WHITE PAPER

APRIL 2017

A HISTORICAL REVIEW OF THE U.S. VEHICLE EMISSION COMPLIANCE PROGRAM AND EMISSION RECALL CASES

Hui He, Lingzhi Jin

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

www.theicct.org

communications@theicct.org

BEIJING | BERLIN | BRUSSELS | SAN FRANCISCO | WASHINGTON

ACKNOWLEDGMENTS

The authors thank the internal and external reviewers of this paper for their guidance and constructive comments, with special thanks to Steve Albu, Charles Freed, Robert Maxwell, Margo Oge, Karl Simon, John Urkov, and Michael P. Walsh for the input they gave through interviews in the early stages of this paper. In addition, we also thank Tom Cackette, Robert Maxwell, Margo Oge, John Urkov, Michael P. Walsh, Yan Ding, Dagang Tang, John German, Fanta Kamakate, Rachel Muncrief, and Zifei Yang for their thoughtful reviews. Funding for this work was generously provided by the ClimateWorks Foundation, the Energy Foundation, and the U.S. Environmental Protection Agency.

1225 I Street NW, Suite 900, Washington DC 20005

communications@theicct.org | www.theicct.org | @TheICCT

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

A/C	Advisory circular
AECD	auxiliary emission control device
CAA	Clean Air Act
CAP 2000	Compliance Assurance Program
CARB	California Air Resources Board
CFR	Code of Federal Regulations
CO	carbon monoxide
COC	certificate of conformity
CY	Calendar year
DEF	diesel exhaust fluid
DOJ	Department of Justice
ECM	electronic control module
EPA	U.S. Environmental Protection Agency
FTP	Federal Test Procedure
GVWR	Gross vehicle weight rating
HDDE	heavy-duty diesel engine
HDV	heavy-duty vehicle
I/M	inspection and maintenance program
IUCP	in-use confirmatory program
IUVP	in-use verification program
LDV	light-duty vehicle
MIL	malfunction indicator lamp
MY	model year
NAAQS	National Ambient Air Quality Standards
NO_x	nitrogen oxides
NTE	not-to-exceed (NTE standard)
OBD	on-board diagnostics
OECA	Office of Enforcement and Compliance Assurance
OEM	original equipment manufacturer
OTAQ	EPA Office of Transportation and Air Quality
OTL	OBD threshold limit
PEMS	portable emissions measurement system
SEA	selective enforcement audit
SEP	Supplemental Environmental Projects
SFTP	Supplemental Federal Test Procedure

EXECUTIVE SUMMARY

Emission recalls are a critical aspect of vehicle emission compliance and enforcement programs. An *emission recall* is a repair, adjustment, or modification program conducted by a manufacturer to remedy an emissions-related problem. An emission recall is quite costly to a manufacturer. A typical recall can cost millions of dollars plus reputational damage to the automakers; therefore, recalls act as a major deterrent against manufacturer emission violations. To avoid recalls, manufacturers are motivated to produce emission controls that not only pass emission certification testing, but also remain functional when vehicles are in real-world use.

Over the decades since the Clean Air Act (CAA) was initially enacted in 1963, regulators from the U.S. Environmental Protection Agency (EPA) and California Air Resources Board (CARB) have developed comprehensive and rigorous compliance and recall programs, including a number of subprograms to detect and verify emission issues. Compliance is important for achieving the public health benefits and air-quality improvements required by the standards, as well as ensuring that all manufacturers are abiding by the same rules and guidelines.

However, many emerging markets still do not have any robust emission compliance programs, even though the corresponding standards have been in place for years. In many countries, adequate legal authority is also lacking. Some markets have a partial program (i.e., a program composed of certain elements of the U.S. compliance program) but have limited resources to pursue a more comprehensive program. Most of these governments may not have adequate data sources to identify emission compliance issues.

This paper aims to provide useful information for governments that are in the early stages of pursuing an effective emission compliance program in their respective regions. This paper only focuses on toxic air pollutant emissions, otherwise known as *criteria emissions*, rather than greenhouse gas emissions, which are related to fuel economy. More specifically, this paper provides a comprehensive historical review of how the U.S. federal vehicle emission compliance program has evolved over the past 4 decades, reviews U.S. emission recall trends, highlights a few representative vehicle and engine emission recall cases and settlements, and provides insight into the data sources needed to inform a successful recall program.

Even though this paper primarily focuses on the U.S. program at a federal level, it should be recognized that the state of California's vehicle emission compliance program, led by CARB, initially blueprinted and pioneered many of the important compliance program elements. In many cases, the U.S. program, led by the EPA, ultimately harmonized with the compliance program adopted in California. In a few areas, this paper will recognize California's unique contribution to the U.S. federal vehicle emission compliance and control program.

The timeline in Figure ES-1 illustrates how the U.S. federal vehicle emission compliance and control program has evolved over the past 6 decades and summarizes the key characteristics of each era. As in other parts of the report, we primarily focus on the federal milestones in motor vehicle emission control and compliance, which in most cases are EPA actions, but we also highlight a few unique contributions from California.

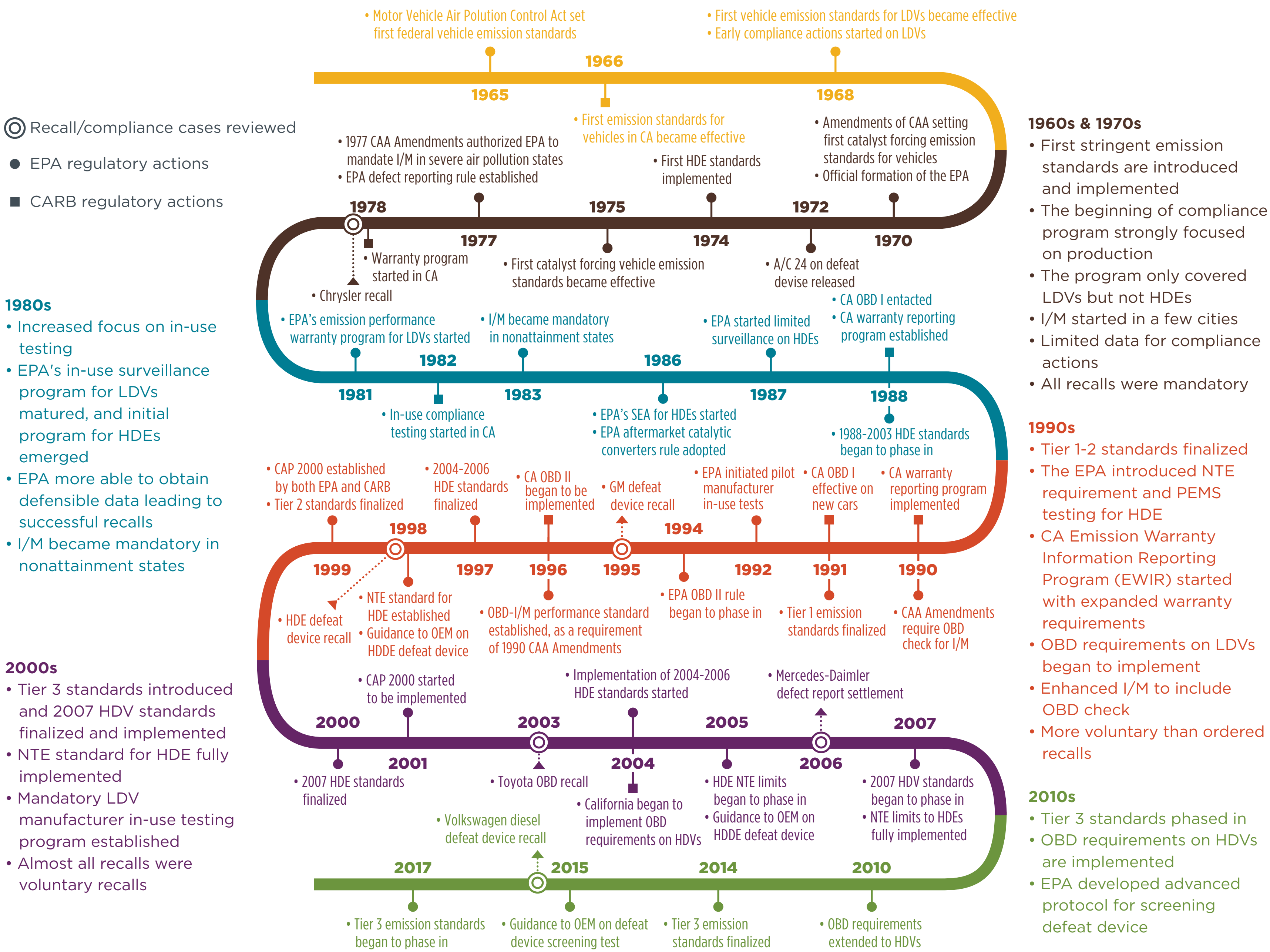

Figure ES-1. Evolution of U.S. vehicle emission compliance and control program

Table ES-1 highlights six noteworthy emission recall and enforcement cases throughout the history of the U.S. compliance program that are reviewed in this paper. The timing of each case is also shown on the timeline in Figure ES-1. The primary focus when reviewing each of these cases was determining the data source used to discover each of the issues and the accompanying lessons. Each case offers rich lessons to regulators with less experience in carrying out recalls.

Table ES-1. Summary of recall and enforcement cases reviewed

Year	Case	Discovery	Lessons
1978	Chrysler recall	Inspection and maintenance (I/M) program data	• In-use performance of engine and after-treatment systems can be very different from their prototype design. • The keys to a successful recall are careful documentation throughout the entire compliance testing and investigation process and allowing manufacturers to oversee the process. • I/M data is useful in identifying certain in-use noncompliance issues.
1995	General Motors defeat device recall	EPA research-oriented testing	• In-use testing under broad driving conditions is important, even for gasoline vehicles.
1998	Heavy-duty diesel engine (HDDE) defeat device recall	EPA research-oriented testing	• During the early stages of regulations, there might be undefined areas, and agencies should seek to clarify the interpretation of regulations as new technologies and testing tools emerge. • The authority to approve a certificate of conformity gave the agencies concrete leverage to enforce emission standards.
2003	Toyota OBD settlement	Certification and in-use testing	• Noncompliance can be flagged at the certification stage with appropriate follow-up in-use testing for verification. • Feedback from in-use testing should be used to inform and improve future regulations, acknowledging a learning curve for regulatory agencies.
2006	Mercedes-Daimler defect report settlement	EPA investigation	• Defect reporting is an important data source for identifying noncompliance. • More recently, the EPA became diligent in recording data and reporting.
2015	Volkswagen diesel defeat device recall	Independent real-world testing projects, followed by rigorous agency (CARB) testing and investigation	• Modern defeat devices are much more technically sophisticated than they were decades ago and require innovative testing approaches to detect them. • Independent research projects can be a good source of data to flag noncompliance.

Based on an extensive review of the history of the U.S. vehicle emission compliance program and trends of past vehicle emission recall cases and data, the following findings and general recommendations are targeted to countries and regions that are just starting to establish a robust vehicle emission compliance program.

Findings

» In addition to their clear missions to protect public health and the environment, the foundation for the robust vehicle emission compliance programs at both the EPA and CARB is strong and clear legal authority. Each agency has the power to establish a test protocol for in-use compliance testing, require manufacturers to conduct tests, provide warranty and defect data to the agencies, and, most importantly, holds the authority to revoke certificate of conformity, to recall vehicles, and to impose punitive fines on noncompliant vehicles. Withholding of the certificate of conformity (or an Executive Order in California), an approval needed to sell vehicles in the U.S. (or California) market, is a powerful tool for regulatory agencies to negotiate with manufacturers on compliance actions. The maximum civil monetary penalties under the Clean Air Act for vehicle emission noncompliance are now $45,268 per vehicle/engine (for violations occurring after Nov 2, 2015 and assessed on or after Jan 15, 2017), up from $25,000 when the act was first enacted (40 CFR §19.4).

» The comprehensive vehicle emission compliance program adopted in the United States was built up over several decades. The process involved a learning curve for both regulators and industry. In the early 1970s and 1980s, there were many contentious cases that ended up in court. Gradually, both the EPA and CARB demonstrated their technical competence to industry by showing their data was able to withstand the scrutiny of industry experts. The courts consistently agreed that the agencies had legal authority to mandate recalls based on sound data. As a result, over time, the agencies have proven successful in working with manufacturers to perform voluntary recalls. Since the 1990s, most cases have been noncontentious and recalls or other remedies were voluntary. This shift is a positive sign that the requirements and enforcement criteria are detailed and clear, making it in the manufacturers' best interest to do the right thing by closely following the regulation to avoid any mandatory recalls.

» Building a strong team and continuously expanding staff capacity is also key to establishing a successful emission compliance program. Beyond dedicated, long-time staffers, both the EPA and CARB were able to recruit top experts, sometimes from industry. It takes time and resources to establish and maintain technical expertise over time, as new technologies emerge. As one former CARB officer noted,

> "*What CARB has done in the past 30 some years is carefully screen the staff, and we have some of the best… The OBD [on-board diagnostics] program is one of the most difficult to get up to speed on because you need to understand all of the software in terms of how the vehicle operates, and how the emission control works. It takes probably 4 to 5 years working with the staff, involving them in lab, in-use testing, reviewing certification and applications that manufacturers submit before production [to get them familiar with the process].*"

» In the United States, compliance is a shared burden between regulatory agencies and manufacturers. The current compliance program has a strong focus on manufacturer responsibility in ensuring their vehicles and engines meet the standards throughout the vehicle's certified useful life. This is done by requiring manufacturers to conduct large scale in-use testing, report warranty data and defects, and conduct voluntary recalls. This allows the regulatory agencies to play more of a supervisory role and focus their limited resources on the most critical issues. In addition, manufacturers pay certification fees, ranging from hundreds of dollars to thousands per type-approval certificate depending on type of vehicle, to the government to carry out compliance efforts.

- U.S. regulatory agencies perform rigorous in-use compliance tests, and these tests are the most direct source of data to consider a recall. It is also important for each agency to have its own testing facilities. In addition, the agencies have a number of indirect data sources to further guide their in-use compliance tests. These include, but are not limited to: (a) certification data, which can be useful in several ways, for example, to target vehicles with a small compliance margin and vehicles deployed containing new technologies; (b) information from state I/M programs, including information from OBD systems; (c) manufacturer warranty data and defect reports; (d) failures discovered during the manufacturer-run in-use verification program (IUVP) testing, required as part of the Compliance Assurance Program (CAP 2000); (e) complaints from consumers and service providers; and (f) independent research projects involving real-world emissions testing.
- A full-scale in-use testing program is quite expensive, as the agencies usually need to recruit a sufficient number of vehicles from consumers and pay for additional substitute vehicles and maintenance, and to provide compensation to the vehicle owners. California used to rent cars and have the authority to allow staff to drive these cars home overnight. Some of the early experiments to discover in-use noncompliance were done on these cars. Even though the scope of these early experiments was extremely limited, they did expose issues. And, more importantly, in-use testing is a strong deterrent to the original equipment manufacturers (OEMs) building vehicles with parts that may lack durability. In all compliance programs, deterrence is a major objective.
- Rigorous documentation of the compliance tests conducted by regulatory agencies and engaging manufacturers in these tests are extremely instrumental steps in implementing a successful recall. In the early years of a compliance program, regulatory agencies encountered situations where manufacturers could easily discredit their data. The agencies learned from this and established protocols to obtain defensible data to provide in court, as necessary.
- Agencies should continue to evolve and improve the certification test procedures based on learning from in-use compliance testing. Emission type-approval certification is the cornerstone and starting point of a compliance program. However, there are still limitations associated with test protocols and methods of certification tests. In-use compliance testing can provide lots of useful data to close the loopholes in current certification procedures. This was evidenced in several of the examples reviewed in this paper, including the enhanced OBD program introduced after the Toyota OBD case in 2003 and the improved portable emissions measurement system (PEMS) testing for heavy-duty vehicles and engines after the 1998 heavy-duty engine defeat device case. Regulators need to revisit their certification procedures and approaches to best reflect emission characteristics during real-world driving.

Recommendations

Building upon the findings, we recommend the following best practices and key elements to build a successful vehicle emissions compliance and recall program:

- Governments should seek to establish strong and clear authority through legislation for environmental regulatory agencies to establish, implement, and enforce emission standards, including clear authority to levy fines and issue recalls.
- Governments should establish requirements for emission warranty provisions and for vehicles and engines to meet emission standards throughout their full "useful life," which is the time span throughout which the emissions performance of a vehicle must comply with the prescribed standards, in the appropriate legislation. For example, the current definition of useful life in the U.S. Tier 3 emission standard for light-duty vehicles is 150,000 miles.
- Once legal authority is established, agencies must recognize and implement their authority. They should impose penalties on vehicle manufacturers and make sure the penalties are large enough to deter manufacturers from noncompliance. If necessary, regulatory agencies should utilize their power to void new vehicle and engine emission type-approval certificates as a deterrent.
- Build internal technical capacity within environmental regulatory agencies to ensure the ability to conduct compliance testing and manage recall programs. Recruit the best experts in the field, including experienced technicians to carry out the laboratory testing.
- A compliance program needs to be executed by government resources free from industry influence. A regulatory agency must have established, sustainable funding to support running and maintaining the compliance program. Some ways to deal with limited resources at the beginning of a program are:
    - Starting the program with robust certification testing and production (assembly line) conformity testing if staff capacity is initially limited. Once regulatory agencies gain sufficient confidence into these two stages, then in-use testing becomes more important.
    - Starting in-use emissions testing with a small fleet: whatever can be obtained with the resources available.
    - Give manufacturers some flexibility to leverage manufacturer resources when introducing new compliance program elements. After a pilot stage to prove their effectiveness, transition the programs to full-scale.
- Create a program that shares the compliance burden among the governments (central and local), industry, and vehicle owners. Establish subprograms requiring industry to provide compliance-related data. Policymakers could investigate whether and how the following subprograms may be adopted in their regional context.
    - Require manufacturers to conduct large-scale in-use testing, with sufficient government confirmatory testing to verify the manufacturer test results.
    - Require an emission warranty program.
    - Require manufacturers to provide emission warranty and defect data. Then use government resources to spot check with dealers and services providers to verify the manufacturer-reported data.

- » Require manufacturers to recall their vehicles if feedback from the above subprograms indicates an emissions violation.
- » Establish credible I/M and other emissions inspection programs such as remote sensing programs at local levels to make sure emission components are not tampered with by users. Integrate OBD in I/M programs to increase test accuracy and credibility. Analyze I/M data to determine if particular brands or models have higher than normal failure rates and then investigate.
- » Collect vehicle certification fees from manufacturers as a sustainable source to support the compliance efforts.

» Establish test protocols to detect defeat devices. This includes, but is not limited to, using a combination of methods such as PEMS-based real-world driving tests, OBD examination, modified driving test cycles, and test procedures for laboratory tests.

» Consider utilizing testing projects from independent third parties or research entities as a data source to trigger government investigation, provided that the test results have a credible basis for concern.

» Establish protocols for documenting vehicle selection, testing, and data collection processes, in order to obtain defensible data for recalls. Consider engaging manufacturers in some of the processes. It is crucial to define "proper maintenance" and ensure the test vehicles used for compliance actions are well maintained for the emissions problem in question.

» Use the feedback from in-use compliance programs to improve the new emission standards and certification procedures. As vehicle and emission control technologies advance and emission regulations become increasingly complicated, there might be further undefined areas. As regulatory agencies learn about these areas, and if there is potential for undercutting the purpose of the regulations, the agencies should try to better define these areas by spelling out specifically what they intended or clarify the interpretation.

1. INTRODUCTION

Major auto markets around the world are adopting more stringent vehicle emission regulations requiring lower exhaust and evaporative emission limits. The purpose of these regulations is to reduce emissions from vehicles while in use under most normal driving conditions, so as to improve air quality and public health. A key question is whether vehicles pollute less when brand new and also throughout their entire useful life.[1] Unfortunately, a substantial amount of evidence has shown that many vehicles emit much higher emissions under on-road real-world conditions than when they are tested in the lab (Franco, German, Posada, & Mock, 2014).

Several factors may lead to increased in-use vehicle emission levels. The pollution controls may be poorly designed or have poor production quality. Manufacturers may use different components in production than were used for type approval. Further, emission controls deteriorate over time. If inferior parts and components are used, emissions may deteriorate rapidly in use. Some real-world driving conditions are tougher than those reflected in type-approval tests—hot or cold temperatures, poor road conditions, high elevations, aggressive driving, etc.—and the initial design of some pollution control systems may be designed to only work under the limited conditions in the lab. Poorly designed or narrowly defined certification tests not representative of on-road driving can allow such designs. A more sophisticated reason is the use of emission defeat devices to bypass or cheat the regulations. A well-designed motor vehicle pollution control program must address all of these manufacturing-related concerns.

In addition, even if vehicles are well-designed and durable, the vehicle owners and operators have a role to play in ensuring good in-use performance. They must maintain the vehicle in accordance with the guidance provided by the manufacturer and avoid tampering with the emission control components. Further, they must only use the fuel the vehicle requires. For example, no vehicle equipped with a catalyst should use fuel that contains lead, a metallic additive. Appropriate sulfur limits are also important for many systems.

Therefore, it is critical to have an effective compliance program in place to ensure that the environmental and health benefits of vehicle emission standards are truly and fully achieved in real-world conditions. A compliance program also helps to ensure fairness in responsibilities by shifting costs of defective or deteriorated emission control from car owners to the manufacturers. For example, a car owner should not be liable if a vehicle fails due to a faulty design or poor production quality.

Emission recalls are a critical aspect of vehicle emission compliance and enforcement programs. An emission recall is a repair, adjustment or modification program conducted by a manufacturer to remedy an emissions-related problem. An emission recall is quite costly to a manufacturer. A typical recall can cost millions of dollars, depending on the number of vehicles involved, plus the additional tainted reputation of the automaker. The cost and reputation damage of a recall create a huge deterrent for manufacturers to avoid emissions violations. The EPA (U.S. EPA, 2009) Mobile Source Civil Penalty Policy states, “ (this Policy) establishes deterrence as an important goal of penalty assessment … any penalty should, at a minimum, remove any significant economic benefit resulting from noncompliance. In addition, it should include an amount beyond recovery of

1 *Vehicle useful life* and *certified useful life* are interchangeable in this paper.

the economic benefit to reflect the seriousness of the violation." To avoid recalls, manufacturers are motivated to build more reliable emission controls that not only pass emission certification testing, but also remain functional to the customer throughout a wide range of normal, real-world driving conditions.

Over the decades since the U.S. Clean Air Act (CAA) was enacted, regulators from the U.S. Environmental Protection Agency (EPA) and the California Air Resources Board (CARB) have developed comprehensive and rigorous compliance and recall programs. These include a number of subprograms to detect and verify emissions violations.

However, many emerging markets still do not have any robust emission compliance programs in place, even though the corresponding standards have been in place for years. In many countries, adequate legal authority is lacking. Some markets have a partial program composed of certain elements in the U.S. compliance program, but lack the resources to pursue a more comprehensive program. Many of these governments also may not have adequate data sources to properly identify emission compliance issues either.

This paper aims to provide useful information to governments that are beginning or in the early stages of pursuing an effective emission compliance program in their respective regions. This paper solely focuses on toxic air pollutant emissions, otherwise known as criteria emissions, rather than greenhouse gas emissions or fuel economy. This paper also focuses on direct or primary emission compliance issues, meaning noncompliance related to emission control systems or vehicle configuration and does not consider secondary compliance issues related to manipulation of test procedures.[2]

The paper takes a closer look at the vehicle emission compliance and enforcement programs adopted by the EPA and the state of California, focusing on emission recalls. The International Council on Clean Transportation (ICCT) has produced a few relevant papers highlighting various elements of the U.S. vehicle emission control and compliance program (Fung, He, Sharpe, Kamakate, & Blumberg, 2011; Maxwell & He, 2012; Bansal, 2013; Bansal & Bandivadekar, 2013; Wagner & Rutherford, 2013). This paper is a major addition to and continuation of these efforts, and includes:

» A detailed review of the evolution of the U.S. compliance program from its inception in the early 1970s to present;
» A review of the general trend in emission compliance and recalls in the United States and California;
» A review of historic vehicle and engine recall cases in the United States that provide important lessons to regulators around the world; and
» A detailed explanation of various subprograms and data sources for determining emission recalls.

Data sources for review and analysis were publications and publicly available data from the EPA and CARB. We also obtained additional details and information regarding recall cases through direct communication and interviews with former or current regulators within those agencies, official case settlements, and news articles.

2 Such secondary compliance issues include coastdown confirmatory testing, how to include optional equipment in calculation of test weight, manual transmissions shift schedules, drive-selectable devices, and setting dynamometer load coefficients.

The paper is organized as follows: Section 2 describes the legal authority of the U.S. vehicle emission compliance program; Section 3 illustrates the evolution of the U.S. compliance program; Section 4 provides a historical review of past vehicle emission recalls in the United States; Section 5 discusses six specific recall and enforcement cases; Section 6 lists useful data sources for identifying in-use noncompliance; Section 7 discusses post-recall actions; and Section 8 highlights overall findings and recommendations to consider when designing future compliance programs.

2. LEGAL AUTHORITY UNDER THE U.S. COMPLIANCE PROGRAM

The United States has established one of the world's most comprehensive and robust vehicle and engine emission compliance programs. This was made possible by giving clear and strong authority to regulatory agencies through the CAA and its amendments. In general, the CAA authorizes the EPA to set standards for vehicles, engines, and fuels that apply to the useful life of the product; create test procedures and protocols to evaluate actual performance against the standards; issue certificates and register fuels prior to their introduction into the market; and enforce perceived noncompliance. This section describes each of the provisions regarding the authority outlined above.

The CAA authorizes the EPA to establish emission standards for new vehicles and engines and issue a certificate of conformity (COC) for all new vehicle models and engines that are certified as meeting relevant emission standards. New vehicles and engines, either domestically produced or imported, without a COC cannot be sold in the U.S. market (Section 203 a(1)). Manufacturers or importers attempting to sell vehicles lacking a certificate face fines of up to $45,268[3] per vehicle and additional penalties (Section 205 a).

The concept of full useful life compliance is a bedrock principle of the CAA. The specific language on useful life is found in the second sentence of CAA Section 202 on motor vehicles, as follows: " … Such standards shall be applicable to such vehicles and engines for their full useful life …"

Over time, the U.S. Congress and the EPA have steadily increased the length of time and number of miles included in the definition of "full useful life." For example, the original CAA in 1970 defined "useful life" for passenger cars as only 5 years or 50,000 miles. This was only half of the lifespan or actual mileage of a typical vehicle. Manufacturers had no obligation to build emission controls to last beyond this period. Amendments to the CAA in 1990 revised section 202(d) to extend the definition of useful life for passenger cars to 10 years or 100,000 miles, whichever came first. And, in Tier 3 regulations that apply to automakers starting with MY2017, the EPA recently raised the definition of useful life to 150,000 miles for passenger cars.[4] As a result of this "full useful life" requirement, new vehicles are typically certified in the United States at one-third to one-half of the emissions limit in order to ensure compliance over the full useful life as emission controls degrade over time (U.S. EPA, 2013).

The CAA includes several provisions to fully define the shared burden between the government and industry on emission compliance. Section 206 requires the EPA to test

3 For violations that occurred after Nov 2, 2015 and assessed on or after Jan 15 2017. For more information see http://www.ecfr.gov/cgi-bin/text-idx?SID=a250616e6f4bd0d9d76b926f38098967&mc=true&node=se40.1.19_14&rgn=div8

4 The EPA can't require a useful life longer than 120,000 miles for LDVs and LDT1s due to the limitations of CAA. But California under separate authority increased this to 150,000 miles in the LEV III program. The industry asked EPA to harmonize its Tier 3 program as much as possible with the CARB LEV III program. In doing so, EPA provided the "option" to certify to a 150,000-mile full life but manufacturers may continue to certify non-California cars to 120,000 miles. But most manufacturers are expected to move to the optional 150,000 so that vehicles can in effect be certified to a single set of standards and be sold nationwide. The Tier 3 NMOG+NOX standards applicable at 120,000 miles were set at numerical levels equal to 85% of the 150,000 standards. The restriction only applied to LDV and LLDT. Heavy LDTs have no restriction in the CAA so these vehicles are required to certify to 150,000 miles of useful life.

new motor vehicles and engines to determine conformity with emission standards, or to require the manufacturer to conduct such tests and provide the corresponding results.

Section 207 requires automakers to warrant certain emission control components on their vehicles and engines.[5] Within the warranty period, manufacturers bear the cost burden of replacing or repairing the failed components as warranted. The provision protects vehicle owners from the cost of repairs for emissions-related failures that cause the vehicle or engine to exceed emission standards. The provision also requires manufacturers to monitor for known defects in emission control systems, and submit reports to the EPA if a substantial number of the same defect appear within the same model year. As noted earlier, this data can be useful for identifying vehicles that should be investigated for potential recalls.

Under the same section (Section 207 (c)(1)), if the EPA determines that a substantial number of vehicles or engines in a certain category or class do not meet emission standards during actual use, even though they are properly maintained and used, the EPA can require the manufacturer to recall and fix the affected vehicles and engines.

Section 203 of the CAA enumerates specific prohibitions, including i) prohibition against the sale and introduction into commerce of a new vehicle or engine unless covered by a COC, ii) prohibition against tampering, i.e. removing or rendering inoperative any device or element of design, iii) prohibition against the manufacture or sale of a defeat device, and iv) prohibition against failure to perform required tests, or provide required records. All of these prohibited acts may be subject to civil penalties. California statutes also provide such safeguards.

Section 205 of the CAA stipulates maximum penalties for different types of violations and how to determine the amount of civil penalties. In the original version of the CAA, the maximum amount was $25,000, and this amount has since been updated to $44,539 (for violations occurring after November 2, 2015) to adjust for inflation. To determine the amount of a civil penalty, multiple factors are taken into consideration, including the seriousness of the violation, how much the manufacturer benefited or saved, their history of compliance, and remedial plan (CAA Section 205).

Section 208 creates an affirmative obligation on the part of the manufacturer to establish and maintain records, perform tests, generate reports, and provide any additional information to the Administrator[6] as requested.

5 California's warranty regulations are generally more stringent than the EPA's regarding coverage.

6 The Administrator of the EPA is the head of the U.S. EPA, and is responsible for overseeing agency-wide initiatives and coordinating with regional and program offices.

3. EVOLUTION OF THE U.S. COMPLIANCE PROGRAM

Even with a solid baseline of legal authority, it took the United States and California regulators a long time to establish their comprehensive vehicle and engine emission compliance systems. Not intended to detail the entire program, the following figures illustrate various elements of the EPA's current compliance and enforcement programs for light-duty vehicles (LDVs), Figure 1, and heavy-duty vehicles (HDVs) and off-road engines, Figure 2, on the scale of vehicle and engine useful life.

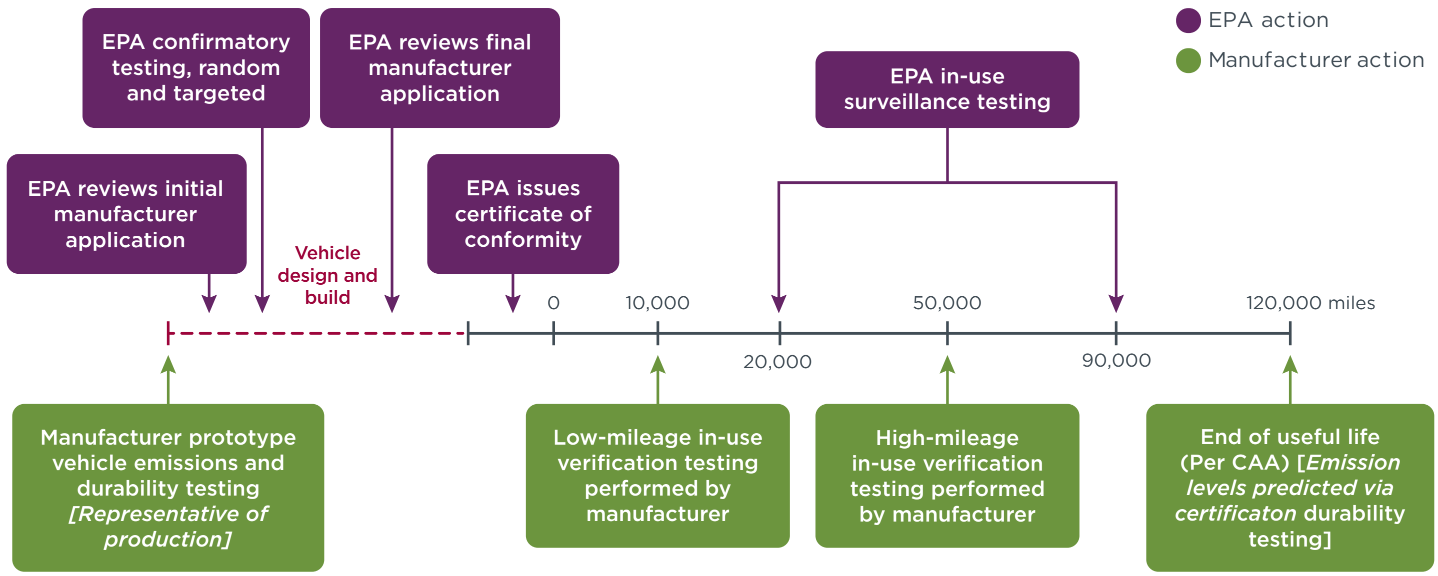

Figure 1. EPA compliance program for light-duty vehicles (LDVs)*

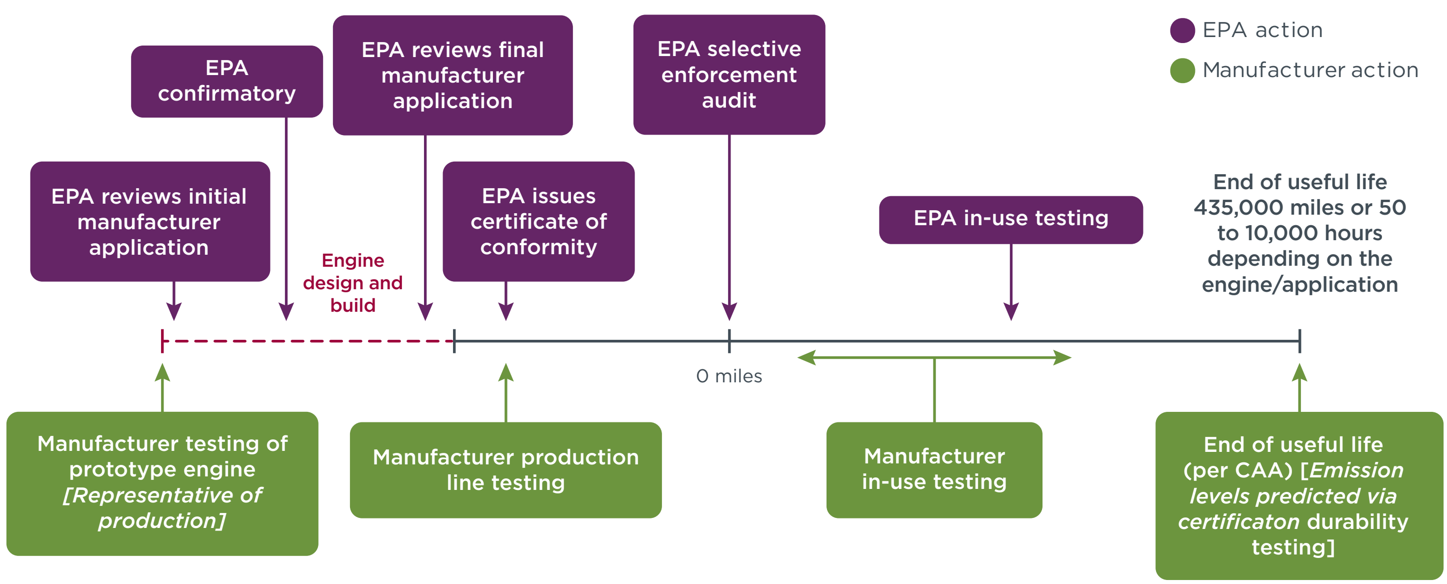

Figure 2. EPA compliance program for heavy-duty vehicles (HDVs) and off-road engines*

** Figure 1 & 2 are re-created by the ICCT based on the EPA's original figures in the EPA progress report (U.S. EPA, 2015), 2012-2013 Vehicle engine compliance activities.*

Today, the U.S. compliance program covers actions by both manufacturers and regulatory agencies during pre-production, production, and post-production stages. Manufacturers are required to conduct a substantial number of tests covering the majority of vehicle model types sold in the market. Regulatory agencies can therefore leverage their limited resources by focusing on the most “suspicious” vehicles for emissions violations. Even though both figures show dense activities before vehicle and engine production (action boxes above or below the dotted line), in practice, the EPA has shifted to an emphasis on post-production and in-use actions. For the light-duty vehicles (LDV)/light-duty trucks (LDT) sector, this has taken the form of granting some relief to manufacturers on burdens associated with pre-production certification in exchange for an increased requirement of manufacturers to perform in-use testing. This is a major shift and shows progress from when the program was first established in the early 1970s.

However, carrying out the program has never been smooth sailing. There was a time when the EPA and CARB, both with limited resources and staff capacity, battled with manufacturers over severe emissions violation cases. Sometimes, though rarely, they had to resort to court to get the contentious cases settled fairly. Over more than four decades, the agencies enhanced their capacities, reorganized internal institutions in order to streamline enforcement actions, filled the gaps in existing laws and regulations, and secured sustainable funding sources to maintain the continuous efforts to ensure emissions reductions. As a result, there are now fewer court-ordered recalls. While the transition is still in the early stages for the newer regulatory categories in the non-road sector, the compliance programs for the light-duty and heavy-duty on-road sectors are operating with a greater degree of manufacturer self-implementation, but with the agencies retaining powerful tools to ensure a high degree of compliance.

1970s

With the passing of the amended Clean Air Act, U.S. vehicle emission compliance program begins. In the initial stages of the program, only light-duty vehicles are regulated, a heavy-duty vehicle program does not yet exist. The program has a strong focus on prototype design and production, with only limited attempts to do in-use testing. Data for determining compliance actions are also limited. In-use testing programs are only performed by the agencies. The majority of emission recalls were ordered. A few states create inspection and maintenance programs. The first official guidance on defeat devices was issued by EPA.

This section provides a detailed historical review of the path of growth of the U.S. vehicle emission compliance program by decade. While focusing on the U.S. federal program, California’s unique program elements are also briefly highlighted. The experience of the United States is valuable to other parts of the world with the desire to establish a similarly powerful system. That said, the U.S. federal program took four decades to build up, step by step, though not every step along the U.S. pathway needs to be repeated in other regions.

In 1970, U.S. Congress passed the first major amendment to the CAA, requiring a 90% reduction in emissions from new automobiles by 1975. This standard would enforce the use of a catalytic converter, then an innovative technology to effectively control tailpipe emissions. In the same year, the EPA was established and was assigned the broad responsibility of regulating motor vehicle pollution, as well as the authority to enforce and ensure compliance, including through emission recalls. Through the enactment of the 1970 CAA and later amendments, the EPA became key to the success of today's U.S. vehicle emission compliance program.[7] The EPA is an agency with a clear mission, whereas in many other countries the regulations are not enforced by an agency with such a mission. In the 1970s, several major components of compliance activities were developed as regulations, including the COC regulation, the Selective Enforcement Audit (SEA) regulation, the defect reporting regulation, and the recall regulation.

The earliest phase of the EPA's vehicle emission compliance program contained the following major components:

» The earliest compliance program took the form of pre-production audit and testing. The pre-production certification review program was initiated in 1968 (EPA progress report, 1985). In order to sell vehicles in the United States, manufacturers need to obtain a COC from the EPA. Manufacturers would do certification testing for all new vehicle test groups and submit applications to the EPA. Upon reviewing the manufacturer's certification application, the EPA may target a vehicle class for confirmatory testing of prototypes at the EPA's Ann Arbor laboratory. The EPA also conducted periodic audits of manufacturing facilities in order to ensure that certification procedures are observed. From 1973 to 1974, for example, the EPA conducted 24 detailed inspections of domestic and foreign facilities (U.S. EPA, 1974).

» Production line testing was also part of the first efforts of the compliance program. There are two types of production testing:

    » The first requires manufacturers to routinely test vehicles as they leave the assembly line to show new vehicles were built like the certification vehicle.

    » The other test is a Selective Enforcement Audit (SEA) for light-duty vehicles. EPA engineers arrive at the manufacturer's assembly plant without prior notice and require the manufacturer to select and test a sample of new vehicles subject to EPA selection. If a manufacturer fails the audit, it must stop production within 10 days (to find and fix the problem), perform a passing SEA, and recall all cars produced and affected. When SEA testing began, audits of new vehicles occasionally failed. To avoid failing, manufacturers usually would voluntarily test thousands of new cars a year to detect any emissions problems before the EPA did, as the cost of stopping production and recalling cars already produced could be tremendous. The SEA has been a very effective program for a few decades and, by 2000, both light- and heavy-duty audits rarely failed. As will be discussed later, into the 2000s, the EPA stopped SEA except in cases of possible fraud so as to save resources and focus more attention on in-use vehicles.

» A few initial efforts were made to test and audit in-use vehicles.

7 In the law, Congress specifically grandfathered the California program since California already had started to put in place a strong program and it arguably had the most severe air pollution problem in the country (Los Angeles).

   - » A spot-check and investigation into the in-use fleet, the anti-tampering program, was initiated. In 1973, the EPA undertook a survey in Washington, D.C., and found components of emission control systems had been removed in 15% of the vehicles surveyed. The EPA later referred five cases to the Justice Department in violation of the CAA's anti-tampering provision.
   - » A preliminary, yet ineffective, warranty program: The CAA requires manufacturers to cover certain emission control parts under warranty. However, the EPA discovered that consumers did not understand what was specifically covered under this warranty and therefore few claims were submitted. Before 1975, the EPA also lacked a way to monitor manufacturers' efforts to fix the vehicles under the warranty.
   - » Apart from efforts at the federal level, California introduced its warranty regulation in 1978 and included a parts list of systems and components it covers (California Air Resources Board, 1978).
   - » Aftermarket part program: voluntary self-certification for manufacturers of emissions-related automotive aftermarket parts to replace the broken parts. In California, before aftermarket parts can be sold, they must be demonstrated to not affect emissions levels pursuant to specific regulations and test procedures.
   - » A simple in-use testing program run by the EPA consisting of screening surveillance testing and more rigorous confirmatory testing.
   - » The EPA proposed the defect reporting rule in 1975 (U.S. EPA, 1974) and it was published in the Federal Register in 1977 (National Archives and Records Administration, 1977). The rule requires manufacturers to report to the agency any significant emission control defects that they found on their vehicles sold to the market. The rule applies to all vehicles and engines MY1972 and later.
- » A recall program based on a regulatory agency's surveillance and investigation, defect reports from government and commercial fleets, and data obtained from state and local inspection and maintenance centers.
- » A transportation control program, including a component of voluntary state vehicle emission I/M. The 1977 amendment to the CAA gave the EPA authority to mandate I/M and require states facing severe air quality challenges to implement I/M. The EPA considered I/M an important strategy for dealing directly with in-use emissions problems. Prior to 1977, the state and local I/M programs were voluntary and were adopted in a few states and cities including New Jersey, Portland, Chicago, and Arizona.
- » On December 11, 1972, the EPA published Advisory Circular 24, which provides guidelines for dealing with detected defeat devices. In the light of rapid advancements to a sophisticated emission control system, and the generality of Advisory Circular 24, the EPA released Advisory Circular 24-2 in 1978 to help manufacturers and EPA evaluate any questionable auxiliary emission control devices (AECDs).

There were two key characteristics of the EPA's earliest phase of compliance actions during the 1970s. First, the agency put the most effort into a certification program and confirmed some of the tests that the industry did for certification. Less effort was put into post-market compliance actions due to a longer learning curve, which needed to effectively develop for an in-use compliance program.

Part of the reason for such a strong emphasis on certification was that, in the early 1970s, the initial leadership of the EPA's mobile source program came from an aerospace regulatory background with the philosophy of certification being the backbone of good compliance. This makes complete sense for the aviation industry, as every aircraft is handmade and there is no difference between a prototype and a production one; a single failing aircraft in use could lead to catastrophe. However, this approach does not hold true for the auto industry where a prototype built for certification tests is a handmade vehicle of high quality, whereas mass-produced vehicles can be very different.

Perhaps more importantly, in the early stages, a big part of the focus on certification came from the fact that neither the industry nor the EPA knew how to build clean cars and a lot of upfront focus was needed to ensure that manufacturers were putting forth their best efforts to develop and apply new technology.[8]

Admittedly, the certification program, facility audits, and the increasingly rigorous SEA program did play an important role in deterring fraudulent reporting of certification results and later compelled manufacturers to test new vehicles extensively at their own costs to ensure production conformity.

Secondly, the only in-use compliance testing was done by the EPA. Manufacturer-run testing programs did not exist. The EPA may hire contractors to do in-use testing, but it was done at the agency's expense. The agency's first approach was called surveillance testing. The EPA randomly picked test groups or engine families and procured in-use vehicles under more lax conditions for a general check. If they looked okay, the agency would do nothing further. If they indicated a problem, the agency would take that data to the manufacturer. However, since the data was loosely screened, the manufacturer could argue that the test vehicles were not properly maintained, which wouldn't lead to a winning recall case.

Then, the agency would move to a second phase called confirmatory in-use testing. For confirmatory testing, the agency spent money and resources to do rigorous screening to ensure that the vehicles tested are well-maintained and well-documented. This ensured that manufacturers could not argue about bad data or that the vehicle failure was due to poor maintenance or tampering by the owner rather than due to any fault of theirs. Even if the surveillance data was convincing, the agency would still go the extra mile to do the additional confirmatory testing.

It was not uncommon to identify problems in surveillance testing. As the in-use testing program matured and EPA staff became more skilled, the agency sometimes did not need to conduct confirmatory testing. Instead, it showed manufacturers the strong surveillance testing data and pointed out that even without screening for perfect maintenance conditions, the emission controls on the vehicles were clearly not working, or the agency showed the manufacturer that the vehicles clearly had a faulty component or some other clear evidence that the vehicle had an emissions problem. Over time, the agency was able to have more success in convincing manufacturers to recall without more rigorous efforts. In general, the EPA's approach in this early phase was very expensive given that the agency needed to rigidly screen every car to determine if it was properly maintained.

8 Communications with a former EPA officer.

1980s

Throughout the 1980s, various programs were refined, expanded, and enhanced. The problem of excessive emissions from in-use vehicles received an increasing amount of attention. In addition to the traditional focus on exhaust emissions, the EPA began some small-scale efforts toward implementing light-duty evaporative emission standards. The EPA's agency-run in-use testing program matured, and the agencies were able to obtain defensible data leading to more successful recalls. The EPA created its initial in-use surveillance program for HDVs.

For production testing, in the late 1970s, the EPA found that the light-duty vehicle SEA program encountered few failures, because, on a voluntary basis, auto manufacturers routinely tested many more vehicles than were strictly required through SEA orders. Therefore, beginning in 1981, the EPA changed its SEA policy to place greater reliance on manufacturer testing programs and less on EPA-mandated audits. The light-duty SEA program started in the early 1970s, but it was not until 1986 that the EPA conducted its first heavy-duty engine audit (U.S. EPA, 1988).

The warranty program was published in the Federal Register in 1980 (National Archives and Records Administration, 1980) and was formally established as covering cars and light-duty trucks MY1981 and later. The EPA responded to complaints and inquiries about warranty coverage and referred to the vehicle manufacturers for solutions. Around 1987, the EPA developed a pamphlet outlining the performance warranty requirements (EPA progress report, 1987). That pamphlet was distributed to state and local I/M programs.

Into the 1980s, the EPA continued issuing anti-tampering audits by conducting surveys. Survey results from the early 1980s indicate a significant fraction (17% in 1983 and 28% in 1984) of the vehicle fleet was subject to gross (U.S. EPA, 1985b). Federal efforts alone cannot effectively address these problems, and the EPA continued to promote the implementation of state and local anti-tampering enforcement programs. For example, in 1983, six local anti-tampering programs were set up as a result of this initiative (U.S. EPA, 1985a). Anti-tampering programs can be set up in a variety of ways: For example, such a program can be added as part of an existing I/M program, safety, or other periodic inspection requirement; a new requirement can be implemented; and various field enforcement efforts can also be used.

A critical element of state and local tampering inspections is the availability of replacement emission control components. In 1986, the EPA adopted a policy regarding aftermarket catalytic converters that established test procedures, performance standards, and installation requirements for aftermarket converters. The policy also contains reporting and recordkeeping requirements to aid the EPA in monitoring the appropriate use of aftermarket converters. The EPA also brought enforcement actions against two automobile dealerships for the aftermarket converter rule violations and proposed penalties of $120,000[9] (U.S. EPA, 1989).

9 In many cases, the original sources only provided the proposed penalty instead of the actually imposed penalty levels.

The recall program has traditionally focused on car exhaust emissions. When new categories of emission standards came into place, the EPA began small-scale efforts to implement a light-duty evaporative emission recall program, as well as light truck and heavy-duty exhaust emission recall programs. In 1987, the EPA expanded its surveillance to heavy-duty engines through field surveys of in-use heavy-duty engine emission control systems.

As with the situation in the 1970s, all of the in-use tests were run by the EPA. CARB's in-use compliance testing began in 1982 and included evaporative emissions testing. To avoid a duplication of efforts, the EPA and CARB began coordinating which engine families would be tested. Throughout the 1980s, the EPA initiated roughly 30 recall investigations and on average conducted more than 600 in-use tests annually (U.S. EPA, 1985a; U.S. EPA, 1985b; U.S. EPA, 1987; U.S. EPA, 1988; U.S. EPA, 1989; U.S. EPA, 1990).

In 1983, the EPA issued a policy statement reaffirming its commitment to I/M as a vital component of pollution control plans in non-attainment areas (EPA progress report, 1983). In doing so, the agency required states to establish the program in areas with air pollution problems, requiring passenger vehicles to undergo periodic testing for malfunctioning emission control systems. By the end of the 1980s, more than 60 areas adopted the program. To ensure that I/M programs in operation were achieving the planned emission reductions, the EPA also initiated a systematic I/M auditing plan.

California implemented the first generation of OBD system requirements in 1988, requiring the system to be installed on all cars MY1991 and later. OBDs monitor the functionality of various emission control components and related systems, and alert the vehicle's driver of potential problems that can affect the emissions performance of the vehicle. OBDs prove to be powerful tools for identifying in-use compliance issues. The California requirement was the very first regulation that targeted the OBD system.

1990s

Tier 1 and Tier 2 emission standards for light-duty vehicles were both finalized during this decade. The in-use testing program began to include pilot manufacturer-run in-use emissions testing. In the wake of widespread defeat devices used on heavy diesel engines, the EPA and the CARB introduced the Not-To-Exceed (NTE) in-use standard paired with real-world (PEMS) testing for heavy-duty engines. California established a warranty-reporting program. Regulators have more data sources to identify in-use noncompliance. The majority of recalls occurred on a voluntary basis. The EPA mandated an OBD check in I/M programs for light-duty vehicles.

The CAA included a durability requirement of 50,000 miles for LDVs, which was later extended to 100,000 miles. In the early stages, the durability tests were done in a way that involved driving the test vehicle of each vehicle family almost continuously around a test track at a constant speed, night and day, until it accumulated 50,000 miles. A mileage accumulation cycle contained a substantial portion of low-speed driving to determine if engine deposits impact emissions. It was emissions tested at 5,000-mile intervals and a regression line was extrapolated to predict emission levels at 100,000 miles (or 100,000-mile emissions). These durability tests did not usually incorporate a driving operation that raised the catalyst temperature—such as high speeds or high loads—because the cycle was developed before catalysts were included on vehicles.

However, the 100,000-mile emissions were usually predicted to be much lower than real-world emissions from cars on the road. The EPA was recalling over 30% of the cars made in the first 10 to 15 years of the compliance program, and a lot of them were due to deterioration and parts failure, or a failure of the durability requirement. In short, the EPA learned that certification durability predictions were not accurate, were expensive for manufacturers, and did not provide the EPA with good data on 100,000-mile emissions. To develop and adopt more rigorous and accurate durability testing, the EPA needed to give the manufacturers some flexibility in how they did this.

In the mid-1990s, the EPA and manufacturers revised the durability procedures and started a pilot program. This signaled the beginning of the initial manufacturer in-use verification program and was the precursor for the Compliance Assurance Program (CAP 2000). With CAP 2000, manufacturers have the flexibility to develop a process, to be approved by the EPA, for determining deterioration factors in the certification. Manufacturers must follow up with in-use testing to prove that their process was accurate, instead of completely following the previous durability testing requirements. If problems were detected during the follow-up in-use testing, manufacturers would need to agree to recall those vehicles and also change their self-determined process for future certification.

That pilot program ran well for about 6 to 8 years, at which point the EPA established a formal program for manufacturer in-use testing via CAP 2000 (U.S. EPA, 1999), which applied to light-duty vehicles of MY2001 and later. CAP 2000 is a compliance assurance program proposed by the EPA in 1998 to adopt revised emission compliance procedures for new light-duty vehicles and light-duty trucks. These are called the manufacturer in-use verification program (IUVP) and the follow-up is a manufacturer in-use confirmatory program (IUCP), conducted if significant failures are identified from the IUVP. CARB also adopted the CAP 2000 regulations, and the agency routinely audited not only the manufacturers, but also the private test facilities performing these tests.

These programs significantly increased the amount of in-use emissions test data for the EPA to determine further compliance actions, and therefore helped release the burden on the EPA's budget and allowed the agency to focus on the most suspicious issues with its limited resources. Many voluntary recalls occurred under these manufacturer-funded testing programs.

An important development in California was the establishment of a warranty data reporting program in 1988, under the California Health and Safety Code. This regulation took effect in 1990 (CCR § 2141). Manufacturers are required to review unscreened warranty claims for each engine family or test group and compile the cumulative number of claims made on an emissions-related component on a quarterly basis. If the cumulative number represents at least 1% or 25 (whichever is greater) of the vehicles or engines of a California-certified engine family or test group, the manufacturer will need to file an emission warranty information report in that same quarter. As follow-up, the manufacturer will need to file an updated report on a quarterly basis after the initial warranty information report unless a recall has been implemented. If the percentage or number of an emissions-related component exceeds the failure level set forth by the rule, the manufacturers will need to issue a recall.

In-use testing of heavy-duty engines started much later than the LDV program, and even later for off-road engines. When the heavy-duty engine emission standards were first implemented in the late 1980s, the EPA mainly audited manufacturers' certification data and sometimes performed only a few engine confirmatory tests due to limited available laboratory capacity.[10] The EPA's initial actions on heavy-duty engine surveillance were very limited, and mainly involved surveys of emission control system performance of in-use vehicles. This is because the standards were set as engine emission standards. Traditional laboratory testing for heavy-duty and non-road engines over a specific test cycle requires the engine to be removed from the vehicle or equipment. This makes it prohibitively expensive and cumbersome to conduct in-use testing for heavy-duty and non-road engines. In addition, heavy-duty and non-road engines operate under a wide range of conditions (e.g., load and speed) that cannot be fully replicated in limited test cycles. Laboratory testing following a specific test cycle cannot ensure that emissions from these vehicles and pieces of equipment are within the range of the applicable standards during normal operation.

During the mid- to late 1990s, the EPA coordinated with universities and developed the portable emissions measurement system (PEMS). PEMS equipment can be installed on heavy-duty vehicles and off-road equipment to measure pollutants as they drive and operate under real-world conditions. Toward the late 1990s, regulators at the EPA intended to apply PEMS to monitor and verify the compliance of heavy-duty and off-road engines.

In 1998, a broad-scale defeat device case involving heavy-duty diesel engines triggered the EPA to set up an in-use testing program for HDVs. An in-use emission standard (the NTE standard) for heavy-duty engines was first introduced in the Consent Decree (D.C. District Court, 1998)[11]. The same year, the EPA released a guidance letter to manufacturers on reporting and evaluating heavy-duty diesel engine auxiliary emission control devices (AECD), reaffirming the prohibition of defeat devices (EPA guidance letter, 1998). This guidance letter expanded the use of the 1978 Advisory Circular that already banned defeat devices. With the formal introduction of PEMS into compliance activities, and by collaborating with both CARB and diesel engine manufacturers, the EPA developed and finalized the NTE rule in 2005 (U.S. EPA, 2005). After 2 years of phase-in, the program became mandatory in 2007.

Throughout this era, the majority of in-use testing is conducted by manufacturers. Under the 2005 NTE rule, manufacturers are required to conduct in-use testing to demonstrate compliance with the NTE limits, which is generally 1.25 or 1.5 times the applicable Federal Test Procedure (FTP) emission limits. For testing every year, the EPA will designate no more than 25% of a manufacturer's engine families with a production volume greater than 1,500 engines. Due to wide variations of the in-use testing measurements, the EPA initiated a comprehensive research, development, and demonstration program designed to identify new accuracy measurement margins for PEMS. EPA in-use testing is conducted at the lab in Ann Arbor, Michigan, and at the Department of Defense's testing lab in Aberdeen, Maryland.

10 The EPA's HD engine test facilities were dedicated almost completely to regulatory development and technology assessment testing.

11 An agreement or settlement to resolve a dispute between two parties without admission of liability (in a civil case) or guilt (in a criminal case)

POST-2000 TO PRESENT

Tier 3 emission standards for light-duty vehicles were finalized in 2014. OBD regulations began to be implemented on heavy-duty vehicles in California and nationwide. Manufacturer-run in-use testing programs were officially established. An NTE standard for HD engines was phased in. More emphasis was put on in-use emission compliance. More detailed guidance on defeat device screening was established after the discovery of a defeat device on several models of Volkswagen diesel cars.

Following the introduction of OBD requirements in California in the late 1980s, OBD regulations were also adopted by the EPA. Starting with MY1994, the EPA required OBD systems on light-duty vehicles and light trucks. This is referred to as the OBD II requirement, in harmonization with California. OBD II overcame shortcomings of California's first generation of OBD requirements and made the system more user-friendly for service technicians by introducing standardized communication codes.

For the emission inspection program, 1990 CAA amendments required the EPA to set guidelines for states on I/M programs, and required OBD system checks as part of the I/M program.

As the IUVP and IUCP started, the EPA was able to leverage the agency's limited resources to conduct more in-use testing on LDVs by requiring manufacturers to do their own in-use testing, in addition to the EPA's in-use testing. In 2005, the NTE standard for heavy-duty engines was phased in, and fully implemented in 2007.

In 2004, CARB first implemented OBD regulations for HDVs. Shortly after, the EPA harmonized with CARB again, and OBD systems became mandatory for all heavy-duty vehicles and engines up to 14,000 lbs gross vehicle weight rating (GVWR) nationwide since 2005. In late 2008, the EPA finalized the OBD regulations for model year 2010 and later heavy-duty engines used in highway vehicles over 14,000 lbs GVWR (U.S. EPA, 2008). The EPA also made changes to the OBD requirements for vehicles up to 14,000 lbs GVWR to align them with the requirements for those over 14,000 lbs GVWR.

In light of the Volkswagen scandal (discussed in section 5), the EPA issued a guidance letter to manufacturers in September 2015 (EPA guidance letter, 2015), detailing additional testing requirements during the confirmatory test process for the purposes of investigating defeat devices.

Figure 3 (Figure ES-1) below illustrates the evolution of the federal U.S. vehicle emission compliance and control program and summarizes key characteristics of each era. In addition, it highlights six enforcement cases, which are each discussed in the following section.

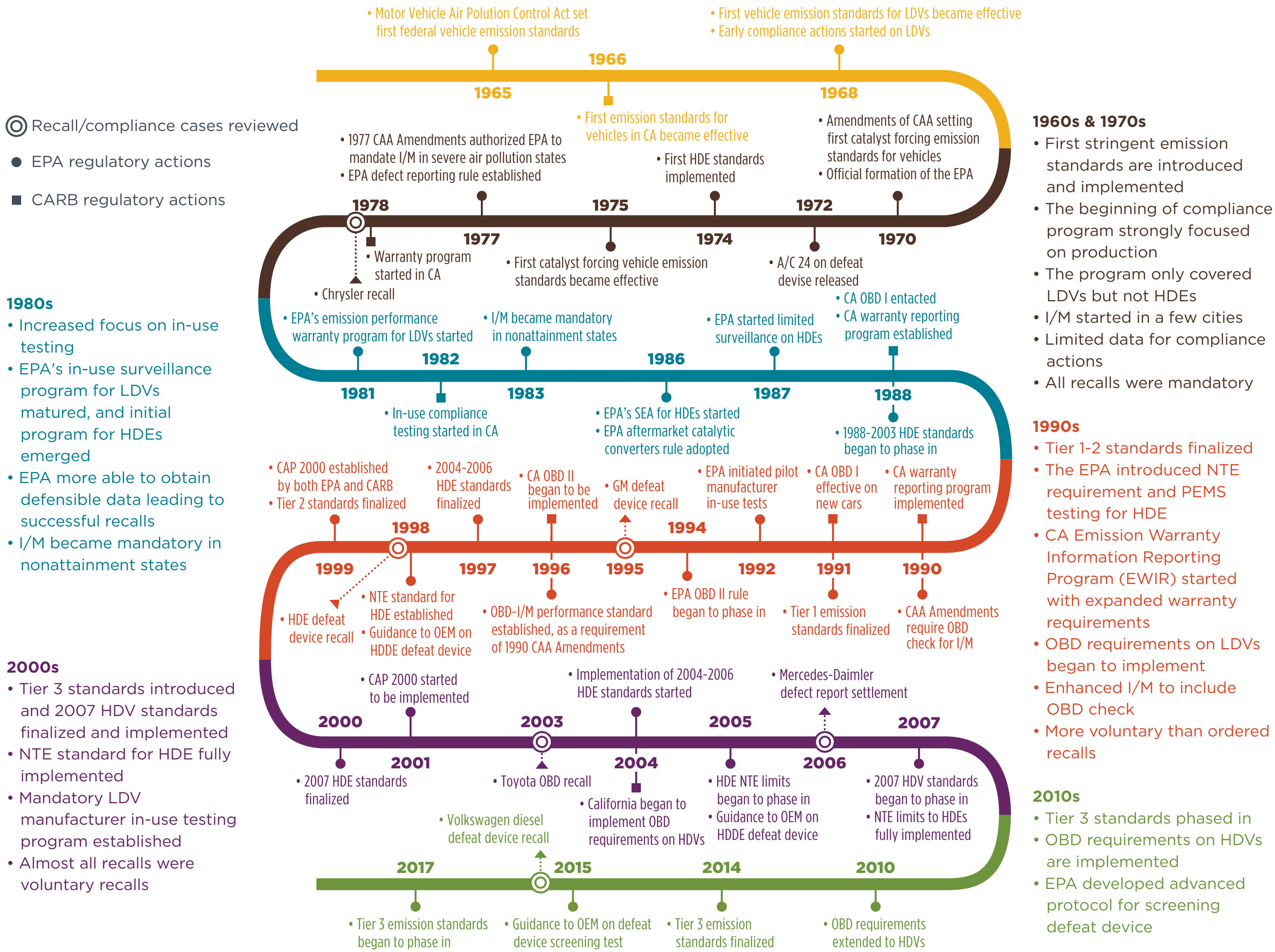

Figure 3. Evolution of U.S. vehicle emission compliance and control program

4. HISTORICAL TRENDS OF U.S. VEHICLE EMISSION RECALLS

This section provides a historical perspective on U.S. vehicle emissions-related recalls and, by reviewing and analyzing recall and compliance data, provides insights into how compliance performance changed in response to tightened compliance requirements introduced by regulatory agencies.

Information and data included in this section were primarily gathered from the EPA's annual vehicle recall summary reports available on the agency's website (U.S. EPA, 2017). These reports include the annual recall data for passenger cars and light trucks from 1996 to 2009 and information such as manufacturers, models or engine families, model years subject to recall, year/date of notification, type of recall (ordered, influenced, or voluntary), reason for recall (or emissions violations), and number of vehicles affected.

The EPA considers past compliance records a valuable data source to help target vehicle classes for current in-use compliance testing. As the auto industry continues to globalize and vehicle emission standards in major markets harmonize, the giant international auto companies have started to build fewer key technology platforms to fit various global markets. Therefore, detailed data from one of the world's largest vehicle markets—the United States—is likely useful for environmental regulators in other parts of the world.

In the United States, there are three types of recalls, depending on the level of engagement or intervention of the regulatory agencies (the EPA or CARB): ordered, influenced voluntary, and manufacturer voluntary recalls. Ordered recalls are mandated from the EPA and CARB, per authority from the CAA and the California Health and Safety Code, and usually involve a lengthy legal process. Influenced voluntary recalls are manufacturer voluntary actions in response to regulators' intervention. The EPA usually encourages manufacturers to voluntarily recall their defective product to avoid ordered recalls. Manufacturer voluntary recalls are independent manufacturer action. Most recalls are initiated voluntarily by manufacturers once potential noncompliance is discovered; however, the EPA also has the authority to order the manufacturer to recall and fix noncompliant vehicles or engines if the manufacturer declines to implement a voluntary recall. In addition, manufacturers could initiate service campaigns[12] before entering the recall phase. These are still considered recalls by the EPA, but are listed separately because the manufacturer is asking the owner to bring in the vehicle only if the problem is apparent. There is usually a warranty extension associated with these types of recalls.

The overall trend of vehicle emission recalls (Figure 4) suggests great success of the U.S. vehicle emission compliance program. During the first 10 to 15 years after the 1970 CAA took effect and the recall program was initiated, the EPA recalled about one-third of all cars and light trucks produced in any year. In contrast, during the 1990s, the EPA recalled only 5% to 10% of vehicles produced in any year. Similarly, CARB's early in-use compliance testing failure rate was 100% and slowly dropped over time.[13] This change is

12 CARB allowed recalls to be called "service campaigns" to curtail lengthy recall negotiations and get vehicles repaired more quickly.

13 Communication with a former EPA officer.

due to both progress made on emission control technologies and the advancement of tools within compliance programs to better detect in-use noncompliance.[14]

Before the mid-1980s, recall rates—the share of vehicles recalled among the annual new vehicle sales for a given model year—were especially high, reaching 30% in quite a few years. At that point, emission control technologies were still in early development and durability was poor. The initial CAA included durability requirements of 50,000 miles for LDVs, and the 1990 amendments extended the requirement to 100,000 miles. As mentioned in a previous section, in the early years, the durability tests were conducted by actually driving a vehicle on an accelerated durability drive cycle at mostly constant speed until it accumulated 50,000 miles. This approach was both expensive and poor in accurately predicting dynamic in-use driving. Limited by both the technologies and the testing approach, overall in-use compliance was poor.

From 1985 to 1990, manufacturers began to successfully implement accelerated bench aging tests,[15] allowed them to better predict durability performance at a lower cost. Thanks to these tests and improved catalyst designs, recall rates dropped dramatically during this period.

The recall rate has increased since the mandatory OBD rule for LDVs, also called OBD II, was introduced in 1994. This is not surprising given that systems as complex as OBDs sometimes fail, and properly functioning OBDs are effective in identifying failing emission components.

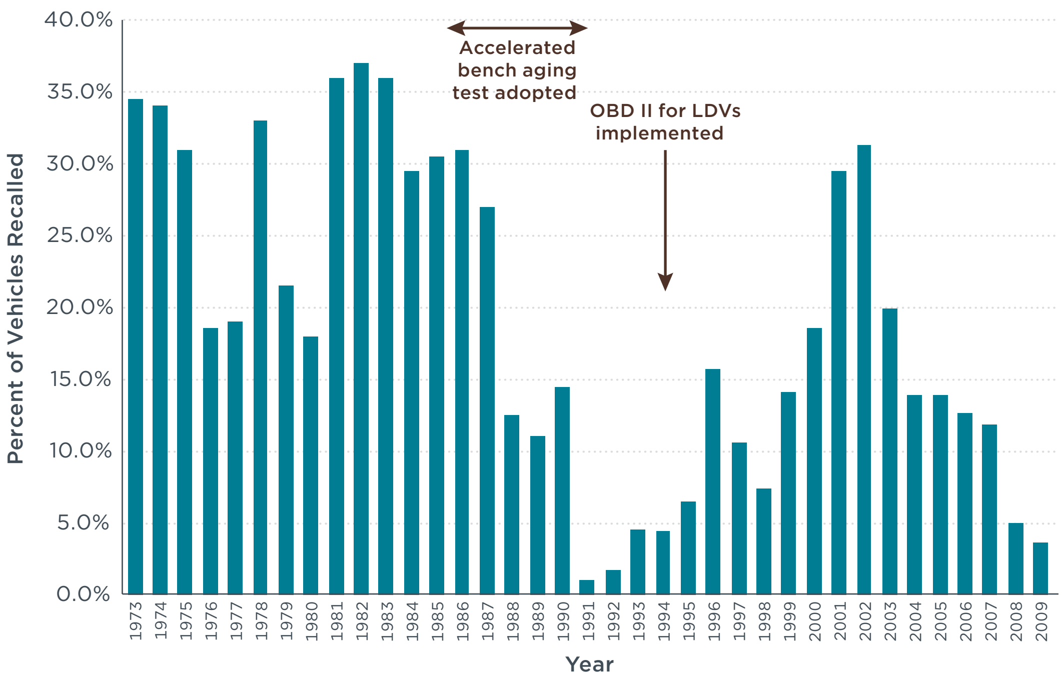

Figure 4. Percent of light-duty vehicles (LDVs) recalled by model year

Data sources: multiple. Year 1973-1999 data were from a non-public presentation made by Charles Freed, former officer at the EPA. Year 2000-2009 data were from various EPA progress reports.

14 Communication with a former EPA officer.

15 Communication with a former EPA officer.

Regulatory agencies also experienced a learning curve on how to make manufacturers comply, and manufacturers gradually learned it was better to cooperate than go to court. In the early years, when testing programs and technical capacity within the EPA were limited, the EPA often had to resort to legal action to settle an emissions violation. Manufacturers felt it was much cheaper to hire top-notch lawyers to challenge the EPA rather than face an expensive recall. As a result, many recalls were mandatory, many were challenged, and most were the result of EPA action pre-1990 (Figure 5). As the EPA compliance program matured, manufacturers tended to agree with the EPA in earlier stages of compliance actions. The majority of the more recent recalls were voluntary with less influence from the EPA, but always with the possibility of the EPA stepping in if manufacturers dropped the ball.

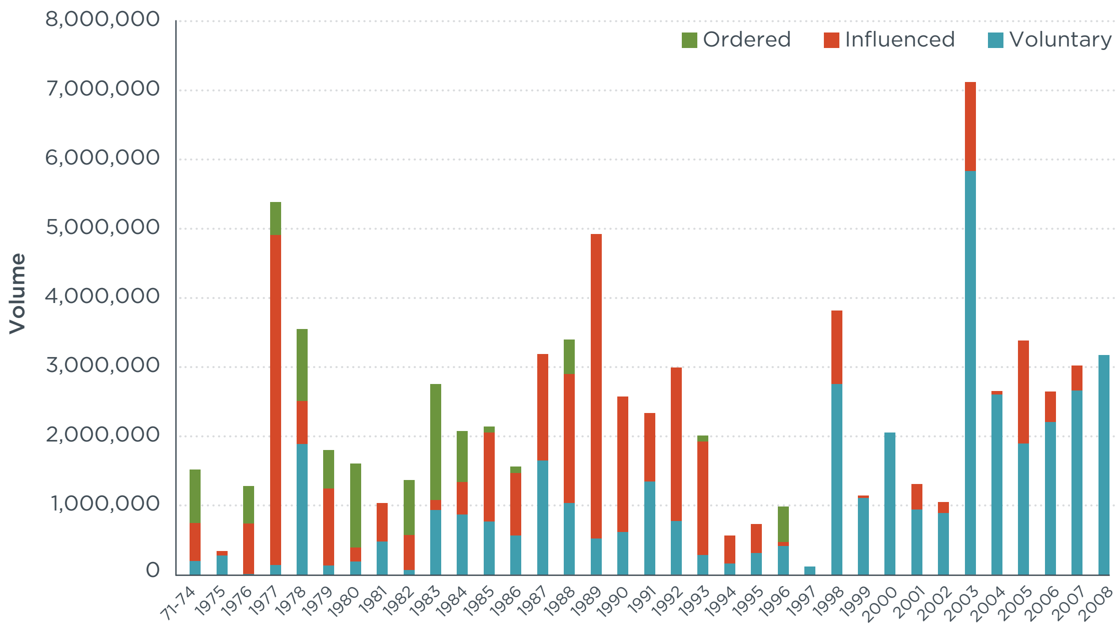

Figure 5. Historic light-duty vehicle (LDV) recall volumes by recall type and calendar year

Source: EPA 2008 progress report: Vehicle and Engine Compliance Activities, p. 32

5. RECALL AND ENFORCEMENT CASES

This section reviews some notable vehicle emission recall cases in U.S. history. Most of the detailed information about each mandatory recall, such as environmental impacts of each violation, how the cases are settled, penalty and remedy, was made public on the government agencies' websites. However, these public documents do not explicitly discuss how the issues were initially discovered, which is a critical piece of information for the purpose of our paper. We were able to obtain such details from interviewing former and existing government officials involved in the cases. The content from individual interviews was then combined with in-depth research into other government reports and media coverage. These cases offer rich lessons to regulatory agencies in other parts of world where their compliance programs are currently in development. All lessons learned are summarized at the end of each case's section.

5.1 CHRYSLER 1978 RECALL

In November 1978, the EPA ordered Chrysler Corporation to recall 208,000 of its MY1975 cars for violating a carbon monoxide (CO) limit set by the in-use emission standard at that time (The Washington Post, 1978).[16] This affected nearly a quarter of Chrysler's production of cars in 1975, including the Cordoba, Newport, Plymouth Fury, Grand Fury, Dodge, Monaco, Charger SE, and Coronet models. The EPA labeled the case "precedent setting" because it was the first mandatory vehicle emission recall issued by the EPA, and also the first time a vehicle recall was ordered for design and maintenance issues rather than for manufacturing defects.

The uncontrolled CO emissions were, based on the EPA investigation and extensive tests, due to carburetor maladjustments; a screw on the carburetor, small yet crucial for controlling air fuel ratio, was extremely sensitive and difficult to adjust when a car underwent maintenance.

This case is the first contested recall action under Section 207(c)(1) that needs to resort to a court. Chrysler filed an appeal after the recall notice was first issued in Dec, 1976 (Shabecoff, 1976). Chrysler argued that the excessive emissions were caused by improper maintenance of the vehicles by consumers. An administrative law judge[17] upheld the order, which was affirmed by the EPA Administrator in 1978 (The Washington Post, 1978). Chrysler later appealed the recall order in court (U.S. Court of Appeals for the D.C. Circuit, 1980), but the court overturned Chrysler's petition and referenced the definition of "proper maintenance" within the meaning of Clean Air Law (Section 207(c)(1)) as well as substantial evidence in the record from the EPA.

Discovery

It is important to mention the context of this case. The Chrysler case happened not long after the EPA initiated the preliminary in-use testing program and streamlined its procedures for compliance investigation actions, including hiring contractors for the testing, engaging manufacturers in certain testing, and creating documentation in order

16 In 1970 Congress passed the Clean Air Act Amendments, which required auto manufacturers to reduce carbon monoxide emissions by 1975 to one-tenth of former levels: to 3.4 grams per mile. In 1973, the Administrator postponed implementation of the 3.4 grams per mile standard and set an interim carbon monoxide emission standard of 15 grams per mile; this was in effect during 1975 when the Chrysler case was concerned.

17 EPA's administrative law judges conduct hearings and render decisions in proceedings between the EPA and the other parties that are, or are alleged to be, regulated under environmental laws.

to provide defensible data to go to court when needed.[18] The U.S. system was structured so that if the manufacturers did not agree with the EPA's data, the case would most certainly go to court. An important lesson from the EPA's compliance activities in the early 1970s was to have concrete data to back up a noncompliance claim.

The issue was initially exposed from I/M program data in the city of Chicago.[19] The data disclosed that Chrysler had a very high failure rate, failing approximately 40% in a very lenient test, for vehicles that were almost brand new.[20] The EPA then brought in some Chrysler vehicles for confirmatory testing in its own lab.

For I/M testing, the vehicles were tested in the condition they were received from consumers, and were not specifically tuned. When the EPA conducted its tests, the agency found that, without tuning, the Chrysler vehicles had lots of failures, while if tuned up they could all pass. With additional careful investigation, EPA regulators found that the Chrysler vehicles of concern had carburetors for air and fuel control, and their carburetors had an adjustment screw. The problem turned out to be poor screw design, causing them to easily loosen up without an extremely careful and difficult tuning process. Without that tuning, the screws would therefore enrich the air fuel mixture and lead to high CO emissions.

The EPA made several efforts to further investigate why the vehicles were not carefully tuned, including extensive tests with the manufacturer's participation (engagement), an examination into the maintenance procedure of the vehicle models of concern, and surveying dealership mechanics about regular maintenance practices. Following the EPA's newly established compliance procedures and guidance, the agency staff kept detailed and careful documentation of each action they took. This careful documentation turned out to be crucial evidence for the agency to ultimately win the case.

With detailed documentation, the EPA was able to provide the judge with the following description of the vehicles' maintenance and adjustment procedures.

> *The adjustment process is cumbersome and time-consuming, taking the mechanic approximately 30 to 40 minutes. The mechanic must first obtain a Chrysler Huntsville exhaust emission analyzer or other approved infrared analyzer, and must verify that it is warmed up and calibrated according to the manufacturer's instructions. He must check to see that the sample lines and connections of the sampling system for the analyzer are free of leaks, and must also warm up the vehicle's engine and allow it to idle for no more than ten minutes. Then the mechanic must remove the plug from the threaded catalyst tap on the vehicle and install the sample line of the analyzer in the tap upstream of the catalyst. This will generally require the mechanic to crawl under the car or to use a hoist. He must then start up the vehicle's engine and verify that the idle RPM and timing are within specification. At this point he must measure the idle carbon monoxide concentration. If it exceeds specified limits he must adjust the mixture screws on the carburetor to achieve a "leaner" mixture of fuel and air in the idle circuit, checking back and forth between the analyzer and the carburetor to monitor the effect of his adjustment on the idle mixture. A clockwise turn of a screw will decrease the amount of fuel discharged through the idle port and into the idle*

18 Communication with a former EPA officer.

19 The Chicago I/M program was one of the earliest, voluntary I/M programs in the United States, before the CAA gave the EPA authority to mandate it.

20 Communication with a former EPA officer.

> *circuit; a counterclockwise turn will increase the amount of fuel, resulting in a "richer" mixture. The adjustment screws are highly sensitive and must be turned in small fractions of a rotation in order to set the adjustment with sufficient precision. After making the proper adjustment the mechanic must also balance the mixture screws on a two-barrel carburetor for lowest level of hydrocarbons or smoothest idle within the prescribed specifications* (U.S. Court of Appeals for the D.C. Circuit, 1980).

Similarly, the EPA documented its survey of 27 mechanics at various Chrysler dealerships. According to EPA survey documentation, Chrysler mechanics concluded that "the procedure is cumbersome, time consuming and most importantly will usually result in customer dissatisfaction." (U.S. Court of Appeals for the D.C. Circuit, 1980)

With the agency's detailed records, the EPA demonstrated three main reasons that the required procedures were cumbersome and difficult to perform. First, the required emission analyzer was often unavailable: "41 percent of non-dealership service facilities lacked such analyzers as of August 1975." (U.S. Court of Appeals for the D.C. Circuit, 1980) Secondly, the Chrysler carburetor adjustment screws were so sensitive that any tiny rotations of the screws will grossly affect the idle fuel-air mixture. "A mere 1/20 of a turn of the mixture screws above Chrysler's specified adjustment range will cause a substantial increase in idle carbon monoxide." (U.S. Court of Appeals for the D.C. Circuit, 1980) Last but not least, even if the maintenance mechanics performed the exact adjustment specified by Chrysler, such an adjustment would lead to disruptions of the vehicles' smooth operation and prompt consumer dissatisfaction. "Generally speaking, a vehicle drives more smoothly and has a smoother idle with a relatively 'rich' fuel-to-air mixture. A Chrysler engineer admitted that the 'lean' idle setting specified by the Chrysler 'certainly affects idle quality'. As a result, to achieve better consumer satisfaction, mechanics are motivated to misadjust the vehicles." (U.S. Court of Appeals for the D.C. Circuit, 1980) Needless to say, these records held up as strong evidence in court.

Lessons

As one of the earliest vehicle emission recall cases in EPA history, the Chrysler case taught the agency several important lessons.

The first of these was simply that in-use performance of an aftertreatment system can be very different from a prototype design. This is a widely accepted fact now, but was a key lesson in the early stages of the U.S. compliance program.

In the Chrysler case, it was learned that components could fail due to bad design flaws that could not be easily identified during certification procedures. In this case, the issue was that the system design was not able to provide an adequate supply of oxygen to the exhaust stream, which was essential to the effective operation of the catalytic converter.

There were two major methods of controlling CO emissions. One used an external air pump to add air into the exhaust. This air would oxidize CO emissions from the engine and reduce CO emissions at the tailpipe. The other method was used to more precisely control the air-to-fuel ratio in the engine, so that the engine emitted less CO. The design of Chrysler's vehicles that were ultimately recalled used the second approach, which could save $50 per car over the first air pump approach. At that time, both technologies were available in the market. In fact, Chrysler used air pumps in its MY1975 vehicles sold to California in order to meet its more stringent emission standards. Chrysler decided to use the other approach for vehicles sold in other states. The second approach, with perfect calibration, could certainly pass the emission standards at the federal level. However, with daily use and maintenance, the system proved extremely difficult in achieving the emissions level of their “golden car” for certification.

The implications for regulatory agencies are the importance of requiring manufacturers to comply with emission standards throughout the vehicle’s useful life, and having an adequate in-use compliance program to follow up on designs of prototypes to make sure they work in practice. In the amendments to the CAA, there was specific language added requiring that “manufacturers must design, build, and equip each new vehicle to conform to emission standards at the time of sale and to be free from defects in material or workmanship that would cause the vehicle to fall below the standards within a five-year or 50,000-mile period after sale.” This was the basis for defining Chrysler’s violation.

The second lesson is the importance of maintaining careful documentation throughout the whole compliance testing and investigation process and allowing manufacturers to oversee the process. These were two important protocols that the EPA established in the 1970s, after additional lessons learned that will be elaborated on below.

Soon after the 1970 CAA was enacted, the EPA received a substantial amount of funding to initiate an in-use compliance program. After testing over a thousand vehicles and finding that a number of them were failing, potential recalls were discussed for the first time. It quickly became apparent in discussions with manufacturers that the manufacturers were going to challenge the data, because it was not collected in a very rigorous way. The engineers that were doing the testing brought the vehicles in, ran the tests, collected data, and sent the vehicles away. They had very poor documentation and did not have good records on whether or not the vehicles were properly maintained. It was an embarrassment to the EPA that the agency had spent a substantial amount of money and collected a lot of data that showed there were a lot of problems, but that the data was not rigorous enough to take to court.

Therefore, the EPA developed internal protocols for compliance actions including detailed documentation and engagement of manufacturers before and during the testing. If manufacturers agree to the qualification of test vehicles and the test procedures beforehand, it would be hard for the manufacturers to challenge the results later. More specifically, the agency allowed manufacturers to look at and examine every car that the agency was going to test beforehand. In other words, manufacturers had the opportunity to point out if there was any evidence that the vehicles were not properly maintained, and therefore should not to be considered part of their fleet for the purpose of the recall. Since manufacturers couldn’t know in advance whether the vehicle was going to pass or fail, their focus had to be on whether the vehicle was properly maintained, tampered with, or anything similar that could disqualify the vehicle. And of course, they couldn’t disqualify all of the vehicles since that was not a reasonable option.

This process was critical in helping the agency identify the issue with Chrysler’s vehicles. When the Chrysler emissions issue was identified by I/M data, the EPA obtained vehicles for its own testing. When Chrysler argued that the vehicles were not “properly maintained,” the agency investigated why so many vehicles could be poorly maintained, hence the discovery of the bad carburetor screw design.

It is also very useful to allow manufacturers to observe the testing. If the manufacturers point out that something is wrong in the testing process, the agency can correct it immediately rather than after the fact. This way, when the EPA receives the testing data, the data should be strong enough to defend the agency's overall result. Over time, the EPA learned how to obtain sensible data. As a result, as the EPA identifies cases, if the issues are clear-cut, manufacturers will likely go ahead and do a voluntary recall.

Throughout the entire process of test vehicle procurement, testing, and further investigation into the Chrysler case, detailed and thorough documentation was key, as was discussed in the discovery of the issue.

The third lesson is that I/M programs are useful for identifying certain emissions violation issues such as broken parts, poor durability of components, and inadequate maintenance, and therefore can be useful data sources for emission recalls.

However, there is an important difference between I/M failure and recall. As an in-use fleet screening program, I/M emission thresholds are set more leniently than the new vehicle emission standards. I/M fails vehicles that emit a few times higher than the certification emission limits, while a recall fails vehicles that emit even a relatively small margin above the certification emission limits (to allow for testing variability). I/M also fails vehicles with issues that consumers are responsible for, such as lack of maintenance. For noncompliance issues due to manufacturer responsibility, regulatory agencies need other data sources. This will be discussed further in the next section.

5.2 GENERAL MOTORS 1995 RECALL

In 1995, the U.S. Department of Justice (DOJ), on behalf of the EPA, alleged that General Motors Corporation (GM) installed illegal devices inside nearly a half-million cars since 1991 to defeat pollution controls, which resulted in carbon monoxide (CO) emissions of up to three times the legal limit. An additional claim involved GM's failure to notify the EPA about all of their emission control strategies for LDVs (Department of Justice [DOJ], 1995). The allegation affected MY1991-1995 Cadillac, including the Seville and Deville models equipped with GM's 4.9-liter engine. The auto company recalled and retrofitted the 470,000 affected vehicles and implemented other remedies to settle the government charge. The company also agreed to pay an $11 million civil penalty for an estimated total cost of $45 million.

The computers in these vehicles were programmed to enrich the fuel by increasing the amount of fuel relative to air when the vehicles' climate control system was in operation for heating or cooling. GM developed this new engine calibration to respond to customer complaints of stalling and other drivability problems in 1991 and also installed the device in its MY1995 Cadillac (Cushman Jr., 1995). However, the resulting air/fuel ratio was too rich for the cars' catalytic converters to oxidize the CO emissions, and the tailpipe emissions doubled or tripled the allowable levels. This calibration is a defeat device that reduced the effectiveness of the vehicles' emission controls during real-world driving; in addition, GM did not adequately disclose this calibration to the EPA.

Discovery

In the fall of 1993, EPA tests showed that the engines emitted up to 10 grams of CO per mile with the climate control on, well above the 3.4 grams/mile limit (DOJ, 1995). However, the vehicles' high pollution levels did not register in federal certification tests since the laboratory tests at the time were not designed to include driving conditions with the climate control system on.

The EPA detected the problem during a research project, led by the EPA Office of Transportation and Air Quality (OTAQ or the EPA's air office), to develop new off-cycle driving cycles, later known as the Supplemental Federal Test Procedure (SFTP). GM loaned a Cadillac to OTAQ for these specially designed tests including conditions with air conditioning on. This special testing indicated the Cadillac car had abnormally high CO emissions. The car performed well on normal FTP testing, but not when the air conditioning was turned on.

GM disagreed with the allegations by the government, and said that it was a matter of interpretation of current regulations, regarding the complex issue of off-cycle emissions. Some observers also defended GM, arguing that CO pollution is primarily an issue in the winter (Adler, 1998), hence the emissions impact of this violation was not as big as the test showed. Even so, the company worked extremely hard to resolve the matter with OTAQ and avoid litigation (Brown & Thomas, 1995).

Unfortunately, the nature of this case was later defined as violating the larger principle due to the use of an emission defeat device. At the time, the EPA Office of Enforcement and Compliance Assurance (OECA, or the EPA's compliance office) was also pulled into the case. OECA handles matters requiring legal action to seek remedies or financial compliance penalties. OECA discovered records showing that GM technicians knew about the emissions impact of their new engine calibration, but buried the information. This became the ultimate proof that GM intentionally installed defeat devices on its vehicles.

Outcome

This defeat device case was discovered as the technology assessment and regulatory development testing was being conducted to develop SFTP standards. This project was initiated due to a new mandate in the 1990 Clean Air Act requiring that the EPA revise the FTP to be more representative of real-world driving. Though this case did not directly cause the development of SFTP test procedures and standards, the case serves as a good example of why expanded FTP test cycles and procedures are necessary. It should be noted that SFTP standards include the SC03 SFTP that represents engine load and emissions associated with the use of air conditioning,

Lessons

This case reinforces that certification and in-use compliance tests in the laboratory are useful, but are a very limited tool in ensuring that manufacturers are not using defeat devices. It is important to also engage in-use testing under real-world driving conditions. Regulators need to revisit their certification procedures and approaches to best reflect real-world driving. Supplemental test cycles can be very effective in representing in-use driving patterns—including extreme driving patterns—and in reducing real-world emissions. However, detection of defeat devices still requires additional in-use testing under off-cycle conditions, which go beyond the conditions represented in the original FTP plus expanded SFTP test cycles.

This is especially important as vehicle technologies evolve rapidly for better drivability, conformability, fuel economy, etc., and consumers' driving behaviors change accordingly. For example, when the EPA initially developed the FTP test cycle, a motor vehicle air conditioning system was so costly that only a small portion of vehicles were equipped with one. By 1969, 54% of domestic automobiles were equipped with air conditioning (National Academy of Engineering, 2016). However, at the time of the GM case in 1995, nearly all vehicles had an air conditioning system as a basic feature, and the system was operating daily when the vehicles were in use.

Secondly, even though defeat devices are more often deployed on diesel vehicles and engines due to the trade-off between NO_X emissions and fuel economy of certain technology options, they can and are installed on gasoline vehicles. This is something that could be easily ignored by regulators.

5.3 HEAVY-DUTY DIESEL ENGINE 1998 DEFEAT DEVICE RECALL

In 1998, the DOJ and the EPA settled a consent decree (D.C. District Court, 1998) with seven diesel truck and engine manufacturers—Caterpillar Inc., Cummins Engine Company, Detroit Diesel Corporation, Mack Trucks, Inc., Navistar International Transportation Corporation, Renault Vehicules Industriels, s.a., and Volvo Truck Corporation—for installing computer-based strategies manipulating the vehicle code to override the emission controls (defeat devices). The defeat devices were designed to disable the emission control system during normal highway driving (real-world conditions) to maximize fuel economy, but kept the system in effect during laboratory testing, so that the engines would meet the EPA's emission standards. The disabling of the system during highway driving meant up to three times the limit of nitrogen oxide (NO_X) was being emitted.

The consent decree levied $83.4 million in civil penalties against the companies. In addition, the EPA required the companies to introduce new cleaner engines, rebuild or retrofit older engines to cleaner emission levels, recall all vehicles and engines with existing defeat device technology installed, and conduct new in-use emissions testing. The companies collectively spent over $1 billion on the largest settlement in environmental enforcement history. This case also had a profound impact on future emission regulations and the diesel engine industry overall. After the settlement, the EPA worked with CARB to develop an NTE standard applicable to all in-use heavy-duty diesel engines, mandatory for MY2007 and later.

Discovery

Prior to this case, EPA emission regulations for heavy-duty diesel engines mainly focused on certification and less on verifying real-world driving emissions. The issue was discovered when the EPA was conducting some research-oriented testing using their newly invented tool for on-board vehicle emissions testing. The tool was invented by an EPA engineer, Leo Breton, and at the time was called the Real-time Onroad Vehicle Emissions Reporter (ROVER) (Johnson, 2002). Today this device is generally referred to as the Portable Emissions Measurement System (PEMS). In the late 1990s, the EPA used the tool to collect data for setting up a new regulation on exhaust gas recirculation systems for diesel engines. EPA engineers deployed the tool on a couple of trucks and drove them around Virginia. What they observed from the real-world emissions profile was that the emission control systems were doing things differently from what was expected. This tool later enabled effective investigation into the diesel engine noncompliance issue, and even later became part of the standard test protocol.

Around the same time, EPA staff got information and data from an anonymous engine manufacturer reporting abnormal emission performance behaviors of some truck engines produced by their competitors[21]. This triggered a broader EPA investigation into in-use diesel engine compliance, using PEMS testing. The PEMS tests were not as accurate as they are today, so they could not be used to charge the manufacturers in

21 Communication with an EPA officer

court. The PEMS data did show that vehicles were producing emissions two, three, or 10 times above the standard, and helped the EPA generate a lot of data relatively cheaply.

The EPA then began to legally request that manufacturers bring in engines for testing under conditions that would mimic the real-world driving conditions during the PEMS tests in which they saw high emissions. They ran the engines on the regulatory test cycle, then on slightly modified cycles in the laboratory, and the results were very different.

The test data allowed EPA staff to talk to the manufacturers and ask for an explanation. The agency believed the most reasonable explanation was a defeat device. The question got sorted out quickly, but the agency spent a lot of time negotiating. The leverage the agency had was the new engine type approval (or certificate of conformity) that is granted only to a product that meets a minimum set of regulatory, technical, and safety requirements. Type approval is generally required before a product is allowed to be sold in a country. For the automotive industry in the United States, a certificate of conformity is the document that the EPA issues to a vehicle manufacturer to certify that a vehicle class conforms to EPA requirements.

Outcome

This case brought significant changes to the certification requirements and procedures of diesel engines. The EPA began to require manufacturers to conduct more testing based on the map of the engine, and to meet NTE emission levels that apply to various operation modes of the engines—high/low load, high/low speed, etc.—with PEMS testing officially adopted. These additional testing requirements and emission limits broadened the conditions under which manufacturers must comply with the emission standards.

This case also triggered the EPA to investigate and start putting resources into HDV compliance. Prior to this case, most of the EPA heavy-duty test cell capacity was dedicated to regulatory development testing in support of an effort to adopt more stringent heavy-duty standards, and little to no confirmatory testing was being done as part of certification. It was expensive to pull heavy-duty engines from commercial vehicles to perform in-use surveillance testing; these engines are certified to engine standards rather than whole vehicle standards. At the time, relatively few resources were allocated toward heavy-duty compliance activities. The defeat device issue was discovered as part of the regulatory development work being done and pursuit of the issue was facilitated as PEMS technology was just beginning to mature. Pursuit of the defeat device case contributed to the acceleration of the agency's development of PEMS technology, which in turn allowed the agency to directionally move its heavy-duty compliance program in the direction of emphasizing in-use compliance testing as had happened much earlier in the case of the light-duty sector.

In recent years, the EPA has improved testing facilities that make it more possible to perform more certification confirmatory testing and/or in-use testing under the full heavy-duty engine test procedures. However, in-use testing based upon PEMS type testing remains the mainstay of heavy-duty in-use compliance testing.

Lessons

A lesson from this case is that unanticipated issues may develop as vehicle and emission control technologies advance and emission regulations become more complicated. Regulatory agencies should clarify their intentions or interpretations in setting regulations, adjusting them as they increase their knowledge. This helps them identify potential for undercutting the purpose of any regulations they set.

Another critical lesson is that environmental authorities need to have clear legal authority and some concrete leverage in order to enforce the emission standards. In this case, the companies in violation were leading global manufacturers that represented about 95% of the U.S. diesel engine market at the time (Reitze, 2001). The EPA's authority to approve the COC for the new engines and vehicles that these companies produce was key leverage to get industry to settle on this case.

5.4 TOYOTA 2003 OBD SETTLEMENT

In 2003, the DOJ and the EPA announced a settlement (D.C. District Court, 2003) of the government's lawsuit against Toyota Motor Corporation (Toyota) for Clean Air Act violations involving 2.2 million vehicles manufactured between 1996 and 1998, including some Camry, Avalon, Corolla, Tercel, Paseo, Lexus, Sienna minivans, 4Runner, RAV4, Tacoma and T100 models. Toyota was charged for not disclosing limitations of the OBD systems on the affected models in monitoring leaks in the vehicles' evaporative emission control systems. Under the settlement, Toyota agreed to conduct a supplemental environmental project, extend the evaporative emission control system warranty on affected vehicles, accelerate its compliance with certain new evaporative emission control requirements, and pay a $500,000 civil penalty. The settlement cost Toyota an estimated $34 million in total.

Discovery

Toyota's evaporative system monitoring issue was first discovered by CARB. The agency had filed a case before the DOJ and the EPA on this, but lost the case. In late 1991, CARB instituted evaporative OBD II regulations and required implementation on all new gasoline cars in 1996. The objective of OBD is to have the OBD system detect emissions-related malfunctions while the car is being driven in the real world. According to the specific requirement of the regulation (sections 1968.1(b)(4)), the OBD monitoring system on the vehicle is supposed to detect evaporative system faults and leaks.

When Toyota applied for certification, CARB staff questioned the design of the company's OBD monitoring system since the description in their application "was too simple compared with the systems of other OEM's."[22] However, based on laboratory tests, Toyota's evaporative system monitor was able to run on the FTP tests. CARB approved the firm's computerized emissions-sampling system in 1995 for its MY1996 vehicles based on laboratory tests. This was repeated for Toyota's MY1997 and 1998 vehicles.

OBD II regulation authorizes CARB to perform confirmatory testing of manufacturers' OBD systems in order to determine compliance with certain malfunction criteria identified in the manufacturer's approved certification documentation. In June 1997, as part of the confirmatory testing process, CARB conducted additional testing to challenge the OBD systems of Toyota's vehicles. The agency found a few employees of California EPA office who owned Toyota cars. The agency punched a 0.04-inch hole in the evaporative systems in each of the vehicles, and drove them (DeLong, 2002). The OBD system in the tested vehicles could not identify the leak in the evaporative emission control systems. The system didn't take samples frequently enough to always trigger the MIL (dashboard-

22 Communication with a former CARB officer.

mounted "check engine" emissions warning light). In September 1998, CARB issued a formal notice of nonconformity, and ordered Toyota to recall approximately 337,700 vehicles that had been manufactured and certified for sale in California.

However, Toyota argued that the OBD regulation (sections 1968.1(a)(1.9) and (b)(4.3)) only required that the evaporative system monitor run during conditions that are "encountered at least once during the first engine start portion of the applicable FTP test." Toyota also argued that, even if the monitors on these cars didn't run, their evaporative emission control systems were so well designed and so durable that they would never fail in-use anyway, hence there would be no emissions problem. In other words, Toyota believed their vehicles met all standards that existed when CARB approved those certifications. Thereafter, Toyota filed a petition for a hearing on the recall order, which CARB referred to an administrative law judge (ALJ) from the California Office of Administrative Hearings.

Outcome

CARB eventually lost that case. On February 22, 2000, the ALJ issued a Proposed Decision, recommending that the CARB recall order be dismissed. CARB decided to prevent this from happening again by strengthening the regulation's language. This is reflected in the entirely new OBD II regulation released in 2002, section 1968.2 of title 13, California Code of Regulations (California Air Resources Board [CARB], 2013), which superseded section 1968.1 for 2004 and subsequent model year vehicles.

The main changes were adding new performance requirements to ensure that monitors ran frequently during real-world driving conditions. Section 1968.2 has new requirements that would require the OBD II systems on vehicles to keep track of how often the vehicle is driven and how often the monitors run in the real world. Section 1968.2 also set minimum performance criteria that manufacturers must meet—the criteria was basically the minimum required number of times the monitor has to run in-use.[23]

Before a decision from the ALJ was made, the federal agencies (DOJ and EPA) began to investigate the issue and filed a lawsuit on July 12, 1999. Instead of charging the Toyota vehicles for excessive evaporative emissions, the court alleged that Toyota did not disclose certain conditions that enable OBD monitoring of the evaporative emission control system to occur, and the result was a less effective OBD system to detect an anomaly in the evaporative emission control systems. This time, Toyota lost in court, and a consent decree (D.C. District Court, 2003) was reached between the company and government in March 2003.

Lessons

There are two major lessons from this recall case. First, noncompliance can be flagged at the certification stage with appropriate follow-up in-use testing for verification. Technical expertise of the regulatory staff at certification is crucial when it comes to a system like OBD.

Second, regulatory agencies should always be prepared for a learning curve on new technologies and should keep a steady growth in their capacity along with the industry. Regulatory agencies should also be able to incorporate their learning into the

23 Details of these "in-use monitor performance" requirements are in the 2002 staff report (starting on page 49 in http://www.arb.ca.gov/regact/obd02/isor.PDF) and in sections 1968.2(d)(3.2), (d)(4), and (d)(5) of the OBD II regulation (starting on page 14 in http://www.arb.ca.gov/msprog/obdprog/section1968_2_clean2013.pdf).

development of future regulations. Improving regulatory programs to reduce real-world emissions is one of the core goals of a compliance program. This is also reflected in the 1998 diesel engine defeat device recall case discussed previously.

5.5 MERCEDES-DAIMLER 2006 DEFECT REPORT SETTLEMENT

In 2006, Mercedes-Benz USA and Daimler-Chrysler AG was fined $1.2 million in civil penalties to resolve its failure to promptly notify the EPA about three emission control defects involving the catalytic converter system and air pumps on numerous MY1998-2006 vehicles. The manufacturer was also required to improve its emissions defect investigation and reporting system to ensure future compliance, at a cost of approximately $1 million per year. The consent decree (D.C. District Court, 2006) also led to voluntary recalls for two of the three defects and extended warranty coverage from the company to address a third defect, at an estimated cost of $59 million.

Lessons

The major lesson learned from this case is that manufacturer defect reporting (to be discussed in fuller detail in the next section) is a critical part of the EPA compliance program, as it is an important data source to identify potential recalls. Even though this case is referring to the EPA's defect reporting program, is it worth noting that California has adopted a more comprehensive and rigorous emission warranty and defect reporting program.

The CAA requires auto manufacturers to file a defect information report[24] with the EPA no more than 15 working days after an emissions-related defect is found to affect 25 or more vehicles. Then the EPA considers whether the defect will cause emission standards to be exceeded and whether a recall is necessary. Based on manufacturer reports, the EPA can test the cars with defects to determine if they should be recalled. While most defect reports do not lead to recalls, many recalls occur because of these defect reports. Manufacturers are penalized if they do not report defects in a timely manner.

Entering the 20th century, the EPA's vehicle emission compliance program had matured, and the agency became more rigorous at data reporting and was able to start coming down hard on manufacturers for things like poor documentation, even when it does not necessarily lead to increased emissions. This helps the agency ensure that the industry does not get sloppy in taking on the responsibility to ensure in-use emission compliance. This also frees up the agency to spend more time and resources on investigating more subtle issues, such as defeat devices.

5.6 VOLKSWAGEN 2015 DIESEL DEFEAT DEVICE RECALL

On September 18, 2015, CARB issued an in-use compliance letter (ARB, 2015b) to Volkswagen AG detailing violations. On the same day, the EPA issued a Notice of Violation (EPA, 2015d) to the company. The agencies alleged the company used defeat devices to circumvent CARB and EPA emissions test procedures on all of its MY2009–MY2015 2-liter engine diesel cars, covering the following models: Jetta, Jetta Sportwagen, Beetle, Beetle Convertible, Golf, Passat, and Audi A3. Shortly after, in November 2015, the EPA issued another notice (EPA, 2015e) to VW with regard to alleged defeat devices on all 3-liter diesel engine models. This recall affected almost 600,000 total vehicles in the United States and roughly 11 million vehicles worldwide (Dieselnet, 2015).

24 Section. 208(a) and 301(a), Clean Air Act, as amended (42 U.S.C. 1857f–6(a) and 1857g(a)).

During official laboratory testing, the vehicles' electronic control module (ECM) ran software that produced compliant emission results, the so-called "lab calibration." Under normal, real-world driving conditions, the vehicle ECM software ran a separate "road calibration," which reduced exhaust gas recirculation (EGR), modified fuel injection timing, reduced the regeneration events of vehicles equipped with lean-NO_x traps (LNTs), and reduced the amount of urea injection for vehicles equipped with selective catalytic reduction (SCR) systems. As a result, NO_x emissions increased by a factor of 10 to 40 times the standard, depending on the type of drive cycle and the vehicle model (EPA, 2015d).

On October 25, 2016, the court approved the Volkswagen AG settlement totaling $14.7 billion between the two related settlements for MY2009–2015 2.0-liter diesel vehicles sold or leased in the United States (DOJ, 2016; Ambrosio, 2016). About $10 billion will be used for vehicle buy-back and around $4 billion will be spent on supplemental projects, including $2.7 billion on a mitigation trust and $2 billion on zero emission vehicles. On January 10, 2017, Volkswagen AG's board signed off on the $4.3 billion settlement of U.S. criminal and civil penalties. Thus far, the scandal has cost the company over $23 billion in the United States and Canada alone (Fist M., 2017), and six executives are facing criminal charges (Tabuchi H., 2017).

Discovery

The EPA and CARB were alerted of the emissions issues with VW's diesel vehicles in May 2014 when the International Council on Clean Transportation (ICCT) and West Virginia University (WVU) published results of a study commissioned by the ICCT, which found significantly higher in-use emissions from two of the three diesel cars tested (EPA, 2015d). The ICCT has been investigating diesel vehicle emissions in various top auto markets for several years and, in 2012, conducted PEMS testing on diesel cars sold in the United States to gain a greater understanding of how effective NO_x control technologies are across various markets.

The two VW light-duty diesel vehicle models involved were a 2012 Jetta and a 2013 Passat.[25] The results confirm that the real-world emissions from these vehicles considerably exceeded U.S. NO_x emission limits (Franco, German, Posada, & Mock, 2014). The other vehicle tested in the study, a BMW X5, was well within the regulated emissions range during real-world driving conditions. CARB collaborated with the ICCT throughout this study and conducted laboratory testing on the official emission test cycles. The ICCT report was released publically on the website on Oct, 2014.

More rigorous follow-up testing was led and conducted by CARB and the EPA. It took both agencies over a year to independently confirm defeat devices were installed on these vehicles. Meanwhile, in December 2014, VW initiated a voluntary recall affecting roughly 500,000 vehicles in the United States, with nearly 50,000 in California alone. VW did not admit the company had installed defeat devices. Instead, the company claimed it was a technical issue that could be fixed by reflashing the engine chip, which didn't work.[26]

---

25 Vehicle models are not named in the original report.

26 On May 6, 2015, CARB conducted confirmatory testing on a MY 2012 Gen2 VW cars (cars with SCR technology) over required certification cycles and on the road using PEMS. On some certification cycles, the vehicles were failing the NO_x standard. PEMS testing showed that the calibration reduced the emissions to some extent, but NO_x emissions were still significantly higher than expected.

For a more controlled evaluation, CARB drove Phase 2 of the FTP test repeatedly. This special cycle showed that the calibration did increase diesel exhaust fluid (DEF) dosing upon initial startup, but it was not sufficient to keep NO_x emissions from rising throughout the cycle. This leads to high NO_x emissions despite the selective catalytic reduction reaching sufficient operating temperature.

On July 8, 2015, CARB shared the test results with both VW and the EPA. None of the potential technical issues suggested by VW could explain the higher test results consistently confirmed during CARB's testing. Finally, CARB and the EPA told VW they would not approve COCs for VW's MY2016 diesel vehicles until VW could more adequately explain the anomalous emissions and assure the agencies that their MY2016 vehicles would not have similar issues. Only then, on September 3, 2015, did VW admit it had designed and installed a defeat device in these vehicle models in the form of a sophisticated software algorithm that detected when a vehicle was undergoing emission testing (EPA, 2015d).

Outcome

The immediate outcome of this case was CARB and the EPA adopting additional testing procedures to ensure diesel vehicles continue to meet emission standards when they are being driven on the road. On September 25, 2015, CARB sent a letter (ARB letter to manufacturers, 2015) to all manufacturers announcing that the agency would soon introduce a defeat device screening test based on newly developed detection methods and may include OBD interrogation, PEMS testing, and special driving cycles, in addition to the standard certification emission test cycles included in their In-use Compliance Program. Shortly after, the EPA also notified automakers that it may test or require testing on any vehicle at a designated location, using driving cycles and conditions that may reasonably be expected to be encountered in normal operation and use, to identify a potential defeat device (EPA, 2015f). Such testing can be expected in addition to the standard emission test cycles when emission data vehicles[27] and fuel economy data vehicles[28] are tested by the EPA.

Lessons

The most important lesson learned from this case is that certification testing alone is not sufficient to address sophisticated issues such as defeat devices. Only when combined with advanced in-use compliance and testing programs can the standards ensure emissions reduction occurs during real-world driving. Even though it seems like history was repeating itself, today's defeat devices are far more complicated than those in the 1998 diesel engine case. In the 2015 VW case, the software of the vehicles detects whether the vehicle is being tested or not based on various inputs. These inputs precisely track the parameters of the federal test procedure used for emission testing for regulatory certification purposes. There are still several additional areas where the current emission testing programs require enhancement to prevent against the modern ways of cheating.

Another valuable lesson is that independent empirical research projects can serve as a valuable source of information and data for the regulatory agencies to flag any issues early on. Partnership between government agencies and research entities can be a useful complement to the limited government resources dedicated to identifying noncompliance issues. The ICCT decided to test diesel cars due to the unique perspective of diesel vehicle

27 Vehicle configuration selected to represent the exhaust emission compliance of the test group

28 Vehicle configuration selected to represent the fuel economy compliance of the test group

emissions in the European market. However, in the U.S. market, diesel engines are less than 1% of the vehicle market, and are therefore not chosen as target classes under EPA or CARB compliance testing programs. The testing project by ICCT and WVU perfectly filled this gap within the existing regulatory program.

Table 1 summarizes the six recall and enforcement cases discussed in this section.

Table 1. Summary of recall and enforcement cases reviewed

Year	Case	Discovery	Lessons
1978	Chrysler recall	Inspection and maintenance program data	• In-use performance of engine and aftertreatment systems can be very different from their prototype design. • Careful documentation throughout the entire compliance testing and investigation process and allowing manufacturers to oversee the process are the keys to a successful recall. • I/M data is useful in identifying certain in-use noncompliance issues.
1995	General Motors defeat device recall	EPA research-oriented testing	• In-use testing under broad driving conditions is important, even for gasoline vehicles.
1998	Heavy-duty diesel engine defeat device recall	EPA research-oriented testing	• During the early stages of regulations, there might be undefined areas, and agencies should seek to clarify the interpretation of regulations as new technologies/testing tools emerge. • The authority to approve a certificate of conformity gave the agencies concrete leverage to enforce emission standards.
2003	Toyota OBD settlement	Certification and in-use testing	• Noncompliance can be flagged at the certification stage with appropriate follow-up in-use testing for verification. • Feedback from in-use testing program should be used to inform and improve future regulations, acknowledging a learning curve for regulatory agencies.
2006	Mercedes-Daimler defect report settlement	EPA investigation	• Defect reporting is an important data source for identifying noncompliance. • More recently, the EPA became diligent in recording data and reporting.
2015	Volkswagen diesel defeat device recall	Independent real-world testing projects, followed by rigorous agency (CARB) testing and investigation	• Modern defeat devices are much more technically sophisticated than they were decades ago and require innovative testing approaches to detect them. • Independent research projects can be a good source of data to flag noncompliance.

6. DATA SOURCES FOR IDENTIFYING IN-USE NONCOMPLIANCE

Emission recalls are an effective enforcement tool utilized by regulatory agencies to penalize for noncompliance. The key to successful recalls is the regulatory agencies' ability to accurately identify noncompliant vehicles with defensible data. The proof used to recall vehicles or bring companies to court come from the regulatory agencies own in-use surveillance testing results. However, the agencies use a broad range of information and data sources to determine the need for further investigations that may lead to recalls. In general, agencies target vehicle classes based on (a) certification data; (b) information from state I/M and OBD programs; (c) failures at manufacturer-run in-use testing ; (d) manufacturer warranty data and defect reports; (e) technical service bulletins and complaints at servicing; (f) technical service bulletins; (g) independent research and tests, etc. Figure 6 illustrates the data sources and class targeting for recalls.

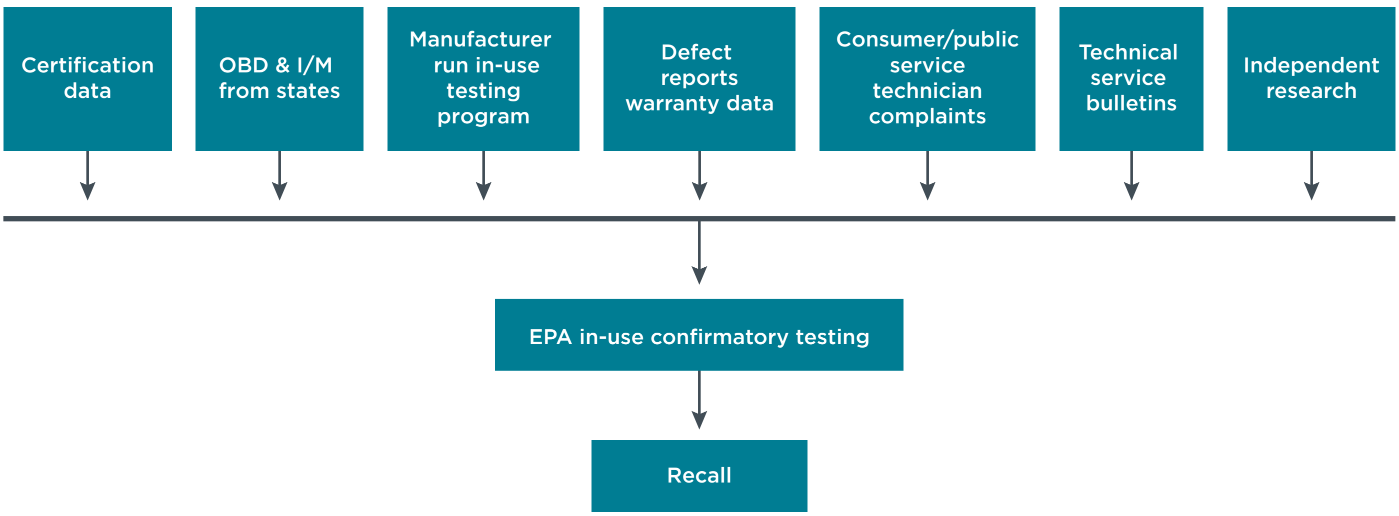

Figure 6. Data sources leading to recalls

It is important to understand that the diagram in Figure 6 shows the EPA's effective data sources utilized today. In the early days, almost none of them worked well, because if the regulatory agency couldn't perform effective in-use testing and have a defensible database to prove the vehicles are failing standards, all other data are considered indirect inferences. Therefore, in the early stages regulatory agencies should focus efforts on in-use testing. All other data sources are used to guide in-use testing. For this reason, this section starts off by explaining the in-use compliance testing performed by regulatory agencies, followed by a description of additional information sources.

6.1 IN-USE COMPLIANCE TESTING PROGRAM RUN BY REGULATORY AGENCY

In-use surveillance testing was one of the earliest established compliance programs at the EPA and CARB. Regulatory agencies generated their own data to verify in-use emission compliance of the vehicles and engines they certified. According to a former CARB officer, "In the early days the only sources that the agency had were simply certification data and in-use testing data generated by the agency. That was it."

For light-duty vehicles, in-use vehicles are tested at the Ann Arbor, Michigan, lab, unless otherwise designated by the EPA, following the same test procedures and fuels used in certification. Manufacturers are informed and invited to watch the maintenance and tests being performed so they have complete confidence in the quality of the tests and the corresponding results.

The tests are performed in two phases.

During the surveillance phase, the tests are intended as a quick screening. The EPA typically recruits in-use vehicles that are between 2 and 3 years old from neighborhoods surrounding the Ann Arbor lab. Vehicles are selected from private owners, government fleets, and rental fleets using a statistical procedure to gain a random sample. Engine families, large and small, are tested and all manufacturers are tested every couple of years. Vehicle owners are given small monetary compensation, about $20 per day up to $200 in total, and a loaner car. Vehicles that have not been properly maintained or have been tampered with are eliminated, although the surveillance phase of tests has more liberal vehicle acceptance criteria. The agency inspects vehicles for things like hose connections, fluid levels, and gross exhaust leaks, to ensure that there have been no oil, air filter, or spark plug changes and no relevant part replacements.

Regulatory agencies, such as the EPA, may hire a contractor to conduct the vehicle recruitment and screening process. However, CARB no longer uses contractors for procuring vehicles for in-use compliance testing, after a situation where test data was inadequate for enforcement actions due to the inclusion of unqualified vehicles, initially recruited by a contractor.[29]

The EPA tests up to five vehicles per class, but cuts off after three vehicles pass to allow more classes to be tested with limited resources. If one or more of the three vehicles fail, the agency will add two additional vehicles from the same test group. If more fail, the EPA will discuss it with the manufacturer. Sometimes the manufacturer will bring testing data to the meeting or will provide explanations that are satisfactory, such as the test vehicles are outliers. If not, the EPA and the manufacturer agree upon some acceptable solutions, such as voluntary recall, field fix, or extended warranty.

The scope of surveillance testing is about 50 test classes and about 150 vehicles each year. Table 2 below shows total vehicles and groups tested in the past few calendar years (CYs).

Table 2. Number of test classes[a] selected in surveillance testing for LDV, CY2007-CY2013

CY	2007	2008	2009	2010	2011	2012	2013
Number of classes	47	45-50[b]	45	45	50	33	25

[a] A test class is a group of vehicles with very similar design characteristics from an emissions standpoint.

[b] Estimated based on number of car lines, manufacturers, and model year tested

Source of data: EPA compliance reports, multiple years

The second and final phase is called in-use confirmatory testing. The testing enters the confirmatory phase when surveillance results indicate that a substantial number of vehicles in the class may exceed emission standards or if the manufacturer declines to voluntarily remedy or recall the vehicles.

29 Communication with a former CARB officer.

Procurement and testing are much more rigorous in this phase than for surveillance testing because vehicles must be shown to fail even when properly maintained and used. The test data needs to be able to stand up in court, and these stages are the prelude to a recall being ordered. The EPA has to conduct more prudent checks and maintenance including screening for oil change receipts, overweight towing, inspection for hose connection, fluid levels, tampering, racing (headers), and compression pressure check. The EPA must also make sure there have been no oil, air filter, or spark plug changes and that no parts have been replaced. Unscheduled maintenance on either emissions-related or non-emissions-related parts are only allowed under select circumstances.[30]

For confirmatory testing, the EPA tests 10 or more randomly selected, properly maintained, and used vehicles. As with surveillance testing, manufacturers are invited to watch the maintenance and testing. Compliance decisions are finalized based on the level of failure in the class and confidence level of the results. There is no set number of failures to trigger the ordered recall process. Typically, if more than two of the vehicles in the sample fail, or if the mean of the sample is over the standard by more than 20% for any pollutant with high statistical confidence, there is reason for further action. If a manufacturer refuses to order a recall, a legal hearing will be initiated. "This rarely happened," according to a former EPA officer.

The purpose of confirmatory testing is to put an emphasis on a voluntary remedy. Ordered recalls are the ultimate deterrent since recalls will lead to bad press for manufacturers and are costly to defend. Voluntary recalls are the norm because of the deterrent effect of the program. In addition, there are also creative alternatives to a recall, such as extended warranties and special service campaigns. These alternatives are much more timely remedies for the in-use problems, are less contentious, and provide better press for the manufacturers.

For heavy-duty and non-road engines, regulatory agencies monitor and verify compliance using PEMS testing, which tests the engines during normal operation and compares the results against NTE in-use emissions limits. The EPA's in-use testing is conducted at the Ann Arbor lab and the Department of Defense testing lab in Aberdeen, Maryland. For HDVs, the majority of in-use tests are conducted by manufacturers as part of the requirements of the heavy-duty in-use testing rule (40 CFR Parts 9 and 86; EPA, 2005; Federal Register, 2008). Manufacturers are required under the rule to conduct in-use testing to demonstrate compliance with the NTE limits, which are generally 1.25 or 1.5 times the applicable standards on laboratory test cycles. The EPA established a mandatory pilot in-use testing program for gaseous pollutants (HC, CO, NO_x) in 2005–2006, and for particulate matter (PM) in 2007-2008. The program became fully enforceable for gaseous pollutants starting in 2007. Exceeding NTE limits during in-use testing does not necessarily indicate a violation or noncompliance. The EPA will make decisions regarding follow-up action on a case-by-case basis, and to date no action has been taken.

In addition, the EPA also uses the in-use data to evaluate the manufacturer's deterioration test methods. If in-use emissions are higher than predicted by the manufacturer during certification, then the manufacturer is required to revise its

30 For example, the part failure or system malfunction, or the repair of such failure or malfunction, does not render the vehicle or engine unrepresentative of vehicles or engines in use and does not require direct access to the combustion chamber, except for spark plug, fuel injection component, or removable prechamber removal or replacement.

deterioration procedure to match the in-use test results. This keeps the deterioration factors derived for certification purposes accurate and relevant.

6.2 CERTIFICATION TEST DATA

A manufacturer must obtain a COC from the EPA before beginning mass production. The certification process begins when a manufacturer submits to the EPA an application for certification for a group of vehicles or engines with similar emission characteristics (families). The application must contain information about engine design, production volume, and type of emission control equipment installed. It also must include manufacturer test and deterioration data to show that the vehicle or engine meets all of the emission standards for its regulatory useful life. The EPA is more likely to conduct confirmatory tests on vehicle models that have had problems during certification, or have emission levels too close to the limit of the standard (with small compliance margins).

CARB has certification procedures similar to the EPA. Additionally, CARB approves OBD systems as part of their certification process. The EPA simply accepts CARB's decisions on OBD systems. For the approval of OBD systems, CARB requires manufacturers to provide a detailed description of how the monitors function.

Since technical judgment at certification is particularly important, certification staff within these regulatory agencies are expected to have extensive knowledge of engines and emission control technologies. They conduct a comprehensive review of the data and description provided by the manufacturers and, if necessary, have meetings with them to address topics such as "how certain emission control can be achieved with the system design described in your application." A typical certification engineer would spend several hours analyzing one engine family. CARB has about 35 staff members responsible for reviewing the certifications of light-duty, heavy-duty, motorcycle, and non-road engines.[31]

This process can also target potential issues down the road, for example, by paying attention to engine and vehicle specifications and margins of the test results. A good example of this is the Toyota OBD case reviewed in the previous section of this paper. According to a former CARB officer, one of the earliest emission recalls issued by the agency was flagged during the review of the manufacturer's certification report, when CARB staff noticed an unusually complex carburetor design. Even though CARB did not receive empirical evidence of excessive emissions in the system design at the certification stage, the agency used the information to target this model for in-use testing.

It is worth noting that, under the robust compliance program the EPA has developed over several decades, new vehicles are typically certified in the United States at one-third to one-half of the emissions limit in order to ensure compliance over the full useful life of the vehicle as emission controls degrade over time (Figure 7). This substantial compliance margin demonstrates that automakers are taking the "useful life" requirement seriously.

31 Communication with a former CARB officer.

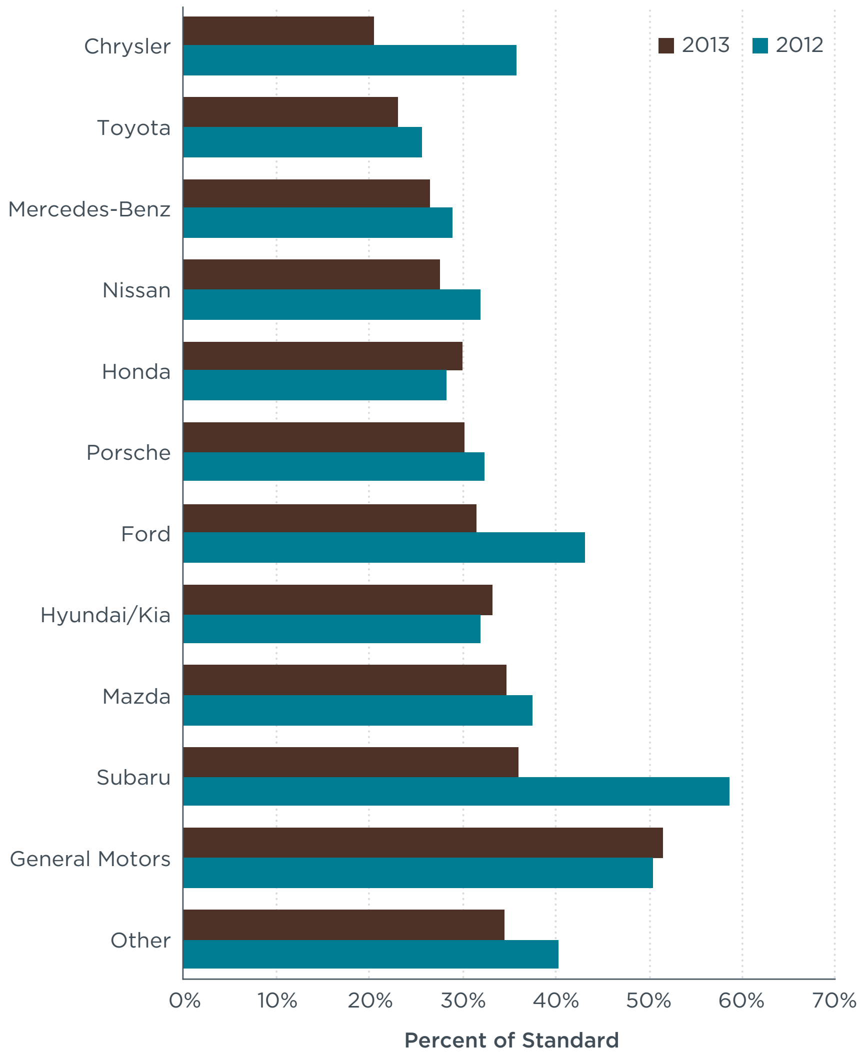

Figure 7. NO_x emission compliance margin at new vehicle certification, CY2012-2013

6.3 I/M AND OBD DATA

Vehicle inspection and maintenance programs (I/M) are another means of in-use vehicle emission control. The programs were created to help improve air quality by identifying high-emitting vehicles (gross emitters) in need of repair and having them fixed before they are allowed to legally operate on the road again. The 1977 amendments to the CAA made I/M mandatory for areas across the country that do not meet the national ambient air quality standards (NAAQS) by 1982. In 1990, the CAA Amendments required certain areas to implement enhanced I/M. More than 30 U.S. states have implemented I/M programs for light-duty vehicles.

High pollution levels cause vehicles to fail I/M tests due to (a) poor design and defects in emissions-related parts, (b) deterioration of those parts, (c) poor maintenance of the vehicle, and (d) removing emission control parts (tampering). Vehicle manufacturers are responsible for the first two problems, and vehicle owners are responsible for the latter two. Therefore, I/M test data can only provide indirect information to help target a possible vehicle recall program. When the I/M data suggests a clear trend or pattern of failure in certain vehicle models, regulators can use the data to discuss potential reasons for the failure and follow up with manufacturers directly. An example is the 1978 Chrysler carburetor failure case reviewed in the last section.

However, there are limitations for I/M data to be used as a direct data source for compliance actions. The I/M emission limits are designed for the in-use vehicle fleet, and are determined differently across states. The pass-fail emission thresholds are often three or four times higher than the certification (type approval) emission limits. This means that a traditional I/M test is becoming less able to properly detect noncompliance. For example, a typical IM240 tailpipe emission test uses a standard of 0.8g/mi for hydrocarbons in California, while current Tier 2 (Bin 5) vehicles are certified to 0.018 g/mi. The most accurate exhaust measurement systems used in I/M programs are not capable of accurately measuring exhaust emissions in the range of the Tier 2 standards (CARB, 2008).

I/M tests are also conducted periodically, usually performed annually or every other year, and often start from the third year of a vehicle's initial registration in most states. Therefore, they cannot reflect real-time emissions violations of in-use vehicles, especially newer in-use vehicles.

The EPA adopted OBD requirements as part of the vehicle emission standards, starting with MY1996 and MY2005 for light- and heavy-duty vehicles, respectively. The OBD requirements include an OBD threshold limit (OTL), usually 1.5 times of the emission standards. OBD monitors emission control components and performs a series of calculations to make sure emission outputs of the vehicle do not exceed the OTLs.

OBD monitors emission components in real time, and alerts consumers of a needed repair by illuminating an "engine check" light (MIL, or malfunction indicator lamp) on the dashboard. When repair technicians receive the vehicles, they can use inspection equipment (a scan tool) to query the fault codes from the OBD to locate the problem. The data provided by OBD can often pinpoint the specific component that has malfunctioned. If manufacturers see many of the same component malfunctions and warranty claims from the OBD alerts, they will have to report such issues to the EPA under a warranty regulation (to be discussed later). OBD data is required in those defect reports. Usually, manufacturers are anxious to recall OBD-identified component failures quickly before warranty complaints mount and owners become annoyed with MIL illumination.

Many states have incorporated an OBD check into the I/M program to enhance its effectiveness. I/M programs may use OBD checks on MY1996 and newer vehicles in lieu of (not in addition to) the more traditional testing. The I/M OBD check includes a simple visual check to see if the MIL is illuminated, and also a query of the OBD fault codes using a scan tool. OBD is calibrated to detect failures at much lower levels than can be detected with the traditional I/M test methods and, therefore, OBD data can be a more reliable data source to infer possible emissions problems than I/M data. That being said, failures between the standards and 1.5x standards (OBD threshold) do not cause the OBD lights to illuminate and would not be found without conducting more rigorous in-use testing.

Of course, the success of using OBD data as a clue to identify in-use emission noncompliance depends on the reliability of OBD systems; OBD must be able to illuminate the MIL when an emission malfunction exists. To this end, CARB and the EPA have introduced increasingly rigorous OBD requirements into the most recent emission standards. OBD failures themselves are also a reason for recalls. Nine out of 37 recalls in 2012 and three out of 30 recalls in 2013 were related to OBD systems. The OBD requirements also include elements designed to prevent fraudulent inspection passing and tampering, therefore helping to improve the effectiveness of I/M programs (Posada & German, 2016).

6.4 MANUFACTURER-RUN IN-USE TESTING PROGRAM

Starting from the CAP 2000 rule (EPA, 1999), the EPA and CARB successfully pushed manufacturers to conduct in-use emissions testing at their own cost. There are two basic categories of the manufacturer-funded in-use testing. One is the in-use verification testing (IUVP) that covers virtually all test groups in each model year, while the other is the in-use confirmatory testing (IUCP) that consists of more rigorous testing of test groups that demonstrated potentially high emissions in the IUVP.

For the IUVP phase, manufacturers were required to test every test group that they sell. IUVP has more lax surveillance criteria to keep costs down. Manufacturers conduct the test twice, normally around a year after production (low mileage) and 4 years after production (high mileage). For large engine families, five to seven cars need to be tested in each test group; for smaller engine families, three or four cars need to be tested. If the vehicles are only marginally failing the standard, then it is not worth the additional cost of investigating it further.

IUVP validates the accuracy of manufacturers' deterioration predictions and processes (including OBD), provides new and comprehensive in-use data that will be useful for other compliance or emission control programs, and prevents problems from being carried over to future model years (see Figure 8). It's very likely that manufacturers remedy in-use emissions problems and defects that are exposed by their IUVP testing. IUVP identifies in-use problems earlier and on a more widespread basis than the EPA's in-use test programs can, since IUVP covers all test groups except for the smallest volumes. In comparison, the EPA's in-use testing typically covers 40 to 50 test groups each year.

The IUVP program provides the EPA with annual real-world in-use testing data representing the majority of certified vehicles. The program includes about 2,000 in-use tests per year, including both low- and high-mileage tests on as-received, minimally screened customer-owned vehicles. The EPA will review and audit IUVP data to better target failing classes and may follow up with in-use confirmatory tests. The data is also used to validate and, if necessary, revise the manufacturer's deterioration estimates used for certification. The EPA publishes summary reports on IUVP results (U.S. EPA, 2017).

Manufacturers are not required to recall based on IUVP data. In practice, if the problem was significant and clear-cut during IUVP, manufacturers often just go straight to remedial actions instead of conducting the more expensive IUCP confirmatory testing. However, if the problem is questionable, manufacturers would still spend the money to conduct IUCP confirmatory testing. If the results show that not many vehicles are failing the standards, manufacturers would not initiate a recall.

The IUCP program requires manufacturers to conduct additional recall-quality in-use tests for test groups that fail IUVP testing criteria. A minimum of 10 test vehicles are required for IUCP. There are two criteria for determining whether a more rigorous follow-up test is needed. If a) 50% of tested vehicles in the test group sample at either the low- or high-mileage test point fail, and b) if the average mean emissions levels (except CO_2, CH_4, and N_2O) are greater than 1.3 times the applicable in-use emission standard limits, the manufacturer needs to conduct the IUCP (40 CFR §86.1845, 1846, 1847). Here is an example from a test group of ten vehicles: Two of the ten vehicles is over the standard by 120%, but all other vehicles comply. The failure rate is then 20% of vehicles, which is under the 50% failure rate threshold. On average, the test group exceeds the standard by about 4%, which is less than the threshold. This test group is considered a pass. The two criteria combined trigger the in-use confirmatory tests at the manufacturer's expense.

Through these requirements, the EPA essentially pushed the manufacturer to do what the agency was doing. At the same time, the EPA continues its own in-use surveillance testing to ensure manufacturers are providing accurate results. Nevertheless, the agency was able to collect dramatically more test results and a more extensive range of tests at manufacturer cost. The EPA now relies more heavily on the manufacturers' testing as the main program and conducts less surveillance and follow-up confirmatory tests. Table 3 shows the IUVP test volumes of light-duty vehicle tests conducted from CY2007 to CY2013.[32]

Table 3. LDV in-use verification program test volumes (number of vehicles)

Model Year	FTP	US06[33]	2-Day Evaporative	ORVR[34]
High-mileage testing				
2000	1,621	618	248	192
2001	2,944	620	359	296
2002	2,881	727	352	290
2003	2,400	536	254	215
2004	1,830	1,245	248	226
2005	1,103	782	142	140
2006	935	671	114	121
2007	1,115	781	120	127
2008	1,383	992	169	185
2009	677	493	108	101
2010	20	14	5	5
2011	8	7	0	1
2012	5	4	1	0
Low-mileage testing				
2004	2,000	1,859	501	450
2005	2,066	1,760	462	432
2006	2,035	1,672	441	444
2007	1,429	1,186	290	303
2008	757	656	149	150
2009	534	482	116	130
2010	568	500	143	153
2011	978	861	256	264
2012	580	520	148	129
2013	73	73	18	15

Source: EPA compliance report, 2007-2013

32 Note that the lower volume in recent model year is due to the delay in CY of the test and MY of the vehicles tested because of the requirement of the program. The latest CY we have data for is 2013. It does not mean that the EPA is testing fewer vehicles.

33 Also known as US06 Supplemental Federal Test Procedure. It supplements the FTP with aggressive driving behavior, including high speed and high acceleration.

34 Onboard refueling vapor recovery.

Figure 8 details the in-use testing procedures for manufacturers and the EPA that lead to recalls.

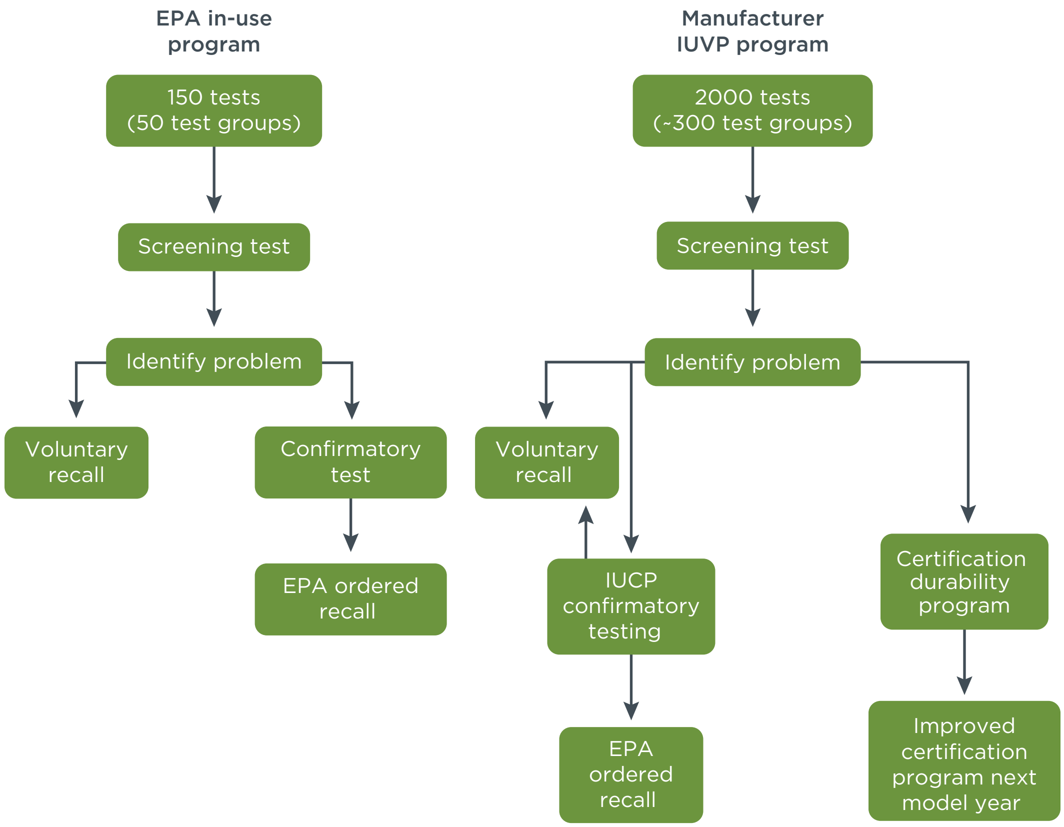

Figure 8. EPA compliance procedures leading to recalls

6.5 WARRANTY DATA AND DEFECT REPORT

The CAA requires manufacturers to warrant certain emission control components on vehicles and non-road engines. The warranties protect vehicle owners from the cost of repairs for emissions-related failures resulting from defects in design, materials, and workmanship that cause the vehicle or engine to exceed the emission standards.

There are two types of warranties: performance warranty and design and defect warranty. The performance warranty covers any repair or adjustment that is necessary to make a vehicle pass a locally required emission test (like an I/M) during the warranty period as long as the vehicle has been properly maintained according to the manufacturers' specifications and has not been misused. The design and defect warranty covers the repair of emissions-related parts that become defective due to a defect in materials or workmanship during the warranty period. The EPA warranty program requires coverage for major emission control components, such as catalytic converters, electronic control units, and onboard diagnostic devices. These components are covered for 80,000 miles of use or the first 8 years (whichever is reached first), and other parts are covered for 24,000 miles of use or the first 2 years.

The California warranty program is more stringent and comprehensive, with longer coverage of critical and expensive components and a fuller list of covered emission control systems.

Specifically, in California and the 13 states that require sale of California-certified vehicles, the emission warranty covers all emissions-related repairs for 3 years or 50,000 miles, whichever comes first (referred to as "3/50K"), while in the rest of the states it is 2/24K. In California, repairs (including parts and labor) costing more than $600 (so-called expensive parts) are warranted for 7/70K, while in the rest of the country only a few parts (catalyst and emission control unit) have a warranty that extends to 8/80K. In addition, California has managed to extend the emission warranty by regulation to 15 years or 150,000 miles, whichever occurs first, for all emissions-related parts, for Partial Zero Emission Vehicle (PZEV). For propulsion batteries on hybrid vehicles, the coverage is 10/150K in California.

Both California and the EPA initiated their emission parts warranty or defect report programs in the 1990s, with slightly different approaches. Both serve as useful data sources for regulatory agencies to target classes for further compliance actions, and often direct inference to voluntary recalls.

In California, manufacturers are required to review warranty claim records for each engine family or test group on a quarterly basis. When the cumulative number of warranty claims, without any prescreening, for a specific emissions-related component or repair represent at least 1% or 25 (whichever is greater) of the vehicles or engines of a California-certified engine family or test group, the manufacturer is required to compile the number of claims made for emissions-related components by cumulative total and report it to CARB. The warranty reports need to be updated quarterly. A manufacturer will need to file a field information report and emissions information report if affected cars reach a certain level after the initial warranty information report.

If there is a more significant share or number of warranty claims subject to a specific emissions issue, the vehicles, engine families, or test groups are subject to recall. Table 4 below shows the threshold failure rates in California by model year. Nearly half of the vehicles recalled in California between 1990 and 2005 were triggered by the warranty report program.[35]

Table 4. Warranty claim levels triggering recall

Model Year	%	NUMBER
1990-1991	4	50
1992-1993	2	50
1994 and later	2[36]	50

Source: 13 CCR §2143, 2144

Equally important, CARB takes a rigorous approach to verifying manufacturer's self-reported warranty data. Field representatives from the agency visit the dealership and talk to the dealership managers and technicians after the initial warranty report is received. The investigators review warranty records and request that dealership managers and technicians show the number of stock of parts on the shelf to be replaced. The technicians also have information on what parts the dealer is stocking more of due to recurring issues and repairs. The agency staff then compare the information from the dealers with what the manufacturers reported. This approach is

35 Raw data were from California's in-use compliance testing and recall activity report 2004-2005.

36 Warranty claim rates have remained at 1%/25 parts for the initial report and at 4%/50 parts for subsequent reports. CARB notified the manufacturers of this decision in a Manufacturers Advisory Correspondence in June 1992.

resource-intense: According to a former officer at CARB, "four people would spend a day at one dealership just going through warranty files."

At the federal level, the EPA requires manufacturers to report emissions-related defects (40 CFR §85.1903). An emissions-related defect is a defect in design, materials, or workmanship in a device, system, or assembly, as described in the approved application for certification. Manufacturers must report a defect even if it does not increase emissions levels. The rule applies to cars, light trucks, SUVs, heavy-duty trucks, buses, and motorcycles as well as non-road equipment. For highway vehicles and most engines (40 CFR §85.1903),[37] when the manufacturer learns of a specific emissions-related defect in more than 25 vehicles or engines of the same class and model year, it must report the emission defect to the EPA within 15 working days. The report must include a description of the defect, number of vehicles affected, any data on how the defect affects emissions, and any additional impact when driving the vehicle. The EPA encourages manufacturers to conduct a voluntary recall when they identify problems from sources such as defect reports, or the EPA can test the vehicles with defects to determine if they should be recalled.

Tables 5 and 6 summarize the number of defect reports and light-duty vehicles affected by manufacturer and by problem category during the 2013 calendar year.

Table 5. CY2013 Light-duty vehicle defect reports by manufacturer

Manufacturer	Number of defect reports	Number of affected vehicles
Audi	10	422,824
BMW	27	943,617
Chrysler	21	5,132,529
Fisker	4	2,835
Ford	15	2,136,197
General Motors	16	1,030,862
Honda	22	14,188,404
Hyundai	11	5,663,236
Isuzu	1	4,465
Jaguar/Land Rover	2	48,831
Kia	12	1,716,271
Lotus	1	5,476
Mazda	16	1,297,365
Mercedes-Benz	12	325,053
Mitsubishi	2	30,263
Nissan	16	1,616,751
Porsche	15	158,344
Rolls Royce	1	523
Subaru	2	576,169
Toyota	3	195,800
Volkswagen	8	304,846
Volvo	4	398,627

37 For other engines, see 40 CFR §1068.501.

Table 6. CY2013 Light-duty vehicle defect reports by problem category

Problem category	Number of defect reports	Number of affected vehicles
Air inlet/intake system	6	943,866
Catalyst system	8	257,317
Computer related (other than OBD)	35	6,730,630
Crankcase ventilation system	1	37,240
EGR system	2	104,979
Electrical, mechanical & cooling systems	23	3,656,946
Emissions control information label	4	46,193
Evaporation emissions system	19	2,834,713
Exhaust system	5	596,083
Fuel delivery component	22	1,260,052
Fuel delivery system	2	68,132
Fuel tank system	8	622,631
Hybrid vehicle system	6	176,757
Ignition system	8	1,716,819
Monitoring/measuring sensor/ system	12	11,593,222
NO_x sensor	6	227,618
OBD system	32	3,244,916
On-board refueling and vapor recovery	1	511,377
Oxygen sensor	8	1,131,552
Secondary air system	2	115,765
Selective catalytic reduction system	6	77,944
Turbocharger/supercharger	4	244,536

Source: EPA compliance report, 2012-2013

The discovery of these defects often leads to voluntary recalls or service campaigns. Manufacturers are also required to report all emissions-related voluntary recalls to the EPA. However, an emissions-related defect does not necessarily lead to an emission recall because not all defects in emissions-related parts increase emissions. More often, this leads to an extended warranty or some other remedy. This is all negotiated between the manufacturers and the agency.

There is no direct correlation among the number of defect reports, recalls, and the number of vehicles that are recalled. A manufacturer may identify many defects that are not significant enough to warrant a recall. On the other hand, a manufacturer could have a few major defects that evolve into major recalls affecting large portions of their product line. Historically, emission recalls affect about 3 million vehicles annually, although the number may vary in any given year (U.S. EPA, 2015a).

Defect reporting provides the EPA with “a valuable source of ‘suspect classes’” to investigate in the recall area. Based on manufacturer reports, the EPA can test the vehicles with defects to determine if they should be recalled. Many recalls occur because of defect reports. Therefore, the EPA has become strict on manufacturer reporting. Manufacturers are penalized if they do not report defects on time. As we reviewed in a previous section, Daimler-Chrysler was fined $5 million in 2005 for not reporting defective catalysts. The same year, VW was fined $1.1 million for waiting over a year to report the discovery of many defective oxygen sensors (U.S. EPA, 2005b).

However, "a weakness in the rule is that the emission defect data completely depends on the manufacturer's reporting as well as defining what a defect was," according a former officer at the EPA. The EPA sets thresholds for reporting defects and the rule gives manufacturers enough leeway to determine when and how to report. For example, if defects cannot be accurately matched to a certain model year and family, manufacturers can use "good engineering judgment" (40 CFR 1068.501 g(1)). Manufacturers can also use statistical methods to project defect rates for vehicles or engines that they are not otherwise able to evaluate (40 CFR §1068.501 g(7)). This might introduce some level of gaming. In addition, the EPA program does not include the rigorous field investigation that the CARB program does.

6.6 OTHER SOURCES

Other data sources used to inform emission recalls include consumer complaints, manufacturer bulletins, direct communication with service technicians, information from competitors, and independent research and tests.

According to a former officer at the EPA, one case was discovered based on consumer and dealer complaints about a gasoline smell inside the car. OECA within the EPA handles complaints concerning environmental violations. OECA received the complaints, pursued the issue, and ultimately discovered this emissions violation: The affected vehicles had a defective device that separated liquid and vapor in the vehicle's fuel control system. The tiny crack caused a gas leak, which is why drivers smelled a strong gasoline odor inside the cars.

Many states also have an environmental complaint program. For example, California has a Smoking Vehicle Complaint Program that guides and encourages the public to report smoking vehicles on the roads (ARB, 2016). Some private companies collect and compile consumer complaints related to vehicle safety and environmental features. For example, a web portal (http://www.carcomplaints.com) allowing consumers to report issues with their vehicles showed multiple complaints about a fuel tank crack and gas leak in the 1997 Hyundai Sonata (Carcomplaints.com, 1997). This was reflected in the voluntary recall of over 30,000 MY1997–1998 Sonatas by the automaker.[38]

EPA staff also reach out to manufacturers, dealers, and service technicians to collect useful information for their vehicle emission compliance program. According to an officer at the EPA, one information source that helped nail down the 1998 diesel engine defeat device case was a competitor of the manufacturers in question.

In addition, independent research projects run by universities and research groups can be another indirect information source to identify emission violations. An example is the 2015 Volkswagen defeat device case reviewed in the last section, where the ICCT-WVU testing and research on real-world diesel car emissions triggered further investigation and action from regulatory agencies.

38 Data are from EPA CY2001 emissions related recall/service campaign report

7. POST-RECALL AND OTHER RELATED ACTIONS

Recall is NOT the overall purpose of the compliance program. The ultimate goal of the program is to ensure the problem is fixed, thereby preventing excessive pollution from vehicles or engines that are already being used by customers. Recalls, and the compliance program in general, provide valuable feedback to improve future regulations and the development of standards.

When an emission recall occurs, the manufacturer must notify vehicle owners and provide instructions on how to have their vehicle repaired. The manufacturer must tell the owners that the manufacturer will repair the vehicles at no cost to the owner. Regulatory agencies develop follow-up requirements and alternative environmental remedy plans after the recall occurs. Manufacturers are required to report all voluntary recalls to the EPA within 15 days of owner notification, then as a follow-up, report the progress of the recall to the EPA on a quarterly basis for six consecutive quarters. If the number of owners repairing vehicles is too low in the initial round, the EPA can request the manufacturer to re-notify owners about the availability of free repair.

In order to make sure that as many recalled vehicles as possible actually get fixed, the manufacturer develops a plan, such as to notify owners in a letter with statements like "unless the car is repaired, it may fail the I/M test and void the warranty." This would encourage more consumers to bring in their vehicles subject to recall. Repair is voluntary, but some states are considering not registering cars that have not been repaired, an effective way to bring those vehicles back for repair. California is the only state with merged registration and recall databases. The state requires recalls to be completed before the vehicle's annual registration can be renewed. The EPA notifies state I/M programs of voluntary and influenced recalls so states may inform owners about emission recalls available for their cars. Manufacturers also need to notify state I/M programs.

Even with these follow-ups, not all problem vehicles are fixed. About 40% of owners who receive a recall notice have their cars repaired. Possible reasons for not repairing is that some people don't see it as a priority since it does not pose an immediate safety threat, or the repair will result in lower performance and fuel economy. With the measures mentioned above, California's recall repair or "capture" rates typically exceed 92% in California, with some recalls approaching 100%, according to a former CARB regulator.

Since a recall plan may not completely solve the excessive emissions problems, regulatory agencies often require manufacturers to submit a Supplemental Environmental Project (SEP) plan (EPA, 2016c) that offsets the possible impact of their violations in the settlement. These SEPs are agreed-upon environmentally beneficial projects related to the violation in exchange for mitigation of the penalty in a settlement agreement. Part of the penalty includes the EPA negotiating the environmental projects the company needs to complete to make up for the emissions due to owners opting to not repair their vehicles. Example SEPs include engine emissions standard pull-ahead, retrofit projects, and programs to reduce pollutant emissions from other sources.

These SEPs do not necessarily involve the products of the manufacturers. For example, in the 2003 settlement involving Toyota's evaporative emission control function of the OBD system, Toyota spent $20 million on a SEP to retrofit up to an estimated 3,000 public in-service diesel fleet vehicles to make them run cleaner, including enhancement of the availability of ultra-low-sulfur diesel fuel. In the 1998 diesel engine settlement, Caterpillar was required to do a MY2004 standard pull-ahead, a non-road engine standard pull-ahead, an adjustment of average banking and trading, a low-NO_x rebuild program, and other SEPs.

Most importantly, in-use compliance and recall programs provide valuable feedback to improve future emission standards and certification procedures. Emission type approval certification is the cornerstone and starting point of a strong compliance program. However, there are still limitations in test protocols and certification testing methods. In-use compliance testing can offer lots of useful data to close the loopholes in current certification procedures. This has been evidenced in several of the examples reviewed, including the enhanced OBD program implemented after the Toyota OBD case in 2003 and the improved PEMS-based test procedures for heavy-duty vehicles and engines following the 1998 HD engine defeat device case. Regulators need to revisit their certification procedures and approaches to best reflect emissions characteristics during real-world driving.

The EPA utilizes Advisory Circulars, a semi-formal document of the agency, to communicate with and provide guidance to the industry, often regarding how to comply with a regulation pertaining to emission control systems. In the late 1970s, electronic control and first generation three-way catalytic converters were introduced, meanwhile the first fuel economy regulation also took effect. During compliance investigations, EPA staff saw very selective calibrations favoring fuel economy over emission control. Based on those observations, EPA staff drafted an Advisory Circular saying that the agency would inspect the actual performance of these systems and, if they exceed a certain amount of NO_x emissions, the agency would consider that defeating the emission control. The EPA has a track record of such Advisory Circulars dating back to the 1970s (EPA, 2017). In the 1970s, the EPA produced more than 50 advisory circulars to clarify different aspects of emission control systems.[39] Figure 9 shows the number of Advisory Circulars issued by the EPA by year over the past several decades.

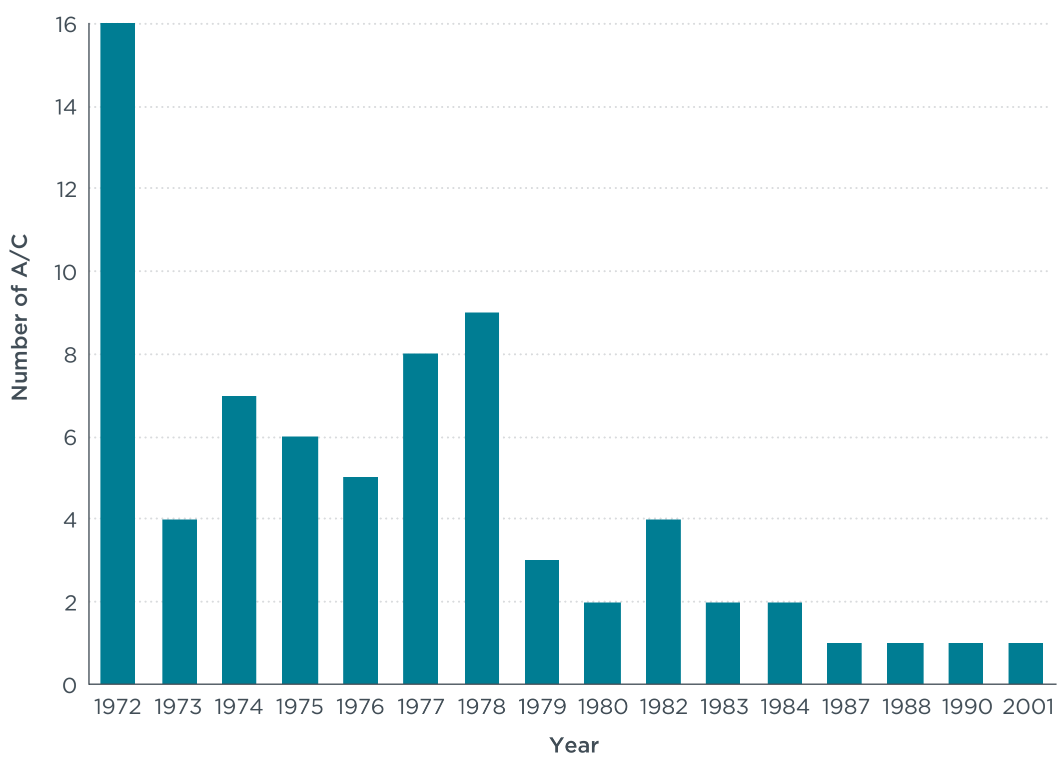

Figure 9. Number of advisory circulars (all years)

39 Communication with a former EPA officer.

The EPA also issues guidance letters to the regulated automotive industry providing information, guidance, and instructions on specific compliance topics and issues. The EPA has a track record of such guidance letters dating back to the late 1970s (EPA, 2017). Figure 10 shows the number of guidance letters issued by the EPA by year.

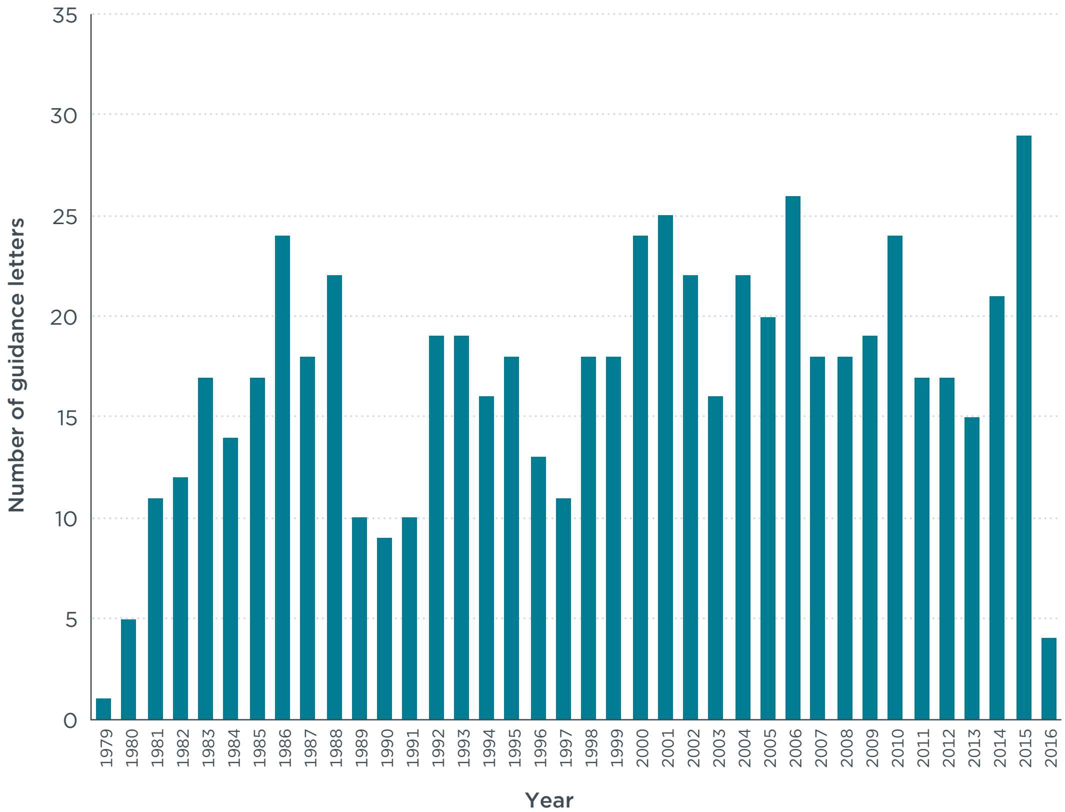

Figure 10. Number of guidance letters from 1979–2016

8. FINDINGS AND RECOMMENDATIONS

8.1 FINDINGS

» In addition to their clear missions to protect public health and the environment, the foundation for the robust vehicle emission compliance programs at both the EPA and CARB is strong and clear legal authority. Each agency has clear authority to establish a test protocol for in-use compliance testing, require manufacturers to conduct tests, provide warranty and defect data to the agencies, and, most importantly, holds the authority to revoke the certificate of conformity, to recall vehicles, and to impose punitive fines on noncompliant vehicles. Withholding of the COC (or an Executive Orders in California), an approval needed to sell vehicles in the U.S. (or California) market, is a powerful tool for regulatory agencies to negotiate with manufacturers on compliance actions. The maximum civil monetary penalties under the Clean Air Act for vehicle emission noncompliance are now $45,268 per vehicle/engine (for violations occurring after Nov 2, 2015 and assessed on or after Jan 15, 2017), up from $25,000 when the act was first enacted (40 CFR §19.4).

» The comprehensive vehicle emission compliance program adopted in the United States was built up over several decades. The process involved a learning curve for both regulators and industry. In the early 1970s and '80s, there were many contentious cases that ended up in court. Gradually, both the EPA and CARB demonstrated their technical competence to industry by showing their data was able to withstand the scrutiny of industry experts. The courts consistently agreed that the agencies had the legal authority to mandate recalls based on sound data. As a result, over time, the agencies have proven successful in working with the manufacturers to perform voluntary recalls. Since the 1990s, most cases have been noncontentious and recalls and other remedies were voluntary. This shift is a positive sign that the requirements and enforcement criteria are clear and detailed, making it in the manufacturers' best interest to do the right thing by closely following the regulation to avoid any mandatory recalls.

» Building a strong team and continuously expanding staff capacity is also key to establishing a successful emission compliance program. Beyond dedicated, longtime staffers, both the EPA and CARB were able to recruit top experts, sometimes from the industry. It takes time and resources to establish and maintain technical expertise over time as new technologies emerge. As one former CARB officer noted,

> "*What CARB has done in the past 30 some years is carefully screen the staff, and we have some of the best... The OBD program is one of the most difficult to get up to speed on because you need to understand all of the software in terms of how the vehicle operates, and how the emission control works. It takes probably 4 to 5 years working with the staff, involving them in lab, in-use testing, reviewing certification and applications that manufacturers submit before production, (to get them familiar with the process).*"

» In the United States, compliance is a shared burden between regulatory agencies and manufacturers. The current compliance program has a strong focus on manufacturer responsibility in ensuring their vehicles and engines meet the standards throughout the vehicle's certified useful life. This is done by requiring manufacturers to conduct large scale in-use testing, reporting warranty data and defects, and conducting voluntary recalls. This allows the regulatory agencies to play more of a supervisory role and focus their limited resources on the most critical issues. In addition, manufacturers pay certification fees, ranging from hundreds of dollars to thousands per type-approval certificate depending on type of vehicle, to the government to carry out compliance efforts.

» U.S. regulatory agencies perform rigorous in-use compliance tests, and these tests are the most direct source of data to consider issuing a recall. It's also important that the agencies have their own testing facilities. In addition, the agencies have a number of indirect data sources to further guide the in-use compliance tests. These include, but are not limited to: (a) certification data, which can be useful in several ways, for example, to target vehicles with a small compliance margin and vehicles deployed containing new technologies; (b) information from state I/M programs, including information from on-board diagnostics(OBD) systems; (c) manufacturer warranty data and defect reports; (d) failures discovered during the manufacturer-run in-use verification program (IUVP) testing, required as a part of the Compliance Assurance Program (CAP2000); (e) complaints from consumers and service providers; and (f) independent research projects involving real-world emissions testing.

» A full-scale in-use testing program is quite expensive, as the agencies usually need to recruit a sufficient number of vehicles from consumers and pay for additional substitute vehicles and maintenance, and compensation to the vehicle owners. California used to rent cars and have the authority to allow staff to drive these cars home overnight. Some of the early experiments aiming to discover in-use noncompliance were done on these cars. Even though the scope of these early experiments was extremely limited, they did expose issues. And more importantly, in-use testing is a strong deterrent to the OEMs building vehicles with parts that may lack durability. In all compliance programs, deterrence is a major objective.

» Rigorous documentation of the compliance tests conducted by regulatory agencies, and engaging manufacturers in these tests, are extremely instrumental steps to implementing a successful recall. In the early years of a compliance program, regulatory agencies encountered situations where manufacturers could easily discredit their data. The agencies learned from this and established protocols to obtain defensible data to provide in court, as necessary.

» Agencies should continue to evolve and improve the certification test procedures based on learning from in-use compliance testing is important. Emission type approval certification is the cornerstone and starting point of a compliance program. However, there are still limitations associated with test protocols and methods of certification tests. In-use compliance testing can provide lots of useful data to close the loopholes in current certification procedures. This was evidenced in several of the examples reviewed in this paper, including the enhanced OBD program introduced after the Toyota OBD case in 2003 and the improved PEMS testing for heavy-duty vehicles and engines after the 1998 heavy-duty engine defeat device case. Regulators need to revisit their certification procedures and approaches to best reflect emissions characteristics during real-world driving.

8.2 RECOMMENDATIONS

Building upon the findings, we recommend the following best practices and key elements to build a successful and robust vehicle emission compliance and recall program:

- Governments should seek to establish strong and clear authority through legislation for environmental regulatory agencies to establish, implement, and enforce emissions standards, including clear authority to levy fines and issue recalls.
- Governments should establish requirements in the appropriate legislation for emission warranty provisions and for vehicles and engines to meet emission standards throughout their full "useful life," which is the time span throughout which the emissions performance of a vehicle must comply with the prescribed standards, in the appropriate legislation. For example, the current definition of useful life in the U.S. Tier 3 emission standard for light-duty vehicles is 150,000 miles.
- Once legal authority is established, agencies must recognize and implement their authority. They should impose penalties on vehicle manufacturers and make sure the penalties are large enough to deter manufacturers from noncompliance. If necessary, regulatory agencies should utilize their power to void new vehicle and engine emission type-approval certificates, if necessary.
- Build internal technical capacity within environmental regulatory agencies to ensure ability to conduct compliance testing and manage recall programs. Recruit the best experts in the field, including experienced technicians to carry out the laboratory testing.
- A compliance program needs to be executed by government resources free from industry influence. A regulatory agency must have established, sustainable funding to support running and maintaining the compliance program. Some ways to deal with limited resources at the beginning of a program are:
    - Starting the program with robust certification testing and production (assembly line) conformity testing if staff capacity is initially limited. Once regulatory agencies gain sufficient confidence into these two stages, then in-use testing becomes more important.
    - Starting in-use emissions testing with a small fleet: whatever can be obtained with the resources available.
    - Give manufacturers some flexibility to leverage manufacturer resources when introducing new compliance program elements. After a pilot stage to prove their effectiveness, transition the programs into full-scale.
- Create a program that shares the compliance burden among the governments (central and local), industry, and vehicle owners. Establish subprograms requiring the industry to provide compliance-related data. Policymakers could investigate whether and how the following subprograms may be adopted in their regional context.
    - Require manufacturers to conduct large-scale in-use testing, with sufficient government confirmatory testing to verify the manufacturer test results.
    - Require an emission warranty program.
    - Require manufacturers to provide emission warranty and defect data. Then use government resources to spot check with dealers and service providers to verify the manufacturer-reported data.

   - Require manufacturers to recall their vehicles if feedback from the above subprograms indicates an emissions violation.
   - Establish credible I/M program and other emissions inspection programs such as remote sensing programs at local levels to ensure emissions components are not tampered with by users. Integrate OBD in I/M programs to increase test accuracy and credibility. Analyze I/M data to determine if particular brands or models have higher than normal failure rates and then investigate.
   - Collect vehicle certification fees from manufacturers as a sustainable source to support the compliance efforts.
- Establish test protocols to detect defeat devices. This includes, but is not limited to, using a combination of methods such as PEMS-based real-world driving tests, OBD examination, modified driving test cycles, and test procedures for laboratory tests.
- Consider utilizing testing projects from independent third parties or research entities as a data source to trigger government investigation provided that the test results have a credible basis for concern.
- Establish protocols for documenting vehicle selection, testing, and data collection processes in order to obtain defensible data for recalls. Consider engaging manufacturers in some of the processes. It is crucial to define “proper maintenance” and ensure the test vehicles used for compliance actions are well maintained for the kind of emissions problem in question.
- Use feedback from in-use compliance programs to improve the new emission standards and certification procedures. As vehicle and emission control technologies advance and emission regulations become increasingly complicated, there might be further undefined areas. As regulatory agencies learn about these areas, and if there is potential for undercutting the purpose of the regulations, the agencies should try to better define these areas by spelling out specifically what they intended.

9. REFERENCES

PART 1: CLEAN AIR ACT PROVISIONS

- Sec. 202 Emission standards for new motor vehicles or new motor vehicle engines (including on board diagnostics (OBD) requirements) https://www.gpo.gov/fdsys/pkg/USCODE-2013-title42/html/USCODE-2013-title42-chap85-subchapII-partA-sec7521.htm
- Sec. 203 Prohibited acts https://www.gpo.gov/fdsys/pkg/USCODE-2013-title42/html/USCODE-2013-title42-chap85-subchapII-partA-sec7522.htm
- Sec. 205 Civil penalties https://www.gpo.gov/fdsys/pkg/USCODE-2013-title42/html/USCODE-2013-title42-chap85-subchapII-partA-sec7524.htm
- Sec. 206 Motor vehicle and motor vehicle engine compliance testing and certification https://www.gpo.gov/fdsys/pkg/USCODE-2013-title42/html/USCODE-2013-title42-chap85-subchapII-partA-sec7525.htm
- Sec. 207 Compliance by vehicles and engines in actual use (including remedy for non-conformity) https://www.gpo.gov/fdsys/pkg/USCODE-2013-title42/html/USCODE-2013-title42-chap85-subchapII-partA-sec7541.htm
- Sec. 208 Information collection (including manufacturer testing) https://www.gpo.gov/fdsys/pkg/USCODE-2013-title42/html/USCODE-2013-title42-chap85-subchapII-partA-sec7542.htm

PART 2: CODE OF FEDERAL REGULATIONS

- 40 CFR Subchapter C Part 85 Subpart S Recall regulations http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=a359458a762e3b7ebaeb3079de90c9d1&mc=true&n=pt40.21.85&r=PART&ty=HTML#sp40.21.85.s
- 40 CFR Subchapter C Part 85 Subpart T Emission defect reporting requirements http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=a359458a762e3b7ebaeb3079de90c9d1&mc=true&n=pt40.21.85&r=PART&ty=HTML#sp40.21.85.t
- 40 CFR Subchapter C Part 86 Subpart S General compliance provisions for control of air pollution from new and in-use light-duty vehicles, light-duty trucks, and heavy-duty vehicles https://www.ecfr.gov/cgi-bin/text-idx?SID=51dc2ccc850745012797e1e12d1d76a9&mc=true&node=sp40.21.86.s&rgn=div6
- 40 CFR Subchapter C Part 85 Subpart V Emissions control system performance warranty regulations and voluntary aftermarket part certification program. http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=a359458a762e3b7ebaeb3079de90c9d1&mc=true&n=pt40.21.85&r=PART&ty=HTML#sp40.21.85.v
- 40 CFR Subchapter U Part 1027 Fees for engine, vehicle, and equipment compliance programs https://www.ecfr.gov/cgi-bin/text-idx?SID=c2b1d2b8213c08f06ee29a3b334abc48&mc=true&node=pt40.36.1027&rgn=div5
- 40 CFR Subchapter U Part 1068 Subpart F Reporting defects and recalling engines/equipment https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=70c9e25a36bdbcc4eb8b258155bfba9d&mc=true&n=pt40.33.1068&r=PART&ty=HTML#se40.33.1068_11
- 40 CFR Subchapter A Part 19 Civil monetary penalty inflation adjustments http://www.ecfr.gov/cgi-bin/text-idx?SID=a250616e6f4bd0d9d76b926f38098967&mc=true&node=se40.1.19_14&rgn=div8

PART 3: CALIFORNIA CODE OF REGULATIONS

» 13 CCR Division 3 Chapter 2 Enforcement of vehicle emission standards and surveillance testing https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=IA4398060D46911DE8879F88E8B0DAAAE&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default)

» 13 CCR Division 3 Chapter 1 Article 2 §1968.1 Malfunction and diagnostic system requirements- 1994 and subsequent model-year passenger cars, light-duty trucks, and medium-duty vehicles and engines https://govt.westlaw.com/calregs/Document/I7402D2F02DDD11E197D9B83B68A61150?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)

PART 4: OTHER REFERENCES

Adler, J. H. (1998). *Bean Counting for a better earth: environmental enforcement at the EPA.* http://object.cato.org/sites/cato.org/files/serials/files/regulation/1998/4/bean2-98.pdf.

Ambrosio, P. (2016, 9 15). *More Volkswagen Criminal Charges Could Be on the Way.* Retrieved 10 14, 2016, from Bloomberg BNA: http://www.bna.com/volkswagen-criminal-charges-n57982077002/

California Air Resources Board. (2002). *Staff report: initial statement of reasons for proposed rulemaking.* http://www.arb.ca.gov/regact/obd02/isor.PDF.

California Air Resources Board. (2005). *Annual summary of in-use compliance testing and recall activity.* https://www.arb.ca.gov/msprog/inusecom/rpt2005.pdf

California Air Resources Board. (2008). *Transition I/M: options for inspection and maintenance in the OBD dominated fleet.* Retrieved from http://www.cetia.us/yahoo_site_admin/assets/docs/2008_IMRC_Recommendation_final.364150328.pdf

California Air Resources Board. (2015a). *Annual enforcement reports*. Retrieved Nov 2015, from http://www.arb.ca.gov/enf/reports/reports.htm

California Air Resources Board. (2015b). *Letter to VW.* http://www.arb.ca.gov/newsrel/in_use_compliance_letter.htm.

California Air Resources Board. (2016). *Case settlements*. Retrieved Nov 2015, from http://www.arb.ca.gov/enf/casesett/casesett.htm

California Air Resources Board. (2016, Aug 29). *Smoking vehicle complaint program*. Retrieved 3 28, 2017, from California Air Resources Board: https://www.arb.ca.gov/enf/complaints/smoke.htm

California Air Resources Board letter to manufacturers. (2015). *Ref number IUC-2015-008.* http://www.arb.ca.gov/newsrel/arb_iuc_2015_09_25_final_signed_letter.pdf.

Bansal, G. (2013). *Vehicle emissions compliance for light-duty vehicles in India.* ICCT. http://www.theicct.org/sites/default/files/publications/ICCT_COP_India_20130820.pdf.

Bansal, G., & Bandivadekar, A. (2013). *India's vehicle emissions control program.* ICCT. http://www.theicct.org/indias-vehicle-emissions-control-program.

Brown, W., & Thomas, P. (1995). *Emissions case costs GM fine, Cadillac recall.* The Washington Post. https://www.washingtonpost.com/archive/politics/1995/12/01/emissions-case-costs-gm-fine-cadillac-recall/ba27a350-1b90-4574-a8c7-2a0ad5312e76/.

Cackette, T. (2016, Jul 19). *Improving emission standards compliance with a defect reporting system for in-use passenger vehicles.* Retrieved from ICCT: http://www.theicct.org/compliance-defect-reporting-system-for-in-use-PVs

California Air Resources Board. (1978). *Emissions Warranty Parts List.* https://www.arb.ca.gov/board/res/1980/83-16.pdf.

Carcomplaints.com. (1997). Retrieved Apr 14, 2016, from http://www.carcomplaints.com/Hyundai/Sonata/1997/fuel_system/fuel_system_gasoline-storage-tank_assembly.shtml

Chrysler Corporation, Petitioner, v. United States Environmental Protection Agency and Douglas M.costle, Administrator, Respondents, 631 F.2d 865 (D.C. Cir. 1980). (1980). Retrieved Mar 28, 2017, from http://law.justia.com/cases/federal/appellate-courts/F2/631/865/86734/

Cushman Jr., J. H. (1995). *Half-million Cadillacs recalled in federal pollution settlement.* The New York Times. http://www.nytimes.com/1995/12/01/us/half-million-cadillacs-recalled-in-federal-pollution-settlement.html.

D.C. District Court. (1995). *Consent Decree, U.S.A. v. General Motors Corporation.* Retrieved from https://nepis.epa.gov/Exe/ZyNET.exe/900L0500.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1995+Thru+1999&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C95thru99%5CTxt%5C00000019%5C900L0500.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

D.C. District Court. (1998). *Consent Decree, U.S.A. v. Cummins Engine Company, Inc.* https://www.epa.gov/sites/production/files/documents/cummins-cd.pdf.

D.C. District Court. (2003). *Consent decree, U.S.A v. Toyota Motor Corporation, et al.* http://www2.epa.gov/sites/production/files/documents/toyotacd.pdf.

D.C. District Court. (2006). *Consent Decree, U.S.A v. DaimlerChrysler AG and Mercedes-Benz USA, LLC.* https://www.epa.gov/enforcement/consent-decree-daimlerchrysler-ag-and-mercedes-benz-usa-llc.

DeLong, J. V. (2002). *Out of bounds, out of control.*

Dieselnet. (2015). *Monthly newsletter (September).* Subscription required.

Dieselnet. (2016). *Emissions test cycles: SFTP-SC03*. Retrieved Apr 14, 2016, from https://www.dieselnet.com/standards/cycles/ftp_sc03.php

Department of Justice. (1995). *U.S. announces $45 million Clean Air settlement with GM, first judicial environmental recall - 470,000 Cadillacs.* https://www.justice.gov/archive/opa/pr/Pre_96/November95/596.txt.html.

Department of Justice. (2016). *Volkswagen to spend up to $14.7 billion to settle allegations of cheating emissions tests and deveiving customers on 2.0 liter diesel vehicles.* https://www.justice.gov/opa/pr/volkswagen-spend-147-billion-settle-allegations-cheating-emissions-tests-and-deceiving.

Environmental Law Reporter. (2000). *United States v. Toyota Motor Corp.* Retrieved Apr 14, 2016, from https://elr.info/sites/default/files/litigation/31.20255.htm

U.S. Environmental Protection Agency. (1999). *Compliance Assurance Program (CAP 2000) Final Rule.* https://www3.epa.gov/otaq/regs/ld-hwy/cap2000/420f05061.pdf.

U.S. Environmental Protection Agency. (2000-2009). *Annual summary of emission-related recall and voluntary service campaigns performed on light-duty vehicles and light-duty trucks.*

U.S. Environmental Protection Agency. (2001). *Performing onboard diagnostic system checks as part of a vehicle inspection and maintenance program.* https://www3.epa.gov/otaq/regs/im/obd/r01015.pdf.

U.S. Environmental Protection Agency. (2003a). *Toyota Motor Corporation settlement*. Retrieved Apr 14, 2016, from http://www2.epa.gov/enforcement/toyota-motor-corporation-settlement

U.S. Environmental Protection Agency. (2003b). *U.S. settles Clean Air case against Toyota—Toyota will convert school buses to run cleaner as part of settlement*. Retrieved Apr 14, 2016, from http://yosemite.epa.gov/opa/admpress.nsf/b1ab9f485b098972852562e7004dc686/69f88fa92e75411585256ce200676104?OpenDocument

U.S. Environmental Protection Agency. (2005). *Final rule on in-use testing for heavy-duty engines and vehicles*. Retrieved Apr 14, 2016, from https://www3.epa.gov/otaq/highway-diesel/regs/420f05021.pdf

U.S. Environmental Protection Agency. (2015a). *Civil cases and settlements*. Retrieved Nov 2015, from https://cfpub.epa.gov/enforcement/cases/

U.S. Environmental Protection Agency. (2015b). *Clean Air Act vehicle and engine enforcement case resolutions*. Retrieved Nov 2015, from https://www.epa.gov/enforcement/clean-air-act-vehicle-and-engine-enforcement-case-resolutions

U.S. Environmental Protection Agency. (2015c). *EPA, California notify Volkswagen of Clean Air Act violations/ Carmaker allegedly used software that circumvents emissions testing for certain air pollutants.* http://yosemite.epa.gov/opa/admpress.nsf/bd4379a92ceceeac8525735900400c27/dfc8e33b5ab162b985257ec40057813b!OpenDocument.

U.S. Environmental Protection Agency. (2015d). *Notice of violation to Volkswagen AG, Audi AG, Volkswagen Group of America, Inc.* https://www.epa.gov/sites/production/files/2015-10/documents/vw-nov-caa-09-18-15.pdf.

U.S. Environmental Protection Agency. (2015e). *Notice of violation to Volkswagen AG, Audi AG and et al.* https://www.epa.gov/sites/production/files/2015-11/documents/vw-nov-2015-11-02.pdf.

U.S. Environmental Protection Agency. (2015f). EPA conducted confirmatory testing. https://www.epa.gov/sites/production/files/2015-10/documents/cd-mfr-guid-ltr-2015-09-25.pdf.

U.S. Environmental Protection Agency. (2016a). *Air enforcement policy, guidance and publications*. Retrieved Apr 14, 2016, from http://www2.epa.gov/enforcement/air-enforcement-policy-guidance-and-publications#Mobile

U.S. Environmental Protection Agency. (2016b). *Enforcement and compliance history online*. Retrieved from http://echo.epa.gov

U.S. Environmental Protection Agency. (2016c). *Supplemental environmental projects*. Retrieved Apr 14, 2016, from http://www2.epa.gov/enforcement/supplemental-environmental-projects-seps

U.S. Environmental Protection Agency. (2016d). *Vehicle programs and compliance guidance letters*. Retrieved Apr 14, 2016, from https://www3.epa.gov/otaq/cert/dearmfr/dearmfr.htm#

U.S. Environmental Protection Agency. (2017). *Guidance letters and advisory circulars for vehicle, engine, and equipment programs*. Retrieved 3 28, 2017, from https://www.epa.gov/vehicle-and-engine-certification/guidance-letters-and-advisory-circulars-vehicle-engine-and

U.S. Environmental Protection Agency compliance report. (2013). *2009-2011 Vehicle engine compliance activities.* https://nepis.epa.gov/Exe/ZyPDF.cgi/P100H9M8.PDF?Dockey=P100H9M8.PDF.

U.S. Environmental Protection Agency guidance letter. (1998). *Heavy-duty diesel engines controlled by onboard computers: guidelines on reporting and evaluating auxiliary emission control devices and the defeat device prohibition of the Clean Air Act.* https://iaspub.epa.gov/otaqpub/display_file.jsp?docid=14148&flag=1.

U.S. Environmental Protection Agency guidance letter. (2015). *EPA conducted confirmatory testing.* https://iaspub.epa.gov/otaqpub/display_file.jsp?docid=35637&flag=1.

U.S. Environmental Protection Agency news release. (2005). *Volkswagen of America, Inc., agrees to pay more than $1 million for Clean Air Act Violation.* https://yosemite.epa.gov/opa/admpress.nsf/c81a1def3bf1b2118525702100555c5e/6946eeaadcfa982b8525702100777c0e!OpenDocument.

U.S. Environmental Protection Agency progess report. (2010). *2008 Vehicle and engine compliance activities.* https://nepis.epa.gov/Exe/ZyPDF.cgi/P1008K2D.PDF?Dockey=P1008K2D.PDF.

U.S. Environmental Protection Agency progress report. (1974). *Progress in the implementation of motor vehicle emission standards through 1974.* Retrieved from https://nepis.epa.gov/Exe/ZyNET.exe/9100YL1D.TXT?ZyActionD=ZyDocument&Client=EPA&Index=Prior+to+1976&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C70thru75%5CTxt%5C00000016%5C9100YL1D.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

U.S. Environmental Protection Agency progress report. (1983). *Progress in the prevention and control of air pollution in 1983.* Retrieved from https://nepis.epa.gov/Exe/ZyNET.exe/9101KVPI.txt?ZyActionD=ZyDocument&Client=EPA&Index=2011%20Thru%202015%7C1995%20Thru%201999%7C1981%20Thru%201985%7C2006%20Thru%202010%7C1991%20Thru%201994%7C1976%20Thru%201980%7C2000%20Thru%202005%7C1986%20Thru%201990%7CPrior%20to%201976%7CHardcopy%20Publications&Docs=&Query=Progress%20prevention%20control%20air%20pollution%201983&Time=&EndTime=&SearchMethod=2&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5CZYFILES%5CINDEX%20DATA%5C81THRU85%5CTXT%5C00000024%5C9101KVPI.txt&User=anonymous&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=15&FuzzyDegree=0&ImageQuality=r85g16/r85g16/x150y150g16/i500&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x

U.S. Environmental Protection Agency progress report. (1985). *Progress in the prevention and control of air pollution in 1985.* Retrieved from http://nepis.epa.gov/Exe/ZyPDF.cgi/2000K7JI.PDF?Dockey=2000K7JI.PDF

U.S. Environmental Protection Agency progress report. (1986). *Progress in the prevention and control of air pollution in 1986.* Retrieved from https://nepis.epa.gov/Exe/ZyNET.exe/2000J16Y.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1986+Thru+1990&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C86thru90%5CTxt%5C00000007%5C2000J16Y.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

U.S. Environmental Protection Agency progress report. (1987). *Progress in the prevention and control of air pollution in 1987.* https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=2000K82F.pdf

U.S. Environmental Protection Agency progress report. (2008). *2007 Vehicle and engine compliance activities.* https://nepis.epa.gov/Exe/ZyPDF.cgi/P1001TY2.PDF?Dockey=P1001TY2.PDF.

U.S. Environmental Protection Agency progress report. (2015). *2012-2013 Vehicle engine compliance activities.* https://nepis.epa.gov/Exe/ZyPDF.cgi/P100NO1R.PDF?Dockey=P100NO1R.PDF.

U.S. Environmental Protection Agency progress reports. (1983-1988). All accessible at https://nepis.epa.gov

Federal Register. (2008, Mar 13). *Amendments to manufacturer-run, heavy-duty highway in-use engine and vehicle testing*. Retrieved Apr 14, 2016, from https://www.gpo.gov/fdsys/pkg/FR-2008-03-13/pdf/E8-4388.pdf

Fist M., E. T. (2017, Jan 10). *VW Board Set to Sign Off on $4.3 Billion U.S. Diesel Penalty*. Retrieved 1 18, 2017, from Bloomberg: https://www.bloomberg.com/news/articles/2017-01-10/vw-says-it-s-in-advanced-talks-with-u-s-on-4-3-billion-penalty

Franco, V., German, J., Posada, F., & Mock, P. (2014). *Real-world exhaust emissions from modern diesel cars.* ICCT. http://www.theicct.org/real-world-exhaust-emissions-modern-diesel-cars.

Fung, F., He, H., Sharpe, B., Kamakate, F., & Blumberg, K. (2011). *Overview of China's vehicle emission control program.* ICCT. http://www.theicct.org/overview-chinas-vehicle-emission-control-program.

Gallucci, M. (2015). *Volkswagen scandal 2015: VW not the first automaker to adopt 'defeat device' and override emissions controls.* International Business Times. http://www.ibtimes.com/volkswagen-scandal-2015-vw-not-first-automaker-adopt-defeat-devices-override-2110859.

Johnson, D. (2002). *A description of real-time on-road vehicle emissions reporter.* https://www.epa.gov/sites/production/files/2015-03/documents/02132002mstrs_johnson.pdf.

Maxwell, R., & He, H. (2012). *In-use testing for CO2 and fuel economy in the United States.* ICCT. http://www.theicct.org/use-testing-co2-and-fuel-economy-united-states.

National Academy of Engineering. (2016). *Air conditioning and refrigeration timeline*. Retrieved Apr 14, 2016, from http://www.greatachievements.org/?id=3854

National Archives and Records Administration. (1977). *Federal Register: 42 Fed. Reg. 28113 (June 2, 1977).* https://www.loc.gov/item/fr042106/.

National Archives and Records Administration. (1980). *Federal Register: 45 Fed. Reg. 34257 (May 22, 1980).* https://www.loc.gov/item/fr045101/.

National OBD Clearinghouse. (n.d.). Retrieved Nov 2015, from http://www.obdclearinghouse.com/index.php

O'Dell, J. (1999). *Toyota faces massive fines in EPA battle.* Los Angeles Times. http://articles.latimes.com/1999/jul/13/news/mn-55474.

Posada, F., & German, J. (2016). *Review of LDV OBD requirements under the European, Korean and Californian emission programs.* ICCT. http://www.theicct.org/review-ldv-obd-requirements-under-european-korean-and-californian-emission-programs.

Reitze, A. (2001). *Air pollution control laws: compliance and enforcement. Chapter 10 Mobile source air pollution control.*

Tabuchi H., E. J. (2017, 1 11). *6 Volkswagen Executives Charged as Company Pleads Guilty in Emissions Case.* Retrieved 1 18, 2017, from The New York Times: https://www.nytimes.com/2017/01/11/business/volkswagen-diesel-vw-settlement-charges-criminal.html?_r=0

The Washington Post. (1978). *Chrysler fails in attempt to block recall of 1975s.* https://www.washingtonpost.com/archive/business/1978/11/23/chrysler-fails-in-attempt-to-block-recall-of-1975s/bd21b434-8775-4266-8057-8e7aeff2c070/?utm_term=.4ed54c1b7329

Toyota Motor Sales, U.S.A., Inc. (1999). *Toyota remains firm in position on emissions performance; maintains its systems comply with regulations.* http://www.prnewswire.com/news-releases/toyota-remains-firm-in-position-on-emissions-performance-maintains-its-systems-comply-with-regulations-73556312.html.

U.S. Environmental Protection Agency. (1974). *Progress in the implementation of motor vehicle emission standards through June 1974.* https://nepis.epa.gov/Exe/ZyNET.exe/9100YL1D.TXT?ZyActionD=ZyDocument&Client=EPA&Index=Prior+to+1976&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C70thru75%5CTxt%5C00000016%5C9100YL1D.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL#.

U.S. Environmental Protection Agency. (2005). *Final rule on in-use testing program for heavy-duty diesel engines and vehicles.* https://nepis.epa.gov/Exe/ZyNET.exe/P1001YUJ.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2000+Thru+2005&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C00thru05%5CTxt%5C00000017%5CP1001YUJ.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL#.

U.S. Environmental Protection Agency. (2008). *EPA finalized regulations requiring onboard diagnostic systems on 2010 and later heavy-duty engines used in highway applications over 14,000 pounds; revisions to onboard diagnostic requirements for diesel highway heavy-duty applications under 14,000 pounds.* https://nepis.epa.gov/Exe/ZyNET.exe/P1002K5E.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2006+Thru+2010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C06thru10%5CTxt%5C00000006%5CP1002K5E.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL#.

U.S. Environmental Protection Agency. (2009, Jan 16). *Clean Air Act Mobile Source Civil Penalty Policy - Vehicle and Engine Certification Requirements*. Retrieved from https://www.epa.gov/sites/production/files/documents/vehicleengine-penalty-policy_0.pdf

U.S. Environmental Protection Agency. (2017). *Compliance activity reports for vehicles and engines.* https://www.epa.gov/vehicle-and-engine-certification/compliance-activity-reports-vehicles-and-engines.

Wagner, V., & Rutherford, D. (2013). *Best practices in emission control of in-use heavy-duty diesel vehicles.* ICCT. http://www.theicct.org/best-practices-emission-control-in-use-hdvs.