Evaluation of Particulate Matter Filters in On-Road Heavy-Duty Diesel Vehicle Applications

May 8, 2015

EXECUTIVE SUMMARY

Since 1987, the U.S. Environmental Protection Agency (U.S. EPA) and the California Air Resources Board (ARB) have required heavy-duty engine manufacturers to submit test data certifying that their engines meet applicable emissions standards before those engines can be sold. Modern emissions standards have required that all diesel engines sold nationally and in California since 2007 achieve a greater than 98% reduction in particulate matter (PM) from uncontrolled engines. To meet this national standard, ARB and U.S. EPA required ultralow sulfur diesel fuel (ULSD, <15 ppm sulfur) and engine manufacturers have installed PM filters, or diesel particulate filters (DPF), on new engines. The PM filter is an exhaust filtration system installed downstream of the engine to collect and remove PM from engine exhaust. Every diesel-powered truck operating on the road that has been manufactured since 2007 in the United States is equipped with a PM filter. Millions of trucks are operating in the United States and in California with a PM filter.

In 1998, the State of California declared PM from diesel engines to be a toxic air contaminant. Health risk assessment studies showed that about 70 percent of all airborne cancer risk was attributable to exposure to diesel PM, and that in some parts of the state, airborne cancer risk exceeded 1,000 cases per million people. In response, ARB adopted the Diesel Risk Reduction Plan, calling for an 85 percent reduction in diesel PM emissions by 2020. Because diesel trucks can operate for 20 years or more, emissions reductions from emissions standards can be slow to materialize. To meet the goals of the Diesel Risk Reduction Plan, ARB implemented in-use rules designed to accelerate the adoption of the cleanest technologies in trucking fleets in California.

In 2008, the Board approved the Truck and Bus Regulation (Regulation) to meet toxic risk reduction goals, help attain federal ambient air quality standards, and protect public health. This in-use regulation requires more than one million trucks that operate annually in California and have a gross vehicle weight rating of over 14,000 pounds to meet particulate matter (PM) and ultimately decreases oxides of nitrogen (NOx) emissions levels on a schedule consistent with the amount of miles driven and vocation or body type of the vehicle. PM compliance is achieved either by purchasing a newer used truck built to the model year (MY) 2007 or later emissions standard and factory equipped with a PM filter, or by installing a retrofit PM filter on an existing truck. Ultimately by 2023, the Regulation requires that trucks operating in most regions of the State have an engine that is MY 2010 or newer, which has significantly lower PM and NOx emissions.

In October 2013, staff updated the Board on the implementation of the Regulation, and many stakeholders voiced concerns regarding the cost, reliability, fire safety of PM filters, and perceived adverse impacts of those filters on the performance of their trucks. In response to these concerns, the Board directed staff to investigate stakeholder claims and evaluate the performance of PM filters in on-road applications. This investigation focused on several questions:

- Do PM filters increase the risk of truck fires?
- Do PM filters effectively reduce diesel PM by 85 percent or more?
- Do PM filters perform reliably in on-road applications?

In this investigation, staff interviewed fleets to evaluate and inspect their trucks, interviewed retrofit installers and truck dealers, and surveyed truck drivers. Staff also reviewed relevant vehicle testing and compliance reporting data to better understand the scope and nature of these concerns.

At its April 2014 meeting, staff updated the Board on the preliminary findings from the evaluation, which indicated filters were effective, and initial indications suggested engine malfunctions and mal-maintenance were the likely causes of most PM filter concerns expressed by stakeholders. At that meeting, staff indicated they would continue to analyze available data, and issue a final report on their findings as soon as the analysis was complete. This report contains the final results of this evaluation.

Staff's overall findings are:

- PM filters do not increase the likelihood of truck fires and are manufactured in accordance with federal and state safety requirements;
- PM filters are effective in removing more than 98 percent of toxic diesel PM emissions;
- PM filters are operating properly, and most trucking fleets are not having problems with their engines or PM filters; and
- Some fleets are experiencing problems with their PM filters, but engine durability issues and inadequate maintenance practices are the primary reasons for these problems.

Our analysis indicates PM filters do not increase the risk of truck or bus fires. There are millions of PM filter-equipped trucks and buses operating on the nation's roads and driving every day without incident. National vehicle fire statistics suggest the frequency of truck fires is decreasing over time. All trucks and buses sold in the United States are subject to national safety standards that cover all components on the vehicle, including PM filters.

Retrofit PM filters must also meet national safety requirements established by the National Highway Traffic Safety Administration, the Federal Motor Carrier Safety Administration, and the Occupational Safety and Health Administration.[1-3] In addition to national requirements, ARB has established strict verification procedures designed to ensure the reliability and safety of each retrofit application.[4] California law requires retrofits to be designed and manufactured to federal safety requirements, and to be properly installed and maintained by the end-user. ARB enforces these requirements, and has issued fines in several cases where the retrofit systems were improperly installed, improperly maintained, or tampered by destroying components or disabling

alarm systems. The California Highway Patrol routinely inspects trucks and buses for safety through its Biennial Inspection of Terminals Program, and annually inspects school buses for safety.

Staff has identified three fires, which occurred between 2011 and 2012, involving two models of previously verified retrofit PM filters, the Cleaire LongMile and the SK Energy Econix system. In all cases, the filters in question were uniquely constructed with metal rather than ceramic filter cores, were impacted by engine component malfunctions, and in addition, were not operated properly. Shortly after the fires, ARB took prompt action to address potential future issues associated with improper operation of these verified retrofit PM filters. The Cleaire Longmile system was recalled in 2012 and that model is no longer sold. ARB suspended sales and initiated an enforcement action to address issues with the SK Energy Econix system in 2012, and a recall was initiated in January 2014. ARB has since strengthened verification procedures to require more extensive training for retrofit installers and consumers, increased the stringency of recall provisions, and set a standard practice to notify the National Highway Traffic Safety Administration in the event of a recall. No issues have been identified with PM filters manufactured with ceramic cores, which are ubiquitous in retrofit and OE applications and operating throughout California and the United States.

Our analysis indicates PM filters are effective and are operating as designed. Testing programs conducted by the ARB and many other organizations all demonstrate that properly functioning PM filters virtually eliminate PM from truck exhaust and that the majority of PM filters in operation are undamaged and in good condition. The air quality impacts following the adoption of PM filters into the on-road fleet have been substantial. Studies along the I-710 freeway demonstrated a 70-percent reduction in airborne black carbon as a result of ARB's Drayage Truck and Statewide Truck and Bus regulations, which required the use of PM filters beginning in 2010. Studies in southern California indicate a 65 percent reduction in cancer risk that was mostly attributable to the installation of PM filters in trucks between 2005 and 2012. These results demonstrate that the PM filter technology developed by engine and emission control manufacturers has dramatically reduced emissions of diesel PM and improved public health in California.

Fleet survey results indicate that some truck owners are experiencing vehicle downtime due to mechanical failures of their engines. Our analysis suggests this downtime is caused by engine component failures, such as a turbocharger or exhaust gas recirculation (EGR) device, that cause the engine to generate excessive PM at rates that exceed designed values for PM filters. These engine component failures are generally caused by underlying durability issues that have occurred over the past decade. Preliminary data suggests the durability of MY 2010 compliant engines is improving. These findings are supported by ARB fleet inspections, interviews with retrofit installers and truck dealers, and analysis of manufacturer reported warranty data. To address these issues, ARB is beginning to work more closely with U.S. EPA and engine manufacturers to monitor engine durability, and where needed, to

strengthen certification, including engine durability and warranty requirements for new on-road engines.

Many engine component failures are initially and incorrectly diagnosed as PM filter issues. In the absence of a PM filter, engine component failures generally trigger the malfunction indicator light, and can result in release of excess diesel PM emissions. When equipped with a PM filter, these emissions are collected as designed, but at rates that exceed the design of the PM filter system. Continued operation of a vehicle with malfunctioning or failed engine components, and/or triggered malfunction indicator lights without proper maintenance that addresses the cause of the problem, can damage the core of the PM filter if not addressed promptly. When this PM filter damage occurs, it is caused by continued vehicle operation after a warning light was triggered that indicated a problem in system performance requiring immediate attention. Damaged PM filters can release excess PM emissions which can be fixed only by replacing the filter core. Real-world measurements of trucks operating in California indicate this is occurring; a small fraction of trucks with damaged PM filters appears responsible for the majority of PM emissions and increased localized risk impacts from the PM filter-equipped fleet.

To meet regulatory requirements, engine manufacturers report warranty claims data to ARB. Complete warranty reports are available for engines sold between 2003 and 2011. Over this period, warranty claim rates for some engine components such as turbochargers and EGR systems indicate that generally between 10 and 40 percent of these components require repair or replacement during the engine warranty period, which generally covers up to the first 100,000 miles of vehicle operation. Results from ARB surveys indicate some fleets are continuing to experience EGR, turbocharger, and other engine problems throughout the life of the truck. According to warranty data, these upstream engine component problems have been occurring since at least 2003, and preceded PM filter requirements.

Staff's analysis of warranty claims data indicates that MY 2010 and newer engines have better durability performance (as measured by warrantable claims for engine component failures) than engines manufactured between 2003 and 2009. Preliminary warranty reports from MY 2012 engines suggest better performance than the MY 2011 engines. Additionally, MY 2013 and newer engines are equipped with standardized on-board diagnostics that staff believes should encourage improved engine durability. This means that as fleets begin to acquire greater numbers of trucks with newer engines that are certified to the MY 2010 standard as required by the Regulation, fleets should experience fewer problems between now and 2023.

Whereas the responsibility for ensuring the durability of engines sold in the marketplace lies with engine manufacturers, staff has identified several programmatic changes that it proposes to take to improve the durability and performance of new engines being sold. For example, regulatory and in-use compliance programs are designed to foster reliability in heavy-duty engines, and ARB intends to begin efforts to improve certification, warranty, and durability requirements, both in the California and national

heavy-duty new engine and vehicle certification programs. In addition, as a result of recent judicial rulings, ARB is considering proposing new regulations to hold manufacturers accountable for high warranty claims. With these actions, ARB will be able to better hold manufacturers accountable for the engines they produce, and to better ensure they operate issue-free beyond their warranty coverage.

While the responsibility for maintaining trucks in good operating condition lies with trucking fleets, it has been incumbent upon ARB to assist fleets in improving their maintenance practices to both identify and prevent problems before they occur. Anecdotal evidence suggests fleets that conduct regular preventive maintenance do not experience the same level of engine issues as other fleets that do not conduct regular maintenance. Therefore, fleets can combat durability issues leading to vehicle downtime by conducting regular preventive maintenance; however, surveys reveal many fleet operators and truck drivers are not fully trained on proper maintenance of engine or after-treatment devices. Staff is working with engine manufacturers; truck dealers, retrofit installers, industry organizations, and trucking associations to identify simple and low-cost preventive maintenance practices and procedures that could help fleets reduce the frequency of engine issues. In support of this effort, staff has developed and will incorporate into its fleet outreach activities brochures, guides and training that will assist fleets in understanding the importance of preventive maintenance practices and their benefits.

RECOMMENDATIONS AND NEXT STEPS

Staff has developed recommendations in five areas that will help better inform the direction of future efforts, actions, and rulemakings:

(1) **Continue Working to Hold Manufacturers Accountable.** Staff and testing resources are being dedicated to new in-use emission measurement programs to better enforce engine certification standards. Additionally, staff is considering amendments to ARB's Emissions Warranty Information Reporting regulations to hold manufacturers accountable for high warranty claims that can result in excess emissions.

(2) **Educate Truck and Bus Owners and Operators.** Staff is working with industry to identify best preventive maintenance practices to maintain properly functioning engines, and to disseminate this information to fleets, dealers, and repair shops through enhancements to ARB's outreach and education activities, and through trucking and other industry organizations.

(3) **Enhance Certification Programs.** Staff is developing improvements to ARB's certification program requirements that will provide broader in-use protections, greater warranty protections, and better assurances of engine component durability over a vehicle's life.

(4) **Develop Stronger Inspection and Maintenance (I/M) Requirements.** Staff is developing a proposal to expand heavy duty truck inspection and maintenance requirements to help ensure these vehicles and their emissions control systems are properly maintained and achieving desired emissions and localized risk reductions.

(5) **Continue to Provide Assistance to Fleets Operating Retrofits in On-Road and Off-Road Applications.** Staff will continue to investigate fleet concerns with retrofit performance in on-road and off-road applications and provide assistance to help ensure proper retrofit operation.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i

RECOMMENDATIONS AND NEXT STEPS v

1. INTRODUCTION 1

   a. Emission Standards and Control Technologies 1

   b. California's Strategies for Reducing Diesel PM Emissions 2

2. PURPOSE OF THIS REPORT 4

3. OVERVIEW OF EVALUATION METHODS 5

4. RESULTS OF PM FILTER EVALUATION 7

   a. PM Filters Do Not Cause Truck Fires 7

   b. Test Programs Demonstrate the Effectiveness of PM Filters 9

   c. Review of Warranty Claim Reports 12

   d. Truck Inspections and Fleet Interviews 15

   e. Random Roadside Surveys 19

   f. Interviews with Retrofit Installers and Truck Dealers 21

   g. Evaluation of Truck Emissions Screening Data 21

5. CONCLUSION 23

6. REFERENCES 25

APPENDIX I (Fleet Survey Form) 28

APPENDIX II (Roadside Survey Form) 35

APPENDIX III (VDECS Installer Form) 40

APPENDIX IV (OE Dealer Form) 47

APPENDIX V (Roadside Survey Statistics) 48

1. INTRODUCTION

a. Emission Standards and Control Technologies

Since 1987, the U.S. Environmental Protection Agency (U.S. EPA) and the California Air Resources Board (ARB or Board) have required heavy-duty engine manufacturers to submit test data certifying their engines meet applicable emissions standards over the expected useful life before those engines can be sold. ARB and U.S. EPA certification program requirements are consistent. Figure 1 below shows these heavy-duty diesel engine emission standards for three criteria pollutants for model year (MY) 1987 through 2010 engines: oxides of nitrogen (NOx), total hydrocarbons (HC), and PM. The emission standards have decreased substantially; the latest standards require 97 percent lower NOx, 89 percent lower HC, and 98 percent lower PM emissions since the first standards in 1987. A combination of these standards, fuel sulfur content reductions, and in-use programs have led to dramatic reductions in ambient concentrations of ozone and fine PM across California, and in particular near ports, railyards, and distribution centers.

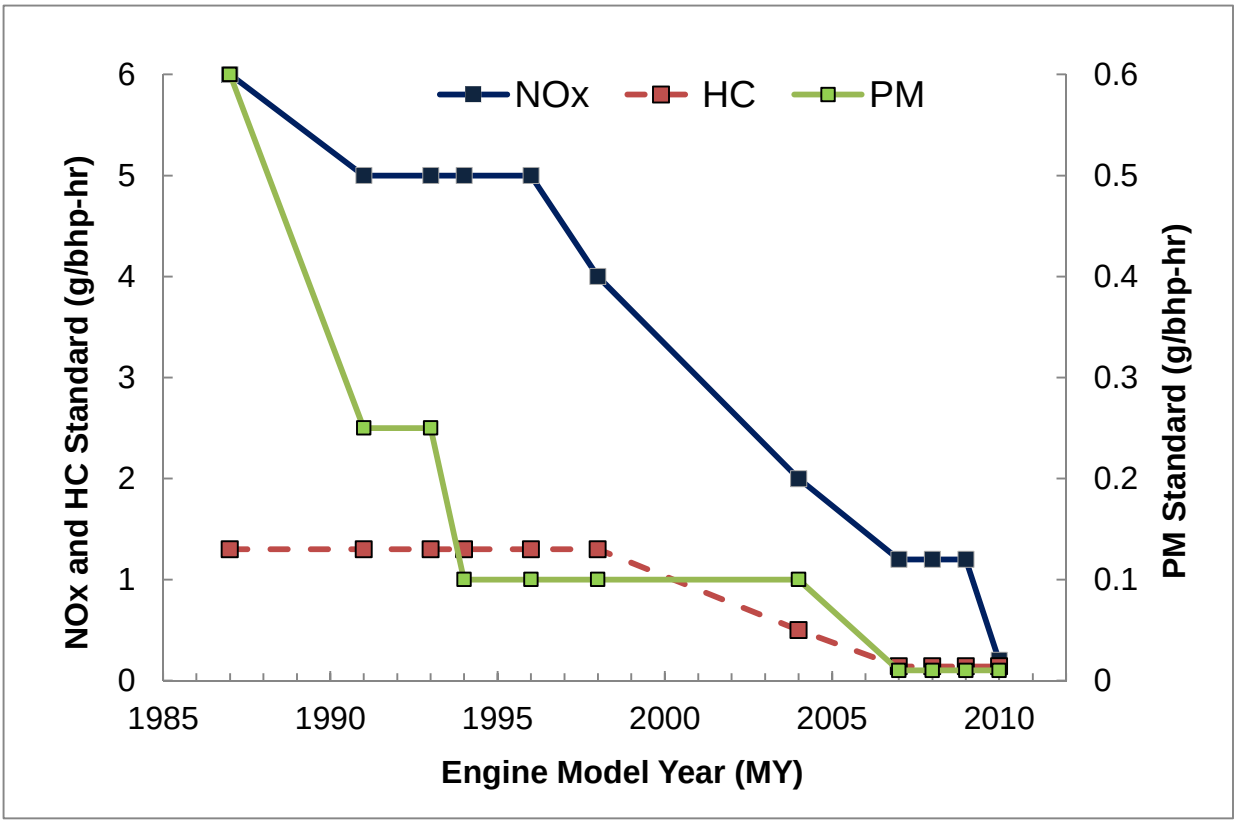

Figure 1. Heavy-duty diesel engine emission standards for MY 1987 through MY 2010 engines in California.

Engine manufacturers must certify their engines using the Federal Test Procedure (FTP) and the Supplemental Emissions Test (SET). ARB and U.S. EPA developed these test procedures to assess the emissions performance of an engine under representative operating conditions. Certification procedures also require demonstrations of durability to 435,000 miles for heavy heavy-duty (HHD) engines and emissions control systems (vehicles over 33,000 lbs gross vehicle weight rating, GVWR), with lower mileage requirements for lighter classifications of heavy-duty vehicles. These demonstrations are completed through a combination of testing and modeling, because testing these large engines to 435,000 miles would require several years of continuous testing. In order for U.S. EPA and ARB to certify engines, manufacturers must offer a minimum 5-year or 100,000-mile warranty, and ARB regulations require reporting California warranty claims for engine emission-related components when those claims exceed one percent of statewide sales. Certified engines must also meet a not-to-exceed (NTE) emissions protocol limit as part of new engine certification processes.

In meeting ever more stringent standards, manufacturers control NOx and PM emissions simultaneously by using several advanced emission control strategies. NOx has long been controlled by a technology called exhaust gas recirculation (EGR), where a fraction of exhaust gases are circulated back into the engine to reduce combustion temperatures and NOx emissions. More recently (typically in MY 2010 and newer engines), aftertreatment is used to provide dramatic NOx reductions through a process called Selective Catalytic Reduction (SCR), which involves injecting a small amount of urea (also known as Diesel Exhaust Fluid, or DEF) into a catalyst to reduce NOx emissions to inert gases.

Optimization of the fuel injection process partially controls PM emissions, but the predominant control technology for reducing PM emissions is the PM filter, which achieves emissions reductions far beyond the levels achieved by combustion strategies alone. PM filters have been standard equipment on nearly every engine manufactured in the United States since 2007, and there are millions of engines in trucks and buses equipped with PM filters operating on the road in the United States every day. Before the introduction of the MY 2007 PM standard, fuel sulfur content was capped to 15 ppm from the previous limit of 500 ppm; ultralow sulfur diesel (ULSD, <15 ppm sulfur) is now ubiquitous in California and the United States and enables PM filters to work effectively as designed. New trucks and buses sold with PM filters are referred to as originally equipped (OE).

b. California's Strategies for Reducing Diesel PM Emissions

Diesel engines power trucks that move California's economy, but also generate diesel PM emissions. There are more than one million diesel-powered trucks operating in California every year. On-road heavy-duty engines are the single largest source of diesel PM in California, and the largest contributor to statewide cancer health risks

posed by toxic air contaminants.[5, 6] Because these trucks operate for 30 years or more emissions reductions from engine standards can take decades to realize. In recognition of the substantial harm that exposure to diesel PM can cause, ARB approved the Diesel Risk Reduction Plan in 2000. This plan set a goal to reduce statewide exposure to diesel PM by 85 percent compared to uncontrolled levels by 2020.[6] In 2002, ARB adopted a new regulation to verify emission reductions from retrofit after-treatment systems designed to reduce emissions from the in-use diesel fleet. ARB's Diesel Emissions Control Strategy Verification (Verification) Procedure established emission and durability testing requirements that manufacturers of emission control technologies must meet in order for retrofit products to comply with emission requirements in California. Devices that are verified using the procedure are referred to as verified diesel emission control strategies (VDECS). Under State law, only devices that have been verified by ARB are permitted for use in California.

Today there are more than 50,000 retrofit PM filters installed and operated in California. Retrofit PM filters must meet national safety requirements established by the National Highway Traffic Safety Administration, the Federal Motor Carrier Safety Administration, and the Occupational Safety and Health Administration.[1-3] California law requires retrofits to be designed and manufactured to federal safety requirements, and to be properly installed and maintained by the end-user. ARB enforces these requirements, and has issued fines in several cases where the retrofit systems were improperly installed, improperly maintained, or tampered by destroying components or disabling alarm systems. The California Highway Patrol routinely inspects trucks and buses for safety through its Biennial Inspection of Terminals Program, and annually inspects school buses for safety.

ARB has established strict verification procedures that ensure the safety and reliability of each retrofit application[4] in terms of emissions reduction capabilities, durability, and compatibility with specific engine families and vehicle operating conditions by imposing rigorous testing requirements. Each of these retrofits is subject to warranty, and if necessary, corrective action or recall requirements. Before a device is installed, the installer is required to verify compatibility between the truck driving cycle and the PM filter, and to demonstrate the engine is operating within normal parameters. Every verified device is equipped with diagnostics including backpressure sensors designed to alert the operator to excessive PM loading on the filter so that the operator can take action to address the issue. This may include periodic maintenance such as initiating PM filter regeneration, where accumulated PM is oxidized to mostly inert gases such as carbon dioxide, having the engine serviced to ensure the engine is operating properly, and/or having the PM filter cleaned, where the components of diesel PM that cannot be oxidized during regeneration are physically removed from the PM filter. Ash cleaning is generally not required more frequently than every 100,000 miles, and is typically conducted at a designated repair shop or dealer. When a PM filter is cleaned the resulting ash is generally considered hazardous waste and must be handled appropriately. Without the PM filter this hazardous waste would have been emitted into the air, leading to increased exposure and adverse health impacts.

After several years of implementing the Verification Procedure, ARB began adopting new regulations that required the retrofit of older trucks in the on-road heavy-duty engine fleet with VDECS, including Urban Bus and Transit Vehicle fleets (adopted in 2000), Solid Waste Collection Vehicle fleets (adopted in 2003), Public Agency and Utility Vehicle fleets (adopted in 2005), and Drayage Truck fleets (adopted in 2007). These regulations required fleet operators to install verified retrofit devices to reduce emissions from the on-road fleet, in most cases achieving at least an 85 percent reduction of diesel PM emissions.

ARB approved the Truck and Bus Regulation (Regulation) in 2008, and amended the Regulation in 2010 and 2014, requiring the one million regulated trucks and buses that operate annually in California to meet PM and NOx emission requirements to achieve air quality and risk reduction goals. Compliance with the regulation is achieved by meeting PM and ultimately NOx emissions levels on a schedule consistent with the amount of miles driven and vocation or body type of the vehicle. PM compliance is achieved either by purchasing a newer used truck built to the MY 2007 or 2010 emissions standard and factory equipped with a PM filter, or by installing an ARB-verified retrofit PM filter on an existing truck. Ultimately by 2023, the Regulation requires that trucks operating in most regions of the State have an engine that was manufactured to the MY 2010 emissions standard.

2. PURPOSE OF THIS REPORT

In October 2013, staff updated the Board on the implementation of the Regulation, and many stakeholders voiced concerns regarding the cost, reliability, fire safety and perceived adverse impacts of those PM filters on the performance of their trucks. In response to these concerns, the Board directed staff to investigate stakeholder claims and evaluate the performance of PM filters. This investigation focused on several questions:

- Do PM filters increase the risk of truck fires?
- Do PM filters effectively reduce diesel PM by 85 percent or more?
- Do PM filters perform reliably in on-road applications?

To answer these questions, staff interviewed fleets to evaluate and inspect their trucks, interviewed retrofit installers and truck dealers, and surveyed truck drivers. Staff also reviewed relevant vehicle testing and compliance reporting data to better understand the scope and nature of these concerns. At its April 2014 meeting, staff updated the Board on the preliminary findings from the evaluation which indicated that filters are effective, and that initial indications suggested engine malfunctions and mal-maintenance were the likely causes of most PM filter concerns. At that meeting, staff indicated they would continue to analyze available data, and issue a final report on their findings as soon as the analysis was complete.

This document serves as the final report on this evaluation, and also recommends specific policy actions that staff will be taking related to in-use and regulatory programs in order to most cost-effectively address the findings of this report and maintain a clean in-use fleet.

3. OVERVIEW OF EVALUATION METHODS

To complete this analysis, staff evaluated available reports and studies, examined results from emissions testing and air quality measurement programs, and reviewed compliance reporting data. To fill data gaps, staff conducted surveys and inspected trucks. This section describes how relevant data were collected and analyzed.

To evaluate any potential relationship between PM filters and vehicle fires, staff conducted a literature search to identify studies and reports related to truck and bus fires in the United States and internationally. Staff evaluated reports and statistics based on the National Fire Information Reporting System, which is a national database of vehicle fires, and examined studies conducted by staff at the Volpe National Transportation Systems Center in the U.S. Department of Transportation, and by insurance companies and other organizations. Staff also assessed and summarized results from previous ARB investigations into truck fires where the truck in question was equipped with a retrofit PM filter.

To evaluate PM filter performance, staff reviewed emissions data from in-house and extramural testing studies. These studies included engine and chassis dynamometer tests of heavy-duty engines and vehicles in the laboratory, on-road plume measurements from individual vehicles, SAE J1667 snap acceleration smoke (opacity) tests, as well as on-roadway measurements to characterize emissions from the fleet at large. Specifically, staff analyzed data from three different measurement approaches to assess the durability of emissions control systems for reducing diesel PM of individual vehicles operating within California:

(1) Opacity tests conducted by ARB staff over the past five years. Under current ARB requirements, if MY 1991 or newer engines exceed a 40 percent opacity reading, fleets are required to make the repairs necessary to bring the engine's opacity to below that level, or replace noncompliant vehicles;

(2) Measurements of real-time PM from trucks undergoing a controlled acceleration through an On-road Heavy-Duty Measurement System (OHMS) developed by researchers at the University of Denver;[7] and

(3) Sampling of black carbon (BC) in exhaust plumes from a freeway overpass by the University of California, Berkeley.[8]

The three studies listed above were used to identify the distribution of emissions from the PM filter-equipped fleet. This information was used to estimate the fraction of high-emitting vehicles that likely have damaged PM filters (if present) and are currently in

operation in California for three groups: trucks without a PM filter, with a retrofit PM filter, and with an OE PM filter certified to MY 2007 and MY 2010 engine standards.

Staff reviewed warranty claims data reported by manufacturers to ARB via the existing Emissions Warranty Information Reporting (EWIR) process to identify the frequency of engine component issues encountered by truck operators during the warranty period of a new truck or bus. According to Title 13, California Code of Regulations (13 CCR), Sections 2141-2149, manufacturers must report warranty claim rates for any engine family exceeding a one percent claim rate for any emission-related part over the first 5 years or 100,000 miles of operation. An engine family is the most specific designation of a manufactured engine that is used for determining compliance. There are often ten or more performance ratings or models nested within one engine family for a specific manufacturer. Staff aggregated heavy-duty vehicle sales and EWIR data representing sales of engine MY 2003 through 2011. Staff then calculated warranty claim rates by component category, for diesel and natural gas (compressed natural gas, CNG or liquefied natural gas, LNG) engines.

To evaluate specific stakeholder concerns expressed in the October 2013 Board Hearing and December 2013 workshops, staff collected additional field data to evaluate the in-use performance of PM filters. Staff contacted the 21 fleets that expressed PM filter concerns at the 2013 Board meeting or subsequent December 2013 workshops to offer an on-site inspection of their trucks experiencing issues with PM filters. About half (11) of the fleets expressing concerns agreed to, and followed through with an on-site inspection of their trucks. In order to survey additional fleets experiencing problems but not reporting concerns to ARB directly, staff used the Truck Regulation Upload, Compliance and Reporting System (TRUCRS) database to select an additional 29 fleets at random for inspection. Combining both stakeholders expressing concerns and those selected randomly from TRUCRS, staff inspected 40 fleets representing 1,927 trucks, of which 432 trucks were present during inspection and of which 386 were equipped with a PM filter. About three-quarters of the trucks from the surveyed fleets were in service, and not present at the time of inspection. Although staff requested the presence of all trucks experiencing issues at the time of the scheduled inspection, there may have been additional vehicles in operation that also were undergoing issues related to the engine or PM filter systems. The vehicle screening form used in the field for fleet surveys is attached to this report in Appendix I.

Staff conducted random roadside inspections of trucks to determine the prominence of operational problems as viewed by truck operators, and to collect additional data to observe PM performance in operation. The truck inspection included the following:

- An examination of the exhaust stack to look for PM residue on the inside of the exhaust pipe downstream of the PM filter, which is a sign of PM filter damage;
- A status check for the malfunction indicator lights on the truck dashboard, or if present on the verified retrofit PM filter to determine if the unit was operating correctly;

- An inspection of the PM filter housing to ensure proper installation;
- An opacity test to screen the truck for PM emissions; and
- Documentation of all pertinent engine, vehicle, or vocational information to check for compliance with engine labeling and related regulations.

Staff asked operators if they had experienced, or were currently experiencing, any problems with the PM filter on the truck they were currently operating or to which they were permanently assigned. The random roadside inspections resulted in a total of 621 additional truck inspections, of which 587 were equipped with a PM filter. The field screening form used for roadside surveys is attached to this report in Appendix II.

Finally, staff surveyed retrofit PM filter installers, retrofit manufacturers, and OE truck dealers to better understand the installation process and the in-field issues experienced by fleets. Staff prepared specific mail-out surveys for each party, which gathered additional information to further supplement and support findings from the field and roadside inspections. The field screening form used for installer and OE dealer surveys are attached to this report in Appendices III and IV, respectively.

4. RESULTS OF PM FILTER EVALUATION

Staff's overall findings are:

- PM filters do not increase the likelihood of truck fires and are manufactured in accordance with federal and state safety requirements;
- PM filters are effective in removing more than 98 percent of toxic diesel PM emissions;
- PM filters are operating properly, and that most trucking fleets are not having problems with their engines or PM filters; and
- Some fleets are experiencing problems with their PM filters, but that engine durability issues and inadequate maintenance practices are the primary reasons for these problems.

This section describes the basis for these findings, and the actions staff is taking to address them.

a. PM Filters Do Not Cause Truck Fires

➢ *Key Finding: PM filters do not increase the likelihood of truck fires and are manufactured in compliance with federal and state safety requirements*

Heavy-duty vehicle fires are an infrequent event, but represent an important safety concern. Before the widespread deployment of the PM filter, between 2004 and 2006,

heavy-duty trucks accounted for 16,300 truck fires nationwide.[9] Between 2008 and 2010, when virtually all new heavy-duty trucks were equipped with PM filters and about one quarter of all truck miles were traveled by PM filter-equipped trucks, heavy-duty trucks accounted for 13,200 truck fires.[10] These data show over this period, truck fires declined by 20 percent. Over this same period, national diesel fuel sales, which are a reliable indicator of the amount of miles driven by trucks, declined by 6 percent.[11] These data indicate during this period heavy-duty truck fires declined at a greater rate than fuel sales, which suggests heavy-duty truck fires may be declining over time.

Additional studies specific to motorcoaches and heavy-duty trucks provide more information describing the causes of truck and bus fires.[12-16] About 70 percent of heavy-duty vehicle fires occur in the engine compartment or wheel well, and less than 2 percent of all heavy-duty vehicle fires originate from the exhaust manifold.[16] Fires in the engine compartment are caused by two main factors: electrical system failures associated with overloaded wiring, high resistance connections, and electrical arching, and engine component failures associated with turbochargers, alternators, heaters, and other components. Fires in the wheel well areas are caused by seized or dragging brakes, underinflated tires that cause frictional heating between the wheel and tire, or failed wheel bearings or hubs. For all causes of heavy-duty vehicle fires, risk reduction can be achieved by closely adhering to vehicle maintenance schedules. Vehicles with dirty or greasy engine compartment surfaces are at risk for igniting when an ignition source is present, such as a loose charged wire from an alternator, or hot surface from a turbocharger.

On heavy-duty trucks, PM filters are installed in the exhaust manifold, and the exhaust system is generally regarded as a component with lower risk for igniting a vehicle fire (the ignition point for less than 2 percent of reported heavy-duty vehicle fires).[16] Because the exhaust manifold can reach high temperatures in any diesel engine, regardless of whether it has a PM filter or not, the failure of the exhaust system heat-shielding materials can increase the risk of vehicle fires. This is why all exhaust manifold systems, whether equipped with a PM filter or not, and all retrofit systems, are designed to comply with Federal Motor Carrier Safety Administration regulations to ensure safety.[1] Through the design and verification process, every retrofit filter sold in California is designed for safe operation.[17] Retrofit PM filters must also meet national safety requirements established by the National Highway Traffic Safety Administration, the Federal Motor Carrier Safety Administration, and the Occupational Safety and Health Administration.[1-3] In addition to national requirements, ARB has established strict verification procedures designed to ensure the reliability and safety of each retrofit application.[4]

In addition, the California Highway Patrol regularly inspects trucks and buses for safety. Inspections are conducted every other year for trucks through the Biennial Inspection of Terminals program, and annually through programs focused on school buses and other buses. Vehicles with unsafe exhaust systems are not allowed into service until they are repaired. When school buses are retrofit with a PM filter, the bus is taken out of service

until cleared by the California Highway Patrol to be placed back into service. The bus is then inspected for safety on an annual basis. Our analysis suggests the risk of a retrofit PM filter causing a vehicle fire is comparable to the risk of fire from a vehicle's standard exhaust or muffler system. The potential for temporary excess heat around retrofit PM filters during regeneration is managed by insulation, heat shielding, and minor modifications to the post retrofit exhaust system which is required as part of the verification process to meet Federal Motor Carrier Safety Administration Regulations.

Through ARB's Retrofit Advocate Program, staff has investigated 13 instances where a truck with a retrofit PM filter was involved in a reported fire of some kind. Of these 13 investigations, only 3 involved the PM filter, while the remainder was caused by an electrical or other engine problem unrelated to the PM filter. Additionally, the 3 vehicle fires involved two previously verified models of PM filters were manufactured with metal rather than ceramic substrates: the Cleaire LongMile and SK Energy Econix systems, which were unique PM filters in on-road applications. In order to prevent additional failure of PM filters with metal substrates for use in on-road trucks, ARB recalled and required redesign and re-verification of all affected systems. The Cleaire LongMile recall was initiated in 2012 and that model is no longer sold. ARB suspended sales and initiated enforcement action on the SK Energy Econix system in 2012. Those systems were ultimately recalled in January 2014 and that recall is nearly complete. The SK Energy Econix system was redesigned, re-verified, and sold as the Boshart Econix DPF and then the Boshart Global DPF. In March 2015 an additional recall was initiated for these units after the manufacturer discontinued supporting warranty repairs.

Under the Regulation, vehicles equipped with recalled retrofits that cannot be repaired are allowed to have the recalled retrofit removed and continue to operate without a replacement PM filter for up to five years from the date of the recall as long as the vehicle remains in the same fleet. The most widely used recalled model was the Cleaire LongMile system. Under the terms of the recall, all LongMile filters installed in the United States were removed. ARB has also approved changes to the Goods Movement Emission Reduction Program to include a limited truck filter substrate replacement program. This program has an allocation of up to $6.3 million and will be implemented for qualifying trucks in 2015.

Staff Recommended Actions

- *Continue to monitor the frequency of truck fires to ensure that there are no changes to the safe operation that PM filters show nationwide*

b. Test Programs Demonstrate the Effectiveness of PM Filters

- *Key Finding: PM Filters effectively eliminate diesel PM emissions.*

Multiple internal and external testing programs and studies all show that properly functioning PM filters effectively eliminate PM emissions from diesel truck exhaust. For example, Figure 2 presents results from in-use HHD trucks tested on a heavy-duty chassis dynamometer binned by engine MY. Those data demonstrate properly functioning PM filter equipped trucks reduce emissions by 99 percent compared to engines manufactured in 1990, just 25 years ago.

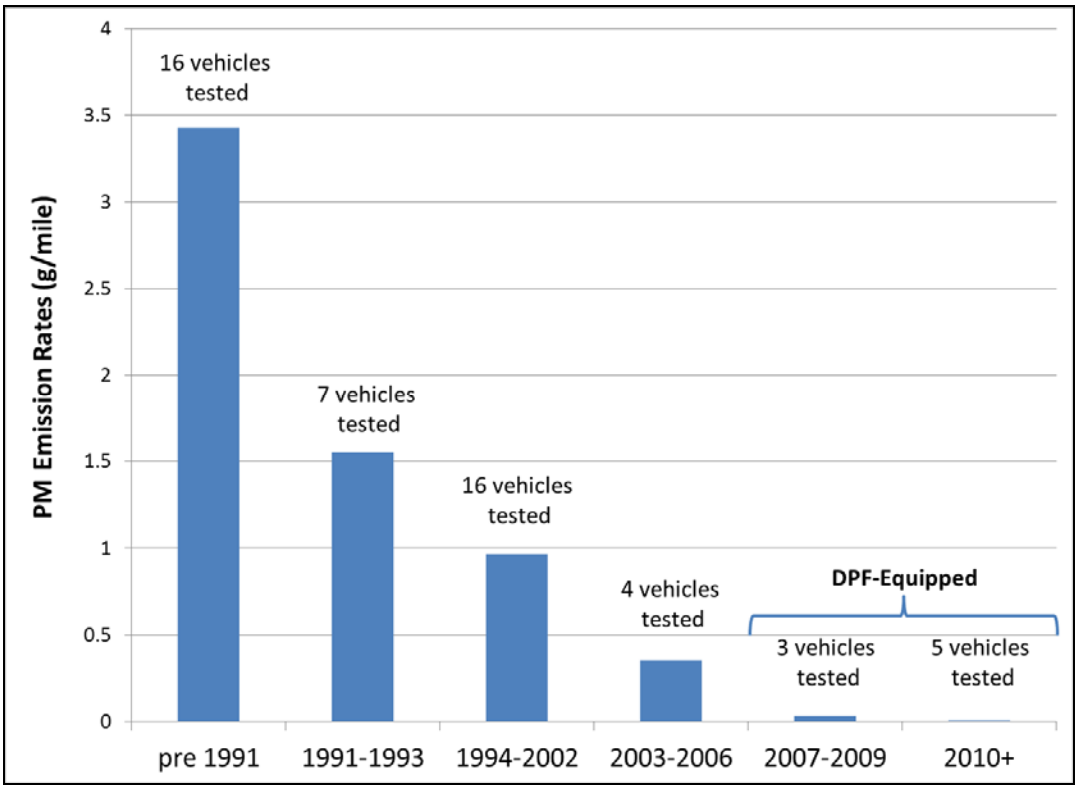

Figure 2. PM emissions on the UDDS chassis cycle from trucks with and without PM Filters measured as part of internal and external measurement projects conducted on chassis dynamometers. Data compiled from CRC E55/59, in-house testing conducted by ARB, and studies funded by the South Coast Air Quality Management District.

Other testing programs verify this result. In-use testing demonstrated retrofit PM filters eliminate more than 98 percent of diesel PM emissions relative to engines without a PM filter.[18,19] Subsequent work on newer engines at Southwest Research Institute (SwRI) showed that four MY 2007 engines from different manufacturers actually have PM emission rates that are 90 percent below the standard itself.[20] A later evaluation demonstrated even lower PM emissions because of the introduction of SCR for NOx control beginning with MY 2010 engines which enabled leaner engine operation and thus lower production of PM.[21]

Ambient PM emission reductions have also been observed throughout the state from various near-roadway air quality measurements since the introduction of PM filter requirements. Figure 3 shows on-road black carbon (BC), a surrogate of diesel PM,

declined by 70 percent on the I-710 freeway in Los Angeles between 2009 and 2011 as a result of the Drayage Truck and Truck and Bus regulations as shown by Figure 3.[22] Another measurement program conducted by the University of Denver evaluated more than 200 trucks and results showed the vehicles with PM filters on average emit 80 percent less PM than those without,[7] demonstrating the real-world benefits the use of PM filters provides. Most recently, the South Coast Air Quality Management District released the results from the Multiple Air Toxics Study IV (MATES IV). This study reported a 65 percent cancer risk reduction that was mostly attributable to reductions in diesel PM between 2005 and 2012 as fleet turnover resulted in greater adoption of the PM filter technology.[23]

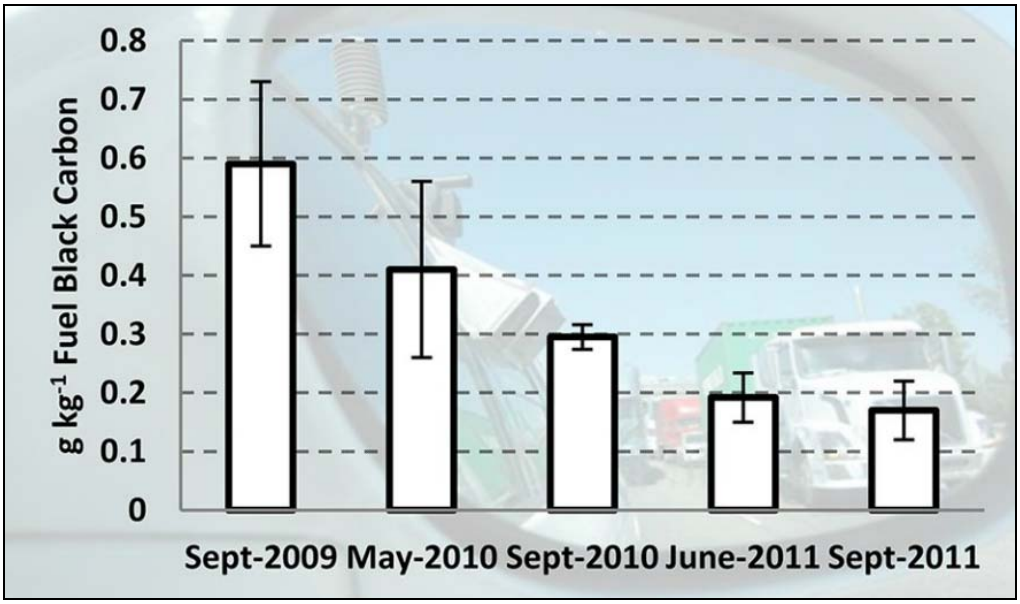

Figure 3. BC emissions measured on the I-710 freeway in Los Angeles during biannual campaigns between 2009 and 2011[22]. BC emissions are reported as emissions factors as a function of fuel consumed.

These results highlight the substantial benefits that PM filters provide in dramatically reducing emissions and exposure to diesel PM. ARB programs, such as the Regulation that requires fleets to use PM filters, and engine and emissions control manufacturers that make and install PM filters, are providing dramatic, measureable, real-world emission reductions. Continuing successful implementation of in-use programs such as these is crucial to reducing emissions of, and exposure to, diesel PM.

Staff Recommended Actions

- *Continue to: (1) uphold certification requirements for new engines, and, (2) continue to successfully implement ARB's Verification and in-use regulations to ensure the continued safe reductions of toxic diesel PM throughout California.*

c. Review of Warranty Claim Reports

- *Key Finding: Warranty claims for engine components suggest engine durability is a concern that can impact PM filter performance.*

As discussed in Section 5, engine and retrofit manufacturers are required to submit warranty claims data over the first 100,000 and 150,000 miles of operation, respectively, to ARB to meet certification and verification requirements. Each warranty claim represents an incident where a vehicle operator took that vehicle out of service and to a maintenance facility, and the part under warranty was replaced. The replaced part may or may not have been defective, and the process for determining whether the replaced part was defective is called a screening process. Warranty claims reported by manufacturers to ARB are unscreened, meaning the components replaced may not have actually been defective. Staff considers an unscreened claim rate, the number of claims for an engine family divided by its sales, to be high when it exceeds 10 percent, a threshold that triggered automatic corrective action under the 2007 EWIR regulations before they were overturned by the Los Angeles Superior Court in December 2008.[24]

Table 1 reports unscreened warranty claims for new HHD engines by engine MY. The table shows unscreened warranty claims rates exceeding 10 percent for injectors, turbochargers, EGR units, EGR coolers, SCR, and PM filters. The table also shows that warranty claims increased in MY 2003-2004 and 2007 when new emissions standards took effect. For example, EGR claims increased in 2004 and 2007, and decreased between 2004 and 2006, and between 2007 and 2011. MY 2011 engines have the lowest overall warranty claims rate since MY 2003, reflecting the on-going maturation of technology since 2007 and 2010 standards took effect. Despite this decline in engine component warranty claims for MY 2011, five component groups still exceed 10 percent unscreened warranty claims rates: injectors, EGR systems, EGR coolers, SCR systems, and other engine components. Preliminary warranty reports for MY 2012 engines suggest better performance and lower overall warranty claim rates than for MY 2011 engines; however, because many MY 2012 and newer engines are still covered under manufacturer emission warranties, staff cannot assess the trends for specific component groups beyond the reported period.

A close examination of the warranty claims suggests upstream engine components could be the root cause of PM filter problems, as shown in Figure 4. Virtually all engine families with reported claims for the PM filter also had reported claims for another engine-related component. A total of 208 heavy-duty diesel engine families were sold between MY 2007 and 2011; of these, 127 engine families reported warranty claims for an upstream engine component, of which 77 had claims reported for an emissions related component and the PM filter, where 44 engine families reported claims for an emissions related component and not the PM filter, and only 6 reported claims for the PM filter alone.

Retrofit PM filter systems are warrantied for five years or 150,000 miles of operation, which is a longer warranty period than for OE PM filters. Retrofit PM filters have a 10 percent warranty claim rate. However, most of these claims are for sensors replaced under warranty; manufacturers report a warranty claim rate for retrofit diesel PM filter core replacement of 0.5 percent.

Table 1. Heavy-Heavy Duty (HHD, >33,000 lbs GVWR) Unscreened Warranty Claim Rates by Component Group for MY 2003-2011 Engines.

	Percent Claims per Engines Sold								
	2003	**2004***	**2005**	**2006**	**2007***	**2008**	**2009**	**2010***	**2011**
Injectors	6%	67%	8%	3%	8%	12%	40%	22%	14%
Engine / ECM / Other	16%	30%	22%	22%	90%	59%	32%	17%	11%
Turbocharger Related	15%	38%	22%	25%	18%	12%	17%	3%	3%
EGR	26%	42%	35%	33%	41%	44%	31%	12%	10%
EGR Cooler	30%	12%	5%	6%	15%	14%	21%	20%	14%
Exhaust Manifold	10%	9%	7%	1%	0%	1%	4%	4%	4%
DOC	0%	0%	0%	0%	0%	2%	1%	1%	0%
PM Filter Related	--	--	--	--	35%	18%	7%	8%	4%
SCR Related	--	--	--	--	--	--	--	20%	10%
Total HHD Sales	6487	5499	8889	7535	3524	4729	4062	2698	5232

ECM = engine control module, DOC = diesel oxidation catalyst, SCR = selective catalytic reduction
(*) Engine standard change (2004, 2.5 g NOx+HC/bhp-hr; 2007, 0.01 g PM/bhp-hr; 2010, 0.02 g NOx/bhp-hr.
(--) Control technology not applicable for these model year ranges

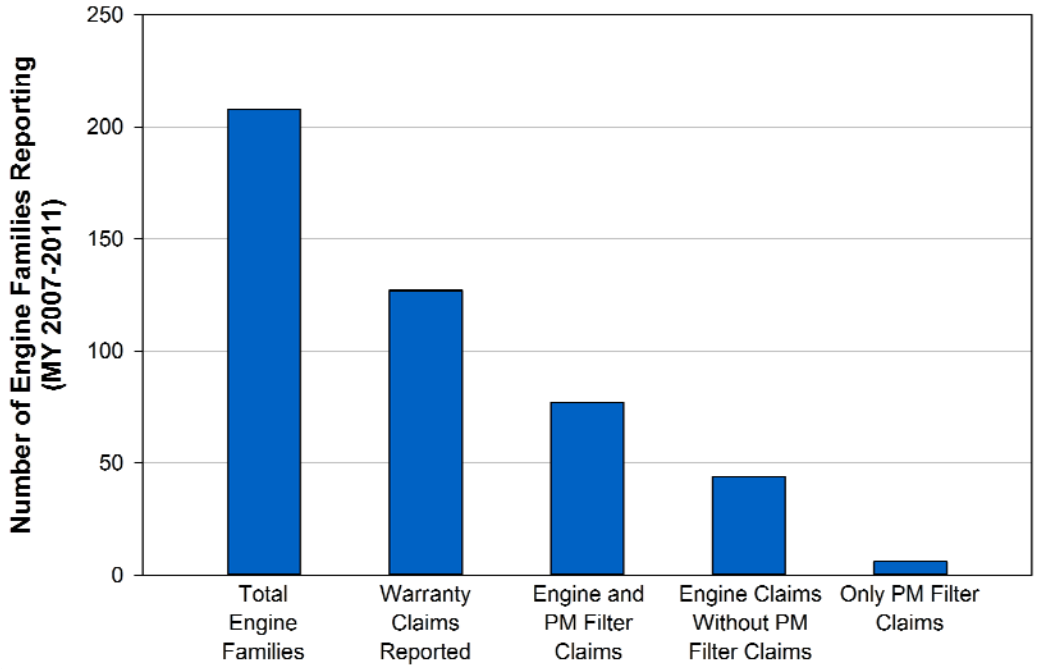

Figure 4. Number of Heavy-Duty Engine Families and Various Warranty Claims Reported for Diesel Engines Sold Between 2007 and 2011 in California. This represents over 50,000 heavy-duty engines sold in California over this period. Warranty claims related to DOC and SCR systems were not considered in this figure and corresponding analysis. Warranty claims suggests upstream engine components are the root cause of PM filter problems.

Staff Recommended Actions

- *Initiate steps to provide greater consumer protections by lengthening warranty periods for heavy-duty engines to improve engine durability*

The regulated warranty period of 100,000 miles is only a small fraction of a HHD engine's regulatory useful life (435,000 miles) and average lifetime for trucks operating in California (800,000 miles). High HHD warranty claim rates reported during the warranty period when a vehicle is relatively new indicate that engine durability is a key concern. Staff intends to engage the U.S. EPA and manufacturers on working to develop new certification and warranty requirements that would mitigate the gap between the emissions warranty and actual lifetime of a truck. Staff anticipates these changes could reduce operational downtime and costs to the end users, and would be most effective if applied nationally through federal regulation.

- *Amend EWIR regulations to hold manufacturers more accountable for high warranty claim rates*

ARB took action to amend EWIR regulations in March 2007 in response to high manufacturer reported heavy-duty warranty claim rates. The amendments stated systemic failures associated with an unscreened 10 percent warranty claim rate in any

single engine component represents a test procedure violation per Health and Safety Code (H&SC) Section 43105 and requires the manufacturer to provide corrective action to repair defects. In 2008, heavy-duty truck manufacturers objected, sued, and prevailed in court; the Court ruled that a systemic emission-related component failure by itself did not constitute a "test procedure" violation within the definition of H&SC Section 43105. This invalidated the most critical portion of the amendments forcing ARB to rescind the proposed amendments to the EWIR regulations. This ruling dramatically limited ARB's ability to address heavy-duty engine durability issues by linking high warranty claim rates to systemic failure of emission-related parts. In the absence of this Rule, ARB cannot force heavy-duty recall based solely on an emission-related warranty claim rate. Instead, ARB must prove that a malfunctioning component materially impacts emissions performance. Developing such proof requires in-use engine-dynamometer based compliance testing, which has historically been difficult to conduct using ARB resources. Unlike light-duty vehicles in California, ARB has not yet been able to conduct the necessary testing to require manufacturers to perform corrective action.

More recent judicial rulings change the scope and impact of the 2008 ruling, and staff is considering taking additional regulatory actions in late 2016 or early 2017 to hold manufacturers accountable to take corrective action for high warranty claim rates.

- *Continue to evaluate compliance of California trucks to in-use emission standards*

Staff is currently engaged in short-term efforts for conducting in-use compliance testing using Portable Emissions Measurement Systems (PEMS) over the NTE standard. This approach allows the truck to operate in normal revenue service on California roadways; emissions can be measured without impacting the vehicle. If engines certified with PM filters lack the durability to maintain compliance to NTE limits, ARB can use PEMS testing to provide the necessary information to initiate enforcement action against potentially offending manufacturers. Staff is implementing a pilot feasibility study designed to determine the most appropriate methods for performing in-use compliance testing. The results, anticipated to be completed in 2015, will be used to help focus longer-term in-use compliance testing programs.

d. Truck Inspections and Fleet Interviews

- *Key Finding: Field studies show PM filter issues can be linked to engine durability problems.*

As discussed in Section 3, as part of this investigation staff visited 40 fleets, interviewing fleet operators, conducting multi-point mechanical inspections on trucks at each facility, and recording fleet-reported issues for a total of 386 inspected trucks with PM filters. Staff categorized these fleet-reported issues by the following component designations:

EGR, Engine (including fuel injectors, transmission, and fuel or oil contamination), turbocharger (TC), electronic control module (ECM, including any electrical issue or illuminated malfunction indicator light), PM filter, and SCR system.

Data collected during fleet inspections are important for identifying trends, but are biased and not necessarily reflective of the California fleet as a whole. For example, staff preferentially selected some fleets for survey that expressed concerns to ARB so that their concerns and experiences could be better understood. While truckers self-reported multiple issues for some trucks, most issues had already been resolved by regular maintenance or warranty repair at the time of inspection, and were not actually observed during staff's inspections. Staff requested previous maintenance records to better understand the maintenance history associated with each individual vehicle, but virtually none of the fleets were able to provide records related to the maintenance of emission-related components.

Despite these limitations, results from these surveys provide additional evidence that fleet-reported PM filter issues are caused by engine component failures that affect PM filter performance. Table 2 provides fleet-reported issue rates for retrofit trucks, trucks meeting the MY 2007 standard, and trucks meeting the MY 2010 standard for each component designation. Results show the majority of identified PM filter issues were related to engine component issues. Fleets reported the largest number of issues for MY 2007 engines, which is consistent with warranty reports. Similar to staff's observations of the warranty reports, fleet reported issues also decreased in engines manufactured since 2007, especially for MY 2010 and newer engines.

Results are shown below for three categories: Retrofit trucks, MY 2007 Standard engines, and MY 2010 Standard engines.

Table 2. Fleet-reported percentage of trucks experiencing engine issues by reported component. Actual issue rates for California trucks are likely lower than shown because the trucks tested were selected from fleets reporting problems with their trucks.

MY	EGR	Engine, ECM	TC	PM Filter Issue Associated With Engine Problem	PM Filter Issue, Cause Not Identified	SCR
Retrofits MY 1990-2006 121 Trucks	10%	20%	11%	10%	6%	--
OE MY 2007-2009 88 Trucks	10%	62%	23%	32%	13%	--
OE MY 2010-2013 177 Trucks	7%	9%	0%	1%	0%	2%

Retrofit trucks

During fleet investigations, ARB staff inspected a total of 121 retrofit trucks. Fleets reported engine issues in 20 percent of these trucks, and EGR and turbocharger issues in about 10 percent of these trucks. Fleets reported a PM filter issue in 16 percent of their retrofit trucks. In two-thirds of those cases, the PM filter issue was associated with an engine problem. In the other cases, there was not sufficient information to attribute the PM filter issue to any cause.

When a fleet owner has a concern about retrofit performance that has not been resolved through discussions with the manufacturer and installer, staff investigates and works to resolve the issue through its Retrofit Advocate Program. In this program, staff acts as a liaison to installers and manufacturers, and oversees the training that manufacturers and installers offer to end-users. In this role, staff has conducted a total of 98 investigations of retrofit issues in on- and off-road applications. The vast majority of these investigations were resolved by ensuring engines were in proper repair, and retrofit PM filter maintenance schedules were followed. While nearly all of the investigations have been resolved, a few remain pending because the investigations have recently begun and sometimes require several months before a resolution is reached. ARB has also taken enforcement action in 23 cases against retrofit manufacturers and installers for non-compliance with the Verification Procedure, collecting settlement agreement penalties and forcing recall and/or redesign for metal substrate PM filters. Overall, ARB works closely with retrofit manufacturers and installers to ensure end-users have the needed resources to retrofit and reduce diesel PM emissions from their vehicles.

MY 2007-2009 Engines

During fleet investigations, staff inspected a total of 88 trucks manufactured to comply with the MY 2007 emission standard. Fleets reported some type of engine issue in 62 percent of these trucks. Fleets reported an EGR issue in 10 percent of these trucks and a turbocharger issue in 23 percent of these trucks. Fleets reported a PM filter issue in 45 percent of these trucks. Like retrofits, two-thirds of PM filter issues were associated with an upstream engine issue, and there was not sufficient information to attribute a cause to the remaining one-third of reported PM filter issues.

A closer evaluation of reported issues in MY 2007 and newer trucks reveals a spike in reported issues for trucks with MY 2007 engines, and a declining trend as the technology matures, as seen in Figure 5. This trend is similar to what was seen in warranty claims data.

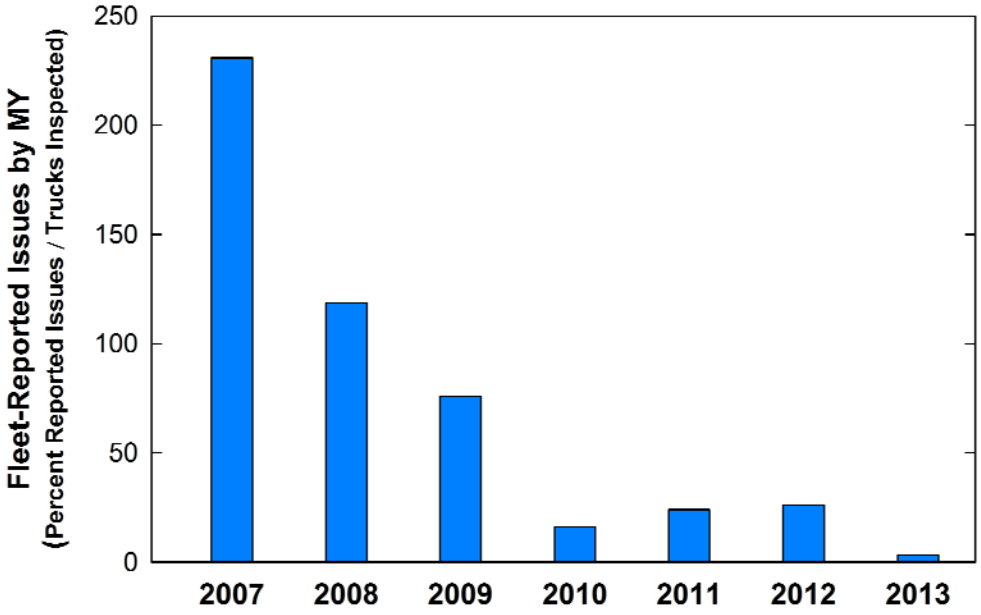

Figure 5. Total fleet-reported issues for all components by engine MY. A reported issue rate exceeding 100 percent indicates more reported issues than trucks inspected in the model year.

A common fleet-reported concern with PM filters was related to the active regeneration device (ARD) used by two Caterpillar engine models. The ARD device was a fuel ignition system designed to heat exhaust gas to enable active regeneration of the PM filter in certain engines manufactured by Caterpillar. The ARD was required to initiate an active regeneration, a procedure that needs to be conducted periodically for some duty cycles. There were four fleets staff surveyed that operated trucks with this specific component, representing 19 out of the 432 inspected trucks. Most of the fleets operating these trucks reported issues associated with the ARD head. The manufacturer correctively updated the hardware and software associated with the ARD and deployed it for warranty claims received related to the component. However, some fleets anecdotally claimed the ARD improvements were not very effective in reducing downtime related to maintenance for their PM filters. Since 2008, Caterpillar no longer produces on-road heavy-duty engines, and this specific problem is not anticipated to recur for any later MY engines.

MY 2010 and Newer Engines

During fleet investigations, staff inspected a total of 177 trucks manufactured to meet the MY 2010 standard. Fleets reported far fewer issues with these trucks than other trucks. For example, fleets reported engine issues on 9 percent of these trucks, and EGR issues on 7 percent of these trucks. Fleets reported only two PM filter issues, and

both were attributable to an engine issue. These results are consistent with warranty claims data which also suggest that trucks manufactured to the MY 2010 standard experience fewer issues than trucks manufactured to the MY 2007 standard. In Figure 5, there appears to be a slight increase in fleet reported issues between MY 2010 and 2012. These differences are small and not relevant to the key messages of this evaluation.

Because evidence suggests trucks manufactured to the MY 2010 standard experience fewer issues than older trucks, and because the Regulation requires gradual phase-in of these trucks into California fleets between now and 2023, staff believes the frequency of fleet-reported issues with engine components and PM filters should decline over time.

Staff Recommended Actions

- *Assess options to improve and revise durability testing procedures to assess real-world engine and truck durability*

Current durability testing procedures do not appear to be providing the durability protections envisioned when the tests were designed. Durability testing requirements could be redesigned for greater effectiveness. Further research and analysis should be conducted to understand how to achieve this goal.

e. Random Roadside Surveys

- *Key Findings: (1) PM filter issues are infrequent on the road; (2) Truckers are generally not familiar with modern diesel technologies, and; (3) Not all fleets are conducting robust maintenance of their trucks.*

As discussed in Section 3, staff conducted 621 roadside truck inspections, 587 of which were trucks equipped with PM filters. The resulting sample of paired truck inspections and operator surveys was representative of the California fleet. Appendix V provides a table showing the number of trucks inspected by body type relative to statistical sample targets.

Based on responses from truck operators, about 2 percent (11 of 587 trucks) reported a past problem with the PM filter on their truck that required service to resolve the problem. Most of these problems appeared to be resolved at the time of the survey. A larger number of operators (58) provided comments and opinions regarding the implementation strategies of the Regulation, the associated maintenance costs relating to PM filters, and the time required to perform regular maintenance procedures. The majority of comments from operators were not actually related to an engine or PM filter problem on their trucks.

ARB staff also asked truck operators if they received PM filter or SCR training from either their fleet or dealer. Training could include any form of instruction related to the after-treatment devices, such as performing an active regeneration or maintaining sufficient diesel exhaust fluid (DEF) levels to avoid driver inducements. Fewer than 50 percent of truck operators reported receiving any training, and some were not familiar with the control technologies on their trucks. With the scheduled phase-in of newer trucks with advanced after treatment, it is important that all drivers receive basic training from the manufacturers, dealers, or fleets to minimize operational disruptions. Several truck operators claimed that their MY 2010 and newer engine equipped with SCR suddenly "broke down" and speeds were reduced. This description is consistent with driver inducements associated with maintaining insufficient DEF fluid levels. Driver inducements are part of the certified design of SCR-equipped trucks, where speeds are reduced when DEF fluid is exhausted. DEF fluid is necessary to achieve NOx control in the SCR. The inducements are included as part of the engine certification process to ensure NOx emissions control consistent with the emission standard is achieved. ARB has distributed general instructions to fleets and operators throughout the State describing the importance of maintaining DEF fluid levels to ensure proper engine and emissions control function.

Staff Recommended Actions

- *Develop and distribute to fleets and dealers best preventive maintenance practices to maintain properly functioning engines and aftertreatment systems*

Anecdotal evidence available today suggests fleets which conduct regularly scheduled preventive maintenance experience less vehicle downtime than other fleets. To investigate the potential for using preventive maintenance to reduce the frequency of reported engine and PM filter issues, staff convened a team of stakeholders representing retrofit installers, truck dealers, trucking associations, diesel technology community college training program instructors, engine manufacturers and industry associations. Staff is working with this team to compile regular maintenance schedules and identify additional cost-effective maintenance practices that might help ensure optimal engine and PM filter performance. The objective of this project is to identify low cost and effective preventive maintenance techniques, demonstrate the potential benefits these techniques could have, and disseminate this information to fleets. These materials will also be integrated into the existing community college California Council on Diesel Education and Technology (CCDET) training program. Fleets subject to the enforcement actions are required to complete two 8-hour CCDET courses as a condition of settlement. Staff anticipates completing this project in the summer of 2015.

ARB staff is further engaged in assembling additional training materials that will be incorporated into its fleet outreach activities brochures, guides and training so that fleets and other end users are aware of preventive maintenance techniques that can help ensure proper operation of trucks, engines, and aftertreatment controls.

f. Interviews with Retrofit Installers and Truck Dealers

- *Key Finding: Surveys confirm engine problems are the root cause of most PM filter issues*

As discussed in Section 3, staff administered a questionnaire to retrofit installers and truck dealers designed to better understand the issues fleets are experiencing. Staff surveys requested information regarding the manufacturers of the PM filters or truck engines involved, typical sales numbers, warranty repair rates, and service patterns such as the more problematic engine models that are difficult to retrofit. Staff received responses from eight retrofit installers and five truck dealers with businesses in California. Results from these surveys indicate that both retrofit installers and truck dealers believe engine-related problems are the leading cause of PM filter damage they observe on in-use trucks, with only a small fraction of problems originating from customer tampering or from the PM filters themselves.

Under ARB's verification procedure, retrofit installers must complete a pre-installation compatibility (PIC) assessment to log duty cycle activity and determine the maintenance condition of the engine. The PIC assessment is required so that the retrofit PM filter can be properly sized, and so that any engine maintenance issues can be resolved prior to install. Survey data suggest that between 10 and 38 percent of trucks initially failed the PIC assessment, indicating that engines were experiencing issues and had not been properly maintained. These trucks are required to undergo restorative maintenance prior to installation of the retrofit PM filter on their trucks. Restorative maintenance often included repair to critical components such as the turbocharger, charge air cooler, and fuel injectors.

Surveys of OE truck dealers suggest that only in limited circumstances does a customer incur a problem with the PM filter that is not also correlated with an upstream engine component problem. The majority of these dealers reported providing preventive maintenance information to their fleet customers. Survey data also confirms fewer reported PM filter problems with MY 2010 and newer trucks, which is consistent with warranty and fleet inspection data.

Staff Recommended Actions

- *Confirmatory findings, no action needed.*

g. Evaluation of Truck Emissions Screening Data

- *Key Finding: A small fraction of the in-use fleet is operating with damaged PM filters and is generating excess PM emissions*

Staff evaluated several different large scale in-use truck emissions measurement studies to evaluate the effectiveness of PM filters on the road, as discussed in Section 3. Results show that while the vast majority of PM filters are operating properly, a small fraction may not be operating properly, and this small fraction appears responsible for most emissions from the PM filtered fleet.

For the past several years ARB staff has administered roadside snap-idle exhaust opacity tests during roadside truck inspections. More than 1,800 trucks have been tested, about half of which were equipped with PM filters. Results show that about 8 percent of these trucks are emitting over 5 percent opacity. At this level of opacity, it is likely these PM filters are not controlling PM emissions effectively and have emissions that exceed the emission standard if the engines were removed and tested using an engine dynamometer over any of the test cycles used to certify new engines. Staff is conducting research to refine estimates of the appropriate opacity level that accurately identifies damaged filters and excess in-use emissions.

Staff also evaluated data from the OHMS study conducted by the University of Denver at the Port of Los Angeles and at the Cottonwood weigh station in northern California, and the plume sampling conducted by the University of California, Berkeley at the Port of Oakland. Both of these studies included PM measurements of exhaust plumes emitted from individually identified vehicles. Results from these two studies are consistent with ARB's roadside snap-idle opacity test measurements, suggesting that the top 10 percent of emitters in the PM filter equipped fleet are responsible for over 70 percent of all emissions from PM filter equipped trucks.

ARB administers two heavy-duty Inspection and Maintenance (I/M) programs that have been critical for identifying high-emitting trucks and reducing their emissions, resulting in thousands of citations since the inception of the program over 20 years ago. One is the Heavy Duty Vehicle Inspection Program (HDVIP) conducted by ARB teams at border crossings, California Highway Patrol weigh stations, and other randomly selected roadside locations. Under HDVIP, owners must maintain engine labels, keep emissions control systems within manufacturer specifications (i.e. not tampered with or defective), and comply with opacity test requirements of 40 or 55 percent depending on engine model year. A second parallel program is the Periodic Smoke Inspection Program (PSIP), where fleets must perform opacity tests and retain records to demonstrate compliance.

Staff Recommended Actions

- *Expand the scope of heavy-duty I/M programs to more cost effectively identify and repair high-emitting vehicles in the fleet*

The current 40-percent opacity limit for MY 1991 and newer engines required by the HDVIP and PSIP programs is inadequate to detect an improperly functioning PM filter. Reducing the opacity limit would require a small fraction of the in-use fleet to repair

emission-related components, which could include repair or replacement of the PM filter core. This short-term solution would provide immediate emission benefits. Compliance costs and emission benefits of this regulatory change are currently under assessment.

Over the longer term, staff anticipates significantly expanding truck I/M programs. Such a program would rely more heavily on on-board diagnostics (OBD) that have been standard equipment on truck engines since MY 2013, and could integrate additional diagnostic or emissions measurement technologies to help flag high-emitting in-use trucks for further evaluation and repair. The advantage of OBD based inspection and maintenance is the reliability of the system coupled with the low cost to perform the compliance check. The advantage of remote sensing programs would enable monitoring of many vehicles operating within California, and not just those inspected at designated locations by the HDVIP or at fleet audits through the PSIP. Staff is initiating several research programs and projects to better understand the feasibility of identification using remote sensing, developing chassis-based emission-testing criteria, and cost-effectively requiring repair to the emission-related components.

5. CONCLUSION

Staff's investigation concludes that PM filters are effective and reliable. All diesel powered trucks manufactured in the United States have been equipped with a PM filter since 2007 resulting in millions of OE installed and retrofit PM filter applications operating effectively on roads in California and the United States every day. Overall, staff concludes:

- PM filters do not increase the likelihood of truck fires and are manufactured in accordance with federal and state safety requirements;
- PM filters are effective in removing more than 98 percent of toxic diesel PM emissions;
- PM filters are operating properly, and most trucking fleets are not having problems with their engines or PM filters; and
- Some fleets are experiencing problems with their PM filters, but engine durability issues and inadequate maintenance practices are the primary reasons for these problems.

Data shows that when fleets do experience a problem that they attribute to the PM filter, in nearly all cases engine component malfunctions are the root cause. Engine component malfunctions often result in the engine generating excess particulate matter in the exhaust, which causes additional loading on the PM filter. If the engine is not repaired, the PM filter will respond through more frequent regeneration, and will require more frequent cleaning. In extreme cases the PM filter may plug and affect the truck's operability, or may become irreparably damaged.

Despite the demonstrated robustness of diesel PM filters, other engine component malfunctions are a concern. Warranty claim rates and surveys of truck operators, retrofit installers, and truck dealers all point to the same conclusion – some engine components such as EGR units, EGR coolers, and turbochargers fail too frequently. Surveys also suggest that while preventive maintenance may be effective in reducing the frequency of engine issues, many fleets do not perform adequate preventive maintenance.

While staff expects these problems to be temporary, because trucks with MY 2010 and newer engines appear more reliable, with fewer fleet reported issues and fewer manufacturer reported warranty claims, than trucks with engines manufactured between 2003 and 2009, new actions to ensure the robustness and durability of HD engines are still needed. Ultimately, the responsibility for ensuring durability of engines sold in the marketplace lies with engine manufacturers and the responsibility for maintaining trucks in good operating performance lies with trucking fleets; and ARB is taking steps to address these issues now. Staff is currently engaged in the recommended actions that are summarized below:

(1) **Continue Working to Hold Manufacturers Accountable.** Staff and testing resources are being dedicated to new in-use emission measurement programs to better enforce engine certification standards. Additionally, staff is considering amendments to ARB's Emissions Warranty Information Reporting regulations to hold manufacturers accountable for high warranty claims that can result in excess emissions.

(2) **Educate Truck and Bus Owners and Operators.** Staff is working with industry to identify best preventive maintenance practices to maintain properly functioning engines, and to disseminate this information to fleets, dealers, and repair shops through enhancements to ARB's outreach and education activities, and through trucking and other industry organizations.

(3) **Enhance Certification Programs.** Staff is developing improvements to ARB's certification program requirements that will provide broader in-use protections, greater warranty protections, and better assurances of engine component durability over a vehicle's life.

(4) **Develop Stronger Inspection and Maintenance (I/M) Requirements.** Staff is developing a proposal to expand heavy duty truck inspection and maintenance requirements to help ensure these vehicles and their emissions control systems are properly maintained and achieving desired emission and localized risk reductions.

(5) **Continue to Provide Assistance to Fleets Operating Retrofits in On-Road and Off-Road Applications.** Staff will continue to investigate fleet concerns with retrofit performance in on-road and off-road applications and provide assistance to help ensure proper retrofit operation.

6. REFERENCES

1. FMCSA, Parts and Accessories Necessary for Safe Operation. *Title 49, Section 393.83. Available at: http://www.fmcsa.dot.gov/regulations/title49/section/393.83*.

2. U.S.Code, Motor Vehicle and Driver Programs, Part A, Motor Vehicle Safety, Subchapter I - General. *49 USC § 30101 et seq, Available at: https://www.law.cornell.edu/uscode/pdf/uscode49/lii_usc_TI_49_ST_VI_PA_A_CH_301_SC_I_SE_30101.pdf.*

3. OAL, Chapter 14: Verification Procedure, Warranty and in-Use Compliance Requirements for in-Use Strategies to Control Emissions from Diesel Engines. *13 CCR 2702(d); 2706(w); 2706(s); 2706(f). Available at: https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I0BC18F70D46A11DE8879F88E8B0DAAAE&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default).*

4. OAL, Chapter 14: Verification Procedure, Warranty and in-Use Compliance Requirements for in-Use Strategies to Control Emissions from Diesel Engines. *13 CCR 2706; 2706(u)(3), 2706(f)(1), 2706(f)(3), and 2711(a). Available at: https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I0BC18F70D46A11DE8879F88E8B0DAAAE&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default).*

5. CARB *Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant (Initial Statement of Reasons)*; Sacramento, CA, 1998.

6. ARB *Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles*; Sacramento, CA, 2000.

7. Bishop, G. A.; Stedman, D. H.; Hottor-Raguindin, R., Data based on Contract 11-309, Investigate the Durability of Diesel Engine Emission Controls. California Air Rresources Board; Sacramento, CA, 2013.

8. Dallmann, T. R.; Harley, R. A.; Kirchstetter, T. W., Effects of Diesel Particle Filter Retrofits and Accelerated Fleet Turnover on Drayage Truck Emissions at the Port of Oakland. *Environmental Science & Technology* **2011,** *45*, (24), 10773-10779.

9. US Department of Homeland Security. *Topical Fire Report Series: Highway Vehicle Fires, Volume 9, Issue 1, September 2008. Available at: http://nfa.usfa.dhs.gov/downloads/pdf/statistics/v9i1.pdf*.

10. US Department of Homeland Security. Topical Fires Report Series: Highway Vehicle Fires (2008-2010). Available at: *http://www.usfa.fema.gov/downloads/pdf/statistics/v13i11.pdf*.

11. EIA, U.S. No 2 Diesel Sales/Deliveries to On-Highway Customers. Available at: *http://tonto.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=K2DVHNNUS1&f=A.* 2015.

12. Ferrone, C. W. In *Commercial Vehicle Fire, Cause and Origin Analysis (Mechanical, Electrical, and Forensic Methods)*, Second International Conference on Fires in Vehicles (FIVE), Chicago, IL, 2012.

13. Smyth, S.; Dillon, S. *Common Causes of Bus Fires*; SAE Technical Paper, 2012-01-0989: 2012.

14. Pearlman, J.; Meltzer, N. R. *Risk of Commercial Truck Fires in the United States: An Exploratory Case Analysis*; John A. Volpe National Transportation Systems Center, U.S. Department of Transportation Research and Innovative Technology Administration: Cambridge, Massachusetts. Available at *http://ntl.bts.gov/lib/46000/46000/46069/Pearlman__Commercial_Truck_Fire_Risk.pdf.*

15. Kokki, E. In *Bus Fires in 2010-2011 in Finland*, Second International Conference on Fires in Vehicles (FIVE), Chicago, IL, 2012.

16. Meltzer, N. R.; Ayres, G.; Truong, M. In *Motorcoach Fire Safety Analysis: The Causes, Frequency, and Severity of Motorcoach Fires in the United States*, Second International Conference on Fires in Vehicles (FIVE), Chicago, IL, 2012.

17. OAL, Chapter 14: Verification Procedure, Warranty and in-Use Compliance Requirements for in-Use Strategies to Control Emissions from Diesel Engines. *13 CCR 2702(d); 2706(w); 2709(p); 2070(s); 2706(u)(3); 2705(e); 2706(f). Available at: https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I0BC18F70D46A11DE8879F88E8B0DAAAE&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default).*

18. Herner, J. D.; Hu, S.; Robertson, W. H.; Huai, T.; Collins, J. F.; Dwyer, H.; Ayala, A., Effect of Advanced Aftertreatment for PM and NOx Control on Heavy-Duty Diesel Truck Emissions. *Environmental Science & Technology* **2009,** *43*, (15), 5928-5933.

19. Khalek, I. A. *Final Report, Project E-66 Phase I*; Coordinating Research Council: Alpharetta, GA, 2005.

20. CRC *Final Report, Phase 1 of the Advanced Collaborative Emissions Study, Coordinating Research Council, Health Effects Institute (HEI)*; 2009.

21. CRC *Final Report, Phase 2 of the Advanced Collaborative Emissions Study, Coordinating Research Council, Health Effects Institute (HEI)*; Alpharetta, GA, 2013.

22. Kozawa, K. H.; Park, S. S.; Mara, S. L.; Herner, J. D., Verifying Emission Reductions from Heavy-Duty Diesel Trucks Operating on Southern California Freeways. *Environmental Science & Technology* **2014,** *48*, (3), 1475-1483.

23. Wallerstein, B. R.; Chang, E.; Miyasato, M.; Fine, P. M.; Hogo, H.; Tisopulos, L.; al., *Multiple Air Toxics Exposure Study (MATES) IV*; South Coast Air Quality Management District (SCAQMD): Diamond Bar, CA, October 2014, 2014.

24. ARB *Updated Informative Digest, Amendments to California's Emission Warranty Information Reporting and Recall Regulations and Emission Test Procedures*; Available at *http://www.arb.ca.gov/regact/recall06/uid.pdf.*

APPENDIX I (Fleet Survey Form)

Updated: 1/14/14

CALIFORNIA AIR RESOURCES BOARD

VEHICLE EVALUATION FORM

Date: _____ Prepared By: _____

PART 1. GENERAL INFORMATION

For ARB use only:
ID:_____

Fleet Name:_____
Fleet Address: _____
Fleet Contact Person (name, title):_____
Cell Phone: _____ **Office Phone:** _____**ext.** _____ **E-mail:**_____
Business card attached: ☐ Yes ☐ No

Unit ID #: _____
The **ownership type** of this vehicle: (Select all that apply)
☐ Owner
☐ Operator. If so, is operator permanently assigned to this vehicle? ☐ Yes ☐ No

Vehicle Function (used for?):	**Vocation consistent**	**Short Haul** ≤ 100 mi	**Long Haul** > 100 mi	**Vehicle Function** (used for?):	**Vocation consistent**	**Short Haul** ≤100 mi	**Long Haul** > 100 mi
☐ Dump Truck	☐ Yes ☐ No	☐	☐	☐ Other (please describe):			
☐ Refuse Truck	☐ Yes ☐ No	☐	☐		☐ Yes ☐ No	☐	☐
☐ Drayage Truck	☐ Yes ☐ No	☐	☐				
☐ Tractor Truck	☐ Yes ☐ No	☐	☐				
☐ Concrete Mixer	☐ Yes ☐ No	☐	☐				
☐ Crane	☐ Yes ☐ No	☐	☐				
☐ Tanker Truck	☐ Yes ☐ No	☐	☐				
Medium-duty (14,001–26,000 lb GVWR):							
☐ Flatbed truck	☐ Yes ☐ No	☐	☐				
☐ Package delivery truck	☐ Yes ☐ No	☐	☐				
☐ Beverage delivery truck	☐ Yes ☐ No	☐	☐				

Copy of **driver's daily vehicle inspection book:** ☐ Yes ☐ No
Copy of **vehicle registration:** ☐ Yes ☐ No
CA commercial fuel used? ☐ Yes ☐ No ☐ I Don't Know
Biodiesel used? ☐ Yes ☐ No ☐ I Don't Know
If Yes, what percentage of fuel? _____

Fuel additives used? ☐ Yes ☐ No ☐ I Don't Know
If Yes, Additive Name:_____ Amount/time period: _____

Track of engine lube oil use? ☐ Yes ☐ No
If Yes, amount /time period _____

Any abnormal rate of turbocharger or intercooler failures?
☐ Abnormal turbocharger failures ☐ Abnormal intercooler failures ☐ None
For Power Take-off (PTO), if applicable:
Estimated annual miles: _____ Estimated annual hours: _____

Has engine been rebuilt?
☐ Yes ☐ No ☐ I Don't Know. If Yes, when? ____/____/____ Engine mileage/hours: _____
(mm) (dd) (yy)
Were there any aftermarket parts installed?
☐ Yes ☐ No ☐ I Don't Know. If Yes, please describe: _____

Page 1 of 7

Who performs engine maintenance?

☐ Self ☐ Maintenance Shop ☐ Dealer ☐ I Don't Know

Please specify:

Company Name:
Company Address:
Contact Name:
Contact Number:

Date of the **last engine maintenance** ____/____/____ (mm) (dd) (yy) Engine mileage/hours: _____ ☐ I Don't Know

Describe **recent engine repairs**: ☐ None ☐ I Don't Know

Turbocharger:	Date:	Engine mileage/hours:
Fuel injectors:	Date:	Engine mileage/hours:
Valves:	Date:	Engine mileage/hours:
Other:	Date:	Engine mileage/hours:

Copy of engine maintenance records: ☐ Yes ☐ No

Is this vehicle equipped with Selective Catalytic Reduction system: ☐ Yes ☐ No

Did operator(s) receive SCR training: ☐ Yes ☐ No

Any issues with SCR? Please describe _____

_____

Does this vehicle have Diesel Particulate Filter?

☐ **Yes.** If yes: ☐ Retrofit ☐ OEM

☐ **No.** If no DPF, **skip to Part 2.**

For DPF-equipped vehicles, what is the DPF type:

Passive	☐			
Active:		☐ Plug-in	☐ Manual	☐ Auto regenerating (fuel)

Did operator(s) receive DPF training: ☐ Yes ☐ No

Please describe the most common DPF complaints, if any:

_____

Select the nature of your DPF complaint (Check all applicable):

- ☐ None
- ☐ Truck Downtime
- ☐ Check Engine Light Comes On
- ☐ Reduced Power from Engine
- ☐ Excessive Plugging or Alarms
- ☐ Non-responsive Installer
- ☐ Non-responsive Manufacturer
- ☐ Warranty Issue
- ☐ Fire
- ☐ High Back Pressure
- ☐ Exhaust Leak
- ☐ Frequent Cleaning
- ☐ Frequent Regeneration
- ☐ Other

How much downtime have these DPF-related issues caused? _____

Any other engine-related problems (e.g., EGR, turbo, coolant leaks, etc.)? Please describe:

DPF Installation Information:

Engine mileage/hours at installation:	Installation Date:
Installing Company name:	Address:
Installer Name:	Phone number:

Was **pre-installation check** conducted? ☐ Yes ☐ No ☐ I Don't Know. (Provide a copy if available)
Was **data logging** conducted? ☐ Yes ☐ No ☐ I Don't Know
Was **opacity** reading made prior to install? ☐ Yes ☐ No ☐ I Don't Know
If Yes, provide engine opacity reading: _____
Are **DPF Warning Lights** in a visible location for driver to see them? ☐ Yes ☐ No

What process are used to determine when the filter needs to be … ? (Check all applicable)

a) Regenerated:	**b) Removed and cleaned (de-ashed):**
☐ Alarms ☐ I Don't Know	☐ Alarms ☐ I Don't Know
☐ Lube oil consumption	☐ Lube oil consumption
☐ Engine power loss	☐ Engine power loss
☐ Mileage	☐ Mileage
☐ Warning lights	☐ Warning lights
☐ Other _____	☐ Other _____

What is the frequency of DPF regeneration: _____ ☐ I Don't Know

Is DPF regeneration cycle ever interrupted? ☐ Yes ☐ No

Why?:

What is the frequency of DPF removal and cleaning (de-ashing)? _____ ☐ I Don't Know

When was the most recent DPF cleaning: ____/____/___ (mm) (dd) (yy) Engine mileage/hours: _____ ☐ I Don't Know

Who conducts the filter inspection and core cleaning (ash removal)?
☐ Self ☐ Maintenance Shop ☐ Dealer ☐ I Don't Know

If Self: Was staff trained by the manufacturer or its representative? ☐ Yes ☐ No

Name of filter core cleaning machine:

Describe inspection and cleaning process:

If cleaning is outsourced, please provide the following information:

Outsourced Business Name:
Address:
Phone:
Contact:

How many times was the DPF removed and cleaned:

Under warranty? _____ Mileage(s): _____

Out of warranty? _____ Mileage(s): _____

Does DPF have **extended warranty**: ☐ Yes ☐ No Length of warranty: _____

Was DPF ever **replaced**: ☐ Yes ☐ No Mileage: _____ Cost: _____

Reason to replace DPF: _____

How did the performance of the vehicle differ post-cleaning?

☐ Significantly improved ☐ Somewhat improved ☐ Stayed the same ☐ Not yet cleaned

PART 2. LABEL AND WARNING LIGHTS INFORMATION: VEHICLE / ENGINE / DPF

ARB staff, please fill out the following information from vehicle registration form:

Unit ID #: _____ **US DOT #:** _____ **CA #:**_____ **DTR #:** _____

License Plate: _____**State:** _____

Vehicle Identification Number (VIN): _____

Vehicle Make: _____ Vehicle Model: _____ Vehicle Year: _____

Gross Vehicle Weight Rating (GVWR): _____

ARB staff, please fill out the following information from engine label / dashboard:

Engine Family: _____ Engine Year: _____

Engine Make: _____ HP Rating: _____ at _____ RPM

Engine Model: _____ Engine Size: _____ C.I.D. ☐ L ☐

Current Mileage: ☐☐,☐☐☐,☐☐☐.☐☐

Emission Control Systems and Special Features: _____

_____

Engine Warning Lights / Error Codes: _____

ARB staff, please fill out the following information based on visual inspection of the vehicle / dashboard:

For SCR-equipped vehicles:

Level of Diesel Exhaust Fluid? _____% ☐ Not Indicated

SCR Warning lights: _____

ARB staff, please fill out the following information from DPF label / dashboard:

For DPF-equipped vehicles:

IF retrofit DPF: Device Name: _____ Serial Number: _____

Device Make:_____ Device Model: _____

DECS Family Name (Found on label and looks like this:
CA/MMM/YYYY/PM#/N##/AP/XXXXX) :

_____

DPF Warning lights: _____

PART 3. CARB INSPECTION CHECKLIST

1) Average Opacity: _____ %
Copy of Opacity Printout: ☐ **Yes** ☐ **No**
Opacity Meter Type: _____ Serial Number: _____
Exhaust Pipe Diameter: _____inches

Stack Direction:
☐ Up. If Up, please specify: ☐ Rain cap ☐ At 90° angle
☐ Down
☐ Sideways

Single or Dual Exhaust Pipe(s): ☐ Single ☐ Dual
Stack Visual Inspection: ☐ Clean ☐ Okay ☐ Dirty

2) PEMS testing: ☐ Yes ☐ No
Please describe: _____

3) Fuel Sample Taken: ☐ Yes ☐ No. If Yes, **Fuel Clean:** ☐ Yes ☐ No
Fuel Sample Pictures: ☐ Yes ☐ No

4) Engine Temperature: _____ ºC ☐ ºF ☐
(Use temperature given by the field representatives)

5) ECU information from engine/DPF downloaded: ☐ Yes ☐ No

6) Engine Physical Inspection (description of engine physical condition, warning lights, etc):

Engine label: ☐ Yes ☐ No

Retrofit Engine Label (official DECS label on engine): ☐ Yes ☐ No ☐ N/A (not a retrofit)

Engine Warning Lights / Error Codes: ☐ On ☐ Off

(Include photos of engine label, engine physical condition, warning lights, etc.)

_____
_____
_____
_____
_____

7) DPF Physical Inspection (description of DPF/SCR physical condition, warning lights, and damage, such as fuel leaks, thermocouple, back pressure lines):

DPF label:	☐ Yes	☐ No	SCR label:	☐ Yes	☐ No
DPF Warning Lights / Error Codes:	☐ On	☐ Off	SCR Warning Lights / Error Codes:	☐ On	☐ Off
DPF core is present:	☐ Yes	☐ No			

(Include photos of DPF/SCR label, DPF/SCR physical condition, warning lights, etc.)

Electronic file name and location: _____

Please name electronic files according to the following format:

mm	dd	yy	fleet ID #	license plate #	section #	file #
☐☐	☐☐	☐☐	☐☐☐☐	☐☐☐☐☐☐☐	☐☐☐	☐☐☐

Comments:_____

APPENDIX II (Roadside Survey Form)

Draft version: 2014-01-09

CALIFORNIA AIR RESOURCES BOARD

ROADSIDE SURVEY FORM

Date: _____ Prepared By: _____

Location of inspection site: _____

Opening
We are doing a survey of owners' and drivers' experience with trucks that are equipped with diesel particulate filters, also known as DPFs. We would like to ask you a few questions about your vehicle and about your overall experience with DPFs.

PART 1. GENERAL INFORMATION

License Plate: _____ **State:** _____

Business card attached: ☐ Yes ☐ No

For ARB use only:
ID:_____

Driver Name:_____

Fleet Name: _____

Fleet Address: _____

Fleet Contact Person (name, title):_____

Cell Phone: _____ **Office Phone:** _____ ext. ____ **E-mail:**_____

Are you the owner or operator of this vehicle? (Select all that apply)
☐ Owner
☐ Operator. If so, are you permanently assigned to this vehicle? ☐ Yes ☐ No

Vehicle Function (used for?):	**Vocation consistent**	**Short Haul** ≤ 100 mi	**Long Haul** > 100 mi	**Vehicle Function** (used for?):	**Vocation consistent**	**Short Haul** ≤ 100 mi	**Long Haul** > 100 mi
☐ Dump Truck	☐ Yes ☐ No	☐	☐	☐ Other (please describe):			
☐ Refuse Truck	☐ Yes ☐ No	☐	☐		☐ Yes ☐ No	☐	☐
☐ Drayage Truck	☐ Yes ☐ No	☐	☐				
☐ Tractor Truck	☐ Yes ☐ No	☐	☐				
☐ Concrete Mixer	☐ Yes ☐ No	☐	☐				
☐ Crane	☐ Yes ☐ No	☐	☐				
☐ Tanker Truck	☐ Yes ☐ No	☐	☐				
Medium-duty (14,001–26,000 lb GVWR):							
☐ Flatbed truck	☐ Yes ☐ No	☐	☐				
☐ Package delivery truck	☐ Yes ☐ No	☐	☐				
☐ Beverage delivery truck	☐ Yes ☐ No	☐	☐				

Can I have a copy of **vehicle registration:** ☐ Yes ☐ No

Do you have any warning lights on? ☐ Yes ☐ No ☐ I Don't Know
(answer is based on driver's knowledge)
If Yes: ☐ Check Engine lights ☐ DPF lights ☐ SCR lights ☐ Others. Please describe: _____

_____

Who performs your engine maintenance?
☐ Self ☐ Maintenance Shop ☐ Dealer ☐ I Don't Know

Page 1 of 5

Is this vehicle equipped with Selective Catalytic Reduction system (based on driver's knowledge)**?**
☐ Yes ☐ No ☐ I Don't Know

If Yes: **Did you receive SCR training:** ☐ Yes ☐ No

Does this vehicle have Diesel Particulate Filter (trap) [based on driver's knowledge]**?**
☐ Yes ☐ No ☐ I Don't Know

If No DPF (or unknown): **skip to Part 2.**

If Yes: **Did you receive DPF training:** ☐ Yes ☐ No

Please describe the most common DPF complaints, if any:	Select the nature of your DPF complaint (Check all applicable):
_____	☐ None
_____	☐ Truck Downtime
_____	☐ Check Engine Light Comes On
_____	☐ Reduced Power from Engine
_____	☐ Excessive Plugging or Alarms
_____	☐ Non-responsive Installer
_____	☐ Non-responsive Manufacturer
_____	☐ Warranty Issue
_____	☐ Fire
_____	☐ High Back Pressure
_____	☐ Exhaust Leak
_____	☐ Frequent Cleaning
_____	☐ Frequent Regeneration
_____	☐ Other

How much downtime have these DPF-related issues caused you? _____

PART 2. LABEL AND WARNING LIGHTS INFORMATION: VEHICLE / ENGINE / DPF

ARB staff, please fill out the following information from vehicle registration form:

Unit ID #: _____ **US DOT #:** _____ **CA #:**_____ **DTR #:** _____

License Plate: _____**State:** _____

Vehicle Identification Number (VIN): _____

Vehicle Make: _____ Vehicle Model: _____ Vehicle Year: _____

Gross Vehicle Weight Rating (GVWR): _____

ARB staff, please fill out the following information from engine label / dashboard:

Engine Family: _____ Engine Year: _____

Engine Make: _____ HP Rating: _____ at _____ RPM

Engine Model: _____ Engine Size: _____ C.I.D. ☐ L ☐

Current Mileage: ☐☐,☐☐☐,☐☐☐.☐☐

Emission Control Systems and Special Features: _____

_____

Engine Warning Lights / Error Codes: _____

ARB staff, please fill out the following information based on visual inspection of the vehicle / dashboard:

Selective Catalytic Reduction system: ☐ Yes ☐ No

SCR Warning lights: _____

ARB staff, please fill out the following information from DPF label / dashboard:

Diesel Particulate Filter: ☐ Yes ☐ No

If Yes: ☐ Retrofit ☐ OEM

IF retrofit DPF: Device Name: _____ Serial Number: _____

Device Make: _____ Device Model: _____

DECS Family Name (Found on label and looks like this:
CA/MMM/YYYY/PM#/N##/AP/XXXXX):

_____

DPF Warning lights: _____

PART 3. CARB INSPECTION CHECKLIST

1) Average Opacity: _____ %

Copy of Opacity Printout: ☐ **Yes** ☐ **No**

Opacity Meter Type: _____ Serial Number: _____

Exhaust Pipe Diameter: _____inches

Stack Direction:

☐ Up. If Up, please specify: ☐ Rain cap ☐ At 90° angle

☐ Down

☐ Sideways

Single or Dual Exhaust Pipe(s): ☐ Single ☐ Dual

Stack Visual Inspection: ☐ Clean ☐ Okay ☐ Dirty

2) Engine Temperature: _____ ºC ☐ **ºF** ☐

(Use temperature given by the field representatives)

3) Engine Physical Inspection (description of engine physical condition, warning lights, etc):

Engine label: ☐ Yes ☐ No

Retrofit Engine Label (official DECS label on engine) ☐ Yes ☐ No ☐ N/A (not a retrofit)

Engine Warning Lights / Error Codes: ☐ On ☐ Off

(Include photos of engine label, engine physical condition, warning lights, etc.)

_____

_____

_____

_____

_____

4) DPF Physical Inspection (description of DPF/SCR physical condition, warning lights, and damage, such as fuel leaks, thermocouple, back pressure lines):

DPF label: ☐ Yes ☐ No	SCR label: ☐ Yes ☐ No
DPF Warning Lights / Error Codes: ☐ On ☐ Off	SCR Warning Lights / Error Codes: ☐ On ☐ Off

(Include photos of DPF/SCR label, DPF/SCR physical condition, warning lights, etc.)

_____

_____

_____

_____

_____

_____

Electronic file name and location: _____

Please name electronic files according to the following format:

mm	dd	yy	license plate #	section #	file #
☐☐	☐☐	☐☐	☐☐☐☐☐☐☐	☐☐☐	☐☐☐

Comments:_____

APPENDIX III (VDECS Installer Form)

Draft version: 2014-01-21

CALIFORNIA AIR RESOURCES BOARD

INSTALLER FORM

Date: _____ Prepared by: _____

Dealer/Distributor Information:

Company Name:		
Address:		
Contact Person/Title:		
Phone:	Email:	Fax:

Please fill out the following information.

1. **For which companies are you an authorized dealer/installer/distributor?**

Boshart, CDTi/ECS, Cleaire, DCL, DET, Donaldson, Engelhard/BASF, ESW, ESW CleanTech, HUG, HUSS, Johnson Matthey, SK Energy

2. **How many VDECS did you sell in 2013? Please list totals by device name (CA/…)**

Device name:	Total

3. **How many VDECS did you install in 2013? Please list totals by device name (CA/…)**

Device name:	Total

4. **How many vehicles initially did not pass the pre-assessment criteria in 2013?** ☐

   a. **What were the typical reasons for not passing? Please check all that may apply.**

   ☐ Oil leaking

   ☐ Excessive oil use

   ☐ Injector problems

   ☐ Opacity higher than DECS manufacturer allows

   ☐ Excessive smoke

   ☐ Oil in diesel fuel

   ☐ Turbo issues

   ☐ Vehicle engine light or ODB lights on

   ☐ Duty cycle incompatibility

   ☐ Engine family not supported

   ☐ Engine/maintenance issue other than listed above. Please describe:

☐ Other. Please describe:

b. **What were the opacities of vehicles which did not initially pass the pre-assessment criteria?**

Vehicle:	Opacity:

5. **How many DECS required service for an installation warranty issue in 2013?**

6. **How many individual VDECS (different serial numbers) did you see for maintenance related events in 2013?** The same VDEC in for multiple events counts once.

7. **How many total service events did you have in 2013? This number may be greater than the number of systems if you saw the same system multiple times. Please provide the total number of service events by device name (CA/..).**

Device name:	Total

a. **How many were for routine maintenance requiring no other action?**

Device name:	Total

b. **How many events were for the same system on different occasions?**

Device name:	Total

c. **What were the typical reasons for seeing the same system on multiple occasions? Check all that apply:**

- ☐ Engine problems
- ☐ Warning lights
- ☐ Duty cycle incompatibility
- ☐ Incomplete regeneration
- ☐ Cleaning required
- ☐ Plugged/overloaded DPF
- ☐ Broken system/system parts
- ☐ Tampering
- ☐ Incorrect sized system for engine/application

☐ Other: Please describe:

8. **How many systems were in proper working order, but had performance issues (warning lights etc.).**

Device name:	Total

a. **What were the typical reasons? Check all that apply:**

☐ Change in duty cycle
☐ Engine problems
☐ Failure to properly maintain DECS (e.g. never cleaned)
☐ Improper cleaning
☐ Tampering
☐ Use of non-approved fuel, additives, or other non-OEM parts (engine)
☐ Other: Please describe:

9. **How many systems were damaged requiring a replacement part? List the number and type of replacement part and the reason(s) for the damage:**

- **Engine problem**
- **Failure to properly maintain DECS**
- **Change in duty cycle**
- **Use of non-approved fuels, additives, or other non-OEM (engine) parts**
- **Tampering**
- **Manufacturer defect**

Total	Type of Replacement Part	Reason(s) for the Damage

a. **How many damaged systems were under warranty?**

Device name:	Total

10. Do any systems seem to be more prone to issues? Please describe:

11. Do any engines seem to be harder to successfully retrofit than others? Please describe:

12. For all service events that (1) occurred while the DECS were still under warranty, and (2) were not routine maintenance, what percentage were determined to be non-warrantable?

a. Why? Please list typical reasons.

b. How many replacement cores (DPF), by system (DECS) did you sell in 2013 which were NOT "spares". In other words, cores which were meant to replace a damaged DPF.

Device name:	Total:

APPENDIX IV (OE Dealer Form)

Draft version: 2013-12-06

CALIFORNIA AIR RESOURCES BOARD

DEALER FORM (OEM)

Date:	Completed by:	Company Name:
Address:		Contact Person/Title:
Phone:	Email:	Fax:

1. For which companies are you an authorized dealer/installer/distributor?

2. In 2012, how many replacement DPF cores were sold to the following MY engines?

2007_____ 2008_____ 2009_____ 2010_____ 2011_____ 2012_____

3. Based on your experience what are the typical reasons replacement DPFs were required? Check all that apply and rank from 1 to 5:
5 = Very common, 4 = Common, 3 = Sometimes, 2 = Once in a while, 1 = Rarely

For MY2007-MY2009:

a. Underlying engine problem not directly related to the DPF (e.g. bad injector, bad turbo, etc.) ☐ b. EGR problems ☐
c. Inappropriate use of fuel or fuel additives ☐ d. Inappropriate DPF maintenance ☐
e. Inherent filter defect (e.g. – poor canning, etc.) ☐ f. Failure of DPF regeneration mechanism ☐
g. Inappropriate duty cycle ☐ h. Operator neglect ☐ i. Tampering ☐
j. Other – please describe ☐ _____

For MY2010 and newer:

a. Underlying engine problem not directly related to the DPF (e.g. bad injector, bad turbo, etc.) ☐ c. EGR problems ☐
c. Inappropriate use of fuel or fuel additives ☐ g. Inappropriate DPF maintenance ☐
h. Inherent filter defect (e.g. – poor canning, etc.) ☐ i. Failure of DPF regeneration mechanism ☐
g. Inappropriate duty cycle ☐ h. Operator neglect ☐ i. Tampering ☐
j. Other – please describe ☐ _____

4. If you have observed obvious tampering (i.e., the system is not in the OEM configuration) what have you observed?

5. Do any engines (make/model/horsepower/engine family name) seem to have more issues than others?

6. How often does a vehicle come in for service due to complaints about the DPF component where you find the vehicle is actually in proper working condition? This could occur if an end-user considered the normal behavior of the filter as impacting the normal use patterns of the vehicle.
1 Never ☐ **2** Infrequent ☐ **3** Sometimes ☐ **4** Frequent ☐ **5** Always ☐

7. Do you provide DPF training for truck drivers? ☐ Yes ☐ No. If Yes, please describe:

8. Do you provide SCR training for truck drivers? ☐ Yes ☐ No. If Yes, please describe:

Page 1 of 1

APPENDIX V (Roadside Survey Statistics)

The targeted number of vehicles for roadside inspections and driver surveys based on the California fleet derived from the DMV registration database.

Body Types	**Number Registered with DMV**	**Percent of Total Registered**	**Number Targeted**	**Number Inspected**
Tractor/Drayage	98,164	50%	**100**	397
Dump	28,022	14%	**28**	28
Concrete	5,135	3%	**6**	7
Refuse	13,200	7%	**14**	29
Cranes	6,449	3%	**6**	6
Tanker	10,344	5%	**10**	46
Flatbed[1]	32,777	17%	**34**	17
Parcel Delivery[1]	2,073	1%	**2**	30
Total	196,164		**200**	587

[1] – Medium-duty vehicles (14,001 to 26,000 lbs. GVWR) were targeted.