[e]pryene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00
3-nitrobenzo[e]pryene	0.00	0.00 ± 0.00	0.00 ± 0.00	0.00	0.00 ± 0.00	0.00 ± 0.00

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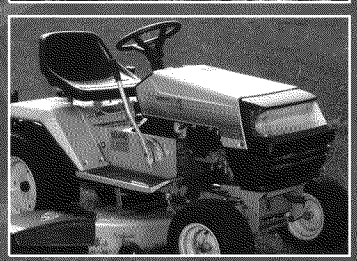

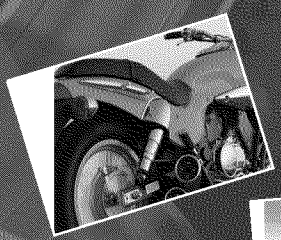

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United States Environmental Protection Agency
Office of Transportation and Air Quality
1200 Pennsylvania Avenue, NW
Washington, DC 20460

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www.epa.gov/otaq

Contributors

Phil Carlson
Emily Chen
Karen Danzeisen
Chris Nevers
Bill Pidgeon
Holly Pugliese
Lynn Sohacki
Trina Vallion
Carl Wick
Ching-Shih Yang

Editors

Amy Bunker
Mark Wolcott

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I. Forward by the Compliance Division Director

2009 – 2011 Compliance Report

This is the third in a series of vehicle and engine compliance reports issued by the U.S. Environmental Protection Agency (EPA) Office of Transportation and Air Quality (OTAQ). These reports offer a convenient reference to the data that OTAQ collects in implementing emissions regulations for vehicles, engines, and other motorized equipment. The environmental programs OTAQ implements apply to virtually every vehicle, engine and gallon of transportation fuel sold in the United States. It is our job to make sure that these regulated mobile sources comply with emissions and fuel economy requirements. OTAQ's role in ensuring comprehensive compliance is essential to realizing national air quality and public health goals.

This report updates and builds upon the data and information presented in the first two reports, the "2007 Progress Report on Vehicle and Engine Compliance Activities" (2007 Compliance Report) and the "2008 Progress Report on Vehicle and Engine Compliance Activities" (2008 Compliance Report). The 2009-2011 Progress Report on Vehicle and Engine Compliance Activities (2009-2011 Compliance Report) presents certification data and other types of information OTAQ collected for model years (MY) 2009 through 2011 and for calendar years 2009-2011[1].

OTAQ oversees a broad set of compliance activities to ensure that vehicle and engine manufacturers satisfy their regulatory obligations. These activities extend from pre- to post-production and range from issuing certificates of conformity before vehicles and engines enter commerce to monitoring in-use testing and reporting after they enter customer service. In addition to regulating vehicles and engines, EPA regulates motor vehicle fuels, including gasoline, diesel and renewable fuels such as ethanol and biodiesel. Please see EPA's fuels web site, http://epa.gov/otaq/fuels/, for further information about OTAQ's fuel compliance program.

We recommend that readers who are unfamiliar with EPA's mobile source emission control programs refer to the 2007 Compliance Report for additional background information, including descriptions of the vehicle, engine, and fuel categories EPA regulates.

The 2009-2011 Compliance Report includes data from the following mobile source sectors: light-duty vehicles, highway motorcycles, heavy-duty highway engines, nonroad compression ignition engines, nonroad spark ignition engines and recreation vehicles.

[1] Some information is reported by model year while other types of information (e.g., recalls and defects) are reported by calendar year.

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The purpose oft tthe compliance reportts is tto ofter a snapshott oft compliance acttvitty over a given ttme ftrame. The years covered by tthe 2009-2011 Compliance Reportt representt a period oft signiftcantt ttransitton in tthe mobile source program. Sttringentt new emission sttandards ttook eftectt ftor many vehicle and engine cattegories, including mottorcycles, heavy-dutty highway engines, nonroad compression-ignitton and marine diesel engines, locomottves, small spark-ignitton and marine spark-ignitton engines, and recreattonal vehicles. In additton, EPA promulgatted tthe ftrstt-ever mobile source greenhouse gas emission sttandards, beginning witth a lightt-dutty vehicle greenhouse gas rule in 2010. Heavy-dutty highway greenhouse gas sttandards ftollowed in 2011. The greenhouse gas regulattons do nott ttake eftectt unttl ftutture years butt manuftactturers were already ttaking stteps in tthe 2009-2011 ttmeftrame tto accrue early creditts and tto prepare ftor compliance mandattes sttarttng in tthe 2012 model year. The 2009-2011 ttme period was also nottable ftor a rapid expansion oft new certtftcatton and compliance acttvitty in tthe recreattonal vehicle, and small nonroad and marine engines secttors, as well as an accelerattng intternattonal dimension tto EPA compliance oversightt.

This reportt is also one oft our deliverables on tthe Presidentt directtves regarding tthe need ftor and importtance oft ttransparency. From tthe Presidentt's memo on Transparency and Open Governmentt onwww.whitehouse.gov: "Transparency promottes accounttabilitty and provides inftormatton ftor cittzens aboutt whatt ttheir Governmentt is doing. Inftormatton mainttained by tthe Federal Governmentt is a nattonal assett." This reportt provides a broad range oft parttners and sttake holders access to the data collected and generated as part of the vehicle and engine certtftcatton and compliance program.

The highlightts tthatt ftollow provide addittonal examples oft inftormatton tthatt is available today and that is explained in more detail in the report.

Byron Bunker
Directtor, Compliance Division
Oftce oft Transporttatton and Air Qualitty
USEPA Nattonal Vehicle and Fuel Emissions Laborattory
2565 Plymouth Road
Ann Arbor, MI 48105

Highlight 1 – Certification

EPA issued nearly 4,000 certificates of conformity in each of model years 2009 - 2011. While it is typical for the number of certificates to fluctuate from year to year, the overall trend has been one of growth. EPA issued 2,520 certificates of conformity in 2000. Certification activity has increased significantly over the last decade.

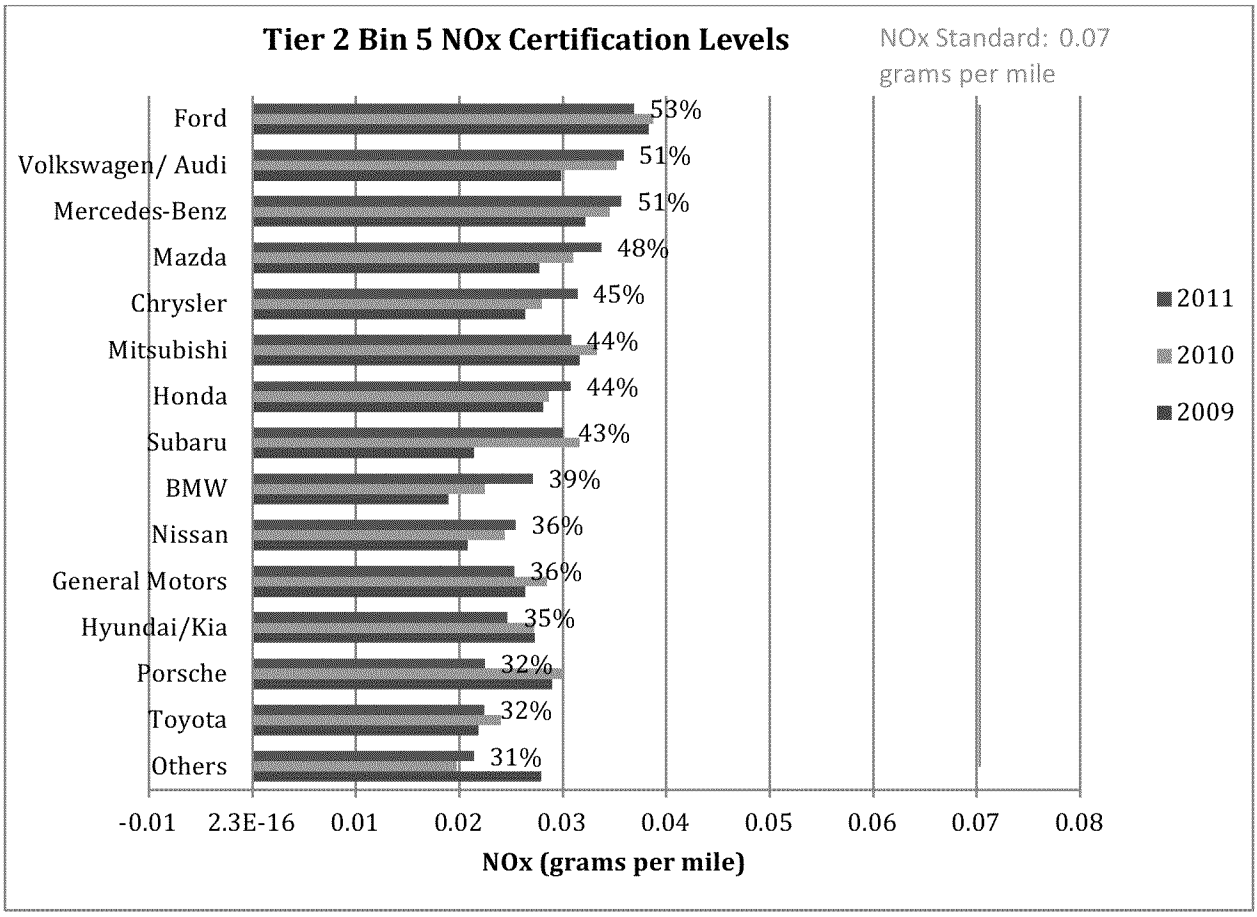
Figure F-1
Certificates of Conformity by Model Year

Industry Sector	Category	MY 2009	MY 2010	MY 2011
Light-Duty Vehicles	Passenger cars and trucks	507	489	464
	Independent commercial importers	21	15	11
	Alternative fuel conversions	74	55	227
Highway Motorcycles	On-highway motorcycles	460	399	337
Heavy-Duty Highway Engines	Compression ignition (mostly diesel)	90	44	52
	Spark ignition (mostly gasoline)	9	9	9
	Alternative fuel conversions	11	13	34
	Evaporative emissions	13	15	17
Nonroad Compression Ignition Engines	Diesel powered equipment, such as tractors, generators, construction equipment, forklifts, welders	616	648	568
	Diesel boats and ships	152	170	210
	Oceangoing vessels per International Maritime Organization requirements	28	37	53
	Locomotives	70	47	60
Nonroad Spark Ignition Engines	Small SI: Small nonroad gasoline powered equipment, such as lawnmowers, string trimmers, chain saws, small compressors, pumps, utility vehicles < 25 mph, snow blowers, rammers, and floor cleaners	1,160	1,020	985
	Marine SI: Gasoline boats and personal watercraft	124	117	124
	Large SI: Large nonroad gasoline powered equipment, such as forklifts, compressors, generators, and stationary equipment	89	124	140
	Evaporative components (mostly intended for small nonroad gasoline and marine gasoline equipment)	161	195	424
Recreational Vehicles	All-terrain vehicles	229	182	143
	Utility vehicles	13	15	23
	Off-highway motorcycles	62	58	46
	Snowmobiles	38	37	35
Total		**3,927**	**3,689**	**3,962**

Highlight 2 – Light-Duty Manufacturers Design to Exceed Standards

EPA confirmatory test results show high compliance margins among light-duty pre-production vehicles, meaning that their emission levels were significantly below the level the standards allow. For example, light-duty vehicle NOx emissions were about one half of the applicable 0.07 grams per mile NOx standard.

Figure F-2
MY 2009-2011 Tier 2 Bin 5 NOx Certification
Levels and Compliance Margins by Manufacturer



Highlight 3 – In-Use Surveillance, Defect Reporting, and Recall Requirements Prevent Potential Problems in Millions of Vehicles and Engines

Manufacturers reported emission defects for a variety of components. The most prevalent defects reported involved onboard diagnostic systems, catalysts, particulate filters, turbochargers, and fuel delivery and exhaust systems. Manufacturers corrected a significant number of these defects through voluntary recalls.

From 2009 through 2011 manufacturers voluntarily recalled some 12 million cars (about 5% of registered light-duty vehicles) and, 900,000 heavy-duty highway engines (more than 20% of heavy-duty registered vehicles).

Highlight 4 - The Characteristics of Mobile Source Industries are Changing

The car and truck manufacturing sectors are dominated by relatively few very large companies. The more recently regulated nonroad, small engine, and recreational vehicle industries are different, with literally hundreds of very small manufacturers comprising the market. In the motorcycle industry, for example, about

one half of the model year 2009 - 2011 certificates were issued to manufacturers who produced a small number of engine families (grouped below as "Other").

Figure F-3
MY 2009-2011 Highway Motorcycle Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Piaggio Group Americas, Inc.	30	31	26
Yamaha Motor Corporation	31	27	28
American Suzuki Motor Corporation	30	23	14
American Honda Motor Co., Inc.	18	13	14
Kawasaki Motors Corp., U.S.A.	16	15	13
Carter Brothers Manufacture Co., Ltd.	9	12	9
Kymco USA	10	11	11
Harley-Davidson Motor Company	12	8	7
Ducati North America, Inc.	7	9	10
BMW	7	8	5
Qlink L.P.	7	7	4
Triumph Motorcycles America Ltd	6	6	7
Cobra Scooters	6	5	3
Big Bear American Made Choppers, Inc.	5	5	0
Xingyue USA, Inc	5	5	3
Other	261	214	183
Total	**460**	**399**	**337**

Furthermore, while the set of vehicle and engine manufacturers historically subject to EPA regulation had their headquarters and/or production facilities in the United States, today's manufacturers are based all over the world.

Figure F-4
MY 2009-2011 Construction and Agricultural Engine Families by Manufacturing Location

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Japan	193	195	179
Germany	83	83	75
China	60	65	43
Italy	46	49	50
England	47	47	32
USA	43	47	21
Korea	31	36	27
India	23	25	22
Mexico	8	7	8
Sweden	8	2	9
Switzerland	7	11	3
France	8	7	2
Czech Republic	2	2	2
Austria	1	1	-

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Brazil	1	1	-
Belgium	0	0	-
Slovakia	-	4	4
Multiple countries[1]	50	59	43

COMPLIANCE REPORT ORGANIZATION

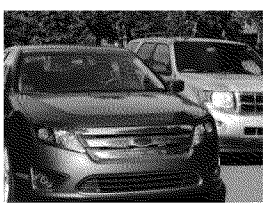
This summary is followed by three chapters that cover the following topics:

- Chapter II, Scope of EPA's Vehicle, Engine, Equipment, and Fuel Compliance Programs, describes the laws that authorize EPA's mobile source compliance activity.

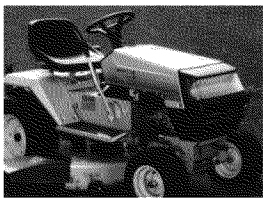
- Chapter III, Compliance Programs and Processes, describes the compliance programs and processes in more detail and provides compliance data and other information organized by industry sector. Please refer to Figure 1 for examples of the vehicles, engines, and equipment that are included in each industry sector.

- Chapter IV, Industry Statistics, presents some interesting statistics that are contained within the compliance information that EPA collects.

Figure 1 - Industry Sectors and Examples

Industry Sector	Examples	Key
Light-Duty Vehicles	Passenger cars, vans, SUVs, small trucks	
Highway Motorcycles	On-highway motorcycles, cruisers, choppers, scooters, touring bikes, mopeds, street bikes	
Heavy-Duty Highway Engines	Tractor-trailers (semi-trucks), buses, delivery and work trucks	

[1] "Multiple countries" means that engines within an engine family are manufactured in more than one country.

Nonroad Compression Ignition Engines (Nonroad CI)	Construction and agricultural equipment, such as tractors, generators, construction and road-work equipment, welders	
	Marine diesel boats and ships, oceangoing vessels	
	Locomotives	
Nonroad Spark Ignition Engines (Nonroad SI)	Small SI: lawnmowers, string trimmers, chain saws, small compressors, pumps, snow blowers	
	Marine SI: inboard and outboard motorboats, jet-skis	
	Large SI: forklifts, large compressors, generators	
	Evaporative components: hoses, fuel tanks	
Recreational Vehicles	All-terrain vehicles (ATVs), utility vehicles (UTVs), sand cars, dune buggies, go karts	
	Off-highway motorcycles	
	Snowmobiles	

II. Scope of EPA's Vehicle, Engine, Equipment, and Fuel Compliance Programs

A. Statutory Authority for EPA Regulation of Vehicles, Engines, Equipment, & Fuels

EPA derives authority to do its work through a variety of environmental statutes enacted by Congress. Figure 2 outlines the primary environmental statutes that give EPA the authority to develop and implement its mobile source clean air programs.

Figure 2 - Environmental Statutes

Statute	Authority
Clean Air Act (CAA)	Emission standards for highway & nonroad vehicles and their fuels
Energy Policy and Conservation Act (EPCA)	Fuel economy information programs for consumers, including vehicle fuel economy labels
Energy Policy Act (EPAct) Energy Independence and Security Act (EISA)	Annual volume standards for renewable fuel content

From locomotives to lawnmowers, EPA's Office of Transportation and Air Quality (OTAQ) has the authority to regulate nearly all engines and vehicles that emit pollutants into the environment. The statutory authority also covers the fuels that power these mobile sources, and includes responsibility for emissions compliance oversight that extends from initial product design to performance on the road or in the field.

B. Scope of EPA Vehicle, Engine, & Equipment Regulations

Compliance programs play an essential role in achieving the benefits of statutes and regulations. OTAQ oversees a comprehensive set of compliance activities to ensure that vehicle and engine manufacturers and fuel refiners and producers satisfy their regulatory obligations. EPA regulation of motor vehicles began in the 1970s; Figure 3 lists vehicle and engine regulations that were proposed or established since 2004. For a comprehensive list of EPA mobile source emission standards, refer to EPA's online Emission Standards Reference Guide, available at www.epa.gov/otaq/standards/index.htm. Please see Section II.C of this report for a list of regulations applicable to motor vehicle fuels.

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Figure 3 - Vehicle and Engine Regulations and Implementation Dates

Affected Industry Sector/Category	Program/Rulemaking Description	Effective Model Year[2]
Light-Duty Vehicles	Tier 2 Emission Standards and Gasoline Sulfur Fuel Control – Strengthened emission standards for light-duty vehicles and significantly reduced sulfur levels in gasoline	2004
	On-Board Diagnostics (OBD) – Established new emissions system monitoring requirements for light-duty diesel vehicles	2005
	Revisions to Motor Vehicle Fuel Economy Labeling – Updated EPA method for determining fuel economy label values to better represent typical driving patterns and more accurately estimate actual consumer fuel economy	2008
	Mobile Source Air Toxics – Set standards to lower gasoline benzene content, reduce cold temperature exhaust emissions, and reduce evaporation and permeation from portable fuel containers	2010
	Clean Alternative Fuel Vehicle and Engine Conversions[3]– Updated anti-tampering provisions applicable to manufacturers of clean alternative fuel conversion systems for highway vehicles and engines	All[4]
	Light-Duty Greenhouse Gas (GHG) Emission Standards – Established the first mobile source emission standards for greenhouse gases including carbon dioxide, methane, and nitrous oxide	2012
	Revisions and Additions to Motor Vehicle Fuel Economy Label – Redesigned label provides new information on vehicle fuel economy, energy use, fuel costs, and environmental impacts for conventional and advanced technology vehicles	2013

[2] Effective model year refers to the first year of a new program. Many programs are phased in over multiple model years.
[3] This rule also applies t o heavy-duty highway clean alternative fuel conversions.
[4] .Although the regulation took effect with its promulgation in 2011, because it applies to tampering, it applies to any model year that is subject to any emissions standard.

Affected Industry Sector/Category		Program/Rulemaking Description	Effective Model Year
Highway Motorcycles		Highway Motorcycle Exhaust Emissions- Class I and II: Established more stringent HC and added new optional hydrocarbons + oxides of nitrogen (HC+NOx) standards; Added Class 1a (<50cc) Class III: Established new Tier 1 HC+NOx standard Class III: More stringent Tier II HC+NOx standard Highway Motorcycle Permeation Emissions- Established new evaporative/permeation standards for fuel tank(s) and lines.	2006 2006 2010 2008
Heavy-Duty Highway Engines and Vehicles		Light Heavy-Duty OBD – Established OBD monitoring requirements for heavy-duty chassis certified vehicles, and for engines certified for use in heavy-duty vehicles between 8,500 and 14,000 pounds gross vehicle weight rating (GVWR) Heavy-Duty Highway Rule – Established more stringent exhaust emission standards for heavy-duty vehicles and engines; required Ultra Low Sulfur Diesel (ULSD) fuel (15 ppm sulfur maximum) Heavy-Duty Engines OBD Rule – New OBD monitoring requirements for engines certified for use in heavy-duty vehicles above 14,000 pounds GVWR Heavy-Duty GHG Standards – Established first emission standards for greenhouse gas pollutants from heavy-duty engines and heavy-duty vehicles	2004 2007 2010 2014
Nonroad Compression Ignition Engines & Equipment	Construction & Agricultural	Tier 3/Interim Tier 4 – Established more stringent emission standards for engines between 37 and 560 kilowatts (50 and 750 hp) Tier 4 Nonroad Diesel Rule– Established more stringent emissions standards for all engines greater than 19 kilowatts (25 hp) and lowered nonroad diesel fuel sulfur to 15 ppm maximum	2006 2010
	Marine Diesel Engines	Tier 3 and Tier 4 Emission Standards for Marine Diesel Engines – Established more stringent emission standards for newly built and remanufactured engines	2009
	Locomotives	Tier 3 and Tier 4 Emission Standards for Locomotive Diesel Engines – Established more stringent emission standards for newly built and remanufactured engines	2011

Affected Industry Sector/Category		Program/Rulemaking Description	Effective Model Year
Nonroad Spark Ignition Engines & Equipment	Small Spark Ignition Engines (Small SI)	Control of Emissions From Nonroad Spark Ignition Engines and Equipment – Established more stringent exhaust emissionstandards for Class I (MY2012) and Class II (MY2011) engines below 19 kilowatts and fuel permeation standards for all engines below 19 kilowatts	2011 2012
	Marine Spark Ignition Engines (Marine SI)	Control of Emissions From Nonroad Spark Ignition Engines and Equipment – Established first federal exhaust emission standards for sterndrive and inboard Marine SI engines and increased the stringency of exhaust emission standards for outboard and personal watercraft engines. Established new evaporative emission standards for all Marine SI engines	2010
	Large Spark Ignition Engines (Large SI)	New Emissions Standards for Large SI Engines – Established new emission standards, diagnostic capability and portable emission testing provisions Tier 1 Tier 2	 2004 2007
Recreational Vehicles		New Exhaust EmissionStandards for RVs – Off-highway motorcycles, ATVs and UTVs Snowmobiles Tier 1 Tier 2 Tire 3 New permeation standards for fuel components	 2006 2006 2010 2012 2008
Aircraft[5]		Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures – Established more stringent NOx exhaust emission standardsfor aircraft engines NOx Emission Standards for Aircraft Gas Turbine Engines – Established new NOx emission standards for aircraft, engines consistent with international standards	2005 2012

[5] The Federal Aviation Administration has primary oversight responsibility for aircraft emissions compliance.

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C. Scope of EPA Fuel Regulations

In addition to regulating vehicles and engines, EPA regulates motor vehicle fuels, including gasoline, diesel, and renewable fuels such as ethanol and biodiesel. Figure 4 describes both historical and current fuels programs and implementation dates. For a comprehensive list of ongoing fuels regulations, please visit http://www.epa.gov/otaq/fuels/publications.htm. Additional information can be found on the OTAQ website at http://www.epa.gov/otaq/fuels/index.htm. Please see Section II.B of this report for recent regulatory actions applicable to vehicles and engines.

Figure 4 - Fuels Regulations and Implementation Dates

Affected Fuel Type- *Applicable Fuel Producer or Importer*	**Program/Rulemaking Description**	**Effective Imple-mentation Date**
Motor vehicle fuels and fuel additives – *Gasoline and diesel refiners and importers, renewable fuel producers and importers, fuel additive producers and importers*	Fuels and Fuel Additives Registration System (FFARS) – Mandatory registration program for motor vehicle gasoline, diesel, and their additives sold in the U.S. Requires all fuel and fuel additive manufacturers to report the chemical composition of their products and other technical, sales and health effects information	1975
Gasoline – *Gasoline Refiners and Importers*	Volatility Standards – Limits the vapor pressure of gasoline sold at retail stations during the summer ozone season to reduce evaporative emissions from gasoline, which contribute to ground-level ozone formation	1989
	Oxygenated Fuel Requirements – Establishes fuel oxygen standards to reduce carbon monoxide emissions from motor vehicles during the winter season	1992
	Reformulated Gasoline (RFG) – Reduce smog-forming and toxic pollutants in U.S. cities with worst smog pollution	1995
	Tier 2 Emission Standards and Gasoline Sulfur Regulations Establishes stringent exhaust emission standards for all fuel types and limits fuel sulfur levels to an average of 30 ppm	2004
	Mobile Source Air Toxics Regulations – Limits the benzene content of gasoline and reduces toxic emissions from passenger vehicles and gas cans	2011
Diesel – *Diesel Producers and Importers*	Highway, Nonroad, Locomotive, and Marine Regulations – Suite of rules for highway, nonroad, locomotive, and marine diesel engines that requires ultra-low sulfur diesel (ULSD), 15 ppm maximum	2006

Affected Fuel Type- *Applicable Fuel Producer or Importer*	**Program/Rulemaking Description**	**Effective Imple-mentation Date**
Renewable Fuels (e.g. ethanol, biodiesel) – *Gasoline Refiners and Importers, Renewable Fuel Producers, Importers, Exporters, Marketers, and Blenders*	The Renewable Fuel Standard (RFS) – RFS1 – Regulations established under the Energy Policy Act (EPAct) of 2005 required 7.5 billion gallons of renewable fuel to be blended into gasoline by 2012. RFS2 – Regulations established under the Energy Independence and Security Act (EISA) of 2007 expanded upon RFS1. The RFS2 regulations require renewable fuel to be blended into both gasoline and diesel fuel, as well as jet fuel and heating oil in volumes that increase from 9 billion gallons in 2008 to 36 billion gallons in 2022.	2007 2010

III. Compliance Programs and Processes

A. Overview

EPA uses a variety of testing and reporting programs to monitor compliance with emissions regulations. The programs may apply to vehicles and engines before they are produced (preproduction), while they are in production and after they are in customer service (postproduction)EPA has the authority and flexibility to choose compliance strategies that best fit an industry sector at any given time. Factors that influence the use of a particular compliance approach include regulatory requirements affecting a given industry sector, the technology being used to meet the emission standards, industry-specific production processes and cycles and sector or manufacturer size. This report describes compliance programs and activities that OTAQ conducted in 2009 - 2011. Specifically, the report presents data we collected and analyzed pertaining to MY 2009 - 2011 vehicles and engines, as well as test results and other types of information OTAQ obtained during calendar years 2009-2011.[6]

EPA regulations typically give manufacturers some flexibility about how they will achieve emissions compliance. Examples include emissions standards phase-ins, averaging, banking and trading (ABT) programs and several types of exemptions. This regulatory flexibility enables manufacturers to align their business model with emissions requirements and sometimes allow manufacturers to earn credit for introducing new technologies early. At the same time, some regulatory flexibilities introduce challenges to compliance oversight because vehicles and engines subject to one regulation and set of standards may legally certify to different emissions levels. This report includes some discussion of flexibility provisions and presents data showing how manufacturers are using them.

[6] This report presents the data we have received and compiled as of the date of publication. In some cases data sets may be incomplete due to agency workload constraints, manufacturer under-reporting or error, and/or other issues. EPA continues to work with manufacturers to improve compliance with all requirements. Failure to comply with the applicable regulations, including failure to comply with all reporting requirements represents a violation of law that may result in enforcement action.

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EPA mobile source compliance programs allow for vehicle and engine testing and other compliance activity that can generally be parsed into three life-cycle categories:

Preproduction activities include certification testing and reporting and other compliance processes conducted before vehicles and engines are produced.

Production activities include audits and other compliance testing conducted on vehicles and engines coming off the production line, but before they enter customer service.

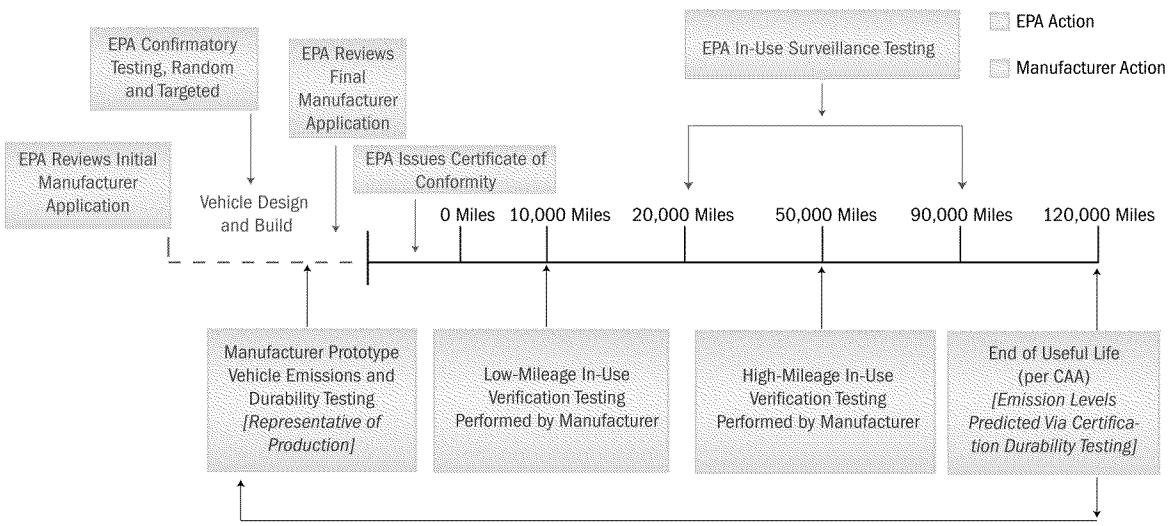
Postproduction activities include in-use testing and reporting and other compliance processes conducted after vehicles and engines enter customer service.

Figure 5 provides how EPA's compliance programs are related to one another.

Figure 5 - Compliance Schedule Examples

EPA's mobile source compliance processes seek to ensure that the vehicles and engines are fully compliant with emissions standards throughout their full useful life. This is accomplished with a variety of testing programs and other requirements that occur over the life of vehicles and engines. This figure shows example compliance schedules for certain sectors. Other mobile source sectors may differ with regard to the timing but generally follow similar protocols.

Compliance Schedule for Light-Duty Vehicles



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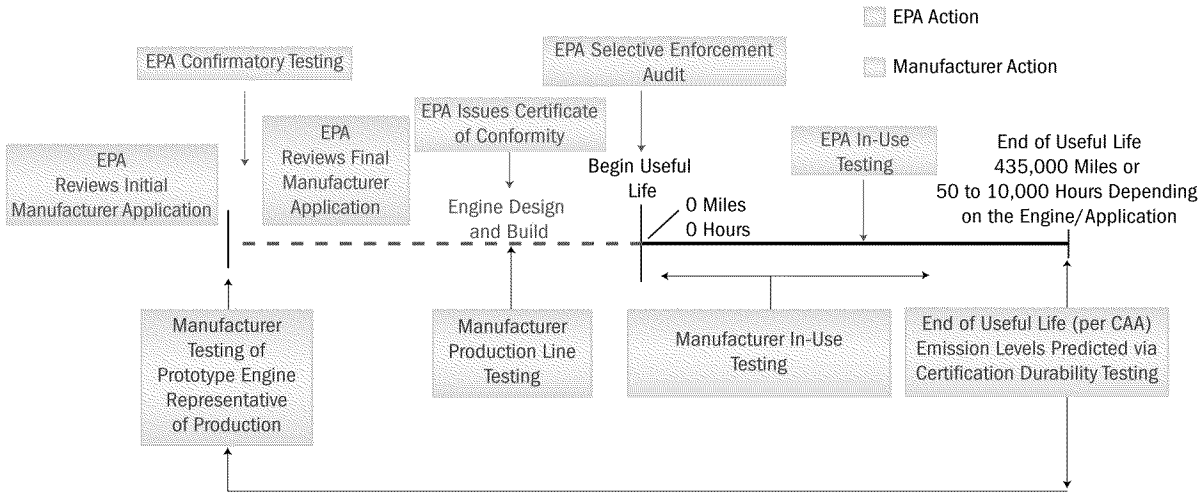
Compliance Schedule for Certain Heavy-Duty Highway and Nonroad Engines



1. Preproduction Programs

CERTIFICATES OF CONFORMITY

Section 206 of the Clean Air Act (CAA) requires all engines and vehicles to be covered by a certificate of conformity before they can enter commerce. A certificate of conformity is a license to produce products for one model year constant with the vehicle description and any terms of the certificate. Certificates of conformity are generally issued to a group of vehicles or engines having similar design and emission characteristics. For light-duty vehicles, certificates are issued for each unique combination of exhaust test group[7] and evaporative family. For heavy-duty vehicles and nonroad equipment subject to engine standards, the unit of certification is called an engine family. Test groups and engine families may include multiple models. Conversely, different versions within a given model may be included in different engine families or test groups.

Figure 6 shows the number of certificates that EPA issued in MY 2009 - 2011. It is typical for the number of certificates to fluctuate from year to year. The drop in total certificates in model year 2010 may have reflected the downturn in the global economy at that time. Overall the trend has been one of growth: certification activity has increased significantly over the last decade. (In 2000 EPA issued 2,520 certificates of conformity.)

[7] An exhaust test group is a group of vehicle models with similar engines, drive trains and emission control systems. It represents a group of vehicles or engines that have a similar design and emission characteristics.

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Figure 6 - Certificates of Conformity by Model Year

Industry Sector	Category	MY 2009	MY 2010	MY 2011
Light-Duty Vehicles	Passenger cars and trucks	507	489	464
	Independent commercial importers	21	15	11
	Alternative fuel conversions	74	55	227
Highway Motorcycles	On-highway motorcycles	460	399	337
Heavy-Duty Highway Engines	Compression ignition (mostly diesel)	90	44	52
	Spark ignition (mostly gasoline)	9	9	9
	Alternative fuel conversions	11	13	34
	Evaporative emissions	13	15	17
Nonroad Compression Ignition Engines	Diesel powered equipment, such as tractors, generators, construction equipment, forklifts, welders	616	648	568
	Diesel boats and ships	152	170	210
	Oceangoing vessels per International Maritime Organization requirements	28	37	53
	Locomotives	70	47	60
Nonroad Spark Ignition Engines	Small SI: Small nonroad gasoline powered equipment, such as lawnmowers, string trimmers, chain saws, small compressors, pumps, utility vehicles < 25 mph, snow blowers, rammers, and floor cleaners	1,160	1,020	985
	Marine SI: Gasoline boats and personal watercraft	124	117	124
	Large SI: Large nonroad gasoline powered equipment, such as forklifts, compressors, generators, and stationary equipment	89	124	140
	Evaporative components (mostly intended for small nonroad gasoline and marine gasoline equipment)	161	195	424
Recreational Vehicles	All-terrain vehicles	229	182	143
	Utility vehicles	13	15	23
	Off-highway motorcycles	62	58	46
	Snowmobiles	38	37	35
Total		**3,927**	**3,689**	**3,962**

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STATIONARY SOURCES-

OTAQ assists EPA's Office of Air Quality Planning and Standards with certification procedures for stationary engines. Stationary engines are used either in a fixed application or in a portable (or transportable) application where the engine resides at a single site for at least one year. A given engine may be certified as a mobile engine, stationary engine, or both. In 2009, of the 89 certificates of conformity for the nonroad large spark ignition engine sector, 16 were for mobile-stationary applications and 17 were for stationary-only applications. The remaining 56 certificates were for mobile-only applications. In 2010, of the 124 certificates of conformity for the nonroad large spark ignition engine sector, 21 were for mobile-stationary applications and 56 were for stationary-only applications. The remaining 47 certificates were for mobile-only applications. In 2011, of the 140 certificates of conformity for the nonroad large spark ignition engine sector, 37 were for mobile-stationary applications and 64 were for stationary-only applications. The remaining 39 certificates were for mobile-only applications. Of the certificates of conformity issued for engines in the nonroad compression ignition diesel powered equipment sector (616 in MY 2009, 648 in MY 2010 and 461 in MY 2011), 128 in MY 2009, 209 in MY 2010 and 189 in MY 2011 were for mobile-stationary engines. In both 2009 and 2010 only 5 engines were certified as stationary-only engine families while 43 engines were certified as stationary-only engine families in 2011.

APPLICATION FOR CERTIFICATION

The certification process begins when a manufacturer submits an application for certification to EPA Applications cover an exhaust test group or engine family that represents a group of vehicles or engines having similar design and emission characteristics. EPA requires manufacturers to provide detailed information in the certification application to show that the vehicles or engines meet all of the applicable emissions requirements and to describe the vehicles or engines to be covered by the certificate of conformity. Each certificate covers only those vehicles or engines specifically described in the application. The list below summarizes the general types of information and data that manufacturers submit to begin the application process:

- A description of the basic engine design and list of distinguishable configurations to be covered by the certification application.
- An explanation of how the emission control system operates
- A description of the vehicle or engine being used to represent the group for certification testing.
- A description of the test procedures and equipment used to test the vehicle or engine
- All emission data obtained on each test vehicle or engine
- The emission deterioration characteristics for each regulated pollutant over the useful life of the vehicles and engines covered by the certification application
- The predicted production volumes of each configuration to be covered by the certificate

• An unconditional statement attesting that vehicles or engines covered by the certification application comply with all requirements of the applicable regulation and the CAA

• Manufacturer representative and official company contact information

• Durability groupings (i.e., groups of vehicles/engines with similar emission deterioration and emission component durability)

• Durability test procedures

• Description of each test group or engine family which is represented by the durability test vehicle or engine

• Description of vehicles or engines used to demonstrate emissions and emission control component durability

• List of all test results, official certification levels, and the applicable emission standards for each vehicle or engine tested

• Statement of compliance with the applicable emission standards for all other configurations not tested but represented by the test vehicles or engine and covered by the certification application

• Evaporative emissions system information

• Description of the evaporative, permeation or refueling families covered by the certification application and test results demonstrating compliance with the applicable standards

• Information on emission control diagnostic systems, where applicable

CONFIRMATORY CERTIFICATION TESTING

Manufacturers conduct the initial testing to support an application for a certificate of conformity and report the results to EPA. Subsequent certification testing, called confirmatory testing, occurs after an application has been submitted. Confirmatory tests are performed by either the manufacturer or by EPA and serve to validate the manufacturer's initial emissions or fuel economy test results.

2. Production Programs

The objective of compliance activities that occur during production is to confirm that vehicles and engines coming off production lines match specifications set forth in the certificate of conformity. In other words, production programs are designed to verify that manufacturers are actually producing the same vehicle or engine that they certified. Some mobile source regulations call for routine production line testing. EPA may also audit production vehicles and engines without prior notice using selective enforcement audits.

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3. Postproduction Programs

IN-USE COMPLIANCE PROGRAMS

In-use compliance programs track emissions performance of production vehicles or engines after they enter customer service. In-use testing programs are conducted by both EPA and manufacturers .

DEFECT REPORTING PROGRAMS

Manufacturers are required to report emission-related defects to EPA. An emission-related defect is a defect in design, materials or workmanship in a device, system or assembly, as described in the approved application for certification. Manufacturers must report a defect even if it does not increase emission levels. EPA regulations generally establish minimum numbers of confirmed defects that trigger defect information reporting requirements An emission-related defect does not necessarily lead to an emission recall because not all defects in emission-related parts increase emissions.

RECALL PROGRAMS

An emissions recall is a repair, adjustment or modification program conducted by a manufacturer to remedy an emission-related problem. Vehicle and engine manufacturers are required to design and build their products to meet emission standards for the useful life of the vehicle or engine specified by law. Under Section 207(c)(1) of the CAA, if EPA determines that a substantial number of vehicles or engines in a category or class do not meet emission standards in actual use, even though they are properly maintained and used, EPA can require the manufacturer to recall and fix the affected vehicles and engines. EPA may use a variety of data sources including EPA and manufacturer test results to determine that a recall is necessary. The purpose of a recall is to make sure the problem gets fixed and thereby prevent excessive pollution from vehicles or engines that are already in customer service. When an emissions recall occurs, the manufacturer must notify vehicle owners and provide instructions about how to have their vehicle repaired. Most recalls are initiated voluntarily by manufacturers once potential noncompliance is discovered; however, EPA also has the authority to order the manufacturer to recall and fix noncompliant vehicles or engines if the manufacturer declines to implement a voluntary recall.

4. Regulatory Flexibility Programs

EPA builds flexibility into its emissions regulations to increase compliance efficiency, decrease costs and encourage manufacturers to introduce new technologies

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

Average Banking and Trading (ABT) provisions allow manufacturers to meet an overall fleet average standard instead of an individual vehicle or engine standard. Manufacturers may comply with ABT provisions by certifying some vehicles and engines at levels above the emission standard, provided that these emission "deficits" are offset by positive credits from vehicles and engines certified below the standard. Compliance is determined by calculating the manufacturer's fleet-wide average of each exhaust test group's production or sales volume and emission level. The flexibility to meet fleet average emission standards by ABT credits can facilitate earlier introduction of clean technology into the market.

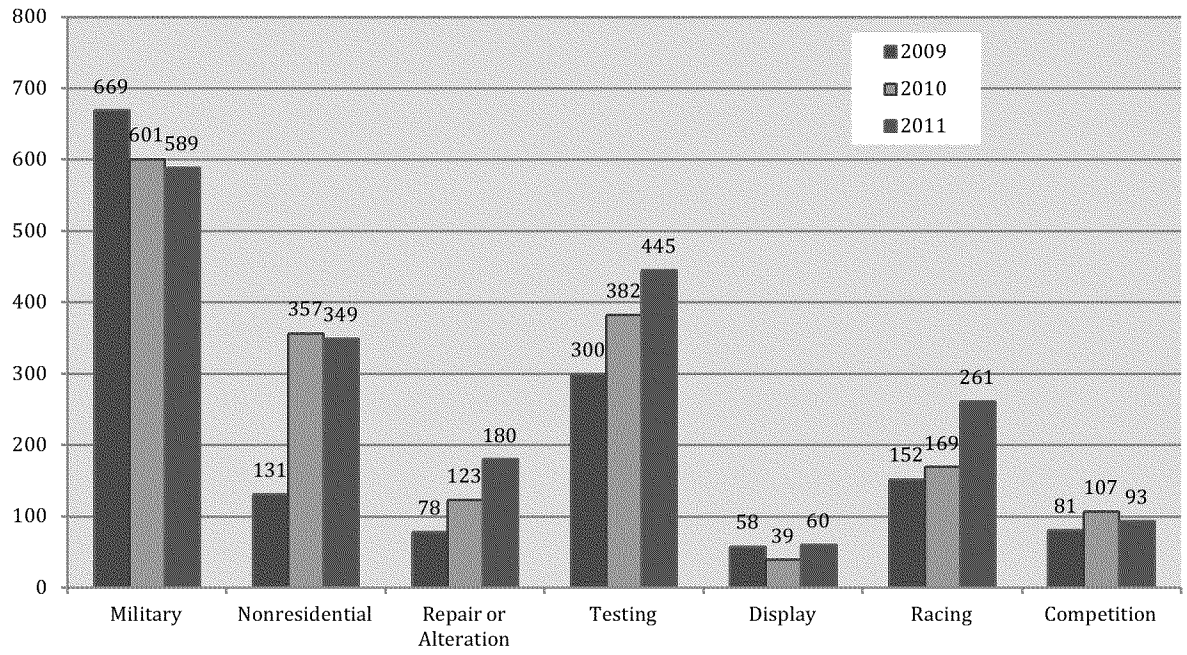
TRANSITION PROGRAM FOR EQUIPMENT MANUFACTURERS

The Transition Program for Equipment Manufacturers (TPEM) recognizes a potential challenge that can face equipment manufacturers when new emission standards take effect. If engines, of which there are relatively few designs, must be redesigned to achieve the required emission reductions, equipment powered by those engines, of which there could be 10,000 or more designs, may also need to be redesigned. TPEM permits equipment manufacturers a transition period during which they may continue to use a limited number of engines meeting previous standards while they update product designs to accommodate engines meeting the new standards.

5. Exemption Programs

Vehicles and engines imported into the United States may be eligible for an exemption from federal emission requirements. For example, vehicles belonging to military personnel or nonresidents may be eligible for exemption. Vehicles that are being imported for testing or display may also be exempt. Depending on the type of exemption, importers must request written EPA approval in advance. EPA works with the Department of Homeland Security U.S. Customs and Border Protection to ensure that proper approvals have been issued before vehicles and engines may enter the United States. The majority of the 1,469 import exemptions EPA issued in 2009, the 1,778 exemptions issued in 2010 and the 1,732 exemptions issued in 2011 were for light-duty vehicles (less than 0.02%). The majority of exemptions EPA issued for heavy-duty highway and nonroad engines or equipment were for test programs. EPA issued 90 heavy-duty or nonroad exemptions in 2009, 158 in 2010 and 245 in 2011 (less than 0.05%). An exemption may cover multiple vehicles and/or engines. Figure 7 summarizes the exemptions that EPA issued in calendar years 2009 – 2011.

Figure 7 - Vehicle and Engine Exemptions



B. Light-Duty Vehicles

SECTOR PROFILE:

- The light-duty vehicle sector includes passenger vehicles such as cars, vans, SUVs, and light-trucks
- Light-duty vehicles have been subject to increasingly stringent emissions and fuel economy standards since the 1970s
- Primary emission standards in effect for MY 2009-2011 are Tier 2 emission standards for HC, CO, NOx, and PM

PRIMARY COMPLIANCE ACTIVITIES IN 2009 -2011:

- Certification and fuel economy
- EPA and manufacturer confirmatory and in-use testing
- Defect reporting
- Recall
- Early credit for reducing greenhouse gas emissions described here.

CERTIFICATION

EPA issued about 500 certificates to light-duty vehicle[8] original equipment manufacturers (OEMs) each year in MY 2009 - 2011 (see Figure 6). Figure 8 shows the number of certified test groups for MY 2009 - 2011 by manufacturer.[9]

PRODUCTION VOLUME

Figure 9 presents by manufacturer the number of MY 2009-2011 cars and light-duty trucks produced for sale in the United States.[10] A comparison of Figures 8 and 9 shows that there is not always a correlation between the number of test groups a manufacturer certifies and the number of vehicles the manufacturer produces. Manufacturers with the most certified test groups do not necessarily produce the most vehicles .

[8] Some heavy-duty vehicles that are between 8,500-14,000 pounds GVWR are chassiscertified and are included in the light-duty vehicle certificate count.

[9] Each light-duty vehicle certificate covers a unique combination of exhaust test group and evaporative emissions family. Therefore the number of light-duty certificates and test groups is usually different. Manufacturers may create test groups that include both cars and trucks.

[10] These production data only include vehicles subject to Corporate Average Fuel Economy standards.

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Figure 8 - MY 2009-2011 Light-Duty Vehicle Test Groups by Manufacturer[11]

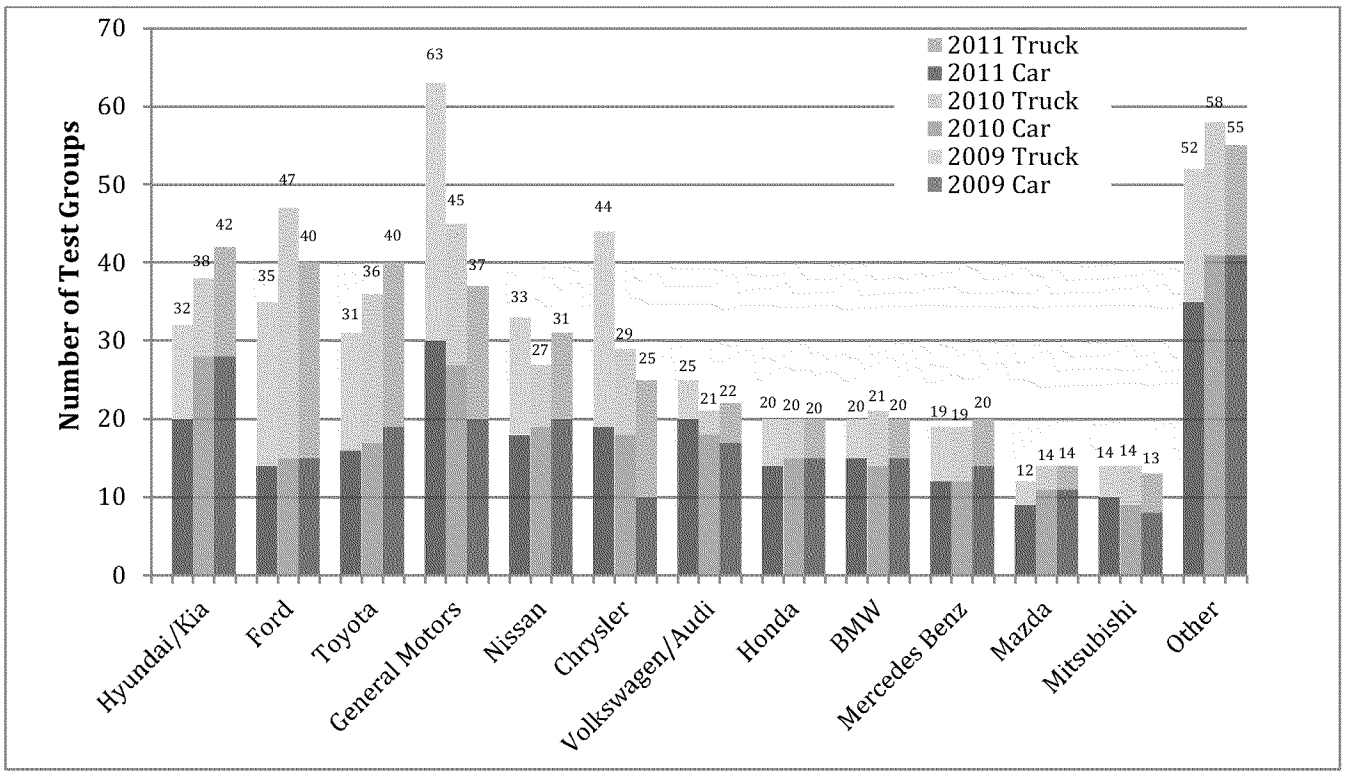
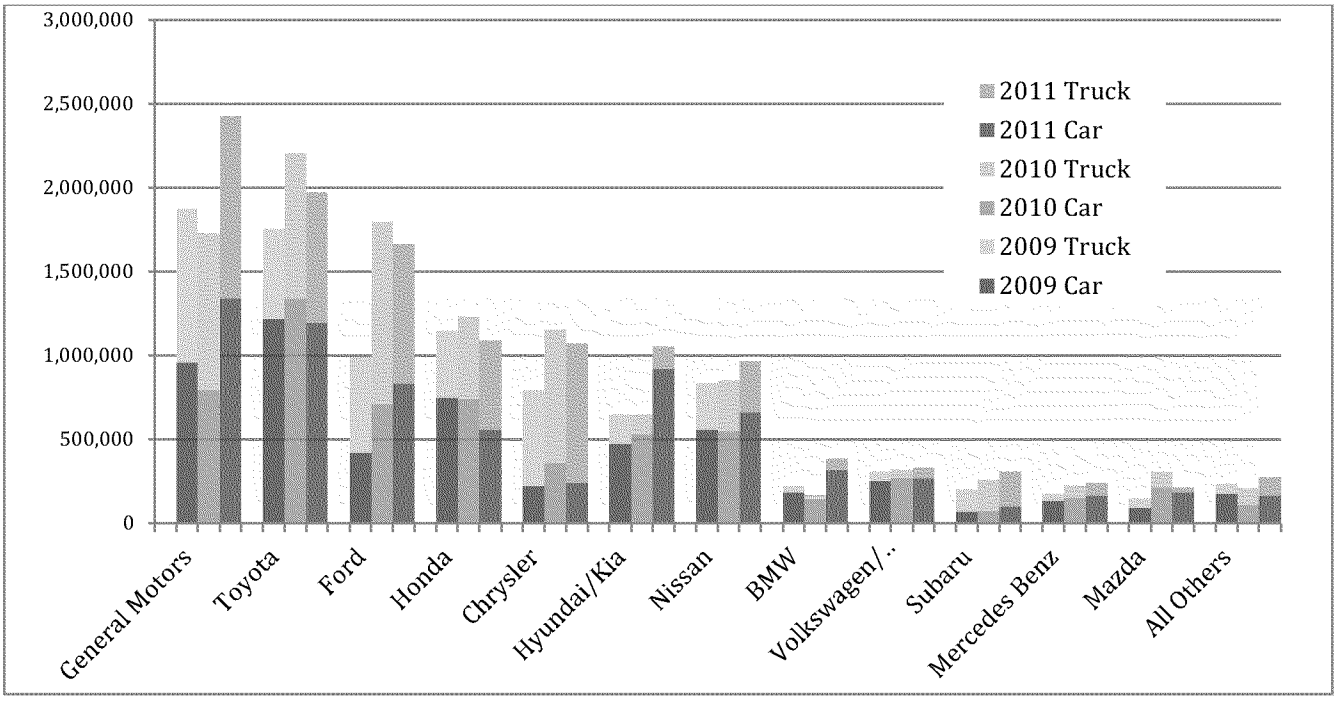


Figure 9 - MY 2009-2011 Light-Duty Production Volume by Manufacturer



[11] In MY 2010, two manufacturers created test groups that included both cars and trucks. One General Motors car/truck test group and two BMW car/truck test groups are counted under the "MY 2010 Car" category in Figure 8.

CONFIRMATORY TESTING

EPA and manufacturers test pre-production vehicles and engines prior to their introduction into commerce to confirm initial manufacturer emission test results.When a vehicle fails a confirmatory test, the manufacturer is allowed one retest to confirm or refute the failureIf the vehicle passes on retest, the retest is deemed the official certification test and the results from the retest stand as the official emission levels for that vehicle. Sometimes a confirmatory test failure can be attributed to problems that render the test vehicle unrepresentative of production vehicles. In those situations, the manufacturer corrects the problem in the test vehicle and retests. In still other cases, failures over the confirmatory test reflect actual engineering problems. These types of failures usually result in manufacturer action to change the vehicle calibration and update the certification application accordingly, resulting in a quantifiable emissions reduction for the vehicles that are ultimately produced. Regardless of whether a confirmatory test failure is due to problems with the test vehicle or problems with the calibration, the problems must be corrected and the vehicle must pass confirmatory testing before EPA will issue a certificate.

FUEL ECONOMY TESTING

EPA and manufacturers perform confirmatory testing for both emissions and fuel economy validation purposes. Fuel economy test results are the source for information that appears on new vehicle fuel economy labels and that EPA and the U.S. Department of Transportation use to assess compliance with corporate average fuel economy (CAFE) standards.

On May 7, 2010, EPA and the National Highway Safety Administration (NHTSA) published a final rule to regulate carbon dioxide (CO_2) and other GHG emissions from light-duty vehicles. The greenhouse gas and fuel economy standards apply to passenger cars, light-duty trucks and medium-duty passenger vehicles, covering model years 2012 through 2016. The program design enables manufacturers to use a single data set to satisfy both greenhouse gas and CAFE compliance requirementsEPA has been working with manufacturers to implement these regulations and expects to begin reporting greenhouse gas data as the program matures.

EPA reports fuel economy test data in an annual Fuel Economy Trends Report[12] which includes both laboratory test value results and results adjusted for real-world driving conditions.

[12] See http://www.epa.gov/oms/fetrends.htm for the latest Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends Report.

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DURABILITY TESTING

The CAA requires EPA emission standards to apply for the full useful life of the vehicle. Since emissions may degrade as vehicles age and accrue miles, manufacturers must perform durability testing to demonstrate that a vehicle will remain compliant for its full useful life, despite any deterioration that may occur over time. EPA regulations establish processes by which manufacturers may demonstrate durability using standard or custom methods. All the other manufacturers chose to use proprietary methods to estimate. Manufacturers who use their own durability aging procedures must provide EPA with an "equivalency factor" that enables comparison between the proprietary method and the published, standard EPA method. This allows a third party who relies on the EPA method to replicate the manufacturer's method.

IN-USE COMPLIANCE TESTING

Both EPA and manufacturers conduct testing to monitor in-use vehicle emissions. EPA conducts in-use vehicle surveillance testing at the National Vehicle and Fuel Emissions Laboratory in Ann Arbor, Michigan. The purpose of the EPA surveillance program is to assess emissions performance a few years after vehicles enter the fleet. EPA typically recruits two- or three-year-old vehicles from volunteers in southeast Michigan. EPA selects vehicles for surveillance both randomly and based on certification data, manufacturer in-use verification data, vehicle production volume, new technology, and public complaints and inquiries. In both 2009 and 2010, EPA selected about 45 classes per year for surveillance and generally tested three vehicles from each selected class. In 2011 EPA selected 50 classes and tested two vehicles per class. If any of the initial vehicles within a class failed a test, EPA recruited additional vehicles from that class for follow-up testing to determine whether an emissions problem was likely to exist and was not an artifact of the small sample size (or even a single defective vehicle) .

EPA also conducts an in-use confirmatory testing program for vehicle classes that merit closer scrutiny. These classes may be indentified through failures in either EPA in-use surveillance or manufacturer in-use testing programs.

Figure 10 on the next page shows the vehicle model year, manufacturer, and carline selected for EPA surveillance testing in 2009 - 2011.

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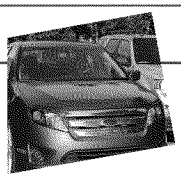
Figure 10 - Vehicles Tested in EPA's In-Use Testing Program in 2009-2011

Model Year	Manufacturer	Model
Surveillance Classes		
2005	Hyundai	Elantra (2.0)
2005	Volkswagen	Touareg (3.2)
2006	BMW	M3, M3 CONVERTIBLE (3.2)
2006	Chrysler	Jeep Liberty 2WD/4WD (3.7)
2006	Ford	Freestar Wagon FWD (4.2); F150 2WD (5.4)
2006	General Motors	Trailblazer, Rainier, Envoy (6.0); Chevrolet Colorado, Canyon, Isuzu I280 (2.8)
2006	Honda	Pilot 2WD (3.5)
2006	Mercedes Benz	E320 CDI (3.2)
2006	Porsche	Carrera (3.8)
2006	Toyota	Scion XB (1.5)
2006	Volkswagen	Jetta (1.9)
2007	Audi	Audi Q7 and Touareg (4.2)
2007	BMW	328i, 328xi (3.0); Mini Cooper (1.6)
2007	DaimlerChrysler	Dodge Caliber (2.4); Pacifica (4.0); Wrangler 2WD,4WD (3.8); Nitro 2WD (3.7)
2007	Ford	Expedition 2WD, Navigator 2WD (5.4); Lincoln-Mercury, MKZ AWD/FWD (3.5); 500 FWD (3.0)
2007	GM-Daewoo	Aveo (1.6)
2007	General Motors	Saturn Outlook 4WD & AWD (3.6); Several 5.3L vehicles; Chevrolet Malibu (2.4); Chevy Impala (3.5); Saab 9-3 (2.3);
2007	Honda	Fit (1.5)
2007	Hyundai	Tucson (2.7)
2007	Jaguar	Jaguar S-type, VDP, XJ8, XK (4.2)
2007	Kia	Sedona, Hyundai Entourage (3.8)
2007	Mazda	CX-7 (2.3); Mazda 3 (2.3);
2007	Mercedes Benz	HL450 4Matic (4.6)
2007	Mitsubishi	Outlander 2WD 4WD (3.0); Galant (2.4)
2007	Nissan	Altima (2.5); Frontier 2WD & 4WD (4.0); Versa (1.8); Frontier (2.5)
2007	Subaru (Fuji)	Impreza AWD, Wagon/Outback (2.5)
2007	Toyota	Camry Hybrid (2.4); Corolla (1.8); Lexus: LS 460, LS 460L (4.6); Sienna (3.5)
2007	Volvo	XD 90 AWD, XC 90 FWD (3.2)
2008	Audi	Audi A6 (3.1); Passat, Gtt, Jetta Passat (2.0)
2008	BMW	335 (3.0)
2008	Chrysler	Jeep Liberty 4WD (3.7); Dodge Dakota 2WD & 4WD (3.7); Charger (5.7)
2008	Ford	F150 (5.4); Focus (2.0); Escape Hybrid (2.3); F150 XL FFV (5.4); Explorer 4WD (4.0)
2008	General Motors	GM Chevrolet Cobalt (2.4); C15 Silverado 2WD (4.3); Saturn Astro (1.8); Yukon Denali + XL (6.2);
2008	GM-Daewoo	Suzuki Forenza Reno (2.0)
2008	Honda	Accord (2.4); Civic Hybrid (1.3); Odyssey (3.5)
2008	Hyundai	Tucson 2WD, 4WD (2.7)
2008	Kia	Kia Rondo (2.4)



Model Year	Manufacturer	Model
Surveillance Classes		
2008	Land Rover	LR2 (3.2)
2008	Mazda	CX-9 2WD, 4WD (3.7)
2008	Mercedes Benz	C300,C350,CLK350,E350 (3.5)
2008	Mitsubishi	Lancer (2.0)
2008	Nissan	Versa (1.8)
2008	Subaru (Fuji)	Impreza (2.5)
2008	Toyota	Toyota Lexus GX470 (4.7); Lexus IS 250 (2.5); Camry (2.4)
2009	Audi	A4, A5, Quattro (2.0)
2009	BMW	335 CI, 335 I (3.0)
2009	Chrysler	Dodge Caravan (3.8); Dodge Ram 1500 (5.7); Dodge Journey (4.0); Dodge Charger (3.5); Dodge Ram 1500 (4.7)
2009	Ford	F150 FFV (5.4); Escape Hybrid (2.5); Escape (2.5); Focus (2.0); Fusion (3.0); F150 (5.4)
2009	General Motors	Saab 9-3 (2.3); Chevrolet Malibu (2.4); Saturn Vue Hybrid (2.4); Chevrolet HHR (2.4); Chevrolet C15 Silverado (5.3); Envoy, Trailblazer (4.2)
2009	Honda	Pilot (3.7); CR-V (2.4); Civic (1.8); Accord (2.4)
2009	Hyundai	Sonata (2.4); Santa Fe (2.7)
2009	Kia	Optima (2.4); Rio (1.6); Sportage (2.0)
2009	Land Rover	LR3, Range Rover Sport (4.4)
2009	Mazda	Mazda 5 (2.3)
2009	Mercedes Benz	Smart for 2 (1.0)
2009	Mitsubishi	Galant (2.4); Eclipse and Eclipse Spyder (2.4)
2009	Nissan	350Z (3.5); Murano (3.5); Versa (1.8)
2009	Subaru (Fuji)	Subaru Forester (2.5); Outback Wagon (3.0)
2009	Suzuki	SX4 (1.9)
2009	Toyota	Sienna (3.5); Highlander Hybrid (303); Yaris (1.5); Corolla (1.8); Camry Hybrid (2.4)
2009	Volkswagen	Jetta (2.5)
2009	Volvo	C30, C70, S40, V50 (2.4)

In addition to its own in-use testing, EPA uses data from the mandatory manufacturer run In -Use Verification Program (IUVP) to monitorin-use light-duty vehicle emissions performance. IUVP tests are required at low mileage (between 10,000 and 50,000 miles) and high mileage (greater than 50,000 miles). Manufacturers must complete low mileage IUVP testing one year after the end of production and complete high mileage IUVP testing five years after the end of production. Figure 11 on the next page shows a sample IUVP test schedule for a MY2010 vehicle.

Figure 11 - Example of IUVP Testing Process for a MY 2010 Vehicle

2009				2010				2011				2012-2013				2014				2015			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1			Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
		Production period				Low Mileage Testing												High Mileage Testing					

★ = *Testing is due for completion on or before this date*

Figure 12 shows the total number of vehicles tested over each test procedure and their corresponding failure rates by vehicle model year for all IUVP testing conducted and reported through January 2011.

Figure 12
Light-Duty Vehicle In-Use Verification Program Test Volumes and Failure Rates

Model Year	FTP		US06		2-Day Evap		ORVR[13]	
	Vehicles Tested	Failure Rate	Vehicles Tested	Failure Rate	Vehicles Tested	Failure Rate	Vehicles Tested	Failure Rate
High-Mileage Testing								
2000	481	6.4%	0	N/A	38	0.0%	20	10%
2001	1147	4.2%	18	5.6%	103	3.9%	76	6.6%
2002	1135	5.2%	91	3.3%	105	3.8%	77	9.1%
2003	1185	4.2%	254	2.0%	121	5.0%	101	7.9%
2004	1173	3.8%	819	1.5%	158	4.4%	142	4.9%
2005	1103	3.5%	782	1.2%	142	4.2%	140	5.7%
2006	935	4.9%	671	0.8%	114	1.8%	121	0.8%
2007	1115	2.9%	781	1.9%	120	4.2%	127	6.3%
2008	264	8.0%	209	0.0%	43	7.0%	53	7.6%
2009	23	0.0%	16	6.3%	6	0.0%	7	14.3%
Low-Mileage Testing								
2004	670	4.8%	621	1.5%	167	5.4%	150	7.3%
2005	654	4.6%	589	0.9%	156	3.9%	145	3.5%
2006	654	3.8%	569	0.9%	152	2.0%	154	5.2%
2007	724	3.9%	602	0.3%	143	1.4%	149	4.0%
2008	649	4.3%	557	0.2%	128	1.6%	130	4.6%
2009	530	3.8%	479	0.4%	116	6.9%	127	0.8%
2010	556	3.1%	489	0.0%	141	2.1%	149	0.7%
2011	480	2.5%	425	1.2%	125	0.8%	130	2.3%

Overall, the test results from this program show that the majority of the in-use fleet continues to comply with the emission standards. However, when IUVP testing identifies potential emissions concerns, EPA and manufacturers work together to implement solutions which may involve voluntary manufacturer action to fix the problem, or, if necessary, an EPA-ordered emissions recall. This process is described in greater detail in the 2007 Compliance Report.

[13] Onboard refueling vapor recovery (ORVR) is a vehicle emission control system that captures fuel vapors from the vehicle gas tank during refueling. This requirement was phased-in from 1998 through 2006. It appears that the failure rate is generally decreasing.

DEFECT REPORTING

Figures 13 and 14 present 2009 - 2011 *calendar year* light-duty vehicle emission defect report information. Defects reported in 2009 -2011 potentially affected more than 57 million vehicles. A single defect incidence may affect multiple *model years* of a given vehicle.

Light-duty vehicle manufacturers are required to notify EPA when they learn of emission-related defects in 25 or more vehicles of the same class (e.g., exhaust test group) and category (e.g., manufacturer, model year).

Figure 13 - 2009-2011 CY Light-Duty Vehicle Defect Reports by Manufacturer

	Reported in CY2009		Reported in CY2010		Reported in CY2011	
Manufacturer	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**
Bentley	5	22,109	-	-	2	2,369
BMW	10	184,143	17	342,059	21	497,010
Chrysler	33	2,647,013	18	2,170,741	16	2,109,506
Cummins	1	157	2	211,305	-	-
Ford	12	2,936,701	11	1,816,928	14	2,123,801
General Motors	10	849,594	11	684,655	12	2,091,073
Honda/Acura	21	5,488,140	9	3,711,978	20	2,871,321
Hyundai	8	963,385	12	469,805	14	1,435,048
Jaguar	3	18,619	4	70,828	4	131,357
Kia	9	572,562	10	620,411	9	475,043
Lamborghini	1	139	-	-	-	0
Land Rover	2	53,237	4	208,491	8	371,850
Mazda	8	761,000	13	807,700	12	1,180,484
Mercedes-Benz	5	954,611	7	292,246	12	936,202
Mitsubishi	5	45,386	1	157,314	3	1,661
Nissan/Infiniti	23	2,576,199	21	3,341,602	15	2,255,282
Porsche	53	253,990	17	56,220	5	62,550
Rolls Royce	-	-	2	595	-	-
Rousch	-	-	-	-	2	1,415
Subaru	5	454,814	1	384,984	4	478,217
Suzuki	-	-	1	11,819	1	4,174
Toyota/Lexus	3	1,705,800	4	892,300	3	668,680
Volkswagen/Audi	28	1,024,318	13	619,951	26	762,073
Volvo	2	231,355	1	6,971	5	737,627
Total	**247**	**21,743,272**	**179**	**16,878,903**	**208**	**19,196,743**

Figure 13 shows the number of defect reports submitted for each manufacturer in 2009 - 2011 *calendar year* and the number of affected vehicles. The vehicle *model years* that are covered by the defect reports

submitted in 2009 - 2011 *calendar years* range from MY 2001 through 2011.[14] Manufacturers are required to report defects up to five years after the end of production.

Figure 14 shows the number of defects by defect category for all the vehicles covered by defect reports in 2009 - 2011 *calendar years*.

Figure 14 - 2009 - 2011 CY Light-Duty Vehicle Defect Reports by Problem Category

	Reported in CY2009		Reported in CY2010		Reported in CY2011	
Problem Category	**Number of Defect Reports**	**Number of Affected Vehicles[15]**	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**
Air Inlet/Intake System					6	752,695
Catalyst System	25	1,651,327	11	1,643,927	7	267,647
Computer Related (other than OBD)	21	4,615,410	19	2,473,670	22	2,754,463
Crankcase Ventilation System	3	187,429	1	1,991,813	3	97557
Drivability Problem	2	2,116,987	1	88,063	0	0
EGR System	2	485,755	2	621,929	3	480,845
Electrical, Mechanical & Cooling Systems	19	2,878,703	13	1,540,914	29	3,188,305
Emission Control Information	3	13,606	3	36,619	4	2,936
Evap Emissions System	14	1,033,398	12	968,646	20	2,252,586
Exhaust System	6	309,888	3	123,221	4	409,419
Fuel Delivery System	23	1,861,491	18	1,529,698	10	185,005
Fuel Tank System	14	2,177,608	11	2,235,022	22	3,150,623
Hybrid Vehicle System	2	25,840	1	25,810	0	0
Ignition System	11	378,428	7	1,876,995	6	575,421
Intake/Exhaust Manifold	10	1,362,544	3	155,205	3	204,248
Internal Engine Component					1	612,518
Monitoring/Measuring Sensor/System	24	6,460,405	27	3,415,266	15	1,086,995
OBD System	58	5,566,516	36	2,500,612	40	2,330,438
Other	1	157	-	-	1	8,314
Oxygen Sensor	9	3,238,400	11	511,651	7	608,779
Selective Catalytic Reduction					2	18,219
Turbocharger/Supercharger					3	209,730
Total	**247**	**34,363,892**	**179**	**21,739,061**	**208**	**19,196,743**

[14] Defect and recall reports can be submitted in the calendar year *prior to* the designated model year because vehicles can be certified and introduced into commerce starting January 2 of the prior year. For example, MY 2014 vehicles can be certified and introduced into commerce starting January 2, 2013.

[15] Vehicles that have defects in more than one category are counted in each problem category. Thus, the total number of affected vehicles can be higher in Figure 16 than the total number of affected vehicles in Figure 15.

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RECALL REPORTING

Figure 15 shows the number of light -duty vehicle recalls by vehicle manufacturer in 2009 - 2011 *calendar years*. Because a recall usually covers a single, specific condition, a vehicle with multiple emissions problems may be subject to multiple recalls. Thus the total number of affected vehicles includes vehicles that have been recalled more than once. Similarly, there is no direct correlation between the number of defect reports, recalls, and the number of vehicles that are recalled. A manufacturer may identify a lot of defects that are not significant enough to warrant a recall. On the other hand, a manufacturer could have a few major defects that evolve into major recalls affecting large portions of their product line. Historically, emissions recalls affect about three million vehicles annually although the number may vary in any given year.

Figure 15 - 2009-2011 CY Light-Duty Vehicle Recalls by Manufacturer

	Recalls in CY2009		Recalls in CY2010		Recalls in CY2011	
Manufacturer	**Number of Recalls**	**Number of Affected Vehicles[18]**	**Number of Recalls**	**Number of Affected Vehicles**	**Number of Recalls**	**Number of Affected Vehicles**
Aston Martin	-	-	-	-	1	3,977
Bentley	1	11,800	-	-	-	-
BMW	5	354,935	2	47,534	7	348,305
Chrysler	11	212,363	1	31,797	2	112,076
Cummins	-	-	2	160,582	1	28,978
Ford	-	-	1	215,764	2	4,632
General Motors	4	89,312	10	543,308	8	1,497,203
Honda/Acura	2	518,181	1	95,611	7	1,304,845
Hyundai	1	65,614	-	-	-	-
Jaguar	1	98,581	1	3,122	-	-
Kia	1	6,680	-	-	1	45,635
Land Rover	1	6,615	-	-	2	10,316
Lamborghini		-	-	-	-	-
Mazda	-	-	1	16,200	1	52,000
Mercedes-Benz	1	16,623	1	65,444	-	-
Mitsubishi	1	6,882	2	56,113	-	-
Nissan/Infiniti	3	379,688	7	1,454,813	3	41,523
Porsche	-	-	1	71,792	1	226
Rolls Royce		-	-	-	-	-
Rousch		-	-	-	2	1,415
Subaru	4	428,578	2	28,156	1	834,045
Suzuki	-	-	1	11,692	1	311
Toyota/Lexus	2	265,600	2	962,661	3	1,581,700
Volkswagen/Audi	4	520,657	3	561,433	9	1,046,881
Volvo	-	-	1	6,971	1	1,597
Total	**42**	**2,982,109**	**39**	**4,332,993**	**53**	**6,915,665**

Figure 16 lists categories of defects that were corrected by recalls in 2009 – 2011. EPA established the defect categories primarily for internal tracking purposes to identify potential, industry-wide problems with a particular component or technology. Recalls in 2009 -2011 *calendar years* affected vehicles spanning 2001 through 2011 *model years*.

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Figure 16 - 2009-2011 CY Light-Duty Vehicle Recalls by Problem Category

	Recalls in CY2009		Recalls in CY2010		Recalls in CY2011	
Problem Category	**Number of Recalls**	**Number of Affected Vehicles**	**Number of Recalls**	**Number of Affected Vehicles**	**Number of Recalls**	**Number of Affected Vehicles**
Catalyst System	7	392,664	7	241,617	3	178,701
Computer Related (other than OBD)	7	638,641	5	22,807	8	2,413,259
Crankcase Ventilation System	1	2,470	-	-	1	115,829
Drivability Problem	1	51,000	-	-	-	-
Electrical, Mechanical & Cooling Systems	-	-	-	-	4	330,740
Emission Control Information Label	2	737	2	231,964	2	1,735
Evap Emissions System	-	-	1	643	3	96,935
Exhaust System	-	-	1	4,156	1	135,740
Fuel Delivery System	8	674,363	4	723,103	8	363,507
Fuel Tank System	3	30,175	5	1,330,691	6	1,158,906
Hybrid Vehicle System	1	18,353	1	566,745	1	46,400
Ignition System	3	501,739	2	572,864	1	237,610
Intake/Exhaust Manifold	1	359,665	-	-	2	129,015
Monitoring/Measuring Sensor/System	2	26,069	3	117,362	6	1,549,407
OBD System	5	156,033	6	412,669	7	157,881
Other	-	-	1	36,580	-	-
Oxygen Sensor	1	130,200	1	71,792	-	-
Total	**42**	**2,982,109**	**39**	**4,332,993**	**53**	**6,915,665**

AVERAGING, BANKING AND TRADING (ABT) PROGRAMS

The 2007 Compliance Report provided an overview of EPA's Tier 2 program. The Tier 2 standards are the current set of emission standards that apply to cars and light-duty trucks. The Tier 2 regulations offer manufacturers a choice ofeight emission bins to which they can certify. Lower bin numbers reflect more stringent emission standards.The Tier 2 ABT program allows manufacturers to use sales-weighted averaging to certify groups of vehicles to different bin levels, as long as the fleet as a whole on average meets Bin 5 standards each year.

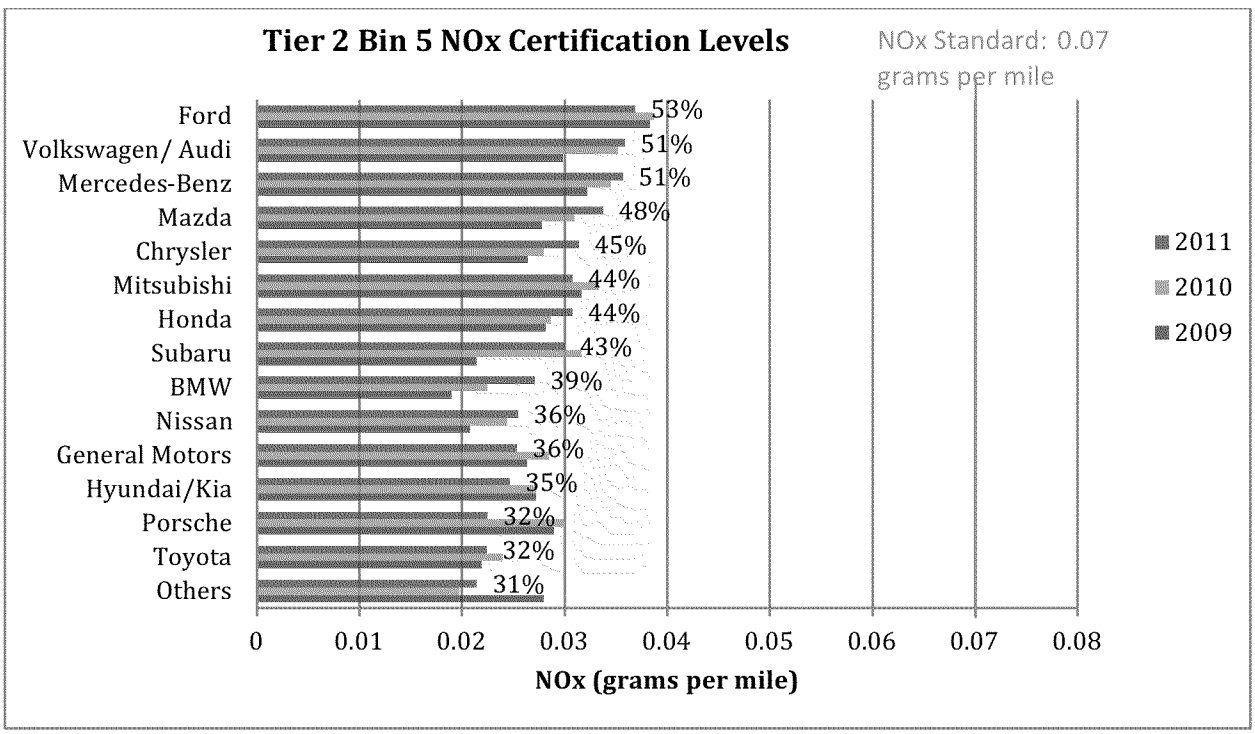
Figure 17 shows the percentage of exhaust test groups by emission certification bin forMY 2009 - 2011. For MY 2009, about 97 percent of test groups were certified to Bin 5 or better. For MY 2010 about 95 percent of test groups were certified to Bin 5 or better. And for MY 2011 about 90 percent of test groups were certified to Bin 5 or better.

Figure 17
MY 2009-2011 Light-Duty Test Group Distribution by Tier 2 Emissions Bins

	Percentage of Light-Duty Test Groups [16]		
Tier 2 Bin	**MY 2009**	**MY 2010**	**MY 2011**
1	0.3%	0.3%	1.9%
2	1.8%	2.6%	3.9%
3	2.4%	5.7%	4.6%
4	10.6%	15.4%	18.0%
5	82.2%	71.5%	61.5%
6	-	0.3%	0.8%
7	-	0.3%	0.2%
8	2.7%	3.9%	9.1%

Figures 18–20 present the average certification levels for NOx, NMOG, and CO respectively along with the standards for Tier 2 Bin 5 for each major manufacturer for 2009 - 2011. The lower the certification levels relative to the standard, the greater the compliance margin.[17]

Figure 18
MY 2009-2011 Tier 2 Bin 5 NOx Certification Levels and Compliance Margins by Manufacturer



[16] Sum of rounded values may not equal 100 percent.

[17] In Figures 20-22, the order from left to right is determined by the 2011 compliance margin, from lowest to highest.

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Figure 19
MY 2009-2011 Tier 2 Bin 5 NMOG Certification Levels and Compliance Margins by Manufacturer

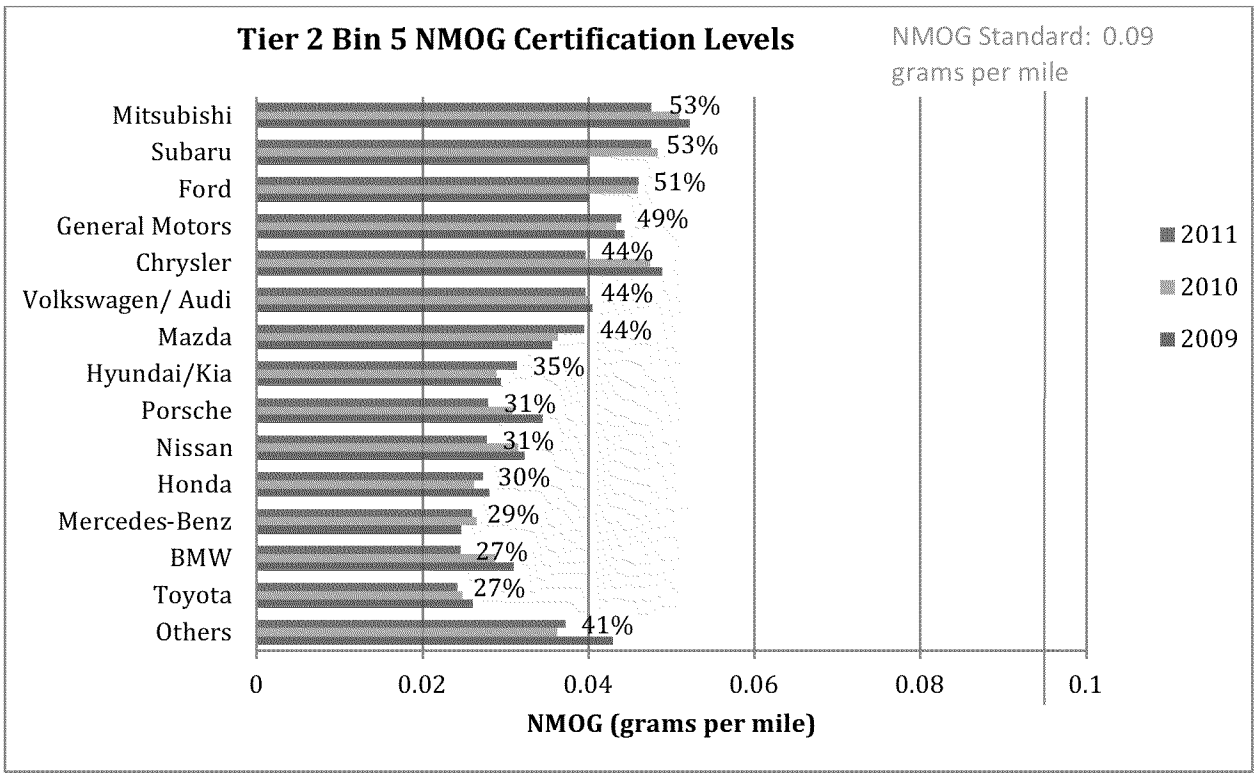
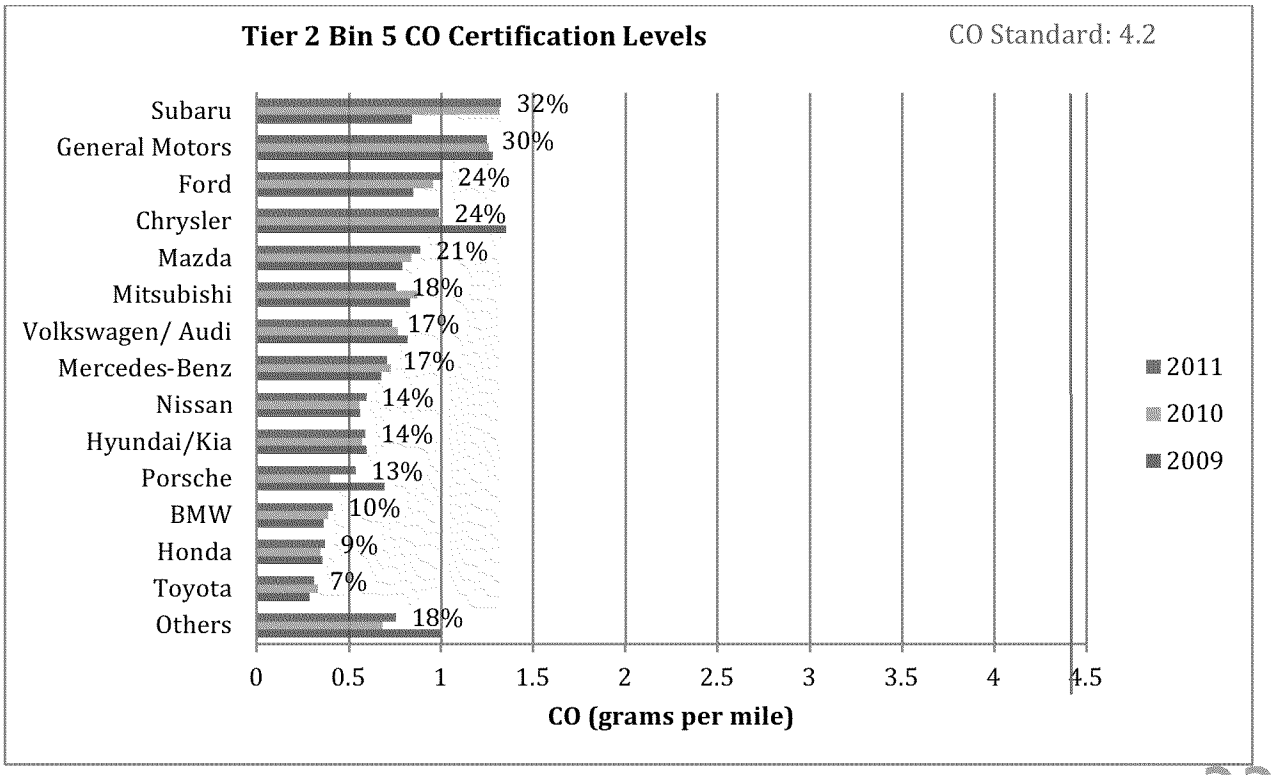


Figure 20
MY 2009-2011 Tier 2 Bin 5 CO Certification Levels and Compliance Margins by Manufacturer



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C. Highway Motorcycles

SECTOR PROFILE:

- Highway and off-highway motorcycles are subject to different sets of regulations and emission standards. This section covers the highway motorcycles. Information about off-highway motorcycles is reported in the Recreational Vehicles section, starting on page 55
- Highway motorcycles have been subject to HC and CO emissions standards since 1978
- A second set of more stringent emission standards took effect in MY2006. Although the CO emission standard remained unchanged at 12.0 g/km, the HC emission standard was reduced from 5 g/km to 1.0 g/km for Class 1 and 2 motorcycles. In addition, an optional HC + NOx 1.4 g/km standard was added.

PRIMARY COMPLIANCE ACTIVITIES IN 2009 – 2011:

- Certification
- Production vehicle testing
- Defect reporting

CERTIFICATION

Figure 21 presents the number of certified highway motorcycle engine families by class.

Figure 21 - MY 2009-2011 Highway Motorcycle Engine Families by Class

Highway Motorcycle Category	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Class Ia (<50cc)	91	77	48
Class Ib (50 -169cc)	96	80	55
Class II (170-279cc)	73	68	44
Class III (>279cc)	196	167	135
Battery electric motorcycles	4	7	8
Total	**460**	**399**	**290**

For MY 2009, 141 manufacturers certified highway motorcycles and 115 manufacturers certified highway motorcycles in MY 2010. For MY 2011, 89 manufacturers certified highway motorcycles.Figure 22 on the next page presents the number of motorcycle manufacturers in MY 2009 - 2011 for each highway motorcycle class.

Figure 22 - MY 2009-2011 Highway Motorcycle Manufacturers by Class

Highway Motorcycle Category	Number of Manufacturers Holding Certificates		
	MY 2009	MY 2010	MY 2011
Class Ia (<50cc)	68	52	47
Class Ib (50 -169cc)	69	51	44
Class II (170-279cc)	41	37	39
Class III (>279cc)	52	44	41
Battery electric motorcycles	4	5	6

Figure 23 presents the number of certified highway motorcycle engine families by manufacturer for MY 2009 - 2011. The manufacturers that certifieda small number of engine families across the three model years are grouped together as "Other".

Figure 23 - MY 2009-2011 Highway Motorcycle Engine Families by Manufacturer

MY 2009		MY 2010		MY 2011	
Manufacturer	Number of Engine Families	Manufacturer	Number of Engine Families	Manufacturer	Number of Engine Families
Yamaha	31	Piaggio	30	Yamaha	28
Suzuki	30	Yamaha	27	Piaggio	26
Piaggio	30	Suzuki	23	Honda	14
Honda	18	Kawasaki	15	Suzuki	14
Kawasaki	16	Honda	13	Kawasaki	13
Harley-Davidson	12	KYMCO	11	KYMCO	11
		Carter Brothers	10	Ducati	10
KYMCO	10			Carter Brothers	9
Carter Brothers	9	Ducati	9	Harley-Davidson	7
BMW	7	BMW	8	Triumph	7
Other	297	Other	253	Other	199
Total	460	Total	399	Total	338
Top Manufacturers	35.4%	Top Manufacturers	36.6%	Top Manufacturers	41.1%

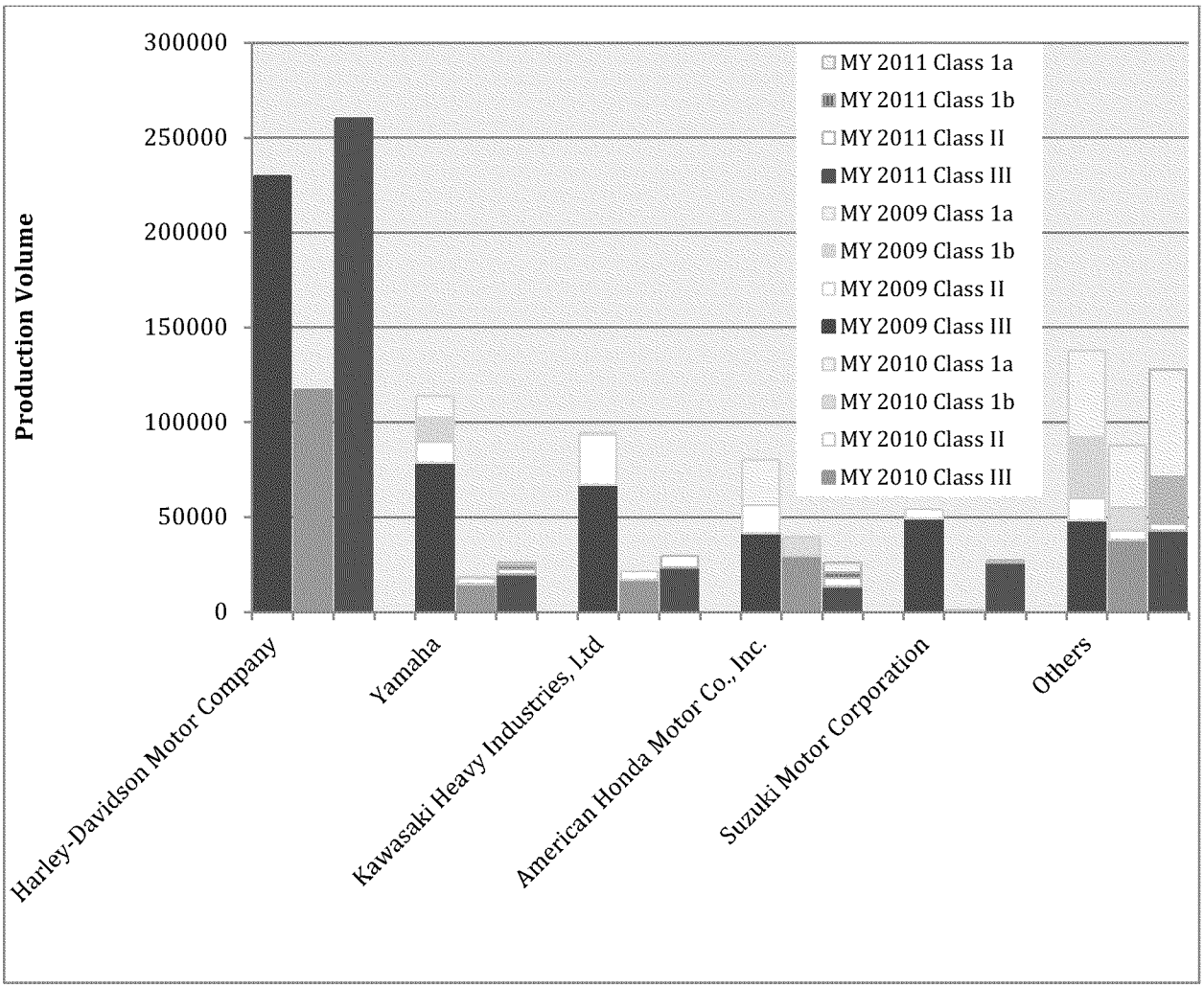
PRODUCTION VOLUME

More than 150 highway motorcycle manufacturers certified products in MY 2009 – 2011, but the vast majority of bikes sold in the United Stateswere produced by just a few companies. Figure 24 shows reported production volumes for the five highest sales volume motorcycle manufacturersin model years 2009 - 2011.[25] The production volume for lower-volume manufacturers is shown in aggregate. The aggregated volume is based on available data manufacturers have reported to EPA As with light-duty vehicles, a comparison of Figures 23 and 24 show that there is not always a correlation between the number of engine families a manufacturer certifies and the number of vehicles the manufacturer

[18] For MY 2009 Kawasaki Heavy Industries produced 1,555 Class 1b motorcycles; For MY 2010 Suzuki Motor Corporation produced 1,033 Class II and 245 Class III motorcycles; for MY 2010, Yamaha produced 516 Class 1a and 228 Class 1b motorcycles. . These low volumes are difficult to discern on the scale of this chart.

produces.[19] Manufacturers with the most certified engine families do not necessarily produce the most vehicles.

Figure 24 - MY 2009-2011 Highway Motorcycle Production Volumes by Manufacturer



PRODUCTION VEHICLE TESTING

EPA may require a manufacturer to supply production vehicles for emissions testing on demand. EPA has found, via inspections at ports and other enforcement related activities, that some imported production motorcycles are not built to the certified configurations.To follow up on this concern, EPA is collaborating with Environment Canada to test productionmotorcycles at an Environment Canada emissions testing facility. Through July 2011, the agencies had tested or were in the process of testing 29 MY 2008-2010 EPA certified engine families and have identified several engine families that may potentially exceed applicable standards. So far, one manufacturer has initiated a voluntary recall for thousands of motorcycles sold in both the United States and Canada based on this testing. EPA is continuing to follow up with other manufacturers.

[19] The economic slowdown may have contributed to the MY 2010 drop in production volume.

DEFECT REPORTING

Figure 25 presents 2009 - 2011 emission defect report information for highway motorcycles. These reports can include multiple model years of a given vehicle and can span more than one problem category. Highway motorcycle manufacturers are required to notify EPA when they learn of the existence of emission-related defects in 25 or more vehicles of the same class (e.g., engine family) and category (e.g., manufacturer, model year).

Figure 25 - 2009-2011 Highway Motorcycle Defect Reports by Problem Category

	Reported in 2009		Reported in 2010		Reported in 2011	
Problem Category	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**
Oxygen sensor	1	12,015	-	-	-	-
Electrical, mechanical & cooling systems	-	-	1	2,782	-	-
OBD system	1	2,447	-	-	-	-
Crankcase ventilation component/system	1	2,447	-	-	-	-
Computer related (other than OBD)	-	-	1	1,452	-	
Carburetor	-	-	-	-	1	16,856
Fuel Delivery Component	-	-	-	-	1	314
Other	-	-	1	59	-	
Total	**3**	**16,909**	**3**	**4,293**	**2**	**17,170**

In calendar years 2009 - 2011, manufacturers submitted defect reports that affected highway motorcycles in model years ranging from MY 2008-2011.

RECALL REPORTING

There was one highway motorcycle recall in 2009 for 5,858 MY 2010 Honda motorcycles with a problem categorized as "defective/incorrect crankcase ventilation component/system." There were no highway motorcycle recalls in calendar year 2010. There was one highway motorcycle recall in 2011 for 314 MY 2011 Bombardier motorcycles with a problem categorized as "defective/incorrect intake/exhaust manifold".

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

The 2006 regulations added provisions allowing highway motorcycle manufacturers to use an EPA specified emission averaging approach to show compliance with the applicable HC+NOx standards. For MY 2009 – 2011 about 6-9 percent of manufacturers availed themselves of this provision.

Class III motorcycles (>279cc) represent the majority of motorcycle sales, and many Class III manufacturers with large sales volumes take advantage of the fleet averaging flexibility for HC+NOx. For model year 2009 about 13 percent of Class III manufacturers used this fleet averaging flexibility. For model year 2010 about 21 percent of Class III manufacturers used the fleet averaging flexibility. And for model year 2011 about 17 percent of Class III manufacturers used the fleet averaging flexibility.

D. Heavy-Duty Highway Engines

SECTOR PROFILE:

- Heavy-duty highway engines are used in highway vehicles such as trucks and buses that are more than 8,500 pounds GVWR
- EPA has regulated heavy-duty highway engine emissions since 1982
- Primary emission standards in effect for MY 2009-2011 were NMHC, CO, NOx, and PM, with final phase-in of a more stringent NOx standard starting in MY2010. Reductions in diesel sulfur content prior to 2007 enabled significant advances in emission controls.

PRIMARY COMPLIANCE ACTIVITIES IN 2009 - 2011:

- Certification
- In-use testing
- Defect reporting

CERTIFICATION

As shown in Figure 6, EPA issued 123 heavy-duty highway certificates for MY 2009, 81 heavy-duty highway certificates for MY 2010 and 112 heavy-duty certificates for MY 2011.[20] These include alternative fuel conversion and evaporative emissions certificates. Most certificates were for diesel engines.

Figures 26 and 27 on the next page present the number of MY 2009 - 2011 engine families certified in each intended service class for compression ignition and spark ignition heavy-duty highway engines. [21]

[20] Some vehicles that are between 8,500-14,000 pounds GVWR are chassiscertified and are included in the light-duty vehicles data.
[21] The number of engine families has is not directly correlated to engine production volumes.

Figure 26
MY 2009-2011 Heavy-Duty Highway Compression Ignition Engine Families by Service Class

Service Class	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Light heavy-duty diesel	14	3	8
Medium heavy-duty diesel	31	12	12
CA only medium-duty	2	-	1
Heavy heavy-duty diesel	39	25	28
Urban Bus	4	3	3
CA only urban bus	-	1	-

Figure 27
MY 2009-2011 Heavy-Duty Highway Spark Ignition Engine Families by Service Class

Service Class	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Heavy-duty gasoline 1 (<=14k lbs)	5	5	5
Heavy-duty gasoline 2 (>14k lbs)	3	3	4
Urban bus	1	1	-

Figures 28 and 29 present the number of MY 2009 - 2011 compression ignition and sparkignition engine families by each heavy-duty highway manufacturer.

Figure 28
MY 2009-2011 Heavy-Duty Highway Compression Ignition Engine Families by Manufacturer

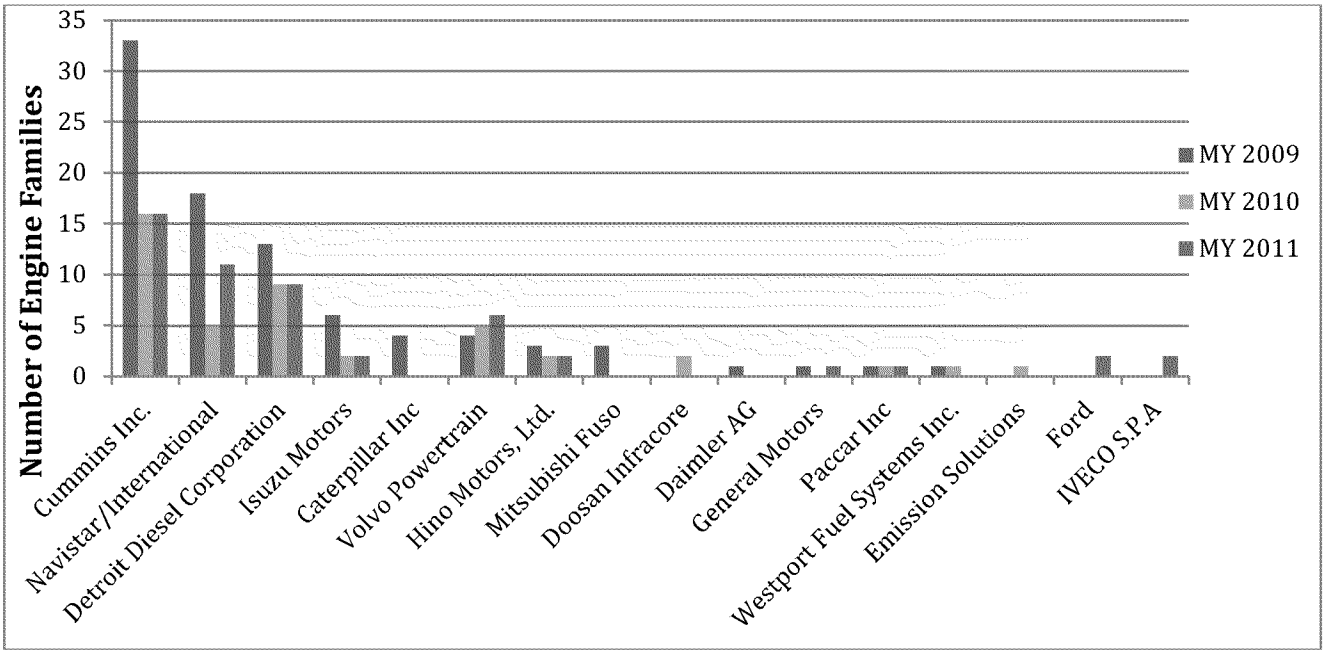
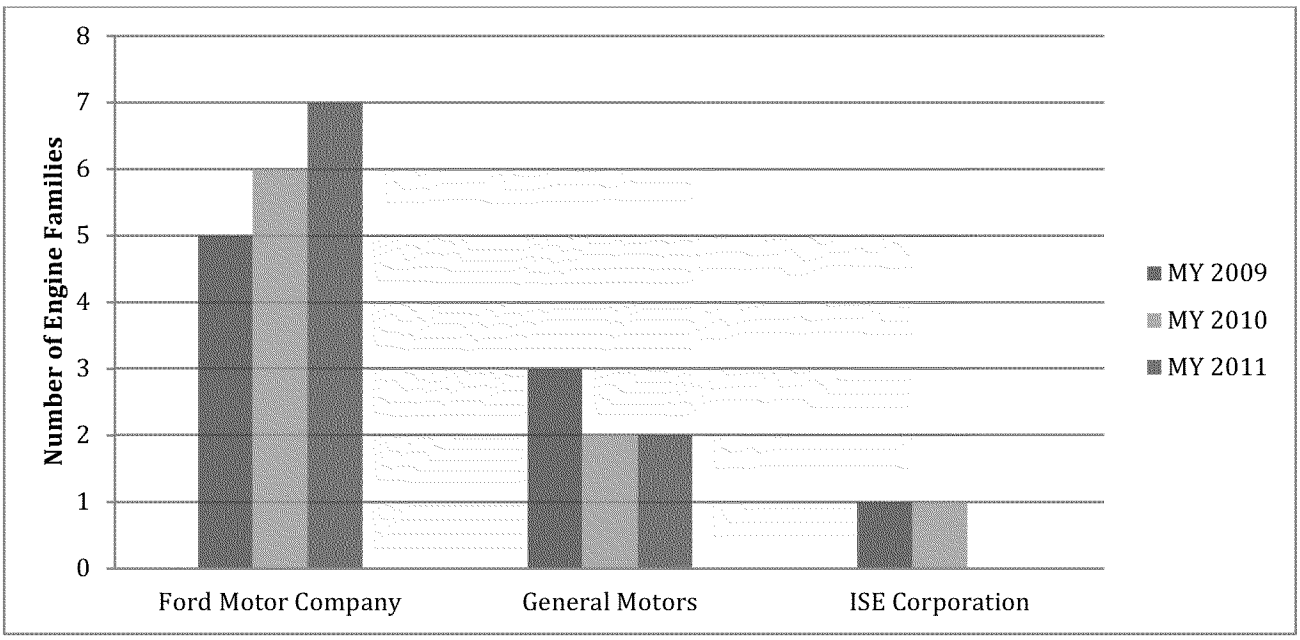


Figure 29
MY 2009-2011 Heavy-Duty Highway Spark Ignition Engine Families by Manufacturer



IN-USE COMPLIANCE TESTING

As is the case for light-duty vehicles, EPA relies on both internal and manufacturer testing programs to assess heavy-duty vehicle compliance with in-use emission standards. Heavy-duty in-use testing differs significantly from light-duty in-use testing. For light-duty vehicles, identical test procedures are used to measure emissions in both certification and in-use testing. The heavy-duty vehicle regulations do not require manufacturers to test in-use engines on a laboratory dynamometer, as they must for certification. Heavy-duty manufacturers may use portable equipment to measure in-use emissions while a vehicle is being driven over the road, instead of removing the engine from an in-use vehicle for laboratory testing. The regulations require manufacturers to measure the percentage of time that a vehicle exceeds certain emission thresholds under real-world driving conditions using devices that monitor emissions of hydrocarbons, carbon monoxide , nitrogen oxides, and particulate matter.

EPA also conducts its own heavy-duty in-use surveillance program, currently focusing on engines with 2010-level emission control systems. Beginning in late 2011 and lasting through 2012, this program focused on testing the most common engines currently used in heavy -duty line-haul tractors and vocational vehicles. This testing included engines from all of the major heavy -duty on-highway diesel engine manufacturers and the engine families tested represent 84% of the estimated large heavy-duty on-highway diesel engine production volume (MY2012 estimate).

All of the engines tested in this program were found to be in compliance with in-use emission standards when evaluated using the prescribed procedures. Emissions performance over non-prescribed conditions, such as extended idle and cold-starting, differed significantly by manufacturer, revealing key differences in calibration philosophy and limitations of current emission control technologies. These findings have been shared with the affected manufacturers and are driving system improvements for future model years.

Currently this testing program is focusing on small and medium sized heavy-duty diesel engine segments.[22]

DEFECT REPORTING

Figure 30 shows the number of defect information reports heavy-duty highway engine manufacturers submitted in 2009 - 2011 *calendar years*. Figure 31 shows the number of defect reportsmanufacturers submitted for each problem category reported in 2009 - 2011 *calendar years*. Defect reports can include multiple model years of a given engine.

Figure 30 - 2009-2011 Heavy-Duty Highway Engine Defect Reports by Manufacturer

Manufacturer	Number of Defect Reports		
	Reported in CY2009	Reported in CY2010	Reported in CY2011
Caterpillar	21	14	11
Cummins	1	10	2
Detroit Diesel Corporation	2	4	4
Ford	1	-	4
FTP Industrial S.p.A			1
General Motors	2	2	2
Hino	-	1	-
Isuzu	1	3	1
John Deere	-	1	-
Navistar	1	8	18
Paccar	-	3	6
Roush Industries, Inc.			2
UD Trucks Corporation			1
Volvo	3	5	15

Figure 31 - 2009-2011 Heavy-Duty Highway Engine Defect Reports by Problem Category

Problem Category	Number of Defect Reports		
	Reported in CY2009	Reported in CY2010	Reported in CY2011
Fuel delivery component / system	9	4	8
Turbocharger/supercharger	5	6	7
Passive diesel particulate filter (DPF)	5	5	5
Active diesel particulate filter (DPF)	4	4	1
Electrical, mechanical & cooling systems	4	2	-
VECI label	2	4	5
EGR system	2	2	12
Exhaust system	2	1	2
Crankcase ventilation component/system	2	-	1
NOx absorber system		-	1
NOx sensor	1	1	1
OBD system	-	6	2

[22] Smith, J., Greuel, J., Ratkos, B., and Schauer, E., "In-Situ Emissions Performance of EPA2010-Compliant On-Highway Heavy-Duty Diesel Engines,"SAE Int. J. Engines 6(3):1490-1499, 2013, doi: 10.4271/201301-2430.

Problem Category	Number of Defect Reports		
	Reported in CY2009	Reported in CY2010	Reported in CY2011
Selective catalytic reduction (SCR) system	-	5	8
Monitoring/measuring sensor/system	-	4	2
Computer related (other than OBD)	-	3	5
Diesel oxidation catalyst (DOC)	-	1	-
Ignition component	-	1	1
Defective / Incorrect Catalyst System (non-diesel engine)	-		3
Oxygen sensor	-		1

RECALL REPORTING

Figure 32 shows the number of heavy -duty highway engine recalls issued in 2009 - 2011 *calendar years*. Figure 33 shows the number of recalls for each problem category reported in 2009 - 2011 *calendar years*. Recalls can include multiple model years of a given engine. Recalls in the 2009 *calendar year* affected engines from 2004 – 2009 *model years*, while recalls in the 2010 *calendar year* affected 2006 – 2010 *model years*. Recalls in 2011 affected 2006 – 2012 *model year* engines.

Figure 32 - 2009-2011 Heavy-Duty Highway Engine Recalls by Manufacturer

Manufacturer	Recalls in CY2009		Recalls in CY2010		Recalls in CY2011	
	Number of Recalls	Number of Affected Engines	Number of Recalls	Number of Affected Engines	Number of Recalls	Number of Affected Engines
Caterpillar	4	153,771	1	7,488	2	25,719
Cummins	1	182	6	101,072	1	1,197
Detroit Diesel					1	3,531
Ford	3	47,639	1	868		
FPT Industrial S.p.A.						
General Motors	1	29,909			2	88,794
Hino	1	7,065				
Isuzu			2	21,679		
International-Navistar	1	128,514				
IVECO S.p.A.					1	1,800
Mitsubishi Fuso Truck	1	616				
PACCAR Inc.					1	31
Roush Industries, Inc.						
Volvo			1	1,065		
Total	**12**	**367,696**	**11**	**132,172**	**8**	**121,072**

Figure 33 - 2009-2011 Heavy-Duty Highway Engine Recalls by Problem Category

	Recalls in CY2009		Recalls in CY2010		Recalls in CY2011	
Problem Category	**Number of Recalls**	**Number of Affected Engines**	**Number of Recalls**	**Number of Affected Engines**	**Number of Recalls**	**Number of Affected Engines**
Crankcase ventilation component/system	1	147,245				
Active diesel particulate filter (DPF)	2	133,964			2	25,719
EGR system	1	29,909				
Electrical, mechanical & cooling systems	1	19,954				
Turbocharger/supercharger	1	19,954				
Fuel delivery component	2	14,796	1	7,488		
Exhaust system	2	965	1	1,117		
OBD system	1	616	5	95,439		
VECI label	1	293	1	21,006	1	31
Selective catalytic reduction (SCR) system			2	6,254	3	82,446
Computer related (other than OBD)			1	868		
NOx Sensor						
Monitoring/measuring sensor/system					1	3,531
Catalyst system					1	9,345
Total	**12**	**367,696**	**11**	**132,172**	**8**	**121,072**

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

In MY 2009, 100 percent of heavy-duty highway compression ignition engine manufacturers participated in ABT programs. Approximately 25 and 45 percent of heavy-duty highway compression ignition engine manufacturers participated in ABT programs in MY 2010 and 2011, respectively.[23]

[23] In MY 2010 a regulatory change took effect that eliminated split engine family accounting.

E. Nonroad Compression Ignition (NRCI) Engines

SECTOR PROFILE-

- EPA regulates several categories of nonroad compression ignition engines including marine diesel engines, locomotives, andcompression ignition engines used in construction and agricultural equipment.
- EPA has regulated emissions from nonroad compression ignition engines since 1996
- Primary emission standards in effect for MY 2009-2011 were NMHC, CO, NOx, and PM

PRIMARY COMPLIANCE ACTIVITIES IN 2009 - 2011:

- Certification
- Compliance programs

CERTIFICATION

Figure 34 presents the number of marine diesel certificates issued by certification Tier and classification. Figure 35 presents the number of marine diesel certificates by manufacturer.Marine diesel engine manufacturers applying for engine certification may request an International Maritime Organization (IMO) certificate in addition to an EPA certificate of conformity for the same engine family. The IMO program, in general, is different from EPA's program, but certain jurisdictions require operators to display an EPA-issued IMO certificate. For the purposes of this compliance report, only one certificate for each engine family was included in the counts listed below.

New marine diesel standards were phased in at different times for different engine sizes. In general, Tier 2 began to take effect around 2005; Tier 3 began in about 2009. Tier 3 will not be in place for all engines until 2018.

Figure 34 - MY 2009-2011 Marine Diesel Engine Certificates by Tier

Certification Tier	Number of Certificates		
	MY 2009	MY 2010	MY 2011
Tier 1	8	4	0
Tier 2	116	131	164
Tier 3	26	26	27
Remanufacture	2	9	19
IMO	28	38	53
Total	**180**	**208**	**263**

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Figure 35 - MY 2009-2011 Marine Diesel Engine EPA and IMO Certificates by Manufacturer

Manufacturer[24]	Number of Certificates		
	MY 2009	MY 2010	MY 2011
AB Volvo Penta	16	28	17
Alaska Diesel Electric	5	4	5
Caterpillar Inc.	32	41	29
Cummins Inc.	22	23	18
Detroit Diesel Corporation	3	3	6
Electro-Motive Diesel, Inc.	3	9	15
IHI Shibaura Machinery Corporation	10	11	11
Iveco N.V.	10	10	11
John Deere Power Systems Group	3	7	46
MAN Nutzfahrzeuge AG	3	3	4
Mitsubishi Heavy Industries, Ltd.	5	6	6
MTU Detroit Diesel, INC.	7	6	9
Perkins Engines Co Ltd	2	4	11
Transportation Systems Business Operations of GE	5	5	6
VM Motori S.P.A.	4	3	3
Yanmar CO., Ltd	19	17	25
Other	31	28	41
Total	**180**	**208**	**263**

Figure 36 shows locomotive certificates. Some engine manufacturers obtain a locomotive certificate of conformity, if a locomotive uses its engine.

Figure 36 - MY 2009-2011 Locomotive and Engine Certificates by Manufacturer

Manufacturer	MY 2009			MY 2010			MY 2011		
	Locomotive Certificates	Engine Manufacturer	Total	Locomotive Certificates	Engine Manufacturer	Total	Locomotive Certificates	Engine Manufacturers	Total
EMD	23	2	23	10	2	12	11	2	13
GE	19	-	19	5	-	5	10	-	10
CSX	6	-	6	2	-	2	8	-	8
Advanced Global Engineering	4	-	4	8	-	8	11	-	11
National Railway Equipment Co.	2	2	4	2	2	4	2	2	4
Motive Power	3	-	3	3	-	3	2	-	2
Kansas City Southern	3	-	3				-	-	0

[24] Manufacturers that certified only a few Marine CI engine families in MY 2009 2011 are aggregated under "Other". For MY 2009 "Other" represents 13 manufacturers; for MY 2010 "Other" represents 15 manufacturers; and for MY 2011 "Other" represents 30 manufacturers.

Manufacturer	MY 2009			MY 2010			MY 2011		
	Locomotive Certificates	Engine Manufacturer	Total	Locomotive Certificates	Engine Manufacturer	Total	Locomotive Certificates	Engine Manufacturers	Total
Cummins	-	2	2	-	4	4	-	4	4
Burlington North Santa Fe	2	-	2	-	-	-	-	-	0
HK Engine Components	2	-	2	-	-	-	1	-	1
OceanAir	1	-	1	3	-	3	3	-	3
Haynes	-	1	1	-	1	1	-	-	0
Progressive Rail	-	-	-	3	-	3	3	-	3
Brookeville Equipment Corp.	-	-	-	1	-	1	-	-	0
RJ Corman Railpower	-	-	-	1	-	1	-	-	0
Bombardier Transport							1	-	1
Total	**65**	**7**	**70**	**38**	**9**	**47**	**52**	**8**	**60**

Nonroad compression ignition engines intended for use in construction and agricultural equipment can be certified for use in one or multiple service classes. Figure 37 presents the number of certificates that were issued covering each power category. There were more than 100 different nonroad compression ignition engine families certified in both the 19-37 kW and the 37-75 kW power ranges. Figure 38 shows the number of engine families certified by each manufacturer for MY 2009 – 2011. There were approximately 90 different manufacturers that certified nonroad compression ignition engines intended for use in construction and agricultural equipment in MY 2009 2011.

Figure 37 - MY 2009-2011 Construction and Agricultural Engine Families by Service Class

Service Class (Power Category)	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
0-8 kW	60	59	41
<130 kW	-	2	2
8-19 kW	73	74	70
8-37 kW	2	-	-
19-37 kW	120	121	111
37-56 kW	20	27	27
37-75 kW	107	107	106
56-75 kW	9	11	14
75-130 kW	52	59	67
75-225 kW			1
75-450 kW	2	2	-
130-225 kW	27	31	9
130-450 kW	5	4	1
130-560 kW	11	13	23
>=130 kW	2	6	-
225-450 kW	49	48	23
225-560 kW	2	2	2
450-560 kW	9	11	2
560-900 kW			2
>560 kW	61	64	19

Service Class (Power Category)	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Total[25]	**611**	**641**	**520**

Figure 38 - MY 2009-2011 Construction and Agricultural Engine Families by Manufacturer

Manufacturer[26]	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Kubota Corporation	49	51	50
Cummins Inc.	46	45	16
Deutz AG	46	45	40
Yanmar Co., Ltd.	42	41	40
Caterpillar Inc.	26	34	16
John Deere Power Systems	27	32	29
Motornfabrik Hatz	28	28	28
Mitsubishi Heavy Industries, Ltd	25	25	25
Iveco NV	22	28	22
Komatsu Ltd.	23	25	15
IHI Shibaura Machinery Corporation	22	22	22
Isuzu Motors Limited	20	20	18
Perkins Engines Co. Ltd.	18	17	13
Lombardini	14	14	13
Mahindra & Mahindra Ltd.	12	13	11
Kukje Machinery Co.	9	12	12
CNH UK LTD	10	10	10
Liebherr Machines Bulle SA	8	12	3
Daedong Industrial Co. Ltd.	9	10	8
Iseki Matsuyama Mfg. Co., Ltd.	9	9	9
AGCO Sisu Power Inc.	7	7	5
Hino Motors, Ltd.	6	5	5
AB Volvo Penta	7		8
Shandong Huayuan Laidong Engine Co.	6	6	6
Other	120	130	96
Total[27]	**611**	**641**	**520**

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

About 10 percent of construction and agricultural engine manufacturers participated in ABT programs in MY 2009 - 2011.

[25] This figure does not include stationary -only engine families.
[26] Manufacturers that certified only a few engine families in MY 2009 - 2011 are aggregated under "Other".
[27] This figure does not include stationary -only engine families.

F. Nonroad Spark Ignition Engines

SECTOR PROFILE:

- Nonroad spark ignition (Nonroad SI) engines are generally divided into three categories for purposes of exhaust emission compliance:
  - Small spark ignition engines (Small SI) are rated below 25 horsepower (19 kW) and are generally used in household and commercial applications, including lawn and garden equipment, utility vehicles, generators, and a variety of other construction, farm, and industrial equipment
  - Marine spark ignition (Marine SI) engines are used in marine vessels, including outboard engines, personal watercraft, and sterndrive/inboard engines
  - Large spark ignition (Large SI) engines are generally rated above 19 kW and used in forklifts, compressors, generators, stationary equipment

- Equipment with NRSI engines installed is also subject to evaporative emissions standards.

- Nonroad SI engines have been subject to emissions regulations since 1997

PRIMARY COMPLIANCE ACTIVITIES IN 2009 - 2011:

- Certification
- Compliance programs

CERTIFICATION

As shown in Figure 6, for the 2009 – 2011 model years EPA certified around1,000 Small SI engine families , around 100 engine emissions families each for Marine SI and Large SI, and between 150 and 425 Evaporative Component families. There are seven classes of Small SI engines. Figure 39 presents the number of families certified in each Small SI class.[28] Figures 40-43 present the number of engine families certified by SmallSI, Marine SI, Large SI and Evaporative Component manufacturers.

Figure 39 - MY 2009-2011 Small Spark Ignition Engine Families by Class

Small SI Class	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Class I	247	231	247
Class II	358	344	287
Class IA	39	16	8
Class IB	59	47	47
Class III	2	3	2

[28] Classes are defined by whether or not the engine in applied in a hand held piece of equipment and by power rating. Classes I through IB describe non hand held equipment whereas classes IV and V are in hand held equipment.

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Class IV	307	268	275
Class V	148	111	119
Total	**1,160**	**1,020**	**985**

Figure 40 - MY 2009-2011 Small Spark Ignition Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Briggs & Stratton Corporation	69	65	57
Andreas Stihl AG & Co KG	62	58	59
Kawasaki Heavy Industries, Ltd.	50	47	37
Husqvarna AB	44	38	42
Echo Incorporated/Kioritz Corporation	37	52	56
Fuji Heavy Industries Ltd.	32	32	29
Husqvarna Consumer Outdoor Products N.A. Inc.	32	32	30
Generac Power Systems Inc.	31	-	17
Honda Motor Co., Ltd.	29	29	33
Kohler Co.	23	28	28
Loncin Industrial Co., Ltd.	-	31	29
Jiangsu Jiangdong Group Co. Ltd.	-	28	27
Other[29]	751	580	541
Total	**1,160**	**1,020**	**985**

Figure 41 - MY 2009-2011 Marine Spark Ignition Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Yamaha Motor Company Ltd.	38	24	23
Mercury Marine	28	31	30
Honda Motor Co., Ltd.	12	11	10
BRP US Inc.	11	14	13
Suzuki Motor Corporation	11	12	11
Tohatsu Corporation	9	8	8
Suzhou Parsun Power Machine Co., Ltd.	5	5	5
Hangzhou Hidea Power Machinery Co., Ltd	4	4	5
Kawasaki Heavy Industries, Ltd.	3	3	3
Weber Automotive GmbH	2	-	-
Volvo Penta of the Americas, Inc.	-	2	5
Zhejiang Shunfeng Power Machinery Manufacturer	-	2	-
Zhejiang Shengqi Motion Apparatus Co.	1	1	1
Flagship Marine Engine Company Inc	-	-	1
Ilmor Engineering, Inc	-	-	1

[29] For MY 2009 "Other" represents 168 manufacturers that collectively produced 751 engine families. For MY 2010 "Other" represents 100 manufacturers that collectively produced 580 engine families. For MY 2011 "Other" represents 93 manufacturers that collectively produced 541 engine families.

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Indmar Products Company, Inc	-	-	2
KEM Equipment, Inc	-	-	3
Pleasurecraft Marine Engine Company	-	-	3
Total	**124**	**117**	**124**

Figure 42 - MY 2009-2011 Large Spark Ignition Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
KEM Equipment, Inc.	15	18	19
Generac Power Systems, Inc.	9	32	34
Bucks Engine Company	8	-	7
NGVI, Inc.	8	2	-
Woodward Governor Company	8	6	7
IMPCO Technologies	7	8	8
Zenith Power Products LLC	6	7	7
Nissan Motor Co., Ltd.	5	3	3
Power Solutions, Inc.	6	11	12
TeleflexGFI Control Systems	4	-	-
Engine Distributors, Inc	3	5	4
Cummins Inc.	2	3	8
Linde Material Handling N.A. Corp.	2	2	2
Wisconsin Motors, LLC	2	3	3
GE Jenbacher	1	1	1
John Deere Power Systems of Deere & Comp	1	1	1
Toyota Industrial Equipment	1	1	1
Westerbeke Corporation	1	1	1
PSI International	-	5	8
Deutz Corporation	-	4	5
GFI Control systems	-	4	-
AFI	-	1	1
Don Hardy Race Cars, Inc.	-	1	1
EControls, Inc.	-	1	-
Industrial Engines Ltd	-	1	2
Juniper Engines, Inc.	-	1	1
KaChing, LLC	-	1	-
SRC Automotive, Inc.	-	1	1
Kohler Company	-	-	1
Kubota Corporation	-	-	1
Vantage Vehicle International, Inc.	-	-	1
Total	**89**	**124**	**140**

Figure 43
MY 2009-2011 Nonroad Spark Ignition Evaporative Component Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Honda Motor Co., Ltd.	22	7	4
Husqvarna Zenoah Co., Ltd.	16	16	8
MTD Southwest Inc.	15	12	5
Andreas Stihl AG & Co KG	10	18	36
Hitachi Koki USA, Ltd.	10	17	17
Kawasaki Heavy Industries, Ltd	7	8	6
Maruyama Mfg. Co., Inc.	7	11	11
Husqvarna AB, Sweden	5	5	1
ECHO Incorporated/Yamabiko Corporation	-	6	8
Husqvarna Consumer Outdoor Products N.A., Inc.	-	5	10
Sichuan Chuanhuan Technology Co. Inc	-	5	5
Other[30]	69	85	313
Total[31]	**161**	**195**	**424**

PRODUCTION LINE TESTING (PLT)

Production line testing requires manufacturers to routinely test engines as they leave the assembly line to demonstrate that production engines meet emission standards. In the Small SI and Marine SI sectors, most engine manufacturers had at least one engine family subject to PLT.[32] All engine families met the PLT test requirements. In the Large SI sector, many engine families are not subject to PLT requirements because the projected sales volume is less than 150 units. These engine families are only required to submit production reports. Large SI manufacturers satisfied all requirements forfamilies with high enough volumes to require PLT testing and data submission in 2009 - 2011.

IN-USE COMPLIANCE TESTING

Marine SI and Large SI manufacturers are required to conduct in-use testing on up to 25 percent of engine families at 50 percent or more of their useful life. The Marine SI program has been in place since 2007.

[30] For MY 2009 "Other" represents 38 manufacturers that collectively produced 69 evaporative families. For MY 2010 "Other" represents 48 manufacturers that collectively produced 85 evaporative families. For MY 2011 "Other" represents 165 manufacturers that collectively produced 313 evaporative families.

[31] The evaporative emissions rule for nonroad spark ignition manufacturers started to phase in for model year 2009. The number of engine families affected by the rule should level off after the 2012 model year.

[32] PLT requirements do not apply to small volume engine manufacturers.

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

In MY 2009 about 15 percent of Small SI manufacturers participated in ABT programs. In MY 2010 and in MY 2011about 21 percent of Small SI manufacturers participated. Prior to MY 2010 all types of Small SI engines were averaged together. However, beginning in MY 2010, handheld and non-handheld engines were averaged separately.

G. RECREATIONAL VEHICLES

SECTOR PROFILE:

- Emissions from recreational vehicles (RVs) were unregulated prior to MY 2006
- The regulations in 40 CFR part 1051 set the first emissions standards for RV categories, including all terrain vehicles (ATVs) certain off-road utility vehicles (UTVs) (less than 30 kW, less than 1, 000 cc, and maximum speed more than 25 mph); off-highway motorcycles; and snowmobiles. Each recreational vehicle category is subject to an individual set of exhaust emission standards which phase in over several years. Regulated pollutants are HC+NOx and CO
- All RVs became subject to the same fuel component based permeation emission standards beginning in MY 2008. The regulated pollutant is HC

PRIMARY COMPLIANCE ACTIVITIES IN 2009 - 2011:

- Certification
- Defect Reporting
- Recall
- ABT

CERTIFICATION

There were 100 different recreational vehicle manufacturers that certified products in MY 2009 - 2011. Figure 44 presents RV manufacturers that certified at least four engine families in one or more RV sectors in MY 2009, 2010 and/or 2011.[33] There were about 100 different recreational vehicle manufacturers that

[33]The number of engine families has no bearing on vehicle production volumes.

certified products each model year 2009 – 2011. Figures 45 - 47 present data for manufacturers that certified at leastone MY 2009, MY 2010 and/or 2011 engine families in the ATV and UTV, off-highway motorcycle, or snowmobile sectors

Figure 44 - MY 2009-2011 Recreational Vehicle Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Yamaha Motor Corporation	28	27	26
Arctic Cat inc	22	21	21
Polaris Industries Inc.	22	21	22
Bombardier Recreational Products, Inc	19	17	18
American Honda Motor Co., Inc.	22	6	12
Kawasaki Motors Corp., U.S.A.	13	12	12
American Suzuki Motor Corporation	11	13	3
Tomoto Industries, Inc.	10	11	4
Kymco USA	9	9	4
Taotao USA Inc.	6	6	6
Xingyue USA, INC	6	6	6
Loncin (USA) Inc.	7	4	2
Baja Inc.	-	11	8
JCL Powersports LLC.	6	4	3
Other	161	124	100
Total	**342**	**292**	**247**

Figure 45 - MY 2009-2011 ATV and UTV Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Yamaha Motor Corporation	15	14	13
Arctic Cat	13	11	12
Polaris Industries Inc.	11	11	12
American Honda Motor Co., Inc.	13	6	8
Kawasaki Motors Corp., U.S.A.	10	9	9
Tomoto Industries, Inc.	10	9	5
American Suzuki Motor Corporation	9	10	3
Kymco USA	9	9	10
Bombardier Recreational Products, Inc	8	7	9
Taotao USA Inc.	5	5	5
Loncin (USA) Inc.	6	3	2
Kandi USA, Inc.	4	4	5
Xingyue USA, INC	4	4	4
High Rev Motorsports, LLC	3	5	3
Linhai USA, Inc.	2	6	6
Asian Ventures Inc.	4	3	3
Hammerhead Off-Road, Inc.	4	3	-
JCL Powersports LLC.	4	3	3
Team Joyner USA	6	-	2
Deere & Company	3	3	4
Easy Vehicle, Inc.	3	3	2
Eton America LLC	3	3	1
XY-Xinyang Motor, Inc.	2	3	-

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Baja Inc.	-	5	-
Other	91	58	45
Total	**242**	**197**	**166**

Figure 46 - MY 2009-2011 Off-Highway Motorcycle Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Yamaha Motor Corporation	7	7	7
American Honda Motor Co., Inc.	9	-	4
Apollo Motorsports, Inc.	4	4	3
Kawasaki Motors Corp., U.S.A.	3	3	3
Pride Enterprise, LLC	1	5	-
Baja Inc.	-	6	8
Xmotos Worldwide, Inc.	3	2	-
American Suzuki Motor Corporation	2	3	-
KTM North America, Inc.	2	3	3
Other	31	25	18
Total	**62**	**58**	**46**

Figure 47 - MY 2009-2011 Snowmobile Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Bombardier Recreational Products, Inc.	11	10	9
Polaris Industries Inc.	11	10	10
Arctic Cat Inc	9	10	9
Yamaha Motor Co., LTD.	6	6	6
HJR	1	1	1
Total	**38**	**37**	**35**

As shown in Figure 48, in model years 2009 - 2011 very few ATV/UTV and off-highway motorcycle manufacturers produced two-stroke engines. However, more than 50% of the snowmobile engine families were two-stroke engines. This represents a technology shift. When the current RV regulations were written, a majority of ATVs sold in the United States and almost all snowmobiles used two-stroke engines (see 67 FR 68262).

Figure 48 - MY 2009-2011 Recreational Vehicle Two-Stroke Engine Families

Category	Percentage of Two Stroke Engine Families		
	MY 2009	MY 2010	MY 2011
ATV/UTV	0%	1%	1%
Off-Highway Motorcycles	2%	10%	17%
Snowmobiles	63%	62%	53%

In addition, in MY 2009-2011 over 50 percent of ATVs and UTV engine families either employed catalyst or fuel injection technologies, or both, to meet the emission standards.

RV CERTIFICATES VOIDED

In 2010 EPA withdrew emissions approval for the import and sale of approximately 200,000 MY 2006 and 2007 gasoline-powered off-road motorcycles and all terrain vehicles. The finding was the first case of its kind. The action to void emissions certificates affects the companies that manufactured and imported these vehicles. Consumers who own models covered by the voided certificates are not responsible for the wrongdoing and can continue to use their vehicles.

In 2013 EPA withdrew its approval of the import and sale of over 70,000 gas-powered on- and off-road motorcycles and all-terrain vehicles because the agency believes that it received either incomplete or falsified certification information. EPA issued the vehicle certificates from 2006 to 2012 to two companies which operate as Snyder Technology, Inc. and Snyder Computer Systems, Inc. (doing business as Wildfire Motors Corporation). As a result of a lengthy investigation, the agency believes that the applications for the certificates contained fallacious information and must be voided. These actions affected between four and nine percent of the highway motorcycles and recreational vehicles produced annually between 2006 and 2012. All vehicles imported into or manufactured in the United States are required to have certificates of conformity.

DEFECT REPORTING

Recreational vehicle manufacturers are required to notify EPA when they learn of the existence of emission-related defects in about 10 percent of the vehicles in an engine family.

Figures 49 and 50 present the 2009 - 2011 emission defect reports submitted by recreational vehicle manufacturers. These reports can include multiple model years of a given vehicle and can span more than one problem category. In calendar years 2009 - 2011, manufacturers submitted defect reports that affected recreational vehicles in model years ranging from MY 2006-2010.

Figure 49 - 2009-2011 Recreational Vehicle Defect Reports by Manufacturer

	Reported in 2009		Reported in 2010		Reported in 2011	
Manufacturer	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**
Arctic Cat	5	9,825	3	4,519	1	5,247
BRP	1	9,425	-	-	2	12,972
Honda					1	8,760
Polaris	2	6,077	2	25,146	-	-
Suzuki	-	-	1	25,458	-	-
Yamaha	1	2,020	-	-	-	-
Total	**9**	**27,347**	**6**	**55,123**	**4**	**26,979**

Figure 50 - 2009-2011 Recreational Vehicle Defect Reports by Problem Category

Problem Category	Reported in 2009		Reported in 2010		Reported in 2011	
	Number of Defect Reports	Number of Affected Vehicles	Number of Defect Reports	Number of Affected Vehicles	Number of Defect Reports	Number of Affected Vehicles
Crankcase Vent System					1	8,656
PCV System					1	4,316
Fuel delivery component	2	11,445	-		-	-
OBD system	2	7,396	2	26,289	-	-
Internal engine component (piston, etc)	1	4,696	-	-	1	5,247
VECI label	1	2,285	-	-	-	-
Drivability problem	2	1,381	-	-	-	-
Miscellaneous	1	144	-	-	-	-
Computer related (other than OBD)	-	-	1	12,573	-	-
Exhaust system	-	-	1	12,573	-	-
Monitoring/measuring sensor/system	-	-	1	2,033	1	8,760
Intake/exhaust manifold	-	-	1	1,655	-	-
Total	**9**	**27,347**	**6**	**55,123**	**4**	**26,979**

RECALL REPORTING

Figures 51 and 52 summarize the recreational vehicle recall actions in 2009 - 2011. The recalls in 2009 - 2011 affected vehicles in model years 2007-2010.

Figure 51 - 2009-2011 Recreational Vehicle Recall Reports by Manufacturer

Manufacturer	Recalls in 2009		Recalls in 2010		Recalls in 2011	
	Number of Recalls	Number of Affected Vehicles	Number of Recalls	Number of Affected Vehicles	Number of Recalls	Number of Affected Vehicles
Arctic Cat	5	9,932	3	4,519	1	5,247
BRP	1	4,530	-	-	2	12,404
Polaris	1	1,381	-	-	-	-
Total	**7**	**15,843**	**3**	**4,519**	**3**	**17,651**

Figure 52 - 2009-2011 Recreational Vehicle Recall Reports by Problem Category

Problem Category	Recalls in 2009		Recalls in 2010		Recalls in 2011	
	Number of Recalls	Number of Affected Vehicles	Number of Recalls	Number of Affected Vehicles	Number of Recalls	Number of Affected Vehicles
Crankcase Vent System					1	8,729
PCV System					1	3,675
Internal engine component (piston, etc)					1	5,247
OBD system	2	7,503	-	831	-	-
Fuel delivery component	1	4,530	-	-	-	-
VECI Label	2	2,285	-	-	-	-

Problem Category	Recalls in 2009		Recalls in 2010		Recalls in 2011	
	Number of Recalls	Number of Affected Vehicles	Number of Recalls	Number of Affected Vehicles	Number of Recalls	Number of Affected Vehicles
Drivability problem	1	1,381	-	-	-	-
Miscellaneous	1	144	-	-	-	-
Monitoring/measuring sensor/system	-	-	1	2,033	-	-
Intake/exhaust manifold	-	-	1	1,655	-	-
Total	**7**	**15,843**	**2**	**4,519**	**3**	**17,651**

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

Only a few of the larger ATV, utility vehicle, and off -highway motorcycle manufacturers took advantage of the ABT and emission averaging. On the other hand, almost all snowmobile manufacturers participated in ABT.

IV. Industry Statistics

This section presents additional information that EPA collects in the course of implementing compliance programs.

ALTERNATIVE FUEL AND ALTERNATIVE FUEL CONVERSIONS[34]

Some vehicles and engines are designed to operate on fuels other than gasoline and diesel. Some are manufactured by the OEM to operate on alternative fuels, while others are certified by the OEM to operate on gasoline or diesel fuel and later converted by an aftermarket manufacturer to operate on an alternative fuel. Generally, the CAA prohibits any aftermarket changes to a certified vehicle or engine configuration that could affect emissions, but a regulatory exemption to the prohibition is available in the case of alternative fuel conversions. Each sector has different criteria under which vehicles and engines can be converted to operate on a new fuel In some sectors fuel conversions are certified using OEM certification provisions.

LIGHT-DUTY VEHICLE ALTERNATIVE FUEL DATA

Figures 53 - 55 present the production of MY 2009 - 2011 OEM light-duty vehicles by fuel type. Gasoline vehicles comprise the dominant fuel type, followed by flexible fuel vehicles. After gasoline and ethanol, diesel is the next most prevalent fuel, but still represents less than one percent of passenger car and light-

[34] While alternative fuels are generally understood to mean non-petroleum alternatives to gasoline and diesel, this section of the report also presents data for diesel-fueled vehicles and engines in the light-duty, motorcycle, and recreational vehicle sectors, sectors that have historically been dominated by gasoline.

duty truck production. Compressed natural gas (CNG) vehicles make up an even smaller fraction of MY 2009 - 2011 vehicle production.

Figure 53 - MY 2009 Light-Duty Vehicle Production Volume by Fuel Type

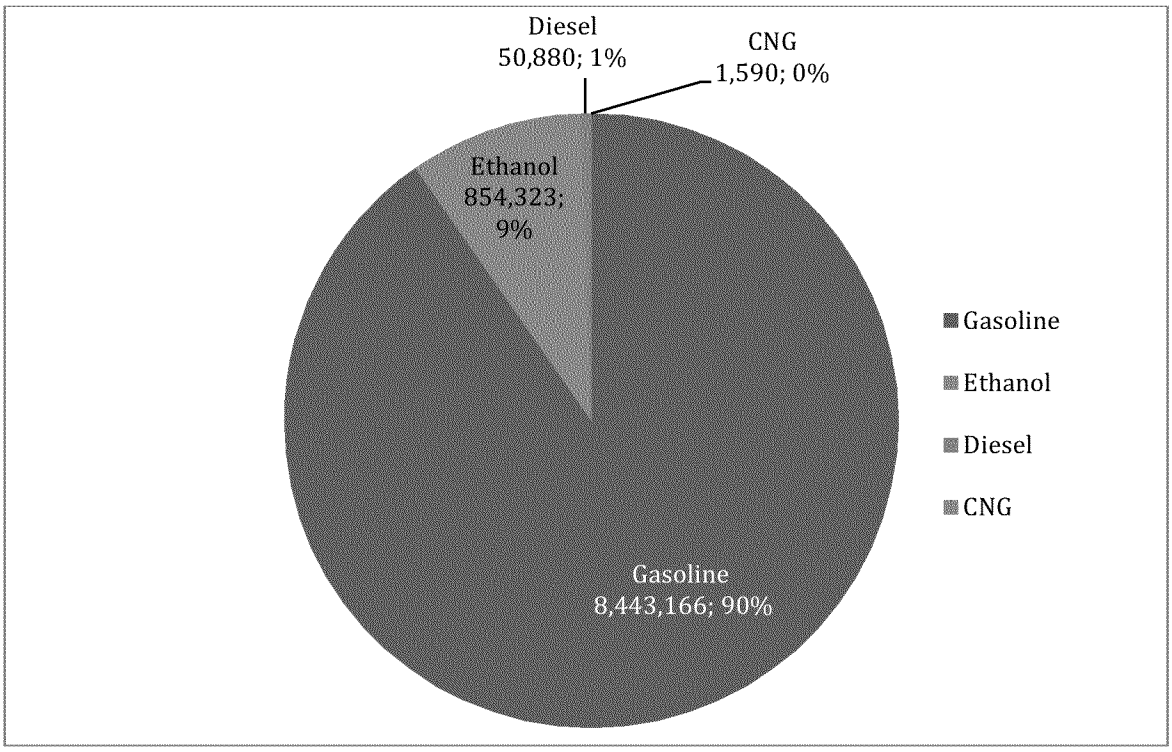


Figure 54 - MY 2010 Light-Duty Vehicle Production Volume by Fuel Type

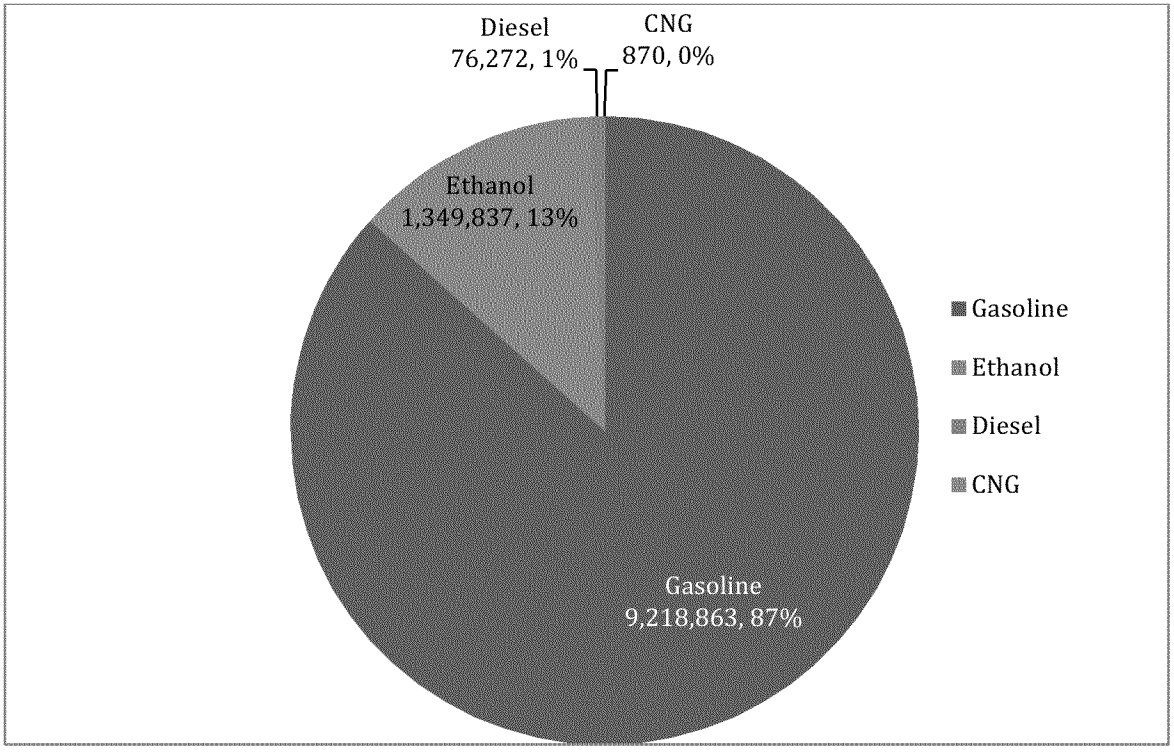
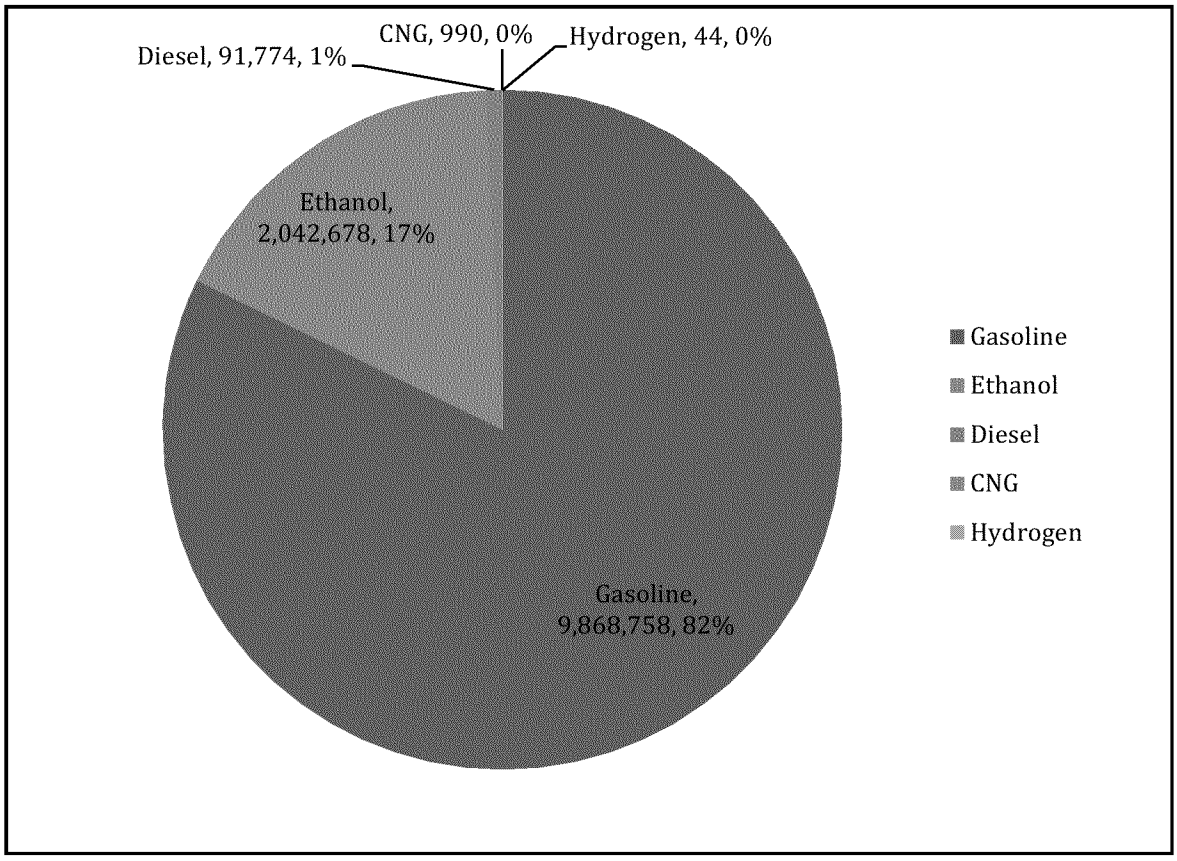


Figure 55 - MY 2011 Light-Duty Vehicle Production Volume by Fuel Type



All MY 2009 – 2011 ethanol vehicles were flexible-fuel vehicles which are capable of operating on gasoline, E85 (85 percent ethanol and 15 percent gasoline), or an intermediate blend.

Figure 56 summarizes the number of OEM light-duty vehicle diesel and alternative fuel test groups by manufacturer.

Figure 56
MY 2009-2011 Light-Duty OEM Diesel and Alternative Fuel Test Groups by Manufacturer

Fuel	Manufacturer	Number of Exhaust Test Groups		
		MY 2009	MY 2010	MY 2011
Battery Electric	Azure Dynamics	0	0	1
	BMW	0	0	1
	Mercedes Benz	0	0	1
	Nissan	0	0	1
	Tesla	0	1	1
	Think	0	0	1
	Wheego	0	0	1
CNG	Honda	1	1	2

Diesel	BMW	2	2	2
	Cummins	2	2	2
	Ford	0	0	2
	General Motors	0	0	2
	Isuzu	0	0	1
	Mahindra &	0	0	1
	Mercedes Benz	3	4	5
E85-Gasoline	Bentley	0	0	1
	Chrysler	4	3	5
	Ford	6	13	14
	General Motors	13	10	10
	Mercedes Benz	1	1	1
	Nissan	1	1	1
	Saab	0	0	1
	Toyota	1	1	1
Hydrogen Fuel Cell	Honda	1	1	1
	Toyota	1	1	1

Vehicles originally designed and certified to operate on gasoline or diesel fuel can be converted to operate on an alternative fuel. Converters of new vehicles must obtain a certificate of conformity to avoid violating the CAA prohibition against tampering.

A new regulation finalized in 2011 established alternative pathways to obtain a regulatory exemption from tampering beyond certification for converters of older vehicles and enginesFor the 2011 model year there were 31 submissions through the Intermediate Age program and four submissions for the Outside Useful Life program.

Figure 57 summarizes the number of certificates issued for light-duty vehicle alternative fuel conversions by manufacturer in MY 2009 - 2011.[35]

Figure 57
MY 2009-2011 Light-Duty Alternative Fuel Conversion Certificates by Manufacturer

Fuel	Manufacturer	Number of Certificates		
		MY 2009	MY 2010	MY 2011
CNG	Altech-Eco	6	3	19
	BAF Technologies	6	3	5
	Baytech	1	2	3
	Evotek	-	5	10
	Go Natural CNG	-	-	2
	Greenkraft	-	-	1
	High Pressure Group	-	-	1
	Landi Renzo USA	-	-	3
	Nat Gas Car	-	-	2
	Natural Drive Partners	2	4	5

[35] Each light-duty vehicle certificate covers a unique combination of exhaust test group and evaporative emissions family. Therefore the number of light-duty certificates and test groups is usually different. MY 2009-2011 conversion certificates may be issued for conversion of either current or earlier model year OEM vehicles.

Fuel	Manufacturer	Number of Certificates		
		MY 2009	MY 2010	MY 2011
	NGV Conversion	-	2	2
	NGV Motori, USA	-	-	1
CNG/E85-Gasoline	Altech-Eco	-	-	4
	BAF Technologies	-	-	1
	Evotek	-	-	1
	Go Natural CNG	-	-	11
	IMPCO Technologies	-	-	15
	Parnell USA	-	-	1
	The CNG Store- Auto Gas	-	-	6
CNG/Gasoline	Altech-Eco	3	5	10
	Baytech	3	3	6
	Evotek	-	-	1
	FuelTek Conversion Corp.	4	-	-
	Go Natural CNG	-	-	5
	IMPCO Technologies	11	-	15
	Nat Gas Car	-	-	2
	The CNG Store- Auto Gas	-	-	3
	Altech-Eco	3	5	10
	Baytech	3	3	6
E85-Gasoline	Flex Fuel U.S.	3	3	2
LPG	Roush Industries	-	11	20
	Technocarb Equipment	7	-	-
	Yellow Checker Star	-	-	2
LPG/E85-Gasoline	American Alternative Fuel	1	2	13
	Evotek	-	-	1
	Icom North America	-	-	7
	IMPCO Technologies	3	-	19
LPG/Gasoline	American Alternative Fuel	5	7	14
	Icom North America	-	-	1
	IMPCO Technologies	10	-	7
	Parnell USA	-	-	3
	Technocarb Equipment	7	-	-
Plug-in Hybrid	A123 Systems	-	1	3

HIGHWAY MOTORCYCLE ALTERNATIVE FUEL DATA

The majority of highway motorcycles are certified to operate on gasoline. However, there are a few highway motorcycle engine families certified to operate as battery-electrics, obtaining energy by charging a battery with electricity from a 120V outlet. See Figure 58 for a breakdown of electric motorcycle manufacturers for MY 2009 - 2011.

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Figure 58
MY 2009-2011 Highway Motorcycle OEM Alternative Fuel Engine Families by Manufacturer

Fuel	Manufacturer	Number of Engine Families		
		MY 2009	MY 2010	MY 2011
Battery Electric[36]	Brammo	1	1	1
	Green Vehicles	1	-	
	Puma	-	2	
	Tom Notch Technology	-	2	
	Xtreme Green	1	-	
	Zero Motorcycles	1	1	3
	ZT Power Station	-	1	
	Current Motors			1
	Evolve Motorcycles			1
	Oxygen World			1
	Ridelectric LLC			

HEAVY-DUTY HIGHWAY ALTERNATIVE FUEL DATA

Figure 59 presents the OEM heavy-duty highway engines that were certified to operate on alternative fuels in model years 2009 - 2011.

Figure 59
MY 2009-2011 Heavy-Duty Highway Engine OEM Alternative Fuel Engine Families by Manufacturer

Fuel	Manufacturer	Number of Engine Families		
		MY 2009	MY 2010	MY 2011
CNG	Cummins Inc.	4	3	3
	Doosan Infracore, Co	2	2	2
CNG/Diesel	Westport Fuel Systems	1	1	1
LPG	Cummins Inc.	1	-	-

HEAVY-DUTY HIGHWAY ALTERNATIVE FUEL CONVERSION DATA

Figure 60 presents the heavy-duty highway alternative fuel conversion certificates issued in model years 2009 - 2011.[37]

Figure 60
MY 2009-2011 Heavy-Duty Highway Engine Alternative Fuel Conversion Certificates by Manufacturer

Fuel	Manufacturer	Number of Certificates		
		MY 2009	MY 2010	MY 2011
CNG	BAF Technologies	1	2	2
	Baytech Corporation	3	3	4

[36] EPA began issuing certificates for battery electric highway motorcycles in MY 2009.
[37] MY 2009-2011 conversion certificates may be issued for conversion of either current or earlier model year OEM highway engines.

	Emission Solutions, Inc.	-	1	1
	Evotek, LLC			5
	Greenkraft Inc			1
CNG/Gasoline	Baytech Corporation	3	1	2
LPG	American Alternative Fuel			4
	Baytech Corporation	2	1	2
	Bi-Phase Technologies, LLC	1	-	3
	Clean Fuel USA Inc.	1	4	1
	Roush			8
LPG/Gasoline	Icom North America LLC	-	1	1

NONROAD COMPRESSION IGNITION ALTERNATIVE FUEL DATA

There were no MY 2009 - 2011 certificates issued for nonroad compression ignition engines that operate on alternative fuels.

NONROAD SPARK IGNITION ALTERNATIVE FUEL AND FUEL CONVERSION DATA

There are numerous engine manufacturers that certify nonroad spark ignition engines to run on alternative fuels, in both Small SI and Large SI categories.[38] About 10 percent of Small SI engine families in MY 2009 - 2011 were certified to operate on alternative fuels. The majority of Large SI engine families are certified to operate on alternative fuels. In MY 2009 of the 89 Large SI engine families, 77 were certified to operate on one or more alternative fuels. In MY 2010, of the 124 Large SI engines families, 91 were certified to operate on one or more alternative fuels. In MY 2011, of the 140 Large SI engines families, 123 were certified to operate on one or more alternative fuels. Figures 61 and 62 summarize information about MY 2009 - 2011 Small SI and Large SI alternative fuel engine families.

Figure 61
MY 2009-2011 Small Spark Ignition Engine OEM Alternative Fuel Engine Families

Fuel	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
E85-Gasoline	2	1	-
Natural Gas/CNG	21	17	15
Natural Gas/CNG / Propane/LPG	28	22	16
Propane/LPG	63	46	42
Propane/LPG / Gasoline	6	5	9
Natural Gas/CNG / Propane/LPG / Gasoline			1

[38] No marine SI engines were certified to operate on alternative fuels in either MY 2009 or 2010. One marine SI engine family was certified to operate on LPG in MY 2011.

Figure 62
MY 2009-2011 Large Spark Ignition Engine OEM Alternative Fuel Engine Families

Fuel	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Natural Gas/CNG	8	10	42
Natural Gas/CNG / Propane/LPG	5	17	23
Natural Gas/CNG / Propane/LPG/ Gasoline	4	7	7
Propane/LPG	20	34	34
Propane/LPG / Gasoline	40	23	27

RECREATIONAL VEHICLE ALTERNATIVE FUEL DATA

The majority of recreational vehicles are certified to operate on gasoline. However, there were two ATV engine families certified to operate on diesel in MY 2009, two in MY 2010 and one in MY 2011. Figure 63 shows a breakdown of diesel recreational vehicle manufacturers.

Figure 63
MY 2009-2011 Recreational Vehicle OEM Diesel Engine Families by Manufacturer

Fuel	Manufacturer	Number of Engine Families		
		MY 2009	MY 2010	MY 2011
Diesel	Tomcar USA Inc.	1	1	0
	Deere & Company	1	1	1

MANUFACTURER LOCATIONS

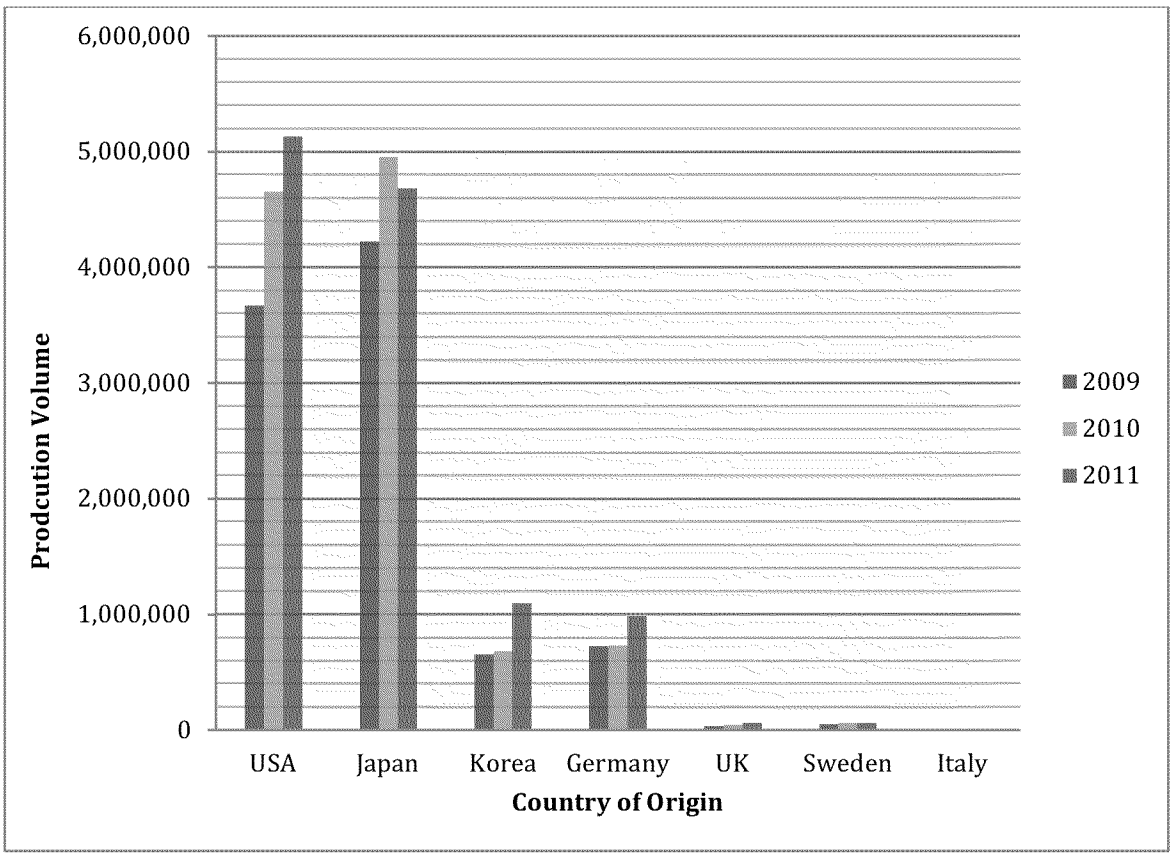
Consistent with past compliance reports, manufacturer locations here are attributed using two different approaches. For light-duty vehicles and locomotives, we report data based on where a manufacturer's headquarters are located, not necessarily where the vehicles are manufactured. For example, Toyota's corporate headquarters are in Japan, so all of Toyota's MY 2009 - 2011 vehicles produced for sale in the United States are presented with Japan listed as the country of origin, even though some Toyota vehicles are built in the United States. For all other sectors, EPA generally reports manufacturer location based on the actual location in which the vehicle or engine was manufactured.

LIGHT-DUTY VEHICLE MANUFACTURER LOCATIONS

Figure 64 presents the country of origin of MY 2009 - 2011 light-duty vehicles produced for sale in the United States.[39]

[39] These production data only include vehicles subject to Corporate Average Fuel Economy standards. Pickup trucks greater than 8,500 pounds Gross Vehicle Weight are not included.

Figure 64
MY 2009-2011 Light-Duty Vehicle Production Volume by Manufacturer's Country of Origin



HIGHWAY MOTORCYCLE MANUFACTURER LOCATIONS

In MY 2009 - 2011, Chinese, Japanese, and Taiwanese manufacturers produced a large fraction of Class Ia and Ib highway motorcycles sold in the United States while American, Japanese and European manufacturers produced the largest share of U.S. Class III highway motorcycles.

HEAVY-DUTY HIGHWAY MANUFACTURER LOCATIONS

Figure 65 presents the number of highway engine families (both compression ignition and spark ignition engine families) that were certified for sale in the United States by engine manufacturing plant location.

Figure 65
MY 2009-2011 Heavy-Duty Highway CI and SI Engines by Manufacturing Location

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
USA	77	39	79
Japan	12	5	5
Germany	3	2	2
Brazil	3	1	1
Canada	1	0	0

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
The Netherlands	1	0	0
Italy	0	0	2
Multiple countries[40]	3	5	3
Total	**100**	**52**	**92**

NONROAD COMPRESSION IGNITION MANUFACTURER LOCATIONS

Figures 66 - 68 present the number of engine families intended for use in marine diesel (both EPA and IMO certificates), locomotive, and construction/agricultural equipment applications that were certified for sale in the United States by engine manufacturing plant location or country of origin.

Figure 66 - MY 2009-2011 Marine Diesel Engine Families by Manufacturing Location

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
USA	86	86	107
Japan	20	20	27
Italy	17	17	19
Sweden	12	20	16
United Kingdom	11	13	18
Korea	10	3	5
The Netherlands	8	8	10
Germany	6	10	15
France	5	10	6
Mexico	4	0	1
Canada	0	0	4
Norway	2	0	0
Finland	1	1	0
Austria	1	1	1
Multiple Countries	16	17	30
Total	**199**	**206**	**259**

Figure 67 - MY 2009-2011 Locomotive Engine Families by Country of Origin

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
USA	70	43	43
Multiple countries	2	4	

[40] "Multiple countries" means that engines within an engine family are manufactured in more than one country.

Figure 68
MY 2009-2011 Construction and Agricultural Engine Families by Manufacturing Location

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Japan	193	195	179
Germany	83	83	75
China	60	65	43
Italy	46	49	50
England	47	47	32
USA	43	47	21
Korea	31	36	27
India	23	25	22
Mexico	8	7	8
Sweden	8	2	9
Switzerland	7	11	3
France	8	7	2
Czech Republic	2	2	2
Austria	1	1	-
Brazil	1	1	-
Belgium	0	0	-
Slovakia	-	4	4
Multiple countries	50	59	43
Total[41]	**611**	**641**	**520**

NONROAD SPARK IGNITION MANUFACTURER LOCATIONS

Figures 69 - 71 present the number of Small SI, Marine SI and Large SI engine families that were certified for sale in the United States by engine manufacturing plant location.

Figure 69 - MY 2009-2011 Small Spark Ignition Engine Families by Manufacturing Location

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
China	542	467	442
USA	308	264	198
Japan	158	153	134
Germany	43	37	12
Sweden	37	31	34
Italy	22	18	8
Mexico	16	20	16
Thailand	6	7	2
Brazil	6	4	60
Taiwan	2	1	-
Czech Republic	1	1	1

[41] This figure does not include stationary -only engine families.

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Multiple countries	19	17	78
Total	**1,160**	**1,020**	**985**

Figure 70 - MY 2009-2011 Marine Spark Ignition Engine Families by Manufacturing Location

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Japan	64	52	52
USA	37	44	52
China	10	12	13
France	5	-	-
Thailand	4	5	5
Canada	2	4	2
Germany	2	-	-
Total	**124**	**117**	**124**

Figure 71 - MY 2009-2011 Large Spark Ignition Engine Families by Manufacturing Location

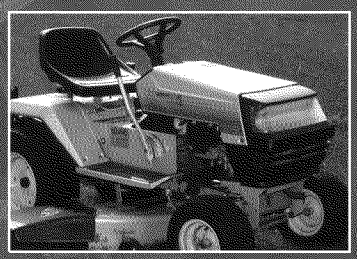
Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
USA	59	95	113
Korea	17	10	7
Canada	4	6	9
Germany	2	6	5
Japan	1	2	2
Mexico	1	1	1
Austria	1	1	1
China	-	1	-
Multiple countries	4	2	2
Total	**89**	**124**	**140**

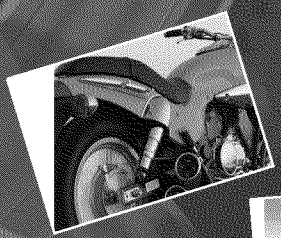
United States
Environmental Protection
Agency

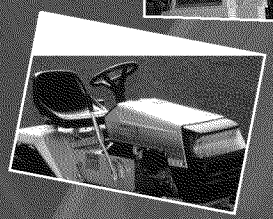
EPA-420-R-13-006

2009-2011 Compliance Report

Vehicle & Engine Compliance Activities







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2009-2011 Compliance Report

Vehicle & Engine Compliance Activities

United States Environmental Protection Agency
Office of Transportation and Air Quality
1200 Pennsylvania Avenue, NW
Washington, DC 20460

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www.epa.gov/otaq

Contributors

Phil Carlson
Emily Chen
Karen Danzeisen
Chris Nevers
Bill Pidgeon
Holly Pugliese
Lynn Sohacki
Trina Vallion
Carl Wick
Ching-Shih Yang

Editors

Amy Bunker
Mark Wolcott

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I. Forward by the Compliance Division Director

2009 – 2011 Compliance Report

This is the third in a series of vehicle and engine compliance reports issued by the U.S. Environmental Protection Agency (EPA) Office of Transportation and Air Quality (OTAQ). These reports offer a convenient reference to the data that OTAQ collects in implementing emissions regulations for vehicles, engines, and other motorized equipment. The environmental programs OTAQ implements apply to virtually every vehicle, engine and gallon of transportation fuel sold in the United States. It is our job to make sure that these regulated mobile sources comply with emissions and fuel economy requirements. OTAQ's role in ensuring comprehensive compliance is essential to realizing national air quality and public health goals.

This report updates and builds upon the data and information presented in the first two reports, the "2007 Progress Report on Vehicle and Engine Compliance Activities" (2007 Compliance Report) and the "2008 Progress Report on Vehicle and Engine Compliance Activities" (2008 Compliance Report). The 2009-2011 Progress Report on Vehicle and Engine Compliance Activities (2009-2011 Compliance Report) presents certification data and other types of information OTAQ collected for model years (MY) 2009 through 2011 and for calendar years 2009-2011[1].

OTAQ oversees a broad set of compliance activities to ensure that vehicle and engine manufacturers satisfy their regulatory obligations. These activities extend from pre- to post-production and range from issuing certificates of conformity before vehicles and engines enter commerce to monitoring in-use testing and reporting after they enter customer service. In addition to regulating vehicles and engines, EPA regulates motor vehicle fuels, including gasoline, diesel and renewable fuels such as ethanol and biodiesel. Please see EPA's fuels web site, http://epa.gov/otaq/fuels/, for further information about OTAQ's fuel compliance program.

We recommend that readers who are unfamiliar with EPA's mobile source emission control programs refer to the 2007 Compliance Report for additional background information, including descriptions of the vehicle, engine, and fuel categories EPA regulates.

The 2009-2011 Compliance Report includes data from the following mobile source sectors: light-duty vehicles, highway motorcycles, heavy-duty highway engines, nonroad compression ignition engines, nonroad spark ignition engines and recreation vehicles.

[1] Some information is reported by model year while other types of information (e.g., recalls and defects) are reported by calendar year.

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The purpose oft tthe compliance reportts is tto ofter a snapshott oft compliance acttvitty over a given ttme ftrame. The years covered by tthe 2009-2011 Compliance Reportt representt a period oft signiftcantt ttransitton in tthe mobile source program. Sttringentt new emission sttandards ttook eftectt ftor many vehicle and engine cattegories, including mottorcycles, heavy-dutty highway engines, nonroad compression-ignitton and marine diesel engines, locomottves, small spark-ignitton and marine spark-ignitton engines, and recreattonal vehicles. In additton, EPA promulgatted tthe ftrstt-ever mobile source greenhouse gas emission sttandards, beginning witth a lightt-dutty vehicle greenhouse gas rule in 2010. Heavy-dutty highway greenhouse gas sttandards ftollowed in 2011. The greenhouse gas regulattons do nott ttake eftectt unttl ftutture years butt manuftactturers were already ttaking stteps in tthe 2009-2011 ttmeftrame tto accrue early creditts and tto prepare ftor compliance mandattes sttarttng in tthe 2012 model year. The 2009-2011 ttme period was also nottable ftor a rapid expansion oft new certtftcatton and compliance acttvitty in tthe recreattonal vehicle, and small nonroad and marine engines secttors, as well as an accelerattng intternattonal dimension tto EPA compliance oversightt.

This reportt is also one oft our deliverables on tthe Presidentt directtves regarding tthe need ftor and importtance oft ttransparency. From tthe Presidentt's memo on Transparency and Open Governmentt onwww.whitehouse.gov: "Transparency promottes accounttabilitty and provides inftormatton ftor cittzens aboutt whatt ttheir Governmentt is doing. Inftormatton mainttained by tthe Federal Governmentt is a nattonal assett." This reportt provides a broad range oft parttners and sttake holders access to the data collected and generated as part of the vehicle and engine certtftcatton and compliance program.

The highlightts tthatt ftollow provide addittonal examples oft inftormatton tthatt is available today and that is explained in more detail in the report.

Byron Bunker
Directtor, Compliance Division
Oftce oft Transporttatton and Air Qualitty
USEPA Nattonal Vehicle and Fuel Emissions Laborattory
2565 Plymouth Road
Ann Arbor, MI 48105

Highlight 1 – Certification

EPA issued nearly 4,000 certificates of conformity in each of model years 2009 - 2011. While it is typical for the number of certificates to fluctuate from year to year, the overall trend has been one of growth. EPA issued 2,520 certificates of conformity in 2000. Certification activity has increased significantly over the last decade.

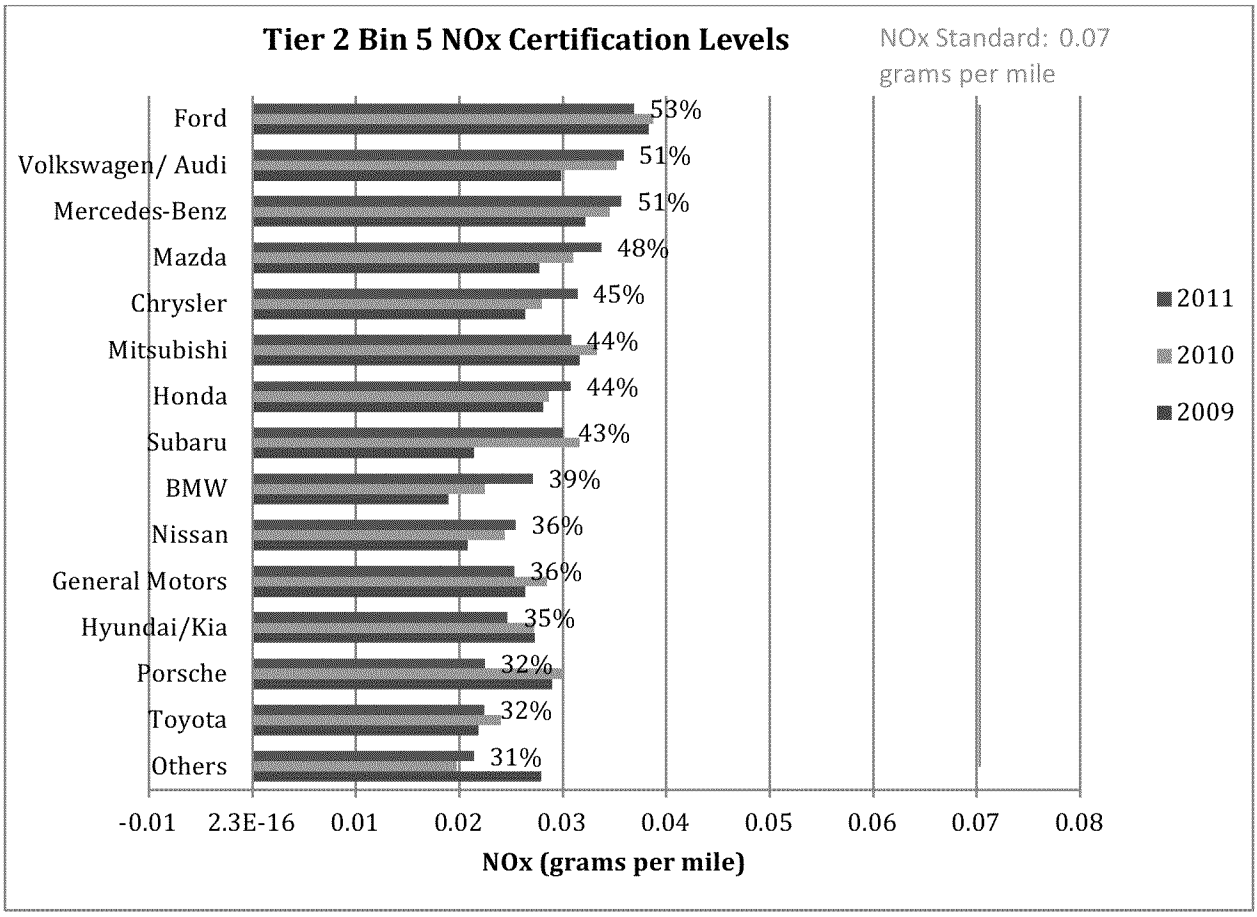
Figure F-1
Certificates of Conformity by Model Year

Industry Sector	Category	MY 2009	MY 2010	MY 2011
Light-Duty Vehicles	Passenger cars and trucks	507	489	464
	Independent commercial importers	21	15	11
	Alternative fuel conversions	74	55	227
Highway Motorcycles	On-highway motorcycles	460	399	337
Heavy-Duty Highway Engines	Compression ignition (mostly diesel)	90	44	52
	Spark ignition (mostly gasoline)	9	9	9
	Alternative fuel conversions	11	13	34
	Evaporative emissions	13	15	17
Nonroad Compression Ignition Engines	Diesel powered equipment, such as tractors, generators, construction equipment, forklifts, welders	616	648	568
	Diesel boats and ships	152	170	210
	Oceangoing vessels per International Maritime Organization requirements	28	37	53
	Locomotives	70	47	60
Nonroad Spark Ignition Engines	Small SI: Small nonroad gasoline powered equipment, such as lawnmowers, string trimmers, chain saws, small compressors, pumps, utility vehicles < 25 mph, snow blowers, rammers, and floor cleaners	1,160	1,020	985
	Marine SI: Gasoline boats and personal watercraft	124	117	124
	Large SI: Large nonroad gasoline powered equipment, such as forklifts, compressors, generators, and stationary equipment	89	124	140
	Evaporative components (mostly intended for small nonroad gasoline and marine gasoline equipment)	161	195	424
Recreational Vehicles	All-terrain vehicles	229	182	143
	Utility vehicles	13	15	23
	Off-highway motorcycles	62	58	46
	Snowmobiles	38	37	35
Total		**3,927**	**3,689**	**3,962**

Highlight 2 – Light-Duty Manufacturers Design to Exceed Standards

EPA confirmatory test results show high compliance margins among light-duty pre-production vehicles, meaning that their emission levels were significantly below the level the standards allow. For example, light-duty vehicle NOx emissions were about one half of the applicable 0.07 grams per mile NOx standard.

Figure F-2
MY 2009-2011 Tier 2 Bin 5 NOx Certification
Levels and Compliance Margins by Manufacturer



Highlight 3 – In-Use Surveillance, Defect Reporting, and Recall Requirements Prevent Potential Problems in Millions of Vehicles and Engines

Manufacturers reported emission defects for a variety of components. The most prevalent defects reported involved onboard diagnostic systems, catalysts, particulate filters, turbochargers, and fuel delivery and exhaust systems. Manufacturers corrected a significant number of these defects through voluntary recalls.

From 2009 through 2011 manufacturers voluntarily recalled some 12 million cars (about 5% of registered light-duty vehicles) and, 900,000 heavy-duty highway engines (more than 20% of heavy-duty registered vehicles).

Highlight 4 - The Characteristics of Mobile Source Industries are Changing

The car and truck manufacturing sectors are dominated by relatively few very large companies. The more recently regulated nonroad, small engine, and recreational vehicle industries are different, with literally hundreds of very small manufacturers comprising the market. In the motorcycle industry, for example, about

one half of the model year 2009 - 2011 certificates were issued to manufacturers who produced a small number of engine families (grouped below as "Other").

Figure F-3
MY 2009-2011 Highway Motorcycle Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Piaggio Group Americas, Inc.	30	31	26
Yamaha Motor Corporation	31	27	28
American Suzuki Motor Corporation	30	23	14
American Honda Motor Co., Inc.	18	13	14
Kawasaki Motors Corp., U.S.A.	16	15	13
Carter Brothers Manufacture Co., Ltd.	9	12	9
Kymco USA	10	11	11
Harley-Davidson Motor Company	12	8	7
Ducati North America, Inc.	7	9	10
BMW	7	8	5
Qlink L.P.	7	7	4
Triumph Motorcycles America Ltd	6	6	7
Cobra Scooters	6	5	3
Big Bear American Made Choppers, Inc.	5	5	0
Xingyue USA, Inc	5	5	3
Other	261	214	183
Total	**460**	**399**	**337**

Furthermore, while the set of vehicle and engine manufacturers historically subject to EPA regulation had their headquarters and/or production facilities in the United States, today's manufacturers are based all over the world.

Figure F-4
MY 2009-2011 Construction and Agricultural Engine Families by Manufacturing Location

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Japan	193	195	179
Germany	83	83	75
China	60	65	43
Italy	46	49	50
England	47	47	32
USA	43	47	21
Korea	31	36	27
India	23	25	22
Mexico	8	7	8
Sweden	8	2	9
Switzerland	7	11	3
France	8	7	2
Czech Republic	2	2	2
Austria	1	1	-

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Brazil	1	1	-
Belgium	0	0	-
Slovakia	-	4	4
Multiple countries[1]	50	59	43

COMPLIANCE REPORT ORGANIZATION

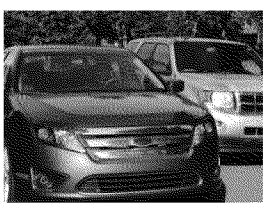
This summary is followed by three chapters that cover the following topics:

- Chapter II, Scope of EPA's Vehicle, Engine, Equipment, and Fuel Compliance Programs, describes the laws that authorize EPA's mobile source compliance activity.

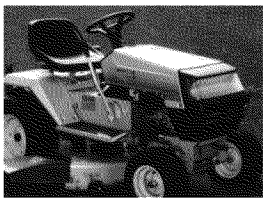
- Chapter III, Compliance Programs and Processes, describes the compliance programs and processes in more detail and provides compliance data and other information organized by industry sector. Please refer to Figure 1 for examples of the vehicles, engines, and equipment that are included in each industry sector.

- Chapter IV, Industry Statistics, presents some interesting statistics that are contained within the compliance information that EPA collects.

Figure 1 - Industry Sectors and Examples

Industry Sector	Examples	Key
Light-Duty Vehicles	Passenger cars, vans, SUVs, small trucks	
Highway Motorcycles	On-highway motorcycles, cruisers, choppers, scooters, touring bikes, mopeds, street bikes	
Heavy-Duty Highway Engines	Tractor-trailers (semi-trucks), buses, delivery and work trucks	

[1] "Multiple countries" means that engines within an engine family are manufactured in more than one country.

Nonroad Compression Ignition Engines (Nonroad CI)	Construction and agricultural equipment, such as tractors, generators, construction and road-work equipment, welders	
	Marine diesel boats and ships, oceangoing vessels	
	Locomotives	
Nonroad Spark Ignition Engines (Nonroad SI)	Small SI: lawnmowers, string trimmers, chain saws, small compressors, pumps, snow blowers	
	Marine SI: inboard and outboard motorboats, jet-skis	
	Large SI: forklifts, large compressors, generators	
	Evaporative components: hoses, fuel tanks	
Recreational Vehicles	All-terrain vehicles (ATVs), utility vehicles (UTVs), sand cars, dune buggies, go karts	
	Off-highway motorcycles	
	Snowmobiles	

II. Scope of EPA's Vehicle, Engine, Equipment, and Fuel Compliance Programs

A. Statutory Authority for EPA Regulation of Vehicles, Engines, Equipment, & Fuels

EPA derives authority to do its work through a variety of environmental statutes enacted by Congress. Figure 2 outlines the primary environmental statutes that give EPA the authority to develop and implement its mobile source clean air programs.

Figure 2 - Environmental Statutes

Statute	Authority
Clean Air Act (CAA)	Emission standards for highway & nonroad vehicles and their fuels
Energy Policy and Conservation Act (EPCA)	Fuel economy information programs for consumers, including vehicle fuel economy labels
Energy Policy Act (EPAct) Energy Independence and Security Act (EISA)	Annual volume standards for renewable fuel content

From locomotives to lawnmowers, EPA's Office of Transportation and Air Quality (OTAQ) has the authority to regulate nearly all engines and vehicles that emit pollutants into the environment. The statutory authority also covers the fuels that power these mobile sources, and includes responsibility for emissions compliance oversight that extends from initial product design to performance on the road or in the field.

B. Scope of EPA Vehicle, Engine, & Equipment Regulations

Compliance programs play an essential role in achieving the benefits of statutes and regulations. OTAQ oversees a comprehensive set of compliance activities to ensure that vehicle and engine manufacturers and fuel refiners and producers satisfy their regulatory obligations. EPA regulation of motor vehicles began in the 1970s; Figure 3 lists vehicle and engine regulations that were proposed or established since 2004. For a comprehensive list of EPA mobile source emission standards, refer to EPA's online Emission Standards Reference Guide, available at www.epa.gov/otaq/standards/index.htm. Please see Section II.C of this report for a list of regulations applicable to motor vehicle fuels.

Figure 3 - Vehicle and Engine Regulations and Implementation Dates

Affected Industry Sector/Category	Program/Rulemaking Description	Effective Model Year[2]
Light-Duty Vehicles	Tier 2 Emission Standards and Gasoline Sulfur Fuel Control – Strengthened emission standards for light-duty vehicles and significantly reduced sulfur levels in gasoline	2004
	On-Board Diagnostics (OBD) – Established new emissions system monitoring requirements for light-duty diesel vehicles	2005
	Revisions to Motor Vehicle Fuel Economy Labeling – Updated EPA method for determining fuel economy label values to better represent typical driving patterns and more accurately estimate actual consumer fuel economy	2008
	Mobile Source Air Toxics – Set standards to lower gasoline benzene content, reduce cold temperature exhaust emissions, and reduce evaporation and permeation from portable fuel containers	2010
	Clean Alternative Fuel Vehicle and Engine Conversions[3]– Updated anti-tampering provisions applicable to manufacturers of clean alternative fuel conversion systems for highway vehicles and engines	All[4]
	Light-Duty Greenhouse Gas (GHG) Emission Standards – Established the first mobile source emission standards for greenhouse gases including carbon dioxide, methane, and nitrous oxide	2012
	Revisions and Additions to Motor Vehicle Fuel Economy Label – Redesigned label provides new information on vehicle fuel economy, energy use, fuel costs, and environmental impacts for conventional and advanced technology vehicles	2013

[2] Effective model year refers to the first year of a new program. Many programs are phased in over multiple model years.
[3] This rule also applies t o heavy-duty highway clean alternative fuel conversions.
[4] .Although the regulation took effect with its promulgation in 2011, because it applies to tampering, it applies to any model year that is subject to any emissions standard.

Affected Industry Sector/Category		Program/Rulemaking Description	Effective Model Year
Highway Motorcycles		Highway Motorcycle Exhaust Emissions- Class I and II: Established more stringent HC and added new optional hydrocarbons + oxides of nitrogen (HC+NOx) standards; Added Class 1a (<50cc) Class III: Established new Tier 1 HC+NOx standard Class III: More stringent Tier II HC+NOx standard Highway Motorcycle Permeation Emissions- Established new evaporative/permeation standards for fuel tank(s) and lines.	2006 2006 2010 2008
Heavy-Duty Highway Engines and Vehicles		Light Heavy-Duty OBD – Established OBD monitoring requirements for heavy-duty chassis certified vehicles, and for engines certified for use in heavy-duty vehicles between 8,500 and 14,000 pounds gross vehicle weight rating (GVWR) Heavy-Duty Highway Rule – Established more stringent exhaust emission standards for heavy-duty vehicles and engines; required Ultra Low Sulfur Diesel (ULSD) fuel (15 ppm sulfur maximum) Heavy-Duty Engines OBD Rule – New OBD monitoring requirements for engines certified for use in heavy-duty vehicles above 14,000 pounds GVWR Heavy-Duty GHG Standards – Established first emission standards for greenhouse gas pollutants from heavy-duty engines and heavy-duty vehicles	2004 2007 2010 2014
Nonroad Compression Ignition Engines & Equipment	Construction & Agricultural	Tier 3/Interim Tier 4 – Established more stringent emission standards for engines between 37 and 560 kilowatts (50 and 750 hp) Tier 4 Nonroad Diesel Rule– Established more stringent emissions standards for all engines greater than 19 kilowatts (25 hp) and lowered nonroad diesel fuel sulfur to 15 ppm maximum	2006 2010
	Marine Diesel Engines	Tier 3 and Tier 4 Emission Standards for Marine Diesel Engines – Established more stringent emission standards for newly built and remanufactured engines	2009
	Locomotives	Tier 3 and Tier 4 Emission Standards for Locomotive Diesel Engines – Established more stringent emission standards for newly built and remanufactured engines	2011

Affected Industry Sector/Category		Program/Rulemaking Description	Effective Model Year
Nonroad Spark Ignition Engines & Equipment	Small Spark Ignition Engines (Small SI)	Control of Emissions From Nonroad Spark Ignition Engines and Equipment – Established more stringent exhaust emissionstandards for Class I (MY2012) and Class II (MY2011) engines below 19 kilowatts and fuel permeation standards for all engines below 19 kilowatts	2011 2012
	Marine Spark Ignition Engines (Marine SI)	Control of Emissions From Nonroad Spark Ignition Engines and Equipment – Established first federal exhaust emission standards for sterndrive and inboard Marine SI engines and increased the stringency of exhaust emission standards for outboard and personal watercraft engines. Established new evaporative emission standards for all Marine SI engines	2010
	Large Spark Ignition Engines (Large SI)	New Emissions Standards for Large SI Engines – Established new emission standards, diagnostic capability and portable emission testing provisions Tier 1 Tier 2	 2004 2007
Recreational Vehicles		New Exhaust EmissionStandards for RVs – Off-highway motorcycles, ATVs and UTVs Snowmobiles Tier 1 Tier 2 Tire 3 New permeation standards for fuel components	 2006 2006 2010 2012 2008
Aircraft[5]		Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures – Established more stringent NOx exhaust emission standardsfor aircraft engines NOx Emission Standards for Aircraft Gas Turbine Engines – Established new NOx emission standards for aircraft, engines consistent with international standards	2005 2012

[5] The Federal Aviation Administration has primary oversight responsibility for aircraft emissions compliance.

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C. Scope of EPA Fuel Regulations

In addition to regulating vehicles and engines, EPA regulates motor vehicle fuels, including gasoline, diesel, and renewable fuels such as ethanol and biodiesel. Figure 4 describes both historical and current fuels programs and implementation dates. For a comprehensive list of ongoing fuels regulations, please visit http://www.epa.gov/otaq/fuels/publications.htm. Additional information can be found on the OTAQ website at http://www.epa.gov/otaq/fuels/index.htm. Please see Section II.B of this report for recent regulatory actions applicable to vehicles and engines.

Figure 4 - Fuels Regulations and Implementation Dates

Affected Fuel Type- *Applicable Fuel Producer or Importer*	**Program/Rulemaking Description**	**Effective Imple-mentation Date**
Motor vehicle fuels and fuel additives – *Gasoline and diesel refiners and importers, renewable fuel producers and importers, fuel additive producers and importers*	Fuels and Fuel Additives Registration System (FFARS) – Mandatory registration program for motor vehicle gasoline, diesel, and their additives sold in the U.S. Requires all fuel and fuel additive manufacturers to report the chemical composition of their products and other technical, sales and health effects information	1975
Gasoline – *Gasoline Refiners and Importers*	Volatility Standards – Limits the vapor pressure of gasoline sold at retail stations during the summer ozone season to reduce evaporative emissions from gasoline, which contribute to ground-level ozone formation	1989
	Oxygenated Fuel Requirements – Establishes fuel oxygen standards to reduce carbon monoxide emissions from motor vehicles during the winter season	1992
	Reformulated Gasoline (RFG) – Reduce smog-forming and toxic pollutants in U.S. cities with worst smog pollution	1995
	Tier 2 Emission Standards and Gasoline Sulfur Regulations Establishes stringent exhaust emission standards for all fuel types and limits fuel sulfur levels to an average of 30 ppm	2004
	Mobile Source Air Toxics Regulations – Limits the benzene content of gasoline and reduces toxic emissions from passenger vehicles and gas cans	2011
Diesel – *Diesel Producers and Importers*	Highway, Nonroad, Locomotive, and Marine Regulations – Suite of rules for highway, nonroad, locomotive, and marine diesel engines that requires ultra-low sulfur diesel (ULSD), 15 ppm maximum	2006

Affected Fuel Type- *Applicable Fuel Producer or Importer*	**Program/Rulemaking Description**	**Effective Imple-mentation Date**
Renewable Fuels (e.g. ethanol, biodiesel) – *Gasoline Refiners and Importers, Renewable Fuel Producers, Importers, Exporters, Marketers, and Blenders*	The Renewable Fuel Standard (RFS) – RFS1 – Regulations established under the Energy Policy Act (EPAct) of 2005 required 7.5 billion gallons of renewable fuel to be blended into gasoline by 2012. RFS2 – Regulations established under the Energy Independence and Security Act (EISA) of 2007 expanded upon RFS1. The RFS2 regulations require renewable fuel to be blended into both gasoline and diesel fuel, as well as jet fuel and heating oil in volumes that increase from 9 billion gallons in 2008 to 36 billion gallons in 2022.	2007 2010

III. Compliance Programs and Processes

A. Overview

EPA uses a variety of testing and reporting programs to monitor compliance with emissions regulations. The programs may apply to vehicles and engines before they are produced (preproduction), while they are in production and after they are in customer service (postproduction)EPA has the authority and flexibility to choose compliance strategies that best fit an industry sector at any given time. Factors that influence the use of a particular compliance approach include regulatory requirements affecting a given industry sector, the technology being used to meet the emission standards, industry-specific production processes and cycles and sector or manufacturer size. This report describes compliance programs and activities that OTAQ conducted in 2009 - 2011. Specifically, the report presents data we collected and analyzed pertaining to MY 2009 - 2011 vehicles and engines, as well as test results and other types of information OTAQ obtained during calendar years 2009-2011.[6]

EPA regulations typically give manufacturers some flexibility about how they will achieve emissions compliance. Examples include emissions standards phase-ins, averaging, banking and trading (ABT) programs and several types of exemptions. This regulatory flexibility enables manufacturers to align their business model with emissions requirements and sometimes allow manufacturers to earn credit for introducing new technologies early. At the same time, some regulatory flexibilities introduce challenges to compliance oversight because vehicles and engines subject to one regulation and set of standards may legally certify to different emissions levels. This report includes some discussion of flexibility provisions and presents data showing how manufacturers are using them.

[6] This report presents the data we have received and compiled as of the date of publication. In some cases data sets may be incomplete due to agency workload constraints, manufacturer under-reporting or error, and/or other issues. EPA continues to work with manufacturers to improve compliance with all requirements. Failure to comply with the applicable regulations, including failure to comply with all reporting requirements represents a violation of law that may result in enforcement action.

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EPA mobile source compliance programs allow for vehicle and engine testing and other compliance activity that can generally be parsed into three life-cycle categories:

Preproduction activities include certification testing and reporting and other compliance processes conducted before vehicles and engines are produced.

Production activities include audits and other compliance testing conducted on vehicles and engines coming off the production line, but before they enter customer service.

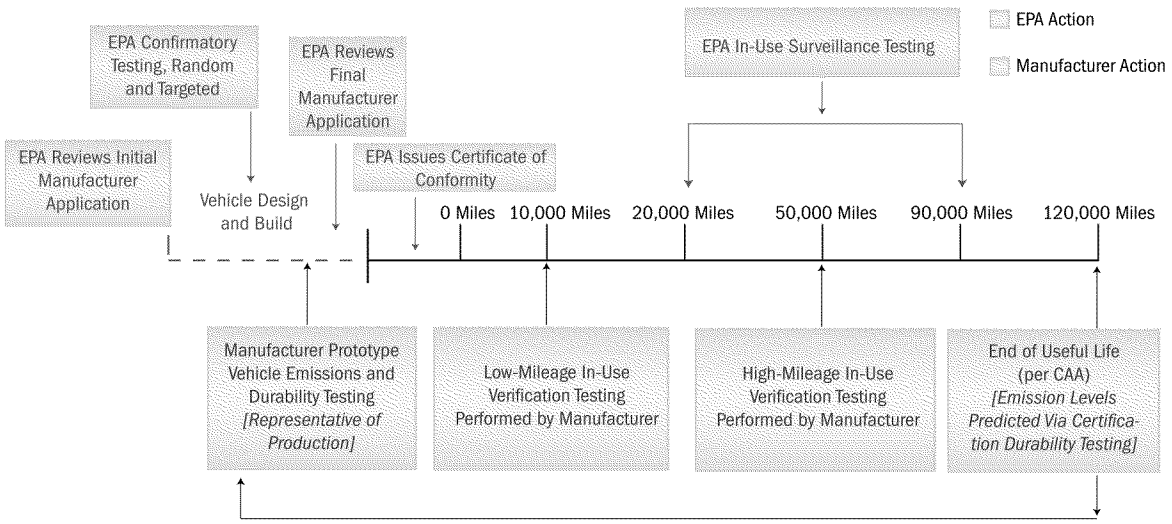
Postproduction activities include in-use testing and reporting and other compliance processes conducted after vehicles and engines enter customer service.

Figure 5 provides how EPA's compliance programs are related to one another.

Figure 5 - Compliance Schedule Examples

EPA's mobile source compliance processes seek to ensure that the vehicles and engines are fully compliant with emissions standards throughout their full useful life. This is accomplished with a variety of testing programs and other requirements that occur over the life of vehicles and engines. This figure shows example compliance schedules for certain sectors. Other mobile source sectors may differ with regard to the timing but generally follow similar protocols.

Compliance Schedule for Light-Duty Vehicles



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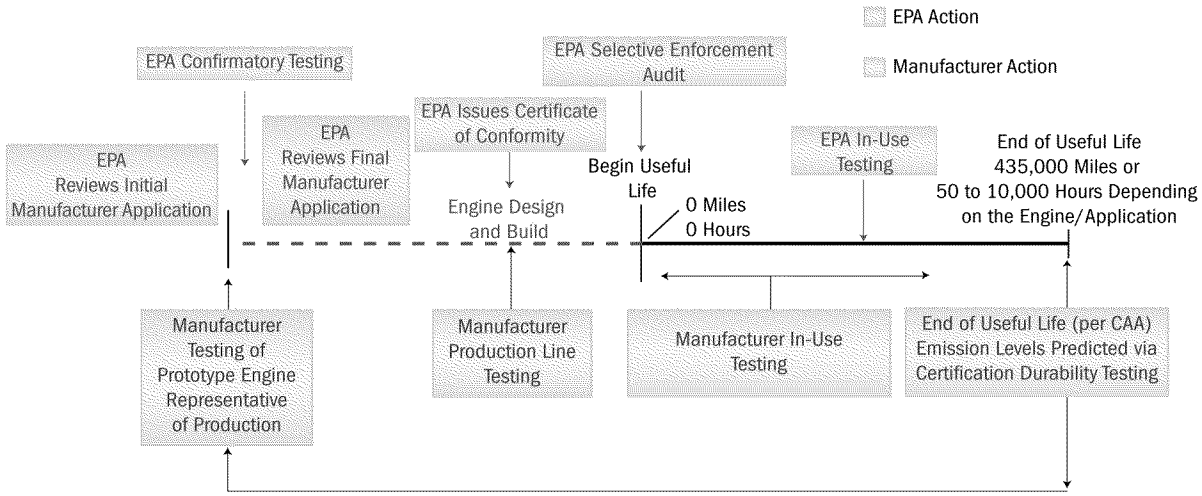
Compliance Schedule for Certain Heavy-Duty Highway and Nonroad Engines



1. Preproduction Programs

CERTIFICATES OF CONFORMITY

Section 206 of the Clean Air Act (CAA) requires all engines and vehicles to be covered by a certificate of conformity before they can enter commerce. A certificate of conformity is a license to produce products for one model year constant with the vehicle description and any terms of the certificate. Certificates of conformity are generally issued to a group of vehicles or engines having similar design and emission characteristics. For light-duty vehicles, certificates are issued for each unique combination of exhaust test group[7] and evaporative family. For heavy-duty vehicles and nonroad equipment subject to engine standards, the unit of certification is called an engine family. Test groups and engine families may include multiple models. Conversely, different versions within a given model may be included in different engine families or test groups.

Figure 6 shows the number of certificates that EPA issued in MY 2009 - 2011. It is typical for the number of certificates to fluctuate from year to year. The drop in total certificates in model year 2010 may have reflected the downturn in the global economy at that time. Overall the trend has been one of growth: certification activity has increased significantly over the last decade. (In 2000 EPA issued 2,520 certificates of conformity.)

[7] An exhaust test group is a group of vehicle models with similar engines, drive trains and emission control systems. It represents a group of vehicles or engines that have a similar design and emission characteristics.

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Figure 6 - Certificates of Conformity by Model Year

Industry Sector	Category	MY 2009	MY 2010	MY 2011
Light-Duty Vehicles	Passenger cars and trucks	507	489	464
	Independent commercial importers	21	15	11
	Alternative fuel conversions	74	55	227
Highway Motorcycles	On-highway motorcycles	460	399	337
Heavy-Duty Highway Engines	Compression ignition (mostly diesel)	90	44	52
	Spark ignition (mostly gasoline)	9	9	9
	Alternative fuel conversions	11	13	34
	Evaporative emissions	13	15	17
Nonroad Compression Ignition Engines	Diesel powered equipment, such as tractors, generators, construction equipment, forklifts, welders	616	648	568
	Diesel boats and ships	152	170	210
	Oceangoing vessels per International Maritime Organization requirements	28	37	53
	Locomotives	70	47	60
Nonroad Spark Ignition Engines	Small SI: Small nonroad gasoline powered equipment, such as lawnmowers, string trimmers, chain saws, small compressors, pumps, utility vehicles < 25 mph, snow blowers, rammers, and floor cleaners	1,160	1,020	985
	Marine SI: Gasoline boats and personal watercraft	124	117	124
	Large SI: Large nonroad gasoline powered equipment, such as forklifts, compressors, generators, and stationary equipment	89	124	140
	Evaporative components (mostly intended for small nonroad gasoline and marine gasoline equipment)	161	195	424
Recreational Vehicles	All-terrain vehicles	229	182	143
	Utility vehicles	13	15	23
	Off-highway motorcycles	62	58	46
	Snowmobiles	38	37	35
Total		**3,927**	**3,689**	**3,962**

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STATIONARY SOURCES-

OTAQ assists EPA's Office of Air Quality Planning and Standards with certification procedures for stationary engines. Stationary engines are used either in a fixed application or in a portable (or transportable) application where the engine resides at a single site for at least one year. A given engine may be certified as a mobile engine, stationary engine, or both. In 2009, of the 89 certificates of conformity for the nonroad large spark ignition engine sector, 16 were for mobile-stationary applications and 17 were for stationary-only applications. The remaining 56 certificates were for mobile-only applications. In 2010, of the 124 certificates of conformity for the nonroad large spark ignition engine sector, 21 were for mobile-stationary applications and 56 were for stationary-only applications. The remaining 47 certificates were for mobile-only applications. In 2011, of the 140 certificates of conformity for the nonroad large spark ignition engine sector, 37 were for mobile-stationary applications and 64 were for stationary-only applications. The remaining 39 certificates were for mobile-only applications. Of the certificates of conformity issued for engines in the nonroad compression ignition diesel powered equipment sector (616 in MY 2009, 648 in MY 2010 and 461 in MY 2011), 128 in MY 2009, 209 in MY 2010 and 189 in MY 2011 were for mobile-stationary engines. In both 2009 and 2010 only 5 engines were certified as stationary-only engine families while 43 engines were certified as stationary-only engine families in 2011.

APPLICATION FOR CERTIFICATION

The certification process begins when a manufacturer submits an application for certification to EPA Applications cover an exhaust test group or engine family that represents a group of vehicles or engines having similar design and emission characteristics. EPA requires manufacturers to provide detailed information in the certification application to show that the vehicles or engines meet all of the applicable emissions requirements and to describe the vehicles or engines to be covered by the certificate of conformity. Each certificate covers only those vehicles or engines specifically described in the application. The list below summarizes the general types of information and data that manufacturers submit to begin the application process:

- A description of the basic engine design and list of distinguishable configurations to be covered by the certification application.
- An explanation of how the emission control system operates
- A description of the vehicle or engine being used to represent the group for certification testing.
- A description of the test procedures and equipment used to test the vehicle or engine
- All emission data obtained on each test vehicle or engine
- The emission deterioration characteristics for each regulated pollutant over the useful life of the vehicles and engines covered by the certification application
- The predicted production volumes of each configuration to be covered by the certificate

• An unconditional statement attesting that vehicles or engines covered by the certification application comply with all requirements of the applicable regulation and the CAA

• Manufacturer representative and official company contact information

• Durability groupings (i.e., groups of vehicles/engines with similar emission deterioration and emission component durability)

• Durability test procedures

• Description of each test group or engine family which is represented by the durability test vehicle or engine

• Description of vehicles or engines used to demonstrate emissions and emission control component durability

• List of all test results, official certification levels, and the applicable emission standards for each vehicle or engine tested

• Statement of compliance with the applicable emission standards for all other configurations not tested but represented by the test vehicles or engine and covered by the certification application

• Evaporative emissions system information

• Description of the evaporative, permeation or refueling families covered by the certification application and test results demonstrating compliance with the applicable standards

• Information on emission control diagnostic systems, where applicable

CONFIRMATORY CERTIFICATION TESTING

Manufacturers conduct the initial testing to support an application for a certificate of conformity and report the results to EPA. Subsequent certification testing, called confirmatory testing, occurs after an application has been submitted. Confirmatory tests are performed by either the manufacturer or by EPA and serve to validate the manufacturer's initial emissions or fuel economy test results.

2. Production Programs

The objective of compliance activities that occur during production is to confirm that vehicles and engines coming off production lines match specifications set forth in the certificate of conformity. In other words, production programs are designed to verify that manufacturers are actually producing the same vehicle or engine that they certified. Some mobile source regulations call for routine production line testing. EPA may also audit production vehicles and engines without prior notice using selective enforcement audits.

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3. Postproduction Programs

IN-USE COMPLIANCE PROGRAMS

In-use compliance programs track emissions performance of production vehicles or engines after they enter customer service. In-use testing programs are conducted by both EPA and manufacturers .

DEFECT REPORTING PROGRAMS

Manufacturers are required to report emission-related defects to EPA. An emission-related defect is a defect in design, materials or workmanship in a device, system or assembly, as described in the approved application for certification. Manufacturers must report a defect even if it does not increase emission levels. EPA regulations generally establish minimum numbers of confirmed defects that trigger defect information reporting requirements An emission-related defect does not necessarily lead to an emission recall because not all defects in emission-related parts increase emissions.

RECALL PROGRAMS

An emissions recall is a repair, adjustment or modification program conducted by a manufacturer to remedy an emission-related problem. Vehicle and engine manufacturers are required to design and build their products to meet emission standards for the useful life of the vehicle or engine specified by law. Under Section 207(c)(1) of the CAA, if EPA determines that a substantial number of vehicles or engines in a category or class do not meet emission standards in actual use, even though they are properly maintained and used, EPA can require the manufacturer to recall and fix the affected vehicles and engines. EPA may use a variety of data sources including EPA and manufacturer test results to determine that a recall is necessary. The purpose of a recall is to make sure the problem gets fixed and thereby prevent excessive pollution from vehicles or engines that are already in customer service. When an emissions recall occurs, the manufacturer must notify vehicle owners and provide instructions about how to have their vehicle repaired. Most recalls are initiated voluntarily by manufacturers once potential noncompliance is discovered; however, EPA also has the authority to order the manufacturer to recall and fix noncompliant vehicles or engines if the manufacturer declines to implement a voluntary recall.

4. Regulatory Flexibility Programs

EPA builds flexibility into its emissions regulations to increase compliance efficiency, decrease costs and encourage manufacturers to introduce new technologies

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

Average Banking and Trading (ABT) provisions allow manufacturers to meet an overall fleet average standard instead of an individual vehicle or engine standard. Manufacturers may comply with ABT provisions by certifying some vehicles and engines at levels above the emission standard, provided that these emission "deficits" are offset by positive credits from vehicles and engines certified below the standard. Compliance is determined by calculating the manufacturer's fleet-wide average of each exhaust test group's production or sales volume and emission level. The flexibility to meet fleet average emission standards by ABT credits can facilitate earlier introduction of clean technology into the market.

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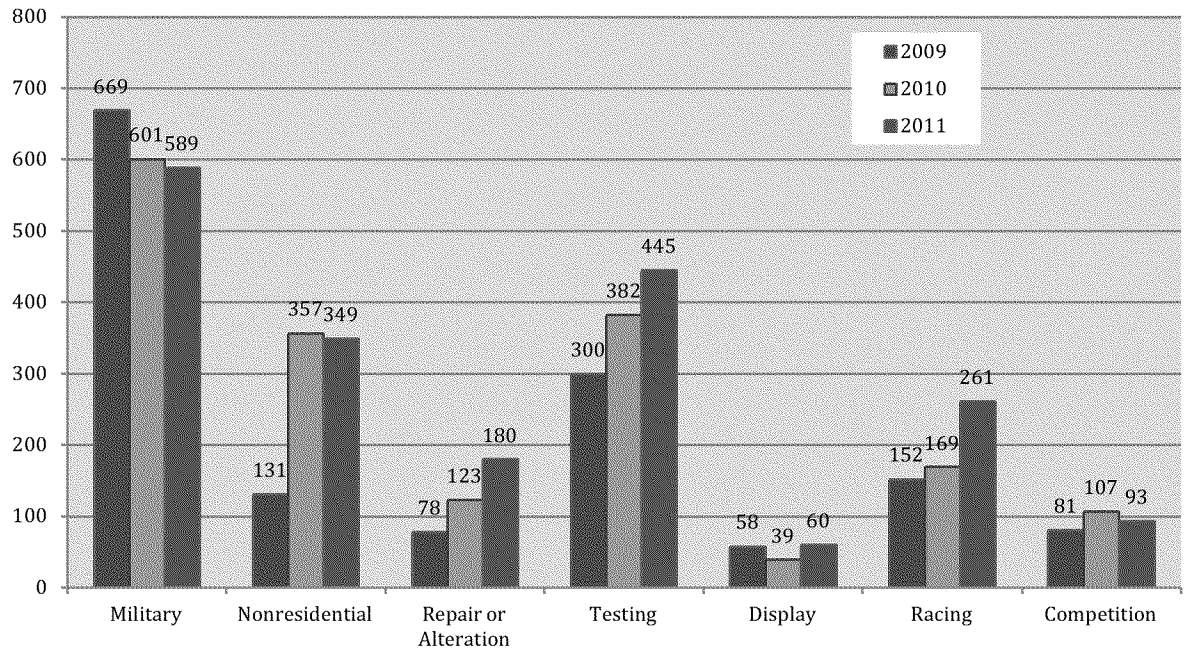
TRANSITION PROGRAM FOR EQUIPMENT MANUFACTURERS

The Transition Program for Equipment Manufacturers (TPEM) recognizes a potential challenge that can face equipment manufacturers when new emission standards take effect. If engines, of which there are relatively few designs, must be redesigned to achieve the required emission reductions, equipment powered by those engines, of which there could be 10,000 or more designs, may also need to be redesigned. TPEM permits equipment manufacturers a transition period during which they may continue to use a limited number of engines meeting previous standards while they update product designs to accommodate engines meeting the new standards.

5. Exemption Programs

Vehicles and engines imported into the United States may be eligible for an exemption from federal emission requirements. For example, vehicles belonging to military personnel or nonresidents may be eligible for exemption. Vehicles that are being imported for testing or display may also be exempt. Depending on the type of exemption, importers must request written EPA approval in advance. EPA works with the Department of Homeland Security U.S. Customs and Border Protection to ensure that proper approvals have been issued before vehicles and engines may enter the United States. The majority of the 1,469 import exemptions EPA issued in 2009, the 1,778 exemptions issued in 2010 and the 1,732 exemptions issued in 2011 were for light-duty vehicles (less than 0.02%). The majority of exemptions EPA issued for heavy-duty highway and nonroad engines or equipment were for test programs. EPA issued 90 heavy-duty or nonroad exemptions in 2009, 158 in 2010 and 245 in 2011 (less than 0.05%). An exemption may cover multiple vehicles and/or engines. Figure 7 summarizes the exemptions that EPA issued in calendar years 2009 – 2011.

Figure 7 - Vehicle and Engine Exemptions



B. Light-Duty Vehicles

SECTOR PROFILE:

- The light-duty vehicle sector includes passenger vehicles such as cars, vans, SUVs, and light-trucks
- Light-duty vehicles have been subject to increasingly stringent emissions and fuel economy standards since the 1970s
- Primary emission standards in effect for MY 2009-2011 are Tier 2 emission standards for HC, CO, NOx, and PM

PRIMARY COMPLIANCE ACTIVITIES IN 2009 -2011:

- Certification and fuel economy
- EPA and manufacturer confirmatory and in-use testing
- Defect reporting
- Recall
- Early credit for reducing greenhouse gas emissions described here.

CERTIFICATION

EPA issued about 500 certificates to light-duty vehicle[8] original equipment manufacturers (OEMs) each year in MY 2009 - 2011 (see Figure 6). Figure 8 shows the number of certified test groups for MY 2009 - 2011 by manufacturer.[9]

PRODUCTION VOLUME

Figure 9 presents by manufacturer the number of MY 2009-2011 cars and light-duty trucks produced for sale in the United States.[10] A comparison of Figures 8 and 9 shows that there is not always a correlation between the number of test groups a manufacturer certifies and the number of vehicles the manufacturer produces. Manufacturers with the most certified test groups do not necessarily produce the most vehicles .

[8] Some heavy-duty vehicles that are between 8,500-14,000 pounds GVWR are chassiscertified and are included in the light-duty vehicle certificate count.

[9] Each light-duty vehicle certificate covers a unique combination of exhaust test group and evaporative emissions family. Therefore the number of light-duty certificates and test groups is usually different. Manufacturers may create test groups that include both cars and trucks.

[10] These production data only include vehicles subject to Corporate Average Fuel Economy standards.

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Figure 8 - MY 2009-2011 Light-Duty Vehicle Test Groups by Manufacturer[11]

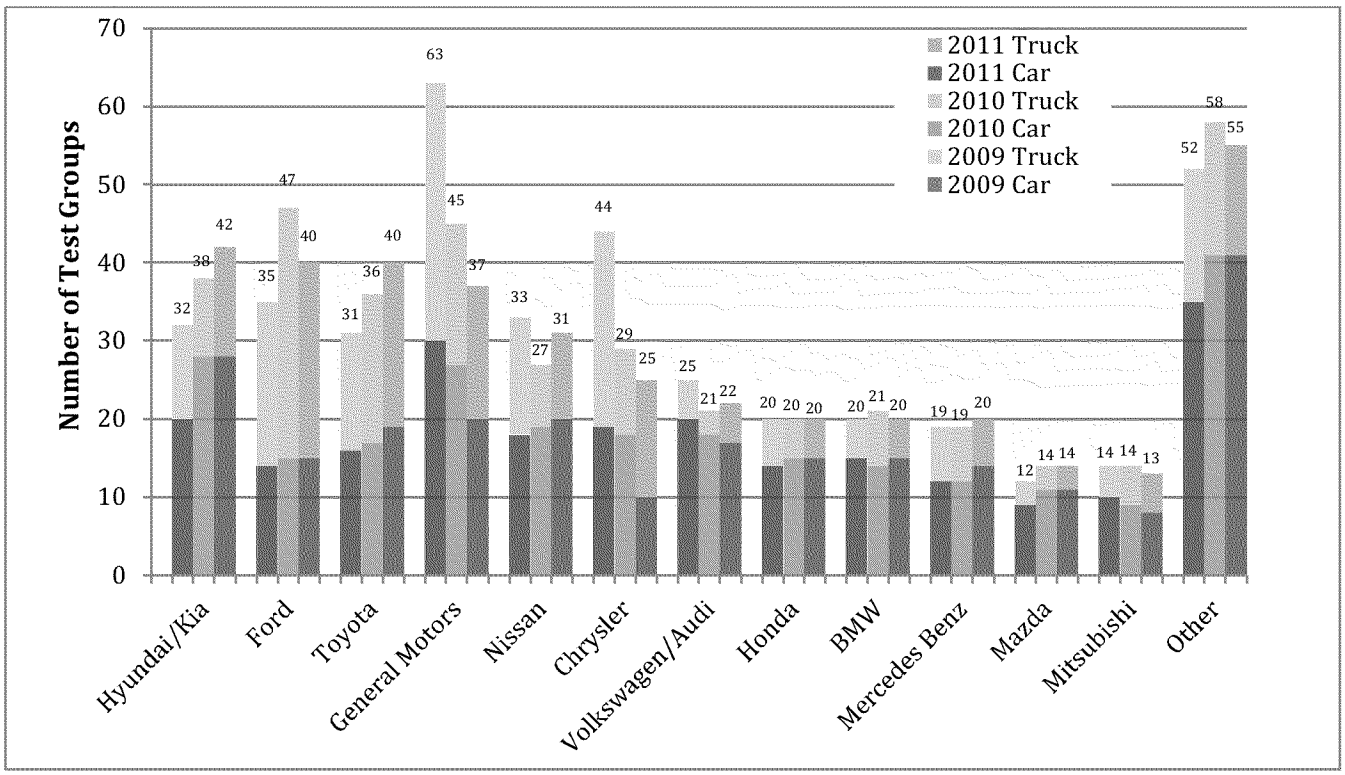
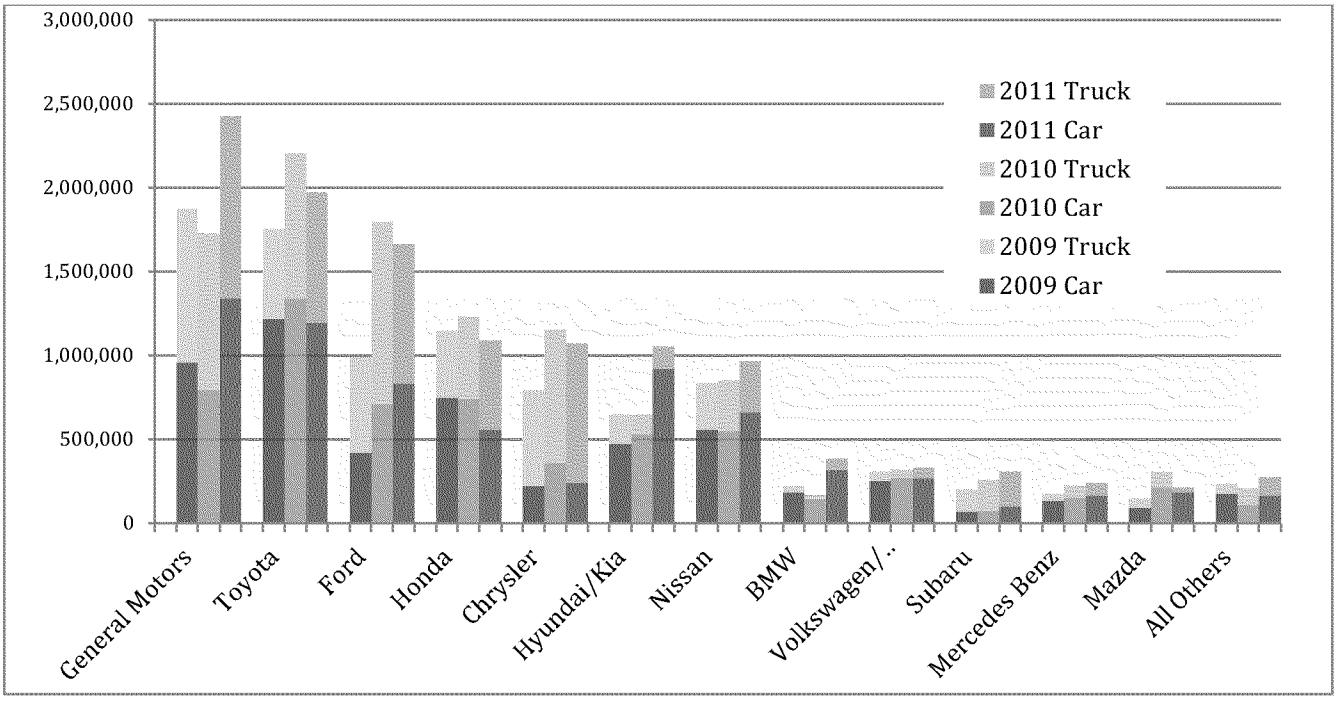


Figure 9 - MY 2009-2011 Light-Duty Production Volume by Manufacturer



[11] In MY 2010, two manufacturers created test groups that included both cars and trucks. One General Motors car/truck test group and two BMW car/truck test groups are counted under the "MY 2010 Car" category in Figure 8.

CONFIRMATORY TESTING

EPA and manufacturers test pre-production vehicles and engines prior to their introduction into commerce to confirm initial manufacturer emission test results.When a vehicle fails a confirmatory test, the manufacturer is allowed one retest to confirm or refute the failureIf the vehicle passes on retest, the retest is deemed the official certification test and the results from the retest stand as the official emission levels for that vehicle. Sometimes a confirmatory test failure can be attributed to problems that render the test vehicle unrepresentative of production vehicles. In those situations, the manufacturer corrects the problem in the test vehicle and retests. In still other cases, failures over the confirmatory test reflect actual engineering problems. These types of failures usually result in manufacturer action to change the vehicle calibration and update the certification application accordingly, resulting in a quantifiable emissions reduction for the vehicles that are ultimately produced. Regardless of whether a confirmatory test failure is due to problems with the test vehicle or problems with the calibration, the problems must be corrected and the vehicle must pass confirmatory testing before EPA will issue a certificate.

FUEL ECONOMY TESTING

EPA and manufacturers perform confirmatory testing for both emissions and fuel economy validation purposes. Fuel economy test results are the source for information that appears on new vehicle fuel economy labels and that EPA and the U.S. Department of Transportation use to assess compliance with corporate average fuel economy (CAFE) standards.

On May 7, 2010, EPA and the National Highway Safety Administration (NHTSA) published a final rule to regulate carbon dioxide (CO_2) and other GHG emissions from light-duty vehicles. The greenhouse gas and fuel economy standards apply to passenger cars, light-duty trucks and medium-duty passenger vehicles, covering model years 2012 through 2016. The program design enables manufacturers to use a single data set to satisfy both greenhouse gas and CAFE compliance requirementsEPA has been working with manufacturers to implement these regulations and expects to begin reporting greenhouse gas data as the program matures.

EPA reports fuel economy test data in an annual Fuel Economy Trends Report[12] which includes both laboratory test value results and results adjusted for real-world driving conditions.

[12] See http://www.epa.gov/oms/fetrends.htm for the latest Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends Report.

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DURABILITY TESTING

The CAA requires EPA emission standards to apply for the full useful life of the vehicle. Since emissions may degrade as vehicles age and accrue miles, manufacturers must perform durability testing to demonstrate that a vehicle will remain compliant for its full useful life, despite any deterioration that may occur over time. EPA regulations establish processes by which manufacturers may demonstrate durability using standard or custom methods. All the other manufacturers chose to use proprietary methods to estimate. Manufacturers who use their own durability aging procedures must provide EPA with an "equivalency factor" that enables comparison between the proprietary method and the published, standard EPA method. This allows a third party who relies on the EPA method to replicate the manufacturer's method.

IN-USE COMPLIANCE TESTING

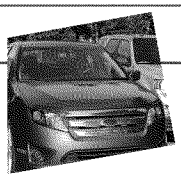
Both EPA and manufacturers conduct testing to monitor in-use vehicle emissions. EPA conducts in-use vehicle surveillance testing at the National Vehicle and Fuel Emissions Laboratory in Ann Arbor, Michigan. The purpose of the EPA surveillance program is to assess emissions performance a few years after vehicles enter the fleet. EPA typically recruits two- or three-year-old vehicles from volunteers in southeast Michigan. EPA selects vehicles for surveillance both randomly and based on certification data, manufacturer in-use verification data, vehicle production volume, new technology, and public complaints and inquiries. In both 2009 and 2010, EPA selected about 45 classes per year for surveillance and generally tested three vehicles from each selected class. In 2011 EPA selected 50 classes and tested two vehicles per class. If any of the initial vehicles within a class failed a test, EPA recruited additional vehicles from that class for follow-up testing to determine whether an emissions problem was likely to exist and was not an artifact of the small sample size (or even a single defective vehicle) .

EPA also conducts an in-use confirmatory testing program for vehicle classes that merit closer scrutiny. These classes may be indentified through failures in either EPA in-use surveillance or manufacturer in-use testing programs.

Figure 10 on the next page shows the vehicle model year, manufacturer, and carline selected for EPA surveillance testing in 2009 - 2011.

Figure 10 - Vehicles Tested in EPA's In-Use Testing Program in 2009-2011

Model Year	Manufacturer	Model
Surveillance Classes		
2005	Hyundai	Elantra (2.0)
2005	Volkswagen	Touareg (3.2)
2006	BMW	M3, M3 CONVERTIBLE (3.2)
2006	Chrysler	Jeep Liberty 2WD/4WD (3.7)
2006	Ford	Freestar Wagon FWD (4.2); F150 2WD (5.4)
2006	General Motors	Trailblazer, Rainier, Envoy (6.0); Chevrolet Colorado, Canyon, Isuzu I280 (2.8)
2006	Honda	Pilot 2WD (3.5)
2006	Mercedes Benz	E320 CDI (3.2)
2006	Porsche	Carrera (3.8)
2006	Toyota	Scion XB (1.5)
2006	Volkswagen	Jetta (1.9)
2007	Audi	Audi Q7 and Touareg (4.2)
2007	BMW	328i, 328xi (3.0); Mini Cooper (1.6)
2007	DaimlerChrysler	Dodge Caliber (2.4); Pacifica (4.0); Wrangler 2WD,4WD (3.8); Nitro 2WD (3.7)
2007	Ford	Expedition 2WD, Navigator 2WD (5.4); Lincoln-Mercury, MKZ AWD/FWD (3.5); 500 FWD (3.0)
2007	GM-Daewoo	Aveo (1.6)
2007	General Motors	Saturn Outlook 4WD & AWD (3.6); Several 5.3L vehicles; Chevrolet Malibu (2.4); Chevy Impala (3.5); Saab 9-3 (2.3);
2007	Honda	Fit (1.5)
2007	Hyundai	Tucson (2.7)
2007	Jaguar	Jaguar S-type, VDP, XJ8, XK (4.2)
2007	Kia	Sedona, Hyundai Entourage (3.8)
2007	Mazda	CX-7 (2.3); Mazda 3 (2.3);
2007	Mercedes Benz	HL450 4Matic (4.6)
2007	Mitsubishi	Outlander 2WD 4WD (3.0); Galant (2.4)
2007	Nissan	Altima (2.5); Frontier 2WD & 4WD (4.0); Versa (1.8); Frontier (2.5)
2007	Subaru (Fuji)	Impreza AWD, Wagon/Outback (2.5)
2007	Toyota	Camry Hybrid (2.4); Corolla (1.8); Lexus: LS 460, LS 460L (4.6); Sienna (3.5)
2007	Volvo	XD 90 AWD, XC 90 FWD (3.2)
2008	Audi	Audi A6 (3.1); Passat, Gtt, Jetta Passat (2.0)
2008	BMW	335 (3.0)
2008	Chrysler	Jeep Liberty 4WD (3.7); Dodge Dakota 2WD & 4WD (3.7); Charger (5.7)
2008	Ford	F150 (5.4); Focus (2.0); Escape Hybrid (2.3); F150 XL FFV (5.4); Explorer 4WD (4.0)
2008	General Motors	GM Chevrolet Cobalt (2.4); C15 Silverado 2WD (4.3); Saturn Astro (1.8); Yukon Denali + XL (6.2);
2008	GM-Daewoo	Suzuki Forenza Reno (2.0)
2008	Honda	Accord (2.4); Civic Hybrid (1.3); Odyssey (3.5)
2008	Hyundai	Tucson 2WD, 4WD (2.7)
2008	Kia	Kia Rondo (2.4)



Model Year	Manufacturer	Model
Surveillance Classes		
2008	Land Rover	LR2 (3.2)
2008	Mazda	CX-9 2WD, 4WD (3.7)
2008	Mercedes Benz	C300,C350,CLK350,E350 (3.5)
2008	Mitsubishi	Lancer (2.0)
2008	Nissan	Versa (1.8)
2008	Subaru (Fuji)	Impreza (2.5)
2008	Toyota	Toyota Lexus GX470 (4.7); Lexus IS 250 (2.5); Camry (2.4)
2009	Audi	A4, A5, Quattro (2.0)
2009	BMW	335 CI, 335 I (3.0)
2009	Chrysler	Dodge Caravan (3.8); Dodge Ram 1500 (5.7); Dodge Journey (4.0); Dodge Charger (3.5); Dodge Ram 1500 (4.7)
2009	Ford	F150 FFV (5.4); Escape Hybrid (2.5); Escape (2.5); Focus (2.0); Fusion (3.0); F150 (5.4)
2009	General Motors	Saab 9-3 (2.3); Chevrolet Malibu (2.4); Saturn Vue Hybrid (2.4); Chevrolet HHR (2.4); Chevrolet C15 Silverado (5.3); Envoy, Trailblazer (4.2)
2009	Honda	Pilot (3.7); CR-V (2.4); Civic (1.8); Accord (2.4)
2009	Hyundai	Sonata (2.4); Santa Fe (2.7)
2009	Kia	Optima (2.4); Rio (1.6); Sportage (2.0)
2009	Land Rover	LR3, Range Rover Sport (4.4)
2009	Mazda	Mazda 5 (2.3)
2009	Mercedes Benz	Smart for 2 (1.0)
2009	Mitsubishi	Galant (2.4); Eclipse and Eclipse Spyder (2.4)
2009	Nissan	350Z (3.5); Murano (3.5); Versa (1.8)
2009	Subaru (Fuji)	Subaru Forester (2.5); Outback Wagon (3.0)
2009	Suzuki	SX4 (1.9)
2009	Toyota	Sienna (3.5); Highlander Hybrid (303); Yaris (1.5); Corolla (1.8); Camry Hybrid (2.4)
2009	Volkswagen	Jetta (2.5)
2009	Volvo	C30, C70, S40, V50 (2.4)

In addition to its own in-use testing, EPA uses data from the mandatory manufacturer run In -Use Verification Program (IUVP) to monitorin-use light-duty vehicle emissions performance. IUVP tests are required at low mileage (between 10,000 and 50,000 miles) and high mileage (greater than 50,000 miles). Manufacturers must complete low mileage IUVP testing one year after the end of production and complete high mileage IUVP testing five years after the end of production. Figure 11 on the next page shows a sample IUVP test schedule for a MY2010 vehicle.

Figure 11 - Example of IUVP Testing Process for a MY 2010 Vehicle

2009				2010				2011				2012-2013				2014				2015			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1			Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
		Production period				Low Mileage Testing												High Mileage Testing					

★ = *Testing is due for completion on or before this date*

Figure 12 shows the total number of vehicles tested over each test procedure and their corresponding failure rates by vehicle model year for all IUVP testing conducted and reported through January 2011.

Figure 12
Light-Duty Vehicle In-Use Verification Program Test Volumes and Failure Rates

Model Year	FTP		US06		2-Day Evap		ORVR[13]	
	Vehicles Tested	Failure Rate	Vehicles Tested	Failure Rate	Vehicles Tested	Failure Rate	Vehicles Tested	Failure Rate
High-Mileage Testing								
2000	481	6.4%	0	N/A	38	0.0%	20	10%
2001	1147	4.2%	18	5.6%	103	3.9%	76	6.6%
2002	1135	5.2%	91	3.3%	105	3.8%	77	9.1%
2003	1185	4.2%	254	2.0%	121	5.0%	101	7.9%
2004	1173	3.8%	819	1.5%	158	4.4%	142	4.9%
2005	1103	3.5%	782	1.2%	142	4.2%	140	5.7%
2006	935	4.9%	671	0.8%	114	1.8%	121	0.8%
2007	1115	2.9%	781	1.9%	120	4.2%	127	6.3%
2008	264	8.0%	209	0.0%	43	7.0%	53	7.6%
2009	23	0.0%	16	6.3%	6	0.0%	7	14.3%
Low-Mileage Testing								
2004	670	4.8%	621	1.5%	167	5.4%	150	7.3%
2005	654	4.6%	589	0.9%	156	3.9%	145	3.5%
2006	654	3.8%	569	0.9%	152	2.0%	154	5.2%
2007	724	3.9%	602	0.3%	143	1.4%	149	4.0%
2008	649	4.3%	557	0.2%	128	1.6%	130	4.6%
2009	530	3.8%	479	0.4%	116	6.9%	127	0.8%
2010	556	3.1%	489	0.0%	141	2.1%	149	0.7%
2011	480	2.5%	425	1.2%	125	0.8%	130	2.3%

Overall, the test results from this program show that the majority of the in-use fleet continues to comply with the emission standards. However, when IUVP testing identifies potential emissions concerns, EPA and manufacturers work together to implement solutions which may involve voluntary manufacturer action to fix the problem, or, if necessary, an EPA-ordered emissions recall. This process is described in greater detail in the 2007 Compliance Report.

[13] Onboard refueling vapor recovery (ORVR) is a vehicle emission control system that captures fuel vapors from the vehicle gas tank during refueling. This requirement was phased-in from 1998 through 2006. It appears that the failure rate is generally decreasing.

DEFECT REPORTING

Figures 13 and 14 present 2009 - 2011 *calendar year* light-duty vehicle emission defect report information. Defects reported in 2009 -2011 potentially affected more than 57 million vehicles. A single defect incidence may affect multiple *model years* of a given vehicle.

Light-duty vehicle manufacturers are required to notify EPA when they learn of emission-related defects in 25 or more vehicles of the same class (e.g., exhaust test group) and category (e.g., manufacturer, model year).

Figure 13 - 2009-2011 CY Light-Duty Vehicle Defect Reports by Manufacturer

	Reported in CY2009		Reported in CY2010		Reported in CY2011	
Manufacturer	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**
Bentley	5	22,109	-	-	2	2,369
BMW	10	184,143	17	342,059	21	497,010
Chrysler	33	2,647,013	18	2,170,741	16	2,109,506
Cummins	1	157	2	211,305	-	-
Ford	12	2,936,701	11	1,816,928	14	2,123,801
General Motors	10	849,594	11	684,655	12	2,091,073
Honda/Acura	21	5,488,140	9	3,711,978	20	2,871,321
Hyundai	8	963,385	12	469,805	14	1,435,048
Jaguar	3	18,619	4	70,828	4	131,357
Kia	9	572,562	10	620,411	9	475,043
Lamborghini	1	139	-	-	-	0
Land Rover	2	53,237	4	208,491	8	371,850
Mazda	8	761,000	13	807,700	12	1,180,484
Mercedes-Benz	5	954,611	7	292,246	12	936,202
Mitsubishi	5	45,386	1	157,314	3	1,661
Nissan/Infiniti	23	2,576,199	21	3,341,602	15	2,255,282
Porsche	53	253,990	17	56,220	5	62,550
Rolls Royce	-	-	2	595	-	-
Rousch	-	-	-	-	2	1,415
Subaru	5	454,814	1	384,984	4	478,217
Suzuki	-	-	1	11,819	1	4,174
Toyota/Lexus	3	1,705,800	4	892,300	3	668,680
Volkswagen/Audi	28	1,024,318	13	619,951	26	762,073
Volvo	2	231,355	1	6,971	5	737,627
Total	**247**	**21,743,272**	**179**	**16,878,903**	**208**	**19,196,743**

Figure 13 shows the number of defect reports submitted for each manufacturer in 2009 - 2011 *calendar year* and the number of affected vehicles. The vehicle *model years* that are covered by the defect reports

submitted in 2009 - 2011 *calendar years* range from MY 2001 through 2011.[14] Manufacturers are required to report defects up to five years after the end of production.

Figure 14 shows the number of defects by defect category for all the vehicles covered by defect reports in 2009 - 2011 *calendar years*.

Figure 14 - 2009 - 2011 CY Light-Duty Vehicle Defect Reports by Problem Category

	Reported in CY2009		Reported in CY2010		Reported in CY2011	
Problem Category	**Number of Defect Reports**	**Number of Affected Vehicles[15]**	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**
Air Inlet/Intake System					6	752,695
Catalyst System	25	1,651,327	11	1,643,927	7	267,647
Computer Related (other than OBD)	21	4,615,410	19	2,473,670	22	2,754,463
Crankcase Ventilation System	3	187,429	1	1,991,813	3	97557
Drivability Problem	2	2,116,987	1	88,063	0	0
EGR System	2	485,755	2	621,929	3	480,845
Electrical, Mechanical & Cooling Systems	19	2,878,703	13	1,540,914	29	3,188,305
Emission Control Information	3	13,606	3	36,619	4	2,936
Evap Emissions System	14	1,033,398	12	968,646	20	2,252,586
Exhaust System	6	309,888	3	123,221	4	409,419
Fuel Delivery System	23	1,861,491	18	1,529,698	10	185,005
Fuel Tank System	14	2,177,608	11	2,235,022	22	3,150,623
Hybrid Vehicle System	2	25,840	1	25,810	0	0
Ignition System	11	378,428	7	1,876,995	6	575,421
Intake/Exhaust Manifold	10	1,362,544	3	155,205	3	204,248
Internal Engine Component					1	612,518
Monitoring/Measuring Sensor/System	24	6,460,405	27	3,415,266	15	1,086,995
OBD System	58	5,566,516	36	2,500,612	40	2,330,438
Other	1	157	-	-	1	8,314
Oxygen Sensor	9	3,238,400	11	511,651	7	608,779
Selective Catalytic Reduction					2	18,219
Turbocharger/Supercharger					3	209,730
Total	**247**	**34,363,892**	**179**	**21,739,061**	**208**	**19,196,743**

[14] Defect and recall reports can be submitted in the calendar year *prior to* the designated model year because vehicles can be certified and introduced into commerce starting January 2 of the prior year. For example, MY 2014 vehicles can be certified and introduced into commerce starting January 2, 2013.

[15] Vehicles that have defects in more than one category are counted in each problem category. Thus, the total number of affected vehicles can be higher in Figure 16 than the total number of affected vehicles in Figure 15.

RECALL REPORTING

Figure 15 shows the number of light -duty vehicle recalls by vehicle manufacturer in 2009 - 2011 *calendar years*. Because a recall usually covers a single, specific condition, a vehicle with multiple emissions problems may be subject to multiple recalls. Thus the total number of affected vehicles includes vehicles that have been recalled more than once. Similarly, there is no direct correlation between the number of defect reports, recalls, and the number of vehicles that are recalled. A manufacturer may identify a lot of defects that are not significant enough to warrant a recall. On the other hand, a manufacturer could have a few major defects that evolve into major recalls affecting large portions of their product line. Historically, emissions recalls affect about three million vehicles annually although the number may vary in any given year.

Figure 15 - 2009-2011 CY Light-Duty Vehicle Recalls by Manufacturer

	Recalls in CY2009		Recalls in CY2010		Recalls in CY2011	
Manufacturer	**Number of Recalls**	**Number of Affected Vehicles[18]**	**Number of Recalls**	**Number of Affected Vehicles**	**Number of Recalls**	**Number of Affected Vehicles**
Aston Martin	-	-	-	-	1	3,977
Bentley	1	11,800	-	-	-	-
BMW	5	354,935	2	47,534	7	348,305
Chrysler	11	212,363	1	31,797	2	112,076
Cummins	-	-	2	160,582	1	28,978
Ford	-	-	1	215,764	2	4,632
General Motors	4	89,312	10	543,308	8	1,497,203
Honda/Acura	2	518,181	1	95,611	7	1,304,845
Hyundai	1	65,614	-	-	-	-
Jaguar	1	98,581	1	3,122	-	-
Kia	1	6,680	-	-	1	45,635
Land Rover	1	6,615	-	-	2	10,316
Lamborghini		-	-	-	-	-
Mazda	-	-	1	16,200	1	52,000
Mercedes-Benz	1	16,623	1	65,444	-	-
Mitsubishi	1	6,882	2	56,113	-	-
Nissan/Infiniti	3	379,688	7	1,454,813	3	41,523
Porsche	-	-	1	71,792	1	226
Rolls Royce		-	-	-	-	-
Rousch		-	-	-	2	1,415
Subaru	4	428,578	2	28,156	1	834,045
Suzuki	-	-	1	11,692	1	311
Toyota/Lexus	2	265,600	2	962,661	3	1,581,700
Volkswagen/Audi	4	520,657	3	561,433	9	1,046,881
Volvo	-	-	1	6,971	1	1,597
Total	**42**	**2,982,109**	**39**	**4,332,993**	**53**	**6,915,665**

Figure 16 lists categories of defects that were corrected by recalls in 2009 – 2011. EPA established the defect categories primarily for internal tracking purposes to identify potential, industry-wide problems with a particular component or technology. Recalls in 2009 -2011 *calendar years* affected vehicles spanning 2001 through 2011 *model years*.

Figure 16 - 2009-2011 CY Light-Duty Vehicle Recalls by Problem Category

	Recalls in CY2009		Recalls in CY2010		Recalls in CY2011	
Problem Category	**Number of Recalls**	**Number of Affected Vehicles**	**Number of Recalls**	**Number of Affected Vehicles**	**Number of Recalls**	**Number of Affected Vehicles**
Catalyst System	7	392,664	7	241,617	3	178,701
Computer Related (other than OBD)	7	638,641	5	22,807	8	2,413,259
Crankcase Ventilation System	1	2,470	-	-	1	115,829
Drivability Problem	1	51,000	-	-	-	-
Electrical, Mechanical & Cooling Systems	-	-	-	-	4	330,740
Emission Control Information Label	2	737	2	231,964	2	1,735
Evap Emissions System	-	-	1	643	3	96,935
Exhaust System	-	-	1	4,156	1	135,740
Fuel Delivery System	8	674,363	4	723,103	8	363,507
Fuel Tank System	3	30,175	5	1,330,691	6	1,158,906
Hybrid Vehicle System	1	18,353	1	566,745	1	46,400
Ignition System	3	501,739	2	572,864	1	237,610
Intake/Exhaust Manifold	1	359,665	-	-	2	129,015
Monitoring/Measuring Sensor/System	2	26,069	3	117,362	6	1,549,407
OBD System	5	156,033	6	412,669	7	157,881
Other	-	-	1	36,580	-	-
Oxygen Sensor	1	130,200	1	71,792	-	-
Total	**42**	**2,982,109**	**39**	**4,332,993**	**53**	**6,915,665**

AVERAGING, BANKING AND TRADING (ABT) PROGRAMS

The 2007 Compliance Report provided an overview of EPA's Tier 2 program. The Tier 2 standards are the current set of emission standards that apply to cars and light-duty trucks. The Tier 2 regulations offer manufacturers a choice ofeight emission bins to which they can certify. Lower bin numbers reflect more stringent emission standards.The Tier 2 ABT program allows manufacturers to use sales-weighted averaging to certify groups of vehicles to different bin levels, as long as the fleet as a whole on average meets Bin 5 standards each year.

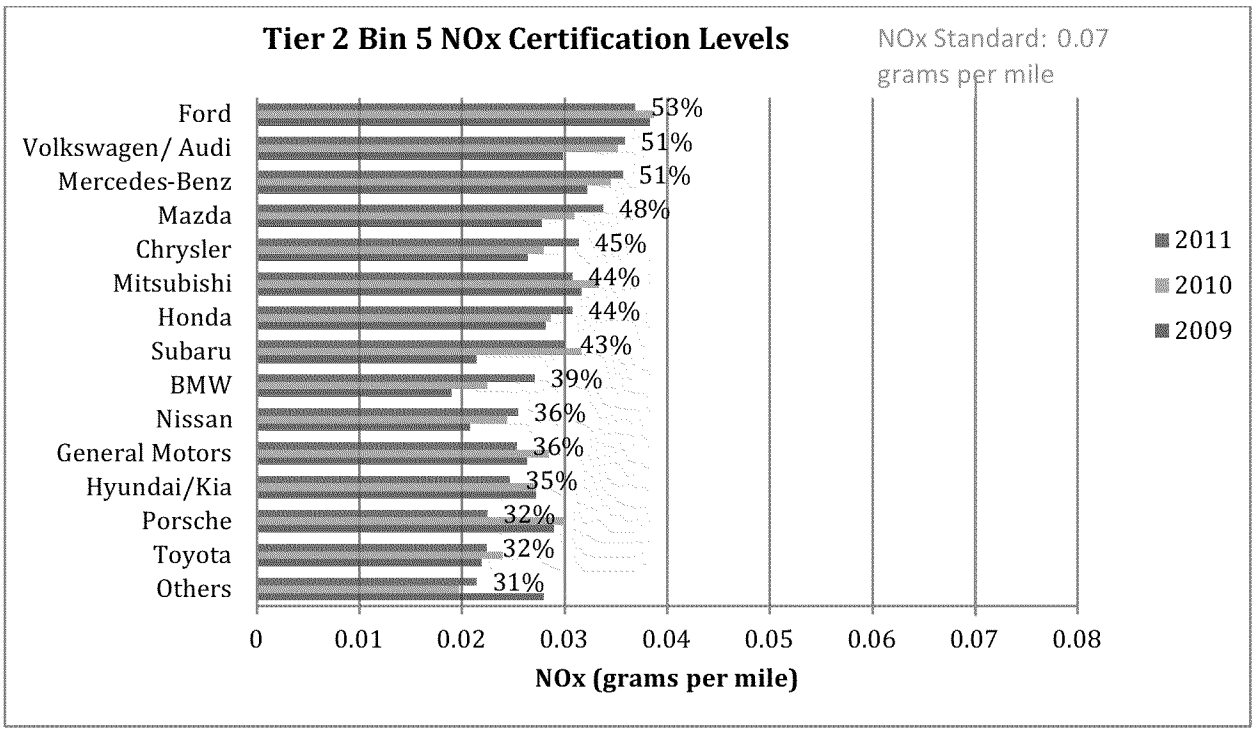
Figure 17 shows the percentage of exhaust test groups by emission certification bin forMY 2009 - 2011. For MY 2009, about 97 percent of test groups were certified to Bin 5 or better. For MY 2010 about 95 percent of test groups were certified to Bin 5 or better. And for MY 2011 about 90 percent of test groups were certified to Bin 5 or better.

Figure 17
MY 2009-2011 Light-Duty Test Group Distribution by Tier 2 Emissions Bins

	Percentage of Light-Duty Test Groups [16]		
Tier 2 Bin	**MY 2009**	**MY 2010**	**MY 2011**
1	0.3%	0.3%	1.9%
2	1.8%	2.6%	3.9%
3	2.4%	5.7%	4.6%
4	10.6%	15.4%	18.0%
5	82.2%	71.5%	61.5%
6	-	0.3%	0.8%
7	-	0.3%	0.2%
8	2.7%	3.9%	9.1%

Figures 18–20 present the average certification levels for NOx, NMOG, and CO respectively along with the standards for Tier 2 Bin 5 for each major manufacturer for 2009 - 2011. The lower the certification levels relative to the standard, the greater the compliance margin.[17]

Figure 18
MY 2009-2011 Tier 2 Bin 5 NOx Certification Levels and Compliance Margins by Manufacturer



[16] Sum of rounded values may not equal 100 percent.

[17] In Figures 20-22, the order from left to right is determined by the 2011 compliance margin, from lowest to highest.

Figure 19
MY 2009-2011 Tier 2 Bin 5 NMOG Certification Levels and Compliance Margins by Manufacturer

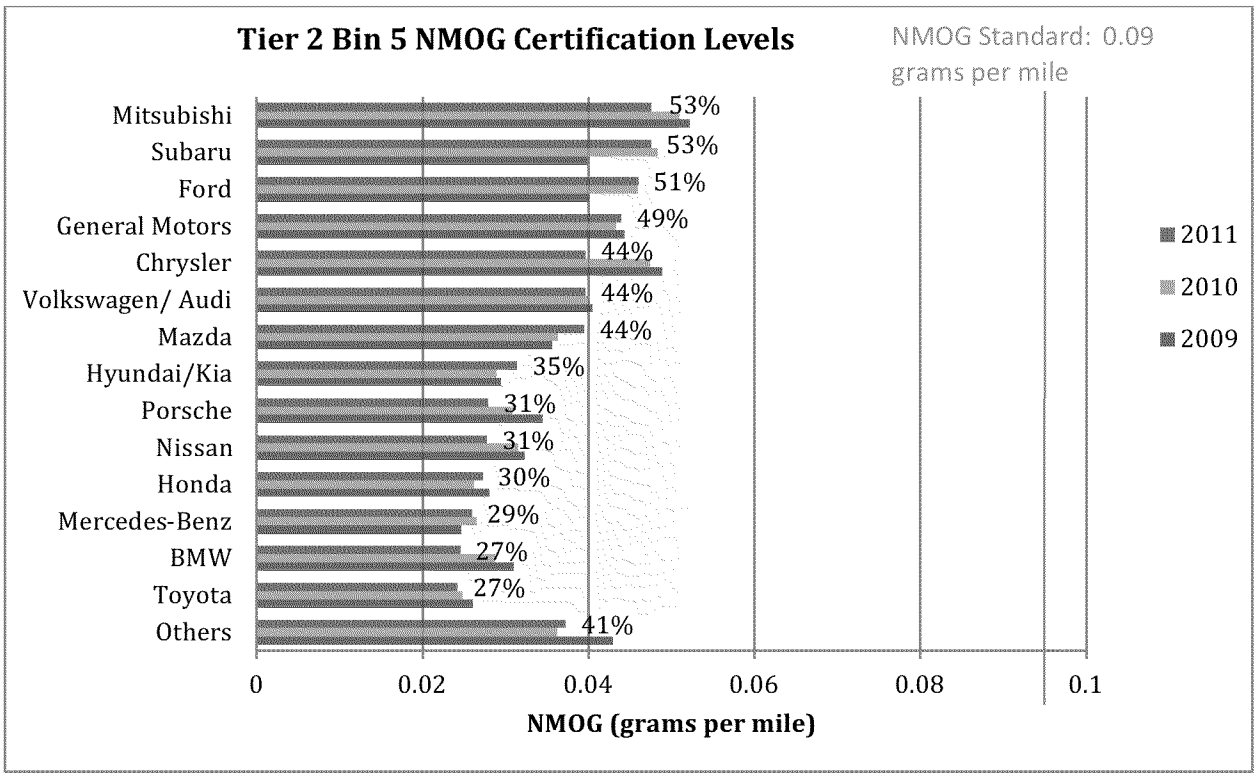
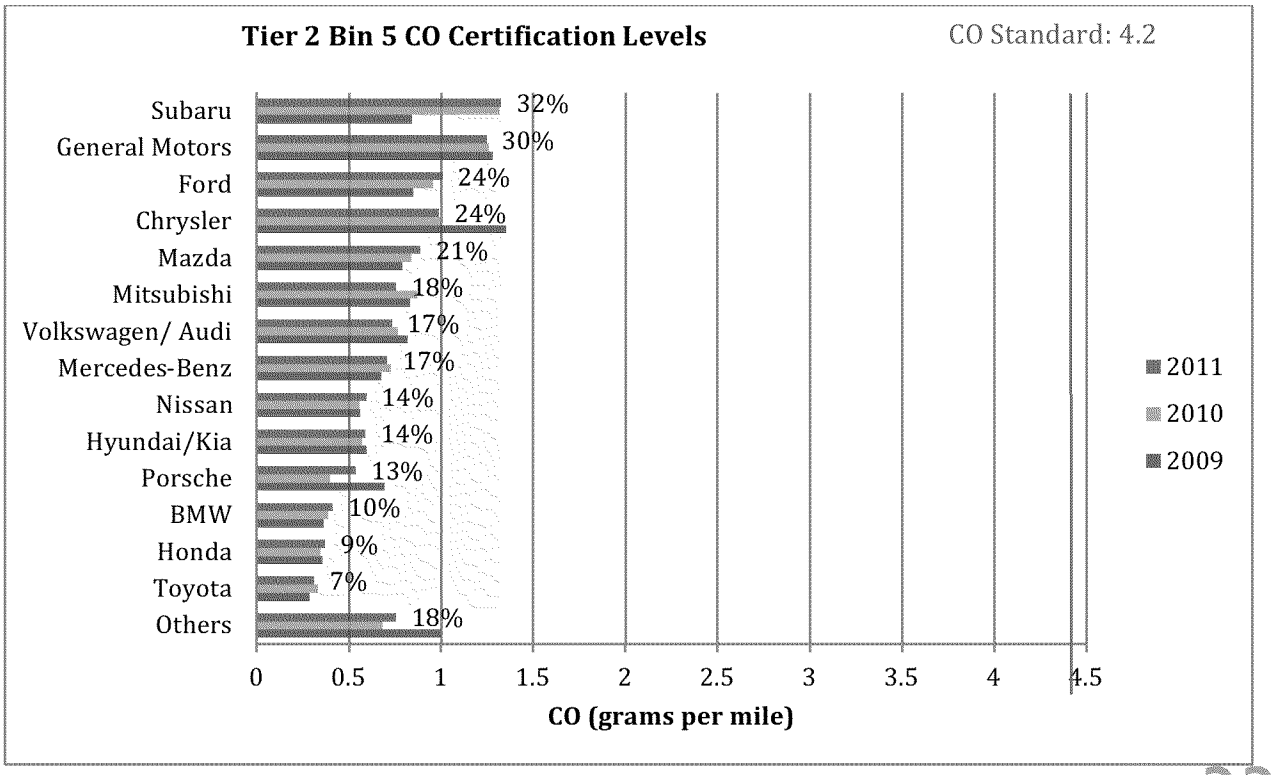


Figure 20
MY 2009-2011 Tier 2 Bin 5 CO Certification Levels and Compliance Margins by Manufacturer



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C. Highway Motorcycles

SECTOR PROFILE:

- Highway and off-highway motorcycles are subject to different sets of regulations and emission standards. This section covers the highway motorcycles. Information about off-highway motorcycles is reported in the Recreational Vehicles section, starting on page 55
- Highway motorcycles have been subject to HC and CO emissions standards since 1978
- A second set of more stringent emission standards took effect in MY2006. Although the CO emission standard remained unchanged at 12.0 g/km, the HC emission standard was reduced from 5 g/km to 1.0 g/km for Class 1 and 2 motorcycles. In addition, an optional HC + NOx 1.4 g/km standard was added.

PRIMARY COMPLIANCE ACTIVITIES IN 2009 – 2011:

- Certification
- Production vehicle testing
- Defect reporting

CERTIFICATION

Figure 21 presents the number of certified highway motorcycle engine families by class.

Figure 21 - MY 2009-2011 Highway Motorcycle Engine Families by Class

Highway Motorcycle Category	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Class Ia (<50cc)	91	77	48
Class Ib (50 -169cc)	96	80	55
Class II (170-279cc)	73	68	44
Class III (>279cc)	196	167	135
Battery electric motorcycles	4	7	8
Total	**460**	**399**	**290**

For MY 2009, 141 manufacturers certified highway motorcycles and 115 manufacturers certified highway motorcycles in MY 2010. For MY 2011, 89 manufacturers certified highway motorcycles.Figure 22 on the next page presents the number of motorcycle manufacturers in MY 2009 - 2011 for each highway motorcycle class.

Figure 22 - MY 2009-2011 Highway Motorcycle Manufacturers by Class

Highway Motorcycle Category	Number of Manufacturers Holding Certificates		
	MY 2009	MY 2010	MY 2011
Class Ia (<50cc)	68	52	47
Class Ib (50 -169cc)	69	51	44
Class II (170-279cc)	41	37	39
Class III (>279cc)	52	44	41
Battery electric motorcycles	4	5	6

Figure 23 presents the number of certified highway motorcycle engine families by manufacturer for MY 2009 - 2011. The manufacturers that certifieda small number of engine families across the three model years are grouped together as "Other".

Figure 23 - MY 2009-2011 Highway Motorcycle Engine Families by Manufacturer

MY 2009		MY 2010		MY 2011	
Manufacturer	Number of Engine Families	Manufacturer	Number of Engine Families	Manufacturer	Number of Engine Families
Yamaha	31	Piaggio	30	Yamaha	28
Suzuki	30	Yamaha	27	Piaggio	26
Piaggio	30	Suzuki	23	Honda	14
Honda	18	Kawasaki	15	Suzuki	14
Kawasaki	16	Honda	13	Kawasaki	13
Harley-Davidson	12	KYMCO	11	KYMCO	11
		Carter Brothers	10	Ducati	10
KYMCO	10			Carter Brothers	9
Carter Brothers	9	Ducati	9	Harley-Davidson	7
BMW	7	BMW	8	Triumph	7
Other	297	Other	253	Other	199
Total	460	Total	399	Total	338
Top Manufacturers	35.4%	Top Manufacturers	36.6%	Top Manufacturers	41.1%

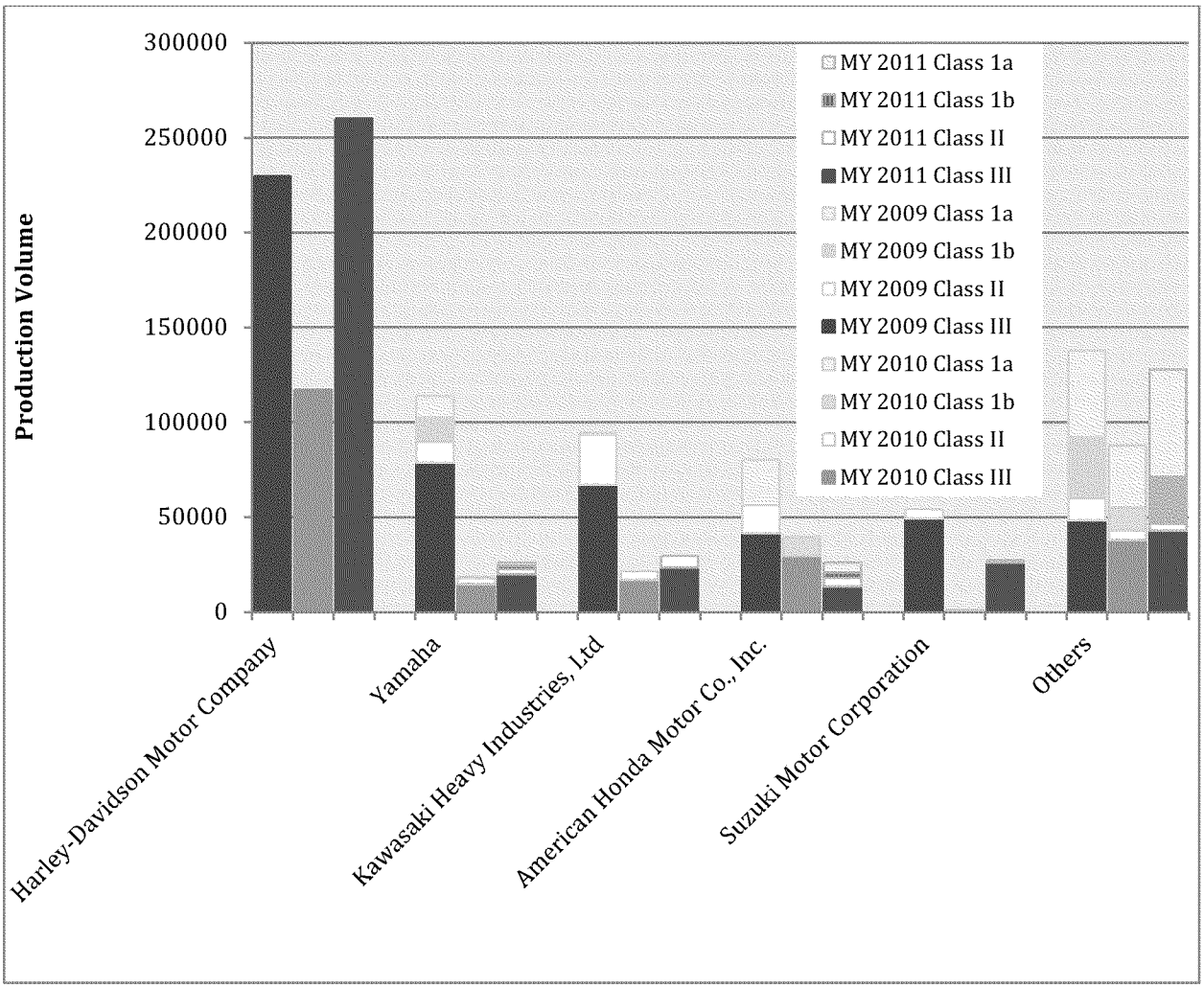
PRODUCTION VOLUME

More than 150 highway motorcycle manufacturers certified products in MY 2009 – 2011, but the vast majority of bikes sold in the United Stateswere produced by just a few companies. Figure 24 shows reported production volumes for the five highest sales volume motorcycle manufacturersin model years 2009 - 2011.[25] The production volume for lower-volume manufacturers is shown in aggregate. The aggregated volume is based on available data manufacturers have reported to EPA As with light-duty vehicles, a comparison of Figures 23 and 24 show that there is not always a correlation between the number of engine families a manufacturer certifies and the number of vehicles the manufacturer

[18] For MY 2009 Kawasaki Heavy Industries produced 1,555 Class 1b motorcycles; For MY 2010 Suzuki Motor Corporation produced 1,033 Class II and 245 Class III motorcycles; for MY 2010, Yamaha produced 516 Class 1a and 228 Class 1b motorcycles. . These low volumes are difficult to discern on the scale of this chart.

produces.[19] Manufacturers with the most certified engine families do not necessarily produce the most vehicles.

Figure 24 - MY 2009-2011 Highway Motorcycle Production Volumes by Manufacturer



PRODUCTION VEHICLE TESTING

EPA may require a manufacturer to supply production vehicles for emissions testing on demand. EPA has found, via inspections at ports and other enforcement related activities, that some imported production motorcycles are not built to the certified configurations.To follow up on this concern, EPA is collaborating with Environment Canada to test productionmotorcycles at an Environment Canada emissions testing facility. Through July 2011, the agencies had tested or were in the process of testing 29 MY 2008-2010 EPA certified engine families and have identified several engine families that may potentially exceed applicable standards. So far, one manufacturer has initiated a voluntary recall for thousands of motorcycles sold in both the United States and Canada based on this testing. EPA is continuing to follow up with other manufacturers.

[19] The economic slowdown may have contributed to the MY 2010 drop in production volume.

DEFECT REPORTING

Figure 25 presents 2009 - 2011 emission defect report information for highway motorcycles. These reports can include multiple model years of a given vehicle and can span more than one problem category. Highway motorcycle manufacturers are required to notify EPA when they learn of the existence of emission-related defects in 25 or more vehicles of the same class (e.g., engine family) and category (e.g., manufacturer, model year).

Figure 25 - 2009-2011 Highway Motorcycle Defect Reports by Problem Category

	Reported in 2009		Reported in 2010		Reported in 2011	
Problem Category	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**
Oxygen sensor	1	12,015	-	-	-	-
Electrical, mechanical & cooling systems	-	-	1	2,782	-	-
OBD system	1	2,447	-	-	-	-
Crankcase ventilation component/system	1	2,447	-	-	-	-
Computer related (other than OBD)	-	-	1	1,452	-	
Carburetor	-	-	-	-	1	16,856
Fuel Delivery Component	-	-	-	-	1	314
Other	-	-	1	59	-	
Total	**3**	**16,909**	**3**	**4,293**	**2**	**17,170**

In calendar years 2009 - 2011, manufacturers submitted defect reports that affected highway motorcycles in model years ranging from MY 2008-2011.

RECALL REPORTING

There was one highway motorcycle recall in 2009 for 5,858 MY 2010 Honda motorcycles with a problem categorized as "defective/incorrect crankcase ventilation component/system." There were no highway motorcycle recalls in calendar year 2010. There was one highway motorcycle recall in 2011 for 314 MY 2011 Bombardier motorcycles with a problem categorized as "defective/incorrect intake/exhaust manifold".

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

The 2006 regulations added provisions allowing highway motorcycle manufacturers to use an EPA specified emission averaging approach to show compliance with the applicable HC+NOx standards. For MY 2009 – 2011 about 6-9 percent of manufacturers availed themselves of this provision.

Class III motorcycles (>279cc) represent the majority of motorcycle sales, and many Class III manufacturers with large sales volumes take advantage of the fleet averaging flexibility for HC+NOx. For model year 2009 about 13 percent of Class III manufacturers used this fleet averaging flexibility. For model year 2010 about 21 percent of Class III manufacturers used the fleet averaging flexibility. And for model year 2011 about 17 percent of Class III manufacturers used the fleet averaging flexibility.

D. Heavy-Duty Highway Engines

SECTOR PROFILE:

- Heavy-duty highway engines are used in highway vehicles such as trucks and buses that are more than 8,500 pounds GVWR
- EPA has regulated heavy-duty highway engine emissions since 1982
- Primary emission standards in effect for MY 2009-2011 were NMHC, CO, NOx, and PM, with final phase-in of a more stringent NOx standard starting in MY2010. Reductions in diesel sulfur content prior to 2007 enabled significant advances in emission controls.

PRIMARY COMPLIANCE ACTIVITIES IN 2009 - 2011:

- Certification
- In-use testing
- Defect reporting

CERTIFICATION

As shown in Figure 6, EPA issued 123 heavy-duty highway certificates for MY 2009, 81 heavy-duty highway certificates for MY 2010 and 112 heavy-duty certificates for MY 2011.[20] These include alternative fuel conversion and evaporative emissions certificates. Most certificates were for diesel engines.

Figures 26 and 27 on the next page present the number of MY 2009 - 2011 engine families certified in each intended service class for compression ignition and spark ignition heavy-duty highway engines. [21]

[20] Some vehicles that are between 8,500-14,000 pounds GVWR are chassiscertified and are included in the light-duty vehicles data.
[21] The number of engine families has is not directly correlated to engine production volumes.

Figure 26
MY 2009-2011 Heavy-Duty Highway Compression Ignition Engine Families by Service Class

Service Class	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Light heavy-duty diesel	14	3	8
Medium heavy-duty diesel	31	12	12
CA only medium-duty	2	-	1
Heavy heavy-duty diesel	39	25	28
Urban Bus	4	3	3
CA only urban bus	-	1	-

Figure 27
MY 2009-2011 Heavy-Duty Highway Spark Ignition Engine Families by Service Class

Service Class	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Heavy-duty gasoline 1 (<=14k lbs)	5	5	5
Heavy-duty gasoline 2 (>14k lbs)	3	3	4
Urban bus	1	1	-

Figures 28 and 29 present the number of MY 2009 - 2011 compression ignition and sparkignition engine families by each heavy-duty highway manufacturer.

Figure 28
MY 2009-2011 Heavy-Duty Highway Compression Ignition Engine Families by Manufacturer

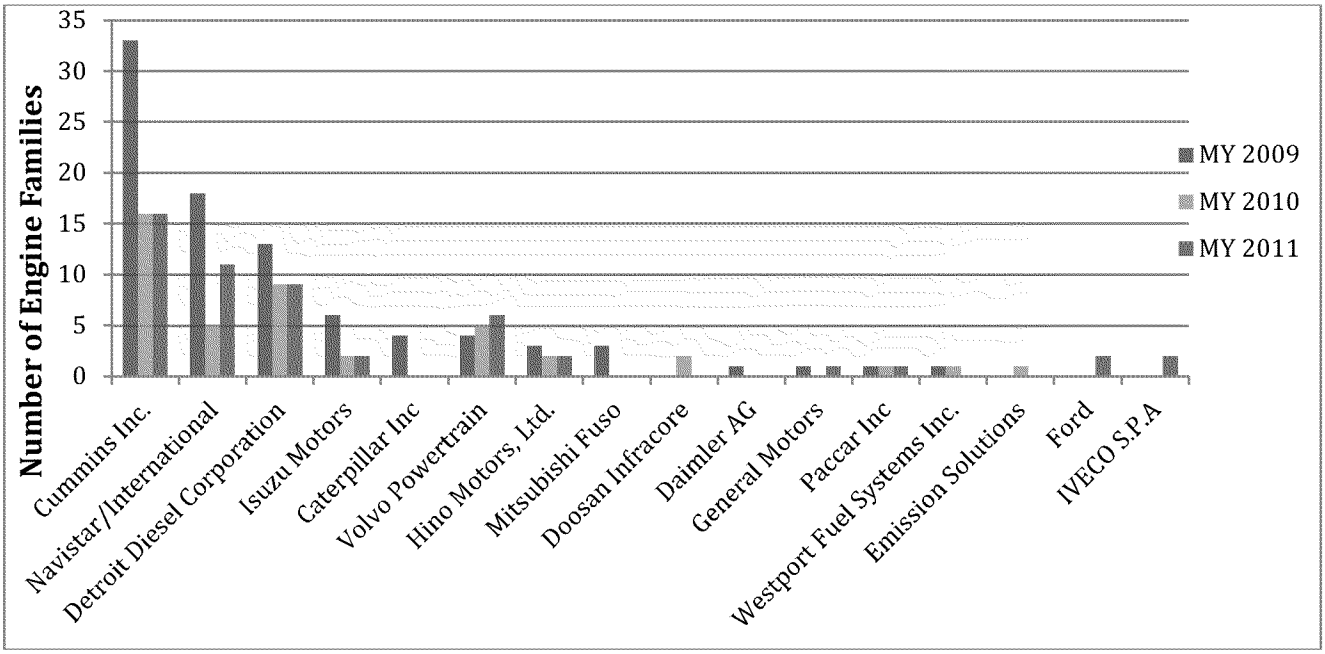
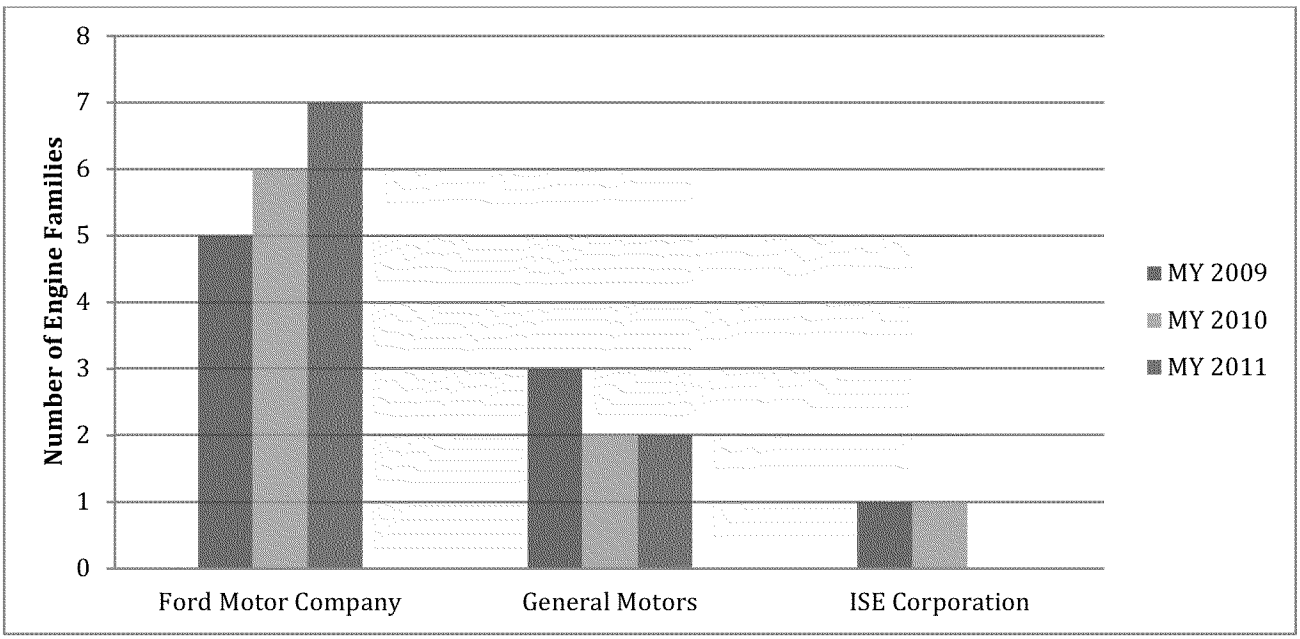


Figure 29
MY 2009-2011 Heavy-Duty Highway Spark Ignition Engine Families by Manufacturer



IN-USE COMPLIANCE TESTING

As is the case for light-duty vehicles, EPA relies on both internal and manufacturer testing programs to assess heavy-duty vehicle compliance with in-use emission standards. Heavy-duty in-use testing differs significantly from light-duty in-use testing. For light-duty vehicles, identical test procedures are used to measure emissions in both certification and in-use testing. The heavy-duty vehicle regulations do not require manufacturers to test in-use engines on a laboratory dynamometer, as they must for certification. Heavy-duty manufacturers may use portable equipment to measure in-use emissions while a vehicle is being driven over the road, instead of removing the engine from an in-use vehicle for laboratory testing. The regulations require manufacturers to measure the percentage of time that a vehicle exceeds certain emission thresholds under real-world driving conditions using devices that monitor emissions of hydrocarbons, carbon monoxide , nitrogen oxides, and particulate matter.

EPA also conducts its own heavy-duty in-use surveillance program, currently focusing on engines with 2010-level emission control systems. Beginning in late 2011 and lasting through 2012, this program focused on testing the most common engines currently used in heavy -duty line-haul tractors and vocational vehicles. This testing included engines from all of the major heavy -duty on-highway diesel engine manufacturers and the engine families tested represent 84% of the estimated large heavy-duty on-highway diesel engine production volume (MY2012 estimate).

All of the engines tested in this program were found to be in compliance with in-use emission standards when evaluated using the prescribed procedures. Emissions performance over non-prescribed conditions, such as extended idle and cold-starting, differed significantly by manufacturer, revealing key differences in calibration philosophy and limitations of current emission control technologies. These findings have been shared with the affected manufacturers and are driving system improvements for future model years.

Currently this testing program is focusing on small and medium sized heavy-duty diesel engine segments.[22]

DEFECT REPORTING

Figure 30 shows the number of defect information reports heavy-duty highway engine manufacturers submitted in 2009 - 2011 *calendar years*. Figure 31 shows the number of defect reportsmanufacturers submitted for each problem category reported in 2009 - 2011 *calendar years*. Defect reports can include multiple model years of a given engine.

Figure 30 - 2009-2011 Heavy-Duty Highway Engine Defect Reports by Manufacturer

Manufacturer	Number of Defect Reports		
	Reported in CY2009	Reported in CY2010	Reported in CY2011
Caterpillar	21	14	11
Cummins	1	10	2
Detroit Diesel Corporation	2	4	4
Ford	1	-	4
FTP Industrial S.p.A			1
General Motors	2	2	2
Hino	-	1	-
Isuzu	1	3	1
John Deere	-	1	-
Navistar	1	8	18
Paccar	-	3	6
Roush Industries, Inc.			2
UD Trucks Corporation			1
Volvo	3	5	15

Figure 31 - 2009-2011 Heavy-Duty Highway Engine Defect Reports by Problem Category

Problem Category	Number of Defect Reports		
	Reported in CY2009	Reported in CY2010	Reported in CY2011
Fuel delivery component / system	9	4	8
Turbocharger/supercharger	5	6	7
Passive diesel particulate filter (DPF)	5	5	5
Active diesel particulate filter (DPF)	4	4	1
Electrical, mechanical & cooling systems	4	2	-
VECI label	2	4	5
EGR system	2	2	12
Exhaust system	2	1	2
Crankcase ventilation component/system	2	-	1
NOx absorber system		-	1
NOx sensor	1	1	1
OBD system	-	6	2

[22] Smith, J., Greuel, J., Ratkos, B., and Schauer, E., "In-Situ Emissions Performance of EPA2010-Compliant On-Highway Heavy-Duty Diesel Engines,"SAE Int. J. Engines 6(3):1490-1499, 2013, doi: 10.4271/201301-2430.

Problem Category	Number of Defect Reports		
	Reported in CY2009	Reported in CY2010	Reported in CY2011
Selective catalytic reduction (SCR) system	-	5	8
Monitoring/measuring sensor/system	-	4	2
Computer related (other than OBD)	-	3	5
Diesel oxidation catalyst (DOC)	-	1	-
Ignition component	-	1	1
Defective / Incorrect Catalyst System (non-diesel engine)	-		3
Oxygen sensor	-		1

RECALL REPORTING

Figure 32 shows the number of heavy -duty highway engine recalls issued in 2009 - 2011 *calendar years*. Figure 33 shows the number of recalls for each problem category reported in 2009 - 2011 *calendar years*. Recalls can include multiple model years of a given engine. Recalls in the 2009 *calendar year* affected engines from 2004 – 2009 *model years*, while recalls in the 2010 *calendar year* affected 2006 – 2010 *model years*. Recalls in 2011 affected 2006 – 2012 *model year* engines.

Figure 32 - 2009-2011 Heavy-Duty Highway Engine Recalls by Manufacturer

Manufacturer	Recalls in CY2009		Recalls in CY2010		Recalls in CY2011	
	Number of Recalls	Number of Affected Engines	Number of Recalls	Number of Affected Engines	Number of Recalls	Number of Affected Engines
Caterpillar	4	153,771	1	7,488	2	25,719
Cummins	1	182	6	101,072	1	1,197
Detroit Diesel					1	3,531
Ford	3	47,639	1	868		
FPT Industrial S.p.A.						
General Motors	1	29,909			2	88,794
Hino	1	7,065				
Isuzu			2	21,679		
International-Navistar	1	128,514				
IVECO S.p.A.					1	1,800
Mitsubishi Fuso Truck	1	616				
PACCAR Inc.					1	31
Roush Industries, Inc.						
Volvo			1	1,065		
Total	**12**	**367,696**	**11**	**132,172**	**8**	**121,072**

Figure 33 - 2009-2011 Heavy-Duty Highway Engine Recalls by Problem Category

	Recalls in CY2009		Recalls in CY2010		Recalls in CY2011	
Problem Category	**Number of Recalls**	**Number of Affected Engines**	**Number of Recalls**	**Number of Affected Engines**	**Number of Recalls**	**Number of Affected Engines**
Crankcase ventilation component/system	1	147,245				
Active diesel particulate filter (DPF)	2	133,964			2	25,719
EGR system	1	29,909				
Electrical, mechanical & cooling systems	1	19,954				
Turbocharger/supercharger	1	19,954				
Fuel delivery component	2	14,796	1	7,488		
Exhaust system	2	965	1	1,117		
OBD system	1	616	5	95,439		
VECI label	1	293	1	21,006	1	31
Selective catalytic reduction (SCR) system			2	6,254	3	82,446
Computer related (other than OBD)			1	868		
NOx Sensor						
Monitoring/measuring sensor/system					1	3,531
Catalyst system					1	9,345
Total	**12**	**367,696**	**11**	**132,172**	**8**	**121,072**

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

In MY 2009, 100 percent of heavy-duty highway compression ignition engine manufacturers participated in ABT programs. Approximately 25 and 45 percent of heavy-duty highway compression ignition engine manufacturers participated in ABT programs in MY 2010 and 2011, respectively.[23]

[23] In MY 2010 a regulatory change took effect that eliminated split engine family accounting.

E. Nonroad Compression Ignition (NRCI) Engines

SECTOR PROFILE-

- EPA regulates several categories of nonroad compression ignition engines including marine diesel engines, locomotives, andcompression ignition engines used in construction and agricultural equipment.
- EPA has regulated emissions from nonroad compression ignition engines since 1996
- Primary emission standards in effect for MY 2009-2011 were NMHC, CO, NOx, and PM

PRIMARY COMPLIANCE ACTIVITIES IN 2009 - 2011:

- Certification
- Compliance programs

CERTIFICATION

Figure 34 presents the number of marine diesel certificates issued by certification Tier and classification. Figure 35 presents the number of marine diesel certificates by manufacturer.Marine diesel engine manufacturers applying for engine certification may request an International Maritime Organization (IMO) certificate in addition to an EPA certificate of conformity for the same engine family. The IMO program, in general, is different from EPA's program, but certain jurisdictions require operators to display an EPA-issued IMO certificate. For the purposes of this compliance report, only one certificate for each engine family was included in the counts listed below.

New marine diesel standards were phased in at different times for different engine sizes. In general, Tier 2 began to take effect around 2005; Tier 3 began in about 2009. Tier 3 will not be in place for all engines until 2018.

Figure 34 - MY 2009-2011 Marine Diesel Engine Certificates by Tier

Certification Tier	Number of Certificates		
	MY 2009	MY 2010	MY 2011
Tier 1	8	4	0
Tier 2	116	131	164
Tier 3	26	26	27
Remanufacture	2	9	19
IMO	28	38	53
Total	**180**	**208**	**263**

Figure 35 - MY 2009-2011 Marine Diesel Engine EPA and IMO Certificates by Manufacturer

Manufacturer[24]	Number of Certificates		
	MY 2009	MY 2010	MY 2011
AB Volvo Penta	16	28	17
Alaska Diesel Electric	5	4	5
Caterpillar Inc.	32	41	29
Cummins Inc.	22	23	18
Detroit Diesel Corporation	3	3	6
Electro-Motive Diesel, Inc.	3	9	15
IHI Shibaura Machinery Corporation	10	11	11
Iveco N.V.	10	10	11
John Deere Power Systems Group	3	7	46
MAN Nutzfahrzeuge AG	3	3	4
Mitsubishi Heavy Industries, Ltd.	5	6	6
MTU Detroit Diesel, INC.	7	6	9
Perkins Engines Co Ltd	2	4	11
Transportation Systems Business Operations of GE	5	5	6
VM Motori S.P.A.	4	3	3
Yanmar CO., Ltd	19	17	25
Other	31	28	41
Total	**180**	**208**	**263**

Figure 36 shows locomotive certificates. Some engine manufacturers obtain a locomotive certificate of conformity, if a locomotive uses its engine.

Figure 36 - MY 2009-2011 Locomotive and Engine Certificates by Manufacturer

Manufacturer	MY 2009			MY 2010			MY 2011		
	Locomotive Certificates	Engine Manufacturer	Total	Locomotive Certificates	Engine Manufacturer	Total	Locomotive Certificates	Engine Manufacturers	Total
EMD	23	2	23	10	2	12	11	2	13
GE	19	-	19	5	-	5	10	-	10
CSX	6	-	6	2	-	2	8	-	8
Advanced Global Engineering	4	-	4	8	-	8	11	-	11
National Railway Equipment Co.	2	2	4	2	2	4	2	2	4
Motive Power	3	-	3	3	-	3	2	-	2
Kansas City Southern	3	-	3				-	-	0

[24] Manufacturers that certified only a few Marine CI engine families in MY 2009 2011 are aggregated under "Other". For MY 2009 "Other" represents 13 manufacturers; for MY 2010 "Other" represents 15 manufacturers; and for MY 2011 "Other" represents 30 manufacturers.

Manufacturer	MY 2009			MY 2010			MY 2011		
	Locomotive Certificates	Engine Manufacturer	Total	Locomotive Certificates	Engine Manufacturer	Total	Locomotive Certificates	Engine Manufacturers	Total
Cummins	-	2	2	-	4	4	-	4	4
Burlington North Santa Fe	2	-	2	-	-	-	-	-	0
HK Engine Components	2	-	2	-	-	-	1	-	1
OceanAir	1	-	1	3	-	3	3	-	3
Haynes	-	1	1	-	1	1	-	-	0
Progressive Rail	-	-	-	3	-	3	3	-	3
Brookeville Equipment Corp.	-	-	-	1	-	1	-	-	0
RJ Corman Railpower	-	-	-	1	-	1	-	-	0
Bombardier Transport							1	-	1
Total	**65**	**7**	**70**	**38**	**9**	**47**	**52**	**8**	**60**

Nonroad compression ignition engines intended for use in construction and agricultural equipment can be certified for use in one or multiple service classes. Figure 37 presents the number of certificates that were issued covering each power category. There were more than 100 different nonroad compression ignition engine families certified in both the 19-37 kW and the 37-75 kW power ranges. Figure 38 shows the number of engine families certified by each manufacturer for MY 2009 – 2011. There were approximately 90 different manufacturers that certified nonroad compression ignition engines intended for use in construction and agricultural equipment in MY 2009 2011.

Figure 37 - MY 2009-2011 Construction and Agricultural Engine Families by Service Class

Service Class (Power Category)	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
0-8 kW	60	59	41
<130 kW	-	2	2
8-19 kW	73	74	70
8-37 kW	2	-	-
19-37 kW	120	121	111
37-56 kW	20	27	27
37-75 kW	107	107	106
56-75 kW	9	11	14
75-130 kW	52	59	67
75-225 kW			1
75-450 kW	2	2	-
130-225 kW	27	31	9
130-450 kW	5	4	1
130-560 kW	11	13	23
>=130 kW	2	6	-
225-450 kW	49	48	23
225-560 kW	2	2	2
450-560 kW	9	11	2
560-900 kW			2
>560 kW	61	64	19

Service Class (Power Category)	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Total[25]	**611**	**641**	**520**

Figure 38 - MY 2009-2011 Construction and Agricultural Engine Families by Manufacturer

Manufacturer[26]	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Kubota Corporation	49	51	50
Cummins Inc.	46	45	16
Deutz AG	46	45	40
Yanmar Co., Ltd.	42	41	40
Caterpillar Inc.	26	34	16
John Deere Power Systems	27	32	29
Motornfabrik Hatz	28	28	28
Mitsubishi Heavy Industries, Ltd	25	25	25
Iveco NV	22	28	22
Komatsu Ltd.	23	25	15
IHI Shibaura Machinery Corporation	22	22	22
Isuzu Motors Limited	20	20	18
Perkins Engines Co. Ltd.	18	17	13
Lombardini	14	14	13
Mahindra & Mahindra Ltd.	12	13	11
Kukje Machinery Co.	9	12	12
CNH UK LTD	10	10	10
Liebherr Machines Bulle SA	8	12	3
Daedong Industrial Co. Ltd.	9	10	8
Iseki Matsuyama Mfg. Co., Ltd.	9	9	9
AGCO Sisu Power Inc.	7	7	5
Hino Motors, Ltd.	6	5	5
AB Volvo Penta	7		8
Shandong Huayuan Laidong Engine Co.	6	6	6
Other	120	130	96
Total[27]	**611**	**641**	**520**

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

About 10 percent of construction and agricultural engine manufacturers participated in ABT programs in MY 2009 - 2011.

[25] This figure does not include stationary -only engine families.
[26] Manufacturers that certified only a few engine families in MY 2009 - 2011 are aggregated under "Other".
[27] This figure does not include stationary -only engine families.

F. Nonroad Spark Ignition Engines

SECTOR PROFILE:

- Nonroad spark ignition (Nonroad SI) engines are generally divided into three categories for purposes of exhaust emission compliance:
  - Small spark ignition engines (Small SI) are rated below 25 horsepower (19 kW) and are generally used in household and commercial applications, including lawn and garden equipment, utility vehicles, generators, and a variety of other construction, farm, and industrial equipment
  - Marine spark ignition (Marine SI) engines are used in marine vessels, including outboard engines, personal watercraft, and sterndrive/inboard engines
  - Large spark ignition (Large SI) engines are generally rated above 19 kW and used in forklifts, compressors, generators, stationary equipment

- Equipment with NRSI engines installed is also subject to evaporative emissions standards.

- Nonroad SI engines have been subject to emissions regulations since 1997

PRIMARY COMPLIANCE ACTIVITIES IN 2009 - 2011:

- Certification
- Compliance programs

CERTIFICATION

As shown in Figure 6, for the 2009 – 2011 model years EPA certified around1,000 Small SI engine families , around 100 engine emissions families each for Marine SI and Large SI, and between 150 and 425 Evaporative Component families. There are seven classes of Small SI engines. Figure 39 presents the number of families certified in each Small SI class.[28] Figures 40-43 present the number of engine families certified by SmallSI, Marine SI, Large SI and Evaporative Component manufacturers.

Figure 39 - MY 2009-2011 Small Spark Ignition Engine Families by Class

Small SI Class	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Class I	247	231	247
Class II	358	344	287
Class IA	39	16	8
Class IB	59	47	47
Class III	2	3	2

[28] Classes are defined by whether or not the engine in applied in a hand held piece of equipment and by power rating. Classes I through IB describe non hand held equipment whereas classes IV and V are in hand held equipment.

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Class IV	307	268	275
Class V	148	111	119
Total	**1,160**	**1,020**	**985**

Figure 40 - MY 2009-2011 Small Spark Ignition Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Briggs & Stratton Corporation	69	65	57
Andreas Stihl AG & Co KG	62	58	59
Kawasaki Heavy Industries, Ltd.	50	47	37
Husqvarna AB	44	38	42
Echo Incorporated/Kioritz Corporation	37	52	56
Fuji Heavy Industries Ltd.	32	32	29
Husqvarna Consumer Outdoor Products N.A. Inc.	32	32	30
Generac Power Systems Inc.	31	-	17
Honda Motor Co., Ltd.	29	29	33
Kohler Co.	23	28	28
Loncin Industrial Co., Ltd.	-	31	29
Jiangsu Jiangdong Group Co. Ltd.	-	28	27
Other[29]	751	580	541
Total	**1,160**	**1,020**	**985**

Figure 41 - MY 2009-2011 Marine Spark Ignition Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Yamaha Motor Company Ltd.	38	24	23
Mercury Marine	28	31	30
Honda Motor Co., Ltd.	12	11	10
BRP US Inc.	11	14	13
Suzuki Motor Corporation	11	12	11
Tohatsu Corporation	9	8	8
Suzhou Parsun Power Machine Co., Ltd.	5	5	5
Hangzhou Hidea Power Machinery Co., Ltd	4	4	5
Kawasaki Heavy Industries, Ltd.	3	3	3
Weber Automotive GmbH	2	-	-
Volvo Penta of the Americas, Inc.	-	2	5
Zhejiang Shunfeng Power Machinery Manufacturer	-	2	-
Zhejiang Shengqi Motion Apparatus Co.	1	1	1
Flagship Marine Engine Company Inc	-	-	1
Ilmor Engineering, Inc	-	-	1

[29] For MY 2009 "Other" represents 168 manufacturers that collectively produced 751 engine families. For MY 2010 "Other" represents 100 manufacturers that collectively produced 580 engine families. For MY 2011 "Other" represents 93 manufacturers that collectively produced 541 engine families.

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Indmar Products Company, Inc	-	-	2
KEM Equipment, Inc	-	-	3
Pleasurecraft Marine Engine Company	-	-	3
Total	**124**	**117**	**124**

Figure 42 - MY 2009-2011 Large Spark Ignition Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
KEM Equipment, Inc.	15	18	19
Generac Power Systems, Inc.	9	32	34
Bucks Engine Company	8	-	7
NGVI, Inc.	8	2	-
Woodward Governor Company	8	6	7
IMPCO Technologies	7	8	8
Zenith Power Products LLC	6	7	7
Nissan Motor Co., Ltd.	5	3	3
Power Solutions, Inc.	6	11	12
TeleflexGFI Control Systems	4	-	-
Engine Distributors, Inc	3	5	4
Cummins Inc.	2	3	8
Linde Material Handling N.A. Corp.	2	2	2
Wisconsin Motors, LLC	2	3	3
GE Jenbacher	1	1	1
John Deere Power Systems of Deere & Comp	1	1	1
Toyota Industrial Equipment	1	1	1
Westerbeke Corporation	1	1	1
PSI International	-	5	8
Deutz Corporation	-	4	5
GFI Control systems	-	4	-
AFI	-	1	1
Don Hardy Race Cars, Inc.	-	1	1
EControls, Inc.	-	1	-
Industrial Engines Ltd	-	1	2
Juniper Engines, Inc.	-	1	1
KaChing, LLC	-	1	-
SRC Automotive, Inc.	-	1	1
Kohler Company	-	-	1
Kubota Corporation	-	-	1
Vantage Vehicle International, Inc.	-	-	1
Total	**89**	**124**	**140**

Figure 43
MY 2009-2011 Nonroad Spark Ignition Evaporative Component Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Honda Motor Co., Ltd.	22	7	4
Husqvarna Zenoah Co., Ltd.	16	16	8
MTD Southwest Inc.	15	12	5
Andreas Stihl AG & Co KG	10	18	36
Hitachi Koki USA, Ltd.	10	17	17
Kawasaki Heavy Industries, Ltd	7	8	6
Maruyama Mfg. Co., Inc.	7	11	11
Husqvarna AB, Sweden	5	5	1
ECHO Incorporated/Yamabiko Corporation	-	6	8
Husqvarna Consumer Outdoor Products N.A., Inc.	-	5	10
Sichuan Chuanhuan Technology Co. Inc	-	5	5
Other[30]	69	85	313
Total[31]	**161**	**195**	**424**

PRODUCTION LINE TESTING (PLT)

Production line testing requires manufacturers to routinely test engines as they leave the assembly line to demonstrate that production engines meet emission standards. In the Small SI and Marine SI sectors, most engine manufacturers had at least one engine family subject to PLT.[32] All engine families met the PLT test requirements. In the Large SI sector, many engine families are not subject to PLT requirements because the projected sales volume is less than 150 units. These engine families are only required to submit production reports. Large SI manufacturers satisfied all requirements forfamilies with high enough volumes to require PLT testing and data submission in 2009 - 2011.

IN-USE COMPLIANCE TESTING

Marine SI and Large SI manufacturers are required to conduct in-use testing on up to 25 percent of engine families at 50 percent or more of their useful life. The Marine SI program has been in place since 2007.

[30] For MY 2009 "Other" represents 38 manufacturers that collectively produced 69 evaporative families. For MY 2010 "Other" represents 48 manufacturers that collectively produced 85 evaporative families. For MY 2011 "Other" represents 165 manufacturers that collectively produced 313 evaporative families.
[31] The evaporative emissions rule for nonroad spark ignition manufacturers started to phase in for model year 2009. The number of engine families affected by the rule should level off after the 2012 model year.
[32] PLT requirements do not apply to small volume engine manufacturers.

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

In MY 2009 about 15 percent of Small SI manufacturers participated in ABT programs. In MY 2010 and in MY 2011about 21 percent of Small SI manufacturers participated. Prior to MY 2010 all types of Small SI engines were averaged together. However, beginning in MY 2010, handheld and non-handheld engines were averaged separately.

G. RECREATIONAL VEHICLES

SECTOR PROFILE:

- Emissions from recreational vehicles (RVs) were unregulated prior to MY 2006
- The regulations in 40 CFR part 1051 set the first emissions standards for RV categories, including all terrain vehicles (ATVs) certain off-road utility vehicles (UTVs) (less than 30 kW, less than 1, 000 cc, and maximum speed more than 25 mph); off-highway motorcycles; and snowmobiles. Each recreational vehicle category is subject to an individual set of exhaust emission standards which phase in over several years. Regulated pollutants are HC+NOx and CO
- All RVs became subject to the same fuel component based permeation emission standards beginning in MY 2008. The regulated pollutant is HC

PRIMARY COMPLIANCE ACTIVITIES IN 2009 - 2011:

- Certification
- Defect Reporting
- Recall
- ABT

CERTIFICATION

There were 100 different recreational vehicle manufacturers that certified products in MY 2009 - 2011. Figure 44 presents RV manufacturers that certified at least four engine families in one or more RV sectors in MY 2009, 2010 and/or 2011.[33] There were about 100 different recreational vehicle manufacturers that

[33]The number of engine families has no bearing on vehicle production volumes.

certified products each model year 2009 – 2011. Figures 45 - 47 present data for manufacturers that certified at leastone MY 2009, MY 2010 and/or 2011 engine families in the ATV and UTV, off-highway motorcycle, or snowmobile sectors

Figure 44 - MY 2009-2011 Recreational Vehicle Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Yamaha Motor Corporation	28	27	26
Arctic Cat inc	22	21	21
Polaris Industries Inc.	22	21	22
Bombardier Recreational Products, Inc	19	17	18
American Honda Motor Co., Inc.	22	6	12
Kawasaki Motors Corp., U.S.A.	13	12	12
American Suzuki Motor Corporation	11	13	3
Tomoto Industries, Inc.	10	11	4
Kymco USA	9	9	4
Taotao USA Inc.	6	6	6
Xingyue USA, INC	6	6	6
Loncin (USA) Inc.	7	4	2
Baja Inc.	-	11	8
JCL Powersports LLC.	6	4	3
Other	161	124	100
Total	**342**	**292**	**247**

Figure 45 - MY 2009-2011 ATV and UTV Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Yamaha Motor Corporation	15	14	13
Arctic Cat	13	11	12
Polaris Industries Inc.	11	11	12
American Honda Motor Co., Inc.	13	6	8
Kawasaki Motors Corp., U.S.A.	10	9	9
Tomoto Industries, Inc.	10	9	5
American Suzuki Motor Corporation	9	10	3
Kymco USA	9	9	10
Bombardier Recreational Products, Inc	8	7	9
Taotao USA Inc.	5	5	5
Loncin (USA) Inc.	6	3	2
Kandi USA, Inc.	4	4	5
Xingyue USA, INC	4	4	4
High Rev Motorsports, LLC	3	5	3
Linhai USA, Inc.	2	6	6
Asian Ventures Inc.	4	3	3
Hammerhead Off-Road, Inc.	4	3	-
JCL Powersports LLC.	4	3	3
Team Joyner USA	6	-	2
Deere & Company	3	3	4
Easy Vehicle, Inc.	3	3	2
Eton America LLC	3	3	1
XY-Xinyang Motor, Inc.	2	3	-

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Baja Inc.	-	5	-
Other	91	58	45
Total	**242**	**197**	**166**

Figure 46 - MY 2009-2011 Off-Highway Motorcycle Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Yamaha Motor Corporation	7	7	7
American Honda Motor Co., Inc.	9	-	4
Apollo Motorsports, Inc.	4	4	3
Kawasaki Motors Corp., U.S.A.	3	3	3
Pride Enterprise, LLC	1	5	-
Baja Inc.	-	6	8
Xmotos Worldwide, Inc.	3	2	-
American Suzuki Motor Corporation	2	3	-
KTM North America, Inc.	2	3	3
Other	31	25	18
Total	**62**	**58**	**46**

Figure 47 - MY 2009-2011 Snowmobile Engine Families by Manufacturer

Manufacturer	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Bombardier Recreational Products, Inc.	11	10	9
Polaris Industries Inc.	11	10	10
Arctic Cat Inc	9	10	9
Yamaha Motor Co., LTD.	6	6	6
HJR	1	1	1
Total	**38**	**37**	**35**

As shown in Figure 48, in model years 2009 - 2011 very few ATV/UTV and off-highway motorcycle manufacturers produced two-stroke engines. However, more than 50% of the snowmobile engine families were two-stroke engines. This represents a technology shift. When the current RV regulations were written, a majority of ATVs sold in the United States and almost all snowmobiles used two-stroke engines (see 67 FR 68262).

Figure 48 - MY 2009-2011 Recreational Vehicle Two-Stroke Engine Families

Category	Percentage of Two Stroke Engine Families		
	MY 2009	MY 2010	MY 2011
ATV/UTV	0%	1%	1%
Off-Highway Motorcycles	2%	10%	17%
Snowmobiles	63%	62%	53%

In addition, in MY 2009-2011 over 50 percent of ATVs and UTV engine families either employed catalyst or fuel injection technologies, or both, to meet the emission standards.

RV CERTIFICATES VOIDED

In 2010 EPA withdrew emissions approval for the import and sale of approximately 200,000 MY 2006 and 2007 gasoline-powered off-road motorcycles and all terrain vehicles. The finding was the first case of its kind. The action to void emissions certificates affects the companies that manufactured and imported these vehicles. Consumers who own models covered by the voided certificates are not responsible for the wrongdoing and can continue to use their vehicles.

In 2013 EPA withdrew its approval of the import and sale of over 70,000 gas-powered on- and off-road motorcycles and all-terrain vehicles because the agency believes that it received either incomplete or falsified certification information. EPA issued the vehicle certificates from 2006 to 2012 to two companies which operate as Snyder Technology, Inc. and Snyder Computer Systems, Inc. (doing business as Wildfire Motors Corporation). As a result of a lengthy investigation, the agency believes that the applications for the certificates contained fallacious information and must be voided. These actions affected between four and nine percent of the highway motorcycles and recreational vehicles produced annually between 2006 and 2012. All vehicles imported into or manufactured in the United States are required to have certificates of conformity.

DEFECT REPORTING

Recreational vehicle manufacturers are required to notify EPA when they learn of the existence of emission-related defects in about 10 percent of the vehicles in an engine family.

Figures 49 and 50 present the 2009 - 2011 emission defect reports submitted by recreational vehicle manufacturers. These reports can include multiple model years of a given vehicle and can span more than one problem category. In calendar years 2009 - 2011, manufacturers submitted defect reports that affected recreational vehicles in model years ranging from MY 2006-2010.

Figure 49 - 2009-2011 Recreational Vehicle Defect Reports by Manufacturer

	Reported in 2009		Reported in 2010		Reported in 2011	
Manufacturer	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**	**Number of Defect Reports**	**Number of Affected Vehicles**
Arctic Cat	5	9,825	3	4,519	1	5,247
BRP	1	9,425	-	-	2	12,972
Honda					1	8,760
Polaris	2	6,077	2	25,146	-	-
Suzuki	-	-	1	25,458	-	-
Yamaha	1	2,020	-	-	-	-
Total	**9**	**27,347**	**6**	**55,123**	**4**	**26,979**

Figure 50 - 2009-2011 Recreational Vehicle Defect Reports by Problem Category

Problem Category	Reported in 2009		Reported in 2010		Reported in 2011	
	Number of Defect Reports	Number of Affected Vehicles	Number of Defect Reports	Number of Affected Vehicles	Number of Defect Reports	Number of Affected Vehicles
Crankcase Vent System					1	8,656
PCV System					1	4,316
Fuel delivery component	2	11,445	-		-	-
OBD system	2	7,396	2	26,289	-	-
Internal engine component (piston, etc)	1	4,696	-	-	1	5,247
VECI label	1	2,285	-	-	-	-
Drivability problem	2	1,381	-	-	-	-
Miscellaneous	1	144	-	-	-	-
Computer related (other than OBD)	-	-	1	12,573	-	-
Exhaust system	-	-	1	12,573	-	-
Monitoring/measuring sensor/system	-	-	1	2,033	1	8,760
Intake/exhaust manifold	-	-	1	1,655	-	-
Total	**9**	**27,347**	**6**	**55,123**	**4**	**26,979**

RECALL REPORTING

Figures 51 and 52 summarize the recreational vehicle recall actions in 2009 - 2011. The recalls in 2009 - 2011 affected vehicles in model years 2007-2010.

Figure 51 - 2009-2011 Recreational Vehicle Recall Reports by Manufacturer

Manufacturer	Recalls in 2009		Recalls in 2010		Recalls in 2011	
	Number of Recalls	Number of Affected Vehicles	Number of Recalls	Number of Affected Vehicles	Number of Recalls	Number of Affected Vehicles
Arctic Cat	5	9,932	3	4,519	1	5,247
BRP	1	4,530	-	-	2	12,404
Polaris	1	1,381	-	-	-	-
Total	**7**	**15,843**	**3**	**4,519**	**3**	**17,651**

Figure 52 - 2009-2011 Recreational Vehicle Recall Reports by Problem Category

Problem Category	Recalls in 2009		Recalls in 2010		Recalls in 2011	
	Number of Recalls	Number of Affected Vehicles	Number of Recalls	Number of Affected Vehicles	Number of Recalls	Number of Affected Vehicles
Crankcase Vent System					1	8,729
PCV System					1	3,675
Internal engine component (piston, etc)					1	5,247
OBD system	2	7,503	-	831	-	-
Fuel delivery component	1	4,530	-	-	-	-
VECI Label	2	2,285	-	-	-	-

Problem Category	Recalls in 2009		Recalls in 2010		Recalls in 2011	
	Number of Recalls	Number of Affected Vehicles	Number of Recalls	Number of Affected Vehicles	Number of Recalls	Number of Affected Vehicles
Drivability problem	1	1,381	-	-	-	-
Miscellaneous	1	144	-	-	-	-
Monitoring/measuring sensor/system	-	-	1	2,033	-	-
Intake/exhaust manifold	-	-	1	1,655	-	-
Total	**7**	**15,843**	**2**	**4,519**	**3**	**17,651**

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

Only a few of the larger ATV, utility vehicle, and off -highway motorcycle manufacturers took advantage of the ABT and emission averaging. On the other hand, almost all snowmobile manufacturers participated in ABT.

IV. Industry Statistics

This section presents additional information that EPA collects in the course of implementing compliance programs.

ALTERNATIVE FUEL AND ALTERNATIVE FUEL CONVERSIONS[34]

Some vehicles and engines are designed to operate on fuels other than gasoline and diesel. Some are manufactured by the OEM to operate on alternative fuels, while others are certified by the OEM to operate on gasoline or diesel fuel and later converted by an aftermarket manufacturer to operate on an alternative fuel. Generally, the CAA prohibits any aftermarket changes to a certified vehicle or engine configuration that could affect emissions, but a regulatory exemption to the prohibition is available in the case of alternative fuel conversions. Each sector has different criteria under which vehicles and engines can be converted to operate on a new fuel In some sectors fuel conversions are certified using OEM certification provisions.

LIGHT-DUTY VEHICLE ALTERNATIVE FUEL DATA

Figures 53 - 55 present the production of MY 2009 - 2011 OEM light-duty vehicles by fuel type. Gasoline vehicles comprise the dominant fuel type, followed by flexible fuel vehicles. After gasoline and ethanol, diesel is the next most prevalent fuel, but still represents less than one percent of passenger car and light-

[34] While alternative fuels are generally understood to mean non-petroleum alternatives to gasoline and diesel, this section of the report also presents data for diesel-fueled vehicles and engines in the light-duty, motorcycle, and recreational vehicle sectors, sectors that have historically been dominated by gasoline.

duty truck production. Compressed natural gas (CNG) vehicles make up an even smaller fraction of MY 2009 - 2011 vehicle production.

Figure 53 - MY 2009 Light-Duty Vehicle Production Volume by Fuel Type

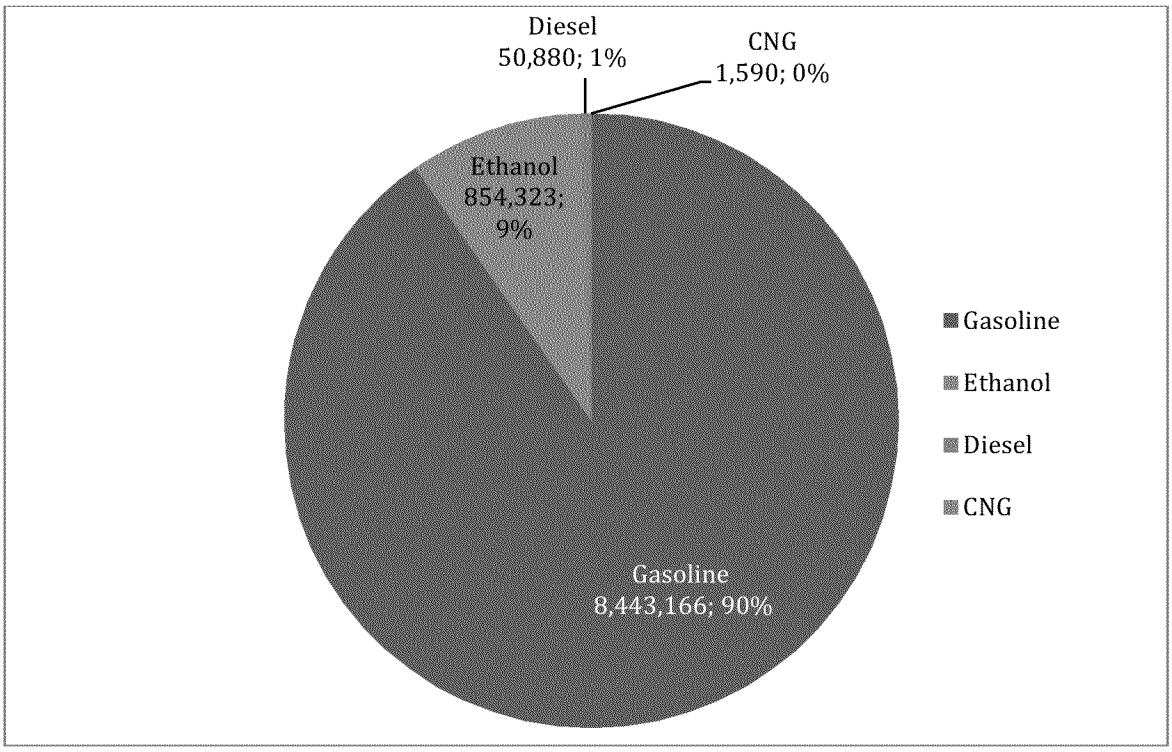


Figure 54 - MY 2010 Light-Duty Vehicle Production Volume by Fuel Type

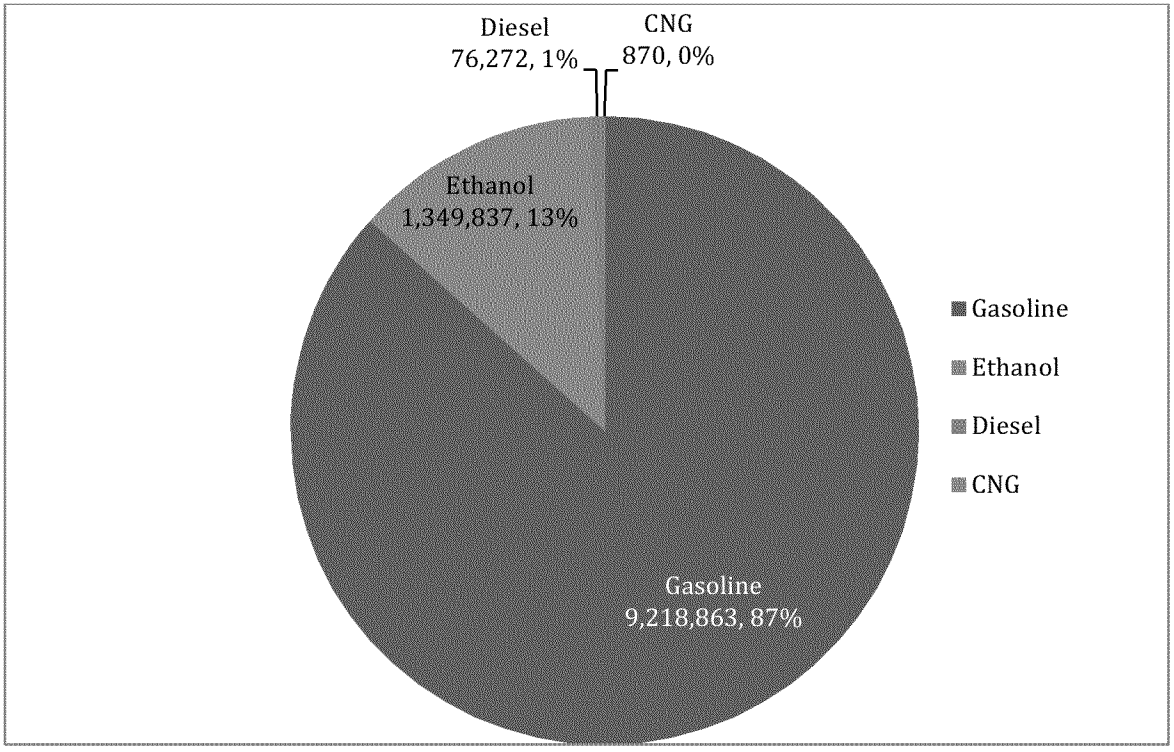
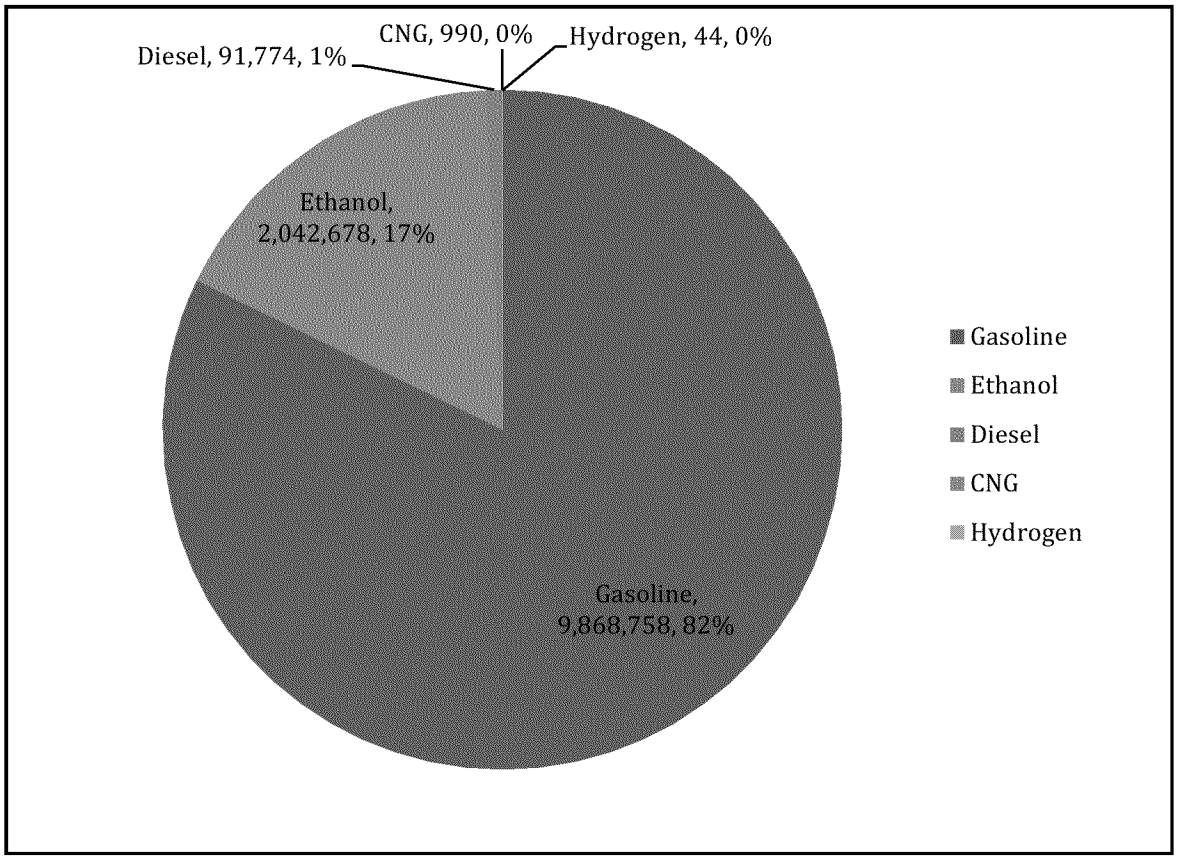


Figure 55 - MY 2011 Light-Duty Vehicle Production Volume by Fuel Type



All MY 2009 – 2011 ethanol vehicles were flexible-fuel vehicles which are capable of operating on gasoline, E85 (85 percent ethanol and 15 percent gasoline), or an intermediate blend.

Figure 56 summarizes the number of OEM light-duty vehicle diesel and alternative fuel test groups by manufacturer.

Figure 56
MY 2009-2011 Light-Duty OEM Diesel and Alternative Fuel Test Groups by Manufacturer

Fuel	Manufacturer	Number of Exhaust Test Groups		
		MY 2009	MY 2010	MY 2011
Battery Electric	Azure Dynamics	0	0	1
	BMW	0	0	1
	Mercedes Benz	0	0	1
	Nissan	0	0	1
	Tesla	0	1	1
	Think	0	0	1
	Wheego	0	0	1
CNG	Honda	1	1	2

Diesel	BMW	2	2	2
	Cummins	2	2	2
	Ford	0	0	2
	General Motors	0	0	2
	Isuzu	0	0	1
	Mahindra &	0	0	1
	Mercedes Benz	3	4	5
E85-Gasoline	Bentley	0	0	1
	Chrysler	4	3	5
	Ford	6	13	14
	General Motors	13	10	10
	Mercedes Benz	1	1	1
	Nissan	1	1	1
	Saab	0	0	1
	Toyota	1	1	1
Hydrogen Fuel Cell	Honda	1	1	1
	Toyota	1	1	1

Vehicles originally designed and certified to operate on gasoline or diesel fuel can be converted to operate on an alternative fuel. Converters of new vehicles must obtain a certificate of conformity to avoid violating the CAA prohibition against tampering.

A new regulation finalized in 2011 established alternative pathways to obtain a regulatory exemption from tampering beyond certification for converters of older vehicles and enginesFor the 2011 model year there were 31 submissions through the Intermediate Age program and four submissions for the Outside Useful Life program.

Figure 57 summarizes the number of certificates issued for light-duty vehicle alternative fuel conversions by manufacturer in MY 2009 - 2011.[35]

Figure 57
MY 2009-2011 Light-Duty Alternative Fuel Conversion Certificates by Manufacturer

Fuel	Manufacturer	Number of Certificates		
		MY 2009	MY 2010	MY 2011
CNG	Altech-Eco	6	3	19
	BAF Technologies	6	3	5
	Baytech	1	2	3
	Evotek	-	5	10
	Go Natural CNG	-	-	2
	Greenkraft	-	-	1
	High Pressure Group	-	-	1
	Landi Renzo USA	-	-	3
	Nat Gas Car	-	-	2
	Natural Drive Partners	2	4	5

[35] Each light-duty vehicle certificate covers a unique combination of exhaust test group and evaporative emissions family. Therefore the number of light-duty certificates and test groups is usually different. MY 2009-2011 conversion certificates may be issued for conversion of either current or earlier model year OEM vehicles.

Fuel	Manufacturer	Number of Certificates		
		MY 2009	MY 2010	MY 2011
	NGV Conversion	-	2	2
	NGV Motori, USA	-	-	1
CNG/E85-Gasoline	Altech-Eco	-	-	4
	BAF Technologies	-	-	1
	Evotek	-	-	1
	Go Natural CNG	-	-	11
	IMPCO Technologies	-	-	15
	Parnell USA	-	-	1
	The CNG Store- Auto Gas	-	-	6
CNG/Gasoline	Altech-Eco	3	5	10
	Baytech	3	3	6
	Evotek	-	-	1
	FuelTek Conversion Corp.	4	-	-
	Go Natural CNG	-	-	5
	IMPCO Technologies	11	-	15
	Nat Gas Car	-	-	2
	The CNG Store- Auto Gas	-	-	3
	Altech-Eco	3	5	10
	Baytech	3	3	6
E85-Gasoline	Flex Fuel U.S.	3	3	2
LPG	Roush Industries	-	11	20
	Technocarb Equipment	7	-	-
	Yellow Checker Star	-	-	2
LPG/E85-Gasoline	American Alternative Fuel	1	2	13
	Evotek	-	-	1
	Icom North America	-	-	7
	IMPCO Technologies	3	-	19
LPG/Gasoline	American Alternative Fuel	5	7	14
	Icom North America	-	-	1
	IMPCO Technologies	10	-	7
	Parnell USA	-	-	3
	Technocarb Equipment	7	-	-
Plug-in Hybrid	A123 Systems	-	1	3

HIGHWAY MOTORCYCLE ALTERNATIVE FUEL DATA

The majority of highway motorcycles are certified to operate on gasoline. However, there are a few highway motorcycle engine families certified to operate as battery-electrics, obtaining energy by charging a battery with electricity from a 120V outlet. See Figure 58 for a breakdown of electric motorcycle manufacturers for MY 2009 - 2011.

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Figure 58
MY 2009-2011 Highway Motorcycle OEM Alternative Fuel Engine Families by Manufacturer

Fuel	Manufacturer	Number of Engine Families		
		MY 2009	MY 2010	MY 2011
Battery Electric[36]	Brammo	1	1	1
	Green Vehicles	1	-	
	Puma	-	2	
	Tom Notch Technology	-	2	
	Xtreme Green	1	-	
	Zero Motorcycles	1	1	3
	ZT Power Station	-	1	
	Current Motors			1
	Evolve Motorcycles			1
	Oxygen World			1
	Ridelectric LLC			

HEAVY-DUTY HIGHWAY ALTERNATIVE FUEL DATA

Figure 59 presents the OEM heavy-duty highway engines that were certified to operate on alternative fuels in model years 2009 - 2011.

Figure 59
MY 2009-2011 Heavy-Duty Highway Engine OEM Alternative Fuel Engine Families by Manufacturer

Fuel	Manufacturer	Number of Engine Families		
		MY 2009	MY 2010	MY 2011
CNG	Cummins Inc.	4	3	3
	Doosan Infracore, Co	2	2	2
CNG/Diesel	Westport Fuel Systems	1	1	1
LPG	Cummins Inc.	1	-	-

HEAVY-DUTY HIGHWAY ALTERNATIVE FUEL CONVERSION DATA

Figure 60 presents the heavy-duty highway alternative fuel conversion certificates issued in model years 2009 - 2011.[37]

Figure 60
MY 2009-2011 Heavy-Duty Highway Engine Alternative Fuel Conversion Certificates by Manufacturer

Fuel	Manufacturer	Number of Certificates		
		MY 2009	MY 2010	MY 2011
CNG	BAF Technologies	1	2	2
	Baytech Corporation	3	3	4

[36] EPA began issuing certificates for battery electric highway motorcycles in MY 2009.
[37] MY 2009-2011 conversion certificates may be issued for conversion of either current or earlier model year OEM highway engines.

	Emission Solutions, Inc.	-	1	1
	Evotek, LLC			5
	Greenkraft Inc			1
CNG/Gasoline	Baytech Corporation	3	1	2
LPG	American Alternative Fuel			4
	Baytech Corporation	2	1	2
	Bi-Phase Technologies, LLC	1	-	3
	Clean Fuel USA Inc.	1	4	1
	Roush			8
LPG/Gasoline	Icom North America LLC	-	1	1

NONROAD COMPRESSION IGNITION ALTERNATIVE FUEL DATA

There were no MY 2009 - 2011 certificates issued for nonroad compression ignition engines that operate on alternative fuels.

NONROAD SPARK IGNITION ALTERNATIVE FUEL AND FUEL CONVERSION DATA

There are numerous engine manufacturers that certify nonroad spark ignition engines to run on alternative fuels, in both Small SI and Large SI categories.[38] About 10 percent of Small SI engine families in MY 2009 - 2011 were certified to operate on alternative fuels. The majority of Large SI engine families are certified to operate on alternative fuels. In MY 2009 of the 89 Large SI engine families, 77 were certified to operate on one or more alternative fuels. In MY 2010, of the 124 Large SI engines families, 91 were certified to operate on one or more alternative fuels. In MY 2011, of the 140 Large SI engines families, 123 were certified to operate on one or more alternative fuels. Figures 61 and 62 summarize information about MY 2009 - 2011 Small SI and Large SI alternative fuel engine families.

Figure 61
MY 2009-2011 Small Spark Ignition Engine OEM Alternative Fuel Engine Families

Fuel	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
E85-Gasoline	2	1	-
Natural Gas/CNG	21	17	15
Natural Gas/CNG / Propane/LPG	28	22	16
Propane/LPG	63	46	42
Propane/LPG / Gasoline	6	5	9
Natural Gas/CNG / Propane/LPG / Gasoline			1

[38] No marine SI engines were certified to operate on alternative fuels in either MY 2009 or 2010. One marine SI engine family was certified to operate on LPG in MY 2011.

Figure 62
MY 2009-2011 Large Spark Ignition Engine OEM Alternative Fuel Engine Families

Fuel	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Natural Gas/CNG	8	10	42
Natural Gas/CNG / Propane/LPG	5	17	23
Natural Gas/CNG / Propane/LPG/ Gasoline	4	7	7
Propane/LPG	20	34	34
Propane/LPG / Gasoline	40	23	27

RECREATIONAL VEHICLE ALTERNATIVE FUEL DATA

The majority of recreational vehicles are certified to operate on gasoline. However, there were two ATV engine families certified to operate on diesel in MY 2009, two in MY 2010 and one in MY 2011. Figure 63 shows a breakdown of diesel recreational vehicle manufacturers.

Figure 63
MY 2009-2011 Recreational Vehicle OEM Diesel Engine Families by Manufacturer

Fuel	Manufacturer	Number of Engine Families		
		MY 2009	MY 2010	MY 2011
Diesel	Tomcar USA Inc.	1	1	0
	Deere & Company	1	1	1

MANUFACTURER LOCATIONS

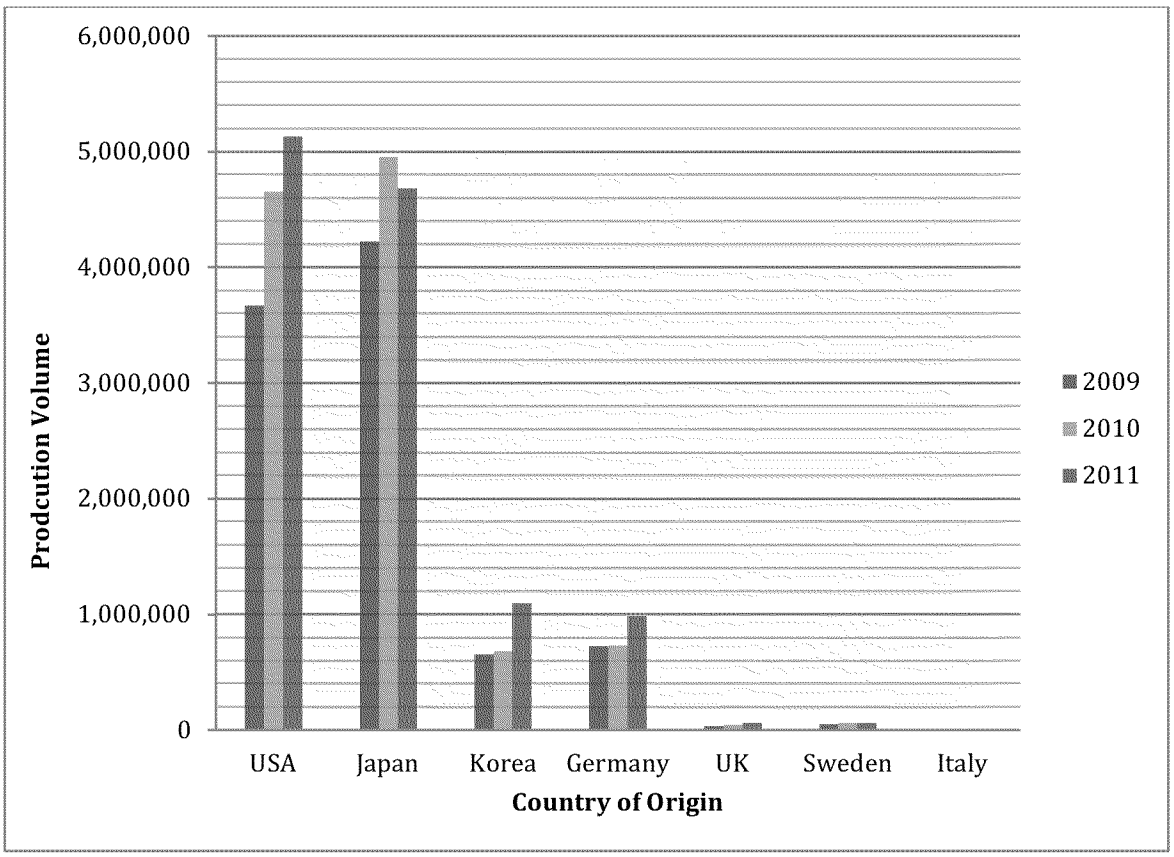
Consistent with past compliance reports, manufacturer locations here are attributed using two different approaches. For light-duty vehicles and locomotives, we report data based on where a manufacturer's headquarters are located, not necessarily where the vehicles are manufactured. For example, Toyota's corporate headquarters are in Japan, so all of Toyota's MY 2009 - 2011 vehicles produced for sale in the United States are presented with Japan listed as the country of origin, even though some Toyota vehicles are built in the United States. For all other sectors, EPA generally reports manufacturer location based on the actual location in which the vehicle or engine was manufactured.

LIGHT-DUTY VEHICLE MANUFACTURER LOCATIONS

Figure 64 presents the country of origin of MY 2009 - 2011 light-duty vehicles produced for sale in the United States.[39]

[39] These production data only include vehicles subject to Corporate Average Fuel Economy standards. Pickup trucks greater than 8,500 pounds Gross Vehicle Weight are not included.

Figure 64
MY 2009-2011 Light-Duty Vehicle Production Volume by Manufacturer's Country of Origin



HIGHWAY MOTORCYCLE MANUFACTURER LOCATIONS

In MY 2009 - 2011, Chinese, Japanese, and Taiwanese manufacturers produced a large fraction of Class Ia and Ib highway motorcycles sold in the United States while American, Japanese and European manufacturers produced the largest share of U.S. Class III highway motorcycles.

HEAVY-DUTY HIGHWAY MANUFACTURER LOCATIONS

Figure 65 presents the number of highway engine families (both compression ignition and spark ignition engine families) that were certified for sale in the United States by engine manufacturing plant location.

Figure 65
MY 2009-2011 Heavy-Duty Highway CI and SI Engines by Manufacturing Location

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
USA	77	39	79
Japan	12	5	5
Germany	3	2	2
Brazil	3	1	1
Canada	1	0	0

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
The Netherlands	1	0	0
Italy	0	0	2
Multiple countries[40]	3	5	3
Total	**100**	**52**	**92**

NONROAD COMPRESSION IGNITION MANUFACTURER LOCATIONS

Figures 66 - 68 present the number of engine families intended for use in marine diesel (both EPA and IMO certificates), locomotive, and construction/agricultural equipment applications that were certified for sale in the United States by engine manufacturing plant location or country of origin.

Figure 66 - MY 2009-2011 Marine Diesel Engine Families by Manufacturing Location

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
USA	86	86	107
Japan	20	20	27
Italy	17	17	19
Sweden	12	20	16
United Kingdom	11	13	18
Korea	10	3	5
The Netherlands	8	8	10
Germany	6	10	15
France	5	10	6
Mexico	4	0	1
Canada	0	0	4
Norway	2	0	0
Finland	1	1	0
Austria	1	1	1
Multiple Countries	16	17	30
Total	**199**	**206**	**259**

Figure 67 - MY 2009-2011 Locomotive Engine Families by Country of Origin

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
USA	70	43	43
Multiple countries	2	4	

[40] "Multiple countries" means that engines within an engine family are manufactured in more than one country.

Figure 68
MY 2009-2011 Construction and Agricultural Engine Families by Manufacturing Location

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Japan	193	195	179
Germany	83	83	75
China	60	65	43
Italy	46	49	50
England	47	47	32
USA	43	47	21
Korea	31	36	27
India	23	25	22
Mexico	8	7	8
Sweden	8	2	9
Switzerland	7	11	3
France	8	7	2
Czech Republic	2	2	2
Austria	1	1	-
Brazil	1	1	-
Belgium	0	0	-
Slovakia	-	4	4
Multiple countries	50	59	43
Total[41]	**611**	**641**	**520**

NONROAD SPARK IGNITION MANUFACTURER LOCATIONS

Figures 69 - 71 present the number of Small SI, Marine SI and Large SI engine families that were certified for sale in the United States by engine manufacturing plant location.

Figure 69 - MY 2009-2011 Small Spark Ignition Engine Families by Manufacturing Location

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
China	542	467	442
USA	308	264	198
Japan	158	153	134
Germany	43	37	12
Sweden	37	31	34
Italy	22	18	8
Mexico	16	20	16
Thailand	6	7	2
Brazil	6	4	60
Taiwan	2	1	-
Czech Republic	1	1	1

[41] This figure does not include stationary -only engine families.

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Multiple countries	19	17	78
Total	**1,160**	**1,020**	**985**

Figure 70 - MY 2009-2011 Marine Spark Ignition Engine Families by Manufacturing Location

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
Japan	64	52	52
USA	37	44	52
China	10	12	13
France	5	-	-
Thailand	4	5	5
Canada	2	4	2
Germany	2	-	-
Total	**124**	**117**	**124**

Figure 71 - MY 2009-2011 Large Spark Ignition Engine Families by Manufacturing Location

Country	Number of Engine Families		
	MY 2009	MY 2010	MY 2011
USA	59	95	113
Korea	17	10	7
Canada	4	6	9
Germany	2	6	5
Japan	1	2	2
Mexico	1	1	1
Austria	1	1	1
China	-	1	-
Multiple countries	4	2	2
Total	**89**	**124**	**140**

United States
Environmental Protection
Agency

EPA-420-R-13-006

A Historical Review of U.S. Vehicle Emission Compliance Program, and Emission Recall Cases

Authors: Hui He, Lingzhi Jin

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Acronyms

A/C	Advisory circular
AECD	Auxiliary emission control device
CAA	Clean Air Act
CAFÉ	Corporate average fuel economy
CAP	Compliance assurance program
CARB	California Air Resources Board
CFR	Code of federal regulations
CO	Carbon monoxide
COC	Certificate of conformity
DEF	Diesel exhaust fluid
DOJ	Department of Justice
ECM	Electronic control module
EDV	Emissions data vehicles
EPA	US Environmental Protection Agency
FEDV	Fuel economy data vehicles
FTP	Federal test procedure
HDDE	Heavy-duty diesel engine
HDV	Heavy-duty vehicle
I/M	Inspection and maintenance program
IUCP	In-use confirmatory program
IUVP	In-use verification program
LDV	Light-duty vehicle
MIL	Malfunction indicator lamp
MY	Model year
NAAQS	National ambient air quality standards
NOx	Nitrogen oxides
NTE	Not-to-exceed standard
OBD	On-board diagnostics
OECA	Office of Enforcement and Compliance Assurance
OEM	Original equipment manufacturer
OTAQ	Office of Transportation and Air Quality
OTL	OBD threshold limit
PEMS	Portable emissions measurement system
SEA	Selective enforcement audit
SEP	Supplemental environmental projects
SFTP	Supplemental federal test procedure

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Executive Summary

Emission recalls are a critical component of vehicle emission compliance and enforcement programs. An emission recall refers to a repair, adjustment or modification program conducted by a manufacturer to remedy an emission-related problem. An emissions recall, especially mandatory recalls, can be quite costly to a manufacturer. A typical recall can cost millions of dollars plus reputational damage to the automakers; and therefore can create a huge deterrent to manufacturers for emissions violations. To avoid recalls, manufacturers are motivated to produce more reliable emission controls that not only pass emission certification testing, but also remain functional during actual use of vehicles.

Over the decades since the Clean Air Act (CAA) was initially enacted, regulators from the U.S. Environmental Protection Agency (EPA) and California Air Resources Board (CARB) have developed comprehensive and rigorous compliance and recall programs. These include a number of subprograms to detect and verify emission violations.

However, many emerging markets still don't have any robust emission compliance programs in place even though the corresponding standards have been enforced for years. Some markets have a partial program (a program composed of certain elements in the U.S.'s compliance program), but face difficulty given limitations in resources to pursue a more comprehensive one. Most of these governments may not have adequate data sources to identify the issues either.

This paper aims at providing useful information for governments that are at the beginning or early stages in pursuing an effective emission compliance program in their regions. Specifically, the paper provides a comprehensive historical review of how the U.S. vehicle emission compliance program has evolved over the past four decades, reviews trends of emission recall in the U.S., spotlights a few representative vehicle and engine emission recall cases and settlements, and provides insights into the data sources needed to inform a successful recall program.

Figure ES-1 illustrates a timeline of evolution of the U.S vehicle emission compliance and control program, summarizing key characteristics of each era.

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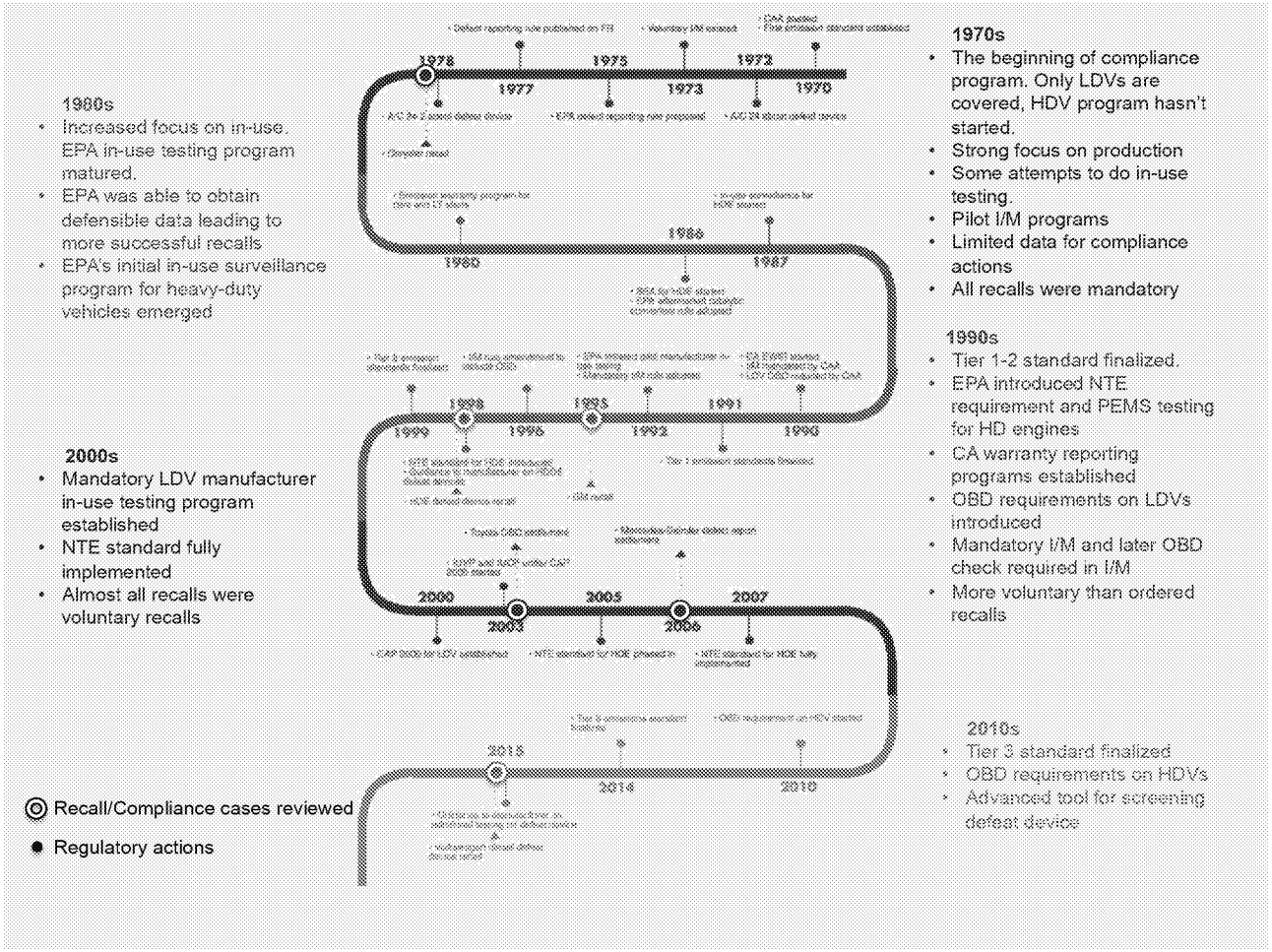

Figure ES-1 Evolution of U.S. vehicle emission compliance and control program

Table ES-1 highlights six noteworthy emissions recall and enforcement cases in the U.S. compliance program's history that are reviewed in this paper. The timing of each case is also shown on the U.S. compliance program timeline in Figure ES-1. The primary focus when reviewing these cases was the data source used to discover each of the issues and lessons. The cases offer rich lessons to regulators with less experience in carrying out recalls.

Table ES-1 Summary of recall and enforcement cases reviewed

YEAR	CASE	DISCOVERY	LESSONS
1978	Chrysler recall	I/M[a] data	• In-use performance of aftertreatment systems can be very different from their prototype design, thus it is an important element of a robust in-use compliance program. • Careful documentation throughout the entire compliance testing and investigation process and allowing manufacturers to oversee the process are the key to a successful recall. • I/M data is useful in identifying certain in-use noncompliance issues.
1995	General Motors defeat device recall	EPA research-oriented testing	• In-use testing under real-world driving conditions is important. • Defeat devices could also appear on gasoline engines.
1998	HDDE[b] defeat device recall	EPA research-oriented testing	• During the early stages of regulations, there might be undefined areas, and agencies should seek to clarify the interpretation of regulations as new technologies/testing tools emerge. • The authority to approve a Certificate of Conformity gave the agencies concrete leverage to enforce emission standards.
2003	Toyota OBD settlement	Certification and in-use testing	• Noncompliance can be flagged at the certification stage with appropriate follow up in-use testing for verification. • Feedback from in-use testing program should be used to inform and improve future regulations, acknowledging a learning curve for regulatory agencies.
2006	Mercedes-Daimler defect report settlement	EPA investigation	• Defect reporting is an important data source for identifying noncompliance. • More recently, EPA became diligent in recording data and reporting.
2015	Volkswagen diesel defeat device recall	Independent real-world testing projects	• Modern defeat devices are much more complicated than they were decades ago and require innovative testing approaches to detect them. • Independent research projects can be a good source of data to flag

noncompliance.

[a] I/M: Inspection and maintenance programs
[b] HDDE: Heavy-duty diesel engine

Based on an extensive review of the history of the U.S. vehicle emission compliance program, trends of past vehicle emission recall data and cases, the following findings and general recommendations are for countries and regions that have just began their journey in establishing a robust vehicle emission compliance program.

Findings

- Strong and clear legal authority is the foundation for EPA's and CARB's robust vehicle emission compliance programs, in addition to their clear missions to protect public health and the environment. Each agency has clear authority to establish a test protocol for in-use compliance testing, require manufacturers to conduct tests, provide warranty and defect data to the agencies, and most importantly, the authority to revoke certificate of conformity, recall, and impose punitive fines on non-compliant vehicles. Withholding of the Certificate of Conformity, an approval to sell vehicles in the U.S., is a powerful tool for regulatory agencies to negotiate with manufacturers on compliance actions.
- The comprehensive vehicle emission compliance program adopted in the U.S. was built up over several decades. The process has involved a learning curve for both regulators and industry. In the early 1970s and 80s, there were many contentious cases that ended up in court. Overtime, the agencies have proven successful in working with the manufacturers to do voluntary recalls. Since the 1990s, most cases have been noncontentious and were done so on a voluntary basis. This shift is a positive sign that the requirements and enforcement criteria are detailed and clear, making it in the manufacturers best interest to do the right thing by following the regulation to avoid mandatory recalls.
- Building a strong team and continuously expanding staff capacity is another key to a successful emission compliance program. Both EPA and CARB were able to build up their programs with top experts hired from the industry. It takes time and resources to establish and maintain technical expertise overtime as new technologies emerge. As one former ARB Officer noted,

  > *"What ARB has done in the past 30 some years is carefully screen the staff, and we have some of the best… The OBD program is one of the most difficult to get up to speed on because you need to understand all of the software in terms of how the vehicle operates, and how the emission control works. It takes probably 4 to 5 years working with the staff, involving them in lab, in-use testing, reviewing certification and applications that manufacturers submit before production, (to get them familiar with the process)."*

- In the U.S., compliance is a shared burden between regulatory agencies and manufacturers. The current compliance program has a strong focus on manufacturer responsibility in ensuring their vehicles/engines meet the standards throughout the vehicle's lifetime, by requiring manufacturers to conduct large scale in-use testing, reporting warranty data and defects, and conducting voluntary recalls. This allows the regulatory agencies to play more of a supervisory role and focus their limited resources on the most critical issues.
- In the U.S., regulatory agencies perform rigorous in-use confirmatory testing, and these tests are the most direct source of data to consider a recall. It's also important that the agencies have their own testing facilities. In addition, the agencies have a number of indirect data sources to further guide the recall tests. These include, but are not limited to: 1) certification data, which can be useful in

several ways, for example, to target vehicles with small compliance margin and vehicles deployed with new technologies; 2) information (including OBD information) from state I/M programs; 3) manufacturer warranty data and defect reports; 4) failures at manufacturer-run in-use verification program (IUVP) testing; 5) complaints from consumers, service providers, independent research projects involving real-world emissions testing.

- A full-scale in-use testing program could be quite expensive, as the agencies usually need to recruit a sufficient amount of vehicles from consumers and pay for additional substitute vehicles, maintenance and provide compensation to the vehicle owners. In the early stages, the U.S. regulatory agencies had insufficient resources to run full-scale in-use testing. CARB began its in-use program by using the government fleet as test vehicles. Even with a limited scope, CARB's initial in-use testing program was very successful in identifying issues like OBD failures.
- Rigorous documentation of the compliance tests conducted by regulatory agencies, and engaging manufacturers in these tests are extremely instrumental steps to implementing a successful recall. In the early years of a compliance program, regulatory agencies encountered situations where manufacturers could easily discredit their data. The agencies had a learning curve and established protocols to obtain defensible data to provide in court.
- A feedback loop for certification test procedures based on learning from in-use compliance testing is important. Emission type approval certification is the cornerstone and starting point of a compliance program. However, there are still limitations associated with test protocols and methods of certification tests. In-use compliance testing can offer lots of useful data to close the loopholes in current certification procedures. This has been evidenced in several examples reviewed, including the enhanced OBD program introduced after the Toyota OBD case in 2003, the improved portable emissions measurement system (PEMS)-based test procedures for heavy-duty vehicles and engines after the 1998 heavy-duty engine defeat device case, and the development of supplemental federal test procedure (SFTP) after the General Motors defeat device case in 1995. Regulators need to revisit their certification procedures and approaches to best reflect emissions characteristics during real world driving.

Recommendations

Building upon the findings, we recommend the following best practices and key elements to build a successful vehicle emissions compliance and recall program:

- Governments should seek to establish strong and clear authority through legislation for environmental regulatory agencies to establish, implement, and enforce emissions standards, including clear authority to levy fines and recalls.
- Governments should establish requirements in the appropriate legislation for emission warranty provisions and for vehicles and engines to meet emissions standards throughout their entire "useful life," which is the time span throughout which the emissions performance of a vehicle must comply with the prescribed standards. For example, the current definition of useful life in the U.S. Tier 3 emissions standard for light-duty vehicles is 150,000 miles.
- Once legal authority is established, agencies must recognize and implement their authority. They should impose penalties on vehicle manufacturers that deter from non-compliance. Regulatory agencies should use their power to void new vehicle/engine emission type approval certificates.

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- Build internal technical capacity within environmental regulatory agencies to conduct compliance testing and manage recall programs. Get the best experts in the field, including experienced technicians to carry out the lab work.
- A compliance program needs to be run by government resources that are not influenced by industry. A regulatory agency must have sustainable funding support for running and maintaining the compliance program. Some ways to deal with limited resources at the beginning of a program are:
    - Starting the program with robust certification testing and production (assembly line) conformity testing if staff capacity is limited at the beginning. Once regulatory agencies gain sufficient confidence into these two stages, then in-use becomes more important.
    - At the beginning of an in-use program consider starting in-use testing with government and public fleets.
    - Give manufacturers some flexibility when introducing new programs to leverage manufacturer resources for the new elements. After a pilot stage to prove their effectiveness, transition the programs into full-scale.
- Create a program that shares the compliance burden among the governments (central and local), industry and vehicle owners. Establish sub-programs to require the industry to provide compliance related data. Policy makers could investigate whether and how these programs may be adopted in their regional context.
    - Require manufacturers to conduct large-scale in-use testing, with sufficient government confirmatory testing to ensure accurate results. This data can inform deterioration calculations for certification.
    - Require an emission warranty program.
    - Require manufacturers, dealers, and the service industry to provide emission warranty and defect data.
    - Require manufacturers to recall their vehicles if feedback from the above sub-programs indicates an emissions violation.
    - Establish credible I/M program and other emission inspection programs such as remote sensing programs at local levels to make sure emissions components are not tampered with by users. Integrate OBD in I/M programs to increase test accuracy and credibility.
- Establish test protocols to detect defeat devices. This includes, but is not limited to, using a combination of methods such as PEMS-based real-world driving tests, OBD examination, modified driving test cycles and test procedures for laboratory tests.
- Consider testing projects from independent third parties/research entities as a data source to trigger government investigation provided that the test results have credible basis for concern.
- Establish protocols for documenting vehicle selection, testing and data collection processes, in order to obtain defensible data for recalls. Consider engaging manufacturers in some of the processes. It is crucial to define "proper maintenance" and make sure the test vehicles used for compliance actions are well maintained for the kind of emission problem in question.
- Use the feedback from in-use compliance programs to improve the new emission standards and certification procedures. As vehicle and emission control

technologies advance and emission regulations become increasingly complicated, there might be further undefined areas. As regulatory agencies learn about these areas, and if there is potential for undercutting the purpose of the regulations, the agencies should try to better define these areas by spelling out specifically what they intended or clarify the interpretation.

1 Introduction

Major auto markets around the world are adopting more stringent vehicle emission regulations that require lower exhaust and evaporative emission limits. A key question is whether the vehicles pollute less not only when new, but also throughout their entire useful life. Unfortunately, a substantial amount of evidences has shown that vehicles emit much higher emissions on road than when they are tested in the laboratories (Franco, German, Posada, & Mock, 2014)

Several factors may lead to increased in-use vehicle emission levels compared to when they were built. For example, emission controls deteriorate over time. Some extreme real world driving conditions that put an excessive burden on the vehicle emission control systems are not captured in the initial design of these systems. Other more sophisticated reasons include using emission defeat devices to bypass/cheat against the regulations. In other cases, poorly designed certification tests can lead to high in-use emissions as well.

Therefore, it is critical to have an effective compliance program in order to assure that the environmental and health benefits of vehicle emission standards are truly and fully achieved. A compliance program also helps to assure fairness in responsibilities by shifting costs of defective or deteriorated emission control from car owners to the manufacturers, if a vehicle fails to comply at in-use.

Emission recalls are a critical component in the vehicle emission compliance and enforcement programs. An emission recall refers to a repair, adjustment or modification program conducted by a manufacturer to remedy an emission-related problem. Emissions recall, especially mandatory recalls, can be quite costly to a manufacturer. A typical recall can cost millions of dollars plus the additional loss of reputation to the automaker, and therefore can create a huge deterrent to manufacturers for emission violations. Generally, the penalties for noncompliance, including the cost for Supplemental Environmental Projects, are higher than the cost to comply. To avoid recalls, manufacturers are motivated to build more reliable emission controls that not only pass emission certification testing, but remain functioning during actual use of vehicles.

Over the decades since the U.S. Clean Air Act (CAA) was enacted, regulators from the U.S. Environmental Protection Agency (EPA) and the California Air Resources Board (CARB) have developed comprehensive and rigorous compliance and recall programs. These include a number of subprograms to detect and verify emissions violations.

However, many emerging markets do not have similar robust emission compliance programs in place, even though standards have been introduced for years. Some of the markets have a partial program (a program composed of a subset of the elements in the U.S. compliance program), but face difficulty and limitations in resources to pursue a complete one. Most of these governments may not have adequate data sources to properly identify the issues.

This paper aims to provide useful information for governments at the beginning or in the early stages of pursuing an effective emission compliance program in their respective regions. This paper focuses on direct/primary emission compliance

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issues.[1] The paper takes a closer look at the vehicle emission compliance and enforcement programs adopted by EPA and California, focusing on emission recall. In fact, the International Council on Clean Transportation (ICCT) has produced a few relevant papers that highlight various elements of the U.S. vehicle emission control and compliance program (Fung, He, Sharpe, Kamakate, & Blumberg, 2011; Maxwell & He, 2012; Bansal, 2013; Bansal & Bandivadekar, 2013; Wagner & Rutherford, 2013). This paper is a major addition to these previous efforts and features:

- A detailed review of the evolution of the U.S. compliance program since its inception in the early 1970s to present,
- Reviews the general trend in emission compliance and recalls in the U.S. and California,
- Reviews historic vehicle and engine recall cases in the U.S. that provides important lessons to regulators around the world, and
- Provides a detailed explanation of various data sources that lead to emission recalls.

Data sources for review and analysis were from publications and publicly available data from EPA and CARB. We've also obtained additional details and information regarding previous recall cases via direct communication and interviews with former or existing regulators with agencies, official case settlements, and news articles.

The paper is organized as follows: Section 2 describes the legal authority for the U.S. vehicle emission compliance program, Section 3 illustrates the evolution of the U.S. compliance program, Section 4 provides a historical review of past vehicle emissions recalls in the U.S., Section 5 discusses six specific recall and enforcement cases, Section 6 lists useful data sources for identifying in-use noncompliance, Section 7 discusses post-recall actions, and Section 8 highlights overall findings and recommendations to consider when designing future compliance programs.

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[1] Not considering secondary compliance issues such as coastdown confirmatory testing, how to include optional equipment in calculation of test weight, manual transmissions shift schedules, drive-selectable devices, and setting dynamometer load coefficients.

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2 Legal authority for the U.S. compliance program

The U.S. has established one of the world's most comprehensive and robust vehicle/engine emission compliance programs. This was made possible with clear and strong authority given to these regulatory agencies through the Clean Air Act and its amendments. In general, the CAA authorizes EPA to set standards for vehicles, engines and fuels that apply to the useful life of the product, create test procedures and protocols to evaluate actual performance against the standards, issue certificates and register fuels prior to their introduction into the market, and enforce for perceived noncompliance. This section describes each of the provisions regarding the authority outlined above.

The CAA authorizes EPA to establish ambient air quality emissions standards for new vehicles and engines and issue a Certificate of Conformity (COC) for all new vehicle models and engines that are certified as meeting relevant emissions standards. New vehicles and engines, either domestically produced or imported, without a COC cannot be sold in the U.S. market (Section 203 a(1)). Manufacturers or importers attempting to sell vehicles lacking a certificate face fines of up to $25,000 per vehicle and additional penalties (Section 205 a).

The concept of full useful life compliance is a bedrock principle of the U.S. Clean Air Act. The specific language on useful life is found in the second sentence of the CAA's section (202) on motor vehicles, as follows: ". . . Such standards shall be applicable to such vehicles and engines for their full useful life . . ."

Overtime, both U.S. Congress and EPA have steadily increased the length of time and number of miles included in the definition of "full useful life." The original U.S. Clean Air Act of 1970 defined "useful life" as only 5 years or 50,000 miles. This was only half of the lifespan of a typical vehicle. Manufacturers had no obligation to build emission controls to last beyond this truncated period. Amendments to the CAA in 1990 revised section 202(d) to extend the definition of useful life to ten years or 100,000 miles for passenger cars, whichever came first. And, in Tier 3 regulations that will apply to U.S. automakers starting with MY2017, the EPA recently raised the definition of useful life to 150,000 miles for passenger cars. As a result of this "full useful life" requirement, new vehicles are typically certified in the U.S. at one-third to one-half of the emissions limit in order to ensure compliance over full useful life as emission controls degrade over time (EPA compliance report, 2013).

The CAA includes several provisions to fully define the shared burden between the government and industry on emission compliance. Section 206 requires EPA to test new motor vehicles and engines to determine conformity with emission standards, or to require the manufacturer to conduct such tests and provide such information.

Section 207 requires automakers to warrant certain emission control components on their vehicles and engines. Within the warranty period, manufacturers bear the cost burden of replacement or repairing the failed components warranted. The provision protects vehicle owners from the cost of repairs for emission-related failures that cause the vehicle or engine to exceed emission standards. The provision also requires manufacturers to monitor for known defects in emission control systems, and submit reports to EPA if a substantial number of same defects appear within the same model year.

Under the same section (Section 207 (c)(1)), if EPA determines that a substantial number of vehicles or engines in a certain category or class do not meet emission

standards during actual use, even though they are properly maintained and used, EPA can require the manufacturer to recall and fix the affected vehicles and engines.

Civil penalties vary by type of violation. For example, for defeat device, the Code of Federal Regulations (CFR) specifies that anyone 'knowingly manufacture, sell, offer to sell, or install, any part that bypasses, impairs, defeats, or disables the control of emissions any regulated pollutant, except as explicitly allowed by the standard-setting part' may be subject to a civil penalty up to $3,750 for each part in violation. Manufacturers are also required to meet their obligations to honor emission-related warranties, fulfill requirements related to defects and recalls, and provide emission-related installation and maintenance instructions. Otherwise, they can receive a civil penalty up to $37,500 for each engine or piece of equipment in violation (40 CFR §1068.101). To determine the amount of a civil penalty, multiple factors will be considered including the seriousness of the violation, how much the manufacturer benefited or saved, its history of compliance, remedial plan, etc.(40 CFR §1068.125).

Section 208 (Information Collection) creates an affirmative obligation on the part of the manufacturer to establish and maintain records, perform tests, generate reports and provide any additional information to the Administrator.

Section 203 of the CAA enumerates specific prohibitions, including i) prohibition against the sale and introduction into commerce of a new vehicle or engine unless covered by a Certificate of Conformity, ii) prohibition against tampering, i.e. removing or rendering inoperative any device or element of design, iii) prohibition against the manufacture or sale of a defeat device, and iv) prohibition against failure to perform required tests, or provide required records.

3 Evolution of the U.S. Compliance Program

Even with a solid baseline of legal authority, it took U.S. and California regulators a long time to establish this comprehensive, world-class vehicle and engine emission compliance system. Figures 1 and 2 illustrate various elements of EPA's current compliance and enforcement programs for light-duty vehicles, and heavy-duty vehicles/off-road engines, respectively, on the scale of vehicle/engine useful life.

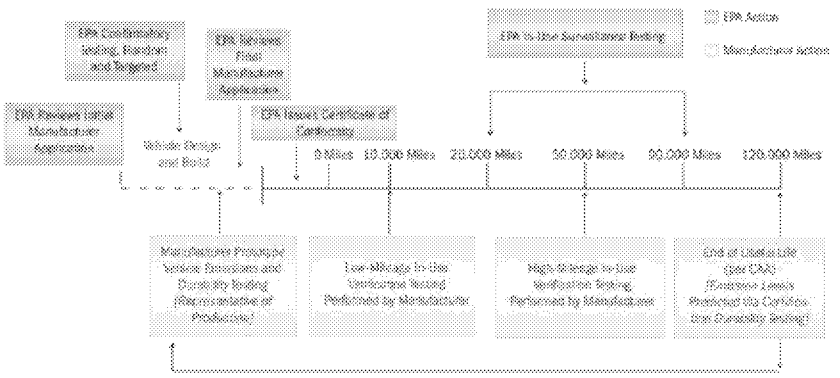

Figure [SEQ Figure * ARABIC]. EPA compliance program for light-duty vehicles (LDVs)

Source: EPA, 2012-2013 Progress report. 2015

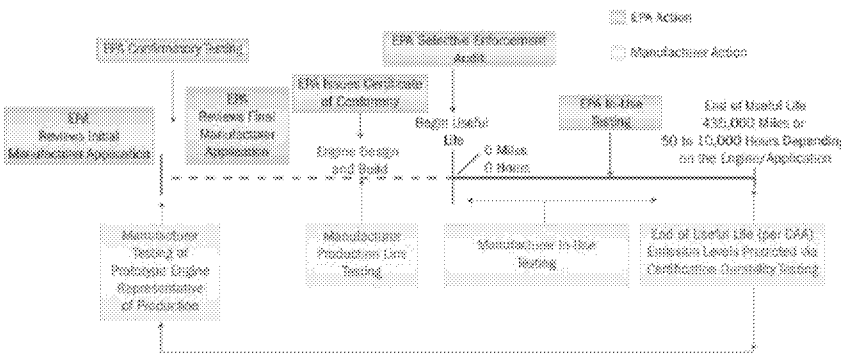

Figure [SEQ Figure * ARABIC]. EPA compliance program for heavy-duty vehicles (HDVs) and off-road engines

Source: EPA, 2012-2013 Progress report. 2015

Today, the U.S. compliance program covers actions by both manufacturers and regulatory agencies at pre-production, production, and post-production stages.

Manufacturers are required to conduct a substantial number of tests covering the majority of vehicle model types sold in the market. Regulatory agencies can therefore leverage their limited resources by focusing on the most "suspicious" vehicles for emission violations. Even though both figures show dense activities before vehicle/engine production (action boxes above or below the dotted line), in practice, EPA is now investing the majority of its resources in post-production/in-use actions. This is a major shift and shows progress from when the program was first established in early 1970s.

However, carrying out the program has never been smooth sailing. There was a time in the history that the EPA and CARB, both with limited resources and staff capacity, struggled with manufacturers over severe emission violation cases. Very often, they had to resort to court to get the contentious cases fairly settled. Over more than three decades, the agencies enhanced their capacity, reorganized internal institutions in order to streamline enforcement actions, filled the gaps in existing laws and regulations, and secured sustainable funding sources to maintain the continuous efforts to ensure emission reduction. As a result, there are now less court ordered recalls. Today, they are among the most powerful and effective regulatory bodies of mobile source emissions control around the world.

This section provides a detailed review of the growth paths of the U.S. vehicle emissions compliance program roughly by decade, which can be valuable to other parts of the world that have the desire or are on the way to establishing a similarly powerful system.

*An Advisory Circular is a semi-formal document produced by EPA to communicate with and provide

1970s

Features the beginning of a vehicle emission compliance program in the U.S., in the context of passing the Clean Air Act. In the initial stages of the program, only light-duty vehicles are covered, a heavy-duty vehicle program hasn't started. The program has a strong focus on production, with only limited attempts to do in-use testing. Data for determining compliance actions are also limited. In-use testing programs are only performed by the agencies. The majority of emission recalls were ordered. Inspection and Maintenance pilot programs emerged in a few states. EPA issued the first advisory circular for defeat device.

guidance to the industry, often regarding how to comply with a regulation pertaining to emission control systems.

In 1970, Congress passed the Clean Air Act, the first major U.S. clean air law, requiring a 90 percent reduction in emissions from new automobiles by 1975 and also established the EPA, assigning it the broad responsibility of regulating motor vehicle pollution and the appropriate authorities to enforce and ensure compliance including emission recall. Through the establishment of the CAA, EPA became key to the success of today's U.S. vehicle emission compliance program. The EPA is an agency with a clear mission – in many other countries the regulations are not enforced by an agency with such a mission. In the 1970s, several major components of compliance activities were developed as regulations, including the Certificate of Conformity regulation, Selective Enforcement Audit regulation, defect reporting regulation, and recall regulation.

The earliest phase of EPA's vehicle emission compliance program contained the following major components:

- Pre-production audit and testing was the earliest compliance program. The pre-production certification review program was initiated in 1968 (EPA progress report, 1985). In order to sell vehicles in the U.S., manufacturers need to obtain the Certificate of Conformity from the EPA. Manufacturers would do certification testing for all new vehicle test groups and submit applications to the EPA. Upon reviewing the manufacturer's certification application, EPA may target vehicle class for confirmatory testing of prototypes at EPA's Ann Arbor laboratory. EPA also conducted periodic audits of manufacturing facilities in order to ensure that certification procedures are observed. From 1973-1974, for example, EPA conducted 24 detailed inspections of domestic and foreign facilities (EPA progress report, 1974).
- Production line testing was also part of the first efforts in the compliance program's history. There are two types of production testing:
    - The first requires manufacturers to routinely test engines as they leave the assembly line to show new engines were built like certification engines. In the 1970s, California required 2% of manufacturer vehicle/engines to be tested.
    - The other test is a Selective Enforcement Audit (SEA) for light-duty vehicles. EPA engineers arrive at the manufacturer's assembly plant without prior notice and require the manufacturer to select and test a sample of new vehicles subject to EPA selection. If a manufacturer fails the audit, it must stop production within 10 days (to find and fix the problem), perform a passing SEA and recall all cars produced and affected. When SEA testing began, audits of new vehicles occasionally failed. To avoid failing, manufacturers would voluntarily test thousands of new cars a year to detect any emission problems before EPA does. By 2000, both light- and heavy-duty engine audits rarely failed. EPA stopped SEA except in cases of possible fraud.
- A few initial efforts were made to test and audit in-use vehicles, including a few programs.
    - Spot check and investigation into in-use fleet, or called anti-tampering program. In 1973, EPA undertook a survey in Washington D.C. and found components of emission control systems had been removed in 15 percent of the vehicles surveyed. EPA later referred five cases to the Justice Department in violation of the CAA's anti-tampering provision.
    - A preliminary, yet ineffective, warranty program: the CAA requires manufactures to cover certain emission control parts under warranty. However, EPA discovered that consumers did not understand what was specifically covered by this warranty and therefore few claims were submitted. Before 1975, EPA also lacked a way to monitor manufacturer's efforts to fix the vehicles under the warranty. In the early 90s, EPA developed a short, simple test, which reasonably correlates with the more sophisticated federal test procedures used on prototypes of new vehicles, and encouraged states to adopt it for in-use emission inspection and maintenance programs (I/M).
    - Aftermarket part program: voluntary self-certification for manufacturers of emission related automotive aftermarket parts to replace the broken parts.
    - A simple in-use testing program run by the agency consisting of screening surveillance testing and more rigorous confirmatory testing.

- EPA proposed the defect reporting rule in 1975 and it was published in the Federal Register in 1977. The rule applies to all vehicles and engines MY1972 and later.

- A recall program based on a regulatory agency's surveillance and investigation, defect reports from government and commercial fleets, and data obtained from state and local inspection/maintenance centers.
- A transportation control program, including a component of voluntary state vehicle emission I/M. The 1977 amendment to the CAA gave EPA authority to implement I/M. EPA considered I/M an important strategy for dealing directly with in-use emission problems. In the early stages, the state and local I/M programs were both voluntary.
- On December 11, 1972, EPA published Advisory Circular (A/C) 24, which provides guidelines for dealing with detected defeat devices. In the light of rapid advancements to a sophisticated emissions control system, and the generality of A/C 24, EPA released A/C 24-2 in 1978 to help manufacturers and their agency evaluate any questionable Auxiliary Emissions Control Devices (AECD).

There were two key characteristics of EPA's earliest phase of compliance actions (in the 1970s). First, the agency put the most effort into a certification program and confirms almost every test that the industry did for certification. As a tradeoff, less effort was put into post-market compliance actions.

Part of the reason for such a strong emphasis on certification was that in the early 1970s, the initial leadership of EPA's mobile source program came from an aircraft regulatory background with the philosophy of certification being the backbone of good compliance. This makes complete sense for the airplane industry, as every aircraft is handmade, and there is no difference between a prototype and a production one. However, this does not hold true for the auto industry where a prototype build for certification tests are handmade vehicles of high quality, whereas mass produced vehicles can be very different and seek cost savings to make a profit.

Admittedly, the certification program, facility audits, and the increasingly rigorous SEA program did play an important role in deterring fraudulent reporting of certification results and later compelled manufacturers to test new vehicles extensively at their own costs to ensure production conformity.

Secondly, the only in-use compliance testing was done by EPA itself. Manufacturer testing programs did not exist. EPA may hire contractors to do in-use testing, but it was done at the agency's expense. The agency tended to do have a first approach of what they called surveillance testing. EPA randomly picked test groups or engine families and procured in-use vehicles under more lax conditions for a general check. If they looked ok, the agency would do nothing further. If they indicated a problem, the agency would take that data to the manufacturer. However, since the data is loosely screened, the manufacturer would argue it was not enough to prove that the car was properly maintained, which wouldn't lead to a winning recall case.

Then the agency would move to a second phase called confirmatory in-use testing. For confirmatory testing, the agency would spend the money and resources to do rigorous screening to ensure that they are producing well-documented and well-maintained vehicles so that manufacturers could not argue about bad data. Even if the surveillance data were convincing, the agency would still go the extra mile to do the additional confirmatory testing.

It was not uncommon to identify problems in surveillance testing. As the in-use testing program matured and EPA staff became more skilled, the agency sometimes

did not need to conduct confirmatory testing, but simply showed manufacturers strong surveillance testing data and pointed out that even without screening for perfect maintenance conditions, the emission controls on the vehicles were clearly not working. Overtime, the agency was able to have more success in convincing manufacturers to recall without more rigorous efforts. In general, EPA's approach was very expensive given that they needed to rigidly screen every car for the exact

1980s

Throughout the 1980s, various programs were refined, expanded and enhanced. Increasing attention was focused on the problem of excessive emissions from in-use vehicles. In addition to the traditional focus on exhaust emissions, EPA began some small-scale efforts toward implementing light-duty evaporative emission standards. The agency-run in-use testing program matured, and the agencies were able to obtain defensible data leading to more successful recalls. EPA's initial in-use surveillance program for heavy-duty vehicles emerged.

maintenance to be quoted as officially properly maintained.

For production testing, in the late 1970s, EPA found that the light-duty vehicle SEA program encountered few failures, because on a voluntary basis auto manufacturers routinely tested many more vehicles than were strictly required through SEA orders. Therefore, beginning in 1981, EPA changed its SEA policy to place greater reliance on manufacturer testing programs and less on EPA-mandated audits. Even though the light-duty SEA program started in the early 1970s, it was not until 1986 that EPA conducted its first heavy-duty engine audit (EPA progress report, 1986).

The warranty program was published in the Federal Register in 1980 and was formally established covering cars and light duty trucks MY1981 and later. EPA responded to complaints and inquiries about warranty coverage and referred to the vehicle manufacturers for solutions. Around 1986, EPA developed a pamphlet outlining the performance warranty requirements that were distributed to state and local I/M programs.

Commented [RM1]: I notice a theme already in this document – I'm not sure the best way to phrase it, but EPA seems able to get the manufacturers to do things they don't want to do (and fight/lobby very hard against) – in many countries I am seeing that the manufacturers lobby is so strong and the government agency so weak that there is no way they could get the manufacturers to do a fraction of the things they comply with in the US. My general question is – how has the EPA managed to overcome the power of the automotive manufacturers lobby? Are there any key strategies? I think many things in this document address that, but maybe it could be pointed out explicitly somewhere.

Into the 1980s, EPA continued issuing the anti-tampering audits by conducting surveys. Survey results from the early 1980s indicate a significant fraction (17% in 1983, and 28% in 1984) of the vehicle fleet was subject to gross tampering. Federal efforts alone cannot effectively address these problems. In the meantime, EPA continued to promote the implementation of state and local anti-tampering enforcement programs. For example, in 1983, 6 local anti-tampering programs were set up as a result of this initiative (EPA progress report, 1983). Anti-tampering programs can be set up in a variety of ways, for example, it can be added as part of an existing I/M program, safety or other periodic inspection requirement, or a new requirement can be implemented, and various field enforcement efforts can also be used.

A critical element of state and local tampering inspections is the availability of replacement emission control components. In 1986, EPA adopted a policy regarding aftermarket catalytic converters that established test procedures, performance standards and installation requirements for aftermarket converters. The policy also contains reporting and record-keeping requirements to aid EPA in monitoring the appropriate use of aftermarket converters. EPA also brought enforcement actions

against two automobile dealerships for the aftermarket converter rule violations and proposed penalties of $120,000 (EPA progress report, 1987).

The recall program has traditionally focused on car exhaust emissions. When new categories of emission standards came into place, EPA began small-scale efforts toward implementing a light-duty evaporative emission recall program as well as light truck and heavy-duty exhaust emission recall programs. In 1987, EPA expanded its surveillance to heavy-duty engines by field surveys of in-use heavy-duty engine emission control systems.

Similarly to the situation in the 70s, all of the in-use tests were run by EPA. Throughout the 80s, EPA initiated about 30 recall investigations and conducted more than 600 in-use tests annually on average (EPA progress reports, 1983-1988).

In 1983, EPA issued a policy statement reaffirming its commitment to I/M as a vital component of pollution control plans in non-attainment areas and established the program in areas with air pollution problems, requiring passenger vehicles to undergo periodic testing for malfunctioning emission control systems. By the end of 1980s, more than 60 areas adopted the program. In order to ensure that I/M programs in operation actually achieve the planned emission reductions, EPA also initiated a systematic I/M auditing plan.

1990s

Tier 1 and Tier 2 emission standards for light-duty vehicles were both finalized in this decade. The in-use testing program began to include pilot manufacture-run in-use emission testing. In the wake of widespread defeat devices used on heavy diesel engines, the agencies introduced the Not-To-Exceed in-use standard paired with conditional real-world (PEMS) testing. California established a warranty report program. Regulators have more data sources to identify in-use noncompliance. The majority of recalls were on a voluntary basis. EPA mandated an OBD check in I/M program for light-duty vehicles.

The CAA included a durability requirement of 50,000 miles for LDVs, which was later extended to 100,000 miles. In the early stages, the test vehicle for each family was driven almost continuously around a test track at a constant speed, night and day, until it accumulated 50,000 miles. A mileage accumulation cycle contained a substantial portion of low speed driving to determine if engine deposits impact emissions. It was emission tested at 5,000-mile intervals and a regression line was extrapolated to predict 100,000-mile emissions. There was little driving operation that raised the catalyst temperature like high speeds/high loads since the cycle was developed before catalysts were included on vehicles.

However, the predicted 100,000-mile emissions were usually much lower than real world emissions from cars on the road. EPA was recalling over 30% of the cars made in the first 10-15 years of the compliance program, and a lot of them were due to deterioration and parts failure, which failed the durability requirements. In short, EPA learned that certification durability predictions were not accurate, expensive for manufacturers, and did not provide EPA with good data about 100,000-mile emissions. In order to develop and adopt more rigorous durability testing, EPA needed to give the manufacturers some flexibility in doing it.

In the mid-1990s, EPA and manufacturers revised the durability procedures and started a pilot program. This signaled the beginning of the initial manufacturer in-use verification program and the precursor for the Compliance Assurance Program 2000 (CAP 2000). With the CAP 2000 program, manufacturers have the flexibility to develop a process (to be approved by EPA) for determining deterioration factors in the certification and must follow-up with in-use testing by the manufacturers to prove that their process was accurate, instead of completely following the previous durability testing requirements. If problems were detected during the follow-up in-use testing, manufacturers would need to agree to recall those vehicles and also change the self-determined process for future certification.

That pilot program ran well enough for about six to eight years, at which point the EPA established a formal program for manufacturer in-use testing via a rule called CAP 2000 (EPA, 1999), which applied to light-duty vehicles of MY2001 and later. CAP 2000 is a compliance assurance program proposed by the EPA in 1998 to adopt revised emissions compliance procedures for new light-duty vehicles and light-duty trucks. These are called manufacturer in-use verification program (IUVP) and a follow up manufacturer in-use confirmatory program (IUCP) if significant failures are found from IUVP.

These programs significantly increased the amount of in-use emissions test data for EPA to determine further compliance actions, and therefore helped release the burden on EPA's budget and allow the agency to focus on the most suspicious issues with its limited resources. A lot of voluntary recalls occurred under these manufacturer-funded testing programs.

An important development in California was the establishment of a warranty data reporting program in 1990. Manufacturers are required to review unscreened warranty claims quarterly for each engine family or test group and compile the cumulative number of claims made on emission-related component. If the cumulative number represents at least one percent or twenty five (whichever is greater) of the vehicles or engines of a California-certified engine family or test group, the manufacturer will need to file an emission warranty information report in that same quarter. As a follow up, a manufacturer will need to file a field information report and emissions information report if the affected cars reach a certain level after the initial warranty information report on a quarterly basis. If the percentage or number of an emission-related component exceeds, the failure level set forth by the rule, the manufacturers will need to issue voluntary recalls.

In-use testing for heavy-duty engines started much later than the LDV program. And even later for off-road engine. In the beginning of implementing the heavy-duty engine emission standards in the late 1980s, EPA mainly audited manufacturer's certification data and performed engine confirmatory tests. EPA's initial actions for heavy-duty engine surveillance were very limited, and mainly involved surveys of emission control system performance of in-use vehicles. This is because the standards were set as engine-out emission standards. Traditional laboratory testing for heavy-duty and non-road engines over a specific test cycle requires the engine to be removed from the vehicle or equipment. This makes it prohibitively expensive and cumbersome to conduct in-use testing for heavy-duty and non-road engines. In addition, heavy-duty and non-road engines operate under a wide range of conditions (load, speed) that cannot be fully replicated in limited test cycles. Laboratory testing following a specific test cycle cannot ensure that emissions from these vehicles and pieces of equipment are within the range of the applicable standards during normal operation.

During the mid to late-1990s, EPA coordinated with universities and developed the portable emissions measurement system (PEMS). The PEMS equipment can be

installed on heavy-duty vehicles and off-road equipment to measure pollutants as they drive on under real road conditions or operate on normal duty. Toward the late 1990s, regulators at EPA intended to apply PEMS to monitor and verify the compliance of heavy-duty and off-road engines.

In 1998, a broad-scale defeat device case involving heavy-duty diesel engines triggered EPA to set up an in-use testing program for HDVs. An in-use emission standard (called Not-To-Exceed, or the NTE standard) for heavy-duty engines was first introduced in the Consent Decree.[2]. During the same year, EPA released a guidance letter to manufacturers on reporting and evaluating heavy-duty diesel engine auxiliary emission control devices and prohibited the use of defeat devices (EPA guidance letter, 1998). With the formal introduction of PEMS into compliance activities, and collaborating with both CARB and diesel engine manufacturers, EPA developed and finalized the NTE rule in 2005. After two years of phase in, the program became mandatory in 2007.

The majority of in-use testing is done by manufacturers. Under the rule, manufacturers are required to conduct in-use testing to demonstrate compliance with the NTE limits, which is generally 1.25 or 1.5 times the applicable federal test procedure (FTP) standards. EPA will designate no more than 25% of a manufacturer's engine families with a production volume greater than 1,500 engines for testing every year. Because of the wider variations of the in-use testing measurements, EPA initiated a comprehensive research, development and demonstration program designed to identify new accuracy measurement margins for PEMS. EPA in-use testing is conducted at the lab in Ann Arbor, Michigan and at the Department of Defense's testing lab in Aberdeen, Maryland.

For the emission inspection program, 1990 CAA amendments required EPA to set guidelines for states on I/M programs, and required OBD system checks as part of the I/M program (OBD on LDV was required by 1990 CAA amendments). EPA published the I/M rule to meet 1990 CAA amendment requirements in 1992, with reserved sections on the OBD-I/M requirement given that the federal OBD certification standards had not yet been published. In 2001, EPA amended the OBD-I/M testing and published the final rulemaking to ensure effective implementation of OBD-I/M testing and guide states on how to implement OBD checks in their existing I/M programs, as a requirement of the 1990 CAA amendments (EPA, 2001).

Post-2000 till today

Tier 3 emission standards for light-duty vehicles were finalized in 2014. Manufacturer-run in-use testing programs officially established. NTE standard for HD engines phased in. More emphasis was put on in-use emission compliance.

As IUVP and IUCP started in 2003, EPA was able to leverage their limited resources to conduct more in-use testing for LDVs by requiring manufacturers to do their own in use testing, in addition to EPA's own in-use testing. In 2005, the NTE standard for heavy-duty engines was phased in, and fully implemented in 2007. In 2004, CARB first implemented OBD regulations for HDVs. EPA later worked with CARB to

[2] An agreement or settlement to resolve a dispute between two parties without admission of liability (in a civil case) or guilt (in a criminal case)

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develop a similar nationwide OBD regulation that took effect for 2010 and later model year heavy-duty engines.

In the light of the Volkswagen case (discussed in section 5), EPA issued a guidance letter to manufacturers in September 2015, stating that they might do additional testing during the confirmatory test process for the purposes of investigating defeat devices.

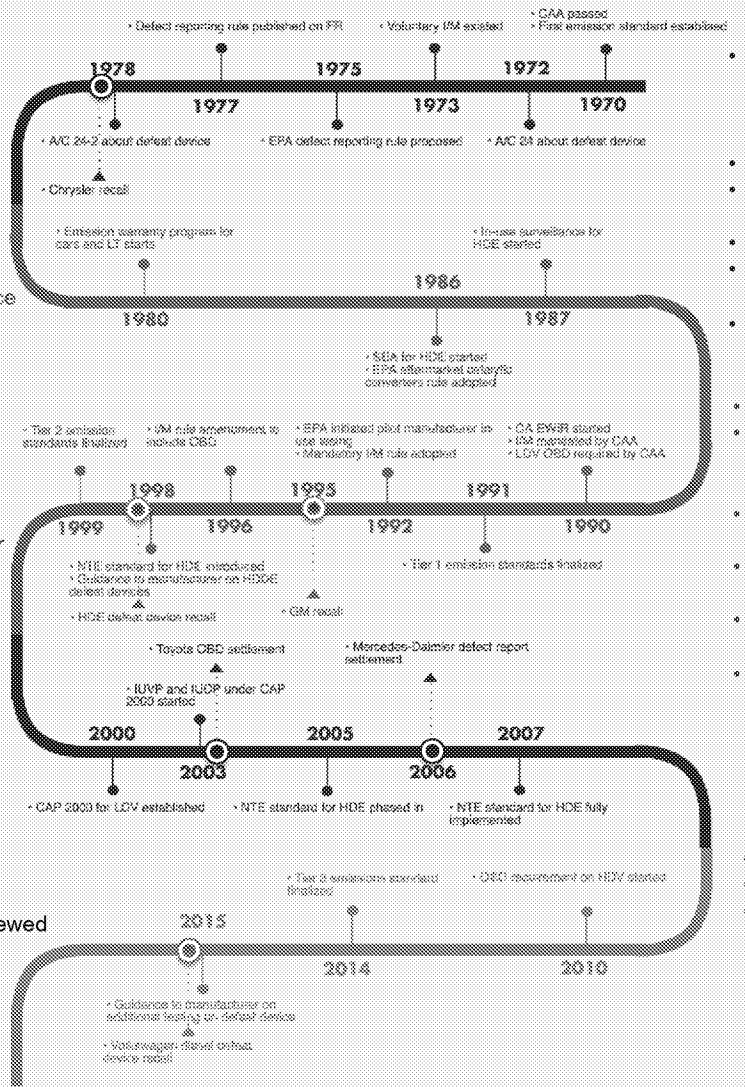
Figure 3 below illustrates the evolution of the U.S. vehicle emission compliance and control program and summarizes key characteristics of each era. In addition, it highlights six enforcement cases, which are each discussed in the next section.

1980s

- Increased focus on in-use. EPA in-use testing program matured.
- EPA was able to obtain defensible data leading to more successful recalls
- EPA's initial in-use surveillance program for heavy-duty vehicles emerged

2000s

- Mandatory LDV manufacturer in-use testing program established
- NTE standard fully implemented
- Almost all recalls were voluntary recalls



◎ Recall/Compliance cases reviewed

● Regulatory actions

1970s

- The beginning of compliance program. Only LDVs are covered, HDV program hasn't started.
- Strong focus on production
- Some attempts to do in-use testing.
- Pilot I/M programs
- Limited data for compliance actions
- All recalls were mandatory

1990s

- Tier 1-2 standard finalized.
- EPA introduced NTE requirement and PEMS testing for HD engines
- CA warranty reporting programs established
- OBD requirements on LDVs introduced
- Mandatory I/M and later OBD check required in I/M
- More voluntary than ordered recalls

2010s

- Tier 3 standard finalized
- OBD requirements on HDVs
- Advanced tool for screening defeat device

GE]

Figure [SEQ Figure * ARABIC]. Evolution of EPA's compliance program

4 Historical trend of vehicle emission recalls in the US

This section provides a historical perspective on vehicle emission-related recalls. It provides insight into what has happened in the U.S. during the past four decades in terms of vehicle emission compliance, and how compliance performance changed in response to the increasingly tightened compliance requirements introduced by regulatory agencies.

Information and data in this section were primarily gathered from EPA's annual vehicle recall summary reports available on the agency's website. These reports include the annual recall data for passenger cars and light trucks from 1996–2009 and include information such as manufacturers, models or engine families, model years subject to recall, year/date of notification, type of recall (ordered, influenced or voluntary), reason for recall (or emissions violations), number of vehicles affected, and a brief description of the remedy including penalty and fixes.

EPA considers past compliance records a valuable data source to help target vehicle classes for current in-use compliance testing. As the auto industry continues to globalize and vehicle emissions standards in major markets harmonize, the giant international auto companies have started to build fewer key technology platforms to fit various global markets. Therefore, detailed data from one of the world's largest vehicle markets – the U.S. – is likely useful for environmental regulators in other parts of the world.

In the U.S., there are three types of recalls, depending on the level of engagement/intervention of the regulatory agencies (EPA or CARB): ordered, influenced voluntary, and manufacturer voluntary recalls. Ordered recalls are mandated from EPA and CARB per authority from the CAA and usually involve a lengthy legal process. Influenced voluntary recalls are manufacturer voluntary actions in response to regulators' intervention. EPA usually encourages manufacturers to voluntarily recall their defective product to avoid ordered recalls. Manufacturer voluntary recalls are independent manufacturer action. Most recalls are initiated voluntarily by manufacturers once potential noncompliance is discovered; However, EPA also has the authority to order the manufacturer to recall and fix noncompliant vehicles or engines if the manufacturer declines to implement a voluntary recall. The three types of recalls are denoted as O, I, and V, respectively. In addition, manufacturers could initiate service campaigns before entering the recall phase. These are still considered recalls under EPA rules, but are listed separately because the manufacturer is asking the owner to bring in the vehicle only if the problem is apparent. There is usually a warranty extension associated with these types of recalls.

An overall vehicle emission recall trend (Figure 4) suggests great success in the U.S. vehicle emission compliance program. During the first 10-15 years since the CAA took effect and the recall program was initiated, EPA recalled about one third of all cars and light trucks produced in any year. During the 1990s, EPA recalled only 5% to 10% of vehicles produced in any year. This change is due to both the progress made on emission control technologies, and the advancement of tools in compliance programs to detect in-use noncompliance.[3]

[3] Communication (email) with Charles Freed.

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Before the mid 1980s, recall rates (defined as the share of vehicles recalled among the annual new vehicle sales for a given model year) were especially high. At that stage, emission control technologies were still in early development and durability was not good. The initial CAA included durability requirements (50,000 miles for LDVs) and the 1990 amendments extended the requirement to 100,000 miles. In the early years, the durability tests were done by actually driving a vehicle over an accelerated durability drive cycle at mostly constant speed until it accumulated 50,000 miles. This approach was both expensive and poor in accurately predicting actual driving that is more dynamic in-use. Limited by both the technologies and testing approach, the overall in-use compliance was poor.

From 1985 to 1990, manufacturers began to successfully use accelerated bench aging tests[4] that allowed them to better predict durability performance at a lower cost. Combined with improved catalyst designs, recall rates were down dramatically during this period.

Since the mandatory OBD rule (also called OBD II) for LDVs was first introduced in 1996, the recall rate has increased because systems as complex as OBD sometimes fail, but also because properly working OBDs were effective in identifying failing emission components.

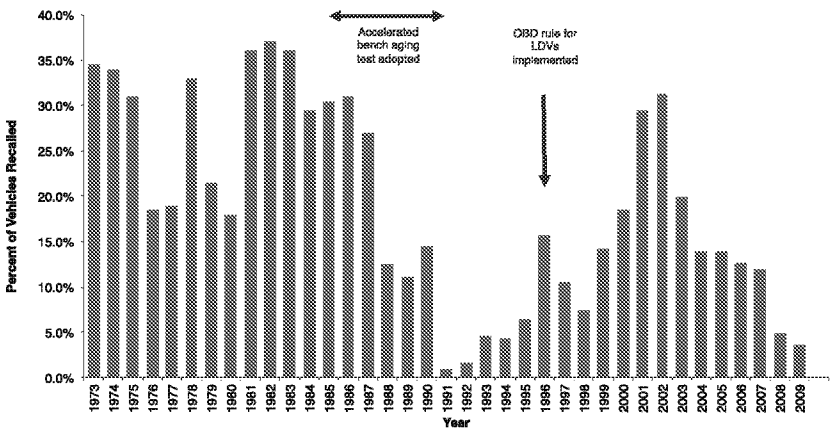

Figure [SEQ Figure * ARABIC]. Percent of light-duty vehicle (LDV) production recalled by model year

Data sources: multiple. Year 1973-1999 data were from a non-public presentation made by Charles Freed, former officer at EPA. Year 2000-2009 data were from various EPA Progress Reports,

Regulatory agencies also experienced a learning curve on how to make manufacturers comply, and manufacturers gradually learned it was better to cooperate than go to court. In the early years, when testing programs and technical capacity within EPA were limited, EPA often had to resort to the court to settle emission violations. Many of recalls were mandatory, and most were the result of EPA action pre-1990 (Figure 5). As EPA's compliance program matured, manufacturers tended to agree with EPA at earlier stages of compliance actions. The majority of the more recent recalls were voluntary with less influence from EPA.

[4] Communication (email) with Charles Freed.

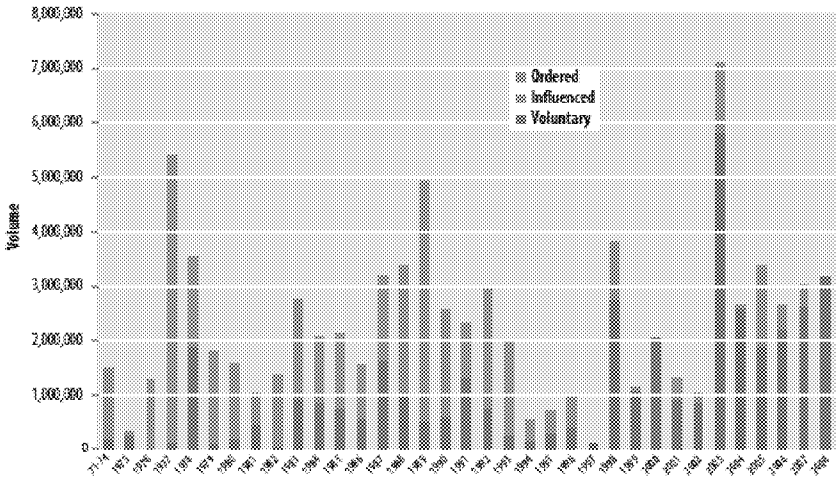

Figure [SEQ Figure * ARABIC]. Historic light-duty vehicle (LDV) recall volumes by recall type and calendar year

Source: EPA 2008 Progess Report: Vehicle and Engine Compliance Activities, page 32

5 Recall and enforcement cases

This section reviews some notable vehicle emission recall cases in U.S. history. Most of the detailed information about each mandatory recall, such as environmental impacts of each violation, how the cases are settled, penalty and remedy, was made public on the government agencies' websites. However, these public documents do not explicitly discuss how the issues were initially discovered – a critical piece of information for the purpose of our paper. We were able to obtain such details from interviewing former and existing government officials who were involved in the cases, which was combined with in-depth research into other government reports and media coverage. These cases offer rich lessons to regulatory agencies in other parts of world where their compliance programs are currently being developed. All lessons learned are summarized at the end of each case's section.

5.1 Chrysler 1978 recall

In November 1978, EPA ordered Chrysler Corporation to recall 208,000 of its MY1975 cars for violating A Carbon Monoxide (CO) limit of the then in-use emission standard,[5] affecting nearly a quarter of Chrysler's production of 1975 cars including the Cordoba, Newport, Plymouth Fury, Grand Fury, Dodge, Monaco, Charger SE and Coronet models. EPA labeled the case "precedent setting" because it was the first mandatory vehicle emission recall issued by EPA, and also the first time a vehicle recall was ordered for design and maintenance issues rather than for manufacturing defects.

The uncontrolled CO emissions were, based on EPA investigation and extensive tests, due to carburetor maladjustments – a small screw on the carburetor, yet crucial for controlling air fuel ratio, was extremely sensitive and difficult to adjust when a car underwent maintenance.

Chrysler filed a petition trying to argue that the excessive emissions were caused by improper maintenance of the vehicles by consumers. This case is the first contested recall action under Section 207(c)(1) to reach the court. The court overturned Chrysler's petition (The Washington Post, 1978) and referenced the definition of "proper maintenance" within the meaning of Clean Air Law (Section 207(c)(1)) as well as substantial evidence in the record from EPA.

Discovery

It is important to mention the context of this case. The Chrysler case happened not long after EPA initiated a preliminary in-use testing program and streamlined its procedures for compliance investigation actions, including hiring contractors for the testing, manufacturer engagement in certain testing, and documentation, in order to

[5] In 1970 Congress passed the Clean Air Act Amendments, which required auto manufacturers to reduce carbon monoxide emissions by 1975 to one-tenth of former levels: to 3.4 grams per mile. In 1973 the Administrator postponed implementation of the 3.4 grams per mile standard and set an interim carbon monoxide emission standard of 15 grams per mile – this was in effect during 1975 when the Chrysler case was concerned.

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provide defensible data to go to court when needed.[6] The nature of the U.S. system was structured so that if the manufacturers did not agree with EPA's data the case would most certainly go to court. An important lesson from EPA's compliance activities in early 1970s was to have concrete data.

The issue was initially exposed from the I/M program data in city of Chicago,[7] which showed Chrysler had a very high failure rate (failing ~40% in a very lenient test) for vehicles that were almost brand new.[8] EPA then brought in some Chrysler vehicles for a confirmatory test in its own lab.

For I/M testing, the vehicles were tested in the condition they were received from consumers, and were not specifically tuned. When EPA conducted their tests, they found that without tuning, the Chrysler vehicles had lots of failures, while if tuned up they could all pass. With additional careful investigation, EPA regulators found that the Chrysler vehicles of concern had carburetors for air/fuel control, and their carburetors had an adjustment screw. The problem turned out to be that the screws were poorly designed and would easily loosen up without an extremely careful and difficult tuning process. Without that tuning, the screws would therefore enrich the air fuel mixture and lead to high CO emission.

The EPA made several efforts to further investigate why the vehicles were not carefully tuned including extensive tests with the manufacture's participation (engagement), an examination into the maintenance procedure of the vehicle models of concern, and surveying dealership mechanics about regular maintenance practices. Following EPA's newly established compliance procedures and guidance, the agency staff kept detailed and careful documentation of each action they took. These careful documentations turned out to be crucial evidence for the agency to ultimately win the case.

With their detailed documentation, EPA was able to provide the judge with the following description of the vehicles' maintenance/adjustment procedures.

> "*The adjustment process is cumbersome and time-consuming, taking the mechanic approximately 30 to 40 minutes. The mechanic must first obtain a Chrysler Huntsville exhaust emission analyzer or other approved infrared analyzer, and must verify that it is warmed up and calibrated according to the manufacturer's instructions. He must check to see that the sample lines and connections of the sampling system for the analyzer are free of leaks, and must also warm up the vehicle's engine and allow it to idle for no more than ten minutes. Then the mechanic must remove the plug from the threaded catalyst tap on the vehicle and install the sample line of the analyzer in the tap upstream of the catalyst. This will generally require the mechanic to crawl under the car or to use a hoist. He must then start up the vehicle's engine and verify that the idle RPM and timing are within specification. At this point he must measure the idle carbon monoxide concentration. If it exceeds specified limits he must adjust the mixture screws on the carburetor to achieve a "leaner" mixture of fuel and air in the idle circuit, checking back and forth between the analyzer and the carburetor to monitor the effect of his*

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[6] Communication with Michael Walsh

[7] The Chicago I/M program was one of the earliest, voluntary I/M programs in the US, before CAA gave EPA authority to mandate it.

[8] Communication with Michael Walsh

adjustment on the idle mixture. A clockwise turn of a screw will decrease the amount of fuel discharged through the idle port and into the idle circuit; a counterclockwise turn will increase the amount of fuel, resulting in a "richer" mixture. The adjustment screws are highly sensitive and must be turned in small fractions of a rotation in order to set the adjustment with sufficient precision. After making the proper adjustment the mechanic must also balance the mixture screws on a two-barrel carburetor for lowest level of hydrocarbons or smoothest idle within the prescribed specifications.[9]"

Similarly, EPA documented its survey of 27 mechanics at various Chrysler dealerships. According to EPA's survey documentation, Chrysler mechanics concluded that "the procedure is cumbersome, time consuming and most importantly will usually result in customer dissatisfaction."

With the agency's detailed records, EPA demonstrated three main reasons that the required procedures were cumbersome and difficult to perform. First, the required emission analyzer was often unavailable – "41 percent of nondealership service facilities lacked such analyzers as of August 1975."[10] Secondly, the Chrysler carburetor adjustment screws were so sensitive that any tiny rotations of the screws will grossly affect the idle fuel-air mixture. – "A mere 1/20 of a turn of the mixture screws above Chrysler's specified adjustment range will cause a substantial increase in idle carbon monoxide."[11] Last, but not least, even if the maintenance mechanics performed the exact adjustment specified by Chrysler, such an adjustment would lead to disruptions of the vehicles' smooth operation and prompt consumer dissatisfaction. "Generally speaking, a vehicle drives more smoothly and has a smoother idle with a relatively 'rich' fuel-to-air mixture. A Chrysler engineer admitted that the 'lean' idle setting specified by the Chrysler 'certainly affects idle quality'. As a result, to achieve better consumer satisfaction, mechanics are motivated to misadjust the vehicles."[12] Needless to say, these records held up as strong evidence in court.

Lessons

As one of the earliest vehicle emission recall cases in the EPA history, the Chrysler case taught the agency several important lessons.

The first simply being that in-use performance of aftertreatment system can be very different from their prototype design. Even if this conclusion is now widely accepted and becomes the rationale for any compliance program, the nature of the issue in the early stage was quite different from that of modern eras, such as intentional cheating, which is reviewed in the next two defeat device cases.

In the Chrysler case, the nature of the issue was that components could fail due to bad design flaws that could not be easily identified during certification procedures. In this case, the issue was that the system design was not able to provide an adequate supply of oxygen to the exhaust stream that was essential to the effective operation of the catalytic converter.

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[9] Chrysler Corporation, Petitioner, v. United States Environmental Protection Agency and Douglas M. Costle, Administrator, Respondents, 631 F.2d 865 (D.C. Cir. 1980)

[10] ibid

[11] ibid

[12] ibid

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There were two major methods of controlling CO emissions. One used an external air pump to add air into the exhaust. This air would oxidize CO emissions from the engine and reduce CO emissions at the tailpipe. The other method was to more precisely control the air/fuel ratio in the engine, so that the engine emitted less CO. The design of Chrysler's vehicles that were ultimately recalled was using the second approach, which could save $50 per car over the first air pump approach. It should be noted that at that time, both technologies were available in the market. In fact, Chrysler used air pumps in its MY1975 vehicles sold to California in order to meet the more stringent emission standards there. Chrysler decided to use the other approach for vehicles sold in other states. The second approach, with perfect calibration, can certainly pass the emissions standard at the federal level. However, with daily use and maintenance, the system proved extremely difficult in achieving the emission level of their "golden car" for certification.

The implications for regulatory agencies are the importance of requiring manufacturers to comply with emission standards throughout the vehicle useful life, and having an adequate in-use compliance program to follow up on designs of prototypes to make sure they work in practice. In the amendments to the CAA of the 1970s, there was specific language requiring "manufacturers must design, build, and equip each new vehicle to conform to emission standards at the time of sale and to be free from defects in material or workmanship that would cause the vehicle to fall below the standards within a five-year or 50,000-mile period after sale." This was the basis for defining Chrysler's violation.

The second lesson is the importance of maintaining careful documentation throughout the whole (compliance testing and investigation) process and allowing manufacturers to oversee the process. These were two important protocols that EPA established in the 1970s, after additional lessons learned that will be elaborated on below.

Soon after the CAA was enacted in 1970, EPA received a substantial amount of funding to initiate an in-use compliance program. After testing over a thousand vehicles and finding that a number of them were failing, potential recalls were discussed for the first time. It quickly became apparent in discussions with manufacturers that the manufacturers were going to challenge the data, because it was not collected in a very rigorous way. The engineers that were doing the testing brought the vehicles in, ran the tests, collected data and sent the vehicles away. They had very poor documentation, did not have good records on whether the vehicles were properly maintained or not. It was an embarrassment to EPA that they had spent a substantial amount of money, collected a lot of data, and the data showed that there were a lot of problems, but they did not have rigorous enough data to go to court with.

Therefore, EPA developed internal protocols for compliance actions including detailed documentation and engagement of manufacturers before and during the testing. The purpose was that if manufacturers agree to the qualification of test vehicles and the test procedures beforehand, it would be hard for the manufacturers to challenge the results later. More specifically, the agency allowed manufacturers to look at and examine every car that the agency was going to test beforehand. In other words, manufacturers had the opportunity to point out if there was any evidence that the vehicles were not properly maintained, and therefore should not to be considered part of their fleet for the purpose of recall. Since manufacturers couldn't know in advance whether the vehicle was going to pass or fail, their focus had to be on whether the vehicle was properly maintained, tampered with, or anything similar that could disqualify the vehicle. And of course, they couldn't disqualify all of the vehicles since that was just not a reasonable option.

This process was critical in helping the agency identify the issue with Chrysler vehicles. When the Chrysler emission issue was found by I/M data, EPA obtained vehicles for their own testing. As Chrysler pointed out, the test vehicles were not "properly maintained," the agency began to investigate the root cause of why so many vehicles could not be well maintained, hence the discovery of the bad carburetor screw design.

It is also very useful to allow manufacturers to observe the testing. If the manufacturers point out that something is wrong in the testing process, it is good for the agency to correct it right away rather than after the fact. This way, when EPA receives the test data, the data should be strong enough to defend the agency's result. Overtime, EPA has learned how to obtain sensible data. As a result, as EPA identifies cases, if the issues are clear-cut manufacturers will go ahead and do a voluntary recall.

Throughout the entire process of test vehicle procurement, testing and further investigation into the Chrysler case, detailed and thorough documentation was key, as was discussed in the discovery of the issue.

The third lesson is that I/M programs are useful for identifying certain emission violation issues such as broken parts and poor durability of components, and inadequate maintenance, and therefore can be useful data sources for emission recalls.

However, there is an important difference between I/M failure and recall. As an in-use fleet screening program, I/M emission thresholds are set more leniently than the new vehicle emissions standards. I/M fails vehicles that emit a few times higher than the certification emission limits, while recall fails vehicles that emit even a relatively small margin above the certification emission limits (to allow for testing variability). I/M also fails vehicles with issues that consumers are responsible for – lack of maintenance. For the types of noncompliance issues due to manufacturer responsibility, regulatory agencies need other data sources. This will be further discussed in the next section.

5.2 General Motors 1995 recall

In 1995, the U.S. Department of Justice (DOJ), on behalf of EPA, alleged that General Motors Corp. (GM) put illegal devices to defeat pollution controls inside nearly a half-million cars since 1991, resulting in carbon monoxide (CO) emissions of up to three times the legal limit. An additional claim involved GM's failure to notify EPA about all of their emission control strategies for light duty vehicles (DOJ, 1995). The allegation affected MY1991-1995 Cadillac, including the Seville and Deville models equipped with GM's 4.9-Liter engine. The auto company agreed to pay an $11 million dollar civil penalty for an estimated total cost of $45 million, including recalling and retrofitting the 470,000 affected vehicles and implementing other remedies to settle the government charge.

The computers in these vehicles were programmed to enrich the fuel (increased the amount of fuel relative to air) when the vehicles' climate control system (air condition system) was in operation for heating or cooling. GM developed this new engine calibration to respond to customer complaints of stalling and other drivability problems in 1991 and then continued to also install the device in its MY1995 Cadillac (Cushman Jr., 1995). However, the resulting air/fuel ratio was too rich for the cars' catalytic converters to oxidize the CO emissions, and the tailpipe emissions doubled

or tripled the allowable levels. This calibration is a defeat device that reduced the effectiveness of the vehicles' emission controls during normal urban driving; in addition, GM did not adequately disclose this calibration to EPA.

Discovery

In the fall of 1993, EPA's tests showed that the engines emitted up to 10 grams of CO per mile with the climate control on, well above the 3.4 grams/mile limit (DOJ, 1995). However, the vehicles' high pollution levels did not register in federal certification tests since the laboratory tests at the time were not designed to include driving conditions with the climate control system on. Additionally, the cars were typically not driven with A/C operating.

The EPA detected the problem during a research project, led by EPA's Office of Transportation and Air Quality (OTAQ or EPA's air office), for developing new off-cycle driving cycles, later known as the Supplemental Federal Test Procedures (SFTP). GM loaned a Cadillac to OTAQ for these specially designed tests including conditions with air conditioning on. It was this special testing that indicated the Cadillac car's abnormally high CO emissions. The car performed well on normal FTP testing, but not when the air conditioning was turned on.

GM disagreed with the allegations by the government, and said that it was a matter of interpretation of current regulations regarding the complex issue of off-cycle emissions. Some observers also defended GM, arguing that CO pollution is primarily an issue in the winter (Adler, 1998), hence the emissions impact of this violation was not as big as the test showed. Even so, the company said, it worked extremely hard to resolve the matter with OTAQ and avoid litigation (Brown & Thomas, 1995).

Unfortunately, the nature of this case was later defined as violating the larger principle – using an emission defeat device. At the time, EPA's Office of Enforcement and Compliance Assurance (OECA, or EPA's compliance office) was also pulled into the issue. OECA handles matters requiring legal action to seek remedies or financial compliance penalties. OECA discovered records showing that GM technicians knew about the emission impact of their new engine calibration, but buried the information. This became the ultimate proof that GM intentionally installed defeat devices on their vehicles.

Outcome

Shortly after the case, EPA introduced the SC03 SFTP that represents engine load and emissions associated with the use of air conditioning in vehicles certified over the FTP-75 test cycle. The SC03 is a chassis dynamometer test performed with the vehicle A/C unit turned on, at a lab temperature of 95°F (35°C), and with simulation of full sun load using heat lamps. Since MY 2008, the SC03 results are also used for the determination of the EPA fuel economy label value ratings using the EPA 5-cycle method (Dieselnet, 2016).

Lessons

This case reinforced that certification and in-use compliance tests in the laboratory are useful, but are a very limited tool in assuring that manufacturers are not using defeat devices. It is important to also engage in-use testing under real-world driving conditions. Regulators need to revisit their certification procedures and approaches to best reflect real world driving. Supplemental test cycles can be very effective in representing in-use driving patterns, including extreme driving patterns, and reducing real world emissions, but detection of defeat devices still requires in-use testing.

This is especially important as vehicle technologies evolve rapidly for better

drivability, conformability, fuel economy, etc., and the consumer's driving behaviors can change accordingly. For example, when EPA initially developed the original FTP test cycle, a motor vehicle air conditioning system was so costly that only a portion of the vehicles were equipped with one. By 1969, 54% of domestic automobiles were equipped with air conditioning (National Academy of Engineering, 2016). However, at the time the GM case occurred in 1995, nearly all vehicles had an AC system as a basic feature and the system was operating daily when the vehicles were in use.

Secondly, even though defeat devices are more often deployed on diesel vehicles and engines due to the trade-off between NOx emissions and fuel economy of certain technology options, they can appear on gasoline vehicles too. This is something that could be easily ignored by regulators.

5.3 Heavy-duty diesel engine 1998 defeat device recall

In 1998, the U.S. DOJ and EPA settled a consent decree with seven diesel truck and engine manufacturers – Caterpillar Inc., Cummins Engine Company, Detroit Diesel Corporation, Mack Trucks, Inc., Navistar International Transportation Corporation, Renault Vehicules Industriels, s.a. and Volvo Truck Corporation – for installing computer-based strategies to defeat emission controls (defeat devices). The defeat devices allow engines to meet EPA's emission standards during laboratory testing, but disable the emission control system during normal highway driving, in order to maximize fuel economy, while emitting up to three times the limit of nitrogen oxides (NOx) emissions as a result.

The settlement levied $83.4 million in civil penalties against the companies. In addition, EPA required the companies to introduce newer cleaner engines, rebuild/retrofit older engines to cleaner levels, recall vehicles and engines that have existing defeat devices installed and conduct new emissions testing. The companies collectively spent over $1 billion dollars, the largest in environmental enforcement history. This case also had a profound impact on future emission regulations and the diesel engine industry. After the settlement, EPA worked with CARB and developed a Not-To-Exceed standard for in-use heavy-duty diesel engines that became mandatory in 2007.

Discovery

Prior to this case, EPA's emission regulations for heavy-duty diesel engines mainly focused on certification and not much on verifying real-world emissions. The issue was discovered when EPA was conducting some research-oriented testing using their newly invented tool for on-board vehicle emissions testing. At the time, the tool was called the Real-time Onroad Vehicle Emissions Reporter (ROVER) and was invented by an EPA engineer, Leo Breton. Today this device is generally referred to as the Portable Emissions Measurement System (PEMS). In the late 1990s, EPA used the tool to collect data for setting up a new regulation on EGR systems for diesel engines. EPA engineers deployed the tool on a couple of trucks and drove them around Virginia. What they observed from the real-world emissions profile was that the emission control systems were doing things differently from what was expected.

This triggered a broader investigation into diesel engine compliance issues. The PEMS were not as accurate as they are today, so they could not be used to charge the manufacturers in court. Though in terms of showing vehicles were producing emissions two, three or ten times above the standard, the PEMS data was good

enough and did help EPA generate a lot of data relatively cheaply, while guiding their investigation.

EPA began to legally request manufacturers bring in engines for testing under different conditions – these conditions were to mimic the real world driving conditions during the PEMS tests in which they saw high emissions. They ran the engines on the regulatory test cycle, then on slightly modified cycles in the laboratory and the results were very different.

The test data allowed EPA staff to talk to the manufacturers and ask for an explanation. The most reasonable explanation was a defeat device. The question got sorted out quickly, but the agency spent a lot of time negotiating. The leverage the agency had was the new engine type approval (or Certificate of Conformity) that is granted only to a product that meets a minimum set of regulatory, technical and safety requirements. Type approval is generally required before a product is allowed to be sold in a country. For the automotive industry in the U.S., a Certificate of Conformity is the document that EPA issues to a vehicle manufacturer to certify that a vehicle class conforms to EPA's requirements.

Outcome

This case brought significant changes to the certification requirements and procedures of diesel engines. EPA began to require manufactures to conduct more testing based on the map of the engine, and to meet not-to-exceed emission levels that apply to various operation modes of the engines – high/low load, high/low speed etc. – with PEMS testing officially adopted. These additional testing requirements and emission limits broadened the conditions under which manufacturers must comply with the emission standards.

This case also triggered EPA to investigate and start putting resources into HDV compliance.[13] During that era, EPA was spending very little resources on heavy-duty engine enforcement. As one former EPA officer recalled in our interview, "*In my division's personnel budget, we had thirty people working on certification and fuel economy issues, but only 1.5 people to do heavy-duty certification. We physically had the capability to a confirmatory test, but we didn't have the budget to do confirmatory testing certifications for HDV.*"[14]

Lessons

A lesson from this case is as vehicle and emission control technologies advance and emission regulations become more complicated, unanticipated issues may develop. As regulatory agencies increase their knowledge, and if there is potential for undercutting the purpose of the regulations, the agencies should try to flesh out those undefined areas into black and white expectations by further spelling out what they specifically intend or clarifying the interpretation.

Another critical lesson is that environmental authorities need to have clear legal authority and some concrete leverage in order to enforce the emission standards. In this case, the companies in violation were leading global manufacturers that represented about 95% of the U.S. diesel engine market at the time (Reitze, 2001). EPA's authority to approve the Certificate of Conformity for the new engines and

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[13] Communication with Robert Maxwell

[14] Communication with Robert Maxwell

vehicles that these companies produce was key leverage to get industry to settle on this case.

5.4 Toyota 2003 OBD settlement

In 2003, the U.S. DOJ and EPA announced a settlement of the government's lawsuit against Toyota Motor Corporation (Toyota) for Clean Air Act violations involving 2.2 million vehicles manufactured between 1996 and 1998, including some Camry, Avalon, Corolla, Tercel, Paseo, Lexus, Sienna minivans, 4Runner, RAV4, Tacoma and T100 models. Toyota was charged for not disclosing limitations of the OBD systems on the affected models in monitoring leaks in the vehicles' evaporative emission control systems. Under the settlement, Toyota agreed to conduct a supplemental environmental project, extend the evaporative emission control system warranty on affected vehicles, accelerate its compliance with certain new evaporative emission control requirements, and pay a $500,000 civil penalty. The settlement cost Toyota an estimated $34 million in total.

Discovery

Toyota's evaporative system monitoring issue was first discovered by CARB. The agency had filed a case before the DOJ and EPA on this, but lost the case.

In late 1991, CARB instituted evaporative OBDII regulations and required implementation on all new gasoline cars in 1996. The objective of OBD is to have the OBD system detect emission-related malfunctions while the car is being driven in the real world. According to the specific requirement of the regulation (sections 1968.1(b)(4)), the OBD monitoring system on the vehicle is supposed to detect evaporative system faults and leaks.

When Toyota applied for certification, ARB staff questioned the design of the company's OBD monitoring system since the description in their application "was too simple compared with the systems of other OEM's."[15] However, based on laboratory tests, Toyota's evaporative system monitor was able to run on the FTP tests. CARB approved the firm's computerized emissions-sampling system in 1995 for its MY1996 vehicles based on laboratory tests. This was repeated for Toyota's MY1997 and 1998 vehicles.

OBD II regulation authorizes CARB to perform confirmatory testing of manufacturers' OBD systems in order to determine compliance with certain malfunction criteria identified in the manufacturer's approved certification documentation. In June 1997, as part of the confirmatory testing process, CARB conducted additional testing to challenge the OBD systems of Toyota's vehicles. The agency found a few employees of California EPA who owned Toyota cars. The agency punched a 0.04-inch hole in the evaporative systems in each of the vehicles, and drove them (DeLong, 2002). The OBD system in the tested vehicles could not identify the leak in the evaporative emissions control systems. The system didn't take samples frequently enough to always trigger the MIL (dashboard-mounted "check engine" emissions warning light). In September 1998, CARB issued a formal notice of non-conformity, and ordered Toyota to recall approximately 337,700 vehicles that had been manufactured and certified for sale in California.

[15] Communication with John Urkov

However, Toyota argued[16] that the OBD regulation (sections 1968.1(a)(1.9) and (b)(4.3)) only required that the evaporative system monitor run during conditions that are "encountered at least once during the first engine start portion of the applicable FTP test." Toyota also argued that, even if the monitors on these cars didn't run, their evaporative emission control systems were so well designed and so durable that they would never fail in-use anyway, hence there would be no emission problem. In other words, Toyota believed their vehicles met all standards that existed when CARB approved those certifications. Thereafter, Toyota filed a petition for a hearing on the recall order, which CARB referred to as an administrative law judge (ALJ) from the California Office of Administrative Hearings.

Outcome

CARB eventually lost that case.[17] On February 22, 2000, the ALJ issued a Proposed Decision, recommending that the CARB recall order be dismissed. CARB decided to prevent this from happening again in the future by strengthening the regulation's language. This is reflected in the entirely new OBD II regulation released in 2002, section 1968.2 of title 13, California Code of Regulations, which superseded section 1968.1 for 2004 and subsequent model year vehicles.

The main changes were adding new performance requirements to ensure that monitors ran frequently in the real world. Section 1968.2 has new requirements that would require the OBD II systems on vehicles to keep track of how often the vehicle is driven and how often the monitors run in the real world. Section 1968.2 also set minimum performance criteria that manufacturers must meet – the criteria was basically the minimum required number of times the monitor has to run in-use.[18]

Before a decision from the ALJ was made, the federal agencies (DOJ and EPA) began to investigate the issue and filed a lawsuit on July 12, 1999. Instead of charging the Toyota vehicles for excessive evaporative emissions, the court alleged that Toyota did not disclose certain conditions that enable OBD monitoring of the evaporative emissions control system to occur, and the result was a less effective OBD system to detect an anomaly in the evaporative emission control systems. This time, Toyota lost in court, and a consent decree was reached between the company and government in March 2003.

Lessons

There are two major lessons from this recall case. First, noncompliance can be flagged at the certification stage with appropriate follow up in-use testing for verification. Technical expertise of the regulatory staff at certification is crucial when it comes to a system like OBD.

Second, regulatory agencies should always be prepared for a learning curve on new technologies and should keep a steady growth in their capacity along with the

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[16] Toyota filed a petition for a hearing on the recall order, which CARB referred to an administrative law judge ("ALJ") from the California Office of Administrative Hearings.

[17] On February 22, 2000, the ALJ issued a Proposed Decision, recommending that the CARB recall order be dismissed.

[18] Details of these "in-use monitor performance" requirements are in the 2002 staff report (starting on page 49 in [HYPERLINK "http://www.arb.ca.gov/regact/obd02/isor.PDF"]) and in sections 1968.2(d)(3.2), (d)(4), and (d)(5) of the OBD II regulation (starting on page 14 in [HYPERLINK "http://www.arb.ca.gov/msprog/obdprog/section1968_2_clean2013.pdf"]).

industry. Regulatory agencies should also be able to incorporate their learning into the development of future regulations. Improving regulatory programs to reduce real-world emissions is one of the core goals of a compliance program. This is also reflected in the 1998 diesel engine defeat device recall case discussed next.

5.5 Mercedes-Daimler 2006 defect report settlement

In 2006, Mercedes-Benz USA and Daimler-Chrysler AG was fined $1.2 million in civil penalties to resolve its failure to promptly notify the EPA about three emission control defects involving the catalytic converter system and air pumps on numerous MY1998-2006 vehicles. The manufacturer also needed to improve its emissions defect investigation and reporting system to ensure future compliance – costing the company approximately $1 million per year. The consent decree also led to voluntary recalls for two of the three defects and extended warranty coverage from the company to address a third defect, at an estimated cost of $59 million.

Lessons

The major lesson learned from this case is that manufacturer defect reporting is a critical part of EPA's compliance program, as it is an important data source to identify potential recalls.

The CAA requires auto manufacturers to file a defect information report[19] with EPA no more than 15 working days after an emission-related defect is found to affect 25 or more vehicles. Then the EPA considers whether the defect will cause emission standards to be exceeded and whether a recall is necessary. Based on manufacturer reports, EPA can test the cars with defects to determine if they should be recalled. While most defect reports do not lead to recalls, many recalls occur because of these defect reports. Manufacturers are penalized if they do not timely report defects.

Entering the 20th century, EPA's vehicle emission compliance program had matured, and the agency became more rigorous at data reporting and were able to start coming down hard on manufacturers for things like poor documentation, even when it does not necessarily lead to increased emissions. This way, the agency clarifies that industry doesn't get sloppy in taking on its own responsibility to ensure in-use emission compliance of their vehicles. Therefore, the agency can spend more time and resources on investigating things that are much subtler – such as defeat devices.

5.6 Volkswagen 2015 diesel defeat device recall

A diesel engine defeat device was recently discovered installed on several models of Volkswagen AG's (VW) light duty diesel vehicles sold in the US. On September 18, 2015, CARB issued an In-use Compliance letter to the company listing violations. EPA issued a Notice of Violation to the company on the same day. The agencies alleged the company used defeat devices to circumvent CARB and EPA emission test procedures on all of its MY2009 to 2015 2-Liter engine diesel cars, covering the following models: Jetta, Jetta Sportwagen, Beetle, Beetle Convertible, Golf, Audi A3 and Passat. Shortly after, in November 2015, EPA sent another notice to VW with regard to alleged defeat devices on all 3-Liter diesel engine models. Almost 600,000

[19] Section. 208(a) and 301(a), Clean Air Act, as amended (42 U.S.C. 1857f–6(a) and 1857g(a)).

total vehicles are affected in the U.S. and about 11 million vehicles worldwide (Dieselnet, 2015).

During official laboratory testing, the vehicles' electronic control module (ECM) ran software that produced compliant emission results (the so-called "lab calibration"). Under normal real world driving conditions, the vehicle ECM software ran a separate "road calibration," which reduced exhaust gas recirculation (EGR), modified fuel injection timing, reduced the regeneration events of vehicles equipped with lean-NOx traps (LNTs), and reduce the amount of urea injection for vehicles equipped with selective catalytic reduction (SCR) systems. As a result, emissions of NOx increased by a factor of 10 to 40 times above the standard, depending on the type of drive cycle and the vehicle (EPA notice of violation, 2015).

On January 4, 2016, the DOJ filed a civil complaint against Volkswagen and the relevant brands for violations of the Clean Air Act (CAA). The company now faces a proposed settlement of $14.7 billion dollars in penalties and federal criminal charges, as one VW engineer has already pleaded guilty (DOJ, 2016; Ambrosio, 2016). Volkswagen is also facing possible investigation in other countries, as well as legal action from shareholders and customers.

Discovery

EPA and CARB were alerted to the emissions problems with these vehicles in May 2014 when the International Council on Clean Transportation (ICCT) and West Virginia University (WVU) published results of a study commissioned by the ICCT that found significantly higher in-use emissions from two diesel cars (EPA notice of violation, 2015). The ICCT has been looking into diesel emissions in various top auto markets for quite some time, and in 2012, decided to conduct PEMS testing on diesel cars sold in the U.S. to gain a greater understanding of how NOx control technologies perform in different markets.

The two VW light duty diesel vehicles involved were a 2012 Jetta and a 2013 Passat.[20] The results show that real-world emissions of these vehicles miserably exceeded the NOx emission limits (Franco, German, Posada, & Mock, 2014). Though the other vehicle involved the study, a BMW X5, was within the regulated emissions range during most real world driving conditions. CARB collaborated with the ICCT during this research and provided laboratory testing on the official emission test cycles.

ICCT's report was issued in March 2014. It took the agencies over a year to confirm defeat devices were installed on these vehicles. Meanwhile, in December 2014 VW initiated a voluntary recall that affected about 500,000 vehicles in the U.S. with nearly 50,000 in California alone. VW did not reveal the fact that they had installed defeat devices. Instead, they claimed it was a technical issue that could be fixed by reflashing the engine chip, which didn't work.[21]

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[20] Vehicle models are not named in the original report.

[21] On May 6, 2015, CARB conducted confirmatory testing on a MY 2012 Gen2 VW cars (cars with SCR technology) over required certification cycles and on the road using PEMS. On some certification cycles, the vehicles were failing the NOx standard. PEMS testing showed that the calibration reduced the emissions to some extent, but NOx emissions were still significantly higher than expected.

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To have a more controlled evaluation, CARB drove Phase 2 of the FTP test repeatedly. This special cycle showed that the calibration did increase Diesel Exhaust Fluid (DEF) dosing upon initial startup, but it was not sufficient to keep NOx emissions from rising throughout the cycle. This leads to high NOx emissions despite the SCR reaching sufficient operating temperature.

On July 8, 2015, CARB shared the results with VW and EPA. None of the potential technical issues suggested by VW explained the higher test results consistently confirmed during CARB's testing. Finally, CARB and EPA told VW they would not approve Certificates of Conformity for VW's MY2016 diesel vehicles until VW could more adequately explain the anomalous emissions and ensure the agencies that the MY2016 vehicles would not have similar issues. Only then, on September 3, 2015, did VW admit it had designed and installed a defeat device in these vehicles in the form of a sophisticated software algorithm that detected when a vehicle was undergoing emissions testing.

Outcome

The immediate outcome of this case was CARB and EPA deciding to adopt additional testing procedures to make sure diesel vehicles continue to meet emission standards when they are being driven on the road. On September 25, 2015, CARB sent a letter to all manufactures announcing the agency will soon introduce a defeat device screening test based on newly-developed detection methods and may include OBD quest, PEMS testing, and special driving cycles, in addition to the standard certification emissions test cycles in its In-Use Compliance Program (ARB letter to manufacturers, 2015). Shortly after, EPA also [HYPERLINK "http://www3.epa.gov/otaq/cert/documents/cd-mfr-guid-ltr-2015-09-25.pdf"] automakers that it may test or require testing on any vehicle at a designated location, using driving cycles and conditions that may reasonably be expected to be encountered in normal operation and use, to identify a potential defeat device (EPA guidance letter, 2015). Such testing can be expected in addition to the standard emissions test cycles when Emissions Data Vehicles (EDV), and Fuel Economy Data Vehicles (FEDV) are tested by EPA.

Lessons

The most important lesson learned from this case is that certification testing alone is not sufficient to address sophisticated issues like defeat devices. Only when combined with advanced in-use compliance and testing program can the standards assure emission reduction occurs during real-world driving. Even though it seems like history was repeating itself, today's defeat devices are far more complicated than those in the 1998 diesel engine case. In the 2015 VW case, the software of the vehicles detects whether the vehicle is being tested or not based on various inputs. These inputs precisely track the parameters of the federal test procedure used for emission testing for regulatory certification purposes. There are still lots of areas where the current emission testing programs need to be enhanced to prevent against the "modern ways of cheating."

Another lesson is that independent empirical research projects can serve as a valuable information and data source for the regulatory agencies to flag any issues early. Partnership between government agencies and research entities can be a useful complement to the limited government resources dedicated to identifying noncompliance. The ICCT chose to test diesel cars due to the unique perspective of diesel vehicles emissions in the European market. However, in the U.S. market, diesel engines are less than one percent of the vehicle market, and are therefore not chosen as target classes under EPA or ARB's compliance testing programs. The

ICCT and WVU testing project had perfectly filled this gap in the existing regulatory program.

Table [SEQ Table * ARABIC]. Summary of recall and enforcement cases reviewed

YEAR	CASE	DISCOVERY	LESSONS
1978	Chrysler recall	I/M[a] data	• In-use performance of aftertreatment systems can be very different from their prototype design, thus it is important to a robust in-use compliance program. • Careful documentation throughout the entire compliance testing and investigation process and allowing manufacturers to oversee the process is the key to successful recall. • I/M data is useful in identifying certain in-use noncompliance issues.
1995	General Motors defeat device recall	EPA research-oriented testing	• In-use testing under real-world driving conditions is important. • Defeat devices could also appear on gasoline engines.
1998	HDDE[b] defeat device recall	EPA research-oriented testing	• In the early stages of regulations, there might be undefined areas, and agencies should clarify the interpretation of regulations as technologies/testing tools advance. • The authority to approve the Certificate of Conformity gave the agencies concrete leverage to enforce emission standards.
2003	Toyota OBD settlement	Certification and in-use testing	• Noncompliance can be flagged at the certification stage with appropriate follow up in-use testing for verification. • Feedback from in-use testing program is important to improve future regulations - a learning curve for regulatory agencies.
2006	Mercedes-Daimler defect report settlement	EPA investigation	• Defect reporting is an important data source for identifying noncompliance. • More recently, EPA became rigorous at data recording and reporting.
2015	Volkswagen diesel defeat device recall	Independent real-world testing projects	• Modern defeat devices are much more complex than they were decades ago, thus require innovative testing approaches to detect them. • Independent research projects can be a good complementary source of data in flagging noncompliance.

[a] I/M: Inspection and maintenance programs
[b] HDDE: Heavy-duty diesel engine

6 Data sources for identifying in-use noncompliance

Emission recalls are an effective enforcement tool utilized by regulatory agencies to punish noncompliance. The key to successful recalls is the regulatory agencies' ability to accurately identify noncompliant vehicles with defensible data. The ultimate data or information used to recall vehicles or bring companies to the court come from regulatory agencies' own in-use surveillance testing. However, the agencies use a broad range of information and data sources to determine the need for further investigations that may lead to recalls. In general, agencies target vehicle classes based on 1) certification data; 2) manufacturer warranty data and defect reports; 3) complaints at servicing (manufacturer service bulletins; 4) information from state I/M programs and OBD information; 5) failures at manufacturer-run in-use testing, and other reasons. Figure 6 below demonstrates data sources and class targeting for recall.

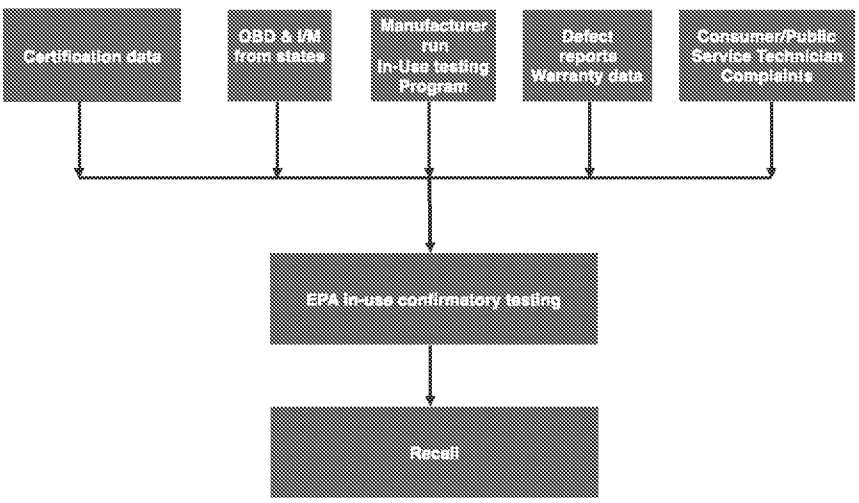

Figure [SEQ Figure * ARABIC]. Data sources leading to recalls

It is important to understand that the Figure 6 diagram shows EPA's effective data sources today. In the early days, almost none of them worked well, because if the regulatory agency couldn't perform effective in-use testing and have a defensible database to prove that the vehicles are failing standards, all the other data are indirect inferences. Therefore, regulatory agencies in the early stages should focus on in-use testing. All other data sources are to guide in-use testing. For this reason, this section starts off by explaining in-use compliance testing performed by regulatory agencies, followed by a description of additional information sources.

6.1 In-use compliance testing program run by regulatory agency

In-use surveillance testing is one of the early-established compliance programs at EPA and CARB. Regulatory agencies generate their own data to verify in-use emission compliance of the vehicles and engines they certified. According to a former CARB officer, "In the early days the only sources that the agency had were

simply certification data and in-use testing data generated by the agency. That was it."

For light-duty vehicles, selected in-use vehicles are tested at the Ann Arbor, Michigan lab (unless otherwise designated by EPA) following the same test procedures and fuels used in certification. Manufacturers are informed and invited to watch the maintenance and tests being performed so they have complete confidence in the quality of the tests and corresponding results.

The tests are performed in two phases.

During the surveillance phase: the tests are intended as a quick screening. EPA typically recruits in-use vehicles between two and three years old from nearby the Ann Arbor lab. Vehicles are selected from owners, government fleets, and rental fleets using a statistical procedure to assure a 'random" sample. Large and small engine families are tested and all manufacturers are tested every few years. Vehicle owners are given small monetary awards (about US$20/day up to US$200 in total) and a loaner car. Vehicles that have not been properly maintained or have been tampered with are eliminated, although the surveillance phase of tests has more liberal vehicle acceptance criteria. The agency inspects vehicles for hose connections, fluid levels and gross exhaust leaks, to ensure no oil or air filter/spark plug changes and no relevant part replacements.

Regulatory agencies, such as the EPA, may hire a contractor for vehicle recruitment and screening. However, CARB previously confronted a situation of inadequate test data for enforcement actions due to unqualified vehicles initially recruited by a contractor. As a result, CARB no longer uses contractors for procuring vehicles for in-use compliance testing.[22]

EPA tests up to five vehicles per class, but cut off after three vehicles pass to allow more classes to be tested with limited resources. If one or more vehicles fail, the agency will add two additional vehicles from the same test group. If more fail, EPA will discuss it with the manufacturer. Sometimes the manufacturer will bring testing data to the meeting or has explanations that are satisfactory (such as the test vehicles are outliers). If not, EPA and the manufacture agree upon some acceptable solutions, such as voluntary recall, field fix, or extended warranty.

The scope of surveillance testing is about 50 test classes and about 150 vehicles each year. Table 2 below shows total vehicles/groups tested in the past few years.

Table [SEQ Table * ARABIC] Number of test classes[a] selected in surveillance testing for LDV, CY07-CY13

CY	2007	2008	2009	2010	2011	2012	2013
Number of classes	47	45-50[b]	45	45	50	33	25

[a] A test class is a group of vehicles with very similar design characteristics from an emissions standpoint.

[b] Estimated based on number of carlines, manufacturers and model year tested

[22] Communication with John Urkov.

Source of data: EPA Compliance Reports

The second and final phase is called in-use confirmatory testing. The testing enters the confirmatory phase when surveillance results indicate that a substantial number of vehicles in the class may exceed emission standards, and if the manufacturer declines to voluntarily remedy or recall the vehicles.

Procurement and testing in confirmatory testing are much more rigorous phases than in surveillance testing because vehicles must be shown to fail when properly maintained and used. The test data needs to be able to stand up in court, and are the prelude to an ordered recall. EPA has to check and conduct maintenance including screening for oil change receipts, overweight towing, inspection for hose connection, fluid levels, tampering, racing (headers), compression pressure check and make sure no oil/air filter/spark plug changes and no parts are replaced. Unscheduled maintenance on either emission related or non-emission related parts are only allowed under select circumstances.[23]

For confirmatory testing, EPA tests ten or more randomly selected, properly maintained and used vehicles. Similarly to the surveillance testing, manufacturers are invited to watch the maintenance and testing. Compliance decisions are made based on level of failure in the class, and confidence level of the results. There is no set number of failures to trigger the ordered recall process. Generally, if more than two of the vehicles in the sample fail, or if the mean of the sample is over the standard by more than 20% for any pollutant with high statistical confidence, there is risk for further action. If a manufacturer refuses to recall, a legal hearing will be initiated. "This rarely happened" according to a former EPA officer.

The purpose of confirmatory tests is to put an emphasis on a voluntary remedy. Ordered recalls are the ultimate deterrent since recalls will lead to bad press for manufacturers and are costly to defend. Voluntary recalls are a norm because of the deterrent effect of the program. In addition, there are also creative alternatives to a recall such as extended warranties, and special service campaigns. Results of these alternatives are much more timely remedies for the in-use problems and less contentious, better press for the manufacturers.

For heavy-duty and non-road engines, regulatory agencies monitor and verify compliance using PEMS testing of the engines during normal operation and compare the results against Not-to-Exceed in-use emission limits. EPA's in-use testing is conducted by the Ann Arbor lab and by the Department of Defense testing lab in Aberdeen, Maryland. For HDVs, the majority of in-use tests are conducted by manufacturers as part of the requirements of the heavy-duty in-use testing rule (40 CFR Parts 9 and 86; EPA, 2005; Federal Register, 2008). Manufacturers are required under the rule to conduct in-use testing to demonstrate compliance with the NTE limits, which is generally 1.25 or 1.5 times the applicable standards on laboratory test cycles. EPA established a mandatory pilot in-use testing program for gaseous pollutants (HC, CO, NOx) in 2005, and 2006, and for particulate matter (PM) pollutants in 2007-2008. The program became fully enforceable for gaseous pollutants starting in 2007. Exceeding NTE limits during in-use testing does not

[23] For example, the part failure or system malfunction, or the repair of such failure or malfunction, does not render the vehicle or engine unrepresentative of vehicles or engines in use and does not require direct access to the combustion chamber, except for spark plug, fuel injection component, or removable prechamber removal or replacement.

necessarily indicate a violation or noncompliance. EPA will make a decision on follow-up action on a case-by-case basis, and to date no action has been taken.

In addition, EPA also uses the in-use data to evaluate the manufacturer's deterioration test methods. If in-use emissions are higher than predicted by the manufacturer during certification, then the manufacturer is required to revise its deterioration procedure to match the in-use test results. This keeps the deterioration factors derived for certification purposes accurate and relevant.

6.2 Certification test data

A manufacturer must obtain a Certificate of Conformity from EPA before beginning mass production. Certification begins when a manufacturer submits an application for certification to EPA for a group of vehicles or engines with similar emission characteristics (families). The application must contain information about engine design, production volume, type of emission control equipment installed, and provides manufacturer test and deterioration data to show that the vehicle or engine meets all of the emission standards for its regulatory useful life. EPA is more likely to conduct confirmatory tests on vehicle models that have had problems in certification, or have emission levels too close to standard limit (with small compliance margins).

CARB has certification procedures similar to EPA. In addition, CARB certifies OBD systems, and EPA accepts CARB's OBD certifications. For OBD certification, CARB requires manufacturers to provide a detailed description of how the monitors function.

Since technical judgment at certification is particularly important, certification staff within these regulatory agencies are expected to have profound knowledge of engines and emission control technologies. They conduct a comprehensive review of the data and description provided by the manufacturers, and if necessary, have meetings with them to address questions like "how certain emissions control can be achieved with the system design described in your application." A typical certification engineer would spend several hours analyzing one engine family. CARB has about 35 staff members responsible for reviewing the certifications for light-duty, heavy-duty, motorcycle and non-road engines.[24]

This process can also target potential issues down the road, for example, by paying attention to engine/vehicle specifications and margins of the test results. A good example of this is the Toyota OBD case reviewed in the previous section of this paper. According to an anonymous former CARB Officer, one of the earliest emission recalls issued by the agency was flagged during the review of the manufacturer's certification report when CARB staff noticed an unusually complex carburetor design. Even though CARB did not receive empirical evidence of excessive emissions in this system design at the certification stage, the agency used the information to target this model for in-use testing. Three years later, the model failed the agency's in-use surveillance testing miserably and a recall was issued.

It is worth noting that, under the robust compliance program EPA has been able to further develop over decades, new vehicles are typically certified in the U.S. at one-third to one-half of the emissions limit in order to ensure compliance over the full useful life of the vehicle as emission controls degrade over time (Figure 7). This

[24] Communication with John Urkov

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substantial compliance margin demonstrates that automakers are taking the "useful life" requirement seriously, and designing cars to ensure compliance.

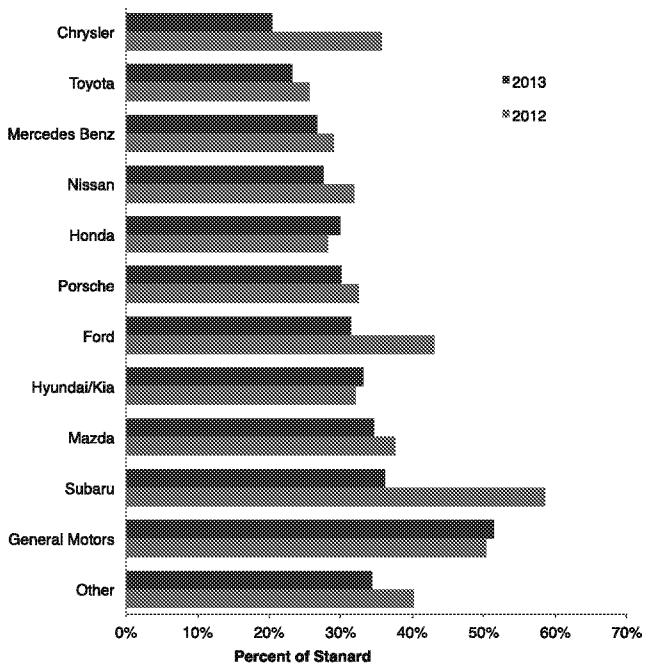

Figure [SEQ Figure * ARABIC]. NOx emission compliance margin at new vehicle certification, CY 2012-2013

6.3 I/M and OBD data

Vehicle inspection and maintenance programs (I/M) are other long-lasting in-use vehicle emission control programs utilized in the U.S. The programs were created to help improve air quality by identifying high-emitting vehicles (gross emitters) in need of repair and having them fixed before they can legally operate on the road again. The 1990 Amendments to the CAA made I/M mandatory for areas across the country that do not meet the national ambient air quality standards (NAAQS). More than thirty states in the U.S. have implemented I/M programs for light-duty vehicles.

High pollution levels cause vehicles to fail I/M tests due to 1) poor design and defects in emission-related parts, 2) deterioration of those parts, 3) poor maintenance of the vehicle, and 4) removing emission control parts (tampering). Vehicle manufacturers are responsible for the first two problems, and vehicle owners are responsible for the other two issues. Therefore, I/M test data can only provide indirect information to help target a possible vehicle recall program. When the I/M data suggests a clear trend/pattern of failure in certain vehicle models, regulators can use the data to discuss potential reasons for the failure and follow up actions with manufacturers directly. One example is the 1978 Chrysler carburetor failure case reviewed in section 5.5.

However, there are limitations for I/M data to be used as a direct data source for compliance actions. The I/M emission limits are designed for the in-use vehicle fleet (and determined differently across states). The emission thresholds (to determine pass and fail) are often three or four times higher than the certification (Type Approval) emission limits. The ability of a traditional I/M test to properly pass/fail noncompliant vehicles is diminishing. For example, a typical IM240 tailpipe emission test uses a standard of 0.8g/mi for hydrocarbons in California, while current Tier 2 (Bin 5) vehicles are certified to 0.018 g/mi. The most accurate exhaust measurement systems used in I/M programs are not capable of accurately measuring exhaust emissions in the range of the Tier 2 standards (ARB, 2008).

I/M tests are also periodical – often performed annually or every other year, and often start from the third year of a vehicle's initial registration in most states. Therefore, they cannot reflect real-time emissions violations of in-use vehicles, especially in newer in-use vehicles.

EPA adopted OBD requirements (as part of vehicle emission standards) starting with MY1996 and MY2005 for light- and heavy-duty vehicles, respectively. The OBD requirements include an OBD threshold limit (OTL), usually 1.5 times of the emission standards. OBD monitors emission control components and performs a series of calculations to make sure emission outputs of the vehicle do not exceed the OTLs.

OBD monitors emission components in real time, and alerts consumers of a needed repair by illuminating an "engine check" light (MIL, or malfunction indicator lamp) on the dashboard. When repair technicians receive the vehicles, they can use inspection equipment (a scan tool) to query the fault codes from the OBD to locate the problem. The data provided by OBD can often pinpoint the specific component that has malfunctioned. If manufacturers see many of the same component malfunctions and warranty claims from the OBD alerts, they will have to report such issues to EPA under a warranty regulation (to be discussed later). OBD data is also an included requirement of the defect reporting requirements. Manufacturers are anxious to recall OBD-identified component failures quickly before warranty complaints mount and owners become annoyed with MIL illumination.

Many states in the U.S. have incorporated an OBD check into the I/M program to enhance its effectiveness The I/M OBD check includes a simple visual check to see if the MIL is illuminated, and also query the OBD fault codes using a scan tool. OBD is calibrated to detect failures at much lower levels than can be detected with the traditional I/M test methods, and therefore, OBD data can be a more reliable data source than I/M data to infer possible emission problems. That being said, failures between the standards and 1.5x standards (OBD threshold) do not cause the OBD lights to illuminate and would not be found without conducting more rigorous in-use testing.

Of course, the success of using OBD data as a clue to identify in-use emission noncompliance depends on the reliability of OBD systems – OBD must be able to illuminate the MIL when an emission malfunction exists. To this end, CARB and EPA have introduced increasingly rigorous OBD requirements into the recent emission standards. OBD failures themselves are also a reason for recalls. In 2012, 9 out of 37 recalls, and 3 out of 30 recalls in 2013 were related to OBD systems. The OBD requirements also include elements designed to prevent fraudulent passing inspections and tampering, therefore helping to improve the effectiveness of I/M programs (Posada & German, 2016).

6.4 Manufacturer-run in-use testing program

Starting from the CAP2000 rule, EPA successfully pushed manufacturers to conduct in-use emissions testing at their own cost. There are two basic categories of the manufacturer-funded in-use testing. One is the in-use verification testing (IUVP) that covers virtually all test groups in each model year, while the other one is the in-use confirmatory testing (IUCP) that consists of more rigorous testing of test groups that demonstrated potentially high emissions in the IUVP.

For the IUVP phase, manufacturers were required to test every test group that they sell. IUVP has more lax surveillance criteria to keep costs down. Manufacturers conduct the test twice, normally around a year after production (low mileage), and 4 years after production (high mileage). For large engine families, 5, 6, or 7 cars need to be tested in each test group; while for smaller engine families, 3 or 4 cars need to be tested. If the vehicles are only marginally failing the standard, then it is not worth the additional cost of investigating it further.

IUVP validates the accuracy of manufacturers' deterioration predictions and processes (including OBD), provides new and comprehensive in-use data that will be useful for other compliance or emissions control programs, and prevents problems from being carried over to future model years (see Figure 7). Manufacturers are more likely to remedy in-use emission problems and defects exposed by their IUVP testing. IUVP identifies in-use problems earlier and on a more widespread basis than EPA's in-use test programs can, since IUVP covers all test groups except for the smallest volumes. EPA's in-use testing typically covers 40-50 test groups each year.

The IUVP program provides EPA with annual real-world in-use test data representing the majority of certified vehicles. The program includes about 2000 in-use tests per year, including both low and high mileage tests on as-received, minimally screened customer-owned vehicles. EPA will review and audit IUVP data to better target failing classes and may follow up with in-use confirmatory tests. The data is also used to validate and, if necessary, revise the manufacturer's deterioration estimates used for certification. EPA will publish summary reports on IUVP results.

Manufacturers are not required to recall based on IUVP data. In practice, if the problem were significant and clear-cut during IUVP, manufacturers often just go straight to remedial actions instead of conducting the more expensive IUCP confirmatory testing. However, if the problem were questionable manufacturers would still spend the money to conduct the IUCP confirmatory testing. If the results show that not a substantial number of vehicles are failing the standards, manufacturers would not initiate a recall.

The IUCP program requires manufacturers to conduct additional recall-quality in-use tests for test groups that fail IUVP testing criteria. A minimum of 10 test vehicles is required for IUCP. There are two criteria for determining whether a more rigorous follow-up test is needed. If 50% of tested vehicles in the test group sample at either the low or high mileage test point fail and the average emissions levels (except CO_2, CH_4, and N_2O) are greater than 1.3 times the standard limits, the manufacturer needs to conduct the IUCP (40 CFR §86.1845, 1846, 1847). To give an example, if six vehicles are tested, and one vehicle is over the standard by 200%, but all the other vehicles comply, on average the test group might exceed 30%. But in reality, most of the cars are okay. These two criteria trigger the in-use confirmatory tests at their expense.

With these programs, essentially EPA pushed the manufacturer to do what the agency was doing. At the same time, EPA still continues its own (in-use surveillance) testing, to ensure manufacturers are providing accurate results. Nevertheless, the

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agency was able to achieve dramatically more test results on a more extensive range of tests at the manufacturer's cost. Since then, EPA relies more on the manufacturers' testing as the main program and conduct less surveillance and follow up confirmatory tests. Table 3 shows the IUVP test volumes of light-duty vehicle tests conducted from calendar year (CY) 2007 to 2013.

Table [SEQ Table * ARABIC]. LDV in-use verification program test volumes

MODEL YEAR	FTP	US06	2-DAY EVAPORATIVE	ORVR
High-Mileage Testing				
2000	1621	618	248	192
2001	2944	620	359	296
2002	2881	727	352	290
2003	2400	536	254	215
2004	1830	1245	248	226
2005	1103	782	142	140
2006	935	671	114	121
2007	1115	781	120	127
2008	1383	992	169	185
2009	677	493	108	101
2010	20	14	5	5
2011	8	7	0	1
2012	5	4	1	0
Low-Mileage Testing				
2004	2000	1859	501	450
2005	2066	1760	462	432
2006	2035	1672	441	444
2007	1429	1186	290	303
2008	757	656	149	150
2009	534	482	116	130
2010	568	500	143	153
2011	978	861	256	264
2012	580	520	148	129
2013	73	73	18	15

Source: US EPA Compliance report, 2007-2013

Figure 8 shows the in-use testing procedures for manufacturers and EPA that lead to recalls.

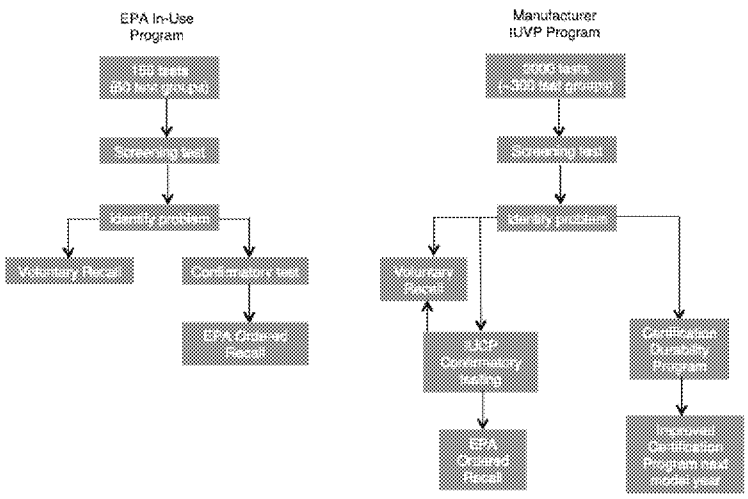

Figure [SEQ Figure * ARABIC]. EPA's compliance procedures leading to recalls

6.5 Warranty data and defect report

The CAA requires manufacturers to warrant certain emission control components on vehicles and non-road engines. The warranties protect vehicle owners from the cost of repairs for emission-related failures resulting from defects in design, materials, and workmanship that cause the vehicle or engine to exceed the emission standards.

There are two types of warranties: performance warranty and design and defect warranty. The performance warranty covers any repair or adjustment that is necessary to make a vehicle pass a locally-required emission test (like an I/M) during the warranty period as long as the vehicle has been properly maintained according to the manufacturers' specifications and has not been misused. The design and defect warranty covers the repair of emission related parts that become defective due to a defect in materials or workmanship during the warranty period. Major emission control components, like catalytic converters, electronic control units, and onboard diagnostic devices, are covered for 80,000 miles of use or the first 8 years (whichever is reached first), and other parts are covered for 24,000 miles of use or the first 2 years.

In the 1990s, California initiated an emission parts warranty report program. In the same decade, EPA introduced an emission defect reporting regulation. These are slightly different approaches, but both serve as useful data sources for regulatory agencies to target classes for further compliance actions, and often direct inference to voluntary recalls.

In California, manufacturers are required to review warranty claim records for each engine family or test group on a quarterly basis. When the cumulative number of warranty claims, without any prescreening, for a specific emission-related component or repair represent at least one percent or twenty-five (whichever is greater) of the

vehicles or engines of a California-certified engine family or test group, the manufacturer is required to compile the number of claims made for emission-related components by cumulative total and report it to CARB. The warranty reports need to be updated quarterly. A manufacturer will need to file a field information report and emissions information report if affected cars reach a certain level after the initial warranty information report.

If there is more significant share or number of warranty claims subject to a specific emission issue, the vehicles, engine families or test groups are subject to recall. Table 4 below shows the threshold failure rates in California by model year. Nearly half of the vehicles recalled in California between 1990 and 2005 were triggered by the warranty report program.[25]

Table [SEQ Table * ARABIC]. Warranty claim levels triggering recall

MODEL YEAR	%	NUMBER
1990-1991	4	50
1992-1993	2	50
1994 and later	2	50

Source: 13 CCR §2143, 2144

CARB takes a rigorous approach to verify manufacturer's self-reported warranty data. Field representatives from the agency visit the dealership and talk to the dealership managers and technicians, after the initial warranty report is received. The investigators go through warranty records, and request dealership managers and technicians to show the number of stock of parts on the shelf to be replaced. The technicians also possess information such as what parts the dealer is stocking more of because of too many recurring issues/repairs. The agency staff then compares the information from the dealers with what the manufacturers reported. This approach is resource-intense, "four people would spend a day at one dealership just going through warranty files," according to a former Officer at CARB.[26]

At the federal level, EPA requires manufacturers to report emission-related defects (40 CFR §85.1903). An emission-related defect is a defect in design, materials or workmanship in a device, system or assembly, as described in the approved application for certification. Manufacturers must report a defect even if it does not increase emission levels. The rule applies to cars, light trucks, SUVs, heavy-duty trucks, buses and motorcycles as well as non-road equipment. For highway vehicles and most engines (40 CFR §85.1903),[27] when the manufacturer learns of a specific emission-related defect in more than 25 vehicles/engines of the same class and model year, it must report the emission defect to EPA within 15 working days. The report must include a description of the defect, number of defective vehicles, any data on how the defect affects emissions as well as any additional impact when driving the vehicle. EPA encourages manufacturers to conduct a voluntary recall

[25] Raw data were from CA's in-use compliance testing and recall activity report 2004-2005.

[26] From interview with John Urkov

[27] For other engines, see 40 CFR §1068.501.

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when they see problems from sources such as defect reports, or EPA can test the vehicles with defects to determine if they should be recalled.

Tables 5 and 6 show the number of defect reports and light-duty vehicles affected by manufacturer and by problem category during the 2013 calendar year.

Table [SEQ Table * ARABIC]. CY2013 Light-duty vehicle defect reports by manufacturer

MANUFACTURER	NUMBER OF DEFECT REPORTS	NUMBER AFFECTED VEHICLES
Audi	10	422,824
BMW	27	943,617
Chrysler	21	5,132,529
Fisker	4	2,835
Ford	15	2,136,197
General Motors	16	1,030,862
Honda	22	14,188,404
Hyundai	11	5,663,236
Isuzu	1	4,465
Jaguar/Land Rover	2	48,831
Kia	12	1,716,271
Lotus	1	5,476
Mazda	16	1,297,365
Mercedes-Benz	12	325,053
Mitsubishi	2	30,263
Nissan	16	1,616,751
Porsche	15	158,344
Rolls Royce	1	523
Subaru	2	576,169
Toyota	3	195,800
Volkswagen	8	304,846
Volvo	4	398,627

Table [SEQ Table * ARABIC]. CY 2013 Light-duty vehicle defect reports by problem category

PROBLEM CATEGORY	NUMBER OF DEFECT REPORTS	NUMBER OF AFFECTED VEHICLES
Air Inlet/Intake System	6	943,866
Catalyst System	8	257,317
Computer Related (other than OBD)	35	6,730,630
Crankcase Ventilation System	1	37,240
EGR System	2	104,979
Electrical, Mechanical &Cooling Systems	23	3,656,946
Emissions Control Information Label	4	46,193
Evaporation Emissions System	19	2,834,713
Exhaust System	5	596,083
Fuel Delivery Component	22	1,260,052
Fuel Delivery System	2	68,132
Fuel Tank System	8	622,631
Hybrid Vehicle System	6	176,757
Ignition System	8	1,716,819
Monitoring/Measuring Sensor/System	12	11,593,222
NOx Sensor	6	227,618
OBD System	32	3,244,916
On-Board Refueling and Vapor Recovery	1	511,377
Oxygen Sensor	8	1,131,552

Secondary Air System	2	115,765
Selective Catalytic Reduction System	6	77,944
Turbocharger/Supercharger	4	244,536

Source: U.S. EPA Compliance report, 2012-2013

The discovery of these defects often leads to voluntary recalls or service campaigns. Manufacturers are also required to report all emission-related voluntary recalls to EPA. However, an emission-related defect does not necessarily lead to an emission recall because not all defects in emission-related parts increase emissions. More often, this leads to an extended warranty or some other remedy. This is all negotiated between the manufacturers and the agency.

There is no direct correlation between the number of defect reports, recalls, and the number of vehicles that are recalled. A manufacturer may identify a lot of defects that are not significant enough to warrant a recall. On the other hand, a manufacturer could have a few major defects that evolve into major recalls affecting large portions of their product line. Historically, emission recalls affect about three million vehicles annually, although the number may vary in any given year (EPA progress report, 2015).

Defect reporting provides EPA with "a valuable source of 'suspect classes'" to investigate in the recall area. Based on manufacturer reports, EPA can then test the vehicles with defects to determine if they should be recalled. Many recalls occur because of defect reports. Therefore, EPA has become strict on manufacturer reporting. Manufacturers are penalized if they do not report defects on time. As we reviewed in a previous section, in 2005, Daimler-Chrysler was fined $5 million for not reporting their defective catalysts. The same year, VW was fined $1.1 million for waiting over a year to report after finding many defective oxygen sensors (EPA news release, 2005).

However, "a weakness in the rule is that the emission defect data completely depends on the manufacturer's reporting as well as defining what a defect was," according a former Officer at EPA.[28] EPA sets thresholds for reporting defects and the rule gives manufacturers enough leeway to determine when/how to report. For example, if defects cannot be accurately matched to certain model year and family, manufacturers can use "good engineering judgment" (40 CFR 1068.501 g(1)). Manufacturers can also use statistical methods to project defect rates for vehicles/engines that they are not otherwise able to evaluate (40 CFR §1068.501 g(7)). This might introduce some level of gaming.

6.6 Other sources

Other data sources to inform emission recalls include consumer complaints, manufacturer bulletins, direct communication with service technicians, information from competitors, independent research, and more.

EPA's Office of Enforcement and Compliance Assurance (OECA) handles complaints of environmental violations. According to a former Officer at EPA, one case was discovered based on consumer (and dealer) complaints about a gasoline smell inside the car. OECA received the complaints, pursued it, and ultimately

[28] Direct communication with Charles Freed

discovered this emission violation case – the affected vehicles had a defective device that separated liquid and vapor in the vehicle's fuel control system. The tiny crack caused a gas leak, which is why drivers smelled a strong gasoline odor inside the cars.

Many states also have an environmental complaint program. For example, California has a Smoking Vehicle Complaint Program that guides and encourages the public to report smoking vehicles on the roads.[29] Some private companies collect and compile consumer complaints related to vehicle safety and environmental features. For example, an online automotive complaints resource showed multiple complaints about a fuel tank crack and gas leak in the 1997 Hyundai Sonata.[30] This was reflected in the voluntary recall of over thirty thousand MY1997-1998 Sonatas by the automaker.[31]

EPA staff also reach out to manufacturers, dealers and service technicians to collect useful information for their vehicle emission compliance program. According to an Officer at EPA,[32] one information source that helped nail down the 1998 diesel engine defeat device case was a competitor of the manufacturers in question.

In addition, independent research projects run by universities and research groups can be another indirect information source to identify emission violations. An example is the 2015 Volkswagen defeat device case reviewed in section 5.6, where the ICCT's research on real-world diesel car emissions, conducted by WVU, triggered further investigation from regulatory agencies.

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[29] See more info at http://www.arb.ca.gov/enf/complaints/smoke.htm

[30] See more info at http://www.carcomplaints.com/Hyundai/Sonata/1997/fuel_system/fuel_system_gasoline-storage-tank_assembly.shtml

[31] Data are from EPA CY2001 emissions related recall/service campaign report

[32] Karl Simon

7 Post-recall actions

Recall is not the overall purpose of the compliance program. The ultimate goal of the program is to make sure the problem gets fixed, thereby preventing excessive pollution from vehicles or engines that are already being used by customers. Recalls, and the compliance program in general, provides valuable feedback to improve future regulations and the development of standards.

When an emissions recall occurs, the manufacturer must notify vehicle owners and provide instructions on how to have their vehicle repaired. The manufacturer must tell the owners that the manufacturer will repair the vehicles at no cost to the owner. Regulatory agencies develop follow up requirements and alternative environmental remedy plans after the recall occurs. Manufacturers are required to report all voluntary recalls to EPA within 15 days of owner notification, then as a follow up, report the progress of the recall to EPA on a quarterly basis for six consecutive quarters. If the number of owners repairing vehicles is too low, EPA can request the manufacturer to re-notify owners about the availability of free repair.

Commented [RM2]: How low...?

After recalls are initiated, the manufacturer and EPA engineers investigate to determine the cause of the emission failure. The manufacturer develops a plan to notify owners and repair the cars that need EPA approval. The letter to owners may notify them that unless the car is repaired, it may fail the I/M test and void their warranty. Repair is voluntary, but some states are considering not registering cars that have not been repaired. California is the only state with merged registration and recall databases. The state requires recalls to be completed before I/M testing is performed. EPA notifies state I/M programs of voluntary and influenced recalls so states may inform owners about emission recalls available for their cars. Manufacturers also need to notify state I/M programs.

Even with these follow ups, not all problem vehicles are fixed. About 40% of owners who receive a recall notice have their cars repaired. Possible reasons are that some people don't see it a priority since it does not pose an immediate safety threat, or the repair will result in lower performance and fuel economy.

Thus, regulatory agencies will require manufacturers to submit supplemental environmental projects (SEP) plans[33] that offset the possible impact of their violations in the settlement. These SEPs are agreed-upon environmentally beneficial projects related to the violation in exchange for mitigation of the penalty in a settlement agreement. Part of the penalty includes EPA negotiating the environmental projects the company needs to do to make up for the emissions due to owners opting to not repair their vehicles. Example SEPs include engine emissions standard pull-ahead, retrofit projects and programs to reduce pollutant emissions from other sources. These SEPs do not necessarily involve the products of the manufacturers. For example, in the 2003 settlement involving Toyota's evaporative emissions control function of the OBD system, Toyota spent $20 million on a SEP to retrofit up to an estimated 3,000 public in-service diesel fleet vehicles to make them run cleaner, including enhancement of the availability of ultra low-sulfur diesel fuel. In the 1998 diesel engine settlement, Caterpillar was required to do a MY2004 standard pull-

[33] See more info at http://www2.epa.gov/enforcement/supplemental-environmental-projects-seps

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ahead, a non-road engine standard pull-ahead, an adjustment of average banking and trading, a low-NOx rebuild program and other SEPs.

Most importantly, in-use compliance and recall programs provide valuable feedback to improve future emissions standards and certification procedures. Emission type approval certification is the cornerstone and starting point of a compliance program. However, there are still limitations in test protocols and methods of certification tests. In-use compliance testing can offer lots of useful data to close the loopholes in current certification procedures. This has been evidenced in several of the examples reviewed, including the enhanced OBD program after the Toyota OBD case in 2003 and the improved PEMS-based test procedures for heavy-duty vehicles and engines following the 1998 HD engine defeat device case. Regulators need to revisit their certification procedures and approaches to best reflect emissions characteristics during real world driving.

As vehicle and emission control technologies advance and emission regulations become increasingly more complicated, additional undefined areas may exist. For example, in the 1970s, electronic controls and the three-way catalytic convertor emerged, while late in the same era the first fuel economy regulation went into effect. Regulators at EPA saw the potential for the electronics to have very selective calibrations. On that basis, EPA staff drafted an Advisory Circulars to industry saying that the agency would inspect the actual performance of these systems and if they exceed a certain amount of NOx emissions the agency would consider that defeating the emissions control.

An Advisory Circular is a semi-formal document produced by EPA to communicate with and provide guidance to the industry, often regarding how to comply with a regulation pertaining to emission control systems. For example, the A/C 24-2 on defeat devices mentioned previously was released partly due to the quick development of new technology, especially electronic control and modulation devices. The A/C provides HwFET NOx guidelines for manufacturers as optional objective criteria for defeat device determination, other guidelines for EPA's determination, and actions to be taken if a device is determined to be a potential defeat device. In the 1970s only, EPA produced more than 50 advisory circulars to clarify different aspects of emission control systems.[34]

The EPA has a track record of such Advisory Circulars dating back to the 1970s.[35] Figure 9 below shows the number of Advisory Circulars issued by EPA by year over the past several decades.

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[34] Communication with Michael Walsh

[35] See more info at [HYPERLINK "https://www3.epa.gov/otaq/cert/dearmfr/dearmfr.htm"]

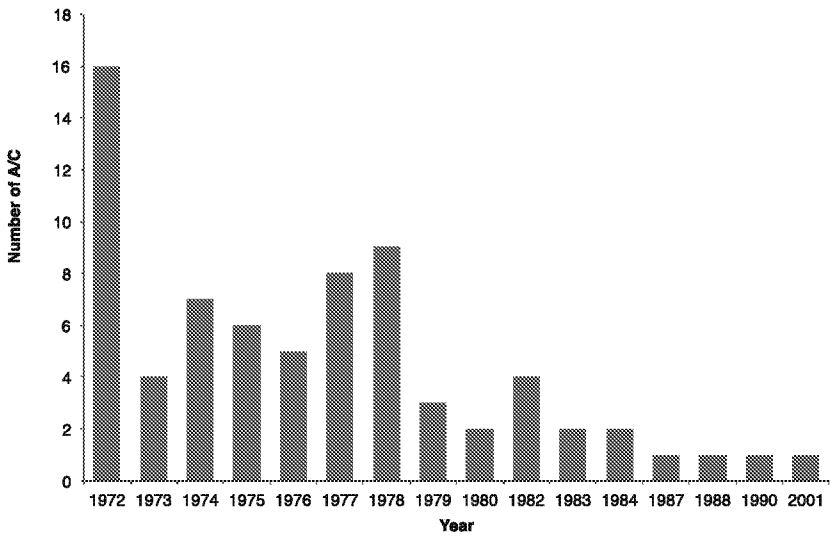

Figure [SEQ Figure * ARABIC]. Number of advisory circulars (all years)

EPA also issues guidance letters to provide information, guidance and instructions to the regulated automotive industry on specific compliance topics and issues. EPA has a track record of such guidance letters dating back to the late 1970s.[36] Figure 10 below shows the number of guidance letters issued by EPA by year.

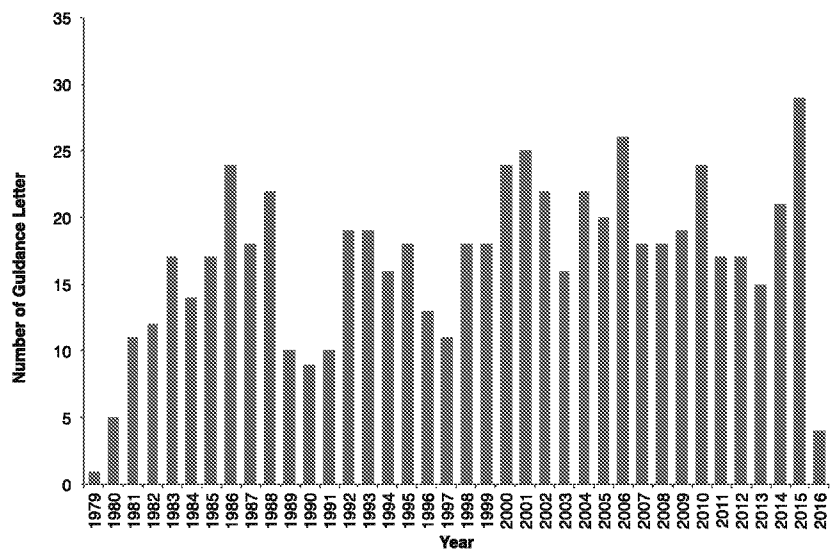

Figure [SEQ Figure * ARABIC]. Number of guidance letters from 1979 to 2016

[36] See more info at [HYPERLINK "https://www3.epa.gov/otaq/cert/dearmfr/dearmfr.htm"]

8 Findings and recommendations

8.1 Findings

- Establishing both the CAA and EPA were key to the historically successful vehicle emission control and compliance program in the U.S. EPA is an agency with a clear mission – whereas in many other countries the regulations are not enforced by an agency with such a mission. Strong and clear legal authority are the foundation for EPA and CARB's robust vehicle emission compliance programs, in addition to their clear missions to protect public health and environment. The agencies have clear authority to establish test protocols for in-use compliance testing, require manufacturers to conduct tests, provide warranty and defect data to the agencies, and most importantly, the authority to revoke Certificates of Conformity, recall, and impose punitive fines on non-compliant vehicles. Withholding of the Certificate of Conformity, which is an approval to sell vehicles in the U.S., is an extremely powerful tool for regulatory agencies to negotiate with manufacturers on compliance actions.
- The comprehensive vehicle emission compliance program adopted in the U.S. was built up over decades. The process has involved a learning curve for both regulators and industry. In the early 1970s and 1980s, there were many contentious cases that ended up in the court. Overtime, the agencies have been successful in working with manufacturers to issue voluntary recalls. Since the 1990s, most cases have not been contentious and were done on a voluntary basis. This shift is a positive sign that the requirements and enforcement criteria are detailed and clear, such that it is also in the best interest of manufacturers to do the right thing by closely following the regulation and avoiding mandatory recalls.
- Strong and continuously growing staff capacity is another key to a successful emission compliance program. Both EPA and CARB were able to build up their programs with top experts hired from industry. It takes time and resources to get the technical expertise established and maintained as new technologies emerge. As one former Officer at ARB noted,

  > *"What ARB has done in the past 30 some years is carefully screen the staff, and we have some of the best… The OBD program is one of the most difficult because you need to understand all of the software in terms of how the vehicle operates, and how the emission control works. It takes probably 4 to 5 years working with the staff, involving them in lab, in-use testing, reviewing certification and applications that manufacturers submit before production, (to get them familiar with the process)."*

- In the U.S., compliance is now a shared burden between regulatory agencies and manufacturers. Today's compliance program has a strong focus on manufacturer responsibility in ensuring their vehicles/engines meet the standards throughout the lifetime of a vehicle, by requiring manufacturers to conduct large scale in-use testing, reporting warranty data and defects, and conducting voluntary recalls. This allows the regulatory agencies to play more of a supervisory role and focus their limited resources on the most critical issues.
- In the U.S., regulatory agencies perform rigorous in-use confirmatory testing, and these tests are the most direct source of data to consider a recall. It's also

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important that the agencies have their own government-run testing facilities, such as EPA's Ann Arbor, Michigan lab. In addition, the agencies have a number of indirect data sources to guide the recall tests. These include, but are not limited to: 1) certification data, which can be useful in several ways, for example, to target vehicles with small compliance margins and vehicles deployed with new technologies; 2) information (including OBD information) from state I/M programs; 3) manufacturer warranty data and defect reports; 4) failures at manufacturer-run in-use verification program (IUVP) testing; 5) complaints from consumers, service providers, independent research projects involving real-world emissions testing.

- A full-scale in-use testing program could be quite expensive, as the agencies usually need to recruit sufficient amount of vehicles from consumers and pay for additional substitute vehicles, maintenance and financial compensation to the vehicle owners. In the early stages, the U.S. regulatory agencies had too little resources to run full-scale in-use testing. CARB started its in-use program by using the government fleet as its test vehicles. Even with a limited scope, CARB's initial in-use testing program was very successful in identifying issues like OBD failures.
- Rigorous documentation of compliance tests conducted by regulatory agencies, and engaging manufacturers in these tests is extremely instrumental to a successful recall. During the early years of each compliance program, regulatory agencies experienced situations where manufacturers could easily discredit their data. In reaction, the agencies realized their learning curve and established protocols to obtain defensible data to utilize in court.
- It is important to have a feedback loop for certification test procedures based on lessons learned from in-use compliance testing. Emission type approval certification is the cornerstone and starting point for a compliance program. However, there are still limitations in test protocols and methods of certification tests. In-use compliance testing can offer lots of useful data to close the loopholes in the current certification procedures, as evidenced in several examples reviewed: the enhanced OBD program after the Toyota OBD case in 2003, the improved portable emissions measurement system (PEMS)-based test procedures for heavy-duty vehicles and engines after the 1998 heavy-duty engine defeat device case, and the development of supplemental federal test procedure (SFTP) after the General Motors defeat device case in 1995. Regulators need to revisit both their certification procedures and approaches to ensure they best reflect emissions characteristics during real world driving.

8.2 Recommendations

Based upon these findings, the following best practices and key elements are recommended to build a successful vehicle emissions compliance and recall program.

- Governments should seek to establish strong and clear authority through legislation for environmental regulatory agencies to establish, implement, and enforce emission standards. This should include clear authority to levy fines and recalls.
- Governments should establish requirements in the appropriate legislation for emission warranty provisions and for vehicles and engines to meet emissions standards throughout their entire "useful life," which is the time span throughout which the emissions performance of a vehicle must comply with the prescribed

standards. For example, the current definition of useful life in the U.S. Tier 3 emission standard for light-duty vehicles is 150,000 miles.

- Once legal authority is established, agencies must exercise authority. Penalties should be imposed on vehicle manufacturers that deter from noncompliance. Regulatory agencies should use their power to void new vehicle/engine emission type approval certificates.
- Build internal technical capacity within environmental regulatory agencies to conduct and manage the compliance testing and recall programs. Recruit the best experts in the field, including experienced technicians to carry out the lab work.
- A compliance program needs to be operated by government resources that are not influenced by industry. It is also important for the regulatory agency to own a purely government-run test lab. The regulatory agency must have sustainable, long-term funding streams to support running the compliance program. When starting a program, there are ways to deal with limited resources in the short term:
    - Start the program with robust certification testing and production (assembly line) conformity testing if staff capacity and resources are limited. Once regulatory agencies gain sufficient confidence into these two stages, then in-use becomes more important.
    - Consider starting in-use testing with government and public fleets.
    - Give manufacturers some flexibility when introducing new programs to leverage manufacturer resources for the new elements. After the pilot stage proves their effectiveness, transition the programs into full-scale.
- Create a program in a way that shares the compliance burden among governments (central and local), industry and vehicle owners. Establish sub-programs requiring industry to provide compliance related data. Policy makers could investigate whether and how these programs may be adopted in their regional context.
    - Require manufacturers to conduct large scale of in-use testing, with sufficient government confirmatory testing to ensure accurate results. This data should have a feedback loop into the deterioration calculations for certification.
    - Require an emission warranty program.
    - Require manufacturers, dealers, and the service industry to provide emission warranty and defect data.
    - Require manufacturers to recall vehicles if feedback from the above sub-programs indicate an emissions violation.
    - Establish a credible I/M program along with other emission inspection programs such as remote sensing programs at local levels to ensure emissions components are not tampered with by users. Integrate OBD into the I/M programs to increase test accuracy and credibility.
- Establish test protocols to detect defeat devices. This includes, but is not limited to, using a combination of methods such as PEMS-based real-world driving tests, OBD examination, modified driving test cycles and test procedures for laboratory tests.

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- Consider utilizing testing projects conducted by independent third parties/research entities as an additional data source.
- Establish protocols for documenting the vehicle selection, testing and data collection processes, in order to obtain defensible data to initiate recalls. Consider engaging manufacturers in some of the processes. It is crucial to define "proper maintenance" and verify the test vehicles used for compliance actions are well maintained for the kind of emission problem in question.
- Use the feedback from in-use compliance programs to improve the new emission standards and certification procedures. As vehicle and emission control technologies continue to advance and emission regulations become increasingly complex, additional undefined areas may arise. As regulatory agencies become aware of these areas, and if there is potential for undercutting the purpose of the regulation, the agencies should try to better define these areas by spelling out specifically what they intended within the wording of the regulation itself to further clarify the intended interpretation.

References

Part 1: Clean Air Act Provisions

- Sec. 202 Emission standards for new motor vehicles or new motor vehicle engines (including on board diagnostics (OBD) requirements)
- Sec. 203 Prohibited acts
- Sec. 205 Civil penalties
- Sec. 206 Motor vehicle and motor vehicle engine compliance testing and certification
- Sec. 207 Compliance by vehicles and engines in actual use (including remedy for non-conformity)
- Sec. 208 Information collection (including manufacturer testing)

40 CFR Subchapter C Part 86 Subpart S

- Recall regulations

40 CFR Subchapter C Part 85 Subpart T

- Emission defect reporting requirements

40 CFR Subchapter C Part 86 Subpart S

- General compliance provisions for control of air pollution from new and in-use light-duty vehicles, light-duty trucks, and heavy-duty vehicles

40 CFR Subchapter U Part 1027

- Fees for engine, vehicle, and equipment compliance programs

40 CFR Subchapter C Part 1068 Subpart F

- Reporting defects and recalling engines/equipment

13 CCR Division 3 Chapter 2

- Enforcement of vehicle emission standards and surveillance testing

13 CCR Division 3 Chapter 1 Article 2 §1968.1

- Malfunction and diagnostic system requirements- 1994 and subsequent model-year passenger cars, light-duty trucks, and medium-duty vehicles and engines

Part 2: Other References

[BIBLIOGRAPHY]

Appendix I

Profile of interviewees of this project
*Names are displayed in the alphabetic order

Commented [HH3]: Need to confirm information with interviewees. Also, importantly, need to ask whether they would like to disclose this information , and whether they would like to be quoted in the paper

NAME	AGENCY	TITLE	DESCRIPTION OF RESPONSIBILITY	INTERVIEW DATE
Steve Albu	ARB	Assistant Chief, Mobile Source Control Division	Led multiple activities within MSCD, 1982-2012	Sept 18, 2015
Adriane Chiu (via email only)	ARB	Staff, OBD Branch, Emissions Compliance, Automotive Regulations and Science Division	OBD program development, Current	Sept 29, 2015
Charles Freed (via email only)	EPA	Director, Manufacturer Operations Division, Office of Mobile Sources	Enforcement such as vehicle recall and SEA the 70s-90s	Oct-Dec, 2015
John German	EPA	Senior Technical Advisor, Office of Mobile Sources	Research and regulations, 1985-1998	Sept 28, 2015
Robert Maxwell	EPA	Director, Certification Division, Office of Mobile Sources	Vehicle and engine certification program during 1972-1996	Sept 18, 2015
Margo Oge	EPA	Director, Office of Transportation and Air Quality[a]	Led OTAQ during 1994-2012	Oct 16, 2015
Karl Simon	EPA	Director, Transportation and Climate Division, OTAQ	Multiple roles from 1989 to now, including compliance and policy.	Oct 16, 2015
John Urkov	ARB	Branch Chief, In-Use Compliance Program, Mobile Source Control Division	In-use testing and recall during 70s-00s	Sept 16, 2015
Michael Walsh	EPA	Deputy Assistant Administrator, Office of Mobile Source Air Pollution Control	Vehicle and engine certification and emission control in the 70s	Oct 1, 2015

[a] OTAQ, or Office of Mobile Sources before the name change

2012-2013 Progress Report

Vehicle & Engine Compliance Activities

United States Environmental Protection Agency

EPA-420-R-15-007

2012-2013 Progress Report

Vehicle & Engine Compliance Activities

United States Environmental Protection Agency
Office of Transportation and Air Quality
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Washington, DC 20460

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www.epa.gov/otaq

Contributors

Peter Caffrey
Phil Carlson *
Emily Chen
Karen Danzeisen
Allen Duncan
Dave Good
Fakhri Hamady *
Stephen Healy
Michelle Ibarra
Gregory Orehowsky
Bill Pidgeon
Christi Poirier *
Holly Pugliese
Michael Sabourin
Lynn Sohacki
David Swain
Carl Wick
Ching-shih Yang

* Compliance Center Editor

General Editor

Mark Wolcott

Graphic Design

Gwen Dietrich

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Compliance Report Organization

1. Chapter I, Forward by the Compliance Division Director and program highlights.

2. Chapter II, Scope of EPA's Vehicle, Engine, Equipment, and Fuel Compliance Programs, describes the laws that authorize EPA's mobile source compliance activity.

3. Chapter III, Compliance Programs and Processes, describes the compliance programs and processes in more detail and provides compliance data and other information organized by industry sector. Please refer to Figure 1 on the next page for examples of the vehicles, engines, and equipment that are included in each industry sector.

4. Chapter IV, Industry Statistics, presents industry statistics that are contained within the compliance information that EPA collects.

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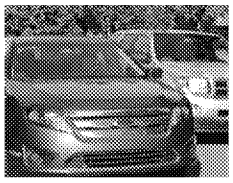

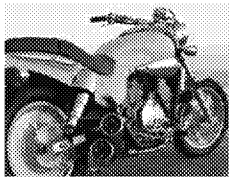

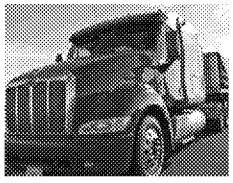

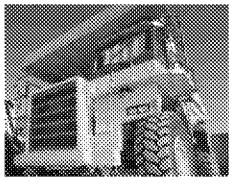

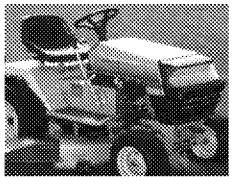

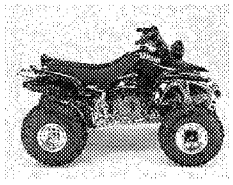

MY 2012 – 2013 Compliance Report

This is the fourth in a series of vehicle and engine compliance reports issued by the U.S. Environmental Protection Agency – Office of Transportation and Air Quality – Compliance Division. These reports offer a convenient reference to the data that the Compliance Division collects in implementing emissions regulations for vehicles, engines, and other motorized equipment. The environmental programs the Compliance Division implements apply to virtually every vehicle, engine and gallon of transportation fuel sold in the United States. It is EPA's job to make sure that these regulated mobile sources comply with emissions and fuel economy requirements. The Compliance Division's role in the Office of Transportation and Air Quality is essential to realizing the Agency's national air quality and public health goals.

The 2012 – 2013 Progress Report on vehicle and engine compliance activities (2012 – 2013 Compliance Report) updates and builds upon the data and information presented in the first three reports which cover compliance activities for the 2007 – 2011 model years. These reports can be found on our web site at http://www.epa.gov/otaq/hwy.htm. This report presents certification data and other types of information EPA collected for model years (MY) 2012 and 2013 and for calendar years (CY) 2012 and 2013.[1]

The Compliance Division oversees a broad set of compliance activities to ensure that vehicle and engine manufacturers satisfy their regulatory obligations. These activities range from issuing certificates of conformity before vehicles and engines enter into commerce to monitoring in-use testing and reporting afterward. In addition to regulating vehicles and engines, EPA regulates motor vehicle fuels, including gasoline, diesel and renewable fuels such as ethanol and biodiesel. Please see EPA's fuels web site, http://epa.gov/otaq/fuels/, for further information about the fuel compliance program.

We recommend that readers who are unfamiliar with EPA's mobile source emission control programs refer to the 2007 Compliance Report for additional background information, including descriptions of the vehicle, engine, and fuel categories EPA regulates.

[1]Some information is reported by model year while other types of information (e.g., recalls and defects) are reported by calendar year.

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On an annual basis, EPA issues a report documenting light duty manufacturers' compliance with the light duty greenhouse gas (GHG) standards. These standards apply to cars and light trucks, beginning with the 2012 model year. Manufacturers must meet standards for tailpipe methane and nitrous oxide emissions, plus increasingly stringent fleet average standards for carbon dioxide in each model year through 2025. Reports for both 2012 and 2013 model years have been published, please refer to these two reports for detailed information on the light duty GHG program.

The highlights that follow provide additional examples of information that is available today and that is explained in more detail in the body of the report.

Byron Bunker
Director, Compliance Division
Office of Transportation and Air Quality
USEPA National Vehicle and Fuel Emissions Laboratory
2565 Plymouth Road
Ann Arbor, MI 48105

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HIGHLIGHTS

Highlight 1 – EPA Investigation Prompts Carmakers to Correct Inflated Fuel Economy Claims

The fuel economy label (the window sticker that appears on new cars) provides consumers with reliable and repeatable estimates of real-world fuel economy for national average drivers and conditions. This allows consumers to compare fuel economy across different car models. EPA requires auto manufacturers to *revise* miles per gallon (MPG) values on fuel economy labels if relevant information becomes available that shows that the original values are too high.

EPA oversees the MPG values on fuel economy labels by:

- conducting independent testing on about 15% of vehicle models each year on pre-production vehicles provided by manufacturers
- testing cars and trucks that are already in use to confirm that the fuel economy labels are accurate for production vehicles placed into commerce
- assessing information provided by consumers, consumer groups, and the auto industry to identify models for further testing.

If testing reveals that fuel economy labels are *in*accurate, EPA will require manufacturers to update the MPG label to provide consumers with the best information available. Such was the case for several manufacturers' 2012–2013 vehicle models described in figures F1 – F6 below.

Figure F-1
Ford 2013-2014 Model Year Fuel Economy (FE) Label Changes

Carline	Model	City FE (MPG)			Highway FE (MPG)		
		old	new	change	old	new	change
Fusion	Hybrid	47	42	-5	47	41	-6
C-Max	Hybrid	45	40	-5	40	37	-3
Lincoln	MKZ Hybrid	45	38	-7	45	37	-8
Fusion	Energi Plug-In	44	38	-6	41	36	-5
C-Max	Energi Plug-In	44	38	-6	41	36	-5

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Figure F-2
Hyundai 2012 Model Year Fuel Economy Label Changes

Carline	Model	City FE (MPG)			Highway FE (MPG)		
		old	new	change	old	new	change
Accent	1.8 L Automatic	30	28	-2	40	37	-3
	1.8 L Manual	30	28	-2	40	37	-3
Azera	3.3L Automatic	20	20	0	29	28	-1
Elantra	1.8 L Automatic	29	28	-1	40	38	-2
	1.8 L Manual	29	28	-1	40	38	-2
Genesis	5.0 L Automatic	17	17	0	26	25	-1
	4.6 L Automatic	17	16	-1	26	25	-1
	5.0 L R-Spec Automatic	16	16	0	25	25	0
	3.8 L Automatic	19	18	-1	29	28	-1
Sonata	Hybrid	35	34	-1	40	39	-1
Tucson	2.4L Automatic 4wd	21	20	-1	28	27	-1
	2.4L Automatic 2wd	22	21	-1	32	30	-2
	2.4L Manual 4wd	20	19	-1	27	25	-2
	2.4L Manual 2wd	21	20	-1	29	27	-2
	2.0L Automatic 2wd	23	22	-1	31	29	-2
	2.0L Manual 2wd	20	20	0	27	26	-1
Veloster	Automatic	29	27	-2	38	35	-3
	Manual	28	27	-1	40	37	-3

Figure F-3
Hyundai 2013 Model Year Fuel Economy Label Changes

Carline	Model	City FE (MPG)			Highway FE (MPG)		
		old	new	change	old	new	change
Accent	Automatic	30	28	-2	40	37	-3
	Manual	30	28	-2	40	37	-3
Azera	3.3L Automatic	20	20	0	30	29	-1
Elantra	1.8 L Automatic	29	28	-1	40	38	-2
	1.8 L Manual	29	28	-1	40	38	-2
	1.8 L Blue Automatic	30	28	-2	40	38	-2
	1.8 L GT Automatic	28	27	-1	39	37	-2
	1.8 L GT Manual	27	26	-1	39	37	-2
	Elantra Coupe Automatic	28	27	-1	39	37	-2
	Elantra Coupe Manual	29	28	-1	40	38	-2
Genesis	5.0 L R-Spec Automatic	16	16	0	25	25	0
	3.8 L Automatic	19	18	-1	29	28	-1
Santa Fe	2.4 L Sport Automatic 4wd	21	20	-1	28	26	-2
	2.4 L Sport Automatic 2wd	22	21	-1	33	29	-4
	2.0 L Sport Automatic 4wd	20	19	-1	27	24	-3
	2.0 L Sport Automatic 2wd	21	20	-1	31	27	-4
Tucson	2.4L Automatic 4wd	21	20	-1	28	27	-1
	2.4L Automatic 2wd	22	21	-1	32	30	-2
	2.4L Manual 4wd	20	19	-1	27	25	-2
	2.4L Manual 2wd	21	20	-1	29	27	-2
	2.0L Automatic 2wd	23	22	-1	31	29	-2
	2.0L Manual 2wd	20	20	0	27	26	-1
Veloster	Automatic	29	28	-1	40	37	-3
	Manual	28	27	-1	40	37	-3
	Turbo Automatic	25	24	-2	34	31	-3
	Turbo Manual	26	24	-2	38	35	-3

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Figure F-4
Kia 2012 Model Year Fuel Economy Label Changes

Carline	Model	City FE (MPG)			Highway FE (MPG)		
		old	new	change	old	new	change
Optima	Hybrid	35	34	-1	40	39	-1
Rio	Automatic	30	28	-2	40	36	-4
	Manual	30	29	-1	40	37	-3
Sorento	2.4 L Automatic 4wd SIDI	21	20	-1	28	26	-2
	2.4 L Automatic 2wd SIDI	22	21	-1	32	30	-2
Soul	1.6 L Soul Eco	29	26	-3	36	31	-5
	1.6 L Soul Automatic	27	25	-2	35	30	-5
	1.6 L Soul Manual	27	25	-2	35	30	-5
	2.0 L Soul Eco	27	24	-3	35	29	-6
	2.0 L Soul Automatic	26	23	-3	34	28	-6
	2.0 L Soul Manual	26	24	-2	34	29	-5
Sportage	2.4 L Automatic 4wd	21	20	-1	28	27	-1
	2.4 L Automatic 2wd	22	21	-1	32	30	-2
	2.4 L Manual 4wd	20	19	-1	27	25	-2
	2.4 L Manual 2wd	21	20	-1	29	27	-2
	2.0 L Automatic 2wd	22	21	-1	29	28	-1
	2.0 L Automatic 4wd	21	20	-1	26	25	-1

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Figure F-5
Kia 2013 Model Year Fuel Economy Label Changes

Carline	Model	City FE (MPG)			Highway FE (MPG)		
		old	new	change	old	new	change
Rio	Automatic	30	28	-2	40	36	-4
	Manual	30	29	-1	40	37	-3
	Eco Automatic	31	30	-1	40	36	-4
Sorento	2.4 L Automatic 4wd SIDI	21	20	-1	28	26	-2
	2.4 L Automatic 2wd SIDI	22	21	-1	32	30	-2
Soul	1.6 L Soul Eco	29	26	-3	36	31	-5
	1.6 L Soul Automatic	27	25	-2	35	30	-5
	1.6 L Soul Manual	27	25	-2	35	30	-5
	2.0 L Soul Eco	27	24	-3	35	29	-6
	2.0 L Soul Automatic	26	23	-3	34	28	-6
	2.0 L Soul Manual	26	24	-2	34	29	-5
Sportage	2.4 L Automatic 4wd	21	20	-1	28	27	-1
	2.4 L Automatic 2wd	22	21	-1	32	30	-2
	2.4 L Manual 4wd	20	19	-1	27	25	-2
	2.4 L Manual 2wd	21	20	-1	29	27	-2
	2.0 L Automatic 2wd	22	21	-1	29	28	-1
	2.0 L Automatic 4wd	21	20	-1	26	25	-1

Figure F-6
Mercedes 2013-2014 Model Year Fuel Economy Label Changes

Carline	Model	City FE (MPG)			Highway FE (MPG)		
		old	new	change	old	new	change
C300	4-Matic FFV	20	19	-1	27	26	-1
C300	4-Matic PZEV	20	19	-1	29	28	-1

Highlight 2 – Some Truck Manufacturers Earned Early Greenhouse Gas Emission Reduction Credits

In September 2011, EPA and the National Highway Traffic Safety Administration (NHTSA) for the first time jointly introduced GHG and fuel efficiency standards for model years 2014 through 2018 medium and heavy duty engines and vehicles.

Under the program, manufacturers required to meet the new greenhouse standards had the option to earn early credits in MY2013 which can then be applied to subsequent model years. Figure F-7 on the next page lists those manufacturers who certified products under these early credit provisions.

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Figure F-7
MY 2013 Early GHG Credit Engine and Vehicle Manufacturers

Manufacturer Name	Number of Vehicle Families		Total
	Tractor	Vocational	
Daimler Trucks	18	12	30
Navistar	11	10	21
PACCAR	0	5	5
Total	29	27	56

Highlight 3 –Certificates of Conformity Issued by EPA Stabilizes at 4000 Per Year

After a period of rapid growth with the advent of the 1990 Clean Air Act amendments, the number of different vehicle and engine families being sold each year appears to have stabilized at around 4,000 certificates of conformity. EPA issued 2,520 certificates of conformity[1] in 2000, 3,641 in 2007, 3,642 in 2008, 3,927 in 2009, 3,689 in 2010 and 3,962 in 2011. In each of the model years 2012 – 2013, EPA issued about 4,000 certificates. Figure F-8 on the next page summarizes the certificates of conformity issued for model years 2012 and 2013.

[1] A Certificate of Conformity is the document that EPA issues to a manufacturer to certify that a vehicle or engine class conforms to EPA requirements. Every class of engines and vehicles introduced into commerce in the United States must have a Certificate of Conformity. Certificates are valid for only one model year of production.

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Figure F-8
Certificates of Conformity by Model Year[2]

Industry Sector	Category	MY 2012	MY 2013
Light-Duty Vehicles	Passenger cars and trucks	486	486
	Independent commercial importers	7	15
	Alternative fuel conversions	140	117
Highway Motorcycles	On-highway motorcycles	285	292
Heavy-Duty Highway Engines	Compression ignition (mostly diesel)	55	34
	Spark ignition (mostly gasoline)	29	32
	Alternative fuel conversions	4	1
	Evaporative emissions	12	13
Nonroad Compression Ignition Engines	Diesel powered equipment, such as tractors, generators, construction equipment, forklifts, welders	525	405
	Diesel boats and ships	205	186
	Oceangoing vessels per International Maritime Organization requirements	23	14
	Locomotives	70	79
Nonroad Spark Ignition (SI) Engines	Small SI: Small nonroad gasoline powered equipment, such as lawnmowers, string trimmers, chain saws, small compressors, pumps, utility vehicles < 25 mph, snow blowers, rammers, and floor cleaners	957	924
	Marine SI: Gasoline boats and personal watercraft	146	155
	Large SI: Large nonroad gasoline powered equipment, such as forklifts, compressors, generators, and stationary equipment	149	153
	Evaporative components (mostly intended for small nonroad gasoline and marine gasoline equipment)	679	765
Recreational Vehicles	All-terrain vehicles / Utility vehicles	183	187
	Off-highway motorcycles	56	42
	Snowmobiles	28	30
Total		**4,039**	**3,930**

[2] Most of the information in this report comes from Verify, EPA's Engine and Vehicle Compliance System. Verify, collects emissions and fuel economy compliance information for all types of engines, vehicles, and equipment used in transportation and other mobile source applications. The Verify information system is used by engine and vehicle manufacturers to report this information to EPA.

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Highlight 4 – ATV / Motorcycle Certificates Voided

In 2013, after an extensive investigation, EPA voided 153 certificates of conformity for engine families covering more than 170,000 on- and off-highway motorcycles and all-terrain vehicles produced between model years 2005 and 2012. The products were imported or manufactured by the following companies: Snyder Technology, Inc., Snyder Computer Systems, Inc. (doing business as Wildfire Motors Corporation), American Lifan Industry Inc., and Jonway Motorcycles (USA) Co., Ltd. Consumers who own models covered by the voided certificates are not responsible for the wrongdoing and can continue to use their vehicles. Voiding certificates is a key step, potentially leading to EPA enforcement actions against companies holding these certificates for violations of the CAA.

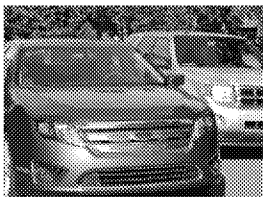
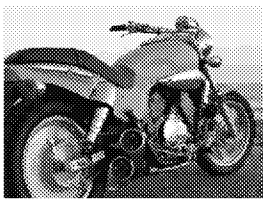
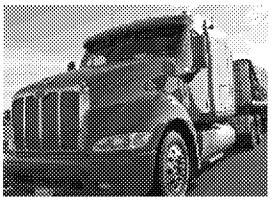
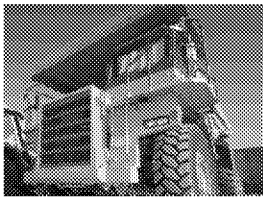
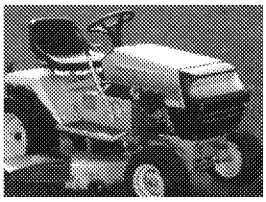
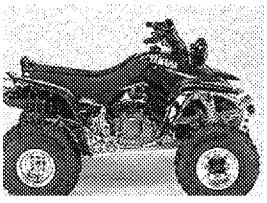
As a result of the August 2014 voiding of certificates of conformity for CF Moto America, Incorporated, the EPA's Office of Enforcement and Compliance Assurance took action that resulted in a civil penalty of $725,000. The settlement also requires CF Moto to institute a recall and fuel tank replacement program, as well as correct emission control labels for nonconforming labels within CF Moto's control. For more information, please see: http://www2.epa.gov//enforcement/cfmoto-powersports-inc-cfmoto-america-inc-zhejiang-cfmoto-power-co-ltd-and-chunfeng

As a result of the October 2013 voiding of certificates of conformity for American Lifan Industry, Incorporated, the EPA's Office of Enforcement and Compliance Assurance took action that resulted in a civil penalty of $630,000 and the posting of a bond of $300,000 to $500,000 to satisfy any Clean Air Act penalty related to future importation of vehicles manufactured by the company in 2014, 2015, and 2016. For more information, please see: http://www2.epa.gov/enforcement/american-lifan-industry-inc-settlement

Highlight 5 –Defect and Recall Requirements Lead to Manufacturers Correcting Potential Problems in Millions of Light Duty Vehicles and Heavy Duty Engines

In calendar years 2012 and 2013 manufacturers recalled approximately 3.7 million cars on the basis of indicators of potential emission problems that were revealed through EPA-mandated surveillance and reporting requirements. Consumers received free repairs, extended warrantees or other remedies to address the emission defects identified in these vehicles. In addition, heavy duty manufacturers recalled more than 340 thousand engines in 2012 and2013.

Figure 1 - Industry Sectors and Examples

Industry Sector	Examples	Key
Light-Duty Vehicles	Passenger cars, vans, SUVs, small trucks	
Highway Motorcycles	On-highway motorcycles, cruisers, choppers, scooters, touring bikes, mopeds, street bikes	
Heavy-Duty Highway Engines	Tractor-trailers (semi-trucks), buses, delivery and work trucks	
Nonroad Compression Ignition Engines (Nonroad CI)	Construction and agricultural equipment, such as tractors, generators, construction and road-work equipment, welders	
	Marine diesel boats and ships, oceangoing vessels	
	Locomotives	
Nonroad Spark Ignition Engines (Nonroad SI)	Small SI: lawnmowers, string trimmers, chain saws, small compressors, pumps, snow blowers	
	Marine SI: inboard and outboard motorboats, jet-skis	
	Large SI: forklifts, large compressors, generators	
	Evaporative components: hoses, fuel tanks	
Recreational Vehicles	All-terrain vehicles (ATVs), utility vehicles (UTVs), sand cars, dune buggies, go karts	
	Off-highway motorcycles	
	Snowmobiles	

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II. Scope of EPA's Vehicle, Engine, Equipment, and Fuel Compliance Programs

A. Statutory Authority for EPA Regulation of Vehicles, Engines, Equipment, & Fuels

EPA derives authority to do its work through a variety of environmental statutes enacted by Congress. Figure 1 on the precious page describes all of the industry sectors included in the scope of EPA's Vehicle, Engine, and Equipment Compliance Programs. Figure 2 outlines the primary environmental statutes that give EPA the authority to develop and implement its mobile source clean air programs.[3]

Figure 2 - Environmental Statutes

Statute	Authority
Clean Air Act (CAA)	Emission standards for highway & nonroad vehicles and their fuels
Energy Policy and Conservation Act (EPCA)	Fuel economy information programs for consumers, including vehicle fuel economy labels
Energy Policy Act (EPAct) Energy Independence and Security Act (EISA)	Annual volume standards for renewable fuel content

From locomotives to lawnmowers, EPA's Office of Transportation and Air Quality (OTAQ) has the authority to regulate nearly all engines and vehicles that emit pollutants into the environment. The statutory authority also covers the fuels that power these mobile sources, and includes responsibility for emissions compliance oversight that extends from initial product design to performance on the road and in the field.

B. Scope of EPA Vehicle, Engine, & Equipment Regulations

Compliance programs play an essential role in achieving the benefits of statutes and regulations. OTAQ oversees a comprehensive set of compliance activities to ensure that vehicle and engine manufacturers and fuel refiners and producers satisfy their regulatory obligations.

[3] This report focuses primarily on engines and vehicles even though fuels are also a part of EPA's clean air program. Additional information on the EPA fuels program can be found in Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975-2014 and in RFS2 EMTS Informational Data.

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EPA regulation of motor vehicles began in the 1970s; Figure 3 on the next page lists vehicle and engine regulations that were proposed or established since 2004. For a comprehensive list of EPA mobile source emission standards, refer to EPA's online Emission Standards Reference Guide, available at www.epa.gov/otaq/standards/index.htm. Please see Section II.C of this report for a list of regulations applicable to motor vehicle fuels.

Figure 3 - Vehicle and Engine Regulations and Implementation Dates

Affected Industry Sector/Category	Program/Rulemaking Description	Effective Model Year[4]
Light-Duty Vehicles	Tier 2 Emission Standards and Gasoline Sulfur Fuel Control – Strengthened emission standards for light-duty vehicles and significantly reduced sulfur levels in gasoline	2004
	On-Board Diagnostics (OBD) – Established new emissions system monitoring requirements for light-duty diesel vehicles	2005
	Revisions to Motor Vehicle Fuel Economy Labeling – Updated EPA method for determining fuel economy label values to better represent typical driving patterns and more accurately estimate actual consumer fuel economy	2008
	Mobile Source Air Toxics – Set standards to lower gasoline benzene content, reduce cold temperature exhaust emissions, and reduce evaporation and permeation from portable fuel containers	2010
	Clean Alternative Fuel Vehicle and Engine Conversions[5]– Updated anti-tampering provisions applicable to manufacturers of clean alternative fuel conversion systems for highway vehicles and engines	All[6]
	Light-Duty Greenhouse Gas (GHG) Emission Standards – Established the first mobile source emission standards for greenhouse gases including carbon dioxide, methane, and nitrous oxide	2012
	Revisions and Additions to Motor Vehicle Fuel Economy Label – Redesigned label provides new information on vehicle fuel economy, energy use, fuel costs, and environmental impacts for conventional and advanced technology vehicles (including electric vehicles and plug-in hybrid electric vehicles)	2013
	2017 and Later Light-Duty vehicle GHG and Corporate Average Fuel Economy Standards (including revisions to 2012-2016 GHG & CAFE Standards	

[4] Effective model year refers to the first year of a new program. Many programs are phased in over multiple model years.

[5] This rule also applies to heavy-duty highway clean alternative fuel conversions.

[6] Although the regulation took effect with its promulgation in 2011, because it applies to tampering, it applies to any model year that is subject to any emissions standard.

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	Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards	2014

Affected Industry Sector/Category		Program/Rulemaking Description	Effective Model Year
Highway Motorcycles		Highway Motorcycle Exhaust Emissions- Class I and II: Established more stringent HC and added new optional hydrocarbons + oxides of nitrogen (HC+NOx) standards; Added Class 1a (<50cc) Class III: Established new Tier 1 HC+NOx standard Class III: More stringent Tier II HC+NOx standard Highway Motorcycle Permeation Emissions- Established new evaporative/permeation standards for fuel tank(s) and lines.	2006 2006 2010 2008
Heavy-Duty Highway Engines and Vehicles		Light Heavy-Duty OBD – Established OBD monitoring requirements for heavy-duty chassis certified vehicles, and for engines certified for use in heavy-duty vehicles between 8,500 and 14,000 pounds gross vehicle weight rating (GVWR) Heavy-Duty Highway Rule – Established more stringent exhaust emission standards for heavy-duty vehicles and engines; required Ultra Low Sulfur Diesel (ULSD) fuel (15 ppm sulfur maximum) Heavy-Duty Engines OBD Rule – New OBD monitoring requirements for engines certified for use in heavy-duty vehicles above 14,000 pounds GVWR Heavy-Duty GHG Standards – Established first emission standards for greenhouse gas pollutants from heavy-duty engines and heavy-duty vehicles	2004 2007 2010 2014
Nonroad Compression Ignition Engines & Equipment	Construction & Agricultural	Tier 3/Interim Tier 4 – Established more stringent emission standards for engines between 37 and 560 kilowatts (50 and 750 hp) Tier 4 Nonroad Diesel Rule – Established more stringent emissions standards for all engines greater than 19 kilowatts (25 hp) and lowered nonroad diesel fuel sulfur to 15 ppm maximum	2006 2010
	Marine Diesel Engines	Tier 3 and Tier 4 Emission Standards for Marine Diesel Engines – Established more stringent emission standards for newly built and remanufactured engines	2009

	Locomotives	Tier 3 and Tier 4 Emission Standards for Locomotive Diesel Engines – Established more stringent emission standards for newly built and remanufactured engines	2011
Nonroad Spark Ignition Engines & Equipment	Small Spark Ignition Engines (Small SI)	Control of Emissions From Nonroad Spark Ignition Engines and Equipment – Established more stringent exhaust emission standards for Class I (MY2012) and Class II (MY2011) engines below 19 kilowatts and fuel permeation standards for all engines below 19 kilowatts	2011 2012
	Marine Spark Ignition Engines (Marine SI)	Control of Emissions From Nonroad Spark Ignition Engines and Equipment – Established first federal exhaust emission standards for sterndrive and inboard Marine SI engines and increased the stringency of exhaust emission standards for outboard and personal watercraft engines. Established new evaporative emission standards for all Marine SI engines	2010
	Large Spark Ignition Engines (Large SI)	New Emissions Standards for Large SI Engines – Established new emission standards, diagnostic capability and portable emission testing provisions Tier 1 Tier 2	 2004 2007
Recreational Vehicles		New Exhaust Emission Standards for RVs – Off-highway motorcycles, ATVs and UTVs Snowmobiles Tier 1 Tier 2 Tire 3 New permeation standards for fuel components	 2006 2006 2010 2012 2008
Aircraft[7]		Control of Air Pollution from Aircraft and Aircraft Engines; Emission Standards and Test Procedures – Established more stringent NOx exhaust emission standards for aircraft engines NOx Emission Standards for Aircraft Gas Turbine Engines – Established new NOx emission standards for aircraft, engines consistent with international standards	2005 2012

C. Scope of EPA Fuel Regulations

In addition to regulating vehicles and engines, EPA regulates motor vehicle fuels, including gasoline, diesel, and renewable fuels such as ethanol and biodiesel. Figure 4 describes both historical and current fuels programs and implementation dates. For a comprehensive list of ongoing fuels regulations, please visit

[7] The Federal Aviation Administration has primary oversight responsibility for aircraft emissions compliance. A general overview can be found at the Federal Aviation Administration Office of Environment and Energy.

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http://www.epa.gov/otaq/fuels/publications.htm. Additional information can be found on the OTAQ website at http://www.epa.gov/otaq/fuels/index.htm. Please see Section II.B of this report for recent regulatory actions applicable to vehicles and engines.

Figure 4 - Fuels Regulations and Implementation Dates

Affected Fuel Type- *Applicable Fuel Producer or Importer*	**Program/Rulemaking Description**	**Effective Imple-mentation Date**
Motor vehicle fuels and fuel additives – *Gasoline and diesel refiners and importers, renewable fuel producers and importers, fuel additive producers and importers*	Fuels and Fuel Additives Registration System (FFARS) – Mandatory registration program for motor vehicle gasoline, diesel, and their additives sold in the U.S. Required all fuel and fuel additive manufacturers to report the chemical composition of their products and other technical, sales and health effects information	1975
Gasoline – *Gasoline Refiners and Importers*	Volatility Standards – Limited the vapor pressure of gasoline sold at retail stations during the summer ozone season to reduce evaporative emissions from gasoline, which contribute to ground-level ozone formation	1989
	Oxygenated Fuel Requirements – Established fuel oxygen standards to reduce carbon monoxide emissions from motor vehicles during the winter season	1992
	Reformulated Gasoline (RFG) – Reduced smog-forming and toxic pollutants in U.S. cities with worst smog pollution	1995
	Tier 2 Emission Standards and Gasoline Sulfur Regulations Established stringent exhaust emission standards for all fuel types and limits fuel sulfur levels to an average of 30 ppm	2004
	Mobile Source Air Toxics Regulations – Limited the benzene content of gasoline and reduces toxic emissions from passenger vehicles and gas cans	2011
Diesel – *Diesel Producers and Importers*	Highway, Nonroad, Locomotive, and Marine Regulations – Established suite of rules for highway, nonroad, locomotive, and marine diesel engines that required ultra-low sulfur diesel (ULSD), 15 ppm maximum	2006
	The C3 Marine Rule changed the diesel fuel program to allow production and sale of diesel fuel up to 1000 ppm for Category 3 marine vessels effective June 2010.	2010
	Modifications to the Transmix Provisions under the Diesel Sulfur Program provided relief to transmix processors and pipeline operators to allow the petroleum distribution system to function efficiently effective Feb. 2013.	2013

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	Heating Oil Rule expanded the definition of heating oil in the RFS program effective December 2013	2013
Renewable Fuels (e.g. ethanol, biodiesel) – *Gasoline Refiners and Importers, Renewable Fuel Producers, Importers, Exporters, Marketers, and Blenders*	The Renewable Fuel Standard (RFS) – RFS1 – Regulations established under the Energy Policy Act (EPAct) of 2005 required 7.5 billion gallons of renewable fuel to be blended into gasoline by 2012. RFS2 – Regulations established under the Energy Independence and Security Act (EISA) of 2007 expanded upon RFS1. The RFS2 regulations require renewable fuel to be blended into both gasoline and diesel fuel, as well as jet fuel and heating oil. EPA is responsible for publishing annual updates to these renewable fuels standards.	2007 2010

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III. Compliance Programs and Processes

A. Overview

EPA uses a variety of testing and reporting programs to monitor compliance with emissions regulations. The programs may apply to vehicles and engines before they are produced (preproduction), while they are in production and after they are in customer service (postproduction). EPA has the authority and flexibility to choose compliance strategies that best fit an industry sector at any given time. Factors that influence the use of a particular compliance approach include regulatory requirements affecting a given industry sector, the technology being used to meet the emission standards, industry-specific production processes and cycles and sector or manufacturer size. This report describes compliance programs and activities that OTAQ conducted in 2012-2013. Specifically, the report presents data we collected and analyzed pertaining to MY 2012-2013 vehicles and engines, as well as test results and other types of information OTAQ obtained during calendar years 2012-2013.

EPA regulations typically give manufacturers some flexibility about how they will achieve emissions compliance. Examples include emissions standard phase-ins, averaging, banking and trading (ABT) programs and several types of exemptions. This regulatory flexibility enables manufacturers to align their business model with emissions requirements and sometimes allow manufacturers to earn credit for introducing new technologies early. At the same time, some regulatory flexibilities introduce challenges to compliance oversight because vehicles and engines subject to one regulation and set of standards may legally certify to different emissions levels. This report includes some discussion of flexibility provisions and presents data showing how manufacturers are using them.

EPA mobile source compliance programs allow for vehicle and engine testing and other compliance activity that can generally be parsed into three life-cycle categories:

Preproduction activities include certification testing and reporting and other compliance processes conducted before vehicles and engines are produced.

Production activities include audits and other compliance testing conducted on vehicles and engines coming off the production line, but before they enter customer service.

Postproduction activities include in-use testing and reporting and other compliance processes conducted after vehicles and engines enter customer service.

Figure 5 on the next page shows how EPA's compliance programs are related to one another.

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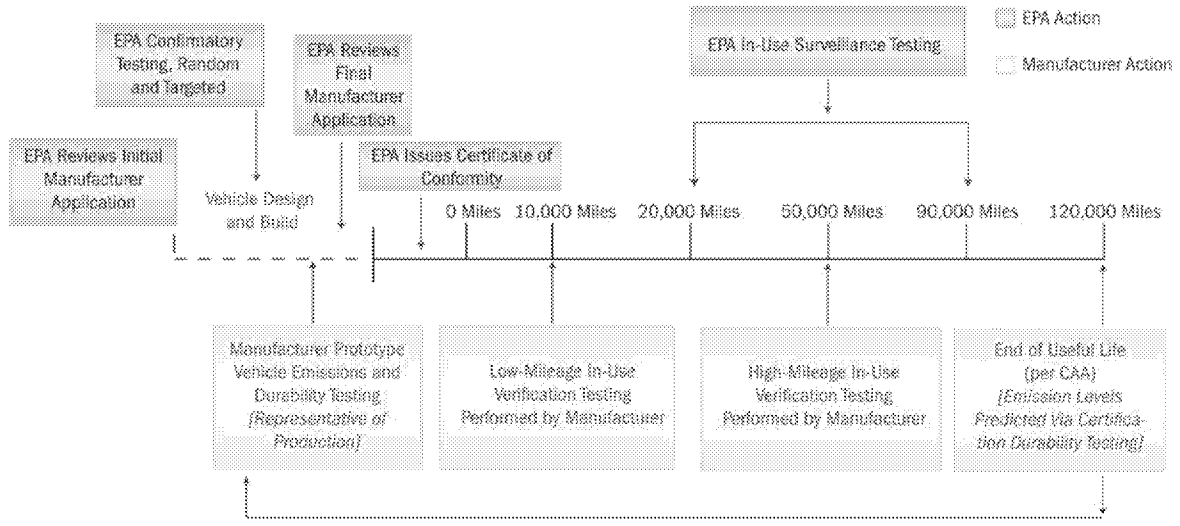
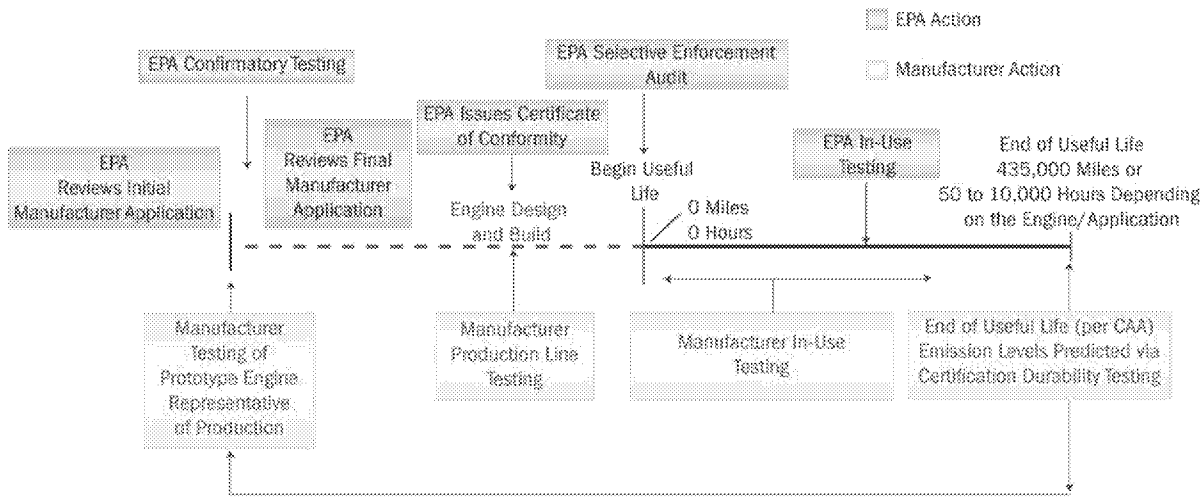
Figure 5 - Compliance Schedule Examples

EPA's mobile source compliance processes seek to ensure that the vehicles and engines are fully compliant with emissions standard throughout their full useful life. This is accomplished with a variety of testing programs and other requirements that occur over the life of vehicles and engines. This figure shows example compliance schedules for certain sectors. Although other mobile source sectors may differ with regard to timing, they generally follow similar protocols.

Compliance Schedule for Light-Duty Vehicles



Compliance Schedule for Certain Heavy-Duty Highway and Nonroad Engines



CERTIFICATES OF CONFORMITY

Section 206 of the Clean Air Act (CAA) requires all engines and vehicles to be covered by a certificate of conformity before they can enter into commerce. A certificate of conformity is a license to produce products for one model year consistent with the vehicle description and any terms of the certificate. Certificates of conformity are generally issued to a group of vehicles or engines having similar design and emission characteristics. For light-duty vehicles, certificates are issued for each unique combination of exhaust test group[8] and evaporative family. For heavy-duty vehicles and nonroad equipment subject to engine standards, the unit of certification is called an engine family. Test groups and engine families may include multiple models. Conversely, different versions within a given model may be included in different engine families or test groups.

Figure 6 on the next page shows the number of certificates that EPA issued in MY 2012-2013.

After a period of rapid growth with the advent of the 1990 Clean Air Act amendments, the number of different vehicle and engine families being sold each year appears to have stabilized at around 4,000. EPA issued 2,520 certificates of conformity[9] in 2000, 3,641 in 2007, 3,642 in 2008, 3,927 in 2009, 3,689 in 2010 and 3,962 in 2011. In each of the model years 2012 – 2013, EPA issued about 4,000 certificates.

[8] An exhaust test group is a group of vehicle models with similar engines, drive trains and emission control systems. It represents a group of vehicles or engines that have a similar design and emission characteristics.

[9] A Certificate of Conformity is the document that EPA issues to a vehicle manufacturer to certify that a vehicle class conforms to EPA requirements. Every class of engines and vehicles introduced into commerce in the United States must have a Certificate of Conformity. Certificates are valid for only one model year of production.

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Figure 6 - Certificates of Conformity by Model Year[10]

Industry Sector	Category	MY 2012	MY 2013
Light-Duty Vehicles	Passenger cars and trucks	486	486
	Independent commercial importers	7	15
	Alternative fuel conversions	140	117
Highway Motorcycles	On-highway motorcycles	285	292
Heavy-Duty Highway Engines	Compression ignition (mostly diesel)	55	34
	Spark ignition (mostly gasoline)	29	32
	Alternative fuel conversions	4	1
	Evaporative emissions	12	13
Nonroad Compression Ignition Engines	Diesel powered equipment, such as tractors, generators, construction equipment, forklifts, welders	525	405
	Diesel boats and ships	205	186
	Oceangoing vessels per International Maritime Organization requirements	23	14
	Locomotives	70	79
Nonroad Spark Ignition (SI) Engines	Small SI: Small nonroad gasoline powered equipment, such as lawnmowers, string trimmers, chain saws, small compressors, pumps, utility vehicles < 25 mph, snow blowers, rammers, and floor cleaners	957	924
	Marine SI: Gasoline boats and personal watercraft	146	155
	Large SI: Large nonroad gasoline powered equipment, such as forklifts, compressors, generators, and stationary equipment	149	153
	Evaporative components (mostly intended for small nonroad gasoline and marine gasoline equipment)	679	765
Recreational Vehicles	All-terrain vehicles / Utility vehicles	183	187
	Off-highway motorcycles	56	42
	Snowmobiles	28	30
Total		**4,039**	**3,930**

APPLICATION FOR CERTIFICATION

The certification process begins when a manufacturer submits an application for certification to EPA. Applications cover an exhaust test group or engine family that represents a group of vehicles or engines having similar design and emission characteristics. EPA requires manufacturers to provide detailed information in the certification application to show that the vehicles or engines meet all of the applicable emissions requirements and to describe the vehicles or engines to be covered by the certificate of conformity. Each certificate covers only those vehicles or engines specifically described in the application.

[10] Most of the information in this report comes from Verify, EPA's Engine and Vehicle Compliance System. Verify, collects emissions and fuel economy compliance information for all types of engines, vehicles, and equipment used in transportation and other mobile source applications. The Verify information system is used by engine and vehicle manufacturers to report this information to EPA.

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The list below summarizes the general types of information and data that manufacturers submit to begin the application process:

- A description of the basic engine design and list of distinguishable configurations to be covered by the certification application

- An explanation of how the emission control system operates

- A description of the vehicle or engine being used to represent the group for certification testing

- A description of the test procedures and equipment used to test the vehicle or engine

- All emission data obtained on each test vehicle or engine

- The emission deterioration characteristics for each regulated pollutant over the useful life of the vehicles and engines covered by the certification application

- The predicted production volumes of each configuration to be covered by the certificate

- An unconditional statement attesting that vehicles or engines covered by the certification application comply with all requirements of the applicable regulation and the CAA

- Manufacturer representative and official company contact information

- Durability groupings (i.e., groups of vehicles/engines with similar emission deterioration and emission component durability)

- Durability test procedures

- Description of each test group or engine family which is represented by the durability test vehicle or engine

- Description of vehicles or engines used to demonstrate emissions and emission control component durability

- List of all test results, official certification levels, and the applicable emission standards for each vehicle or engine tested

- Statement of compliance with the applicable emission standards for all other configurations not tested but represented by the test vehicles or engine and covered by the certification application

- Evaporative emissions system information

- Description of the evaporative, permeation or refueling families covered by the certification application and test results demonstrating compliance with the applicable standards

- Information on emission control diagnostic systems, where applicable

CONFIRMATORY CERTIFICATION TESTING

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Manufacturers conduct the initial testing to support an application for a certificate of conformity and report the results to EPA. Subsequent certification testing, called confirmatory testing, occurs after an application has been submitted. Confirmatory tests are performed by either the manufacturer or by EPA and serve to validate the manufacturer's initial emissions or fuel economy test results.

2. Production Programs

The objective of compliance activities that occur during production is to confirm that vehicles and engines coming off production lines match specifications set forth in the certificate of conformity. In other words, production programs are designed to verify that manufacturers are actually producing the same vehicle or engine that they certified. Some mobile source regulations call for routine production line testing. EPA may also audit production vehicles and engines without prior notice using selective enforcement audits.

3. Postproduction Programs

IN-USE COMPLIANCE PROGRAMS

In-use compliance programs track emissions performance of production vehicles or engines after they enter customer service. In-use testing programs are conducted by both EPA and manufacturers.

DEFECT REPORTING PROGRAMS

Manufacturers are required to report emission-related defects to EPA. An emission-related defect is a defect in design, materials or workmanship in a device, system or assembly, as described in the approved application for certification. Manufacturers must report a defect even if it does not increase emission levels. EPA regulations generally establish minimum numbers of confirmed defects that trigger defect information reporting requirements. An emission-related defect does not necessarily lead to an emission recall because not all defects in emission-related parts increase emissions.

RECALL PROGRAMS

An emissions recall is a repair, adjustment or modification program conducted by a manufacturer to remedy an emission-related problem. Vehicle and engine manufacturers are required to design and build their products to meet emission standards for the useful life of the vehicle or engine specified by law. Under Section 207(c)(1) of the CAA, if EPA determines that a substantial number of vehicles or engines in a category or class do not meet emission standards in actual use, even though they are properly maintained and used, EPA can require the manufacturer to recall and fix the affected vehicles and engines. EPA may use a variety of data sources including EPA and manufacturer test results to determine that a recall is necessary. The purpose of a recall is to help ensure the problem gets fixed and thereby prevent excessive pollution from vehicles or engines that are already in customer service. When an emissions recall occurs, the manufacturer must notify vehicle owners and provide instructions about how to have the vehicle repaired. Most recalls are initiated voluntarily by manufacturers once potential noncompliance is discovered; however, EPA also has the authority to order the manufacturer to recall and fix noncompliant vehicles or engines, if the manufacturer fails to implement a voluntary recall.

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4. Regulatory Flexibility Programs

EPA builds flexibility into its emissions regulations to increase compliance efficiency, decrease costs and encourage manufacturers to introduce cleaner technologies sooner.

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

Average Banking and Trading (ABT) provisions allow manufacturers to meet an overall fleet average standard instead of an individual vehicle or engine standard. Manufacturers may comply with ABT provisions by certifying some vehicles and engines at levels above the emission standard, provided that these emission "deficits" are offset by positive credits from vehicles and engines certified below the standard. Compliance is determined by calculating the manufacturer's fleet-wide average of each exhaust test group's production or sales volume and emission level. The flexibility to meet fleet average emission standards by ABT credits can facilitate earlier introduction of clean technology into the market.

TRANSITION PROGRAM FOR EQUIPMENT MANUFACTURERS

The Transition Program for Equipment Manufacturers (TPEM) recognizes a potential challenge that can face equipment manufacturers when new emission standards take effect. If engines, of which there are relatively few designs, must be redesigned to achieve the required emission reductions, equipment powered by those engines, of which there could be 10,000 or more designs, may also need to be redesigned. TPEM permits equipment manufacturers a transition period during which they may continue to use a limited number of engines meeting previous standards while they update product designs to accommodate engines meeting the new standards.

5. Exemption Programs

Vehicles and engines imported into the United States may be eligible for an exemption from federal emission requirements. For example, vehicles belonging to military personnel or nonresidents may be eligible for exemption. Vehicles that are being imported for testing or display may also be exempt. Depending on the type of exemption, importers must request in advance written EPA approval. EPA works with the Department of Homeland Security U.S. Customs and Border Protection to ensure that proper approvals have been issued before vehicles and engines may enter the United States. The majority of the 2314 import exemptions EPA issued in 2012 and the 2453 exemptions issued in 2013 were for light-duty vehicles. The majority of exemptions EPA issued for heavy-duty highway and nonroad engines or equipment were for test programs. EPA issued 309 heavy-duty or nonroad exemptions in 2012 and 284 in 2013. An exemption may cover multiple vehicles and/or engines.

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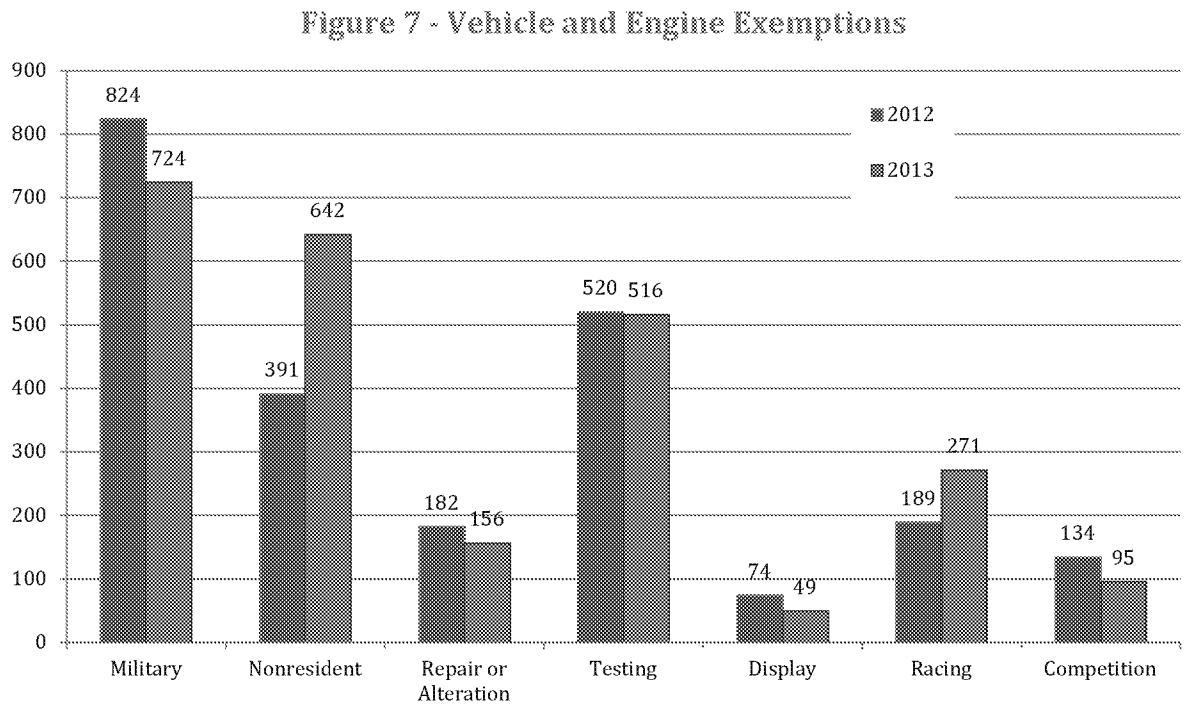
Figure 7 summarizes the exemptions that EPA issued in calendar years 2012 – 2013.



B. Light-Duty Vehicles

SECTOR PROFILE:

- The light-duty vehicle sector includes passenger vehicles such as cars, vans, SUVs, and light-trucks
- Light-duty vehicles have been subject to increasingly stringent emissions and fuel economy standards since the 1970s
- Primary emission standards in effect for MY 2012-2013 are Tier 2 emission standards for HC, CO, NOx, and PM and GHG standards for CO_2 and other GHGs

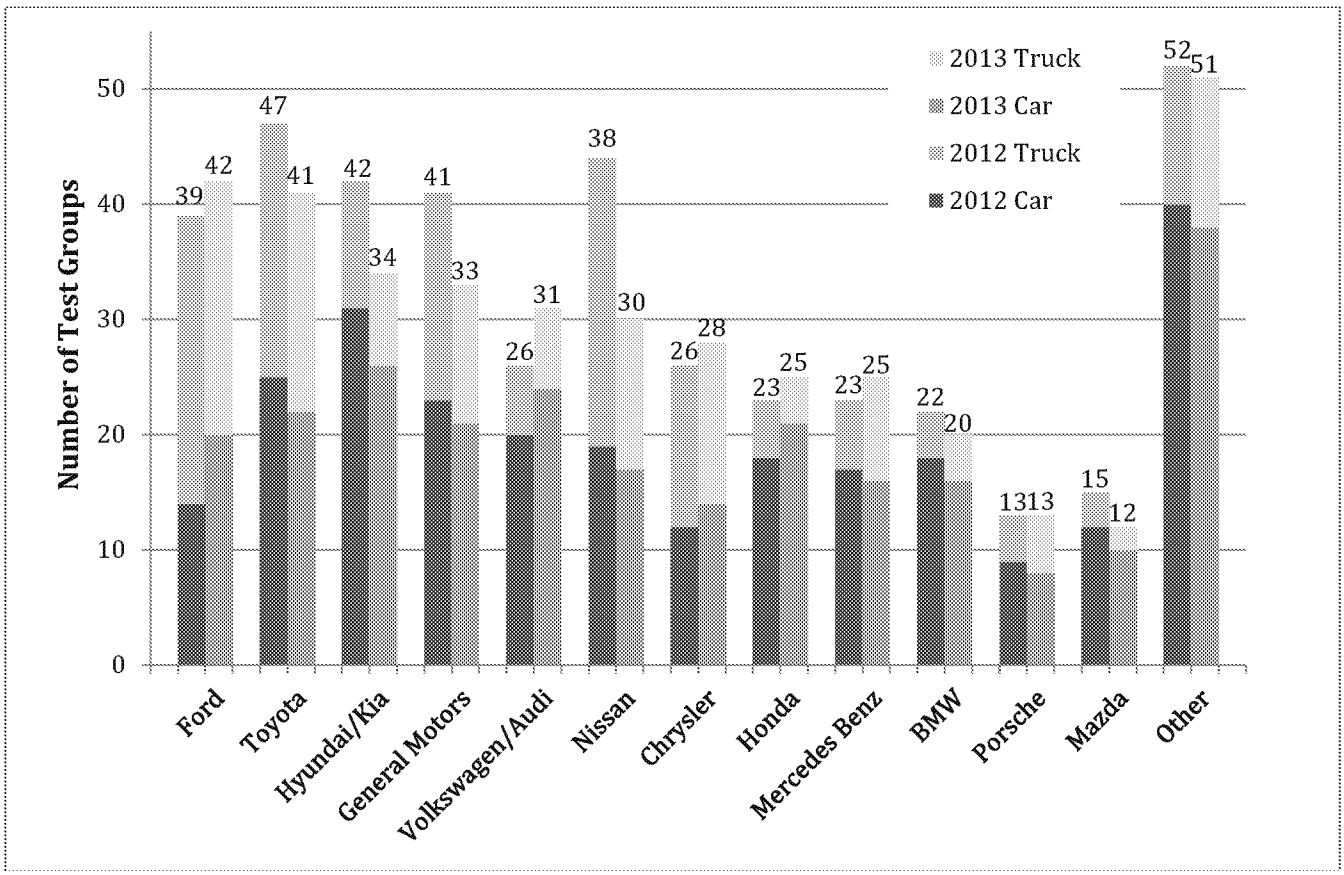
CERTIFICATION

EPA issued 486 certificates to light-duty vehicle[11] original equipment manufacturers (OEMs) each year in MY 2012-2013. Figure 8 shows the number of certified test groups for MY 2012 -2013 by manufacturer.[12], [13]

PRODUCTION VOLUME

Figure 9 on the next page presents by manufacturer the number of MY 2012-2013 cars and light-duty trucks produced for sale in the United States.[14] A comparison of Figures 8 and 9 shows that there is not always a correlation between the number of test groups a manufacturer certifies and the number of vehicles the manufacturer produces. Manufacturers with the most certified test groups do not necessarily produce the most vehicles.

Figure 8 - MY 2012-2013 Light-Duty Vehicle Test Groups by Manufacturer



[11] Some heavy-duty vehicles that are between 8,500-14,000 pounds GVWR are chassis-certified and are included in the light-duty vehicle certificate count.

[12] Each light-duty vehicle certificate covers a unique combination of exhaust test group and evaporative emissions family. Therefore the number of light-duty certificates and test groups is usually different. Manufacturers may create test groups that include both cars and trucks.

[13] 'Other' in Figure 8 includes more than 20 manufacturers, each of whom had only a small number of test groups.

[14] These production data only include vehicles subject to Corporate Average Fuel Economy standards.

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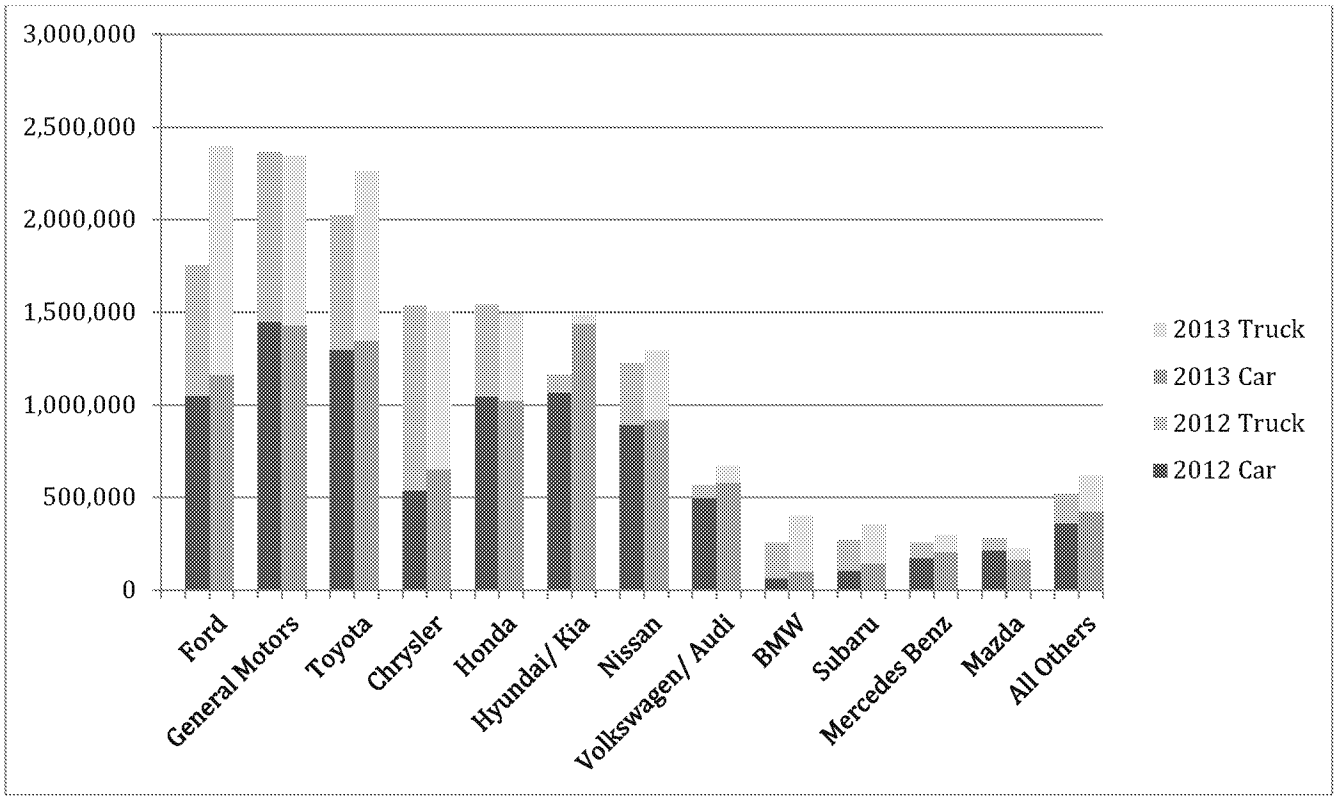
Figure 9 - MY 2012-2013 Light-Duty Production Volume by Manufacturer[15]



CONFIRMATORY TESTING

EPA and manufacturers test pre-production vehicles and engines prior to their introduction into commerce to confirm initial manufacturer emission test results. When a vehicle fails a confirmatory test, the manufacturer is allowed one retest to confirm or refute the failure. If the vehicle passes on retest, the retest is deemed the official certification test and the results from the retest stand as the official emission levels for that vehicle. Sometimes a confirmatory test failure can be attributed to problems that render the test vehicle unrepresentative of production vehicles. In those situations, the manufacturer corrects the problem in the test vehicle and retests. In still other cases, failures over the confirmatory test reflect actual engineering problems. These types of failures usually result in manufacturer action to change the vehicle calibration and update the certification application accordingly, resulting in a quantifiable emissions reduction for the vehicles that are ultimately produced. Regardless of whether a confirmatory test failure is due to problems with the test vehicle or problems with the calibration, the problems must be corrected and the vehicle must pass confirmatory testing before EPA will issue a certificate.

FUEL ECONOMY TESTING

EPA and manufacturers perform confirmatory testing for both emissions and fuel economy validation. Fuel economy test results are the source for information that appears on new vehicle fuel economy labels

[15] Total annual production for light-duty vehicle manufacturers in 2012 Model Year was over 13.7 million and for 2013 Model Year was over 15.3 million.

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and that EPA and the U.S. Department of Transportation use to assess compliance with corporate average fuel economy (CAFE) standards.

EPA reports fuel economy test data in an annual Fuel Economy Trends Report which includes both laboratory test value results and results adjusted for real-world driving conditions.

EPA INVESTIGATION PROMPTS CARMAKERS TO CORRECT INFLATED FUEL ECONOMY CLAIMS

The fuel economy label (the window sticker that appear on new cars) provides consumers with reliable and repeatable estimates of real-world fuel economy for national average drivers and conditions. This allows consumers to compare fuel economy across different car models. EPA requires auto manufacturers to *revise* miles per gallon (MPG) values on fuel economy labels if relevant information becomes available that shows that the original values are too high.

EPA oversees the MPG values on fuel economy labels by:

- conducting independent testing on about 15% of vehicle models each year on pre-production vehicles provided by manufacturers
- testing in-use cars and trucks to confirm that the fuel economy labels are accurate for production vehicles placed into commerce
- assessing information provided by consumer groups, the auto industry and fueleconomy.gov to identify models for further testing.

If testing reveals that fuel economy labels are *in*accurate, EPA will require manufacturers to update the MPG label to provide consumers with the best information available. Such was the case for several manufacturers' 2012–2013 vehicle models described in Figures 10-15 starting on the next page.

As a result of an enforcement action made possible by an OTAQ investigation, automakers Hyundai and Kia will pay a $100 million civil penalty to resolve alleged Clean Air Act violations based on their sale of more than 1 million vehicles that collectively will emit approximately 4.75 million metric tons of greenhouse gases (GHG) in excess of what the automakers certified to the EPA. The companies will forfeit GHG emission credits in order to put the companies in the place they would have been had they accurately reported the GHG emissions from these vehicles in the first place. The companies also will take measures to prevent future violations. On November 3, 2014, the EPA's Office of Enforcement and Compliance Assurance (OECA) and the U.S. Department of Justice (DOJ) announced this settlement, and lodged a consent decree embodying the settlement in the United States District Court for the District of Columbia. The California Air Resources Board joined the United States as a co-plaintiff in this settlement. For more information, please see: http://www2.epa.gov/enforcement/hyundai-and-kia-clean-air-act-settlement

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Figure 10
Ford 2013-2014 Model Year Fuel Economy Label Changes

Carline	Model	City FE (MPG)			Highway FE (MPG)		
		old	new	change	old	new	change
Fusion	Hybrid	47	42	-5	47	41	-6
C-Max	Hybrid	45	40	-5	40	37	-3
Lincoln	MKZ Hybrid	45	38	-7	45	37	-8
Fusion	Energi Plug-In	44	38	-6	41	36	-5
C-Max	Energi Plug-In	44	38	-6	41	36	-5

Figure 11
Hyundai 2012 Model Year Fuel Economy Label Changes

Carline	Model	City FE (MPG)			Highway FE (MPG)		
		old	new	change	old	new	change
Accent	1.8 L Automatic	30	28	-2	40	37	-3
	1.8 L Manual	30	28	-2	40	37	-3
Azera	3.3L Automatic	20	20	0	29	28	-1
Elantra	1.8 L Automatic	29	28	-1	40	38	-2
	1.8 L Manual	29	28	-1	40	38	-2
Genesis	5.0 L Automatic	17	17	0	26	25	-1
	4.6 L Automatic	17	16	-1	26	25	-1
	5.0 L R-Spec Automatic	16	16	0	25	25	0
	3.8 L Automatic	19	18	-1	29	28	-1
Sonata	Hybrid	35	34	-1	40	39	-1
Tucson	2.4L Automatic 4wd	21	20	-1	28	27	-1
	2.4L Automatic 2wd	22	21	-1	32	30	-2
	2.4L Manual 4wd	20	19	-1	27	25	-2
	2.4L Manual 2wd	21	20	-1	29	27	-2
	2.0L Automatic 2wd	23	22	-1	31	29	-2
	2.0L Manual 2wd	20	20	0	27	26	-1
Veloster	Automatic	29	27	-2	38	35	-3
	Manual	28	27	-1	40	37	-3

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Figure 12
Hyundai 2013 Model Year Fuel Economy Label Changes

Carline	Model	City FE (MPG)			Highway FE (MPG)		
		old	new	change	old	new	change
Accent	Automatic	30	28	-2	40	37	-3
	Manual	30	28	-2	40	37	-3
Azera	3.3L Automatic	20	20	0	30	29	-1
Elantra	1.8 L Automatic	29	28	-1	40	38	-2
	1.8 L Manual	29	28	-1	40	38	-2
	1.8 L Blue Automatic	30	28	-2	40	38	-2
	1.8 L GT Automatic	28	27	-1	39	37	-2
	1.8 L GT Manual	27	26	-1	39	37	-2
	Elantra Coupe Automatic	28	27	-1	39	37	-2
	Elantra Coupe Manual	29	28	-1	40	38	-2
Genesis	5.0 L R-Spec Automatic	16	16	0	25	25	0
	3.8 L Automatic	19	18	-1	29	28	-1
Santa Fe	2.4 L Sport Automatic 4wd	21	20	-1	28	26	-2
	2.4 L Sport Automatic 2wd	22	21	-1	33	29	-4
	2.0 L Sport Automatic 4wd	20	19	-1	27	24	-3
	2.0 L Sport Automatic 2wd	21	20	-1	31	27	-4
Tucson	2.4L Automatic 4wd	21	20	-1	28	27	-1
	2.4L Automatic 2wd	22	21	-1	32	30	-2
	2.4L Manual 4wd	20	19	-1	27	25	-2
	2.4L Manual 2wd	21	20	-1	29	27	-2
	2.0L Automatic 2wd	23	22	-1	31	29	-2
	2.0L Manual 2wd	20	20	0	27	26	-1
Veloster	Automatic	29	28	-1	40	37	-3
	Manual	28	27	-1	40	37	-3
	Turbo Automatic	25	24	-2	34	31	-3
	Turbo Manual	26	24	-2	38	35	-3

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Figure 13
Kia 2012 Model Year Fuel Economy Label Changes

Carline	Model	City FE (MPG)			Highway FE (MPG)		
		old	new	change	old	new	change
Optima	Hybrid	35	34	-1	40	39	-1
Rio	Automatic	30	28	-2	40	36	-4
	Manual	30	29	-1	40	37	-3
Sorento	2.4 L Automatic 4wd SIDI	21	20	-1	28	26	-2
	2.4 L Automatic 2wd SIDI	22	21	-1	32	30	-2
Soul	1.6 L Soul Eco	29	26	-3	36	31	-5
	1.6 L Soul Automatic	27	25	-2	35	30	-5
	1.6 L Soul Manual	27	25	-2	35	30	-5
	2.0 L Soul Eco	27	24	-3	35	29	-6
	2.0 L Soul Automatic	26	23	-3	34	28	-6
	2.0 L Soul Manual	26	24	-2	34	29	-5
Sportage	2.4 L Automatic 4wd	21	20	-1	28	27	-1
	2.4 L Automatic 2wd	22	21	-1	32	30	-2
	2.4 L Manual 4wd	20	19	-1	27	25	-2
	2.4 L Manual 2wd	21	20	-1	29	27	-2
	2.0 L Automatic 2wd	22	21	-1	29	28	-1
	2.0 L Automatic 4wd	21	20	-1	26	25	-1

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Figure 14
Kia 2013 Model Year Fuel Economy Label Changes

Carline	Model	City FE (MPG)			Highway FE (MPG)		
		old	new	change	old	new	change
Rio	Automatic	30	28	-2	40	36	-4
	Manual	30	29	-1	40	37	-3
	Eco Automatic	31	30	-1	40	36	-4
Sorento	2.4 L Automatic 4wd SIDI	21	20	-1	28	26	-2
	2.4 L Automatic 2wd SIDI	22	21	-1	32	30	-2
Soul	1.6 L Soul Eco	29	26	-3	36	31	-5
	1.6 L Soul Automatic	27	25	-2	35	30	-5
	1.6 L Soul Manual	27	25	-2	35	30	-5
	2.0 L Soul Eco	27	24	-3	35	29	-6
	2.0 L Soul Automatic	26	23	-3	34	28	-6
	2.0 L Soul Manual	26	24	-2	34	29	-5
Sportage	2.4 L Automatic 4wd	21	20	-1	28	27	-1
	2.4 L Automatic 2wd	22	21	-1	32	30	-2
	2.4 L Manual 4wd	20	19	-1	27	25	-2
	2.4 L Manual 2wd	21	20	-1	29	27	-2
	2.0 L Automatic 2wd	22	21	-1	29	28	-1
	2.0 L Automatic 4wd	21	20	-1	26	25	-1

Figure 15
Mercedes 2013-2014 Model Year Fuel Economy Label Changes

Carline	Model	City FE (MPG)			Highway FE (MPG)		
		old	new	change	old	new	change
C300	4-Matic FFV	20	19	-1	27	26	-1
C300	4-Matic PZEV	20	19	-1	29	28	-1

DURABILITY TESTING

The CAA requires EPA emission standards to apply for the full useful life of the vehicle. Since emissions may degrade as vehicles age and accrue miles, manufacturers must perform durability testing to demonstrate that a vehicle will remain compliant for its full useful life, despite any deterioration that may occur over time or distance. EPA regulations establish processes by which manufacturers may demonstrate durability using standard or custom methods. Manufacturers that use their own durability aging procedures must provide EPA with an "equivalency factor" that enables comparison between the proprietary method and the published, standard EPA method. This allows a third party that relies on the EPA method to replicate the manufacturer's method.

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IN-USE COMPLIANCE TESTING

Both EPA and manufacturers conduct testing to monitor in-use vehicle emissions. EPA conducts in-use vehicle surveillance testing at the National Vehicle and Fuel Emissions Laboratory in Ann Arbor, Michigan. The purpose of the EPA surveillance program is to assess emissions performance a few years after vehicles enter the fleet. EPA typically recruits two- or three-year-old vehicles from volunteers in southeast Michigan. EPA selects vehicles for surveillance both randomly and based on certification data, manufacturer in-use verification data, vehicle production volume, new technology, and public complaints and inquiries. In CY2012 EPA selected about 33 classes for surveillance and generally tested three vehicles from each selected class. In CY2013 EPA selected 25 classes and tested approximately three vehicles per class. If any of the initial vehicles within a class failed a test, EPA recruited additional vehicles from that class for follow-up testing to determine whether an emissions problem was likely to exist and was not an artifact of the small sample size (or even a single defective vehicle).

EPA also conducts an in-use confirmatory testing program for vehicle classes that merit closer scrutiny. These classes may be identified through failures in either EPA in-use surveillance or manufacturer in-use testing programs.

Figure 16 on the next page shows the vehicle model year, manufacturer, and carline selected for EPA surveillance testing in 2012-2013.

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Figure 16 - Vehicles Tested in EPA's In-Use Testing Program in 2012-2013 CYs

Model Year	Manufacturer	Model
Surveillance Classes		
2006	Ford	Taurus
2007	Nissan	Frontier 2WD
2009	Audi	A4 & A5 Audi Quattro
2009	Chrysler	Town & Country, Dodge Caravan
2009	Ford	Mustang
2009	Fuji Subaru	Legacy, Outback, Tribeca
2009	General Motors	Envoy, Trailblazer 2WD
2009	Mazda	6
2010	American Honda	Accord 4DR Sedan
2010	American Honda	Insight
2010	BMW	128, 328, 528; Mini Clubman, Mini Convertible, Mini Cooper
2010	Chrysler	VW Routan; Chrysler Commander 4WD, Jeep Grand Cherokee 4WD; Dodge Caliber; Dodge Nitro, Jeep Liberty; Chrysler 300, 300/SRT-8 Dodge Challenger, Charger
2010	Ford	Transit Connect; Edge FWD; Mercury Grand Marquis FFV
2010	Fuji Subaru	Forester AWD, Impreza AWD, Impreza Wagon/Outback Sport, Legacy Awd
2010	General Motors	GMC Acadia FWD; Chevrolet Camaro; Chevrolet Equinox, GMC Terrain; Chevrolet Impala
2010	GM Daewoo	Chevrolet Aveo, Aveo 5
2010	Honda	Acura TSX
2010	Hyundai	Elantra, Elantra Blue; Genesis; Genesis Coupe; Accent
2010	Kia	Soul; Forte
2010	Land Rover	LR 4, Range Rover, Range Rover Sport
2010	Mazda	3; CX-7 2WD
2010	Mercedes Benz	GL 450 4Matic, GL 550 4Matic
2010	Mitsubishi	Outlander
2010	Nissan	Altima; Frontier, Pathfinder, & Xterra
2010	Toyota	Camry ; Prius; RAV4 2WD
2010	Volkswagen	2.0L Diesel: Golf, Jetta, Jetta Sportwagen
2010	Volvo	Volvo S80, V70, XC60, XC70, XC90
2011	Audi	Volkswagen CC
2011	Chrysler	Jeep Compass & Patriot 4WD
2011	Ford	Escape FWD
2011	General Motors	Cruze; Traverse FWD
2011	Honda	Odyssey 2WD
2011	Kia	Sorento 2WD
2011	Nissan	Sentra
2011	Nissan	Maxima
2011	Toyota	Avalon
2012	Chrysler	Fiat 500
Confirmatory Class		
2006	Ford	Ford Taurus

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In addition to its own in-use testing, EPA uses data from the mandatory manufacturer run In-Use Verification Program (IUVP) to monitor in-use light-duty vehicle emissions performance. IUVP tests are required at low mileage (between 10,000 and 50,000 miles) and high mileage (greater than 50,000 miles). Manufacturers must complete low mileage IUVP testing one year after the end of production and complete high mileage IUVP testing five years after the end of production. Figure 17 shows a sample IUVP test schedule for a MY2014 vehicle.

Figure 17 - Example of IUVP Testing Process for a MY 2014 Vehicle

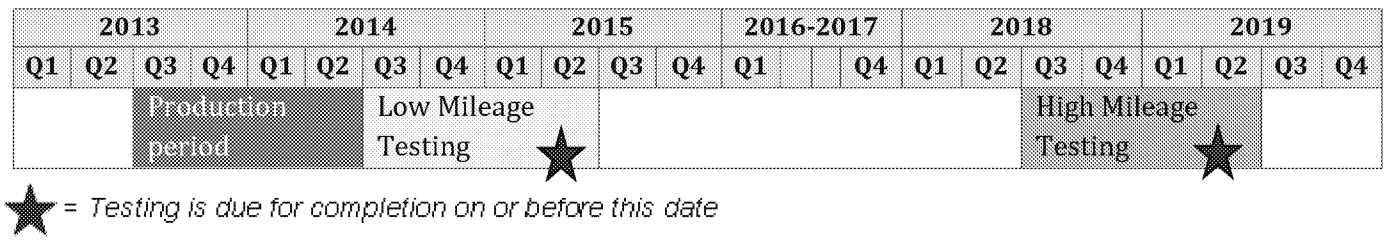

Figure 18 shows the total number of vehicles tested over each test procedure and their corresponding failure rates by vehicle model year for all IUVP testing conducted.

Figure 18
Light-Duty Vehicle In-Use Verification Program Test Volumes and Failure Rates in 2012-2013 CYs

Model Year	FTP		US06		2-Day Evap		ORVR[16]	
	Vehicles Tested	Failure Rate	Vehicles Tested	Failure Rate	Vehicles Tested	Failure Rate	Vehicles Tested	Failure Rate
High-Mileage Testing								
2008	1119	9.0%	783	1.0%	126	6.4%	132	6.8%
2009	654	8.7%	477	0.6%	102	4.9%	94	5.3%
2010	20	10.0%	14	0.0%	5	0.0%	5	0.0%
2011	8	0.0%	7	0.0%	0	0.0%	1	0.0%
2012	5	20.0%	4	0.0%	1	0.0%	0	0.0%
Low-Mileage Testing								
2008	8	0.0%	2	50.0%	1	0.0%	1	0.0%
2009	4	0.0%	3	0.0%	0	0.0%	3	0.0%
2010	12	8.3%	11	0.0%	2	50.0%	4	0.0%
2011	498	3.6%	436	1.2%	131	3.8%	134	3.0%
2012	580	2.8%	520	0.4%	148	2.7%	129	1.6%
2013	73	2.7%	73	0.0%	18	5.6%	15	0.0%

Overall, the test results from this program show that the majority of the in-use fleet continues to comply with the emission standards. However, when IUVP testing identifies potential emissions concerns, EPA and manufacturers work together to implement solutions which may involve voluntary manufacturer action to fix the problem, or, if necessary, an EPA-ordered emissions recall. This process is described in greater detail in the 2007 Compliance Report.

[16] Onboard refueling vapor recovery (ORVR) is a vehicle emission control system that captures fuel vapors from the vehicle gas tank during refueling. This requirement was phased-in from 1998 through 2006.

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Figures 19 and 20 present 2012-2013 *calendar year* light-duty vehicle emission defect report information. Defects reported in 2012 -2013 potentially affected more than 48 million vehicles. A single defect incidence may affect multiple *model years* of a given vehicle.

Light-duty vehicle manufacturers are required to notify EPA when they learn of emission-related defects in 25 or more vehicles of the same class (e.g., exhaust test group) and category (e.g., manufacturer and model year).

Figure 19 - 2012-2013 CY Light-Duty Vehicle Defect Reports by Manufacturer

	Reported in CY2012		Reported in CY2013	
Manufacturer	Number of Defect Reports	Number of Affected Vehicles	Number of Defect Reports	Number of Affected Vehicles
Audi	16	415,501	10	422,824
Bentley	2	15,893	0	0
BMW	22	520,290	27	943,617
Chrysler	8	514,069	21	5,132,529
Fisker	8	2,753	3	2,835
Ford	7	1,133,253	15	2,136,197
General Motors	14	2,726,536	16	1,030,862
Honda	9	2,216,687	22	14,188,404
Hyundai	0	0	11	5,663,236
Isuzu	0	0	1	4,465
Jaguar	3	9,999	0	0
Jaguar/Land Rover	0	0	2	48,831
Kia	0	0	12	1,716,271
Land Rover	4	49,808	0	0
Lotus	0	0	1	5,476
Mazda	4	203,248	16	1,297,365
Mercedes-Benz	15	230,680	12	325,053
Mitsubishi	1	400	2	30,263
Nissan	19	2,102,476	16	1,616,751
Porsche	19	235,618	15	158,344
Rolls Royce	0	0	1	523
Subaru	6	469,540	2	576,169
Toyota	2	310,800	3	195,800
Volkswagen	10	879,789	8	304,846
Volvo	3	131,268	4	398,627
Total	**172**	**12,168,608**	**220**	**36,199,288**

Figure 19 shows the number of defect reports submitted for each manufacturer in 2012-2013 *calendar years* and the number of affected vehicles. The vehicle *model years* that are covered by the defect reports

submitted in 2012-2013 *calendar years* range from MY 2003 through 2014.[17] Manufacturers are required to report defects up to five years after the end of production.

Figure 20 shows the number of defects by defect category for all the vehicles covered by defect reports in 2012-2013 *calendar years.*

Figure 20 - 2012-2013 CY Light-Duty Vehicle Defect Reports by Problem Category

	Reported in CY2012		Reported in CY2013	
Problem Category	Number of Defect Reports	Number of Affected Vehicles[18]	Number of Defect Reports	Number of Affected Vehicles
Air Inlet/Intake System	7	1,708,931	6	943,866
Catalyst System	3	22,977	8	257,317
Computer Related (other than OBD)	11	639,937	35	6,730,630
Crankcase Ventilation System	5	204,688	1	37,240
Diesel Particulate Filter System	2	108,303	0	0
EGR System	2	225,952	2	104,979
Electrical, Mechanical & Cooling Systems	27	2,400,355	23	3,656,946
Emission Control Information Label	4	47,782	4	46,193
Evap Emissions System	14	1,209,577	19	2,834,713
Exhaust System	6	415,271	5	596,083
Fuel Delivery Component	14	752,429	22	1,260,052
Fuel Delivery System	2	87,120	2	68,132
Fuel Tank System	10	783,198	8	622,631
Hybrid Vehicle System	8	5,184	6	176,757
Ignition System	0	0	8	1,716,819
Monitoring/Measuring Sensor/System	24	2,148,244	12	11,593,222
NOx Absorber System	1	184,167	0	0
NOx Sensor	2	12,014	6	227,618
OBD System	23	1,077,276	32	3,244,916
On-Board Refueling and Vapor Recovery (ORVR)	0	0	1	511,377
Oxygen Sensor	2	9,009	8	1,131,552
Secondary Air System	0	0	2	115,765
Selective Catalytic Reduction System	3	36,545	6	77,944
Turbocharger/Supercharger	2	89,649	4	244,536
Total	**172**	**12,168,608**	**220**	**36,199,288**

[17] Defect and recall reports can be submitted in the calendar year *prior to* the designated model year because vehicles can be certified and introduced into commerce starting January 2 of the prior calendar year. For example, MY 2014 vehicles can be certified and introduced into commerce starting January 2, 2013.

[18] Vehicles that have defects in more than one category are counted in each problem category. Thus, the total number of affected vehicles can be higher in Figure 16 than the total number of affected vehicles in Figure 15.

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Figure 21 shows the number of light-duty vehicle recalls by vehicle manufacturer in 2012-2013 *calendar years*. Because a recall usually covers a single, specific condition, a vehicle with multiple emissions problems may be subject to multiple recalls. Thus the total number of affected vehicles includes vehicles that have been recalled more than once. Similarly, there is no direct correlation between the number of defect reports, recalls, and the number of vehicles that are recalled. A manufacturer may identify a lot of defects that are not significant enough to warrant a recall. On the other hand, a manufacturer could have a few major defects that evolve into major recalls affecting large portions of their product line. Historically, emissions recalls affect about three million vehicles annually although the number may vary in any given year.

Figure 21 - 2012-2013 CY Light-Duty Vehicle Recalls by Manufacturer

	Recalls in CY2012		Recalls in CY2013	
Manufacturer	Number of Recalls	Number of Affected Vehicles[18]	Number of Recalls	Number of Affected Vehicles
Audi	3	13,106	2	192,037
BMW	4	62,616	1	15,961
Chrysler	7	388,728	7	474,175
Ford	5	220,613	4	663,211
General Motors	4	196,774	2	40,673
Honda	0	0	4	80,290
Lotus	0	0	1	5,476
Mazda	1	3,144	0	0
Nissan	11	470,228	3	11,618
Subaru	1	168,810	1	102,077
Toyota	0	0	2	133,188
Volkswagen	1	167	3	470,533
Total	**37**	**1,524,186**	**30**	**2,189,239**

Figure 22 on the next page lists categories of defects that were corrected by recalls in 2012 – 2013. EPA established the defect categories primarily for internal tracking purposes to identify potential, industry-wide problems with a particular component or technology. Recalls in 2012-2013 *calendar years* affected vehicles spanning 2004 through 2014 *model years.*

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Figure 22 - 2012-2013 CY Light-Duty Vehicle Recalls by Problem Category

	Recalls in CY2012		Recalls in CY2013	
Problem Category	Number of Recalls	Number of Affected Vehicles	Number of Recalls	Number of Affected Vehicles
Air Inlet/Intake System	0	0	2	45,773
Computer Related (other than OBD)	6	208,188	8	544,614
EGR System	0	0	1	201,308
Electrical, Mechanical & Cooling Systems	6	247,441	0	0
Emission Control Information Label	3	10,310	2	39,747
Evap Emissions System	1	58,008	2	16,049
Exhaust System	1	225,254	1	102,077
Fuel Delivery Component	3	31,540	4	599,722
Fuel Delivery System	2	79,275	0	0
Fuel Tank System	1	1,739	1	1,789
Hybrid Vehicle System	0	0	2	133,175
Ignition System	1	138,717	0	0
Monitoring/Measuring Sensor/System	2	3,304	2	270.315
NOx Sensor	1	139,790	0	0
OBD System	9	323,986	3	68,023
Oxygen Sensor	0	0	1	935
Secondary Air System	0	0	1	165,712
Turbocharger/Supercharger	1	56,634	0	0
Total	**37**	**1,524,186**	**30**	**2,189,239**

AVERAGING, BANKING AND TRADING (ABT) PROGRAMS

The 2007 Compliance Report provided an overview of EPA's Tier 2 program. The Tier 2 standards are the set of emission standards that applied to cars and light-duty trucks during the period covered by this report.[19] The Tier 2 regulations offer manufacturers a choice of eight emission bins to which they can certify. Lower bin numbers reflect more stringent emission standards. The Tier 2 ABT program allows manufacturers to use sales-weighted averaging to certify groups of vehicles to different bin levels, as long as the fleet as a whole on average meets Bin 5 standards each year.

Figure 23 on the next page shows the percentage of exhaust test groups by emission certification bin for MY 2012-2013. For MY 2012, about 94 percent of test groups were certified to Bin 5 or better. For MY 2013 about 95 percent of test groups were certified to Bin 5 or better.

[19] The final Tier 3 standards were published April 28, 2014.

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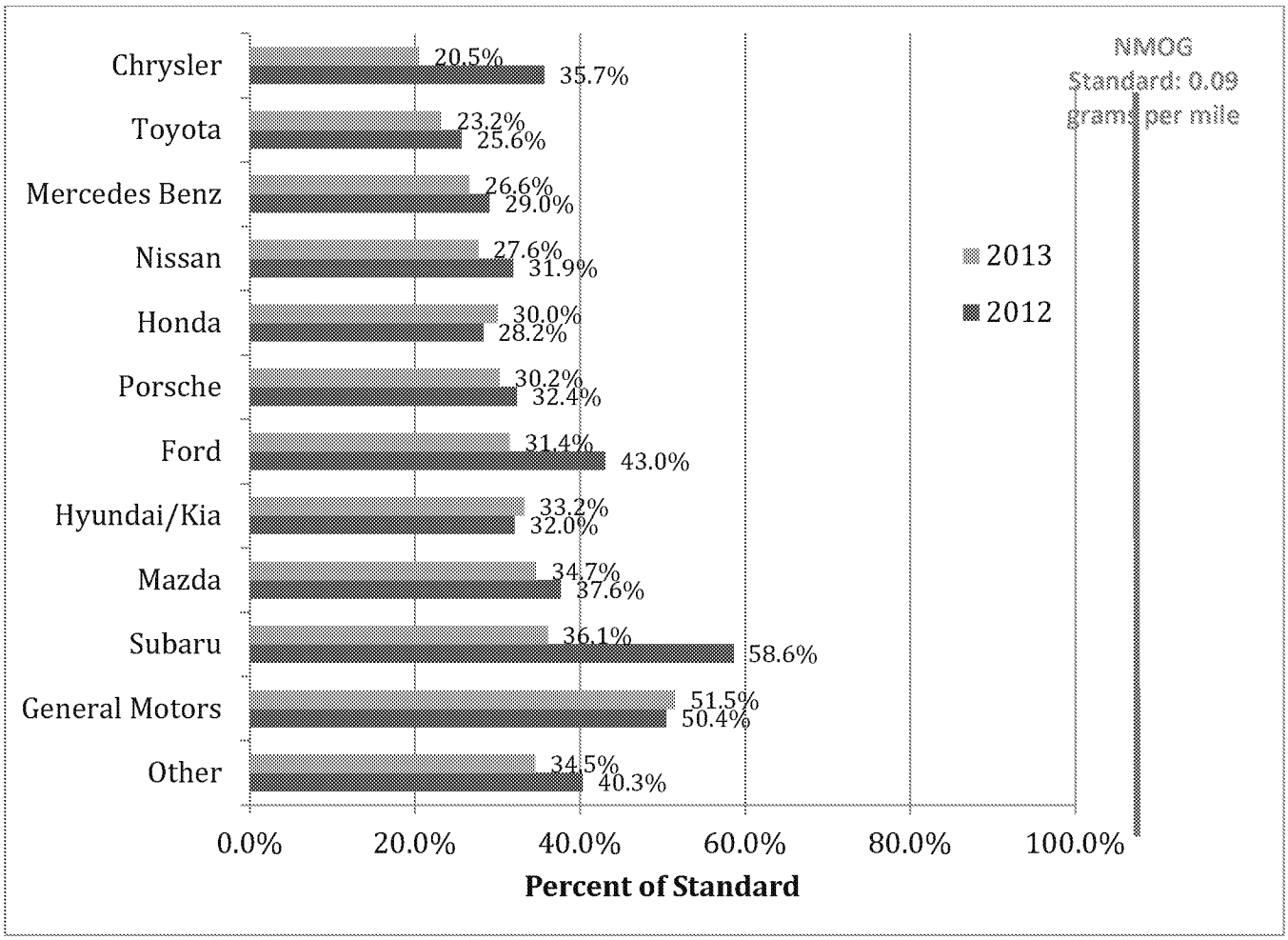
Figure 23
MY 2012-2013 Light-Duty Test Group Distribution by Tier 2 Emissions Bins

	Percentage of Light-Duty Test Groups[20]	
Tier 2 Bin	MY 2012	MY 2013
1	0.2%	0.4%
2	1.0%	2.4%
3	4.0%	4.9%
4	23.1%	26.8%
5	65.5%	60.6%
6	0%	0%
7	0%	0%
8	6.2%	4.9%

Figures 24–26 present the average certification levels for NOx, NMOG, and CO respectively along with the standards for Tier 2 Bin 5 for each major manufacturer for MY 2012-2013. The lower the certification levels relative to the standard, the greater the compliance margin.

Figure 24
MY 2012-2013 Tier 2 Bin 5 NOx Certification Levels and Compliance Margins by Manufacturer



[20] Sum of rounded values may not equal 100 percent.

Figure 25
MY 2012-2013 Tier 2 Bin 5 NMOG Certification Levels and Compliance Margins by Manufacturer

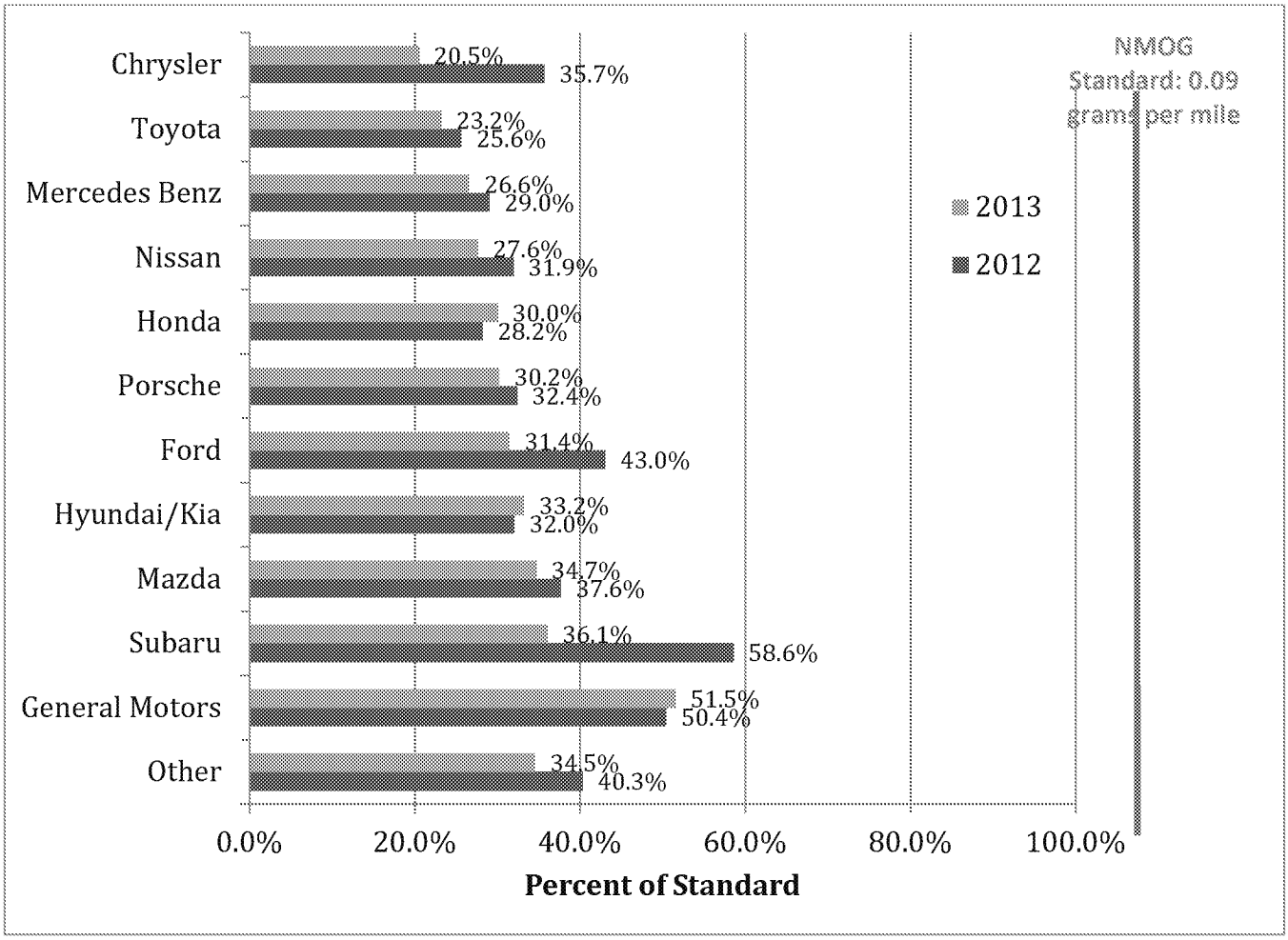
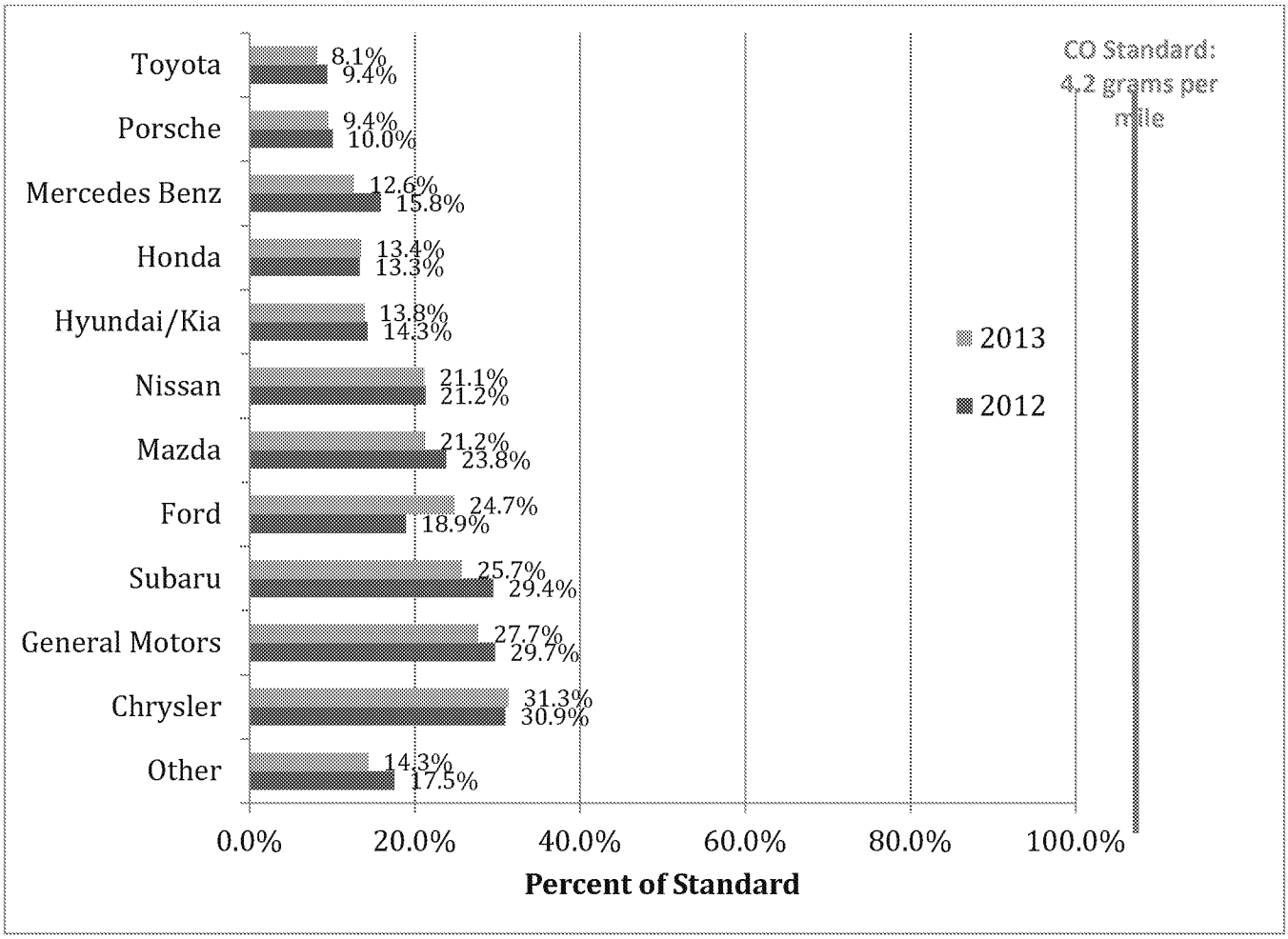


Figure 26
MY 2012-2013 Tier 2 Bin 5 CO Certification Levels and Compliance Margins by Manufacturer



C. Highway Motorcycles

SECTOR PROFILE:

- Highway and off-highway motorcycles are subject to different sets of regulations and emission standards. This section covers the highway motorcycles. Information about off-highway motorcycles is reported in the Recreational Vehicles section
- Highway motorcycles have been subject to HC and CO emissions standards since 1978
- A second set of more stringent emission standards took effect in MY2006. Although the CO emission standard remained unchanged at 12.0 g/km, the HC emission standard was reduced from 5 g/km to 1.0 g/km for Class 1 and 2 motorcycles. In addition, an optional HC + NOx 1.4 g/km standard was added.

CERTIFICATION

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Figure 27 presents the number of certified highway motorcycle engine families by class.

Figure 27 - MY 2012-2013 Highway Motorcycle Engine Families by Class

Highway Motorcycle Category	Number of Engine Families	
	MY 2012	MY 2013
Class Ia (<50cc)	42	44
Class Ib (50 -169cc)	54	53
Class II (170-279cc)	44	39
Class III (>279cc)	137	153
Battery electric motorcycles	8	3
Total	**285**	**292**

For MY 2012, 87 manufacturers certified highway motorcycles; 87 manufacturers also certified highway motorcycles in MY 2013. Figure 28 presents the number of motorcycle manufacturers in MY 2012-2013 for each highway motorcycle class.

Figure 28 - MY 2012-2013 Highway Motorcycle Manufacturers by Class

Highway Motorcycle Category	Number of Manufacturers Holding Certificates	
	MY 2012	MY 2013
Class Ia (<50cc)	40	39
Class Ib (50 -169cc)	39	42
Class II (170-279cc)	27	28
Class III (>279cc)	35	36
Battery electric motorcycles	5	3

Figure 29 on the next page presents the number of certified highway motorcycle engine families by manufacturer for MY 2012-2013. The manufacturers that certified a small number of engine families across the two model years are grouped together as "Other".

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Figure 29 - MY 2012-2013 Highway Motorcycle Engine Families by Manufacturer

MY 2012		MY 2013	
Manufacturer	**Number of Engine Families**	**Manufacturer**	**Number of Engine Families**
Yamaha Motor Corporation	26	Yamaha Motor Corporation	28
American Honda Motor Co., Inc.	15	American Honda Motor Co., Inc.	19
Suzuki Motor Corporation	15	Suzuki Motor Corporation	18
Piaggio Group Americas, Inc.	20	Piaggio Group Americas, Inc.	17
Kawasaki Motors Corp., U.S.A.	15	Kawasaki Motors Corp., U.S.A.	15
KYMCO USA	9	KYMCO USA	12
Ducati North America, Inc.	11	Ducati North America, Inc.	10
Triumph Motorcycles America Ltd	8	Triumph Motorcycles America Ltd	10
BMW	6	BMW	9
Harley-Davidson Motor Company	7	Harley-Davidson Motor Company	7
KTM North America, Inc.	4	KTM North America, Inc.	6
Other	149	Other	141
Total	**285**	**Total**	**292**

PRODUCTION VOLUME

More than 80 highway motorcycle manufacturers certified products in MY 2012 – 2013, but the vast majority of bikes sold in the United States were produced by just a few companies. Figure 30 on the next page shows reported production volumes for the six highest sales volume motorcycle manufacturers in model years 2012-2013. The production volume for lower-volume manufacturers is shown in aggregate. The aggregated volume is based on available data manufacturers have reported to EPA. As with light-duty vehicles, a comparison of Figures 29 and 30 show that there is not always a correlation between the number of engine families a manufacturer certifies and the number of vehicles the manufacturer produces. Manufacturers with the most certified engine families do not necessarily produce the most vehicles.

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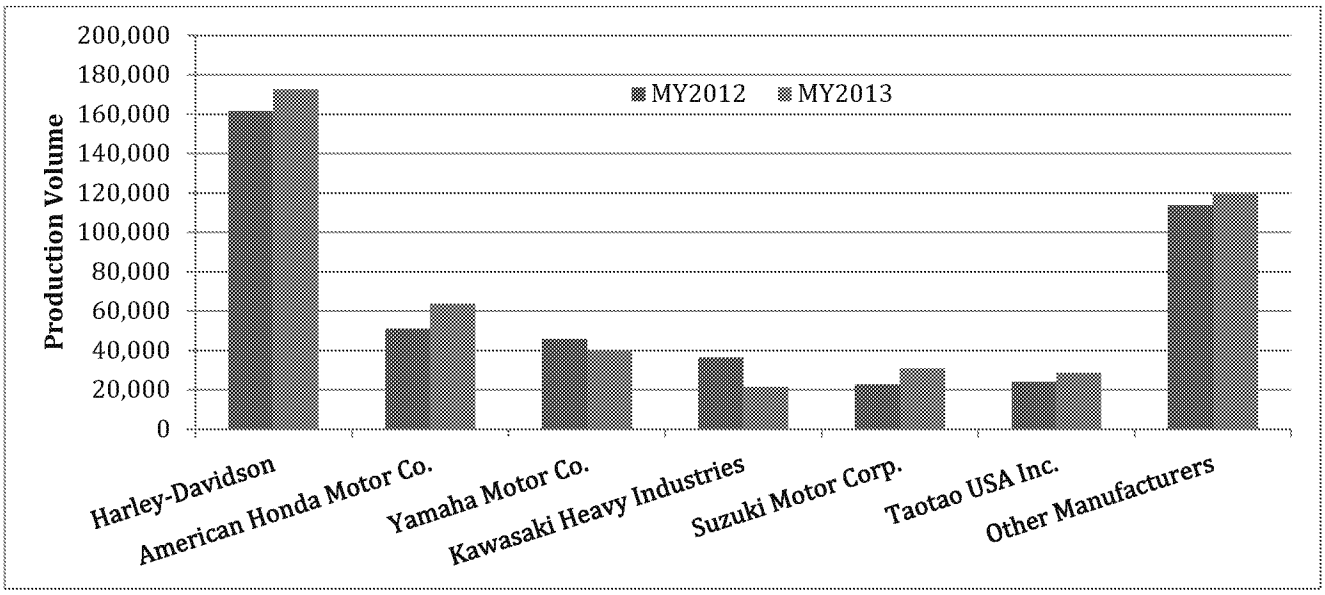
Figure 30 - MY 2012-2013 Highway Motorcycle Production Volumes by Manufacturer



DEFECT REPORTING

Figure 31 presents 2012-2013 emission defect report information for highway motorcycles. These reports can include multiple model years of a given vehicle and can span more than one problem category. Highway motorcycle manufacturers are required to notify EPA when they learn of the existence of emission-related defects in 25 or more vehicles of the same class (e.g., engine family) and category (e.g., manufacturer, model year).

Figure 31 - 2012-2013 Highway Motorcycle Defect Reports by Problem Category

	Reported in 2012		Reported in 2013	
Problem Category	Number of Defect Reports	Number of Affected Vehicles	Number of Defect Reports	Number of Affected Vehicles
Catalytic converter	0	0	1	208
Evaporative canister	0	0	1	615
Engine Control Unit (ECU)	0	0	1	11,097
Fuel related components - Cap	1	273,875	0	0
Total	**1**	**273,875**	**3**	**11,920**

In calendar years 2012-2013, manufacturers submitted defect reports that affected highway motorcycles in model years ranging from MY 2008-2011.

RECALL REPORTING

There was one highway motorcycle recall in 2012 for 273,875 motorcycles with a fuel cap problem. There were three highway motorcycle recalls in 2013 for 11,920 motorcycles with problems categorized as catalytic converter misbuilds, canister defects, and ECU defects.

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AVERAGE BANKING AND TRADING (ABT) PROGRAMS

The 2006 regulations added provisions allowing highway motorcycle manufacturers to use an EPA specified emission averaging approach to show compliance with the applicable HC+NOx standards. For MY 2012 – 2013 four manufacturers availed themselves of this provision.

Class III motorcycles (>279cc) represent the majority of motorcycle sales, and many Class III manufacturers with large sales volumes take advantage of the fleet averaging flexibility for HC+NOx. For model year 2012 and model year 2013 over 50 percent of the Class III motorcycle production used the fleet averaging flexibility.

D. HEAVY-DUTY HIGHWAY ENGINES

SECTOR PROFILE:

- Heavy-duty highway engines are used in highway vehicles such as trucks and buses that are more than 8,500 pounds GVWR.
- EPA has regulated heavy-duty highway engine emissions since 1982. Reductions in diesel sulfur content prior to 2007 enabled significant advances in emission controls. Final phase-in of a more stringent NOx standard started in MY2010.
- For MY2012-2013 the primary emission standards in effect were NMHC, CO, NOx and PM.

CERTIFICATION

EPA issued 62 heavy-duty highway certificates for MY 2012 and 39 heavy-duty certificates for MY 2013.[21] These include alternative fuel conversion and evaporative emissions certificates. Most certificates were for diesel engines.

Figures 32 and 33 on the next page present the number of MY 2012-2013 engine families certified in each intended service class for compression ignition and spark ignition heavy-duty highway engines. [22]

[21] Some vehicles that are between 8,500-14,000 pounds GVWR are chassis-certified and are included in the light-duty vehicles data.

[22] The number of engine families is not directly correlated to engine production volumes.

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Figure 32
MY 2012-2013 Heavy-Duty Highway Compression Ignition Engine Families by Service Class

Service Class	Number of Engine Families	
	MY 2012	MY 2013
Light heavy-duty diesel	10	8
Medium heavy-duty diesel	15	10
CA only medium-duty	0	0
Heavy heavy-duty diesel	33	18
Urban Bus	3	2
CA only urban bus	1	1

Figure 33
MY 2012-2013 Heavy-Duty Highway Spark Ignition Engine Families by Service Class

Service Class	Number of Engine Families	
	MY 2012	MY 2013
Heavy-duty gasoline 1 (<=14k lbs)	8	8
Heavy-duty gasoline 2 (>14k lbs)	21	24

Figures 34 and 35 present the number of MY 2012-2013 compression ignition and spark ignition engine families by each heavy-duty highway manufacturer.

Figure 34
MY 2012-2013 Heavy-Duty Highway Compression Ignition Engine Families by Manufacturer

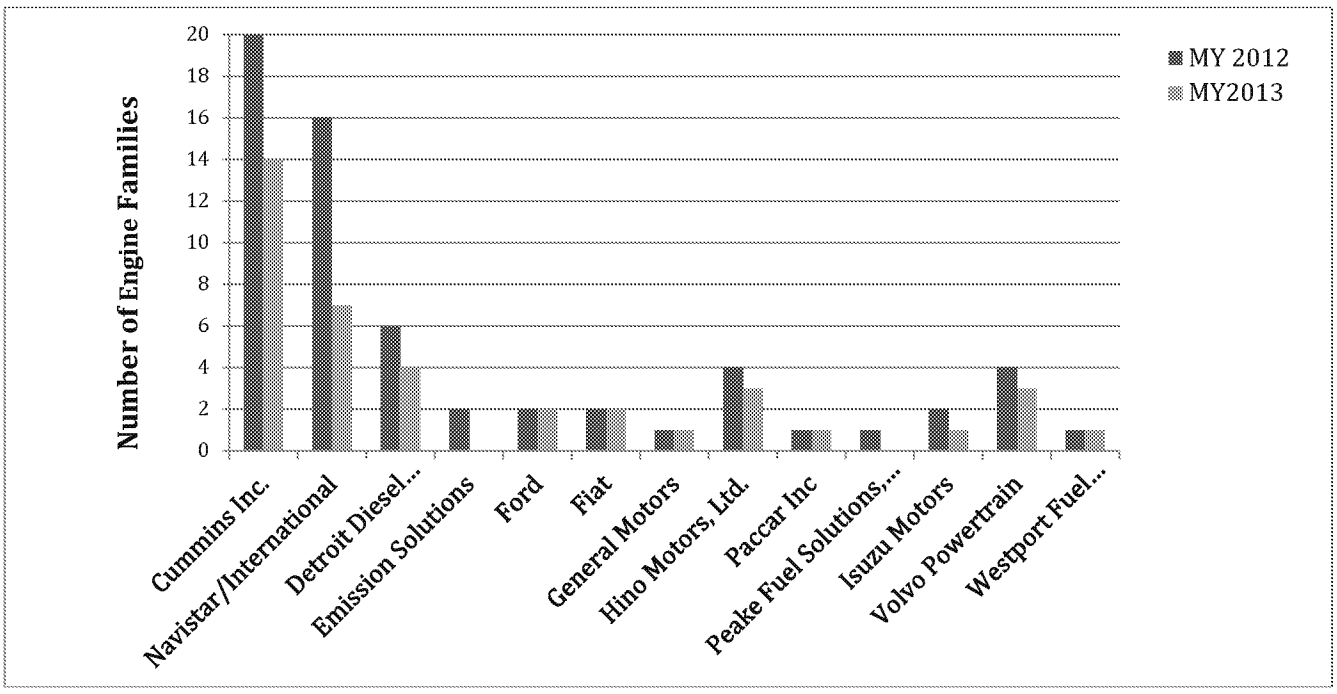
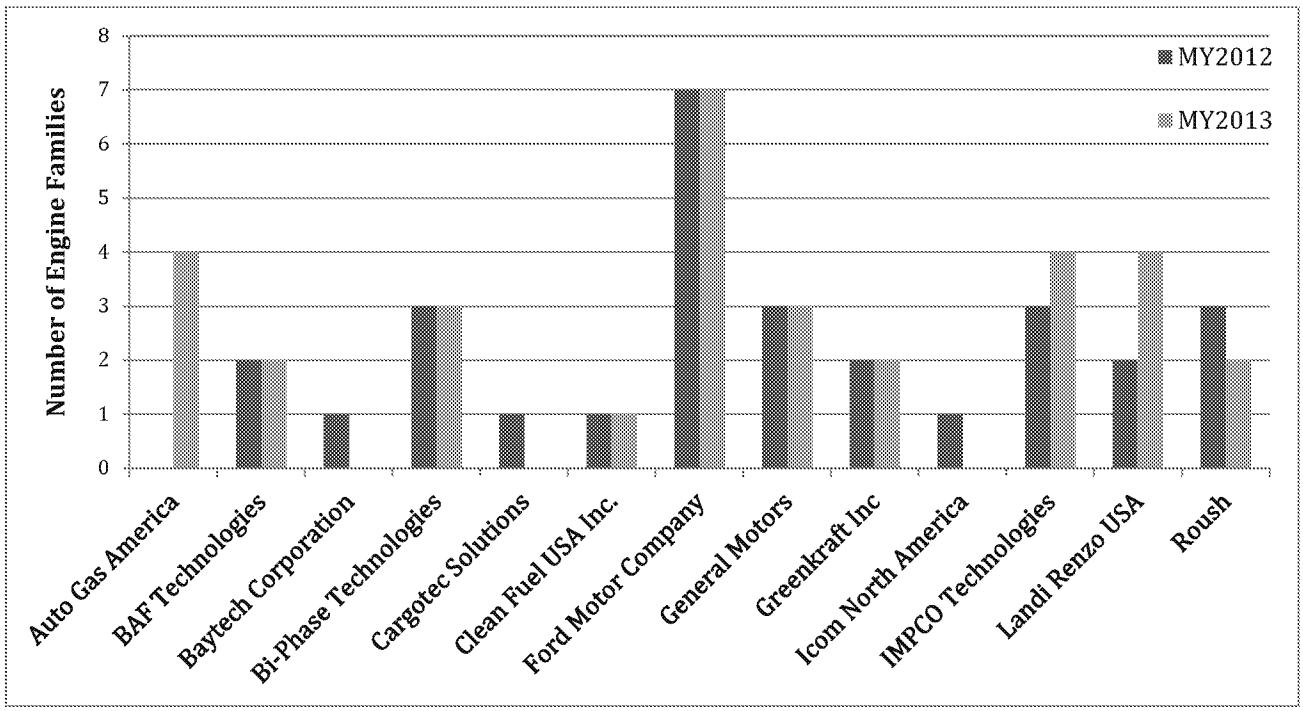


Figure 35
MY 2012-2013 Heavy-Duty Highway Spark Ignition Engine Families by Manufacturer



IN-USE COMPLIANCE TESTING

The in-use compliance testing program assesses emission levels (hydrocarbons, carbon monoxide, nitrogen oxides and particulate matter) from the engines of manufacturers' test fleets or customer-owned in-use heavy-duty diesel trucks using portable emission measurement systems. Portable systems placed inside of the vehicles measure emissions performance during real-world operating conditions. (Previously, engine emission testing involved removing the engine from the truck and testing it in a laboratory on an engine dynamometer.)

Manufacturers monitor compliance by testing in-use diesel engines during normal vehicle operation. If non-complying engines are identified, the manufacturer tests more engines for the purpose of determining if any further action is necessary. EPA also uses the in-use data to make independent evaluations about the possible need to pursue further actions. The in-use test data are used by EPA to assure that emission standards are being met, and by manufacturers to improve their engine designs.

All of the engines tested in this program were found to be in compliance with in-use emission standards when evaluated using the prescribed testing procedures.

DEFECT REPORTING

Figure 36 shows the number of defect information reports heavy-duty highway engine manufacturers submitted in 2012-2013 *calendar years*. Figure 37 shows the number of defect reports manufacturers submitted for each problem category reported in 2012 – 2013 *calendar years*. Defect reports can include multiple model years of a given engine.

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Figure 36 - 2012-2013 Heavy-Duty Highway Engine Defect Reports by Manufacturer

Manufacturer	Number of Defect Reports	
	Reported in CY2012	Reported in CY2013
Caterpillar	0	0
Cummins	1	8
Detroit Diesel Corporation	1	4
Ford	0	1
FTP Industrial S.p.A	0	0
General Motors	0	0
Hino	0	11
IVECO S.p.A	0	1
Isuzu	1	2
John Deere	0	0
Navistar	12	5
Paccar	1	4
Roush Industries, Inc.	0	0
UD Trucks Corporation	1	0
Volvo	4	9

Figure 37 - 2012-2013 Heavy-Duty Highway Engine Defect Reports by Problem Category

Problem Category	Number of Defect Reports	
	Reported in CY2012	Reported in CY2013
Fuel delivery component / system	3	4
Turbocharger/supercharger	3	3
Passive diesel particulate filter (DPF)	0	7
Active diesel particulate filter (DPF)	0	7
Electrical, mechanical & cooling systems	0	2
VECI label	3	1
EGR system	5	4
Exhaust system	1	3
Crankcase ventilation component/system	0	0
NOx absorber system	0	0
NOx sensor	1	1
OBD system	0	4
Selective catalytic reduction (SCR) system	3	11
Monitoring/measuring sensor/system	1	0
Computer related (other than OBD)	0	2
Diesel oxidation catalyst (DOC)	1	2
Ignition component	0	0
Defective / Incorrect Catalyst System (non-diesel engine)	0	0
Oxygen sensor	0	0

RECALL REPORTING

Figure 38 shows the number of heavy-duty highway engine recalls issued in 2012-2013 *calendar years*. Figure 39 on the next page shows the number of recalls for each problem category reported in 2012-2013 *calendar years*. Recalls can include multiple model years of a given engine. Recalls in the 2012

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calendar year affected engines from 2007 - 2012 *model years*, while recalls in the 2013 *calendar year* affected 2008 - 2013 *model years*.

Figure 38 - 2012-2013 Heavy-Duty Highway Engine Recalls by Manufacturer

	Recalls in CY2012		Recalls in CY2013	
Manufacturer	Number of Recalls	Number of Affected Engines	Number of Recalls	Number of Affected Engines
Caterpillar	0	0	0	0
Cummins	0	0	0	0
Detroit Diesel	1	72,399	0	0
Ford	2	196,424	0	0
FPT Industrial S.p.A.	0	0	0	0
General Motors	0	0	0	0
Hino	0	0	9	51,309
Isuzu	1	18,795	0	0
International-Navistar	0	0	0	0
IVECO S.p.A.	1	1,800	0	0
Mitsubishi Fuso Truck	0	0	0	0
PACCAR Inc.	1	31	0	0
Roush Industries, Inc.	0	0	0	0
Volvo	0	0	0	0
Total	**6**	**289,449**	**9**	**51,309**

Figure 39 - 2012-2013 Heavy-Duty Highway Engine Recalls by Problem Category

	Recalls in CY2012		Recalls in CY2013	
Problem Category	Number of Recalls	Number of Affected Engines	Number of Recalls	Number of Affected Engines
Crankcase ventilation component/system	0	0	0	0
Active diesel particulate filter (DPF)	0	0	1	16,338
EGR system	0	0	1	2,672
Electrical, mechanical & cooling systems	0	0	0	0
Turbocharger/supercharger	2	17,808	1	4,980
Fuel delivery component	0	0	0	0
Exhaust system	0	0	1	4,980
OBD system	0	0	0	0
VECI label	1	31	0	0
Selective catalytic reduction (SCR) system	2	74,199	4	25,492
Computer related (other than OBD)	0	0	0	0
NOx Sensor	1	139,790	1	4,980
Monitoring/measuring sensor/system	0	0	0	0
Catalyst system	0	0	0	0
Total	**6**	**231,828**	**9**	**59,442**

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AVERAGE BANKING AND TRADING (ABT) PROGRAMS

Approximately 30 percent of heavy-duty highway compression ignition engine manufacturers participated in ABT programs in both MYs 2012 and 2013.

MEDIUM AND HEAVY DUTY ENGINES AND VEHICLE GREENHOUSE GAS EMISSIONS

The years 2012 – 2013 marked the beginning of EPA's heavy duty greenhouse gas emission program (GHG) In September 2011, EPA and NHTSA jointly introduced the first ever GHG and fuel efficiency standards for model years 2014 through 2018 medium and heavy duty engines and vehicles.

Under the GHG program manufacturers required to meet the new greenhouse standards have the option to earn early credits in MY2013 which can then be applied to subsequent model years. Figure 40 lists those manufacturers who availed themselves of this opportunity.

Figure 40
MY 2013 Early GHG Credit Engine and Vehicle Manufacturers

Manufacturer Name	Number of Vehicle Families		Total
	Tractor	Vocational	
Daimler Trucks	18	12	30
Navistar	11	10	21
PACCAR	0	5	5
Total	29	27	56

E. NONROAD COMPRESSION IGNITION (NRCI) ENGINES

SECTOR PROFILE-

- EPA regulates several categories of nonroad compression ignition engines including marine diesel engines, locomotives, and compression ignition engines used in construction and agricultural equipment.
- EPA has regulated emissions from nonroad compression ignition engines since 1996.
- Primary emission standards in effect for MY 2012-2013 were NMHC, CO, NOx, and PM.

CERTIFICATION

Figure 41 on the next page presents the number of marine diesel certificates issued by certification tier and classification. Figure 42 on the next page presents the number of marine diesel certificates by manufacturer. Marine diesel engine manufacturers applying for engine certification may request an International Maritime Organization (IMO) certificate in addition to an EPA certificate of conformity for the same engine family. The IMO program, in general, is different from EPA's program, but certain

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jurisdictions require operators to display an EPA-issued IMO certificate. For the purposes of this compliance report, only one certificate for each engine family was included in the counts listed below.

New marine diesel standards were phased in at different times for different engine sizes. In general, Tier 2 began to take effect around 2005; Tier 3 began in about 2009. Tier 3 phases in through 2018. Tier 4 begins for some engines in 2014 and will capture all engines *to which it applies* by 2017.

Figure 41 - MY 2012-2013 Marine Diesel Engine Certificates by Tier

Certification Tier	Number of Certificates	
	MY 2012	MY 2013
Tier 1	0	10
Tier 2	141	86
Tier 3	44	82
Remanufacture	18	16
IMO	23	25
Total	**226**	**219**

Figure 42 - MY 2012-2013 Marine Diesel Engine EPA and IMO Certificates by Manufacturer

Manufacturer[23]	Number of Certificates	
	MY 2012	MY 2013
AB Volvo Penta	17	17
Alaska Diesel Electric	4	6
Caterpillar Inc.	28	29
Cummins Inc.	17	15
Detroit Diesel Corporation	5	4
Doosan Engine Co., Ltd.	0	12
Electro-Motive Diesel, Inc.	17	11
FPT Industrials p.A.	13	8
IHI Shibaura Machinery Corporation	11	10
John Deere Power Systems Group	26	24
MAN Nutzfahrzeuge AG	4	5
Marinediesel Sweden AB	6	2
Mitsubishi Heavy Industries, Ltd.	6	5
MTU Detroit Diesel, INC.	4	4
NANNI INDUSTRIES SAS	5	3
Perkins Engines Co Ltd	8	1
Scania-CV AB	6	6
Transportation Systems Business Operations of GE	5	3
Yanmar CO., Ltd	18	11
Other	26	43
Total	**226**	**219**

Figure 43 on the next page shows locomotive certificates. Some engine manufacturers who make engines for locomotives certify those engines to both non-road compression ignition standards and to locomotive standards.

[23] Manufacturers that certified only a few Marine CI engine families in MY 2012 2013 are aggregated under "Other". For MY 2012 "Other" represents 13 manufacturers; for MY 2013 "Other" represents 20 manufacturers.

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Figure 43 - MY 2012-2013 Locomotive Certificates by Manufacturer

Manufacturer	MY 2012	MY 2013
Advanced Global Environmental	11	11
Bombardier Transport	1	0
CIT Rail	2	0
CSX Transportation, Inc.	7	8
Cummins Inc.	4	4
Electro-Motive Diesel, Inc. (EMD)	16	16
HK Engine Components LLC	1	1
MotivePower Inc.	1	1
National Railway Equipment Co. (NREC)	5	5
OceanAir Environmental, LLC	3	3
Peaker Services, Inc.	1	2
Progress Rail Services	3	3
RJ Corman Railpower LLC	1	1
Thoroughbred Emissions Research, LLC	0	2
TransPar Corporation	0	0
Transportation Systems Business Operations of General Electric Company (GE)	14	17
Total	**70**	**74**

Nonroad compression ignition engines intended for use in construction and agricultural equipment can be certified for use in one or multiple service classes. Figure 44 presents the number of certificates that were issued covering each power category. As new emission standards became effective for the 2013 model year, the number of engine families certified below 56 kilowatts dropped significantly. Figure 45 on the next page shows the number of engine families certified by each manufacturer for MY 2012 – 2013. The number of certifying engine manufacturers dropped from 67 in MY 2012 to 36 in MY 2013.

Figure 44 - MY 2012-2013 Construction and Agricultural Engine Families by Service Class

Service Class (Power Category)	Number of Engine Families	
	MY 2012	MY 2013
0-8 kW	50	24
8-19 kW	74	62
19-37 kW	106	43
37-56 kW	78	45
56-75 kW	16	14
75-130 kW	42	50
130-560 kW	115	120
>560 kW	44	47
Total[24]	**525**	**405**

[24] This figure does not include stationary-only engine families.

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Figure 45 - MY 2012-2013 Construction and Agricultural Engine Families by Manufacturer

Manufacturer[25]	Number of Engine Families	
	MY 2012	MY 2013
Caterpillar (CPX)	35	36
Changchai (CHC)	5	0
Changchai Kaito (CZK)	1	0
Changfa Group (JCG)	1	0
Cummins (CEX)	31	32
Daedong (DCL)	12	4
Deere and Company (JDX)	29	23
Detroit Diesel (DDX)	2	2
Deutz (DZX)	38	33
Daihatsu Motor Company (DHX)	2	0
Doosan (DIC)	5	6
Escorts Limited (AEL)	2	0
FPT Industrial S.p. (FPX)	20	22
Fuzhou Leading Power (FLP)	1	0
Fuzhou Lingli (FZL)	1	0
Greaves Farymann Di (FDU)	4	0
Hailin (FHM)	1	0
Hino (HMX)	4	4
H-Power (WXP)	2	1
Huayuan Laidong (SHL)	6	0
Iseki (ICL)	8	2
ISM (H3X)	23	32
Isuzu (SZX)	14	9
ITC Power (CTE)	1	0
JCB Power Systems (JCB)	1	2
Jiangdong (JDG)	1	0
Jiangsu Changfa Agr (JCA)	1	0
Jiangsu Jin Hongxia (JGH)	2	0
Jindong (SZJ)	1	0
Kapur (FZK)	1	0
Kohler Co. (KHX)	12	4
Komatsu Ltd. (KLX)	10	10
Koop (CKP)	1	0
Kubota (KBX)	43	34
Kukje Machinery (KMC)	9	6
Launtop(FLT)	1	0
Lion (LES)	1	0
Lister Petter Limit (L5X)	4	0
Liebherr Machines Bulle (LHA)	9	10
LS Mtron (LGC)	3	0
M&M (MML)	11	12
Mercedes-Benz (MBX)	4	4
Mitsubishi Fuso (MFT)	2	1
Mitsubishi (MVX)	19	12
Motorenfabrik Hatz (HZX)	25	21

[25] Manufacturers that certified only a few engine families in MY 2012-2013 are aggregated under "Other".

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Manufacturer[25]	Number of Engine Families	
	MY 2012	MY 2013
MTU DD (MDD)	7	7
Navistar (NVX)	0	1
Nissan Diesel (NDX)	2	0
Nissan Forklift Co. (NFX)	1	1
Perkins (PKX)	17	17
PSA Peugeot Citroen (PEX)	0	1
Shineray (CSP)	2	0
Simpson & Co Limited (SCL)	4	0
Scania (Y9X)	2	2
Sinopower (FZW)	1	0
Sisu Diesel (SID)	4	4
Suntom (FZS)	1	0
Toyota Industrial Equipment Manufacturing (TIE)	2	0
Volkswagen (VWX)	3	1
Volvo Construction Equipment (VSX)	3	3
AB Volvo Penta (VPX)	11	11
Winsun (NWS)	2	0
World Best Kama (WWB)	3	0
Wuxi Kipor Power Co (WKP)	2	0
Xinchai (ZHX)	2	0
Xingguang (YKX)	1	0
Xingyue(CXG)	1	0
Yangdong (YND)	4	0
Yanmar (YDX)	41	34
Zongshen (CZH)	0	1
Total[26]	**525**	**405**

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

Five construction and agricultural engine manufacturers participated in ABT programs in MY 2012; seven manufacturers participated in MY 2013.

[26] This figure does not include stationary-only engine families.

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F. Nonroad Spark Ignition Engines

SECTOR PROFILE:

- Nonroad spark ignition (Nonroad SI) engines are generally divided into three categories for purposes of exhaust emission compliance:
  - Small spark ignition engines (Small SI) are rated below 25 horsepower (19 kW) and are generally used in household and commercial applications, including lawn and garden equipment, utility vehicles, generators, and a variety of other construction, farm, and industrial equipment
  - Marine spark ignition (Marine SI) engines are used in marine vessels, including outboard engines, personal watercraft, and sterndrive/inboard engines
  - Large spark ignition (Large SI) engines are generally rated above 19 kW and used in forklifts, compressors, generators, stationary equipment

- Equipment with NRSI engines installed is also subject to evaporative emissions standards.

- Nonroad SI engines have been subject to emissions regulations since 1997.

CERTIFICATION

For the 2012 – 2013 model years EPA certified more than 900 Small SI engine families, around 150 engine emissions families each for Marine SI and Large SI, and over 650 Evaporative Component families. There are five classes of Small SI engines. Figure 46 presents the number of families certified in each Small SI class.[27] Figures 47-49 on the next page present the number of engine families certified by Small SI, Marine SI, and Large SI. Figure 50 on the next page shows the number of families certified by Evaporative Component type (e.g., fuel tank, and fuel line).

Figure 46 - MY 2012-2013 Small Spark Ignition Engine Families by Class

Small SI Class	Number of Engine Families	
	MY 2012	MY 2013
Class I	216	205
Class II	325	311
Class III	2	1
Class IV	271	257
Class V	143	150
Total	**957**	**924**

[27] Classes are defined by whether or not the engine is applied in a hand held piece of equipment and by power rating. Classes I and II describe non-hand held equipment whereas class III, IV, and V engines are in hand held equipment.

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Figure 47 - MY 2012-2013 Small Spark Ignition Engine Families by Manufacturer

Manufacturer	Number of Engine Families	
	MY 2012	MY 2013
Andreas Stihl AG & Co KG	57	55
Echo Incorporated/Kioritz Corporation	54	57
Briggs & Stratton Corporation	46	44
Husqvarna AB	36	35
Kawasaki Motors Corp., U.S.A.	35	36
American Honda Motor Co., Inc.	26	25
Fuji Heavy Industries	26	23
Kohler Co.	26	28
Loncin Motor Co., Ltd.	25	21
Husqvarna Outdoor Products N.A. Inc.	24	23
Jiangsu Jiangdong Group Co. Ltd.	22	27
Chongqing Zongshen General Power Machinery	21	22
Lifan Industry (Group) Co., Ltd.	21	23
Chongqing Rato Power Co., Ltd.	20	24
Husqvarna Zenoah Co., Ltd.	20	21
Shandong Huasheng Zhongtian Machinery	18	23
Other[28]	480	437
Total	**957**	**924**

[28] For MY 2012 "Other" represents 96 manufacturers that collectively produced 480 Small SI engine families. For MY 2013 "Other" represents 83 manufacturers that collectively produced 437 Small SI engine families.

Figure 48 - MY 2012-2013 Marine Spark Ignition Engine Families by Manufacturer

Manufacturer	Number of Engine Families	
	MY 2012	MY 2013
Mercury Marine	35	34
Yamaha Motor Corporation	23	25
Bombardier Recreational Products, Inc	16	15
American Honda Motor Co., Inc.	11	11
Suzuki Motor Corporation	11	12
Tohatsu Corporation	8	8
Indmar Products Co., Inc.	6	5
Hangzhou Hidea Power Machinery Co., Ltd.	5	5
Suzhou Parsun Power Machine Co., Ltd.	5	5
Volvo Penta of the Americas, LLC	5	7
KEM Equipment, Inc.	4	4
Pleasurecraft Marine Engine Company	3	4
Briggs & Stratton Corporation	2	2
Kawasaki Motors Corp., U.S.A.	2	2
LEHR Incorporated	2	3
Albert Weber Manufacturing, Inc.	1	2
Ilmor Engineering, Inc.	1	4
Other[29]	6	7
Total	**146**	**155**

[29] For MY 2012 "Other" represents six manufacturers that collectively produced six Marine SI engine families. For MY 2013 "Other" represents seven manufacturers that collectively produced seven Marine SI engine families.

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Figure 49 - MY 2012-2013 Large Spark Ignition Engine Families by Manufacturer

Manufacturer	Number of Engine Families	
	MY 2012	MY 2013
Generac Power Systems, Inc.	47	43
Power Solutions International, Inc.	13	12
KEM Equipment, Inc.	12	12
Bucks Engines	10	9
Cummins Inc.	8	9
IMPCO Technologies, Inc.	8	8
Power Solutions International	8	8
Zenith Power Products	6	5
Engine Distributors, Inc.	5	3
Woodward, Inc.	5	3
Wisconsin Motors, LLC.	4	4
Nissan Forklift Co., Ltd.	3	0
SRC Power Systems, Inc.	3	3
Kubota Corporation	2	4
Global Component Technologies Corporation	0	3
Guascor Power S.A.U.	0	5
Tognum America, Inc.	0	3
Other[30]	15	19
Total	**149**	**153**

Figure 50
MY 2012-2013 Nonroad Spark Ignition Evaporative Component Families by Type

Manufacturer	Number of Engine Families	
	MY 2012	MY 2013
Fuel Line	108	117
Fuel Tank	183	222
Fuel Cap	10	15
Marine Diurnal	28	30
Handheld Equipment	45	59
Non handheld Equipment	302	318
Marine Vessel	3	4
Total	**679**	**765**

[30] For MY 2012 "Other" represents 13 manufacturers that collectively produced 15 Large SI engine families. For MY 2013 "Other" represents 15 manufacturers that collectively produced 19 Large SI engine families.

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PRODUCTION LINE TESTING (PLT)

Production line testing requires manufacturers to routinely test engines as they leave the assembly line to demonstrate that production engines meet emission standards. In the Small SI and Marine SI sectors, most engine manufacturers had at least one engine family subject to PLT.[31] In the Large SI sector, many engine families are not subject to PLT requirements because the projected sales volume is less than 150 units. These engine families are only required to submit production reports. Under the PLT program manufacturers submit emissions data on thousands of production engines across the many engine families certified each year. Based on the data submitted by manufacturers, nearly all engine families demonstrate compliance with the emission requirements of the PLT program. The PLT program has identified a small number of engine families in which manufacturers have had to make production changes to improve the emission performance of their engines.

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

Prior to MY 2010 all types of Small SI engines were averaged together. However, beginning in MY 2010, *handheld* and *non-handheld* engines were averaged separately.

In MY 2012 and MY 2013, about 20 percent of Small SI engine manufacturers participated in the ABT program.

G. Recreational Vehicles

SECTOR PROFILE:

- Emissions from recreational vehicles (RVs) were unregulated prior to MY 2006.
- The regulations in 40 CFR part 1051 set the first emissions standards for RV categories, including all-terrain vehicles (ATVs); certain off-road utility vehicles (UTVs) (less than 30 kW, less than 1,000 cc, and maximum speed more than 25 mph); off-highway motorcycles; and snowmobiles. Each recreational vehicle category is subject to an individual set of exhaust emission standards which phase in over several years. Regulated pollutants are HC+NOx and CO.
- All RVs became subject to the same fuel component based permeation emission standards beginning in MY 2008. The regulated pollutant is HC.

[31] PLT requirements do not apply to small volume engine manufacturers.

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There were 79 different recreational vehicle manufacturers that certified products in MY 2012-2013. Figure 51 presents RV manufacturers that certified a total of at least five engine families in one or more RV sectors in MY 2012 and/or 2013.[32] Figures 52 - 54 present data for manufacturers that certified MY 2012 and/or 2013 engine families in the ATV and UTV, off-highway motorcycle or snowmobile sectors, respectively.

Figure 51 - MY 2012-2013 Recreational Vehicle Engine Families by Manufacturer

Manufacturer	Number of Engine Families	
	MY 2012	MY 2013
Yamaha Motor Corporation	26	25
Polaris Industries Inc.	21	22
American Honda Motor Co., Inc.	20	20
Bombardier Recreational Products,	20	19
Arctic Cat	19	20
Kawasaki Motors Corp., U.S.A.	12	10
Baja Inc.	11	5
KYMCO USA	10	11
BMS Motorsports, Inc.	6	3
CF Moto Powersports, Inc.	6	7
Deere & Company	6	6
Linhai USA, Inc.	6	4
Suzuki Motor Corporation	6	6
Taotao USA Inc.	6	9
Hisun Motors	5	11
LIL PICK UP INC.	5	4
Other	82	77
Total	**267**	**259**

[32]The number of engine families has no bearing on vehicle production volumes.

Figure 52 - MY 2012-2013 ATV and UTV Engine Families by Manufacturer

Manufacturer	Number of Engine Families	
	MY 2012	MY 2013
Yamaha Motor Corporation	14	13
Polaris Industries Inc.	13	14
Arctic Cat	13	13
American Honda Motor Co., Inc.	11	11
Bombardier Recreational Products, Inc	11	11
KYMCO USA	10	11
Kawasaki Motors Corp., U.S.A.	9	7
CF Moto Powersports, Inc.	6	7
Deere & Company	6	6
Linhai USA, Inc.	6	4
BMS Motorsports, Inc.	6	3
Hisun Motors	5	10
Taotao USA Inc.	5	8
Suzuki Motor Corporation	5	5
LIL PICK UP INC.	5	4
Kandi USA, Inc.	4	4
BV Powersports, LLC	3	4
Shenke USA, Inc.	3	4
High Rev Motorsports, LLC	3	2
Baja Inc.	3	1
XY POWERSPORTS LLC	3	1
U-Storm Power Corporation	0	3
Other	39	41
Total	**183**	**187**

Figure 53 - MY 2012-2013 Off-Highway Motorcycle Engine Families by Manufacturer

Manufacturer	Number of Engine Families	
	MY 2012	MY 2013
American Honda Motor Co., Inc.	9	9
Baja Inc.	8	4
Yamaha Motor Corporation	7	7
XMotos USA, Inc.	4	0
Kawasaki Motors Corp., U.S.A.	3	3
KTM North America, Inc.	3	4
AB Distribution, Inc. dba American Beta	2	2
Apollo Motorsports, Inc.	2	0
Xingyue USA, INC	2	0
Yukon Trail, Inc.	2	0
Apollo Motorsports USA, Inc.	1	2
Maxtrade	1	2
Other	12	9
Total	**56**	**42**

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Figure 54 - MY 2012-2013 Snowmobile Engine Families by Manufacturer

Manufacturer	Number of Engine Families	
	MY 2012	MY 2013
Bombardier Recreational Products, Inc.	9	8
Polaris Industries Inc.	8	8
Arctic Cat Inc	6	7
Yamaha Motor Co., LTD.	5	5
HJR	0	1
Richmond Manufacturing Group	0	1
Total	**28**	**30**

As shown in Figure 55, in model years 2012-2013 very few ATV/UTV or off-highway motorcycle manufacturers produced two-stroke engines. However, approximately 50% of the snowmobile engine families were two-stroke engines. This represents a technology shift to four-stroke engines. When the current RV regulations were written, a majority of ATVs sold in the United States and almost all snowmobiles used two-stroke engines (see 67 FR 68262).

Figure 55 - MY 2012-2013 Recreational Vehicle Two-Stroke Engine Families

Category	Percentage of Two Stroke Engine Families	
	MY 2012	MY 2013
ATV/UTV	0.5%	0.5%
Off-Highway Motorcycles	11%	5%
Snowmobiles	50%	47%

In addition, in MY 2012-2013 over 70 percent of ATVs and UTV engine families either employed catalyst or fuel injection technologies, or both, to meet the emission standards.

ATV / MOTORCYCLE CERTIFICATES VOIDED

In 2013 EPA voided certificates covering more than 170,000 on- and off-highway motorcycles and all-terrain vehicles produced in model years between 2005 and 2012. The products were imported or manufactured by the following companies: Snyder Technology, Inc., Snyder Computer Systems, Inc. (doing business as Wildfire Motors Corporation), American Lifan Industry Inc., and Jonway Motorcycles (USA) Co., Ltd. Consumers who own models covered by the voided certificates are not responsible for the wrongdoing and can continue to use their vehicles. Voiding certificates is a key step leading to enforcement actions for violations of the CAA.

As a result of the August 2014 voiding of certificates of conformity for CF Moto America, Incorporated, the EPA's Office of Enforcement and Compliance Assurance took action which resulted in a civil penalty of $725,000. The settlement also requires CF Moto to institute a recall and fuel tank replacement program, as well as correct emission control labels for nonconforming labels within CF Moto's control. For more information, please see: http://www2.epa.gov//enforcement/cfmoto-powersports-inc-cfmoto-america-inc-zhejiang-cfmoto-power-co-ltd-and-chunfeng

As a result of the October 2013 voiding of certificates of conformity for American Lifan Industry, Incorporated, the EPA's Office of Enforcement and Compliance Assurance took action which resulted in a

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civil penalty of $630,000 and the posting of a bond of $300,000 to $500,000 to satisfy any Clean Air Act penalty related to future importation of vehicles manufactured by the company in 2014, 2015, and 2016. For more information, please see: http://www2.epa.gov/enforcement/american-lifan-industry-inc-settlement

AVERAGE BANKING AND TRADING (ABT) PROGRAMS

Only a few of the larger ATV, utility vehicle, and off-highway motorcycle manufacturers made use of ABT. On the other hand, almost all snowmobile manufacturers participated in ABT.

IV. Industry Statistics

This section presents additional information that EPA collects in the course of implementing compliance programs.

Alternative Fuel and Alternative Fuel Conversions[33]

Some vehicles and engines are designed to operate on fuels other than gasoline and diesel. Some are manufactured by the OEM to operate on alternative fuels, while others are certified by the OEM to operate on gasoline or diesel fuel and later converted by an aftermarket manufacturer to operate on an alternative fuel. Generally, the CAA prohibits any aftermarket changes to a certified vehicle or engine configuration that could affect emissions, but a regulatory exemption to the prohibition is available in the case of alternative fuel conversions. Each sector has different criteria under which vehicles and engines can be converted to operate on a new fuel. In some sectors fuel conversions are certified using OEM certification provisions.

LIGHT-DUTY VEHICLE ALTERNATIVE FUEL DATA

Figures 56 - 57 on the next page present the production of MY 2012-2013 OEM light-duty vehicles by fuel type. Gasoline vehicles comprise the dominant fuel type, followed by flexible fuel vehicles. After gasoline and ethanol, diesel is the next most prevalent fuel, but still represents only about one percent of passenger car and light-duty truck production. Compressed natural gas (CNG) vehicles make up an even smaller fraction of MY 2012-2013 vehicle production.

[33] While alternative fuels are generally understood to mean non-petroleum alternatives to gasoline and diesel, this section of the report also presents data for diesel-fueled vehicles and engines in the light-duty, motorcycle, and recreational vehicle sectors, sectors that have historically been dominated by gasoline.

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Figure 56 - MY 2012 Light-Duty Vehicle Production Volume by Fuel Type [34]

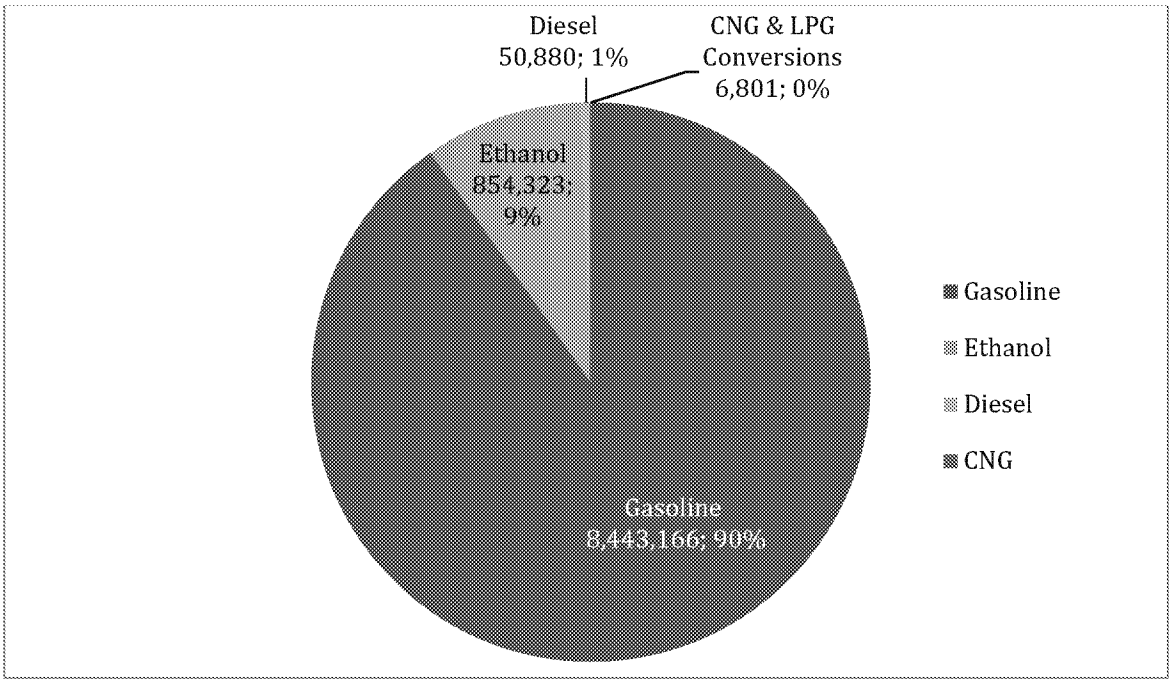
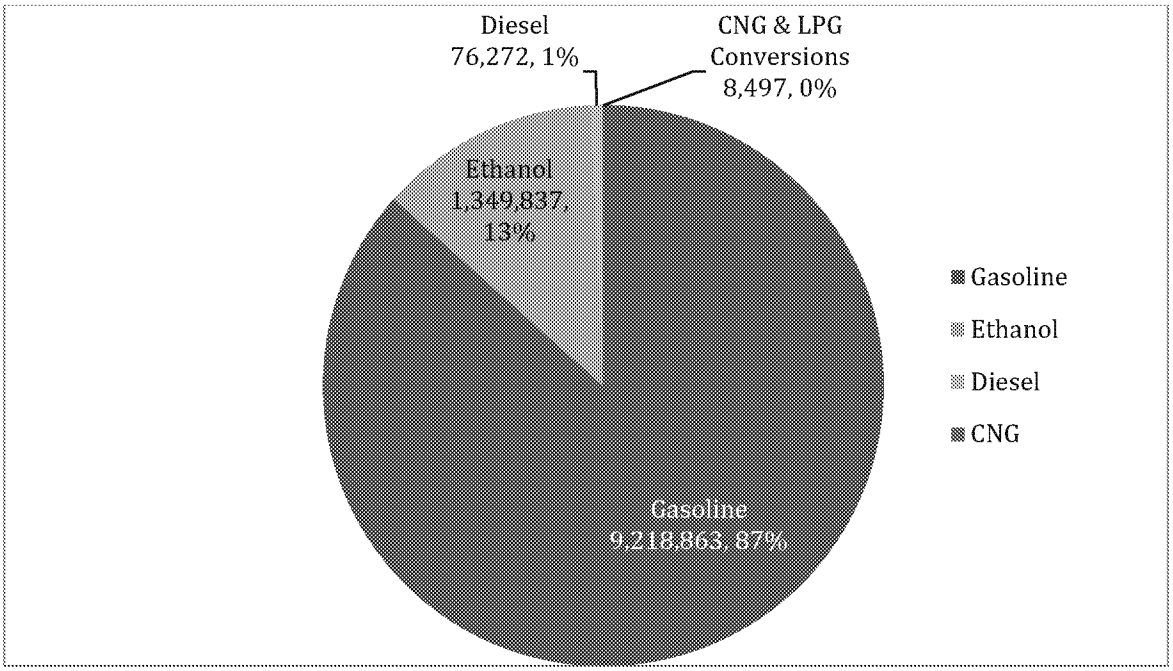


Figure 57 - MY 2013 Light-Duty Vehicle Production Volume by Fuel Type[35]



All MY 2012 – 2013 ethanol vehicles were flexible-fuel vehicles which are capable of operating on gasoline, E85 (85 percent ethanol and 15 percent gasoline), or an intermediate blend.

[34] Ethanol represents ethanol fuel blend of 85% denatured ethanol fuel and 15% gasoline
[35] Ethanol represents ethanol fuel blend of 85% denatured ethanol fuel and 15% gasoline

Figure 58 summarizes the number of OEM light-duty vehicle diesel and alternative fuel test groups by manufacturer.

Figure 58
MY 2012-2013 Light-Duty OEM Diesel and Alternative Fuel Test Groups by Manufacturer

Fuel	Manufacturer	Number of Exhaust Test Groups	
		MY 2012	MY 2013
Battery Electric	Azure Dynamics	1	0
	BYD Motors	1	1
	Coda	1	1
	Nissan	1	1
	Tesla	1	1
	Ford	1	1
	Wheego	0	1
	Toyota	1	2
	Mitsubishi	1	1
	Chrysler Group	0	1
CNG	American Honda	1	1
	Chrysler Group LLC	1	1
	The Vehicle Production Group LLC	1	1
Diesel	Audi	2	3
	BMW	1	1
	Cummins	2	2
	Ford	2	2
	General Motors Inc.	3	3
	Isuzu	1	1
	Mahindra & Mahindra	0	0
	Mercedes Benz	6	8
	Porsche AG	0	1
	Volkswagen	2	2
E85-Gasoline	Amer. Honda	1	0
	Audi	0	2
	Bentley Motors Ltd.	2	2
	Chrysler Group LLC	12	14
	Ford	19	17
	General Motors LLC	22	30
	Jaguar Land Rover Ltd.	0	1
	Mercedes Benz	3	3
	Nissan Motor Co. Ltd	1	1
	SAAB	1	0
	Toyota Motor	1	1
Hydrogen Fuel Cell	American Honda	1	1
	Toyota Mercedes Benz	1	0

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Vehicles originally designed and certified to operate on gasoline or diesel fuel can be converted to operate on an alternative fuel. Converters of new vehicles must generally obtain a certificate of conformity to avoid violating the CAA prohibition against tampering.

A regulation finalized in 2011 established alternative pathways to obtain a regulatory exemption from tampering beyond certification for converters of older vehicles and engines (40 CFR part 85, subpart F).

In the light-duty vehicle alternative fuel conversion sector, a total of 18 alternative fuel conversion manufacturers were issued conversion certificates for either the 2012 model year, the 2013 model year or both model year vehicle test groups and thereby received an exemption from the CAA tampering prohibition.

For the 2012 model year light-duty vehicle program, there were 140 conversion certificates issued to alternative fuel conversion manufacturers, 45 conversion postings through the Intermediate Age program which covers vehicles and engines at least two years old but within their regulatory useful life, and no conversion postings through the Outside Useful Life program vehicles and engines that have exceeded their regulatory useful life. For the 2013 model year program, there were 117 conversion certificates issued, 16 conversion postings through the Intermediate Age program and 2 conversion postings through the Outside Useful Life program.

Figure 59 on the next page summarizes the number of certificates issued for light-duty vehicle alternative fuel conversions by alternative fuel type and by manufacturer in MY 2012-2013.[36]

[36] Each light-duty vehicle certificate covers a unique combination of exhaust test group and evaporative emissions family. Therefore the number of light-duty certificates and test groups is usually different. MY 2012-2013 conversion certificates may be issued for conversion of either current or earlier model year OEM vehicles.

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Figure 59
MY 2012-2013 Light-Duty Alternative Fuel Conversion Certificates by Manufacturer

Fuel	Manufacturer	Number of Certificates	
		MY 2012	MY 2013
CNG	Altech-Eco	14	6
	BAF Technologies	4	5
	Go Natural CNG	4	0
	Landi-Renzo	1	5
	Nat Gas Car	8	0
	NaturalDrive Partners	3	0
	IMPCO Technologies	5	4
	PowerFuel CNG conversions	0	4
CNG/E85-Gasoline	Altech-Eco	4	0
	The CNG Store; dba Auto Gas	5	1
	BAF Technologies	5	4
	Go Natural CNG	1	0
	Landi-Renzo	3	0
	Nat Gas Car	10	2
	Westport Light-Duty	3	0
	IMPCO Technologies	11	0
	Powerfuel CNG Conversions	0	6
	Altech-ECO	6	5
	The CNG Store; dba Auto Gas	2	3
	BAF Technologies	6	1
	CNG Interstate	0	2
	Westport Light-Duty	0	3
	Land Reno	0	3
	Nat Gas Car	0	10
	IMPCO Technologies	0	10
	M-Tech Solutions	0	1
E85-Gasoline		0	0
LPG	RGR Alternative Fuels	1	0
	Roush Industries	7	4
	ICOM North America	0	2
	Yellow Checker Star	1	1
LPG/E85-Gasoline	American Alternative Fuel	3	0
	IMPCO Technologi	8	0
	ICOM North America	22	8
LPG/Gasoline	American Alternative Fuel	0	6
	Icon North America	0	2
	IMPCO Technologies	3	5
	Blossman Industries	0	12
Plug In Hybrid		0	0

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HIGHWAY MOTORCYCLE ALTERNATIVE FUEL DATA

The majority of highway motorcycles are certified to operate on gasoline. However, there are a few highway motorcycle engine families certified to operate as battery-electrics, obtaining energy by charging a battery with electricity from a 120V outlet. See Figure 60 for a breakdown of electric motorcycle manufacturers for MY 2012-2013.

Figure 60
MY 2012-2013 Highway Motorcycle OEM Alternative Fuel Engine Families by Manufacturer

Fuel	Manufacturer	Number of Engine Families	
		MY 2012	MY 2013
Battery Electric[37]	Brammo Inc.	2	0
	Electric Vehicle	1	0
	Hyosung Motors America,	1	0
	Oxygen World, Inc.	1	0
	Zero Motorcycles Inc.	3	0
	Peel Engineering	0	1
	Peraves AG	0	1
	Westward Industries	0	1

HEAVY-DUTY HIGHWAY ALTERNATIVE FUEL DATA

Figure 61 presents the OEM heavy-duty highway engines that were certified to operate on alternative fuels in model years 2012-2013.

Figure 61
MY 2012-2013 Heavy-Duty Highway Engine OEM Alternative Fuel Engine Families by Manufacturer

Fuel	Manufacturer	Number of Engine Families	
		MY 2012	MY 2013
CNG	Cummins Inc.	3	9
	Doosan Infrcore, Co	2	2
	Emission Solutions Inc.	2	-
CNG/Diesel	Westport Fuel Systems	1	1
LPG	Cummins Inc	0	0

[37] EPA began issuing certificates for battery electric highway motorcycles in MY 2009.

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Figure 62 shows the heavy-duty highway alternative fuel conversion certificates issued in model years 2012-2013.[38]

Figure 62
MY 2012-2013 Heavy-Duty Highway Engine Alternative Fuel Conversion Certificates by Manufacturer

Fuel	Manufacturer	Number of Certificates	
		MY 2012	MY 2013
CNG	BAF Technologies	1	1
	Baytech Corporation	1	1
	Emission Solutions, Inc.	1	2
	Evotek, LLC	0	0
	Greenkraft, Inc.	2	2
CNG/Gasoline	Baytech Corporation	0	0
	Bi-Phase Technologies, LLC	3	3
	Clean Fuel USA, Inc.	1	1
	Roush	3	2
LPG/Gasoline	Icom North America, LLC	1	0

[38] MY 2012-2013 conversion certificates may be issued for conversion of either current or earlier model year OEM highway engines.

NONROAD SPARK IGNITION ALTERNATIVE FUEL AND FUEL CONVERSION DATA

There are numerous engine manufacturers that certify nonroad spark ignition engines to run on alternative fuels in both the Small SI and the Large SI categories.[39] The following sections detail these two categories.

SMALL SPARK IGNITION ALTERNATIVE FUEL MANUFACTURERS

Figure 63 shows the model years2012 – 2013 small spark ignition engine manufacturers by the type of alternative fuel used.

Figure 63
MY 2012-2013 Alternative Fuel Small SI Engine Manufacturers

Fuel	Manufacturer	Number of Certificates	
		MY 2012	MY 2013
Gasoline – E85	Kohler Co.	0	1
Natural Gas	Aisin World Corp. of America	2	1
	Arrow Engine Company	6	6
	Cummins Power Generation	1	1
	Kubota Corporation	1	1
	Repair Processes, Incorporated	1	1
	Yanmar Co., Ltd.	1	2
	Intellichoice Energy	0	1
Propane	Amano Pioneer Eclipse Corporation	2	1
	Aztec Products Inc.	2	2
	BETCO Corporation	1	1
	Briggs & Stratton Corporation	1	1
	ChongQing AM Pride Power & Machinery Co., Ltd	1	0
	Chongqing Dajiang Power Equipment CO.,LTD	2	0
	Chongqing Hybest Power Products Manufacturing Co., Ltd.	1	1
	Chongqing Maifeng Power Machinery Co., Ltd	1	0
	Chongqing Orbiswork Power Equipment Co., Ltd.	2	0
	Cummins Power Generation	6	4
	Feldmann Eng. & Mfg. Co., Inc.	1	1
	Fuji Heavy Industries	2	1
	Generac Power Systems, Inc.	3	3
	Jiangsu Jiangdong Group Co. Ltd.	2	4
	Kawasaki Motors Corp., U.S.A.	1	1
	Kohler Co.	1	2
	METROLAWN, LLC	6	8
	Nilfisk Advance	2	2
	ONYX ENVIRONMENTAL SOLUTIONS	8	4
	Power Solutions, Inc.	1	0
	Shanghai Grow Development Co., Ltd.	1	1
	Stonekor LLC	2	2
	Tacony Corporation	1	1

[39] Of the marine SI engines certified in MY 2012 and 2013, two MY2012 families were designed to operate on alternative fuels and three MY2013 families were designed to operate on alternative fuels.

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	Whitestorm Inc.	1	1
	Yanmar Co., Ltd.	1	2
	Intellichoice Energy	0	1
	Linyi Sanhe Yongjia Power Co.Ltd.	0	1
	Loncin Motor Co. Ltd.	0	2
	Zhejiang Yaofeng Power Technology Co. Ltd.	0	3
Natural Gas / Propane	American Honda Motor Co., Inc.	1	1
	Briggs & Stratton Corporation	7	5
	CHONGQING SANDING GENERAL POWER MACHINERY CO.,LTD	1	1
	Carburetion & Turbo Systems, Inc.	1	1
	Fuji Heavy Industries	1	1
	Generac Power Systems, Inc.	3	5
	Kohler Co.	2	2
	Marathon Engine Systems	1	1
	Shanghai Grow Development Co., Ltd.	2	2
	Chongqing Dajiang Power Equipment CO.LTD	0	2
Propane/Gasoline	Chongqing Dajiang Power Equipment CO.,LTD	2	0
	Chongqing Huansong Industries (Group) Co., Ltd.	1	1
	Chongqing Maifeng Power Machinery Co., Ltd	1	1
	Kubota Corporation	2	2
	Power Solutions International	1	1
	Wenling Jennfeng Industry Inc.	1	1
	Yongkang Xingguang Electrical Manufacture Co., Ltd	2	4
	Yueqing Hejie Electric Co., Ltd	1	3
	Zhejiang Yaofeng Power Technology Co. Ltd.	0	2
Natural Gas / Propane/Gasoline	Winco	1	1
	Chongqing Dajiang Power Equipment CO.LTD	0	2
	CHONGQING SANDING GENERAL POWER MACHINERY CO.LTD	0	2

LARGE SPARK IGNITION ALTERNATIVE FUEL MANUFACTURERS

Figure 64 shows the model years 2012 – 2013 large spark ignition engine manufacturers by the type of alternative fuel used.

Figure 64
MY 2012-2013 Alternative Fuel Large SI Engine Manufacturers

Fuel	Manufacturer	Number of Certificates	
		MY 2012	MY 2013
Natural Gas	GE Jenbacher, Ltd.	1	1
	Industrial Engines Ltd.	2	2
	IMPCO Technologies, Inc.	2	2
	Bucks Engines	6	4
	Cummins Inc.	3	5
	Generac Power Systems, Inc.	27	26
	KEM Equipment, Inc.	1	1
	Power Solutions International	1	1
	Wisconsin Motors, LLC.	1	1
	Guascor Power S.A.U.	0	5
	ENER-G Rudox Inc.	0	1
Natural Gas / Propane	Bucks Engines	1	2
	Cummins Inc.	5	4
	Don Hardy Race Cars, Inc.	1	1
	KEM Equipment, Inc.	5	6
	Origin Engines	1	2
	Power Solutions International, Inc.	8	8
	Power Solutions International	6	6
	SRC Power Systems, Inc.	3	3
	Westport Light Duty Inc.	1	1
	Westport Power Inc.	0	1
	Chongqing Panda Machinery Co., Ltd.	0	2
	Kubota Corporation	0	1
	Dresser, Inc.	0	1
	MTU America, Inc.	0	3
Natural Gas / Propane/ Gasoline	IMPCO Technologies, Inc.	1	1
	Kubota Corporation	1	2
	Engine Distributors, Inc.	3	3
	Power Solutions International, Inc.	2	2
	Toyota Industrial Equipment Manufacturing	1	1
	Zenith Power Products	2	2
Propane	IMPCO Technologies, Inc.	3	3
	Deere & Company	1	1
	Bucks Engines	1	1
	Generac Power Systems, Inc.	20	17
	KEM Equipment, Inc.	2	2
	Kohler Co.	1	1

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	Linde Material Handling N.A. Corp.	2	2
	Power Solutions International, Inc.	2	1
	Power Solutions International	1	1
	Woodward, Inc.	2	1
Propane / Gasoline	IMPCO Technologies, Inc.	2	2
	Kubota Corporation	1	1
	Global Component Technologies Corporation	3	3
	Bucks Engines	2	2
	EControls, Inc.	1	0
	Engine Distributors, Inc.	2	0
	KEM Equipment, Inc.	4	3
	Power Solutions International, Inc.	1	1
	Woodward, Inc.	3	2
	Wisconsin Motors, LLC.	1	1
	Zenith Power Products	4	3

About 10 percent of Small SI engine families in MY 2012-2013 were certified to operate on alternative fuels. The majority of Large SI engine families were certified to operate on alternative fuels. In MY 2012 of the 149 Large SI engine families, 144 were certified to operate on one or more alternative fuels. In MY 2013, of the 153 Large SI engines families, 149 were certified to operate on one or more alternative fuels. Figures 65 and 66 summarize information about MY 2012-2013 Small SI and Large SI alternative fuel engine families.

Figure 65
MY 2012-2013 Small Spark Ignition Engine OEM Alternative Fuel Engine Families

Fuel	Number of Engine Families	
	MY 2012	MY 2013
E85-Gasoline	0	1
Natural Gas/CNG	12	13
Natural Gas/CNG / Propane/LPG	19	21
Propane/LPG	53	50
Propane/LPG / Gasoline	12	16
Natural Gas/CNG / Propane/LPG / Gasoline	1	5

Figure 66
MY 2012-2013 Large Spark Ignition Engine OEM Alternative Fuel Engine Families

Fuel	Number of Engine Families	
	MY 2012	MY 2013
Natural Gas/CNG	44	49
Natural Gas/CNG / Propane/LPG	31	41
Natural Gas/CNG / Propane/LPG / Gasoline	10	11
Propane/LPG	35	30
Propane/LPG / Gasoline	24	18

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RECREATIONAL VEHICLE ALTERNATIVE FUEL DATA

The majority of recreational vehicles are certified to operate on gasoline. However, there were three ATV engine families certified to operate on diesel in MY 2012 and four in MY 2013. Figure 67 shows a breakdown of diesel recreational vehicle manufacturers.

Figure 67
MY 2012-2013 Recreational Vehicle OEM Diesel Engine Families by Manufacturer

Fuel	Manufacturer	Number of Engine Families	
		MY 2012	MY 2013
Diesel	Tomcar NA Distribution	1	1
	Deere & Company	1	1
	JCB, Inc.	1	1
	Polaris Industries	0	1

MANUFACTURER LOCATIONS

Consistent with past compliance reports, manufacturer locations here are attributed using two different approaches.

For light-duty vehicles and locomotives, data are reported based on where a manufacturer's headquarters are located, not necessarily where the vehicles are manufactured. For example, Toyota's corporate headquarters are in Japan, so all of Toyota's MY 2012-2013 vehicles produced for sale in the United States are presented with Japan listed as the country of origin, even though some Toyota vehicles are built in the United States. For all other sectors, EPA generally reports manufacturer location based on the actual location in which the vehicle or engine was manufactured.

LIGHT-DUTY VEHICLE MANUFACTURER LOCATIONS

Figure 68 on the next page presents the country of origin of MY 2012-2013 light-duty vehicles produced for sale in the United States.[40]

[40] These production data only include vehicles subject to Corporate Average Fuel Economy standards. Pickup trucks greater than 8,500 pounds Gross Vehicle Weight are not included.

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Figure 68
MY 2012-2013 Light-Duty Vehicle Production Volume by Manufacturer's Country of Origin

Country	Production Volume	
	MY 2012	MY 2013
USA	5,657,856	6,270,952
Japan	5,433,737	5,691,017
Korea	1,164,920	0
Germany	1,108,916	1,071,996
UK	55,378	64,143
Sweden	71,807	73,354
Italy	6,454	2,780
China	11	32
Total	**13,499,079**	**13,174,274**

HIGHWAY MOTORCYCLE MANUFACTURER LOCATIONS

Figure 69 presents the highway motorcycles sold in the United States. Chinese, Japanese, and Taiwanese manufacturers produced a large fraction of Class Ia and Ib motorcycles while American, Japanese and European manufacturers produced the largest share of U.S. Class III highway motorcycles.

Figure 69
MY 2012-2013 Motorcycle Manufacturer Engine Families by Country of Origin

Country	Number of Engine Families	
	MY 2012	MY 2013
Austria	4	6
Canada	4	6
China[41]	104	89
Germany	0	1
India	2	2
Italy	37	35
Japan	37	40
Poland	0	1
Russia	1	1
Slovenia	1	1
South Korea	2	3
Switzerland	0	0
Taiwan	16	22
Thailand	7	9
United Kingdom	8	11
USA	54	61
Vietnam	0	1
Total	**277**	**289**

[41] Two of the 104 engine families were subsequently voided by EPA.

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ATV MANUFACTURER LOCATIONS

Figure 70 presents Chinese and U.S. manufacturers produced most of the ATVs sold in the United States.

Figure 70
MY 2012-2013 ATV Manufacturer Engine Families by Country of Origin

Country	Number of Engine Families	
	MY 2012	MY 2013
Austria	3	4
Brazil	2	2
Canada	9	9
China	107	98
Italy	3	2
Japan	14	12
Mexico	1	1
Taiwan	22	24
Thailand	1	1
USA	74	76
Vietnam	1	1
Total	**237**	**230**

HEAVY-DUTY HIGHWAY MANUFACTURER LOCATIONS

Figure 71 presents the number of highway engine families (both compression ignition and spark ignition) that were certified for sale in the United States by engine manufacturing plant location.

Figure 71
MY 2012-2013 Heavy-Duty Highway CI and SI Engines by Manufacturing Location

Country	Number of Engine Families	
	MY 2012	MY 2013
USA	51	32
Japan	7	4
Germany	0	0
Brazil	0	0
Canada	1	1
Netherlands	1	0
Italy	0	0
Multiple countries[42]	0	0
Total	**60**	**37**

NONROAD COMPRESSION IGNITION MANUFACTURER LOCATIONS

Figures 72 - 74 present the number of engine families intended for use in marine diesel (both EPA and IMO certificates), locomotive, and construction/agricultural equipment applications that were certified for sale in the United States by engine manufacturing plant location or country of origin.

[42] "Multiple countries" means that engines within an engine family are manufactured in more than one country.

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Figure 72 - MY 2012-2013 Marine Diesel Engine Families by Manufacturing Location

Country	Number of Engine Families	
	MY 2012	MY 2013
USA	99	96
Japan	23	13
Italy	16	16
Sweden	18	11
United Kingdom	15	12
Korea	2	24
The Netherlands	8	8
Germany	12	12
France	10	11
Mexico	0	0
Croatia	0	2
Canada	0	0
Norway	1	1
Finland	0	0
Austria	1	1
Multiple Countries	21	12
Total	**226**	**219**

Figure 73 - MY 2012-2013 Locomotive Engine Families by Country of Origin

Country	Number of Engine Families	
	MY 2012	MY 2013
USA	65	70
Multiple countries	5	4

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Figure 74
MY 2012-2013 Construction and Agricultural Engine Families by Manufacturing Location

Country	Number of Engine Families	
	MY 2012	MY 2013
Brazil	1	1
China	47	2
Finland	4	4
France	7	10
Germany	76	61
India	19	14
Italy	20	16
Japan	146	105
Republic of Korea	29	16
Mexico	4	2
Slovakia	4	0
Sweden	14	16
Switzerland	9	10
United Kingdom	10	10
United States	48	54
Multiple countries	87	84
Total[43]	**525**	**405**

NONROAD SPARK IGNITION MANUFACTURER LOCATIONS

Figures 75 - 77 present the number of Small SI, Marine SI and Large SI engine families that were certified for sale in the United States by engine manufacturing plant location.

Figure 75 - MY 2012-2013 Small Spark Ignition Engine Families by Manufacturing Location

Country	Number of Engine Families	
	MY 2012	MY 2013
China	435	431
USA	220	207
Japan	134	104
Germany	14	15
Sweden	28	25
Italy	7	8
Mexico	18	14
Brazil	58	56
Multiple countries	43	64
Total	**957**	**924**

[43] This figure does not include stationary-only engine families.

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Figure 76 - MY 2012-2013 Marine Spark Ignition Engine Families by Manufacturing Location

Country	Number of Engine Families	
	MY 2012	MY 2013
Japan	55	57
USA	66	70
China	17	18
Thailand	5	6
Canada	2	2
Germany	1	2
Total	**146**	**155**

Figure 77 - MY 2012-2013 Large Spark Ignition Engine Families by Manufacturing Location

Country	Number of Engine Families	
	MY 2012	MY 2013
USA	128	123
Korea	0	4
Canada	9	10
Spain	0	5
Japan	5	7
Mexico	1	1
Austria	1	1
China	0	2
Multiple countries	5	0
Total	**149**	**153**

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United States
Environmental Protection
Agency

EPA-420-R-15-007

To: Wehrly, Linc[wehrly.linc@epa.gov]
From: Cohen, Janet[/O=EXCHANGELABS/OU=EXCHANGE ADMINISTRATIVE GROUP (FYDIBOHF23SPDLT)/CN=RECIPIENTS/CN=D94B854E69CD4F9E80DB946BF9D1C1B2-COHEN, JANET]
Sent: Tue 9/29/2015 3:02:39 PM (UTC)
Subject: FW: Volkswagen Clips 9/29/2015

Fyi. Lots of press. If you intend to read everything this will keep you busy for a while. – j. -

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From: Birgfeld, Erin
Sent: Tuesday, September 29, 2015 10:48 AM
To: Bunker, Byron
Cc: Cohen, Janet; Hengst, Benjamin; Grundler, Christopher
Subject: Fwd: Volkswagen Clips 9/29/2015

Sent from my iPhone
Begin forwarded message:

> **From:** "Gong, Kristiene" <Gong.Kristiene@epa.gov>
> **To:** "Purchia, Liz" <Purchia.Liz@epa.gov>, "Allen, Laura" <Allen.Laura@epa.gov>, "Abrams, Dan" <Abrams.Dan@epa.gov>, "Reynolds, Thomas" <Reynolds.Thomas@epa.gov>, "Conger, Nick" <Conger.Nick@epa.gov>, "Senn, John" <Senn.John@epa.gov>, "Millett, John" <Millett.John@epa.gov>, "Birgfeld, Erin" <Birgfeld.Erin@epa.gov>, "Hull, George" <Hull.George@epa.gov>, "Daguillard, Robert" <Daguillard.Robert@epa.gov>, "Valentine, Julia" <Valentine.Julia@epa.gov>
> **Cc:** "Smith, Roxanne" <Smith.Roxanne@epa.gov>, "Urrutia, Katiana" <Urrutia.Katiana@epa.gov>
> **Subject: RE: Volkswagen Clips 9/29/2015**
>
> AP:
> http://hosted.ap.org/dynamic/stories/V/VOLKSWAGEN?SITE=AP&SECTION=HOME&TEMPLATE=DEFAULT
>
> VW: 1.8M COMMERCIAL VEHICLES, 700,000 SEAT CARS AFFECTED
>
> BERLIN (AP) -- Volkswagen said Tuesday that 1.8 million commercial vehicles are among those affected by the emissions-rigging scandal, while Spanish unit SEAT said 700,000 of its cars were fitted with the diesel engine in question.
>
> Volkswagen AG has admitted using a piece of engine software to cheat on diesel car emissions tests in the U.S. It said last week the engines concerned are in some 11 million vehicles worldwide, far more than the 482,000 originally identified by U.S. authorities.
>
> Details have emerged gradually of how many were made by which VW division. Guenther Scherelis, a spokesman for the commercial vehicles unit - which makes vans and pickups - on Tuesday confirmed a report in the daily Hannoversche Allgemeine Zeitung that 1.8 million of its vehicles were affected. He didn't give further details.
>
> Spanish subsidiary SEAT said it fitted 700,000 vehicles with the EA 189 diesel engines in which Volkswagen has said there are "discrepancies."
> SEAT said the cars were sold worldwide and it was seeking to determine how many were sold in each market.
>
> Also fitted with the suspect software were 5 million VW brand cars, 2.1 million Audis and 1.2 million Skodas.
>
> SEAT and Volkswagen-Audi Spain on Tuesday ordered a suspension of sales of all SEAT, Volkswagen, Audi, Skoda and Volkswagen commercial vehicles with the EA 189 diesel engine. It said this decision would affect 3,320 vehicles currently in stock.
>
> In Brussels, European Union Industry Commissioner Elzbieta Bienkowska was scheduled to meet Tuesday with Volkswagen brand chief Herbert Diess.

"We expect Volkswagen to explain the situation," said EU spokesman Ricardo Cardoso. "The Commission wants facts and wants to get to the bottom of this."

The German government last week set up a commission of inquiry on the scandal. Transport Ministry spokesman Martin Susteck said that the panel is in contact with the U.S. Environmental Protection Agency.

Reuters:
http://www.reuters.com/article/2015/09/29/volkswagen-emissions-plan-idUSL5N11Z11920150929

UPDATE 1-Volkswagen to refit cars affected by emissions scandal

BERLIN, Sept 29 (Reuters) - Volkswagen signaled on Tuesday it would recall up to 11 million vehicles as it tries to address the scandal over its admission that it cheated U.S. diesel emissions tests.

New Chief Executive Matthias Mueller said the German carmaker had drawn up a "comprehensive" refit plan to be submitted to regulators aimed at ensuring its diesel models complied with emissions standards.

It will ask customers "in the next few days" to have diesel models equipped with manipulated software refitted and brief authorities on technical fixes in October, Matthias Mueller told a closed-door gathering of about 1,000 top managers at Volkswagen's Wolfsburg headquarters late on Monday.

The company is under huge pressure to tackle the biggest business-related crisis in its 78-year history. Germany's KBA regulator had set an Oct. 7 deadline for it to present a plan to bring diesel emissions into line with the law.

Volkswagen has said previously about 11 million vehicles were fitted with software capable of cheating emissions tests, including 5 million at its namesake brand, 2.1 million at luxury brand Audi, 1.2 million at Czech division Skoda and 1.8 million light commercial vehicles.

"We are facing a long trudge and a lot of hard work," Mueller, appointed CEO of Europe's biggest automaker last Friday, said in the speech text seen by Reuters. "We will only be able to make progress in steps and there will be setbacks."

Separately, Mueller said Volkswagen's troubled core VW division, struggling with high fixed costs and low profit margins, would in future be able to act as independently as premium flagship brands Audi and Porsche.

"The new company structure is a first step and the basis for a modernization of VW, for a new and better company," he said. (Reporting by Andreas Cremer; Editing by Ludwig Burger<http://blogs.reuters.com/search/journalist.php?edition=us&n=ludwig.burger&> and Mark Potter)

BBC News:
http://www.bbc.com/news/business-34390369

Seat says 700,000 cars have 'cheat' emissions software VW crisis
Seat has said about 700,000 of its cars are fitted with the software that allowed parent company Volkswagen to cheat US emissions tests.

A spokesman said they are currently trying to work out how many were sold in each national market.
In Spain slightly over 3,000 new cars are affected but showrooms have been told to put them aside.
VW has said a total of 11m diesel engines are involved in the emission's scandal.
Broken down brand-by-brand they are:

* VW - 5m
* Audi - 2.1m

* Skoda - 1.2m
* Seat - 700,000
* Vans - 1.8m

Seat said it planned to contact owners so their cars can undergo tests.
It will also set up a search engine on its website to allow customers to find out if their vehicles are affected.
The Spanish carmaker said it had temporarily suspended the sale and delivery of all new vehicles with the EA 189 engines which contain the software.

Volkswagen scandal
11 million
Vehicles affected worldwide

* €6.5bn Set aside by VW
* $18bn Potential fines
* No. 1 Global carmaker in sales

Scandal spilling over
The scandal is continuing to hit VW's share price. On Tuesday it fell another 1.5%<http://www.bbc.co.uk/news/business/market_data/shares/5/113230/one_month.stm> during morning trade in Frankfurt. The company has lost 35% of its market value since last Monday.

A survey of 62 institutional investors by the investment banking advisory firm Evercore, showed 66% of them would not invest in VW for 6 months or until it clarified what costs, fines, and legal proceedings it faced.

The effects are also spilling over into the local economy around VW's headquarters in Wolfsburg. The city is expecting a fall in business tax revenue from VW and the mayor has announced a budget freeze and hiring ban on public sector workers.

The scandal was revealed after the US Environmental Protection Agency found that some VW diesel cars were fitted with devices that could detect when the engine was being tested, and could change the car's performance to improve results.

The German company has apologised for breaching consumers' trust, and on Friday announced that Matthias Mueller was replacing Martin Winterkorn as chief executive. Mr Mueller promised a "relentless" investigation to uncover what went wrong.

He said the group was "facing the severest test in its history."

German prosecutors announced on Monday that it was conducting a criminal investigation of Volkswagen's former chief executive.

Bloomberg:
http://www.bloomberg.com/news/articles/2015-09-29/volkswagen-close-to-diesel-fix-as-sales-of-rigged-cars-halted

Volkswagen Close to Diesel Fix as Sales of Rigged Cars Halted
Elisabeth Behrmann<http://www.bloomberg.com/authors/AP6ltgka_yg/elisabeth-behrmann>
September 29, 2015 — 8:06 AM EDT

A brand new Volkswagen Passat and a Golf 7 car are stored in a tower at the Volkswagen Autostadt complex near the Volkswagen factory in Wolfsburg, Germany.
Sales halted in Spain, Switzerland, Italy and the Netherlands

* Volkswagen to inform customers soon of plans for repairs

Volkswagen AG is close to announcing a fix to emissions systems that cheated on pollution tests, as sales of vehicles with the rigged diesel engines get halted in a growing number of European countries.

Cars with the affected diesel engines are being pulled from markets including Spain, Switzerland, Italy, the Netherlands and Belgium, while prosecutors in Sweden consider opening an investigation on potential corruption. For vehicles already sold, Volkswagen is looking to inform customers soon about the steps it will take to repair the vehicles.
"It's going to depress their market share for a while, maybe even up to one to two years," said Richard Gane, an automotive specialist at supply-chain consultancy Vendigital Ltd. "This is going to run and run."

Almost two weeks after it publicly admitted to cheating on diesel emissions tests in the U.S., Volkswagen has yet to provide a comprehensive breakdown of the car models and markets affected. Information has emerged piecemeal in the scandal over a type of diesel engine installed in as many as 11 million vehicles worldwide. The number includes about 5 million VW brand cars, 2.1 million Audi models, 1.2 million from the Skoda unit and 700,000 from the Spanish Seat nameplate.

German Deadline
To reach out to customers, Volkswagen is looking into setting up websites in various countries so drivers can check on actions locally. The company has already set up a site<http://www.vwdieselinfo.com/> in the U.S., where the scandal started.
The German government has set an Oct. 7 deadline for Volkswagen to say how it'll bring some 2.8 million diesels in its home market up to standard, threatening to pull the cars off the road if the carmaker fails to do so.

As Volkswagen seeks to recover, the executive committee of its supervisory board, made up of union officials as well as shareholder representatives from the Porsche family and Lower Saxony, is meeting Wednesday to discuss the latest results from the investigation, a person familiar with the situation said.

Volkswagen Chief Executive Officer Matthias Mueller, who was appointed on Friday, said a project team devised a plan over the weekend and the company will start informing customers in the coming days that the emissions of their vehicles will need to be improved. The fix will be presented to regulators for approval in October.

'Long Road'
"We have a long road and a lot of work ahead of us," Mueller said in a speech to Volkswagen's management late Monday, confirming that the company hired law firmJones Day to assist with its internal investigation. "To this end, thoroughness is more important than speed."
Still, pressure is building on the company to come up with a solution. Swedish prosecutors at the National Anti-Corruption Unit are evaluating whether they have jurisdiction to start their own probe, said Alf Johansson, a chief prosecutor at the unit. In the Netherlands, the government is exploring regionwide recall of the vehicles.

"We would like you to consider the possibilities of a European recall," Dutch State Secretary Wilma Mansveld said in a Sept. 25 letter to the European Commission. "This has to ensure that all faulty software is removed from the market and replaced by proper software that allows proper emission reduction."

Bloomberg:
http://www.bloomberg.com/politics/articles/2015-09-29/california-teachers-pension-scolds-volkswagen-on-emissions-dupe

California Teachers' Pension Scolds Volkswagen on Emissions Dupe
Alison Vekshin<http://www.bloomberg.com/politics/authors/AOWq1oX1-C4/alison-vekshin> <http://twitter.com/alisonvekshin> Margaret Collins<http://www.bloomberg.com/politics/authors/APs6rgY-8H4/margaret-collins>Tim Jones<http://www.bloomberg.com/politics/authors/AQIjj4Bpzcg/tim-jones>
September 29, 2015 — 5:00 AM EDT

California's $184 billion pension fund for school teachers chided Volkswagen AG for rigging some diesel engines to cheat on U.S. emission tests and said it is evaluating its exposure to losses from the scandal.

The California State Teachers' Retirement System, the second biggest U.S public pension, held 37,580 Volkswagen shares valued at $4.85 million as of Sept. 25 and 284,856 of the company's preferred shares worth $34.2 million.

The Wolfsburg, Germany-based company admitted Sept. 18 that it programmed some of its cars' diesel engines to meet emissions standards only when undergoing official tests while letting them exceed legal pollutant limits on the road. Volkswagen's market value has plunged 27 billion euros ($30.3 billion) since the announcement.

"As owners we actively monitor our holdings and expect our portfolio companies to govern themselves responsibly."

- Michael Sicilia, Calstrs spokesman

"Calstrs is clearly disappointed that a company in our portfolio has managed to simultaneously damage both its shareholder value and the environment that we're pledging to protect," said Michael Sicilia, a Calstrs spokesman. "As owners we actively monitor our holdings and expect our portfolio companies to govern themselves responsibly."

About 11 million vehicles around the world were fitted with the defeat devices. The company has set aside 6.5 billion euros to cover damages including fixes, potential regulatory fines and lawsuits.

Not only is California home to the two biggest public pension funds, it has more of the cars on its roads than any other state and has the toughest carbon emission standards in the U.S.

Following the admission that the company cheated in order to try and gain U.S. market share, Chief Executive Officer Martin Winterkorn stepped down and the U.S. Federal Bureau of Investigation has opened a criminal probe. U.S. states also are looking into the company's actions.

Volkswagen is facing more than 80 federal court lawsuits by consumers alleging the company committed fraud by cheating on emissions tests, inducing them to pay more for their vehicles. Those lawsuits were filed as class actions representing all consumers in the U.S. or in individual states who leased or bought the vehicles.

A Michigan pension fund for police and firefighters alleges in a lawsuit that holders of VW's American depositary receipts lost hundreds of millions of dollars.

The $286 billion California Public Employees' Retirement System said it has about $165 million invested in Volkswagen. The fund, the biggest in the U.S., is "examining the situation and continue to monitor," said spokesman Joe DeAnda.

New York state's pension fund -- which was worth $184.5 billion as of March 31 -- has 22,927 ordinary shares of Volkswagen valued at about $5 million, according to Matt Sweeney, a spokesman for state Comptroller Thomas DiNapoli, the fund's sole trustee. It has another 159,979 shares of Volkswagen's non-voting preferred shares worth $33.3 million, Sweeney said by e-mail.

The $50 billion Alaska Permanent Fund Corporation held 15,009 shares of Volkswagen stock as of June 30, valued at $3.47 million. "It doesn't exactly move the needle, does it?" said Laura Achee, the fund's director of communications.

The Teacher Retirement System of Texas declined to comment on its holdings but said that any investment in Volkswagen would be a drop in the bucket of its $132 billion assets, according to communications director Howard Goldman. At the $26 billion Employees Retirement System of Texas, which provides retirement

benefits for state employees, retirees and their dependents, VW holdings are similarly negligible.

“We have some in equities and in fixed income, but very small,” said spokeswoman Mary Jane Wardlow in an e-mail.

Volkswagen shares are also held in the pension plans of private companies including General Motors Co. and International Business Machines Corp., according to their latest filings with the Labor Department.

GM doesn’t comment on individual holdings in its pension plans, spokesman Pat Morrissey said in an e-mail. The company reported shares in Volkswagen valued at about $1 million in its latest filing with the Labor Department as of Sept. 30, 2014. That’s a small portion of the plan’s about $80 billion.

From: Gong, Kristiene
Sent: Monday, September 28, 2015 1:42 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/28/2015

CBS News:
http://www.cbsnews.com/news/volkswagen-faces-daunting-challenges-in-fixing-emissions-cheating/

VW faces daunting challenges in fixing emissions cheating

DETROIT - Volkswagen faces daunting challenges in fixing software that enables cheating on diesel engine emissions tests, a task that's becoming more urgent because of growing anger from customers.

The company has set aside $7.3 billion to pay for the scandal. But experts say it's likely to cost much more as VW tries to comply with U.S. clean air regulations while appeasing diesel owners who paid extra for the cars, thinking they could help the environment without sacrificing performance.

"We understand that owners of the cars affected by the emissions compliance issues are upset," VW said on a consumer website launched Sunday. The company asked for patience and said it would address the issue as fast as it can. A spokeswoman wouldn't comment further.

But experts said VW will have to strike a careful balance to appease government regulators, make customers happy and avoid emptying the company cash box. A cheap remedy of software fixes likely would hurt performance and gas mileage, further antagonizing customers. A more expensive fix that adds a treatment system wouldn't hurt performance, but it would cost thousands per car and by one analyst's estimate, could total more than $20 billion including vehicles in the U.S. and Europe.

That's in addition to a potential $18 billion fine in the U.S. and the cost of numerous class-action lawsuits alleging that VW's cheating reduced the value of its customers' cars.

The scandal broke on Sept. 18, when the U.S. Environmental Protection Agency and the California Air Resources Board accused VW of installing secret software on 2-liter four-cylinder diesel engines that turned on pollution controls for lab tests and shut them off during real-world driving. As a result, 482,000 Jettas, Beetles, Golfs and Passats from the 2009 to 2015 model years belched out 10 to 40 times as much ozone-causing nitrogen oxide as U.S. law allows.

A few days later, VW admitted the same "defeat device" that switched the pollution controls on and off was on 11 million cars worldwide. Germany says 2.8 million cars there are affected.

Software in the main engine control computer figured out when the cars were being tested on a treadmill-like device called a dynamometer that the EPA used for verification and turned the controls on.

With the pollution controls on, the cars are less efficient and won't accelerate as fast, the two main reasons why people bought the VW diesels, said Matt DeLorenzo, managing editor and a diesel expert for Kelley Blue Book. VW could change the software and leave the controls on to satisfy the EPA and California regulators. But that would anger customers and likely would force VW to compensate them for the reduced mileage, just as Hyundai did when it got caught with inflated fuel economy estimates, DeLorenzo said.

"If it's really sluggish and doesn't get out of its own way, that's a bigger issue (to customers) than fuel economy," DeLorenzo said. "People notice that big of a change in performance."

The other option is to add a diesel exhaust treatment system that's used by other manufacturers and even by VW on larger diesel engines. The treatment involves adding a tank of a chemical called urea, which enables the cars to separate nitrogen oxide into harmless nitrogen and oxygen. That would cost $2,000 or more per car, DeLorenzo said.

Engineers would have to find room for a tank to store the blue urea fluid, which has to be refilled about every 7,500 miles, DeLorenzo said. And VW probably would have to compensate customers for years of urea cost, which is about $13 for 2.5 gallons.

VW probably tried to avoid urea systems in the beginning because their cost would have driven Jetta and Golf prices above competitors, especially gas-electric hybrids, DeLorenzo said. Now, adding it after the fact will cost even more, he said.

The scandal has forced Volkswagen to tell U.S. dealers not to sell cars with the suspect diesel engines. VW said on Sunday that it's working to get government approval to sell 2016 models with updated engines "which we believe do not have any of the issues the government has identified in other vehicles."

The 2015 and 2016 models have a new version of the 2-liter diesel engine that probably runs cleaner and could need just a software change to comply, DeLorenzo said.

But on older models from 2009 to 2014, the fix may be more difficult. Mike Jackson, CEO of AutoNation, the largest dealership chain in the U.S., said he was told by VW that it will take hardware and software changes to fix the older models. The EPA says it may take VW a year to develop a fix.

Before the 2009 model year, U.S. diesel emissions standards weren't as strict, so those cars likely passed the tests without a defeat device, DeLorenzo said.

Whenever the fix comes, it's possible that owners might not get it done if it hurts their cars' mileage and performance, and the EPA can't force people to take their cars in for repairs. The agency only has authority over automakers, not car owners.

The EPA says some states require proof that emissions recalls have been fixed before license plates are renewed. And the possibility of failing emissions inspections in states that require them apparently won't be an issue because of the cheating software. "The defeat device was specifically designed to ensure that vehicles would pass inspection," the agency says on its website.

In wake of the scandal, the automaker's stock dropped about 30 percent this past week alone, CBS News correspondent Kris Van Cleave reported.

Volkswagen introduced is new CEO on Friday. Matthias Mueller, the former head of Porsche, will try to restore VW's reputation.

The Guardian:
http://www.theguardian.com/business/2015/sep/26/volkswagen-scandal-emissions-tests-john-german-research

Meet John German: the man who helped expose Volkswagen's emissions scandal
Automative engineer's research connected the dots to how the automaker manipulated diesel emissions tests – but that was never the intention
Rupert Neate in New York

John German has barely had time to catch his breath all week between appearances on TV news channel and radio phone-in shows. He's an unlikely media star, not a pop singer or reality TV contestant, but a grey-haired automotive engineer thrust into the global spotlight after he and his colleagues were credited with helping uncover one of the biggest ever corporate scandals.

"We really didn't expect to find anything," German said of his research that found Volkswagen had installed sophisticated software designed to cheat strict emission tests across the world. His simple test – checking the car's emissions on real roads rather than in lab test conditions – led to the resignation of VW's chief executive after the German company was forced to admit it installed "defeat devices" in 11m cars. The scandal has wiped more than €24bn ($26.8bn) off VW's market value.

Many questions remain but one thing is clear to German: "It was not an accident," he said. "A lot of work has gone into this."

When German finally found a moment of peace this week he called his wife in Ann Arbor, Michigan. "She said: 'You know you've made it now, you can retire and be very happy'," German told the Guardian as he prepared to board a plane back to Michigan after a week in the spotlight in Washington DC. "No, no, no, I can't afford to yet," German told his disappointed wife.

He may have helped uncover one of the world's biggest corporate scandals, but German earns a modest salary as US co-lead of the International Council on Clean Transportation (ICCT) a small nonprofit organisation dedicated to helping to reduce vehicle emissions and has an annual budget of just $12m.

"It has been totally overwhelming," German said of the global interest in his research this week. "I've been doing nothing else [but responding to the media and politicians] for 12 hours a day since Friday," when US regulators announced their findings against VW based on German's research] "We're a small organisation that primarily deals with information on diesel filters, so this is unprecedented and overwhelming.

"As an organisation that is trying to reduce emissions and improve efficiency it is always gratifying to see results from our work, but we never dreamed we would have this kind of impact."

German explained that the idea to carry out the test, which he described as "very ordinary", came from Peter Mock, a colleague in Europe, who noticed discrepancies in the emissions of the diesel VW Passat and VW Jetta. He said they decided to carry out on-the-road tests in the US as the emissions regulations are much stricter than in the EU. They expected the cars to pass and they could use this as proof to show Europeans that it was possible to run diesels with cleaner emissions.

German, who has a degree in physics from the University of Michigan and said he "got over halfway through an MBA before he came to his senses", sought out the assistance of the West Virginia University's Center for Alternative Fuels, Engines and Emissions. The WVU provided a portable emission measurement system that could be put in the car's boot (trunk) with an attached probe placed in the exhaust pipe.

Then German sourced a Passat, Jetta and a BMW X5 (which also showed emissions discrepancies in Europe) and "had a drive around". "The VWs were massively exceeding their official emissions readings in normal driving conditions, which was completely inexplicable and totally surprised us," German said.

Thinking it must be a technical error, the tests were expanded and the cars were driven more than 1,200 miles from San Diego to Seattle – almost the entire length of the west coast of the US.

The VWs nitrogen oxide emissions – which creates smog and has been linked to increased asthma attacks and other respiratory illnesses – still exceeded the US standards by up to 35 times. The BMW X5 was within the

regulated range.

Arvind Thiruvengadam, a research assistant professor at WVU, who conducted the tests said: "We were doubting ourselves and our procedures and making sure to double check that we were not doing anything wrong. We did so much testing we couldn't possibly doing the same mistake again and again.

"We were like 'OK, we're going to write a lot of journal papers, and we'll be happy if three people read these journal papers,'" he told National Public Radio last week. "That's our happiness at that point."

German published the research in May 2014 and handed it over to the Environment Protection Agency (EPA). "There was an expectation that they would find out what was causing the higher-than-expected emissions," he said. "We did send a courtesy copy to VW to say 'vehicles B and C are your vehicles and you might like to know', we had no response."

There was no response from the EPA either, but keen-eyed German noticed an EPA press release in which VW agreed to recall almost 500,000 vehicles in December 2014 to reinstall software, which it said would solve the higher-than-expected emissions.

However, a couple of months later the California Air Resources Board (Carb) carried out spot checks and discovered that the "defeat device" software – used to dramatically reduces nitrogen oxide (NOx) emissions only when the cars are undergoing strict emission tests – was still present.

"That is actually the single most inexplicable thing about this whole business," German said. "VW had a chance to fix the problem, and they continued to try and cheat and do what they had done. That's just amazing."

"Only then did VW admit it had designed and installed a defeat device in these vehicles in the form of a sophisticated software algorithm that detected when a vehicle was undergoing emissions testing," the EPA said in a statement last week.

German said it was unclear how the defeat device software worked, but the software could work by detecting periods when the steering column wasn't turning but the wheels were which would indicate the car was on dynamo-meters for testing, or could also test for the precise uniform temperature that the tests are carried out at.

"The kind of software it takes to first detect when you're driving on the official test would be very hard to develop. And then you would need duplicate software to tell the car to have two different emission controls."

UK, France and Germany lobbied for flawed car emissions tests, documents reveal
He said it was impossible to know how far up the food chain at VW the fraudulent activity went, but said: "It would have had to be quite a few people involved. It certainly won't have just been one individual."

German said VW could have continued in the deceit for the foreseeable future if no one had thought to test the cars emissions on real roads. He said there is no way to know if other car companies may also have been using similar methods to trick official emission tests, but welcomed UK, German and US regulators moves to retest cars emissions on real roads.

German, who drives a 1997 Honda Accord station wagon that he says has pretty good emissions for a manual transmission, said he hopes his work will act as a wake-up call and scare the whole industry into making certain that their vehicles comply with all emissions regulations. "Companies should realise they might get away with stuff for a little while, but it will catch up with them."

He refused to enter into discussion about what sort of action should be taken against VW, which is facing a fine of up to $16bn in the US alone and a possible criminal investigation. "That's really up to others, I'm just an engineer from Michigan it's really beyond my field of reach."

Consumerist:
http://consumerist.com/2015/09/28/report-volkswagen-knew-of-defeat-devices-eight-years-before-epa-action/

Report: Volkswagen Knew Of "Defeat Devices" Eight Years Before EPA Action
By Ashlee Kieler September 28, 2015

An internal review spurred by the emissions scandal that has engulfed Volkswagen over the past week found that the carmaker knew that so-called "defeat devices," used to trick emissions tests, were used in more than 11 million VW and 2.1 million Audi diesel vehicles for several years before the Environmental Protection Agency issued a violation notice to the manufacturer ordering it to recall some 500,000 million sedans.

The Associated Press, citing two German publications, reported Monday that VW's internal investigation has so far found at least two incidents in which VW was made aware that the use of defeat devices were against the law.

The Frankfurter Allgemeine Sonntagszeitung, a German publication, reported on Sunday that VW's internal investigation shows one of the company's own technicians was aware of the software.

Back in 2011, an engineer reportedly expressed concern that using the device was illegal, but was ignored.

The same investigation turned up a letter, dated 2007, from parts supplier Bosch that warned the car company not to use the software during regular operations of vehicles.

According to Bild am Sonntag, sources uncovered the internal communications between Bosch and VW, with the parts supplier insisting that the software was for test purposes and that using it in regular operation would be against the law.

Bosch, one of the largest car parts suppliers in the world, admitted last week that it supplied many of the key components for the defeat devices as a way to evade emissions standards for certain pollutants with a range of serious health effects.

According to the EPA's order [PDF], the "sophisticated software algorithm" in the vehicles is programmed to detect when the car is undergoing official emissions testing, and to only turn on full emissions control systems during that testing.

However, the effectiveness of these vehicles' pollution emissions control devices is greatly reduced during all normal driving situations.

Volkswagen declined to address the new reports, saying it doesn't comment on "rumors and speculation."

"Volkswagen is working with all its strength to conduct a thorough and merciless investigation of this matter," a spokesperson tells the AP.

In addition to new revelations that VW was aware that the defeat devices were illegal, CNBC reports that the company's now former CEO Martin Winterkorn is under criminal investigation by German prosecutors related to fraud.

Winterkorn stepped down last week, noting that he took full responsibility for irregularities in nearly 11 million diesel vehicles found to contain "defeat devices," the former CEO is at the center of the latest investigation into the manufacturer.

Mothers Jones:
http://www.motherjones.com/kevin-drum/2015/09/vw-tries-blame-engine-emissions-fraud-low-level-engineers-and-technicians

VW Tries to Blame Engine Emissions Fraud on Low-Level "Engineers and Technicians"
—By Kevin Drum

I guess it was just a few bad apples. That's a relief:

Volkswagen has blamed its emissions scandal on a “small group” of people and has suspended a number of staff as Matthias Müller was unveiled as its new chief executive.

....Berthold Huber, the acting head of VW’s supervisory board, called the crisis a “moral and policy disaster”....“The test manipulations are a moral and political disaster for Volkswagen. The unlawful behaviour of engineers and technicians involved in engine development shocked Volkswagen just as much as it shocked the public.”

This is ridiculous. What incentive do low-level engineers and technicians have to do this on their own? Hell, they couldn't even take on a project like this unless their managers OKed the time to do it, and their managers wouldn't do it unless they were being pressed by higher-ups. Anybody who's ever worked at a big corporation knows this perfectly well. And according to Bloomberg, that's exactly what happened:

Volkswagen AG executives in Germany controlled the key aspects of emissions tests whose results the carmaker now admits were faked, according to three people familiar with the company’s U.S. operations.

....Their accounts show the chain of command and those involved in the deception stretched to Volkswagen headquarters.... Ulrich Hackenberg.... Wolfgang Hatz are among those who will leave the company in the wake of Winterkorn’s resignation two days ago, two people familiar with the matter said. The two previously ran units at the heart of the affair — Hackenberg, a Winterkorn confidant, was responsible for VW brand development from 2007 to 2013, while Hatz ran the group’s motor development from 2007 to 2011.

Will it go even higher? Stay tuned. However, I'll call BS on UBS, which apparently thinks this scandal "could signal the eventual end of the combustion engine." Please. There's no difficulty "amassing accurate data" on engine emissions, as one of their analysts suggests. VW amassed very precise data. They just chose to hide it by means of a calculated, premeditated, multi-year fraud. Anyone who hasn't done the same should be in fine shape.

From: Gong, Kristiene
Sent: Monday, September 28, 2015 10:03 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/28/2015

AP (via Boston Globe):
https://www.bostonglobe.com/business/2015/09/27/facing-tsunami-legal-trouble-emissions-scandal/vWsc8yAvQgqtzSxPtCT1sJ/story.html

Legal woes mounting for Volkswagen as criminal cases loom
Volkswagen admitted that 11 million of its diesel vehicles sold worldwide contained software specifically designed to help cheat emissions tests.
By Michael Biesecker and Eric Tucker ASSOCIATED PRESS SEPTEMBER 28, 2015

WASHINGTON — Who knew about the deception, when did they know it, and who directed it?

Those are among the questions that state and federal investigators want answered as they plunge into the emissions scandal at Volkswagen, which has cost the chief executive his job, caused stock prices to plummet, and could result in billions of dollars in fines.

Legal experts say the German automaker is likely to face significant legal problems, including potential criminal charges, arising from its admission that 11 million of its diesel vehicles sold worldwide contained software specifically designed to help cheat emissions tests.

The Environmental Protection Agency has accused VW of installing sophisticated stealth software that enabled ''clean diesel'' versions of its Passat, Jetta, Golf, and Beetle models to detect when they were being tested and emit less-polluting exhaust than in real-world driving conditions. The agency says the ''defeat devices'' allowed those models to belch up to 40 times the allowed amounts of harmful fumes in order to improve driving performance.

The Justice Department says it's ''working closely'' with EPA investigators.

''If there is sufficient evidence to show that Volkswagen intentionally programmed its vehicles to override the emission control devices, the company and any individuals involved could face criminal charges under the Clean Air Act, and for conspiracy, fraud, and false statements,'' said David M. Uhlmann, a former chief of the Justice Department's Environmental Crimes Section who is now a law professor at the University of Michigan. He called criminal charges ''almost certain.''

But Uhlmann cautioned that hauling the executives involved into a US courtroom could be challenging, because much of the conduct at issue probably occurred overseas. While the United States has an extradition treaty with Germany, European regulators also are investigating and could claim first dibs on prosecuting company officials.

'[Volkswagen is] facing a tsunami of possible state and federal enforce-ment actions.'
William Carter, former federal prosecutor who specialized in environmental crimes

It's not the first time that Volkswagen has been accused of cheating on emissions testing by the EPA. In July 1973, the agency found that VW had installed temperature-sensitive devices that turned off emissions controls on about 25,000 Fastback, Squareback, and bus models. The company agreed to remove the devices and eventually settled with the Justice Department, paying a $120,000 penalty.

Chief executive Martin Winterkorn resigned on Wednesday, and Volkswagen announced it would set aside $7.3 billion to cover the cost of the scandal, but even that may not be enough.

The company has apologized, but has not yet detailed who was responsible for the defeat devices.

German media reported Sunday that Volkswagen had received warnings years ago about the use of illegal tricks to defeat emissions tests. Bild am Sonntag said VW's internal investigation has found a 2007 letter from parts supplier Bosch warning Volkswagen not to use the software during regular operation. Frankfurter Allgemeine Sonntagszeitung said a Volkswagen technician raised concerns about illegal practices in connection with emissions levels in 2011.

A Volkswagen spokesman declined to comment on the reports.

The Clean Air Act allows for fines of up to $37,500 for each of the 482,000 suspect VWs sold in the United States, potentially totaling more than $18 billion. Attorneys general for nearly 30 states and the District of Columbia have announced a coordinated investigation and said they are issuing subpoenas for company records.

There's also a high likelihood of class-action lawsuits by angry VW owners.

''They're facing a tsunami of possible state and federal enforcement actions, and a potential large number of violations — including administrative, civil, and criminal,'' said William Carter, a former federal prosecutor in Los Angeles who specialized in environmental crimes and served as general counsel of the California Environmental Protection Agency.

Investigators will almost certainly look for any false statements made to the EPA and for signs that VW has tried to conceal wrongdoing or obstruct regulators. Fraud charges could be considered if evidence emerges that company executives used the Internet or the mail system to carry out the deception. And money laundering allegations will be explored if investigators suspect that VW sent illicit proceeds overseas.

''If a software package such as this were intentionally designed to defeat the emissions testing, there may well be e-mail traffic, meetings, records that would establish that intent,'' said Gregory Linsin, a former environmental crimes prosecutor at the Justice Department.

But Linsin said he expected the Justice Department also to take into account the multiple investigations likely to take place worldwide, and to not punish the automaker in a way that jeopardizes its ability to stay in business.

The problems at VW come as the Justice Department faces growing pressure to prosecute individual executives and employees for corporate misdeeds. The last two major criminal investigations against auto companies — Toyota and General Motors — yielded massive fines over car safety problems but have resulted in no prosecutions of executives. Those outcomes dismayed consumer watchdog groups and grieving victims' relatives, who demanded better accountability for failure to disclose vehicle defects.

A memo this month by Deputy Attorney General Sally Yates sought to reaffirm the Justice Department's commitment to prosecuting employees and executives, directing among other policy mandates that corporations pushing for credit for cooperating with the government must first turn over evidence against individuals.

''Volkswagen has a fundamental choice to make,'' said Uhlmann, the former prosecutor. ''That is whether it intends to cooperate and seek leniency, or whether it wants to fight the charges. Every indication over the last several days from Volkswagen is that it intends to cooperate.''

Asked whether that meant he expected company executives to voluntarily come to the United States to stand trial, he laughed.

''Absolutely not,'' he said.

AP (via Dallas Morning News):
http://www.dallasnews.com/business/headlines/20150927-sell-sue-or-stay-put-considerations-for-volkswagen-owners.ece

Sell, sue or stay put: considerations for Volkswagen owners
Tom Krisher and Dee-Ann Durbin
Updated: 27 September 2015 11:10 PM

DETROIT — If you're driving a diesel-powered four-cylinder Volkswagen, you're stuck with a fun-to-drive machine that's belching unhealthy pollutants from its tailpipe.

Until the company figures out how to fix its bogus emissions controls, there isn't much you can do about your dirty diesel.

Following disclosures that Volkswagen developed software for its 2-liter diesel engine that could better control pollutants during testing than in real-world driving, there's a lot up in the air for owners of Jettas, Golfs, Passats and Beetles and Audi's A3.

Here are some things to consider if you're thinking of suing, selling or are unsure of what to do next.

The problem

VW's software turned on pollution controls for government tests, which are done on a treadmill device called a dynamometer. When the software deduced that the cars were back on the street, the controls went off and the cars polluted too much. About 500,000 of the cars were sold in the U.S.

VW hasn't said how it will fix the problem.

Owners worry the repairs will cut fuel economy and performance — the reasons they bought the "clean" diesels in the first place.

"I really hope they fix this thing," said Zandy Hartig, an actress in Los Angeles who owns a diesel 2013 Jetta SportWagen. "I assume since they did it on purpose they can undo it."

The EPA has told VW to fix the cars so they comply with pollution regulations, but there's no word from the company on how or when that will be done. The EPA said it could take a year.

"We understand that owners of the cars affected by the emissions compliance issues are upset," VW said on a consumer website launched Sunday. The company asked for patience and said it would address the issue as fast as it can. A spokeswoman wouldn't comment further.

A recall fix may be coming soon for 2015 and 2016 models, neither of which can be sold until repairs are made. Mike Jackson, CEO of AutoNation, the country's largest auto dealership chain, said that he was told by VW officials that a software change will bring the last two model years into compliance.

But it's a mystery how the company will fix models from 2009 through 2014, including whether software and equipment changes will be needed, he said.

Did my car lose value?

Worried about their cars losing value, some owners might rush to put the car up for sale.

Eric Ibara, senior analyst for Kelley Blue Book, is encouraging owners to hang on to their VWs, at least until the company comes up with a fix.

Ibara said the impact on VW's resale values may not be known for two or three weeks. The price that dealers agree to pay for vehicles being auctioned this week will be the first indication.

VW diesels traditionally have higher resale values than gasoline counterparts, but the scandal might erode that premium, Ibara said, especially if the fix cuts mileage or impacts their sporty performance.

If repairs are made, history shows there might not be a lasting impact. General Motors' residual values weren't affected by ignition switch recalls, and Toyota's car values returned to normal within a year of an unintended acceleration crisis.

Some owners are hoping for rebates, while a consumer group called on VW to buy back the diesels.

Legal action?

Joining a lawsuit against VW is one option for owners, although it is likely to take years to get any relief.

Several U.S. lawsuits have been filed, some alleging the cars' values will fall because of the scheme.

Consumers could have some success in the courtroom. In 2012, for example, Toyota agreed to pay more than $1 billion to resolve hundreds of lawsuits filed by owners who said their vehicles lost value after the company's unintended acceleration problems.

Also, politicians are calling on the Federal Trade Commission to investigate, because VW often advertised the

cleanliness of the vehicles. The FTC, which monitors advertising claims, can seek remedies for all of the car owners.

Don Marron, 58, a banker from Allentown, Pa., wants Volkswagen to take back his 2012 SportWagen and apply the credit toward a new car. He'd also consider a repair that didn't compromise performance or fuel economy.

"I'm going to wait and see what they do, but I'm not going to do nothing," he said. "It's just dumb that they did this. How could they think that it wasn't going to be discovered? What arrogance, what bad judgment."

WSJ:
http://www.wsj.com/articles/auto-parts-makers-hit-by-vw-scandal-1443395198

Auto-Parts Makers Hit by VW Scandal
Suppliers move to defend diesel technology, fearing shift toward alternatives
By JEFF BENNETT
Updated Sept. 27, 2015 7:50 p.m. ET

Auto-parts makers with big exposure to the diesel-car market are racing to salvage the technology's reputation in the wake of the Volkswagen AG emissions-cheating scandal.

Shares of the parts makers, which include Tenneco Inc., BorgWarner Inc., Delphi Automotive PLC and Continental AG, were pummeled last week following the Environmental Protection Agency's disclosure that VW cheated for years on emissions tests of its diesel-powered cars.

The parts industry's focus has shifted to defending the viability of diesel technology amid concerns that betrayed consumers or auto makers, which face tighter government scrutiny of diesel, will turn their attention to hybrids and electric-powered vehicles.

"You can't have an event like this without questions being raised, but that doesn't mean the technology doesn't work," said Terrence Hahn, chief executive of Honeywell International Inc.'s $3.8 billion Transportation Systems unit.

"We have seen proven results around clean-diesel technology, and we don't want what one auto maker has done to tarnish the industry or the technology," Mr. Hahn said.

Wall Street wasn't convinced, however. Shares of Honeywell, a major supplier of the turbochargers often used to make diesel-powered cars peppier, fell 10 cents Friday to $93.52, down about 5% from their close on Sept. 18. That was the day the EPA accused VW of installing illegal software that sharply reduces nitrogen-oxide emissions, but only when the cars are undergoing strict emission tests.

VW later acknowledged its use of the software and issued an apology.

The company promised to find a remedy to repair the 482,000 VW diesel cars in the U.S. as soon as possible. On Sunday, it launched the website vwdieselinfo.com to tell VW diesel owners about the company's plans to fix their vehicles.

Shares of Tenneco, which makes emissions systems and gets 8% of its revenue from VW, sank almost 8% last week, while those of BorgWarner, which generates 17% of its revenue from the auto maker, fell 6%, finishing the week at $40.

BorgWarner recently opened plants in Portugal and South Korea, partly to produce more components used in starting diesel engines.

Continental, a German supplier of engine components, also was under pressure. Its stock lost nearly 6% of its

market value last week.

Closely held Robert Bosch GmbH, the German giant that supplied the components now at the center of the emissions probe, has said VW was responsible for how the parts were installed.

On Friday, the EPA indicated it would step up scrutiny of diesel vehicles by overhauling the way it oversees the industry's compliance with emissions standards.

The regulator sent a letter to auto makers saying that it will conduct tests of 2015 and 2016 vehicles under normal driving conditions, rather than accepting lab results, as it has done in the past.

In the U.S., diesel engines are largely confined to heavier trucks, with diesel-powered cars representing just a small part of the passenger-car market. But diesel is dominant in Europe, accounting for more than 50% of the passenger-car market in 2015, according to Barclays.

Before the scandal broke, J.D. Power & Associates expected diesel to expand to 7% of the U.S. light-vehicle market by 2017 from 3% this year.

Barclays analyst Brian Johnson suggests those growth expectations need to change, both in the U.S. and Europe. And that will squeeze some parts makers.

"Whatever the specifics that emerge from a VW investigation, we believe strongly that the VW scandal will heighten the pressure on diesel in Europe," he said in a research note last week.

"The end result of the VW issues will be to accelerate a move away from diesel in the European mass market, pressuring suppliers leveraged to diesel," Mr. Johnson said.

Mike Jackson, chief executive of AutoNation Inc., the largest U.S. auto retailer, said it would tough to rebuild trust with potential diesel buyers in the U.S. "It is another black eye for diesel engines overall," he said.

Mr. Johnson of Barclays added that auto makers might need to accelerate development efforts of electric vehicles, hybrid and more-efficient gasoline engines.

That could help parts makers, since many of the same companies will have to supply those component. But their investments in diesel-powered cars could be lost if the industry shifts to those alternatives.

Telegraph (UK):
http://www.telegraph.co.uk/finance/newsbysector/industry/11895848/BREAKING-2.1-million-Audi-cars-fitted-with-VW-emissions-cheat-devices.html

VW scandal: German prosecutors probe Winterkorn as Volkswagen emissions-rigging crisis spreads to 2.1 million Audi cars and Skoda models
By Julia Bradshaw10:31AM BST 28 Sep 2015

Prosecutors in Germany have opened a criminal investigation into former Volkswagen chief executive Martin Winterkorn in the wake of the emissions-rigging scandal.

The probe is understood to concentrate on accusations of fraud after it was revealed that VW had fitted 'defeat' devices in millions of its diesel cars worldwide to cheat government emissions tests.

The investigation aims to establish who was responsible, according to the statement from prosecutors in Braunschweig, Germany, and will look at Mr Winterkorn's role in the worst crisis to hit VW in its 78-year history.

The prosecutors have also received a number of criminal complaints, including one from Volkswagen itself.

Winterkorn quit saying he was "not aware of any wrongdoing on my part"

Under the German system, anyone can file a criminal complaint with prosecutors, who then must examine the complaint and decide whether there is enough evidence to open a formal investigation and for charges to be brought.

It is essentially the equivalent of a police investigation in the UK.

Prosecutors say it is too early to determine if and when they may try and interview Mr Winterkorn himself.

"This is a very broad case and in other such investigations it has taken many months, sometimes years," a spokesman said.

Mr Winterkorn stepped down as CEO last week and was replaced by former Porsche boss Matthias Mueller after the emissions-rigging scandal wiped billions of pounds off the value of VW and tarnished its previously solid reputation for reliability and quality.

Mr Winterkorn has denied knowing about the pollution-cheating software, and issued a statement at the time of his resignation saying: "I am doing this in the interests of the company even though I am not aware of any wrongdoing on my part."

Dr Hans-Christoph Hirt, a director at fund manager Hermes, criticised VW's choice of corporate insiders to take charge of the company, saying the move "raises some real doubts whether the key shareholders have recognised the need for fundamental reform and a real new beginning".

He said: "Following intensive engagement with Volkswagen on corporate governance issues between 2006 and 2009, we have repeatedly raised concerns about aspects of Volkswagen's corporate governance.

"We plan to attend the Extraordinary General Meeting of Volkswagen on November 9 and on behalf of a group of investors will explain our concerns and suggest changes to the company's corporate governance and culture to other shareholders and the management and supervisory boards."

The news came as Audi announced that the device used in parent company Volkswagen's cars to manipulate emissions tests was also fitted in 2.1 million of its own luxury cars.

Of the 2.1 million autos, some 1.42 million diesel-powered Audi vehicles are registered in Western Europe, with 577,000 in Germany.

There are almost 13,000 cars containing the cheat software in the United States, a spokesman for Ingolstadt-based Audi said today.

The engine in question was built into 1.6-litre and 2-litre turbo diesel models in the A1, A3, A4, A6, TT, Q3 and Q5 ranges.

The cars involved have engines in the "euro 5" emissions category. Those with the newer "euro 6" engines aren't affected by the emissions scandal.

"We're working at full speed to find a technical solution," said Juergen de Graeve, a spokesman for Audi.

"Once we have that solution, we'll write to customers and we'll upgrade the cars so that they're within emissions regulations."

Skoda, which is also part of the VW family, has said that 1.2 million of its cars worldwide contain the software cheat, according to reports.

Volkswagen shares have fallen by more than 7pc so far today.

It has also emerged that VW has suspended the R&D chiefs of its core VW brand, luxury division Audi and sports-car maker Porsche, sources familiar with the matter told reporters.

The carmaker's supervisory board last Friday agreed to put a number of employees on leave until the details of affair were cleared up.

VW sparked global outrage last week when it admitted that 11 million of its diesel cars are fitted with special gadgets that activate pollution controls during tests but secretly turn them off when the car is on the road.

The deception has wiped billions off the value of the car giant and is set to land the German auto maker with substantial penalties and recall costs as governments and regulators around the world launch investigations - some of the criminal - into the scandal.

The nations carrying out probes include the UK, South Korea, India, Brazil, Australia, France, Italy, South Africa and Norway - whose economic crime unit has opened an investigation.

The US Justice Department has also launched a criminal probe.

Executives at VW have been accused of masterminding the emissions scandal from the company's headquarters in Wolfsburg.

The chain of command of those involved in the rigging deception stretched all the way back from the US to VW's home patch, it has been claimed, with executives in Germany controlling the key aspects of tests which the firm now admits were manipulated.

It was said that the cars that missed US emissions targets were reported to managers in Wolfsburg.
Testers at a California site evaluated vehicles and results were sent back to Germany before being passed to the US Environmental Protection Agency.

If any car failed to meet emissions targets, a team of engineers from Volkswagen headquarters or Audi's base in Ingolstadt was flown in.

UK Prime Minister David Cameron has condemned Volkswagen over its rigging of emissions tests.
"If companies are breaking the rules and fiddling their figures, that is unacceptable," Mr Cameron said as he flew to New York for a visit to the United Nations. "Emissions standards matter and they have to be properly policed and delivered."

Any move to restrict sales would be "all a matter for the Transport Department," he said.
German authorities have also demanded the carmaker present a timetable for fixing affected vehicles.

The regulators have asked VW to come up with a plan by October 7 to show when its cars will meet emissions requirements.

The German government has also insisted that it did not know about the rigged diesel emissions tests at VW before the story broke.

"The transport minister found out about the allegations of manipulation the weekend before last," a spokesman said.

"We had no previous knowledge that this system was being used."

Volkswagen has set aside €6.5bn to cover damages including fixes for the vehicles, potential regulatory fines and lawsuits, but the cost of the fallout is expected to be much larger.

The FBI in Detroit is reportedly handling a US criminal investigation of the German company, while 27 state attorney generals have unleashed a joint investigation into the blighted car maker.

Thse 27 states are reportedly going to send subpoenas to the company - these are essentially writs compelling testimony or evidence to be produced or face a penalty.

Private law firms are also lining up to take on VW, with a class action suit already being filed by a Seattle law firm.

The automobile giant already faces at least 60 lawsuits filed in federal courts in the US by consumers alleging the company committed fraud by cheating on emissions tests, which means their cars might not be as efficient as they believed them to be.

Dutch investor group VEB, which represents shareholders, has issued a liability claim against Volkswagen for the losses incurred by investors in the wake of the emissions fraud.

The group said: "The liability in question concerns the incorrect, incomplete and misleading information provided by Volkswagen…this manipulation kept the Volkswagen share price artificially high.

"In doing so Volkswagen acted unlawfully; not only towards car owners but also its own shareholders."

Meanwhile, European environmental organisation, Transport & Environment, has said it has found some new models of Mercedes, Volkswagens, BMWs and other new cars consume much more petrol than lab tests claim, according to reports from PA.

The organisation said it had found no proof the cars are equipped with the same sort of "defeat devices" installed on diesel-powered Volkswagens, but called on European Union governments to broaden their probes into the scandal to cover petrol cars as well.

Both the EU and US have announced plans to crack down on the way car emissions are measured.
Currently, manufacturers test emissions in near-perfect lab settings, using smooth tyres unsuitable for roads, engine lubricants so expensive they're beyond the reach of most consumers and even clip off wing mirrors to achieve required emission results.
US regulators and the European Commission have both said they will introduce rules forcing manufacturers to test car emissions under real world road conditions.

The EU is expected to introduce new legislation in early 2106, although French ministers on Thursday called for this to be brought forward to before the end of the year.

New VW boss Matthias Mueller has pledged to win back the trust of customers.

"My most urgent task is to win back trust for the Volkswagen Group by leaving no stone unturned and with maximum transparency, as well as drawing the right conclusions from the current situation," he said on Friday.

Despite the turmoil at VW, the European Central Bank has not suspended the purchase of assets backed by VW loans, under its quantitative easing programme.

Contrary to reports over the weekend, the latest list of eligible collateral purchased by the ECB still includes securities issued by the carmaker.

Dispatch Times:
http://www.dispatchtimes.com/what-to-do-if-you-have-volkswagen-affected-by-the-emissions-scan/106617/

What to do if you have Volkswagen affected by the emissions scan
BY NEWSMEDIAON SEPTEMBER 28, 2015

Regulators will add more spot-checks to cars already on the road as part of a toughening of USA environmental oversight following Volkswagen's admission that it fitted as many as 11 million diesel cars worldwide with software that rigged pollution tests.

The software tells a auto when it is under an official test, triggering emissions control systems that do not seem to be operating under normal driving conditions.

Volkswagen appointed Matthias Mueller as its new chief executive officer, to help the German automaker recover from a scandal over its rigging of USA vehicle emissions tests.

"We are not going to tell them what these tests are; they do not need to know", said Christopher Grundler, director of the EPA's Office of Transportation and Air Quality.

EPA officials insisted on a call with reporters Friday that the previous testing procedures were sophisticated and sufficient to accurately detect the emissions from the diesel cars as long as a manufacturer is not deliberating trying to cheat the process.

The EPA move comes amid a widening scandal over Volkswagen's diesel vehicles, as the automaker has admitted it installed a cheat device to remove nitrous oxide from exhaust emissions during lab testing. Volkswagen CEO Martin Winterkorn issued an apology, stating that he was "deeply sorry that we have broken the trust of our customers and the public".

The EPA's findings regarding the scandal saw that 482,000 cars in the U.S. were involved including the brands made by VW such as the Audi A3 and the VW models Jetta, Beetle, Golf and Passat.

The US Department of Justice (DoJ) has said that the United States would be taking part in an investigation by the Environmental Protection Agency (EPA) into the vehicle company.

Why did successive governments not discourage the proliferation of diesel vehicles which now account for about half of new cars in Britain?

The Air Resources Board sent a letter to all vehicle manufacturers Friday notifying them of the change that will be effective immediately.

Private owners of the 2009-15 VW and Audi models equipped with the violating 2.0-liter diesel may continue driving the cars, and do not have to do anything until Volkswagen of America and the EPA agree on a timeline for a recall.

From: Gong, Kristiene
Sent: Friday, September 25, 2015 3:03 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/25/2015

The Atlantic:
http://www.theatlantic.com/business/archive/2015/09/volkswagen-scandal-cheating-emission-virginia-epa/407425/

The Academic Paper That Broke the Volkswagen Scandal
Last year, a group of researchers at West Virginia University uncovered one of the biggest frauds in automotive history while working under a small $50,000 grant.
BOURREE LAM 1:23 PM ET

Every day since the story first broke a week ago, the ripples of Volkswagen's scandal have extended further and further. Initially, the Environmental Protection Agency ordered Volkswagen to recall nearly half a million vehicles after discovering illegal devices intended to cheat emissions testing. Then, Volkswagen announced the number of vehicles affected is closer to 11 million worldwide—and that the company has set side $7.2 billion to fix the problem. Volkswagen's CEO at the time, Martin Winterkorn, soon resigned.

The company's board is expected to pick Matthias Mueller, the chief executive of Porsche, to take over. There are reportedly nearly 30 class-action lawsuits pending from car owners in all 50 states, plus 5 provinces in Canada. All these furious drivers bought their cars believing that they were highly fuel-efficient—which appears to not be the case, affecting their resale values significantly.

But how did this whole thing begin? At a small lab in West Virgina, it turns out. In 2012, a group of researchers at West Virginia University won a $50,000 grant from the International Council on Clean Transportation to do performance testing on clean diesel cars. Arvind Thiruvengadam, a research assistant professor in mechanical and aerospace engineering, told NPR this week that the team was merely excited do the research—which involved driving the clean diesel cars outside the lab—and write a journal paper based on the data. They never expected that they would discover one of the biggest frauds in automotive history.

When Thiruvengadam and his colleagues tested Volkswagen's clean diesel cars, they found discrepancies up to 35 times the expected emissions levels. The researchers suspected cheating, but couldn't be sure. David Carder, another researcher on the West Virginia University team, told Reuters that the fallout at hand is surprising because this data was made public over a year and a half ago.

The stakes were upped when the Volkswagen cars in question were tested by the California Air Resources Board (CARB) in an investigation starting May of last year, and the CARB and EPA started discussions with Volkswagen on why there were such discrepancies. Volkswagen insisted to EPA officials that the discrepancies were due to a technical issue rather than deliberate cheating. Only when the EPA threatened not to approve Volkswagen's 2016 clean diesel cars for sale in the U.S. did the company finally fess up.

Volkswagen will survive this scandal (even though its stock has plunged 30 percent, wiping out a quarter of its market value), but now the future of diesel cars are at stake and it's expected that the consumers who wanted clean diesel cars for their greenness will likely switch to hybrids, while those who care for performance might try to dodge the recall. Either way, Volkswagen will be held responsible for clean diesel's coming existential crisis.

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Sent: Friday, September 25, 2015 2:42 PM
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Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/25/2015

International Business Times:
http://www.ibtimes.com/does-epas-response-volkswagens-emissions-cheating-go-far-enough-2114563

Does EPA's Response To Volkswagen's Emissions Cheating Go Far Enough?
By Cole Stangler

Auto regulators are now on the offensive after being deceived by Volkswagen for years. They unveiled a response Friday to the company's stunning admission that it systematically cheated on emissions tests from 2009 to 2015. In a letter to automakers, the U.S. Environmental Protection Agency said it will bolster testing procedures to detect so-called defeat devices like the ones Volkswagen used to shut down pollution control systems outside of testing conditions.

Jesse Prentice-Dunn, a policy analyst at the Sierra Club, applauds the move. But he says "long-term" fixes are still needed. "The testing regime needs to be revamped."

Critics have long said as much. Under the current testing system, automakers in the United States conduct their own examinations and report the data to federal officials. The EPA, meanwhile, conducts spot checks, but its resources are stretched thin.

Dan Becker is the director of the safe climate campaign at the Center for Auto Safety. For companies to respect emissions standards, he says, officials need to remove the tests from private hands and transfer them to labs with federal supervision. "Right now, you've got the foxes in control of the chicken coop, and that's never going to be a good show."

In an ideal world, Becker says, automakers would simply follow the law. But in the last few decades, companies have shown a remarkable penchant for gaming the standards, and the current structure of the testing system makes it exceedingly easy to do so.

"If these companies were being honest, we wouldn't need an elaborate system to make sure they don't cheat," Becker said. "But they've proven that they do cheat." Not just Volkswagen -- but "virtually every major automaker," he asserted.

A History of Gaming The System

It started in the 1970s, just after the EPA was created and began to regulate auto emissions under the Clean Air Act. Volkswagen, in fact, was among the first to equip its cars with defeat devices to override emissions control systems. In 1973, it confessed to installing them on 25,000 cars. The following year, Chrysler was forced to recall more than 800,000 cars after it was found to have installed a similar device in radiators.

The 1990s saw a couple of major scandals. In 1995, General Motors settled with the Justice Department and the EPA for $45 million, acknowledging it installed a computer chip in 500,000 Cadillacs that tripled the amount of carbon monoxide output when the cars' heating and cooling systems were running. Three years later, Caterpillar, Mack Trucks and Volvo Trucks reached a similar settlement, worth $1 billion, for equipping trucks with defeat devices.

Kia and Hyundai followed suit more recently. Last November, the South Korean corporations copped to overstating fuel economy standards on 1.2 million cars from 2010 and 2012, settling with the Justice Department and the EPA for $300 million.

A representative for the Alliance of Automobile Manufacturers, a trade group that represents automakers operating in the United States, declined to comment.

What Is To Be Done?

The Sierra Club's Prentice-Dunn says one path to reform could simply be to increase the number of spot checks. Indeed, Christopher Grundler, director of the EPA's Office of Transportation and Air Quality, recently told the Associated Press that the agency may soon do this.

Grundler was less forthcoming about the EPA's plans to enhance detection of defeat devices -- the subject of Friday's letter to automakers. On a call with reporters, he wouldn't say what changes the agency is enacting to audit lab results submitted by car companies.

"They don't need to know," he said, of the automakers. "They only need to know that we will be keeping their cars a little bit longer, and we're going to driving them more."

Becker says more oversight is a good step, but regulators need to go further by eliminating their reliance on companies' test data altogether.

"This is an industry that has proven it's not trustworthy," said Becker. "The EPA shouldn't trust them when they say, 'our vehicles meet your standards, everything's just peachy keen.' The government needs to set up a

better testing system and not rely on the auto companies' assertions."

He's not sure exactly how that would look -- whether it would be in-house or conducted at independent labs with federal supervision -- either way, he says, it would need to be firmly outside the control of companies. Taxpayers, in theory, could cover a portion of the cost, but companies should be forced to foot most of the bill.

Congressional Republicans, who have made frequent targets of the EPA, would likely oppose such a plan. Since 2010, the agency has seen its budget decline by a fifth, or about $2 billion. Earlier this month, 20 Republican members of Congress filed articles of impeachment against Gina McCarthy, head of the agency.

Luke Tonachel, director of clean vehicles and fuels at the Natural Resources Defense Council, says all this makes it harder for the agency to do its job. "If the EPA's resources are constantly under attack, it's only gonna be harder for them go out and catch the cheaters."

Fortune:
http://fortune.com/2015/09/25/gm-volkswagen-emissions/

Former GM Vice Chair: "I almost feel sorry" for Volkswagen
by Chris Matthews

Bob Lutz says the competition wondered how VW could get low emissions cheaply

For six years, Volkswagen has been installing software in its cars to help them cheat on EPA emissions test. As former GM Vice Chair Bob Lutz told CNBC Friday, the rest of the industry was wondering just how the company was able to get clean emissions so cheaply.

Lutz said that he consistently pressed his engineers to figure out what his competitor was doing, ""They said, 'We can't answer that question," according to Lutz. "Honda asked the same question. They couldn't figure it out either because with near identical engines and hardware from the same suppliers, they could not get themselves to pass."

Lutz also predicted that to fix the problem will be, "incredibly expensive" after factoring in government fines and consumer lawsuits for complaints like loss of value. He even went so far to say that he "almost" feels sorry for his former competitor.

From: Gong, Kristiene
Sent: Friday, September 25, 2015 2:11 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/25/2015

International Business Times:
http://www.ibtimes.com/volkswagen-whistleblower-we-gave-epa-diesel-emissions-data-2014-2114511

Volkswagen Whistleblower: "We Gave EPA The Diesel Emissions Data In 2014"
By Mike Brown

The Volkswagen scandal has shaken the automotive world. It all started with two men: Peter Mock and John German. The pair worked with West Virginia University to try to show that clean emissions tech doesn't necessarily effect automotive performance. Instead, they discovered that the chosen cars were pumping 40 times more emissions into the air than they were supposed to. They submitted their findings to the California Air Resources Board and the federal Environmental Protection Agency.

This week, German, senior fellow at the International Council on Clean Transportation, suddenly became one of the key figures in a story about how the global car manufacturer had cheated on EPA emissions tests. The shocking revelations have had widespread impact on the industry and started an international conversation on emissions testing. They also cost Volkswagen CEO Martin Winterkorn his job. Here, German speaks to International Business Times about how Volkswagen got away with it, the wider implications, and what happens next.

International Business Times: Now, as I understand it, Volkswagen was using a "defeat device" to measure the conditions of the car, but this wasn't actually a device. It was a piece of software, correct? What was that software measuring for?

John German: We don't know. You are correct it is software, it has to do with the computer looking for the conditions under which test procedure was conducted, and if it detects the conditions, the emission controls behave the way they were designed. But if it does not detect those conditions, it switches to a different control where it reduces the effect of the system. The specifics as to how they reduce effectiveness, though, we don't know. There's quite a number of ways they could detect how they could see that the car was being tested.

IBT: Who could have known about this?

German: One aspect that's really interesting is that we turned data and report over to CARB and the EPA back in May 2014 and they discussed the problems with Volkswagen. Then in December 2014, Volkswagen issued a field fix, and they reflashed the computers in the cars to install the field fix. A few months later they assessed, and found the defeat device was still in the field fix. That is incomprehensible to me, so the interpretation is that this was only a relatively small part of the company.

IBT: Is this something that's ever happened before?

German: There have been a number of other defeat device cases. The best-known case was in the late 1990s with heavy-duty engine manufacturers, ones for really big freight trucks. They did something similar; they were concerned with driving long distances. So they looked for a steady state highway speed for more than x mins, after which they would change calibrations, pushing the NOx up.

IBT: But I'm assuming before they didn't have as advanced computers and electronics. How did they control it before?

German: The systems were simpler. Before NOx after treatment, it was all in calibration. One example of this was what's known as exhaust gas recirculation. That was the first step of control. You could put in one of those to reduce NOx, but it would also increase fuel consumption, so you could switch it off.

IBT: When will we find out what Volkswagen was doing? Are we talking more in months or years?

German: We will only find out if CARB or EPA reveal it. It might be part of the settlement with Volkswagen, as part of the legal agreement. There is a good chance that the EPA will release the info, but we're probably talking more in months. At this stage, though, it's definitely in Volkswagen's interest to get it fixed and behind them as fast as possible.

IBT: Could we conduct tests to find out for ourselves how Volkswagen were doing this?

German: Maybe. It would be difficult. The kind of time and expertise it takes to reverse-engineer calibrations ... these computers are really powerful and complex, and it would take a large amount of time and expertise.

IBT: But we know the car was looking for certain conditions. What are these conditions they could have been measuring for?

German: There are several factors. On an official test the non-drive wheels don't spin, the front wheels do not

turn. The test is run at a consistent ambient temperature. It's always run with a cold engine, and the test has a defined speed trace, i.e. the speed for each second. Volkswagen could have looked for any of those.

IBT: Thank you for your time, this has been very interesting. Is there anything else you wanted to say about this that you don't think we covered?

German: The main point is that governments need to do a better job of oversight and enforcement. Worldwide, in China, India, Brazil ... the primary lesson is that there needs to be better oversight and more data.

CBC News (Canada):
http://www.cbc.ca/news/business/volkswagen-emissions-testing-1.3243656

EPA works with Canadian regulators to retest VW vehicles
U.S. regulators warn they will revamp testing protocols after learning of VW cheat device

The U.S. Environmental Protection Agency is looking to revamp the way it tests emissions for all automobiles in the wake of the scandal over Volkswagen's manipulation of emissions data.

The EPA will also be working closely with Environment Canada, which has an "excellent laboratory," to co-ordinate widespread testing around the Volkswagen emissions, EPA officials said in a conference call on Friday.

Affected vehicles have yet to be recalled, but the EPA said it is looking for "recall solutions." Part of the problem is that there is no fix that won't negatively impact vehicle performance.

An estimated half million vehicles in the U.S. are affected, with Environment Canada estimating 100,000 VW diesels are in service in Canada.

The EPA said it is sending a letter to automakers outlining plans for more extensive testing of all vehicle models.

That echoes an initiative by European regulators, who plan to move in 2017 to a system of road testing for vehicle emissions standards.

Light commercial trucks

The EPA move comes amid a widening scandal over Volkswagen's diesel vehicles, as the automaker has admitted it installed a cheat device to remove nitrous oxide from exhaust emissions during lab testing.

On Friday, Germany's transport minister said that light commercial trucks made by Volkswagen appeared to have the same software geared toward cheating on U.S. emissions tests.

Transport Minister Alexander Dobrindt told lawmakers Friday that 2.8 million vehicles in Germany may be affected.

Meanwhile, Daimler AG, the maker of Mercedes cars, is rejecting claims by a German environmental group that it appears to have been involved in manipulation of emissions data.

The Deutsche Umwelthilfe group said Friday it had information that almost all German manufacturers of diesel cars exceed emissions limits and speculated that the cars were declared road-worthy by regulators because of cheat devices.

"We sharply deny the allegation that we manipulated our cars during emissions tests. We never did and do not now use a defeat device," Daimler said in a statement.

Questions over emissions testing

Volkswagen cars as far back as 2009 are equipped with the defeat software that is geared toward passing emissions standards.

The revelation has put the EPA, and testing agencies around the world, on the alert.

Chris Grundler, head of the EPA's office of transportation and air quality, was clearly on the defensive, saying the EPA had left it to European regulators to do more extensive tests of diesel as the fuel is in wider use there.

It wasn't the EPA that uncovered the high nitrous oxide emissions from VW diesel cars, but the International Council on Clean Transportation (ICCT), a nonprofit research organization based in Virginia.

"Do I wish we had uncovered it sooner? Absolutely," he said.

VW was able to fool the EPA because the agency only tested the cars on treadmill-like devices called dynamometers and didn't use portable test equipment on real roads. The software in the cars' engine-control computers checked the speed, steering wheel position, air pressure and other factors to determine when dynamometer tests were under way. It then turned on pollution controls that reduced the output of nitrogen oxide, an ingredient in harmful ozone, the EPA has said.

The agency does have on-road testing equipment, but it is used to monitor automaker gas mileage estimates and heavy-duty diesel trucks, which create more emissions.

"It's not a question of equipment or technology or capability. It's a question of where we deploy those resources," Grundler said.

Any new testing will include investigations that will uncover any software designed to fool emissions testers, Grundler said.

More extensive road testing is also on the way, he warned automakers, though he did not specify exactly which tests the EPA plans.

The scandal has also exposed holes in the European testing system, where tests are done in laboratory conditions on special pre-production models provided by the manufacturers. Norway, France and Italy announced moves today to investigate VWs sold in their countries.

Europe's tests have not been upgraded since 1996 and critics say its testing is less rigorous than North American testing.

The EU has proposed real-world testing from 2017, with new proposals to close loopholes and design testing to more closely resemble real-world road conditions.

ICCT testing of diesel cars hints at trouble for many automakers around diesel emissions, with poor results for Volvo, Renault and Hyundai as well as Volkswagen.

From: Gong, Kristiene
Sent: Friday, September 25, 2015 1:26 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/25/2015

Detroit Free Press:
http://www.freep.com/story/money/cars/2015/09/25/epa-expands-emissions-tests-wake-vw-

scandal/72794218/

EPA expands emissions tests in wake of VW scandal
By Greg Gardner
The EPA also will test diesel vehicles produced by other automakers.

The U.S. Environmental Protection Agency will introduce new tests to detect devices like the one Volkswagen used to cheat on its emission test to comply with the Clean Air Act, agency officials said today.

The German automaker said Matthias Mueller, currently the head of its Porsche unit, will become CEO, replacing Martin Winterkorn who resigned earlier this week because of the emissions cheating scandal.

The EPA apply the new regimen to diesel vehicles produced by other automakers. The agency is also asking owners to allow EPA researchers to test their diesel vehicles to learn more about how the German automaker disguised their violations, that could lead to a fine of up to $18 billion in the U.S. alone. More broadly Volkswagen has said 11 million vehicles worldwide used some type of software to game various countries' environmental standards.

"We're going to adapt new practices and more demanding tests to improve our enforcement," said Chris Grundler, director the EPA's office of transportation & air quality. "We are not going to tell manufacturers what these new tests are. They don't need to know."

In the U.S., the EPA found that 482,000 Volkswagen cars sold between the 2009 and 2015 model year used a defeat device when testing the vehicles.

They include:

Jetta (model years 2009-15)
Beetle (model years 2009-15)
Audi A3 (model years 2009-15)
Golf (model years 2009-15)
Passat (model years 2014-15)

Without the defeat devices, which were deactivated after Volkswagen met the emission requirements, the VW and Audi vehicles were emitting nitrogen oxides (NOx), a greenhouse gas, at levels up to 40 times the permissible standard.

Grundler and Janet McCabe, EPA acting assistant administrator for the office of air and radiation, asserted that neither their agency nor the California Air Resources Board, which can also penalize Volkswagen and Audi, don't allow any manufacturer to "self-certify," or conduct their tests without regulatory involvement.

EPA and CARB uncovered the defeat device software after independent analysis by researchers at West Virginia University, working with the International Council on Clean Transportation, a nongovernmental organization.

Grundler said EPA has the money and staff to expand its emission testing.

"We have the equipment. We have the people. We have 23 of these measurement systems and they are not cheap," he said.

Washington Post:
http://www.washingtonpost.com/business/economy/epa-to-begin-more-rigorous-testing-of-all-diesel-cars-after-vw-scandal/2015/09/25/f20fa39a-6393-11e5-8e9e-dce8a2a2a679_story.html

EPA to begin more rigorous testing of all diesel cars after VW scandal

By Thad Moore

Federal regulators are launching more aggressive testing of diesel-engine cars across all manufacturers in the wake of the Volkwagen emissions-cheating scandal, the Environmental Protection Agency said Friday.

The EPA also says it will add additional tests designed to ferret out "defeat devices" like the software VW used to circumvent emissions tests.

The agency had been focused its diesel testing on big-rig trucks because they are more common than diesel cars and account for more pollution in the U.S., said Christopher Grundler, director of the EPA's Office of Transportation and Air Quality.

The EPA will begin testing cars Friday, Grundler said, and it will seek out test vehicles from rental car fleets and consumers. The agency doesn't know how long the testing would take, but Grundler said it is working with regulators in California and Canada to speed the process.

VW acknowledged that 11 million of its vehicles worldwide, including nearly 500,000 in the United States, were involved in a deception that allowed the vehicles to pass emissions tests while emitting nitrogen oxide at up to 40 times the federal standard. Its' CEO, Martin Winterkorn, stepped down this week and the company is under criminal investigation and faces billions in fines. VW also set aside more than $7 billion to fix the problems with its cars and begin to repair its reputation with customers.

Neither the EPA nor Volkswagen have said how long it will take to fix the nearly half-million cars in the U.S. with defeat devices. But it expects cars in the 2015 model year will be patched "relatively quickly," Grundler said.

Older versions of the Passat should be fixed soon after that, but other models will take longer because designing a solution "will require additional engineering development that will take longer," Grundler said.

US News & World Report:
http://www.usnews.com/news/articles/2015/09/25/epa-beefing-up-emissions-tests-in-wake-vw-audi-cheating-scandal

EPA Beefing Up Emissions Tests in Wake of VW Scandal
The agency also says it plans to test gasoline and diesel vehicles that are on the road today.
By Alan Neuhauser

One week after Volkswagen copped to cheating on federal emissions tests of popular VW and Audi "clean-diesel" cars, the Environmental Protection Agency sent a letter to vehicle manufacturers Friday announcing it was toughening its emissions tests. The agency also will be launching audits of every current make and model of light-duty diesel passenger vehicle, reflecting concern that cheating might be widespread.

The expanded checks will include on-road testing to better emulate real-world driving conditions. Some critics had previously alleged that the tests were outdated and easily outsmarted. The new audits will also include gasoline vehicles, an EPA official said

In this photo taken Feb. 14, 2013, a Volkswagen logo is seen on the grill of a Volkswagen on display in Pittsburgh. The Environmental Protection Agency (EPA) says nearly 500,000 Volkswagen and Audi diesel cars built in the past seven year are intentionally violating clean air standards by using software that evades EPA emissions standards.
RELATED

Volkswagen Sees Billions Erased From Market Value After Rigging Claims

The agency also confirmed that affected VW and Audi vehicles – diesel Passats, Jettas, Beetles, Golfs, and

A3s, together numbering around 500,000 cars in the U.S. – would be recalled as the German auto group devises solutions to make the cars compliant with U.S. air standards.

"These violations are very serious," Janet McCabe, acting assistant administrator for the EPA's Office of Air and Radiation, said during a call with reporters. "VW was concealing the acts from EPA, from the state of California, and from consumers."

The California Air Resources Board tests vehicle emissions and was among the groups that uncovered the cheating regimen.

Volkswagen Group CEO Martin Winterkorn resigned Wednesday amid the continuing fallout from the scandal, stating he was "shocked by the events of the past few days" and "stunned that misconduct on such a scale was possible in the Volkswagen Group."

VW and Audi may ultimately face a penalty of up to $18 billion, or $37,500 per vehicle in violation. By comparison, Hyundai and Kia were penalized $300 million last year for overstating vehicles' fuel economy and greenhouse gas emissions.

The Justice Department has also reportedly opened a criminal investigation of Volkswagen AG.

EPA officials intimated that they expected VW and Audi penalties – as well as the expanded audits – to reflect the flagrancy of the violations. The cars, from model years 2009 through 2015, contained "defeat devices" buried in the software governing their engine controls. These lines of code automatically reduced emissions of nitrous oxide, or NOx, during tests, then switched off the restrictions during normal driving.

The cars were found to emit as much as 40 times the legal limit of NOx, the EPA said, which causes smog and a range of health problems. With 11 million of the vehicles on the road worldwide, one "back-of-the-napkin" calculation by Vox's Brad Plumer found they churned out as much as 20 times the NOx of a typical power plant, contributing to anywhere from dozens to hundreds of premature deaths.

"The facts before us show us that this firm sadly developed a very sophisticated scheme to defeat this test using software very deep in the engine control," Christopher Grundler, director of the EPA's Office of Transportation and Air Quality, said during Friday's call.

The EPA is partnering with the California Air Resources Board and bringing about Environment Canada – that nation's version of the EPA – to carry out its audits of gas and diesel vehicles. The agency said it would test cars from private owners who volunteer, as well as vehicles from rental companies. Officials declined to speculate how long the testing would take or how much it would cost the agency, but did acknowledge that expected recalls of VW and Audi vehicles would take longer for older models.

"We expect the first generation of vehicles, all pre-2015 vehicles except for the Passat, will require additional engineering … that will take longer," Grundler said.

VW's four-cylinder diesel vehicles for 2016 also have not yet received required emissions certification from the EPA because officials aren't yet certain the vehicles will perform as required.

The EPA's testing procedures date to 1975 and were most recently updated in the "early 2000s," Grundler said, when they were expanded to reflect aggressive driving, high-speed driving, and driving in hot and cold weather.

In light of the VW and Audi practices, he added, "we are going to be adopting some new approaches and new tests as a continuous improvement of our oversight."

CNBC:
http://www.cnbc.com/2015/09/25/epa-expect-range-of-penalties-for-vw-amid-scandal.html

EPA: Expect range of penalties for VW amid scandal
Fred Imbert

The Environmental Protection Agency said Friday it will be cracking down on Volkswagen after the German automaker admitted it added software on its vehicles to deceive emissions tests.

The EPA said it will hit the company with a range of penalties as a result of the investigation, but added that it has not issued a recall since the discovery.

"We are upping our game," Chris Grundler, head of transportation and air quality at the Environmental Protection Agency, told reporters in a teleconference.

The automaker, one of the largest car companies in the world, could face fines of $37,500 per vehicle in the U.S., the EPA said last week. With around 482,000 of its diesel vehicles sold in the U.S. since 2008, this could mean a penalty of up to $18 billion.

Rain clouds are seen over a Volkswagen symbol at the main entrance gate at Volkswagen production plant on September 23, 2015 in Wolfsburg, Germany. Volkswagen CEO Martin Winterkorn and other members of the supervisory board are believed to be meeting inside the headquarters to discuss the Volkswagen Diesel emission scandal, which affects 11 million vehicles worldwide.

Europe's carmakers caught up in VW storm
The agency also said it has already begun new testing of all diesel-powered vehicles, and is planning even more new tests.

The EPA said it will improve its ability to detect so-called defeat devices or software that can reduce emissions during testing. But it will not tell automakers specifically how it is improving the testing.

"They don't need to know," Grundler said.

It added that the vehicles are safe to drive. Nevertheless, it also said these events make it clear it needs to improve its oversight over automakers and that Canada's Department of the Environment would be an active partner in testing vehicles more quickly.

Volkswagen German-listed shares have fallen nearly 30 percent in the last week, according to FactSet.

From: Gong, Kristiene
Sent: Friday, September 25, 2015 1:07 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/25/2015

LA Times:
http://www.latimes.com/business/la-fi-hy-epa-auto-testing-20150925-story.html

VW cheating scandal prompts EPA to widen testing of diesel cars
By JERRY HIRSCH

Working with regulators in California and Canada, the Environmental Protection Agency launched a new testing program Friday to look at the emissions from every make and model of diesel passenger cars on U.S. roads.

The increased oversight is a response to the discovery earlier this month that Volkswagen was using sophisticated software to cheat on pollution tests on 482,000 diesel vehicles sold in the U.S.

The automaker, which faces a federal criminal investigation and other regulator sanctions, admitted cheating and said the software could be on as many as 11 million vehicles worldwide.

“Clearly this is a concern for air quality and public health,” said Janet McCabe, acting assistant administrator of the EPA office of air and radiation. “The Volkswagen violations before us now show that we must continue to improve our oversight.”

Both the California Air Resources Board and the Environment Canada will join in the testing.

“This will allow us to move more quickly to test more models,” said Christopher Grundler, director of the EPA’s office of transportation and air quality.

The agency sent a letter Friday to all automakers explaining that their vehicles will undergo extra scrutiny.

The EPA said it now will test or require testing on any vehicle in a setting that emulates normal driving specifically for investigating the presence of a so-called defeat device, the industry term for systems that hide a vehicle’s true emissions.

This will be in addition to the five standard emissions tests all new vehicles undergo and may require additional time, the agency said.

The agency and its partners also will use portable devices to measure the real life emissions of vehicles as they are driven on open roads, Grundler said.

Environmental groups welcome testing expansion and said it will deter other automakers from evading emissions regulations.

“EPA is on the job,” said Luke Tonachel, director of clean vehicles and fuels project at the Natural Resources Defense Council. “This expansion of testing will is another signal that cheating will not be tolerated.”

There is no evidence at this point to suggest that any other companies are cheating.

After tips from researchers in Europe and the University of West Virginia, California and federal regulators discovered that VW had buried an algorithm in 100 million lines of computer code in its vehicle electronics that allows the cars to emit up to 40 times the legally allowed amount of nitrogen oxide.

The cars met environmental regulations when tested on a dynamometer -- a kind of treadmill for vehicles -- in a laboratory. But they spewed pollution when driven on roads.

VW’s software senses the testing environment by analyzing a variety of data -- steering position, speed, duration of engine operation, barometric pressure and changes in the car’s performance.

The affected cars are the 2009 to 2015 Volkswagen Jetta TDI, 2009 to 2014 Volkswagen Jetta SportWagen TDI, 2012 to 2015 Volkswagen Beetle TDI, 2013 to 2015 Volkswagen Beetle Convertible TDI, 2010 to 2015 Audi A3 TDI, 2010 to 2015 Volkswagen Golf TDI, 2012 to 2015 Volkswagen Passat TDI, 2015 Volkswagen Golf SportWagen TDI.

Additionally, Volkswagen suspended new and used sales of the all 2.0-liter TDI four-cylinder diesel engines, including 2015 Beetle, Jetta, Golf, Passat TDI, as well as the Audi A3 TDI. Sales of VW's 2016, 4-cylinder diesel models are held up as they await EPA certification.

Grundler said the EPA is working with Volkswagen to evaluate potential remedies for the diesel vehicles’ emission systems. The 2015 models will be the first fixed, followed by the 2012-15 Passats.

Because the range of cars affected include three generations of diesel engines, the remedies for the other

vehicles could take much longer to develop.

Other automakers said they are ready for more rigorous testing of their diesel vehicles.

“We are prepared for testing,” said Annalisa Bluhm, a GM spokeswoman. “We are not changing our diesel strategy as a result of what is going on with Volkswagen.”

The automaker sells diesel pickup trucks and a diesel version of the Cruze sedan.

Bluhm said GM is “committed to the robust emissions compliance of all our vehicles” and expects its employees to know the regulations and “act legally and ethically.”

Only about 3% of all autos and light truck sales involve diesel power trains.

According to the Diesel Technology Forum, there are 39 diesel-powered passenger vehicles being sold in the U.S. Those are made by Audi, BMW, Chevrolet, Jaguar, Jeep, Land Rover, Mercedes-Benz, Porsche, Ram and Volkswagen.

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That number will grow, the forum said, by 15 more vehicles within the next year. Among the new entries will be light trucks from GMC, Chevrolet and Nissan.

Meanwhile, other German automakers issued statements saying that they have not gamed emission testing for their diesel offerings.

BMW said it observes “the legal requirements in each country.... Our exhaust treatment systems are active whether rolling on the test bench or driving on the road.”

Mercedes-Benz said that it has never used defeat devices to evade testing, in response to allegations by a German environmental group that other automakers' diesels also exceed smog-forming nitrogen oxide emissions. The company said it sticks to all laws and rules and isn't aware of any measurements showing that its vehicles fail to keep to legal requirements.

Mercedes said it supports efforts to develop new testing methods to measure emissions based on real driving conditions.

The VW cheating scandal prompted the resignation of the automaker's chief executive, Martin Winterkorn. The company is expected to name a new CEO later Friday or in the coming days.

Financial Times:
http://www.ft.com/intl/cms/s/0/8c6d5aec-6392-11e5-a28b-50226830d644.html#axzz3mgG3bZd2

EPA warns other carmakers it will test for defeat devices
Chris Bryant in Frankfurt and Barney Jopson in Washington

The US environmental regulator put all vehicle manufacturers “on notice” on Friday that it will intensify its emissions testing on diesel-powered vehicles to discover whether “defeat devices” were being used more widely.

Janet McCabe, acting assistant administrator of the Environmental Protection Agency, told reporters: “We are stepping up our testing activities in response to VW’s alleged violation.”

The new testing regime will start immediately and Christopher Grundler, director of the EPA’s office of transportation and air quality, said that for manufacturers it meant “we’ll be keeping their vehicles a little bit longer and driving them more”.

The EPA's announcement came as Volkswagen's board gathered to appoint a new chief executive to lead the carmaker, with Matthias Müller, head of Porsche, widely viewed as the favourite candidate.

The supervisory board meeting at VW's Wolfsburg headquarters follows Martin Winterkorn's resignation after eight years at the helm of the group.

Mr Müller is close to the Porsche and Piech families, who together control a majority of VW's voting shares, knows Volkswagen inside out and has a reputation for speaking his mind. The company declined to comment.

The board is also expected to decide on Friday which managers must leave the company over the scandal, with attention focusing on high-level engineers and designers.

VW has been reeling since the EPA revealed last Friday that the group had rigged its diesel cars to pass emissions tests, potentially laying itself open to criminal charges and substantial fines.

The EPA said that VW had installed defeat device software that turned off emissions controls during regular driving and turned them on during an emissions test. The software meant cars emitted up to 40 times the amount of nitrogen oxides that US environmental standards allow.

The EPA said 482,000 vehicles sold in the US since 2008 were affected, but VW later raised that figure to 11m worldwide. It said it would take a €6.5bn charge to cover the costs of the crisis.

A senior official at the EPA told the Financial Times that Volkswagen had orchestrated an unprecedented effort to beat the EPA's rigorous testing regime. "The level of deceit the company went through to game the system was enormous," the official said.

The EPA operated a cutting-edge testing regime to police compliance with clean air regulations, the official said, and it took an "elaborate, aggressive, ongoing, co-ordinated effort" to beat it. "We've seen uses of defeat devices, but nothing to this scale," the official added.

Forbes:
http://www.forbes.com/sites/neilwinton/2015/09/25/vw-struggles-to-agree-new-ceo-but-heres-some-advice-for-the-eventual-incumbent/

VW Struggles To Agree New CEO, But Here's Some Advice For The Eventual Incumbent
Neil Winton ,CONTRIBUTOR

A meeting in Wolfsburg, Germany, of Volkswagen executives to appoint a new CEO was dragging on into the evening, suggesting a lack of agreement on who should replace Martin Winterkon.

Winterkorn resigned this week in the wake of the scandal in which VW duped the EPA with false diesel data. VW's shares dived on stock markets, and the company's 20-member supervisory board is apparently torn between appointing the media favourite Porsche CEO Matthias Mueller or VW brand chief Herbert Diess to replace Winterkorn.

Max Warburton, analyst with Bernstein Research, said Diess was his first choice.

"He's the best candidate if VW wants to show everyone – internally and externally – that the regime has changed," Warburton said.

Diess was recently hired from BMW so is not tainted by any of the VW scandals.VWLogo.jpg

"Diess would also be the best choice for shareholders who would like other changes after the EPA scandal has been dealt with. Our second vote goes to Hans Dieter Poetsch. He would be a good option in the short-term

as VW needs an eloquent, unflappable face to put in front of U.S. Congress and media," Warburton said.

Poetsch, currently VW's finance chief, was nominated earlier this month as the replacement for Ferdinand Piech as Chairman of the board. Poetsch faces a shareholder vote in November to confirm his appointment.

Whoever gets the new CEO job should do the following, Warburton said.

Offer to buy back and scrap every 2.0 diesel sold in the U.S. – all 482,000 of them – cost $6 billion.

Announce that VW will henceforth abandon all efforts to sell diesel engines in the U.S., but will embrace gasoline and plug-in hybrids.

Send the new CEO to the U.S. Monday to meet government officials, the EPA and media.

Announce the immediate suspension of the 100 engineers most closely linked with the engine and software development.

Announce the cessation of all motorsport activities immediately, turning all the funding over the electric, plug-in hybrid and environmental research in a new research facility located in the U.S. employing U.S engineers.

CNN:
http://money.cnn.com/2015/09/25/news/companies/volkswagen-epa-emission-scandal/index.html?section=money_latest

EPA to automakers: We'll test everyone for VW problems
By Chris Isidore and Ahiza Garcia @CNNMoney

Federal regulators are putting U.S. automakers on notice.
The EPA said Friday it will test emissions at every automaker to make sure no other company is trying to dodge pollution regulations like Volkswagen did.

The agency will send a letter to all manufacturers to notify them that it's stepping up its emissions policing.

The EPA said it will test every model of diesel car, SUV and pickup that's now on the road in the U.S. The testing won't include large vehicles such as semi-tractors and buses, which also use diesel.

It added that the new testing procedures will be more vigorous to prevent automakers from cheating, and will more closely approximate the emissions from a vehicle in real-world driving conditions.

Last week, the EPA found that Volkswagen had falsified pollution tests on 482,000 VW and Audi diesel cars in the U.S.

Those models include the VW Jetta, the Passat from 2014-2015, the Beetle and the Golf from 2009 through 2015, and the Audi A3, model years 2009-2015. Audi is owned by Volkswagen (VLKAY) Group.

Volkswagen manipulated software so its cars would seem cleaner when they were being tested. But when they were on the road, the cars pumped out nearly 40 times the legal level of nitrogen oxide. Volkswagen has since admitted it cheated.

EPA officials insisted on a call with reporters Friday that the previous testing procedures were sophisticated and sufficient to accurately detect the emissions from the diesel cars as long as a manufacturer is not deliberating trying to cheat the process.

Since the EPA plans to test older cars that are no longer available from the manufacturers, the agency said it will borrow cars from individuals as well as businesses, such are rental car companies, which own the vehicles

it wants to test.

Volkswagen's directors are meeting Friday to name a new CEO after Martin Winterkorn stepped down earlier this week.

Winterkorn said he was unaware of the emissions cheating and apologized for the possible data manipulation in roughly 11 million cars worldwide.

VW has had to set aside €6.5 billion ($7.3 billion) to deal with the issue, but the final total could far exceed that. The automaker is also facing criminal probes from U.S. state attorneys generals and possibly the federal government. The EPA could impose a civil penalty of $37,500 per violation, which would come to $18 billion.

Volkswagen's share price has plunged 50% in the wake of the scandal.

Newsweek:
http://www.newsweek.com/epa-volkswagen-emissions-defeat-device-retest-announcement-376641

EPA to Begin Retesting All Light Diesel Cars on the Road for Defeat Devices
BY ZOË SCHLANGER

The search for more "defeat devices" installed in cars and meant to cheat emissions tests has begun. The U.S. Environmental Protection Agency announced on Friday it would begin systematically re-testing all models of light diesel vehicles currently on the road in the U.S. The goal is to weed out any other potential defeat devices following the discovery that Volkswagen designed and installed software in their cars that for years tricked the EPA's testing system.

"Today we are putting vehicle manufacturers on notice" that there will be additional testing to look for defeat devices, Christopher Grundler, director of EPA's Office of Transportation & Air Quality, said on a call with reporters Friday. "We aren't going to tell them what these tests are, they don't need to know. They only need to know we will be keeping their cars a little bit longer, and driving them a little bit more."

EPA maintains that it has the necessary expertise and equipment to detect defeat devices. However, the regulator did not catch Volkswagen's alleged fraud on the U.S. portion of the 11 million cars globally that contained the defeat device. The cars range from model years 2009 to 2015. According to EPA, the cars 'knew' when they were being tested for emissions, and were able to temporarily present much lower emissions than they did while on the road.

"As you know, the company, very deeply, within 100 million lines of software code, had a very specific algorithm to defeat the test," Grundler said. "They developed a very sophisticated scheme to defeat the test. It was a deliberate attempt to have two calibrations on the vehicle."

Each VW car was able to emit up to 40 times the allowed amount of NOx. EPA still has not calculated the additional amount of NOx the cars contributed to the atmosphere, but Janet McCabe, EPA's acting assistant director, said the agency "need[s] to address this." One estimate puts the number at between 250,000 to 1 million extra metric tons of NOx pollution per year, according to The Guardian.

NOx emissions have been found to contribute to respiratory illness and heart disease as well as early death.

Buzzfeed News:
http://www.buzzfeed.com/danvergano/volkswagen-deception-spurs-epa-to-start-defeat-device-tests#.huywrmMbNN

Volkswagen Deception Spurs EPA To Start "Defeat Device" Tests Of All Cars
The Environmental Protection Agency will start auditing all cars for "defeat devices" designed to cheat on

emissions tests. The decision was spurred by Volkswagen diesel cars violating clean air laws in this fashion.
Dan Vergano

The U.S. Environmental Protection Agency told all major auto companies on Friday that it would now audit cars for emissions test "defeat devices," following revelations that Volkswagen diesel cars cheated on pollution standards.

The environmental agency announced last week that software in Volkswagen diesel cars – perhaps 11 million vehicles worldwide – was designed to turn off exhaust cleaning controls in engines except when the vehicle underwent emissions tests. With the controls off, the vehicle's exhaust contained up to 40 times more pollutants than allowed by law.

"Today we are putting vehicle makers on notice," EPA's Christopher Grundler said during a news conference. Unlike past emissions test, the details of how the agency, along with Canada's environmental agency, will test vehicles for emissions cheating would not be provided to car makers, he said. That will prevent them from writing software allowing cars to recognize when they are being tested and turn on emissions controls.

In the past, the agency had focused on heavy diesel trucks for such tests because of their significant emissions and history of defeat devices, Grundler said. But now all cars will face added inspection for emissions cheating.

Volkswagen's chief, Martin Winterkorn, resigned in light of the revelations on Wednesday. And claims that BMW cars might have similar emissions questions affected the company's stock on Thursday, leading to a 9.7% drop.

The nonprofit International Council on Clean Transportation (ICCT), which had helped alert EPA to the Volkswagen emissions cheating, said in a statement last week that "defeat devices" are a worldwide problem in cars. European studies, "repeatedly found large and growing gaps between real world emissions and the regulatory certification levels."

"This is a global problem that will require a coordinated global solution," said ICCT's Drew Kodjak.

From: Gong, Kristiene
Sent: Friday, September 25, 2015 11:46 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/25/2015

The New York Times:
http://www.nytimes.com/2015/09/26/business/epa-to-bolster-testing-because-of-volkswagen-scandal.html?_r=0

E.P.A. to Bolster Testing Because of Volkswagen Scandal
By THE NEW YORK TIMES SEPT. 25, 2015

Government regulators said Friday that they planned to step up the testing requirements of cars in the wake of the Volkswagen scandal.

The Environmental Protection Agency, which disclosed last week that it had learned that Volkswagen diesel cars had equipment to evade smog-testing standards, said it had sent a letter to manufacturers of gasoline and diesel cars saying that regulators would be looking for so-called defeat devices in all vehicles.

The agency said Volkswagen had used a device programmed to fool emissions testers into thinking that the car was emitting much less pollution than it was during regular driving.

"Manufacturers should expect that this additional testing may add time to the confirmatory test process," the E.P.A. wrote in its brief letter. The agency said that the new procedures would start immediately and that the California Environmental Protection Agency and Canada's environmental regulators were involved with the stricter requirements.

"We are not going to tell them what these tests are, and they don't need to know," Chris Grundler, director of the agency's office of transportation and air quality, said during a conference call with reporters.

Bloomberg:
http://www.bloomberg.com/news/articles/2015-09-25/u-s-epa-said-to-alter-diesel-emissions-tests-due-to-vw-cheating

U.S. EPA Toughens Emissions Oversight After VW Cheating
Jeff Plungis
September 25, 2015 — 8:42 AM EDT Updated on September 25, 2015 — 10:41 AM EDT

U.S. environmental regulators will add more spot-checks to cars already on the road following Volkswagen AG's admission that it fitted as many as 11 million diesel cars worldwide with software that rigged pollution tests.
"We are upping our game," said Christopher Grundler, director of the Environmental Protection Agency's Office of Transportation and Air Quality.

The U.S. Justice Department is conducting a criminal investigation of Volkswagen, and the company said it's cooperating with regulators. The admission has marred the reputation of the world's largest automaker and sent its shares to the lowest levels in years. Volkswagen's board is expected to name a successor Friday to former Chief Executive Officer Martin Winterkorn, who resigned this week.
The EPA is sending a letter Friday to automakers informing them that emissions monitoring is being enhanced. Grundler wouldn't say what changes the agency will make to the testing.

"They don't need to know," Grundler, speaking to reporters on a conference call, said of the automakers. "They need to know that we will be keeping their cars a little bit longer."
Grundler earlier told the Associated Press that the agency may add on-road testing. It already has on-road testing ability but it's only been used to check carmaker gas mileage estimates and diesel trucks, two situations in which they had uncovered emissions cheating in the past.

Past Cheating
The scandal now engulfing VW, which has admitted to outfitting cars with software designed to give false readings on emission tests, is unique both for the number of vehicles involved, and the digital complexity. But it's not the first emissions-cheating case, even for the Wolfsburg, Germany-based company.

In 1973, the EPA accused the automaker of installing defeat devices in cars it wanted to sell in the 1974 model year. VW then admitted it had sold 1973 model year cars with the devices, which consisted of temperature-sensing switches that cut out pollution controls at low temperatures.
General Motors Co. agreed in 1995 to pay $45 million after being accused of circumventing pollution controls on 470,000 Cadillac luxury sedans. The cars' 4.9-liter V-8 engines were tuned to turn off pollution controls when the air conditioning ran, the EPA said at the time.

The current VW case resembles a 1998 case involving seven manufacturers of heavy-duty truck engines: Caterpillar Inc., Cummins Inc., Detroit Diesel Corp., Mack Trucks Inc., Navistar International Transportation Corp., Renault Vehicules Industriels, S.A. and Volvo Truck Corp.
The companies agreed to spend more than $1 billion, including $83.4 million in penalties, to settle the case -- the biggest civil fine to that point for violating an environmental law.

The Hill:

http://thehill.com/policy/energy-environment/254935-epa-steps-up-emissions-testing-after-volkswagen-scandal

EPA steps up emissions testing after Volkswagen scandal
By Timothy Cama - 09/25/15 11:22 AM EDT
The Environmental Protection Agency (EPA) is stepping up its emissions testing for diesel cars in an attempt to root out companies that cheat the tests.

The agency, working with officials in California's air pollution agency and Canada, plans to test every model of diesel car on the road to see if other automakers programmed their cars to skirt the tests like Volkswagen Group did.

"We're putting vehicle manufacturers on notice that our testing is now going to include additional evaluation and tests designed to look for potential defeat devices," Chris Grundler, director of the EPA's transportation office, told reporters Friday.
"We aren't going to tell them what these tests are. They don't need to know," he said. "They only need to know we will be keeping their vehicles a little bit longer and we're going to be driving them a little bit more."

The new procedure comes a week after the EPA announced that Volkswagen had programmed many of its diesel cars sold since 2009 to figure out when they were undergoing EPA tests and change their pollution output to comply with the tests.

In real-world driving, the cars emit up to 40 times more nitrogen oxides than allowed under the Clean Air Act.

Officials with the different agencies hope that their tests can find any emissions problems that were not revealed in the testing that all new cars undergo, which is very standardized and does not usually involve on-road driving.

"We must continue to improve and adapt our oversight, and we will," said Janet McCabe, acting head of the EPA's air pollution office.

The emissions issue, to which Volkswagen has admitted, has quickly evolved into an international scandal, with government officials in Europe, Germany, the United Kingdom, France and elsewhere taking action.

Domestically, the Justice Department is conducting a criminal investigation, and a House committee will soon hold a hearing on the scandal.

Volkswagen's chief executive officer resigned this week, and the head of its United States operations is expected to resign as well.

The EPA initially identified less than 500,000 cars with Volkswagen and Audi branding affected. But the company later said the problem extended to 11 million cars worldwide, although the issue only applies to United States emissions standards.

The EPA has 23 devices for testing on-road driving emissions, but Grundler said those have usually been dedicated to heavy-duty truck use.

Grundler and McCabe repeatedly declined to outline the new test procedures, saying they do not want automakers to try to defeat them.

"The smart engineers at EPA, California Air Resources Board and Environment Canada have come up with clever ways to do this," Grundler said.

The announcement does not change the standard testing that applies to new vehicles. Instead, the EPA is using its authority to test cars currently in operation, including those from rental car fleets and individual consumers.

The new tests started Friday, Grundler said, declining to say how long it would take to test all diesel car models.

From: Gong, Kristiene
Sent: Friday, September 25, 2015 10:58 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/25/2015

AP (via Washington Times):
http://www.washingtontimes.com/news/2015/sep/25/epa-change-diesel-tests-thwart-volkswagen-cheating/?utm_source=RSS_Feed&utm_medium=RSS

EPA to change diesel tests to thwart Volkswagen-like cheating
By Tom Krisher and Matthew Daly - Associated Press - Friday, September 25, 2015

DETROIT (AP) — The U.S. Environmental Protection Agency plans sweeping changes to the way it tests for diesel emissions after getting duped by clandestine software in Volkswagen cars for seven years.

Chris Grundler, head of the EPA's office of transportation and air quality, indicated the agency would add on-road testing to its regimen. VW's sophisticated software allowed its cars to pass tests in the lab and then spew pollution into the atmosphere while on the highway.

The revelations meant unwanted scrutiny for the EPA. Its testing procedures have been criticized for being predictable and outdated, making it relatively easy for VW to cheat. What's more, the EPA did not initially uncover the problem; researchers at West Virginia University did, using on-road testing.

Grundler says the changes are designed to detect software and other methods automakers might use to rig a test.

The EPA and the California Air Resources Board have engineers who are "developing clever ways in which these things can be detected," Grundler says.

He also notes that testing of diesel engines, which make up only 1 percent of the vehicles on U.S. roads, wasn't the top priority for the EPA. The agency did have on-road testing equipment — but it was assigned to monitor automaker gas mileage estimates and heavy-duty diesel trucks, where cheating had been uncovered in the past.

Grundler, who has been with the EPA for more than three decades, says the lack of on-road testing for diesels "might change in the future." An announcement of the changes could come on Friday.

VW has admitted to installing software on Volkswagen and Audi cars with four-cylinder diesel engines that switches on pollution controls when they are being tested. When the software, called a "defeat device," determines that the cars are back on real roads, the controls are turned off. The EPA says about 500,000 U.S. cars including the Jetta, Golf, Beetle, Passat and Audi A3 have the cheating software, and VW says a total of 11 million cars have it worldwide.

VW was able to fool the EPA because the agency only tested the cars on treadmill-like devices called dynamometers and didn't use portable test equipment on real roads. The software in the cars' engine-control computers checked the speed, steering wheel position, air pressure and other factors to determine when dynamometer tests were under way. It then turned on pollution controls that reduced the output of nitrogen oxide, an ingredient in harmful ozone, the EPA has said.

VW started the scheme with the 2009 model year, and may not have been caught without testing performed at

West Virginia University on behalf of the International Council on Clean Transportation, a nonprofit group that advises governments on regulations. EPA and California regulators confronted VW with those findings to VW in May 2014. The automaker eventually did a recall late last year, without much improvement, the EPA says.

Only when the EPA and CARB refused to approve VW's 2016 diesel models for sale did the company admit what it had done.

The EPA announced the violations a week ago and said VW could face billions in fines. The agency said the cars are safe to drive but VW will have to pay to recall and fix them. The agency also is going to test diesels from other manufacturers to make sure they don't have similar devices.

Sen. Bill Nelson of Florida is frustrated that regulatory agencies such as the EPA are failing to protect the public. "Seven years is way too long a time that the EPA has been asleep at the switch," he says.

He says the VW case has similarities to those involving General Motors ' defective ignition switches and Takata Corp.'s exploding air bag inflators, where it also took years before those problems were disclosed to consumers.

"When there is this kind of deception, we've got to get these agencies to be able to cut through it and catch it," Nelson says.
It's not the first time the EPA has had to change testing to make sure automakers are playing by the rules. Earlier this year the agency updated gas mileage tests after some automakers were caught with inflated window sticker estimates.

Grundler disputes the notion that EPA would never have caught VW without the outside help. European regulators were looking into VW's on-road diesel emissions as far back as 2012, and since diesels make up half the cars there, the EPA decided to let Europe take the lead, he says.

"I don't think it's fair to say that this would never have been uncovered," he says. "Do I wish we had uncovered it sooner? Absolutely."

USA Today:
http://www.usatoday.com/story/money/cars/2015/09/25/epa-volkswagen-emissions-testing/72793818/

EPA to road-test cars after Volkswagen emissions scandal
Nathan Bomey, USA TODAY 10:40 a.m. EDT September 25, 2015
The change comes after Volkswagen fooled regulators into believing that its 4-cylinder diesel cars were compliant with emissions rules.

The Environmental Protection Agency told automakers on Friday that it will begin road tests of all new and used vehicle models to examine emissions claims following the exposure of Volkswagen's regulation cheating scandal.

The agency sent a letter to manufacturers notifying them that it will no longer rely exclusively on laboratory testing to validate emissions performance.

EPA also plans to begin testing all diesel models already on the road in the U.S. to check for similar violations.

"EPA may test or require testing on any vehicle at a designated location, using driving cycles and conditions that may reasonably be expected to be encountered in normal operation and use, for the purposes of investigating a potential defeat device," EPA told automakers in the letter.

The agency warned that the new process could mean it will take longer for automakers to secure certification required to sell new vehicles in the U.S.

"We aren't going to tell them what these tests are," said Christopher Grundler, director of the EPA Office of Transportation and Air Quality, in a conference call with reporters. "They don't need to know."

The change comes after Volkswagen fooled regulators into believing that its 4-cylinder diesel cars were compliant with emissions rules by installing sophisticated software to manipulate lab tests.

In reality, 11 million Volkswagen cars worldwide are emitting nitrogen oxides — which can exacerbate respiratory conditions such as asthma — at rates of up to 40 times acceptable U.S. standards.

The scandal has severely damaged Volkswagen's reputation, led to the resignation of the automaker's CEO and called into question the future of diesel cars. Several criminal investigations and numerous lawsuits have also followed.

The automaker set aside more than $7 billion to pay for fixes and fines. The episode is expected to trigger a massive recall.

Fortune:
http://fortune.com/2015/09/25/volkswagen-golf-emissions-epa/

The Volkswagen scandal has sparked a huge change in car emissions testing
by Benjamin Snyder @WriterSnyder SEPTEMBER 25, 2015, 10:39 AM EDT

Critics have wanted this move for years.

The U.S. Environmental Protection Agency will being testing vehicles' ability to meet emissions standards under real-world driving situations, it announced Friday. The agency formerly conducted random testing of vehicles in a way that critics have argued failed to simulate actual driving.

The change comes less than a week after German automaker Volkswagen admitted that 11 million of its diesel vehicles worldwide were loaded with software designed to trick the emissions testing process. About half a million of those vehicles were sold in the U.S.

EPA may test or require testing on any vehicle at a designated location, using driving cycles and conditions that may reasonably be expected to be encountered in normal operation and use, for the purposes of investigating a potential defeat device," reads a letter the EPA sent to automakers Friday, using an industry term for the illicit software found on Volkswagen's cars.

EPA officials said on a call with reporters Friday that the agency is "actively" testing diesel cars to ensure they meet emissions standards following the Volkswagen's revelations. Environmental agencies in the State of California and Canada are spearheading efforts to ensure there's a "broader and more robust presence" of testing, officials added.

The EPA also said it's working with Volkswagen to determine how to modify the affected vehicles already sold in the American market.

Volkswagen's stock price has tanked amid the scandal, which forced Volkswagen AG CEO Martin Winterkorn to resign Wednesday.

From: Gong, Kristiene
Sent: Friday, September 25, 2015 10:47 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/25/2015

WSJ:
http://www.wsj.com/articles/epa-to-overhaul-air-emissions-testing-in-wake-of-volkswagen-cheating-revelation-1443187913

EPA to Overhaul Air-Emissions Testing in Wake of Volkswagen Cheating Revelation
By AMY HARDER
Sept. 25, 2015 9:31 a.m. ET

WASHINGTON—The U.S. Environmental Protection Agency is overhauling the way it polices auto-maker compliance with air-emissions standards after Volkswagen cheated on its testing for seven years, an agency official said Friday.

The EPA is sending a letter to auto manufacturers to explain that it may test or require testing of vehicles in an environment that would resemble normal driving conditions, the official said.

The EPA's current protocol doesn't test under real-word driving conditions, and requires auto makers instead to submit design certificates for compliance. The EPA has conducted random testing, but those are done in a controlled environment. Volkswagen had installed software designed to evade those tests.

Since at least 2008, Volkswagen has been using software, dubbed defeat devices, in several light-duty diesel models around the world—nearly a half-million cars in the U.S. and as many as 11 million world-wide—that disabled air-emissions controls under normal driving conditions.

The EPA's announcement Friday caps a tumultuous week for Volkswagen, whose CEO resigned following the revelations, and for the U.S. government, which scrambled to respond to the German auto maker's cheating.

The Justice Department is pursuing a criminal investigation.

"We have to be concerned about whether or not there are other defeat devices out there that we have not been able to detect," EPA Administrator Gina McCarthy said at an event hosted by The Wall Street Journal this week. "This was particularly difficult for us to detect. We got there."

It wasn't immediately clear Friday how comprehensive the new testing in normal driving conditions would be. Some experts have been calling on the agency to conduct such testing.

"The most important change that could take place is if EPA started incorporating real-world testing throughout their compliance process," said Drew Kodjak, executive director of the International Council on Clean Transportation, a nonprofit research organization. The organization, alongside West Virginia University researchers, uncovered the testing anomalies in two Volkswagen model cars in 2014.

"The agency certainly has the authority to do this type of thing, but typically doesn't do them because, frankly, they're quite expensive," Mr. Kodjak said on Thursday.

In 2014, Mr. Kodjak's group and the university researchers conducted emissions testing, including under normal-driving conditions, that found two Volkswagen cars—a 2012 Jetta and 2013 Passat—had significantly higher nitrogen oxide emissions during normal driving conditions than what was certified with the EPA. Another car the researchers tested, a diesel-powered BMW, didn't have higher nitrogen oxide emissions.

Fortune:
http://fortune.com/2015/09/25/volkswagen-scandal-epa/

EPA to change diesel tests to prevent VW-like cheating
by Chris Matthews @crobmatthews SEPTEMBER 25, 2015, 7:50 AM EDT

Diesel 'wasn't the top priority for the EPA.'

The U.S. Environmental Protection Agency is planning wholesale reform of its procedure for testing diesel engines, following revelations that Volkswagen VLKPY -5.72% installed software in its cars that allowed it to fool regulators into thinking the vehicles were cleaner than they actually were, according to the Associated Press.

Chris Grundler, head of the EPA's office of transportation and air quality, told the news service that his agency would begin testing cars on the road in addition to the tests performed with cars on treadmills.

Grundler told the AP that cars with diesel engines, which make up only 1% of the vehicles on U.S. roads, "wasn't the top priority for the EPA."

"The agency did have on-road testing equipment — but it was assigned to monitor automaker gas mileage estimates and heavy-duty diesel trucks, where cheating had been uncovered in the past," the report said.

The EPA's testing procedures have been criticized for being predictable and outdated, the AP said, potentially making it easier forVW to cheat. And it was researchers at West Virginia University—not the EPA—that uncovered the problem using on-road testing, the AP added. An announcement of the changes could come on Friday.

Financial Times:
http://www.ft.com/intl/cms/s/0/d4feb2e2-628e-11e5-9846-de406ccb37f2.html#axzz3mgG3bZd2

Volkswagen board gathers to appoint replacement for Winterkorn
Chris Bryant in Frankfurt and Barney Jopson in Washington

Volkswagen's board are gathering to appoint a new chief executive to lead the troubled carmaker out of the worst scandal in its history, with Matthias Müller, head of Porsche, as the favourite candidate.
The supervisory board meeting at VW's Wolfsburg headquarters — which may take several hours — follows Martin Winterkorn's resignation after eight years at the helm of the group.

People close to VW indicated that Mr Müller is the frontrunner in the succession race.
He is close to the Porsche and Piech families, who together control a majority of VW's voting shares, knows Volkswagen inside out and has a reputation for speaking his mind. The company declined to comment.

The board is also expected to decide on Friday which managers must leave the company over the scandal, with attention focusing on high-level engineers and designers.

VW has been reeling since the US Environmental Protection Agency revealed last Friday that the group had rigged its diesel cars to pass emissions tests, potentially laying itself open to criminal charges and substantial fines.

The EPA said that VW had installed "defeat device" software that activated technology designed to reduce emissions from the vehicles only when it detected that they were being tested. The emissions then returned to much higher levels during regular driving.

The EPA said 482,000 vehicles sold in the US since 2008 were affected, but VW later raised that figure to 11m worldwide. It said it would take a €6.5bn charge to cover the costs of the crisis.

A senior official at the EPA told the Financial Times that Volkswagen had orchestrated an unprecedented effort to beat the EPA's rigorous testing regime. "The level of deceit the company went through to game the system was enormous," the official said.

The EPA operated a cutting-edge testing regime to police compliance with clean air regulations, the official said, and it took an "elaborate, aggressive, ongoing, co-ordinated effort" to beat it. "We've seen uses of defeat devices, but nothing to this scale," the official said.

From: Gong, Kristiene
Sent: Thursday, September 24, 2015 5:36 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/24/2015

Reuters:
http://www.reuters.com/article/2015/09/24/usa-volkswagen-deception-idUSL1N11U1OB20150924

INSIGHT-After year of stonewalling, VW stunned US regulators with confession
WASHINGTON/DETROIT SEPT 24 | BY TIMOTHY GARDNER, PAUL LIENERT AND DAVID MORGAN

The confession of cheating that's embroiled Volkswagen AG in one of the biggest scandals in auto industry history came on a cool California morning, on the sidelines of an academic conference focused on green transportation.

After more than a year of stonewalling investigators, Volkswagen stunned two senior officials with the U.S. Environmental Protective Agency and California's environmental watchdog by admitting the automaker hacked its own cars to deceive U.S. regulators about how much their diesel engines pollute.

That disclosure on Aug. 21, confirmed by two people with knowledge of the exchange, shows Volkswagen buckled to pressure from environmental regulators almost a month earlier than the scandal was made public. The admission to regulators came after a year during which VW officials insisted to regulators that tests on its diesel cars showing a spike in pollution levels on the road were in error.

U.S. officials exposed the deception on Sept. 18, triggering Volkswagen's admission that it had installed software in its cars to detect when they were being tested and alter settings to conceal the true emissions of 11 million cars sold worldwide. The delay between VW's confession and the U.S. exposure of the scandal occurred as regulators prepared their response to the disclosure.

As a result, Volkswagen, the world's largest automaker by sales, faces EPA fines that could reach $18 billion, class action and other lawsuits that could add billions of dollars more in liability and a U.S. criminal investigation. VW's leadership is in turmoil after chairman Martin Winterkorn was forced to resign and sources said other executives including the head of U.S operations were soon to follow.

Now, the story of how investigators unraveled systemic cheating in the face of consistent denials from the company may have implications for the sanctions VW will face and for an auto industry certain to face more scrutiny about its environmental claims. The company's lack of cooperation could figure into punitive action by the government.

At first, regulators were surprised that Volkswagen would make its confession at the conference, held in Pacific Grove, California. Minutes before Christopher Grundler, director of the EPA's transportation and air quality office, was to deliver a 9 a.m. speech to the conference, a Volkswagen representative told him about the deception. At the same meeting, representatives of the California Air Resources Board, a state agency that had been pushing VW hard, were also given a verbal notice of the deception, people with knowledge of the events said.

Volkswagen declined to comment on the sequence of events described to Reuters. It isn't clear who the VW representative was who delivered the news of the deception to Grundler and the CARB. Stuart Johnson, head

of VW's engineering and environmental office in the United States, was registered to attend the Aug. 21 conference, which was organized by the University of California, Davis. Johnson, who still works for VW in Auburn Hills, Michigan, did not respond immediately to a request for comment.

Norbert Krause, who was head of VW's U.S. environmental office until 2009 and who retired from VW in 2011, said nobody at Volkswagen of America was involved in the process of engineering the diesel cars.

"I don't know anything about the modification of the software," Krause said when reached by telephone in Germany. "The software was okay when we certified the vehicle and we made our durability runs. Everything was fine."

DECEPTION ACKNOWLEDGED

A formal acknowledgement of the deception came on Sept. 3, when the EPA and California officials held a conference call with Volkswagen executives in Germany and the U.S. During the call, the automaker went over written details provided to the participants explaining how software used in its diesel cars was able to manipulate emissions tests in the United States.

That admission came after the EPA threatened to withhold approval for the company's 2016 Volkswagen and Audi diesel models, according to a letter sent by the EPA to Johnson and VW's attorney. The letter detailed some of the timetable of the EPA's actions.

So ended 15 months of back-and-forth between Volkswagen and U.S. and California regulators who had come to suspect that the diesel engines were producing higher nitrogen oxide emissions during normal driving conditions than what was certified by the EPA and California, people involved said. Nitrogen oxide emissions have been linked to smog and acid rain.

Volkswagen had heavily marketed what it called "clean diesel" engines starting in 2008 with the 2009-model Jetta TDI. It appeared to have found a sweet spot between high-performance and fuel-efficiency with a zippy, fun-to-drive car that topped 40 miles per gallon in highway driving. Named "Green Car of the Year" at the Los Angeles auto show in 2008, the Jetta TDI was seen as a breakthrough in a country where diesel passenger cars occupy a tiny niche compared with Europe, where they are about half of the market.

GRANDFATHER'S DIESEL

"It's not your grandfather's diesel," Krause said in a September 2008 presentation to U.S. regulators, according to a video of the remarks.

Krause and other VW officials promised a diesel that would meet pollution laws in all states, including California where diesel engines had long been associated with smog and cancer-causing soot.

By that point, VW and other automakers had lobbied for almost a decade for regulators to give diesel another chance. In 2000, VW and other companies with an interest in promoting diesel, including Mazda, formed the Diesel Technology Forum to lobby for increased use in the United States as a way to reduce reliance on imported oil. In 2005, an energy bill signed by President George W. Bush offered tax credits for diesel buyers. That gave the first wave of diesel Jetta buyers an income tax credit of $1,300 each.

In 2009, after the new Jetta went on sale, VW dealers initially sold out, including in California where regulations had effectively shut the market to diesels earlier in the decade.

Around the same time, in Europe, regulators were skeptical. A European Commission study concluded in 2013 that European car makers were exploiting test loopholes. Separate findings by the EC's Joint Research Centre showed a discrepancy between test results and real world performance in European diesel engines.

California began its inquiry after EC regulators sought to obtain American data on the on-road emissions performance of diesel engines, said Stanley Young, CARB's communications director. The Europeans had a

working theory that diesels should run more cleanly in the United States, where regulations are stricter, than in Europe.

To produce that data, they commissioned the U.S.-based nonprofit International Council on Clean Transportation in February 2013, which hired researchers at a West Virginia University lab.

The WVU researchers placed emission-monitoring equipment on a rented 2012 Jetta and a 2013 Passat. Over seven weeks in spring 2013, they drove the cars around Los Angeles and up the West Coast to Seattle, comparing them to a BMW X5 sport-utility with a diesel engine, said Daniel Carder, who led the WVU team. While the BMW's emission results came in under what the vehicles produced in laboratory tests, those of the Jetta were 15 to 35 times higher than the legal limit and the Passat 10 to 20 times higher.

Soon after, the same rental cars tested by WVU were monitored in CARB's El Monte, California, test facility east of Los Angeles. There were no irregular emissions.

Over the next 12 months, the West Virginia University researchers analyzed the data. They presented their findings at a March 31, 2014, conference in San Diego partly sponsored by California regulators and the EPA.

EXECUTIVES ON ALERT

"That data put our executives on alert that there was clearly a problem for the U.S. and California," said Young, the CARB official.

At meetings between California officials and Volkswagen that began in the summer of 2014, engineers from the German carmaker tried to "discredit the findings" by challenging the data and methodology of the study, Young said. "They were recalcitrant," he said. "It was a range of issues. Every time it was something different."

Among other things, VW said that "our calibration was off" and that the discrepancies had to do with "the conditions under which the test was done," Young said.

On Dec. 2, Volkswagen shared the results of its own tests, blaming its increased emissions on "various technical issues and unexpected in-use conditions," according to the EPA. Then Volkswagen agreed to recall vehicles to fix their engine-control software.

Engineers at CARB kept testing and found the proposed software fix did not significantly reduce emissions. A break came when they looked at diagnostic data stored in the cars' own computer system.

"We discovered some very strange anomalies," Young said. "For instance, the car was running more cleanly when it was cold than when it was warm, which is the opposite of what every other car does - because once you warm a car up that's when it begins to deliver its best pollution controls. This was not the case. So clearly something else was going on. Over time we assembled enough proof and questions that they could no longer provide any reasonable explanation for what was going on."

On July 8, CARB shared its results with VW, but there was no change in Volkswagen's position. Some officials privately questioned whether Volkswagen was deliberately violating the federal Clean Air Act by installing defeat devices -- software programmed to switch engines to a cleaner mode during official emissions testing, according to a person involved in the process.

During normal driving, the software then shuts off, enabling cars to emit as much as 40 times the legal limit of pollutants.

In early August, Oliver Schmidt, who followed Krause and preceded Johnson in VW's U.S. engineering and environmental office, attended a conference in Traverse City, Michigan and told regulators Volkswagen stood by its conclusions that the problem was technical, said people involved said. Schmidt declined to speak to Reuters.

"I'm just amazed," said Alan Lloyd, who headed CARB from 1999 to 2004 and helped open California's market to diesels. "Why someone would think they could cheat in this way and get away with it is beyond me."

AP (via ABC News):
http://abcnews.go.com/Business/wireStory/volkswagen-scandal-tarnish-made-germany-image-34017356

Will Volkswagen Scandal Tarnish 'Made in Germany' Image?
By DAVID RISING, ASSOCIATED PRESS
BERLIN — Sep 24, 2015, 4:54 PM ET

The "Made in Germany" label has stood for precision and reliability for decades, but since Volkswagen admitted to cheating on U.S. car emissions tests, many are questioning whether the automaker's problems could taint the rest of the country.

It's the second serious blow to a major German company's reputation in six months, following the tragic crash of a Germanwings jet that killed 150 people. Parent company Lufthansa has faced questions over why it failed to identify the psychological issues suffered by the pilot who intentionally flew the plane into a French mountain.

Will such crises tarnish the hard-won, valuable reputations for quality of other German brands, such as BMW, Daimler or Bosch?

Experts say VW's problems could hurt the economy in the short term due to the company's sheer size, but that long-term damage to the country is unlikely.

That doesn't mean others won't try to capitalize. Companies will try to grab market share. And across Europe, people in countries that have been lectured by Germany for years about the virtues of financial honesty could be feeling smug.

"Not only does this make Germany look bad, I think that Germany has been very good at moralizing to the rest of Europe about the financial crisis and other things," said Michael Hewson, chief market analyst for CMC Markets in London.

"Germans have a word for it — 'schadenfreude' — and Germany's getting a big dose of it now," he said, referring to the German word for taking pleasure at the misfortune of others.

Indeed, Internet memes of VWs covered in clouds of smog were already making the rounds, and media commentators were quick to pounce on the issue.

"In Europe, there is a strong dose of schadenfreude ... after the Germans, and primarily Chancellor Angela Merkel, have for years been giving lectures others," wrote Thilo Schaefer for Spain's La Marea news magazine.

Still, in Lufthansa's case, the airline has not appeared to suffer any serious damage following the March crash.

Volkswagen's case could prove more costly for the company, though by how much is still unclear. CEO Martin Winterkorn resigned Wednesday and the company is expected to name a replacement Friday.

The EPA accused VW of installing the so-called "defeat device" in 482,000 cars sold in the U.S. VW later acknowledged that similar software exists in 11 million diesel cars worldwide and set aside 6.5 billion euros ($7.3 billion) to cover the costs of the scandal.

It still faces possible criminal investigations and maybe as much as $18 billion in U.S. fines. The final cost could also depend on a host of class action lawsuits being filed by consumers who feel duped.

This is by no means the first time in recent years that a major German company's reputation for probity has taken a huge knock — though perhaps the first time that the damage has stemmed directly from a product that was popular with consumers.

Volkswagen itself was at the center of an unappetizing scandal less than a decade ago — before Winterkorn took over — that resulted in criminal convictions for the company's then-personnel chief and employee council chief, among others. That case centered on allegations that VW's influential employee representatives received illegal privileges, including lavish foreign trips involving prostitutes paid for by the company. The probe started after Volkswagen alerted prosecutors to possible wrongdoing.

Industrial conglomerate Siemens AG acknowledged dubious payments of up to 1.3 billion euros in a bribery case that came to light in 2007 and prompted the departure of the company's then-CEO and board chairman.

The company's biggest bank, Deutsche Bank, has also struggled to put behind it lawsuits and legal issues that in some cases date back years.

In April, Deutsche Bank agreed to pay $2.5 billion to authorities in the U.S. and Britain to settle allegations its traders rigged important market interest-rate benchmarks used to determine rates on a variety of debt.

Hartmut Dziemballa, who conducts image research for Germany's GfK institute with a focus on the automotive and airline sectors, said past scandals have not had lingering effects and that he didn't expect the Volkswagen scandal would significantly affect other German manufacturers — even car companies.

"The quality and the German engineering is still there, and people know that," he said.

Still, if a scandal with any brand has the potential to smear the whole "Made in Germany" label, it's Volkswagen, which is deeply interconnected with the country's people and politics.

Germany is the world's third largest exporter, vehicles are its largest export, and Volkswagen is its largest automaker. It employs over half a million people globally.

It's the largest single employer in its home state of Lower Saxony, which owns 20 percent of the company and whose governor and economy minister sit on its board of directors. VW's former personnel director Peter Hartz was also an adviser of former Chancellor Gerhard Schroeder, and today's welfare system is still called "Hartz IV" after his reforms.

Carsten Brzeski, an analyst with ING in Frankfurt, said while "the reputational damage is currently impossible to assess," because of its size even if the main impact of the scandal is limited to Volkswagen it could have serious economic effects on the German economy overall.

"While the German economy defied Greece, the euro crisis and the Chinese slowdown, it could now be facing the biggest downside risk in a long while," he said in a research note.

Analysts say there is the possibility that the fallout from the scandal might affect other car companies, whether through the need for tougher regulation or a shift away from the diesel engines at the center of the U.S. scandal.

Vice Chancellor Sigmar Gabriel told reporters at the auto show in Frankfurt after the news broke that the VW scandal would mean nothing to the "Made in Germany" label — before adding "I hope."

From: Gong, Kristiene
Sent: Thursday, September 24, 2015 4:18 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne

Subject: RE: Volkswagen Clips 9/24/2015

AP (via Lansing State Journal):
http://www.lansingstatejournal.com/story/news/local/2015/09/24/dealers-owners-frustrated-vw-scandal/72750326/

Dealers, owners frustrated over VW scandal
Associated Press 3:21 p.m. EDT September 24, 2015

LOS ANGELES — Bob Rand bought his Volkswagen Passat last year for its clean emissions and high gas mileage. He liked the car so much he convinced his son and a friend to buy one, too.

Now, as Volkswagen comes clean about rigging diesel emissions to pass U.S. tests, Rand is desperately trying to sell the fully loaded model with white leather seats for $10,000 below what he paid. His sole bite has been from a man who offered $7,500 on speculation that he could resell it in Mexico.

"Volkswagen was somebody that you could rely on for cutting-edge products and quality and all those things and now you find out that they're not above lying just flat out," said Rand, who plans to join a class-action lawsuit against VW. "That's probably about as bad a thing as a company can do is lie to your face when you're buying a $35,000 car."

Rand's anger at the world's top-selling car company was echoed Wednesday by private dealers, auto wholesalers and owners across the U.S. as fallout from the smog test trickery mounted.

The EPA first disclosed Friday that stealth software makes VW's 2009-2015 model cars powered by 2.0-liter diesel engines run cleaner during emissions tests than in actual driving. On Wednesday, Volkswagen CEO Martin Winterkorn resigned and took responsibility for the "irregularities" found by U.S. inspectors — a scandal that has wiped out billions in the company's market value and raised the possibility of criminal investigations and billions more in fines.

The revelations left dealers sitting on hundreds of diesel cars they could not sell. Many also dealt with a flood of angry calls, emails and tweets from Volkswagen owners who felt betrayed because they believed they had bought a car that polluted less without sacrificing the good gas mileage and performance that comes with a diesel engine.

"I think their feet should be held to the fire. I think apologies don't mean anything when something is so premeditated," said Joe DeCarolis, of Cary, North Carolina, who owns a 2012 TDI Jetta Sport Wagon — a car he bought after careful comparison shopping for its clean emissions and good gas mileage.

Jon Vitale of Fowlerville, Michigan, listed his 2012 Volkswagen Passat for sale on the Internet last month, barely getting any interested callers.

But after finding out about the scandal, he's thinking the news might actually make it easier to sell his car.

"I don't know if the news will help me or hurt me," said Vitale, who bought the car used two years ago for its gas mileage. "I didn't get much interest before the news came out. If someone wants it, maybe they'll pay more because there's a stop sale on the new models."

Dealers can't give customers good answers because Volkswagen hasn't said a whole lot, said AutoNation CEO Mike Jackson, the leader of the largest auto dealership chain in the U.S.

AutoNation's six Volkswagen and eight Audi dealerships in the U.S. are telling customers that the cars are safe to drive and promising to call them as soon as they know more about repairs. "That's not adequate," Jackson said. "We need answers by next week."

A lot of people within VW had to know about the software that turned emissions controls on during

government tests and off for regular driving, especially because the scheme went on for multiple years, Jackson said.

"This tells me that it's not a bad apple. It's not a rogue employee. It's deliberate deception," Jackson said. "It's a systemic failure. This took a lot of meetings. This took a lot of engineers. This took a lot of software programmers to put in place and keep in place."

Meanwhile, concern was growing at private dealerships about what to do with inventory that's now gathering dust.

At Volkswagen of Oakland, California, nearly two dozen new diesel cars have no chance of being sold in the short-term, while 25 2016 model vehicles are being held up at the Port of San Diego because they can't pass emissions standards, sales manager Chris Murphy said. Customers have been calling and emailing to demand the dealership buy their cars back or offer refunds.

"We can't afford to buy all those cars back. We're just one dealer," he said, adding that diesel models make up about 30 percent of the business. "This is definitely going to impact our business. We're trying to focus on positive, not negative things because there's nothing we can do."

Williams Volkswagen in Lansing declined to comment on how the company's actions affected its sales. It's the only Volkswagen dealer in the region.

Vitale thinks used models may become more valuable to some people who aren't as environmentally conscious, particularly because Michigan doesn't require emissions testing.

"I got a call a few days ago and the guy asked me about the news, and despite all that, he still wanted it," said Vitale, who is selling the car because he no longer needs it. "It's not illegal to drive in Michigan because there's no emissions testing here."

Volkswagen has taken steps to help out the dealership, Murphy said. That includes guaranteeing reimbursement for sales objectives for two quarters whether or not the goals are met and waiving the interest the local franchise normally pays on unsold cars on their sales floor, he said.

"They're making all the right steps. … I'm just waiting for everything to get uncovered to see how deep this really goes. I'm not mad at anyone except the people higher up who made these decisions," Murphy said.

Lash Volkswagen of White Plains, N.Y., has been scrambling to accommodate affected Volkswagen owners by giving them loaner cars and picking up or dropping off their cars when it's time for repair, said Tom Backer, general manager of the dealership in New York's Westchester County.

Dealers, he said, were told that there will be both software and hardware changes to fix the problem. They're already on 2016 models and are awaiting approval from the Environmental Protection Agency, Backer said. Older models will get the same fixes, he said.

But not every Volkswagen dealer is fielding calls from angry customers.

Bill Haggerty, a sales manager at a VW dealership in the Chicago suburb of Oak Lawn, Illinois, said he hasn't heard concerns from customers so far. Diesels make up less than 20 percent of his business and draw the most interest from customers looking for better gas mileage, he said.

"We have 200 Volkswagens in stock; three of them are Jetta diesels," he said. "So, it's not like every Volkswagen out there has got a diesel motor in it. They sell an awful lot of cars with good gas mileage and great safety records."

International Business Times:

http://www.ibtimes.com/volkswagen-diesel-scandal-epa-partly-blame-2112674

Volkswagen Diesel Scandal: Is The EPA Partly To Blame?

By Cole Stangler @colestangler c.stangler@ibtimes.com<mailto:c.stangler@ibtimes.com> on September 24 2015 2:10 PM EDT

Are emissions tests too easy? A Volkswagen car is pictured at a technical and testing center in Zenica, Bosnia and Herzegovina, Sept. 23, 2015. Reuters/Dado Ruvic

Since Volkswagen admitted this week to cheating on pollution tests for years, there has been a flood of outrage. Overwhelmingly, it is directed at the most obvious culprit: the German automaker, which admitted to equipping 11 million of its diesel cars worldwide with software specifically designed to reduce emissions during tests. But some critics argue Volkswagen is not the only one to blame. Are the regulators at fault, too?

"Automakers have been able to exploit lax testing systems in the U.S. and Europe," declared a Bloomberg editorial this week. "Regulators owe it to both car buyers and the environment to make these systems more rigorous."

In the United States, critics say, the Environmental Protection Agency isn't as strong a watchdog as it should be. The editorial board at Bloomberg says the EPA gives automakers like Volkswagen too much latitude in determining testing conditions. The agency doesn't have engineers on hand at the labs that actually conduct the exams, doesn't vary its testing routines enough and should have done more to detect the sneaky software gambit that will likely lead to the recall of some 500,000 cars in the U.S.

The EPA did not respond to requests for comment.

Volkswagen's deception may be particularly widespread and therefore more egregious. But it's not the first company to cheat American emissions standards. Hyundai and Kia acknowledged they overstated fuel economy standards on 1.2 million cars from 2010 to 2012. Last November, the companies agreed to a combined $300 million settlement with the Justice Department and the EPA for doing so.

Still, Tyson Slocum, director of the energy program at consumer advocacy group Public Citizen, said it's unfair "to claim the EPA is responsible for a very sophisticated deception."

Emissions tests in the United States consist of the following: Automakers put their cars on rollers at various testing sites and run them through a set of federally approved maneuvers. Volkswagen duped the system by writing code into its diesel cars' software that automatically switched them into a sort of "low-emissions mode" during these moves.

Even with a beefed-up team of monitors on hand at testing sites, Slocum said, Volkswagen's trick "would have been very hard to catch." "Stopping a determined criminal is tough," he said, and "at the end of the day, you've got to hold the primary entity accountable."

At the same time, Slocum said, those complaining about the agency's oversight methods or regulatory capabilities should turn to federal legislators.

"Congress is to blame for the EPA's light touch," he said. He scoffed at the "Chicken Little" attacks from federal lawmakers and industry alike that frequently deride the agency as a jobs killer. Since 2010, the agency has seen its budget decline by 20 percent, or about $2 billion. (Earlier this month, before the emissions scandal broke, 20 members of Congress filed articles of impeachment against Gina McCarthy, head of the EPA.)

Europe's testing system, on the other hand, is widely seen as more hands-off than the United States'. Automakers there comply with the New European Driving Cycle, a test that got its last major revision in the 1990s. It takes less time to complete than its American counterpart and doesn't properly simulate real-world conditions, critics contend, and therefore is easier to game. A recent report from the U.K. Committee on Climate Change found the gap between official and real-world emissions of new passenger cars rose from 10 to 35 percent between 2002 and 2014.

Officials from the European Environment Agency did not respond to requests for comment.

Bill Becker is the executive director of the National Association of Clean Air Agencies, a group that represents state and local pollution control agencies. He said "the EPA certainly has a role but they don't deserve a severe whipping about what happened."

Those concerned with preventing similar conspiracies in the future should look toward the judicial system, which has the ability to set a strong deterrent effect, he said. Penalties wield far more influence over automaker behavior than any changes to emissions testing procedures.

"The solution here is for the courts and the Justice Department to impose as severe a penalty as possible," he said, "to penalize so harshly that no other employer would ever consider this again."

From: Gong, Kristiene
Sent: Thursday, September 24, 2015 2:48 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/24/2015

AP (via Washington Post):
https://www.washingtonpost.com/world/europe/board-member-expects-further-resignations-at-volkswagen/2015/09/24/f5ef9382-628d-11e5-8475-781cc9851652_story.html

Germany: VW cars with suspect software in Europe too
By Geir Moulson | AP September 24 at 12:19 PM

BERLIN — The software at the center of Volkswagen's emissions scandal in the U.S. was built into the automaker's cars in Europe as well, Germany said Thursday, though it isn't yet clear if it helped cheat tests as it did in the U.S.

A day after longtime CEO Martin Winterkorn resigned over the scandal, a member of Volkswagen's supervisory board said he expects more executives to step down. The company's supervisory board meets Friday and could announce new resignations then as well as a new CEO.

The U.S. Environmental Protection Agency disclosed Friday that stealth software makes VW's 2009-2015 model cars powered by 2.0-liter diesel engines run cleaner during emissions tests than in actual driving.

The EPA accused VW of installing the so-called "defeat device" in 482,000 cars sold in the United States. VW later acknowledged that similar software exists in 11 million diesel cars worldwide and set aside 6.5 billion euros ($7.2 billion) to cover the costs of the scandal.

The company has told officials that the vehicles in question included VW cars with 1.6-liter and 2-liter diesel engines in Europe, German Transport Minister Alexander Dobrindt said Thursday.

"We don't yet have figures for how many of these 11 million cars that are apparently affected are in Europe," Dobrindt said. "That will be cleared up in the next few days."

Authorities will continue working with Volkswagen to determine what cars exactly are involved.

It isn't yet clear to what extent the scandal affects other brands in the Volkswagen Group, which has 12 brands in all — including Seat, Audi, Skoda and Porsche. It was also not clear whether the software would have led to VW cheating on emissions tests outside the U.S. as well.

Dobrindt this week set up a commission of inquiry to look into the scandal. The motor transport authority is conducting static and road tests on Volkswagen models and spot tests on cars made by other manufacturers, German and foreign.

In neighboring France, Environment Minister Segolene Royal on Thursday announced random tests of about 100 French cars to ensure that their engines meet pollution standards in the wake of Volkswagen's emissions scandal.

And the European Union's executive Commission called on national authorities "to look into the implications for vehicles sold in Europe and ensure that EU pollutant emission standards are scrupulously respected."

Olaf Lies, economy and transport minister of VW's home state Lower Saxony, which holds a 20 percent stake in the company, said the investigation into the scandal was only just starting.

"There must be people responsible for allowing the manipulation of emission levels to happen," he told rbb-Inforadio.

Winterkorn said Wednesday he took responsibility for the "irregularities" found by U.S. inspectors in VW's diesel engines, but insisted he had personally done nothing wrong.

VW is filing a criminal complaint with German prosecutors, seeking to identify those responsible for any illegal actions in connection with the scandal.

Other auto companies have seen their shares drop, too, though there have been no allegations they cheated emissions tests.

On Thursday, shares in BMW dropped 5.2 percent to close at 75.68 euros after Germany's Auto Bild magazine reported that road tests by the International Council on Clean Transportation showed the BMW X3 xdrive model exceeding European emissions limits by more than 11 times. It did not say what the cause for the alleged problem was.

BMW said in a statement that it was not familiar with the test and would ask the ICCT for clarification. It said that "the BMW Group does not manipulate or rig any emissions tests."

Reuters:
http://uk.reuters.com/article/2015/09/24/uk-usa-volkswagen-letters-exclusive-idUKKCN0RO0AY20150924

Exclusive - VW recall letters in April warned of an emissions glitch
SAN FRANCISCO | BY ALEXANDRIA SAGE

In April of 2015, Volkswagen of America, Inc.(VOWG_p.DE) sent letters to California owners of diesel-powered Audis and Volkswagens informing them of an "emissions service action" affecting the vehicles.

Owners were told they would need to take their cars to a dealer for new software to ensure tailpipe emissions were "optimised and operating efficiently."

The company didn't explain that it was taking the action in hopes of satisfying government regulators, who were growing increasingly sceptical about the reason for discrepancies between laboratory emissions test results and real world pollution from Volkswagen's diesel cars.

Officials at the California Air Resources Board and the EPA agreed in December of 2014 to allow a voluntary recall of the company's diesel cars to fix what Volkswagen insisted was a technical – and easily solved - glitch. The recall was rolled out nationally over a period of months.

On Wednesday, California Air Resources Board spokesman Dave Clegern confirmed that the letters were part

of that recall. “This is one of the fixes they presented to us as a potential solution. It didn’t work,” he said.

Volkswagen, which had no obligation at the time it initiated the recall to disclose the discussions that had led to it, declined to comment on the letter.

The controversy came to public attention last week after Volkswagen acknowledged it had deliberately deceived officials about how much its diesel cars polluted.

The recall letter instructed owners of certain 2010-2014 Volkswagen vehicles with 2-liter diesel engines to contact dealers for a software update in order to fix an issue with the malfunction indicator light illuminating.

“If the [light] illuminates for any reason, your vehicle will not pass an IM emissions inspection in some regions,” the letter warned, noting that California required the update before it would renew vehicle registrations.

"The vehicle's engine management software has been improved to assure your vehicle's tailpipe emissions are optimised and operating efficiently," read the letter, which said an earlier software update increased the likelihood of the light illuminating.

It is customary for carmakers to perform updates to their cars through dealerships to fix or update software.

Volkswagen has said that 11 million of its cars around the world could be affected in the scandal that broke last week. The German company has set aside 6.5 billion euros ($7.3 billion) in its third-quarter accounts to help cover the costs of any fallout.

The U.S. Justice Department has launched a criminal probe and at least 25 proposed class actions on behalf of consumers have already been filed in seven states.

WSJ:
http://www.wsj.com/articles/vws-customers-feel-confusion-remorse-1443051169

VW’s Customers Feel Confusion, Remorse
Auto owners worry how emissions scandal will affect vehicles’ performance, resale value and compliance with clean-air standards
By CHRISTINA ROGERS in Detroit and ERIC SYLVERS in Milan

Deborah Scott went shopping for a new car in 2010 and came back home with a diesel station wagon made by Volkswagen AG. Fuel efficiency, low emissions and a peppy engine won her heart.

Now, she finds herself suffering from a case of buyer’s remorse. “I feel very confused,” said the 61-year-old retired nurse practitioner from Chattanooga, Tenn.

Less than a week ago, the Environmental Protection Agency said the German maker of her car lied about its diesel-emissions performance and is demanding a fix on nearly 500,000 affected vehicles on U.S. roads. That leaves owners, such as Ms. Scott, wondering how that will affect performance, resale value and compliance with clean-air standards.

“I feel like I’m eventually not going to have the car that I initially agreed to buy,” said Eric Schoenecker, a Minnesota owner of a 2013 diesel Jetta. A recent visit to Craigslist.com indicated resale value on cars like his have fallen 20% since the emissions scandal emerged. The EPA says affected Volkswagens emit nitrogen oxides at up to 40 times the standard.

Volkswagen’s emissions headache has gone global, with the auto maker now saying 10.5 million additional vehicles could be affected outside the U.S. On Wednesday, the company’s chief executive resigned amid a sharp decline in market value and many investigations initiated in various countries.

Buyers, however, are primarily interested in answers that aren't immediately forthcoming.

"All we've received so far are talking points from VW emphasizing that we tell customers this is not a safety issue," Mike Jackson, chief executive of No. 1 car dealer chain AutoNation Inc., said. "They tell us they will get back to us on how they will bring cars into compliance."

Volkswagen representatives said the company is investigating the matter and will be in touch with dealers and buyers as soon as possible.

Dealers say traffic in Volkswagen showrooms is drying up in the U.S., deepening the pressure the auto maker has experienced in recent years as market share has fallen. "As this story matures, we expect it to have more of an impact on sales," said one dealer, choosing to remain anonymous.

Volkswagen has 650 dealers in the U.S., and sold 238,000 vehicles through August—a 2.8% decline from the same period in 2014 and far below other major auto makers selling cars in America. About 20% of those deliveries are diesel.

At some point, those dealers will need to employ a fix, according to EPA guidelines. Volkswagen, setting aside $7 billion for the crisis, will have to pay for repairs. Meanwhile, cars are likely to pass emissions standards because they are fitted with a device that enables cheating on emissions tests, the EPA said.

Anna Stefanopoulou, a mechanical-engineering professor and engine expert at the University of Michigan, said a permanent fix could be as simple as downloading new software for the car. Or, Volkswagen could be looking at a cost of $2,000 a vehicle if new hardware needs to be installed.

Fuel economy, rated at more than 40 miles a gallon for some diesel models sold by VW, will take a hit. Consumption could rise 5% to 7% at high speeds or other driving conditions because components needed to clean emissions can dent engine performance.

Some doubt the solution will be simple.

"A software fix in the U.S. seems very unlikely because the emissions are so much higher than is allowed," Paolo Martino, a Frost & Sullivan consultant, said. Any adjustment would probably so radically "change the performance of the cars that consumers would no longer want to own them.

Wired:
http://www.wired.com/2015/09/vw-going-pay-smog-scandal-much/

Eric Niiler

VOLKSWAGEN ISN'T GOING to get away with this. You don't (allegedly!) fake emissions data for a few million cars and just walk away. But what the German automaker's punishment will be, and how much it's going to hurt—those are still open questions.

The final decision will be up to lawyers at the US Environmental Protection Agency and Department of Justice. That latter agency has opened a criminal probe into the company's (alleged!) emissions software tampering shenanigans. But based on precedent and the outlines of what Volkswagen actually seems to have done, we can make a few predictions.

If US officials absolutely throw the book at VW, EPA rules stipulate a maximum fine of $37,000 per affected car. At 482,000 cars on American roads, that comes to $18 billion. But according to attorneys who work on these kind of cases, that number is way too high for what'll actually happen. The biggest fine of this kind to date was $1.2 billion, a criminal penalty that Toyota paid in 2014 for concealing information about faulty ignition switches that triggered sudden accelerations.

But that was for a mechanical breakdown. For a closer analogy we could look back to 1998, when seven truck manufacturers including Caterpillar and Mack together paid $1 billion for installing defeat devices—sounds familiar—in tractor trailer and pickup trucks. A year before, Ford paid a relatively paltry $7.8 million to settle allegations the company violated the Clean Air Act by yes, installing defeat devices—this time in Econoline vans. But the company also paid $2.5 million in emissions offsets and $1 million to study new technology that fought emissions. So it's possible VW might have to pony up for regulatory violations as well as smog offsets for what they actually emitted.

As a matter of process, regulators will want a fine that's big enough to work not only as punishment for VW but as a deterrent to anyone else who might think about trying something similar. It can't just be the cost of doing business. "There aren't a lot of examples of this kind of conduct," said one private attorney who has handled pollution settlements between major companies and the government. "There are a fair number for failure to disclose, or even covering it up. But to actually plan a violation? That's pretty extraordinary. This will be the highest penalty EPA ever assesses."

Yeah, but how high? To figure that out, EPA lawyers have a lot to consider. Specifically, EPA will want to know what kind of economic benefit VW got from rigging emissions controls. The company claimed greater engine power, performance, and gas mileage, and charged more for the engine than a gasoline engine in a comparable vehicle. VW also got a marketing benefit, donning a green mantle by touting its "clean diesel" technology.

On the other hand, EPA regulators will also factor in what VW does to fix the problem. The company said Tuesday it was setting aside more than $7 billion for repairs. EPA might build that consideration into its calculations and lower the fine accordingly.

That's all on the civil, regulatory side. DOJ's criminal probe could lead to prosecutions of the executives in Germany who approved the so-called "defeat device." Like the bumper sticker says, a fine is a tax for doing wrong. Prison time, though? That's a whole other kind of serious.

But if you believe Gilbert and Sullivan and think the punishment should fit the crime, than what was this (alleged!) crime's actual shape? Yes, VW diesel-powered Jettas, Passats, Golfs, and Beetles (and an Audi) polluted more during real-world driving than their annual smog tests said they would. But how much more? Tests performed by the International Council on Clean Transportation in 2013 revealed that the VW cars emitted anywhere from 5 to 35 times more nitrogen oxide pollution than allowed by law. So with the help of some air pollution experts, let's do a little back-of-the-envelope figuring. Making it easy on ourselves, we'll use a midpoint of a 20X increase in emissions. Assuming 482,000 cars in the United States with, oh, say, a 120,000-mile lifetime of a diesel engine, VW's US fleet produced 46,657 more tons of harmful, smog-forming NOx pollution than anyone knew.

Now, cars in California alone emitted 161,000 tons of NOx in 2011, according to EPA. (California has a lot of cars.) But still—that's a lot more smog than anyone planned for.

Vox:
http://www.vox.com/2015/9/23/9383641/volkswagen-scandal-pollution

How many deaths did Volkswagen's pollution scandal cause?
A back-of-the-envelope estimate.
Updated by Brad Plumer on September 24, 2015, 8:58 a.m. ET @bradplumer
brad@vox.com<mailto:brad@vox.com>

This week, Volkswagen admitted that it had secretly rigged as many as 11 million diesel cars worldwide so that their pollution controls only worked when they were being tested by regulators. The rest of the time, while the cars were actually being driven, they emitted smog-forming nitrogen oxides at 15 to 35 times higher than the US legal limit.

So how much extra pollution is Volkswagen's deception responsible for? And, since we know air pollution is already harmful, how many additional deaths might those extra emissions cause? What follows is a very rough, back-of-the-envelope estimate based on what we know so far. (Spoiler: the premature death numbers range from single digits to hundreds per year. Like I said, rough.)

1) How much extra pollution do Volkswagen's cars cause? By my calculations, Volkswagen's 482,000 deceitful US cars are currently adding between 5,800 to 14,200 additional tons of nitrogen oxide pollution (NOx) to the atmosphere per year, assuming the cars are driven the US average.*

Extrapolating that out to 11 million cars around the world, and assuming the rest of the cars are driven the European average, we get somewhere between 86,800 and 212,500 additional tons of NOx emissions per year.**

Now, there are lots of assumptions and simplifications embedded in those estimates, particularly around how many miles VW's cars are actually driven. But that's ... potentially a large amount of extra NOx pollution. At the high end globally, it's 20 times what a typical coal plant without emission controls puts out in a year.

2) How many deaths might that extra pollution cause? We know NOx pollution is harmful — current emissions from all the world's cars, trucks, factories, and power plants already cause various health ailments and contribute to thousands of deaths each year. What we're interested in is the additional toll caused by Volkswagen's illegal pollution.

This is a bit trickier to calculate. Certain types of nitrogen oxides are harmful both both because they can irritate the lungs and because they can help form damaging particulate pollution and smog. Higher smog levels have been linked to respiratory illnesses, increased asthma attacks, and even premature deaths (especially among the sick or elderly). The complicated part is that the exact levels of smog formation can vary from place to place, depending on sunlight, temperature, local winds, and other factors. What's more, the exact harm can depend on where the pollution occurs, how dense the area is, and so on.

Still, we can get ballpark figures using data from the Environmental Protection Agency, which calculates that every ton of NOx from vehicles in the United States leads to somewhere between 0.00085 and 0.0019 premature deaths. (Note that this only includes impacts from particulate formation, not smog effects, which are harder to quantify. See p. 40 of this report.)

Using these figures, the estimated extra pollution from Volkswagen's US cars can be expected to lead to an additional 5 to 27 premature deaths per year. If we extrapolated worldwide to all 11 million vehicles, that would come to somewhere between 74 and 404 premature deaths each year.***

Again, this is a back-of-the-envelope exercise, not a peer-reviewed scientific analysis. Criticisms and refinements are welcome. But the broader point is that air pollution can cause genuine harm, up to and including killing people. The United States and Europe have been trying to limit that health damage over the last 50 years by putting pollution limits in place. And, by evading those limits, Volkswagen's actions had real consequences.

(As counterpoint, Volkswagen's cheating might have been mildly helpful for global warming efforts. The company appears to have rigged the cars so that they would get slightly better fuel economy. And NOx emissions can have an indirect cooling effect. That said, this effect is likely to be smaller in the grand scheme of things. And this really isn't the way to go about solving climate change...)

Footnotes and updates:

* Here's how I estimate US pollution: the current Tier2-Bin5 lifetime standard for NOx emissions in the United States is 0.07 grams per mile driven. Testing by the ICCT has said Volkswagen's 482,000 clean diesel cars in the United States were emitting NOx at 15 to 35 times that standard, depending on how they were driven. And the average US car is driven 11,244 miles in a year. So multiply those numbers together, subtract

out the "legal" pollution, convert to tons, and you get your range of additional pollution caused by VW's cars.

(Note that this estimate is for the current year. VW's cars were obviously sold in stages, so the pollution impact is smaller the further you go back in time.)

** For the global figures, I'm assuming the pollution controls in the remaining 10.5 million Volkswagen diesel cars with a Type EA 189 engine worked the same way and produced similar levels of additional pollution. I've updated this section by also assuming the rest of the cars were driven the European average of around 7,170 miles per year (since most of them were likely in Europe). That lowered the global pollution estimates from an earlier version.

*** This global estimate of health impacts might well be low, since a simple extrapolation from US data isn't ideal. The World Health Organization's research suggests that NOx pollution can have even higher mortality effects in some parts of Europe (due to higher population density), but we'd really have to know where the rest of Volkswagen's 11 million problematic diesel cars are being driven to get any more precise.

From: Gong, Kristiene
Sent: Thursday, September 24, 2015 2:19 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/24/2015

Bloomberg:
http://www.bloombergview.com/articles/2015-09-23/volkswagen-and-the-epa-s-dirty-little-secret

Volkswagen and the EPA's Dirty Little Secret
87 SEPT 23, 2015 3:50 PM EDT
By Editorial Board

Cheating reflects badly, first and foremost, on the cheater -- and so it is with Volkswagen, whose shocking manipulation of U.S. emissions tests continues to exact a price in market value, legal costs and reputation. At the same time, it's not unreasonable to ask how the cheating happened in the first place, and that question implicates more than just Volkswagen.

For years, automakers have been able to exploit lax testing systems in the U.S. and Europe. Regulators owe it to both car buyers and the environment to make these systems more rigorous.

As things work now in the U.S., carmakers test their own vehicles and send the results to the Environmental Protection Agency, whose engineers review them and, usually, apply a rubber stamp. The EPA allows manufacturers broad latitude in determining test conditions, an invitation to hanky-panky. The agency does some independent, random testing -- but on just 10 percent to 15 percent of new models. Only in rare cases does it test cars that have actually been driven off the lot.

The problems with this regime were obvious even before VW's shenanigans. In 2013, Consumer Reports found that 55 percent of hybrids and 28 percent of turbocharged cars fell short of their EPA fuel-efficiency ratings. Last year, the Justice Department reached a $350 million settlement with Hyundai and Kia for overstating gas mileage. Ford, Mercedes, Mini and other manufacturers have restated their official mileage ratings in the last three years, usually under threat of consumer lawsuits.

Europe, where automakers also test their own vehicles, has its own issues. Just before the VW scandal broke, a European environmental advocacy group released test results showing major discrepancies between lab and real-world emissions in cars made by BMW, Mercedes and Opel. The European Commission has announced that all passenger cars will be undergo "real world" emissions testing starting in 2017.

Any system will inevitably rely on self-reporting to some extent. Government regulators simply don't have the

money or personnel to test every new vehicle. But they can enact safeguards on a system that is all too easy for carmakers to game.

First, the EPA should have some of its engineers on hand at the industry labs to oversee compliance. Carmakers have a bevy of little tricks that can increase efficiency -- low-resistance tires, removing side mirrors and taping over cracks between panels -- and while the EPA has done better than the Europeans at closing loopholes, vigilance must be maintained. The agency should also vary the testing routines periodically so that carmakers won't know in advance exactly what they are in for. (The current regime's predictability may well have been a big part of VW's successful deception.) The EPA should consider following the EU's lead with on-the-road studies, for gas mileage as well as pollutants.

Also, the so-called defeat device VW used to game the emissions test was actually a pretty simple software tweak. It shouldn't be too hard for the EPA to invest in some computer forensic capabilities to track what's going on in our increasingly computerized vehicles.

Just as important, there need to be greater consequences for cheating. Any company caught in violation should lose its self-monitoring rights for a number of years. It should have to dig into its own pockets for trials by neutral third parties, such as parts manufacturers, which have the necessary equipment.

What Volkswagen did appears to be in a category all its own, and it deserves special condemnation. But other carmakers game the system, and regulators tolerate it. That is the dirty little secret of emissions and efficiency testing, and the EPA needs to clean it up.

Financial Times:
http://www.ft.com/intl/cms/s/0/bbd61c58-62d7-11e5-9846-de406ccb37f2.html#axzz3mgG3bZd2

EPA surprised by scale of Volkswagen's deceit
Barney Jopson in Washington and Andy Sharman in London

The US regulator that exposed Volkswagen for cheating on emissions tests has been taken aback by revelations that the German carmaker's deception extended to millions of vehicles far beyond American shores.

"It's clear that the company went above and beyond in its efforts to game the system and deceive consumers. The agency has a very robust emissions testing programme. So this deceit was significant," according to a senior Environmental Protection Agency official close to the investigation.

The EPA announced on Friday that VW had admitted installing "defeat device" software on 482,000 cars in the US.
But VW then shocked the regulator and the markets — sparking a two-day 37 per cent fall in its share price — by revealing that up to 11m vehicles worldwide could be affected.
"It's been surprising to see the scale of the deceit in terms of the number of vehicles impacted," the official said.

On Thursday the German government said VW executives had admitted to manipulating emissions tests on diesel-powered vehicles in Europe as well as the US.
The EPA official told the Financial Times the US regulator had been "engaged" with the German government over the matter even as it continued its own investigation.

"You'll continue to see news coming out of the agency on this" relating to VW, the official added.
The regulator is also "considering what our options are" regarding other auto manufacturers.
Several companies have come forward to say they have not engaged in similar cheating, the official said, and the EPA will continue working to ensure that is the case.

The EPA's concern about VW behaviour relates not just to the installation of defeat devices but to more than

a year of dialogue between the regulator and the carmaker, another EPA official said. During that period VW repeatedly sought to attribute the difference between its cars' test results in the lab and on the road to a "technical glitch".

In May 2014, the EPA and a California state regulator were alerted to emissions discrepancies with a 2012 Jetta and a 2013 Passat by researchers at West Virginia University, which had analysed the results with the International Council on Clean Transportation, a non-profit research group.

Laboratory tests showed the VW cars complied with Clean Air Act rules, but when tested on the road the Passat's emissions were five to 20 times the official test result and the Jetta's emissions were 15 to 35 times the lab reading.

The German carmaker is engulfed in the worst scandal in its 78-year history over findings it manipulated diesel emissions test data in the US and Europe to make its vehicles appear less polluting
Following the West Virginia study, VW continued to assert that the increased emissions from the vehicles could be attributed to "various technical issues and unexpected in-use conditions", according to an EPA letter to VW about the violations last week.

VW tried — and failed — to fix the apparent problem with a voluntary recall last December affecting half a million vehicles in the US.
Only when the EPA told VW that it would not certify its 2016 models as emissions compliant did VW admit to the regulator on September 3 that it had used the defeat device.
The EPA carried out additional inquiries over the following 10 days to two weeks before deciding that it would send the company the official "Notice of Violation" released last Friday, the senior official said.

Reuters:
http://www.reuters.com/article/2015/09/24/us-usa-volkswagen-idUSKCN0RL0II20150924

Volkswagen boss quits over diesel emissions scandal
BERLIN | BY ANDREAS CREMER

Volkswagen (VOWG_p.DE) Chief Executive Martin Winterkorn resigned on Wednesday, succumbing to pressure for change at the German carmaker, which is reeling from the admission that it deceived U.S. regulators about how much its diesel cars pollute.

"Volkswagen needs a fresh start - also in terms of personnel. I am clearing the way for this fresh start with my resignation," Winterkorn said, following a marathon meeting with the executive committee of the VW board.

The world's biggest carmaker by sales has admitted to U.S. regulators that it programmed its cars to detect when they were being tested and alter the running of their diesel engines to conceal their true emissions.

Volkswagen did not name a successor, but said proposals on management appointments would be made to a full board meeting on Friday.

Porsche chief Matthias Mueller, Audi chief Rupert Stadler and the head of the VW brand, Herbert Diess, are seen as the front-runners to replace Winterkorn, three people familiar with the matter said. Mueller is seen as the favourite among the three due to his years of experience within the group, two of the people said.

Mueller, a former head product strategist, is also a management board member of Porsche SE (PSHG_p.DE), and so close to the Piech-Porsche family that controls Volkswagen.

Winterkorn, who during his eight years in charge oversaw a doubling in Volkswagen's sales and an almost tripling in profit, said he was shocked that misconduct on such a massive scale had been possible at the company.

The carmaker was under huge pressure to take decisive action, with its shares down more than 30 percent in value since the crisis broke.

German Chancellor Angela Merkel had urged Volkswagen to move "as quickly as possible" to restore confidence in a company held up for generations as a paragon of German engineering prowess.

The U.S. Environmental Protection Agency (EPA) said on Friday Volkswagen could face penalties of up to $18 billion.

Since then the crisis has snowballed, with the U.S. Justice Department launching a criminal inquiry, according to a source familiar with the matter. European and Asian countries as well as Canada have also said they are investigating the matter.

Senior members of Volkswagen's board said in a statement they expected more heads to roll as an internal investigation seeks to identify who was responsible for the wrongdoing.

German Economy Minister Sigmar Gabriel said Winterkorn was taking responsibility for decisions made when he was at the helm of Audi, rather than Volkswagen.

WSJ:
http://www.wsj.com/articles/the-vw-emission-bug-1443047920

The VW Emission Bug
Why would the company install a 'defeat device' on its U.S. cars?
Sept. 23, 2015 6:38 p.m. ET

Volkswagen AG's reputation and share price have taken major hits after the Environmental Protection Agency and California Air Resources Board (CARB) last week accused the German auto maker of gaming vehicle-emission rules. VW deserves a keelhauling if the charges are true. But regulators and VW first should produce the motive and method for the alleged malfeasance.

On Friday the EPA in conjunction with CARB charged VW with installing "defeat devices" that disable nitrogen oxide emission controls in five of its clean-burning diesel models. EPA has threatened up to $18 billion in fines for the nearly half million cars VW sold in the U.S. between 2009 and 2015 that contain the device. The Justice Department is investigating.

VW's stock has since plummeted nearly a third. On Sunday CEO Martin Winterkorn promised to cooperate with regulators "to clearly, openly, and completely establish all of the facts of this case," including an external investigation. Volkswagen's U.S. chief Michael Horn apologized and said the company had been "dishonest."

On Tuesday VW said 11 million diesel cars world-wide were equipped with the device and it would set aside $7.3 billion, more than half of its annual profits, to cover penalties and recall costs. On Wednesday Mr. Winterkorn resigned. The slow-rolling revelations raise more questions.

To wit: Who decided to install the bugs, and what was their motivation? Did VW executives approve or know? Do the devices serve a purpose other than evading U.S. emission regulations? The public knows little outside the government narrative provided by EPA and CARB letters to VW last Friday.

The government investigation was prompted by a 2014 research project between West Virginia University and environmental nonprofit International Council on Clean Transportation, which found that NOx emissions from VW's 2012 Jetta and 2013 Passat soared in real world driving conditions and exceeded Clean Air Act regulations by five to 35 times.

After CARB confirmed the disparity between on-road and lab testing, VW in December 2014 recalled a half million cars to make software fixes. In May CARB reran its on-road test and determined that VW's

adjustments didn't significantly reduce NOx emissions. CARB says it then met several times with VW, which suggested potential technical justifications for the discrepancy.

However, after the agencies threatened to withhold government certification for its 2016 diesel models, VW on Sept. 3 said the vehicles contained a "defeat device" to disable NOx emission-controls under normal driving conditions.

According to EPA, a software switch senses whether the car "is being tested or not based on various inputs including position of steering wheel, vehicle speed, the duration of the engine's operation and barometric pressure" and these "inputs precisely track the parameters of the federal test procedure." Under normal driving conditions, the switch activates a separate engine calibration.

In other words, the cars are electronically programmed to produce compliant emissions results only during government testing. On highways and streets, they spew 10 to 40 times as much as allowed under U.S. law.

Defeat devices aren't new or a diabolical German invention. As EPA notes, mechanisms that deactivate emissions controls may serve a legal purpose if they protect vehicles against damage. But manufacturers are then required to disclose to regulators their presence in certification applications, which VW didn't.

Two decades ago GM had to cough up $45 million for installing defeat devices in nearly half a million cars that overrode carbon monoxide controls. In 1998 seven U.S. manufacturers of heavy-duty diesel engines, including Caterpillar and Volvo Truck, settled federal charges of implanting devices that disabled NOx controls for $1 billion.

What regulators don't ever explain is that these defeat devices serve a functional purpose, which is usually to increase performance and fuel efficiency. They want to pretend that emissions regulations are a clean, free ride. Until now, VW—which advertised its environmental friendly and powerful engines—was in on the charade.

Auto experts have posited that VW's defeat device was intended to boost fuel economy and torque, which are two big draws of modern diesel cars. VW's 2015 Passat gets 44 miles per gallon on highways. Trouble is, engines that are designed to burn more efficiently—and therefore emit less carbon—release more NOx. They also have less oomph. EPA and CARB should fess up to this trade-off, and the wrongdoing involved ought to be precisely identified.

The immediate upshot is that VW will have to recall the lemons to bring them in compliance with government rules. Any fix will likely cost several thousand dollars per vehicle, reduce performance and increase carbon emissions. Will drivers even want the government's clean bill of health?

VW deserves to pay for any intentional wrongdoing, but the rest of the industry and the country need to know whether this is the great deception that EPA alleges or the kind of well-known regulatory trade-off that is being harshly punished for the first time.

TIME:
http://time.com/4048115/volkswagen-golf-emissions-researchers/

This Small Study Helped Expose Volkswagen's Deception
Victor Luckerson @VLuck 11:15 AM ET

Their findings have been public for months

Before the Environmental Protection Agency was threatening Volkswagen with up to $18 billion in fines for cheating on emissions tests, a small research team in West Virginia already knew something was wrong with the automakers' vehicles.

A five-person engineering team at West Virginia University led by Daniel Carder first discovered discrepancies in the emissions rates for VW vehicles way back in 2013. The findings were made public about a year and a half ago, according to Reuters. "We actually presented this data in a public forum and were actually questioned by Volkswagen," Carder said.

Carder and his team initially though their testing was faulty because the results of their road tests were so out of whack with EPA standards. The findings were later corroborated by the EPA and the California Air Resources Board, leading to Volkswagen's admission that it installed illegal software in 11 million of its diesel cars to cheat on emissions tests. Volkswagen AG CEO Martin Winterkorn stepped down Wednesday; a replacement has not yet been named.

Carder said seeing his findings confirmed and watching Volkswagen become embroiled in controversy was not especially exciting for him. "Obviously, we don't want to see something spewing emissions and polluting the environment," he told Reuters. "But we really have no horse in the race, as they say."

Detroit News:
http://www.detroitnews.com/story/business/autos/foreign/2015/09/24/vw-caught/72715074/

How VW got caught cheating emissions tests
David Shepardson, Detroit News Washington Bureau 12:14 a.m. EDT September 24, 2015

Washington — Volkswagen's monumental crisis over emissions-test cheating — which forced the resignation of its longtime CEO on Wednesday and threatens to cost the German automaker at least $7.3 billion — began with a routine test led by researchers in West Virginia two years ago.

Without that chance finding, VW might never have been caught using a bit of hidden software that allows pollution-control systems on 2.0-liter diesel cars to work normally when being tested for harmful emissions coming out of the tailpipe — but shuts those systems off during regular driving. That allowed 11 million cars worldwide to produce up to 40 times the allowable smog-forming pollution allowed in the United States.

"We're a tiny, non-governmental organization," Drew Kodjak, executive director of the International Council for Clean Transportation, said in an interview Wednesday. "It was really happenstance that this was ultimately uncovered."

In 2013, his organization commissioned a study of VW diesels by West Virginia University after questions were raised about European diesel emissions standards and whether European vehicles were emitting too much nitrogen oxides linked to smog. Testers looked at three diesel cars for the U.S. market: a 2012 VW Jetta, a 2013 VW Passat and a BMW X5.

The group expected the cars they tested would perform better than those in Europe, because U.S. regulations are tougher. They were surprised the two Volkswagens had significantly higher-than-expected emissions, while the BMW performed well. They were so certain they had done something wrong that they tested the cars two more times with similar results.

The researchers made their findings public in May 2014 in a report that got little attention. But it caught the notice of the Environmental Protection Agency and California Air Resources Board, which opened investigations.

The Detroit News has learned that, in response to tests by the EPA and CARB, the automaker actually issued two separate recalls labeled as service campaigns for certain cars: one in December 2014, another in March. Software patches were VW's remedy, and the automaker assured the EPA and CARB that they fixed the problem. Out of 390,000 cars identified by VW at the time, about 196,000 were reflashed with new software.

CARB began testing VW's remedy in May. The California agency had developed a special dynamometer that showed the emission controls in the Volkswagens were not working properly. The software patch, in fact, did

not cut exhaust emissions.

At the time, government officials never suspected VW was intentionally cheating. They kept looking for other potential problems. All summer long, VW kept offering "explanation after explanation," a person involved in the talks said Wednesday. "They did not add up."

Even through early August, government officials believed the automaker was acting in good faith. They thought other issues like a bad "dosing sensor" or a test problem could have accounted for the results.

In early August, EPA and CARB officials met with VW at an annual automotive conference in Traverse City to talk about the problem. By that time, California and EPA were withholding certification allowing 2016 diesel models to be sold until they were sure the recall fix would address the problem. VW said it had everything fixed.

Finally, at a conference in California on Aug. 20, an official from VW could not answer technical questions and admitted it had been intentionally cheating through so-called "defeat devices."

After months of work and testing, government officials were shocked at VW's admission of fraud.

The deception was sophisticated: Electronic control modules told the emissions controls to only work during emissions testing — something the computer could determine by the steering wheel position and other factors. That turned out to be a big clue for government investigators.

In a typical car, a dashboard indicator is supposed to light up if it's emitting more than allowable emissions. The Detroit News has learned the VW diesels were programmed not to activate those onboard diagnostics required of all cars since 1996 under the Clean Air Act.

On Friday, the EPA and CARB announced Volkswagen had admitted to installing defeat devices on 482,000 2009-15 Volkswagen Jetta, Passat, Sportwagen, Beetle and Audi A3 cars with 2.0-liter engines sold in the U.S. That included the 390,000 cars initially identified by the automaker, plus another 92,000. The cheat caused the cars to emit 10-40 times the allowable pollution.

By Tuesday, the automaker disclosed that 11 million diesel cars worldwide may have evaded clean-air rules. It could face U.S. fines of up to $18 billion — $37,500 per vehicle — as well as criminal prosecution.

People are shocked at the fraud, Kodjak said, "because of the deliberate nature, and the fact that this came from one of the greenest countries that's known for being extremely law-abiding."

Analysts speculated there are only three advantages to such a device: VW may have wanted to get higher fuel economy for the cars, better performance or avoid more expensive emissions controls like those on larger diesel VWs.

Industry, government and researchers say the automaker could have avoided criminal investigations and massive worldwide lawsuits linked to the admission that they cheated on emissions tests if their software fix had actually worked.

"Why didn't it work? That is literally one of my biggest questions is why didn't it work," Kodjak said. If it had, investigators may never have learned about VW's intentional fraud. "California told you they were going to check. If they had just fixed it then ... the only answer I can surmise is it is not easy."

Government officials expect VW will have to come up with three separate fixes since there are three generations of diesel engines that use different systems to prevent the release of smog-causing nitrogen oxides. It is not yet known whether a new software patch will suffice, or if new pollution-control equipment must be installed.

Boston Globe:
https://www.bostonglobe.com/business/2015/09/23/how-many-volkswagen-vehicles-massachusetts-are-affected-recall-lot/nxliz8S0LU9v5aEPyXbNmJ/story.html

How many Volkswagen vehicles in Mass. are affected by the recall? A lot
By Callum Borchers GLOBE STAFF SEPTEMBER 23, 2015

The tally is in on the number of diesel-engine Volkswagens in Massachusetts that will be subject to recall: 11,674.

According to the Registry of Motor Vehicles, that's how many cars fit the makes, models and years identified by the US Environmental Protection Agency as having a so-called "defeat device" that made them appear cleaner in emissions tests than they actually were on the road.

The EPA determined the vehicles — marketed as "clean" diesel cars — spew as much as 40 times what federal pollution limits allow.

Volkswagen chief executive Martin Winterkorn resigned Wednesday but claimed he did not know about the company's effort to cheat emissions tests, saying he was "stunned that misconduct on such a scale was possible in the Volkswagen Group."

Combining the EPA's description of affected vehicles with RMV statistics, the following list shows how many diesel cars of each type have been recalled in Massachusetts:

• Jetta model years 2009 to 2015: 3,562

• Jetta Sportwagen model years 2009-2014: 3,926

• Beetle model years 2012 to 2015: 81

• Beetle Convertible model years 2012 to 2015: 95

• Golf model years 2010 to 2015: 1,489

• Golf Sportwagen model year 2015: 159

• Passat model years 2012 to 2015: 1,998

• Audi A3 model years 2010 to 2015: 364

The EPA said roughly 482,000 cars nationwide are affected by the recall, and Volkswagen said the worldwide total exceeds 11 million.

From: Gong, Kristiene
Sent: Tuesday, September 22, 2015 4:38 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/22/2015

The Tennessean:
http://www.tennessean.com/story/news/politics/2015/09/22/tn-senate-leader-requests-hearing-on-volkswagen-issues/72625196/

TN Senate leader requests hearing on VW cheating issues
Dave Boucher

A leader in the Tennessee Senate is asking a fellow lawmaker to call a hearing to look at how cheating revelations regarding Volkswagen may affect the state.

Senate Speaker Pro Tem Bo Watson, R-Hixson, notes the German automaker's significant investment in Tennessee as a reason he wants Senate Finance, Ways and Means Committee Chairman Randy McNally, R-Oak Ridge, to schedule a hearing.

"While all of the relevant facts may remain unreported at this time, I am very concerned as to the financial impact these violations could present to the state of Tennessee," Watson writes.

"As the chairman is aware, Tennesseans have made a significant investment in Volkswagen and any action that threatens the stability and sustainability of the investment should be reviewed by the finance committee, without delay," he continued later in the letter.

Tennessee provided Volkswagen with $165 million in grants in connection to its massive facility in Chattanooga, where more than 3,200 people are employed. Volkswagen received more than $577 million in incentives to build the plant in Chattanooga in 2008, The Associated Press reported. The AP also noted another state and local package worth up to $300 million was offered last year to persuade VW to expand the Chattanooga plant to build a new SUV in Tennessee as opposed to elsewhere.

Volkswagen CEO Martin Winkerton apologized Tuesday in the wake of accusations from the U.S. Environmental Protection Agency that the company had intentionally installed software that allowed its cars to cheat in emissions tests. The company said the emissions software affected 11 million cars worldwide.

On Tuesday it was reported the company has set aside more than $7 billion in anticipation of fines. USA TODAY reported recently that the car company could face $18 billion in fines from the federal government.

Volkswagen sets aside $7.3B over emissions scandal

On Monday Gov. Bill Haslam said he was concerned when he heard the revelations. He said he'd only spoken briefly with representatives from the EPA and Volkswagen.

"Volkswagen is somebody that is a major partner for us in the state of Tennessee, both in terms of investment and the jobs created. We're obviously very interested in their continued growth, but they're going to have to address this issue," Haslam told reporters Monday.

Lt. Gov. Ron Ramsey, R-Blountville, told the Chattanooga Times Free Press that the revelations are "depressing, hard to believe. On and on. We've made a huge investment."

Watson asked McNally to call the public meeting to discuss potential impact on Tennessee as soon as possible.

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To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/22/2015

NBC News:
http://www.nbcnews.com/business/autos/volkswagen-11-million-vehicles-could-have-suspect-software-emissions-scandal-n431456

Volkswagen Sets Aside $7.2 Billion to Pay for Emissions Cheating Scandal
by PAUL A. EISENSTEIN

Volkswagen said Tuesday it is setting aside more than $7.2 billion to cover the anticipated cost of resolving its diesel emissions cheating scandal, a figure that could be eclipsed by potential penalties and lawsuits facing the German automaker in the U.S.

The issue, meanwhile, now is spreading to other markets, with VW confirming it used the same illicit software - dubbed a "defeat device" by U.S. regulators - on 11 million diesel vehicles sold worldwide. That has triggered calls for new investigations in markets from South Korea to the European Union.

The money that VW is setting aside, 6.5 billion euros, is part of the company's efforts to "win back the trust of our customers," VW said in a statement Tuesday.

Meanwhile, it noted that it is "working intensely" to find a technical solution to removing the software without reducing the performance of affected VW products. A total of 488,000 VW and Audi brand vehicles equipped with four-cylinder engines were recalled Friday, while the automaker ordered dealers to stop selling products equipped with those diesels.

Concerns about the mounting costs and potential impact to VW's reputation have led to a panic among the company's investors. On Monday, the value of VW shares plunged by 17 percent, and the sell-off was continuing midday Tuesday on the German exchange.

The crisis could lead to a shake-up in management at Volkswagen AG, industry analysts have warned.

The U.S. Environmental Protection Administration announced Friday that the automaker had surreptitiously equipped its diesel vehicles with software designed to recognize when those products were being tested on a dynamometer, essentially an automotive treadmill. In such a situation, the full complement of emissions controls systems would operate at their maximum, bringing the vehicles into compliance with U.S. - and even tougher California - emissions standards.

But once the testing would be completed, according to the EPA, the vehicles would revert to a different mode, effectively allowing emissions levels to increase by as much as 40 times.

In its new statement, VW gave more details, admitting that "discrepancies" related to vehicles with Type EA 189 engines and involved some 11 million vehicles worldwide.

"A noticeable deviation between bench test results and actual road use was established solely for this type of engine," the VW statement said. "Volkswagen is working intensely to eliminate these deviations through technical measures."

While the maker acknowledged the computer control systems on 11 million vehicles contain the code, it also claimed that the "majority of these engines the software does not have any effect."

The U.S. has the world's toughest diesel emissions standards, largely focusing on levels of micro-fine particulates and smog-causing oxides of nitrogen. In Europe, where the emphasis is on global warming gases like CO2, diesels handily meet test standards because they are so energy efficient.

Even so, there are mounting calls in Europe for a full investigation of the VW diesel test scandal, and CEO Martin Winterkorn has told Germany's transit ministry the company will fully cooperate with its investigation. Officials in South Korea also have called for an investigation.

Meanwhile, the U.S. Justice Department has reportedly taken the preliminary steps to open a criminal investigation.

Whether the $7.3 billion set aside is enough to cover VW's costs from the scandal remains to be seen. According to EPA rules, VW could be fined up to $37,500 for each vehicle not in compliance with emissions regulations, or a total of around $18 billion. California regulators could issue their own fines.

Several law firms also have taken initial steps of their own to bring class action lawsuits against Volkswagen on behalf of owners.

But perhaps the biggest question concerns the impact the scandal will have on VW's image and sales. The maker overtook Toyota to become the world's best-selling automaker during the first half of 2015. But it has been struggling to build momentum in the critical American market where about a quarter of its sales are diesel-powered vehicles. For now, VW has halted the sale of those models until it can come up with a fix for the faulty software.

From: Gong, Kristiene
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To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/22/2015

Bloomberg (via Chicago Tribune):
http://www.chicagotribune.com/news/sns-wp-blm-news-bc-vw-states22-20150922-story.html

Volkswagen probed by states over pollution cheating
Christie Smythe, Bloomberg News

Several states have begun an investigation into Volkswagen's admission that it equipped cars with technology to cheat federal air pollution tests, joining federal investigators and a growing list of countries probing the German automaker.

Wolfsburg, Germany-based Volkswagen said on Sept. 18 that it used "defeat device" software to beat emissions tests in labs. The diesel vehicles spewed as much as 40 times the legal limit of pollutants when they were on the road, the Environmental Protection Agency alleges. Volkswagen said it's cooperating with U.S. officials.

The matter may cost Volkswagen $18 billion in penalties from the EPA, based on a maximum $37,500 violation for each of nearly a half-million diesel versions of the VW Jetta, Golf, Beetle and Passat and the Audi A3.

Matt Mittenthal, a spokesman for New York Attorney General Eric Schneiderman, said in an e-mail today that he could confirm New York is part of the multistate group but was unable to say what other states were part of the probe.

The U.S. Justice Department has also begun a criminal probe, according to officials who spoke on a condition of anonymity.

The German government opened its own probe on Tuesday. Environment Canada also started an investigation, promising unspecified "enforcement action" if the car maker cheated in that country.

From: Gong, Kristiene
Sent: Tuesday, September 22, 2015 1:28 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/22/2015

NY Times:
http://www.nytimes.com/2015/09/23/business/dealbook/volkswagen-debacle-on-financial-par-with-bp-oil-spill.html

Volkswagen Debacle on Financial Par With BP Oil Spill
SEPT. 22, 2015
By ANTONY CURRIE and OLAF STORBECK

— Volkswagen's cheating on clean air rules in the United States has driven investors into a deep funk.

The German carmaker's market capitalization shrank 16.6 billion euros, or $18.6 billion, in just over a day, after it was caught falsifying emissions on certain cars sold in the United States. The eventual cost could be higher. Although other carmakers have paid less for misdeeds, the better analogy might be oil: BP's 2010 Deepwater Horizon fiasco.

Rival carmakers got off relatively lightly for recent transgressions in the United States with more disastrous immediate consequences. General Motors paid $900 million to settle a lawsuit over faulty ignition switches linked to 124 deaths. Toyota paid $1.2 billion last year for malfunctioning accelerators tied to fewer fatalities.

No deaths can be directly pinpointed to Volkswagen blocking accurate checks on emissions – though the software installed in some vehicles hid levels of harmful nitrogen oxide up to 40 times above permitted levels.

The environmental twist perhaps makes BP's disastrous Gulf of Mexico oil spill a better comparison. Initial total cost estimates by analysts were as low as $3.5 billion. The final bill under the Clean Water Act was $5.5 billion, less than half the maximum fine. But BP's other costs, including damages, ballooned. All in, BP ended up setting aside almost $55 billion in fines, compensation and cleanup costs.

The Clean Air Act allows the Environmental Protection Agency to charge up to $37,500 a vehicle for any breaches. With 482,000 affected cars, that's $18 billion. The E.P.A. could be kinder than that, but Volkswagen, run by Martin Winterkorn, cheated government tests for six years, dissembled when confronted and meanwhile lauded Volkswagen's status as an environmentally sustainable carmaker.

Volkswagen can pay $18 billion, over time, and retain its credit rating. It has €21 billion in net cash, with more coming from planned divestitures.

That, though, doesn't factor in other costs, including recalls, refits, vehicle buybacks and class-action lawsuits – or the possibility that Volkswagen's emissions shenanigans were more pervasive. Diesel cars account for more than half its sales in Europe, its largest market, though with more lenient nitrogen oxide standards. If the scandal undermines the business case for Volkswagen's diesel engines, a €16.6 billion drop in value will look like a country jaunt.

From: Gong, Kristiene
Sent: Tuesday, September 22, 2015 1:18 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/22/2015

Washington Post:
http://www.washingtonpost.com/news/wonkblog/wp/2015/09/22/anatomy-of-volkswagons-deception-the-recall-that-never-fixed-any-cars/

Anatomy of Volkswagen's deception: The recall that never fixed any cars.
By Peter Whoriskey and Joby Warrick September 22 at 12:20 PM

Volkswagen's decision to equip 11 million vehicles with devices to cheat emissions tests worldwide has sent the company into an acute corporate crisis in recent days. But on December 2, 2014, the company assured U.S. and California regulators that their engineers had a straightforward solution.

Volkswagen told officials then that a software change would remedy the overflow of pollution emitted by their diesel cars, according to state and federal letters to the company. At the time, Volkswagen proposed a "voluntary recall" of about 500,000 vehicles. State and federal officials approved the plan.

That fix was either a technical failure or, some officials said, another ruse.

By May of this year, California tests showed that "the recall calibration did reduce emissions to some degree but NOx emissions were still significantly higher than expected."

The extent of the recall, which is discussed in letters between government and company officials, is unknown. Company officials wouldn't say this week how many recall notification letters Volkswagen issued to consumers, and how many consumers brought their cars in for the purported fix.

But the incident is one of the highlights in what federal and state officials have likened to a cat-and-mouse game between regulators and one of the world's largest automakers.

"They basically ran out of excuses," said Stanley Young, spokesperson for the California Air Resources Board. "They would say the tests weren't at the right temperature, or some other issue. We had them in [to our offices] several times."

EPA administrator Gina McCarthy said on Tuesday that the agency would step up efforts to look for cheating by other manufacturers, though she suggested that Volkswagen was an "outlier" in the extent of its cheating to defeat emissions standards.

"We are not going to sit down around and worry about whether or not there are other devices. We're going to find it," she said. "So right now we're upping our game in terms of going out and doing the work to take a look at what we need to do with other vehicles."

The company's dire diesel troubles have erupted over just a few days, but they were a long time in gestation.

The regulations that shaped the design of the diesel engines were put in place more than 15 years ago, when the EPA finalized rules that raised the emission standards for diesel cars.

After a years-long grace period, the tough standards were phased in between 2004 and 2007. At the time, the government acknowledged that meeting the standards for NOx, or nitrogen oxide, as well as soot, would be difficult.

"Manufacturers have expressed concerns that diesel-fueled vehicles would have difficulty meeting NOx and particulate matter levels like those contained in today's rule," EPA officials wrote in issuing the new standards. "Clearly, these standards will be challenging."

For a time, Volkswagen and other automakers stepped back from the U.S. diesel car market. It was a time to retool. Experts said the challenge of making a diesel engine clean enough for the U.S. standards - without compromising how the engine works - is very difficult.

"NOx is more of a challenge for diesel engines than it is for gasoline engines," said John Storey, distinguished research and development staff member at Oak Ridge National Laboratory. "The strategies companies use to clean them up all have an impact on performance, fuel economy and maintenance."

The engineering hurdles in controlling diesel emissions are high enough, some experts said, that they may provide an incentive for companies to skirt the rules.

"I can't say I'm surprised," John M. DeCicco, Ph.D. Research Professor at the University of Michigan Energy Institute, of the recent revelations. "The temptation to game the system with a defeat device is definitely high because of the technical challenges."

In 2008, Volkswagen came back with a diesel version of the Jetta. The company touted it as an example of the "clean diesel." It won raves, including "Green Car of the Year" at the Los Angeles Auto Show.

"After a three-year break that seemed interminable to fans, Volkswagen's back in the U.S. diesel-car market with a clean-burning diesel in its popular Jetta compact sedan," USA Today told readers.

But what seemed like a breakthrough seems now, in the light of recent revelations, like a massive cheat.

The company's two-liter diesel engines in the U.S. had been equipped with a "defeat device" that allowed the cars to pass federal emissions tests despite emitting more than 10 times the permitted amounts of NOx when it is on the road. Those emissions help produce smog on hot summer days, triggering a variety of health problems, particularly for asthmatics and other people with breathing difficulties.

As has been widely reported, the emission problems were detected in a May 2014 report by the International Council on Clean Transportation and West Virginia University.

The results were presented to the company and several months later, in December 2014, the company told California regulators that they had a fix. They would "recalibrate" the software that runs the engine.

"Based on this meeting, VW initiated a voluntary recall...This recall was claimed to have fixed among other things, the increased real world driving NOx issue," according to a recent letter from the California Air Resources Board to the company.

By May of this year, California officials had run road tests on cars altered as under the recall. Despite the fix, the car showed higher than expected NOx emissions. California engineers also created a special dynamometer test, apparently to address company concerns that the previous testing was unfair.

California Air Resources Board "has determined that the previous recall did not address the high on-road NOx emissions, and also resulted in the vehicle failing certification standards," it told the company earlier this month.

McCarthy, speaking to reporters in Washington, acknowledged that the Volkswagen software ruse was "particularly difficult for us to detect. We haven't found similar types before but we'll take a look and make sure we're attacking it successfully," she said.

McCarthy defended the EPA's regulatory standards as reasonable, and said most other car manufacturers appear to have found a way to comply.

"This is about a NOX emission standard that was put in place a few decades ago. The industry knew what was happening. We feel pretty confident the industry has been innovating to be able to meet this standard," she said. "So we don't think that this problem with the standards at all."

McCarthy said she was gratified by Volkswagen's aggressive response in acknowledging its mistakes, even as she criticized the company for its years of deliberate deception.

"I think it will be very difficult for Volkswagen at this going to be looked at as anything other than a real outlier," she said.

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Financial Times:
http://www.ft.com/intl/cms/s/0/ac6742b2-611d-11e5-a28b-50226830d644.html#axzz3mU7mhPP8

How VW's 'defeat device' cheated on EPA emissions tests
Clive Cookson, Science Editor

The "defeat device" that Volkswagen used to cheat on US emissions testing sounds as if a secret little black box was hidden deep in the diesel engine just waiting to switch anti-pollution controls on during government inspections.

During normal driving, these controls are relaxed, which improves performance and reduces engine wear.

"The test cycles are very formal and well established, so priming a vehicle to sense when it is being tested is potentially quite straightforward," said Professor Alastair Lewis, an air pollution expert at York University in the UK. "For example are only its drive wheels turning, is the acceleration unnaturally smooth, or constant speeds too precise for a human driver?"

Modern "clean diesel" engines aim to reduce pollution in a series of computer-controlled steps. For example, the computer may adjust the ratio of air to fuel in the combustion chamber, change the operating temperature or alter the rate at which exhaust gases flow through catalytic converters and filters.

Another refinement is to inject a chemical called urea into the exhaust stream. It then reacts with polluting nitrogen oxides (NOx) and converts them into harmless nitrogen and water.

"A huge amount of complex electronics controls it all," said Roger Kemp, professor of engineering at Lancaster University. "The code in the software gives thousands of different usage patterns corresponding to different combinations of inputs.

"There is a trade-off between pollution control and engine performance," Prof Kemp added. For example running at a hotter temperature may cut emissions but reduce engine life.

Bosch, the German car parts company, supplies components to VW, including fuel injection and exhaust treatment systems that reduce emissions. But people familiar with the cars said VW writes the software that deploys the equipment.

According to the EPA's notice of violation, the software ran the engine with "dyno calibration" settings designed to minimise pollution when it detected testing in progress (dyno refers to dynamometer equipment at the test centre). For the rest of the time it ran on "road calibration" which puts less emphasis on reducing emissions.

Even when the software switches to road running, a modern diesel engine is much less polluting than its filthy predecessors, Prof Kemp pointed out. Its filters and combustion chamber are particularly effective at cutting emissions of the tiny soot particles that used to belch out of ill-tuned engines (and still do in parts of the developing world).

The EPA allegations focus on NOx, reactive gases that are one of the main sources of urban smog and lung-irritating ozone pollution. The violation came to light when researchers at West Virginia University tracked emissions from VW diesel cars on the road and found that NOx soared to levels 10 to 40 times higher than the EPA permits.

Many air pollution experts have long believed that other manufacturers operate their own versions of VW's defeat devices.

"Virtually all new vehicles in recent years appear to emit substantially more NOx in the real-world than they do when tested in labs, irrespective of manufacturer," said Prof Lewis. "VW appear to have been caught red-

handed, but it would seem highly likely that others have also played dubious games to pass emissions tests."

Ian Colbeck, professor of aerosol science at the University of Essex, commented: "It has been observed for some time that real world driving conditions do not deliver the emission reductions shown in the laboratory. The European Commission will require real world tests in 2017."

USA Today:
http://www.usatoday.com/story/money/cars/2015/09/22/volkswagen-emissions-scandal/72605874/

Volkswagen emission scandal widens: 11 million cars affected
Nathan Bomey

Investors crush Volkswagen shares as company sets aside $7.3 billion to address software that manipulates emissions tests.

Volkswagen's emissions scandal ballooned Tuesday as the automaker said it affects 11 million vehicles worldwide and will require the company to set aside 6.5 billion euro ($7.3 billion).

The startling admission instantly makes the crisis one of the most expensive automotive scandals in recent memory.

The crisis also threatens to upend the company on its rapid path to becoming the world's largest automaker. Volkswagen had seized the title from Toyota for the first six months of 2015.

"This could damage the Volkswagen brand globally for years to come," said former automotive marketing executive Peter De Lorenzo, blogger at Autoextremist.com, in an interview. "Trust and belief in the brand has been broken."

Volkswagen CEO Martin Winterkorn pledged to regain the public's trust and rectify the company's mistakes, amid speculation that he could lose his job over the crisis. Winterkorn's contract, coincidentally, is up for renewal at the automaker's board meeting Friday.

In a video statement Tuesday he said he's "endlessly sorry" for the situation but pledged to stay on the job, according to several reports translating the German remarks.

Investors crushed the Germans automaker's stock, driving shares down 18% as of 9:47 a.m. ET, a day after the stock plunged 19%.

The crisis began Friday when the U.S. Environmental Protection Agency accused Volkswagen of installing sophisticated software on nearly 500,000 U.S. vehicles to manipulate emissions tests.

The technology tricks regulators into believing that 4-cylinder diesel vehicles comply with emissions standards, but the cars are actually admitting harmful pollutants at rates of up to 40 times acceptable standards. Volkswagen quickly halted sales of the cars after the allegations surfaced.

The U.S. Justice Department has opened a criminal probe into the automaker's actions. The EPA's own investigation is ongoing, and foreign regulators are expected to launch their own probes.

"Volkswagen is working at full speed to clarify irregularities concerning a particular software used in diesel engines," the company said Tuesday in a statement.

The "discrepancies" affect vehicles with what it called "Type EA 189 engines," causing "a notable deviation between bench test results and actual road use."

The company added: "Volkswagen is working intensely to eliminate these deviations through technical

measures."

Volkswagen said it would set aside 6.5 billion euro in its third quarter to address the matter and warned that the number could change.

In the U.S., the EPA could fine Volkswagen up to $37,500 per car, which would equal a maximum fine of some $18 billion.

"Volkswagen does not tolerate any kind of violation of laws whatsoever. It is and remains the top priority of the Board of Management to win back lost trust and to avert damage to our customers," the company said.

The scandal raises serious questions about whether high-level executives knew about the software, which had been installed on some nameplates for at least six consecutive model years.

Earlier this month a subcommittee of Volkswagen's board recommended that the full panel extend Winterkorn's contract through 2018. The official renewal at Friday's board meeting was viewed as a routine matter, but now it may be up in the air.

Winterkorn kept his job earlier this year after then-chairman Ferdinand Piech tried to displace him. Piech exited the company shortly after his failed effort.

De Lorenzo, the automotive marketing veteran, said Winterkorn will be forced to answer questions about his knowledge of the emissions scandal.

"He's very much detailed-oriented. He's always regaled his underlings with his depth of knowledge of detailed items that they would assume he wouldn't bother with," De Lorenzo said. "I think heads will roll and this could bring down Winterkorn and some of his trusted lieutenants."

Dave Sullivan, an analyst with AutoPacific, said the "chances of him coming out unscathed have got to be very small."

The EPA has said the company admitted to installing the software. The agency said the software affected the four-cylinder diesel versions of the 2009 to 2015 Jetta, Beetle, Golf, the 2014 and 2015 Passat and the 2009 to 2015 Audi A3.

The episode is likely to trigger a recall and a flurry of consumer lawsuits. It may prompt the company to compensate individual car owners or other measures.

European regulators are expected to place Volkswagen under intense scrutiny. But it scandal also could bode poorly for Volkswagen in the world's largest vehicle market, China, where Volkswagen is No. 1 by market share.

"The problem is the Chinese are starting to realize they have got to do something with their air and this could have an effect on the relationship the Chinese have with Volkswagen," Sullivan said.

The Environmental Protection Agency is working on new tests to detect cheating on the part of automakers in the wake of Volkswagen AG's massive cheating scandal.

EPA Administrator Gina McCarthy told reporters at a Wall Street Journal forum on Tuesday that the agency won't sit still and is "upping its game" to catch cheaters.

VW was able to evade U.S. emissions requirements for 482,000 2009-2015 diesel cars by using sophisticated software that only turned on emissions equipment during testing. It's not clear if VW did that to boost low-end torque, raise fuel efficiency or avoid more costly emissions requirements.

The fact that VW was able to get away with the cheating for nearly seven years suggests the agency must take

new steps to detect bad behavior, analysts say. Cars are very sophisticated machines with more than 100 million lines of code.

The VW emissions issue came to the attention of the EPA in 2014 after independent analysis by researchers at West Virginia University — working with the International Council on Clean Transportation, a non-governmental organization — raised questions about emissions levels. After extensive testing, EPA confirmed that the vehicles were emitting up to 40 times the allowable pollution in road use.

The EPA told The Detroit News on Friday that it was investigating whether other automakers had similar problems. But McCarthy said so far it appears VW is an "outlier."

This will not be the first time in recent years that EPA has had to change its rules to ensure companies are complying with emissions.

In February, the EPA issued new guidelines to automakers for conducting fuel economy testing. The move came after five major automakers have had to restate mileage ratings for certain models.

The guidelines detail how vehicles must be prepared before being tested — including what is an acceptable level of wear on the tires and how vehicles should be broken in prior to testing.

Also at issue are tests used to determine the impact of aerodynamic drag and tire rolling resistance on gas mileage. Currently, that is measured at 50 miles per hour. Under the new guidelines, automakers must measure the results at all speeds up to 70 mph.

In 2014, the agency said it was considering writing new formal regulations covering mileage labeling by automakers. Instead, it is opting to issue the guidelines. It typically takes EPA two to three years to write new legal binding mandates.

Chris Grundler, the EPA's director of the Office of Transportation and Air Quality, said in an interview in February that "it's a very dynamic time" in the auto industry, and the agency doesn't want to spend several years crafting rules that could be outdated when issued.

"Writing regulations takes time," Grundler said. "When you are working in the rapidly changing environment that we're in right now, we want to make sure that we are agile enough and flexible enough to change with those times."

He said new guidelines are aimed at getting better results. He noted that the EPA will follow the guidelines when it conducts audits of automaker testing.

In November, Korean automakers Hyundai Motor Co. and Kia Motors Corp. agreed to a record-setting $360 million settlement for overstating fuel economy ratings for 1.2 million 2011-13 U.S. vehicles. The settlement includes a $100 million civil penalty, forfeiting $210 million in greenhouse gas emission credits and spending $50 million to ensure independent auditing of its current and future vehicles.

After an investigation by the EPA, Hyundai and Kia in November 2012 agreed to restate expected gas mileage for 1.1 million vehicles in North America, including 900,000 in the United States. That reduced Hyundai-Kia's fleetwide average fuel economy from 27 to 26 mpg for the 2012 model year. Hyundai was forced to abandon claims that four models got 40 mpg.

In August 2013, Ford Motor Co. dropped mileage ratings for the 2013 C-Max hybrid from a combined 47 mpg to 43 mpg. In June 2014, Ford Motor Co. said it is lowering the fuel ratings on six new cars and would make payments of $125 to $1,050 to more than 200,000 owners.

The move was a significant embarrassment to Ford, which has emphasized the fuel efficiency of vehicles in its lineup. It was he second time in a year that Ford has had to correct its mileage numbers.

Under current rules, Ford was able to assign the same fuel efficiency rating to the C-Max as the Fusion hybrid because they're in the same family. While that's worked for conventional cars, it hasn't been as accurate for hybrids.

Other German automakers besides VW have faced EPA scrutiny. In October, BMW AG agreed to reduce its fuel economy ratings on four 2014 Mini Cooper models.

BMW reduced the combined fuel economy of the three-door manual transmission to 33 miles per gallon from 34 mpg, the three-door semi-automatic from 33 to 32, the Cooper S 3-door manual from 29 to 28 and the semi-automatic version from 31 to 30. The biggest fall is in the highway rating for the Cooper S 3-door manual will fall from 38 to 34 mpg.

Also last year, another Daimler AG agreed to lower the mpg ratings on two of its Mercedes-Benz vehicles after a government audit turned up a problem.

Mercedes-Benz made minor changes to two models. It will reduce the city mpg figure for the 2013-14 C300 to 19 mpg from 20 mpg, but the combined 22 mpg and 27 mpg highway value will remain the same. For the 2013-14 4-Matic PZEV the combined mpg fell to 22 mpg from 23 mpg, while the city and highway mpg figures both fell by 1 mpg to 19 and 28, respectively.

From: Gong, Kristiene
Sent: Tuesday, September 22, 2015 11:44 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/22/2015

AP (via Washington Post):
https://www.washingtonpost.com/world/europe/volkswagen-sets-aside-73-billion-over-emissions-scandal/2015/09/22/3fe272e8-6112-11e5-8475-781cc9851652_story.html

VW CEO: 'Endlessly sorry' as emissions scandal escalates
By Geir Moulson and Pan Pylas | AP September 22 at 11:32 AM

BERLIN — The crisis enveloping Volkswagen AG, the world's top-selling carmaker, escalated Tuesday as the company issued a profit warning following a stunning admission that some 11 million of its diesel vehicles worldwide were fitted with software at the center of a U.S. emissions scandal.

The German company said it was setting aside around 6.5 billion euros ($7.3 billion) to cover the fallout from the scandal that has tarnished VW's reputation, raised questions over the future of CEO Martin Winterkorn and battered its share price.

Winterkorn pledged a fast and thorough investigation.

"Millions of people across the world trust our brands, our cars and our technologies," he said in a video message. "I am endlessly sorry that we have disappointed this trust. I apologize in every way to our customers, to authorities and the whole public for the wrongdoing."

"We are asking, I am asking for your trust on our way forward," he said. "We will clear this up."

The VW Logo is photographed at a car at the Car Show in Frankfurt, Germany, Tuesday, Sept. 22, 2015. Volkswagen has admitted that it intentionally installed software programmed to switch engines to a cleaner mode during official emissions testing. The software then switches off again, enabling cars to drive more powerfully on the road while emitting as much as 40 times the legal pollution limit. (Michael Probst/Associated Press)

The damage to Volkswagen's reputation is reflected in the market's response. Volkswagen's share price slid a further 16.2 percent Tuesday to a near four-year low of 112 euros. The fall comes on top of Monday's 17 percent decline.

The trigger to the company's market woes was last Friday's revelation from the U.S.'s Environmental Protection Agency that VW rigged nearly half a million cars to defeat U.S. smog tests.

The company told U.S. regulators that it intentionally installed software programmed to switch engines to a cleaner mode during official emissions testing. The software then switches off again, enabling cars to drive more powerfully on the road while emitting as much as 40 times the legal pollution limit.

"In my German words: we have totally screwed up," the head of Volkswagen's U.S. division, Michael Horn, told an audience in New York on Monday.

In a statement Tuesday, Volkswagen gave more details, admitting that there were "discrepancies" related to vehicles with Type EA 189 engines and involving some 11 million vehicles worldwide. The number of vehicles involved is more than the 10 million or so cars it sold in 2014.

Volkswagen said it is "working intensely" to solve the problem and that it "does not tolerate any kind of violation of laws whatsoever."

To cover the necessary service measures and what Volkswagen says are "other efforts to win back the trust" of customers, the company said it is setting aside some 6.5 billion euros in the current quarter. There was no mention of fines or penalties in the company's statement. The EPA has indicated that it could, in theory, fine VW up to $18 billion.

The Guardian:
http://www.theguardian.com/business/2015/sep/22/vw-scandal-caused-nearly-1m-tonnes-of-extra-pollution-analysis-shows

VW scandal caused nearly 1m tonnes of extra pollution, analysis shows
Emissions could have far greater impact in Europe, where almost half passenger cars are diesel, than the US
Karl Mathiesen and Arthur Neslen

Volkswagen's rigging of emissions tests for 11m cars means they may be responsible for nearly a million tonnes of air pollution every year, roughly the same as the UK's combined emissions for all power stations, vehicles, industry and agriculture.

The carmaker has recalled 482,000 VW and Audi brand cars in the US after the Environmental Protection Agency (EPA) found models with Type EA 189 engines had been fitted with a device designed to reduce emissions of nitrous oxides (NOx) under testing conditions.

A Guardian analysis found those US vehicles would have spewed between 10,392 and 41,571 tonnes of toxic gas into the air each year, if they had covered the average annual US mileage. If they had complied with EPA standards, they would have emitted just 1,039 tonnes of NOx each year in total.

On Tuesday the company admitted the device may have been fitted to 11 million of its vehicles worldwide. If that proves correct, VW's defective vehicles could be responsible for between 237,161 and 948,691 tonnes of NOx emissions each year, 10-40 times the pollution standard for new models in the US. Western Europe's biggest power station, Drax in the UK, emits 39,000 tonnes of NOx each year.

In the US, just 3% of passenger cars are diesel compared to almost half in the EU. Professor Martin Williams from King's College London said the US's low percentage of diesel cars meant higher diesel emissions in some cars would have a "limited effect" on air quality there.

"[In the US it would be] nowhere near the effect it would have in this country and in the rest of Europe for that matter," he said. In the UK, Williams added, emissions from diesel cars cause roughly 5,800 premature deaths each year. "If you were to make the cars emit at the legal limit you could reduce those deaths by at least a factor of two and maybe more. Maybe a factor of five."

The Clean Air in London campaign called for a royal commission to investigate carmaker's activities in the UK.

"Diesel is without doubt the biggest public health catastrophe in UK history. Even the black plague didn't affect everyone in the population," said founder Simon Birkett.

Not all NOx emissions – which include nitrogen dioxide (NO2) and nitrogen oxide (NO) – are dangerous. But an increasing proportion of the toxic NO2 gas has been detected in EU diesel emissions. A study in the British Medical Journal in May found that short term exposure to NO2 increased the number of premature deaths from heart and lung disease by 0.88% and 1.09%.

For years, UK air pollution measurements have failed to show improvements in air quality, even as standards have tightened.

"Since 2003 scientists have been saying things are not right. It's not just the VW story, this is part of something much bigger," said Dr Gary Fuller, also of King's College. "It has a serious public health impact."

Last week, a report from NGO Transport & Environment found that Europe's testing regime was allowing nine out of every 10 new diesel vehicles to breach EU limits. Testing regimes in the EU are known to fail to pick up "real world" emissions because cars are not driven in the same way in the laboratory as on the road. Some studies suggest the discrepancy may be up to seven times the legal limit.

Williams said being able to mask their NOx emissions would also enable carmakers to pass carbon emissions tests more easily as there was a trade-off between NOx and CO2 in diesel engines.

Catherine Bearder MEP, a lead negotiator on the EU's new air quality laws, said: "Manufacturers in the US have been caught out, but we know that pollution limits are also being breached in Europe... Unless we take action, thousands of lives will continue to be tragically cut short by air pollution."

In a sign that the emissions scandal will not remain restricted to the US, a Venice court will next month hear a case against VW and Fiat for misleading test advertising.

The Italian consumer rights group Altroconsumo is due to press its case for a class action suit against VW and Fiat on 2 October, after laboratory tests showed that fuel consumption and CO2 emissions from the VW Golf 1.6 and Fiat Panda 1.2 were up to 50% higher than claimed.

Altroconsumo wants the German car firm to pay damages of €502 (£365) to the owner of a VW Golf, in a case that raises the possibility of widescale compensation payouts by the car industry.

Monique Goyens, the director of the European consumer rights umbrella group BEUC, which includes Altroconsumo, called for an investigation by the European Commission into the use of software programmes to 'game' European emissions tests.

"The VW scandal has compounded our concern that underhand tactics are also being used in fuel consumption and CO2 testing programmes in Europe," she said. "One of the problems in the EU, unlike in the US, is the absence of a market surveillance system which would require independent in-use conformity testing. The EU needs to implement such a system to restore trust amongst consumers."

On Tuesday, the Italian government launched an investigation into VW's emissions testing regime.

Wired:
http://www.wired.com/2015/09/vw-fool-epa-couldnt-trick-chemistry/

VW Could Fool the EPA, But It Couldn't Trick Chemistry

Eric Niiler

FOR DECADES, AUTOMAKERS HAVE been caught between building an engine that squeezes a lot of energy out of the fuel it burns and one that has low emissions. It's not an easy tension to resolve. "Negotiating both fuel consumption and emissions is a hard tradeoff," says Anna Stefanopolou, professor of mechanical engineering at the University of Michigan.

When engineers at Volkswagen allegedly inserted a few lines of code into the diesel cars' electronic brains to circumvent emissions testing, they found a solution to this existential automotive conflict. Drivers got low emissions during the test, and high performance the rest of the time. The only problem: It's way outside of the rules. The company might have gotten away with it, too, if it hadn't been for those pesky engineers—and the basic chemistry of the diesel engine.

According to the US EPA, those lines of code hid the fact that nearly half a million diesel VWs in the US spewed up to 40 times more nitrogen oxide from their tailpipes than testing indicated. Volkswagen has now confirmed that the problem actually affects approximately 11 million diesel cars worldwide. Diesel engines use a different mix of fuel than gasoline engines and don't use spark plugs to induce combustion—relying instead on highly compressed, heated air and fuel injected as droplets. If a diesel engine doesn't get enough oxygen to combust the fuel, it'll emit all kinds of gunk—nitrogen oxides, uncombusted fuel, and particulate matter (soot, basically).

All that gunk is a big problem. Exposed to sunlight, nitrogen oxides convert to ozone—making smog. How much depends on a bunch of variables, like sunlight exposure and what happens to the hydrocarbon emissions (the uncombusted fuel), plus the temperature and local winds.

However much extra crap came from the VWs, it won't be good. Exposure to nitrogen oxide and ozone is linked to increased asthma attacks, respiratory illnesses, and in some cases premature death. Ozone also worsens existing cardiovascular and lung disease.

To deal with those emissions, "you have a whole chemical factory at the tailpipe that traps the oxides," Stefanopolou says. This bumps the sticker price for diesel cars by $5,000 to $8,000 per vehicle. (On the other hand, diesels get better mileage, especially in highway driving.)

For years, diesel trucks and buses were the biggest polluters on the highway. But carmakers adapted a relatively new technology called selective catalytic reduction—the same tech that scrubs pollutants from factory smokestacks—to the tailpipe of the diesel engine.

Here's how it works: Inside a honeycombed chamber, the scrubbing system sprays a liquid made of 30 percent urea and 70 percent water into the diesel exhaust. This sets off a chemical reaction that converts nitrogen oxides into nitrogen, oxygen, water and small amounts of carbon dioxide—molecules that aren't as harmful to human health. Catalytic scrubbing was supposed to cut diesel NOx emissions up to 90 percent, according to the Diesel Technology Forum, an industry group based outside Washington. That made diesel engines clean enough to use in passenger cars, which have stricter emissions rules.

The scrubbing chemistry is also what gave away Volkswagen's alleged cover-up. In 2013, a small non-profit group decided to compare diesel emissions from European cars, which are notoriously high, with the US versions of the same vehicles. A team led by Drew Kodjak, executive director of the International Council on Clean Transportation, worked with emissions researchers at West Virginia University to test three four-cylinder 2.0-liter diesel cars in the Los Angeles area: a Jetta, a Passat, and a BMW. Only the BMW passed.

"We felt that it would be possible to get low emissions for diesels," Kodjak said. "You can imagine our surprise when we found two of the three vehicles had significant emissions."

The ICCT reported its findings to the EPA and the California Air Resources Board. Regulators met with VW officials in 2014 and the automaker agreed to fix the problem with a voluntary recall. But in July 2015, CARB did some follow up testing and again the cars failed—the scrubber technology was present, but off most of the time.

How this happened is pretty neat. Michigan's Stefanopolou says computer sensors monitored the steering column. Under normal driving conditions, the column oscillates as the driver negotiates turns. But during emissions testing, the wheels of the car move, but the steering wheel doesn't. That seems to have have been the signal for the "defeat device" to turn the catalytic scrubber up to full power, allowing the car to pass the test.

Stefanopolou believes the emissions testing trick that VW used probably isn't widespread in the automotive industry. Carmakers just don't have many diesels on the road. And now that number may go down even more.

IEEE Spectrum:
http://spectrum.ieee.org/cars-that-think/transportation/advanced-cars/how-professors-caught-vw-cheating

How Engineers at West Virginia University Caught VW Cheating
By Philip E. Ross

Volkswagen, which had just become the biggest-selling automaker in the world, has now been nabbed committing perhaps the biggest corporate cybercrime of all time.

Its diesel cars were found to have cheated systematically on emissions tests run by the United States Environmental Protection Agency (EPA) over the past seven years. When the control system sensed that a test was under way, it would order the engine to ix-nay on the ox-nay—NOx that is, or nitrous oxides—long the bugbear of diesel engines. Later, when the coast was clear, the system would let the NOx pour out at up to 40 times the allowed levels in order to optimize fuel economy.

This dirty trick allowed for a clean getaway for some 482,000 cars under the VW and Audi brand names, including the VW Jetta and the Audi A3. The EPA found out, VW admitted wrongdoing, and it stopped selling the offending vehicles. Its shares lost more than 0ne-fifth of their value in the early hours of the next trading day.

But the guys who found the clues to the crime say they weren't looking for trouble—they were just working under contract to a clean-transportation group that wanted to convince European regulators to adopt stricter emissions standards, as the United States has done.

"We had no cause for suspicion; we thought the vehicles would be clean," John German, of the International Council on Clean Transportation, told Bloomberg news.

The ICCT subcontracted the testing to the University of West Virginia's Center for Alternative Fuels, Engines and Emissions (CAFEE). Its engineers compared emissions measured on a road trip to results from the same cars that their colleagues were getting in the lab. The discrepancies were great.

Dan Corder, head of WVU's Center for Alternative Fuels, Engines, and Emissions (CAFEE)
Some people have mischaracterized what our role was," says Dan Corder, who heads up CAFEE. "Some have used the phrase 'tipped off the EPA.' We didn't."

The engineers from CAFEE reported on these preliminary results in spring of 2014 at the Coordinating Research Council's Real-World Emissions Workshop, which was held in San Diego that year. Corder hastens to add that the results, based as they were on a handful of cars, were preliminary and that they researchers drew no conclusions. According to Corder:

We said, these are two vehicles. We're presenting what we can present. EPA people were in the audience. And the ICCT publicized the results on its website, then delivered them to the EU's Joint Research Center.

From: Gong, Kristiene
Sent: Tuesday, September 22, 2015 11:31 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/22/2015

NY Times:
http://www.nytimes.com/2015/09/23/business/international/volkswagen-diesel-car-scandal.html

Volkswagen Says 11 Million Cars Worldwide Are Affected in Diesel Deception
By JACK EWING SEPT. 22, 2015

FRANKFURT — A scandal that has undermined Volkswagen in the United States spread to its core market of Europe on Tuesday, after the company said that 11 million of its diesel cars worldwide were equipped with software that was used to cheat on emissions tests.

Volkswagen did not provide information on where the affected cars are, but the overwhelming majority are probably in Europe, where the company dominates the market and accounts for more than one of every four cars sold.

The German automaker said it was setting aside the equivalent of half a year's profits — 6.5 billion euros, or about $7.3 billion — to cover the cost of fixing the cars to comply with pollution standards and to cover other expenses, which are likely to include fines as well as responses to civil lawsuits from angry customers.

The carmaker's statement was its first admission that diesel cars outside the United States may contain the software that led the Environmental Protection Agency to accuse the company of deliberately evading pollution tests. Previously, Volkswagen had acknowledged only that the problem affected about 500,000 vehicles in the United States.

The tampered vehicles use what is known as Type EA 189 engines, which are 2-liter engines. The company said on Tuesday that "a noticeable deviation between bench-test results and actual road use was established" for the engines.

Volkswagen said it would also make "other efforts to win back the trust of our customers."

The number of cars involved suggests that the scale of the damage to Volkswagen's reputation and its financial standing may be even greater than thought.

Volkswagen shares fell by nearly 18 percent through late-afternoon trading in Frankfurt on Tuesday, after falling by 16 percent on Monday.

The diesel cars were programmed to sense when emissions were being tested and to turn on equipment that reduced emissions, according to United States officials. At other times, the cars had better fuel economy and performance, but produced as much as 40 times the allowed amount of nitrogen oxide, a pollutant that can contribute to respiratory problems including asthma, bronchitis and emphysema.

"Volkswagen is working intensely to eliminate these deviations through technical measures," the company said.

It is not clear, though, how fully Volkswagen might be able to correct the problem on the 11 million vehicles. The company could presumably alter the engines, so that the cars on the road begin actually meeting the required emissions standards. But doing so would probably degrade the vehicles' fuel economy and

performance, and might cause the engines to wear out sooner.

The E.P.A. has ordered Volkswagen to recall almost a half-million vehicles sold in the United States from 2009 to 2015. The affected Golf, Passat, Jetta and Beetle cars were equipped with 2-liter diesel engines. Some Audi models also use the same diesel engine.

Volkswagen has halted sales of cars with the engines in the United States.

Reuters:
http://www.reuters.com/article/2015/09/22/us-usa-volkswagen-idUSKCN0RL0II20150922

Volkswagen CEO's days appear numbered as emissions crisis deepens
BERLIN | BY ANDREAS CREMER

Martin Winterkorn's days as head of Volkswagen AG appeared numbered on Tuesday after the German carmaker said a scandal over falsified vehicle emission tests in the United States could affect 11 million of its cars worldwide.

The Tagesspiegel newspaper, citing unidentified sources on Volkswagen's supervisory board, said the board would decide on Friday to replace Winterkorn with Matthias Mueller, the head of the automaker's Porsche sports car business.

A Volkswagen spokesman denied the report. The company later said it would post a video statement by Winterkorn at 1500 GMT. A spokesman for Porsche said Mueller was attending a Volkswagen board meeting at its headquarters in Wolfsburg.

A key Winterkorn ally withheld public support for the under-fire chief executive on Tuesday.

"I don't want to preempt the upcoming intense deliberations and will not comment on details or any consequences," Stephan Weil, head of the German state of Lower Saxony, told reporters in Hanover when asked about Winterkorn's future.

Weil, a supervisory board member representing Volkswagen's second-largest shareholder, earlier this year helped Winterkorn to see off a challenge to his leadership by long-time chairman Ferdinand Piech.

Shares in Europe's biggest carmaker plunged almost 20 percent on Monday after it admitted using software that deceived U.S. regulators measuring toxic emissions in some of its diesel cars.

The stock tumbled another 20 percent to a four-year low on Tuesday after some countries in Europe and Asia said they would launch investigations themselves.

Volkswagen said it would set aside 6.5 billion euros ($7.3 billion) in its third-quarter accounts to help cover the costs of the biggest scandal in its 78-year-history, blowing a hole in analysts' profit forecasts.

It also warned that sum could rise, adding diesel cars with so-called Type EA 189 engines built into about 11 million Volkswagen models worldwide had shown a "noticeable deviation" in emission levels between testing and road use.

Volkswagen sold 10.1 million cars in the whole of 2014.

The U.S. Environmental Protection Agency (EPA) said on Friday Volkswagen could face penalties of up to $18 billion for cheating emissions tests. The carmaker also faces lawsuits and damage to its reputation that could hit sales, while media reports have said the U.S. Department of Justice has opened a criminal inquiry into the matter.

The crisis has sent shockwaves through Germany, with Chancellor Angela Merkel calling for "complete transparency" from a company long seen as a beacon of the country's engineering excellence, and newspapers putting the blame squarely on Winterkorn.

The 68-year-old was due to have his contract extended at a supervisory board meeting on Friday, but is now facing questions over why the scandal wasn't averted.

Volkswagen, which for several years has been airing U.S. TV commercials lauding its "clean diesel" cars, was challenged by authorities as far back as 2014 over tests showing emissions exceeded California state and U.S. federal limits.

The company attributed the excess emissions to "various technical issues" and "unexpected" real-world conditions.

It wasn't until the EPA and the California Air Resources Board threatened to withhold certification for its 2016 diesel models that Volkswagen in early September admitted its wrongdoing.

"Winterkorn either knew of proceedings in the U.S. or it was not reported to him," Evercore ISI analyst Arndt Ellinghorst said. "In the first instance, he must step down immediately. In the second, one needs to ask why such a far-reaching violation was not reported to the top and then things will get tough too."

Porsche's Mueller was promoted to Volkswagen's executive board on March 1 and was previously its head product strategist. As a management board member of family-owned Porsche SE, he is also close to the Porsche-Piech clan that has a controlling shareholding in Volkswagen.

"TOTALLY SCREWED UP"

Winterkorn has built Volkswagen into a global powerhouse since he took the helm in 2007, with brands ranging from budget Seats and Skodas to premium Audis and top-end Porsches and Lamborghinis.

But he has also faced criticism for a centralized management style which some analysts say has hampered the company's efforts to address long-standing underperformance in North America.

Workers in Wolfsburg, where Volkswagen employs over 50,000 people, were dismayed by the damage to the company's image. "If Winterkorn knew of the manipulation, then he must go," said one staffer who works at the plant's human resources department.

From: Gong, Kristiene
Sent: Tuesday, September 22, 2015 10:57 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert; Valentine, Julia
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/21/2015

LA Times:
http://www.latimes.com/business/autos/la-fi-vw-subsidies-20150922-story.html

U.S. taxpayers duped into shelling out $51 million in green subsidies for 'clean' VW vehicles
By JERRY HIRSCH

The federal government paid out as much as $51 million in green car subsidies for Volkswagen diesel vehicles based on falsified pollution test results, according to a Times analysis of the federal incentives.

On Friday, federal and state regulators said the German automaker used software in 482,000 of its diesel vehicles since the 2009 model year to cheat on U.S. emissions tests. Environmental Protection Agency

officials said Monday that the U.S. Department of Justice is also investigating.

The Times analysis matched Internal Revenue Service data with Volkswagen sales figures to determine the value of subsidies VW diesel buyers were eligible to collect in 2009, the first and only year the vehicles qualified. The $1,300 tax credit would have been available to buyers of about 39,500 Jetta and Jetta Sportwagen models that sold that year, according to Motor Intelligence, an industry research firm.

"It is really unfortunate," said Luke Tonachel, director of clean vehicles and fuels project at the Natural Resources Defense Council. "The government has been effective to help advance clean technologies, but it is a waste of taxpayer dollars when they aren't actually helping to clean the environment."

He said regulators should factor in the $51 million in subsidies when determining penalties for Volkswagen's Clean Air Act violations.

Such green car incentives have also gone to buyers of hybrid, electric and hydrogen fuel cell cars. But the EPA does not track aggregate figures for incentives paid out to buyers of specific models or brands.

The Volkswagen diesels qualified for the federal incentives in the same year the automaker first installed the software trick it used to cheat on emissions tests. The so-called defeat device employed an algorithm that automatically detects when the vehicle is undergoing pollution tests and changes the way the engine performs.

The algorithm senses whether the car is in a testing environment by analyzing a variety of data — steering position, speed, duration of engine operation and barometric pressure.

Away from the laboratory, during everyday driving, the cars emit up to 40 times the legally allowed amount of nitrogen oxide, environmental officials said.

The Environmental Protection Agency and the California Air Resources Board discovered the software. The EPA said Monday it will coordinate with federal prosecutors on further enforcement and penalties.

How Volkswagen cheated on emissions rules
Autos editor Brian Thevenot explains how Volkswagen used a software trick to hide illegal pollution levels in half a million diesel cars.

"Determinations regarding potential penalties and other remedies will be assessed as part of the investigation EPA has opened in conjunction with the U.S. Department of Justice," said EPA spokeswoman Liz Purchia.

The Justice Department has lately taken on a leading role in major investigations of automakers, usually leveraging the threat of criminal charges to exact huge fines.

Last week, General Motors agreed to pay a $900-million fine to settle an investigation into why it did not promptly recall cars with a defective ignition switch that has led to crashes causing 124 deaths. Last year Toyota signed a $1.2-billion settlement and admitted to deceiving regulators about deadly safety defects that allegedly caused unintended sudden-acceleration incidents.

No individuals were charged in the GM and Toyota probes.

"This might be the perfect case for Department of Justice to come down on the criminal side against individuals and not just the company," said Carl Tobias, a University of Richmond law professor. "Someone had to do the computer programming. Someone had to OK this, and all in what is known as an autocratic, top-down company."

The German automaker admitted installing the software after it was confronted by regulators. In a statement Sunday, VW Chief Executive Martin Winterkorn said, "I personally am deeply sorry that we have broken the trust of our customers and the public."

Winterkorn said the automaker "will cooperate fully with the responsible agencies, with transparency and urgency, to clearly, openly and completely establish all of the facts of this case."

He said VW has also ordered an external investigation into the matter, pledging to "do everything necessary in order to reverse the damage this has caused."

Volkswagen declined to comment on the Times analysis of its revenue from the federal Alternative Motor Vehicle Credit.

Volkswagen shares fell $33.89, or 18.5%, to close Monday at $149.68.

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This was the second time Volkswagen has been charged with using devices to evade U.S. emission-control rules.

In 1974, the automaker paid a $120,000 fine to settle EPA charges that it gamed pollution control systems in four models by changing carburetor settings and shutting off an emissions-control system at low temperatures. VW didn't admit guilt but pledged management changes to ensure future compliance with EPA regulations.

This time the monetary damage could be much greater.

The automaker will have to recall all the vehicles and modify the emissions systems at its own expense, regulators said. Additionally it could face a fine of as much as $18 billion, or $37,500 per car. And for now it has suspended sales of thousands of new and used diesel models sitting on dealer lots — cars that are depreciating rapidly while the automaker develops a fix for the emissions system.

The affected diesel models are Jetta (model years 2009-15), Beetle (2009-15), Audi A3 (2009-15), Golf (2009-15) and Passat (2012-15).

Volkswagen also will face civil lawsuits on two fronts, including consumer fraud cases and class-action litigation for what is called a "diminished value" lawsuit. The vehicles are likely to lose some of their resale value because of the problem.

The Volkswagen case breaks new ground for how corporations can make "end runs" around legal requirements, said Ryan Calo, a University of Washington professor and expert in robotics and autonomous systems law and policy.

A company, for example, might learn of an inspection at a construction site and then make sure that workers wear helmets or it might clean a food plant thoroughly before a scheduled review even if it doesn't operate that way all the time.

"But this is encoded," Calo said. "I bet that it happens elsewhere but it is rare we detect it because we typically don't go through the code. There could be many examples in everyday things."

The VW issue demonstrates why regulators need more technical expertise, including a federal robotics commission, he said.

"We need experts in a centralized place whether the issues are drones, driverless cars or things like the VW example," Calo said.

From: Gong, Kristiene
Sent: Tuesday, September 22, 2015 10:34 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/21/2015

WSJ:
http://www.wsj.com/articles/epa-is-upping-its-game-after-volkswagen-allegations-1442929373

EPA is 'Upping its Game' After Volkswagen Allegations
Top administrator is pleased with auto maker's 'aggressive stance' on tackling problem
By JEFFREY SPARSHOTT
Sept. 22, 2015 9:42 a.m. ET

WASHINGTON—The top official at the Environmental Protection Agency said the agency is "upping its game" in the search for possible violations of U.S. pollution rules following allegations that Volkswagen AG circumvented emissions standards.

"We are not going to sit around and worry about whether others have it, we are going to find it," Gina McCarthy said at a Wall Street Journal breakfast Tuesday. "Right now, we are upping our game in terms of going out and doing work to take a look at what we need to do with other vehicles."

The EPA last week accused Volkswagen of dodging air-pollution rules on nearly half a million cars sold in the U.S. The German company has since halted American sales of the diesel-powered cars at issue and apologized for violating customers' trust.

Volkswagen allegedly used software, dubbed a "defeat device," in the cars to make diesel-powered engines appear to have lower levels of emissions than they actually did. About 482,000 Volkswagen diesel-powered cars sold in the U.S. since 2008 were affected.

Ms. McCarthy said the alleged violation was difficult to detect, but she is "pleased Volkswagen is taking such an aggressive stance on admitting the problem and attacking it."

"I think we have to be concerned whether there are other defeat devices out there that we have not been able to detect," she said. But the auto industry is well aware of the pollution rules and has been working to comply.

"I think it will be very difficult for Volkswagen at this point to be looked at as nothing other than an outlier," Ms. McCarthy said.

Detroit Free Press:
http://www.freep.com/story/news/2015/09/21/us-house-panel-hold-hearing-vw/72583066/

Congress to hold hearing on VW air emissions violation
Todd Spangler and Nathan Bomey, Detroit Free Press and USA Today 8:15 p.m. EDT September 21, 2015

WASHINGTON — Congressional investigators will hold a hearing in the coming weeks to take testimony on allegations raised by the U.S. Environmental Protection Agency that Volkswagen sold hundreds of thousands of diesel-powered vehicles with software to get around air emission limits.

U.S. Rep. Fred Upton, who chairs the House Energy and Commerce Committee, said Monday that the committee's Oversight and Investigations Subcommittee will look into the EPA's allegations, which were first raised Friday. VW's stock value plunged Monday in the aftermath of the revelations, which could affect some 500,000 vehicles and potentially result in fines totaling as much as $18 billion.

Volkswagen's CEO said he was "deeply sorry" for violating U.S. emissions standards and on Sunday ordered an external investigation, two days after the EPA accused the automaker of purposefully manipulating emissions tests for almost 500,000 vehicles.

The German automaker ordered its U.S. dealerships to stop selling cars impacted by the probe until its engineers can deliver a fix.

A date was not set for the congressional hearing but Energy and Commerce staff said it would come within the next several weeks.

“Strong emissions standards are in place for the benefit of public health," Upton, R-St. Joseph, and subcommittee Chairman Tim Murphy, R-Pa., said in a joint statement. “We will follow the facts. We are ... concerned that auto consumers may have been deceived — that what they were purchasing did not come as advertised."

As the Free Press reported Friday, the EPA and the state of California accused VW of violating the Clean Air Act by using software in some 482,000 diesel-powered vehicles that could detect when the car was undergoing official emissions testing and turn full emissions controls on only during the test. The effectiveness of pollution control equipment was reduced otherwise.

EPA's violation notice covered model year 2009-15 Jettas, Beetles, Audi A3s and Golfs and model year 2014-15 Passats.

As a result, Volkswagen had a hand in potentially exposing people to harmful pollutants at levels 40 times the acceptable standard and that could exacerbate respiratory conditions such as asthma, the EPA charges.

"I personally am deeply sorry that we have broken the trust of our customers and the public," Martin Winterkorn, Volkswagen's CEO, said in a statement. "We will cooperate fully with the responsible agencies, with transparency and urgency, to clearly, openly and completely establish all of the facts of this case."

"We do not and will not tolerate violations of any kind of our internal rules or of the law," Winterkorn said. The company's board takes the allegations "very seriously," he said.

The violations could expose Volkswagen — the world's largest vehicle manufacturer through the first six months of 2015 — to up to $18 billion in federal fines if the EPA assesses the maximum possible penalty of $37,500 per vehicle.

The violations could invite charges of false marketing by regulators, a vehicle recall and payment to car owners, either voluntarily or through lawsuits. Volkswagen advertised the cars under the "Clean Diesel" moniker.

The state of California is investigating the emissions violations.

The EPA accused the German automaker of adopting what it called a "defeat device" to trick U.S. regulators into believing its cars met Clean Air Act standards for nitrogen oxides. Volkswagen admitted to investigators it had installed the defeat device, the EPA said.

Volkswagen told dealers they cannot sell the 4-cylinder diesel versions of those cars until a fix is available, Volkswagen spokesman Mario Guerreiro said Sunday.

The sales halt could put a significant dent in the company's September sales performance. About 20% of Volkswagen's vehicle sales are diesel engines, said AutoPacific analyst Dave Sullivan.

"It totally goes against all of the marketing they have had of a clean diesel," Sullivan said of the violations. "That’s one of the biggest selling points for Volkswagen."

"The trust of our customers and the public is and continues to be our most important asset," Winterkorn said Sunday. "We at Volkswagen will do everything that must be done in order to re-establish the trust that so many people have placed in us, and we will do everything necessary in order to reverse the damage this has caused. This matter has first priority for me, personally, and for our entire Board of Management."

Chicago Tribune:
http://www.chicagotribune.com/business/ct-volkswagen-owners-0921-biz-20150921-story.html

Volkswagen owners should be nervous about emissions scandal, experts say
Becky Yerak and Gregory Karp

Volkswagen hit with class-action suit over emissions cheating.
Automobile recalls, even huge, highly publicized ones, typically don't hurt new or used car sales, but the Volkswagen scandal involving tricking emissions testers is different and could be cause for worry among VW diesel vehicle owners, experts say.

At least one class-action lawsuit has already been filed on behalf of Volkswagen and Audi owners. It claims fraud and breach of contract, citing the "diminished value" of the nearly 500,000 recalled diesel vehicles, which usually sell for a premium price over their gasoline counterparts. Specifically, after recalled Volkswagen diesels are fixed, the cars might have degraded horsepower and fuel efficiency, the suit says.

The EPA says Volkswagen violated the federal Clean Air Act by installing "defeat devices" — software programmed to switch engines to a cleaner mode during official emissions testing. The software then switches off again, enabling cars to emit as much as 40 times the legal limit of pollutants during normal driving.

Volkswagen marketed the diesel-powered cars as being better for the environment. The affected diesel cars, according to the EPA's letter to Volkswagen on Friday, include: Jetta, 2009 to 2015; Jetta SportWagen TDI, 2009 to 2014; Beetle, 2012 to 2015; Beetle Convertible, 2013 to 2015; Audi A3, 2010 to 2015; Golf, 2010 to 2015; Golf SportWagen TDI, 2015; and Passat, 2012 to 2015.

Consumer Reports called the Volkswagen scandal "outrageous" and a violation of law.

"Volkswagen was ripping off the consumer and hurting the environment at the same time," said Ellen Bloom, senior director of federal policy for Consumers Union, the policy and advocacy arm of Consumer Reports.

The EPA has ordered VW to fix the cars at its own expense but said car owners do not need to take any immediate action. The EPA insisted that the violations do not pose any safety hazard and said cars on the road remain legal to drive. Volkswagen has ordered a stop to sales of new and used TDI cars in stock.

The EPA said, however, that the cars pose a threat to public health. The agency said the carmaker could be fined more than $18 billion.

The automaker is also part of a criminal probe by the U.S. Justice Department, unnamed sources told The Associated Press and Bloomberg News.

In the Chicago region, Volkswagen dealerships were not responding to inquiries Monday, except one that said it hadn't heard from any consumers about the issue and expressed confidence the problem would be taken care of.

For consumers, whether diesel Volkswagens from seven model years will really have less value is an open question.

During recent high-profile recalls by GM, Toyota and Honda, there has been very little, if any, impact on sales, said officials from Kelley Blue Book, Black Book and Edmunds.

"With so many recalls in the news, they easily become white noise for a lot of consumers, and they don't appear to have much of an influence on shopping decisions," according to Edmunds.com.

Even when there's intense media coverage, the impact on resale value is "fleeting," as with the Toyota recall for accelerators that would stick, said Eric Ibara, a senior analyst with Kelley Blue Book. "It lasted for maybe six or eight months, and their resale values popped back to where they normally were.

Still, the Volkswagen recall is different.

First, it doesn't involve a safety issue but more a breach of public trust. "The impact on that could be longer-lasting," Ibara said. "Our concern is their image is tarnished ... I imagine if you own a Volkswagen, you're reading the coverage of what they've done."

Indeed, when a car is recalled for a safety reason, the recall could actually improve goodwill with the customer, said Anil Goyal, vice president of Automotive Valuation and Analytics for Black Book.

Another concern for current owners is how the resale values will react when Volkswagen eventually restarts selling the diesel models now sitting idle on lots after it stopped selling. "If they show up with higher incentive levels, that certainly impacts the used-car values," Ibara said.

In other words, if VW chooses to get rid of that inventory by offering great incentives and significantly lowering diesel car prices, demand for used cars would drop along with their prices.

Volkswagen offers some of the least expensive diesel models and in recent years had been a market leader in that segment of the vehicle market, said John Voelcker, editor of GreenCarReports.com. "Diesels in this country have mostly been confined to trucks," Voelcker said. "VW was the only volume maker of diesel cars."

According to Edmunds, VW and Audi account for 17 of 44 vehicle models that offer diesel engines, or 39 percent.

Diesel vehicles fetch a premium price both in the new and used markets. The premium price paid by new-car buyers for the diesel version of the recalled cars varies from $1,000 to almost $7,000, according to list prices.

In a quick analysis by Swapalease.com, a 3-year-old base model Volkswagen Golf using gasoline sold for 51 percent of its original value, while a diesel sold for 57 percent, said Scot Hall, executive vice president of operations for Swapalease.com. "That's a significant difference," he said.

It's an open question whether the VW diesels, which have TDI as part of the name for turbocharged direct injection, will retain the premium over their gasoline counterparts, Ibara said. "It would not surprise me if they drop a little bit, but I do not expect the premium to entirely disappear."

What fix Volkswagen will employ is unclear, whether it's a software solution or some physical repair or retrofit. It may just restate the fuel economy to be lower on diesels — maybe 3 to 5 mpg — and then be faced with offering some compensation to owners, Ibara said.

So far, it's difficult to say for sure that a fix would hurt the vehicle's fuel mileage, performance or reliability. But some current owners are expecting that, Hall said.

Hall said there's talk that some Volkswagen owners would avoid the fix because they prefer more power, better performance and greater fuel economy and care less about the emissions.

Consumer Reports said that, as a result of the scandal, it has suspended its "recommended" rating of two VW vehicles, the Jetta diesel and Passat diesel, until it can retest the cars with the recall repair performed. It said it will also assess whether the repair hurts performance or fuel economy.

The potential downgrade in performance was also mentioned in the class-action lawsuit,

filed on behalf of David Fiol, a California resident and 2012 VW Jetta SportWagen TDI owner. He seeks class-action status both nationally and in California, for unspecified punitive damages and legal fees, among other things.

Fiol, in his lawsuit, mentions "future additional fuel costs" and the "diminished value" of his vehicle, despite

the recall.

Volkswagen won't be able to make the vehicles "comply with emissions standards without substantially degrading their performance characteristics, including their horsepower and their efficiency," the lawsuit said. "As a result, even if Volkswagen is able to make" plaintiffs' vehicles EPA compliant, the owners "will nonetheless suffer actual harm and damages because their vehicles will no longer perform as they did when purchased and as advertised."

Volkswagen didn't immediately respond to a request for comment about the lawsuit, filed last Friday by Seattle law firm Hagens Berman Sobol Shapiro in a U.S. District Court in the Northern District of California.

In Illinois, diesel vehicles like the VWs in question don't require emissions inspections like gasoline models, so the flap won't affect owners in that way, according to a spokeswoman for the Illinois Environmental Protection Agency.

From: Gong, Kristiene
Sent: Tuesday, September 22, 2015 10:12 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/21/2015

NY Times:
http://www.nytimes.com/2015/09/22/business/it-took-epa-pressure-to-get-vw-to-admit-fault.html?_r=0

It Took E.P.A. Pressure to Get VW to Admit Fault
By BILL VLASIC and AARON M. KESSLER SEPT. 21, 2015

Volkswagen executives told environmental regulators for more than a year that discrepancies between pollution tests on its diesel cars and the starkly higher levels out on the road were a technical error, not a deliberate attempt to deceive Washington officials.

But this month, the executives made a startling admission: The diesel vehicles it sold in the United States used software meant to cheat on the tests.

VW made the admission only when the Environmental Protection Agency took the extraordinary action of threatening to withhold approval for the company's 2016 Volkswagen and Audi diesel models, according to letters sent to company officials by the E.P.A. and California regulators.

Since that deception became public on Friday, Volkswagen has scrambled to conduct damage control. The chief executive apologized and the company said it would stop selling diesel-powered cars from the 2015 and 2016 model years.

All this was possible because environmental regulators had tools and powers at their disposal that another area of enforcement — auto safety regulation — does not have, despite the efforts of lawmakers, consumer advocates and, more recently, auto safety regulators themselves. Often, the auto industry has beaten back more stringent laws.

The National Highway Traffic Safety Administration, for example, can impose a maximum penalty of $35 million on an automaker that flouts safety regulations — a relatively low sum for a company like General Motors, which last year paid such a fine for a defect that has now been linked to at least 124 deaths.

By contrast, under the Clean Air Act, Volkswagen, the world's largest automaker, could be fined as much as $37,500 for each recalled vehicle, for a possible total penalty of as much as $18 billion.

“The Clean Air Act statutory scheme gives E.P.A. more power and flexibility to move more quickly than N.H.T.S.A.,” said Carl Tobias, a law professor at the University of Richmond, who has studied the government’s response to auto safety issues. “E.P.A. also seems more tough-minded and savvy about how to be effective in this arena.”

Still, the time it takes to investigate auto companies is often extensive, and getting the facts can be a challenge. “Even E.P.A. took a year to finally crack this case open,” he said.

Beyond the E.P.A., the government has other tools at its disposal when it comes to enforcing environmental regulation.

As G.M. did, Volkswagen now faces a criminal investigation by the Justice Department, according to a person briefed on the inquiry. It is being conducted, though, by the department’s Environment and Natural Resources Division, which is devoted to violations of environmental law. “Nearly one-half of the division’s lawyers bring cases against those who violate the nation’s civil and criminal pollution-control laws,” the department’s website says.

And on Monday, a subcommittee of the House Energy and Commerce Committee said it would hold a hearing on the issue.

It’s only part of the pressure being applied to Volkswagen. An official with the Environmental Protection Agency said that discussions are continuing with Volkswagen, as the company grapples with how to handle a recall of the affected vehicles.

“We still have many questions for the company,” said Christopher Grundler, head of the agency’s transportation office. “It’s the responsibility of Volkswagen and Audi to prepare a remedy for these vehicles.”

There is no timetable for Volkswagen to submit a comprehensive plan to recall and fix the affected vehicles. But government officials are urging the company to take action quickly — both on developing a fix for the cars and starting a campaign to educate consumers on the problem.

“This does not happen immediately,” Mr. Grundler said. “And we’ve been trying to be clear with the consumers that their vehicles are safe and they don’t have to do anything right now.” The assessment of fines for the violations will also not happen immediately. “That is down the road,” he said.

“But we feel a sense of urgency to address the emissions of these vehicles that are already on the road.”

A Volkswagen spokesman, John Schilling, said the automaker was “committed to fixing this issue as soon as possible” and to developing “a remedy that meets emissions standards and satisfies our loyal and valued customers.”

Even with the looming punishment, the company almost got away with it. In fact, it most likely would have if not for a strange twist of fate and the curiosity of several auto researchers.

Two years ago, the International Council on Clean Transportation, a nonprofit environmental group staffed by a number of former E.P.A. officials, had been testing the real-world performance of so-called clean diesel cars in Europe, and were less than impressed with the emissions results.

The group decided it would test diesel-powered cars in the United States, where regulations were much more strict, as a way of almost shaming the European automakers to tighten their compliance. The group fully expected the American cars to do well, and run cleaner than their counterparts across the pond.

What they could not have foreseen was that they would stumble onto one of the biggest frauds in recent automotive history.

Further, on the campus of West Virginia University, a group of emissions researchers who mainly dealt with

heavy trucks noticed an unusual posting by the transportation council, which was looking for a partner to test diesel-powered cars.

"No one had done that before in the U.S.," said Arvind Thiruvengadam, a professor at the university. "It sounded very interesting, to test light-duty diesel vehicles in real-world conditions. We looked around at each other said, 'Let's do it.' "

The university's team bid on the project and got the contract. Mr. Thiruvengadam and his colleagues never envisioned where it would lead. "We certainly didn't have an aim of catching a manufacturer cheating," he said. "It didn't even cross our minds."

The study also did not target Volkswagen specifically. It was something of a fluke, he said, that two out of three diesel vehicles bought for the testing were VWs.

It did not take long for suspicions to set in. The West Virginia researchers were well-versed in diesel performance on real roads, and had certain expectations for how the test cars should ebb and flow in their emissions. But the two Volkswagens behaved strangely.

"If you're idling in traffic for three hours in L.A. traffic, we know a car is not in its sweet spot for good emissions results," Mr. Thiruvengadam said. "But when you're going at highway speed at 70 miles an hour, everything should really work properly. The emissions should come down. But the Volkswagens didn't come down."

Even then, however, it is difficult for most researchers to be sure exactly what is going on. There are so many factors involved in real-world driving — speed, temperature, topography, braking habits. It is not unheard-of for cars to perform much differently in on-the-road tests than one expected.

But this time there was a key difference: The California Air Resources Board heard about the groups' tests and signed on to participate. The regulators tested the same vehicles in their specially equipped lab used to judge cars' compliance with state emissions standards. That gave the project what most studies lacked: a baseline.

"That broke loose everything," Mr. Thiruvengadam said.

In the lab, the two VWs performed flawlessly. But when they were taken out on the roads in California, they were belching out levels of nitrogen oxide that were 30 to 40 times higher than the regulatory standards. Even the heavy-duty trucks the researchers had tested had never performed that poorly by comparison.

"It just didn't make sense," said John German, one of the leaders on the project at the transportation council. "That was the real red flag for us."

Forbes:
http://www.forbes.com/sites/maggiemcgrath/2015/09/22/goldman-chief-lloyd-blankfein-discloses-highly-curable-cancer/

Volkswagen Credit Spreads Soar After EPA Charges Co. With Evading Pollution Controls
John Atkins, CONTRIBUTOR

Credit spreads referencing German automaker Volkswagen widened sharply today after the U.S. Environmental Protection Agency on Friday charged the company with evading government pollution controls through software designed to allow diesel models to meet clean-air standards, but only during official emissions testing. The government demand for recalls affects roughly 500,000 vehicles.

Volkswagen five-year CDS costs increased 80% today, rising 60 bps to the 135 bps area, or a high since 2012, trade data show. The 2.45% notes due Nov. 20, 2019 issued by subsidiary Volkswagen Group of America

Finance last November, at T+85, changed hands today as much as 77 bps wider on the session, reaching at G-spread equivalents as wide as T+180, according to MarketAxess.

Credit analysts today noted the significant potential risks to VW's credit standing and reputation. "VW's operating margins have lagged peers (BMW, Daimler) for some time, and the automaker has cited encouraging U.S. vehicle sales in the context of its 2015 revenue and profit outlook," stated FTN Financial senior credit strategist Benjamin Millard in a credit note.

While it acknowledged uncertainties regarding the impact of the scandal on Volkswagen's brand image and reputation – and terming the development a "crisis" for VW – Fitch today said the scandal is unlikely to trigger an immediate downgrade of Volkswagen's A rating, even though Volkswagen reportedly faces a maximum penalty of $18 billion as well as any costs related to a recall effort.

"We believe the fine is unlikely to amount to the theoretical maximum amount of USD37,500 per car, although there have been only very few precedents of such cases and associated fines. In addition, the group's financial structure is sound and its free cash flow (FCF) generation extremely robust," Fitch stated today.

The outlooks on the respective A/A2 ratings at S&P and Moody's are currently stable, through S&P warned as recently as Sept. 7 that stricter carbon rules were fueling high capital spending demands on Europe's carmakers.

TIME:
http://time.com/money/4042745/volkswagen-epa-diesel-scandal/

The Volkswagen Diesel Emissions Scandal, By the Numbers
Ethan Wolff-Mann @ewolffmann Sept. 21, 2015

VW is accused of faking pollution tests on a grand scale.

Last week, the EPA accused Volkswagen of deliberately falsifying tests of its diesel engine cars so that the vehicles would pass anti-pollution standards. A massive recall of nearly half a million Volkswagen diesel cars was ordered, causing a major stir in the industry—and especially among VW owners who had been drawn to the vehicles because of the automaker's "clean diesel" claims.

Let's look at the situation by the numbers.

482,000 Diesel cars affected, which include TDI Jettas, Beetles, Golfs, and Audi A3s from 2009-15 and Passats from 2014-15.

$37,500 Fine per vehicle that the German automaker could face in the U.S.

$18 billion Possible total penalties faced by Volkswagen, and that figure doesn't include fixing the recalled cars.

40 Times over the legal limit of certain types of pollution emitted by the vehicles, including nitrogen oxide—which can cause respiratory problems.

$6,855 Premium that buyers were paying for Passat TDI cars over standard gasoline versions.

-20% The hit Volkswagen stock has taken since the scandal.

12 Number of months Volkswagen has been denying cheating on the emissions test.

2017 When Volkswagen may sell diesel cars again in the U.S., now that sales have been halted.

2.0 Liter 4-cylinder engines affected. Larger diesel engines used in SUVs don't have the software at the center of the controversy.

$0 Current resale value of affected cars in California, because the cars were sold as "non-compliant" (and therefore cannot be resold).

14.28% Of affected cars that are registered in California

23 Percentage of Volkwagens sold in August that were diesels.

Automotive News:
http://www.autonews.com/article/20150921/OEM11/150929980/vws-diesel-sales-frozen-until-compliance-is-proven-epa-official-says

VW's diesel sales frozen until compliance is proven, EPA official says
Fix must be approved before recall can begin
Chris Grundler: "It will take more work to determine what the appropriate remedy for these vehicles is."
By Ryan Beene

WASHINGTON -- With its diesel car lineup grounded by an emissions-test cheating scandal, Volkswagen now bears the burden of proving that these vehicles comply with federal emissions standards, the EPA's top auto regulator said.

Until then, said Chris Grundler, director of the EPA's Office of Transportation Air Quality, no sales.

Meanwhile, Grundler said, the EPA and California regulators are now probing all light-duty diesel vehicles in the U.S. market from all manufacturers to check for illegal software designed to fool U.S. emissions tests.

U.S. regulators accused VW on Friday of violating the Clean Air Act by selling 482,000 diesel-powered vehicles with such illegal software. The agency said the company admitted to fitting seven model years' worth of diesel cars with the softwared -- termed a "defeat device" -- that would activate the cars' emission controls during testing, but deactivate them in real-world driving.

In order to be able to resume sales of diesels, Grundler said, VW has to engineer a fix to bring those vehicles into compliance, and receive EPA approval before a recall can commence. It's not clear yet whether that fix will consist of a change to the engine's emission control software or more substantial engineering changes to vehicle hardware, Grundler said.

According to the EPA's website, it could take up to one year to identify "corrective actions," develop a recall plan and issue recall notices. But Grundler declined to discuss a specific timetable.

"Until we gather that information and are convinced ... we're not going to go forward with the recall," Grundler said. "It will take more work to determine what the appropriate remedy for these vehicles is."

Capitol Hill
U.S. lawmakers want more answers, too.

Republican leaders of the House Energy and Commerce Committee today announced plans to hold a hearing on the VW emissions scandal in the near future. The hearing will be held before the panel's Oversight and Investigations Subcommittee, though no date has been set.

"We will follow the facts. We are also concerned that auto consumers may have been deceived – that what they were purchasing did not come as advertised," U.S. Reps. Fred Upton, R-Mich., and chairman of the Energy and Commerce Committee and Tim Murphy, R-Pa., chairman of the investigations subcommittee, said in a joint statement.

"The American people deserve answers and assurances that this will not happen again. We intend to get those answers."

Also in Washington, the White House said today it was "quite concerned" about reports it was seeing concerning VW's conduct in complying with U.S. Clean Air Act requirements.

"It's fair to say that we're quite concerned by some of the reports that we've seen about the conduct of this particular company, but ultimately this is the responsibility of the EPA to take a look at it and that's exactly what they're doing," said White House spokesman Josh Earnest.

California questions
VW will also have to convince the EPA and California's Air Resources Board that its 2016 model year diesel vehicles will comply with emissions standards and are free of any illegal software, Grundler said. Until then, the agency will continue to withhold the emission certifications needed to begin sales of those models, which are currently being withheld from dealers.

The sales suspensions are a blow to Volkswagen, which counts on diesels for more than one-fifth of the VW brand's sales volume, and has touted its "clean diesel" technology as a key differentiator in the marketplace.

"We've been working with the company for a long time trying to get answers and it wasn't until very recently that VW admitted that these vehicles contained software designed to defeat the emissions standards," Grundler said. "We want to make sure that 2016 model vehicles don't operate the same way."

Popular Mechanics:
http://www.popularmechanics.com/cars/a17430/ezra-dyer-volkswagen-diesel-controversy/

This VW Diesel Scandal Is Much Worse Than a Recall
This isn't cost-cutting. This is outright cynical deceit.
By Ezra Dyer

Most of the time, media test cars are distinguished only by a license plate that might bear a discreet "manufacturer" tag. Audi diesels, though, are a different matter. Whether a Q7 or an A3, the diesel press cars from Audi (which is part of the Volkswagen group) always bear towering "TDI Clean Diesel" decals across their flanks. I guess the theory is that when the cars are out on the road they're serving double duty as billboards, spreading the gospel about the Volkswagen group's engineering prowess.

A few years ago I bought a nasty Ford F350 diesel for an engine swap, and I parked it next to an Audi A3 and took a few shots to capture the juxtaposition: truck from the dirty diesel past, Audi harkening to the clean-burning future. That certainly looks ironic today.

If you're not up to speed on Volkswagen's shenanigans, you can catch up here. Suffice to say that it seems the A3's sanctimonious TDI Clean Diesel stickers were relevant only when the cars were actually undergoing an EPA emissions test. Out in the real world, 2.0-liter Volkswagens and Audis were as much as 40 times above the legal emissions limit for nitrogen oxides (NOx). According to the EPA, about 482,000 four-cylinder Volkswagens and Audis built since 2009 included what the agency defines as a "defeat device," which is really just software that detects an emissions test and "turns full emissions controls on only during the test." The cheater software was discovered by researchers at West Virginia University who were trying to document the cleanliness of modern diesels. Volkswagen surely wishes they hadn't bothered.

The revelation of this emissions subterfuge answers at least two questions about VW's mighty little diesel. The first concerns urea injection, which every other modern diesel uses to pass emissions tests. The urea-injection systems help to neutralize NOx emissions, but they also add weight and cost to the car, and saddle car buyers with yet another tank of liquid that must be monitored. If you run out of this diesel exhaust fluid, it's like running out of fuel—on trucks with such systems, running dry on urea triggers a severe limp-home mode with

a 5 mph speed limiter. That's how seriously the EPA takes NOx.

Everyone wondered how VW met emissions standards while foregoing urea injection. As it turns out, they didn't. It wasn't magical German engineering. Just plain old fraud.

The second question concerned fuel economy. It's been widely noted that four-cylinder TDIs tend to smash their EPA fuel economy estimates in real-world driving. The last TDI Jetta SportWagen I drove was rated at 42 mpg highway, but on 60-mph two-lane roads I averaged more like 50 mpg. That's a huge difference. Did running non-compliant emissions improve fuel economy? That's possible. And if so, that raises an interesting question: When the cheater VWs emitted too much NOx, were they also emitting a lot less CO2 thanks to improved economy? Maybe the good doesn't offset the bad, but it's something to consider. You can bet that VW's lawyers will.

THE INTENTIONALITY BEHIND THE DECEIT MAKES THIS SITUATION DIFFERENT FROM EVEN A HUGE-SCALE RECALL.
So, how is Volkswagen going to fix this? Putting aside the inevitable fines, possible criminal charges, and massive public disgrace, there are half a million cars running an emissions setup that never should've left the factory. And there's no quick fix to make up for VW's lies.

All the other carmakers control diesel emissions by spraying a urea solution into the exhaust stream, where a catalyst converts it to ammonia. The ammonia breaks down NOx into nitrogen and water. If all of that sounds like it would be tough to bolt right in, you're correct. Maybe VW can meet the standards without adding equipment—say, by tweaking the engine control unit (ECU) with a different tuning. But what if that new tuning meets the emissions standards but sacrifices performance or fuel economy? Now you've got 482,000 customers on a class action lawsuit.

There's no easy way out of this, but they'd better figure something out, and pronto. Right now dealers are banned from selling 2.0-liter TDIs, which make up about a quarter of VW's U.S. sales. News of the scandal caused VW to lose about a quarter of its market value, indicating that investors understand how bad this is. There's no cheap fix nor easy settlement here.

The intentionality behind the deceit makes this situation different from even a huge-scale recall. This isn't a story about a part that was made one cent cheaper than it should've been, where a car company cut a corner to save a little cash. It's about a huge corporation eying the rulebook and deciding there's a competitive advantage in violating the Clean Air Act. Incompetence is one thing, but calculated mendacity is quite another.

It's too bad. That Golf SportWagen TDI is a punchy, fun car. It's got great fuel economy, tons of torque and a bargain price. But when something seems a little too good to be true, maybe that's because it is.

From: Gong, Kristiene
Sent: Monday, September 21, 2015 4:33 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/21/2015

Chicago Tribune:
http://www.chicagotribune.com/business/columnists/ct-rosenthal-vw-emissions-0922-biz-20150921-column.html

VW comes clean on dark heart of its diesel cars. Can it clear the air?
Phil Rosenthal

Seems VW fought diesel wars with smoke and mirrors, mostly smoke. What the fahrvergnügen?! Volkswagen called it clean diesel. Clean like Lance Armstrong. Clean like the Chicago River.

Seriously, what the fahrvergnügen?!

VW has admitted to the Environmental Protection Agency that hundreds of thousands of its diesel cars have been using what is literally a killer app.

The software allowed the vehicles to sail through U.S. emissions tests while reportedly spewing 10 to 40 times the level of certain pollutants as allowed in ordinary use.

It's been smoke and mirrors — mostly smoke — for the last seven model years.

We're talking about 2009, 2010, 2011, 2012, 2013, 2014 and 2015 VW Golfs, Jettas and Beetles, along with Audi A3s, equipped four-cylinder, 2.0-liter turbodiesel engines. Oh, almost forgot the 2012-15 Passats.

That's nearly half-a-million vehicles in all, belching nitrogen oxide to preserve mileage ratings and performance no other carmaker could seem to match, thanks to emissions control systems programmed to operate only when testing protocols were detected.

So we get more smog and ozone and poisons tied to a litany of health problems, such as asthma attacks and other respiratory diseases, along with premature death. VW gets more car sales.

Score one for German engineering and systematic subterfuge, trading our health for its profits.

Apparently the EPA was first tipped to VW's plot when discrepancies showed up in independent testing. But it seems like precisely the sort of thing James Bond is told of when strapped to a nuclear missile about to launch.

The word diabolical comes to mind.

So does evil.

One pictures even C. Montgomery Burns, king of the corner-cutters on "The Simpsons," looking askance. And we don't know yet if VW is the only offender.

The auto industry isn't overburdened by high expectations, particularly in the last 12 months or so.

General Motors last week agreed to a $900 million settlement to end a criminal investigation into its failure to disclose a deadly ignition defect.

Toyota last year agreed to a $1.2 billion penalty for withholding information about its vehicles' unintended acceleration linked to other fatalities.

Takata, it's been revealed, knew of dangerous, potentially fatal defects in its airbags long before alerting federal regulators, leading to the recall of millions of Honda, Toyota, Chrysler, Subaru, GM, Mitsubishi, BMW, Mazda, Nissan and Ford vehicles.

Yet, as Automotive News noted, "Compared with other run-ins between the EPA and automakers, VW's alleged violation stands out in its brazenness."

This takes that kind of amoral corporate behavior to a whole other threat level.

VW didn't just conceal something it discovered endangering people. It created technology for the specific purpose of allowing it to benefit from endangering people.

Even if you're one of those people who somehow isn't a fan of clean-air standards, it's not a political statement to press on and try to throw authorities off the trail. It's just a crime.

Tampering with emissions control systems, under terms of the Clean Air Act, could mean a fine for VW as

high as $37,500 per vehicle or roughly $18 billion, though you know what happens when you start to haggle with car guys.

But even if VW is fined and there's a mandatory recall, some drivers will be reluctant to embrace the fix because it likely will make the vehicle less effective and efficient than the one they thought they bought.

Funny we never caught wind of any of this in those slightly discomfiting VW commercials with the old ladies hitting on a salesman. Least we don't remember any mention of it.

VW pulled the ads off the air and, to the extent it could, off YouTube as word of its scandal came out, yet more proof that a carmaker can indeed move fast to protect something it actually cares about — like its bottom and bottom line.

This isn't the Olympics. It's one thing to try to keep test results from showing banned substances in one's own body, quite another to try to mask bad stuff being inflicted on others.

Cough.

This goes beyond the venality of one corporation to whether there's any confidence left in diesel cars and credibility in the entire auto industry. Even if this is as far as it goes, it will take quite a while to clear the air.

VW recently surpassed Toyota to become the world's largest carmaker, an achievement now eclipsed by the suspicion that there is nothing it wouldn't do.

From: Gong, Kristiene
Sent: Monday, September 21, 2015 4:13 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/21/2015

Bloomberg (via Australian Financial Review):
http://www.afr.com/news/world/volkswagen-faces-us-criminal-probe-on-emissions-20150921-gjrtss

Volkswagen faces US criminal probe on emissions

The US Justice Department is conducting a criminal investigation of Volkswagen's admission to cheating on federal air pollution tests, according to two US officials familiar with the inquiry.

Volkswagen said last week it's cooperating with regulators probing gaps between emissions on the road and lab tests on some diesel models, affecting more than half a million cars. The US officials described the inquiry on condition of anonymity because it's a continuing investigation.

The Wolfsburg, Germany-based automaker plunged as much as 23 per cent Monday to 125.40 euros in Frankfurt, wiping out about 15.6 billion euros ($US17.6 billion) in market value. The stock closed at 132.2 euros, its lowest in more than three years.

Volkswagen's admission is putting pressure on Chief Executive Officer Martin Winterkorn to repair the reputation of the world's biggest carmaker. Winterkorn, whose contract renewal is scheduled for a supervisory board vote on Friday, now faces a serious challenge to his leadership, said Arndt Ellinghorst, a London-based analyst for Evercore ISI.

"This latest saga may help catalyze further management changes at VW," Ellinghorst wrote in a note Monday.

Justice Department spokesman Wyn Hornbuckle declined to comment.

Criminal inquiries can take months or years and lead to charges against individuals and companies. They can also result in fines and deferred-prosecution agreements, such as the one recently struck with General Motors Co., to spur companies into improving their behaviour and addressing problems revealed during the investigations.

Volkswagen admitted on September 18 to fitting some of its US diesel vehicles with software that turns on full pollution controls only when the car is undergoing official emissions testing, the Environmental Protection Agency said Friday. Affected are diesel versions of the VW Jetta, Golf, Beetle and Passat and the Audi A3.

During normal driving, the cars with the software -- known as a "defeat device" -- would pollute 10 times to 40 times the legal limits, the EPA estimated. The discrepancy emerged after the International Council on Clean Transportation commissioned real-world emissions tests of diesel vehicles including a Jetta and Passat, then compared them to lab results.

VW said it's cooperating with regulators probing gaps between emissions on the road and lab tests on some diesel models. According to the EPA, the company insisted for a year that discrepancies were mere technical glitches.

Winterkorn, who has led VW since 2007, was forced to halt sales of the cars on Sunday and issue a public apology, saying he's "deeply sorry" for breaking the public's trust and that VW would do "everything necessary in order to reverse the damage this has caused."

The violations could result in as much as $US18 billion in fines, based on the cost per violation and the number of cars.

The US accusations are "grave" and must be clarified swiftly, said Stephan Weil, prime minister of the German state of Lower Saxony, which owns 20 percent of Volkswagen's voting shares. "Possible consequences can be decided after that."

The European Commission also said it's taking VW's cheating seriously and is in contact with US regulators and the company about details of the case.

The Guardian:
http://www.theguardian.com/business/2015/sep/21/volkswagen-emissions-scandal-sends-shares-in-global-carmakers-reeling

Volkswagen emissions scandal could snare other companies, whistleblower claims
Billions wiped off value of industry heavyweights amid concerns that manipulation of air pollution data could be ‘very widespread’
Joanna Walters Graham Ruddick and Sean Farrell

The emissions-fixing scandal that has engulfed Volkswagen in the US could extend to other companies and countries, one of the officials involved in uncovering the alleged behavior told the Guardian on Monday.

Billions of pounds have been wiped off the value of global carmakers amid growing concerns that emissions tests may have been rigged across the industry.

“We need to ask the question, is this happening in other countries and is this happening at other manufacturers? Some part of our reaction is not even understanding what has happened exactly,” said John German, one of the two co-leads on the US team of the International Council for Clean Transportation (ICCT), the European-based NGO that raised the alarm.

Shares in Volkswagen fell by almost a fifth after the world’s second biggest carmaker issued a public apology in response to US allegations that it used a “defeat device” to falsify emissions data.

The US Justice Department is conducting a criminal investigation of Volkswagen admission, according to Bloomberg, which cited two officials familiar with the inquiry.

The company could face a fine of up to $18bn (£11.6bn), criminal charges for its executives, and legal action from customer and shareholders. The US law firm Hagens Berman has already launched a class-action law suit on behalf of customers who bought the affected cars.

VW shares fell by 19% in Frankfurt, wiping almost €15bn (£10.8bn) off its value. Shares in Renault, Volkswagen's French rival, also dropped by 4%, while Peugeot was down 2.5%, Nissan 2.5% and BMW 1.5% amid concerns they could be caught up in investigations.

The US Environmental Protection Agency said on Friday that VW had installed illegal software to cheat emission tests, allowing its diesel cars to produce up to 40 times more pollution than allowed. The US government ordered VW to recall 482,000 VW and Audi cars produced since 2009.

In response, Martin Winterkorn, chief executive of VW, said on Sunday he was "deeply sorry" for breaking the trust of the public and ordered an external investigation.

German tipped off regulators at the California Air Resources Board (Carb) and the US Environmental Protection Agency (EPA) after conducting tests that showed major discrepancies in the amount of toxic emissions some VW cars were pumping out compared with the legal limits.

Max Warburton, an analyst at the financial research group Bernstein, said: "There is no way to put an optimistic spin on this – this is really serious."

A British expert in low-emission vehicles claimed the manipulation of air pollution data could be "very widespread" and that tests in Europe are "much more open to this sort of abuse".

Greg Archer, a former government adviser and head of clean vehicles at the respected Transport & Environment thinktank, said: "I am not surprised. There has been a lot of anecdotal evidence about carmakers using these 'defeat devices'. All credit to the US's EPA for investigating and finding the truth."

Archer, the former managing director of the UK's Low Carbon Vehicle Partnership and non-executive director for the government's Renewable Fuels Agency, said the scandal could spread into petrol cars and CO2 levels. "It is probably not limited to diesel and not limited to emissions," he added.

The "defeat devices" are thought to work by injecting more urea – an exhaust fluid – into the car when it is being tested. This limits nitrogen oxide emissions. The car detects it is being tested because devices such as the anti-collision systems have to be turned off when it is in the laboratory. The extra urea is not injected into the car when it is on the road because it would quickly run out.

Archer claims European tests are more open to abuse because they are conducted before the car goes into mass production and by companies that have been paid by the carmakers. These testing companies have been verified by regulators in each country, such as the Vehicle Certification Agency, but in the US the tests are conducted by an independent body.

Industry leaders in Britain claimed there was "no evidence" that manufacturers are cheating the system in Europe but admitted it needs to be reformed.

Mike Hawes, chief executive of the Society of Motor Manufacturers and Traders, the industry trade body, said: "The EU operates a fundamentally different system to the US – with all European tests performed in strict conditions as required by EU law and witnessed by a government-appointed independent approval agency. There is no evidence that manufacturers cheat the cycle.

"The industry acknowledges, however, that the current test method is outdated and is seeking agreement from the European Commission for a new emissions test that embraces new testing technologies and is more

representative of on-road conditions."

The US allegations involve a series of diesel cars produced by VW and the brands it owns, such as Audi. These include the Audi A3, VW Jetta, Beetle, Golf and Passat models. VW has halted sales of these models.

Jochen Flasbarth, a senior environment official in the German government, accused Volkswagen of "blatant consumer deception" over the scandal. The country's economy minister, Sigmar Gabriel, also warned it could damage the reputation of the country's vital automotive industry.

"That this is a bad case, I think is clear," Gabriel said. "You will understand that we are worried that the justifiably excellent reputation of the German car industry and in particular that of Volkswagen suffers." The German government has launched its own investigation into VW and held talks with executives.

The scandal puts the future of Volkswagen chief Winterkorn in serious doubt. Earlier this year he won an internal power struggle with Ferdinand Piëch, who stepped down as chairman. The board of the company is due to meet on Friday to discuss extending Winterkorn's contract.

Winterkorn has been at the helm of VW since 2007 and has been directly responsible for research and development since then.

Guido Reinking, a German automotive analyst, told German television station n-tv: "It's almost impossible to imagine that he didn't know about this special way of programming the engine."

David Bailey, professor of industrial strategy at Aston University in Birmingham, said: "If it is the case that they have been trying to hoodwink regulators, it's a really dumb thing to do. Regulators will look at this more closely now. There has been growing concern about diesel cars and nitrous oxide emissions. The industry has been trying to make the case that the latest regulations largely deal with that issue but regulators will now look more closely at whether they have."

In the wake of the scandal two senior VW executives cancelled a planned appearance at a media event in New York with rock star Lenny Kravitz scheduled for Monday evening.

Herbert Diess, chairman of the VW brand's management board, and Heinz-Jakob Neusser, VW's board member in charge of technical development, had planned to attend the event to introduce the latest version of the Passat mid-size sedan.
The chief executive of VW's US arm, Michael Horn, was still due to attend the event. He is expected to provide a statement about the situation.

Jalopnik:
http://jalopnik.com/volkswagen-is-now-the-target-of-a-criminal-investigatio-1732130214

Volkswagen Is Now The Target Of A Criminal Investigation: Report
Michael Ballaban

In a move that seemed like an inevitability at this point, the United States Department of Justice is said to have opened a criminal investigation into Volkswagen's admission to cheating on diesel emissions tests, a report from Bloomberg said.

While we had heard rumblings of a possible criminal probe earlier, this news appears to confirm that VW is in fact the subject of an investigation that could lead to prosecutions.

It's way too early to tell whether or not any individuals will personally be held criminally liable for the company's deceptions, but it's not out of the realm of possibility. We haven't seen a case in a long time where a company has admitted intentionally circumventing the law, rather than just a plea of massive institutional incompetence, so it's anyone's guess as to what will happen.

The U.S. Environmental Protection Agency has said that the company can be held responsible for up to $18 billion in fines.

From: Gong, Kristiene
Sent: Monday, September 21, 2015 4:02 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/21/2015

Business Insider:
http://www.businessinsider.com/the-us-government-is-launching-a-criminal-investigation-into-vws-falsified-emissions-figures-2015-9

The US government is launching a criminal investigation into VW's falsified emissions figures
Benjamin Zhang

The US Department of Justice has launched a criminal probe into Volkswagen's falsification of emissions data, Bloomberg news is reporting.

Last week, the Environmental Protection Agency accused the automaker of falsifying the data using secret software in nearly 500,000 cars.

According to Bloomberg's Del Quentin Wilber, two government officials close to the situation say the Justice Department is conducting a criminal investigation into the allegations.

Last week, the EPA accused VW of using the hidden software — called a "defeat device" — to dodge clean-air standard during emissions testing.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," assistant administrator for the Office of Enforcement and Compliance Assurance Cynthia Giles said in a statement on Friday.

“Working closely with the California Air Resources Board, EPA is committed to making sure that all automakers play by the same rules. EPA will continue to investigate these very serious matters.”

The EPA alleges that VW installed software that detects when the car is undergoing emissions testing, at which point the software would turn on all of the car's emissions control systems. But the EPA claims that the software greatly reduces the cars' pollution-control systems during normal driving conditions.

"This results in cars that meet emissions standards in the laboratory or testing station, but during normal operation, emit nitrogen oxides, or NOx, at up to 40 times the standard," the EPA said in a statement.

Across the Atlantic, the German government is also taking a look at Volkswagen's emissions data. A spokesperson for the country's Motor Vehicle Agency told the Wall Street Journal that is has asked automakers to provide accurate emissions information to "determine whether similar instances of manipulation have taken place in Germany or Europe," However, there is no word of any official investigation on the part of the German government.

Over the weekend, VW CEO Martin Winterkorn issued the following statement:

The U.S. Environmental Protection Agency and the California Air Resources Board (EPA and CARB) revealed their findings that while testing diesel cars of the Volkswagen Group they have detected manipulations that violate American environmental standards.

The Board of Management at Volkswagen AG takes these findings very seriously. I personally am deeply sorry that we have broken the trust of our customers and the public. We will cooperate fully with the responsible agencies, with transparency and urgency, to clearly, openly, and completely establish all of the facts of this case. Volkswagen has ordered an external investigation of this matter.

The recall affects 482,000 diesel-powered cars sold in the US since 2008. They include:

Volkswagen Jetta TDI: 2009-20015
Volkswagen Beetle TDI: 2009-2015
Audi A3 TDI: 2009-2015
Volkswagen Golf TDI: 2009-2015
Volkswagen Passat TDI: 2014-2015
We have reached out to Volkswagen and the DOJ for comment. We will update when when we hear back.

Fortune:
http://fortune.com/2015/09/21/volkswagen-emissions-recall-scandal/

Dear Volkswagen: Exaggeration? Not so bad. Deception? Never okay
by Jennifer Reingold @jennrein SEPTEMBER 21, 2015, 3:44 PM EDT

One wonders what would have happened had Volkswagen opted for exaggerating its results rather than falsifying them.

The business world—and the journalists who cover it—have always rewarded a healthy bit of hype. Best Ever! New and Improved! Now with enhanced whatevers!

Actually, the love of the big claim goes far beyond the business world and is interwoven throughout society. Donald Trump's current popularity is only the latest example of bombast, er, trumping reality.

But we do have limits, as the scandal at Volkswagen shows. So far, the company's stock price has fallen almost 20% since it admitted on September 18 that it had installed software that allowed its cars to fake their performance on emissions testing in order to fool the EPA.

No one knows what will happen to the $221 billion in sales car company—the world's largest—going forward, and whether the deception stretches all the way to the CEO, Martin Winterkorn. But one wonders what would have happened had the company opted for exaggerating its results rather than falsifying them.

Don't get me wrong: I'm not advocating that any performance standards—particularly those that affect safety and health—should ever be presented with anything but the full truth. But this move was so brazen, so breathtakingly full of chutzpah, that it is hard to imagine VW's brand recovering for a very, very long time; nor, one imagines, will its culture.

The plot goes far beyond one or two people hiding out in a cubicle and must have involved hundreds of people building such a system and making sure it was implemented inside of 428,000 cars. One wonders what the company might have been able to accomplish instead if it put all that brainpower toward meeting emissions requirements rather than circumventing them.

Consider the alternative: VW tried—and failed—to meet the EPA's emissions standards, after saying that they believed they had diesel engines that did the job. The EPA (which, it's worth noting, relies primarily on self-tested data) would have—hopefully—tested its engines, found Volkswagen deficient, and fined the company. It would have been costly, yes, but it wouldn't have been all that surprising. And VW's credibility wouldn't have been destroyed in the process. After all, exaggeration, for better or worse, is just how the game is played.

MarketWatch:
http://www.marketwatch.com/story/white-house-quite-concerned-about-volkswagen-emissions-charges-2015-09-21

White House 'quite concerned' about Volkswagen emissions charges
'Quite concerned': How White House press secretary Josh Earnest characterized Obama administration reaction to the allegations against Volkswagen.
By ROBERT SCHROEDER

The Obama administration is "quite concerned" over allegations that Volkswagen cheated on U.S. emissions tests, a White House spokesman said Monday, but added it is up to the Environmental Protection Agency to investigate the matter.

"I think it's fair to say that we're quite concerned by some of the reports that we've seen about the conduct of this particular company," spokesman Josh Earnest told reporters at a regular briefing.

On Friday, the Environmental Protection Agency and the California Air Resources Board alleged that Volkswagen VLKAY, -17.38% VOW3, -18.19% used software in cars to make diesel-powered engines appear to have lower levels of emissions than they actually did. The company halted U.S. sales of some diesel-powered cars.

Earnest said it is ultimately the responsibility of the EPA to look at the issue, "and that's exactly what they're doing."

Reaction from Congress was minimal — though that could change.

"VW should expect scrutiny from Congress, legal problems, a potential multibillion-dollar fine and a batch of uncomfortable headlines," wrote Forbes contributor Micheline Maynard on Monday.

"If Volkswagen willfully sought to evade the Clean Air Act and fraudulently sold cars to millions of consumers with this technology, EPA should pursue the most severe action possible to deter others from doing the same," Rep. Frank Pallone, a New Jersey Democrat, said on Friday.

"We must ensure that this does not happen again and that consumers can trust the products that they buy," said Pallone, the top Democrat on the House Energy and Commerce Committee. The panel's oversight and investigations subcommittee held one of the several hearings into the General Motors GM, +0.43% ignition-switch recall in April 2014.

The allegations reportedly include Volkswagen Passats made at the company's Chattanooga, Tenn., facility in 2014 and 2015. A Volkswagen spokesperson did not immediately return a request for comment.

MarketWatch reached out to members of Tennessee's congressional delegation, but none offered any comment.

The 1,400-acre Chattanooga plant has more than 3,200 Volkswagen employees, the company says.

From: Gong, Kristiene
Sent: Monday, September 21, 2015 3:39 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/21/2015

Vox:
http://www.vox.com/2015/9/21/9365667/volkswagen-clean-diesel-recall-passenger-cars

Volkswagen's appalling clean diesel scandal, explained
Brad Plumer

It sounds like the sinister plot of some straight-to-DVD movie. Since 2009, Volkswagen had been installing elaborate software in 482,000 "clean diesel" vehicles sold in the US, so that the cars' pollution controls only worked when being tested by regulators. The rest of the time, the vehicles could freely spew hazardous, smog-forming nitrogen oxides.

Suffice to say, regulators were livid once they caught on. On Friday, the Environmental Protection Agency announced that Volkswagen had very flagrantly violated the Clean Air Act. Not only did the EPA order the German company to fix the affected vehicles,** but the agency has the authority to levy fines as high as $37,500 per car, a maximum of $18 billion. (To put that in perspective, the company's pretax net income was about $4.7 billion last year.) The US government is also mulling criminal charges.

Volkswagen, in other words, is in deep shit. The company's CEO, Martin Winterkorn, is now apologizing profusely and pledging an external probe to find out what happened. VW just halted US sales of its 2015 and 2016 clean diesel vehicles, including Passat, Jetta, Golf, and Beetle models. Meanwhile, VW's stock price plummeted on Monday morning, the company losing nearly one-fifth its market cap in a blink:

This scandal raises a few larger questions, though: Why did Volkswagen cheat in the first place? And why was it so easy for the company to evade regulators for years? To get a better handle on the story, we need to take a brief trip through the tangled history of clean diesel vehicles — the specific cars that VW was selling.

Clean diesel cars were supposed to offer great mileage and low pollution — a tricky task

One basic fact to understand here is that there are two main types of combustion engines widely available today: diesel and gasoline. And there are real trade-offs to each.

Diesel engines have long been popular in Europe, and one of their major advantages is fuel economy. Diesel fuel contains more energy per gallon than gasoline, and the diesel engines themselves are more efficient. Put it together, and the typical diesel car can travel up to 30 percent farther on a gallon of fuel than its gasoline counterpart.

But there's a catch. While diesel cars get better mileage and emit fewer carbon-dioxide emissions, they also emit more nitrogen oxides (NOx), which help form smog, and particulate matter, which can damage lungs. Both types of pollution can have serious health effects.

Historically, Europe has dealt with this trade-off by imposing looser emissions standards on diesel cars in order to pursue higher fuel economy. That's one reason European cities like Athens have a serious smog problem. In the United States, by contrast, we've imposed much stricter rules around smog and other conventional pollutants since the 1970s, one reason diesel cars haven't caught on as widely here. (Heavy trucks favor diesel engines, though.)

In recent years, however, things have shifted. The Obama administration has been ratcheting up fuel-economy standards in the United States, which puts a higher premium on mileage. At the same time, diesel technology has gradually been getting cleaner through a combination of lower-sulfur fuel, advanced engines, and new emission-control technology. So automakers have shown a renewed interest in "clean diesel" cars that, in theory, don't suffer from that trade-off between performance and pollution.

These vehicles have proved popular in the United States. Since 2009, Volkswagen has sold more than 482,000 clean diesel cars containing a four-cylinder turbocharged direct injection engine. This included versions of the Passat, Jetta, Golf, Beetle, and Audi's A3. Drivers liked them.

Except, as it turns out, VW was lying about its clean diesel cars.

Volkswagen couldn't balance performance with low pollution. So it cheated.

Since 2009, we now know, Volkswagen had been inserting intricate code in its vehicle software that tracked steering and pedal movements. When those movements suggested that the car was being tested by regulators in the laboratory for nitrogen-oxide emissions, the car automatically turned its pollution controls on. The rest of the time, the pollution controls switched off.

Regulators didn't notice this ruse for years. The problem was only uncovered by an independent group, the International Council on Clean Transportation, which wanted to investigate why there was such a discrepancy between laboratory tests and real-road performance for several of VW's diesel cars in Europe. So they worked with researchers at West Virginia University, who stuck a probe up the exhaust pipe of VW's clean diesel cars and drove them from San Diego to Seattle. (These details come from Dana Hull and Jeff Plungis' excellent Bloomberg tick-tock.)

What the researchers found was jaw-dropping. On the road, VW's Jetta was emitting 15 to 35 times as much nitrogen oxide as the allowable standard. The VW Passat was emitting 5 to 20 times as much. These cars were emitting much more pollution than they had in the labs.

Both California's air-pollution regulator and the EPA ordered Volkswagen to investigate and fix the problem in May 2014, and the company said it had worked on a software patch. Once again, the cars performed well in testing. And once again, real-world performance didn't match up. At that point, regulators started grilling Volkswagen's engineers about the discrepancy, and the company eventually cracked, admitting the existence of these defeat devices, which had been carefully hidden in the software code. Hence the scandal.

Volkswagen hasn't explained exactly why it cheated, but outside analysts have a pretty good guess. The NOx emission controls likely degraded the cars' performance when they were switched on — the engines ran hotter, wore out more quickly, and got worse mileage. Some experts have suggested that the emission controls may have affected the cars' torque and acceleration, making them less fun to drive. (Indeed, some individual car owners have been known to disable their cars' emission controls to boost performance, though this is against the law.)

In other words, Volkswagen wasn't able to produce diesel cars that had the ideal mix of performance, fuel economy, and low pollution. (Or, at least, they couldn't do this profitably.) So they "solved" this trade-off by sacrificing cleanliness and loosening the emission controls. And they accomplished this via software designed to deceive regulators. This was wildly illegal, and they got caught.

The VW scandal exposes problems with current emission tests

Volkswagen isn't the first company to cheat on its emission tests. As Frank O'Donnell of Clean Air Watch pointed out to me, the EPA caught a number of truck manufacturers, including Caterpillar and Volvo, doing something similar back in 1998 — programming their diesel trucks to emit fewer pollutants in lab tests than they did on the road. (The trucks would slowly emit more and more NOx as they traveled longer distances at constant speed, something that labs couldn't catch.)

Part of the problem here is that regulators tend to test these vehicles in laboratory conditions, which are fairly predictable and hence easier to game. Combined with the fact that automakers are developing ever-more-elaborate software that can control and fine-tune engines, and there are ample opportunities for fraud.

EUROPEAN REGULATORS WILL SOON START REQUIRING ON-ROAD EMISSIONS TESTING

In theory, there are ways to make cheating harder. Starting with model year 2017 vehicles, European regulators are going to start requiring automakers to test their passenger cars on the road in addition to laboratory testing. That sort of regime would've made it harder for Volkswagen to do what it did. But it's also unlikely that this is the last time we'll see an automaker come up with a fiendishly clever way to cheat.

Meanwhile, the VW scandal raises another issue surrounding car regulations, as Alex Davies explains at Wired. Modern-day cars feature complex computer systems and software. And, right now, this software is

protected under the 1998 Digital Millennium Copyright Act — it's illegal to fiddle with it. The ostensible rationale is to make it harder for consumers to tamper with emissions controls. But these protections also make it harder for independent researchers to scrutinize that code and identify problems like VW's little emissions trick. Some experts have proposed DMCA exemptions to allow researchers to test and evaluate these engines, but so far automakers and the EPA have resisted this. Presumably, if those exemptions had existed, Volkswagen might've been caught sooner.

Volkswagen is now facing serious consequences

At this point, Volkswagen has been caught red-handed and has to face the consequences. The company straight-up lied about its cars and exacerbated the country's air-pollution problem. (Getting a precise estimate of the health consequences here could be difficult, since it depends on where the cars were located, how much extra smog actually resulted, and so forth.)

In response, the company has pledged to stop selling 2015 and 2016 Volkswagen and Audi models equipped with clean diesel engines and will likely end up recalling the 482,000 cars now on the road to fix the software.** It's unclear how many customers will want to "fix" the problem, however, since, again, any patch might degrade gas mileage and/or performance.

Meanwhile, Volkswagen could face criminal prosecution — not to mention billions of dollars in fines, potentially. The Clean Air Act allows a fine of $37,500 per noncompliant vehicle. If the EPA really wanted to lower the hammer, that would amount to $18 billion. Again, VW's pretax net income was about $4.7 billion last year, so that would be a crippling hit. Volkswagen is the world's biggest automaker by sales, but it's not quite as profitable as competitors like Toyota and has already struggled to gain a foothold in the US market. This could be a huge deal for the company.

It also raises questions about the future of clean diesel vehicles. Clean diesel appears to be a promising technology — in theory, these vehicles could get both excellent mileage and low emissions. But this scandal raises serious questions about how well automakers can actually achieve both goals in practice.

** For any concerned car owners, the models expected to be recalled include: The 2009-2015 VW Beetle 2.0L TDI; 2009-2015 VW Golf 2.0L TDI; 2009-2015 VW Jetta 2.0L TDI; 2009-2015 Audi A3 2.0L TDI; and 2014-2015 VW Passat 2.0L TDI.

Ledger Gazette:
http://www.ledgergazette.com/epa-accuses-vw-of-cheating-on-emissions-tests/79148/

EPA accuses VW of cheating on emissions tests
BY JORGE WEINER ON SEPTEMBER 21, 2015 BUSINESS

VW halted sales of the models involved on Sunday and said it's cooperating with the probe and ordered its own external investigation into the issue.

"The charges here are truly appalling: that Volkswagen knowingly installed software that produced much higher smog-forming emissions from diesel vehicles in the real world than in pre-sale tests", said Frank O'Donnell, president of Clean Air Watch, a Washington-based advocacy group.

VW is to stop selling four cylinder diesel cars in the USA after the firm was found to have rigged emissions test on up to 500,000 vehicles, it has emerged. The reality is that Volkswagen will face huge fines, rumoured to be as high as 18 billion US dollars.

German competitors BMW AG and Daimler AG said on Monday they aren't aware of a similar USA probe into their cars.

Once on the road, the cars produced nitrogen oxide pollutants at up to 40 times the legal standard.

The EPA and California authorities acted quickly after being told of the violation, German said.

Volkswagen, which recently edged out Japan's Toyota to become the world's top-selling automaker, has had a hard year, its share price having fallen from more than 250 euros amid signs of faltering sales in the US and China. He said he was "deeply sorry" for the violation of United States rules. The models include Jetta, Beetle, Golf, Passat and Audi A3.

Stefan Bratzel, director at the Center for Automotive Management, a research group, said the damage to VW's image would be as great as the financial fines.

"Our climate policy stands for itself and I think it's internationally recognized that Germany is one of the drivers on the way to (the global climate summit in) Paris", he said. The potential wonderful is $37,500 per vehicle and 482,000 autos are a part of the case, yielding a possible superb of greater than $18 billion, Giles stated on a telephone name with reporters Friday.

The EPA in November 2014 hit South Korean auto makers Hyundai Motor Co. and Kia Motors Corp. with a record $100 million penalty for overstating fuel-economy claims and forced the companies to cough up another $200 million in regulatory credits.

The cars allegedly do so with software that detects when the vehicle is undergoing emissions testing, and then turns full emissions controls on only during the test. When vehicles are being driven normally, the computer disables the emissions controls.

According to the The New York Times, this latent software within numerous Volkswagen vehicles switches on emissions control systems only during an inspection. The California Air Resources Board issued a similar letter.

"Our goal is to ensure that the affected cars are brought into compliance, to dig more deeply into the extent and implications of Volkswagen's efforts to cheat on clean air rules and to take appropriate further action".

The feature, which the EPA called a "defeat device", masks the true emissions only during testing.

From: Gong, Kristiene
Sent: Monday, September 21, 2015 1:57 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/21/2015

Washington Post:
http://www.washingtonpost.com/business/economy/vw-shares-plunge-as-epa-accuses-automaker-of-cheating/2015/09/21/3c7b2f2e-607b-11e5-8e9e-dce8a2a2a679_story.html

VW under fire amid EPA accusations it cheated on emissions tests
By Thad Moore

Volkswagen shares plunged Monday after U.S. regulators accused the German automaker of cheating on emissions tests, alleging that nearly 500,000 cars weren't meeting federal standards.

An apology Sunday from VW's chief executive did nothing to temper anxious investors, who wiped out nearly a fifth of the company's value in a single day. VW's stock closed the day Monday at 132.20 euros, down 19 percent.

The selloff comes on the heels of Environmental Protection Agency allegations that the automaker had

designed software to let its diesel cars detect when they were being tested for emissions.

VW, one of the world's largest automakers, has halted sales of some vehicles in the United States and pledged to cooperate with regulators. "We at Volkswagen will do everything that must be done in order to re-establish the trust that so many people have placed in us, and we will do everything necessary in order to reverse the damage this has caused," Martin Winterkorn, VW's chief executive, said in a statement.

In the lab, they met standards. On the road, regulators say, they emitted nitrous oxide at up to 40 times federal standards. The software, known as a "defeat device," was installed in some 482,000 cars, spanning model years 2009 through 2015, regulators say.

The EPA and California regulators began asking questions in May 2014 after West Virginia University researchers published a study that found lab results didn't match up with road tests.

For more than a year, VW told regulators that the difference owed to "various technical issues and unexpected in-use conditions," the EPA said in a letter sent to the automaker Friday. But company officials didn't admit to the practice until earlier this month when regulators threatened not to approve its 2016 line of diesel cars.

The years-long practice could carry a hefty price tag for the automaker. The company could be fined $37,500 for each car it sold with a defeat device installed — a potential fine of $18 billion.

"The company will have to recall nearly 500,000 affected cars, which will cost it millions of dollars, and that's even before the damage to its brand and potential fines," Michael Hewson, chief market analyst at CMC Markets, told the Associated Press.

The revelation also led Consumer Reports[consumerreports.org] to pull its recommendation of VW's Jetta and Passat diesel model. (The magazine said it would reconsider its decision once the automaker introduces a fix to lower emissions.)

For his part, Winterkorn apologized Sunday, saying the company would cooperate "with transparency and urgency."

"I personally am deeply sorry that we have broken the trust of our customers and the public," he said in a statement. "We do not and will not tolerate violations of any kind of our internal rules or of the law."

From: Gong, Kristiene
Sent: Monday, September 21, 2015 11:56 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/21/2015

NY Times:
http://www.nytimes.com/2015/09/22/business/international/volkswagen-shares-recall.html

Volkswagen Denied Deception to E.P.A. for Nearly a Year
By JACK EWING SEPT. 21, 2015

FRANKFURT — For nearly a year, Volkswagen officials told the Environmental Protection Agency that discrepancies between the formal air-quality tests on its diesel cars and the much higher pollution levels out on the road were the result of technical errors, not a deliberate attempt to deceive Washington officials.

But early this month, Volkswagen executives finally made a startling admission: The diesels it sold in the United States had software deliberately designed to cheat on the tests.

The company was evidently concerned that actually meeting the federal emissions standards would degrade

the power of the engines, which it marketed as comparable in performance to gasoline engines. Meeting the standard would also undercut the fuel efficiency that is one of the main selling points of diesels.

The admission came only after the E.P.A. threatened to withhold approval for Volkswagen's new 2016 models, according to letters sent to company officials by the E.P.A. and California regulators.

Since news of that mass deception broke on Friday, Volkswagen has scrambled to conduct damage control, with its chief executive issuing an apology and the company saying it would not sell its 2015 and 2016 diesel cars in the United States.

But that did not stop Volkswagen shares from plummeting when trading opened in Europe on Monday. And the apology has not relieved pressure on Martin Winterkorn, the Volkswagen chief executive, whom analysts said would have tough questions to answer, seeking to know when he and other top executives at the company, which is ruled from the top with Germanic precision, were aware of the diesel deception.

Adding to pressure on Volkswagen, the German government said on Monday that it would also begin an inquiry to make sure that Volkswagen and other carmakers are complying with laws on auto emissions.

The E.P.A. disclosed the yearlong series of letters with Volkswagen as part of accusations it made against the company on Friday. The agency will require the company to recall nearly half-a-million vehicles equipped with 2-liter diesel engines dating to the 2009 model year. Volkswagen also faces fines that could run into the billions of dollars.

Volkswagen shares plunged about 20 percent on Monday, as investors registered alarm at the damage the company could suffer.

Mr. Winterkorn issued an apology on Sunday, saying the company had "broken the trust of our customers and the public."

But the sophistication of the software used to manipulate emissions tests in the United States, and extensive attempts by Volkswagen to deflect official scrutiny before admitting misconduct this month, are sure to raise questions about Mr. Winterkorn's effectiveness only months after he survived an internal power struggle.

"Either he knew, or he didn't know, which is even worse," said Ferdinand Dudenhöffer, a professor at the University of Duisburg-Essen who is a longtime Volkswagen critic. "Any politician in his situation would have to resign."

Volkswagen's supervisory board, which Mr. Winterkorn reports to, will hold a regularly scheduled meeting on Friday, and it is certain to discuss the E.P.A. action.

After being confronted last year with evidence that some diesel models did not comply with pollution standards under certain conditions, Volkswagen executives originally offered technical explanations, according to a letter of complaint sent to the company by the E.P.A. and the California Air Resources Board.

It was only on Sept. 3, according to the letters, that executives at Volkswagen of America, the company's United States unit, admitted that cars equipped with the 2-liter diesel motors contained the software.

The software measured factors such as the position of the steering wheel, the vehicle's speed and even barometric pressure to sense when the car was being subjected to testing, the E.P.A. said. The car then configured itself to reduce emissions of nitrogen oxide, a gas that is a major contributor to smog and is linked to an array of respiratory ailments including asthma, emphysema and bronchitis, the E.P.A. said on Friday.

Volkswagen is known for being a tightly controlled, autocratic organization, raising questions about how such a sophisticated system could have been installed in nearly half a million vehicles without knowledge of top management.

The plunge in Volkswagen shares was a clear indication that investors believe that company profit and sales could suffer because of the E.P.A. accusations. However, Volkswagen is relatively immune to stock market pressure because only 12 percent of its voting shares are traded. Porsche Automobil Holding, controlled by members of the Porsche family, holds a slight majority. The state of Lower Saxony owns 20 percent and the sovereign wealth fund of Qatar owns 17 percent.

Stephan Weil, the prime minister of Lower Saxony, where Volkswagen has its headquarters and major manufacturing operations, said in a statement on Monday, "Manipulation of an emissions test is completely unacceptable and without any justification."

But Mr. Weil said consequences could be discussed only after a thorough investigation of the circumstances.

In Berlin, the government of Chancellor Angela Merkel said it would ask carmakers for information as the first step in an inquiry.

"We expect reliable information from carmakers so that the Federal Office for Vehicles can check whether similar manipulation in the exhaust systems has taken place in Germany or Europe," Andreas Kübler, a spokesman for the Environment Ministry, told reporters in Berlin.

The European Commission has contacted Volkswagen as well as the E.P.A. for details about the accusations, a commission spokeswoman said.

"It is premature to comment on whether any specific immediate surveillance measures are also necessary in Europe and whether vehicles sold by Volkswagen in Europe are also affected," the spokeswoman said in an email. "We are taking the matter very seriously."

South Korea also planned to test Volkswagen cars to make sure they were in compliance with pollution rules, according to news reports.

More than half of all vehicles sold in Europe are diesels, which are popular because they typically offer better fuel economy than gasoline. European Union pollution rules were more favorable to diesels than United States rules, but they have been progressively tightened. The most recent standard, known as Euro 6, took effect for all new cars sold on Sept. 1.

Technology exists to reduce the amount of nitrogen oxides emitted by diesels. But the technology also tends to reduce fuel economy as well as performance. The software installed by Volkswagen on vehicles sold in the United States avoided this trade-off, which could have come as a disappointment to American customers, by scaling back pollution controls when the car was not being tested.

The accusations by the E.P.A. are a blow to Volkswagen's efforts to build up its meager market share in the United States, in part by promoting "clean diesel" technology.

The silver lining for Volkswagen, though, may be that its most profitable vehicles in the United States are Porsche and Audi cars not affected by the E.P.A. action. The cars affected are Volkswagen Golf, Jetta, Beetle and Passat models from 2009 through 2015 that are equipped with 2-liter diesel engines.

Another silver lining for Volkswagen may be that diesel powered cars account for only a tiny fraction of sales in China, which is the company's largest market.

Among Audi models, only the compact A3 is affected in the United States. The A3 accounted for less than a fifth of the 111,000 vehicles that Audi sold in the United States from January through August, and only a fraction of those A3s would have been equipped with diesels.

The E.P.A. said on Friday that Volkswagen would be required to recall the affected vehicles for repairs to make them compliant with smog regulations. Car owners would not have to pay for the repairs. Many owners may not bother, though, because the changes are likely to reduce fuel consumption and performance.

John Schilling, a Volkswagen spokesman, said on Sunday that the company would stop selling 2015 and 2016 Volkswagen and Audi models equipped with the 2-liter diesel engines, which the company had marketed as "clean diesel." The company will also stop selling used cars that have the engines, Mr. Schilling said.

He said he did not know how many models would be stuck on dealer lots as a result of the decision. This month, Volkswagen had said that 23 percent of new cars sold in August in the United States were diesels, or 7,400 vehicles. Some diesels, such as those used in Volkswagen S.U.V.s, are not affected by the E.P.A. action.

From: Gong, Kristiene
Sent: Monday, September 21, 2015 10:54 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/21/2015

AP (via US News & World Report)
http://www.usnews.com/news/business/articles/2015/09/21/vw-stock-crashes-after-admitting-it-rigged-us-emission-tests

Faulty Tests Cost VW Billions
By FRANK JORDANS and PAN PYLAS, Associated Press

BERLIN (AP) — Around 15 billion euros ($16.9 billion) was wiped off the market value of Volkswagen AG on Monday following revelations that the German carmaker rigged U.S. emissions tests for about 500,000 diesel cars.

By midday trading in Frankfurt, Volkswagen's share price was 19.3 percent lower at a three-year low of 130.20 euros. Its dramatic fall weighed heavily on Germany's main stock index, the DAX, which underperformed its peers in Europe with a 0.6 percent decline.

Volkswagen's market woes Monday follow a weekend that saw the company's reputation for probity seriously damaged by revelations from the Environmental Protection Agency in the U.S. that it had skirted clean air rules. All told, the EPA indicated that VW faces fines that could run up to more than $18 billion.

The EPA said VW used a device programmed to detect when the cars are undergoing official emissions testing. The software device then turns off the emissions controls during normal driving situations, allowing the cars to emit more than the legal limit of pollutants.

Volkswagen marketed the diesel-powered cars, which account for about 25 percent of sales, as being better for the environment. The cars, built in the last seven years, include the Audi A3, VW Jetta, Beetle, Golf and Passat models.

"The company will have to recall nearly 500,000 affected cars, which will cost it millions of dollars, and that's even before the damage to its brand and potential fines," said Michael Hewson, chief market analyst at CMC Markets.

The agency has ordered VW to fix the cars at its own expense but said car owners do not need to take any immediate action. The EPA insisted that the violations do not pose any safety hazard and said the cars remain legal to drive and sell while Volkswagen comes up with a plan to recall and repair them. However, it said the cars posed a threat to public health.

The EPA also indicated the scale of the fines that could be imposed on VW. It said the carmaker could be hit up to $37,500 per vehicle for the violations — a total of more than $18 billion. The California Air Resources Board is also investigating.

Volkswagen has had a difficult year, its share price having fallen from over 250 euros amid signs of faltering sales in the U.S. and China.

VW edged out Toyota to become the world's top-selling automaker the first half of 2015. But a hit to its reputation from the emissions revelations could hamper its efforts at a sales rebound in the U.S.

If other regulatory authorities decide VW has a case to answer, then the carmaker faces the potential for even bigger fines.

"The news so far revolves around the U.S. impact, but if European investigators become interested the potential penalties could multiply very quickly," said Chris Beauchamp, senior market analyst at IG.

Washington Examiner:
http://www.washingtonexaminer.com/volkswagen-sorry-promises-probe-on-epa-violations/article/2572497

Volkswagen 'sorry,' promises probe on EPA violations
By DANIEL CHAITIN (@DANIELCHAITIN7) • 9/20/15 3:23 PM

Volkswagen apologized Sunday following allegations by the Environmental Protection Agency and the state of California that hundreds of thousands of diesel cars made by the German automaker are breaking emissions laws in the United States.

"The Board of Management at Volkswagen AG takes these findings very seriously," wrote Martin Winterkorn, CEO of Volkswagen. "I personally am deeply sorry that we have broken the trust of our customers and the public. We will cooperate fully with the responsible agencies, with transparency and urgency, to clearly, openly, and completely establish all of the facts of this case. Volkswagen has ordered an external investigation of this matter."

On Friday, the EPA and California charged Volkswagen with willfully installing software in its 4-cylinder diesel cars that would allow cars to bypass emission standards. The cars cited for violations include signature Volkswagen cars manufactured between 2009 and 2015, including the Jetta, Passat, Beetle and Golf, as well as the A3 from Audi, Volkswagen's luxury line.

All together, about 482,000 diesel passenger cars sold in the United States since 2008 are included in the allegations.

The statement promises that Volkswagen will "re-establish trust" it may have lost and that the company will reverse any damage done.

"We do not and will not tolerate violations of any kind of our internal rules or of the law," Winterkorn added.

The EPA issued a notice of violation to Volkswagen, while the state of California sent an In-Use Compliance letter. Both the EPA and the California Air Resources Board are conducting separate investigations into the alleged misbehavior.

Recalls are likely, and the combined fines could add up to $18 billion if the result of the investigations support the allegations.

The EPA alleges that the Volkswagen cars are fitted with software to trick emission testers, but that under normal operation emit nitrogen oxides at up to 40 times the standard. Under the Clean Air Act, such an instrument is classified as a "defeat device."

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," said Cynthia Giles, EPA assistant administrator for the Office of Enforcement and Compliance Assurance. "Working

closely with the California Air Resources Board, EPA is committed to making sure that all automakers play by the same rules. EPA will continue to investigate these very serious matters."

The Epoch Times:
http://www.theepochtimes.com/n3/1755607-volkswagen-circumvents-epa-rule-its-not-the-first-time/

Volkswagen Skirts EPA Rules; It's Not the First Time
By Arleen Richards

Volkswagen Group of America admitted to sidestepping clean air standards after the EPA and California's clean air watchdog confronted the German automaker with evidence of high in-use emissions from light-duty diesels.

On Friday, Sept. 18, the EPA slapped VW with a notice of violation for using sophisticated software to circumvent national emissions standards. The software, which the EPA calls a "defeat device," is designed to implement full emissions control systems when the car is undergoing state emissions testing. During normal driving, the emissions control is turned off, permitting the significantly harmful diesel fumes to be expelled—40 times more than allowed under the Clean Air Act. VW and the California Air Resources Board (CARB) have both initiated investigations.

Volkswagen CEO Dr. Martin Winterkorn, on Sunday, apologized for breaking the public's trust and vowed to cooperate fully with agency investigations.

He ordered an internal investigation, saying in a statement, "We do not and will not tolerate violations of any kind of our internal rules or of the law."

But this episode is not the first time the EPA or CARB has had run-ins with VW. In the past, both agencies charged VW with similar violations, which resulted in penalties.

Defective Oxygen Sensors
VW previously failed to report its discovery of emission defects in at least 329,000 of its 1999, 2000, and 2001 Golf, Jetta, and New Beetle vehicles.

In May 2001, after conducting a random test, the EPA identified a problem with tailpipe emissions in the 1999 model vehicles caused by a failed oxygen sensor. It turns out, VW knew about the problem for a year already—since it had received numerous warranty claims associated with cracked oxygen sensors—but failed to report it. According to the Clean Air Act, any emission-related defect found in 25 vehicles or engines of the same model year has to be reported within 15 days.

VW spent $26 million in January 2002 to recall all the vehicles and replace or repair the part. Another estimated $660,000 was spent on an enhanced defect tracking system.

The EPA finally settled its case with VW in 2005, penalizing the delinquent car maker $1.1 million.

The state of California has been working closely with the EPA in testing VW cars and issued a separate notice of violation to VW in the current case.

California has been a leader in clean energy investments and set the stage in 2006 for transitioning to a sustainable, low-carbon future with the passage of AB 32, a law requiring sharp reduction in greenhouse gases. Since then, several legislative initiatives have been implemented to build the next generation of clean, fuel-efficient cars.

The CARB implements the state's vehicle regulations through a vigorous certification process, as well as compliance and enforcement programs. It regularly tests vehicles to ensure compliance with air quality standards.

In 2004, VW settled a case with CARB for $552,500 for selling cars in California that had not been properly certified. VW admitted to selling 84 new 2002 vehicles from several retail locations throughout the state, attributed to an error in its electronic ordering system.

The EPA is expected to compel VW to issue a recall notice in order to remedy the current emissions problem, which could take up to a year after identifying the appropriate corrective action and a recall plan.

Jalopnik:
http://jalopnik.com/volkswagen-tells-dealers-to-halt-sales-of-new-tdi-cars-1731923302

Volkswagen Tells Dealers To Halt Sales Of New TDI Cars Amid Diesel Cheating Scandal
Alanis King

Following the government investigation of Volkswagen's diesel emissions, The Detroit News reports the automaker ordered its U.S. dealerships to halt sales of new 2016 and remaining 2015 TDI car models with 2.0-liter diesel engines.

According to the Environmental Protection Agency and California Air Resources Board, VW dodged federal emissions requirements for some 482,000 of its diesel cars — including the Passat, Jetta, Golf, Beetle, SportWagens and Audi A3 — manufactured from 2009 to 2015. The models contain a "defeat device" which exists to detect when the car is under testing conditions, allowing for it to activate the full emissions-control systems only in those circumstances.

In other words, environmental officials say that the street cars are emitting between 10 and 40 times the amount of allowable nitrogen oxide pollution, which is not only illegal but harmful to both the environment and public.

The EPA is taking action on 2016 diesel models. Christopher Grundler, director of the EPA Office of Transportation of Air Quality, said that the government will not grant VW a "certificate of conformity" to sell the 2016 models with 2.0-liter diesel engines, meaning they cannot be sold.

VW dealers have been waiting for the 2016 models to replenish showrooms. Most U.S. VW dealers don't have any remaining 2015 diesel cars to sell.

VW is barred from selling 2016 model vehicles with the 2.0 liter diesel engine until "they get answers to the questions of how these vehicles are being operated. Volkswagen couldn't explain why we're getting these excess emissions," Grundler said.

Meanwhile, whatever 2015 models remain on lots have also been ordered not to be sold. As Automotive News notes, four-cylinder TDI models account for 20 to 25 percent of VW's U.S. sales, so this is going to hurt.

In addition, VW has ordered an outside investigation to find out what happened and "reverse the damage this has caused," CEO Martin Winterkorn said in an apologetic statement.

According to the EPA, the agency is now checking to see if other automakers are bypassing the laws on diesel engines as well.

While no official recall is underway just yet, the News reports:

EPA said VW violated federal law and, in theory, could face fines of up to $18 billion — $37,500 per vehicle — as well as criminal prosecution. Both agencies issued notices of non-compliance to VW Friday, a step necessary before ordering a recall.

The EPA will not take action to stop VW owners from driving their personal cars until a solution is made

available, but VW did remove its “clean diesel” advertisements from YouTube and television.

CBC News (Canada):
http://www.cbc.ca/news/business/volkswagen-emissions-rigging-1.3236548

Volkswagen shares plunge on emissions rigging scandal
Consumer Reports suspends 'recommended' rating for Jetta and Passat diesels
CBC News Posted: Sep 21, 2015 9:00 AM ET Last Updated: Sep 21, 2015 9:00 AM ET

Volkswagen's CEO apologized but investors were not in a forgiving mood as the company's stock plunged almost 20 per cent Monday following revelations late last week that the automaker had rigged emissions tests for almost 500,000 diesel cars in the U.S.

"I personally am deeply sorry that we have broken the trust of our customers and the public," Martin Winterkorn said in a weekend statement.

On Friday, the U.S. Environmental Protection Agency (EPA) revealed that half a million diesel-powered VWs had been programmed to bypass emission controls except during emissions tests. The cars include the Audi A3, VW Jetta, Beetle, Golf and Passat models made in the last seven years.

The EPA ordered VW to fix the cars and VW said it would co-operate with regulators. But the damage to the automaker's image is nothing less than catastrophic.

VW had marketed its diesel-powered cars as being better for the environment. The Associated Press reports, citing an anonymous source with knowledge of the matter, that VW has told dealers to stop selling its 2015 diesel cars with 2.0-litre engines.

The EPA said the VW cars under investigation seemed to pass emissions tests, but in the real world, were actually emitting up to 40 times the national standard for nitrogen oxide, which is linked to asthma and lung illnesses.

Consumer Reports announced it would remove its "recommended" rating from the Jetta and Passat diesels until it can retest the vehicles.

VW could face fines of up to $18 billion US, according to the EPA.

Volkswagen shares plunged 19.4 per cent in Monday trading in Germany, chopping $21 billion Cdn from the market value of the company.

"The company will have to recall nearly 500,000 affected cars, which will cost it millions of dollars, and that's even before the damage to its brand and potential fines," said Michael Hewson, chief market analyst at CMC Markets.

Diesel-powered models account for about a quarter of VW's sales.

Impact in Canada unclear

At this point, it isn't clear what the revelations mean for owners of VW diesels in Canada. Volkswagen Canada told CBC News on Friday that it first learned of the EPA action earlier that morning. It said it would co-operate with Environment Canada "to understand the implications for the Canadian market and what actions, if any, may be required in Canada."

Environment Canada, for its part, said it was in talks with the EPA "to further examine this issue and assess potential implications for Canada." Environment Canada also said it collaborates on emissions verification activities with the U.S. EPA "to ensure our common environmental outcomes are achieved," and pointed out

that its emissions standards are aligned with U.S. standards.

The EPA and Environment Canada both stressed that the effectiveness of a vehicle's air pollutant control devices is not a safety issue. The cars remain legal to drive.

From: Gong, Kristiene
Sent: Monday, September 21, 2015 10:35 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/21/2015

NY Times:
http://www.nytimes.com/2015/09/21/business/international/volkswagen-chief-apologizes-for-breach-of-trust-after-recall.html?_r=0

Volkswagen to Stop Sales of Diesel Cars Involved in Recall
By JACK EWING and CORAL DAVENPORTSEPT. 20, 2015

FRANKFURT — Volkswagen said on Sunday that it would halt sales of cars in the United States equipped with the kind of diesel motors that had led regulators to accuse the German company of illegally installing software to evade standards for reducing smog.

John Schilling, a Volkswagen spokesman, said that the company would stop selling 2015 and 2016 Volkswagen and Audi models equipped with 4-cylinder turbo diesel engines, which the company has marketed as “clean diesel.” The company will also stop selling used cars that have the engines, Mr. Schilling said.

He said he did not know how many models would be stuck on dealer lots as a result of the decision. Earlier this month, Volkswagen had said that 23 percent of new cars sold in August in the United States were diesels, or 7,400 vehicles.

The confirmation of the halt in sales came on the same day that Martin Winterkorn, the chief executive of Volkswagen, apologized for conduct that prompted the Environmental Protection Agency to order Volkswagen to recall nearly half a million vehicles.

An employee on the Audi A3 limousine. The recall involves four-cylinder Volkswagen and Audi vehicles from the model years 2009 to 2015. Credit Szilard Koszticsak/European Pressphoto Agency
Volkswagen could face billions of dollars in fines for what the E.P.A. said was a deliberate attempt to evade rules on emissions. The decision to stop sales was first reported by The Wall Street Journal.

“I personally am deeply sorry that we have broken the trust of our customers and the public,” Mr. Winterkorn said in a statement.

He said the company would “cooperate fully” with the authorities and order its own independent investigation into the accusations.

In his statement, Mr. Winterkorn did not contest assertions by the E.P.A. that Volkswagen sold cars equipped with software that could detect when periodic state government emissions testing was taking place.

Only during such tests are the cars’ full emissions control systems turned on. During normal driving situations, the controls were turned off, allowing the cars to spew as much as 40 times the pollution allowed under the Clean Air Act, the E.P.A. said.

Diesel-driven cars have enjoyed something of a renaissance in recent years, shedding much of their old stigma for being dirty, clanky and sluggish to drive, said Karl Brauer, an analyst at Kelley Blue Book. And in the

United States, he said, Volkswagen has clearly led the pack — offering diesel vehicles that performed just like their gasoline counterparts.

"Now, we have to wonder if the technology really advanced as far as we thought at VW," Mr. Brauer said. "They must have had a problem making it work in a way that delivered truly clean diesel. At least clean enough to meet the regulations."

Mr. Brauer said the higher nitrous oxide emissions probably allowed better drivability. Fuel economy also improves with more nitrous emissions, and engines can run cooler, and thus wear out more slowly.

"They must have had a mix of performance, economy and durability that they liked, but realized they couldn't achieve that and still get the emissions," he said.

Diesels in particular are known — and marketed — these days as having tremendous torque, or low-end thrust from a stop. If achieving the required emissions affected the torque, making it anemic, then "drivers are going to scratch their heads, thinking, isn't this why I got a diesel?" Mr. Brauer said.

Volkswagen was going through a difficult period even before the accusations became public on Friday. Mr. Winterkorn recently survived a power struggle with the chairman of Volkswagen's supervisory board, Ferdinand Piëch, a scion of the Porsche family who dominated the company for more than two decades before resigning in April.

Following Mr. Piëch's departure, some analysts have raised questions about whether Mr. Winterkorn would be strong enough to hold together the sprawling Volkswagen empire, which also includes Audi and Bentley luxury cars, Porsche and Lamborghini sports cars, Scania and MAN heavy trucks, and Ducati motorcycles.

Although Volkswagen recently surpassed Toyota as the world's biggest automaker measured by the number of cars sold, it is significantly less profitable than its Japanese rival and far weaker in the United States market.

A push by Volkswagen to increase sales in the United States, which included building a factory in Chattanooga, Tenn., to produce Passat sedans, has fallen short.

"For Volkswagen, it's a huge scandal," said Ferdinand Dudenhöffer, a professor at the University of Duisburg-Essen, who follows the automobile industry. "The timing is extremely unfortunate."

Professor Dudenhöffer said the case could damage all German automakers, which have tried to build acceptance in the United States for diesel engines, a sector in which they believe they have a technological lead.

Until recently, Professor Dudenhöffer said, the United States applied stricter standards to diesel engines than those applied by European regulators. But the European authorities, concerned about the health effects of diesel pollution, have tightened standards, prompting complaints from the auto industry.

Professor Dudenhöffer said that as a result of the E.P.A. action, Mr. Winterkorn could come under pressure to resign.

"Winterkorn was already damaged," Professor Dudenhöffer said. "Now there is an accusation of illegal behavior. This story is not over."

E.P.A. officials issued the car company a notice of violation and said it had admitted to the use of a so-called defeat device.

The recall involves 4-cylinder Volkswagen and Audi vehicles from the model years 2009 to 2015.

The software was designed to conceal the cars' emission of nitrogen oxide, a pollutant that contributes to the creation of ozone and smog, which are linked to a range of health problems, including asthma attacks, other

respiratory diseases and premature death.

Disengaging the pollution controls on a diesel-fueled car can yield better performance, including increased torque and acceleration.

California has issued a separate notice of violation to the company. California, the E.P.A. and the Justice Department are working together on an investigation of the allegations.

Over the next year, E.P.A. officials said, owners of the affected vehicles should expect to receive recall notices from Volkswagen, including information about how to get their cars repaired at no cost to them. The recall covers roughly 482,000 diesel passenger cars sold in the United States since 2009.

Affected diesel models include the 2009-15 Volkswagen Jetta, 2009-15 Beetle, 2009-15 Golf, 2014-15 Passat and 2009-15 Audi A3.

The American investigation could ultimately result in fines or penalties for the company. Under the terms of the Clean Air Act, the Justice Department could impose fines of as much as $37,500 for each recalled vehicle, for a possible total penalty of as much as $18 billion.

The notice of violation came days after the company promoted plans at the Frankfurt International Motor Show to introduce 20 plug-in hybrid or all-electric vehicles by 2020 as part of a campaign to reduce vehicle emissions.

Mr. Winterkorn said in his statement on Sunday that Volkswagen would "do everything necessary in order to reverse the damage this has caused."

"This matter has first priority for me, personally," he said, "and for our entire board of management."

Financial Times:
http://www.ft.com/intl/cms/s/0/c4f4745c-5f98-11e5-9846-de406ccb37f2.html#axzz3mNpq5JFM

VW apologises for cheating US car exhaust emissions tests
Andy Sharman in London

The chief executive of Volkswagen has apologised and ordered an external investigation into findings that the carmaker cheated on US emissions tests to make its vehicles appear less polluting.

In a statement on Sunday, Martin Winterkorn, chief executive of the German carmaker, said the board of management took the findings "very seriously".

He added: "I personally am deeply sorry that we have broken the trust of our customers and the public. We will co-operate fully with the responsible agencies, with transparency and urgency, to clearly, openly and completely establish all of the facts of this case."

The Environmental Protection Agency on Friday said diesel variants of several VW and Audi models sold in the US over six years — including the VW Passat, Beetle and Audi A3 — had been fitted with sophisticated algorithms designed to deceive the laboratory testing regime.

The authorities ordered VW to recall 482,000 cars because of the use of so-called defeat devices — which use software to detect when the car is being tested and runs treatments to reduce nitrogen oxides. Once out on the road, the cars were discovered to produce pollutants up to 40 times the legal limits.

The discovery leaves the German carmaker — which has admitted to using the defeat devices — potentially facing billions of dollars in fines and warranty costs, possible criminal charges for executives and class-action lawsuits from US drivers.

Mr Winterkorn did not say who would be carrying out the external investigation, and the company declined to provide further details.

It was Mr Winterkorn's first formal statement on an issue that also threatens to seriously undermine its attempts to turnround its sputtering performance in the US.

Max Warburton, analyst at Bernstein Research, said: "The best case for VW is probably still a multibillion-dollar fine, pariah status in the US with government — and possibly consumers — [and] damage to its leading position in diesel in the US."

VW now has to initiate a process to fix the cars' emissions systems, though the EPA has said the violations do not present a safety hazard and the vehicles remain legal to drive and resell. Owners of cars of models covering the 2009-2015 period do not need to take any action, the agency said.

I personally am deeply sorry that we have broken the trust of our customers and the public. We will co-operate fully with the responsible agencies, with transparency and urgency, to clearly, openly, and completely establish all of the facts of this case
- Martin Winterkorn, VW chief

In addition to the costs of the recall campaign, VW could theoretically also face fines of up to $37,500 per vehicle — a total of more than $18bn — though analysts have said VW is likely to face a much lower penalty.

The case is a rare but not unique example of this type of manipulation by the motor industry. In 1998, a group of truckmakers including Navistar, Renault and Volvo paid more than $1bn to resolve claims they installed defeat devices on heavy duty diesel engines. These devices allowed an engine to pass the emissions test, but then turn off emission controls when on the road, the EPA said at the time.

The EPA has been active in the past year, securing a record $300m settlement with Hyundai and Kia over claims the Korean affiliates overstated the fuel economy of their cars.

The Guardian:
http://www.theguardian.com/business/2015/sep/20/vw-software-scandal-chief-apologises-for-breaking-public-trust

VW software scandal: chief apologises for breaking public trust
Martin Winterkorn orders external investigation after US regulators found cars gave inaccurate data on toxic emissions

Volkswagen has ordered an external investigation after US regulators found that the carmaker designed software for close to half a million diesel cars that gave false emissions data, its CEO said, adding he was "deeply sorry" for the violation of US rules.

"I personally am deeply sorry that we have broken the trust of our customers and the public," Martin Winterkorn said in a statement published on Sunday by the carmaker on Sunday. "Volkswagen has ordered an external investigation of this matter."

The US Environmental Protection Agency (EPA) said on Friday the software deceived regulators measuring toxic emissions, adding that Volkswagen could face fines of up to $18bn (£11.5bn) as a result. The carmaker could face penalties of $37,500 for each car not in compliance with clean air rules. The diesel-powered models from 2009-2015 are the VW Jetta, Beetle and Golf, the Passat model from 2014-15, and the Audi A3 from 2009 to 2015.

"We do not and will not tolerate violations of any kind of our internal rules or of the law," said Winterkorn, adding the company was fully co-operating with the relevant agencies. He gave no details on who would carry

out the external investigation.

Cynthia Giles, an enforcement officer at the EPA, said on Friday that the cars in question "contained software that turns off emissions controls when driving normally and turns them on when the car is undergoing an emissions test".

"VW was concealing the facts from the EPA, the state of California and from consumers. We expected better from VW," she said. "Using a defeat device in cars to evade clean air standards is illegal and a threat to public health."

The EPA accused Volkswagen of using the device in 482,000 four-cyclinder Volkswagen and Audi diesel cars in the US since 2008. VW must recall all the cars, remove the defeat device and improve the cars' NOx emissions, which creates smog and has been linked to increased asthma attacks and other respiratory illnesses.

The feature, which the EPA called a defeat device, masks the true emissions only during testing and therefore when the cars are on the road they emit as much as 40 times the level of pollutants allowed under clean air rules meant to ensure public health is protected, said Giles.

Volkswagen suspended sales of cars containing the company's four-cylinder turbo direct injection (TDI) engine on Friday in light of the investigation. The "clean diesel" engine is commonly used in models including VW's Beetle, Golf, Jetta, Passat and the A3 luxury compact made by VW-owned Audi.

Richard Corey, executive officer of the California Air Resources Board (Carb), said on Friday: "Our goal now is to ensure that the affected cars are brought into compliance, to dig more deeply into the extent and implications of Volkswagen's efforts to cheat on clean air rules, and to take appropriate further action."

The EPA and Carb discovered the defeat device software following independent analysis by researchers at West Virginia University, who were promoted into action by the International Council on Clean Technology, an NGO.

When confronted with the EPA and Carb's evidence, VW admitted that its cars were fitted with the defeat device.

The crackdown on Volkswagen comes as the Obama administration is attempting to cut air pollution from an array of sources, including the vehicle industry, power plants and oil and natural-gas providers. The EPA set new carbon rules for big trucks earlier this year and has told all vehicle makers they must sell light vehicles averaging 54.5 miles a gallon by 2025.

In Europe, new laws have forced manufacturers to test their cars under real world conditions and not in laboratories, helping to reduce unrealistic claims about emissions. By 2017 all new cars will have to be more stringently tested, effectively ending an era when car makers could exaggerate the performance of their machines.

UK car industry group the SMMT claims that, because of European legislation to cut tailpipe pollution, Britain's air quality is better now than it has been for centuries.

From: Gong, Kristiene
Sent: Monday, September 21, 2015 10:26 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/21/2015

The Hill:
http://thehill.com/policy/energy-environment/254323-volkswagen-head-apologizes-for-epa-accusations

Volkswagen head apologizes after EPA accusations
By Timothy Cama - 09/20/15 01:28 PM EDT

The head of German automaker Volkswagen Group apologized Sunday after allegations surfaced that his company deliberately tried to evade United States air pollution laws.

Martin Winterkorn, the company's chief executive officer, said he was "deeply sorry" for violating the trust of customers and the public, and said that Volkswagen had ordered an external investigation into the matter.

Volkswagen faces up to $18 billion in fines for the violations under the Clean Air Act, under which the Environmental Protection Agency (EPA) sets air pollution rules for motor vehicles.

"We will cooperate fully with the responsible agencies, with transparency and urgency, to clearly, openly, and completely establish all of the facts of this case," Winterkorn said in a Sunday statement

"We do not and will not tolerate violations of any kind of our internal rules or of the law."

Winterkorn stopped short of admitting to the EPA's allegations.

On Friday, the EPA said it had discovered that about 482,000 diesel vehicles sold by VW and its subsidiary Audi in the United States had "defeat devices" that detect when the vehicle is undergoing an EPA emissions test and turn on equipment that controls output of nitrogen oxides to acceptable levels.

At all other times, the EPA said, the vehicles emitted more pollutants, sometimes exceeding allowable volumes by 40 times.

The agency has not yet officially charged Volkswagen with any civil or criminal penalties, nor did it order any recalls of the affected vehicles. California, which has its own emissions regulations, is also accusing the company of violating air rules.

"We at Volkswagen will do everything that must be done in order to re-establish the trust that so many people have placed in us, and we will do everything necessary in order to reverse the damage this has caused," Winterkorn said, adding that the issue is the top priority for him and the entire management team.

Reuters:
http://www.reuters.com/article/2015/09/21/usa-volkswagen-idUSL1N11R0L020150921

Volkswagen could face $18 billion penalties from EPA
WASHINGTON | BY TIMOTHY GARDNER

Volkswagen AG could face penalties up to $18 billion after being accused of designing software for diesel cars that deceives regulators measuring toxic emissions, the U.S. Environmental Protection Agency said on Friday.

"Put simply, these cars contained software that turns off emissions controls when driving normally and turns them on when the car is undergoing an emissions test," Cynthia Giles, an enforcement officer at the EPA, told reporters in a teleconference.

Volkswagen can face civil penalties of $37,500 for each vehicle not in compliance with federal clean air rules. There are 482,000 four-cylinder VW and Audi diesel cars sold since 2008 involved in the allegations. If each car involved is found to be in noncompliance, the penalty could be $18 billion, an EPA official confirmed on the teleconference.

A U.S. Volkswagen spokesman said the company "is cooperating with the investigation; we are unable to comment further at this time."

The feature in question, which the EPA called a "defeat device," masks the true emissions only during testing and therefore when the cars are on the road they emit as much as 40 times the level of pollutants allowed under clean air rules meant to ensure public health is protected, Giles said.

The EPA accused Volkswagen of using software in four-cylinder Volkswagen and Audi diesel cars from model years 2009 to 2015 made to circumvent emissions testing of certain air pollutants.

The cars are not facing recall at this time, the EPA said.

The diesel-powered vehicles involved from the 2009 to 2015 model years are the VW Jetta, VW Beetle, VW Golf and the Audi A3, as well as the VW Passat from model years 2014 and 2015.

Christian Post:
http://www.christianpost.com/news/volkswagen-to-recall-almost-500000-cars-in-the-us-over-epa-violation-145778/

Volkswagen to recall almost 500,000 cars in the US over EPA violation
BY LORRAINE CABALLERO , CHRISTIAN POST CONTRIBUTOR

Volkswagen will recall almost 500,000 vehicles released from 2009 to 2015 in the United States after the carmaker allegedly violated the law by using illegal software, which helped it go past environmental restrictions.

The Environmental Protection Agency (EPA) said Volkswagen broke the law by installing a "defeat device" in Volkswagen and Audi units with four-cylinder turbo diesel engines released from the year 2009 to 2015. Under normal driving conditions, the emission control devices installed in the said cars worked with reduced efficacy, according to the Dispatch Times.

In the wake of the violation, Volkswagen chief executive Martin Winterkorn delivered a statement apologizing to their customers and vowing to cooperate with EPA's investigation. However, he did not deny the allegations regarding the illegal software, the International Business Times reports.

"I personally am deeply sorry that we have broken the trust of our customers and the public," said Winterkorn in his statement.

Because of the notice of violation from the EPA, Volkswagen is now facing penalties amounting to more than $18 billion, or around $37,500 per unit, based on the U.S.A. federal Clean Air Act. EPA and CARB discovered the illegal software after researchers at the West Virginia University conducted an independent study in cooperation with the global Council on Clean Transportation, the report adds.

Volkswagen has been struggling to sell cars in the United States because of the rising cases of asthma and other respiratory illnesses caused by air pollutants. The diesel vehicles affected by the recall were being counted on to pull up the company's sales in the United States.

Based on the findings of the EPA, Volkswagen had included a certain algorithm in the cars' emissions software that could detect when an emission test is being conducted.

Owners of the diesel cars affected by the recall will be notified by Volkswagen by next year, EPA said. Until Consumer Reports can "retest" the said cars, the recommended rating for the Passat, Jetta, Golf, Beetle, and Audi A3 luxury compact will remain on hold, the report relays.

From: Gong, Kristiene
Sent: Monday, September 21, 2015 10:14 AM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John;

Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/21/2015

AP (via Boston Globe):
https://www.bostonglobe.com/business/2015/09/20/chief-sorry-after-epa-says-firm-skirted-clean-air-law/3NNTCf2cVxUI1qYNBfMe7L/story.html

Volkswagen chief apologizes for rigging tests of emissions
By Paul Wiseman and Tom Krisher ASSOCIATED PRESS SEPTEMBER 21, 2015

WASHINGTON — The chief executive of Volkswagen apologized Sunday and VW customers said they felt duped after the Environmental Protection Agency revealed that the German automaker had skirted clean air rules by rigging emissions tests for about 500,000 diesel cars.

''I personally am deeply sorry that we have broken the trust of our customers and the public,'' Volkswagen chief Martin Winterkorn said in a statement. He said VW has ordered an investigation and promised that the company would cooperate with regulators.

On Friday, the EPA said VW used software that allowed its diesel cars to release fewer smog-causing pollutants during tests than in real-world driving conditions.

The cars, built in the last seven years, include the Audi A3, VW Jetta, Beetle, Golf, and Passat models. The agency ordered VW to fix the cars at its own expense. VW also faces fines that could add up to billions of dollars.

VW edged out Toyota to become the world's top-selling automaker in the first half of 2015. But a hit to its reputation from the emissions revelations could hamper its efforts at a sales rebound in the United States. Between 2013 and 2014, VW sales plummeted 10 percent, even as overall industry sales rose 6 percent. US buyers want SUVs, and Volkswagen doesn't have competitive vehicles to offer them.

The magazine Consumer Reports almost immediately suspended its ''recommended'' rating on the Jetta and Passat diesels until it can get recall repairs and retest the cars.

Volkswagen marketed the diesel-powered cars, which account for about 25 percent of its sales, as being better for the environment. After the EPA acted, VW withdrew ads for its diesel cars from Youtube.com and asked dealers to stop selling 2015 diesel cars with 2.0-liter engines, according to a person familiar with the matter.

Some VW customers were furious.

Zeeshan Shah, 39, of Fulton, Md., said that he bought a Volkswagen Diesel Passat 2015 in July after he totaled his Jetta two years ago.

''The selling point" for the Diesel Passat was that the technology was so good, he said. Now, Shah plans to return the car back to the dealer to have it examined and doesn't want to buy another Volkswagen. ''Once they cheat you on this issue, what other issues can they cheat you on?'' he said. ''You don't trust them.''

John German, senior fellow at the International Council on Clean Transportation, the group that blew the whistle on VW, said it didn't expect to find any violators when it contracted with West Virginia University to test cars with diesel engines.

The council, a research group that helps governments write regulations, did the US tests in an effort to show that automakers were complying with US nitrogen oxide emissions standards, which are stricter than in other countries, he said.

The EPA said VW faces fines of up to $37,500 per vehicle for the violations, a total of more than $18 billion.

WSJ:
http://www.wsj.com/articles/volkswagen-ceo-apologizes-after-epa-accusations-1442754877

Volkswagen Halts U.S. Sales of Certain Diesel Cars
Auto maker also begins external probe after EPA accuses company of dodging emissions rules
By WILLIAM BOSTON, AMY HARDER and MIKE SPECTOR
Updated Sept. 20, 2015 8:57 p.m. ET

Volkswagen AG's crisis over allegedly cheating on U.S. emissions tests deepened, with the German auto maker halting American sales of popular diesel-powered cars and issuing a sweeping apology for violating customers' trust.

It also launched an external investigation. Shares in the company slumped more than 20% in early trading Monday in response to the crisis.

The company could face billions of dollars in fines and the crisis could further weaken Volkswagen Chief Executive Martin Winterkorn's position. He narrowly survived efforts by a major shareholder to oust him earlier this year and was passed over for the chairman's job, the company's top post, this month.

"I personally am deeply sorry that we have broken the trust of our customers and the public," Mr. Winterkorn said in a statement issued by the company on Sunday, adding that VW is cooperating with authorities and has commissioned an external probe.

The U.S. is crucial in Volkswagen's efforts to become the world's leading auto maker by sales. The German company has built its campaign to grow in the U.S. market on a promise that its clean-diesel engines deliver better performance and low emissions. It is neck-and-neck with reigning sales leader Toyota Motor Corp. and overtook the Japanese car maker during the first half of this year. But the emissions test probes could stall its progress.

Even prior to the emissions issue, the auto maker's namesake Volkswagen brand has been battling declining sales in the U.S. market. And Audi AG, its luxury car maker, is finding it hard to catch up in the U.S. with rivals BMW AG and Daimler AG, which makes Mercedes-Benz vehicles.

On Friday, the U.S. Environmental Protection Agency and the California Air Resources Board alleged that Volkswagen used software, dubbed a "defeat device," in the cars to make diesel-powered engines appear to have lower levels of emissions than they actually did.

About 482,000 Volkswagen diesel-powered cars were affected.

The EPA probe could force Volkswagen and its Audi unit to recall thousands of vehicles that contain the company's "clean diesel" engines. The four-cylinder 2.0-liter turbo direct injection, or TDI, engine is commonly found in Volkswagen's Passat, Jetta, Golf, Beetle and in Audi's A3 luxury compact model.

A Volkswagen spokesman on Sunday said the auto maker halted the sale of all 2015 and 2016 models containing the four-cylinder 2.0 liter TDI engine. The EPA investigation affects cars sold since 2008. The company hasn't issued a recall, the spokesman said.

Realization that Volkswagen may have cheated to get better emissions results could undermine its U.S. recovery and further weaken its shares, which are down 37% from their peak on March 16, said analysts.

"There is no way to put an optimistic spin on this—this is really serious," said Max Warburton, an analyst with Bernstein Research. "The best case for VW is probably still a multi-billion dollar fine."

Consumer Reports, an influential magazine when it comes to car reviews, last week suspended

"recommended" ratings on the auto maker's Jetta and Passat diesel-engine models after the EPA disclosed its allegations. Consumer Reports said the recommendations would be suspended until it can retest the vehicles once they are repaired. The magazine said it would then assess whether the cars' fuel economy worsened.

A production line at a Volkswagen plant in Wolfsburg, Germany. ENLARGE
A production line at a Volkswagen plant in Wolfsburg, Germany. PHOTO: REUTERS
Laurie Cleveland, a 54-year-old English teacher from Lowville, N.Y., said she bought a new 2015 VW Passat TDI over the Labor Day weekend. She isn't sure what to do now. She said it is her fourth Volkswagen diesel car since 2006.

"I feel like I've been deceived," she said. "I'm a person who likes to be environmentally friendly," she added.

Mr. Winterkorn on Sunday vowed to do "everything necessary" to regain public trust in the company.

"We do not and will not tolerate violation of any kind of our internal rules or of the law," he said. "This matter has first priority for me."

U.S. officials said Volkswagen violated two parts of the federal Clean Air Act and could face fines of as much as $37,500 per car, or more than $18 billion. It remained unclear whether the government would seek such an onerous penalty.

The EPA in November 2014 hit South Korean auto makers Hyundai Motor Co. and Kia Motors Corp. with a record $100 million penalty for overstating fuel-economy claims and forced the companies to cough up another $200 million in regulatory credits.

The EPA has said the vehicles remain safe and legal to drive. The agency is working with the Justice Department and an investigation is continuing.

Officials alleged that Volkswagen used software that activates full emissions controls only during testing but then reduces their effectiveness during normal driving. The result is that cars can emit nitrogen oxides at up to 40 times the allowable standard, the agency said. Diesel-powered cars are a small part of overall U.S. car and light-truck sales.

Experts say that the software enables cars to get better fuel economy at the expense of higher nitrogen-oxide emissions, which was likely one reason VW was using them, according to Margo Oge, who recently retired as director of the EPA's Office of Transportation and Air Quality after more than 30 years at the agency.

Volkswagen's apparent motivations on the emissions tests were unclear. An EPA spokeswoman has said it would be "premature to speculate on why VW did this."

A Volkswagen spokesman in Wolfsburg, Germany, on Sunday said, "We are now in the investigation phase and have no comment beyond what is in the statement that we published today."

California is separately investigating the auto maker.

The International Council on Clean Transportation, a nonprofit research organization that works with governments to cut air pollution from mobile sources, and West Virginia University researchers uncovered Volkswagen's alleged use of defeat devices in research and testing over the last couple of years.

Reuters:
http://www.reuters.com/article/2015/09/20/us-usa-volkswagen-ceo-idUSKCN0RK0IK20150920

Volkswagen to halt U.S. sales of some 2015 diesel cars
FRANKFURT/HAMBURG | BY CHRISTOPH STEITZ AND JAN SCHWARTZ

Volkswagen (VOWG_p.DE) told U.S. dealers to halt sales of some 2015 diesel cars after regulators found software it designed for the affected vehicles gave false emissions data, the company said Sunday, announcing it had launched an investigation.

In a statement published by the carmaker on Sunday, Chief Executive Officer Martin Winterkorn said, "I personally am deeply sorry that we have broken the trust of our customers.

"Volkswagen has ordered an external investigation of this matter," he said.

The U.S. Environmental Protection Agency (EPA) said on Friday the software deceived regulators measuring toxic emissions, adding that Volkswagen could face fines of up to $18 billion as a result.

The Detroit News reported late Friday that VW dealers still had some 2015 diesel Jetta, Passat and Beetle cars for sale.

A VW representative on Sunday confirmed the partial halt of sales of the affected vehicles but did not give any numbers.

Winterkorn said, "We do not and will not tolerate violations of any kind of our internal rules or of the law," adding that the company was fully cooperating with the relevant agencies.

He gave no details on who would carry out the external investigation.

"This is not your usual recall issue, an error in calibration or even a serious safety flaw," Bernstein analysts wrote in a note on Sunday. "There is no way to put an optimistic spin on this - this is really serious."

Cynthia Giles, an enforcement officer at the EPA, said on Friday the cars in question "contained software that turns off emissions controls when driving normally and turns them on when the car is undergoing an emissions test".

The feature, which the EPA called a "defeat device," masks the true emissions only during testing. When the cars are on the road, they emit as much as 40 times the level of pollutants allowed under clean air rules meant to ensure public health is protected, Giles said.

"We have admitted to it to the regulator. It is true. We are actively cooperating with the regulator," a Volkswagen spokesman said on Sunday.

Volkswagen could face civil penalties of $37,500 for each vehicle not in compliance with federal clean air rules. Some 482,000 four-cylinder VW and Audi diesel cars sold since 2008 are involved in the allegations.

If each car involved is found to be in noncompliance, the penalty could be $18 billion, an EPA official confirmed during the telephone conference on Friday.

Volkswagen peer Daimler, meanwhile, signaled it may not be subject to the same violation.

"I have a rough idea of what is happening and that it does not apply to us," Daimler Chief Executive Dieter Zetsche said on Sunday at an event in Hamburg.

"But it is much too early to make a final statement on this," he added.

USA Today:
http://www.usatoday.com/story/money/cars/2015/09/20/volkswagen-ceo-martin-winterkorn-apologizes-epa-clean-air-act-emissions-violations/72519678/

Volkswagen issues sales halt; CEO apologizes on emissions cheating

Nathan Bomey, USA TODAY 8:02 a.m. EDT September 21, 2015

Volkswagen has admitted cheating U.S. diesel emissions tests, sending company shares plunging as much as 23 percent in Frankfurt and potentially leaving the company open to billions of dollars in fines. Bloomberg

Martin Winterkorn ordered an external investigation after the EPA disclosed the violations.

Volkswagen's CEO said he is "deeply sorry" for violating U.S. emissions standards and ordered an external investigation Sunday, two days after the Environmental Protection Agency (EPA) accused the automaker of purposefully manipulating emissions tests for almost 500,000 vehicles.

The German automaker ordered its U.S. dealerships to stop selling cars impacted by the probe until its engineers can deliver a fix.

The EPA accused Volkswagen of installing software on 482,000 diesel cars in the USA that allowed it to cheat emissions tests, potentially exposing people to harmful pollutants at levels of 40 times the acceptable standard and respiratory conditions such as asthma.

"I personally am deeply sorry that we have broken the trust of our customers and the public," Martin Winterkorn, Volkswagen's CEO, said in a statement. "We will cooperate fully with the responsible agencies, with transparency and urgency, to clearly, openly and completely establish all of the facts of this case." Winterkorn pledged to regain the public's trust.

The violations could expose Volkswagen — the world's largest vehicle manufacturer through the first six months of 2015 — to up to $18 billion in federal fines if the EPA assesses the maximum possible penalty of $37,500 per vehicle.

The violations could invite charges of false marketing by regulators, a vehicle recall and payment to car owners, either voluntarily or through lawsuits. Volkswagen advertised the cars under the "Clean Diesel" moniker.

The state of California is investigating the emissions violations.

"We do not and will not tolerate violations of any kind of our internal rules or of the law," Winterkorn said. The company's board takes the allegations "very seriously," he said.

The EPA accused the German automaker of adopting what it called a "defeat device" to trick U.S. regulators into believing its cars met Clean Air Act standards for nitrogen oxides. Volkswagen admitted to investigators it had installed the defeat device, the EPA said.

The EPA said impacted cars include the 2009 to 2014 Volkswagen Jetta, Beetle and Golf, the 2014 and 2015 Volkswagen Passat and the 2009 to 2015 Audi A3.

Volkswagen told dealers they cannot sell the 4-cylinder diesel versions of those cars until a fix is available, Volkswagen spokesman Mario Guerreiro said Sunday.

The sales halt could put a significant dent in the company's September sales performance. About 20% of Volkswagen's vehicle sales are diesel engines, said AutoPacific analyst Dave Sullivan.

"It totally goes against all of the marketing they have had of a clean diesel," Sullivan said of the violations. "That's one of the biggest selling points for Volkswagen."

"The trust of our customers and the public is and continues to be our most important asset," Winterkorn said Sunday. "We at Volkswagen will do everything that must be done in order to re-establish the trust that so many people have placed in us, and we will do everything necessary in order to reverse the damage this has caused. This matter has first priority for me, personally, and for our entire Board of Management."

From: Gong, Kristiene
Sent: Friday, September 18, 2015 3:22 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

Sacramento Bee:
http://www.sacbee.com/news/business/article35709432.html

Regulators order Volkswagen recalls over device used to trick smog tests
BY DALE KASLER

In a joint probe with California air regulators, the federal government Friday told Volkswagen to recall 480,000 diesel-fuel cars, charging the automaker with equipping the cars with software designed to circumvent pollution limits.

The U.S. Environmental Protection Agency and California Air Resources Board sent notices to the German automaker over its alleged use of something called a "defeat device," a piece of software that controls emissions during smog tests but not when the vehicles are actually on the road.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," said Cynthia Giles, assistant EPA administrator, in a prepared statement. "Working closely with the California Air Resources Board, EPA is committed to making sure that all automakers play by the same rules."

The EPA sent Volkswagen a "notice of violation" and told car owners they can expect a recall notice. The agency said all repairs will be done at Volkswagen's expense. It added that the cars are safe to drive. The EPA has the authority to order automotive recalls.

Stanley Young, a spokesman for the ARB, said the federal and state agencies were first notified of the problem by independent researchers at West Virginia University and the International Council on Clean Transportation. Months of followup testing, including tests at an ARB lab in El Monte, confirmed the analyses.

Volkswagen officials in early September "admitted to CARB and EPA staff that these vehicles were designed and manufactured with a defeat device," according to an enforcement letter the California agency sent Friday to Volkswagen officials.

Young said "our major goal is to ensure that these cars come into compliance, that they're the same in the real world as they are on the test bench." The automaker eventually could face fines or other enforcement actions, he said.

The agencies plan to "dig more deeply into the extent and implications of Volkswagen's efforts to cheat on clean air rules, and to take appropriate further action," said Richard Corey, executive officer of ARB, in a prepared statement.

The EPA said the recall affects VW Jettas, Beetles, Golfs and Audi A3s made in the 2009 to 2015 model years. It also covers VW Passats made in the 2014 and 2015 model years. Only diesel cars are affected. Young said ARB believes there are as many as 50,000 affected vehicles on the road in California.

Under the federal Clean Air Act, California has the authority to set its own regulatory standards for car emissions.

Volkswagen of America spokesman Darryll Harrison Jr. said the company is cooperating with the federal and state agencies but had no further comment.

From: Gong, Kristiene
Sent: Friday, September 18, 2015 3:10 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

The Atlantic:
http://www.theatlantic.com/technology/archive/2015/09/volkswagens-game-of-make-belief/406159/

Volkswagen's Game of Make-Believe
The company inserted a device into almost 500,000 cars meant to trick emissions testing, the EPA says.
ROBINSON MEYER

One of the great lessons of the pioneering computer scientist Alan Turing is this: Computers are only pretending machines. Software is always just imitating something else.

Volkswagen seems to have taken this maxim to new heights. The Environmental Protection Agency alleges that the company installed "defeat devices" in its four-cylinder Volkswagen and Audi-brand diesel cars from 2009 to 2015.

These devices, essentially, let the cars pretend to not break the law. The software could sense when the car was undergoing emissions testing and activate its pollution-control systems accordingly. When the car was being driven during normal use, these systems largely did not activate—making the car a much heavier polluter in real-life than it looked on paper.

With those systems deactivated, the car's emissions violated the Clean Air Act and California's state pollution-control regulation.

"Using a defeat device in cars to evade clean-air standards is illegal and a threat to public health," said Cynthia Giles, assistant administrator for the EPA's Office of Enforcement and Compliance Assurance, in a statement.

There are almost 500,000 vehicles on American roads with the devices installed, according to the EPA. Volkswagen must now pay to repair the emissions systems in affected cars. The government may also fine the company as much as $18 billion.

The device was discovered by researchers at West Virginia University, who notified the EPA and California state authorities. The two authorities investigated further, and after demanding "an explanation for the identified emission problems, Volkswagen admitted that the cars contained defeat devices," said a statement from the agency.

I reached out to Volkswagen for comment and haven't heard back yet. The Times reports that the company is complying with investigations.

From: Gong, Kristiene
Sent: Friday, September 18, 2015 2:58 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

Mashable:
http://mashable.com/2015/09/18/volkswagen-recall-emissions/#uL1ctrM4JZkb

Volkswagen urged to recall cars for allegedly cheating emissions test

BY CHRIS PERKINS

Automakers are under intense pressure to meet emissions regulations put in place by the world's governments. Volkswagen allegedly had a slightly different solution.

The U.S. Environmental Protection Agency (EPA) ordered a recall of almost 500,000 Volkswagen and Audi vehicles equipped with four-cylinder diesel engines, for software designed to sidestep emissions regulations, reports the New York Times.

In total, 482,000 vehicles are being implicated, including the 2009-2015 Volkswagen Golf, Beetle, Jetta and Beetle, the 2014-2015 Volkswagen Passat and the 2009-2015 Audi A3. The cars were possibly installed with a "defeat device," a piece of software designed to detect when the car is undergoing emissions testing and turn on all of the car's emissions control systems then. In normal driving, the systems would turn off, causing 40 times larger nitrogen oxide emissions, according to the E.P.A.

Nitrogen oxide is a major contributor to smog, which can lead to increased respiratory problems and premature death.

The installation of this software is in violation of the Clean Air Act, and as such, the E.P.A, the State of California and the Department of Justice will launch an investigation. The installation of this software is in violation of the Clean Air Act, and as such, the E.P.A, the State of California and the Department of Justice will launch an investigation.

U.S. regulators hope that this recall will send a message to automakers to not develop software to skirt regulations. Last November, Hyundai and Kia were fined $100 million for violating the Clean Air Act. The two companies inflated their fuel economy figures for their 2012 vehicles.

The likely reason why Volkswagen could go the trouble to develop and use software like this is to boost performance; emissions control equipment tends to suck power out of an engine.

Researchers from West Virginia University, working with the International Council on Clean Transportation, discovered the software, according to the EPA's press release.

"Volkswagen Group of America, Inc., Volkswagen AG and Audi AG received today notice from the US Environmental Protection Agency, US Department of Justice and the California Air Resources Board of an investigation related to certain emissions compliance matters. VW is cooperating with the investigation; we are unable to comment further at this time," said a representative for Volkswagen.

A representative for the EPA wasn't immediately available for comment.

It's unclear if this issue only pertains to U.S. model Volkswagens and Audis equipped with four-cylinder diesels, or their world-market counterparts as well.

A report from Jalopnik notes that all of Volkswagen's ads for its diesel models have been deleted from YouTube, apparently at the company's request.

From: Gong, Kristiene
Sent: Friday, September 18, 2015 2:51 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

Christian Science Monitor:
http://www.csmonitor.com/Business/In-Gear/2015/0918/Why-the-EPA-is-forcing-Volkswagen-to-recall-

nearly-500-000-cars

Why the EPA is forcing Volkswagen to recall nearly 500,000 cars
Volkswagen AG, the German car manufacturer, is under investigation by California and US emissions regulators for allegedly circumventing emission tests with a new device.
By Corey Fedde, Staff SEPTEMBER 18, 2015

Volkswagen AG is under investigation for circumventing clean air rules.

German automotive company Volkswagen AG is under investigation by California and US environmental regulators. The US Environmental Protection Agency told Reuters Volkswagen allegedly used software to circumvent emissions testing of specific air pollutants.

"Put simply, these cars contained software that turns off emissions controls when driving normally and turns them on when the car is undergoing an emissions test," Cynthia Giles, an EPA enforcement officer, told Reuters via teleconference.

The feature, known as a "defeat device," is allegedly present in 4 cylinder Volkswagen and Audi vehicles from 2009-2015, which total nearly 500,000 vehicles. The device is programmed to detect when the car is undergoing an emissions test and turn on the full emissions controls. The device then turns the emission controls off during normal driving. The result being far more pollution than the company reported, the EPA told The New York Times.

The pollutant the "defeat device" is designed to conceal, nitrogen oxide, has been linked by public health officials to variety of health problems, including asthma.

The 500,000 diesel vehicle models affected include 2009-2015 Volkswagen Jettas, Beetles, Golfs, Passats, and Audi A3s.

The violation and investigation belie a growing trend in more aggressive environmental enforcement from federal regulators. In November 2014, the administration announced its largest ever penalty for a violation of the Clean Air Act on Korean automakers Hyundai Motor and Kia Motors. The fine involved a $300 million settlement for overstating vehicle fuel-economy standards on more than 1 million cars.

According to The New York Times, analysts say the crackdown is meant to send a clear message to automakers that circumventing federal rules will not be tolerated.

California, the EPA, and the Justice Department are working together on the investigation.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health. Working closely with the California Air Resources Board, EPA is committed to making sure that all automakers play by the same rules. E.P.A. will continue to investigate these very serious violations," Ms. Giles told the Times.

This report includes material from Reuters.

From: Gong, Kristiene
Sent: Friday, September 18, 2015 2:27 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

Reuters:
http://www.reuters.com/article/2015/09/18/us-usa-volkswagen-idUSKCN0RI1VK20150918

Volkswagen could face $18 billion penalties from EPA

WASHINGTON | BY TIMOTHY GARDNER

Volkswagen AG (VOWG_p.DE) could face penalties up to $18 billion after being accused of designing software for diesel cars that deceives regulators measuring toxic emissions, the U.S. Environmental Protection Agency said on Friday.

"Put simply, these cars contained software that turns off emissions controls when driving normally and turns them on when the car is undergoing an emissions test," Cynthia Giles, an enforcement officer at the EPA, told reporters in a teleconference.

Volkswagen can face civil penalties of $37,500 for each vehicle not in compliance with federal clean air rules. There are 482,000 four-cylinder VW and Audi diesel cars sold since 2008 involved in the allegations. If each car involved is found to be in noncompliance, the penalty could be $18 billion, an EPA official confirmed on the teleconference.

A U.S. Volkswagen spokesman said the company "is cooperating with the investigation; we are unable to comment further at this time."

The feature in question, which the EPA called a "defeat device," masks the true emissions only during testing and therefore when the cars are on the road they emit as much as 40 times the level of pollutants allowed under clean air rules meant to ensure public health is protected, Giles said.

The EPA accused Volkswagen of using software in four-cylinder Volkswagen and Audi diesel cars from model years 2009 to 2015 made to circumvent emissions testing of certain air pollutants.

The cars are not facing recall at this time, the EPA said.

The diesel-powered vehicles involved from the 2009 to 2015 model years are the VW Jetta, VW Beetle, VW Golf and the Audi A3, as well as the VW Passat from model years 2014 and 2015.

From: Gong, Kristiene
Sent: Friday, September 18, 2015 1:40 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

The Hill:
http://thehill.com/policy/energy-environment/254188-epa-accuses-vw-of-going-around-federal-emissions-standards

Feds accuse VW of going around federal emissions standards
By Devin Henry - 09/18/15 12:50 PM EDT

The Environmental Protection Agency (EPA) is accusing Volkswagen of looking to circumvent federal air pollutant emission standards for the last six years.

EPA officials alleged Friday that about 482,000 VW vehicles sold since 2008 violate the Clean Air Act due to software installed on the vehicles that turns off required air pollution protections.

Janet McCabe, an acting assistant administrator, said the EPA “intends to hold VW responsible to recall the vehicles” and fix the emissions problem. The company could face up to an $18 billion fine for the violations.

The EPA issued VW a Clean Air Act violation notice Friday, alleging it used a software algorithm on certain vehicles that would turn on emission controls only when they undergo official emissions testing.

This "defeat device," the EPA said, would switch off those controls during normal operation, which means the vehicles could emit up to 40 times the amount of nitrogen oxide allowed under federal air pollution standards.

"These violations are very serious … not only because they result in excess emissions, but also because VW was concealing the fact from EPA, the state of California and from consumers," Assistant Administrator Cynthia Giles said. "We expected better from VW."

Federal law requires manufacturers to certify to the EPA that their cars meet emissions standards before selling their vehicles in the U.S. Cars with defeat devices cannot be certified, the EPA said.

A VW statement said only that the company had received the violation notice and is cooperating with the investigation.

The EPA and the California Air Resources Board discovered the defeat device during an analysis at West Virginia State University, the EPA said. Officials said their investigation into the incident is ongoing and wouldn't give many more details about how it developed or what the outcome might be.

The agency is not ordering a recall or announcing penalties at the moment, and officials said the cars are safe and legal to drive. The Friday announcement, Giles said, was meant to "inform the public right away and to put VW on notice of our continuing investigation."

The EPA said the announcement covers VW Jettas, Beetles, Golfs and Audi A3s with model years between 2009 and 2015, as well as the VW Passat with model years 2014 and 2015.

Fortune:
http://fortune.com/2015/09/18/volkswagen-recall-epa-smog/

Volkswagen ordered to recall almost a half-million cars over emissions trick
by Benjamin Snyder

The Environmental Protection Agency is ordering Volkswagen to recall nearly a half-million cars after the company allegedly used a computer software trick to make the cars seem more environmentally friendly during state emissions tests.

The VW models involved include the diesel versions of the following models: The 2009-15 Volkswagen Jetta, the 2009–15 Beetle, the 2009–15 Golf, the 2014-15 Passat and the 2009-15 Audi A3. The recall affects 482,000 vehicles in total.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," said Cynthia Giles, Assistant Administrator for the Office of Enforcement and Compliance Assurance, in a statement. "Working closely with the California Air Resources Board, EPA is committed to making sure that all automakers play by the same rules. EPA will continue to investigate these very serious matters."

"Volkswagen Group of America, Inc., Volkswagen AG and Audi AG received today notice from the US Environmental Protection Agency, US Department of Justice and the California Air Resources Board of an investigation related to certain emissions compliance matters," Volkswagen says. "VW is cooperating with the investigation; we are unable to comment further at this time."

Auto Guide:
http://www.autoguide.com/auto-news/2015/09/volkswagen-used-illegal-software-to-cheat-emissions-tests-epa.html

Volkswagen Used Illegal Software to Cheat Emissions Tests: EPA
By Stephen Elmer Sep 18, 2015

Volkswagen may be forced to recall almost 500,000 diesel passenger cars after an investigation revealed illegal software was allowing the vehicles to pass government emissions standards.

A software algorithm, known as a defeat device, used on roughly 482,000 Volkswagen vehicles with four-cylinder diesel engines is able to detect when the car is undergoing official emissions testing, and will activate full emissions controls only during the test.

The EPA says that this results in cars that meet emissions standards while being tested, but emit 40 percent more nitrogen oxides while driving.

Independent analysis at West Virginia University uncovered the defeat devices. After being questioned by the EPA and CARB, Volkswagen admitted that its cars did contain defeat devices.

The EPA says "it is incumbent" on Volkswagen to initiate a recall fix for all the affected cars, although they note that these vehicles are still safe to drive and do not present a safety hazard at this time.

Volkswagen may be liable for civil penalties over the findings, which could total up to $18 billion if the EPA leverages its maximum find of $37,500 per vehicles.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," said Cynthia Giles, Assistant Administrator for the Office of Enforcement and Compliance Assurance. "Working closely with the California Air Resources Board, EPA is committed to making sure that all automakers play by the same rules. EPA will continue to investigate these very serious matters."

Models affected by the issue include the 2009-2015 Volkswagen Jetta, Beetle and Gold. The 2009-2015 Audi A3 is also affected, along with the 2014-2015 Passat.

Volkswagen acknowledged that it has received notice of the investigation. "VW is cooperating with the investigation; we are unable to comment further at this time," said the brand.

From: Gong, Kristiene
Sent: Friday, September 18, 2015 1:36 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

Washington Post:
http://www.washingtonpost.com/news/energy-environment/wp/2015/09/18/epa-volkswagen-used-defeat-device-to-circumvent-air-pollution-controls/

EPA: Volkswagen used 'defeat device' to circumvent air pollution controls
By Joby Warrick September 18 at 1:04 PM

The Environmental Protection Agency on Friday accused Volkswagen of installing a software "defeat device" that circumvented pollution controls on nearly a half-million Volkswagens and Audis.

The regulatory agency filed a notice of violation against the German automaker, saying the company deliberately cheated on clean-air rules by installing the software of five of its models since 2008. An EPA statement warned of possible civil penalties and hinted of a future possible recall, saying it was "incumbent on Volkswagen to initiate the process" to fix the affected cars' emissions systems.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," said Cynthia Giles, the EPA's assistant administrator for EPA's Office of Enforcement and Compliance Assurance.

EPA officials, in a joint probe with California's regulatory agency, determined that Volkswagen had inserted a sophisticated algorithm in the cars' emissions software that could detect when a vehicle was undergoing emissions testing. The software, which the EPA called a "defeat device," would turn on full emissions controls during testing, and switch them off again under normal driving conditions.

As a result, the cars emitted far more pollution–up to 40 times the federal standard for the pollutant known as NOx, a component in urban smog, the EPA said.

The software was installed in Volkwagen's Golfs, Jettas and Beetles and Audi A3s beginning in the model year 2009, and in Volkswagen's Passat models beginning in 2014. EPA officials said no action was required by owners of the car, but they suggested that Volkswagen would be compelled to address the problem.

"Our goal now is to ensure that the affected cars are brought into compliance, said Richard Corey, the executive officer for California's Air Resources Board." He said federal and state agencies intended to "dig more deeply into the extent and implications of Volkswagen's efforts to cheat on clean air rules, and to take appropriate further action."

From: Gong, Kristiene
Sent: Friday, September 18, 2015 1:31 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

Wall Street Journal:
http://www.wsj.com/articles/epa-accuses-volkswagen-of-dodging-emissions-rules-1442595129

EPA Accuses Volkswagen of Dodging Emissions Rules
Agency says German auto maker circumvented air-pollution standards with software
By AMY HARDER

WASHINGTON—The U.S. Environmental Protection Agency issued a notice on Friday alleging that Volkswagen AG circumvented air-pollution standards with software installed on nearly a half million cars sold in the U.S. since 2008.

Officials said Volkswagen could face penalties of up to $37,500 per vehicle, or a total of more than $18 billion, though it remained unclear whether the government would eventually levy such a large penalty. Officials said the German auto maker violated the federal Clean Air Act.

The agency said that owners of these cars don't need to take any action right now and that while the cars have emissions exceeding federal standards, "these violations do not present a safety hazard and the cars remain legal to drive," according to the EPA.

Officials said a recall hasn't been announced and an investigation continues. They plan to at some point order Volkswagen to fix the vehicles, officials said.

Top EPA officials made the announcement alongside the California Air Resources Board, which is separately investigating the alleged use of the software, which EPA describes as a "defeat device." The software reduces the effectiveness of a car's emission control system during normal driving conditions and enables the car to emit nitrogen oxides at up to 40 times the allowable standard, according to the EPA.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," said Cynthia Giles, Assistant Administrator for the Office of Enforcement and Compliance at the EPA.

"Volkswagen Group of America Inc., Volkswagen AG and Audi AG received today notice from the U.S. Environmental Protection Agency, U.S. Department of Justice and the California Air Resources Board of an

investigation related to certain emissions compliance matters," Volkswagen said in a statement. "VW is cooperating with the investigation; we are unable to comment further at this time."

EPA said that its allegations cover roughly 482,000 diesel passenger cars with model years between 2009 and 2015 and sold in the U.S. since 2008. They include the following models: the Jetta, Beetle, Audi A3, Golf and Passat.

The Clean Air Act requires vehicle manufacturers to certify to EPA that their products meet federal air-pollution standards. EPA said Friday that by making and selling vehicles with the "defeat device" software, Volkswagen was violating two parts of the Clean Air Act.

From: Gong, Kristiene
Sent: Friday, September 18, 2015 1:19 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

NPR:
http://www.npr.org/sections/thetwo-way/2015/09/18/441467960/volkswagen-used-defeat-device-to-skirt-emissions-rules-epa-says

Volkswagen Used 'Defeat Device' To Skirt Emissions Rules, EPA Says
BILL CHAPPELL

Saying Volkswagen violated the Clean Air Act, the Environmental Protection Agency says the company's diesel-powered cars have sophisticated software that detects emissions testing – and "turns full emissions controls on only during the test."

Installed on four-cylinder cars, the software, which the EPA calls a "defeat device" that's meant to trick official tests, allowed diesel Jettas, Beetles, and other cars to "emit up to 40 times more pollution" than allowed under U.S. emission standards.

The agency says that after the carmaker was confronted with emission test results this month, it admitted that the cars contain defeat devices.

Volkswagen must now fix the cars' emissions control systems, the agency says, adding that Volkswagen could be liable for civil penalties and other punishment. The cars in question are popular Volkswagen and Audi models that were made from 2009 to this year.

The affected diesel cars include:

- Jetta (Model Years 2009 – 2015)
- Beetle (Model Years 2009 – 2015)
- Audi A3 (Model Years 2009 – 2015)
- Golf (Model Years 2009 – 2015)
- Passat (Model Years 2014-2015)

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," said Cynthia Giles, assistant administrator for the Office of Enforcement and Compliance Assurance.

The Verge:
http://www.theverge.com/2015/9/18/9352757/epa-volkswagen-recall-emissions

Volkswagen ordered to recall 500,000 cars for gaming emissions testing

By Colin Lecher

The federal government has ordered Volkswagen to recall almost 500,000 vehicles, saying the company unlawfully used special software to get around missions regulations.

VOLKSWAGEN ALLEGEDLY USED A "DEFEAT DEVICE."

Volkswagen allegedly used a so-called "defeat device" on certain models made in the past six years. The device works by only turning on emissions control when undergoing emissions testing, but not when the car is actually being driven normally and pollution is at its peak. "This results in cars that meet emissions standards in the laboratory or testing station, but during normal operation, emit nitrogen oxides, or NOx, at up to 40 times the standard," the EPA said in a statement.

Using such a device is a violation of the Clean Air Act, which, as The New York Times points out, the EPA has been increasingly cracking down on. In November, the agency hit Hyundai and Kia with a record $100 million fine for violations under the act.

The cars affected by the recall include the 2009 to 2015 Jetta, Beetle, Golf, and Audi A3. The 2014 and 2015 Passat is also included. According to the EPA, that adds up to 482,000 cars.

Jalopnik:
http://jalopnik.com/epa-orders-volkswagen-to-recall-482-000-diesel-cars-for-1731665972

EPA Orders Volkswagen To Recall 482,000 Diesel Cars For Cheating On Emissions
Patrick George

The New York Times reports Volkswagen has been ordered by the Environmental Protection Agency to recall 482,000 diesel cars in the U.S. over software they say was intentionally designed to circumvent smog regulations.

The cars, all diesels from 2009 to 2015, have a “defeat device” programmed to detect when the car is undergoing official emissions testing that only then turns on the full emissions control systems, the Times reports.

These controls are turned off in other situations, leading to far greater emissions than VW let on — which is against the law. The devices were designed to conceal nitrogen oxide emissions.

It’s not immediately clear why VW had such a system on these cars, how the system detected official testing versus normal driving, or if the cars operated differently in normal driving when the defeat device was off. What effect did reducing NOx emissions have on fuel economy or performance?

“Using a defeat device in cars to evade clean air standards is illegal and a threat to public health,” said Cynthia Giles, the E.P.A.’s assistant administrator for the Office of Enforcement and Compliance. “Working closely with the California Air Resources Board, E.P.A. is committed to making sure that all automakers play by the same rules. E.P.A. will continue to investigate these very serious violations.”
The state of California and the Justice Department are also investigating the violation, the paper reports.

The vehicles affected are the 2009-2015 diesel Jetta, Beetle, Golf, Passat and Audi A3.

More on this as we get it.

From: Gong, Kristiene
Sent: Friday, September 18, 2015 1:10 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert

Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

Detroit Free Press:
http://www.freep.com/story/money/cars/2015/09/18/epa-volkswagen-used-software-skirt-emissions-rules/72399372/

EPA: Volkswagen used software to skirt emissions rules
By Greg Gardner

The U.S. Environmental Protection Agency and California are accusing Volkswagen of violating the Clean Air Act by using software that allows hundred of thousands of VW and Audi diesel-powered cars to get around emission standards.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," said Cynthia Giles, EPA assistant administrator for enforcement and compliance assurance. "Working closely with the California Air Resources Board, EPA is committed to making sure that all automakers play by the same rules. EPA will continue to investigate these very serious matters."

The agency's notice of violation covers about 482,000 diesel cars sold between 2009 and 2015 model years.

Affected diesel models include:

Jetta (model years 2009 – 2015)
Beetle (model years 2009 – 2015)
Audi A3 (model years 2009 – 2015)
Golf (model years 2009 – 2015)
Passat (model years 2014-2015)

California is separately issuing an In-Use Compliance letter to Volkswagen, and EPA and the California Air Resources Board (CARB) have both initiated investigations based on Volkswagen's alleged actions.

"Working with U.S. EPA we are taking this important step to protect public health thanks to the dogged investigations by our laboratory scientists and staff," said CARB executive officer Richard Corey. "Our goal is to ensure that the affected cars are brought into compliance, to dig more deeply into the extent and implications of Volkswagen's efforts to cheat on clean air rules, and to take appropriate further action."

The federal and California regulators say Volkswagen used a sophisticated software algorithm on certain Volkswagen vehicles that detects when the car is undergoing official emissions testing and turns full emissions controls on only during the test. The effectiveness of these vehicles' pollution emissions control devices is greatly reduced during all normal driving situations.

As a result the cars met emissions standards in the laboratory or testing station, but during normal operation, emit nitrogen oxides, or NOx, at up to 40 times the permissible standard. The software produced by Volkswagen is a "defeat device," as defined by the Clean Air Act.

Corey said testing groups in Europe found information that indicated Volkswagen may have manipulated its emission tests and told California regulators about their suspicions.

NOx pollution contributes to nitrogen dioxide, ground-level ozone and fine particulate matter. Exposure to these pollutants has been linked with a range of serious health effects, including increased asthma attacks and other respiratory illnesses that can be serious enough to send people to the hospital. Exposure to ozone and particulate matter have also been associated with premature death due to respiratory-related or cardiovascular-related effects. Children, elderly people and those with pre-existing respiratory disease are particularly at risk for health effects of these pollutants.

The Clean Air Act requires vehicle manufacturers to certify to EPA that their products will meet applicable federal emission standards to control air pollution, and every vehicle sold in the U.S. must be covered by an EPA-issued certificate of conformity. Motor vehicles equipped with defeat devices, which reduce the effectiveness of the emission control system during normal driving conditions, cannot be certified. By making and selling vehicles with defeat devices that allowed for higher levels of air emissions than were certified to EPA, Volkswagen violated two important provisions of the Clean Air Act.

EPA and CARB uncovered the defeat device software after independent analysis by researchers at West Virginia University, working with the International Council on Clean Transportation, a non-governmental organization. The researchers raised questions about emissions levels, and the agencies began further investigations into the issue. In September, after EPA and CARB demanded an explanation for the emission problems, Volkswagen admitted that the cars contained defeat devices.

VW may be liable for civil penalties of up to $37,500 per vehicle found to be violating the standard, or potentially more than $18 billion.

It is incumbent upon Volkswagen to initiate the process that will fix the cars' emissions systems. Car owners should know that although these vehicles have emissions exceeding standards, these violations do not present a safety hazard and the cars remain legal to drive and resell. Owners of cars of these models and years do not need to take any action at this time.

Wired:
http://www.wired.com/2015/09/epa-accuses-volkswagen-cheating-emissions-testing-482000-cars/

EPA ACCUSES VOLKSWAGEN OF CHEATING EMISSIONS TESTING ON 482,000 CARS
Alex Davies

THE EPA IS accusing Volkswagen of illegally using software to cheat emissions standards, allowing the German automaker to sell half a million cars that produce smog at 40 times the legal limit.

In a notice of violation of the Clean Air Act sent to Volkswagen AG, Audi AG, and Volkswagen Group of America, Inc today, the EPA said diesel-powered VW cars used a "defeat device," a kind of "a sophisticated software algorithm [that] detects when the car is undergoing official emissions testing, and turns full emissions controls on only during the test. The effectiveness of these vehicles' pollution emissions control devices is greatly reduced during all normal driving situations."

The accusation applies to 482,000 diesel-powered, four-cyclinder Jetta, Beetle, Audi A3, Golf, and Passat cars sold between 2008 and 2015 in the US. The news comes as the Frankfurt motor show, one of the biggest events of the year for the automaker, opens to the press. VW will be required to fix the problem, at no cost to car owners.

The Week:
http://www.theweek.com/speedreads/578080/epa-catches-volkswagen-blatantly-cheating-smog-tests

EPA catches Volkswagen blatantly cheating on smog tests
Jeva Lange

Almost half a million Volkswagen cars, including recent diesel models of Jettas, Beetles, Audi A3s, Golfs, and Passats, may be recalled in an enormous crackdown on the German carmaker's alleged blatant circumvention of smog standards, The New York Times reports.

The Environmental Protection Agency has demanded that the cars be recalled, and specifically accused Volkswagen of installing software, called a "defeat device," in their cars that basically just lies about what a car's emissions are during tests:

The device is programmed to detect when the car is undergoing official emissions testing, and to only turn on full emissions control systems during that testing. Those controls are turned off during normal driving situations, when the vehicles pollute far more heavily than reported by the manufacturer, the E.P.A. said. [The New York Times]

Car emissions contain nitrogen oxide, which creates smog, as well as pollutants that cause asthma.

From: Gong, Kristiene
Sent: Friday, September 18, 2015 12:56 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

LA Times:
http://www.latimes.com/business/autos/la-fi-hy-volkswagen-probe-20150918-story.html

Volkswagen is accused of sidestepping emissions rules, 'cheating' pollution tests
By JERRY HIRSCH

Federal and California environmental regulators accused Volkswagen of using software that "cheats" pollution testing in nearly 500,000 recent model VWs and Audis by circumventing emission standards in its diesel cars.

The German automaker will eventually have to recall all of the vehicles and change the emissions systems at its own expense, regulators said. Additionally it could face a fine of about $18 billion, or $35,500 per car, federal environmental officials said.

The Environmental Protection Agency on Friday issued the German automaker a "notice of violation" of the Clean Air Act for both VW models and the company's Audi luxury brand. It covers models equipped with four-cylinder diesel engines. The California Air Resources Board issued a similar letter.

Volkswagen and Audi vehicles from model years 2009-2015 have the software, which uses an algorithm that detects when the vehicle is undergoing pollution tests and changes the way it performs from when it is being driven on the open road.

It "is illegal and a threat to public health," said Cynthia Giles, assistant administrator for the Office of Enforcement and Compliance Assurance. "EPA is committed to making sure that all automakers play by the same rules."

"We expected better from VW," Giles said.

Air Resources Board Executive Officer Richard Corey said the California agency wants to bring the cars "into compliance, to dig more deeply into the extent and implications of Volkswagen's efforts to cheat on clean air rules, and to take appropriate further action."

Volkswagen said it is cooperating with the investigation.

"We are unable to comment further at this time," the company said in a statement.

The affected diesel models include: Jetta (model years 2009 – 2015,) Beetle (model years 2009 – 2015,) Audi A3 (model years 2009 – 2015,) Golf (model years 2009 – 2015) and Passat (model years 2014-2015.)

International Business Times:
http://www.ibtimes.com/volkswagen-audi-recall-500000-cars-broke-environmental-rules-white-house-says-

Volkswagen And Audi Recall: 500,000 Cars Broke Environmental Rules, White House Says
By Christopher Harress

The Obama administration Friday forced car manufacturer Volkswagen to recall nearly 500,000 cars after it was discovered the German automaker had fitted its vehicles with special technology that can beat environmental tests for reducing smog, according to a new report.

The recall, which was imposed after an investigation by the Environmental Protection Agency, is expected to affect four-cylinder Volkswagen and Audi cars that were manufactured between 2009 and 2015.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," Cynthia Giles, the E.P.A.'s assistant administrator for the Office of Enforcement and Compliance, told the New York Times.

"Working closely with the California Air Resources Board, E.P.A. is committed to making sure that all automakers play by the same rules. E.P.A. will continue to investigate these very serious violations."

From: Gong, Kristiene
Sent: Friday, September 18, 2015 12:52 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

Detroit News:
http://www.detroitnews.com/story/business/autos/foreign/2015/09/18/epa-vw-diesel-vehicles-violated-emissions-rules/72401296/

EPA: 482K VW diesel vehicles violated emissions rules
David Shepardson

Washington — The Environmental Protection Agency and the state of California said Volkswagen AG violated federal law by allowing 482,000 diesel VW and Audi cars sold since 2009 to evade emissions requirements using sophisticated software.

The announcement is a big setback to the German automaker that has made diesel vehicles a big part of its U.S. strategy. VW could face fines or criminal prosecution and must immediately prevent those vehicles from being able to defeat emissions rules.

VW concealed facts but has now admitted wrongdoing, said Cynthia Giles, assistant administrator for the Office of Enforcement and Compliance Assurance. "We expected better from VW," she said.

The agencies allege that four-cylinder Volkswagen and Audi diesel cars from model years 2009-2015 include software that circumvents EPA emissions standards for certain air pollutants. California is separately issuing an In-Use Compliance letter to Volkswagen, and EPA and the California Air Resources Board have initiated investigations based on Volkswagen's alleged actions.

EPA said the vehicles software "detects when the car is undergoing official emissions testing, and turns full emissions controls on only during the test." The vehicles include diesel Golf, Jetta, Sportwagen, Beetle and Audi A3 vehicles built from 2009-2015.

EPA said "the effectiveness of these vehicles' pollution emissions control devices is greatly reduced during all normal driving situations. This results in cars that meet emissions standards in the laboratory or testing station, but during normal operation, emit nitrogen oxides, or NOx, at up to 40 times the standard. The software

produced by Volkswagen is a 'defeat device,' as defined by the Clean Air Act."

NOx pollution contributes to nitrogen dioxide, ground-level ozone, and fine particulate matter. EPA said exposure has been linked to serious health issues, including increased asthma attacks and other respiratory illnesses that can be serious enough to send people to the hospital. "Exposure to ozone and particulate matter have also been associated with premature death due to respiratory-related or cardiovascular-related effects. Children, the elderly, and people with pre-existing respiratory disease are particularly at risk for health effects of these pollutants," EPA said.

This is the latest example of automakers not following the miles per gallon and emissions rules.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," said Giles. "Working closely with the California Air Resources Board, EPA is committed to making sure that all automakers play by the same rules. EPA will continue to investigate these very serious matters."

The Clean Air Act requires vehicle manufacturers to certify to EPA that their products will meet applicable federal emission standards to control air pollution, and every vehicle sold in the U.S. must be covered by an EPA-issued certificate of conformity. Motor vehicles equipped with defeat devices, which reduce the effectiveness of the emission control system during normal driving conditions, cannot be certified.

"Working with U.S. EPA we are taking this important step to protect public health thanks to the dogged investigations by our laboratory scientists and staff," said Air Resources Board Executive Officer Richard Corey. "Our goal now is to ensure that the affected cars are brought into compliance, to dig more deeply into the extent and implications of Volkswagen's efforts to cheat on clean air rules, and to take appropriate further action."

The issue first came to the attention of the agencies in 2014 after independent analysis by researchers at West Virginia University, working with the International Council on Clean Transportation, a non-governmental organization, raised questions about emissions levels, and the agencies began further investigations into the issue.

In September, after EPA and CARB demanded an explanation for the identified emission problems, Volkswagen admitted that the cars contained defeat devices, the agencies said.

EPA said VW must recall the vehicles. EPA said "owners should know that although these vehicles have emissions exceeding standards, these violations do not present a safety hazard and the cars remain legal to drive and resell. Owners of cars of these models and years do not need to take any action at this time."

AP (via ABC News):
http://abcnews.go.com/Politics/trump-candidates-criticize-donald-muslim-comments/story?id=33858500

EPA Says VW Intentionally Violates Clean Air Standards
By MATTHEW DALY, ASSOCIATED PRESS WASHINGTON — Sep 18, 2015, 12:42 PM ET

The Environmental Protection Agency says nearly 500,000 Volkswagen and Audi diesel cars built in the past seven year are intentionally violating clean air standards by using software that evades EPA emissions standards.

The EPA says the cars include a device programmed to detect when the car is undergoing official emissions testing. The cars only turn on full emissions control systems during that testing. The EPA says the controls are turned off during normal driving situations.

The EPA called the company's use of the device illegal and a threat to public health.

The EPA called on VW to fix the cars' emissions systems, but said car owners do not need to take any

immediate action.

VW said in a statement it is cooperating with the investigation.

Bloomberg:
http://www.bloomberg.com/news/articles/2015-09-18/epa-says-volkswagon-software-circumvented-car-emissions-testing

EPA Says Volkswagen Circumvented Car Emissions Tests
Jeff Plungis

Volkswagen AG sold diesel cars with software that circumvented U.S. emissions standards for air pollution, the Environmental Protection Agency said.

The company sold Volkswagen and Audi brand cars from model years 2009-2015 that contained a "sophisticated software algorithm" that detects when the car is undergoing official emissions testing, and turns on full emissions control, the agency said. During normal driving times, the systems don't operate fully, regulators said.

The potential fine is $37,500 per vehicle and 482,000 autos are part of the case, yielding a potential fine of more than $18 billion, Cynthia Giles, EPA assistant administrator for enforcement and compliance, said on a phone call with reporters Friday.

California is also investigating the claims.

Volkswagen said in a statement it is cooperating with the investigation and unable to comment further.

Business Insider:
http://www.businessinsider.com/vw-told-to-recall-500000-cars-after-us-government-accuses-it-of-dodging-clean-air-standards-2015-9

VW told to recall 500,000 cars after US government accuses it of dodging clean air standards
Benjamin Zhang

The Environmental Protection Agency has ordered the recall of 500,000 Volkswagen cars.

According to Coral Davenport of the New York Times, the EPA accused VW of using hidden software — called a "defeat device" — to dodge clean air standard during emissions testing.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," assistant administrator for the Office of Enforcement and Compliance Assurance said Cynthia Giles said in a statement.

"Working closely with the California Air Resources Board, EPA is committed to making sure that all automakers play by the same rules. EPA will continue to investigate these very serious matters."

In response to the recall, Volkswagen issued the following statement to Business Insider.

"Volkswagen Group of America, Inc., Volkswagen AG and Audi AG received today notice from the US Environmental Protection Agency, US Department of Justice and the California Air Resources Board of an investigation related to certain emissions compliance matters. VW is cooperating with the investigation; we are unable to comment further at this time."

The recall affects 482,000 diesel powered cars sold in the US since 2008. They include:

Volkswagen Jetta TDI: 2009-20015
Volkswagen Beetle TDI: 2009-2015
Audi A3 TDI: 2009-2015
Volkswagen Golf TDI: 2009-2015
Volkswagen Passat TDI: 2014-2015

This story is developing. We will update when more information is available.

From: Gong, Kristiene
Sent: Friday, September 18, 2015 12:42 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

Washington Examiner:
http://www.washingtonexaminer.com/epa-says-audi-vw-cheating-on-emissions/article/2572404

EPA says Audi, VW cheating on emissions
By JOHN SICILIANO

The Environmental Protection Agency and California regulators charged automakers Volkswagen and Audi on Friday with purposefully violating emission standards in their line of diesel cars.

EPA accused the automakers of using a device in their vehicles to get around the pollution rules. According to EPA, the device regulates emissions, but only turns on and works while emissions are being tested.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," said Cynthia Giles, EPA assistant administrator for the agency's enforcement office. "Working closely with the California Air Resources Board, EPA is committed to making sure that all automakers play by the same rules. EPA will continue to investigate these very serious matters."

Giles said VW was "concealing facts" about the devices. The vehicle models involved include the popular Jetta, Audi A-3, Passat and the iconic Beetle, and in model years 2009-2015. The violations cover 482,000 diesel passenger cars.

The EPA's announcement isn't a final decision, but is a clear sign that the EPA believes it has a case against the automakers, one that could lead to fines as large as $37,000 per vehicle. All together, the combined fines could pile up to $18 billion.

An EPA statement said "California is separately issuing an In-Use Compliance letter to Volkswagen, and EPA and the California Air Resources Board ... have both initiated investigations based on Volkswagen's alleged actions."

"Working with US EPA we are taking this important step to protect public health thanks to the dogged investigations by our laboratory scientists and staff," the California board's CEO Richard Corey said. "Our goal now is to ensure that the affected cars are brought into compliance, to dig more deeply into the extent and implications of Volkswagen's efforts to cheat on clean air rules, and to take appropriate further action."

WPTZ:
http://www.wptz.com/money/epa-accuses-vw-of-cheating-on-emission-rules/35352250

EPA accuses VW of cheating on emission rules
Published 12:29 PM EDT Sep 18, 2015

NEW YORK (CNNMoney) —Diesel cars from Volkswagen and Audi cheated on clean air rules by including software that made the cars look cleaner than they actually were, according to federal and California regulators.

The regulators say that the software on the cars turned up the emission controls only when it could tell that the car was being tested.

"The effectiveness of these vehicles' pollution emissions control devices is greatly reduced during all normal driving situations," said the Environmental Protection Agency's notice to the company. "This results in cars that meet emissions standards in the laboratory or testing station, but during normal operation, emit nitrogen oxides at up to 40 times the standard."

There are nearly 500,000 of the diesel cars on U.S. roads. The models include the VW Jetta, the Beetle and the Golf from model years 2009 through 2015, the Passat from 2014-2015 as well as the Audi A3, model years 2009-2015. The luxury brand is owned by Volkswagen.

Owners of the affected cars do not face health risks according to the EPA and can to continue to drive or sell the cars. But the EPA says that VW will be responsible for fixing the problem.

Volkwagen did not immediately respond to a request for comment.

City AM:
http://www.cityam.com/224676/volkswagen-told-recall-500000-vehicles-over-emissions

Volkswagen told to recall 500,000 vehicles over emissions
by Catherine Neilan

Volkswagen has been ordered to recall nearly half a million cars in the US by the Obama administration, which claims the German car group used software that was purposely designed to dodge environmental standards for reducing smog.

The US government's Environmental Protection Agency issued the company a notice of violation this afternoon, accusing Volkswagen of having installing a "defeat device" into its four-cylinder Volkswagen and Audi vehicles between 2009 and 2015, according to the New York Times.

The device is programmed to detect when the car is undergoing emissions test, during which time it will turn on its full emissions control systems. These controls are reportedly then turned off when the car is driving in "normal" situations, when the cars pollute more heavily than reported by Volkswagen, the EPA claims.

The government agency estimates that 482,000 diesel passenger vehicles are affected.

Volkswagen could not be contacted at the time of publication.

From: Gong, Kristiene
Sent: Friday, September 18, 2015 12:33 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

Washington Times:
http://www.washingtontimes.com/news/2015/sep/18/epa-volkswagen-used-software-cheat-emissions-tests/

EPA: Volkswagen used ‘sophisticated software’ to cheat emissions tests
By Ben Wolfgang - The Washington Times - Friday, September 18, 2015

The Obama administration on Friday accused Volkswagen of using a "sophisticated software algorithm" to cheat on emissions testing and mask the fact that some models emit too much harmful pollution.

Some Volkswagen cars from model years 2009 to 2015, the Environmental Protection Agency said, include software that can detect when they're undergoing emissions testing. Full emissions controls were activated only during testing and then automatically shut down during normal operation, the agency charged.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," said Cynthia Giles, assistant administrator for the EPA's Office of Enforcement and Compliance Assurance. "Working closely with the California Air Resources Board, EPA is committed to making sure that all automakers play by the same rules. EPA will continue to investigate these very serious matters."

During normal operation, the "defeat device" allowed Volkswagen cars to emit nitrogen oxides at up to 40 times the federal threshold as laid out in the Clean Air Act.

The EPA has issued "a notice of violation" to the automaker, and the state of California has launched its own investigation into the matter. Volkswagen could face civil penalties for the violations, the agency said.

The allegations apply to about 482,000 diesel passenger cars sold since 2008, including Jettas, Beetles, Audi A3s, Golfs and other models.

From: Gong, Kristiene
Sent: Friday, September 18, 2015 12:26 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: RE: Volkswagen Clips 9/18/2015

USA Today:
http://www.usatoday.com/story/money/cars/2015/09/18/epa-accuses-volkswagen-audi-evading-emission-laws/72400018/

EPA accuses Volkswagen, Audi of evading emission laws
Nathan Bomey, USA TODAY 12:12 p.m. EDT September 18, 2015

The German automaker adopted a "defeat device" to trick regulators, the EPA said.

The Environmental Protection Agency on Friday accused Volkswagen of installing software on certain cars in the U.S. to evade federal emission regulations, potentially exposing people to harmful pollutants.

The German automaker adopted what the EPA called a "defeat device" to trick U.S. regulators into believing that its cars met Clean Air Act standards, the federal agency said in a statement.

The agency said 482,000 cars violated federal standards, including four-cylinder Volkswagen cars from 2009-15 and Audi diesel cars from the same period. They included the Volkswagen Jetta, Beetle, Golf and Passat, and the Audi A3.

Volkswagen, whose brands include the luxury Audi lineup, may face fines or other penalties, the EPA said.

The cars are still safe to drive, the EPA said, and owners do not need to take immediate action. But the agency will require Volkswagen to fix the cars for free.

Newsweek:
http://www.newsweek.com/epa-volkswagen-software-cheat-clean-air-rules-373869

EPA: Volkswagen Used Software in Cars to Cheat on Clean Air Rules
BY ZOË SCHLANGER 9/18/15 AT 12:14 PM

A U.S. Environmental Protection Agency investigation has concluded that for years Volkswagen has been installing software in its vehicles that circumvents federal emissions standards for air pollution, the agency announced Friday.

EPA alleges that Volkswagen installed a "sophisticated software algorithm on certain Volkswagen vehicles" that could detect when the car was being tested for emissions. The software would turn full emissions controls on only during the official test. "This results in cars that meet emissions standards in the laboratory or testing station, but during normal operation, emit nitrogen oxides, or NOx, at up to 40 times the standard," EPA said in a press release. They called the software a "defeat device," deliberately installed to evade the Clean Air Act standards.

This "defeat device" was found in several car models, from 2009 models up to 2015 models, according to EPA:

Jetta (Model Years 2009 – 2015)
Beetle (Model Years 2009 – 2015)
Audi A3 (Model Years 2009 – 2015)
Golf (Model Years 2009 – 2015)
Passat (Model Years 2014-2015)
In total, this includes about 482,000 passenger cars.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," Cynthia Giles, EPA's Assistant Administrator for the Office of Enforcement and Compliance Assurance, said in a statement emailed Friday. The agency worked with California regulators to investigate the automobile manufacturer and issue a notice of violation.

"Our goal now is to ensure that the affected cars are brought into compliance, to dig more deeply into the extent and implications of Volkswagen's efforts to cheat on clean air rules, and to take appropriate further action," California Air Resources Board Executive Officer Richard Corey said in the statement.

Volkswagen has yet to respond publicly to the EPA allegations. Newsweek has reached out to the company for comment, and we will update if they respond.

From: Gong, Kristiene
Sent: Friday, September 18, 2015 12:20 PM
To: Purchia, Liz; Allen, Laura; Abrams, Dan; Reynolds, Thomas; Conger, Nick; Senn, John; Millett, John; Birgfeld, Erin; Hull, George; Daguillard, Robert
Cc: Smith, Roxanne
Subject: Volkswagen Clips 9/18/2015

NY Times:
http://www.nytimes.com/2015/09/19/business/volkswagen-is-ordered-to-recall-nearly-500000-vehicles-over-emissions-software.html?_r=0

Volkswagen Is Ordered to Recall Nearly 500,000 Vehicles Over Emissions Software
By CORAL DAVENPORT SEPT. 18, 2015

WASHINGTON — The Obama administration on Friday ordered Volkswagen to recall nearly a half million cars from the road, saying the German automaker used software intentionally designed to circumvent environmental standards for reducing smog.

The Environmental Protection Agency issued the company a notice of violation and accused the company of breaking the law by installing software known as a "defeat device" in 4-cylinder Volkswagen and Audi vehicles from model years 2009-15. The device is programmed to detect when the car is undergoing official emissions testing, and to only turn on full emissions control systems during that testing. Those controls are turned off during normal driving situations, when the vehicles pollute far more heavily than reported by the manufacturer, the E.P.A. said.

"Using a defeat device in cars to evade clean air standards is illegal and a threat to public health," said Cynthia Giles, the E.P.A.'s assistant administrator for the Office of Enforcement and Compliance. "Working closely with the California Air Resources Board, E.P.A. is committed to making sure that all automakers play by the same rules. E.P.A. will continue to investigate these very serious violations."

The software was designed to conceal the cars' emissions of the pollutant nitrogen oxide, which contributes to the creation of ozone and smog. The pollutants are linked to a range of health problems, including asthma attacks and other respiratory diseases.

The state of California has issued a separate notice of violation to the company. California, the E.P.A. and the Justice Department are working together on an investigation of the allegations.

The allegations cover roughly 482,000 diesel passenger cars sold in the United States since 2009.

Affected diesel models include the Volkswagen Jetta (model years 2009-15), Volkswagen Beetle (model years 2009–15), Audi A3 (model years 2009–15), Volkswagen Golf (model years 2009–15) and Volkswagen Passat (model years 2014-15).

The notice of violation is part of a broader, more aggressive enforcement effort by federal environmental regulators on the auto industry. Analysts said it was meant to send a clear message to automakers that they will be harshly treated for compromising federal rules.

It follows a November 2014 announcement of the administration's largest-ever penalty for a violation of the Clean Air Act, in which the government fined the Korean automakers Hyundai Motor and Kia Motors a combined $300 million as part of a settlement for overstating vehicle fuel-economy standards on 1.2 million cars.

"They want to make it clear that they're going to crack down on cheaters," said Frank O'Donnell, president of the environmental advocacy group Clean Air Watch. "They're cheating not only car buyers but the breathing public. They want to lay down the law, enforce the law, and show they're not going to tolerate cheaters. The laws and regulation are only as good as the enforcement."

The software was designed to conceal the cars' emissions of the pollutant nitrogen oxide, which contributes to the creation of ozone and smog. The pollutants are linked to a range of health problems, including asthma attacks and other respiratory diseases.

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Certification of Diesels

BMW and Diesel

US Market Introduction Plans

Emission Aftertreatment Technology

Exhaust System

Particulate Filter

DeNOx-System (SCR)

Certification Issues

Heating Concept

Refill Concept

Tampering

Wrong Medium

Warning Sequence

UREA Aging Effects

UREA Infrastructure

Certification Process

Durability Procedure

Cyclic Emissions

Emission of Unregulated Pollutants

Evaporative Emissions

Grouping, Worst Case Selection

Summary

BMW and Diesel

Decades of Diesel-Competence

1983 1985 1990 1995 2000 2004

1983
- 1st BMW Diesel-engine (6-Cyl.)
- 524td, fastest Diesel Passenger Car

1987
- Digital-Diesel-Electronis (DDE)

1990
- BMW Diesel-Oxy-Catalyst

1998
- Introduction of Direct Injection for BMW Dieselengines
- Historical Victory: BMW 320d wins 24h-race at Nürburgring

1999
- First V8-DI-Diesel for Passenger car

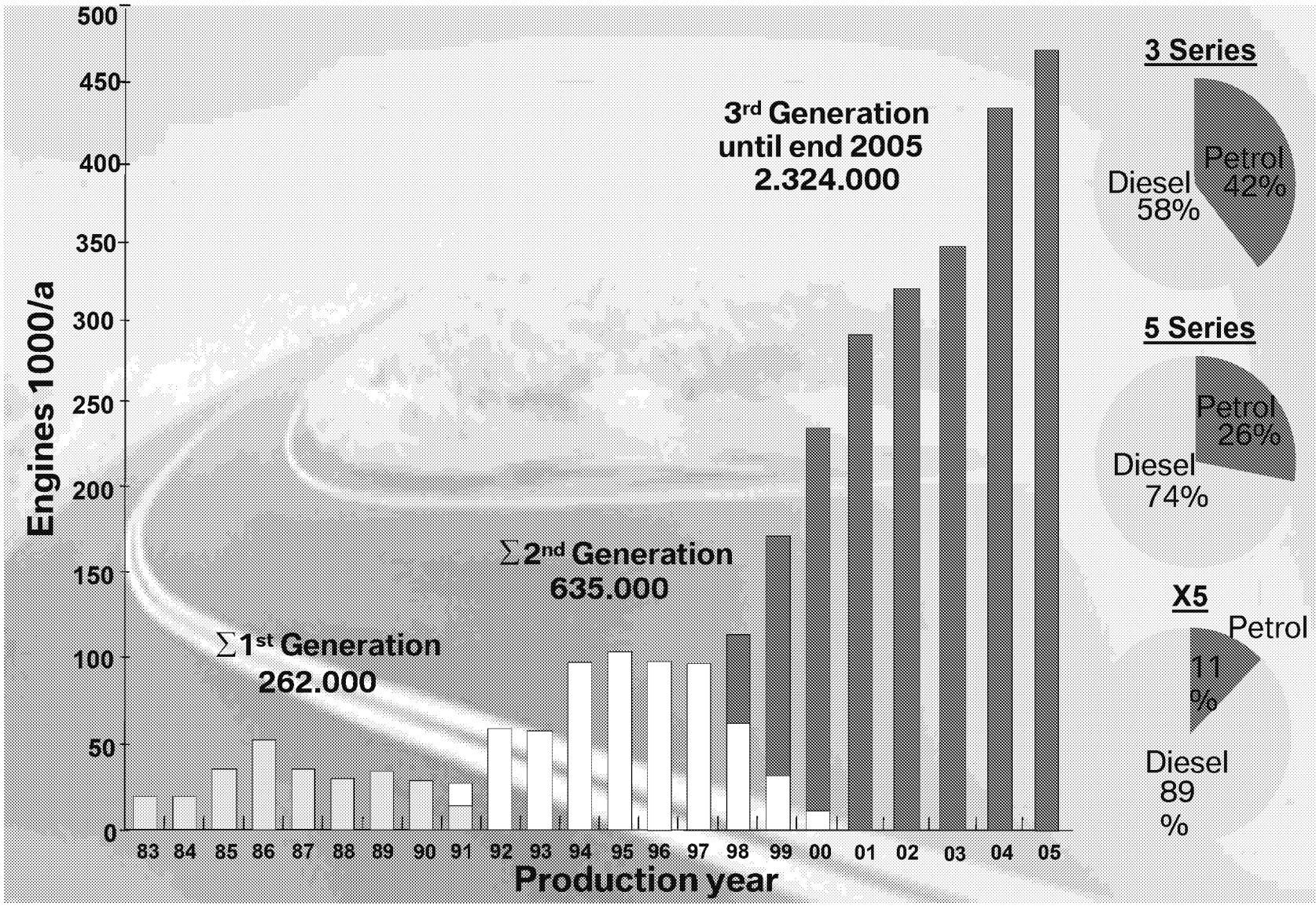
2001
- DI 2nd Generation: Common Rail, 1600 bar

2004
- Variable Twin Turbo
- Diesel Particulate Trap (2nd Generation)

BMW 524td

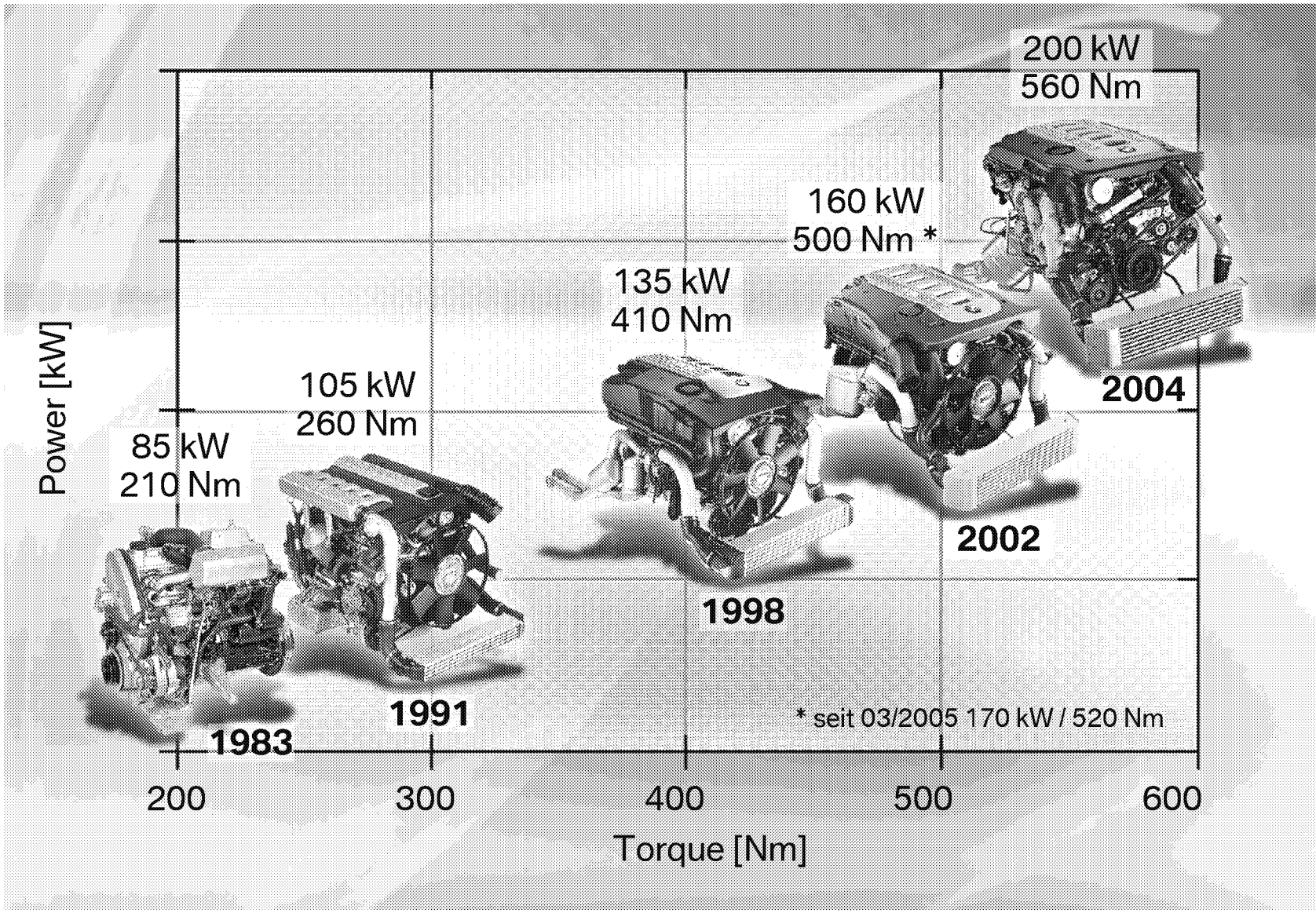
BMW and Diesel

Production Volumes Europe



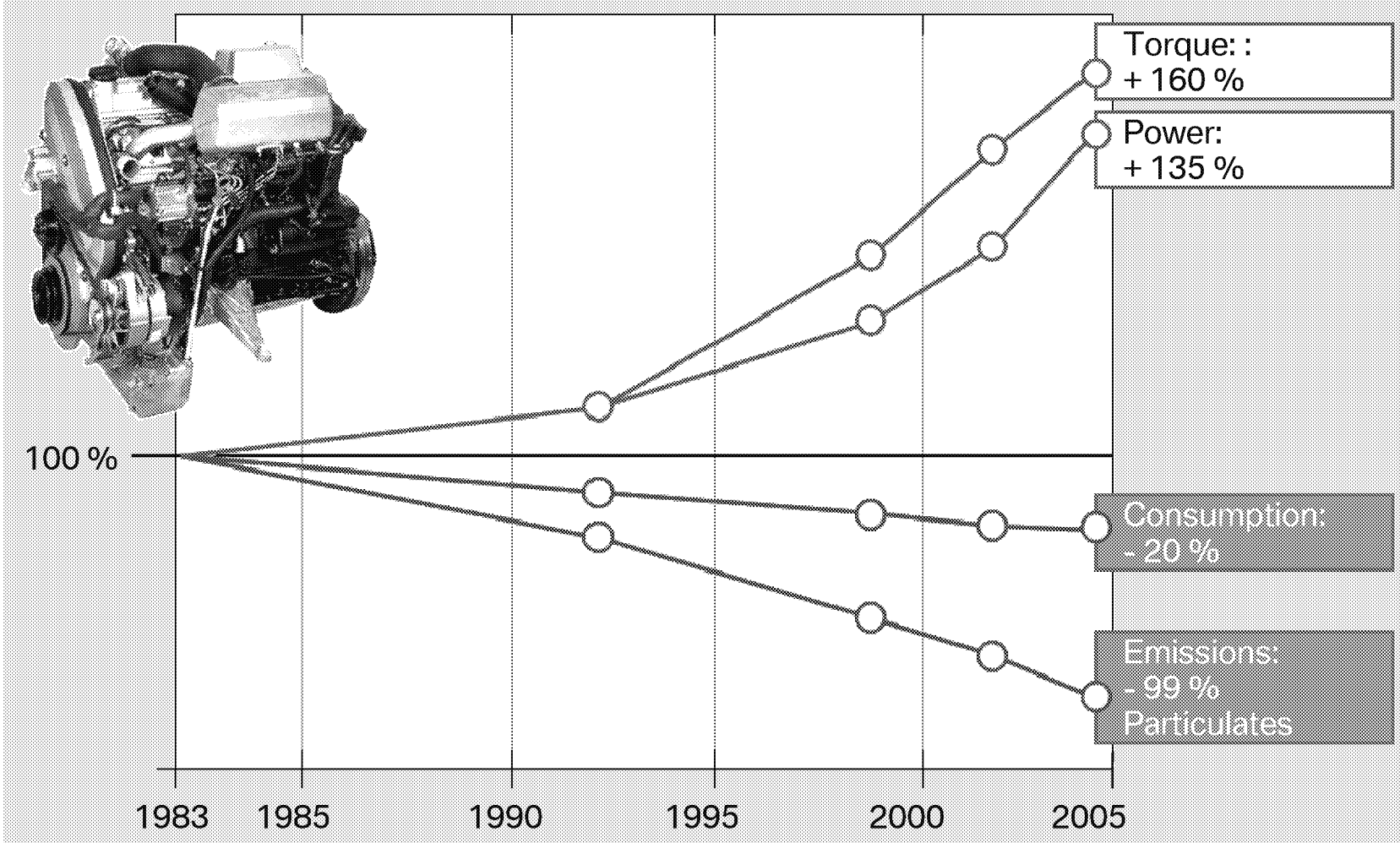
BMW and Diesel

History of 6-Cylinder Diesel Engine



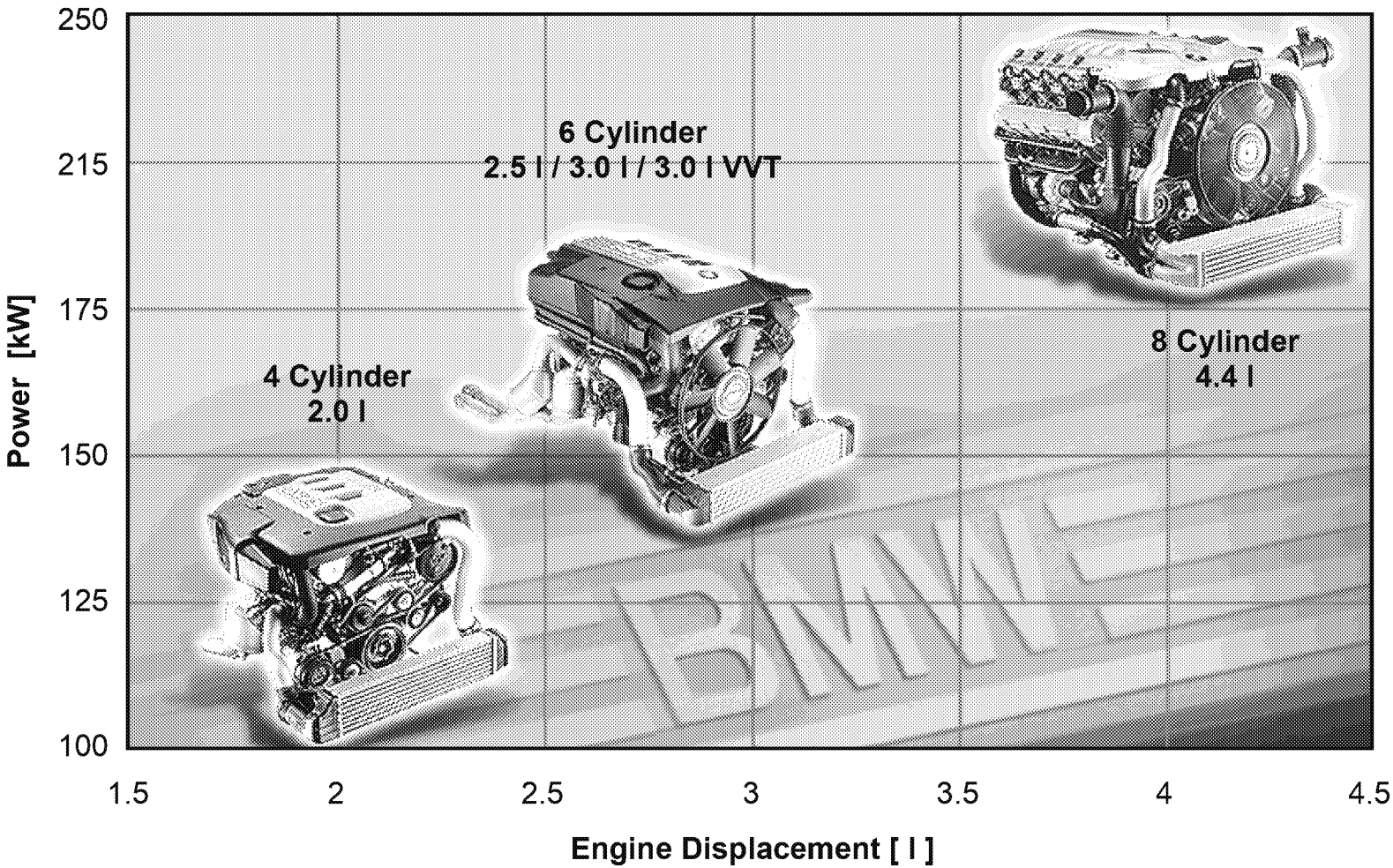
BMW and Diesel

Evolution of Product Features



BMW and Diesel

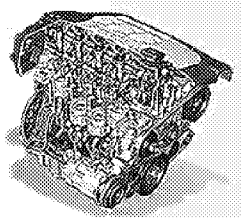
Engine Line up



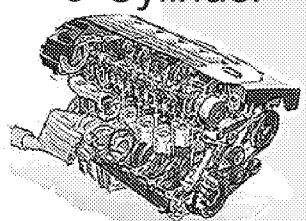
BMW and Diesel

Diesel Cars

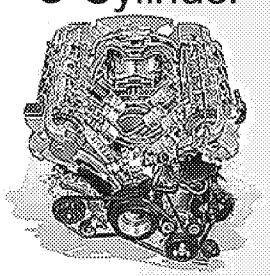
4-Cylinder



6-Cylinder



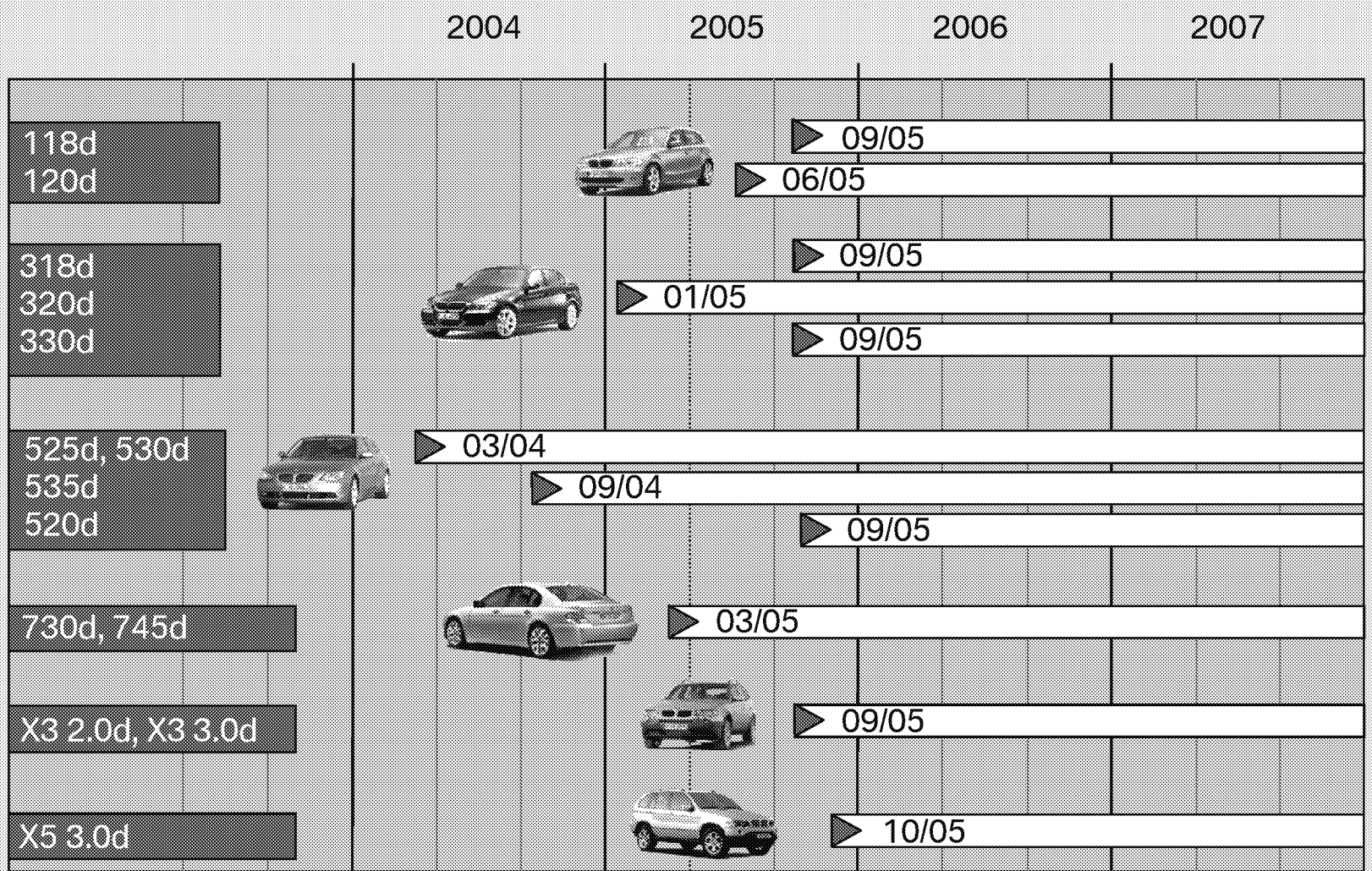
8-Cylinder



Mini	1er	3er	5er	7er	X3	X5
One D	118d 120d	318d 320d 320cd	520d		X3 2.0d	
		330d 330cd 330xd	525d 530d 530xd 535d	730d	X3 3.0d	X5 3.0d
				745d		

BMW and Diesel

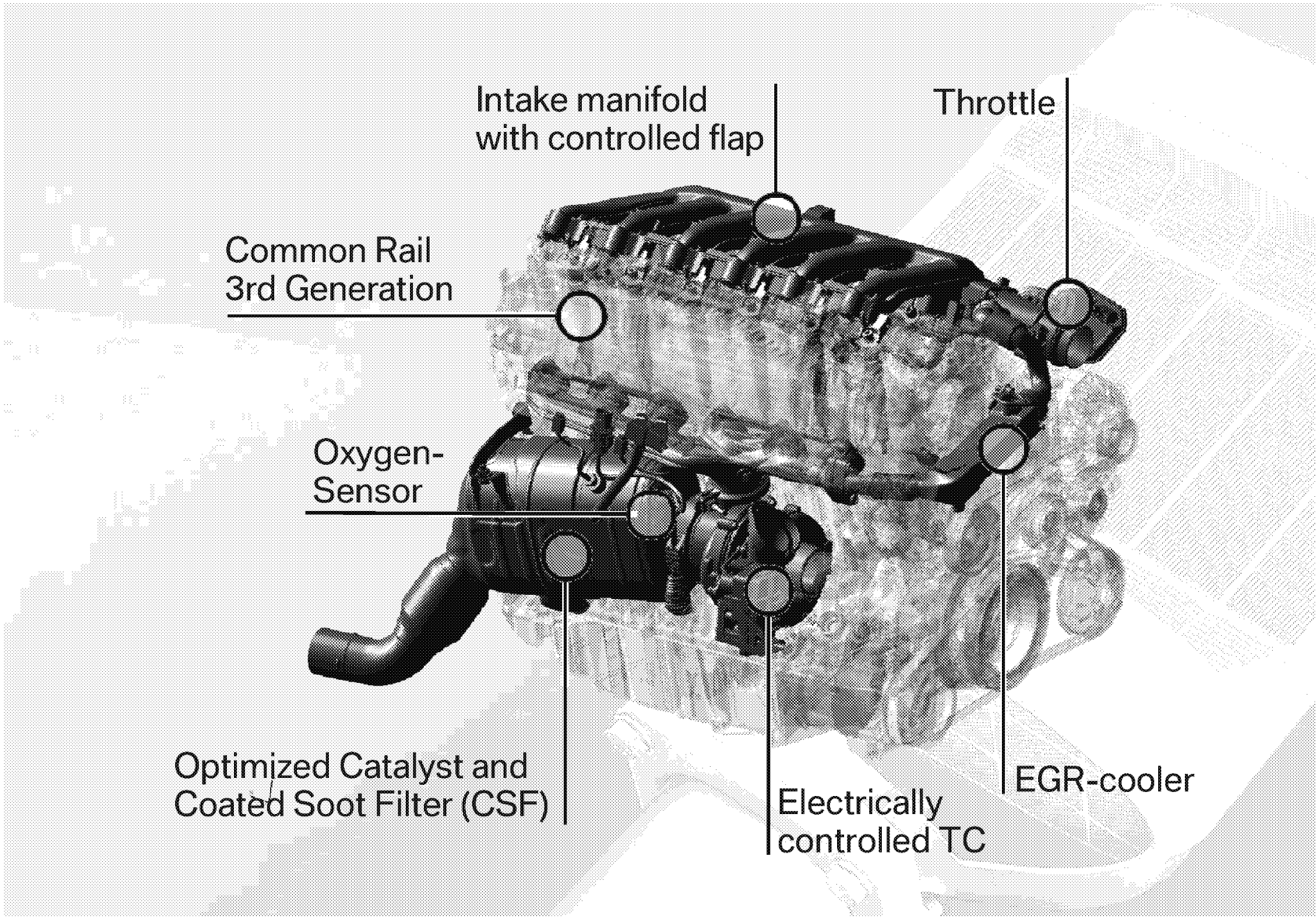
Clean Diesel – Introduction of Particulate Filter



Ex. 4 CBI

Ex. 4 CBI

Emission Technology
Concept Euro 4



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Emission Aftertreatment Technology

Functionalities Particulate Filter

- Particles are filtered and burnt in the ceramic filter with its catalytic coating
- No Power Loss
- Reduced HC/CO-Emissions
- No Maintenance necessary
- Reduced System Effort

Ex. 4 CBI

Ex. 4 CBI

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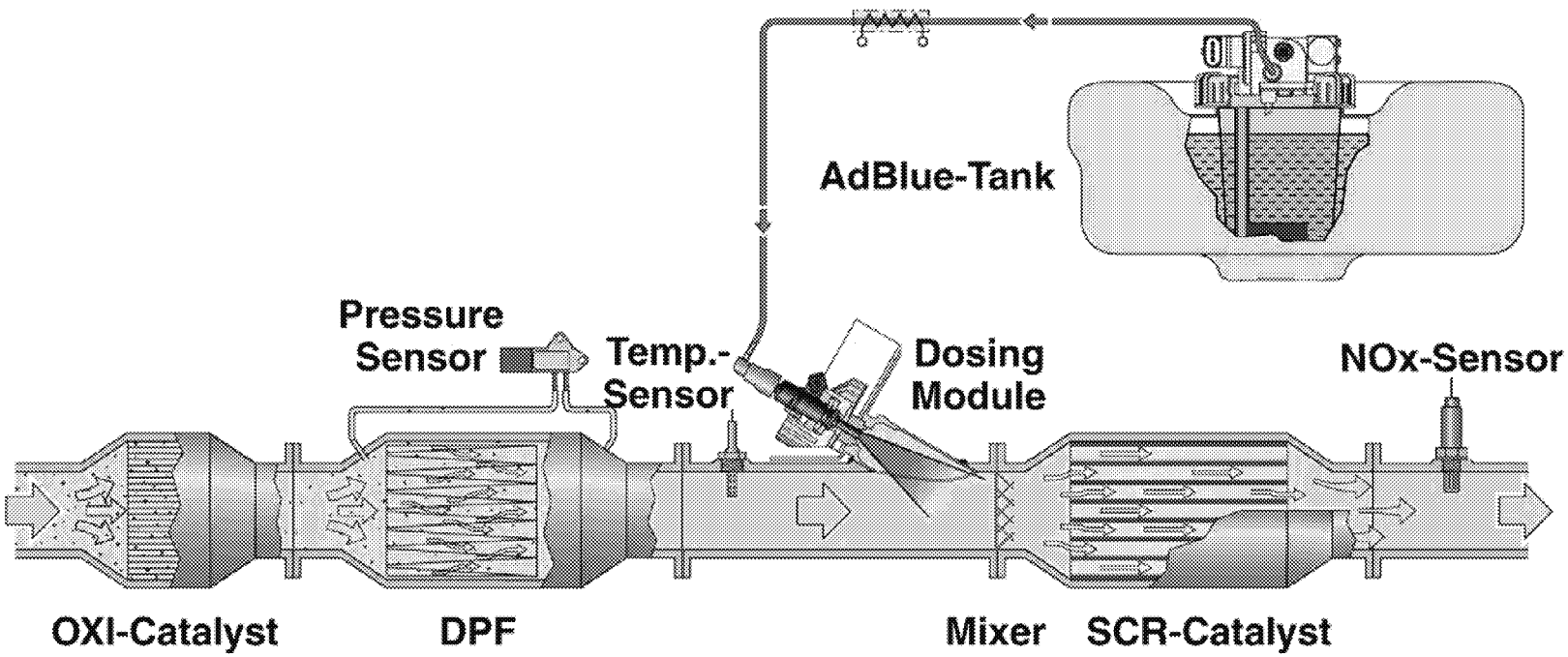
Emission Aftertreatment Technology

DeNOx-System (SCR)



Source: Bosch

Ex. 4 CBI

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Ex. 4 CBI

Certification Issues
Tampering

Tampering of the SCR system

- **The warning sequence is activated via sensors in the UREA tank when a low UREA level is detected. To avoid the activation of the warning sequence these sensors could be manipulated or disconnected.**
- **UREA pump and sensors are mounted inside the tank. Access to the electric and electronic components of the tank system is only possible when the tank is removed.**
- **Anti-tampering measures therefore are realized due to the mounting position of the UREA tank in the vehicle. UREA tank removal will require "high criminal energy“.**

OBD system

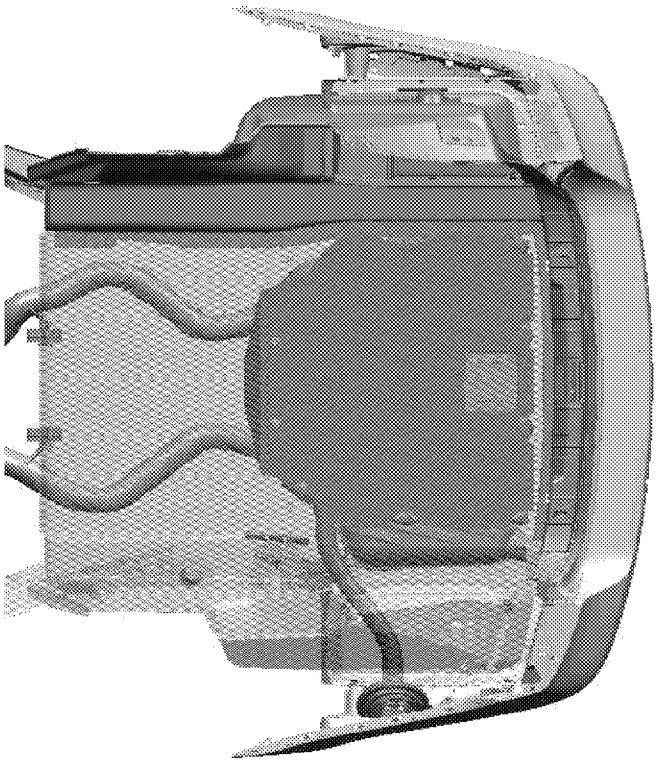
- **There is no possibility to differentiate between emission defects and tampering thus the OBD system can only detect emission problems but can not prevent tampering.**

Ex. 4 CBI

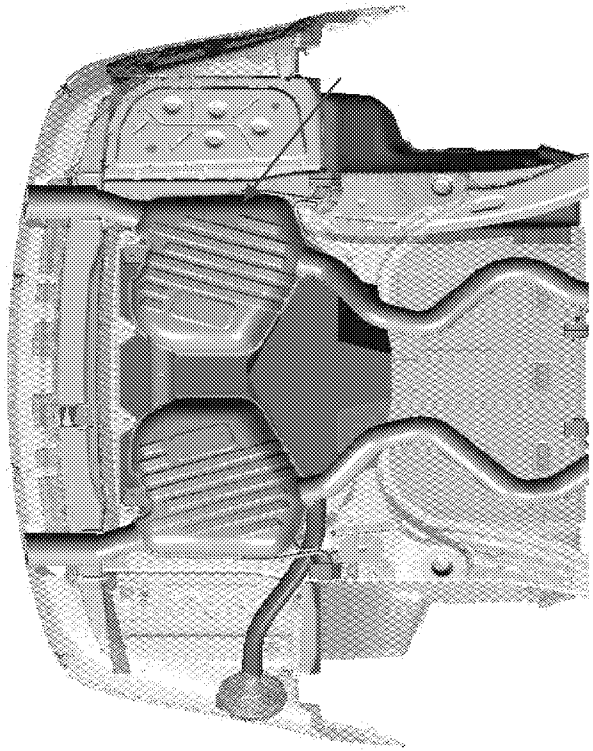
Certification Issues

Tampering - 3 Series Mounting Position of the UREA Tank **confidential**

TOP View



Bottom View



Certification Issues
Wrong Medium

- **Increasing N0x-emissions will be detected via N0x-sensor.**
- **In case of exceeding the OBD threshold the MIL will be activated.**
- **Increasing N0x emissions will be detected independent of the source.**

Ex. 4 CBI

Ex. 4 CBI

Certification Issues
UREA Infrastructure

Target:

80% of the US population to have UREA available within 20 miles. UREA can be offered at diesel filling stations and all other outlets (including quick-lubes or dealers)

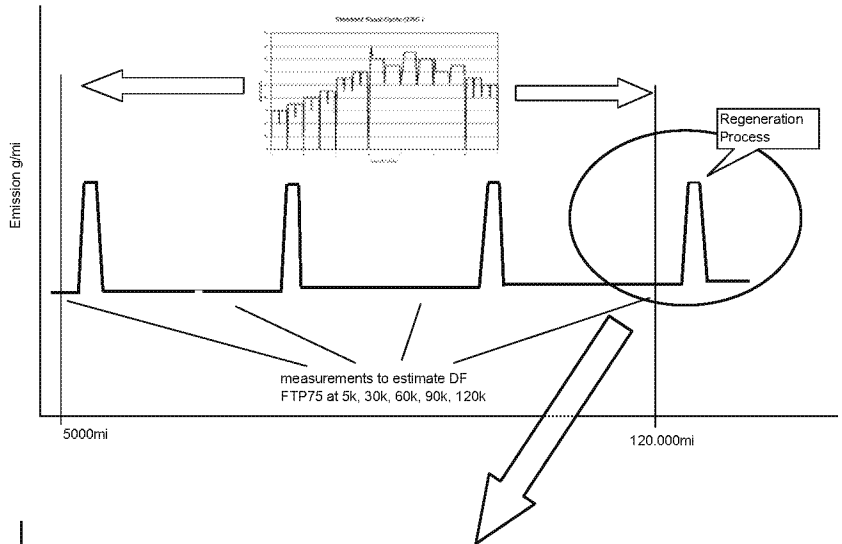
- **German OEMs started first negotiations with Shell, Exxon and BP. BMW will contact Shell and BP respectively.**
- **BMW will participate in a one provider purchasing concept in cooperation with German manufacturers. To be discussed: Specification sheet, refill standards, labeling, transport aspects and size of containers.**
- **We would like to discuss how EPA can contribute building up the UREA Infrastructure.**
- **How will the introduction of SCR Systems for Trucks influence the UREA Infrastructure ?**

Ex. 4 CBI

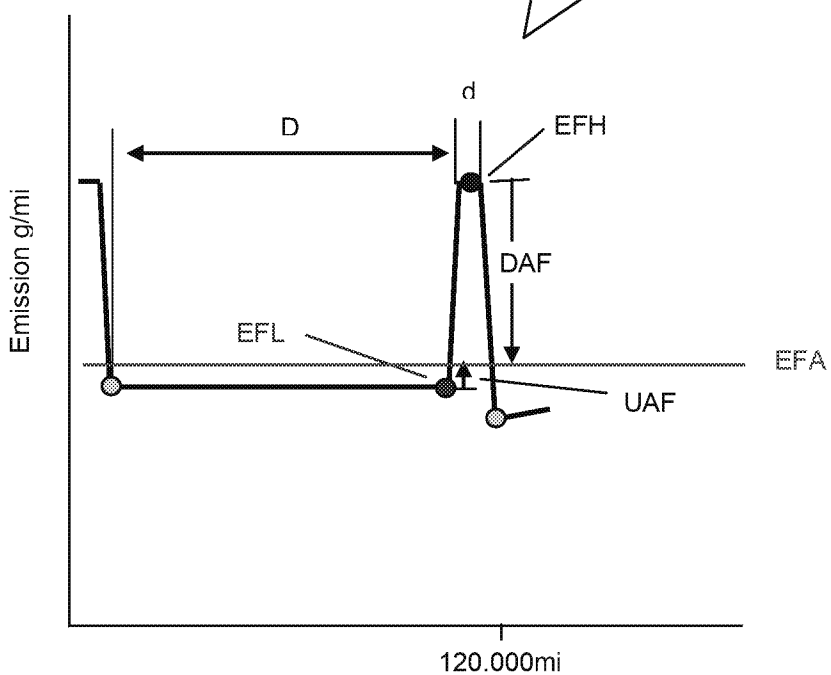
Ex. 4 CBI

Certification Process

Cyclic Emissions (According to Heavy Duty Procedures §86.004-28)



- **Highest emissions during regeneration are expected at the useful life mileage.**
- **Estimation of adjustment factors will be done with the DDV at 120.000mi.**



Calculation of Adjustment Factors:

Measurement at the end of the durability procedure

EFH = emissions from a test with regeneration
EFL = emissions from a test without regeneration
EFA = average emission rate
D = distance between regeneration cycles (average of 120.000mi)
d = distance where regeneration occurs (regeneration during FTP 75)

$$EFA^{1} = \frac{d}{d+D} \times EFH + \left(1 - \frac{d}{d+D}\right) \times EFL$$

[1]EFA is detemined by performing FTP 75 tests

Adjustment for emission tests (FTP75,HWFET,US06,SC03) without regeneration:

UAF = EFA - EFL Measured Emission [g/mi] + UAF < Standard
UAF = upward adjustment factor

Adjustment for emission tests (FTP75,HWFET,US06,SC03) with regeneration:

DAF = EFA - EFH Measured Emission [g/mi] - DAF < Standard
DAF = downward adjustment factor
The occurance of the regenration can be identified via ?

Certification Process

Detection of the Occurance of Regenerations

- **§86.004-28: "The occurance of the regeneration must be identified in a manner that is readily apparent during all testing."**
- **The occurance of a regeneration can be identified by BMW service tools. Does the paragraph require to additionally identify regenerations by common tools such as the OBD Scan Tool ?**
- **Checking the last regeneration occurrence can not assure that no regeneration will occur during a test.**
- **In case of a failed test, it should be identified if a regeneration occurred. If so DAF is used to adjust the emission values. Other option would be to repeat the test, this is favoured by BMW**

Ex. 4 CBI

Certification Process

Refuelling Emissions

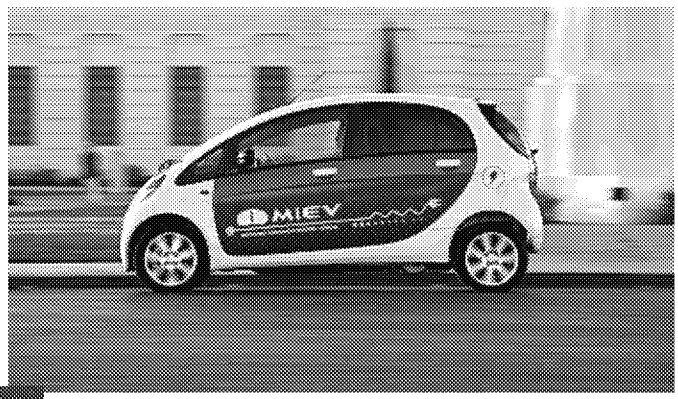
- Diurnal-Plus-Hot Soak and Running Loss Standards are not applicable for Diesels
- Diesel vehicles have to ensure the Refueling Emission Standard of 0,2 gHC/ gallon
- A compliance statement based on manufacturer tests will be provided in lieu of certification testing as allowed in the California Test Procedures
- Diesel vehicles are exempted from durability demonstration procedures for refueling emissions
- In Use testing for Diesel vehicles for Refueling Emissions *is* not required

Ex. 4 CBI

Ex. 4 CBI

Green Cars at the 2009 Washington, DC Auto Show

Chevrolet Equinox Fuel Cell
GM's fourth-generation hydrogen fuel cell vehicle, with a range of 160-200 miles and a top speed of 100 mph. This vehicle is being demonstrated in Project Driveway, where 100 vehicles are being driven by customers in selected areas.



Mitsubishi iMiev EV
Based on Mitsubishi's Japanese-market "kei car," this is a small, rear drive EV with a range of about 100 miles on Li-Ion batteries. It can be 80% charged in about 30 minutes and will enter production in Japan, then possibly the U.S.

VW Jetta TDI

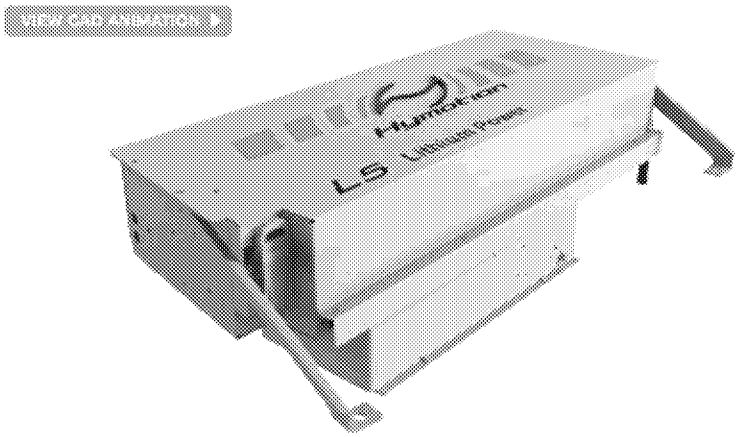
The VW Jetta TDI is VW's new clean-diesel entry with a FE label of 29/40. It uses a lean NOx trap system to meet Tier 2, bin 5 emissions levels. It is on sale now.

Mercedes-Benz BlueEfficiency B-Class natural gas vehicle
This is a B-Class car (about the size of a Honda Civic or Fit) that is powered by natural gas or gasoline (dual-fuel). It has a range of about 185 miles on NG. This vehicle may also have stop-start capability like the gasoline-fueled BlueEfficiency package, but press materials are unclear on this point.

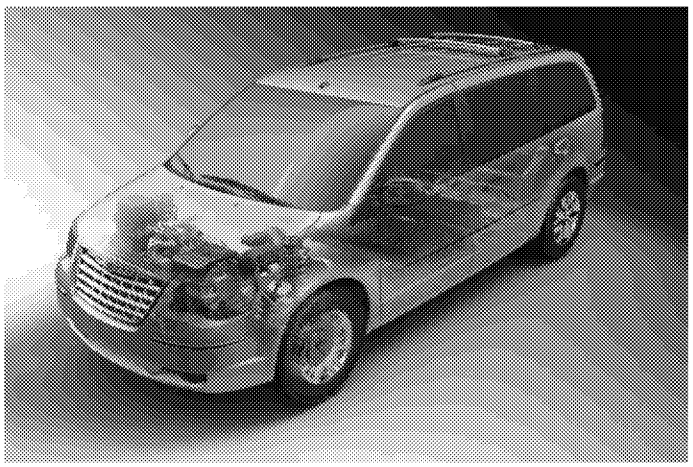
Roush Ford F-150 Propane Pickup

This is a conversion kit for the Ford F150 from a major Detroit engineering services company with close ties to Ford. The kit costs between $7500 for a version with a 250 mile range to $8500 for a kit with a 500 mile range. The 250 mile range kit has a tank that fits in the spare tire storage area to maintain full cargo capability.

HyMotion Prius Plug-In Hybrid



HyMotion is a Toronto-based company that converts standard Toyota Priuses to Plug-In capability by replacing the battery with a larger Li-Ion battery pack and modifying the control system. They claim a 30-40 mile range at 100 mpg. Note that claims of 100mpg may not include electricity consumption. Although the vehicle can cruise electrically at up to about 55 mph, in most driving the system is limited to speeds under about 35 mph for all-electric mode due to the extra power demands for accelerating in traffic. HyMotion is not affiliated or supported by Toyota. They also have a competitor in California called E-Drive Systems.



Chrysler Town and Country Electric Concept

One of three Chrysler EV concepts, the Town and Country is a range-extended EV (similar to the Chevy Volt) with a gasoline engine to keep the vehicle powered after the batteries are exhausted. Chrysler claims 40 miles on electric power and up to 400 miles total range including the 8 gallons of gasoline on board.

BMW X5 diesel

BMW is offering a clean-diesel version of their X5 SUV in the US. Early label FE estimate is City/Highway of 19/26 with a price around $47,000. The X5 meets Tier 2 Bin 5 emission standards using selective catalyst reduction (SCR). The SCR system uses diesel exhaust fluid (urea) to reduce Nitrogen Oxide emissions. The exhaust fluid refill schedule is 12000 miles.

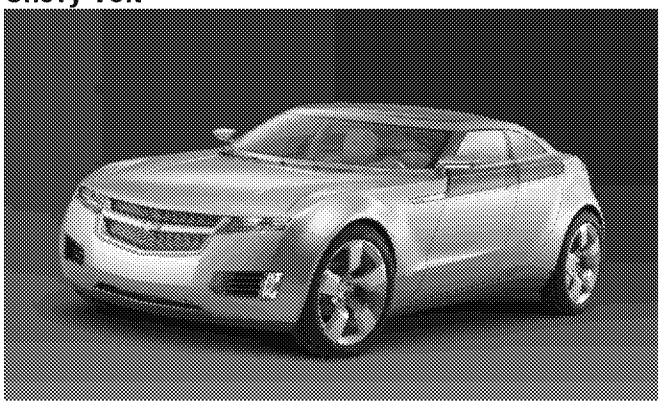
BMW Mini Cooper EV

The 2008 Model Year Mini Cooper EV labeled range is 100 miles per charge. Top speed is 95mph and it can quick charge in as little as 3 hours with a high amperage electrical service. The Mini EV uses Lithium Ion batteries. About 500 are scheduled to be leased in California, New York and New Jersey.

Ford Fusion/ Mercury Milan Hybrid

The 2010 Ford Fusion Hybrid has a FE label of 41/36 City/Highway. For 2010, the Fusion has an improved engine and expanded hybrid operation. The 2010 Fusion hybrid can achieve 47 mph in all electric mode with the engine off. Pricing is set to start at $27,300. Ford has announced that this hybrid will qualify for $3400 in tax credits. It will be on sale early this year

Chevy Volt



The Volt is advertised to run 40 miles per full electric charge, the adjusted label range will most likely be less. Claims of over 100 mpg gasoline may not include electricity consumption, but could be technically correct. The Volt is advertised as an EREV (Electric Range Extended Vehicle). The Volt is said to operate like a series Plug-In Hybrid Electric Vehicle where the engine only runs to charge the battery or to power the electric motor after the battery has depleted itself. As long as there is sufficient charge, the Volt could perform under all conditions and at all speeds without the use of the engine. Production dates will not been confirmed.

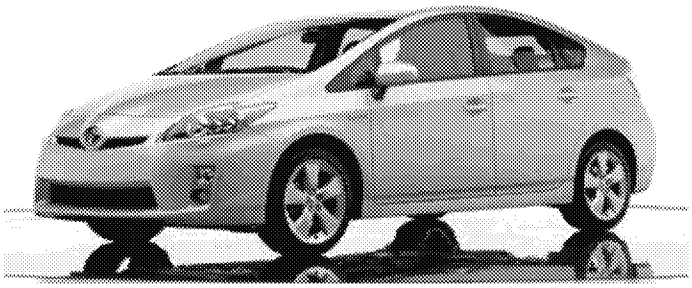
DOE Challenge X and EcoCar Challenge

Several universities will be showing their Challenge X and newer EcoCAR Challenge entries. This DOE-run competition is designed to train the next generation of engineers in green vehicle technologies and the vehicle development process. The competition is sponsored heavily by General Motors which supplies vehicles and parts and engineering expertise to the teams from major universities across the country.

2010 Honda Insight

Honda's 2010 Insight is a new lower-cost dedicated HEV with a remarkable resemblance to the Toyota Prius, but is smaller and retains Honda's signature Integrated Motor Assist system. Honda plans to sell the Insight at below $20,000. FE is not finalized, but label values of around 40/43 are expected. Eco Assist modifies operation for increased efficiency w/Eco-display to teach/encourage more efficient driving habits.

2010 Toyota Prius



New version is slightly bigger, roomier and faster with a larger engine (1.8 v.1.6L) but at an estimated 50mpg combined, gets 4mpg better than before thanks to tech advances such as lightweight drive components and solar powered vent system. Expect minor increase to $22,000 base price.

Below is an article from Green Car Journal
http://www.greencar.com/features/washington-auto-show-cars-meet-politics/

Washington Auto Show: Cars Meet Politics

by Ron Cogan

01/19/2009

The Washington Auto Show is ideally situated to live up to its tagline, 'The Automotive Seat of Power.' With all the goings-on in Washington DC that stand to influence, if not overtly direct, the activities of some of the world's major auto powers in the years ahead, this is an increasingly important show. In fact, the Washington show's media day on February 3 has been retitled Policy Day, which accurately reflects the potential for this show to influence the perspectives of legislators in that town. With a new Administration and 65 freshman legislators being sworn in the 111th Congress, opportunity abounds.

The new Administration in Washington will be dealing with the automotive bailout, an untenable reliance on imported oil, a national highway infrastructure sorely in need of repair, consumer difficulty in attaining new car loans, and more automotive issues than any Administration has had to deal with in the past. Is the Washington Auto Show important? In a word, 'yes,' and perhaps more so than at any time in its 88 year history.

The show points out that its timing – two weeks after the Presidential inauguration – will make for an historic event. Sometimes, timing is everything. The 2008 Los Angeles Auto Show last November was very 'green,' presented the first major auto show opportunity for automakers to show their new 2009 product to media and the public, and had the good fortune of being held in advance of the brunt of the auto industry meltdown.

The Washington show is being held in the very center of the policymaking universe for the most important auto market in the world, offering the auto industry's first opportunity to present its advanced technologies and 'green' activities to the new Administration and policymakers. As has been the case in the past, government officials and members of Congress will attend the show. So too will a few hundred thousand attendees who simply want to see the latest and greatest in automotive iron.

This year, attendees will view more than 700 new makes and models during the show's public days on February 4-8. Along with the 'green' vehicles on the show floor, Green Car Journal will present a Green Car Pavilion that highlights 25 of the most exciting advanced technology vehicles on the road and in development. These include the hydrogen powered Chevrolet Equinox Fuel Cell, natural gas Mercedes-Benz BlueEfficiency B-Class, Roush Ford F-150 propane pickup, HyMotion Prius plug-in

hybrid, Chrysler Town & Country electric concept van, clean diesel BMW X5 xDrive35d, and the VW Jetta TDI, Green Car Journal's 2009 Green Car of the Year®. Unique battery powered vehicles from the Electric Vehicle Association of Greater Washington DC will be shown, among them an electric Pontiac Fiero and a restored MIT Aztec solar race car.

Other university competition vehicles will be at the Green Car Pavilion. Ohio State University and West Virginia University will be showing their advanced Chevrolet Equinox entries from the Department of Energy's Challenge X competition. A Saturn Vue from DOE's new competition, EcoCAR: The NeXt Challenge, will also be on hand.

Focusing on vehicles that envision the road ahead, Green Car Journal will announce its 2009 Green Car Vision Award™ winner on the show's Policy Day. Finalists include the Chevrolet Volt, Fisker Karma, Honda FCX Clarity, MINI E, and Mitsubishi i-MiEV – representing range extended electric, plug-in hybrid, hydrogen fuel cell, and battery electric cars. Last year's Vision Award winner, Chevrolet's Equinox Fuel Cell, will be displayed at the Green Car Pavilion.
Green Car Journal's 2009 Green Car Summit™ takes on greater importance this year with its move to Capitol Hill on February 2. Here, industry leaders will explore the technologies, fuels, and vehicles that will shape our transportation future, focusing on the kinds of issues the new Administration will be facing in the months and years ahead. This event kicks off the Washington Auto Show's 'green' activities in a high-profile way, at a time when green vehicles are more important to the auto industry's future than ever.