Northeast States
Heavy-Duty Diesel Engine Repair Study

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Northeast States Heavy-Duty Diesel Engine Repair Study: Analysis in Support of a Proposed Change in Smoke Opacity Cutpoints

Executive Summary

Several northeast states that conduct smoke inspections on heavy-duty diesel trucks and/or buses are currently reviewing a proposal to make roadside and periodic Inspection and Maintenance (IM) programs more stringent by lowering existing opacity cutpoints. Most of these states have air quality problems and have implemented programs to reduce visible black smoke from on-road heavy-duty diesel engines. This study addresses several questions concerning the impact of a change in opacity cutpoints: Are the proposed cutpoints so low that truck engines cannot be repaired to meet them? What are the most common repairs associated with smoke reduction? How expensive will the repairs be? To explore these issues, the states that are considering a cutpoint revision reviewed previous studies and assessed data from several states' smoke programs.

While few previous studies have directly examined smoke opacity tests, failures, repairs and repair costs, some data are available from these studies and states' vehicle inspection records. They suggest that trucks can and are being repaired to the lower cutpoints being considered. Data from California, Connecticut, Maryland, Massachusetts, New Jersey, and New York show that average smoke opacity levels after repair are generally well under the proposed cutpoints.

Available repair data also provide information on the common malfunctions that cause excessive smoke and how they can be remedied, including the repair or replacement of components in the air and/or fuel systems. Other common repairs involve the control of air-fuel ratios. While information on the cost of repairs is also limited, available data point to average costs well below $1,000 for the repairs needed to bring most trucks into compliance. The data also suggest that some trucks are receiving minimal repairs to bring smoke levels just below current opacity cutpoints. Lower cutpoints may mean additional repair costs but until the lower cutpoints are implemented, the data to evaluate these additional costs do not exist.

On the other hand, lower cutpoints may also stimulate repairs that improve fuel economy and thereby reduce operating costs. Black smoke, which is the focus of smoke opacity programs, usually indicates incomplete fuel combustion, meaning that fuel is not being used efficiently. Repairs that reduce smoke may result in more efficient engine operation and associated fuel savings. Based on the average cost of repairs and the average annual mileage of the trucks that most often fail smoke inspections, increased compliance costs may amount to ten cents per mile or less. In some cases, this additional cost can be completely offset by the fuel savings associated with a well-tuned engine.

To assess the cost impact of lower opacity cutpoints, available data from studies focusing on operating costs were reviewed. These studies, unrelated to the repair of smoke

failures, estimate operating costs from as low as $1.24 to as high as $8.35 per mile for heavy-duty diesel trucks. In that context, small increases in compliance costs that are likely to simultaneously reduce fuel expenses do not seem overly burdensome. This assessment is, of course, based on average costs calculated with available repair data. Individual repairs may be more or less costly than the average.

A related question that arose in the process of analyzing repair data concerns the impact of lower cutpoints on the failure rate of states' smoke inspection programs. While the impact on failure rates was not included in the original scope of this study, information on this question may be useful to policy-makers as they evaluate proposed changes to smoke cutpoints.

Unfortunately, it is impossible to accurately predict increased failure rates resulting from the adoption of proposed cutpoints. To avoid having a vehicle fail its inspection or be ticketed and/or fined, owners and/or fleet managers often inspect and repair their vehicles before periodic IM inspections or to meet the cutpoints of states with roadside programs. Failure rates may not be affected because smoke failures and/or roadside fines have been avoided due to these maintenance and repair efforts. Nonetheless, available data from existing IM and roadside programs provide some assessment of a possible change in failure rates. Specifically, this study reviews information from large IM databases of smoke inspections performed in Massachusetts and New Jersey and from roadside inspection programs in Connecticut and Maryland.

The data from the IM state databases suggest a small rise in smoke failures: the 1.6 percent failure rate increases to 4.5 percent, a 2.9 percent increase in Massachusetts and the 2 percent failure rate increases to 5.8 percent, a 3.8 percent increase in New Jersey. Analysis of the roadside inspection data from Connecticut and Maryland suggest a higher failure rate, with increases of 9 percent, from 13.8 percent to 22.8 percent and 10.6 percent, from 15.4 percent to 26.0 percent, respectively. The higher projected failure rates for Connecticut and Maryland might be explained by the nature of roadside inspection programs; enforcement personnel tend to target trucks with higher levels of visible smoke and the inspection databases may reflect that bias. It is worth noting, however, that as newer trucks with advanced emissions technologies replace older vehicles, the average opacity levels will come down. The lower cutpoints reflect these technological advances that are designed to reduce visible smoke.

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Section One: Introduction, Background, and Current Programs

Introduction

Trucks and buses powered by heavy-duty diesel engines play a critical role in transportation and are vital to the U.S. economy. Heavy-duty diesel engines are also a major source of emissions that affect air quality. Reducing emissions from heavy-duty diesel engines has been a major goal of air regulatory programs for over three decades in the United States. In 1974, the U.S. Environmental Protection Agency (US EPA) set the first emissions standards for smoke, hydrocarbons and oxides of nitrogen (HC+NOx) and carbon monoxide (CO) for new diesel engines. Emissions standards for particulate matter were adopted later, beginning with model year 1988 diesel engines. Emissions levels have continued to decline over the decades: modern diesel engines are over 90 percent cleaner than their predecessors because of stricter new engine standards and more advanced emission controls.

US EPA's engine standards apply to new engines at the time of manufacture. Deterioration and/or inappropriate adjustments can affect diesel-engine performance over time, causing excessive levels of pollution including visible black smoke. Many states, including California and several states in the northeast, have implemented smoke opacity inspection programs to identify these vehicles and ensure that they are repaired.

States have developed different programs to perform smoke opacity inspections, including roadside inspections by law enforcement personnel and periodic inspections as part of Inspection and Maintenance (IM) programs. Some states require smoke opacity inspections for both trucks and buses,[1] while other states require them only for trucks. In the northeast, states use the same smoke opacity test protocol and similar cutpoints. In 1999, nine northeastern states[2] signed a Memorandum of Understanding to maintain as much consistency as possible in smoke inspection programs from state to state.

The trucking industry supports consistency between different states' programs and recognizes the benefit of reciprocity to minimize the time required to perform roadside smoke inspections. In addition, enforcement personnel practice reciprocity while reserving the right to pull over a commercial vehicle for inspection; they recognize that compliance with smoke opacity cutpoints in one state generally means compliance in neighboring northeastern states.

Background

The proposal to lower smoke opacity cutpoints is motivated by states' interest in reviewing their IM and/or roadside inspection data, further advances in engine technology, the near-term introduction of more stringent federal certification standards, and the widespread use of ultra

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[1] For purposes of this study, data for trucks are used in the analysis; data for buses are not readily available.
[2] The northeast states that signed the 1999 Regional Smoke Opacity Testing of Heavy-Duty Diesel Highway Vehicles Memorandum of Understanding were Connecticut, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont.

low-sulfur diesel fuel.[3] To evaluate the impact of more stringent cutpoints, this study compiles a survey of existing studies and seeks to address the following questions:

- Are the proposed cutpoints so low that heavy-duty diesel engines cannot be mechanically repaired to meet them?
- What are the most common repairs currently performed to bring engines into compliance with current smoke cutpoints?
- What are the average costs of those repairs?
- What repair data are available that relate directly to smoke opacity testing programs?
- How relevant are those data to the proposal to lower cutpoints?

Members of the NESCAUM Heavy-duty Diesel Workgroup, informally known as the Repair Study Subgroup, performed this analysis.[4] The team reviewed a number of studies from a variety of sources that have analyzed heavy-duty diesel maintenance programs, along with several studies of heavy-duty diesel inspection programs.

The team found only limited information that specifically relates smoke inspection failures, smoke-specific repair work, repair costs, and post-repair inspection results. Though the studies differ in focus, some provide data on the repair work that is commonly performed to bring failing vehicles into compliance, while others provide information on the smoke reductions associated with various repairs. In addition, a few studies provide limited information on the cost of repairs. Data from states with smoke opacity programs were used to help fill the gaps in the published studies. By drawing on these various sources of information, some of the questions about smoke opacity inspections, cutpoints, and repairs can be addressed.

Current Smoke Opacity Inspection Programs

US EPA requires sophisticated test procedures to certify emissions of particulate matter (PM) and oxides of nitrogen (NOx) from new diesel engines. PM and NOx are the two pollutants from diesel engines that are of greatest concern to regulators, health advocates, and environmentalists. Excessive smoke from diesel engines is a symptom of some kind of engine malfunction or the effects of poor maintenance over time. State smoke opacity inspection programs are designed to identify engines in need of repair or maintenance that develops over age and use and to ensure that the maintenance or repair of the malfunction is performed to reduce excessive emissions.

The opacity inspection protocol most commonly used in the northeast states is the SAE J1667 Snap-Acceleration Smoke Test Procedure for Heavy-Duty Diesel Powered Vehicles.[5] The

[3] Staff from the State of New Jersey, Department of Environmental Protection, analyzed the inspection records of some 70,000 New Jersey smoke opacity inspections and introduced the lower cutpoint proposal to other regional states.

[4] Members of the subgroup team include Julie Ross, Commonwealth of Massachusetts, Department of Environmental Protection; Ariel Garcia, State of Connecticut, Department of Environmental Protection; Joseph Iannotti and Anthony Tagliaferro, New York State Department of Environmental Conservation; David Love, State of Vermont, Department of Environmental Conservation and current Chair of the NESCAUM Heavy-Duty Diesel Workgroup.

[5] SAE J1667, Society of Automotive Engineers, The Engineering Society For Advancing Mobility Land Sea Air and Space International, issued 1996-02.

inspection protocol requires that smoke be measured by shining a beam of light through a smoke sample. The thicker the smoke, the less light can pass through it and the higher the opacity reading. The inspection protocol is repeatable, reliable, and can be performed with relative ease by enforcement personnel and/or certified or licensed smoke inspectors in IM programs. The equipment to perform the inspection must meet specific engineering requirements, is produced by a number of manufacturers, and is relatively inexpensive.

SAE J1667 sets equipment specifications and defines the protocol for performing the inspection. The SAE J1667 protocol does not, however, recommend pass/fail cutpoints. In a separate document, the SAE has recommended the 55 percent and 40 percent cutpoints that are commonly used in northeast now. Finally, US EPA's 1999 "Guidance to States on Smoke Opacity Cutpoints To Be Used With The SAE J1667 In-Use Smoke Test Procedure" also supports the same cutpoints.

Some states had established a less stringent cutpoint of 70 percent for older trucks with the intention of phasing this cutpoint out over time for a maximum cutpoint at 55 percent. Other states did not allow cutpoints for any vehicle higher than 55 percent. Additionally, some northeastern states apply the same cutpoints for buses as trucks[6] while others require buses (school bus, transit and/or motor coaches) to meet lower cutpoints than trucks.[7] The rationale for more protective (i.e., lower) cutpoints for buses is that they operate in an environment that directly exposes more people to their exhaust than do some truck operations.

The following tables compare current and proposed cutpoints for the northeast states.

Table 1. Current Smoke Opacity Cutpoints

Vehicle Type and Model Year	Percent Opacity
Diesel trucks	
1973[8] and older	70%
1974 – 1990 model years	55%
1991 and newer	40%
Diesel buses (states with separate limits for buses)	
1984 – 1993 model years	40%
1994 and newer	30%

[6] New York State

[7] Massachusetts and New Jersey

[8] Several northeastern states adopted 55% smoke opacity as its highest cutpoint rather than phasing down from the 70% cutpoint. 70% cutpoint in Connecticut and Maine has been phased out; 55% now applies.

Table 2. Proposed Smoke Opacity Cutpoints

Vehicle Type and Model Year	Percent Opacity
Diesel trucks	
1990 and older	40%
1991 – 1996 model year	30%
1997 and newer	20%
Diesel buses	
1987 and older	40%
1988 – 1993	30%
1994 and newer	20%

While each state reserves the right to set its own cutpoints as well as the vehicle type and weight categories to which the cutpoints apply, maintaining consistency across state programs provides the benefits of reciprocity for the trucking industry and enforcement personnel and offers guidelines for vehicle maintenance and repair. With common cutpoints, mechanics and fleet operators can recommend and perform repairs that would bring failing vehicles into compliance throughout the region.

Summary of Studies Reviewed

As part of this assessment, the Repair Study team identified and reviewed as many relevant studies as possible. The studies reviewed include:

- "Relationship of Underground Diesel Engine Maintenance to Emissions," Bureau of Mines, US Dept. of Interior, 1983
- "Mine Ventilation" Ed. Mousset-Jones, Mackay School of Mines, 1985
- "Comprehensive Truck Size and Weight Study, Phase 1, Truck Costs and Truck Size and Weight Regulations, Working Paper #7," February 1995, for FHWA, US DOT by the Battelle Team
- "Quantifying the Emissions Benefit of Opacity Testing and Repair of Heavy-Duty Diesel Vehicles," McCormick, et al, Colorado School of Mines, 2000
- "Quantifying the Emissions Benefits of Opacity Testing and Repair of Heavy-Duty Diesel Vehicles," McCormick, et al, Colorado School of Mines, 2003
- "Expenses Per Mile for the Motor Carrier Industry: 1990 – 2000 and Forecasts Through 2005" response to DTFH61-01-P-00304 for Federal Highway Administration, Office of Freight Management and Operation, author unknown
- "ATA Twenty from the Top, A Benchmarking Guide to the Operations of For-Hire Truckload Carriers 2001"
- "Fleet Maintenance, Maintenance and Repair Costs," December 2000 (data from study for *Heavy Duty Trucking* by the National Aftermarket Data Exchange
- "Operating Costs of Trucks in Canada – 2001," for Transport Canada by Trimac Logistics, Inc., Consulting Services
- "Per Mile Cost of Operating Auto & Trucks," MN DOT, 2003
- "Scoping Study: State Diesel Emissions Inspection Programs: Trends and Outcomes" prepared for Diesel Technology Forum, 2004

- "UPS CNG Truck Fleet, Final Results" by Chandler, et al, produced for the US Dept. of Energy, August 2002

Data from California, Connecticut, Maryland, Massachusetts, New Jersey, and New York inspection programs provided additional information on smoke opacity levels, including results from both failing and passing inspections. Limited information was also available on the repairs that were performed on failing engines and, in some cases, on the costs of those repairs. The states that were able to provide some of this information include California, Connecticut, New York and Vermont. More details about these states' programs, the data they provided, and the limitations of that data are presented in the following sections.

Section Two: Analysis of Inspection Data

Analysis of Current vs. Proposed Cutpoints with Respect to Inspection Failures

As mentioned earlier, there is no single study that evaluates vehicle failures under the current cutpoints to vehicle failures under the proposed new cutpoints. Some limited data are available, however, about vehicles that failed current cutpoints, were repaired, and subsequently passed inspection. These data were analyzed to see if the proposed lower cutpoints were so low that engines could not be repaired to meet the proposed cutpoints. In many cases, vehicles that passed the opacity inspection after repair under the current cutpoints were also well below the more stringent proposed new cutpoints. Proposed cutpoints can also be compared to average smoke inspection results to help determine if they are so low that vehicles cannot be repaired to meet them.

California

The California Air Resources Board (CARB) provided data for this study that was compiled from vehicles that failed roadside smoke inspections. The CARB data comes from 314 heavy-duty diesel vehicle inspections conducted from 2001 through 2005. All of the vehicles that failed inspection were repaired to comply with California's opacity cutpoints (40 percent for 1991 and newer year vehicles and 55 percent for 1990 and older vehicles).

Table 3 presents a summary of the number of vehicles that failed the roadside inspections and the calculated average opacity levels before and after engine repair. Opacity results are presented as averages for the model years corresponding with current smoke opacity cutpoints.

Table 3. California Roadside Inspection Program Results

Model Year	Number of Trucks	Average Opacity Levels for Failing Vehicles	Average Opacity Levels for Passing Vehicles After Repair[9]
1997 and Newer	7	66%	20%
1991 – 1996	20	63%	21%
1990 and Older	287	74%	19%

[9] Note average post repair opacity results may be somewhat higher due to several missing post-repair opacity results.

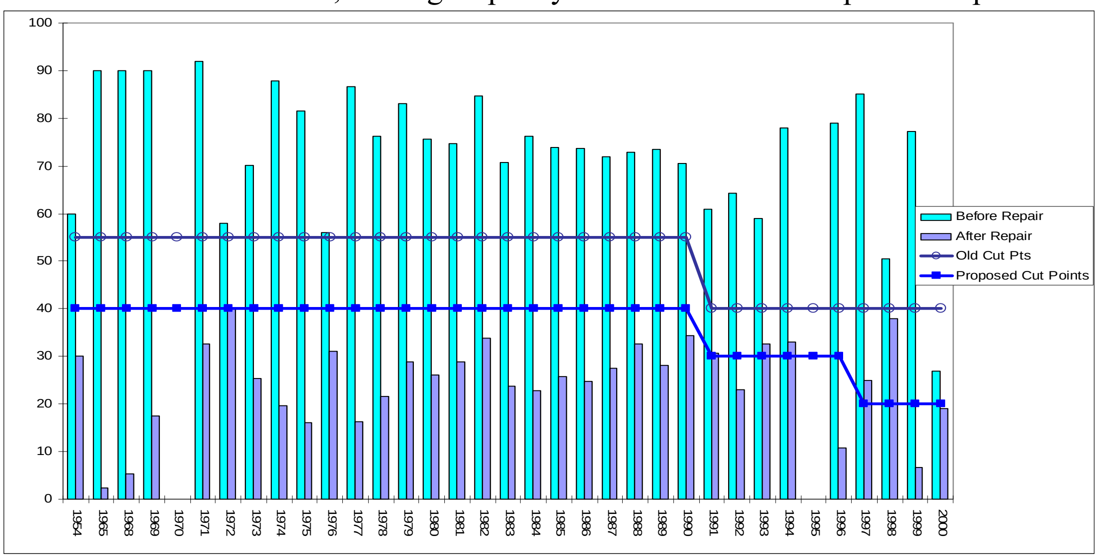
Table 4 indicates what percentage of trucks in this sample would have passed the proposed cutpoints after repairs. (Note that the percent figures shown in the table represent the number of trucks that would pass, rather than their average opacity results.)

Table 4. Percent of California Trucks That Would Pass Proposed New Cutpoints

Model Years: 1990 and Older Proposed 40% Opacity	Model Years: 1991 – 1996 Proposed 30% Opacity	Model Years: 1997 and Newer Proposed 20% Opacity
77%	60%	72%

Chart 1 compares opacity results for vehicles in the CARB sample before and after repair against current and proposed cutpoints. Clearly, the vast majority of trucks that were repaired after initially failing the roadside inspection were able to meet the proposed new cutpoints.

Chart 1. California Vehicles, Average Opacity with Current and Proposed Cutpoints



Connecticut

The State of Connecticut has a roadside heavy-duty diesel vehicle inspection program. All trucks over 26,000 pounds Gross Vehicle Weight (GVWR) are subject to inspection. Before calendar year 2003, Connecticut implemented the 40, 55, and 70 percent opacity cutpoints for 1991 and newer, 1974-1990, and 1973 and older model year vehicles, respectively. Since 2003, Connecticut has applied opacity cutpoints of 55 percent for all model year 1990 and older heavy-duty diesel vehicles and 40 percent for 1991 and newer vehicles.

Inspectors from Connecticut's Department of Motor Vehicles (CT DMV) generally conduct some 1,500 inspections a year. Although the Connecticut program is designed to be a semi-random roadside program, it accomplishes the goal of targeting gross polluters. Table 5 summarizes the number of smoke inspections and overall failure rates for the last four years.

Table 5. Connecticut Heavy-Duty Diesel Vehicle Roadside Inspection Program 2002-2005

Calendar Year	Cutpoints – Percent Opacity) 1991&Newer, 1974-1990, 1973&Older	Total Inspections	Failure Rates
2002	40, 55, 70	1,847	17 %
2003	40, 55, 55	1,447	17 %
2004	40, 55, 55	2,082	12.8 %
2005	40, 55, 55	1,267	15.5 %

Connecticut staff provided an inspection database for this analysis containing 3,349 inspection records from 2004 and 2005. Of these inspections, 2,886 trucks (86.2 percent) passed based on the current cutpoints and 463 trucks (13.8 percent) failed.

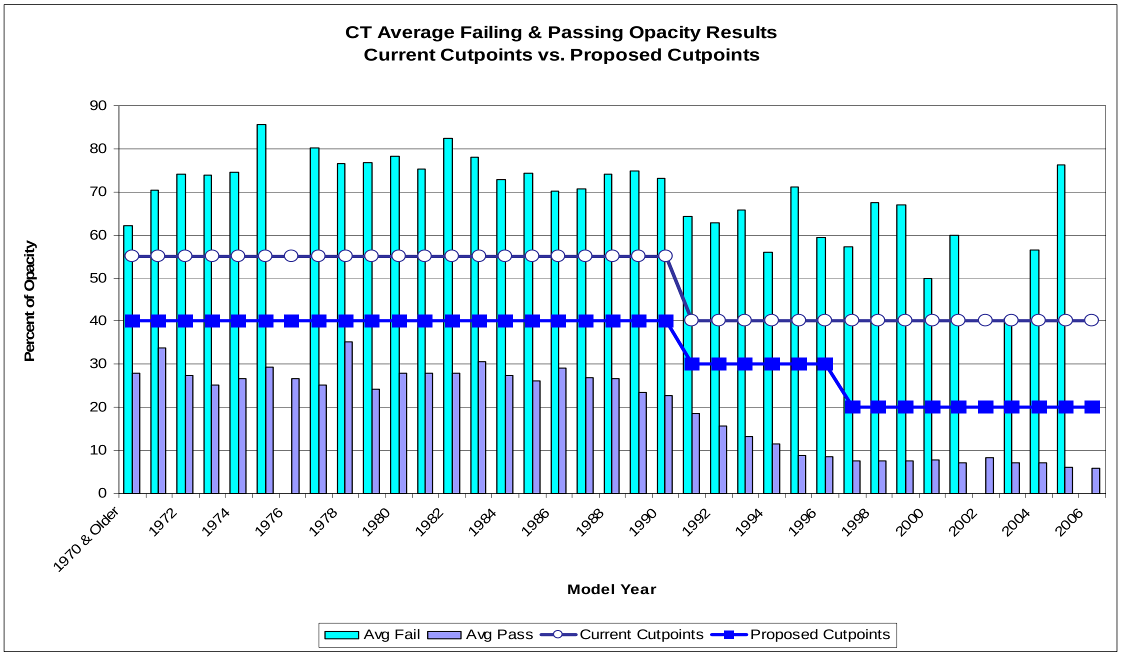
More detailed information about inspection results from the Connecticut database is presented in Table 6. Over 80 percent of the failing trucks are 1990 and older.

Table 6. Connecticut Heavy-Duty Diesel Vehicle Roadside Opacity Results

Vehicle Model Year Intervals	Failing Trucks Under Current Cutpoints	Average Failing Opacity Levels	Average Passing Opacity Levels
1997 & Newer	26 / 5.6%	59.4%	7.3%
1991 – 1996	57 / 12.3%	63.3%	12.8%
1990 & Older	380 / 82.1%	74.9%	27.5%

Chart 2 shows that, for each model year, the average opacity of trucks that passed current cutpoints would also fall below the proposed new cutpoints. Additional information that assesses the possible impact of more stringent cutpoints on failure rates based on individual truck smoke values will be presented in a later section of this report.

Chart 2, Connecticut Vehicles, Average Opacity with Current and Proposed Cutpoints



Maryland

Maryland implemented a roadside smoke inspection program in August 2000. The state's database contains records of 5,308 inspections conducted by Maryland State Police and Maryland Transportation Authority Police on vehicles registered in Maryland and other states. Maryland's current smoke opacity cutpoints are 40 percent for model years 1991 and newer, 55 percent for model years 1974–1990, and 70 percent for model years 1973 and older.

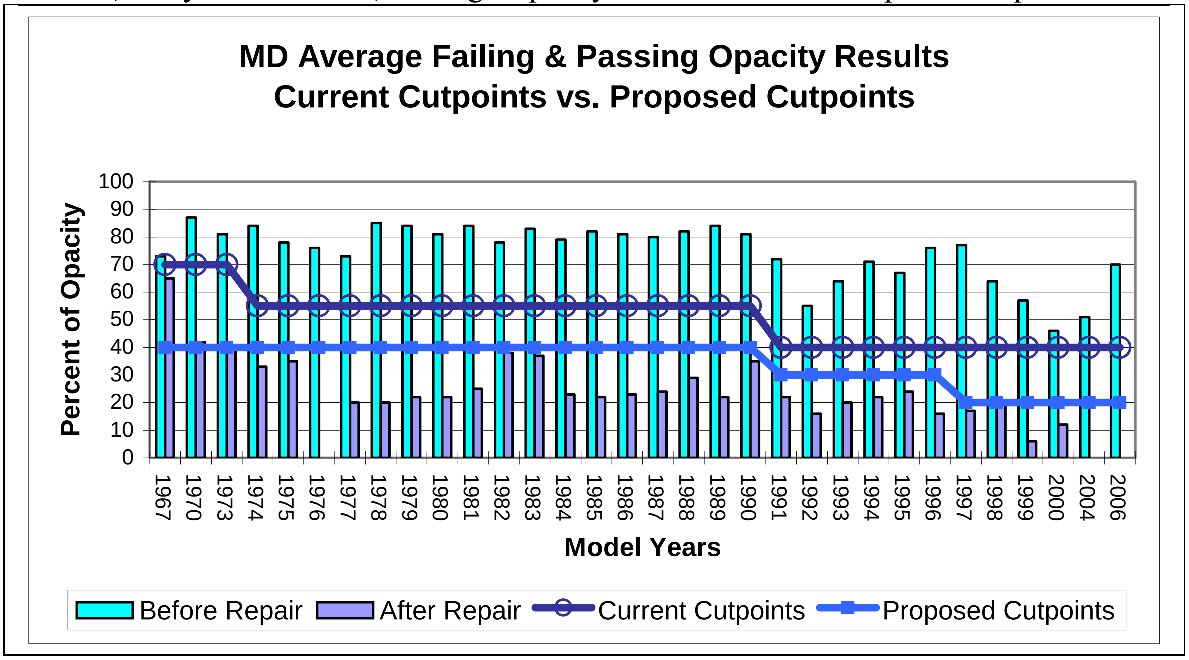
The database noted above includes 2,780 trucks registered in Maryland. Of these, 596 trucks failed the smoke inspection. Repair and retest is required of these Maryland-based trucks, and 543 were retested. While Maryland does not obtain specific repair information, it does require a retest to show the vehicle has been brought back to acceptable opacity levels. Table 7 shows the average opacity levels for the 596 Maryland-based trucks that failed current cutpoints and the average opacity level for the 543 trucks that were retested after repair. Similar to the trend observed in the California and Connecticut data, the average opacity levels of the Maryland trucks after repair are at or below the proposed cutpoints.

Table 7. Maryland Heavy-Duty Diesel Vehicle Roadside Opacity Results

Vehicle Model Year Intervals	Failing MD Trucks Under Current Cutpoints	Average Failing Opacity Levels	Average Passing Opacity Levels
1991 & newer	117 / 19.6%	69%	20%
1974 – 1990	474 / 79.5%	82%	25%
1973 & older	5 / 0.8%	84%	25%

Similar to other states, the average opacity values of the trucks that pass current cutpoints would also pass the proposed new cutpoints. Chart 3 shows these averages by model year.

Chart 3, Maryland Vehicles, Average Opacity with Current and Proposed Cutpoints



Massachusetts

Massachusetts inspects heavy-duty diesel vehicles as part of its IM program, which requires an annual safety inspection and a biennial emissions inspection using a decentralized network of inspection stations. Most new vehicles are exempt from emissions inspections for the first two years. After the new vehicle exemption period, emissions inspections are required of model year 1984 and newer vehicles. Smoke inspections of most heavy-duty diesel vehicles 10,001 GVWR and over are required to meet the emissions requirement of the program. While the IM database does not provide information about the repairs made on engines that fail initial inspection, opacity data are available for failing trucks before and after repair.

The Massachusetts database includes 724 trucks that failed the smoke inspection for the two-year period January 1, 2004–December 31, 2005 (one emissions inspection cycle). Of the 724 failing trucks, 434 (60 percent) were model year 1984–1990, 180 (25 percent) were model year 1991–1996, and 110 (15 percent) were 1997 and newer.

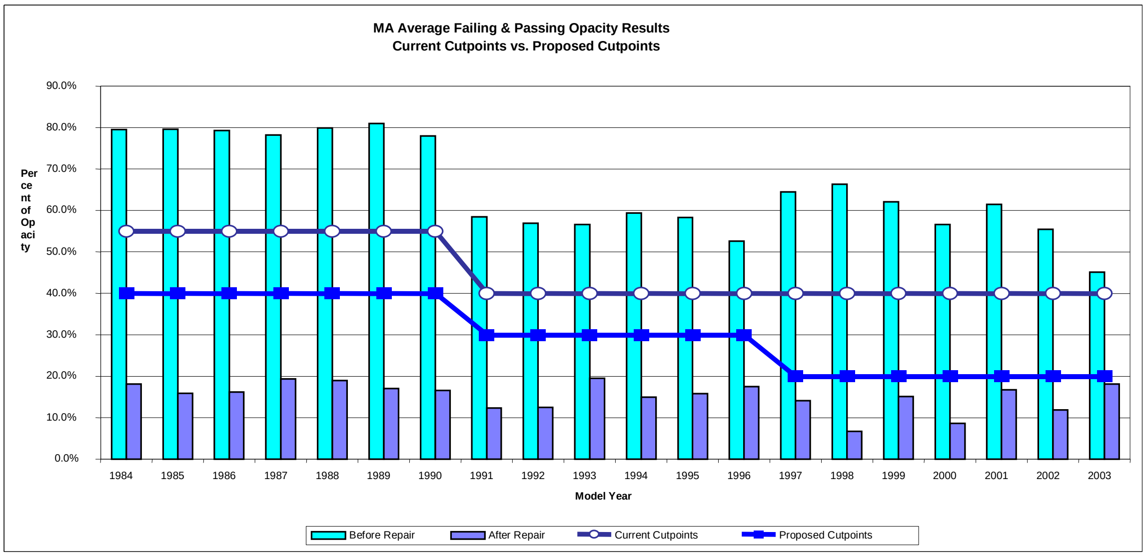
Table 8 provides a profile of the failing vehicles by the age groupings relevant to current cutpoints. The oldest model year cohort makes up some 60 percent of the total failing trucks under the current cutpoints.

Table 8. Massachusetts IM Opacity Results Before and After Repair

Vehicle Model Year Intervals	Failing MA Trucks Under Current Cutpoints	Average Failing Opacity Levels	Average Passing Opacity Levels
1997 & Newer	110 / 15.2%	60.5%	12.4%
1991 – 1996	180 / 24.9%	58.1%	15.6%
1984 – 1990	434 / 59.9%	79.3%	17.7%

Chart 4 presents the average failing and post-repair passing opacity results under current and proposed cutpoints in Massachusetts. Similar to the previous states, the data indicate that the average failing truck would pass the proposed cutpoints after repair.

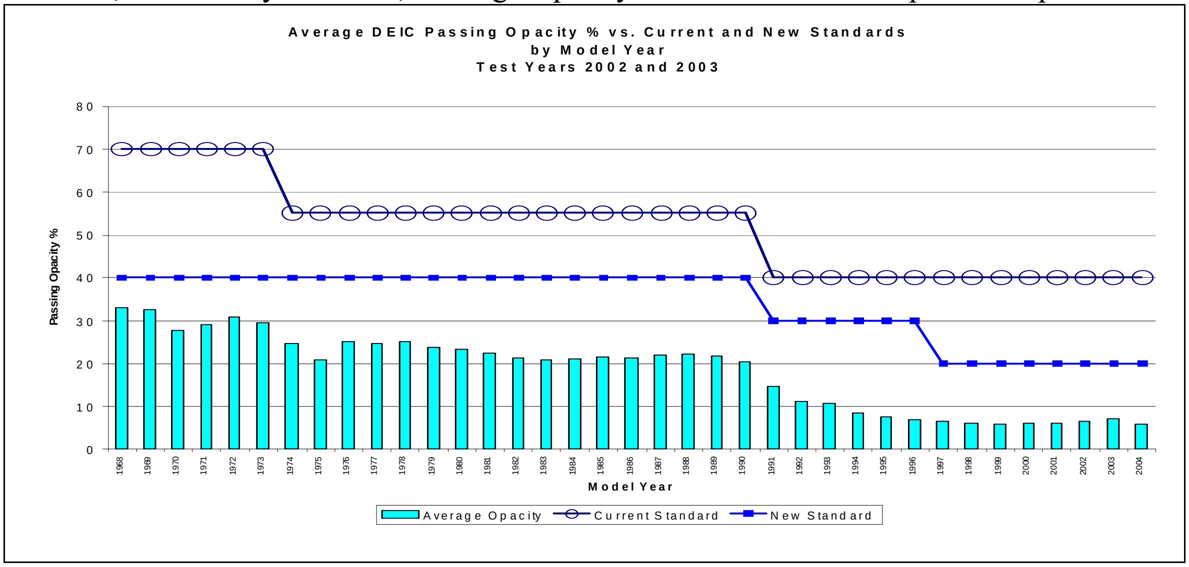
Chart 4, Massachusetts Vehicles, Average Opacity with Current and Proposed Cutpoints



New Jersey

The State of New Jersey requires periodic smoke inspections of heavy-duty diesel vehicles over 18,000 GVWR as part of its IM program. These inspections are performed at Diesel Emission Inspection Center (DEIC) locations throughout the state. In addition, New Jersey conducts roadside testing. Chart 5 presents inspection data for heavy-duty diesel vehicles from the state IM program for calendar years 2002 and 2003 under the current and proposed cutpoints.

Chart 5, New Jersey Vehicles, Average Opacity with Current and Proposed Cutpoints



New York

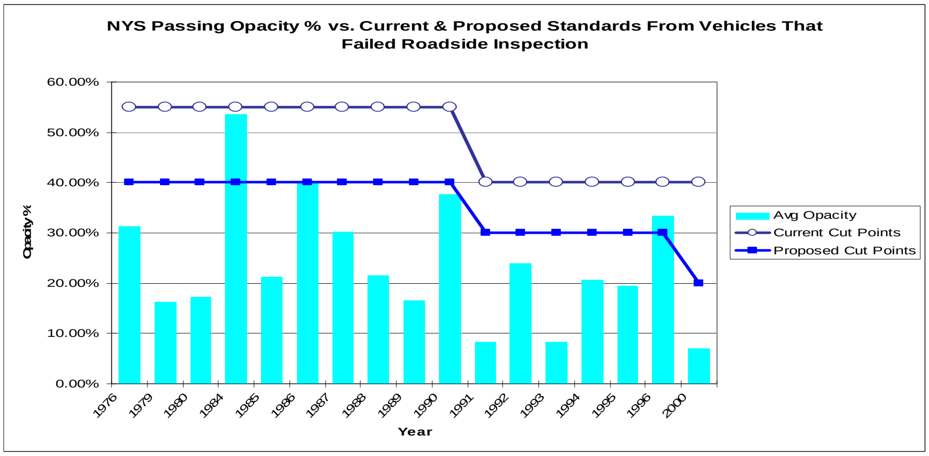
The State of New York performs roadside smoke opacity inspections. The New York opacity cutpoints are 40 percent for 1991 and newer vehicles, 55 percent for 1974–1990 vehicles, and 70 percent for 1973 and older vehicles. In some cases, vehicles failed roadside inspections for reasons other than excessive smoke (for example, a vehicle that met the opacity cutpoints could be cited for failing to display a valid annual emissions inspection certificate).

New York's current database contains some repair information along with post-repair opacity results on 36 heavy-duty diesel vehicles inspected in 2005 that initially failed roadside inspection. Of these vehicles, 23 were model year 1974–1990 and 13 were model year 1991 and newer.

Average post-repair opacity for the 1974–1990 engines was 26 percent; for the 1991 and newer engines it was 19 percent. Most (26 of the 36 engines or 72 percent) had post-repair opacity results below the proposed new opacity cutpoints. Of the 10 engines with post-repair opacity higher than the proposed new cutpoints, six were pre-1991, three were 1991–1996; and one was post-1996.

Chart 6 illustrates average opacity results from the New York database in relation to current and proposed cutpoints.

Chart 6, New York Vehicles, Average Opacity with Current and Proposed Cutpoints



Impact of Proposed Cutpoints on Overall Failure Rates

Much of the data used in this analysis to this point are from trucks that have likely been targeted and subsequently failed roadside smoke inspections with current cutpoints; the data available for analysis, therefore, are limited to the extent of that bias. Using such biased data to assess the impact of implementing the proposed cutpoints does not capture the majority of trucks that pass current cutpoints, nor do they predict additional repairs and/or maintenance owners or fleet managers will perform to keep their trucks compliant.

Two states however, Massachusetts and New Jersey, have large databases from their IM programs that show all smoke inspection results. These more complete data may help to estimate how many additional smoke inspection failures might occur under the proposed cutpoints. In addition, the Connecticut and Maryland roadside inspection databases contain information on trucks that pass as well as trucks that fail current cutpoints. While the data sets are smaller than those of Massachusetts and New Jersey, they can provide additional information on the impact of the proposed cutpoints.

Massachusetts IM data contain inspection records for 68,189 trucks that were smoke tested during the 2003–2004 biennial inspection period. Tables 9 and 10 show the number and percent of trucks that fail under current and proposed cutpoints. The data indicate that an additional 1,986 trucks would fail the proposed cutpoints if no additional maintenance or repair work was done, increasing the failure rate from 1.6 percent to 4.5 percent.

Table 9. Massachusetts Inspections with Current Cutpoints (IM Data)

Current Cutpoints	Model Year	Number of Truck Inspections	Number of Failures	Percent of Failures
55 Percent Opacity	1984-1990	14,080	613	4.4%
40 Percent Opacity	1991 and newer	54,109	472	0.9%
Totals		68,189	1,085	1.6%

Table 10. Massachusetts Inspections with Proposed Cutpoints (IM Data)

Proposed Cutpoints	Model Year	Number of Truck Inspections	Number of Failures	Percent of Failures
40 Percent Opacity	1984 – 1990	14,080	1,225	8.7%
30 Percent Opacity	1991 – 1996	18,776	811	4.3%
20 Percent Opacity	1997 and newer	35,333	1,035	2.9%
Totals		68,189	3,071	4.5%

New Jersey's annual IM data include smoke inspection results for 47,401 trucks. The number and percent of trucks that fail under the current and proposed cutpoints are presented in Tables 11 and 12. An additional 1,780 trucks in the New Jersey database would fail under the proposed cutpoints if no additional maintenance or repair work was done; increasing the failure rate from 2.0 percent to 5.8 percent.

Table 11. New Jersey Inspections with Current Cutpoints (IM Data)

Current Cutpoints	Model Year	Number of Truck Inspections	Number of Failures	Percent of Failures
55 Percent Opacity	1990 and older	9,201	212	2.3%
40 Percent Opacity	1991 and newer	38,200	737	1.9%
Totals		47,401	949	2.0%

Table 12. New Jersey Inspections with Proposed Cutpoints (IM Data)

Proposed Cutpoints	Model Year	Number of Truck Inspections	Number of Failures	Percent of Failures
40 Percent Opacity	1990 and older	9,201	1,053	11.4%
30 Percent Opacity	1991 – 1996	11,690	495	4.2%
20 Percent Opacity	1997 and newer	26,510	1,181	4.5%
Totals		47,401	2,729	5.8%

Similar data from Connecticut's roadside program are summarized in Tables 13 and 14. They indicate that an additional 299 trucks that would fail the proposed cutpoints, raising the overall failure rate from 13.8 percent under current cutpoints to 22.8 percent under the proposed cutpoints.

Compared to data from the Massachusetts and New Jersey IM programs, the higher failure rates indicated in the Connecticut data are likely a function of the fact that roadside inspection programs tend to target gross emitters—that is, trucks with visible smoke.

Table 13. Connecticut Inspections with Current Cutpoints (Roadside Data)

Current Cutpoints	Model Year	Number of Truck Inspections	Number of Failures	Percent of Failures
55 Percent Opacity	1990 and older	1,450	380	11.3%
40 Percent Opacity	1991 and newer	1,900	84	2.5%
Totals		3,350	464	13.8%

Table 14. Connecticut Inspections with Proposed Cutpoints (Roadside Data)

Proposed Cutpoints	Model Year	Number of Truck Inspections	Number of Failures	Percent of Failures
40 Percent Opacity	1984 – 1990	1,450	601	17.9%
30 Percent Opacity	1991 – 1996	740	86	2.6%
20 Percent Opacity	1997 and newer	1,160	76	2.2%
Totals		3,350	763	22.8%

Similarly higher failure rates are found in Maryland's roadside inspection data, which are summarized in Tables 15 and Table 16. There are 5,308 inspection records in the Maryland database of which 818 correspond to trucks that fail the current cutpoints. That number would increase to 1,381 with the proposed cutpoints, increasing the failure rate from 15.4 percent under current cutpoints to 26.0 percent with the proposed cutpoints.

Table 15. Maryland Inspections with Current Cutpoints (Roadside Data)

Current Cutpoints	Model Year	Number of Truck Inspections	Number of Failures	Percent of Failures
70 Percent Opacity	1973 and older	11	7	63.6%
55 Percent Opacity	1974 – 1990	1444	642	44.5%
40 Percent Opacity	1991 and newer	3853	169	4.4%
Totals		5308	818	15.4%

Table 16. Maryland Inspections with Proposed Cutpoints (Roadside Data)

Current Cutpoints	Model Year	Number of Truck Inspections	Number of Failures	Percent of Failures
40 Percent Opacity	1973 and older	11	8	72.7%
30 Percent Opacity	1974 – 1990	1444	940	65.1%
20 Percent Opacity	1991 and newer	3853	433	11.2%
Totals		5308	1381	26.0%

Summary of Inspection Programs & Impact of Adopting Lower Cutpoints

Data on smoke opacity inspections provided by CARB and several northeastern states for this analysis suggest that the truck engines can and are being repaired to bring smoke levels within the proposed cutpoints. The lack of thorough vehicle repair information for all truck engines that failed smoke opacity inspections makes the use of pre- and post-repair average opacity results a reasonable substitute. Large data sets from Connecticut, Massachusetts and New Jersey show average opacity results that fall well below the proposed cutpoints. A few model year opacity averages based on smaller data sets in California and New York are higher than the proposed cutpoints. This may be because of the small data set and/or because the limited number of truck engines may have been repaired only enough to meet the current cutpoints. The overall results of the analysis indicate that truck engines can be repaired to meet the proposed cutpoints.

Lower cutpoints will result in additional smoke inspection failures, but the increase appears moderate. By applying the lower cutpoints to current smoke inspection results, failures in Massachusetts rise 2.9 percent from 1.6 percent failure rate to 4.5 percent, and in New Jersey rise 3.8 percent from 2 percent failure rate to 5.8 percent. Failures in Connecticut rise 9 percent, from a failure rate of 13.8 percent to 22.8 percent and in Maryland rise 10.6 percent, from a failure rate of 15.4 percent to 24 percent. These estimates are based on the truck fleet profile in the databases and do not consider advances in heavy-duty diesel engine emissions technologies expected to be introduced over the next few years. Additionally, current cutpoints influence maintenance practices by fleet managers to keep their vehicles compliant; there is no reason to believe they won't continue the same practices with the lower cutpoints.

Section Three: Common Repairs and Estimated Repair Costs

Excessive smoke is usually indicative of a malfunctioning engine. The following section discusses some of the more common reasons for excessive smoke and the costs associated with repair.

Reasons for Failures, Common Repairs, and Costs of Repair

Studies suggest that the more common reasons for smoke failures are malfunctioning intake air systems or fuel systems. Air intake system failures can arise from dirty air filters, leaky turbochargers, faulty oil seals, etc. Problems with fuel intake systems can often be traced to governor tampering, air-fuel ratio controls, fouled injectors, or an injection pump that is out of range.[10] Loss of lubricating oil or compression in engines that are in poor mechanical condition can also cause high smoke levels. Malfunctioning cooling systems and exhaust treatment have also been identified as reasons for increased emissions.[11]

Some states that have failed trucks for excessive smoke require a description of the repairs that were performed on the vehicle to bring it back into compliance. While detailed records on specific repairs and the costs of those repairs are limited, the following sections provide some insight into repair costs with available data. The descriptions of the repairs are consistent with the causes of smoke failures found in other earlier studies.

[10] McCormick, R.L., Graboski, M.S., Alleman, T.L. Quantifying the Emissions Benefit of Opacity Testing and Repair of Heavy-Duty Diesel Vehicles, Colorado School of Mines, June 30, 2000
[11] Brandstetter, R., Burrahm, R., Dietzmann, H. Relationship of Underground Diesel Engine Maintenance to Emissions, Vol. 1, 1983.

California

CARB[12] has kept detailed records on the engine components of 219 trucks that were repaired as a result of a smoke inspection failure. These records show repairs to the following engine components or systems: air filter, governor, turbo charger, blower, and the fuel system (including fuel filter, fuel injection pump, fuel injectors, and puff limiters). CARB records also included repair information on exhaust gas recirculation, thermostat, and computer controls. Based on the general descriptions included in the CARB data, the most common repairs, adjustments, or replacements performed to bring excessively smoky trucks into compliance involved the fuel injection pump (65 percent of vehicles repaired); fuel filter (53 percent of vehicles repaired); air filter (50 percent of vehicles repaired); and fuel injectors (42 percent of vehicles repaired). The calculated average cost of several common types of repair (including parts & labor) came to $712 for the fuel injection pump; $247 for fuel/air filters; and $404 for fuel injectors.

CARB data provide information on repair costs for different model years of vehicles. According to these data, the average repair cost (parts plus labor) incurred to bring 1990 & older trucks into compliance with the 40 percent opacity cutpoint was $438. The average repair cost (parts plus labor) incurred to bring 1991–1996 trucks into compliance with the 30 percent opacity cutpoint was $483. The average repair cost (parts plus labor) for 1997 & newer trucks to meet the 20 percent opacity cutpoint was $757.

Connecticut

The Connecticut roadside inspection program also requires proof of repair after a smoke failure. Repair records[13] for 91 vehicles from 2005 were reviewed for this analysis. The individual records, sent to Connecticut DMV by the owners of cited trucks to show compliance, supply varying degrees of detail. Some records provide details of each engine component, whether it was adjusted, repaired or replaced, along with the costs for parts and labor costs. Other records sent in by truck owners simply state that the vehicle now meets opacity cutpoints and provide little or no repair and cost information. For this analysis, repair records for seven trucks were removed as they provided no information on repairs or repair costs. This left 84 records with usable repair information, of which 26 records provided information only on what was repaired without also showing repair costs. Data from these records were included in the analysis of common repairs but obviously could not be included in the calculation of average repair costs.

The Connecticut data indicate that the two most common repairs involved air-fuel ratio controls and air filters. Most common was the adjustment, repair and/or replacement of air-fuel ratio controls, which applied to 44 percent of vehicles serviced, including 26 puff limiters and 11 throttle relays. The highest cost of repairs in this category was $402, the lowest was $48 and the average was $167. Other adjustments or repairs to air-fuel ratio controls were listed for 14 trucks, of which only one included replacement of the air-fuel control valve at a cost of $180. Air cleaners/filters were the second most common repair, involving 29 trucks or 35 percent of the vehicles in the sample. Costs for this type of repair ranged from a high of $260 to a low of $33; the calculated average cost was $47.

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[12] California Air Resources Board, Repair Cost Worksheet, 2005.
[13] CT Roadside Repair Data Worksheet, 2005

Repair, adjustment and/or replacement of fuel system components were likewise very common. Data on the frequency and cost of repair to different fuel-system components are summarized below.

Fuel pump:
  - 19 trucks (12 adjusted, 7 replaced or repaired pumps); 6 records with cost information
  - Highest cost: $1,513; lowest cost: $85; average cost: $846.
- Fuel filters:
  - 16 trucks replaced fuel filters; 6 records include cost information
  - Highest cost: $39; lowest cost: $5; average cost: $17.
- Fuel injectors:
  - 16 trucks repaired or adjusted injectors; 5 records include cost information
  - Highest cost: $3,233 (replace all); lowest cost: $277; average cost: $1,214.
- Fuel timing:
  - 14 trucks (12 adjusted, 2 repaired); 2 records with cost information
  - Highest cost: $93; lowest cost: $21; average cost: $57.

Less common repairs noted in the database include two trucks that had work done on the engine governors and two trucks that had fuel racks adjusted. No cost information is available for these trucks or categories of repair. Records for five trucks indicate replacement of the turbochargers; of these, four include cost information. Based on these four records, costs for turbocharger replacement ranged from $773 to $1,153; the calculated average was $946. Records for one Connecticut truck indicate a full engine rebuild at a cost of $8,383.[14]

Overall the Connecticut records provide cost information on 57 trucks. The average repair cost for all repairs and all vehicles was $798.

New York

New York State found from its 36-vehicle database that many of the repairs, adjustments, or replacements performed to bring failing trucks back into compliance involved puff limiters, air and/or fuel filters, injection pumps and/or fuel injectors. No repair cost data or actual pre-repair (failing) opacity limits are available.

Vermont

The State of Vermont responds to complaints about excessively smoking trucks by sending letters to the owners of the vehicles and asking them to provide details of the repair work that was done to the vehicle. Although these data do not contain pre- and post-repair opacity readings, they do provide some limited insight into common types of repairs and the associated costs of those repairs for 67 vehicles.

The most common repairs noted in the Vermont records involve fuel system and/or air-fuel ratio control components and air filters. Repair, adjustment, or replacement of fuel system

[14] The cost associated with a complete engine rebuild goes beyond the normal expense of smoke repairs and tends to skew cost averages upward. The expense was kept in the data set analysis as the engine rebuild has a direct effect on the truck's emissions. Similarly, a complete engine rebuild on a Vermont truck that cost $11,870 was included in the analysis.

components and air filters were indicated for 33 trucks, representing almost half of the trucks in the database. Thirteen of these 33 records provided separate repair costs for the fuel system and air-fuel ratio control components and filters. The highest cost was $354 to replace the puff valve and reversing relay, while the lowest cost item was $30 to replace air filters, yielding an average cost of $111, for the combined repair of fuel systems and filters. Records for 15 trucks, or 22 percent of the total, show replacement of just the air filters. Eight of these include repair costs, which range from a low of $30 to a high of $180 and average $68 for just air filter replacements.

As mentioned, the adjustment, repair or replacement of fuel system components was common. Data on the frequency and cost of these repairs, by fuel-system component, are summarized below.

- Fuel pump:
    - 14 trucks repaired or replaced fuel pump; 3 provide repair costs
    - Highest cost: $210; lowest cost: $63; average cost: $115.
- Fuel filters:
    - 6 trucks replaced fuel filter; 3 provide cost information
    - Highest cost: $60; lowest cost: $30; average cost: $45.
- Fuel injectors:
    - 10 trucks repaired or replaced injectors and/or valves; none provided separate costs for injectors alone

Less common repairs involved intercoolers, turbochargers, throttle relays, and governors. Because limited cost information is available for these repairs, they are not included.

Repairs to reduce smoke opacity levels varied from truck to truck, as did associated costs. The most expensive repair was a complete engine rebuild that cost $11,870, the lowest repair cost was to replace an air filter at $30. The average cost of all repairs was $618.

Summary of Common Repair and Cost Data

There are many reasons why a truck might fail a smoke inspection based on exceeding opacity cutpoints. State records indicate some of the more common repairs performed on engines to bring them back into compliance, and the repairs appear to be consistent with the failing components found in the published studies review for this analysis. It is impossible to predict needed repairs or repair costs on a particular truck without knowing its current condition. The limited repair data available from several states' programs, however, suggest that many of the repairs required to bring trucks back within acceptable smoke opacity limits cost less than $1,000 on average. In fact, average repair costs on older trucks, the group with the highest failure rates, are under $500.

Compliance Cost Estimates

Costs associated with keeping an engine in good repair and in compliance with smoke opacity cutpoints are part of overall operating expenses. A few studies are available that provide average operating costs for specific segments of the transportation industry—these show a wide range of operating costs. For example, a 2000 study by the Federal Highway Administration (FHA)[15] estimates operating expenses for heavy-duty diesel trucks, including the costs of maintenance and repair, at $1.78 per mile. This study does not, however, reflect current fuel costs. A study by the American Trucking Association[16] estimated 2001 operating costs per mile for the top twenty carriers from $1.24 to $2.42 per mile. Another study by the National Aftermarket Data Exchange[17] for *Heavy Duty Trucking* estimates that operating costs range from $6.54 to $8.35 per mile including costs associated with scheduled maintenance.

An assessment of average per-mile maintenance and repair costs for compliance with smoke opacity cutpoints requires information on the average annual miles traveled. For example, the Massachusetts data describe many of the failing trucks as dump trucks– these vehicles, by design, generally operate on short hauls and many show annual mileage of some 10,000 miles or less. The 2000 FHA study[18] corroborates the Massachusetts profile, finding that local trucks, like dump trucks, trash/refuse and cement trucks, average 9,300 annual miles in 2,080 hours.

Based on the average repair costs identified in California, Connecticut, and Vermont, it is not unreasonable to assume that maintenance and/or repair costs would average well under 10 cents per mile ($1,000 average cost of repairs divided by 10,000 annual miles). The average repair cost for older trucks, which represent most of the smoke failures in the northeast, is half that estimate based on average reported repair costs of less than $500. Routine maintenance costs, such as the cost of replacing air and/or fuel filters, are often less than $100 a year, or 1 cent per mile. These expenses seem minor in comparison with other estimated operating costs such as the cost of fuel.

Excessive black smoke is usually indicative of unburned fuel. Repairs that reduce smoke also result in the more efficient combustion of diesel fuel. As the price of diesel fuel rises to levels approaching $3.00 per gallon, it is likely that the costs associated with excessive smoke repairs would be offset by fuel savings over time.

Section Four: Additional Questions and Conclusion

Additional Questions

Additional questions arose during the cutpoint and repair analysis that are beyond the scope of this study:

[15] "Expenses Per Mile for the Motor Carrier Industry: 1990 – 2000 with Forecasts to 2005" for the Federal Highway Administration, Office of Freight Management and Operation

[16] "ATA, Twenty from the Top, A Benchmarking Guide to the Operations of For-Hire Truckload Carriers Ops", 2001

[17] "Fleet Maintenance, Maintenance and Repair Costs," December 2000 (data from study for *Heavy Duty Trucking* by the National Aftermarket Data Exchange

[18] "Expenses Per Mile for the Motor Carrier Industry: 1990 – 2000 with Forecasts to 2005" for the Federal Highway Administration, Office of Freight Management and Operation

1) Are there additional inspection protocols or alternatives to the SAE J1667 smoke opacity protocol to identify gross polluters?

Enforcement officials and smoke inspectors report that some trucks emit excessive black smoke immediately after passing the SAE J1667 smoke opacity inspection. Anecdotal information suggests that there may be some engine setting, either deliberately installed or as a result of engine computer programming, that allows an engine to produce less smoke during the smoke test than it does under load. Is there an inspection protocol that could better replicate the smoke levels that are produced under load?

Alternatives to the SAE J1667 smoke opacity test should be considered. Research by the Colorado School of Mines[19] suggest that measuring emissions of hydrocarbons (HC) and carbon monoxide (CO) might be a better surrogate for predicting high levels of particulate matter emissions than smoke opacity tests.

Another option is to integrate onboard diagnostic systems (OBD) in heavy-duty vehicles. State inspections using OBD protocols could identify gross polluting trucks and buses. CARB announced in late 2006 that it will require OBD in California heavy-duty vehicles over 14,000 GVWR beginning in model year 2010. Similarly, U.S. EPA in December, 2006 proposed regulations that would require OBD systems for these same vehicles.

2) How many owners are repairing their engines only to meet smoke cutpoints rather than to bring the vehicle back into engine manufacturers' specifications?

This study utilized available data, which tend to be general in nature; no attempt was made to research individual decisions that affect the amount of repair invested in an individual truck. Older trucks make up a sizable proportion of the smoke failures in the northeast and some of the data suggest that a small percentage of truck owners are investing only enough money to bring their vehicles' smoke emissions within current cutpoints. For example, records for a few of the trucks in the states' databases indicate that $30 was spent on a new air filter that brought smoke levels from over the passing limit to just under existing cutpoints.

Other anecdotal information suggests that after repair, some truck engines are "adjusted" to increase smoke emissions to levels just under existing cutpoints, based on an opinion that forcing more fuel through the internal combustion process creates more power. Additional research into the potential power boost achieved and the operating and maintenance expenses associated with this practice might assist policy-makers and truck operators in designing strategies to discourage excessive smoke levels.

3) Are heavy-duty diesel repair technicians adequately trained to address emissions-related repairs?

Heavy-duty diesel engine technology has changed dramatically in the past several years and 2007 engine standards require additional emissions devices. Engine manufacturers have stepped

[19] Robert McCormick, et al, "Quantifying the Emissions Benefit of Opacity Testing and Repair of Heavy-Duty Diesel Vehicles," Colorado Institute for Fuels and Engine Research, Colorado School of Mines, June 30, 2000.

up training opportunities for technicians, but training opportunities seem to be limited and could be expanded. Repairer training for advanced technology engines needs to be provided to all repairers including fleet operators and independent repair shops.

4) Will the smoke testing equipment continue to produce results that are as reliable and repeatable with lower opacity cutpoints?

As cutpoints continue to get lower, the equipment used to measure opacity may begin to approach the accuracy limitations in SAE J1667 specification for bandwidth and zero drift. While the lowest proposed smoke opacity limit of 20 percent is significantly higher than the 2 percent variation allowed in the SAE specification, states will need to ensure that the equipment continues to work as dependably as it has to prevent false failures due to testing equipment issues. The answer to this question won't be available without inspection experience.

Conclusion

The smoke opacity test data for inspected vehicles indicate that many trucks are passing inspections with smoke opacity significantly below current cutpoints. The data also indicates that most failing trucks can be and are already being repaired to the proposed lower cutpoints. Average smoke opacity results after repair show that most trucks would pass the lower cutpoints by a comfortable margin.

Repair data identify common malfunctions that cause excessive smoke and repair cost data indicate that most repairs to correct these malfunctions cost under $1,000. If these repairs are performed as routine maintenance instead of in response to smoke opacity inspection failures, the costs to keep visible smoke low enough to pass the proposed cutpoints would result in an additional operating cost of no more than ten cents per mile. Most of that expense would be in the first year of the repair with the routine maintenance and expense of changing filters and other adjustments in subsequent years. Long-term maintenance costs would probably be closer to 1–5 cents per mile. Since black smoke is associated with unburned fuel, operators may find that the fuel savings resulting from more efficient engine operation may, depending on fuel costs, offset additional maintenance costs.

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Fleet Maintenance, Maintenance and Repair Costs, December 2000 (data from study for *Heavy Duty Trucking* by the National Aftermarket Data Exchange

Appendix A: California Repair Data

Vehicle ID Number	Model Year	Make	Engine Model Year	Engine Model	Failed Opacity	Post Repair Opacity	Tamper Test	Air Filter	Governor	Turbo	Blower	Overhead / Rack	Fuel Filter	Throttle Delay	Fuel Injection Pump	Fuel Injection Timing	Fuel Injectors	AFRC / Puff Limiter	Exhaust Gas Recirculation	Computer Controls	Thermostat	Part Cost	Labor Cost	Total Repair
192	1954	KW	1954	NTC400	60	30.	F	S	A			A	S				A					$140.00	$100.00	
150	1968	KW	1968		96	5.3	F					A	S		R		A					$400.00	$190.00	
90	1969	WHIT	1969		90	16.	F	R	K	K		A	R	R	K	K					K	$210.61	$200.00	
3	1969	KW	1969		90	19.	F								S							$722.43	$50.00	
52	1972	PETE	1971	NTC335	91	25.	F	S					S		S		S					$208.45	$369.90	
22	1971	PETE	1971	NTC350	87	44.	F	S					S		K	K	K					$250.00	$100.00	
195	1971	KW	1971	NTC335	98	29.	F	K	K	K			S	K	S	K	K				K	$420.00	$125.00	
81	1972	KW	1972		58	40.	F	S	K				S		R		R					$78.12	$20.00	
11	1973	PETE	1973	3406B	60	32.	F							A								$1.65	$123.50	
185	1973	KW	1973	NTCC325	70	12.	P	K				A	S	A	A							$60.16	$100.00	
148	1973	IHC	1973	8V71	60	6.9	P	K	K	K		A	K	R	K	K	K					$100.00	$580.00	
14	1973	PETE	1973	NTC400	70	32.	F								S							$341.25	$99.00	
120	1973	KW	1973		98	18.	F	S					S		S	A	S					$405.00	$290.00	
24	1973	Pete	1973	NA	68	17	P	S				R	S		S		S					$637.79	$60.00	
112	1974	KW	1974		84	16.	F	S	K	K		K	S	K	R	K	R					$202.50	$50.00	
38	1974	MACK	1974		99	32.	F	K	A	K		K	K		A	K	K					$570.00	$195.00	
1	1974	KW	1974	NTC400	65	8.2	F	S		S		A	S		A	A						$752.01	$957.00	
164	1974	MACK	1974	NTC400	95		F	K	K	K			S	K	S	A	K				K	$769.40	$680.00	
43	1975	IHC	1975		96	27	F	S							R							$129.54	$91.50	
169	1975	WHIT	1975	NA	67	5.4	P	K	A	K		A	K	S			S				K	$1,655.38	$544.50	
133	1976	KW	1976		56	31.	F	R					R		A		R					$462.00	$300.00	
30	1977	KW	1977	3406B	56	21.	F															$17.80	$67.00	
187	1977	PTRB	1977	8V92	86	27.	F		A					A								$75.00	$75.00	
36	1977	KW	1977	NTC400	88	20.	F	S					S		R	K						$150.00	$50.00	
190	1977	FRHT	1977		61	11.	F	S				A	S		A							$263.00	$330.00	
98	1978	IHC	1977	NTCC350	94	19.	F	S					S		S	R	R					$429.62	$305.38	
78	1978	intl	1977	NTC290	78	27.	F								S							$487.00	$130.00	
211	1977	WHIT	1977		96	4.93	F	S	K	K		K	S	R	R	K	S					$735.00	$250.00	
109	1977	GMC	1977		96	.9	F	K	K	K		K	K		R	R	R				K	$1,903.80	$2,200.00	
110	1978	FRHT	1978	NA	60	25.	P	S					S									$45.02	$60.00	
176	1978	KW	1978	335	88	12.	P	K	K	K		K	K	K	K	K	K				K	$121.70	$188.00	
137	1978	KW	1978		81	28.	P	S									S					$460.43	$395.00	
42	1978	PETE	1978		92	51.	F	S	S	A		R	S		R	R	R					$600.00	$200.00	
127	1972	IHC	1979	NTC350	93	26.	F	R	A	K		K	R	K	R	A	K				R	$100.00	$500.00	
173	1979	FORD	1979	NTC300	93		F	S	K	K		K	S								S	$147.38	$192.50	
41	1979	PETE	1979		74	36.	F	K	A	K		A	K	A	K	A	S				K	$162.39	$236.25	
156	1979	INTL	1979	CV92TA	74	13.	P	S					S				S					$169.00	$520.00	
93	1978	KW	1979		99	27.	P	A	A	A		A	A		A		A					$194.00	$100.00	
199	1980	PETE	1979	NTCC350	98	26.	P															$290.00	$97.50	
188	1979	KW	1979	NTC290	94	43.	F	K	K	K		A	S	A	K	K	S				K	$430.00	$716.00	
155	1980	PETE	1980	NA	58	49.	F															$40.06	$92.00	
34	1980	MACK	1980		69	14.	F								R	R						$65.00	$138.00	
100	1980	FRHT	1980	NA	84	25	F	S	R	K		K	S	S	S	K	K				K	$331.00	$568.27	
27	1980	IHC	1980		74	42.	F	S							S							$500.00	$100.00	
174	1980	KW	1980		60	17.	F								R		R					$555.00	$43.01	
170	1980	PETE	1980	8V92	76	21.	P	K	S	K		A	K	S	K	K	K					$561.35	$1,050.00	
25	1990	PETE	1980	6V92	74	8.3	F	R	R	R		A	R	R	K	K	K				K	$1,899.80	$1,215.00	
75	1980	KW	1980	NTC400	92	20	P	S					S		S	A						$2,014.30	$2,094.75	
9	1980	KW	1980		93	39.	F		A				S		A	A	S					$2,408.55	$1,650.00	
29	1982	KW	1981	NTCC350	70	28.	P															$22.40	$320.00	
51	1981	FORD	1981	NTC300	89	20.	F	S							A							$45.00	$100.00	
143	1981	PETE	1981	NTC400	63	47.	F	S	K	K		K		K	K	K	K				K	$47.56	$79.00	
8	1981	KW	1981		83	42.	F	S					S		A							$76.00	$100.00	
108	1981	FRHT	1981	3406A	99	49.	F															$135.00	$260.00	
125	1983	PETE	1981	NTC475	88	40.	F					A	S		A		S					$253.30	$200.00	
76	1981	intl	1981	NTC350	59	47.	F	R							A		A					$353.00	$575.00	
142	1981	KW	1981	3406B	63	15.	F	S	K	K		A	S		K	K	K				K	$400.00	$1,544.00	
117	1982	FRHT	1981	NTCC400	67	18.	F	S	K	K		A	S	A	R	A	R				A	$428.41	$675.00	
147	1981	KW	1981	NTC350	75	7.3	F															$657.80	$350.00	
102	1981	KW	1981		80	15.	F	S				A	A		R		R					$744.65	$240.00	
13	1982	PETE	1982		70	38.	F										R					$198.00	$30.00	
106	1982	FRHT	1982	NA	95	41.	F								R							$424.91	$40.00	
39	1983	KW	1983		57	8.4	F	S					S		A							$50.00	$60.00	
77	1983	FRHT	1983	NTC475	63	29.	P								R							$265.00	$382.00	
28	1984	IHC	1983	NA	57	38.	F	S					S		S		S					$579.00	$200.00	
130	1983	KW	1983	NA	98	15.	F	S	K	K		S	R	A	R						A	$2,000.00	$1,100.00	
87	1984	fht	1984		83	35.	F	K	K	K		K	K		A	K	K				K	$15.00	$110.00	$125.00
113	1984	PETE	1984	NA	93	23	P	K	A	K		K	S	R	K	K	A					$28.27	$110.00	$138.27

Repair Abbreviations: A = Adjusted; R = Repaired; S = Replaced; K = Checked OK

Vehicle ID Number	Model Year	Make	Engine Model Year	Engine Model	Failed Opacity	Post Repair Opacity	Tamper Test	Air Filter	Governor	Turbo	Blower	Overhead / Rack	Fuel Filter	Throttle Delay	Fuel Injection Pump	Fuel Injection Timing	Fuel Injectors	AFRC / Puff Limiter	Exhaust Gas Recirculation	Computer Controls	Thermostat	Part Cost	Labor Cost	Total Repair
114	1984	KW	1984	NA	71	.04	P	S	K	K		K	S	K	S	K	K				K	$59.00	$90.00	$149.00
213	1984	PETE	1984	NTC400	69	18.	F	S	A													$150.00	$75.00	$225.00
182	1984	KW	1984	3406B	89	8.8	P	S														$31.31	$324.50	$355.81
89	1984	PETE	1984	NA	61	29.	F	S					S				S					$168.00	$250.00	$418.00
124	1984	PETE	1984	NA	86	30.	P	S	A				S		A		S					$274.07	$195.00	$469.07
204	1984	KW	1984		73		F	K		K			S		K	K						$400.00	$100.00	$500.00
140	1984	MACK	1984		86	17.	P	S				A	S									$120.00	$432.00	$552.00
141	1984	INTL	1984		61	24.	F	S	K	K		K	S	K	R	R	R				K	$422.58	$160.00	$582.58
62	1984	FRHT	1984	NTC400	62	48.	F	S		K			S		R	A	A					$506.00	$200.00	$706.00
115	1984	PETE	1984	NTCC350	79	6.1	F	S		K			S		S	K	S					$430.00	$300.00	$730.00
84	1984	FRHT	1984		62	9.2	F	S					S		R	A						$367.89	$366.73	$734.62
80	1984	FRHT	1984	NTC400	95	35.	P	S					S		S		A					$630.00	$150.00	$780.00
103	1984	PETE	1984		65	32.	P	S	K	K		A	R	K	R	K	S				K	$552.40	$325.00	$877.40
144	1984	PETE	1984	NTC400	91	17.	P	S				A	S		R		R					$634.68	$450.00	$1,084.68
91	1985	FRHT	1985		94	24.	F															$10.93	$55.00	$65.93
162	1985	FORD	1985	NTC400	79	48.	F								S							$250.00	$50.00	$300.00
167	1985	KW	1985		83	31.	F								R							$250.00	$50.00	$300.00
68	1985	IHC	1985		87	26.	F								R							$108.25	$250.00	$358.25
21	1985	KW	1985		64	40.	F	S					S		A	A	R					$250.00	$230.00	$480.00
180	1990	KW	1985	NTC400	61	26.	F	S							A		S					$460.50	$40.00	$500.50
71	1985	PETE	1985		69	25.	P	S							S		A					$272.78	$335.00	$607.78
94	1985	PETE	1985		67	12.	P	K	R	K		A	S	K	K	K	S				K	$316.79	$420.00	$736.79
145	1985	PETE	1985	NTCC400	75	34.	P	S	S	K		K	S	K	S	A	S				K	$599.82	$200.00	$799.82
44	1985	FRHT	1985	NTC350	68	10.	P	S	A				S		R							$375.00	$455.00	$830.00
17	1990	whgm	1985	LTA10	61	47	F								R		R					$452.00	$385.00	$837.00
203	1985	KW	1985		62	30.	F	S					S		R		S					$809.88	$305.00	$1,114.88
64	1985	KW	1985	NA	77	21.	F	S				S	S		R		S					$980.00	$600.00	$1,580.00
218	1985	FRHT	1985	NTC400	68	3.8	F	K					K		K		K					$3,000.00	$2,000.00	$5,000.00
198	1986	FRHT	1985	NTC400	96	12.	F	S				A	S			A	S				S	$6,160.00	$2,500.00	$8,660.00
56	1986	FRHT	1986		72	9.9	F	S							A							$86.48	$35.00	$121.48
40	1986	FRHT	1986	NA	85	28.	F	S						A	A	A						$80.00	$45.00	$125.00
139	1986	MACK	1986		78	21.	P		A				R		A	A						$12.90	$180.00	$192.90
165	1986	IHC	1986		62	30	F								R							$250.00	$50.00	$300.00
18	1986	PETE	1986	NTC350	77	41.	F									A						$225.00	$108.00	$333.00
69	1986	IHC	1986		68	41.	F						S		R	R						$258.00	$100.00	$358.00
59	1986	IHC	1986		91	40	F	R	R				R									$95.00	$302.83	$397.83
31	1987	FRHT	1986	NTCC400	58	4.0	F	S				A	S									$195.00	$204.00	$399.00
149	1986	INTL	1986		87	14.	F	S	K	K		K	S	K	R	K	R					$92.00	$315.00	$407.00
186	1986	FRHT	1986	NTC315	64	46.	F								A							$293.00	$175.00	$468.00
178	1986	PETE	1986		66	45.	P								S							$388.71	$105.00	$493.71
160	1986	IHC	1986		63	41.	F								A		R					$506.66	$86.00	$592.66
209	1986	FORD	1986	NTCC350	85	34.	F	S	K					K	K	K						$177.02	$448.41	$625.43
168	1986	INTL	1986		70	17.	F	S					S		S		S					$203.00	$425.00	$628.00
105	1986	INTL	1986	NTCC300	72	24	F	S					S		A	A	A					$518.16	$280.00	$798.16
73	1986	FRHT	1986	NTCC300	76	3.9	F	K	K	K		R	K				S					$621.26	$364.00	$985.26
158	1986	KW	1986		56	11.	F															$400.00	$1,250.00	$1,650.00
181	1986	FORD	1986		57	11.	F	K					K				K					$1,200.00	$600.00	$1,800.00
134	1987	FRHT	1986	3306	89	42.	P	K	R	R		K	K	A	K	K	K					$110.91	$1,738.04	$1,848.95
171	1986	GMC	1986		92	5.6	F	S	K	K		K	K	K	A	S	K				K	$1,204.17	$825.00	$2,029.17
20	1985	WHIT	1986	LTA10	60	29.	F	K							A							$1,551.50	$684.00	$2,235.50
121	1986	KW	1986		82	9.9	P	S	A	K			S		K	K	K					$2,448.00	$244.80	$2,692.80
104	1987	INTL	1986	NTC400	74	15.	F	S	R	S		R	S		R		R				K	$3,300.00	$735.00	$4,035.00
88	1987	PETE	1986	NTC350	95	41.	F	S	K	K		A	S		R	A	R				K	$1,869.89	$2,954.65	$4,824.54
172	1987	FRHT	1987		85	16.	F	S					S		R	A	A					$4.28	$42.75	$47.03
175	1987	PETE	1987	350	64	21.	P	S	K	K		K	S	K	A	K	K				K	$90.00	$45.00	$135.00
119	1987	KW	1987	NTC444	88	.5	F	S	K	K		K	R									$62.50	$100.00	$162.50
184	1987	FRHT	1987	LTA10	57	11.	F	K					K		K							$12.86	$227.50	$240.36
65	1987	FRHT	1987	NA	80	17.	F	S					S		A		A					$180.00	$70.00	$250.00
83	1988	KW	1987	NTC400	57	45.	F	S		R			S		K	K						$150.00	$125.00	$275.00
166	1987	FRHT	1987		63	52.	F	R							R							$240.00	$40.00	$280.00
66	1987	FRHT	1987	NA	84	12.	F	K	K	K			K	K	K	K	K					$93.27	$230.00	$323.27
67	1987	intl	1987		86	37.	F	S				A	S		A		R					$231.00	$250.00	$481.00
72	1987	IHC	1987	NA	57	51.	F										S					$303.10	$200.00	$503.10
2	1987	KW	1987		97	38.	F	S	S			R	S	S								$375.00	$190.00	$565.00
214	1987	intl	1987	NTC350	70	49.	F	S	K	K		A	S	K	A	K	A				K	$519.00	$100.00	$619.00
70	1987	PETE	1987		73	6.3	F	R					R		R		R					$175.00	$568.31	$743.31
122	1987	KW	1987		96	7.1	P	S	K	K		A	S	K	R	A	R				K	$460.00	$300.00	$760.00
99	1987	IHC	1987		90	32.	P		R													$76.97	$886.50	$963.47

Repair Abbreviations: A = Adjusted; R = Repaired; S = Replaced; K = Checked OK

Vehicle ID Number	Model Year	Make	Engine Model Year	Engine Model	Failed Opacity	Post Repair Opacity	Tamper Test	Air Filter	Governor	Turbo	Blower	Overhead / Rack	Fuel Filter	Throttle Delay	Fuel Injection Pump	Fuel Injection Timing	Fuel Injectors	AFRC / Puff Limiter	Exhaust Gas Recirculation	Computer Controls	Thermostat	Part Cost	Labor Cost	Total Repair
48	1987	PETE	1987	NA	65	12.	F	S					S		S	S						$990.00	$350.00	$1,340.00
16	1987	IHC	1987		61	37.	P								R		R					$785.19	$586.25	$1,371.44
177	1987	IHC	1987		61	35.	P					A					S					$709.62	$688.00	$1,397.62
5	1987	MACK	1987	NTCC400	86	.35	F					A			R		R					$936.83	$780.00	$1,716.83
116	1988	PETE	1988	NA	81	48.	F								A							$50.00	$50.00	$100.00
15	1988	PETE	1988		61	19.	P	S														$60.00	$80.00	$140.00
157	1988	PETE	1988		88	09.	F	S	K	K		K	S		A	K	K				K	$80.00	$95.00	$175.00
19	1988	PETE	1988	NTC400	84	51.	P	S		K		A	S		A		S					$198.00	$15.84	$213.84
219	1988	KW	1988	3406B	86	10.	F	S	A				S			A						$150.00	$150.00	$300.00
7	1988	IHC	1988	NTC315	59	42.	F	S					S									$152.70	$155.00	$307.70
132	1988	KW	1988		92	48.	P	K	A	K		A	S	K	K	A	K				K	$100.00	$250.00	$350.00
35	1988	KW	1988	NTC350	97	53.	F								S		S					$250.00	$165.00	$415.00
196	1988	PETE	1988		61	40.	F								S		A					$350.00	$200.00	$550.00
61	1988	FRHT	1988		60	32	F	K				K	S		R		K					$424.04	$170.00	$594.04
26	1988	KW	1988	NTC315	84	23.	F	S					S		R		S					$577.00	$120.00	$697.00
216	1988	KW	1988	335	74	26.	F	R					R		R							$543.70	$200.00	$743.70
118	1988	FRHT	1988	NA	67	23.	P	S	A				S		S	S	S					$700.00	$300.00	$1,000.00
50	1989	FRHT	1988	NTC400	57	15.	F	S							R							$949.09	$1,222.40	$2,171.49
217	1988	IHC	1988	NTC350	63	33.	F	S					S			R	K					$600.00	$3,500.00	$4,100.00
136	1989	KW	1989		60	24.	F										K					$2.42	$59.00	$61.42
146	1989	KW	1989	NTC350	76	52.	F	S					S		R							$36.66	$50.00	$86.66
111	1989	FRHT	1989	NA	73	24.	F	S		K		A	S		A							$109.75	$60.00	$169.75
138	1989	intl	1989	NTC290	60	39.	F	S					S									$135.78	$60.00	$195.78
107	1989	FRHT	1989	NTC350	65	32.	P	K	K	K		K	K	A	A	K	K					$34.09	$163.00	$197.09
58	1989	IHC	1989	NA	69	49.	P						S		A							$86.00	$120.00	$206.00
6	1989	FRHT	1989	NTC365	57	5.1	P	S					S		A							$125.00	$109.00	$234.00
47	1989	IHC	1989	NA	64	23.	F	S							A							$95.00	$150.00	$245.00
60	1989	INT	1989		65	42	F						R		R							$250.00	$50.00	$300.00
79	1989	FRHT	1989	NA	80	41	F						R		S							$70.92	$230.92	$301.84
123	1989	PETE	1989	NTC444	62	39.	F	K	K	K		A	S	K	A	K	K					$96.79	$230.00	$326.79
191	1989	FRHT	1989	3406B	76	10.	F															$177.09	$162.50	$339.59
205	1989	intl	1989	NTC315	63	30.	F						K		K							$300.00	$75.00	$375.00
32	2000	FRHT	1989		77	19.5	F								R							$147.21	$284.86	$432.07
129	1989	KW	1989		83	10.	P	S														$340.70	$105.00	$445.70
4	1989	PETE	1989	3406B	85	9.5	P								R							$166.18	$437.40	$603.58
208	1989	FRHT	1989	315	71	3.9	F	K	K	K		K	K	K	R		R				K	$440.00	$180.00	$620.00
45	1989	PETE	1989	3406B	91	55	F					A			A	A	R					$201.49	$441.00	$642.49
101	1989	PETE	1989	NA	58	15.	F	S					S		A							$484.00	$180.00	$664.00
53	1990	PETE	1989	NTC400	68	11.	F	S							R		A					$165.13	$540.00	$705.13
206	1989	intl	1989	NTC350	90	44.	F	K	K	K		K	S		R	K	S				K	$505.15	$290.00	$795.15
163	1990	KW	1989	NTC365	87	12.	F								S							$656.31	$206.48	$862.79
161	1989	PETE	1989		84	16.	F	K	K	K		K	S	S	K	K	K				K	$445.10	$661.50	$1,106.60
126	1989	PETE	1989	TC400PUM	77	46.	F	S	K	K		K	S		R	R	R					$1,078.09	$219.04	$1,297.13
10	1989	intl	1989	NTC315	65	41.	F										S					$800.00	$500.00	$1,300.00
197	1989	FRHT	1989		81	29.	P	K	K	K		K	S	K	S	A	S				K	$600.00	$1,200.00	$1,800.00
57	1989	INTL	1989		90	8.6	P					S	S		R		R					$1,391.84	$480.00	$1,871.84
37	1989	FRHT	1989	LTA10	73		F					A			R	R	S					$2,722.31	$2,025.00	$4,747.31
202	1991	FRHT	1990	NTC315	62	32.	F	S	K	K		K	K	K	A	K	K				K	$49.68	$100.00	$149.68
55	1991	FHR	1990		63	51.	F								R							$100.00	$100.00	$200.00
152	1990	KW	1990	TC450FF15	95	11.	F								R							$161.00	$61.20	$222.20
85	1990	FRHT	1990		58	34.	F	S	K	K		A	S		S	K	A				K	$181.66	$75.00	$256.66
189	1990	FRHT	1990	NTC350	73	32.	F	S	K	K		K	S	K	A	K	K				K	$178.31	$90.00	$268.31
194	1991	IHC	1990	NTC315	77	50.	F	S	A	K		A	S		A	K	A				K	$76.00	$240.00	$316.00
154	1990	FRHT	1990	NA	80	46	F	S														$250.00	$75.00	$325.00
46	1990	IHC	1990		59	53.	F								S							$275.00	$95.00	$370.00
86	1991	FRHT	1990		60	35.	F	S							R							$300.00	$100.00	$400.00
128	1990	PETE	1990		64	41.	F	K	K	K		R	K	K	R	K	K					$45.00	$357.00	$402.00
54	1990	FRHT	1990		85	35.	F	R					R		R							$325.00	$90.00	$415.00
82	1990	IHC	1990	NA	66	55.	F	S	K	K		K	S	K	A	K	K				K	$292.00	$132.00	$424.00
92	1990	FRHT	1990		70	51.	F	K	R	K		A	S	K	S	K	A				K	$310.00	$275.00	$585.00
63	1990	FRHT	1990	NA	67	40	F	S					S		R	A	R					$440.00	$230.00	$670.00
74	1990	FHRT	1990		73	21.	F	S	A	A			S		R	R	R					$427.44	$300.00	$727.44
151	1990	WHIT	1990		65	25.	F	S				A	S				S					$673.92	$262.97	$936.89
96	1990	WGMC	1990	L10	59	47.	P	S		S												$718.41	$552.00	$1,270.41
49	1991	IHC	1990	NA	66	19.	F								S		S					$505.16	$1,200.00	$1,705.16
215	1990	WGMC	1990	LTA10	75	37.	F								S	A	S					$718.38	$1,350.00	$2,068.38
210	1992	FORD	1991		74	19.	P	S	K	K		A	S									$39.86	$360.00	
159	1992	KW	1991		42	30.	F	S	K	K		K	S	R	R	K	K				K	$100.00	$90.00	

Repair Abbreviations: A = Adjusted; R = Repaired; S = Replaced; K = Checked OK

Vehicle ID Number	Model Year	Make	Engine Model Year	Engine Model	Failed Opacity	Post Repair Opacity	Tamper Test	Air Filter	Governor	Turbo	Blower	Overhead / Rack	Fuel Filter	Throttle Delay	Fuel Injection Pump	Fuel Injection Timing	Fuel Injectors	AFRC / Puff Limiter	Exhaust Gas Recirculation	Computer Controls	Thermostat	Part Cost	Labor Cost	Total Repair
193	1991	PETE	1991	N14-350P	73	30.	F						S				S					$519.63	$250.00	
207	1991	WGMC	1991	LT-A10	64	47%	P	K	A	A		A	K		A		K					$682.35	$204.67	
135	1991	FRHT	1991		79	22	F	S	A	K		K	K	A	A	A	K				K	$1,025.00	$250.00	
33	1992	KW	1992	NTC350	59	19.5	F	S	K	K		K	S	K	R	K	K				K	$100.00	$300.00	
12	1994	PETE	1993	N14	40		F															$34.73	$268.00	
212	1993	IHC	1993	NTC350	52	40.	F	K	K	K		A	K	K	K	K	A				K	$593.60	$260.00	
179	1993	FRHT	1993	NTC400	95	38.		S	K	K		K	S	K	S	A	R				K	$791.00	$200.00	
201	1993	PETE	1993	NTC350	43	21.	F					K			K		K					$845.32	$220.00	
95	1994	PETE	1994	N14 430	78	33.	F						R		R		R					$924.00	$350.00	
97	1996	PETE	1996		87	2.7	P								R		S					$500.00	$420.00	
23	1996	PETE	1996		71	19	F	S							R		R					$750.00	$150.00	
200	1998	KW	1997	3406B	85	25.	F															$23.04	$92.00	
183	2000	FRHT	1999	S60	92	10.	P															$157.00	$158.00	
131	1999	PETE	1999		63	5.3	P	S	K	S		A	R	K	K	K	A				R	$1,680.29	$417.00	
153	2001	FRHT	2000	SERIES 60	47	19.	P	K		K		K	K				S				K	$1,952.59	$375.00	

Repair Abbreviations: A = Adjusted; R = Repaired; S = Replaced; K = Checked OK

Vehicle ID Number	Model Year	Make	Engine	Failed Opacity	Air Filter	Cost	Air/Fuel Control	Cost	Gov	Cost	Turbo	Cost	Blower	Cost	Overhead Rack	Cost	Fuel Filter	Cost	Throttle Relay	Cost	Fuel Pump
65	1963	Mack	Mack	89.3%							Replaced clamp										
66	1970	Mack	Mack	84.3%															Replaced		
2	1972	Ford	Unknown	72.4%	Replaced	$38.00											Replaced	$12.50			Adjusted
24	1972	Mack	Mack	72.0%	Replaced	$86.46															
23	1972	Mack	Mack	58.1%	Replaced	$39.00											Replaced	$20.80			Repaired
1	1973	Autocar	Cummins	94.6%							Replaced	$858.97									
26	1974	Mack	Mack	70.6%																	Replaced
25	1974	Mack	Mack	60.6%							Repaired	$1,152.98									
67	1974	Mack	Mack	71.4%																	
27	1977	Mack	Mack	87.0%															Replaced		
15	1978	Int	Cummins	56.7%	Replaced																
28	1978	Mack	Mack	65.8%															Replaced	$157.70	
3	1979	Ford	Unknown	58.8%																	Repaired
29	1979	Mack	Mack	86.8%															Replaced	$159.60	
68	1979	Mack	Mack	90.5%	Replaced												Replaced				Adjusted
50	1980	Ptrb	Detroit	95.4%															Replaced		
4	1981	Ford	CAT	89.8%																	Adjusted
19	1981	Kenworth	CAT	70.1%	Replaced		Repaired		Adjusted												
86	1981	Mack	Mack	59.7%																	
69	1981	Mack	Mack	86.9%																	
51	1981	Ptrb	Cummins	94.8%	Replaced		Adjusted														
81	1981	Ptrb	Detroit	61.7%																	
30	1982	Mack	Mack	64.7%																	
31	1982	Mack	Mack	83.7%															Replaced	$133.00	
59	1983	Ford	CAT	82.4%			Repaired														checked - OK
70	1983	Mack	Mack	75.2%					Adjusted												Repaired
32	1984	Mack	Mack	58.9%															Replaced	$56.00	
71	1984	Mack	Mack	78.3%													Replaced				
60	1985	Freightliner	Cummins	71.4%	Replaced												Replaced				
87	1985	Mack	Mack	76.5%																	
33	1985	Mack	Mack	91.3%													Replaced	$12.82	Replaced	$152.00	
52	1985	Ptrb	CAT	57.4%			Adjusted	$1.57													
11	1986	Freightliner	Detroit	67.2%							Checked				Adjusted						
63	1986	Kenworth	Cummins	58.2%	Replaced																
37	1986	Mack	Mack	71.7%			Adjusted														
88	1986	Mack	Mack	57.1%																	
38	1986	Mack	Mack	82.8%																	
35	1986	Mack	Mack	64.3%																	
36	1986	Mack	Mack	68.1%																	
34	1986	Mack	Mack	55.9%	Replaced	$90.00															
72	1986	Mack	Mack	61.1%																	
73	1986	Mack	Mack	75.1%	Replaced												Replaced				
62	1987	Int	Cummins	73.5%	Replaced												Replaced				
39	1987	Mack	Mack	58.9%																	
41	1987	Mack	Mack	83.8%																	
40	1987	Mack	Mack	64.6%															Replaced	$221.94	
74	1987	Mack	Mack	69.6%																	

Vehicle ID Number	Model Year	Make	Engine	Failed Opacity	Air Filter	Cost	Air/Fuel Control	Cost	Gov	Cost	Turbo	Cost	Blower	Cost	Overhead Rack	Cost	Fuel Filter	Cost	Throttle Relay	Cost	Fuel Pump
5	1988	Ford	Unknown	64.9%													Replaced				Adjusted
6	1988	Ford	CAT	84.0%	Replaced																
85	1988	Int	Cummins	67.7%	Replaced																
20	1988	Kenworth	Cummins	60.1%																	
64	1988	Kenworth	Cummins	66.2%																	
42	1988	Mack	Mack	58.1%											Adjusted						
43	1988	Mack	Mack	94.7%															Replaced	$129.57	
75	1988	Mack	Mack	69.3%																	
76	1988	Mack	Mack	83.2%	Replaced												Replaced				
77	1988	Mack	Mack	86.1%	Replaced												Replaced				
78	1988	Mack	Mack	91.4%	Replaced																
89	1988	Mack	Mack	80.2%																	
53	1988	Ptrb	CAT	93.0%			Repaired														
83	1988	Volvo	Volvo	55.9%			Adjusted														
12	1989	Freightliner	CAT	58.2%	Replaced	$78.92											Replaced	$38.64			
13	1989	Freightliner	Cummins	72.0%	Replaced												Replaced				
16	1989	Int	Cummins	79.3%													Replaced	$4.98			Adjusted
46	1989	Mack	Mack	90.0%																	Replaced
44	1989	Mack	Mack	71.7%																	Replaced
45	1989	Mack	Mack	84.4%																	
90	1989	Mack	Mack	80.7%																	
55	1989	Ptrb	CAT	89.6%			Repaired		Repaired												
54	1989	Ptrb	Cummins	80.3%	Replaced 2	$260.00															Adjusted
84	1989	Western Sta	CAT	69.6%			Repaired														Adjusted
7	1990	Ford	Cummins	69.9%			Adjusted														Adjusted
61	1990	Freightliner	Cummins	75.8%	Replaced		Adjusted														Repaired
79	1990	Mack	Mack	57.8%																	
56	1990	Ptrb	Cummins	59.6%	Adjusted								Repair hose								Adjusted
17	1991	Int	Cummins	55.2%																	
8	1992	Ford	CAT	90.4%																	Adjusted
9	1994	Ford	Cummins	73.8%	Replaced	$42.17	Adjusted														
22	1994	Kenworth	Unknown	49.6%	Replaced																
21	1994	Kenworth	Unknown	49.5%																	
47	1994	Mack	Mack	44.8%							Replace	$998.25									
57	1994	Ptrb	Cummins	44.4%																	Adjusted
14	1995	Freightliner	Detroit	90.3%																	
10	1997	Ford	CAT	88.3%			Repaired														
82	1997	Ptrb	CAT	41.3%	Replaced												Replaced				Adjusted
58	1997	Western Sta	Unknown	47.0%	Replaced	$91.45	Replaced v	$179.80													
48	1998	Mack	Mack	72.2%	Replaced	$33.12															
80	1998	Mack	Mack	42.8%	Replaced																
18	2003	Int	CAT	40.7%	Replaced	$86.35					Replaced	$773.38					Replaced	$11.83			
49	2005	Mack	Mack	60.8%															Replaced	$157.70	

Vehicle ID Number	Model Year	Make	Cost	Fuel Timing	Cost	Fuel Inj	Cost	Puff Lim	Cost	EGR	Cost	Computer Cntrls	Cost	Thermst	Cost	Misc.	Misc. Costs	Labor	Total Cost	Notes
65	1963	Mack						Repaired												Cost unknown
66	1970	Mack						Replaced												Cost unknown
2	1972	Ford																	$53.53	Reflashed
24	1972	Mack		Replace va	$20.96													$276.50	$406.96	
23	1972	Mack	$1,475.00																$1,993.65	
1	1973	Autocar															$51.54		$910.51	
26	1974	Mack	$1,298.00			Replaced	$276.90										$78.75		$1,653.65	
25	1974	Mack		Adjusted															$1,743.47	
67	1974	Mack						Replaced												Cost unknown
27	1977	Mack						Replaced											$402.48	
15	1978	Int																	$61.97	Probably repaired to cutpoint
28	1978	Mack															$24.37	$142.50	$324.57	
3	1979	Ford	$596.18														$55.25	$148.00	$799.43	
29	1979	Mack						Replaced										$595.00	$866.11	
68	1979	Mack		Adjusted				Adjusted												Cost unknown
50	1980	Ptrb														gaskets	$20.00	$202.50	$297.50	
4	1981	Ford	$100.00														$6.00		$106.00	
19	1981	Kenworth		Adjusted														$400.00	$494.10	
86	1981	Mack																	$78.72	Repairs unknown
69	1981	Mack						Repaired												Cost unknown
51	1981	Ptrb														Manifold leak			$100.00	
81	1981	Ptrb				Repaired														Cost unknown
30	1982	Mack						Replaced	$285.49								$25.40	$138.00	$448.89	
31	1982	Mack						Repaired	$48.10							Manifold leak			$1,452.81	Includes non-emissions repairs
59	1983	Ford																		Cost unknown
70	1983	Mack				Repaired														Cost unknown
32	1984	Mack						Repaired	$159.60									$285.00	$585.51	Includes non-emissions repairs
71	1984	Mack		Adjusted																Cost unknown
60	1985	Freightliner				Replaced														Cost unknown
87	1985	Mack																	$133.23	Repairs unknown
33	1985	Mack															$46.76		$224.27	
52	1985	Ptrb																$37.00	$40.88	
11	1986	Freightliner		Adjusted		Adjusted													$146.25	
63	1986	Kenworth				Inj cleaner														Cost unknown - repaired to cutpoint
37	1986	Mack														Plugged air line		$95.00	$102.71	
88	1986	Mack																	$102.71	Repairs unknown
38	1986	Mack						Repair	$148.90								$27.04		$247.98	
35	1986	Mack						Repaired	$311.25									$311.25	$331.00	
36	1986	Mack						Replaced									$326.16	$420.00	$730.00	About $60 non-emissions repairs
34	1986	Mack						Replace	$75.00							exhaust manifold gasket	$210.00	$375.00	$882.00	
72	1986	Mack						Replaced												Cost unknown
73	1986	Mack		Adjusted		Adjusted		Adjusted												Cost unknown
62	1987	Int		Adjusted		Adjusted														Cost unknown
39	1987	Mack						Replace	$48.47								$11.69	$142.50	$206.48	
41	1987	Mack						Repaired	$271.96										$271.96	
40	1987	Mack															$19.40	$95.00	$342.68	
74	1987	Mack		Adjusted				Adjusted												Cost unknown

Vehicle ID Number	Model Year	Make	Cost	Fuel Timing	Cost	Fuel Inj	Cost	Puff Lim	Cost	EGR	Cost	Computer Cntrls	Cost	Thermst	Cost	Misc.	Misc. Costs	Labor	Total Cost	Notes
5	1988	Ford		Adjusted		Adjusted								needs it				$592.00	$832.67	Includes non-emissions repairs
6	1988	Ford														Repaired bent tailpipe				Cost unknown
85	1988	Int																		Repairs unknown
20	1988	Kenworth				Replaced	$766.38									Fuel system cleaner	$41.68		$929.20	
64	1988	Kenworth		Adjusted		Adjusted														Cost unknown
42	1988	Mack						Replace	$72.66								$14.37	$105.00	$192.03	
43	1988	Mack						Adjusted									$14.79	$246.50	$400.97	
75	1988	Mack						Replaced												Cost unknown
76	1988	Mack																		Cost unknown
77	1988	Mack		Adjusted				Repair												Cost unknown
78	1988	Mack						Replace												Puff - valve and relay switch; Cost unknown
89	1988	Mack																		Repairs & cost unknown
53	1988	Ptrb																	$333.87	
83	1988	Volvo																		Cost unknown
12	1989	Freightliner															$36.06		$162.84	Probably repaired to cutpoint
13	1989	Freightliner				Adjusted												$180.00	$393.29	
16	1989	Int		Adjusted														$518.00	$597.03	
46	1989	Mack	$1,513.08															$300.00	$1,921.86	
44	1989	Mack															$293.33		$3,687.50	
45	1989	Mack														Engine Rebuilt			$8,383.43	
90	1989	Mack																		Repairs & cost unknown
55	1989	Ptrb																$385.00	$462.16	
54	1989	Ptrb																$240.00	$500.00	
84	1989	Western Sta																		Cost unknown
7	1990	Ford														Manifold leak			$127.50	
61	1990	Freightliner																		Cost unknown
79	1990	Mack						Adjusted												Cost unknown
56	1990	Ptrb																	$450.00	Total cost may include NON-emissions repairs
17	1991	Int				Replaced	$993.48												$993.48	
8	1992	Ford	$85.00														$5.20		$90.10	
9	1994	Ford																$185.00	$251.40	
22	1994	Kenworth																	$52.99	
21	1994	Kenworth				Replaced	$3,232.85												$3,232.85	
47	1994	Mack															$59.90		$1,058.15	
57	1994	Ptrb				Replaced 1											$44.73	$296.00	$613.50	
14	1995	Freightliner		Repaired	$93.37												$23.68	$265.05	$291.55	
10	1997	Ford															$8.95	$275.00	$284.58	
82	1997	Ptrb																		Cost unknown
58	1997	Western Sta																$140.00	$411.25	
48	1998	Mack				Replaced	$802.62										$50.14		$885.88	
80	1998	Mack						Adjusted												Cost unknown
18	2003	Int										Reflashed							$1,349.46	May be just an estimate
49	2005	Mack																$190.00	$375.93	

Appendix C: Vermont Repair Data

Vehicle ID Number	Model Year	Make	Truck / Bus	Repair	Cost	Notes
35	1974	MACK	TRUCK	PUFF VALVE REPLACEMENT/CYLINDER REPLACEMENT/FUEL PUMP SERVICE	$661.72	
12	1974	MACK	TRUCK	FUEL INJECTOR VALVES		
61	1977	MACK	TRUCK	AIR FILTER REPLACEMENT		
20	1978	MACK	TRUCK	SOLD TRUCK		
40	1978	NTERNATIONA	TRUCK	FUEL FILTER REPLACEMENT		
39	1979	MACK	TRUCK	PUFF VALVE REPLACED/ENGINE OVERHAUL		
14	1980	MACK	TRUCK	PUFF LIMITER	$30.00	
15	1980	MACK	TRUCK	PUFF LIMITER	$30.00	
42	1980	MACK	TRUCK	TUNE-UP		
45	1982	MACK	TRUCK	AIR FILTER REPLACEMENT/PUFF LIMITER INSPECTION		
50	1984	FORD	TRUCK	REPLACED INJECTORS/REPLACED AIR FILTER/REBUILT AIR-FUEL CONTROL	$1,138.63	
9	1984	FORD	TRUCK	GOVERNOR/FUEL SETTINGS		
43	1984	MACK	TRUCK	PUFF VALVE INSTALLED/ENGINE OVERHAUL PLANNED		
49	1984	MACK	TRUCK	PUFF VALVE ORDERED		
62	1985	MACK	TRUCK	PUFF LIMITER ADJUSTMENT	$0.00	
10	1985	MACK	TRUCK	PUFF LIMITER/FUEL FILTERS	$60.00	
1	1985	MACK	TRUCK	AIR FILTER/PUFF LIMITER	$77.80	
48	1985	MACK	TRUCK	PUFF VALVE REPLACEMENT/FUEL SETTING ADJUSTMENT	$162.46	
44	1985	MACK	TRUCK	AIR FILTER REPLACEMENT/PUFF LIMITER INSPECTION		
31	1985	FORD	TRUCK			
21	1986	MACK	TRUCK	FUEL FILTERS/AIR FILTERS	$30.00	
70	1986	MACK	TRUCK	PUFF LIMITER ADJUSTMENT	$30.00	
72	1986	GMC	TRUCK	AIR FILTER REPLACEMENT	$30.00	
54	1986	MACK	TRUCK	PUFF LIMITER VALVE REPLACEMENT	$85.00	
57	1986	FORD	TRUCK	TIMING/AIR-FUEL RATIO ADJUSTMENT	$437.47	
63	1986	FORD	TRUCK	REBUILT TIMING ADVANCE	$1,051.33	

Vehicle ID Number	Model Year	Make	Truck / Bus	Repair	Cost	Notes
34	1986	GMC	TRUCK	INTAKE & EXHAUST ROCKER ARM REPLACEMENT/INJECTOR ARM REPLACEMENT/FUEL INJECTOR REPLACEMENT/VALVE ADJUSTMENT/CROSS BRIDGE REPLACEMENTS/THROTTLE DELAY ADJUSTMENT/FUEL FILTER REPLACEMENTS/AIR FILTER REPLACEMENT	$2,099.26	
64	1986	FORD	TRUCK	ENGINE OVERHAUL	$11,869.94	
2	1986	FORD	TRUCK	FUEL SYSTEM CALIBRATION		
4	1986	GMC	TRUCK	FUEL INJECTORS/TURBOCHARGER		
53	1986	GMC	TRUCK	SOLD TRUCK		
5	1987	MACK	TRUCK	FUEL FILTERS	$30.00	
16	1987	MACK	TRUCK	PLE/AIR FILTERS	$30.00	
52	1987	MACK	TRUCK	AIR FILTER REPLACMENT	$32.63	
36	1987	MACK	TRUCK	FUEL PUMP SERVICE	$72.64	
66	1987	MACK	TRUCK	PUFF LIMITER	$80.00	
59	1987	FORD	TRUCK	AIR-FUEL RATIO ADJUSTMENT	$335.58	
58	1987	FORD	TRUCK	REPLACED TURBOCHARGER	$1,645.66	
33	1987	FORD	TRUCK	FILTER		
26	1987	FORD	TRUCK	SOLD TRUCK	NA	
67	1987	FORD	TRUCK			

Vehicle ID Number	Model Year	Make	Truck / Bus	Repair	Cost	Notes
22	1988	MACK	TRUCK	PUFF LIMITER	$30.00	
41	1988	FORD	TRUCK	FUEL SYSTEM ADJUSTMENT	$62.89	
30	1988	MACK	TRUCK	PUFF LIMITER	$200.00	
37	1988	MACK	TRUCK	REPLACEMENT/CYLINDER ASSEMBLY REPLACEMENT/FUEL PUMP ADJUSTMENT	$262.18	
19	1988	FORD	TRUCK		$421.68	
17	1988	FORD	TRUCK	AFTERCOOLER	$1,190.10	
6	1988	FORD	TRUCK	TURBOCHARGER		
25	1988	FORD	TRUCK	GOVERNOR		
55	1988	MACK	TRUCK	REPLACEMENT/REVERSING RELAY REPLACEMENT		
27	1989	MACK	TRUCK	REVERSING RELAY	$40.00	
60	1989	MACK	TRUCK	EVALUATED TRUCK AND FOUND NO PROBLEM - SUSPECT DRIVER LUGGING ENGINE	$50.48	
8	1989	MACK	TRUCK	PLE/FUEL-INJECTION SYSTEM ADJUSTED	$60.00	
71	1989	MACK	TRUCK	PUFF LIMITER REPLACEMENT	$177.07	
3	1989	KENWORTH	TRUCK	FUEL SETTINGS	$210.21	
47	1989	MACK	TRUCK	REPLACEMENT	$353.85	
7	1989	MACK	TRUCK	PUFF LIMITER AND JAKE BRAKE REPAIR	$420.00	
46	1989	WESTERN STAR	TRUCK	AIR FUEL CONTROL FITTING REPLACEMENT/FUEL INJECTOR SERVICE	$812.77	
13	1989	MACK	TRUCK	REVERSING (PLE) RELAY AND TURBOCHARGER REPLACEMENT	$935.79	
11	1990	FORD	TRUCK	AIR FILTER	$30.00	
18	1990	GMC/VOLVO	TRUCK	STC VALVE	$56.00	
38	1990	MACK	TRUCK	FUEL INJECTION PUMP & CONTROLS ADJUSTMENT/PLE VALVE TEST & RESET	$60.18	
24	1990	GMC	TRUCK		$660.80	
68	1991	MACK	TRUCK	FUEL INJECTOR REPLACEMENT/FUEL PUMP REPAIR	$1,070.48	

Vehicle ID Number	Model Year	Make	Truck / Bus	Repair	Cost	Notes
32	1994	MACK	TRUCK	COOLER REPLACEMENT	$1,315.29	
23	1995	CHEVROLET	TRUCK	GOVERNOR		
29	1995	NTERNATIONA	BUS	TIMING/FUEL FILTERS/AIR FILTER/FUEL INJECTION PUMP		
65	1996	NTERNATIONA	TRUCK	AIR FILTER REPLACEMENT	$50.00	ENGINE IS A '90 MODEL INSTALLED IN A '96 GLIDER KIT
56	1996	MACK	TRUCK	CHARGE AIR COOLER REPLACEMENT	$784.68	
28	1996	NTERNATIONA	TRUCK	FUEL INJECTOR PUMP REPLACEMENT, FUEL INJECTOR ADJUSTMENT, ENGINE VALVE ADJUSTMENT		
69	1997	MACK	TRUCK	TURBOCHARGER REPAIR	$100.00	TURBO GASKET REPLACEMENT; 2 HRS. LABOR + GASKET
51	1997	MACK	TRUCK	FUEL PUMP ADJUSTMENT		