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Part II

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40 CFR Parts 69, 80, and 86
Control of Air Pollution From New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards; Highway Diesel Fuel Sulfur Control Requirements; Proposed Rules

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 69, 80, and 86

[AMS–FRL–6705–2]

RIN 2060–AL69

Control of Air Pollution From New Motor Vehicles: Proposed Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements

AGENCY: Environmental Protection Agency.

ACTION: Notice of proposed rulemaking.

SUMMARY: Diesel engines contribute considerable pollution to our nation's continuing air quality problems. Even with more stringent heavy-duty highway engine standards set to take effect in 2004, these engines will continue to emit large amounts of nitrogen oxides and particulate matter, both of which contribute to serious public health problems in the United States. These problems include premature mortality, aggravation of respiratory and cardiovascular disease, aggravation of existing asthma, acute respiratory symptoms, chronic bronchitis, and decreased lung function. Numerous studies also link diesel exhaust to increased incidence of lung cancer.

The diesel engine is a vital workhorse in the United States, moving much of the nation's freight, and carrying out much of its farm, construction, and other labor. Diesel engine sales have grown over the last decade, so that now about a million new diesel engines are put to work in the U.S. every year. Diesels overwhelmingly dominate the bus and large truck markets and have been capturing a growing share of the light heavy-duty vehicle market over the last decade.

We are proposing a comprehensive national control program that would regulate the heavy-duty vehicle and its fuel as a single system. We are proposing new emission standards that would begin to take effect in 2007, and would apply to heavy-duty highway engines and vehicles. These proposed standards are based on the use of high-efficiency catalytic exhaust emission control devices or comparably effective advanced technologies. Because these devices are damaged by sulfur, we are also proposing to reduce the level of sulfur in highway diesel fuel significantly by the middle of 2006.

Diesel engines are more durable and get better fuel economy than gasoline engines, but also pollute significantly more. If this program is implemented as proposed, diesel trucks and buses will have dramatically reduced emission levels. This proposed program will bring heavy-duty diesel emissions on par with new cars. The results of this historic proposal would be comparable to the advent of the catalytic converter on cars, as the proposed standards would, for the first time, result in the widespread introduction of exhaust emission control devices on diesel engines.

By 2007, we estimate that heavy-duty trucks and buses will account for as much as 30 percent of nitrogen oxides emissions from transportation sources and 14 percent of particulate matter emissions. In some urban areas, the contribution will be even greater. The standards for heavy-duty vehicles proposed in this rule would have a substantial impact on the mobile source inventories of oxides of nitrogen and particulate matter. Beginning the program in the 2007 model year ensures that emission reductions start early enough to counter the upward trend in heavy-duty vehicle emissions that would otherwise occur because of the increasing number of vehicle miles traveled each year.

This proposed program would result in particulate matter and oxides of nitrogen emission levels that are 90% and 95% below current standards levels, respectively. In order to meet these more stringent standards for diesel engines, the proposal calls for a 97% reduction in the sulfur content of diesel fuel. As a result, diesel vehicles would achieve gasoline-like exhaust emission levels, in addition to their inherent advantages over gasoline vehicles with respect to fuel economy, lower greenhouse gas emissions, and lower evaporative hydrocarbon emissions. We are also proposing more stringent standards for heavy-duty gasoline vehicles.

The clean air impact of this program would be dramatic when fully implemented. By 2030, this program would reduce annual emissions of nitrogen oxides, nonmethane hydrocarbons, and particulate matter by a projected 2.8 million, 305,000 and 110,000 tons, respectively. We project that these reductions and the resulting significant environmental benefits of this program would come at an average cost increase of about $1,700 to $2,800 per new vehicle in the near term and about $1000 to $1600 per new vehicle in the long term, depending on the vehicle size. In comparison, new vehicle prices today can range up to $250,000 for larger heavy-duty vehicles. The cost of reducing the sulfur content of diesel fuel would result in an estimated increase of approximately four cents per gallon.

DATES: *Comments:* We must receive your comments by August 14, 2000.

Hearings: We will hold public hearings on June 19, 20, 22, 27, and 29, 2000. See **ADDRESSES** below for the locations of the hearings.

ADDRESSES: *Comments:* You may send written comments in paper form and/or by e-mail. We must receive them by the date indicated under ''DATES'' above. Send paper copies of written comments (in duplicate if possible) to the contact person listed below. Send e-mail comments to diesel@epa.gov.

EPA's Air Docket makes materials related to this rulemaking available for review in Docket No. A–99–06 located at U.S. Environmental Protection Agency (EPA), Air Docket (6102), Room M–1500, 401 M Street, SW, Washington, DC 20460 (on the ground floor in Waterside Mall) from 8 a.m. to 5:30 p.m., Monday through Friday, except on government holidays. You can reach the Air Docket by telephone at (202) 260–7548 and by facsimile at (202) 260–4400. We may charge a reasonable fee for copying docket materials, as provided in 40 CFR part 2.

Hearings: We will hold five public hearings at the following locations:

- June 19, 2000, Crowne Plaza Hotel, 1605 Broadway, New York, NY, 10019
- June 20, 2000, Rosemont Convention Center, 5555 N. River Rd., Rosemont, IL 60018
- June 22, 2000, Renaissance Atlanta Hotel, 590 W. Peachtree St, NW, Atlanta, GA, 30308
- June 27, 2000, Hyatt Regency, 711 S. Hope Street, Los Angeles, CA, 90017
- June 29, 2000, Doubletree Hotel, 3203 Quebec St., Denver, CO, 80207

We request that parties who want to testify at a hearing notify the contact person listed below ten days before the date of the hearing. Please see section X, ''Public Participation'' below for more information on the comment procedure and public hearings.

FOR FURTHER INFORMATION CONTACT: Margaret Borushko, U.S. EPA, National Vehicle and Fuel Emissions Laboratory, 2000 Traverwood, Ann Arbor MI 48105; Telephone (734) 214–4334, FAX (734) 214–4816, E-mail borushko.margaret@epa.gov.

SUPPLEMENTARY INFORMATION:

Regulated Entities

This proposed action would affect you if you produce or import new

heavy-duty engines which are intended for use in highway vehicles such as trucks and buses or heavy-duty highway vehicles, or convert heavy-duty vehicles or heavy-duty engines used in highway vehicles to use alternative fuels. It would also affect you if you produce, distribute, or sell highway diesel fuel.

The table below gives some examples of entities that may have to follow the proposed regulations. But because these are only examples, you should carefully examine the proposed and existing regulations in 40 CFR parts 69, 80, and 86. If you have questions, call the person listed in the **FOR FURTHER INFORMATION CONTACT** section above.

Category	NAICS Codes [a]	SIC Codes [b]	Examples of potentially regulated entities
Industry	336112 336120	3711	Engine and truck manufacturers.
Industry	811112 811198	7533 7549	Commercial importers of vehicles and vehicle components.
Industry	324110	2911	Petroleum refiners.
Industry	422710 422720	5171 5172	Diesel fuel marketers and distributors.
Industry	484220 484230	4212 4213	Diesel fuel carriers.

[a] North American Industry Classification System (NAICS).
[b] Standard Industrial Classification (SIC) system code.

Access to Rulemaking Documents Through the Internet

Today's proposal is available electronically on the day of publication from the Environmental Protection Agency Internet Web site listed below. Electronic copies of the preamble, regulatory language, Draft Regulatory Impact Analysis, and other documents associated with today's proposal are available from the EPA Office of Transportation and Air Quality (formerly the Office of Mobile Sources) Web site listed below shortly after the rule is signed by the Administrator. This service is free of charge, except any cost that you incur for connecting to the Internet.

Environmental Protection Agency Web Site:

http://www.epa.gov/fedrgstr/

(Either select a desired date or use the Search feature.)

Office of Transportation and Air Quality (OTAQ) Web Site:

http://www.epa.gov/otaq/

(Look in ''What's New'' or under the ''Heavy Trucks/Busses'' topic.)

Please note that due to differences between the software used to develop the document and the software into which document may be downloaded, changes in format, page length, etc. may occur.

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I. A Brief Overview

This proposal covers the second of two phases in a comprehensive nationwide program for controlling emissions from heavy-duty engines (HDEs) and vehicles. It builds upon the phase 1 program we proposed last October (64 FR 58472, October 29, 1999). That action reviewed and proposed to confirm the 2004 model year emission standards set in 1997 (62 FR 54693, October 21, 1997), proposed stringent new emission standards for gasoline-fueled heavy-duty vehicles (HDVs), and proposed other changes to the heavy-duty program, including provisions to ensure in-use emissions control. Today's proposal takes the provisions of the October 1999 proposal as a point of departure.

This second phase of the program looks beyond 2004, based on the use of high-efficiency exhaust emission control devices and the consideration of the vehicle and its fuel as a single system. In developing this proposal, we took into consideration comments received in response to an advance notice of proposed rulemaking (ANPRM) published in May of last year (64 FR 26142, May 13, 1999), and comments we received in response to our discussion of future standards in the heavy-duty 2004 standards proposal last October. We welcome comment on all facets of this proposal and its supporting analyses, including the levels and timing of the proposed emissions standards and diesel fuel quality requirements. We ask that commenters provide any technical information that supports the points made in their comments.

This proposed program would result in particulate matter (PM) and oxides of nitrogen (NO_X) emission levels that are 90% and 95% below current standards levels, respectively. In order to meet these more stringent standards for diesel engines, the proposal calls for a 97% reduction in the sulfur content of diesel fuel. This proposal would make clean diesel fuel available in time for implementation of the light-duty Tier 2 standards. The heavy-duty engine standards would be effective starting in the 2007 model year and the low sulfur diesel fuel needed to facilitate the standards would be widely available by the middle of 2006. As a result, diesel vehicles would achieve gasoline-like exhaust emission levels, in addition to their inherent advantages over gasoline vehicles with respect to fuel economy, lower greenhouse gas emissions, and lower evaporative hydrocarbon emissions. We are also proposing more stringent standards for heavy-duty gasoline vehicles.

The standards proposed would result in substantial benefits to public health and welfare and the environment through significant reductions in emissions of NO_X, PM, nonmethane hydrocarbons (NMHC), carbon monoxide (CO), sulfur oxides (SO_X), and air toxics. We project that by 2030, this proposed phase 2 program would reduce annual emissions of NO_X, NMHC, and PM by 2.8 million, 305,000 and 110,000 tons, respectively. Especially in the early years of this program, large reductions in the amount of direct and secondary PM caused by the existing fleet of heavy-duty vehicles would occur because of the improvement in diesel fuel quality.

A. What Is Being Proposed?

There are two basic parts to this proposal: (1) New exhaust emission standards for heavy-duty highway engines and vehicles, and (2) new quality standards for highway diesel fuel. The systems approach of combining the engine and fuel standards into a single program is critical to the success of our overall efforts to reduce emissions, because the emission standards would not be feasible without the fuel change. This is because the emission standards, if promulgated, are expected to result in the use of high-efficiency exhaust emission control devices that would be damaged by sulfur in the fuel. This proposal, by providing extremely low sulfur diesel fuel, would also enable cleaner diesel passenger vehicles and light-duty trucks. This is because the same pool of highway diesel fuel also services these light-duty diesel vehicles, and these vehicles can employ technologies similar to the high-efficiency heavy-duty exhaust emission control technologies that would be enabled by the fuel change. We believe these technologies are needed for diesel vehicles to comply with our recently adopted Tier 2 emissions standards for light-duty highway vehicles (65 FR 6698, February 10, 2000).

We believe that this systems approach is a comprehensive way to enable promising new technologies for clean diesel affecting all sizes of highway diesel engines and, eventually, diesel engines used in nonroad applications too. The fuel change, in addition to enabling new technologies, would also produce emissions and maintenance benefits in the existing fleet of highway diesel vehicles. These benefits would include reduced sulfate and sulfur oxides emissions, reduced engine wear and less frequent oil changes, and longer-lasting exhaust gas recirculation (EGR) components on engines equipped with EGR. Heavy-duty gasoline vehicles would also be expected to reach cleaner levels due to the transfer of recent technology developments for light-duty applications, and the recent action taken to reduce sulfur in gasoline as part of the Tier 2 rule.

The basic elements of the proposal are outlined below. Detailed provisions and justifications for our proposal are discussed in subsequent sections.

1. Heavy-Duty Emission Standards

We are proposing a PM emissions standard for new heavy-duty engines of 0.01 grams per brake-horsepower-hour (g/bhp-hr), to take full effect in the 2007 HDE model year. We are also proposing standards for NO_X and NMHC of 0.20 g/bhp-hr and 0.14 g/bhp-hr, respectively. These NO_X and NMHC standards would be phased in together between 2007 and 2010, for diesel engines. The phase-in would be on a percent-of-sales basis: 25 percent in 2007, 50 percent in 2008, 75 percent in 2009, and 100 percent in 2010. Because of the more advanced state of gasoline engine emissions control technology, gasoline engines would be fully subject to these standards in the 2007 model year, although we request comment on phasing these standards in as well. A potential delay in the implementation date of the gasoline engine and vehicle standards to the 2008 model year arising from issues connected with the 2004 model year standards is discussed in section III.D.2. In addition, we are proposing a formaldehyde (HCHO) emissions standard of 0.016 g/bhp-hr for all heavy-duty engines, to be phased in with the NO_X and NMHC standards, and the inclusion of turbocharged diesels in the existing crankcase emissions prohibition, effective in 2007.

Proposed standards for complete HDVs would be implemented on the same schedule as for engine standards. For certification of complete vehicles between 8500 and 10,000 pounds gross vehicle weight rating (GVWR), the proposed standards are 0.2 grams per mile (g/mi) for NO_X, 0.02 g/mi for PM, 0.195 g/mi for NMHC, and 0.016 g/mi for formaldehyde.[1] For vehicles between 10,000 and 14,000 pounds, the proposed standards are 0.4 g/mi for NO_X, 0.02 g/mi for PM, 0.230 g/mi for NMHC, and 0.021 g/mi for formaldehyde. These standards levels are roughly comparable to the proposed engine-based standards in these size ranges. Note that these standards would not apply to vehicles above 8500 pounds that we classify as medium-duty passenger vehicles as part of our Tier 2 program.

Finally, we are proposing to revise the evaporative emissions standards for heavy-duty engines and vehicles, effective on the same schedule as the gasoline engine and vehicle exhaust emission standards. The proposed standards for 8500 to 14,000 pound vehicles are 1.4 and 1.75 grams per test for the 3-day diurnal and supplemental 2-day diurnal tests, respectively. Slightly higher standards levels of 1.9 and 2.3 grams per test would apply for vehicles over 14,000 pounds. These proposed standards represent more than a 50 percent reduction in the numerical standards as they exist today.

2. Fuel Quality Standards

We are proposing that diesel fuel sold to consumers for use in highway vehicles be limited in sulfur content to a level of 15 parts per million (ppm), beginning June 1, 2006. This proposed sulfur standard is based on our assessment of how sulfur-intolerant advanced exhaust emission control technologies will be, and a corresponding assessment of the feasibility of low-sulfur fuel production and distribution. We are seeking comment on voluntary options for providing refiners with flexibility in complying with the low sulfur highway diesel fuel program. In addition, we request comment on some potential flexibility provisions to assist small refiners in complying with the program.

With minor exceptions, existing compliance provisions for ensuring diesel fuel quality that have been in effect since 1993 would remain unchanged (55 FR 34120, August 21, 1990).

B. Why Is EPA Making This Proposal?

1. Heavy-Duty Vehicles Contribute to Serious Air Pollution Problems

As will be discussed in detail in section II, emissions from heavy-duty vehicles contribute greatly to a number of serious air pollution problems, and will continue to do so into the future absent further controls to reduce these emissions. First, heavy-duty vehicles contribute to the health and welfare effects of ozone, PM, NO_X, SO_X, and volatile organic compounds (VOCs), including toxic compounds such as formaldehyde. These adverse effects include premature mortality, aggravation of respiratory and cardiovascular disease (as indicated by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days), changes in lung function and increased respiratory symptoms, changes to lung tissues and structures, altered respiratory defense mechanisms, chronic bronchitis, and decreased lung function. Ozone also causes crop and forestry losses, while PM also causes damage to materials, and soiling. Second, both NO_X and PM contribute to substantial visibility impairment in many parts of the U.S. Third, NO_X emissions from heavy-duty trucks contribute to the acidification, nitrification and eutrophication of water bodies.

Millions of Americans live in areas with unhealthful air quality that currently endangers public health and welfare. Without emission reductions from the proposed standards for heavy-duty vehicles, there is a significant risk that an appreciable number of areas across the country will violate the 1-hour ozone national ambient air quality standard (NAAQS) during the period when these standards will take effect. Furthermore, our analysis shows that PM_{10} concentrations in 10 areas with a combined population of 27 million people face a significant risk of exceeding the PM_{10} NAAQS without significant additional controls in 2007 or thereafter. Under the mandates and authorities in the Clean Air Act, federal, State, and local governments are working to bring ozone and particulate levels into compliance with the 1-hour ozone and PM_{10} NAAQS through State Implementation Plan (SIP) attainment and maintenance plans, and to ensure that future air quality reaches and continues to achieve these health-based standards. The reductions proposed in this rulemaking would play a critical part in these important efforts.

Emissions from heavy-duty vehicles account for substantial portions of the country's ambient PM and NO_X levels. (NO_X is a key precursor to ozone formation). By 2007, we estimate that heavy-duty vehicles will account for 29 percent of mobile source NO_X emissions and 14 percent of mobile source PM emissions. These proportions are even higher in some urban areas, such as in Albuquerque, where HDVs contribute 37 percent of the mobile source NO_X emissions and 20 percent of the mobile source PM emissions. The PM and NO_X standards for heavy-duty vehicles proposed in this rule would have a substantial impact on these emissions. By 2030, NO_X emissions from heavy-duty vehicles under today's proposed standards would be reduced by 2.8 million tons, and PM emissions would decline by about 110,000 tons, dramatically reducing this source of NO_X and PM emissions. Urban areas, which include many poorer neighborhoods, can be disproportionately impacted by HDV emissions, and these neighborhoods would thus receive a relatively larger portion of the benefits expected from new HDV emissions controls. Over time,

[1] Vehicle weight ratings in this proposal refer to GVWR (the curb weight of the vehicle plus its maximum recommended load of passengers and cargo) unless noted otherwise.

the relative contribution of diesel engines to air quality problems will go even higher if diesel-equipped light-duty vehicles become more popular, as is expected by some automobile manufacturers.

In addition to its contribution to PM inventories, diesel exhaust PM is of special concern because it has been implicated in an increased risk of lung cancer and respiratory disease in human studies. The EPA draft Health Assessment Document for Diesel Emissions is currently being revised based on comments received from the Clean Air Scientific Advisory Committee (CASAC) of EPA's Science Advisory Board. The current EPA position is that diesel exhaust is a likely human carcinogen and that this cancer hazard applies to environmental levels of exposure.[2] In the draft Health Assessment Document for Diesel Emissions, EPA provided a qualitative perspective that the upper bounds on environmental cancer risks may exceed 10^{-6} and could be as high as 10^{-3}. Several other agencies and governing bodies have designated diesel exhaust or diesel PM as a ''potential'' or ''probable'' human carcinogen. In addition, diesel PM poses nonmalignant respiratory hazards to humans, not unlike, in some respects, hazards from exposure to ambient $PM_{2.5}$, to which diesel PM contributes. State and local governments, in their efforts to protect the health of their citizens and comply with requirements of the Clean Air Act (CAA or ''the Act''), have recognized the need to achieve major reductions in diesel PM emissions, and have been seeking Agency action in setting stringent new standards to bring this about.[3]

2. Technology-Based Solutions

Although the air quality problems caused by diesel exhaust are formidable, we believe they can be resolved through the application of high-efficiency emissions control technologies. As discussed in detail in section III, the development of diesel emissions control technology has advanced in recent years so that very large emission reductions (in excess of 90 percent) are possible, especially through the use of catalytic emission control devices installed in the vehicle's exhaust system (and integrated with the engine controls). These devices are often referred to as ''exhaust emission control'' or ''aftertreatment'' devices. Exhaust emission control devices, in the form of the well-known catalytic converter, have been used in gasoline-fueled automobiles for 25 years, but have had only limited application in diesel vehicles.

Because the Clean Air Act requires us to set heavy-duty engine standards that reflect the greatest degree of emission reduction achievable through the application of available technology (subject to a number of criteria as discussed in section I.B.3), this notice proposes these standards, and proposes a justification for their adoption based on the air quality need, their technological feasibility, costs, and other criteria listed in the Act (see section III of this document). As part of this proposal, we are also proposing changes to diesel fuel quality in order to enable these advanced technologies (section IV). Heavy-duty gasoline engines would also be able to reach the significantly cleaner levels envisioned in this proposal by relying on the transfer of recent technology developments for light-duty applications, given the recent action taken to reduce sulfur in gasoline (65 FR 6698, February 10, 2000).

We believe the proposed standards would require the application of high-efficiency PM and NO_X exhaust emission controls to heavy-duty diesel vehicles. High-efficiency PM exhaust emission control technology has been available for several years, although engine manufacturers have generally not needed this technology in order to meet our PM emission standards. This technology has continued to improve over the years, especially with respect to durability and robust operation in use. It has also proven extremely effective in reducing exhaust hydrocarbon emissions. Thousands of such advanced-technology systems are now in use in fleet programs, especially in Europe. However, as discussed in detail in section III, these advanced-technology systems are very sensitive to sulfur in the fuel. For the technology to be viable and capable of meeting the proposed standards, we believe, based on information currently available, that it will require diesel fuel with sulfur content at the 15 ppm level.

Similarly, high-efficiency NO_X exhaust emission control technology will be needed if heavy-duty vehicles are to attain the proposed standards. We believe this technology, like the PM technology, is dependent on 15 ppm diesel fuel sulfur levels to be feasible, marketable, and capable of achieving the proposed standards. High-efficiency NO_X exhaust emission control technology has been quite successful in gasoline direct injection engines that operate with an exhaust composition fairly similar to diesel exhaust. However, as discussed in section III, application of this technology to diesels has some additional challenges and so has not yet gotten to the field trial stage. We are confident that the certainty of low-sulfur diesel fuel that would be provided by promulgation of the proposed fuel standard would allow the application of this technology to diesels to progress rapidly, and would result in systems capable of achieving the proposed standards. However, we acknowledge that our proposed NO_X standard represents an ambitious target for this technology, and so we are asking for comment on the appropriateness of a technology review of diesel NO_X exhaust emission controls.

The need to reduce the sulfur in diesel fuel is driven by the requirements of the exhaust emission control technology that we project would be needed to meet the proposed standards. The challenge in accomplishing the sulfur reduction is driven by the feasibility of needed refinery modifications, and by the costs of making the modifications and running the equipment. In consideration of the impacts that sulfur has on the efficiency, reliability, and fuel economy impact of diesel engine exhaust emission control devices, we believe that controlling the sulfur content of highway diesel fuel to the 15 ppm level will be necessary. Furthermore, although the refinery modifications and process changes needed to meet a 15 ppm restriction are expected to be substantial, we propose that this level is both feasible and cost effective. However, we are asking for comment on various concepts to provide implementation flexibility for refiners.

3. Basis for Action Under the Clean Air Act

Section 202(a)(1) of the Act directs us to establish standards regulating the emission of any air pollutant from any class or classes of new motor vehicles or engines that, in the Administrator's judgment, cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare. Section 202(a)(3) requires that EPA set standards for heavy-duty trucks that reflect the greatest degree of emission reduction achievable through the application of technology which we determine will be available for the

[2] Environmental Protection Agency (1999) Health Assessment Document for Diesel Emissions: SAB Review Draft. EPA/600/8–90/057D Office of Research and Development, Washington, D.C. The document is available electronically at www.epa.gov/ncea/diesel.htm

[3] For example, see letter dated July 13, 1999 from John Elston and Richard Baldwin on behalf of the State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials (docket A–99–06, item II–D–78).

model year to which the standards apply. We are to give appropriate consideration to cost, energy, and safety factors associated with the application of such technology. We may revise such technology-based standards, taking costs into account, on the basis of information concerning the effects of air pollution from heavy-duty vehicles or engines and other sources of mobile source related pollutants on the public health and welfare. Section 202(a)(3)(C) requires that promulgated standards apply for no less than three years and go into effect no less than 4 years after promulgation. This proposal has been developed in conformance with these statutory requirements.

We believe the evidence provided in section III and the draft Regulatory Impact Analysis (RIA) indicates that the stringent technology-forcing standards proposed today are feasible and reflect the greatest degree of emission reduction achievable in the model years to which they apply. We have given appropriate consideration to costs in choosing these standards. Our review of the costs and cost-effectiveness of these proposed standards indicate that they would be reasonable and comparable to the cost-effectiveness of other emission reduction strategies that have been required or could be required in the future. We have also reviewed and given appropriate consideration to the energy factors of this rule in terms of fuel efficiency and effects on diesel production and distribution, as discussed below, as well as any safety factors associated with these proposed standards.

The information regarding air quality and the contribution of heavy-duty engines to air pollution in section II and the Draft RIA provides strong evidence that emissions from such engines significantly and adversely impact public health or welfare. First, there is a significant risk that several areas will fail to attain or maintain compliance with the NAAQS for 1-hour ozone concentrations or PM_{10} concentrations during the period that these proposed new vehicle and engine standards would be phased into the vehicle population, and that heavy-duty engines contribute to such concentrations, as well as to concentrations of other NAAQS-related pollutants. Second, EPA currently believes that diesel exhaust is a likely human carcinogen. The risk associated with exposure to diesel exhaust includes the particulate and gaseous components. Some of the toxic air pollutants associated with emissions from heavy-duty vehicles and engines include benzene, formaldehyde, acetaldehyde, dioxin, acrolein, and 1,3-butadiene. Third, emissions from heavy-duty engines contribute to regional haze and impaired visibility across the nation, as well as acid deposition, POM deposition, eutrophication and nitrification, all of which are serious environmental welfare problems.

Based on this evidence, EPA believes that, for purposes of section 202(a)(1), emissions of NO_X, VOCs, SO_X and PM from heavy-duty trucks can reasonably be anticipated to endanger the public health or welfare. In addition, this evidence indicates that it would not be appropriate to modify the technology based standards pursuant to section 202(a)(3)(B). EPA believes that it is required under section 202(a)(3)(A) to set technology based standards that meet the criteria of that provision, and is not required to make an affirmative determination under section 202(a)(1). Instead EPA is authorized to take air quality into consideration under section 202(a)(3)(B) in deciding whether to modify or not set standard under section 202(a)(3)(A). In this case, however, EPA believes the evidence would fully support a determination under section 202(a)(1) to set standards, and a determination not to modify such standards under section 202(a)(3)(B).

In addition, there is significant evidence that emissions from heavy-duty trucks contribute to levels of ozone such that large segments of the national population are expected to experience prolonged exposure over several hours at levels that present serious concern for the public health and welfare. The same is true for exposure to fine PM. These public health and welfare problems are expected to occur in many parts of the country, including areas that are in compliance with the 1-hour ozone and PM_{10} NAAQS (PM_{10} is particulate matter that is 10 microns or smaller). This evidence is an additional reason why the controls proposed today are justified and appropriate under the Act. While EPA sees this as additional support for this action, EPA also believes that the evidence of air pollution problems summarized above and described in greater detail elsewhere is an adequate justification for this rule independent of concern over prolonged exposure to ozone levels.

Section 211(c) of the CAA allows us to regulate fuels where emission products of the fuel either: (1) Cause or contribute to air pollution that reasonably may be anticipated to endanger public health or welfare, or (2) will impair to a significant degree the performance of any emission control device or system which is in general use, or which the Administrator finds has been developed to a point where in a reasonable time it would be in general use were such a regulation to be promulgated. This proposal meets each of these criteria. The discussion of the first test is substantially the same as the above discussion for the heavy-duty engine standards, because SOx emissions from heavy-duty diesel vehicles are due to sulfur in diesel fuel. The substantial adverse effect of high diesel sulfur levels on diesel control devices or systems expected to be used to meet the heavy-duty standards is discussed in depth in section III.F and in the Draft RIA. In addition, our authority under section 211(c) is discussed in more detail in appendix A to the draft RIA.

C. Putting This Proposal in Perspective

There are several helpful perspectives to establish in understanding the context for this proposal: the growing popularity of diesel engines, past progress and new developments in diesel emissions control, Tier 2 light-duty emission standards and other related EPA initiatives (besides the above-discussed rulemaking for highway heavy-duty engine emission standards in 2004), and recent actions and plans to control diesel emissions by the States and in other countries.

1. Diesel Popularity

The diesel engine is increasingly becoming a vital workhorse in the United States, moving much of the nation's freight, and carrying out much of its farm, construction, and other labor. Diesel engine sales have grown impressively over the last decade, so that now about a million new diesel engines are put to work in the U.S. every year. Unfortunately, these diesel engines emit large quantities of harmful pollutants annually.

Furthermore, although diesel emissions in this country come mostly from heavy-duty trucks and nonroad equipment, an additional source may grow out of auto manufacturers' plans to greatly increase the sales of diesel-powered light-duty vehicles (LDVs) and especially of light-duty trucks (LDTs), a category that includes the fast-selling sport-utility vehicles, minivans, and pickup trucks. These plans reflect the continuation of an ongoing dieselization trend, a trend recently most evident in the growing popularity of diesel-powered light heavy-duty trucks (8500 to 19,500 pounds). Diesel market penetration is working its way from larger to smaller highway applications and to a broader array of nonroad equipment applications. Finally, especially in Europe where diesels have

already gained a broad consumer acceptance, the diesel engine is increasingly viewed as an attractive technology option for reducing emissions of gases that contribute to global warming, because it has greater operating efficiency than a gasoline engine.

2. Past Progress and New Developments

Since the 1970's, highway diesel engine designers have employed numerous strategies to meet our emissions standards, beginning with smoke controls, and focusing in the 1990's on increasingly stringent NO_X, hydrocarbon, and PM standards. These strategies have generally focused on reducing engine-out emissions and not on exhaust emission controls, although low-efficiency oxidation catalysts have been applied in some designs to reduce PM (and even their effectiveness has been limited by sulfur in the fuel). On the fuel side, we set quality standards that provided emissions benefits by limiting the amount of sulfur and aromatics in highway diesel fuel beginning in 1993 (55 FR 34120, August 21, 1990). Our most recent round of standard setting for heavy-duty highway diesels occurred in 1997 (62 FR 54693, October 21, 1997), effective with the 2004 model year. These standards were recently reviewed in a proposed rulemaking (64 FR 58472, October 29, 1999), which proposed to confirm them. These actions will result in engines that emit only a fraction of the NO_X, hydrocarbons, and PM produced by engines manufactured just a decade ago. We consider this an important first phase of our current initiative to reconcile the diesel engine with the environment.

Nevertheless, certain characteristics inherent in the way diesel fuel combustion occurs have prevented achievement of emission levels comparable to those of today's gasoline-fueled vehicles. Although diesel engines provide advantages in terms of fuel economy, durability, and evaporative emissions, and have inherently low exhaust emissions of hydrocarbons and carbon monoxide, controlling NO_X emissions is a greater challenge for diesel engines than for gasoline engines, primarily because of the ineffectiveness of three-way catalysis in the oxygen-rich and relatively cool diesel exhaust environment. Similarly, PM emissions, which are inherently low for properly operating gasoline engines, are more difficult to control in diesel engines, because the diesel combustion process tends to form soot particles. The challenge is somewhat complicated by the fact that historical diesel NO_X control approaches tend to increase PM, and vice versa, but both are harmful pollutants that need to be controlled.

Considering the air quality impacts of diesel engines and the potential for growth of diesels in the lighter-duty portion of the market, it is imperative that progress in diesel emissions control continue. Fortunately, encouraging progress is now being made in the design of exhaust emission control devices for diesel applications, driven in part by the challenge presented by the stringent Tier 2 standards for light-duty vehicles. As discussed in detail in section III, promising new exhaust emission control technologies for NO_X, PM, and hydrocarbon reduction show potential for a major advancement in diesel emissions control of a magnitude comparable to that ushered in by the automotive catalytic converter in the 1970's. However, changes in diesel fuel quality will be needed to enable these high-efficiency exhaust emission control devices. With these promising technologies, diesel vehicles have potential to achieve gasoline-like exhaust emission levels, in addition to their inherent advantages over gasoline vehicles with respect to fuel economy, lower greenhouse gas emissions, and lower evaporative hydrocarbon emissions.

3. Tier 2 Emissions Standards

Auto manufacturers' design plans for new light-duty diesel vehicle models will be greatly affected by our recent adoption of stringent new emission standards for light-duty highway vehicles (referred to as ''Tier 2'' standards) that will phase in between 2004 and 2009. These Tier 2 standards will require significant improvements in electronic engine controls and catalysts on gasoline vehicles. (We anticipate that these advances will be transferred over to heavy-duty gasoline vehicles in meeting the standards proposed in this document). The Tier 2 NO_X and PM standards (that apply equally to gasoline and diesel vehicles) are far more challenging for diesel engine designers than the most stringent light- or heavy-duty vehicle standards promulgated to date, and so will require the use of advanced emission control technologies. However, the low sulfur highway diesel fuel proposed in this notice would make it possible for designers to employ advanced exhaust emission control technologies in these light-duty applications, and the timing of the proposed fuel change provides for the use of these devices in time to satisfy Tier 2 phase-in requirements.

The Tier 2 program phases in interim and final standards over a number of years, providing manufacturers the option of delaying some of their production of final Tier 2 designs until later in the phase-in. For vehicles up to 6000 lbs GVWR (LDVs) and light light-duty trucks (LLDTs)), the interim standards begin in 2004 and phase out by 2007, as they are replaced by the final Tier 2 standards. For vehicles between 6000 and 8500 lbs (heavy light-duty trucks (HLDTs)), the interim standards begin in 2004 and phase out by 2009 as they are replaced by the final Tier 2 standards. A new category of vehicles between 8,500 and 10,000 lbs, medium-duty passenger vehicles (MDPVs), will follow the same phase-in schedule as HLDTs.

Our assessment in the Tier 2 final rule is that the interim standards are feasible for diesel vehicles without a need for fuel quality changes. Manufacturers can take advantage of the flexibilities provided in the Tier 2 program to delay the need for light-duty diesels to meet the final Tier 2 levels until late in the phase-in period (as late as 2007 for LDVs and LLDTs, and 2009 for HLDTs and MDPVs). However, low sulfur fuel is expected to be needed for diesel vehicles designed to meet the final NO_X and PM standards, because these vehicles are likely to employ light-duty versions of the sulfur-sensitive exhaust emission control technologies discussed in Section III. The gasoline quality changes and light-duty gasoline engine developments that will result from the Tier 2 rule would also help make it feasible for heavy-duty gasoline engines to meet the standards proposed in this document.

4. Mobile Source Air Toxics Rulemaking

Passenger cars, on-highway trucks, and nonroad equipment emit hundreds of different compounds and elements. Several of these are considered to be known, likely, or possible human carcinogens. These include diesel exhaust, plus several VOCs such as acetaldehyde, benzene, 1,3-butadiene, formaldehyde, and acrolein. Trace metals may also be present in heavy-duty diesel engine emissions, resulting from metals in fuels and lubricating oil, and from engine wear. Several of these metals have carcinogenic and mutagenic effects.

These and other mobile source air toxics are already controlled under existing programs established under Clean Air Act sections 202(a) (on-highway engine requirements), 211 (the fuel requirements), and 213 (nonroad engine requirements). Although these programs are primarily designed for control of criteria pollutants, especially ozone and PM_{10}, they also achieve

important reductions in air toxics through VOC and hydrocarbon controls.

In addition to these programs, section 202(l)(2) of the Act directs us to consider additional controls to reduce emissions of hazardous air pollutants from motor vehicles, their fuels, or both. Those standards are to reflect the greatest degree of emission reduction achievable through the application of technology which will be available, taking into account existing standards, costs, noise, energy, and safety factors. We anticipate that this section 202(l)(2) rulemaking, which we expect to propose in July 2000 and finalize in December 2000, will consist of three parts. First, we will identify a list of hazardous air pollutants emitted from motor vehicles and determine which of these endanger human health and welfare. Diesel particulate matter will be considered as part of this determination because, as discussed in section II, human epidemiological studies have suggested that diesel exhaust is associated with increased risk of adverse respiratory effects and lung cancer. Second, we will consider more comprehensively the contribution of mobile sources to the nation's air toxics inventory and evaluate the toxics benefits of existing and proposed emission control programs. The benefits of the program proposed in today's action will be included in this analysis. Finally, we will consider whether additional controls are appropriate at this time, given technological feasibility, cost, and the other criteria specified in the Act.

5. Nonroad Engine Standards and Fuel

Although this proposal covers only highway diesel engines and fuel, it is clear that potential requirements for nonroad diesel engines and fuel are related. It is expected that nonroad diesel fuel quality, currently unregulated, may need to be controlled in the future in order to reduce the large contribution of nonroad engines to NO_X and PM inventories. Refiners, fuel distributors, states, environmental organizations, and others have asked that we provide as much information as possible about the future specifications for both types of fuel as early as possible.

We do plan to give further consideration to further control of nonroad engine emissions. As discussed below in section IX, an effective control program for these engines requires the resolution of several major issues relating to engine emission control technologies and how they are affected by fuel sulfur content. The many issues connected with any rulemaking for nonroad engines and fuel warrant serious attention, and we believe it would be premature today for us to attempt to propose resolutions to them. We plan to initiate action in the future to formulate thoughtful proposals covering both nonroad diesel fuel and engines.

6. Actions in California

The California Air Resources Board (ARB) and local air quality management districts within California are also pursuing measures to better control diesel emissions. Key among these efforts is work resulting from the Board's designation of particulate emissions from diesel-fueled engines as a toxic air contaminant (TAC) on August 27, 1998. TACs are air pollutants that may cause or contribute to an increase in death or serious illness or may pose a present or future hazard to human health. The TAC designation was based on research studies showing that emissions from diesel-fueled engines may cause cancer in animals and humans, and that workers exposed to higher levels of emissions from diesel-fueled engines are more likely to develop lung cancer.

The ARB has now begun a public process to evaluate the need to further reduce the public's exposure to organic gases and PM emissions from diesel-fueled engines, and the feasibility and cost of doing so.[4] This evaluation is being done in consultation with the local air districts, affected industries, and the public, and will result in a report on the appropriate degree of control. Based on this report, if cost effective measures are identified that will reduce public exposure, then specific control measures applicable in California will be developed in a public process.

The ARB also recently adopted stringent new emission requirements for urban transit buses and is considering similar requirements for school buses.[5] This program is aimed at encouraging the use of clean alternative fuels and high-efficiency diesel emission control technologies. Their program includes requirements for zero-emissions buses, fleet average NO_X levels, and retrofits for PM control, as well as model year 2007 NO_X and PM standards levels of 0.2 and 0.01 g/bhp-hr, respectively (equal to the levels proposed in this document). It also requires that all diesel fuel used by transit agencies after July 1, 2002 must meet a cap of 15 ppm sulfur. This is the same as the sulfur level proposed in this document, but in batch amounts and on a much earlier schedule to support the ARB's proposed PM retrofit schedule.

California's urban bus program is focused on only a portion of the highway diesel fleet and fuel, characterized by short-range trips and captive fuel supplies. The large amount of interstate truck traffic in California and the fact that these trucks can travel many miles between refuelings would dramatically reduce the effectiveness of a more comprehensive State program, and would also subject California businesses to competitive disadvantages. As a result, the ARB has stressed the need for action at a Federal level, and is depending on our efforts to control HDV NO_X and PM emissions and to regulate diesel fuel. We agree that a national program is appropriate to ensure the effectiveness of such a program.

7. Retrofit Programs

Many States facing air quality improvement challenges have expressed strong interest in programs that would reduce emissions from existing highway and nonroad diesel engines through the retrofitting of these engines with improved emission control devices. The urban bus program proposed by the California ARB includes such a retrofit requirement as one of its major components (see section I.C.6). These retrofit programs are appealing because the slow turnover of the diesel fleet to the new low-emitting engines makes it difficult to achieve near-term air quality goals through new engine programs alone. Some of the exhaust emission control technologies discussed in this proposal are especially appealing for use in retrofits because they can be fitted to an existing vehicle as add-on devices without major engine modifications, although some of the more sophisticated systems that require careful control of engine parameters may be more challenging.

Because of the uncertainty at this time in how and when such programs may be implemented, this proposal does not calculate any benefits from them. Nevertheless, we believe that this proposed program can enable the viability of these retrofit technologies. We expect that large emission benefits from the existing fleet could be realized as a result of the fuel changes we are proposing here, combined with retrofit versions of the technologies that would be developed in response to the proposed engine standards. These

[4] Regularly updated information on this effort can be obtained at a website maintained by the ARB staff: www.arb.ca.gov/toxics/diesel/diesel.htm

[5] ''Notice of Public Hearing To Consider the Adoption of a Public Transit Bus Fleet Rule and Emission Standards For New Urban Buses'', California ARB, November 30, 1999, and ARB Resolution 00–2, dated February 24, 2000.

benefits would be especially important in the early years of the program when new vehicles standards are just beginning to have an impact, and when States and local areas need to gain large reductions to attain air quality goals.

8. Actions in Other Countries

There is substantial activity taking place in many countries of the world related to the regulation of diesel fuel and engines. The large light-duty vehicle market share enjoyed by diesels in many European countries has helped to stir innovation in dealing with diesel emissions problems. Advanced emissions control technologies are being evaluated there in the in-use fleet and experience gained from these trials is helping to inform the diesel emissions control discussion in the U.S. In addition, several European countries have low sulfur diesel fuel, with maximum sulfur levels varying from 10 to 50 ppm, and so experience gained from the use of these fuels, though not completely transferable to the U.S. situation, also helps to inform the discussion. European Union countries will limit sulfur in diesel fuel to 50 ppm by 2005, and even more aggressive plans are being discussed or implemented. The United Kingdom made a rapid conversion to 50 ppm maximum sulfur diesel fuel last year by offering tax incentives. This change occurred with much smaller refinery investments than had been predicted, and some refinery production there is actually at levels well below the 50 ppm cap. Germany is moving forward with plans to introduce a 10 ppm sulfur cap for diesel fuel by 2003, also via tax incentives, and is attempting to get the 50 ppm specification that was adopted by the European Commission revised downward to the 10 ppm cap level.

One European country has had extensive experience with the transition to low sulfur diesel fuel. In the early 1990's, Sweden decided to take advantage of the environmental benefits of 10 ppm sulfur/low aromatics fuel by introducing it with a reduction in the diesel fuel tax. The program has been quite successful, and in excess of 90 percent of the road fuel used there is of this 10 ppm maximum sulfur class.[6] The ability of the Swedish fuel distributors to maintain these low sulfur levels at the fuel stations has also been quite good.

Section VII.H discusses how differences between the future fuel specifications in the U.S. and those in Canada and Mexico may affect the emissions control program proposed in this document.

II. The Air Quality Need and Projected Benefits

A. Overview

Heavy-duty vehicle emissions contribute to air pollution with a wide range of adverse health and welfare impacts. Emissions of VOC, CO, NO_X, SO_X, and PM from HD vehicles contribute a substantial percentage to ambient concentrations of ozone, PM, sulfur and nitrogen compounds, aldehydes, and substances known or considered likely to be carcinogens. VOC and diesel PM emissions include some specific substances known or suspected to cause cancer, and diesel exhaust emissions are associated with non-cancer health effects. These ambient concentrations in turn cause human health effects and many welfare effects including visibility reductions, acid rain, nitrification and eutrophication of water bodies.

Emissions from heavy-duty vehicles, which are predominantly diesel-powered, account for substantial portions of the country's ambient PM and ground-level ozone levels. (NO_X is a key precursor to ozone formation). By 2007, we estimate that heavy-duty vehicles would account for 29 percent of mobile source NO_X emissions, and 14 percent of mobile source PM emissions. These proportions are even higher in some urban areas, such as New York and Los Angeles. Urban areas, which include many poorer neighborhoods, can be disproportionately impacted by HDV emissions because of heavy traffic in and out of densely populated urban areas. Of particular concern is human epidemiological evidence linking diesel exhaust to an increased risk of lung cancer. Based on information provided in the draft Health Assessment Document for Diesel Emissions[7] and other sources of information, we believe that emissions from heavy-duty diesel vehicles contribute to air pollution that warrants regulatory attention under section 202(a)(3) of the Act.

Thirty-six metropolitan areas with a total population of 111 million people have recently violated or are currently violating the 1-hour ozone NAAQS, and have ozone modeling or other factors which indicate a risk of NAAQS violations in 2007 or beyond. Another six areas with 11 million people have recently experienced ozone concentrations within 10 percent of exceeding the NAAQS between 1996 and 1998 and have some evidence of a risk of future violations. Ten PM_{10} nonattainment areas with 27 million people face a significant risk of experiencing particulate matter levels that violate the PM_{10} standard during the time period when this proposal would take effect. Without reductions from these proposed standards, there is a significant risk that an appreciable number of these areas would violate the 1-hour ozone and PM_{10} standards during the time period when these proposed standards would apply to heavy-duty vehicles. Under the mandates and authorities in the Clean Air Act, federal, State, and local governments are working to bring ozone and particulate levels into compliance with the 1-hour ozone and PM_{10} NAAQS through SIP attainment and maintenance plans, and to ensure that future air quality continues to achieve these health-based standards. The reductions proposed in this rulemaking would assist these efforts.

The proposed heavy-duty vehicle and engine emission standards, along with the diesel fuel sulfur standard proposed today, would have a dramatic impact in reducing the large contribution of HDVs to air pollution. The proposed standards would result in substantial benefits to public health and welfare through significant annual reductions in emissions of NO_X, PM, NMHC, carbon monoxide, sulfur dioxide, and air toxics. For example, we project a 2 million ton reduction in NO_X emissions from HD vehicles in 2020, which would increase to 2.8 million tons in 2030 when the current HD vehicle fleet is completely replaced with newer HD vehicles that comply with these proposed emission standards. When coupled with the emission reductions projected to result from the Phase 1 (model year 2004) HDV standards, the emission reductions from heavy-duty vehicles are projected to be as large as the substantial reductions the Agency expects from light-duty vehicles as a result of its recently promulgated Tier 2 rulemaking.

B. Public Health and Welfare Concerns

The following subsections present the available information on the air pollution situation that is likely to exist without this rule for each ambient pollutant. We also present information on the improvement that would result from this rule. The Agency's analysis and this proposal are supported by the numerous letters received from States and environmental organizations calling for significant emission reductions from heavy-duty vehicles in order to enable

[6] Memo from Thomas M. Baines to Docket A–99–06, October 29, 1999, Docket #A–99–06, Item II–G–12.

[7] EPA is revising this draft document in response to comments by the CASAC.

these areas to achieve and sustain clean, healthful air.[8]

1. Ozone and Its Precursors

a. Health and Welfare Effects From Short-Term Exposures to Ozone

NO_X and VOC are precursors in the photochemical reaction which forms tropospheric ozone. A large body of evidence shows that ozone can cause harmful respiratory effects including chest pain, coughing, and shortness of breath, which affect people with compromised respiratory systems most severely. When inhaled, ozone can cause acute respiratory problems; aggravate asthma; cause significant temporary decreases in lung function of 15 to over 20 percent in some healthy adults; cause inflammation of lung tissue; may increase hospital admissions and emergency room visits; and impair the body's immune system defenses, making people more susceptible to respiratory illnesses. Children and outdoor workers are likely to be exposed to elevated ambient levels of ozone during exercise and, therefore, are at greater risk of experiencing adverse health effects. Beyond its human health effects, ozone has been shown to injure plants, reducing crop yields.

b. Current and Future Nonattainment Status With the 1-Hour Ozone NAAQS

Exposure to levels of ozone that are not in compliance with the 1-hour ozone NAAQS are a serious public health and welfare concern. The following sections discuss the present situation and outlook regarding attainment in areas of the country where ozone levels presently fail to comply with this NAAQS, or where they have come close to failing to comply in recent years.

Over the last decade, emissions have declined and national air quality has improved for all six criteria pollutants, including ozone.[9] Some of the greatest emissions reductions have taken place in densely-populated urban areas, where emissions are heavily influenced by mobile sources such as cars and trucks. For example, VOC and NO_X emissions in several urban areas in the Northeast declined by 15 percent and 14 percent from 1990 to 1996.[10] However, when ozone trends are normalized for annual weather variations between 1989 and 1998, they reveal a downward trend in the early 1990's followed by a leveling off, or an upturn in ozone levels, over the past several years in many urban areas.[11]

Despite impressive improvements in air quality over the last decade, present concentrations of ground-level ozone continue to endanger public health and welfare in many areas. As of December, 1999, 92 million people (1990 census) lived in 32 metropolitan areas designated nonattainment under the 1-hour ozone NAAQS.[12] In addition, there are 14 areas with a 1996 population of 17 million people not currently listed as non-attainment areas because the 1-hour ozone standard was revoked for these areas (we have proposed to re-instate the standard).[13] These 14 areas are relevant to this proposal because ozone concentrations above the health-based ozone standard, should they occur, endanger public health and welfare independent of the applicability of the 1-hour standard or an area's official attainment or nonattainment status. Ozone also has negative environmental impacts. For example, exposure of vegetation to ozone can inhibit photosynthesis, and alter carbohydrate allocation, which in turn can suppress the growth of crops, trees, shrubs and other plants.

The next two sections present lists of metropolitan areas, in two tables, with potential for violating the ozone standard in the future. The first section presents a table with 33 metropolitan areas that were predicted by Tier 2 modeling to have exceedances in either 2007 or 2030, and accompanying text identifies an additional nine areas for which we have other evidence of a risk of future exceedances. The second section discusses the air quality prospects for these 42 areas, which are divided into several groups. These groups are presented in Table II.B–2.

i. Ozone Predictions Made in the Tier 2 Rulemaking and Other Information on Ozone Attainment Prospects

In conjunction with its Tier 2 rulemaking efforts, the Agency performed ozone air quality modeling for nearly the entire Eastern U.S. covering metropolitan areas from Texas to the Northeast, and for a western U.S. modeling domain. The ozone modeling we did as part of the Tier 2 rulemaking predicted that without further emission reductions, a significant number of areas recently experiencing ozone exceedances across the nation are at risk of failing to meet the 1-hour ozone NAAQS in 2007 and beyond, even with Tier 2 and other controls currently in place.

The general pattern observed from the Tier 2 ozone modeling is a broad reduction between 1996 and 2007 in the geographic extent of ozone concentrations above the 1-hour NAAQS, and in the frequency and severity of exceedances. Despite this improvement from 1996 to 2007, many ozone exceedances were predicted to occur in 2007 even with reductions from Tier 2 standards and other controls currently in place, affecting 33 metropolitan areas across the nation. Assuming no additional emission reductions beyond those that will be achieved by current control programs,[14] a slight decrease below 2007 levels in modeled concentrations and frequencies of exceedances was predicted for 2030 for most areas. Exceedances were still predicted in 2030 in most of the areas where they were predicted in 2007.[15]

Although we did not model ozone concentrations for years between 2007 and 2030, we may expect that they would broadly track the national emissions trends. Based on these emission trends alone, national ozone concentrations, on average, would be projected to decline after 2007 largely due to penetration of Tier-2 compliant vehicles into the light duty vehicle fleet, but begin to increase around 2015 or 2020 due to economic growth until they reach the 2030 levels just described. However, the change in ozone levels from the expected NO_X reduction is relatively small compared to the effects of variations in ozone due to meteorology. Furthermore, in some areas, where growth exceeds national averages, emissions levels would begin increasing sooner and reach higher levels in 2030.

[8] Letters from States and environmental organizations are located in the docket for this proposal.

[9] National Air Quality and Emissions Trends Report, 1997, US EPA, December 1998.

[10] National Emissions Trends database.

[11] Trends in Daily Maximum 1-hour Ozone in Selected Urban Areas, 1989–1998.

[12] Memorandum to Air Docket, January 12, 2000. Information on ozone nonattainment areas and population as of December 13, 1999 from US EPA website www.epa.gov/airs/nonattn.html, USA Air Quality Nonattainment Areas, Office of Air Quality Planning and Standards. The reader should note that the 32 areas mentioned here are designated nonattainment areas, while the 36 areas noted in the overview section have recent (1995–1998) or current violations, and predicted exceedances in 2007 or 2030 based on air quality modeling or other evidence discussed in more detail later in this preamble, and in the draft RIA.

[13] 64 FR 57424 (October 25, 1999)

[14] Current control programs assumed for the predictions summarized here included the Tier 2/Gasoline Sulfur program and some specific programs that are legally required but not yet fully adopted, such as the regional Ozone Transport Rule and not-yet-adopted MACT standards that will affect VOC emissions.

[15] Achieving attainment with the ozone standard is only one measure of air quality improvement. EPA found that the Tier 2 program significantly lowers the model-predicted number of exceedances of the ozone standard by one tenth in 2007, and by almost one-third in 2030 across the nation (Tier 2 RIA).

Table II.B–1 lists the 33 areas with predicted 1-hour ozone exceedances in 2007 and/or 2030 based on the Tier 2 modeling, after accounting for the emission reductions from the Tier 2 program and other controls. [16] There are areas that are not included in this table that will be discussed shortly. A factor to consider with respect to the ozone predictions in Table II.B–1 is that recent improvements to our estimates of the current and future mobile source NO_X inventory have resulted in an increase in our estimate of aggregate NO_X emissions from all sources by more than eight percent since the air quality modeling performed for the Tier 2 rule. The adjusted NO_X inventory level in 2015 is greater than the NO_X inventory used in the Tier 2 air quality analysis for 2030. If we were to repeat the ozone modeling now for the 2015 time frame, using the new emissions estimates, it would most likely predict exceedances in 2015 for all the areas that had 2030 exceedances predicted in the modeling done for the Tier 2 rulemaking. As summarized in Table II.B–1, the Tier 2 modeling predicted that there will be 33 areas in 2007 or 2030 with about 89 million people predicted to exceed the 1-hour ozone standard, even after Tier 2 and other controls currently in place. Additional information on ozone modeling is found in the draft RIA and the technical support document for the Tier 2 rule, which is in the docket for this rulemaking. We request comment on the inventory estimates and ozone air quality modeling analysis described in this proposal.

TABLE II.B–1.—METROPOLITAN AREAS WITH PREDICTED EXCEEDANCES IN 2007 OR 2030 FROM TIER 2 AIR QUALITY MODELING INCLUDING EMISSION REDUCTIONS FROM TIER 2 AND OTHER CURRENT/COMMITTED CONTROLS

CMSA/MSAs	2007 Control case	2030 Control case	1996 Population (millions)
Boston, MA CMSA	X	X	5.6
Chicago, IL CMSA	X	X	8.6
Cincinnati, OH CMSA**	X		1.9
Cleveland, OH CMSA*	X	X	2.9
Detroit, MI CMSA*	X	X	5.3
Houston, TX CMSA	X	X	4.3
Milwaukee, WI CMSA	X	X	1.6
New York City, NY CMSA	X	X	19.9
Philadelphia, PA CMSA	X	X	6.0
Washington,-Baltimore, DC-VA-WV-MD CMSA	X	X	7.2
Atlanta, GA MSA	X	X	3.5
Barnstable, MA MSA	X	X	0.2
Baton Rouge, LA MSA	X	X	0.6
Benton Harbor, MI MSA	X	X	0.2
Biloxi, MS MSA*	X	X	0.3
Birmingham, AL MSA	X	X	0.9
Charlotte, NC MSA	X	X	1.3
Grand Rapids, MI MSA	X	X	1.0
Hartford, CT MSA	X	X	1.1
Houma, LA MSA	X	X	0.2
Huntington, WV MSA	X		0.3
Indianapolis, IN MSA	X		1.5
Louisville, KY MSA	X	X	1.0
Memphis, TN MSA	X	X	1.1
Nashville, TN MSA	X	X	1.1
New London, CT MSA	X	X	1.3
New Orleans, LA MSA*	X	X	0.3
Pensacola, FL MSA*	X		0.4
Pittsburgh, PA MSA	X		2.4
Providence, RI MSA	X	X	1.1
Richmond, VA MSA	X		0.9
St. Louis, MO MSA	X	X	2.5
Tampa, FL MSA*	X	X	2.2
33 areas / 88.7 million people	32 areas/86.3 million people	28 areas/83.7 million people	.....

*These areas have registered recent (1995–1998) ozone levels within 10% of the 1-hour ozone standard.
**Based on more recent air quality monitoring data not considered in the Tier 2 analysis, and on 10-year emissions projections, we expect to redesignate Cincinnati-Hamilton to attainment soon.

Ozone modeling for the Tier 2 rulemaking did not look at the effect on ozone attainment and maintenance beyond current/committed controls and the Tier 2/Gasoline Sulfur Program itself. Therefore, Table II.B–1 should be interpreted as indicating what areas are at risk of ozone violations in 2007 or 2030 without federal or state measures that may be adopted and implemented after this rulemaking is proposed. We expect many of the areas listed in Table

[16] Table II.B–1 excludes areas for which the Tier 2 modeling predicted exceedances in 1996 but for which the actual ozone design values in 1995–1997 and 1996–1998 were both less than 90 percent of the NAAQS. For these areas, we considered the ozone model's predictions of 2007 or 2030 exceedances to be too uncertain to play a supportive role in our rulemaking determinations. Also, 2007 ozone was not modeled for western areas. For 2030, all areas were modeled for fewer episode days which, along with a general model under-prediction bias, may result in an underestimation of 2030 exceedances. Without these factors, there could have been more western areas listed in Table II.B–1, and more areas with predicted exceedances in 2030.

II.B-1 to adopt additional emission reduction programs, but the Agency is unable to quantify the future reductions from additional State programs since they have not yet been adopted.

In addition, Table II.B–1 reflects only the ozone predictions made in the modeling for the Tier 2 rulemaking. The Tier 2 modeling did not predict (or did not provide information regarding) 2007 or 2030 violations for a number of areas for which other available ozone modeling has shown 2007 violations, or for which the history and current degree of nonattainment indicates some risk of ozone violations in 2007 or beyond. These nine areas had a 1996 population of 30 million people. They include seven ozone nonattainment areas in California (Los Angeles, San Diego, Southeast Desert, Sacramento, Ventura County, San Joaquin Valley, and San Francisco), and two Texas areas (Beaumont-Port Arthur and Dallas). A more detailed discussion is presented in the Draft RIA. The following section will discuss the air quality prospects of these 42 areas (*i.e.,* the 33 shown in Table II.B–1, plus the nine additional areas identified in this paragraph).

For the final rule, the Agency plans to use the same modeling system as was used in its Tier 2 air quality analysis with updated inventory estimates for 2030 and a further characterization of the inventory estimates for the interim period between 2007 and 2030 We plan to release the products of these revised analyses into the public record on a continuous basis as they are developed. Interested parties should check docket number A–99–06 periodically for updates.

ii. Areas At Risk of Exceeding the 1-Hour Ozone Standard

This section presents the Agency's conclusions about the risk of future nonattainment for the 42 areas identified above. These areas are listed in Table II.B–2, and are subdivided into three groups. The following discussion follows the groupings from top to bottom. A more detailed discussion is found in the Draft RIA.

In general, EPA believes that the proposed new standards for heavy-duty vehicles are warranted by a sufficient risk that without these standards, some areas would experience violations of the 1-hour NAAQS at some time during the period when this rulemaking would achieve its emission reductions, despite efforts that EPA, States and localities are now making through SIPs to reach attainment and to preserve attainment by developing and implementing maintenance plans. Because ozone concentrations causing violations of the 1-hour ozone standard are well established to endanger public health and welfare, this indicates that it is appropriate for the Agency to propose setting new standards for heavy-duty vehicles.

Our belief regarding the risk of future violations of the 1-hour NAAQS is based upon our consideration of predictive ozone air quality modeling and analysis we performed for U.S. metropolitan areas for the recent Tier 2 rulemaking, and the predictive ozone modeling and other information that has come to us through the SIP process, and other local air quality modeling for certain areas. We have assessed this information in light of our understanding of the factors that influence ozone concentrations, taking due consideration of current and future federal, state and local efforts to achieve and maintain the ozone standard through air quality planning and implementation.

Ten metropolitan areas that fall within ozone nonattainment areas have statutorily-defined attainment dates of 2007 or 2010, or have requested attainment date extensions to 2007 (including two requests on which we have not yet proposed any action). These 10 areas are listed at the top of Table II.B–2, and are New York City, Houston, Hartford, New London, Chicago, Milwaukee, Dallas, Beaumont-Port Arthur, Los Angeles, and Southeast Desert. The Los Angeles (South Coast Air Basin) ozone attainment demonstration is fully approved, but it is based in part on reductions from new technology measures and actions that have yet to be identified. Accordingly, the State will be able to benefit from, and will need, the reductions from this proposed rule in order to meet the NO_X and VOC shortfalls identified in the South Coast Air Basin's SIP. The 2007 attainment demonstration for the Southeast Desert area is also approved. However, because ozone travels from the South Coast to the Southeast Desert, attainment in the Southeast Desert may depend on progress in reducing ozone levels in the South Coast Air Basin.

The process of developing adequate attainment plans has been difficult. While the efforts by EPA and the States have been more prolonged than expected, they are nearing completion. Of the remaining eight areas discussed above, two—Chicago and Milwaukee—do not have EPA-identified shortfalls in their 1998 attainment demonstrations. However, these two areas are revising their local ozone air quality modeling, which will be taken into account in the final rule. We have recently proposed to approve attainment plans for New York, Houston, Hartford and New London, and we hope to receive attainment plans and propose such approval soon for Dallas and Beaumont-Port Arthur. EPA has proposed, or expects to propose, that attainment in 2007 in each of these six areas depends upon either achieving specified additional emission reductions in the area itself, or achieving ozone reductions in an upwind nonattainment area that has such a shortfall. Those areas with shortfalls will be able to take credit for the expected reductions from the proposed rule in their attainment demonstrations, once the rule is promulgated. We expect to rely in part on these reductions in reaching our final conclusion as to whether each of the eight areas for which we have reviewed an attainment demonstration, or expect to review an attainment demonstration soon, is more likely than not to attain on its respective date, whether or not the State formally relies on these reductions as part of its strategy to fill the identified shortfall in its attainment demonstration, if any.

The proposed new standards for heavy-duty vehicles would help address some of the uncertainties and risks that are inherent in predicting future air quality over a long period. Actual ozone levels may be affected by increased economic growth, unusually severe weather conditions, and unexpectedly large changes in vehicle miles traveled. For example, the emissions and air quality modeling that forms the basis for the 2007-to-2030 emissions and ozone trend described earlier used a 1.7 percent national VMT growth rate. Historical growth in national VMT for LDVs over the last 30 years has averaged 2.7 percent per year, but over the past 10 years, annual VMT growth has fluctuated from 1.2 percent to 3.5 percent. The growth rates can also vary from locality to locality. The reported annual VMT growth rate experienced in Atlanta, a fast-growing metropolitan area, was six percent from 1986–1997, or more than twice the 30-year national average, and year-to-year variations in Atlanta's reported annual VMT ranged from a 12% increase to no increase over the same period. While some factors influencing previous VMT growth rates, such as increased participation of women in the workforce, may be declining, other factors, such as widening suburbanization, more suburb-to-suburb commuting and the rise of healthier and wealthier older age drivers, may result in increased VMT growth rates.[17] Activity by other source

[17] See Tier 2 Response to Comments document for a longer decision.

types also varies due to economic factors. Actual future VMT and other economic growth in specific areas may vary from the best predictions that have been used in each attainment demonstration. Over a number of years, differences in annual growth can cause substantial differences in total emissions. These uncertainties, and others, dictate that a prudent course for the Agency is to protect public health by increasing our confidence that the necessary reductions will be in place. This proposed rulemaking would provide significant and needed reductions to those areas at risk of violating the 1-hour ozone standard during the time period when this rule would take effect.

The reductions from this proposal would begin in 2007 and would continue to grow over time as the existing heavy-duty fleet is replaced by newer vehicles meeting the proposed emission standards. Even assuming attainment is achieved, areas that wish a redesignation to attainment may rely on further reductions generated by this rulemaking to support their 10-year maintenance plan. Even if an area does not choose to seek redesignation, the continuing reductions from this proposed rulemaking would help ensure maintenance with the 1-hour standard after attainment is reached.

Thus, a total of six metropolitan areas need additional measures to meet the shortfalls in the applicable attainment demonstrations, or are subject to ozone transport from an upwind area that has an identified shortfall. In addition, two areas are expected to need additional emission reductions to demonstrate attainment in future SIPs. EPA believes that the States responsible may need, among other reductions, the level of reductions provided by this rule in order to fill the shortfalls. We expect to rely in part on these reductions in reaching our final conclusion as to whether each of the eight areas for which we have reviewed an attainment demonstration is more likely than not to attain on its respective date, whether or not the State formally relies on these reductions as part of its strategy to fill the identified shortfall in its attainment demonstration. As to all ten areas, even if all shortfalls were filled by the States, there is some risk that at least some of the areas will not attain the standards by their attainment dates of 2007, or 2010 for Los Angeles. In that event, the reductions associated with this proposed program, which increase substantially after 2007, would help assure that any residual failures to attain are remedied. Finally, there is also some risk that the areas will be unable to maintain attainment after 2007. Considered collectively, there is a significant risk that some areas would not be in attainment throughout the period when the proposed rule would reduce heavy-duty vehicle emissions.

The next group of 26 areas have required attainment dates prior to 2007, or have no attainment date but are subject to a general obligation to have a SIP that provides for attainment and maintenance. EPA and the States are pursuing the established statutory processes for attaining and maintaining the ozone standard where it presently applies. EPA has also proposed to re-apply the ozone standard to the remaining areas. The Agency believes that there is a significant risk that future air quality in a number of these areas would exceed the ozone standard at some time in the 2007 and later period. This belief is based on three factors: (1) Recent exceedances in 1995–1997 or 1996–1998, (2) predicted exceedances in 2007 or 2030 after accounting for reductions from Tier 2 and other local or regional controls currently in place or required, and (3) our assessment of the magnitude of recent violations, the variability of meteorological conditions, transport from areas with later attainment dates, and other variables inherent in predicting future attainment such as the potential for some areas to experience unexpectedly high economic growth rates, growth in vehicle miles traveled, varying population growth from area to area, and differences in vehicle choice.

Only a subset of these areas have yet adopted specific control measures that have allowed the Agency to fully approve an attainment plan. For some of these areas, we have proposed a finding, based on all the available evidence, that the area will attain on its attainment date. In one case, we have proposed that an area will maintain over the required 10-year time period. However, in many cases, these proposals depend on the State adopting additional emission reduction measures. The draft RIA provides more information on our recent proposals on attainment demonstrations and maintenance plans.[18] Until the SIPs for these areas are actually submitted, reviewed and approved, there is some risk that these areas will not adopt fully approvable SIPs. Furthermore, some of these areas are not under a current requirement to obtain EPA approval for an attainment plan. The mechanisms to get to attainment in areas without a requirement to submit an attainment demonstration are less automatic, and more uncertain. Even with suitable plans, implementation success is uncertain, and therefore there is some risk that 2007 attainment, or maintenance thereafter, would not happen.

Finally, there are six additional metropolitan areas, with another 11.4 million people in 1996, for which the available ozone modeling and other evidence is less clear regarding the need for additional reductions. These areas include Biloxi-Gulfport-Pascagoula, MS, Cleveland-Akron, OH, Detroit-Ann Arbor-Flint, MI, New Orleans, LA, Pensacola, FL, and Tampa, FL. Our own ozone modeling predicted these six areas to need further reductions to avoid exceedances in 2007 or 2030. The recent air quality monitoring data for these six areas shows ozone levels with less than a 10 percent margin below the NAAQS. This suggests that ozone concentrations in these areas may remain below the NAAQS for some time, but we believe there is still a risk of that future ozone levels will be above the NAAQS because meteorological conditions may be more severe in the future.

In sum, without these reductions, there is a significant risk that an appreciable number of the 42 areas, with a population of 123 million people in 1996, will violate the 1-hour ozone standard during the time period when these proposed standards will apply to heavy-duty vehicles. The 42 areas consist of the 27 areas with predicted exceedances in 2007 or 2030 under Tier 2 air quality modeling and recent violations of the 1-hour ozone standard, plus seven California areas (South Coast Air Basin, San Diego, Ventura County, Southeast Desert, San Francisco, San Joaquin Valley, Sacramento), two Texas areas (Dallas and Beaumont-Port Arthur), and six areas that have recent ozone concentrations within 10% of exceeding the standard and predicted exceedances. Additional information about these areas is provided in the draft RIA.

iii. Conclusion

We have reviewed the air quality situation of three broad groups of areas: (1) Those areas with recent violations of the ozone standard and attainment dates in 2007 or 2010, (2) those areas with recent violations and attainment dates (if any) prior to 2007, and (3) those areas with recent ozone concentrations within 10% of a violation of the 1-hour ozone

[18] We have recently proposed favorable action, in some cases with a condition that more emission reductions be obtained, on attainment demonstrations in these areas with attainment dates prior to 2007: Philadelphia, Washington-Baltimore, Atlanta, and St. Louis. We expect to give final approval soon to a maintenance plan and redesignation to attainment for Cincinnati.

standard, with predicted exceedances, and without proposed or approved SIP attainment demonstrations. In general, the evidence summarized in this section, and presented in more detail in the draft RIA, supports the Agency's belief that emissions of NO_X and VOC from heavy-duty vehicles in 2007 and later will contribute to a national ozone air pollution problem that warrants regulatory attention under section 202(a)(3) of the Act.

TABLE II.B–2

Metropolitan area/State	Proposed reinstatement of ozone standard	1996 population (in millions)
Areas with 2007/2010 Attainment Dates (Established or Requested):		
New York City, NY-NJ-CT		19.9
Houston, TX		4.3
Hartford, CT		1.1
New London, CT		1.3
Chicago, IL-IN		8.6
Milwaukee, WI		1.6
Dallas, TX		4.6
Beaumont-Port Arthur, TX		0.4
Los Angeles, CA		15.5
Southeast Desert, CA		0.4
Subtotal of 10 areas		57.7
Areas with Pre-2007 Attainment Dates or No Specific Attainment Date, with a Recent History of Nonattainment:**		
Atlanta, GA		3.5
Philadelphia-Wilmington-Atlantic City, PA-NJ-DE-MD		6.0
Sacramento, CA		1.5
San Joaquin Valley, CA *possible future reclassification and change of attainment date to 2005		2.7
Ventura County, CA		0.7
Washington-Baltimore, DC-MD-VA-WV		7.2
Charlotte-Gastonia, NC	X	1.3
Grand Rapids, MI	X	1.0
Huntington-Ashland, WV-KY	X	0.3
Indianapolis, IN	X	1.5
Memphis, TN	X	1.1
Nashville, TN	X	1.1
Barnstable-Yarmouth, MA	X	0.2
Boston-Worcester-Lawrence, MA	X	5.6
Houma, LA	X	0.2
Providence-Fall River-Warwick, RI-MA	X	1.1
Richmond-Petersburg, VA	X	1.0
Benton Harbor, MI	X	0.2
Baton Rouge, LA		0.6
Birmingham, AL		0.9
Cincinnati-Hamilton, OH-KY-IN*		1.9
Louisville, KY-IN		0.3
Pittsburgh, PA MSA		2.4
San Diego, CA		2.8
San Francisco Bay Area, CA		6.2
St. Louis, MO-IL		2.5
Subtotal of 26 areas		53.8
Areas with Pre-2007 Attainment Dates and Recent Concentrations within 10% of an Exceedance, But With No Recent History of Nonattainment:		
Biloxi-Gulfport-Pascagoula, MS MSA	X	0.3
Cleveland-Akron, OH CMSA	X	2.9
Detroit-Ann Arbor-Flint, MI CMSA	X	5.3
New Orleans, LA MSA	X	0.3
Pensacola, FL MSA	X	0.4
Tampa, FL MSA	X	2.2
Subtotal of 6 areas		11.4
Total 1996 Population of All Areas at Risk of Exceeding the Ozone Standard in 2007 or Thereafter:		
42 Areas—total population		122.9

*Based on more recent air quality monitoring data not considered in the Tier 2 analysis, and on 10-year emissions projections, we expect to redesignate Cincinnati-Hamilton to attainment soon.

**The list includes certain areas that are currently not violating the 1-hour NAAQS.

c. Public Health and Welfare Concerns From Prolonged and Repeated Exposures to Ozone

A large body of scientific literature regarding health and welfare effects of ozone has associated health effects with certain patterns of ozone exposures that do not include any hourly ozone concentration above the 0.12 parts per million (ppm) level of the 1-hour NAAQS. The science indicates that there are health effects attributable to prolonged and repeated exposures to lower ozone concentrations. Studies of 6 to 8 hour exposures showed health effects from prolonged and repeated exposures at moderate levels of exertion to ozone concentrations as low as 0.08

ppm. Prolonged and repeated ozone concentrations at these levels are common in areas throughout the country, and are found in areas that are exceeding, and areas that are not exceeding, the 1-hour ozone standard. For example, in 1998, almost 62 million people lived in areas with 2 or more days with concentrations of 0.09 ppm or higher, excluding areas currently violating the 1-hour NAAQS. Since prolonged exposures at moderate levels of ozone are more widespread than exceedances of the 1-hour ozone standard, and given the continuing nature of the 1-hour ozone problem described above, adverse health effects from this type of ozone exposure can reasonably be anticipated to occur in the future in the absence of this rule. Adverse welfare effects can also be anticipated, primarily from damage to vegetation. See the draft RIA for further details.

Studies of acute health effects have shown transient pulmonary function responses, transient respiratory symptoms, effects on exercise performance, increased airway responsiveness, increased susceptibility to respiratory infection, increased hospital and emergency room visits, and transient pulmonary respiratory inflammation. Such acute health effects have been observed following prolonged exposures at moderate levels of exertion at concentrations of ozone well below the current standard of 0.12 ppm. The effects are more pronounced at concentrations above 0.09 ppm, affecting more subjects or having a greater effect on a given subject in terms of functional changes or symptoms. A more detailed discussion may be found in the Draft RIA.

With regard to chronic health effects, the collective data have many ambiguities, but provide suggestive evidence of chronic effects in humans. There is a biologically plausible basis for considering the possibility that repeated inflammation associated with exposure to ozone over a lifetime, as can occur with prolonged exposure to moderate ozone levels below peak levels, may result in sufficient damage to respiratory tissue that individuals later in life may experience a reduced quality of life, although such relationships remain highly uncertain.

We believe that the evidence in the Draft RIA regarding the occurrence of adverse health effects due to prolonged and repeated exposure to ozone concentrations in the range discussed above, and regarding the populations that are expected to receive exposures at these levels, supports a conclusion that emissions of NO_X, and VOC from heavy-duty vehicles in 2007 and later will be contributing to a national air pollution problem that warrants regulatory attention under section 202(a)(3) of the Act.

Ozone has many welfare effects, with damage to plants being of most concern. Plant damage affects crop yields, forestry production, and ornamentals. The adverse effect of ozone on forests and other natural vegetation can in turn cause damage to associated ecosystems, with additional resulting economic losses. Ozone concentrations of 0.10 ppm can be phytotoxic to a large number of plant species, and can produce acute injury and reduced crop yield and biomass production. Ozone concentrations at or below 0.10 ppm have the potential over a longer duration of creating chronic stress on vegetation that can result in reduced plant growth and yield, shifts in competitive advantages in mixed populations, decreased vigor, and injury from other environmental stresses. The forestry, crop and other environmental damage from ozone in times and places where the 1-hour NAAQS is attained adds support to the Agency's belief that there will be air pollution in 2007 and thereafter that warrants regulatory attention under section 202(a)(3) of the Act.

2. Particulate Matter

a. Health and Welfare Effects

i. Particulate Matter Generally

Particulate matter (PM) represents a broad class of chemically and physically diverse substances. It can be principally characterized as discrete particles that exist in the condensed (liquid or solid) phase spanning several orders of magnitude in size. All particles equal to and less than 10 microns are called PM_{10}. Fine particles can be generally defined as those particles with an aerodynamic diameter of 2.5 microns or less (also known as $PM_{2.5}$), and coarse fraction particles are those particles with an aerodynamic diameter greater than 2.5 microns, but equal to or less than a nominal 10 microns. The health and environmental effects of PM are strongly related to the size of the particles.

The emission sources, formation processes, chemical composition, atmospheric residence times, transport distances and other parameters of fine and coarse particles are distinct. Fine particles are directly emitted from combustion sources and are formed secondarily from gaseous precursors such as sulfur dioxide, nitrogen oxides, or organic compounds. Fine particles are generally composed of sulfate, nitrate, chloride and ammonium compounds; organic and elemental carbon; and metals. Combustion of coal, oil, diesel, gasoline, and wood, as well as high temperature process sources such as smelters and steel mills, produce emissions that contribute to fine particle formation. In contrast, coarse particles are typically mechanically generated by crushing or grinding and are often dominated by resuspended dusts and crustal material from paved or unpaved roads or from construction, farming, and mining activities. Fine particles can remain in the atmosphere for days to weeks and travel through the atmosphere hundreds to thousands of kilometers, while coarse particles deposit to the earth within minutes to hours and within tens of kilometers from the emission source.

Particulate matter, like ozone, has been linked to a range of serious respiratory health problems. Scientific studies suggest a likely causal role of ambient particulate matter (which is attributable to a number of sources including diesel) in contributing to a series of health effects. The key health effects categories associated with ambient particulate matter include premature mortality, aggravation of respiratory and cardiovascular disease (as indicated by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days), aggravated asthma, acute respiratory symptoms, including aggravated coughing and difficult or painful breathing, chronic bronchitis, and decreased lung function that can be experienced as shortness of breath. For additional information on health effects, see the draft RIA. Both fine and coarse particles can accumulate in the respiratory system. Exposure to fine particles is most closely associated with such health effects as premature mortality or hospital admissions for cardiopulmonary disease. PM also causes damage to materials and soiling. It is a major cause of substantial visibility impairment in many parts of the U.S.

Diesel particles are a component of both coarse and fine PM, but fall mostly in the fine range. Noncancer health effects associated with exposure to diesel PM overlap with some health effects reported for ambient PM including respiratory symptoms (cough, labored breathing, chest tightness, wheezing), and chronic respiratory disease (cough, phlegm, chronic bronchitis and some evidence for decreases in pulmonary function).

ii. Special Considerations for Diesel PM

Primary diesel particles mainly consist of carbonaceous material, ash (trace metals), and sulfuric acid. Many of these particles exist in the atmosphere as a carbon core with a coating of organic carbon compounds, sulfuric acid and ash, sulfuric acid aerosols, or sulfate particles associated with organic carbon.

Most diesel particles are in the fine and ultrafine size range. Diesel PM contains small quantities of numerous mutagenic and carcinogenic compounds. While representing a very small portion (less than one percent) of the national emissions of metals, and a small portion of diesel particulate matter (one to five percent), we note that several trace metals of toxicological significance are also emitted by diesel engines in small amounts including chromium, manganese, mercury and nickel. In addition, small amounts of dioxins have been measured in diesel exhaust, some of which may partition into the particle phase, though the impact of these emissions on human health is not clear.

Because the chemical composition of diesel PM includes these hazardous air pollutants, or air toxics, diesel PM emissions are of concern to the agency beyond their contribution to general ambient PM. Moreover, as discussed in detail in the draft RIA, there have been health studies specific to diesel PM emissions which indicate potential hazards to human health that appear to be specific to this emissions source. For chronic exposure, these hazards included respiratory system toxicity and carcinogenicity. Acute exposure also causes transient effects (a wide range of physiological symptoms stemming from irritation and inflammation mostly in the respiratory system) in humans though they are highly variable depending on individual human susceptibility.

b. Potential Cancer Effects of Diesel Exhaust

The EPA draft Health Assessment Document for Diesel Emissions (draft Assessment) is currently being revised based on comments received from the Clean Air Scientific Advisory Committee (CASAC) of EPA's Science Advisory Board.[19] The current EPA position is that diesel exhaust is a likely human lung carcinogen and that this cancer hazard exists for occupational and environmental levels of exposure.[20]

In evaluating the available research for the draft Assessment, EPA found that individual epidemiological studies numbering about 30 show increased lung cancer risks associated with diesel emissions within the study populations of 20 to 89 percent depending on the study. Analytical results of pooling the positive study results show that on average the risks were increased by 33 to 47 percent. Questions remain about the influence of other factors (e.g., effect of smoking), the quality of the individual epidemiology studies, exposure levels, and consequently the precise magnitude of the increased risk of lung cancer. From a weight of the evidence perspective, EPA believes that the epidemiology evidence, as well as supporting data from certain animal and mode of action studies, support the Agency's proposed conclusion that exposure to diesel exhaust is likely to pose a human health hazard at occupational exposure levels, as well as to the general public exposed to typically lower environmental levels of diesel exhaust.

Risk assessments on epidemiological studies in the peer-reviewed literature which have attempted to assess the lifetime risk of lung cancer in workers occupationally exposed to diesel exhaust suggests that lung cancer risk may range from 10^{-4} to 10^{-}.[21 22 23] The Agency recognizes the significant uncertainties in these studies, and has not used these estimates to assess the possible cancer unit risk associated with ambient exposure to diesel exhaust.

While available evidence supports EPA's conclusion that diesel exhaust is a likely human lung carcinogen, and thus is likely to pose a cancer hazard to humans, the absence of quantitative estimates of the lung cancer unit risk for diesel exhaust limits our ability to quantify with confidence the actual magnitude of the cancer risk. In the draft 1999 Assessment, EPA acknowledged these limitations and provided a discussion of the possible cancer risk consistent with general occupational epidemiological findings of increased lung cancer risk and relative exposure ranges in the occupational and environmental settings.[24] The Agency believes that the techniques that were used in the draft Assessment to qualitatively gauge the potential for and possible magnitude of risk are reasonable. The details of this approach are provided in the draft RIA.

In the absence of a quantitative unit cancer risk to assess environmental risk, EPA has considered the relevant epidemiological studies and principles for their assessment, the risk from occupational exposure as assessed by others, and relative exposure margins between occupational and ambient environmental levels of diesel exhaust exposure. Based on this epidemiological and other information, there is the potential that upper bounds on environmental cancer risks from diesel exhaust may exceed 10^{-6} and could be as high as 10^{-3}.[25] While uncertainty exists in estimating risk, the likely hazard to humans together with the potential for significant environmental risks leads the Agency to believe that diesel exhaust emissions should be reduced in order to protect the public's health. We believe that this is a prudent measure in light of the designation of diesel exhaust as a likely human carcinogen, the exposure of almost the entire population to diesel exhaust, the significant and consistent finding of an increase in lung cancer risk in workers exposed to diesel exhaust, and the potential overlap and/or small difference between some occupational and environmental exposures.

As discussed in section I.C.6, ''Actions in California'', the Office of Environmental Health Hazard

[19] U.S. EPA (1999) Health Assessment Document for Diesel Emissions: SAB Review Draft. EPA/600/8–90/057D Office of Research and Development, Washington, DC. The document is available electronically at www.epa.gov/ncea/diesel.htm.

[20] The EPA designation of diesel exhaust as a likely human carcinogen is subject to further comment by CASAC in 2000. The designation of diesel exhaust as a likely human carcinogen under the 1996 Proposed Guidelines for Carcinogen Risk Assessment is very similar to the current 1986 Guidelines for Carcinogen Risk Assessment that designate diesel exhaust as a probable carcinogen (B–1 carcinogen). The new guidelines, once finalized, will incorporate a narrative approach to assist the risk manager in the interpretation of the carcinogen's mode of action, the weight of evidence, and any risk related exposure-response or protective exposure recommendations.

[21] California Environmental Protection Agency, Office of Health Hazard Assessment (CAL-EPA, OEHHA) (1998) Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant. Appendix III Part B Health Risk Assessment for Diesel Exhaust. April 22, 1998.

[22] Steenland, K., Deddens, J., Stayner, L. (1998) Diesel Exhaust and Lung Cancer in the Trucking Industry: Exposure-Response Analyses and Risk Assessment. Am. J Indus. Medicine 34:220–228.

[23] Harris, J.E. (1983) Diesel emissions and Lung Cancer. Risk Anal. 3:83–100.

[24] See Chapter 8.3 and 9.6 of the draft Health Assessment for Diesel Exhaust. U.S. EPA (1999) Health Assessment Document for Diesel Emissions: SAB Review Draft. EPA/600/8–90/057D Office of Research and Development, Washington, D.C. The document is available electronically at www.epa.gov/ncea/diesel.htm.

[25] As used in this proposal, environmental risk is defined as the risk (i.e. a mathematical probability) that lung cancer would be observed in the population after a lifetime exposure to diesel exhaust. Exposure levels may be occupational lifetime or environmental lifetime exposures. A population risk in the magnitude of 10^{-6} translates as the probability of lung cancer being evidenced in one person in one million over a lifetime exposure.

Assessment (OEHHA, California EPA) has identified diesel PM as a toxic air contaminant.[26] California is in the process of determining the need for, and appropriate degree of control measures for diesel PM. Apart from the EPA draft Assessment and California EPA's actions, several other agencies and governing bodies have designated diesel exhaust or diesel PM as a ''potential'' or ''probable'' human carcinogen.[27 28 29] The International Agency for Research on Cancer (IARC) considers diesel exhaust a ''probable'' human carcinogen and the National Institutes for Occupational Safety and Health have classified diesel exhaust a ''potential occupational carcinogen.'' Thus, the concern for the health hazard resulting from diesel exhaust exposures is widespread.

c. Noncancer Effects of Diesel Exhaust

The noncancer effects of diesel exhaust emissions are also of concern to the Agency. EPA believes that chronic diesel exhaust exposure, at sufficient exposure levels, increases the hazard and risk of an adverse consequence (including respiratory tract irritation/inflammation and changes in lung function). The draft 1999 Assessment discussed an existing inhalation reference concentration (RfC) for chronic effects that EPA intends to revise in the next draft Assessment in response to CASAC comments. The revised RfC will be reviewed by CASAC at a future meeting. An RfC provides an estimate of the continuous human inhalation exposure (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious noncancer effects during a lifetime.

d. Attainment and Maintenance of the PM_{10} NAAQS

Under the CAA, we are to regulate HD emissions if they contribute to air pollution that can reasonably be anticipated to endanger public health and welfare. We have already addressed the question of what concentration patterns of PM endanger public health, in setting the NAAQS for PM_{10} in 1987. The PM NAAQS were revised in 1997, largely by adding new standards for fine particles ($PM_{2.5}$) and modifying the form of the daily PM_{10} standard. On judicial review, the revised standards were remanded for further proceedings, and the revised PM_{10} standards were vacated. EPA has sought Supreme Court review of that decision; pending final resolution of the litigation, the 1987 PM_{10} standards continue to apply.

i. Current PM_{10} Nonattainment

The most recent PM_{10} monitoring data indicates that 12 designated PM_{10} nonattainment areas, with a population of 19 million in 1990, violated the PM_{10} NAAQS in the period 1996–1998. Table II.B–3 lists the 12 areas. The table also indicates the classification and 1990 population for each area.

TABLE II.B–3.—PM_{10} NONATTAINMENT AREAS VIOLATING THE PM_{10} NAAQS IN 1996–1998[a]

Area	Classification	1990 population (millions)
Clark Co., NV	Serious	0.741
El Paso, TX[b]	Moderate	0.515
Hayden/Miami, AZ	Moderate	0.003
Imperial Valley, CA[b]	Moderate	0.092
Owens Valley, CA	Serious	0.018
San Joaquin Valley, CA	Serious	2.564
Mono Basin, CA	Moderate	0.000
Phoenix, AZ	Serious	2.238
Fort Hall Reservation, ID	Moderate	0.001
Los Angeles South Coast Air Basin, CA	Serious	13.00
Nogales, AZ	Moderate	0.019
Wallula, WA[c]	Moderate	0.048
Total population		19.24

[a] In addition to these designated nonattainment areas, there are 15 unclassified counties, with a 1996 population of 4.2 million, for which States have reported PM_{10} monitoring data for this period indicating a PM_{10} NAAQS violation. Although we do not believe that we are limited to considering only designated nonattainment areas as part of this rulemaking, we have focused on the designated areas in the case of PM_{10}. An official designation of PM_{10} nonattainment indicates the existence of a confirmed PM_{10} problem that is more than a result of a one-time monitoring upset or a result of PM_{10} exceedances attributable to natural events. We have not yet excluded the possibility that one or the other of these is responsible for the monitored violations in 1996–1998 in the 15 unclassified areas. We adopted a policy in 1996 that allows areas whose PM_{10} exceedances are attributable to natural events to remain unclassified if the State is taking all reasonable measures to safeguard public health regardless of the source of PM_{10} emissions. Areas that remain unclassified areas are not required to submit attainment plans, but we work with each of these areas to understand the nature of the PM_{10} problem and to determine what best can be done to reduce it.

[b] EPA has determined that PM_{10} nonattainment in these areas is attributable to international transport. While reductions in heavy-duty vehicle emissions cannot be expected to result in attainment, they will reduce the degree of PM_{10} nonattainment to some degree.

[c] The violation in this area has been determined to be attributable to natural events.

ii. Risk of Future Exceedances of the PM_{10} Standard

The proposed new standards for heavy-duty vehicles will benefit public health and welfare through reductions in direct diesel particles and NO_X, VOCs, and SO_X which contribute to secondary formation of particulate matter. Because ambient particle concentrations causing violations of the PM_{10} standard are well established to endanger public health and welfare, this information supports the proposed new standards for heavy-duty vehicles. The Agency's recent PM modeling analysis

[26] Office of Environmental Health Hazard Assessment (1998) Health risk assessment for diesel exhaust, April 1998. California Environmental Protection Agency, Sacramento, CA.

[27] National Institute for Occupational Safety and Health (NIOSH) (1988) Carcinogenic effects of exposure to diesel exhaust. NIOSH Current Intelligence Bulletin 50. DHHS, Publication No. 88–116. Centers for Disease Control, Atlanta, GA.

[28] International Agency for Research on Cancer (1989) Diesel and gasoline engine exhausts and some nitroarenes, Vol. 46. Monographs on the evaluation of carcinogenic risks to humans. World Heath Organization, International Agency for Research on Cancer, Lyon, France.

[29] World Health Organization (1996) Diesel fuel and exhaust emissions: International program on chemical safety. World Health Organization, Geneva, Switzerland.

performed for the Tier 2 rulemaking predicts that a significant number of areas across the nation are at risk of failing to meet the PM_{10} NAAQS even with Tier 2 and other controls currently in place. These reductions will assist states as they work with the Agency through SIP development and implementation of local controls to move their areas into attainment by the applicable deadline, and maintain the standards thereafter.

The Agency believes that the PM_{10} concentrations in 10 areas shown in Table II.B–4 have a significant risk of exceeding the PM_{10} standard without further emission reductions during the time period when this rulemaking would take effect. This belief is based on the PM_{10} modeling conducted for the Tier 2 rulemaking. Table II.B–4 presents information about these 10 areas and subdivides them into two groups. The first group of six areas are designated PM_{10} nonattainment areas which had recent monitored violations of the PM_{10} NAAQS in 1996–1998 and were predicted to be in nonattainment in 2030 in our PM_{10} air quality modeling. These areas have a population of over 19 million. Included in the group are the nonattainment areas that are part of the Los Angeles, Phoenix, and Las Vegas metropolitan areas, where traffic from heavy-duty vehicles is substantial. These six areas would clearly benefit from the reductions in emissions that would occur from the proposed new standards for heavy-duty vehicles.

The second group of four counties listed in Table II.B–4 with a total of 8 million people in 1996 also had predicted exceedances of the PM_{10} standard. However, while these four areas registered, in either 1997 or 1998, single-year annual average monitored PM_{10} levels of at least 90 percent of the PM_{10} NAAQS, these areas did not exceed the formal definition of the PM_{10} NAAQS over the three-year period ending in 1998.[30] Unlike the situation for ozone, for which precursor emissions are generally declining over the next 10 years or so before beginning to increase, we estimate that emissions of PM_{10} will rise steadily unless new controls are implemented. The small margin of attainment which the four areas currently enjoy will likely erode; the PM air quality modeling suggests that it will be reversed. We therefore consider these four areas to each individually have a significant risk of exceeding the PM_{10} standard without further emission reductions. The emission reductions from the proposed new standards for heavy-duty vehicles would help these areas with attainment and maintain in conjunction with other processes that are currently moving these areas towards attainment.

TABLE II.B–4.—AREAS WITH SIGNIFICANT RISK OF EXCEEDING THE PM_{10} NAAQS WITHOUT FURTHER EMISSION REDUCTIONS

Area	1990 population (millions)
Areas Currently Exceeding the PM_{10} Standard:	
Clark Co., NV	0.741
El Paso, TX[a]	0.515
Imperial Valley, CA[a]	0.092
San Joaquin Valley, CA	2.564
Phoenix, AZ	2.238
Los Angeles South Coast Air Basin, CA	13.00
Subtotal for 6 Areas	19.15
Areas within 10% of Exceeding the PM_{10} Standard:	
New York Co., NY	1.49
Cuyahoga Co., OH	1.41
Harris, Co., TX	2.83
San Diego Co., CA	2.51
Subtotal for 4 Areas	8.24
Total 1996 Population of All 10 Areas at Risk of Exceeding the PM_{10} Standard: 10 Areas, Total 1990 Population	27.39

[a] EPA has determined that PM_{10} nonattainment in these areas is attributable to international transport. While reductions in heavy-duty vehicle emissions cannot be expected to result in attainment, they will reduce the degree of PM_{10} nonattainment to some degree.

Future concentrations of ambient particulate matter may be influenced by the potentially significant influx of diesel-powered cars and light trucks into the light duty vehicle fleet. At the present time, virtually all cars and light trucks being sold are gasoline fueled. However, the possibility exists that diesels will become more prevalent in the car and light-duty truck fleet, since automotive companies have announced their desire to increase their sales of diesel cars and light trucks. For the Tier 2 rulemaking, the Agency performed a sensitivity analysis using A.D.Little's ''most likely'' increased growth scenario of diesel penetration into the light duty vehicle fleet which culminated in a 9 percent and 24 percent penetration of diesel vehicles in the LDV and LDT markets, respectively, in 2015 (see Tier 2 RIA, Table III.A.–13). This scenario is relevant for the purpose of this rulemaking because, according to the analysis performed in Tier 2, an increased number of diesel-powered light duty vehicles will increase LDV PM emissions by about 13 percent in 2010 rising to 19 percent in 2030, even with the stringent new PM standards established under the Tier 2 rule. If manufacturers elect to certify a portion of their diesel-powered LDVs to the least-stringent PM standard available under the Tier 2 bin structure, the increase in LDV PM emissions could be

[30] In fact, in two of these areas, New York Co., NY and Harris Co., TX, the average PM_{10} level in 1998 was above the 50 micrograms per cubic meter value of the NAAQS. These two areas are not characterized in Table II.B–4 as areas with a high risk of failing to attain and maintain because lower PM_{10} levels in 1996 and 1997 caused their three-year average PM_{10} level to be lower than the NAAQS. Official nonattainment determinations for the annual PM_{10} NAAQS are made based on the average of 12 quarterly PM_{10} averages.

even greater, thus potentially exacerbating PM_{10} nonattainment problems.

EPA recognizes that the SIP process is ongoing and that many of the six current nonattainment areas in Table II.B–4 are in the process of, or will be adopting additional control measures to achieve the PM_{10} NAAQS in accordance with their attainment dates under the Clean Air Act. EPA believes, however, that as in the case of ozone, there are uncertainties inherent in any demonstration of attainment that is premised on forecasts of emission levels and meteorology in future years. Therefore, even if these areas adopt and submit SIPs that EPA is able to approve as demonstrating attainment of the PM_{10} standard, the modeling conducted for Tier 2 and the history of PM_{10} levels in these areas indicates that there is still a significant risk that these areas would need the reductions from the proposed heavy-duty vehicle standards to maintain the PM_{10} standards in the long term. The other four areas in Table II.B–4 also have a significant risk of experiencing violations of the PM_{10} standard.

In sum, the Agency believes that all 10 areas have a significant risk of experiencing particulate matter levels that violate the PM_{10} standard during the time period when this proposed rule would take effect. These 10 areas have a combined population of 27 million, and are located throughout the nation. In addition, this list does not fully consider the possibility that there are other areas which are now meeting the PM_{10} NAAQS that have at least a significant probability of requiring further reductions to continue to maintain it.

e. Public Health and Welfare Concerns From Exposure to Fine PM

Many epidemiologic studies have shown statistically significant associations of ambient PM levels with a variety of human health endpoints in sensitive populations, including mortality, hospital admissions and emergency room visits, respiratory illness and symptoms measured in community surveys, and physiologic changes in mechanical pulmonary function. These effects have been observed in many areas with ambient PM levels at or below the current PM_{10} NAAQS. The epidemiologic science points to fine PM as being more strongly associated with some health effects, such as premature mortality, than coarse fraction PM.

Associations of both short-term and long-term PM exposure with most of the above health endpoints have been consistently observed. (A more detailed discussion may be found in the RIA.) The general internal consistency of the epidemiologic data base and available findings have led to increasing public health concern, due to the severity of several studied endpoints and the frequent demonstration of associations of health and physiologic effects with ambient PM levels at or below the current PM_{10} NAAQS. The weight of epidemiologic evidence suggests that ambient PM exposure has affected the public health of U.S. populations. Specifically, increased mortality associated with fine PM was observed in cities with longer-term average fine PM concentrations in the range of 16 to 21 ug/m3. For example, over 113 million people (46 percent of continental US population, 1990) lived in areas in 1996 where long term ambient fine particulate matter levels were at or above 16 $\mu g/m^3$, which is the long term average $PM_{2.5}$ concentration that prevailed in Boston during the study which found that acute mortality was statistically significantly associated with daily fine PM concentrations.[31] It is reasonable to anticipate that sensitive populations exposed to similar or higher levels, now and in the 2007 and later time frame, will also be at increased risk of premature mortality associated with exposures to fine PM. In addition, statistically significant relationships have also been observed in U.S. cities between PM levels and increased respiratory symptoms and decreased lung functions in children.

While uncertainty remains in the published data base regarding specific aspects about the nature and magnitude of the overall public health risk imposed by ambient PM exposure, we believe that the body of health evidence is supportive of our view that PM exposures that can reasonably be anticipated to occur in the future are a serious public health concern warranting a requirement to reduce emissions from heavy-duty vehicles, even at levels below the PM_{10} NAAQS. EPA believes the risk is significant from an overall public health perspective because of the large number of individuals in sensitive populations that we expect to be exposed to ambient fine PM in the 2007 and later time frame, as well as the importance of the negative health affects.

We believe the evidence regarding the occurrence of adverse health effects due to exposure to fine PM concentrations, and regarding the populations that are expected to receive exposures at these levels, supports a proposed conclusion that emissions from heavy-duty vehicles that lead to the formation of fine PM in 2007 and later will be contributing to a national air pollution problem that warrants action under section 202(a)(3).

f. Visibility and Regional Haze Effects of Ambient PM

Visibility impairment, also called regional haze, is a complex problem caused by a variety of sources, both natural and anthropogenic (*e.g.,* motor vehicles). Regional haze masks objects on the horizon and reduces the contrast of nearby objects. The formation, extent, and intensity of regional haze are functions of meteorological and chemical processes, which sometimes cause fine particle loadings to remain suspended in the atmosphere for several days and to be transported hundreds of kilometers from their sources (NRC, 1993).

Visibility has been defined as the degree to which the atmosphere is transparent to visible light (NRC, 1993). Visibility impairment is caused by the scattering and absorption of light by particles and gases in the atmosphere. Fine particles (0.1 to 1.0 microns in diameter) are more effective per unit mass concentration at impairing visibility than either larger or smaller particles (NAPAP, 1991). Most of the diesel particle mass emitted by diesel engines falls within this fine particle size range. Light absorption is often caused by elemental carbon, a product of incomplete combustion from activities such as burning diesel fuel or wood. These particles cause light to be scattered or absorbed, thereby reducing visibility.

Heavy-duty vehicles contribute a significant portion of the emissions of direct PM, NO_X, and SO_X that result in ambient PM that contributes to regional haze and impaired visibility. The Grand Canyon Visibility Transport Commission's report found that reducing total mobile source emissions is an essential part of any program to protect visibility in the Western U.S. The Commission identified mobile source pollutants of concern as VOC, NO_X, and elemental and organic carbon. The Western Governors Association, in later commenting on the Regional Haze Rule and on protecting the 16 Class I

[31] In the absence of quality-assured $PM_{2.5}$ monitoring data, we have used an air quality model called Regional Modeling System for Aerosols and Deposition (REMSAD) to estimate recent $PM_{2.5}$ concentrations across the U.S. for 1996. Essentially, REMSAD is a three-dimensional grid-based Eulerian air quality model designed to simulate long-term (*e.g.,* annual) concentrations and deposition of atmospheric pollutants (*e.g.,* particulates and toxics) over large spatial scales (e.g., over the contiguous United States). A more detailed explanation of the methodology is found in the draft RIA.

areas on the Colorado Plateau, stated that the federal government, and particularly EPA, must do its part in regulating emissions from mobile sources that contribute to regional haze in these areas. As described more fully later in this section, today's proposal would result in large reductions in these pollutants. These reductions are expected to provide an important step towards improving visibility across the nation. Emissions reductions being achieved to attain the 1-hour ozone and PM_{10} NAAQS will assist in visibility improvements, but not substantially. Moreover, the timing of the reductions from the proposed standards fits very well with the goals of the regional haze program. We will work with the regional planning bodies to make sure they have the information to take account of the reductions from any final rule resulting from this proposal in their planning efforts.

The Clean Air Act contains provisions designed to protect national parks and wilderness areas from visibility impairment. In 1999, EPA promulgated a rule that will require States to develop plans to dramatically improve visibility in national parks. Although it is difficult to determine natural visibility levels, we believe that average visual range in many Class I areas in the United States is significantly less (about 50–66% of natural visual range in the West, about 20% of natural visual range in the East) than the visual range that would exist without anthropogenic air pollution. The final Regional Haze Rule establishes a 60-year time period for planning purposes, with several near term regulatory requirements, and is applicable to all 50 states. One of the obligations is for States to conduct visibility monitoring in mandatory Class I Federal areas and determine baseline conditions using data for year 2000 to 2004. Reductions of particles, NO_X, sulfur, and VOCs from this rulemaking would have a significant impact on moving all states towards achieving long-term visibility goals, as outlined in the 1999 Regional Haze Rule.

g. Other Welfare Effects Associated With PM

The deposition of airborne particles reduces the aesthetic appeal of buildings, and promotes and accelerates the corrosion of metals, degrades paints, and deteriorates building materials such as concrete and limestone. This materials damage and soiling are related to the ambient levels of airborne particulates, which are emitted by heavy-duty vehicles. Although there was insufficient data to relate materials damage and soiling to specific concentrations, and thereby to allow the Agency to establish a secondary PM standard for these impacts, we believe that the welfare effects are real and that heavy-duty vehicle PM, NO_X, SO_X, and VOC contribute to materials damage and soiling.

h. Conclusions Regarding PM

There is a significant risk that, despite statutory requirements and EPA and state efforts towards attainment and maintenance, some areas of the U.S. will violate the PM_{10} NAAQS in 2007 and thereafter. We believe that the information provided in this section shows that there will be air pollution that warrants regulatory attention under section 202(a)(3) of the Act. Heavy-duty vehicles contribute substantially to PM_{10} levels, as shown in section II.C below.

It is also reasonable to anticipate that concentrations of fine PM, as represented for example by $PM_{2.5}$ concentrations, will endanger public health and welfare also even if all areas attain and maintain the PM_{10} NAAQS. Heavy-duty vehicles will also contribute to this air pollution problem.

There are also important environmental impacts of PM_{10}, such as regional haze which impairs visibility. Furthermore, while the evidence on soiling and materials damage is limited and the magnitude of the impact of heavy-duty vehicles on these welfare effects is difficult to quantify, these welfare effects support our belief information that this proposal is necessary and appropriate.

3. Other Criteria Pollutants

The standards being proposed today would help reduce levels of three other pollutants for which NAAQS have been established: carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). The extent of nonattainment for these three pollutants is small, so the primary effect of today's proposal would be to provide areas concerned with maintaining their attainment status a greater margin of safety. As of 1998, every area in the United States has been designated to be in attainment with the NO_2 NAAQS. As of 1997, only one area (Buchanan County, Missouri) did not meet the primary SO_2 short-term standard, due to emissions from the local power plant. In 1997, only 6 of 537 monitoring sites reported ambient CO levels in excess of the CO NAAQS. There are currently 20 designated CO nonattainment areas, with a combined population of 34 million. There are also 23 designated maintenance areas with an additional combined population of 34 million. The broad trends indicate that ambient levels of CO are declining.

4. Other Air Toxics

In addition to NO_x and particulates, heavy-duty vehicle emissions contain several other substances that are known or suspected human or animal carcinogens, or have serious noncancer health effects. These include benzene,1,3-butadiene, formaldehyde, acetaldehyde, acrolein, and dioxin. For some of these pollutants, heavy-duty engine emissions are believed to account for a significant proportion of total nation-wide emissions. Although these emissions will decrease in the short term, they are expected to increase in 2007–2020 without the proposed emission limits, as the number of miles traveled by heavy-duty trucks increases. In the Draft RIA, we present current and projected exposures to benzene, 1,3-butadiene, formaldehyde, and acetaldehyde from all on-highway motor vehicles.

By reducing hydrocarbon and other organic emissions, both in gas phase and bound to particles, the emission control program proposed in today's action would have a significant impact on direct emissions of air toxics from HDVs. We are also proposing a new formaldehyde standard for heavy-duty vehicles. Today's action would reduce exposure to these substances and therefore help reduce the impact of HDV emissions on cancer and non-cancer health effects. We are currently conducting a risk assessment to assess the risk of cancer in the population that can be attributed to motor vehicle emissions of benzene, 1,3-butadiene, formaldehyde, and acetaldehyde.

a. Benzene

Highway mobile sources account for 52 percent of nationwide emissions of benzene and HDVs account for 7 percent of all highway vehicle benzene emissions.[32] The EPA has recently reconfirmed that benzene is a known human carcinogen by all routes of exposure (including leukemia at high, prolonged air exposures), and is associated with additional health effects including genetic changes in humans and animals and increased proliferation

[32] 1990 Emissions Inventory of Forty Potential Section 112(k) Pollutants: Supporting Data for EPA's Section 112(k) Regulatory Strategy—Final Report. Emission Factors and Inventory Group, Office of Air Quality Planning and Standards, May, 1999.

of bone marrow cells in mice.[33] [34] [35] EPA believes that the data indicate a causal relationship between benzene exposure and acute lymphocytic leukemia and suggest a relationship between benzene exposure and chronic non-lymphocytic leukemia and chronic lymphocytic leukemia. Respiration is the major source of human exposure and at least half of this exposure is attributable to gasoline vapors and automotive emissions. A number of adverse noncancer health effects including blood disorders, such as preleukemia and aplastic anemia, have also been associated with low-dose, long-term exposure to benzene.

b. 1,3-Butadiene

Highway mobile sources account for 51 percent of the annual emissions of 1,3-butadiene and HDVs account for 15 percent of the highway vehicle portion. Today's program would play an important role in reducing in the mobile contribution of 1,3-butadiene. This compound causes a variety of reproductive and developmental effects in mice and rats exposed to long-term, low doses. There is, however, no human data on 1,3-butadiene. EPA's recently prepared draft health assessment document presents evidence that suggests this substance is a known human carcinogen.[36] The Environmental Health Committee of EPA's Science Advisory Board, in reviewing EPA's draft Health Assessment for 1,3-butadiene, recommended that 1,3-butadiene should be classified as a probable human carcinogen.[37]

c. Formaldehyde

Highway mobile sources contribute 27 percent of the national emissions of formaldehyde, and HDVs account for 35 percent of the highway portion. EPA has classified formaldehyde as a probable human carcinogen based on evidence in humans and in rats, mice, hamsters, and monkeys.[38] Epidemiological studies in occupationally exposed workers suggest that long-term inhalation of formaldehyde may be associated with tumors of the nasopharyngeal cavity (generally the area at the back of the mouth near the nose), nasal cavity, and sinus. Formaldehyde exposure also causes a range of noncancer health effects, including irritation of the eyes (tearing of the eyes and increased blinking) and mucous membranes. Sensitive individuals may experience these adverse effects at lower concentrations than the general population and in persons with bronchial asthma, the upper respiratory irritation caused by formaldehyde can precipitate an acute asthmatic attack.

d. Acetaldehyde

Highway mobile sources contribute 20 percent of the national acetaldehyde emissions and HDVs are responsible for approximately 33 percent of these highway mobile source emissions. Acetaldehyde is classified as a probable human carcinogen and is considered moderately toxic by the inhalation, oral, and intravenous routes. The primary acute effect of exposure to acetaldehyde vapors is irritation of the eyes, skin, and respiratory tract. At high concentrations, irritation and pulmonary effects can occur, which could facilitate the uptake of other contaminants.

e. Acrolein

HDVs are responsible for approximately 53 percent of the mobile source highway emissions and about 8% of the total inventory (1996 NTI). Acrolein is extremely toxic to humans when inhaled, with acute exposure resulting in upper respiratory tract irritation and congestion. The Agency has developed a reference concentration for inhalation (RfC) of acrolein of 0.02 micrograms/m^3.[39] Although no information is available on its carcinogenic effects in humans, based on laboratory animal data, EPA considers acrolein a possible human carcinogen.

f. Dioxins

Recent studies have confirmed that dioxins are formed by and emitted from heavy-duty diesel trucks. These trucks are estimated to account for 1.2 percent of total dioxin emissions. In general, dioxin exposures of concern have primarily been noninhalation exposures associated with human ingestion of certain foods (*e.g.,* beef, vegetables, and dairy products contaminated by dioxin). EPA has classified dioxin as a probable human carcinogen. Acute and chronic effects have also been reported for dioxin from oral and inhalation routes of exposure.[40]

5. Other Environmental Effects

a. Acid Deposition

Acid deposition, or acid rain as it is commonly known, occurs when SO_2 and NO_X react in the atmosphere with water, oxygen, and oxidants to form various acidic compounds that later fall to earth in the form of precipitation or dry deposition of acidic particles.[41] It contributes to damage of trees at high elevations and in extreme cases may cause lakes and streams to become so acidic that they cannot support aquatic life. In addition, acid deposition accelerates the decay of building materials and paints, including irreplaceable buildings, statues, and sculptures that are part of our nation's cultural heritage. To reduce damage to automotive paint caused by acid rain and acidic dry deposition, some manufacturers use acid-resistant paints, at an average cost of $5 per vehicle—a total of $61 million per year if applied to all new cars and trucks sold in the U.S.

Acid deposition primarily affects bodies of water that rest atop soil with a limited ability to neutralize acidic compounds. The National Surface Water Survey (NSWS) investigated the effects of acidic deposition in over 1,000 lakes larger than 10 acres and in thousands of miles of streams. It found that acid deposition was the primary cause of acidity in 75 percent of the acidic lakes and about 50 percent of the acidic streams, and that the areas most sensitive to acid rain were the Adirondacks, the mid-Appalachian highlands, the upper Midwest and the high elevation West. The NSWS found that approximately 580 streams in the Mid-Atlantic Coastal Plain are acidic primarily due to acidic deposition. Hundreds of the lakes in the Adirondacks surveyed in the NSWS

[33] International Agency for Research on Cancer, IARC monographs on the evaluation of carcinogenic risk of chemicals to humans, Volume 29, Some industrial chemicals and dyestuffs, International Agency for Research on Cancer, World Health Organization, Lyon, France, p. 345–389, 1982.

[34] Irons, R.D., W.S. Stillman, D.B. Calogiovanni, and V.A. Henry, Synergistic action of the benzene metabolite hydroquinone on myelopoietic stimulating activity of granulocyte/macrophage colony-stimulating factor *in vitro*, Proc. Natl. Acad. Sci. 89:3691–3695, 1992.

[35] Environmental Protection Agency, Carcinogenic Effects of Benzene: An Update, National Center for Environmental Assessment, Washington, DC. 1998.

[36] Environmental Protection Agency, Health Risk Assessment of 1,3-Butadiene. EPA/600/P–98/001A, February 1998.

[37] An SAB Report: Review of the Health Risk Assessment of 1,3-Butadiene. EPA–SAB–EHC–98, August, 1998.

[38] Environmental Protection Agency, Assessment of health risks to garment workers and certain home residents from exposure to formaldehyde, Office of Pesticides and Toxic Substances, April 1987.

[39] U.S. EPA (1993) Environmental Protection Agency, Integrated Risk Information System (IRIS), Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH.

[40] U.S. EPA (1994) Health Assessment Document for 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) and Related Compounds: Volume III Summary Draft Document. EPA/600/BP–92/001c.

[41] Much of the information in this subsection was excerpted from the EPA document, Human Health Benefits from Sulfate Reduction, written under Title IV of the 1990 Clean Air Act Amendments, U.S. EPA, Office of Air and Radiation, Acid Rain Division, Washington, DC 20460, November 1995.

have acidity levels incompatible with the survival of sensitive fish species. Many of the over 1,350 acidic streams in the Mid-Atlantic Highlands (mid-Appalachia) region have already experienced trout losses due to increased stream acidity. Emissions from U.S. sources contribute to acidic deposition in eastern Canada, where the Canadian government has estimated that 14,000 lakes are acidic. Acid deposition also has been implicated in contributing to degradation of high-elevation spruce forests that populate the ridges of the Appalachian Mountains from Maine to Georgia. This area includes national parks such as the Shenandoah and Great Smoky Mountain National Parks.

The SO_X and NO_X reductions from today's proposal would help reduce acid rain and acid deposition, thereby helping to reduce acidity levels in lakes and streams throughout the country and help accelerate the recovery of acidified lakes and streams and the revival of ecosystems adversely affected by acid deposition. Reduced acid deposition levels would also help reduce stress on forests, thereby accelerating reforestation efforts and improving timber production. Deterioration of our historic buildings and monuments, and of buildings, vehicles, and other structures exposed to acid rain and dry acid deposition also would be reduced, and the costs borne to prevent acid-related damage may also decline. While the reduction in sulfur and nitrogen acid deposition would be roughly proportional to the reduction in SO_X and NO_X emissions, respectively, the precise impact of today's proposal would differ across different areas.

b. Eutrophication and Nitrification

Nitrogen deposition into bodies of water can cause problems beyond those associated with acid rain. The Ecological Society of America has included discussion of the contribution of air emissions to increasing nitrogen levels in surface waters in a recent major review of causes and consequences of human alteration of the global nitrogen cycle in its Issues in Ecology series.[42] Long-term monitoring in the United States, Europe, and other developed regions of the world shows a substantial rise of nitrogen levels in surface waters, which are highly correlated with human-generated inputs of nitrogen to their watersheds. These nitrogen inputs are dominated by fertilizers and atmospheric deposition.

Human activity can increase the flow of nutrients into those waters and result in excess algae and plant growth. This increased growth can cause numerous adverse ecological effects and economic impacts, including nuisance algal blooms, dieback of underwater plants due to reduced light penetration, and toxic plankton blooms. Algal and plankton blooms can also reduce the level of dissolved oxygen, which can also adversely affect fish and shellfish populations. This problem is of particular concern in coastal areas with poor or stratified circulation patterns, such as the Chesapeake Bay, Long Island Sound, or the Gulf of Mexico. In such areas, the ''overproduced'' algae tends to sink to the bottom and decay, using all or most of the available oxygen and thereby reducing or eliminating populations of bottom-feeder fish and shellfish, distorting the normal population balance between different aquatic organisms, and in extreme cases causing dramatic fish kills.

Collectively, these effects are referred to as eutrophication, which the National Research Council recently identified as the most serious pollution problem facing the estuarine waters of the United States (NRC, 1993). Nitrogen is the primary cause of eutrophication in most coastal waters and estuaries.[43] On the New England coast, for example, the number of red and brown tides and shellfish problems from nuisance and toxic plankton blooms have increased over the past two decades, a development thought to be linked to increased nitrogen loadings in coastal waters. Airborne NO_X contributes from 12 to 44 percent of the total nitrogen loadings to United States coastal water bodies. For example, approximately one-quarter of the nitrogen in the Chesapeake Bay comes from atmospheric deposition.

Excessive fertilization with nitrogen-containing compounds can also affect terrestrial ecosystems.[44] Research suggests that nitrogen fertilization can alter growth patterns and change the balance of species in an ecosystem. In extreme cases, this process can result in nitrogen saturation when additions of nitrogen to soil over time exceed the capacity of the plants and microorganisms to utilize and retain the nitrogen. This phenomenon has already occurred in some areas of the U.S.

Deposition of nitrogen from heavy-duty vehicles contributes to these problems. In the Chesapeake Bay region, modeling shows that mobile source deposition occurs in relatively close proximity to highways, such as the I–95 corridor which covers part of the Bay surface. The proposed new standards for heavy-duty vehicles would reduce total NO_X emissions by 2.8 million tons in 2030. The NO_X reductions should reduce the eutrophication problems associated with atmospheric deposition of nitrogen into watersheds and onto bodies of water, particularly in aquatic systems where atmospheric deposition of nitrogen represents a significant portion of total nitrogen loadings.

c. POM Deposition

EPA's Great Waters Program has identified 15 pollutants whose deposition to water bodies has contributed to the overall contamination loadings to the these Great Waters.[45] One of these 15 pollutants, a group known as polycyclic organic matter (POM), are compounds that are mainly adhered to the particles emitted by mobile sources and later fall to earth in the form of precipitation or dry deposition of particles. The mobile source contribution of the 7 most toxic POM is at least 62 tons/year and represents only those POM that adhere to mobile source particulate emissions.[46] The majority of these emissions are produced by diesel engines.

POM is generally defined as a large class of chemicals consisting of organic compounds having multiple benzene rings and a boiling point greater than 100°C. Polycyclic aromatic hydrocarbons are a chemical class that is a subset of POM. POM are naturally occurring substances that are byproducts of the incomplete combustion of fossil fuels and plant and animal biomass (e.g., forest fires). Also, they occur as byproducts from steel and

[42] Vitousek, Peter M., John Aber, Robert W. Howarth, Gene E. Likens, et al. 1997. Human Alteration of the Global Nitrogen Cycle: Causes and Consequences. Issues in Ecology. Published by Ecological Society of America, Number 1, Spring 1997.

[43] Much of this information was taken from the following EPA document: Deposition of Air Pollutants to the Great Waters-Second Report to Congress, Office of Air Quality Planning and Standards, June 1997, EPA–453/R–97–011. A Third Report to Congress on Deposition of Air Pollutants to the Great Waters will be forthcoming the the next month. We will update this section with information from the Third Report in the final rule.

[44] Terrestrial nitrogen deposition can act as a fertilizer. In some agricultural areas, this effect can be beneficial.

[45] Much of this information was taken from the following EPA document: Deposition of Air Pollutants to the Great Waters-Second Report to Congress, Office of Air Quality Planning and Standards, June 1997, EPA–453/R–97–011. You are referred to that document for a more detailed discussion. A Third Report to Congress on Deposition of Air Pollutants to the Great Waters will be forthcoming the the next month. We will update this section with information from the Third Report in the final rule.

[46] The 1996 National Toxics Inventory, Office of Air Quality Planning and Standards, October 1999.

coke productions and waste incineration.

Evidence for potential human health effects associated with POM comes from studies in animals (fish, amphibians, rats) and in human cells culture assays. Reproductive, developmental, immunological, and endocrine (hormone) effects have been documented in these systems. Many of the compounds included in the class of compounds known as POM are classified by EPA as probable human carcinogens based on animal data.

The particulate reductions from today's proposal would help reduce not only the particulate emissions from highway diesel engines but also the deposition of the POM adhering to the particles, thereby helping to reduce health effects of POM in lakes and streams, accelerate the recovery of affected lakes and streams, and revive the ecosystems adversely affected.

C. Contribution from Heavy-Duty Vehicles

Nationwide, heavy-duty vehicles contribute about 15 percent of the total NO_X inventory, and 29 percent of the mobile source inventory. Heavy-duty NO_X emissions also contribute to fine particulate concentrations in ambient air due to the transformation in the atmosphere to nitrates. The NO_X reductions resulting from today's proposed standards would therefore have a considerable impact on the national NO_X inventory. Light and heavy-duty mobile sources account for 24 percent of the PM_{10} (excluding the contribution of miscellaneous and natural sources), and heavy-duty vehicles account for 14 percent of the mobile source portion of national PM_{10} emissions. The heavy-duty portion of the inventory is often greater in the cities, and the reductions proposed in this rulemaking would have a relatively greater benefit in those areas.

1. NO_X Emissions

Heavy-duty vehicles are important contributors to the national inventories of NO_X emissions, and they contribute moderately to national VOC pollution. The Draft RIA for this proposal describes in detail recent emission inventory modeling completed by EPA. HDVs are expected to contribute approximately 15 percent of annual NO_X emissions in 2007 (Table II.C–1).

TABLE II.C–1.—2007 HEAVY-DUTY VEHICLE CONTRIBUTION TO URBAN NO_X INVENTORIES

[Amounts in percent]

Metropolitan statistical area	Portion of total NO_X	Portion of mobile source NO_X
National	15%	29%
Albuquerque	25%	38%
Atlanta	23%	36%
San Francisco	23%	29%
Spokane	23%	29%
Seattle	22%	26%
Dallas	22%	28%
Charlotte	21%	34%
Washington	20%	37%
Los Angeles	20%	26%
San Antonio	20%	31%
New York	19%	30%
Miami	18%	23%
Phoenix	18%	28%
Philadelphia	18%	30%
Cleveland	17%	30%
St. Louis	16%	34%

The contribution of heavy-duty vehicles to NO_X inventories in many MSAs is significantly greater than that reflected in the national average. For example, HDV contributions to NO_X in Albuquerque, Atlanta, San Francisco, Spokane, Seattle, and Dallas are projected to be 22 to 25 percent of the MSA-specific inventories in 2007, which is significantly higher than the national average. These data are based largely on our Tier 2 inventories and have been adjusted to reflect new information regarding the VMT split between light-duty and heavy-duty vehicles as discussed in the draft RIA. These data will be further updated for the final rule to reflect more recent modeling.

2. PM Emissions

Nationally, we estimate that primary emissions of PM_{10} to be about 33.2 million tons/year in 2007. Fugitive dust, other miscellaneous sources and crustal material (wind erosion) comprise approximately 90 percent of the 2007 PM_{10} inventory. However, there is evidence from ambient studies that emissions of these materials may be overestimated and/or that once emitted they have less of an influence on monitored PM concentration than this inventory share would suggest. Mobile sources account for 24 percent of the PM_{10} inventory (excluding the contribution of miscellaneous and natural sources) and highway heavy-duty engines, the subject of today's action, account for 14 percent of the mobile source portion of national PM_{10} emissions.

The contribution of heavy-duty vehicle emissions to total PM emissions in some metropolitan areas is substantially higher than the national average. This is not surprising, given the high density of these engines operating in these areas. For example, in Albuquerque, Pittsburgh, St. Louis, and Atlanta, the estimated 2007 highway heavy-duty vehicle contribution to mobile source PM_{10} ranges from 16 to 21 percent, and the national percent contribution to mobile sources for 2007 is projected to be about 14 percent. As illustrated in Table II.C–2 , heavy-duty vehicles operated Washington, Fairbanks, Billings, and Detroit also account for a slightly higher portion of the mobile source PM inventory than the national average. These data are based largely on our Tier 2 inventories and have been adjusted to reflect new information regarding the VMT split between light-duty and heavy-duty vehicles as discussed in the draft RIA. These data will be further updated for the final rule to reflect more recent modeling. Importantly, these estimates do not include the contribution from secondary PM which is an important component of diesel PM.

TABLE II.C–2.—2007 HEAVY-DUTY VEHICLE CONTRIBUTION TO URBAN MOBILE SOURCE PM INVENTORIES

Metropolitan statistical area	PM_{10} contribution from HDVs (in percent)
National	14
Albuquerque	21
Pittsburgh	18
St. Louis	17
Atlanta	16
Washington	15
Fairbanks	15
Billings	15
Detroit	15

In addition to the national inventories, investigations have been conducted in certain urban areas which provide information about the contribution of HD diesel vehicles and engines to ambient $PM_{2.5}$ concentrations. This is particularly relevant as diesel PM, for the most part, is composed of fine particles under 2.5 microns. Information about ambient concentrations of diesel PM and the relative contribution of diesel engines to ambient PM levels is available from source-receptor models, dispersion models, and elemental carbon measurements. The most commonly used receptor model for quantifying concentrations of diesel PM at a

receptor site is the chemical mass balance model (CMB). Input to the CMB model includes PM measurements made at the receptor site as well as measurements made of each of the source types suspected to impact the site. Because of problems involving the elemental similarity between diesel and gasoline emission profiles and their co-emission in time and space, it is necessary to carefully quantify chemical molecular species that provide markers for separation of these sources. Recent advances in chemical analytical techniques have facilitated the development of sophisticated molecular source profiles, including detailed speciation of organic compounds, which allow the apportionment of PM to gasoline and diesel sources with increased certainty. Older studies that made use of only elemental source profiles have been published and are summarized here, but are subject to more uncertainty. It should be noted that since receptor modeling is based on the application of source profiles to ambient measurements, this estimate of diesel PM concentrations does not distinguish between on-road and non-road sources for diesel PM. In addition, this model accounts for primary emissions of diesel PM only; the contribution of secondary aerosols is not included.

Dispersion models estimate ambient levels of PM at a receptor site on the basis of emission factors for the relevant sources and the investigator's ability to model the advection, mixing, deposition, and chemical transformation of compounds from the source to the receptor site. Dispersion models can provide the ability to distinguish on-highway from off-highway diesel source contributions and can be used to estimate the concentrations of secondary aerosols from diesel exhaust. Dispersion modeling is being conducted by EPA to estimate county-specific concentrations of, and exposures to, several toxic species, including diesel PM. Results from this model are expected in 2000.

Elemental carbon is a major component of diesel exhaust, contributing approximately 60-80 percent of diesel particulate mass, depending on engine technology, fuel type, duty cycle, lube oil consumption, and state of engine maintenance.[47] [48] [49] [50] In most ambient environments, diesel PM is one of the major contributors to elemental carbon, with other potential sources including gasoline exhaust; combustion of coal, oil, or wood; charbroiling; cigarette smoke; and road dust. Because of the large portion of elemental carbon in diesel PM, and the fact that diesel exhaust is one of the major contributors to elemental carbon in most ambient environments, diesel PM concentrations can be bounded using elemental carbon measurements. One approach for calculating diesel PM concentrations from elemental carbon measurements is presented in the draft Health Assessment Document for Diesel Emissions. The surrogate diesel PM calculation is a useful approach for estimating diesel PM in the absence of a more sophisticated modeling analysis for locations where elemental carbon concentrations are available.

Ambient concentrations of diesel PM reported for the period before 1990 when no nationwide PM controls were in place for HDVs suggest that annually averaged diesel PM levels in urban and suburban environments ranged from approximately 1.9 to 11.6 micrograms/m^3 (Table II.C–3a and Table II.C–3b). On individual days, diesel PM concentrations as high as 22 micrograms/m^3 were reported. Studies reporting annual average diesel PM concentrations in urban and suburban areas after 1990 indicate that diesel PM concentrations range from approximately 0.5 to 3.6 micrograms/m^3, with studies over short periods amidst dense bus traffic averaging 29.2 micrograms/m^3 and ranging up to 46.7 micrograms/m^3 (Table II.C–3a and Table II.C–3b). Dispersion modeling conducted in Southern California reported that the highway contribution to the reported diesel PM levels ranged from 63–89 percent of the total diesel PM (Table II.C–3b). In the two dispersion model studies reporting diesel PM in Southern California in August 1987 and September 1996, secondary formation of diesel PM accounted for 27 percent to 67 percent of the total diesel PM (Table II.C–3b). Using elemental carbon as a surrogate for diesel PM suggests that diesel PM concentrations measured in some urban and rural areas in the 1990s range from approximately 0.4 to 4.5 micrograms/m^3 in urban environments and 0.2 to 1.3 micrograms/m^3 in rural environments (Table II.C–3c).

TABLE II.C–3a.—AMBIENT DIESEL PM CONCENTRATIONS AND CONTRIBUTION TO TOTAL AMBIENT PM_{10} AND $PM_{2.5}$ FROM CHEMICAL MASS BALANCE STUDIES

Location	Year of sampling	Diesel $PM_{2.5}$ $\mu g/m^3$	Diesel PM % of total PM
West LA, CA	1982, annual	4.4	13
Pasadena, CA	1982, annual	5.3	19
Rubidoux, CA	1982, annual	5.4	13
Downtown LA, CA[a]	1982, annual	11.6	36
Phoenix area, AZ[b]	1989–90, Winter	*4–22	50
Phoenix, AZ[c]	1994–95, Winter	0–5.3	0–27
California, 15 Air Basins[d]	1988–92, annual	*0.2–3.6	†
Manhattan, NY[e]	1993, Spring, 3 d	*13.2–46.7	31–68
Welby and Brighton, CO[f]	1996–97, Winter, 60 d	0–7.3	0–26

*PM_{10}. The reader should note that 80–95% of diesel PM is $PM_{2.5}$.

†Not Available.

[a] Schauer, J.J., Rogge, W.F., Hildemann, L.M., Mazureik, M.A., Cass, G.R., and B.R.T. Simoneit (1996) Source Apportionment of Airborne particulate Matter Using Organic Compounds as Tracers. Atmos. Environ. 30(22):3837–3855.

[47] Zaebst, D.D., Clapp D.E., Blake L.M., Marlow D.A., Steenland K., Hornung R.W., Scheutzle D. and J. Butler (1991) Quantitative Determination of Trucking Industry Workers Exposures to Diesel Exhaust Particles. Am. Ind. Hyg. Assoc. J., 52:529–541.

[48] Graboski, M. S., McCormick, R.L., Yanowitz, J., and L.B.A. Ryan (1998) Heavy-Duty Diesel Testing for the Northern Front Range Air Quality Study. Colorado Institute for Fuels and Engine Research.

[49] Warner-Selph, M. A., Dietzmann, H.E. (1984) Characterization of Heavy-Duty Motor Vehicle Emissions Under Transient Driving Conditions. Southwest Research Institute. EPA–600/3–84–104.

[50] Pierson, W.R., Brachazek, W. W. (1983) Particulate Matter Associated with Vehicles on the Road. Aerosol Sci. & Tech. 2:1–40.

[b] Chow, J.C., Watson, J.G., Richards, L.W., Haase, D.L., McDade, C., Dietrich, D.L., Moon, D., and C. Sloane (1991) The 1989–1990 Phoenix PM_{10} Study. Volume II: Source Apportionment. Final Report. DRI Document No. 8931.6F1, prepared for Arizona Department of Environmental Air Quality, Phoenix, AZ, by Desert Research Institute, Reno, NV.
[c] Maricopa Association of Governments. The 1999 Brown Cloud Project for the Maricopa Association of Governments Area, Revised Draft Report, November 1999.
[d] California Environmental Protection Agency (1998) Report to the Air Resources Board on the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant. Appendix III, Part A: Exposure Assessment, April 1998.
[e] Wittorff, D.N., Gertler, A.W., Chow, J.C., Barnard, W.R. Jongedyk, H.A. The Impact of Diesel Particulate Emissions on Ambient Particulate Loadings. Air & Waste Management Association 87th Annual Meeting, Cincinnati, OH, June 19–24, 1994.
[f] Fujita, E., Watson, J.G., Chow, J.C., Robinson, N.F., Richards, L.W., Kumar, N. (1998) The Northern Front Rage Air Quality Study Final Report Volume C: Source Apportionment and Simulation Methods and Evaluation. http://nfraqs.cira.colostate.edu/

TABLE II.C–3b.—AMBIENT DIESEL PM CONCENTRATIONS AND CONTRIBUTION TO TOTAL AMBIENT $PM_{2.5}$ FROM DISPERSION MODELING STUDIES

Location	Year of sampling	Diesel $PM_{2.5}$ $\mu g/m^3$	Diesel PM % of total PM
Azusa, CA	1982, annual	**1.4	5
Pasadena, CA	1982, annual	**2.0	7
Anaheim, CA	1982, annual	**2.7	12
Long Beach, CA	1982, annual	**3.5	13
Downtown LA, CA	1982, annual	**3.5	11
Lennox, CA	1982, annual	**3.8	13
West LA, CA[a]	1982, annual	**3.8	16
Claremont, CA[b]	18–19 Aug 1987	2.4	8
Long Beach, CA	24 Sept 1996	+1.9(2.6)	8
Fullerton, CA	24 Sept 1996	+ 2.4(3.9)	9
Riverside, CA[c]	25 Sept 1996	+ 4.4(13.3)	12

+ Value in parenthesis includes secondary diesel PM (nitrate, ammonium, sulfate and hydrocarbons) due to atmospheric reactions of primary diesel emissions of NO_X, SO_2 and hydrocarbons.
** On-road diesel vehicles only; All other values are for on-road plus nonroad diesel emissions.
[a] Cass, G.R. and H.A. Gray (1995) Regional Emissions and Atmospheric Concentrations of Diesel Engine Particulate Matter: Los Angeles as a Case Study. In: Diesel Exhaust: A Critical Analysis of Emissions, Exposure, and Health Effects. A Special Report of the Institute's Diesel Working Group. Health Effects Institute, Cambridge, MA, pp. 125–137.
[b] Kleeman, M.J., Cass, G.R. (1999a) Identifying the Effect of Individual Emissions Sources on Particulate Air Quality Within a Photochemical Aerosol Processes Trajectory Model. Atmos. Eviron. 33:4597–4613.
[c] Kleeman, M.J., Hughes, L.S., Allen, J.O., Cass, G.R. (1999b) Source Contributions to the Size and Composition Distribution of Atmospheric Particles: Southern California in September 1996. Environ. Sci. Technol. 33:4331–4351.

TABLE II.C–3c.—AMBIENT DIESEL PM CONCENTRATIONS AND CONTRIBUTION TO TOTAL AMBIENT $PM_{2.5}$ FROM ELEMENTAL CARBON MEASUREMENTS

Location	Year of sampling	Diesel $PM_{2.5}$ $\mu g/m^3$	Diesel PM % of total PM
Boston, MA	1995, annual	0.7–1.7	3–15
Rochester, NY	1995, annual	0.4–0.8	2–9
Quabbin, MA	1995, annual	0.2–0.6	1–6
Reading, MA	1995, annual	0.4–1.3	2–7
Brockport, NY[a]	1995, annual	0.2–0.5	1–5
Washington, DC[b]	1992–1995, annual	1.3–1.8	6–10
South Coast Air Basin[c]	1995–1996, annual	‡2.4–4.5	†

‡ The Multiple Air Toxics Exposure Study in the South Coast Air Basin reported average annual values for 8 sites in the South Coast Basin.
† Not Available.
[a] Salmon, L.G., Cass, G.R., Pedersen, D.U., Durant, J.L., Gibb, R., Lunts, A., and M. Utell (1997) Determination of fine particle concentration and chemical composition in the northeastern United States, 1995. Progress Report to Northeast States for Coordinated Air Use Management (NESCAUM), September 1999.
[b] Sisler, J.F. (1996) Spatial and Seasonal Patterns and Long Term Variability of the Composition of the Haze in the United States: An Analysis of Data from the IMPROVE Network. Cooperative Institute for Research in the Atmosphere. Colorado State University. ISSN: 0737–5352–32.
[c] South Coast Air Quality Management District (2000) Multiple Air Toxics Exposure Study in the South Coast Air Basin (MATES–II), Final Report and Appendices, March 2000.

The city-specific emission inventory analysis and independent investigations of ambient $PM_{2.5}$ summarized here indicate that the contribution of diesel engines to PM inventories in several urban areas around the U.S. is much higher than indicated by the national PM emission inventories only. One possible explanation for this is the concentrated use of diesel engines in certain local or regional areas which is not well represented by the national, yearly average presented in national PM emission inventories. Another reason may be underestimation of the in-use diesel PM emission rates. Our current modeling incorporates deterioration only as would be experienced in properly maintained, untampered vehicles. We are currently in the process of reassessing the rate of in-use deterioration of diesel engines and vehicles which could greatly increase the contribution of HDVs to diesel PM.

Moreover, heavy-duty vehicles will have a more important contributing role in ambient $PM_{2.5}$ concentrations than in ambient PM_{10} concentrations. In addition, the absolute contribution from heavy-duty vehicles is larger in relationship to the numerically lower $PM_{2.5}$ standard, making them more

important to attainment and maintenance.

3. Environmental Justice

Environmental justice is a priority for EPA. The Federal government documented its concern over this issue through issuing Executive Order 12898, Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations (February 11, 1994). This Order requires that federal agencies make achieving environmental justice part of their mission. Similarly, the EPA created an Office of Environmental Justice (originally the Office of Environmental Equity) in 1992, commissioned a task force to address environmental justice issues, oversees a Federal Advisory Committee addressing environmental justice issues (the National Environmental Justice Advisory Council), and has developed an implementation strategy as required under Executive Order 12898.

Environmental justice is a movement promoting the fair treatment of people of all races, income, and culture with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment implies that no person or group of people should shoulder a disproportionate share of any negative environmental impacts resulting from the execution of this country's domestic and foreign policy programs.

For the last several years, environmental organizations and community-based citizens groups have been working together to phase out diesel buses in urban areas. For example, the Natural Resources Defense Council initiated a ''Dump Dirty Diesel'' campaign in the mid-1990s to press for the phase out of diesel buses in New York City. Other environmental organizations operating in major cities such as Boston, Newark, and Los Angeles have joined this campaign. The Coalition for Clean Air worked with NRDC and other experts to perform exposure monitoring in communities located near distribution centers where diesel truck traffic is heavy. These two organizations concluded that facilities with heavy truck traffic are exposing local communities to diesel exhaust concentrations far above the average levels in outdoor air. The report states: ''These affected communities, and the workers at these distribution facilities with heavy diesel truck traffic, are bearing a disproportionate burden of the health [51-62] risks.'' [63] Other diesel ''hot spots'' identified by the groups are bus terminals, truck and bus maintenance facilities, retail distribution centers, and busy streets and highways.

Although the new standards proposed in this rulemaking would not reroute heavy-duty truck traffic or relocate bus terminals, they would be expected to improve air quality across the country and would provide increased protection to the public against a wide range of health effects, including chronic bronchitis, respiratory illnesses, and aggravation of asthma symptoms. These air quality and public health benefits could be expected to mitigate some of the environmental justice concerns related to heavy-duty vehicles since the proposal would provide relatively larger benefits to heavily impacted areas.

D. Anticipated Emissions Benefits

This subsection presents the emission benefits we anticipate from heavy-duty vehicles as a result of our proposed NO_X, PM, and NMHC emission standards for heavy-duty engines. The graphs and tables that follow illustrate the Agency's projection of future emissions from heavy-duty vehicles for each pollutant. The baseline case represents future emissions from heavy-duty vehicles at present standards (including the MY2004 standards). The controlled case quantifies the future emissions of heavy-duty vehicles if the new standards proposed in this rulemaking are finalized and implemented.

1. NO_X Reductions

The Agency expects substantial NO_X reductions on both a percentage and a tonnage basis from this proposal. As illustrated in the following graph, the air quality benefit expected from this proposal is a reduction in NO_X emissions from HDVs of 2.0 million tons in 2020.[64] The Draft RIA provides additional projections between 2007 and 2030. As stated previously, HDVs contribute about 15 percent to the national NO_X inventory for all sources. The NO_X standards proposed in this rule would have a substantial impact on the total NO_X inventory so that in 2030, HDVs under today's proposed standards would account for only 3 percent of the national NO_X inventory. Figure II.D–1 shows our national projections of total NO_X emissions with and without the proposed engine controls. This includes both exhaust and crankcase emissions. The proposed standards should result in about a 90 percent reduction in NO_X from new engines.[65]

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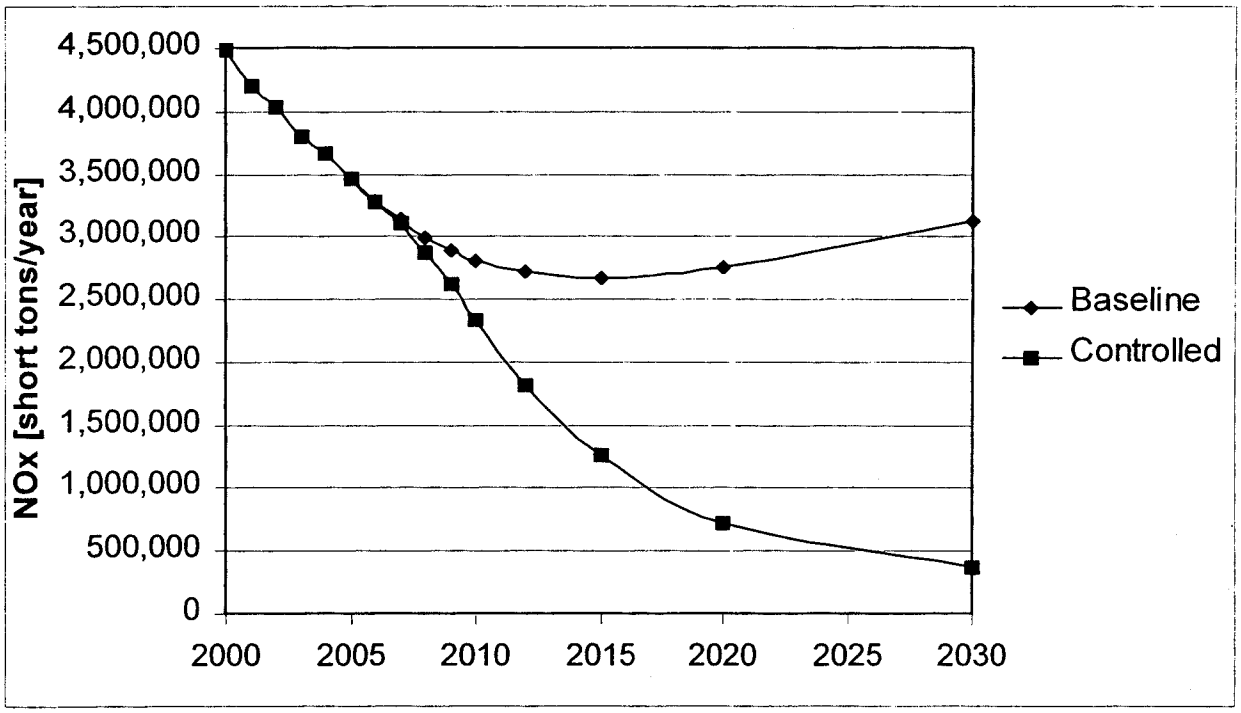
[51-62] [Reserved]

[63] *Exhausted by Diesel: How America's Dependence on Diesel Engines Threatens Our Health,* Natural Resources Defense Council, Coalition for Clean Air, May 1998.

[64] The baseline used for this calculation is the 2004 HDV standards (64 FR 58472). These reductions are in addition to the NO_X emissions reductions projected to result from the 2004 HDV standards.

[65] We include in the NO_X projections excess emissions, developed by the EPA's Office of Enforcement and Compliance, that were emitted from many model year 1988–98 diesel engines. This is described in more detail in Chapter 2 of the draft RIA.

Figure II.D-1: Projected Nationwide Heavy-Duty Vehicle NOx Emissions



2. PM Reductions

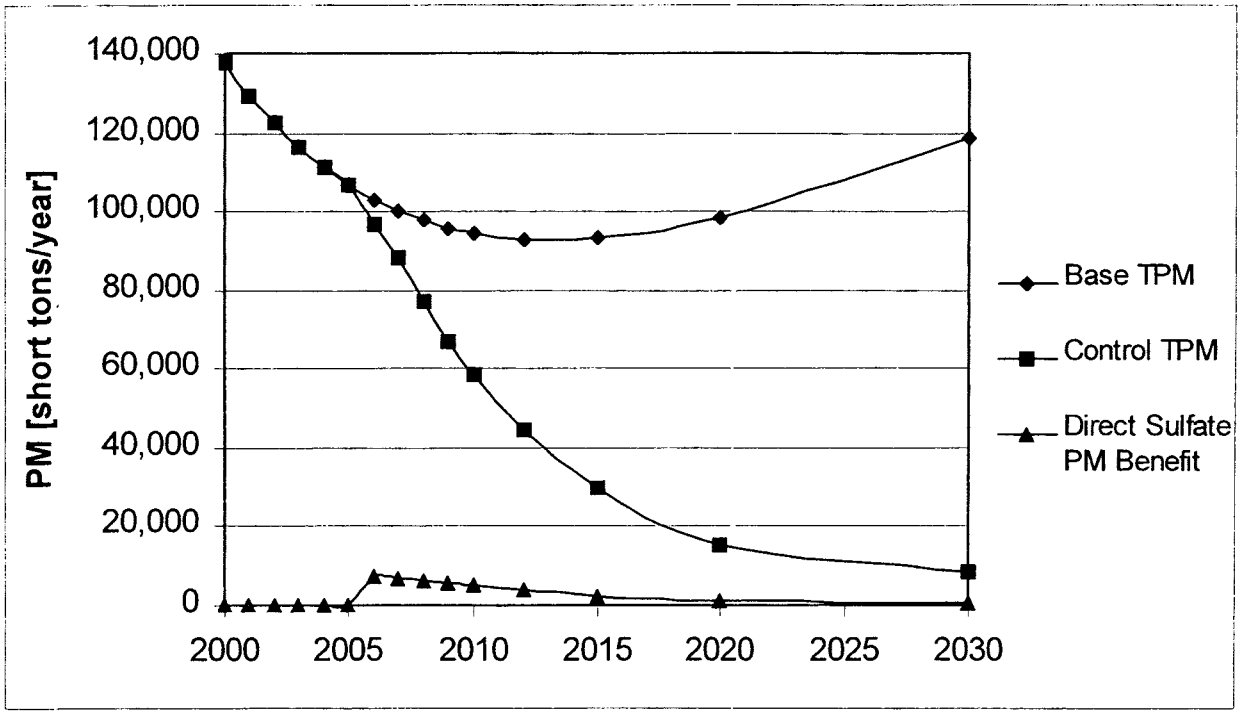
As stated previously, HDVs contribute about 14 percent to the national PM_{10} inventory for mobile sources. The 90 percent reduction in the PM standard for HDVs proposed in this rule would have a substantial impact on the mobile source PM inventory, so that in 2030 HDVs under today's proposed standards would account for only 3 percent of the national mobile source PM inventory.

The majority of the projected PM reductions are directly a result of the proposed exhaust PM standard. However, a modest amount of PM reductions would come from reducing sulfur in the fuel. For the existing fleet of heavy-duty vehicles, a small fraction of the sulfur in diesel fuel is emitted directly into the atmosphere as direct sulfate, and a portion of the remaining fuel sulfur is transformed in the atmosphere into sulfate particles, referred to as indirect sulfate. Reducing sulfur in the fuel decreases the amount of direct sulfate PM emitted from heavy-duty diesel engines and the amount of heavy-duty diesel engine SO_X emissions that are transformed into indirect sulfate PM in the atmosphere.[66] For engines meeting the proposed standards, we consider low sulfur fuel to be necessary to enable the PM control technology. In other words, we do not claim an additional benefit beyond the proposed standard for reductions in direct sulfate PM. However, once the proposed low sulfur fuel requirements go into effect, pre-2007 model year engines would also be using low sulfur fuel. Because these engines would be certified with high sulfur fuel, they would achieve reductions in PM beyond their certification levels.

Figure II.D–2 shows our national projections of total HDV PM emissions with and without the proposed engine controls. This figure includes crankcase emissions and the direct sulfate PM benefits due to the use of low sulfur fuel by the existing fleet. These direct sulfate PM benefits from the existing fleet are also graphed separately. The proposed standards should result in about a 90 percent reduction in total PM from new engines. The proposed low sulfur fuel should result in about a 95 percent reduction in direct sulfate PM from pre-2007 engines. Due to complexities of the conversion and removal processes of sulfur dioxide, we do not attempt to quantify the indirect sulfate reductions that would be derived from this rulemaking. Nevertheless, the Agency believes that these indirect sulfate PM reductions are likely to contribute significant additional benefits to public health and welfare. The air quality benefit of the new PM standards and low sulfur diesel fuel are presented in Figure II.D–2, indicating a 83,000 ton direct PM reduction in 2020.

[66] Sulfate forms a significant portion of total fine particulate matter in the Northeast. Chemical speciation data in the Northeast collected in 1995 shows that the sulfate fraction of fine particulate matter ranges from 20 and 27 percent of the total fine particle mass. *Determination of Fine Particle and Coarse Particle Concentrations and Chemical Composition in the Northeastern United States, 1995,* NESCAUM, prepared by Cass, et al., September 1999.

Figure II.D-2: Projected Nationwide Heavy-Duty Vehicle PM Emissions and Direct Sulfate Emission Reductions

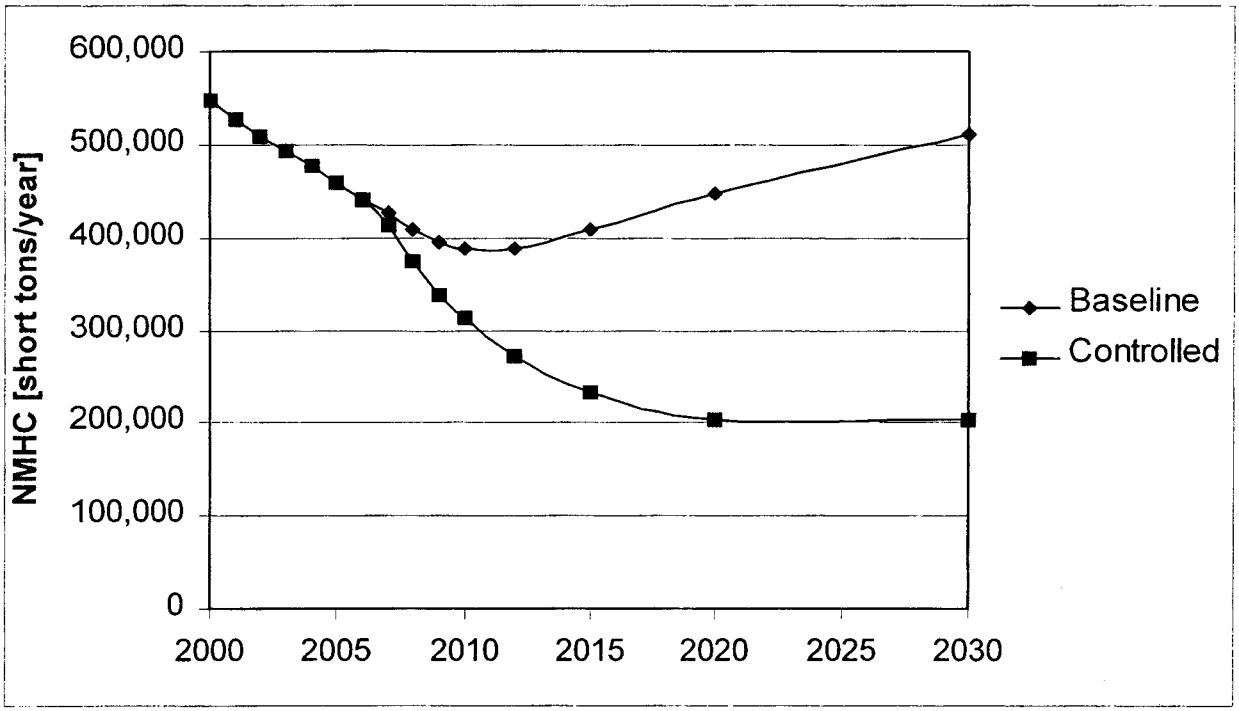


3. NMHC Reductions

The standards described in section III are designed to be feasible for both gasoline and diesel heavy-duty vehicles. The NMHC standards are expected to be more of a challenge for the gasoline vehicles than for the diesel vehicles, however. (The converse is true for the PM standards.) Based on our analysis of the aftertreatment technology described in section III, diesel engines meeting the proposed PM standard are expected to have NMHC emissions levels well below the standard in use. Furthermore, although the proposed standards give manufacturers the same phase-in for NMHC as for NO_X, we model the NMHC reductions for diesel vehicles to be fully in place in 2007. We believe the use of aftertreatment for PM control would cause the NMHC levels to be below the proposed standards as soon as the PM standard goes into effect in 2007. We request comment on this assumption.

HDVs account for about 3 percent of national VOC and 8 percent from mobile sources in 2007. Figure II.D–3 shows our national projections of total NMHC emissions with and without the proposed engine controls. This includes both exhaust emissions and evaporative emissions. As presented in Figure II.D–3, the Agency projects a reduction of 230,000 tons of NMHC in 2020 due to the proposed standards.

Figure II.D-3: Projected Nationwide Heavy-Duty Vehicle NMHC Emissions



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4. Additional Emissions Benefits

This subsection looks at tons/year emission inventories of CO, SO_X, and air toxics from HDEs. Although we are not including stringent standards for these pollutants in our proposed standards, we believe the proposed standards would result in reductions in CO, SO_X, and air toxics. Here, we present our anticipated benefits.

a. CO Reductions

In 2007, HDVs are projected to contribute to approximately 5 percent of national CO and 9 percent of CO from mobile sources. Although it does not propose new CO emission standards, today's proposal would nevertheless be expected to result in a considerable reduction in CO emissions from heavy-duty vehicles. CO emissions from heavy-duty diesel vehicles, although already very low, would likely be reduced by an additional 90 percent due to the presence of aftertreatment devices. CO emissions from heavy-duty gasoline vehicles would also likely decline as the NMHC emissions are decreased. Table II.D–1 presents the projected reductions in CO emissions from HDVs.

TABLE II.D–1.—ESTIMATED REDUCTIONS IN CO

Calendar year	CO benefit (thousand short tons)
2007	71
2010	405
2015	911
2020	1,250
2030	1,640

b. SO_X Reductions

HDVs are projected to emit approximately 0.5 percent of national SO_X and 7 percent of mobile source SO_X in 2007. We are proposing significant reductions in diesel fuel sulfur to enable certain emission control devices to function properly. We expect SO_X emissions to decline as a direct benefit of low sulfur diesel fuel. The majority of these benefits would be from heavy-duty highway diesel vehicles; however, some benefits would also come from highway fuel burned in other applications. As discussed in greater detail in the section on PM reductions, the amount of sulfate particles (direct and indirect) formed as a result of diesel exhaust emissions would decline for all HD diesel engines operated on low sulfur diesel fuel, including the current on-highway HD diesel fleet, and those non-road HD diesel engines that may operate on low sulfur diesel fuel in the future. Table II.D–2 presents our estimates of SO_X reductions resulting from the proposed low sulfur fuel.

TABLE II.D–2.—ESTIMATED REDUCTIONS IN SO_X DUE TO LOW SULFUR FUEL

Calendar year	SO_X benefit (thousand short tons)
2007	101
2010	106
2015	115
2020	124
2030	139

c. Air Toxics Reductions

This proposal establishes new hydrocarbon and formaldehyde standards for heavy-duty vehicles. Hydrocarbons are a broad class of chemical compounds containing carbon and hydrogen. Many forms of hydrocarbons, such as formaldehyde, are directly hazardous and contribute to what are collectively called ''air toxics.'' Air toxics are pollutants known to cause or suspected of causing cancer or other serious human health effects or ecosystem damage. The Agency has identified as least 20 compounds emitted from on-road gasoline vehicles that have toxicological potential, 19 of which are emitted by diesel vehicles as well as an additional 20 compounds which have been listed as toxic air

contaminants by California ARB.[67] [68] This proposal also seeks to reduce emissions of diesel exhaust and diesel particulate matter (see section II.B for a discussion of health effects).

Our assessment of heavy-duty vehicle (gasoline and diesel) air toxics focuses on the following compounds with cancer potency estimates that have significant emissions from heavy-duty vehicles: benzene, formaldehyde, acetaldehyde, and 1,3-butadiene. These compounds are an important, but limited, subset of the total number of air toxics that exist in exhaust and evaporative emissions from heavy-duty vehicles. The reductions in air toxics quantified in this section represent only a fraction of the total number and amount of air toxics reductions expected from the proposed new hydrocarbon standards.

For this analysis, we estimate that air toxic emissions are a constant fraction of hydrocarbon exhaust emissions. Because air toxics are a subset of hydrocarbons, and new emission controls are not expected to preferentially control one type of air toxic over another, the selected air toxics chosen for this analysis are expected to decline by the same percentage amount as hydrocarbon exhaust emissions. We have not performed a separate analysis for the new formaldehyde standard since compliance with the hydrocarbon standard should result in compliance with the formaldehyde standard for all petroleum-fueled engines. The Draft RIA provides more detail on this analysis. Table II.D–3 shows the estimated air toxics reductions associated with the anticipated reductions in hydrocarbons.

TABLE II.D–3.—ESTIMATED REDUCTIONS IN AIR TOXICS

[Short tons]

Calendar year	Benzene	Formaldehyde	Acetaldehyde	1,3-Butadiene
2007	153	831	318	65
2010	932	4,750	1,870	382
2015	2,080	11,400	4,460	909
2020	2,780	15,800	6,120	1,250
2030	3,510	20,500	7,850	1,600

E. Clean Heavy-Duty Vehicles and Low-Sulfur Diesel Fuel Are Critically Important for Improving Human Health and Welfare

Despite continuing progress in reducing emissions from heavy-duty engines, emissions from these engines continue to be a concern for human health and welfare. Ozone continues to be a significant public health problem, and affects not only people with impaired respiratory systems, such as asthmatics, but healthy children and adults as well. Ozone also causes damage to plants and has an adverse impact on agricultural yields. Diesel exhaust also continues to be a significant public health concern.

Today's proposal would reduce NO_X, VOC, CO, PM, and SO_X emissions from these heavy-duty vehicles substantially. These reductions would help reduce ozone levels nationwide and reduce the frequency and magnitude of predicted exceedances of the ozone standard. These reductions would also help reduce PM levels, both by reducing direct PM emissions and by reducing emissions that give rise to secondary PM. The NO_X and SO_X reductions would help reduce acidification problems, and the NO_X reductions would help reduce eutrophication problems. The PM and NO_X standard proposed today would help improve visibility. All of these reductions could be expected to have a beneficial impact on human health and welfare by reducing exposure to ozone, PM, and other air toxics and thus reducing the cancer and noncancer effects associated with exposure to these substances.

III. Heavy-Duty Engine and Vehicle Standards

In this section, we describe the vehicle and engine standards we are proposing today to respond to the serious air quality needs discussed in section II. Specifically, we discuss:

- The CAA and why we are proposing new heavy-duty standards.
- The technology opportunity for heavy-duty vehicles and engines.
- Our proposed HDV and HDE standards, and our proposed phase-in of those standards.
- Why we believe the stringent standards being proposed today are feasible in conjunction with the low-sulfur gasoline required under the recent Tier 2 rule and the low-sulfur diesel fuel being proposed today.
- The effects of diesel fuel sulfur on the ability to meet the proposed standards, and what happens if high sulfur diesel fuel is used.
- A possible reassessment of the technology and diesel fuel sulfur level needed for diesels to comply with today's proposed NO_X standard.

We welcome comment on the levels and timing of the proposed emissions standards, and on the technological feasibility discussion and supporting analyses. We also request comment on the timing of the proposed diesel fuel standard in conjunction with these proposed emission standards. We ask that commenters provide any technical information that supports the points made in their comments.

A. Why Are We Setting New Heavy-Duty Standards?

We are proposing heavy-duty vehicle and engine standards and related provisions under section 202(a)(3) of the CAA which authorizes EPA to establish emission standards for new heavy-duty motor vehicles (see 42 U.S.C. 7521(a)(3)). Section 202(a)(3)(A) requires that such standards ''reflect the greatest degree of emission reduction achievable through the application of technology which the Administrator determines will be available for the model year to which such standards apply, giving appropriate consideration to cost, energy, and safety factors associated with the application of such technology.'' Section 202(a)(3)(B) allows EPA to take into account air quality information in revising such standards. Because heavy-duty engines contribute greatly to a number of serious air pollution problems, especially the health and welfare effects of ozone, PM, and air toxics, and because millions of Americans live in areas that exceed the

[67] National Air Quality and Emissions Trends Report, 1997, (EPA 1998), p. 74.

[68] California Environmental Protection Agency (1998) Report to the Air Resources Board on the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant, Appendix III, Part A: Exposure Assessment, April 1998.

national air quality standards for ozone or PM, we believe the air quality need for tighter heavy-duty standards is well founded. This, and our belief that a significant degree of emission reduction from heavy-duty vehicles and engines is achievable through the application of new diesel emission control technology, further refinement of well established gasoline emission controls, and reductions of diesel fuel sulfur levels, leads us to believe that new emission standards are warranted.

B. Technology Opportunity for Heavy-Duty Vehicles and Engines

For the past 30 or more years, emission control development for gasoline vehicles and engines has concentrated most aggressively on exhaust emission control devices. These devices currently provide as much as or more than 95 percent of the emission control on a gasoline vehicle. In contrast, the emission control development work for diesels has concentrated on improvements to the engine itself to limit the emissions leaving the combustion chamber.

However, during the past 15 years, more development effort has been put into diesel exhaust emission control devices, particularly in the area of PM control. Those developments, and recent developments in diesel NO_X control devices, make the advent of diesel exhaust emission controls feasible. Through use of these devices, we believe emission control similar to that attained by gasoline applications will be possible with diesel applications. However, without low-sulfur diesel fuel, these technologies cannot be implemented on heavy-duty or light-duty diesel applications.

Several exhaust emission control devices have been developed to control harmful diesel PM constituents—the diesel oxidation catalyst (DOC), and the many forms of particulate filters, or traps. DOCs have been shown to be durable in use, but they control only a relatively small fraction of the total PM and, consequently, do not address our PM concerns sufficiently. Uncatalyzed diesel particulate traps demonstrated high efficiencies many years ago, but the level of the PM standard was such that it could be met through less costly ''in-cylinder'' control techniques. Catalyzed diesel particulate traps have the potential to provide major reductions in diesel PM emissions and provide the durability and dependability required for diesel applications. Therefore, as discussed in the feasibility portion of this section, at this time we believe the catalyzed PM trap will be the control technology of choice for future control of diesel PM emissions. However, as discussed in detail in the draft RIA, we believe that catalyzed PM traps cannot be brought to market on diesel applications unless low-sulfur diesel fuel is available.

Diesel NO_X control is arguably at an earlier stage of development than is diesel PM control. Even so, several exhaust emission control technologies are being developed to control NO_X emissions, and the industry seems focused on a couple of these as the most promising technologies for enabling lower NO_X emission standards. Diesel selective catalytic reduction, or SCR, has been developed to the point of nearing market introduction in Europe. SCR has significant NO_X control potential, but it also has many roadblocks to marketability in this country. These roadblocks, discussed in more detail in the draft RIA, include infrastructure issues that we believe would prove exceedingly difficult and potentially costly to overcome. Because of that, we believe that the NO_X adsorber is the best technology for delivering significant diesel NO_X reductions while also providing market and operating characteristics necessary for the U.S. market.[69] However, as is discussed in detail in the draft RIA, the NO_X adsorber, like the catalyzed PM trap, cannot be brought to market on diesel applications unless low-sulfur diesel fuel is available.

Improvements have also been made to gasoline emission control technology during the past few years, even the past 12 months. Such improvements include those to catalyst designs in the form of improved washcoats and improved precious metal dispersion. Much effort has also been put into improved cold start strategies that allow for more rapid catalyst light-off. This can be done by retarding the spark timing to increase the temperature of the exhaust gases, and by using air-gap manifolds, exhaust pipes, and catalytic converter shells to decrease heat loss from the system.

These improvements to gasoline emission control have been made in response to the California LEV–II standards and the federal Tier 2 standards. Some of this development work was contributed by EPA in a very short timeframe and with very limited resources in support of our Tier 2 program.[70] These improvements should transfer well to the heavy-duty gasoline segment of the fleet. With such migration of light-duty technology to heavy-duty vehicles and engines, we believe that considerable improvements to heavy-duty emissions can be realized, thus enabling much more stringent standards.

The following discussion provides more detail on the technologies we believe are most capable of enabling very stringent heavy-duty emission standards. The goal of this discussion is to highlight the emission reduction capability of these emission control technologies and to highlight their critical need for diesel sulfur levels as low as those being proposed today. But first, we present the details of the emission standards being proposed today.

C. What Engine and Vehicle Standards Are We Proposing?

1. Heavy-Duty Engine Standards

a. Federal Test Procedure

The emission standards being proposed today for heavy-duty engines are summarized in Table III.C–1.

TABLE III.C–1.—PROPOSED FULL USEFUL LIFE HEAVY-DUTY ENGINE EMISSION STANDARDS AND PHASE-INS

		Standard (g/bhp-hr)	Phase-in by model year (In percent)			
			2007	2008	2009	2010
Diesel	NO_X	0.20	25	50	75	100
	NMHC	0.14				
	HCHO	0.016				
Gasoline	NO_X	0.20	100			
	NMHC	0.14				

[69] The NO_X adsorber was originally developed for stationary source emission control and was subsequently developed for use in the lean operating environment of gasoline direct injection engines.

[70] See Chapter IV.A of the final Tier 2 Regulatory Impact Analysis, contained in Air Docket A–97–10.

TABLE III.C–1.—PROPOSED FULL USEFUL LIFE HEAVY-DUTY ENGINE EMISSION STANDARDS AND PHASE-INS—Continued

		Standard (g/bhp-hr)	Phase-in by model year (In percent)			
			2007	2008	2009	2010
Diesel & Gasoline	HCHO	0.016	100			
	PM	0.01				

With respect to PM, this proposed new standard would represent a 90 percent reduction for most heavy-duty diesel engines from the current PM standard, which was not proposed to change in model year 2004.[71] The current PM standard for most heavy-duty engines, 0.1 g/bhp-hr, was implemented in the 1994 model year; the PM standard for urban buses implemented in that same year was 0.05 g/bhp-hr. The proposed PM standard of 0.01 g/bhp-hr is projected to require the addition of a highly efficient PM trap to diesel engines, including urban buses; it is not expected to require the addition of any new hardware for gasoline engines. We request comment on the feasibility and appropriateness of this proposed PM standard.

With respect to NMHC and NO_X, these new standards would represent roughly a 90 percent reduction in diesel NO_X and roughly a 70 percent reduction in diesel NMHC levels compared to the 2004 heavy-duty diesel engine standard. The 2004 heavy-duty diesel engine standard is 2.5 g/bhp-hr NMHC+NO_X, with a cap on NMHC of 0.5 g/bhp-hr. Like the PM standard, the proposed NO_X standard is projected to require the addition of highly efficient NO_X aftertreatment to diesel engines. For gasoline engines, the standard proposed in the 2004 heavy-duty rule is 1.0 g/bhp-hr NMHC+NO_X. Therefore, for gasoline engines, the standards proposed today would represent roughly a 70 percent reduction. We request comment on the feasibility and appropriateness of these proposed NO_X and NMHC standards.

With respect to formaldehyde, a hazardous air pollutant that is emitted by heavy-duty engines and other mobile sources, we are proposing standards to prevent excessive emissions. The standards are comparable in stringency to the formaldehyde standards recently finalized in the Tier 2 rule for passenger vehicles; they are also consistent with the CARB LEV II formaldehyde standards. These standards would be especially important for methanol-fueled engines because formaldehyde is chemically similar to methanol and is one of the primary byproducts of incomplete combustion of methanol. Formaldehyde is also emitted by engines using petroleum fuels (i.e., gasoline or diesel fuel), but to a lesser degree than is typically emitted by methanol-fueled engines. We recognize that petroleum-fueled engines able to meet the proposed NMHC standards should comply with the formaldehyde standards with large compliance margins. Based upon the analysis of similar standards recently finalized for passenger vehicles, we believe that formaldehyde emissions from petroleum-fueled engines when complying with the PM, NMHC, and NO_X standards should be as much as 90 percent below the standards.[72] Thus, to reduce testing costs, we are proposing a provision that would permit manufacturers of petroleum-fueled engines to demonstrate compliance with the formaldehyde standards based on engineering analysis. This provision would require manufacturers to make a demonstration in their certification application that engines having similar size and emission control technology have been shown to exhibit compliance with the applicable formaldehyde standard for their full useful life. This demonstration would be similar to that recently finalized for light-duty vehicles to demonstrate compliance with the Tier 2 formaldehyde standards.

Because the NO_X exhaust emission control technology we expect would be required to meet the proposed NO_X standard is at an early stage of development, we believe a phase-in of the NO_X standard is appropriate. With a phase-in, manufacturers are able to introduce the new technology on a limited number of engines, thereby gaining valuable experience with the technology prior to implementing it on their entire fleet. Also, we are proposing that the NO_X, HCHO, and NMHC standards be phased-in together for diesel engines. That is, engines would be expected to meet each of these proposed new standards, not just one or the other. We propose this because the standard as proposed in the 2004 heavy-duty rule would be a combined NMHC+NO_X standard. Separating the phase-ins for NMHC and NO_X would create a problem because it would not be clear to what NMHC standard an engine would certify were it to certify to the proposed NO_X standard independent of certifying to the proposed NMHC standard (and vice versa for engines certifying to the proposed NMHC standard independent of the proposed NO_X standard).[73] We request comment on the phase-in for diesel engines of these proposed NO_X, HCHO, and NMHC standards and the requirement that they be phased-in together. We also request comment on alternative phase-in schedules and percentages, such as a phase-in over three years (2007–2009), a phase-in over two years (2007–2008), and no phase-in (100% in 2007). We are not proposing a phase-in for gasoline engines because we want to maintain consistency with the proposed heavy-duty gasoline vehicle standards which are not phased-in; those standards are discussed below.[74] Nonetheless, we request comment on possible alternative phase-ins for the proposed gasoline engine standards, such as a phase-in consistent with the proposed phase-in for diesel engine standards shown in Table III.C–

[71] From 64 FR 58472, October 29, 1999, ''* * * diesel fuel quality, and in particular, diesel fuel sulfur level, can play an important role in enabling certain PM and NO_X control technologies. Some DOCs and continuously regenerable PM traps, as well as current generation lean NO_X adsorber catalysts can be poisoned by high sulfur levels. Given this information, EPA has not included more stringent PM standards for the 2004 model year or later in today's proposal.''

[72] See the Tier 2 Response to Comments document contained in Air Docket A–97–10.

[73] Note that, despite the concurrent phase-in of NO_X and NMHC standards for diesel engines, the NMHC standards should be easily met through use of a PM trap as is fully discussed in section III.E. Since the PM standards would be implemented on 100 percent of new engines in the 2007 model year, all new engines would have a PM trap and would, therefore, control NMHC emissions to levels below the proposed standards. Therefore, while the NMHC standard is phased-in with NO_X due to the 2004 combining of the NO_X and NMHC standards, the proposed NMHC standards would be met by all new engines in the 2007 model year. This is reflected in our emission inventory analysis as was discussed in section II.

[74] Please refer to section III.D.2 below for a discussion of implementing these proposed standards in the 2007 or 2008 model years, and the relationship between today's proposed implementation and the implementation of the proposed 2004 emission standards.

1, or a phase-in consistent with that used for heavy light-duty trucks and medium-duty passenger vehicles under the light-duty highway Tier 2 program.

The specifics of the Averaging, Banking, and Trading program associated with today's proposed standards are discussed in section VII of this preamble. The reader should refer to that section for more details.

b. Not-to-Exceed and Supplemental Steady-State Test

To help ensure that heavy-duty engine emissions are controlled over the full range of speed and load combinations commonly experienced in use, we have previously proposed to apply Not-To-Exceed (NTE) limits to heavy-duty diesel engines (64 FR 58472, October 29, 1999). As proposed, the NTE approach establishes an area (the ''NTE zone'') under the torque curve of an engine where emissions must not exceed a specified value for any of the regulated pollutants.[75] As proposed, the specified value under which emissions must remain is 1.25 times the FTP standards. The NTE standard would apply under any conditions that could reasonably be expected to be seen by that engine in normal vehicle operation and use. In addition, we have proposed that the whole range of real ambient conditions be included in NTE testing.

Similarly, to help ensure that heavy-duty engine emissions are controlled during steady-state type driving (such as a line-haul truck operating on a freeway), we have previously proposed a new supplemental steady-state test (64 FR 58472, October 29, 1999). The supplemental steady-state test consists of 13 steady-state modes, each weighted according to the amount of time that might be expected at each mode during typical real world conditions. As proposed, the supplemental steady-state test has emission limits of 1.0 times the FTP standards.

Today's document proposes to apply the heavy-duty diesel NTE and supplemental steady-state test provisions intended to be finalized as part of the 2004 standards rulemaking. The October 29, 1999, proposal for that rule contained the description of these provisions. We expect that a number of modifications will be made to those provisions in the FRM for that rule based on feedback received during the comment period. While the details of the final provisions are not yet available, we will provide the necessary information in the docket for this rule as soon as it becomes available in order to allow for comment.

We have not proposed that the NTE requirements, or the supplemental steady-state test, apply to heavy-duty gasoline engines. However, we are working with several industry members to pursue a proposal in a separate action with the intention of having NTE requirements in place for heavy-duty gasoline engines beginning in the 2004 model year.[76] Today's proposal intends that those provisions, when developed, would apply to the gasoline engines subject to today's proposed standards as well. We currently have no intention of pursuing supplemental steady-state test requirements for heavy-duty gasoline engines.

We request comment and data on the feasibility of technology meeting the proposed emission standards in the context of the NTE and supplemental steady-state tests as proposed in the 2004 heavy-duty rule, and the potential changes to the supplemental tests should changes be made from what was proposed. As stated above, should such changes be made, we will provide the necessary information in the docket for this rule as soon as it becomes available in order to allow for comment.

c. Crankcase Emissions Control

Crankcase emissions are the pollutants that are emitted in the gases that are vented from an engine's crankcase. These gases are also referred to as ''blowby gases'' because they result from engine exhaust from the combustion chamber ''blowing by'' the piston rings into the crankcase. These gases are vented to prevent high pressures from occurring in the crankcase. Our existing emission standards prohibit crankcase emissions from all highway engines except turbocharged heavy-duty diesel engines. The most common way to eliminate crankcase emissions has been to vent the blowby gases into the engine air intake system, so that the gases can be recombusted. We made the exception for turbocharged heavy-duty diesel engines because of concerns in the past about fouling that could occur by routing the diesel particulates (including engine oil) into the turbocharger and aftercooler. Our concerns are now alleviated by newly developed closed crankcase filtration systems, specifically designed for turbocharged heavy-duty diesel engines. These new systems (discussed more fully in section III.E and in Chapter III of the draft RIA) are already required for new on-highway diesel engines under the EURO III emission standards.

We are proposing to eliminate the exception for turbocharged heavy-duty diesel engines starting in the 2007 model year. This is an environmentally significant proposal since most heavy-duty diesel trucks use turbocharged engines, and a single engine can emit over 100 pounds of NO_x, NMHC, and PM from the crankcase over the lifetime of the engine. We request comment on this proposal.

2. Heavy-Duty Vehicle Standards

a. Federal Test Procedure

The emission standards being proposed today for heavy-duty vehicles are summarized in Table III.C–2. We have already proposed that all complete heavy-duty gasoline vehicles, whether for transporting passengers or for work, be chassis certified (64 FR 58472, October 29, 1999). Current federal regulations do not require that complete diesel vehicles over 8,500 pounds be chassis certified, instead requiring certification of their engines. Today's proposal does not make changes to those requirements.

The Tier 2 final rule created a new vehicle category called ''medium-duty passenger vehicles''.[77] These vehicles, both gasoline and diesel, are required to meet requirements of the Tier 2 program, which carries with it a chassis certification requirement. As a result, applicable complete diesel vehicles must certify using the chassis certification test procedure. Today's proposed chassis standards for 2007 and later model year heavy-duty gasoline vehicles would apply to the remaining (work-oriented) complete gasoline vehicles under 14,000 pounds.

[75] Torque is a measure of rotational force. The torque curve for an engine is determined by an engine ''mapping'' procedure specified in the Code of Federal Regulations. The intent of the mapping procedure is to determine the maximum available torque at all engine speeds. The torque curve is merely a graphical representation of the maximum torque across all engine speeds.

[76] Letters from Margo Oge, EPA, to Kelly Brown, Ford Motor Company, and Samuel. Leonard, General Motors Corp., both dated September 17, 1999; and letter from Samuel. Leonard, GM, and Kelly Brown, Ford, to Margo Oge, EPA, dated August 10,1999; all of these letters are available in EPA Air Docket #A–98–32.

[77] Medium-duty passenger vehicles are defined as any complete vehicle between 8,500 and 10,000 pounds GVWR designed primarily for the transportation of persons. The definition specifically excludes any vehicle that (1) has a capacity of more than 12 persons total or, (2) is designed to accommodate more than 9 persons in seating rearward of the driver's seat or, (3) has a cargo box (e.g., pick-up box or bed) of six feet or more in interior length. (See the Tier 2 final rulemaking, 65 FR 6698, February 10, 2000)

TABLE III.C–2.—PROPOSED 2007+ FULL USEFUL LIFE HEAVY-DUTY VEHICLE EXHAUST EMISSION STANDARDS FOR COMPLETE GASOLINE VEHICLES*

[grams/mile]

Weight range (GVWR)	NO_X	NMHC	HCHO	PM
8500 to 10,000 lbs	0.2	0.195	0.016	0.02
10,000 to 14,000 lbs	0.4	0.230	0.021	0.02

* Does not include medium-duty passenger vehicles.

These NO_X standards represent a 78 percent reduction and a 60 percent reduction from the standards for 8,500–10,000 pound and 10,000–14,000 pound vehicles, respectively, proposed in the 2004 heavy-duty rule. The 2004 heavy-duty rule would require such vehicles to meet the California LEV–I NO_X standards of 0.9 g/mi and 1.0 g/mi, respectively. The proposed NO_X standards shown in Table III.C–2 are consistent with the CARB LEV–II NO_X standard for low emission vehicles (LEVs). We have proposed, and CARB has put into place in their LEV–II program, a slightly higher NO_X standard for 10,000 to 14,000 pound vehicles because these vehicles are tested at a heavier payload. The increased weight results in using more fuel per mile than vehicles tested at lighter payloads; therefore, they tend to emit slightly more grams per mile than lighter vehicles.[78]

The NMHC standards represent a 30 percent reduction from the proposed 2004 standards for 8500–10,000 and 10,000–14,000 pound vehicles. The 2004 heavy-duty rule would require such vehicles to meet NMHC standard levels of 0.28 g/mi and 0.33 g/mi, respectively (equal to the California LEV–I nonmethane organic gases (NMOG) standard levels). The proposed NMHC standards are consistent with the CARB LEV–II NMOG standards for LEVs in each respective weight class. The NMHC standard for 10,000–14,000 pound vehicles is higher than for 8,500–10,000 pound vehicles for the same reason as stated above for the higher NO_X standard for such vehicles.

The formaldehyde standards are comparable in stringency to the formaldehyde standards recently finalized in the Tier 2 rule for passenger vehicles; they are also consistent with today's proposed engine standards and the CARB LEV II formaldehyde standards. Formaldehyde is a hazardous air pollutant that is emitted by heavy-duty vehicles and other mobile sources, and we are proposing these formaldehyde standards to prevent excessive formaldehyde emissions. These standards would be especially important for methanol-fueled vehicles because formaldehyde is chemically similar to methanol and is one of the primary byproducts of incomplete combustion of methanol. Formaldehyde is also emitted by vehicles using petroleum fuels (i.e., gasoline or diesel fuel), but to a lesser degree than is typically emitted by methanol-fueled vehicles. We recognize that petroleum-fueled vehicles able to meet the proposed NMHC standards should comply with the formaldehyde standards with large compliance margins. Based upon the analysis of similar standards recently finalized for passenger vehicles, we believe that formaldehyde emissions from petroleum-fueled vehicles when complying with the PM, NMHC and NO_X standards should be as much as 90 percent below the standards.[79] Thus, to reduce testing costs, we are proposing a provision that would permit manufacturers of petroleum-fueled vehicles to demonstrate compliance with the formaldehyde standards based on engineering analysis. This provision would require manufacturers to make a demonstration in their certification application that vehicles having similar size and emission control technology have been shown to exhibit compliance with the applicable formaldehyde standard for their full useful life. This demonstration would be similar to that recently finalized for light-duty vehicles to demonstrate compliance with the Tier 2 formaldehyde standards.

The PM standard represents over an 80 percent reduction from the CARB LEV–II LEV category PM standard of 0.12 g/mi. Note that the PM standard shown in Table III.C–2 represents not only a stringent PM level, but a new standard for federal HDVs where none existed before. The California LEV–II program for heavy-duty vehicles, and the federal Tier 2 standards for over 8,500 pound vehicles designed for transporting passengers, both contain PM standards. The PM standard proposed today is consistent with the Tier 2 bin 8 level of 0.02 g/mi.

The standards shown in Table III.C–2 are, we believe, comparable in stringency to the proposed diesel and gasoline engine standards shown in Table III.C–1. We request comment on this issue, including any supporting data. We also request comment on other possible vehicle exhaust emission standards. For example, the CARB LEV–II ULEV standards are identical in NO_X levels, but have NMOG levels of 0.143 and 0.167 g/mi for 8,500 to 10,000 pound and 10,000 to 14,000 pound vehicles, respectively. We request comment on whether these standards (0.143 and 0.167 g/mi NMHC for 8,500 to 10,000 pound and 10,000 to 14,000 pound vehicles, respectively), or lower standards, may be more appropriate emission standards. We also request comment on whether we should instead include a 40 percent/60 percent split of standards at the LEV–II LEV and ULEV levels, respectively. To clarify, the CARB LEV–II program requires a compliance split of vehicles certified to the LEV versus the ULEV levels; that split is 40 percent LEV and 60 percent ULEV. We request comment on whether we should employ such a split.

We are not proposing a phase-in for the HDV standards. As proposed, the HDV standards would apply only to complete gasoline vehicles, consistent with our current regulations. We believe that emission control technology for gasoline engines is in an advanced enough state to justify a simple implementation requirement in the 2007 model year. However, please refer to section III.D.2, below, for a discussion of the appropriate implementation schedule associated with these proposed standards, and the relationship between today's proposed implementation and the implementation of the proposed 2004 emission standards. We believe that our proposed implementation schedule provides consistency with our Tier 2 standards and our expectation of probable certification levels for similarly sized light-duty trucks and medium-duty

[78] Engine standards, in contrast, are stated in terms of grams per unit power rather than grams per mile. Therefore, engine emission standards need not increase with weight because heavier engines do not necessarily emit more per horsepower even though they tend to emit more per mile.

[79] See the Tier 2 Response to Comments document contained in Air Docket A–97–10.

passenger vehicles. Although these vehicles are allowed to certify at fairly high emission levels under the Tier 2 bin structure, we believe that Tier 2 gasoline applications will be designed to certify to standards of 0.20 g/mi NO_X and 0.09 g/mi NMHC by the 2007 model year, and possibly lower to allow for diesels certifying in higher emission bins within the NO_X averaging scheme. This makes the proposed HDV standards and associated phase-in consistent with Tier 2. We request comment on the appropriateness of not having a phase-in associated with the vehicle standards. We also request comment on possible alternative phase-ins for the proposed gasoline vehicle standards, such as a phase-in consistent with the proposed phase-in for diesel engine standards shown in Table III.C–1, or a phase-in consistent with that used for heavy light-duty trucks and medium-duty passenger vehicles under the light-duty highway Tier 2 program.

Consistent with current regulations, we are not proposing to allow complete heavy-duty diesel vehicles to certify to the heavy-duty vehicle standards. Instead, manufacturers would be required to certify the engines intended for such vehicles to the engine standards shown in Table III.C–1. However, we request comment on whether complete heavy-duty diesel vehicles should be allowed, or perhaps should be required, to certify to the vehicle standards. Any comments on this topic should also address whether a phase-in, consistent with the phase-in of engine standards, would be appropriate.

The specifics of the Averaging, Banking, and Trading program associated with today's proposed standards are discussed in section VII of this document. The reader should refer to that section for more details.

We request comment on the feasibility and appropriateness of the proposed standards for heavy-duty complete vehicles shown in Table III.C–2.

b. Supplemental Federal Test Procedure

We are not proposing new supplemental FTP (SFTP) standards for heavy-duty vehicles. The SFTP standards control off-cycle emissions in a manner analogous to the NTE requirements for engines. We believe that the SFTP standards are an important part of our light-duty program just as we believe the NTE requirements will be an important part of our heavy-duty diesel engine program. Although we are not proposing SFTP standards for heavy-duty vehicles, we intend to do so via a separate rulemaking. We request comment on such an approach, and on appropriate SFTP levels for heavy-duty vehicles along with supporting data.

3. Heavy-Duty Evaporative Emission Standards

We are proposing new evaporative emission standards for heavy-duty vehicles and engines. The proposed standards are shown in Table III.C–3. These standards would apply to heavy-duty gasoline-fueled vehicles and engines, and methanol-fueled heavy-duty vehicles and engines. Consistent with existing standards, only the standard for the three day diurnal test sequence would apply to liquid petroleum gas (LPG) fueled and natural gas fueled HDVs.

TABLE III.C–3.—PROPOSED HEAVY-DUTY EVAPORATIVE EMISSION STANDARDS*

[Grams per test]

Category	3 day diurnal + hot soak	Supplemental 2 day diurnal + hot soak**
8,500–14,000 lbs	1.4	1.75
>14,000 lbs	1.9	2.3

* Proposed to be implemented on the same schedule as the proposed gasoline engine and vehicle exhaust emission standards shown in Tables III.C–1 and III.C–2. These proposed standards would not apply to medium-duty passenger vehicles, and would not apply to diesel fueled vehicles.

** Does not apply to LPG or natural gas fueled HDVs.

These proposed standards represent more than a 50 percent reduction in the numerical standards as they exist today. The 2004 heavy-duty rule (64 FR 58472, October 29, 1999) proposed no changes to the numerical value of the standard, but it did propose new evaporative emission test procedures for heavy-duty complete gasoline vehicles.[80] Those test procedures would effectively increase the stringency of the standards, even though the numerical value was not proposed to change. For establishing evaporative emission levels from complete heavy-duty vehicles, the standards shown in Table III.C–3 presume the test procedures proposed in the 2004 heavy-duty rule.

The proposed standards for 8,500 to 14,000 pound vehicles are consistent with the Tier 2 standards for medium-duty passenger vehicles (MDPV). MDPVs are of consistent size and have essentially identical evaporative emission control systems as the remaining work-oriented HDVs in the 8,500 to 10,000 pound weight range. Therefore, the evaporative emission standards should be equivalent. We are proposing those same standards for the 10,000 to 14,000 pound HDVs because, historically, the evaporative emission standards have been consistent throughout the 8,500 to 14,000 pound weight range. We believe that the HDVs in the 10,000 to 14,000 pound range are essentially equivalent in evaporative emission control system design as the lighter HDVs; therefore, continuing this historical approach is appropriate.

We are proposing slightly higher evaporative emission standards for the over 14,000 pound HDVs because of their slightly larger fuel tanks and vehicle sizes. This is consistent with past evaporative emission standards. The levels chosen for the over 14,000 pound HDVs maintains the same ratio relative to the 8,500 to 14,000 pound HDVs as exists with current evaporative standards. To clarify, the current standards for the 3 day diurnal test are 3 and 4 grams/test for the 8,500 to 14,000 and the over 14,000 pound categories, respectively. The ratio of 3:4 is maintained for the proposed 2007 standards, 1.4:1.9.

The proposed standards levels are slightly higher than the California LEV–II standards levels. The California standards levels are 1.0 and 1.25 for the 3-day and the 2-day tests, respectively. We believe that our standards are appropriate for federal vehicles certified on the higher-volatility federal test fuel.

We are proposing that the proposed evaporative emission standards be implemented on the same schedule as the proposed gasoline engine and vehicle exhaust standards shown in Tables III.C–1 and III.C–2. We request comment on this proposal. Also, we are proposing the revised durability provisions finalized in the Tier 2 rulemaking, which require durability demonstration using fuel containing at least 10 percent alcohol. Alcohol can break down the materials used in evaporative emission control systems. Therefore, a worst case durability demonstration would include a worst case alcohol level in the fuel (10 percent) as some areas of the country

[80] The proposed test procedure changes sought to codify a commonly approved waiver allowing heavy-duty gasoline vehicles to use the light-duty driving cycle for demonstrating evaporative emission compliance. The urban dynamometer driving schedule (UDDS) used for heavy-duty vehicles is somewhat shorter than that used for light-duty vehicles, both in terms of mileage covered and minutes driven. This results in considerably less time for canister purge under the heavy-duty procedure than under the light-duty procedure. We recognize this discrepancy and have routinely provided waivers under the enhanced evaporative program that allow the use of the light-duty procedures for heavy-duty certification testing. We do not believe that this approach impacts the stringency of the standards. Further, it is consistent with CARB's treatment of equivalent vehicles.

use alcohol fuels to improve their air quality. We request comment on extending this durability provision to HDVs.

We request comment on the feasibility and appropriateness of the proposed evaporative emission standards shown in Table III.C–3.

D. Standards Implementation Issues

1. Alternative Approach to Phase-In

Although we are proposing the standards and diesel phase-ins shown in Section III.C, we request comment on the possibility of structuring the proposed diesel engine standards as a ''declining'' standard rather than the standard level ''phase-in'' being proposed. Under such an approach, the final NO_X and NMHC standards of 0.20 and 0.14 g/bhp-hr would be achieved via a ramping down of the standards from the NO_X and NMHC levels assumed under the 2004 NMHC+NO_X standard (i.e., 2.0 g NO_X and 0.5 g NHMC) to the final levels provided it did not compromise the air quality benefits in any given year. Such a declining standard would result in 2007 standards for all engines lower than the 2004 standards, but not as low as today's proposed standards. The 2008 standards for all engines would then be lower than the 2007 standards, and the 2009 standards for all engines would be lower than the 2008 standards. In 2010, the standards would become 0.20 g/bhr-hr NO_X and 0.14 g/bhp-hr NMHC.

Under such a declining standard approach, an engine manufacturer would probably have to redesign most, if not all, of its engines to reduce their emissions from the 2004 standard levels to the 2007 model year declining standard levels. In contrast, under the proposed approach, 25 percent of an engine manufacturer's engines would have to certify to the 0.20/0.14 g/bhp-hr standards. Although the phase-in levels would be more stringent, the manufacturer would have to redesign only that 25 percent of its engines during the 2007 model year. The same would be true for the ensuing years. Under the declining standard approach, some level of redesign would probably have to be done on every engine in every year to meet the declining standard unless a manufacturer had extensive ABT credits at its disposal to apply against the standard. Under the phase-in, each new model year would entail a redesign of only 25 percent of a manufacturer's engines. In the end, both approaches result in the entire fleet meeting the proposed standard levels in 2010, but both achieve that in different ways.

We request comment on this declining standard approach for the diesel engine standards. We also request suggestions on appropriate declining standards for each model year that would result in stringency levels and emission reductions consistent with those of the proposed phase-in approach.

We also request comment on the possibility of structuring the phase-in of the proposed diesel engine standards as a ''cumulative'' phase-in rather than the 25–50–75–100 percent phase-in being proposed. Under such an approach, a manufacturer could phase-in compliance with the proposed standards in whatever percentages were most beneficial to that manufacturer, provided the cumulative total in each year met or exceeded the cumulative total of the proposed phase-in. Whatever the phase-in schedule chosen by the manufacturer, all of its engines sold in model year 2010 would be required to demonstrate compliance with the proposed standards. For example, a manufacturer could phase-in its engines according to a schedule of 50–50–50–100 percent, or 35–50–65–100 percent, or 30–60–60–100, etc. Note that the cumulative percentages would have to be based on cumulative engine sales to avoid the possibility that variations in market conditions would not compromise air quality benefits. We believe that such a phase-in could provide manufacturers with more flexibility in product planning while possibly enhancing the air quality benefits of the proposed standards because some manufacturers may accelerate their phase-in. Manufacturers should indicate their interest in such an approach in their comments and should indicate how they might utilize it.

2. Implementation Schedule for Gasoline Engine and Vehicle Standards

The October 1999 proposal of new heavy-duty engine and vehicle standards included revised standards for gasoline heavy-duty engines and vehicles (64 FR 58472, October 29, 1999). These standards were proposed to take effect in the 2004 model year. Commenters on that proposal raised concerns that these standards could not take effect until model year 2005 or later because of the applicability of Clean Air Act section 202(a)(3)(C) to these engines and vehicles. Those commenters argued that this provision requires 4 years of implementation leadtime following the promulgation of new or revised standards, and that these standards had not been promulgated in a final rule in time to satisfy this leadtime provision. We are still in the process of finalizing this rule and so at this time we are not able to announce the outcome of the leadtime issue. However, we do expect that, should the gasoline engine and vehicle standards be delayed to model year 2005, the standards being proposed today for gasoline engines and vehicles would first apply in model year 2008, rather than 2007, due to another part of the Clean Air Act section 202(a)(3)(C) provision that requires 3 model years of stability between changed standards. We invite comment on the appropriateness of this expectation and on any issues that might arise in connection with the model year 2008 implementation schedule.

E. Feasibility of the Proposed New Standards

For more detail on the arguments supporting our assessment of the technological feasibility of today's proposed standards, please refer to the Draft RIA in the docket for this rule. The following discussion summarizes the more detailed discussion found in the Draft RIA.

1. Feasibility of Stringent Standards for Heavy-Duty Diesel

Diesel engines have made great progress in lowering engine-out emissions from 6.0 g/bhp-hr NO_X and 0.6 g/bhp-hr PM in 1990 to 4.0 g/bhp-hr NO_X and 0.1 g/bhp-hr PM in 1999. These reductions came initially with improvements to combustion and fuel systems. Introduction of electronic fuel systems in the early 1990s allowed lower NO_X and PM levels without sacrificing fuel economy. This, combined with increasing fuel injection pressures, has been the primary technology that has allowed emission levels to be reduced to current 1999 levels. Further engine-out NO_X reductions to the levels necessary to comply with the 2004 standard of 2.5 g/bhp-hr NO_X+NMHC will come primarily from the addition of cooled EGR.

Engine out emission reductions beyond the 2.5 g/bhp-hr level are expected with low sulfur fuel and more experience with cooled EGR systems. Low sulfur fuel will allow more EGR to be used at lower temperatures because of the reduced threat of sulfuric acid formation. In addition, recirculating the exhaust gases from downstream of a PM trap may allow different EGR pumping configurations to be feasible. Such pumping configurations could provide a better NO_X/fuel consumption tradeoff.

These potential engine-out emission reductions are expected to be modest and are not expected to be sufficient to meet the emission standards proposed

today. However, they would allow greater flexibility in choosing the combination of technologies used to meet the proposed emission standards. With lower engine-out emissions, it might be most cost effective to use smaller and less expensive exhaust emission control devices, for instance. Also, the combination of engine-out and exhaust emission control could be chosen for the best fuel economy. The fuel economy trade-offs between lower engine-out emissions and more effective exhaust emission control might be such that a combination of the two methods provide fuel economy that is better than either method on its own. As a result, additional engine-out emission reductions are expected to add additional flexibility in combination with exhaust emission control in jointly optimizing costs, fuel economy, and emissions.

a. Meeting the Proposed PM Standard

Diesel PM consists of three primary constituents: unburned carbon particles, which make up the largest portion of the total PM; the soluble organic fraction (SOF), which consists of unburned hydrocarbons that have condensed into liquid droplets or have condensed onto unburned carbon particles; and sulfates, which result from oxidation of fuel borne sulfur in the engine's exhaust.

Several exhaust emission control devices have been developed to control harmful diesel PM constituents—the diesel oxidation catalyst (DOC), and the many forms of particulate filters, or traps. DOCs have been shown to be durable in use, but they effectively control only the SOF portion of the total PM which, especially on today's engines, constitutes only around 10 to 30 percent of the total PM. Therefore, the DOC does not address our PM concerns sufficiently.

At this time, only the PM trap is capable of providing the level of control sought by today's proposed PM standards. In the past, the PM trap has demonstrated highly efficient trapping efficiency, but regeneration of the collected PM has been a serious challenge. The PM trap works by passing the exhaust through a ceramic or metallic filter to collect the PM. The collected PM, mostly carbon particles but also the SOF portion, must then be burned off the filter before the filter becomes plugged. This burning off of collected PM is referred to as ''regeneration,'' and can occur either:

- on a periodic basis by using base metal catalysts or an active regeneration system such as an electrical heater, a fuel burner, or a microwave heater; or,
- on a continuous basis by using precious metal catalysts.

Uncatalyzed diesel particulate traps demonstrated high PM trapping efficiencies many years ago, but the level of the PM standard was such that it could be met through less costly ''in-cylinder'' control techniques. Also, the regeneration characteristics were not dependable. As a result, some systems employed electrical heaters or fuel burners to improve upon regeneration, but these complicated the system design and still could not provide the durability and dependability required for HD diesel applications.

We believe the most desirable PM trap, and the type of trap that will prove to be the industry's technology of choice, is one capable of regenerating on an essentially continuous basis. We also believe that such traps are the most promising for enabling very low PM emissions because:

- They are highly efficient at trapping all forms of diesel PM;
- They employ precious metals to reduce the temperature at which regeneration occurs, thereby allowing for passive regeneration under normal operating conditions typical of a diesel engine;[81]
- Because they regenerate continuously, they have lower average backpressure thereby reducing potential fuel economy impacts; and,
- Because of their passive regeneration characteristics, they need no extra burners or heaters like would be required by an active regeneration system thereby reducing potential fuel economy impacts.

These catalyzed PM traps are able to provide in excess of 90 percent control of diesel PM. However, as discussed in detail in the Draft RIA, the catalyzed PM trap cannot regenerate properly with current fuel sulfur levels as such sulfur levels inhibit the NO to NO_2 reaction to the point of stopping trap regeneration.[82] Also, because SO_2 is so readily oxidized to SO_3, very low PM standards cannot be achieved with current sulfur levels because of the resultant increase in sulfate PM emissions.[83]

More than one exhaust emission control manufacturer is known to be developing these precious metal catalyzed, passively regenerating PM traps and to have them in broad field test programs in areas where low sulfur diesel fuel is currently available. In field trials, they have demonstrated highly efficient PM control and promising durability with some units accumulating in excess of 360,000 miles of field use.[84] The experience gained in these field tests also helps to clarify the need for very low sulfur diesel fuel. In Sweden and some European city centers where below 10 ppm diesel fuel sulfur is readily available, more than 3,000 catalyzed diesel particulate filters have been introduced into retrofit applications without a single failure. The field experience in areas where sulfur is capped at 50 ppm has been less definitive. In regions without extended periods of cold ambient conditions, such as the United Kingdom, field tests on 50 ppm cap low sulfur fuel have been extremely positive, matching the success at, 10 ppm. However, field tests in Finland where colder winter conditions are sometimes encountered (similar to northern parts of the United States) have revealed a failure rate of 10 percent. This 10 percent failure rate has been attributed to insufficient trap regeneration due to fuel sulfur in combination with low ambient temperatures.[85] As the ambient conditions in Sweden are expected to be no less harsh than Finland, we are left to conclude that the increased failure rates noted here are due to the higher fuel sulfur level in a 50 ppm cap fuel versus a 10 ppm cap fuel. From these results, we can also theorize that lighter applications (such as large pick-up trucks and other light heavy-duty applications), having lower exhaust temperatures than heavier applications, may experience similar results and would, therefore, need very low sulfur fuel. These results are understood to be due to the effect of sulfur on the trap's ability to create sufficient NO_2 to carry out proper trap regeneration. Without the NO_2, the trap continues to trap at high efficiency, but it is unable to oxidize, or regenerate, the trapped PM. The possible result is a plugged trap.

Diesel particulate traps reduce particulate matter (PM) by capturing and burning particles. Ninety percent of

[81] For PM trap regeneration without precious metals, temperatures in excess of 650°C must be obtained. At such high temperatures, carbon will burn provided sufficient oxygen is present. However, although the largest heavy-duty diesels may achieve temperatures of 650°C under some operating conditions, smaller diesel engines, particularly light-duty and light heavy-duty diesel engines, will rarely achieve such high temperatures. For example, exhaust temperatures on the HDE Federal Test Procedure cycle typically range from 100°C to 450°C. Precious metal catalyzed traps use platinum to oxidize NO in the exhaust to NO_2, which is capable of oxidizing carbon at temperatures as low as 250°C to 300°C.

[82] Cooper and Thoss, Johnson Matthey, SAE 890404.

[83] See the Draft RIA for more detail on the relationship of fuel sulfur to sulfate make.

[84] Allansson, et at., SAE 2000–01–0480.

[85] Letter from Dr. Barry Cooper to Don Lopinski US EPA, EPA Docket A–99–06.

the PM mass resides in particle sizes that are less than 1000 nanometers (nm) in diameter, and half of these particles are less than 200 nm. Fortunately, PM traps have very high particle capture efficiencies. PM less than 200 nm is captured efficiently by diffusion onto surfaces within the trap walls. Larger particles are captured primarily by inertial impaction onto surfaces due to the tortuous path that exhaust gas must take to pass through the porous trap walls. Capture efficiency for elemental carbon (soot) and metallic ash is nearly 100 percent; therefore, significant PM can only form downstream of the trap. Volatile PM forms from sulfate or organic vapors via nucleation, condensation, and/or adsorption during initial dilution of raw exhaust into the atmosphere. Kleeman,[86] et. al., and Kittelson,[87] et. al., independently demonstrated that these volatile particles reside in the ultra-fine PM range (i.e. <100 nm range).

Modern catalyzed PM traps have been shown to be very effective at reducing PM mass. In addition, they can significantly reduce the overall number of emitted particles when operated on low sulfur fuel. Hawker, et al., found that a modern catalyzed PM trap reduced particle count by over 95 percent, including ultrafine particles (< 50 nm) at most of the tested conditions. The lowest observed efficiency in reducing particle number was 86 percent. No generation of particles by the PM trap was observed under any tested conditions.[88] Kittelson, et al., confirmed that ultrafine particles can be reduced by a factor of ten by oxidizing volatile organics, and by an additional factor of ten by reducing sulfur in the fuel. Catalyzed PM traps efficiently oxidize nearly all of the volatile organic PM precursors, and elimination of as much fuel sulfur as possible will dramatically reduce the number of ultrafine PM emitted from diesel engines. Therefore, the combination of PM traps with low sulfur fuel is expected to result in a very large reduction in PM mass, and ultrafine particles will be almost completely eliminated.

Now that greater than 90 percent effective PM emission control has been demonstrated, focus has turned to bringing PM exhaust emission control to market. One of the drivers is the Euro IV PM standard set to become effective in 2005.[89] This standard sets a PM trap forcing emission target. In anticipation of the 2005 introduction date, field tests are already underway in several countries with catalyzed particulate filters. We believe the experience gained in Europe with these technologies will coincide well with the emission standards in this proposal. The timing of today's proposal harmonizes the heavy-duty highway PM technologies with those expected to be used to meet the light-duty highway Tier 2 standards. Our own testing with fuel sulfur levels below 10 ppm shows that these systems are viable.[90] With this level of effort already under way, we believe that the proposed PM standards which would require a 90 percent reduction in the mass of particulate emissions could be met provided low sulfur fuel is made available.

The data currently available show that catalyzed particulate filters can provide significant reductions in PM. Catalyzed particulate filters, in conjunction with low sulfur fuel, have been shown to be more than 90 percent efficient over the FTP and at most supplemental steady-state modes.[91] However, with the application of exhaust emission control technology and depending on the sulfur level of the fuel, there is the potential for sulfate production during some operating modes covered by the NTE and the supplemental steady-state test. We believe that, with the 15 ppm diesel sulfur level proposed today, the NTE and the supplemental steady-state test, as proposed in the 2004 heavy-duty rule, would be feasible. This belief, as discussed in greater detail in the draft RIA, is supported by data generated as part of the Diesel Emission Control Sulfur Effects (DECSE) test program.[92] We request comment and relevant data on this issue.

We request comment on the potential need to remove, clean, and reverse these traps at regular intervals to remove ash build-up resulting from engine oil. Small amounts of oil can enter the exhaust via the combustion chamber (past the pistons, rings and valve seals), and via the crankcase ventilation system. This can lead to ash build-up, primarily as a result of the metallic oil additives used to provide pH control. Such pH control is necessary, in part, to neutralize sulfuric acid produced as a byproduct of burning fuel containing sulfur. However, with reduced fuel sulfur, these oil additives could be reduced, thereby reducing the rate of ash build-up and lengthening any potential cleaning intervals. It may also be possible to use oil additives that are less prone to ash formation to reduce the need for periodic maintenance. We believe that catalyzed PM traps should be able to meet the required emissions reduction goals over their useful life with minimal maintenance. Nonetheless, we request comment on the appropriate minimum allowable maintenance interval for PM traps. Commenters should consider whether the maintenance interval should include design provisions to ensure quick and easy maintenance and should make suggestions for how performance of the maintenance by the owner would be ensured.

b. Meeting the Proposed NO_X Standard

The NO_X standard proposed today requires approximately a 90 percent reduction in NO_X emissions beyond the levels expected from the 2004 emission standards. Historically, catalytic reduction of NO_X emissions in the oxygen-rich environment typical of diesel exhaust has been difficult because known NO_X reduction mechanisms tend to be highly selective for oxygen rather than NO_X. Nonetheless, there are exhaust emission control devices that reduce the NO_X to form harmless oxygen and nitrogen. These devices are the lean NO_X catalyst, the NO_X adsorber, selective catalytic reduction (SCR), and non-thermal plasma.

The lean NO_X catalyst has been shown to provide up to a 30 percent NO_X reduction under limited steady-state conditions. Despite a large amount of development effort, NO_X reductions over the heavy-duty transient federal test procedure (FTP) have been demonstrated only on the order of 12 percent.[93] Consequently, the lean NO_X

[86] Kleeman, M.J., Schauer, J.J., Cass, G.R., 2000, Size and Composition Distribution of Fine Particulate Matter Emitted From Motor Vehicles, Environmental Science and Technology, Vol. 34, No. 7.

[87] Kittelson, D.B., 2000, Presentation on Fuel and Lube Oil Sulfer and Oxidizing Aftertreatment System Effects on Nano-particle Emissions from Diesel Engines. Presented in United Kingdom April 12, 2000.

[88] Hawker, P., et al., Effect of a Continuously Regenerating Diesel Particulate Filter on Non-Regulated Emissions and Particle Size Distribution, SAE 980189.

[89] The Euro IV standards are 2.6 g/hp-hr NO_X and 0.015 g/hp-hr PM.

[90] Memorandum from Charles Schenk, EPA, to Air Docket A–99–06, ''Summary of EPA PM Efficiency Data,'' May 8, 2000.

[91] Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Low Emission Levels, Manufacturers of Emissions Controls Association, June 1999.

[92] Diesel Emission Control Sulfur Effects (DECSE) Program—Phase II Interim Data Report No. 4, Diesel Particulate Filters—Final Report, January 2000, Table C1, www.ott.doe.gov/decse.

[93] Kawanami, M., et al., Advanced Catalyst Studies of Diesel NO_X Reduction for On-Highway Trucks, SAE 950154.

catalyst does not appear to be capable of enabling the significantly lower NO_X emissions required by the proposed NO_X standard.

NO_X adsorbers were first introduced in the power generation market less than five years ago. Since then, NO_X adsorber systems in stationary source applications have enjoyed considerable success. In 1997, the South Coast Air Quality Management District of California determined that a NO_X adsorber system provided the ''Best Available Control Technology'' NO_X limit for gas turbine power systems.[94] Average NO_X control for these power generation facilities is in excess of 92 percent.[95]

Recently, the NO_X adsorber's stationary source success has caused some to turn their attention to applying NO_X adsorber technology to lean burn engines in mobile source applications. With only a few years of development effort, NO_X adsorber catalysts have been developed and are now in production for gasoline direct injection vehicles in Japan. The 2000 model year will see the first U.S. application of this technology with the introduction of the Honda Insight, which will be certified to the California LEV–I ULEV category standard.

Although diesel vehicle manufacturers have not yet announced production plans for NO_X adsorber-based systems, they are known to have development efforts underway to demonstrate their potential. In Europe, both Daimler-Chrysler and Volkswagen, driven by a need to meet stringent Euro IV emission standards, have published results showing how they would apply the NO_X adsorber technology to their diesel powered passenger cars. Volkswagen reports that it has already demonstrated NO_X emissions of 0.137 g/km (0.22 g/mi) on a diesel powered Passat passenger car equipped with a NO_X adsorber catalyst.[96]

Likewise, in the United States, heavy-duty engine manufacturers have begun investigating the use of NO_X adsorber technologies as a more cost effective means to control NO_X emissions when compared to more traditional in-cylinder approaches. Cummins Engine Company reported, at DOE's 1999 Diesel Engine Emissions Reduction workshop, that they had demonstrated an 80 percent reduction in NO_X emissions over the Supplemental Steady State test and 58 percent over the heavy-duty FTP cycle using a NO_X adsorber catalyst.

In spite of these promising developments, work in the United States on NO_X adsorbers has been limited in comparison to the rest of the world for at least a couple of reasons: (1) prior to today's proposal, emission standards have not necessitated the use of NO_X exhaust emission controls on heavy-duty diesel engines; and, (2) there has not been a commitment in the U.S. to guarantee the availability of low sulfur diesel fuel. This is in stark contrast to Europe where the Euro IV and Euro V emission standards, along with the commitment to low sulfur diesel fuel, have led to rapid advancements of NO_X exhaust emission control technology. We believe, based on input from industry members that develop and manufacture emission control devices such as NO_X adsorbers, that the prospect of low sulfur diesel fuel in the U.S. market will drive rapid advancement of this promising NO_X control technology.[97]

NO_X adsorbers work by providing a NO_X storage feature, a NO_X adsorber, during periods of fuel lean operation. This is then combined with the typical three-way catalyst, like those used for years in stoichiometric gasoline applications. The combination of adsorber plus three-way catalyst allows storage of NO_X on the adsorber during fuel lean-oxygen rich operation, then removal of NO_X from the adsorber and reduction of NO_X over the three-way catalyst during fuel rich-oxygen lean operation. This removal of NO_X from the adsorber is termed ''NO_X regeneration'' and generally requires purposeful controlled addition of small amounts of fuel into the exhaust stream at regular intervals.

Improving NO_X reduction efficiencies over the diesel exhaust temperature range is key to meeting the proposed standards. Current NO_X adsorbers, for instance, have a high reduction efficiency (over 90 percent NO_X reduction) over a fairly broad temperature range (exhaust temperatures from 250°C to 450°C) allowing today's proposed standard to be met over this range.[98] Extending the range of high NO_X reduction efficiency at both high temperatures and low temperatures will allow higher average reduction efficiencies over the FTP and in use. The performance of the NO_X adsorber may vary somewhat with exhaust temperature across the NTE. For that reason, engine-out NO_X emissions will have to be flattened over the NTE to accommodate these variations in NO_X reduction performance. We believe that such an approach would allow the NO_X NTE and supplemental steady-state composite to be met. We seek comment and data on the relationship between NO_X adsorber performance and engine operating mode.

The greatest hurdle to the application of the NO_X adsorber technology has been its sensitivity to sulfur in diesel fuel. The NO_X adsorber stores sulfur emissions in a manner directly analogous to its storage of NO_X under lean conditions. Unfortunately, the stored sulfur is not readily removed from the adsorber during the type of operating conditions under which NO_X is readily removed. This leads to an eventual loss of NO_X adsorber function and, thus, a loss of NO_X emission control. This potential loss of NO_X adsorber function can most effectively be addressed through the reduction of sulfur in diesel fuel. For a more complete description of the sensitivity of this technology to sulfur in diesel fuel, and for an explanation of the need for low sulfur diesel fuel, please refer to section III.F.

The preceding discussion of NO_X adsorbers assumes that SO_X (SO_2 and SO_3) emissions will be ''trapped'' on the surface of the catalyst effectively poisoning the device and requiring a ''desulfation'' (sulfur removal event) to recover catalyst efficiency. We believe that, at the proposed 15 ppm cap fuel sulfur level, this strategy will allow effective NO_X control with moderately frequent desulfation and with a modest fuel consumption of one percent, which we anticipate will be more that offset by reduced reliance on current more expensive (from a fuel economy standpoint) NO_X control strategies (see discussion in section III.F for estimates of overall fuel economy impacts). In order to reduce the fuel economy impact and to simplify engine control, some manufacturers are investigating the use of SO_X ''traps'' (sometimes called SO_X ''adsorbers'') to remove sulfur from the exhaust stream prior to it flowing through the NO_X adsorber catalyst.

The SO_X trap is, in essence, a modified NO_X adsorber designed to preferentially store (trap) sulfur on its surface rather than NO_X. It differs from a NO_X adsorber in that it is not effective at storing NO_X and it more easily releases stored sulfur. A SO_X trap placed upstream of a NO_X adsorber could effectively remove very modest

[94] Letter from Barry Wallerstein, Acting Executive Officer, SCAQMD, to Rober Danziger, Goal Line Environmental Technologies, dated December 8, 1997, www.glet.com.

[95] Reyes and Cutshaw, $SCONO_X$ Catalytic Absorption System, December 8, 1998. www.glet.com.

[96] Pott, E., et al., Potential of NO_X-Trap Catalyst Application for DI–Diesel Engines.

[97] Letter from Bruce Bertelsen, Executive Director, Manufacturers of Emission Controls Association, to Margo Oge, EPA, dated April 5, 2000.

[98] Dou, D., Bailey, O., Investigation of NO_X Adsorber Catalyst Deactivation, SAE 982594.

amounts of sulfur from the exhaust, thereby limiting sulfur's effect on the NO_X adsorber. Unfortunately, the SO_X trap like the NO_X adsorber, will eventually fill every available storage site with sulfate and will cease to function unless the sulfur is removed. Desulfating the SO_X adsorber on the vehicle is problematic since it would be upstream of the NO_X adsorber which could then be poisoned quite rapidly by the SO_X released from the SO_X trap. This problem could presumably be solved through some form of NO_X adsorber by-pass during SO_X trap desulfation (although control of NO_X during this event may be problematic). Alternatively, removal and replacement of the SO_X adsorber on a fixed service interval would solve this problem, albeit at some cost. In an oral presentation made to EPA, an engine manufacturer estimated the storage capacity of a SO_X trap at approximately one pound of SO_2 per cubic foot of catalyst.[99] For fuel with a seven ppm average sulfur level, this would mean replacement of a 48 liter SO_X trap approximately every 100,000 miles.[100] This more than doubles the catalyst size we have projected for a typical heavy heavy-duty vehicle in this proposal, while only providing protection for a small fraction of its useful life. Because of practical limitations on SO_X trap size, we do not believe that the use of SO_X traps can avoid the need for very low-sulfur diesel fuel, and we have received no information from manufacturers that contradicts this belief. We invite comment on the use of a SO_X trap to protect NO_X adsorbers and on the appropriateness of SO_X traps being replaced on a fixed interval as described here. Further, we request comment and supporting data to indicate the interval at which SO_X traps would require replacement.

Selective Catalytic Reduction (SCR), like NO_X adsorber technology, was first developed for stationary applications and is currently being refined for the transient operation found in mobile applications.[101] With the SCR system, a urea solution is injected upstream of the catalyst which breaks down the urea into ammonia and carbon dioxide. Catalysts containing precious metals (platinum) can be used at the inlet and outlet of SCR systems designed for mobile applications to improve low temperature NO_X reduction performance and to oxidize any ammonia that may pass through the SCR, respectively. Such SCR systems are referred to as ''Compact SCR.'' The use of these platinum catalysts enable Compact SCR systems to achieve large NO_X reductions, but introduce sensitivity to sulfur in much the same way as for diesel particulate filter technologies. Sulfur in diesel fuel inhibits low temperature performance and results in high sulfate make leading directly to higher particulate emissions. For a further discussion of Compact SCR system sensitivity to sulfur in diesel fuel, and of its need for low sulfur diesel fuel, refer to section III.F.

The reduction efficiency window for Compact SCR is similar to the NO_X adsorber, with greater than 80 percent efficiency at exhaust temperatures as low as 250°C.[102] Peak efficiency values of over 90 percent are possible under certain conditions, but the cool exhaust temperature characteristics of diesel engines make excursions outside the optimum efficiency window of current Compact SCR systems quite frequent. As a result, the cycle average NO_X reduction efficiency is on the order of 77 percent over the heavy-duty FTP.[103] Over the Supplemental Steady State test modes, the SCR has been shown to have 65–99 percent efficiency.[104] The high efficiency over a broad temperature range should also allow the NTE to be met. With additional development effort, we believe the NO_X reduction efficiency of SCR can be further improved to meet NO_X levels as low as those proposed today.

However, significant challenges remain for Compact SCR systems to be applied to mobile source applications. In addition to the need for very low sulfur diesel fuel to achieve high NO_X conversion efficiencies and to control sulfate PM emissions, Compact SCR systems require vehicles to be refueled with urea. The infrastructure for delivering urea at the pump needs to be in place for these devices to be feasible in the marketplace; and before development of the infrastructure can begin, the industry must decide upon a standardized method of delivery for the urea supply. In addition to this, there would need to be adequate safeguards in place to ensure the urea is used throughout the life of the vehicle, since, given the added cost of urea, there would be incentive not to refill the urea tank. Because urea is required for the SCR system to function, urea replenishment would need to be assured.

Another, very recent approach to NO_X reduction is the non-thermal plasma assisted catalyst. This system works by applying a high voltage across two metal plates in the exhaust stream to form ions that serve as oxidizers. Essentially, the plasma would displace a conventional platinum based oxidation catalyst in function. Once oxidized to NO_2, NO_X can be more readily reduced over a precious metal catalyst. While the concept is promising, this technology is so new that essentially no data exists showing its effectiveness at controlling NO_X. We expect that, if and when the non-thermal plasma approach to NO_X control becomes viable, it will also require the use of low sulfur diesel fuel due to its reliance on a precious metal catalyst to reduce the NO_2.[105]

Based on the discussion above, we believe that NO_X aftertreatment technology, in combination with low sulfur diesel fuel, is capable of meeting the very stringent NO_X standards we have proposed. The clear intent that this proposal provides to make very low sulfur diesel fuel available in the future and to establish emission standards which necessitate advanced NO_X controls should enable rapid development of these technologies. The NO_X adsorber technology has shown incredible advancement in the last five years, moving from stationary source applications to lean-burn gasoline, and now to heavy-duty diesel engines. Given this rapid progress, the availability of very low sulfur diesel fuel, and the lead time provided by today's proposal, we believe that applying NO_X adsorbers to heavy-duty diesel engines would enable manufacturers to comply with our proposed standards. Compact SCR has been slower in developing than NO_X adsorbers but could be applied to mobile source applications if the

[99] Memorandum from Byron Bunker, US EPA to Air Docket A–99–06, ''Meeting between EPA, OMB, representatives of major oil companies, and representatives of major diesel engine manufacturers,'' Item II–E–17.

[100] This estimate assumes that a heavy-duty vehicle averages six miles per gallon of fuel, that diesel fuel weighs seven pounds per gallon, that diesel fuel has seven ppm sulfur, and that a sulfur trap could store one pound of SO_2 in a cubic foot of catalyst.

[101] SRC systems being developed for mobile applications are more appropriately called ''compact SCR'' systems, which incorporate on oxidation catalyst. Generally, reference to SCR throughout this preamble should be taken to mean compact SCR.

[102] Klein, H., et al., NO_X Reduction for Diesel Vehicles, Degussa-Huls AG, Corning Clean Diesel Workshop, Sept. 27–29, 1999.

[103] ''Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Low Emission Levels,'' Manufacturers of Emission Controls Association, June 1999.

[104] ''Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Low Emission Levels,'' Manufacturers of Emission Controls Association, June 1999.

[105] ''The Impact of Sulfur in Diesel Fuel on Catalyst Emission Control Technology,'' report by the Manufacturers of Emission Controls Association, March 15, 1999.

difficult urea infrastructure issues can be addressed.

c. Meeting the Proposed NMHC Standard

Meeting the NMHC standards proposed today should not present any special challenges to diesel manufacturers. Since all of the devices discussed above—catalyzed particulate filters, NO_X adsorbers, and SCR—contain platinum and other precious metals to oxidize NO to NO_2, they are also very efficient oxidizers of hydrocarbons. Reductions of greater than 95 percent have been shown over transient FTP and supplemental steady-state modes.[106] Given that typical engine-out NMHC is expected to be in the 0.2 g/bhp-hr range for engines meeting the 2004 standards, this level of NMHC reduction will easily allow the 0.14 g/bhp-hr NMHC standard to be met over the transient FTP, the supplemental steady-state test, and the NTE zone.

d. Meeting the Crankcase Emissions Requirements

The most common way to eliminate crankcase emissions has been to vent the blow-by gases into the engine air intake system, so that the gases can be recombusted. Until today's proposal, we have required that crankcase emissions be controlled only on naturally aspirated diesel engines. We have made an exception for turbocharged heavy-duty diesel engines because of concerns in the past about fouling that could occur by routing the diesel particulates (including engine oil) into the turbocharger and aftercooler. However, this is an environmentally significant exception since most heavy-duty diesel trucks use turbocharged engines, and a single engine can emit over 100 pounds of NO_X, NMHC, and PM from the crankcase over the lifetime of the engine.

Therefore, we have proposed to eliminate this exception. We anticipate that the heavy-duty diesel engine manufacturers will be able to control crankcase emissions through the use of closed crankcase filtration systems or by routing unfiltered blow-by gases directly into the exhaust system upstream of the emission control equipment. The closed crankcase filtration systems work by separating oil and particulate matter from the blow-by gases through single or dual stage filtration approaches, routing the blow-by gases into the engine's intake manifold and returning the filtered oil to the oil sump. These systems are required for new heavy-duty diesel vehicles in Europe starting this year. Oil separation efficiencies in excess of 90 percent have been demonstrated with production ready prototypes of two stage filtration systems.[107] By eliminating 90 percent of the oil that would normally be vented to the atmosphere, the system works to reduce oil consumption and to eliminate concerns over fouling of the intake system when the gases are routed through the turbocharger. An alternative approach would be to route the blow-by gases into the exhaust system upstream of the catalyzed diesel particulate filter which would be expected to effectively trap and oxidize the engine oil and diesel PM. This approach may require the use of low sulfur engine oil to ensure that oil carried in the blow-by gases does not compromise the performance of the sulfur sensitive emission control equipment. We request comment on the use of either approach to crankcase emissions control.

e. The Complete System

We expect that the technologies described above would be integrated into a complete emission control system. The engine-out emissions will be traded off against the exhaust emission control package in such a way that the result is the most beneficial from a cost, fuel economy and emissions standpoint. The engine-out characteristics will also have to be tailored to the needs of the exhaust emission control devices used. The NO_X adsorber, for instance, will require periods of oxygen depleted exhaust flow in order to regenerate. This may be most efficiently done by reducing the air-fuel ratio that the engine is operating under during the regeneration to reduce the oxygen content of the exhaust. Further, it is envisioned that the PM device will be integrated into the exhaust system upstream of the NO_X reduction device. This placement would allow the PM trap to take advantage of the engine-out NO_X as an oxidant for the particulate, while removing the particulate so that the NO_X exhaust emission control device will not have to deal with large PM deposits which may cause a deterioration in performance. Of course, there is also the possibility of integrating the PM and NO_X exhaust emission control devices into a single unit to replace a muffler and save space. Particulate free exhaust may also allow for new options in EGR system design to optimize its efficiency.

We expect that the exhaust emission control emission reduction efficiency will vary with temperature and space velocity [108] across the NTE zone. Consequently, to maintain the NTE emission cap, the engine-out emissions would have to be calibrated with exhaust emission control performance characteristics in mind. This would be accomplished by lowering engine-out emissions where the exhaust emission control was less efficient. Conversely, where the exhaust emission control is very efficient at reducing emissions, the engine-out emissions could be tuned for higher emissions and better fuel economy. These trade-offs between engine-out emissions and exhaust emission control performance characteristics are similar to those of gasoline engines with three-way catalysts in today's light-duty vehicles. Managing and optimizing these trade-offs will be crucial to effective implementation of exhaust emission control devices on diesel applications.

2. Feasibility of Stringent Standards for Heavy-Duty Gasoline

Gasoline emission control technology has evolved rapidly in recent years. Emission standards applicable to 1990 model year vehicles required roughly 90 percent reductions in exhaust NMHC and CO emissions and a 75 percent reduction in NO_X emissions compared to uncontrolled emissions. Today, some vehicles' emissions are well below those necessary to meet the current federal heavy-duty gasoline standards, the proposed 2004 heavy-duty gasoline standards, and the California Low-Emission Vehicle standards for medium-duty vehicles. The continuing emissions reductions have been brought about by ongoing improvements in engine air-fuel management hardware and software plus improvements in exhaust system and catalyst designs.

We believe that the types of changes being seen on current vehicles have not yet reached their technological limits and continuing improvement will allow them to meet today's proposed standards. The Draft RIA describes a range of specific emission control techniques that we believe could be used. There is no need to invent new technologies, although there will be a need to apply existing technology more effectively and more broadly. The focus of the effort will be in the application and optimization of these existing technologies.

[106] ''The Impact of Sulfur in Diesel Fuel on Catalyst Emission Control Technology,'' report by the Manufacturers of Emission Controls Association, March 15, 1999, pp. 9 & 11.

[107] Letter from Marty Barris Donaldson Corporation to Byron Bunker US EPA, March 2000. EPA Air Docket A–99–06.

[108] The term, ''space velocity,'' is a measure of the volume of exhaust gas that flows through a device.

In our light-duty Tier 2 rule, we have required that gasoline sulfur levels be reduced to a 30 ppm average, with an 80 ppm maximum. This sulfur level reduction is the primary enabler for the Tier 2 standards. Similarly, we believe that the gasoline sulfur reduction, along with refinements in existing gasoline emission control technology, will be sufficient to allow heavy-duty gasoline vehicles and engines to meet the emission standards sought by today's proposal.

However, we recognize that the emission standards are stringent, and considerable effort would have to be undertaken. For example, we expect that every engine would have to be recalibrated to improve upon its cold start emission performance. Manufacturers would have to migrate their light-duty calibration approaches to their heavy-duty offerings to provide cold start performance in line with what they will have to achieve to meet the Tier 2 standards.

We also project that the proposed 2007 heavy-duty standards would require the application of advanced engine and catalyst systems similar to those projected for their light-duty counterparts. Historically, manufacturers have introduced technology on light-duty gasoline applications and then applied those technologies to their heavy-duty gasoline applications. The proposal would allow manufacturers to take this same approach for 2007. In other words, we expect that manufacturers would meet the proposed 2007 standards through the application of technology developed to meet light-duty Tier 2 standards for 2004.

Improved calibration and systems management would be critical in optimizing the performance of the engine with the advanced catalyst system. Precise air/fuel control must be tailored for emissions performance and must be optimized for both FTP and SFTP type driving. Calibration refinements may also be needed for EGR system optimization and to reduce cold start emissions through methods such as spark timing retard. We also project that electronic control modules with expanded capabilities would be needed on some vehicles and engines.

We also expect increased use of other technologies in conjunction with those described above. We expect some increased use of air injection to improve upon cold start emissions. We may also see air-gap manifolds, exhaust pipes, and catalytic converter shells as a means of improving upon catalyst light-off times thereby reducing cold start emissions. Other, non-catalyst related improvements to gasoline emission control technology include, as already stated, higher speed computer processors which enable more sophisticated engine control algorithms and improved fuel injectors providing better fuel atomization thereby improving fuel combustion.

Catalyst system durability is, and will always be, a serious concern. Historically, catalysts have deteriorated when exposed to very high temperatures. This has long been a concern especially for heavy-duty work vehicles. However, catalyst manufacturers continue to make strides in the area of thermal stability and we expect that improvements in thermal stability will continue for the next generation of catalysts.

We believe that, by optimizing all of these technologies, manufacturers will be able to achieve the proposed emission levels. Advanced catalyst systems have already shown potential to reduce emissions to close to the proposed levels. Some current California vehicles are certified to levels below 0.2 g/mi NO_X. California tested an advanced catalyst system on a vehicle loaded to a test weight comparable to a heavy-duty vehicle test weight and achieved NO_X and NMOG levels of 0.1 g/mi and 0.16 g/mi, respectively. The California vehicle with the advanced catalyst had not been optimized as a system to take full advantage of the catalyst's capabilities.

The ABT program can also be an important tool for manufacturers in implementing a new standard. The program allows manufacturers to transition to the more stringent standards by introducing emissions controls over a longer period of time, as opposed to a single model year. Manufacturers plan their product introductions well in advance. With ABT, manufacturers can better manage their product lines so that the new standards don't interrupt their product introduction plans. Also, the program allows manufacturers to focus on higher sales volume vehicles first and use credits for low sales volume vehicles.

We request comment on the feasibility of the proposed standards and request data that would help us evaluate advanced system durability.

3. Feasibility of the Proposed Evaporative Emission Standards

The proposed evaporative emission standards appear to be feasible now. Many designs have been certified that already meet these standards. A review of 1998 model year certification data indicates that five of eight evaporative system families in the 8,500 to 14,000 pound range comply with the proposed 1.4 g/test standard, while all evaporative system families in the over 14,000 pound range comply with the proposed 1.9 g/test standard.

The proposed evaporative emission standards would not require the development of new materials or, in many cases, even the new application of existing materials. Low permeability materials and low loss connections and seals are already used to varying degrees on current vehicles. Today's proposed standards would likely ensure their consistent use and discourage manufacturers from switching to cheaper materials or designs to take advantage of the large safety margins they have under current standards.

There are two approaches to reducing evaporative emissions for a given fuel. One is to minimize the potential for permeation and leakage by reducing the number of hoses, fittings and connections. The second is to use less permeable hoses and lower loss fittings and connections. Manufacturers are already employing both approaches.

Most manufacturers are moving to ''returnless'' fuel injection systems. Through more precise fuel pumping and metering, these systems eliminate the return line in the fuel injection system. The return line carries unneeded fuel from the fuel injectors back to the fuel tank. Because the fuel injectors are in such close contact with the hot engine, the fuel returned from the injectors to the fuel tank has been heated. This returned fuel is a significant source of fuel tank heat and vapor generation. The elimination of the return line also reduces the total length of hose on the vehicle through which vapors can permeate, and it reduces the number of fittings and connections through which fuel can leak.

Low permeability hoses and seals, and low loss fittings are available and are already used on many vehicles. Fluoropolymer materials can be added as liners to hose and component materials to yield large reductions in permeability over such conventional materials as monowall nylon. In addition, fluoropolymer materials can greatly reduce the adverse impact of alcohols in gasoline on permeability of evaporative components, hoses and seals.

F. Need for Low-Sulfur Diesel Fuel

The following discussion will build upon the brief sulfur sensitivity points made earlier in this section by providing a more in depth discussion of sulfur's effect on the most promising diesel exhaust emission control technologies. In order to evaluate the effect of sulfur

on diesel exhaust control technologies, we used three key factors to categorize the impact of sulfur in fuel on emission control function. These factors were efficiency, reliability, and fuel economy. Taken together these three factors lead us to believe that diesel fuel sulfur levels of 15 ppm will be required in order to make feasible the proposed heavy-duty vehicle emission standards (a discussion of higher sulfur fuel standards, and what they might mean is included in Section VI.B). Brief summaries of these factors are provided below. A more in-depth review is given in the following subsections and the RIA associated with this proposal.

The **efficiency** of emission control technologies to reduce harmful pollutants is directly affected by sulfur in diesel fuel. Initial and long term conversion efficiencies for NO_X, NMHC, CO and diesel PM emissions are significantly reduced by catalyst poisoning and catalyst inhibition due to sulfur. NO_X conversion efficiencies with the NO_X adsorber technology in particular are dramatically reduced in a very short time due to sulfur poisoning of the NO_X storage bed. In addition, total PM control efficiency is negatively impacted by the formation of sulfate PM. As explained in detail in the following sections, all of the advanced NO_X and PM technologies described here have the potential to make significant amounts of sulfate PM under operating conditions typical of heavy-duty vehicles. The formation of sulfate PM is likely to be in excess of the total PM standard proposed today, unless diesel fuel sulfur levels are at or below 15 ppm. Based on the strong negative impact of sulfur on emission control efficiencies for all of the technologies evaluated, we believe that 15 ppm represents an upper threshold of acceptable diesel fuel sulfur levels.

Reliability refers to the expectation that emission control technologies must continue to function as required under all operating conditions for the life of the vehicle. As discussed in the following sections, sulfur in diesel fuel can prevent proper operation of both NO_X and PM control technologies. This can lead to permanent loss in emission control effectiveness and even catastrophic failure of the systems. Sulfur in diesel fuel impacts reliability by decreasing catalyst efficiency (poisoning of the catalyst), increasing diesel particulate filter loading, and negatively impacting system regeneration functions. Among the most serious reliability concerns with sulfur levels greater than 15 ppm are those associated with failure to properly regenerate. In the case of the NO_X adsorber, failure to regenerate will lead to rapid loss of NO_X emission control as a result of sulfur poisoning of the NO_X adsorber bed. In the case of the diesel particulate filter, sulfur in the fuel reduces the reliability of the regeneration function. If regeneration does not occur, catastrophic failure of the filter could occur. It is only by the availability of very low-sulfur diesel fuels that these technologies become feasible. The analysis given in the following section makes clear that diesel fuel sulfur levels will need to be consistent with today's proposed standard in order to ensure robust operation of the technologies under the variety of operating conditions anticipated to be experienced in the field.

Fuel economy impacts due to sulfur in diesel fuel affect both NO_X and PM control technologies. The NO_X adsorber sulfur regeneration cycle (desulfation cycle) can consume significant amounts of fuel unless fuel sulfur levels are very low. The larger the amount of sulfur in diesel fuel, the greater the adverse effect on fuel economy. As sulfur levels increase above 15 ppm, the adverse effect on fuel economy becomes more significant, increasing above one percent and doubling with each doubling of fuel sulfur level. Likewise, PM trap regeneration is inhibited by sulfur in diesel fuel. This leads to increased PM loading in the diesel particulate filter and increased work to pump exhaust across this restriction. With very low sulfur diesel fuel, diesel particulate filter regeneration can be optimized to give a lower (on average) exhaust backpressure and thus better fuel economy. Thus for both NO_X and PM technologies the lower the fuel sulfur level the better.

1. Diesel Particulate Filters and the Need for Low-Sulfur Fuel

As discussed earlier in this section, un-catalyzed diesel particulate filters require exhaust temperatures in excess of 650°C in order for the collected PM to be oxidized by the oxygen available in diesel exhaust. That temperature threshold for oxidation of PM by exhaust oxygen can be decreased to 450°C through the use of base metal catalytic technologies. Unfortunately, for a broad range of operating conditions diesel exhaust is significantly cooler than 400°C. If oxidation of the trapped PM could be assured to occur at exhaust temperatures lower than 300°C, then diesel particulate filters would be expected to be robust for most applications and operating regimes. The only means that we are aware of to ensure oxidation of PM (regeneration of the trap) at such low exhaust temperatures is by using oxidants which are more readily reduced than oxygen. One such oxidant is NO_2.

NO_2 can be produced in diesel exhaust through the oxidation of the nitrogen monoxide (NO), created in the engine combustion process, across a catalyst. The resulting NO_2-rich exhaust is highly oxidizing in nature and can oxidize trapped diesel PM at temperatures as cool as 250°C.[109] Some platinum group metals are known to be good catalysts to promote the oxidation of NO to NO_2. Therefore in order to ensure passive regeneration of the diesel particulate filters, significant amounts of platinum group metals (primarily platinum) are being used in the wash-coat formulations of advanced diesel particulate filters. The use of platinum to promote the oxidation of NO to NO_2 introduces several system vulnerabilities affecting both the durability and the effectiveness of the catalyzed diesel particulate filter when sulfur is present in diesel exhaust. The two primary mechanisms by which sulfur in diesel fuel limits the robustness and effectiveness of diesel particulate filters are inhibition of trap regeneration (i.e., inhibition of the oxidation of NO to NO_2) and a dramatic loss in total PM control effectiveness due to the formation of sulfate PM. Unfortunately, these two mechanisms trade-off against one another in the design of diesel particulate filters. Changes to improve the reliability of regeneration by increasing catalyst loadings lead to increased sulfate emissions and thus loss of PM control effectiveness. Conversely, changes to improve PM control by reducing the use of platinum group metals and, therefore, limiting ''sulfate make'' leads to less reliable regeneration. We believe the only means of achieving good PM emission control and reliable operation is to reduce sulfur in diesel fuel to the level proposed today, as shown in the following subsections.

a. Inhibition of Trap Regeneration Due to Sulfur

The passively regenerating diesel particulate filter technologies rely on the generation of a very strong oxidant, NO_2, to ensure that the carbon captured by the PM trap's filtering media is oxidized under normal operating conditions. NO_2 is produced through the oxidation of NO in the exhaust across a platinum catalyst. This oxidation is inhibited by the presence of

[109] Hawker, P. et al, Experience with a New Particulate Trap Technology in Europe, SAE 970182.

SO_2 in the exhaust stream because the preferential reaction across the platinum is oxidation of SO_2 to SO_3, rather than oxidation of NO to NO_2.[110] This inhibition limits the total amount of NO_2 available for oxidation of the trapped diesel PM, thereby raising the minimum exhaust temperature required to ensure trap regeneration. Without sufficient NO_2, the amount of PM trapped in the diesel particulate filter will continue to increase and can lead to excessive exhaust back pressure, low engine power, and even catastrophic failure of the diesel particulate filter itself.

Full field test evaluations and retrofit applications of these catalytic trap technologies are occurring in parts of Europe where low-sulfur diesel fuel is already available.[111] The experience gained in these field tests helps to clarify the need for very low-sulfur diesel fuel. In Sweden and some European city centers where below 10 ppm diesel fuel sulfur is readily available, more than 3,000 catalyzed diesel particulate filters have been introduced into retrofit applications without a single failure. Given the large number of vehicles participating in these test programs and the extended time periods of operation (some vehicles have been operating with traps for more than 4 years and in excess of 300,000 miles [112]), this is a strong indication of the robustness of this technology on 10 ppm low-sulfur diesel fuel. The field experience in areas where sulfur is capped at 50 ppm has been less definitive. In regions without extended periods of cold ambient conditions, such as the United Kingdom, field tests on 50 ppm cap low-sulfur fuel have also been positive, matching the success at 10 ppm. However, field tests in Finland where colder winter conditions are sometimes encountered (similar to many parts of the United States) have revealed a failure rate of 10 percent. This 10 percent failure rate has been attributed to insufficient trap regeneration due to fuel sulfur in combination with low ambient temperatures.[113] As the ambient conditions in Sweden are expected to be no less harsh than Finland, we are left to conclude that the increased failure rates noted here are due to the higher fuel sulfur level in a 50 ppm cap fuel versus a 10 ppm cap fuel. The failure of some fraction of the traps to regenerate on 50 ppm cap fuel is believed to be primarily due to inhibition of the NO to NO_2 conversion as described here.

The failure mechanisms experienced by diesel particulate filters due to low NO_2 availability vary significantly in severity and long term consequences. In the most fundamental sense, the failure is defined as an inability to oxidize the stored particulate at a rate fast enough to prevent net particulate accumulation over time. The excessive accumulation of PM over time blocks the passages through the filtering media, making it more restrictive to exhaust flow. In order to continue to force the exhaust through the now more restrictive filter the exhaust pressure upstream of the filter must increase. This increase in exhaust pressure is commonly referred to as increasing ''exhaust backpressure'' on the engine.

The increased exhaust backpressure represents increased work being done by the engine to force the exhaust gas through the increasingly restrictive particulate filter. Unless the filter is frequently cleansed of the trapped PM, this increased work can lead to reductions in engine performance and increases in fuel consumption. This loss in performance may be noted by the vehicle operator in terms of poor acceleration and generally poor driveability of the vehicle. In some cases, engine performance can be so restricted that the engine stalls, stranding the vehicle. This progressive deterioration of engine performance as more and more PM is accumulated in the filter media is often referred to as ''trap plugging.'' Trap plugging also has the potential to cause engine damage. If the exhaust backpressure gets high enough to open the exhaust valves prematurely, the exhaust valves can then strike the piston causing catastrophic engine failure. Whether trap plugging occurs, and the speed at which it occurs, will be a function of many variables in addition to the fuel sulfur level; these variables include the vehicle application, its duty cycle, and ambient conditions. However, if the fuel sulfur level is sufficient to prevent trap regeneration in any real world conditions experienced, trap plugging can occur. This is not to imply that any time a vehicle is refueled once with high sulfur fuel trap plugging will occur. Rather, it is important to know that the use of fuel with sulfur levels higher than 15 ppm significantly increases the chances of particulate filter failure.

Catastrophic failure of the filter can occur when excessive amounts of PM are trapped in the filter due to a lack of NO_2 for oxidation. This failure occurs when excessive amounts of trapped PM begin to oxidize at high temperatures (combustion-like temperatures of over 1000°C) leading to a ''run-away'' combustion of the PM. This can cause temperatures in the filter media to increase in excess of that which can be tolerated by the particulate filter itself. For the cordierite material commonly used as the trapping media for diesel particulate filters, the high thermal stresses caused by the high temperatures can cause the material to crack or melt. This can allow significant amounts of the diesel particulate to pass through the filter without being captured during the remainder of the vehicle's life. That is, the trap is destroyed and PM emission control is lost.

As shown above, sulfur in diesel fuel inhibits NO oxidation leading to increased exhaust backpressure, reduced fuel economy, compromised reliability, and potentially engine damage. Therefore, we believe that, in order to ensure reliable and economical operation over a wide range of expected operating conditions, diesel fuel sulfur levels should be at or below 15 ppm. With these very low sulfur levels we believe, as demonstrated by experience in Europe, that catalyzed diesel particulate filters will prove to be both durable and effective at controlling diesel particulate emissions to the very low levels that would be required by today's proposed standard. We request comment on the inhibition of trap regeneration due to fuel sulfur, along with supporting data.

b. Loss of PM Control Effectiveness

In addition to inhibiting the oxidation of NO to NO_2, the sulfur dioxide (SO_2) in the exhaust stream is itself oxidized to sulfur trioxide (SO_3) at very high conversion efficiencies by the precious metals in the catalyzed particulate filters. The SO_3 serves as a precursor to the formation of hydrated sulfuric acid (H_2SO_4+H_2O), or sulfate PM, as the exhaust leaves the vehicle tailpipe. Virtually all of the SO_3 is converted to sulfate under dilute exhaust conditions in the atmosphere as well in the dilution tunnel used in heavy-duty engine testing. Since virtually all sulfur present in diesel fuel is converted to SO_2, the precursor to SO_3, as part of the combustion process, the total sulfate PM is directly proportional to the amount of sulfur present in diesel fuel. Therefore, even though diesel particulate filters are very effective at trapping the carbon and the SOF portions of the total PM, the

[110] Hawker, P. et al, Experience with a New Particulate Trap Technology in Europe, SAE 970182.

[111] Through tax incentives 50 ppm cap sulfur fuel is widely available in the United Kingdom and 10 ppm sulfur fuel is available in Sweden and in certain European city centers.

[112] Allansson, et al. SAE 2000–01–0480.

[113] Letter from Dr. Barry Cooper, Johnson Matthey, to Don Kopinski, US EPA, Air Docket A–99–06.

overall PM reduction efficiency of catalyzed diesel particulate filters drops off rapidly with increasing sulfur levels due to the production of sulfate PM.

SO_2 oxidation is promoted across a catalyst in a manner very similar to the oxidation of NO, except it is converted at higher rates, with peak conversion rates in excess of 50 percent. The SO_2 oxidation rate for a platinum based oxidation catalyst typical of the type which might be used in conjunction with, or as a washcoat on, a catalyzed diesel particulate filter can vary significantly with exhaust temperature. At the low temperatures typical of some urban driving and the heavy-duty federal test procedure (HD–FTP), the oxidation rate is relatively low, perhaps no higher than ten percent. However at the higher temperatures that might be more typical of non-urban highway driving conditions and the Supplemental Steady State Test (also called the EURO III or 13 mode test), the oxidation rate may increase to 50 percent or more. These high levels of sulfate make across the catalyst are in contrast to the very low SO_2 oxidation rate typical of diesel engines (less than 2 percent). This variation in expected diesel exhaust temperatures means that there will be a corresponding range of sulfate production expected across a catalyzed diesel particulate filter.

The U.S. Department of Energy in cooperation with industry conducted a study entitled Diesel Emission Control Sulfur Effects (DECSE) to provide insight into the relationship between advanced emission control technologies and diesel fuel sulfur levels. Interim report number four of this program gives the total particulate matter emissions from a heavy-duty diesel engine operated with a diesel particulate filter on several different fuel sulfur levels. A straight line fit through this data is presented in Table III.F–1 below showing the expected total direct PM emissions from a heavy-duty diesel engine on the supplemental steady state test cycle.[114]

TABLE III.F–1.—ESTIMATED PM EMISSIONS FROM A HEAVY-DUTY DIESEL ENGINE AT THE INDICATED AVERAGE FUEL SULFUR LEVELS

Avg. Fuel Sulfur [ppm]	Supplemental steady state	
	Tailpipe PM [g/bhp-hr]	Relative to 3 ppm sulfur
3	0.003	
7*	0.006	100%
15*	0.009	200%
30	0.017	470%
150	0.071	2,300%

*The PM emissions at these sulfur levels are based on a straight-line fit to the DECSE data; PM emissions at other sulfur levels are actual DECSE data. (Diesel Emission Control Sulfur Effects (DECSE) Program—Phase II Interim Data Report No. 4, Diesel Particulate Filters-Final Report, January 2000, Table C1.) Although DECSE tested diesel particulate filters at these fuel sulfur levels, they do not conclude that the technology is feasible at all levels, but they do note that testing at 150 ppm is a moot point as the emission levels exceed the engine's baseline emission level.

Table III.F–1 makes it clear that there are significant PM emission reductions possible with the application of catalyzed diesel particulate filters and low-sulfur diesel fuel. At the observed sulfate PM conversion rates, the DECSE program results show that the proposed total PM standard is feasible for diesel particulate filter equipped engines operated on fuel with a sulfur level at or below 15 ppm. The results also show that diesel particulate filter control effectiveness is rapidly degraded at higher diesel fuel sulfur levels due to the high sulfate PM make observed with this technology.

It is clear that PM reduction efficiencies are limited by sulfur in diesel fuel and that, in order to realize the PM emissions benefits sought in this rule, diesel fuel sulfur levels must be as low as possible. As discussed in Section IV, we believe that a 15 ppm sulfur cap for highway diesel fuel is the correct level given consideration to all factors. We request comment on the loss of PM control effectiveness due to fuel sulfur along with supportive data.

c. Increased Maintenance Cost for Diesel Particulate Filters Due to Sulfur

In addition to the direct performance and durability concerns caused by sulfur in diesel fuel, it is also known that sulfur can lead to increased maintenance costs, shortened maintenance intervals, and poorer fuel economy for particulate filters. Diesel particulate filters are highly effective at capturing the inorganic ash produced from metallic additives in engine oil. This ash is accumulated in the filter and is not removed through oxidation, unlike the trapped carbonaceous PM. Periodically the ash must be removed by mechanical cleaning of the filter with compressed air or water. This maintenance step is anticipated to occur on intervals of well over one hundred thousand miles. However, sulfur in diesel fuel increases this ash accumulation rate through the formation of metallic sulfates in the filter, which increases both the size and mass of the trapped ash. By increasing the ash accumulation rate, the sulfur shortens the time interval between the required maintenance of the filter and negatively impacts fuel economy. We request comment on the issue of PM filter maintenance costs and maintenance intervals along with supportive data.

2. Diesel NO_X Catalysts and the Need for Low-Sulfur Fuel

All of the NO_X exhaust emission control technologies discussed previously in Section III are expected to utilize platinum to oxidize NO to NO_2 to improve the NO_X reduction efficiency of the catalysts at low temperatures or as in the case of the NO_X adsorber, as an essential part of the process of NO_X storage. This reliance on NO_2 as an integral part of the reduction process means that the NO_X exhaust emission control technologies, like the PM exhaust emission control technologies, will have problems with sulfur in diesel fuel. In addition NO_X adsorbers have the added constraint that the adsorption function itself is blocked by the presence of sulfur. These limitations due to sulfur in the fuel affect both overall performance of the technologies and, in fact, the very feasibility of the NO_X adsorber technology.

a. Sulfate Particulate Production for NO_X Control Technologies

Two advanced NO_X control technologies that are likely to be able to meet the NO_X emission standard being proposed today are advanced NO_X adsorber catalyst systems and advanced Compact-SCR systems. The NO_X adsorber technology relies on an oxidation function to convert NO to NO_2 over the catalyst bed. For the NO_X adsorber this is a fundamental step prior to the storage of NO_2 in the catalyst bed as a nitrate. Without this oxidation function the catalyst will only trap that small portion of NO_X emissions from a diesel engine which is NO_2. This would reduce the NO_X adsorber effectiveness for NO_X reduction from in excess of 90 percent to something well below 20 percent. The NO_X adsorber relies on platinum to provide this oxidation function due to the need for high NO

[114] Note that direct emissions are those pollutants emitted directly from the engine or from the tailpipe depending on the context in which the term is used, and indirect emissions are those pollutants formed in the atmosphere through the combination of direct emissions and atmospheric constituents.

oxidation rates under the relatively cool exhaust temperatures typical of diesel engines.

The Compact-SCR technology, like the NO_X adsorber technology, uses an oxidation catalyst to promote the oxidation of NO to NO_2 at the low temperatures typical of much of diesel engine operation. By converting a portion of the NO_X emissions to NO_2 upstream of the ammonia SCR reduction catalyst, the overall NO_X reductions are improved significantly at low temperatures. As discussed previously in section III, platinum group metals, primarily platinum, are known to be good catalysts to promote NO oxidation, even at low temperatures. Therefore, future Compact-SCR systems are expected to rely on a platinum oxidation catalyst in order to provide the required NO_X emission control.

The NO_X adsorber technology may be able to limit its impact on sulfate PM emissions by releasing stored sulfur as SO_2 under rich operating conditions. The Compact-SCR technology, on the other hand, has no means to limit sulfate emissions other than through lower catalytic function or lowering sulfur in diesel fuel. The degree to which the NO_X control aftertreatment technologies increase the production of sulfate PM through oxidation of SO_2 to SO_3 varies somewhat from technology to technology, but it is expected to be similar in magnitude and environmental impact to that for the PM control technologies discussed previously. Thus, we believe that diesel fuel sulfur levels will likely need to be below 15 ppm in order to apply these advanced NO_X control technologies (see discussion in section III.F.1). Without this low-sulfur fuel, the advanced NO_X control technologies are expected to create PM emissions in excess of the PM standard regardless of the engine-out PM levels. We invite comment on sulfate PM production by NO_X control technologies due to fuel sulfur along with supportive data.

b. Sulfur Poisoning (Sulfate Storage) on NO_X Adsorbers

The NO_X adsorber technology relies on the ability of the catalyst to store NO_X as a nitrate on the surface of the catalyst, or adsorber (storage) bed, during lean operation. Because of the similarities in chemical properties of SO_X and NO_X, the SO_2 present in the exhaust is also stored by the catalyst surface as a sulfate. The sulfate compound that is formed is significantly more stable than the nitrate compound and is not released and reduced during the NO_X release and reduction step. Since the NO_X adsorber is essentially 100 percent effective at capturing SO_2 in the adsorber bed, the poisoning of the catalyst occurs rapidly. As a result, sulfate compounds quickly occupy all of the NO_X storage sites on the catalyst thereby rendering the catalyst ineffective for NO_X reduction (poisoning the catalyst).

The stored sulfur compounds can be removed by exposing the catalyst to hot (over 650 °C) and rich (air-fuel ratio below the stoichiometric ratio of 14.5 to 1) conditions for a brief period.[115] [116] Under these conditions, the stored sulfate is released and reduced in the catalyst.[117] Because the exhaust must be taken to a hot and rich condition, there is a fuel consumption impact associated with the desulfation cycle. We have developed a spreadsheet model that estimates the frequency of desulfation cycles from published data and then estimates the fuel economy impact from this event.[118] Table III–F.2 shows the estimated fuel economy impact for desulfation of a NO_X adsorber at different fuel sulfur levels assuming a desired 90 percent NO_X conversion efficiency. The estimates in the table are based on assumed average fuel sulfur levels associated with different sulfur level caps.

TABLE III.F–2.—ESTIMATED FUEL ECONOMY IMPACT FROM DESULFATION OF A 90% EFFICIENT NO_X ADSORBER

Fuel sulfur cap [ppm]	Average fuel sulfur [ppm]	Fuel economy penalty
500	350	27%
50	30	2%
25	15	1%
15	7	<1%
5	2	<<<1%

The table highlights that the fuel economy penalty associated with sulfur in diesel fuel is noticeable even at average sulfur levels as low as 15 ppm and increases rapidly with higher sulfur levels. It also shows that the use of a NO_X adsorber at the proposed 15 ppm sulfur cap would be expected to result in a fuel economy impact of less than 1 percent absent other changes in engine design. However, as discussed in Section G below, we anticipate that other engine modifications could be made to offset this fuel economy impact. For example, a NO_X control device in the exhaust system could allow use of fuel saving engine strategies, such as advanced fuel injection timing, that could be used to offset the increased fuel consumption associated with the NO_X adsorber. The result is that low-sulfur fuel enables the NO_X adsorber, which in turn enables fuel saving engine modifications. Such a system level fuel economy impact, which we estimate to be zero under a 15 ppm cap program, is discussed below in section III.G.

Future improvements in the NO_X adsorber technology are expected and needed if the technology is to provide the environmental benefits we have projected today. Some of these improvements are likely to include improvements in the means and ease of removing stored sulfur from the catalyst bed. However because the stored sulfate species are inherently more stable than the stored nitrate compounds (from stored NO_X emissions), we expect that a separate release and reduction cycle (desulfation cycle) will always be needed in order to remove the stored sulfur. Therefore, we believe that fuel with a sulfur level at or below 15 ppm sulfur will be necessary in order to avoid an unacceptable fuel economy impact. We request comment on sulfur poisoning of NO_X adsorbers by fuel sulfur along with supportive data.

c. Sulfur Impacts on Catalytic Efficiency

The technologies discussed in today's proposal generally rely on some form of catalytic function in order to promote favorable chemical reactions needed in order to accomplish the desired NO_X emission reductions. In each case platinum and/or other precious group metal catalysts are anticipated to be used to accomplish these functions. From our experience with gasoline three-way catalysts and from the extensive body of work in the literature we know that these catalytic functions are inhibited by sulfur. Sulfur deposits on the precious metal sites in the catalyst and causes a decrease in the catalytic function of the device. This causes an increase in the light-off temperature for the catalyst along with a significant reduction in the oxidation and reduction efficiencies of all of the devices.[119] As discussed at length in the Tier 2 rulemaking, sulfur reductions in the fuel are a very effective way to reduce catalyst poisoning of this type in

[115] [Reserved]

[116] Dou, Danan and Bailey, Owen, ''Investigation of NO_X Adsorber Catalyst Deactivation,'' SAE 982594.

[117] Guyon, M. et al., ''Impact of Sulfur on NO_X Trap Catalyst Activity—Study of the Regeneration Conditions,'' SAE 982607.

[118] Memo from Byron Bunker, to docket A–99–06, ''Estimating Fuel Economy Impacts of NO_X Adsorber De-Sulfurization.''

[119] The Impact of Sulfur in Diesel Fuel on Catalyst Emissions Control Technology—Manufacturers of Emission Controls Association (MECA), March 15, 1999, www.meca.org.

order to maintain high catalyst efficiency and to ensure reliable operation. We invite comment on fuel sulfur impact on catalyst efficiency along with supportive data.

3. What About Sulfur in Engine Lubricating Oils?

Current engine lubricating oils have sulfur contents which can range from 2,500 ppm to as high as 8,000 ppm by weight. Since engine oil is consumed by heavy-duty diesel engines in normal operation, it is important that we account for the contribution of oil derived sulfur in our analysis of the need for low-sulfur diesel fuel. One way to give a straightforward comparison of this effect is to express the sulfur consumed by the engine as an equivalent fuel sulfur level. This approach requires that we assume specific fuel and oil consumption rates for the engine. Using this approach, estimates ranging from two to seven ppm diesel fuel sulfur equivalence have been made for the sulfur contribution from engine oil.[120, 121] If values at the upper end of this range accurately reflect the contribution of sulfur from engine oil to the exhaust this would be a concern as it would represent 50 percent of the total sulfur in the exhaust under a 15 ppm diesel fuel sulfur cap (with an average sulfur level assumed to be approximately seven ppm). However, we believe that this simplified analysis, while valuable in demonstrating the need to investigate this issue further, overstates the likely sulfur contribution from engine oil by a significant amount.

Current heavy-duty diesel engines operate with open crankcase ventilation systems which ''consume'' oil by carrying oil from the engine crankcase into the environment. This consumed oil is correctly included in the total oil consumption estimates, but should not be included in estimates of oil entering the exhaust system for this analysis, since as currently applied this oil is not introduced into the exhaust. At present we estimate that the majority of lube oil consumed by an engine meeting the 0.1 g/bhp-hr PM standard is lost through crankcase ventilation, rather than through the exhaust. Based on assumed engine oil to PM conversion rates and historic soluble organic fraction breakdowns we have estimated the contribution of sulfur from engine oil to be less than two ppm fuel equivalency. With the proposal today to close the crankcase, coupled with the use of closed crankcase ventilation systems that separate in excess of 90 percent of the oil from the blow-by gases, we believe that this very low contribution of lube oil to sulfur in the exhaust can be maintained. For a further discussion of our estimates of the sulfur contribution from engine oil refer to the draft RIA associated with this proposal.

Although there are good indications to date that oil borne sulfur is not a significant contributor to exhaust sulfur, EPA remains concerned about this issue. We invite comment on the potential for engine lubricating oils to introduce significant amounts of sulfur into the exhaust. Of particular value to EPA is data indicating the expected oil consumption rates of future engines and estimates of future engine oil characteristics specifically with regard to sulfur content. We also invite comment on the potential for new ''low-sulfur'' engine oils to be developed for these vehicles equipped with sulfur sensitive emission control technologies.

G. Fuel Economy Impact of Advanced Emission Control Technologies

The advanced emission control technologies expected to be applied in order to meet the proposed NO_X and PM standards involve wholly new system components integrated into engine designs and calibrations, and as such may be expected to change the fuel consumption characteristics of the overall engine design. After reviewing the likely technology options available to the engine manufacturers, we believe that the integration of the engine and exhaust emission control systems into a single synergistic emission control system will lead to heavy-duty vehicles which can meet demanding emission control targets without increasing fuel consumption beyond today's levels.

1. Diesel Particulate Filters and Fuel Economy

Diesel particulate filters are anticipated to provide a step-wise decrease in diesel particulate (PM) emissions by trapping and oxidizing the diesel PM. The trapping of the very fine diesel PM is accomplished by forcing the exhaust through a porous filtering media with extremely small openings and long path lengths.[122] This approach results in filtering efficiencies for diesel PM greater than 90 percent but requires additional pumping work to force the exhaust through these small openings. The additional pumping work is anticipated to increase fuel consumption by approximately one percent.[123] However, we believe this fuel economy impact can be regained through optimization of the engine-PM trap-NO_X adsorber system, as discussed below. We request comment and data on the magnitude of the fuel economy impact of diesel particulate filters.

2. NO_X Control Technologies and Fuel Economy

NO_X adsorbers are expected to be the primary NO_X control technology introduced in order to provide the reduction in NO_X emissions envisioned in this proposal. NO_X adsorbers work by storing NO_X emissions under fuel lean operating conditions (normal diesel engine operating conditions) and then by releasing and reducing the stored NO_X emissions over a brief period of fuel rich engine operation. This brief periodic NO_X release and reduction step is directly analogous to the catalytic reduction of NO_X over a gasoline three-way-catalyst. In order for this catalyst function to occur the engine exhaust constituents and conditions must be similar to normal gasoline exhaust constituents. That is, the exhaust must be fuel rich (devoid of excess oxygen) and hot (over 250C). Although it is anticipated that diesel engines can be made to operate in this way, it is assumed that fuel economy while operating under these conditions will be worse than normal. We have estimated that the fuel economy impact of the NO_X release and reduction cycle would, all other things being equal, increase fuel consumption by approximately one percent. Again, we believe this fuel economy impact can be regained through optimization of the engine-PM trap-NO_X adsorber system, as discussed below.

In addition to the NO_X release and regeneration event, another step in NO_X adsorber operation may affect fuel economy. As discussed earlier, NO_X adsorbers are poisoned by sulfur in the fuel even at the low sulfur levels we are proposing. As discussed in the draft RIA, we anticipate that the sulfur poisoning of the NO_X adsorber can be reversed through a periodic ''desulfation'' event. The desulfation of the NO_X adsorber is accomplished in a similar manner to the NO_X release and regeneration cycle described above. However it is anticipated that the

[120] Whitacre, Shawn. ''Catalyst Compatible'' Diesel Engine Oils, DECSE Phase II, Presentation at DOE/NREL Workshop ''Exploring Low Emission Diesel Engine Oils.'' January 31, 2000.

[121] This estimate assumes that a heavy-duty diesel engine consumes 1 quart of engine oil in 2,000 miles of operation, consumes fuel at a rate of 1 gallon per 6 miles of operation and that engine oil sulfur levels range from 2,000 to 8,000 ppm.

[122] Typically the filtering media is a porous ceramic monolith or a metallic fiber mesh.

[123] Engine, Fuel, and Emissions Engineering, Incorporated, ''Economic Analysis of Diesel Aftertreatment System Changes Made Possible by Reduction of Diesel Fuel Sulfur Content,'' December 14, 1999, Air Docket A–99–06.

desulfation event will require extended operation of the diesel engine at rich conditions.[124] This rich operation will, like the NO_X regeneration event, require an increase in the fuel consumption rate and will cause an associated decrease in fuel economy. With a 15 ppm fuel sulfur cap, we are projecting that fuel consumption for desulfation would increase by one percent or less, which we believe can be regained through optimization of the engine-PM trap-NO_X adsorber system as discussed below.

While NO_X adsorbers require non-power producing consumption of diesel fuel in order to function properly and, therefore, have an impact on fuel economy, they are not unique among NO_X control technologies in this way. In fact NO_X adsorbers are likely to have a very favorable NO_X to fuel economy trade-off when compared to other NO_X control technologies like cooled EGR and injection timing retard that have historically been used to control NO_X emissions. EGR requires the delivery of exhaust gas from the exhaust manifold to the intake manifold of the engine and causes a decrease in fuel economy for two reasons. The first of these reasons is that a certain amount of work is required to pump the EGR from the exhaust manifold to the intake manifold; this necessitates the use of intake throttling or some other means to accomplish this pumping. The second of these reasons is that heat in the exhaust, which is normally partially recovered as work across the turbine of the turbocharger, is instead lost to the engine coolant through the cooled EGR heat exchanger. In the end, cooled EGR is only some 50 percent effective at reducing NO_X. Nonetheless, cooled EGR, which we anticipate to be the technology of choice for meeting the proposed 2004 heavy-duty standards, still has a considerable advantage over the previous solutions such as injection timing retard. Injection timing retard is the strategy that has historically been employed to control NO_X emissions. By retarding the introduction of fuel into the engine, and thus delaying the start of combustion, both the peak temperature and pressure of the combustion event are decreased; this lowers NO_X formation rates and, ultimately, NO_X emissions. Unfortunately, this also significantly decreases the thermal efficiency of the engine (decreases fuel economy) while also increasing PM emissions. As an example, retarding injection timing eight degrees can decrease NO_X emissions by 45 percent, but this occurs at a fuel economy penalty of more than seven percent.[125]

Today, most diesel engines rely on injection timing control (retarding injection timing) in order to meet the 4.0 g/bhp-hr NO_X emission standard. For 2002/2004 model year compliance, we expect that engine manufacturers will use a combination of cooled EGR and injection timing control to meet the 2.0 g/bhp-hr NO_X standard. Because of the more favorable fuel economy trade-off for NO_X control with EGR when compared to timing control, we have forecast that less reliance on timing control will be needed in 2002/2004. Therefore, fuel economy will not be changed even at this lower NO_X level.

NO_X adsorbers have a significantly more favorable NO_X to fuel economy trade-off when compared to cooled EGR or timing retard alone, or even when compared to cooled EGR and timing retard together.[126] We expect NO_X adsorbers to be able to accomplish greater than 90 percent reduction in NO_X emissions, while only increasing fuel consumption by a very reasonable two percent or less. Therefore, we expect manufacturers to take full advantage of the NO_X control capabilities of the NO_X adsorber and project that they will decrease reliance on the more expensive (from a fuel economy standpoint) technologies, especially injection timing retard. We would therefore predict, that the fuel economy impact currently associated with NO_X control from timing retard would be decreased by at least three percent. In other words, through the application of advanced NO_X exhaust emission control technologies, which are enabled by the use of low-sulfur diesel fuel, we expect the NO_X trade-off with fuel economy to continue to improve significantly when compared to today's technologies. This will result in both much lower NO_X emissions, and potentially overall improvements in fuel economy. Improvements could easily offset the fuel consumption of the NO_X adsorber itself and, in addition, the one percent fuel economy loss projected to result from the application of PM filters. Consequently, we are projecting no fuel economy penalty to result from this rule. We invite comment and data concerning the relationships between the various types of NO_X control technologies and fuel economy as described here and in the cited references. In particular we ask for comments and data on NO_X adsorber fuel economy and methods of recovering that fuel economy through injection timing changes.

3. Emission Control Systems for 2007 and Net Fuel Economy Impacts

We anticipate that, in order to meet the stringent NO_X and PM emission standards proposed today, the manufacturers would integrate engine-based emission control technologies and post-combustion emission control technologies into a single systems-based approach that would fundamentally shift historic trade-offs between emissions control and fuel economy. As outlined in the preceding two sections, individual components in this system would introduce new constraints and opportunities for improvements in fuel efficient control of emissions. Having considered the many opportunities to fundamentally improve these relationships, we believe that it is unlikely that fuel economy will be lower than today's levels and, in fact, may improve through the application of these new technologies and this new systems approach. Therefore, for our analysis of economic impacts in section V, no penalty or benefit for changes to fuel economy are considered. We request comment on our analysis of the likely fuel economy offsets of the NO_X and PM emission control technologies that would be needed in order to meet today's proposed standards.

H. Future Reassessment of Diesel NO_X Control Technology

We are considering conducting a future reassessment of diesel NO_X control technologies and associated fuel sulfur requirements, and we request comment on the need for such a reassessment. Given the relative state of development of NO_X emission control technology versus PM and NMHC control technologies, we would expect to focus the control technology reassessment solely on NO_X control technologies. We believe that the clear intent of this proposal to provide low-sulfur diesel fuel will allow the development of this technology to progress rapidly, and will result in systems capable of achieving the proposed standards. However, we acknowledge that our proposed NO_X standard represents an ambitious target for this technology, and that the degree of uncertainty surrounding the feasibility of high-efficiency NO_X control technology would be higher if

[124] Dou, D. and Bailey, O., ''Investigation of NO_X Adsorber Catalyst Deactivation'' SAE982594.

[125] Herzog, P. et al., NO_X Reduction Strategies for DI Diesel Engines, SAE 920470, Society of Automotive Engineers 1992 (from Figure 1).

[126] Zelenka, P. et al., Cooled EGR—A Key Technology for Future Efficient HD Diesels, SAE 980190, Society of Automotive Engineers 1998. Figure 2 from this paper gives a graphical representation of how new technologies (including aftertreatment technologies) can shift the trade-off between NO_X emissions and fuel economy.