SUMMARY OF BOARD ITEM

ITEM # 00-9-1: PUBLIC HEARING TO CONSIDER THE APPROVAL OF THE PROPOSED RISK REDUCTION PLAN FOR DIESEL-FUELED ENGINES AND VEHICLES

STAFF RECOMMENDATION: Staff recommends that the Board approve the Proposed Risk Reduction Plan for Diesel-Fueled Engines and Vehicles ("plan").

DISCUSSION: Particulate matter emissions from diesel-fueled vehicles and engines are about 28,000 tons per year in California. These emissions come from a wide variety of sources including over one million on-road and off-road vehicles, about 15,000 stationary engines, and close to 50,000 portable engines. On-road engines account for about 27% of the emissions, off-road engines about 66%, with the remaining 7% from stationary and portable engines.

In 1998, following an exhaustive 10-year scientific assessment process, the Air Resources Board (ARB or Board) identified particulate matter from diesel-fueled engines as a toxic air contaminant (TAC). On a statewide basis, the average potential cancer risk associated with these emissions is over 500 potential cases per million. Compared to other air toxics the Board has identified and controlled, diesel PM emissions are estimated to be responsible for about 70% of the total ambient air toxics risk. Diesel PM can also present elevated localized or near-source exposures. Depending on the activity and nearness to receptors, these potential risks can range from small to 1,500 per million or more. As a result of this significant potential risk, when the Board identified diesel PM as a TAC, it directed staff to convene an advisory committee of interested parties to engage in a dialogue on the steps that can be taken to reduce these emissions.

The Diesel Risk Reduction Plan (Diesel RRP) represents the staff's proposal for a comprehensive plan to significantly reduce diesel PM emissions.

The basic premise behind the plan is to require all new diesel-fueled engines and vehicles to use state-of-the-art catalyst-based diesel particulate filters (DPFs) and very low-sulfur diesel fuel. Further, all existing vehicles and engines should be evaluated, and wherever technically feasible and cost-effective, retrofitted with DPFs. As with new engines, very low-sulfur diesel fuel should be used by retrofitted vehicles and engines.

Diesel PM filter control technology is now available and has been demonstrated in over 20,000 applications worldwide. It is staff's vision that well before the end of this decade these filters will become as commonplace on diesel-fueled engines as catalysts are now on gasoline-fueled vehicles.

The Diesel RRP envisions four new regulations for on-road vehicles, four regulations for off-road equipment, five air toxic control measures for stationary and portable equipment, and a new Phase 2 diesel fuel regulation.

Upon the Board's approval of this comprehensive plan with its various control measures, staff will begin the full regulatory process to develop the actual regulations envisioned by this plan. During the regulatory development process, the details associated with each specific regulation will be fully developed. Over the next several years, staff will be developing these regulations and bringing them to the Board for consideration of adoption. To assist staff in evaluating retrofit applications and provide technical advice to staff, the Board created an Advisory Committee on Toxic Air Contaminant Emissions from Diesel-Fueled Engines and Vehicles.

While the principal focus of this plan is the reduction in emissions of diesel PM, staff are well aware that there are a number of viable alternative technologies, such as compressed natural gas and electrification that in many cases could be used to accomplish the same results. It is staff's full intent, as it develops the regulations proposed in this plan, to fully explore and engage in dialogue with interested parties concerning opportunities for using these alternatives to reduce diesel PM emissions.

SUMMARY AND IMPACTS:

The projected benefits associated with the implementation of this plan are reductions in diesel PM emissions and associated cancer risks of 75% by 2010 and 85% by 2020. The measures recommended in this plan will also significantly reduce the localized risks associated with activities that expose nearby individuals to diesel PM emissions. Further, there are other benefits associated with reducing diesel PM emissions. These include reduced ambient fine particulate matter levels, increased visibility, less material damage due to soiling of surfaces, and reduced incidences of noncancer health effects, such as bronchitis and asthma.

Staff expects that the costs associated with carrying out this plan will be significant and will be on the order of the costs associated with other major ARB programs. At this point, however, staff believes that the costs are necessary for protection of public health of Californians.

The main issues identified concerning the plan have to do with issues that will need to be addressed during the control measure development process. These issues include considerations for specific source categories (such as emergency standby engines), cost of control, environmental impacts, and applicability of controls to specific source categories. Other issues raised pertained to the unit risk factor for diesel PM and assumptions used in developing estimates of potential risk from emissions of diesel PM.

The plan itself is non-regulatory.

CALIFORNIA AIR RESOURCES BOARD

NOTICE OF PUBLIC MEETING TO CONSIDER THE ADOPTION OF THE PROPOSED RISK REDUCTION PLAN FOR DIESEL-FUELED ENGINES & VEHICLES AND THE PROPOSED RISK MANAGEMENT GUIDANCE FOR THE PERMITTING OF NEW STATIONARY DIESEL-FUELED ENGINES

The Air Resources Board (Board or ARB) will conduct a public meeting at the time and place noted below to consider the adoption of the proposed Risk Reduction Plan for Diesel-Fueled Engines and Vehicles (RRP) and the proposed Risk Management Guidance for the Permitting of New Stationary Diesel-Fueled Engines (Guidance):

DATE: September 28, 2000

TIME: 9:00 a.m.

PLACE: Air Resources Board
Hearing Room, Lower Level
2020 L Street
Sacramento, CA 95814

These items will be considered at a meeting of the Board, which will commence at 9:00 a.m., September 28, 2000 and may continue at 8:30 a.m., September 29, 2000. These items may not be considered until September 29, 2000 and they may be considered separately. Please consult the agenda for the meeting, which will be available at least 10 days before September 28, 2000, to determine the day on which these items will be considered.

In the first item, the ARB staff is recommending a comprehensive program to further reduce emissions and resultant health risks associated with emissions of diesel particulate matter (diesel PM). This effort builds upon existing regulations and other initiatives underway to reduce diesel PM emissions. This comprehensive program consists of:

1. Developing additional regulatory emissions standards for all new on-road, off-road, and stationary diesel-fueled engines and vehicles that will reduce diesel PM emissions by an overall 90 percent from current levels;
2. Developing retrofit requirements for existing on-road, off-road, and stationary diesel-fueled engines and vehicles that will reduce diesel PM emissions from these engines; and

3. Developing requirements to reduce the sulfur content of diesel fuel so that on-road, off-road, and stationary diesel-fueled engines will be able to use the low-sulfur diesel fuel needed by advanced diesel PM control technology.

In the second item, the ARB staff is proposing guidance to assist local air pollution control and air quality management districts (districts) in making risk management decisions associated with the permitting of new stationary diesel-fueled engines. This proposed Guidance defines a technology-based approach that retains a risk-based review under certain conditions. Under this Guidance, all new stationary diesel-fueled engines meet either minimum technology requirements or engine performance standards. For most engines, a permit is approvable once the appropriate minimum technology requirement or performance standard is met. For engines that operate more than 400 hours a year, staff is recommending that a site-specific health risk assessment be required prior to permit approval.

At the September 28, 2000, public meeting, staff will recommend the adoption of the proposed Diesel RRP and the Guidance. The Board will discuss and take public comments on these two items.

The public may present comments relating to this matter orally or in writing at the hearing, and in writing or by e-mail before the hearing. To be considered by the ARB, written submissions must be addressed to and received by the Clerk of the Board, Air Resources Board, P.O. Box 2815, Sacramento, California 95812, or 2020 L Street, 4th Floor, Sacramento, California 95814, no later than 12:00 noon, September 27, 2000, or received by the Clerk of the Board at the meeting. To be considered by the ARB, e-mail submissions must be addressed to dslrrp00@listserv.arb.ca.gov (for the Diesel RRP) and to dslpg00@listserv.arb.ca.gov (for the Guidance), and received at the ARB no later than 12:00 noon, September 27, 2000.

The ARB requests, but does not require, 30 copies of any written submission. Also, the ARB requests that written and e-mail statements be filed at least 10 days prior to the hearing so that ARB staff and Board Members have time to fully consider each comment.

Copies of the Diesel RRP and Guidance documents may be obtained from the Board's Public Information Office, 2020 L Street, Sacramento, CA 95814, (916) 322-2990, at least 10 days prior to the scheduled meeting. Copies are also available on the web at http://www.arb.ca.gov/toxics/diesel/diesel.htm.

This facility is accessible to persons with disabilities. If accommodation is needed, please contact ARB's Clerk of the Board at (916) 322-5594, or Telephone Device for the Deaf (TDD) at (916) 324-9531, or (800) 700-8326 for TDD calls from outside the Sacramento area at least 14 days before the hearing.

Further inquiries regarding this matter should be directed to Dr. Randy Pasek, Manager, Technical Analysis Section, Stationary Source Division, Air Resources Board, P.O. Box 2815, Sacramento, California 95812, (916) 327-7213.

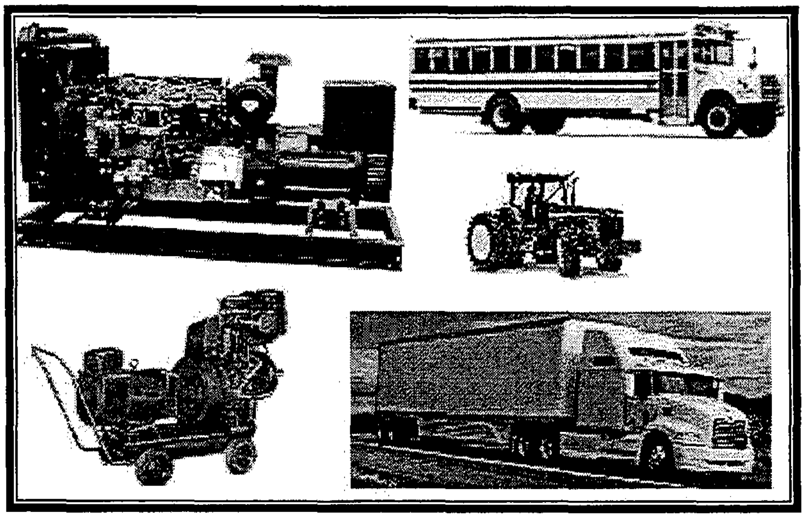
CALIFORNIA AIR RESOURCES BOARD

Michael P. Kenny
Executive Officer

Date: August 25, 2000

DRAFT – DO NOT CITE OR QUOTE

Proposed Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles



California Environmental Protection Agency
Air Resources Board

Mobile Source Control Division
Stationary Source Division

September 13, 2000

Primary Authors

Grant Chin
Louis Chiu
Jim Guthrie
Ron Hand
Robert Hughes, P.E.
Lisa Jennings
Alexander Santos
Nancy Steele, D.Env.
Glen Villa

Contributors

Tony Brasil
David Chou, D. Env
Kevin Cleary
Charles Emmett
Greg Harris
Peggy Jenkins
Marcia Jorgensen
Michele Komlenic
Melanie Marty, Ph.D.
Angus McPherson
Scott Rowland
Tony Servin, P.E.
Lisa Williams

Acknowledgements:

In appreciation of their participation, the Air Resources Board staff extends its appreciation to the members of the Advisory Committee, Risk Management Subcommittee, Stationary Source Subcommittee, Mobile Source Subcommittee, and Fuels Subcommittee.

TABLE OF CONTENTS

Contents | Page

TABLE OF CONTENTS (cont.)

Contents | Page

I. EXECUTIVE SUMMARY

Particulate matter emissions from diesel-fueled vehicles and engines are about 28,000 tons per year in California. These emissions come from a wide variety of sources including over one million on-road and off-road vehicles, about 15,000 stationary engines, and close to 50,000 portable engines. On-road engines account for about 27% of the emissions, off-road engines about 66%, with the remaining 7% from stationary and portable engines. With full implementation of the current vehicle standards on the books and with vehicle turnover, diesel particulate matter (diesel PM) will still be about 23,000 tons per day in 2010 and about 19,000 tons per day in 2020.

In 1998, following an exhaustive 10-year scientific assessment process, the Air Resources Board (ARB or Board) identified particulate matter from diesel-fueled engines as a toxic air contaminant (TAC). On a statewide basis, the average potential cancer risk associated with these emissions is over 500 potential cases per million. In the South Coast Air Basin, the potential risk associated with diesel PM emissions is estimated to be 1,000 per million. Compared to other air toxics the Board has identified and controlled, diesel PM emissions are estimated to be responsible for about 70% of the total ambient air toxics risk. In addition to these general risks, diesel PM can also present elevated localized or near-source exposures. Depending on the activity and nearness to receptors, these potential risks can range from small to 1,500 per million or more. As a result of this significant potential risk, when the Board identified diesel PM as a TAC, it directed staff to convene an advisory committee of interested parties to engage in a dialogue on the steps that can be taken to reduce these emissions.

This plan, the Diesel Risk Reduction Plan or Diesel RRP, represents the staff's proposal for a comprehensive plan to significantly reduce diesel PM emissions. The basic premise behind the staff proposal is simple. It is to require all new diesel-fueled vehicles and engines to use state-of-the-art catalyst-based diesel particulate filters (DPFs) and very low-sulfur diesel fuel. Further, all existing vehicles and engines should be evaluated, and wherever technically feasible and cost-effective, retrofitted with DPFs. As with new engines, very low-sulfur diesel fuel should be used by retrofitted vehicles and engines. In short, the staff's proposed plan contains the following three components:

1. New regulatory standards for all new on-road, off-road, and stationary diesel-fueled engines and vehicles to reduce diesel PM emissions by about 90% overall from current levels;

2. New retrofit requirements for existing on-road, off-road, and stationary diesel-fueled engines and vehicles where determined to be technically feasible and cost-effective; and

3. New Phase 2 diesel fuel regulations to reduce the sulfur content levels of diesel fuel to no more than 15 ppm to provide the quality of diesel fuel needed by the advanced diesel PM emission controls.

Diesel PM filter control technology is now available and has been demonstrated in over 20,000 applications worldwide. It is staff's vision that well before the end of this decade these filters will become as commonplace on diesel-fueled engines as catalysts are now on gasoline-fueled vehicles.

Upon the Board's approval of this comprehensive plan with its various control measures, staff will begin the full regulatory process to develop the actual regulations envisioned by this plan. During the regulatory development process, the details associated with each specific regulation will be fully developed. Over the next several years, staff will be developing these regulations and bringing them to the Board for consideration of adoption. To assist staff in evaluating retrofit applications and provide technical advice to staff, the Board created an Advisory Committee on Toxic Air Contaminant Emissions from Diesel-Fueled Engines and Vehicles.

While the principal focus of this plan is the reduction in emissions of diesel PM, staff are well aware that there are a number of viable alternative technologies, such as compressed natural gas and electrification that in many cases could be used to accomplish the same results. It is staff's full intent, as it develops the regulations proposed in this plan, to fully explore and engage in dialogue with interested parties concerning opportunities for using these alternatives to reduce diesel PM emissions.

The projected benefits associated with the implementation of this plan are reductions in diesel PM emissions and associated cancer risks of 75% by 2010 and 85% by 2020. The measures recommended in this plan will have a great impact on reducing the localized risks associated with activities that expose nearby individuals to diesel PM emissions. Further, there are other benefits associated with reducing diesel PM emissions. These include reduced ambient fine particulate matter levels, increased visibility, less material damage due to soiling of surfaces, and reduced incidences of noncancer health effects, such as bronchitis and asthma. Staff expects that the costs associated with carrying out this plan will be significant and will be on the order of the costs associated with other major ARB programs.

II. BACKGROUND

The public's exposure to TACs is a significant public health issue in California. In 1983, the California Legislature enacted a program to identify the health effects of TACs and to reduce exposure to these contaminants to protect the public health (Assembly Bill (AB) 1807: Health and Safety Code sections 39650-39674). The Legislature established a two-step process to address the potential health effects from TACs. The first step is the risk assessment (or identification) phase. The second step is the risk management (or control) phase of the process.

In August 1998, the ARB identified diesel PM as a TAC, following a 10-year review process. This marked the completion of the identification phase of the process to address the potential for adverse health effects associated with diesel PM emissions.

This Diesel RRP is the first formal product of the risk management phase of the AB 1807 process. This report presents information that identifies the available options to reduce diesel PM, and identifies recommended control measures to achieve further reductions. The recommended control measures would be developed as mobile source regulations or stationary source airborne toxic control measures (ATCMs).

The next step in the AB 1807 process, following approval of this plan by the Board, is the development of the specific ATCMs and fuel or vehicular emissions regulations designed to reduce diesel PM emissions. The goal of each regulation is to reduce diesel PM to the greatest extent feasible. These regulations must be technically feasible and be cost-effective, and they will provide an opportunity to address issues associated with the application of controls on a specific source categories. In developing rules to implement the Diesel RRP, the staff will consider the availability and cost of engine modifications, add-on control technology, changes in fuel parameters, alternative fuels, and alternative methods of performing the function of the diesel engine application. Thus, although most of the Board's regulatory activities are expected to be focused on emission controls that can be added to or built into diesel-fueled engines, staff will also fully integrate alternative "non-diesel" technologies (e.g., electrification and compressed natural gas (CNG)) as possible control options for reducing diesel PM emissions.

ARB staff will develop the ATCMs and regulations with full public involvement and dialogue through public workshops and meetings with groups and individuals. Draft versions of the ATCMs and regulations will be presented to the public for review and comment, and a final draft version will be presented to the Board for approval. Public outreach is an essential element in the development of any ATCM or regulation to ensure that all affected and interested parties have full opportunity to provide input and shape rules that are both effective and workable.

As part of the identification process, the Office of Environmental Health Hazard Assessment (OEHHA) evaluated the potential for diesel exhaust to affect human health. The OEHHA found that exposures to diesel PM resulted in an increased risk of cancer and an increase in chronic noncancer health effects including a greater incidence of cough, labored breathing, chest tightness, wheezing, and bronchitis. The OEHHA estimated that based upon available studies, the potential cancer risk from exposure to diesel PM in concentrations of one microgram per cubic meter ranged from 130 to 2400 excess cancers per million. The Scientific Review Panel (SRP) approved the OEHHA's determinations concerning health effects and approved range of risk for particulate matter from diesel-fueled engines. The SRP concluded that a value of 300 excess cancers per million, per microgram per cubic meter of diesel PM, was appropriate as a point estimate of unit risk for diesel PM.

The OEHHA also concluded that exposure to diesel PM in concentrations exceeding 5 micrograms per cubic meter can result in a number of long-term (chronic) noncancer health effects including greater incidence of cough, phlegm, and bronchitis. The 5 microgram per cubic meter value is referred to as the Chronic Reference Exposure Value (REL) for diesel PM. The SRP supported the OEHHA's conclusion and noted that the REL may need to be lowered further as more data emerge on potential adverse noncancer effects of diesel PM.

As part of its formal identification of diesel PM as a TAC, the Board accepted the OEHHA and SRP's conclusions and directed the ARB staff to begin the risk management process. The staff was directed to develop control measures to reduce both diesel PM and other potentially harmful pollutants. The staff was also directed to form a diesel risk management working group to advise the staff during its risk management efforts. This working group, the Advisory Committee and subcommittees, are discussed in Section B., below.

A. How is this report structured?

This report consists of a main report and appendices that summarize and discuss the proposed Diesel RRP to reduce emissions, exposure, and potential cancer risk associated with particulate matter from diesel-fueled engines.

The main report provides the following information:

- defines the term "diesel-fueled engine" and identifies the categories of diesel-fueled engines and vehicles evaluated in this report;
- summarizes current regulations that address diesel PM emissions from diesel-fueled engines and vehicles;
- presents diesel PM emission inventory estimates, estimated ambient concentrations, and associated potential cancer risk information for the years 1990, 2000, 2010, and 2020;
- presents current near-source diesel PM emissions exposure and potential cancer risk estimates;
- discusses available diesel PM emissions control technology options;
- present's ARB staff's recommendation, based upon the above information, to further control particulate matter emissions from diesel-fueled engines and vehicles;

- estimates the reduction in diesel PM emissions, exposure, and risk by 2010 and 2020 that could be achieved if all recommended measures were implemented; and
- recommends specific measures to be developed to further reduce diesel PM emissions from diesel-fueled engines and vehicles.

Appendix I is a list of terms, definitions and acronyms used in both the main report and appendices. Appendix II is a report on the need for further regulation of stationary and portable diesel-fueled engines. Appendix III is a report on the need for further regulation of mobile on-and off-road diesel-fueled engines (excluding portable equipment, which is addressed in Appendix II). Appendix IV is a report on the need for further regulation of diesel fuel. Appendix V is a summary of existing regulations addressing diesel-fueled engines, vehicles, and diesel fuel. Appendix VI is a discussion of the methodology for estimating the ambient concentrations of diesel PM emissions from diesel-fueled engines and vehicles. Appendix VII is a discussion of the potential risks associated with typical activities where diesel-fueled engines and vehicles are used (risk characterization scenarios). Appendix VIII is Health and Safety Code Section 39665, which identifies the requirements this report must meet. Appendix IX is a discussion of diesel PM control technologies.

B. What does this report contain, and how was it developed?

In accordance with California Health and Safety Code Section 39665 (see Appendix VIII), this report includes the following information:

- number (population) and categories of diesel-fueled engines and vehicles;
- consideration of all past and current measures for reducing diesel PM;
- emissions and associated ambient and near-source potential risk levels for diesel PM;
- available technologies for reducing diesel PM;
- initial estimates for the costs of reducing diesel PM;
- alternative methods of emission reductions;
- recommended measures to be developed to reduce emissions and potential risk;
- potential adverse health, safety, or environmental impacts from implementation of the recommended measures; and
- impact of the recommended measures on diesel PM emissions and potential risk.

While the above items are addressed in this plan, staff will further refine and update this information as it develops the various control measures identified in this plan.

To ensure full opportunity for public consultation and input in developing this report, an Advisory Committee was created to serve as a forum for on-going communication, cooperation, and coordination in identifying opportunities to reduce diesel PM emissions. The Advisory Committee consists of the Stationary Source, Fuels, Mobile Source/Alternative Strategies, and Risk Management subcommittees. The Advisory Committee and each of the four subcommittees include representatives from industry, local districts, environmental organizations, ARB, the United States Environmental Protection Agency (U.S. EPA), and the public.

ARB staff presented a draft of this document to each of the four subcommittees and the Advisory Committee for review and comment. All comments were considered and the draft report was revised in a number of ways to reflect these comments.

III. DIESEL-FUELED ENGINES: DEFINITION AND USES

A. How is "diesel-fueled engine" defined?

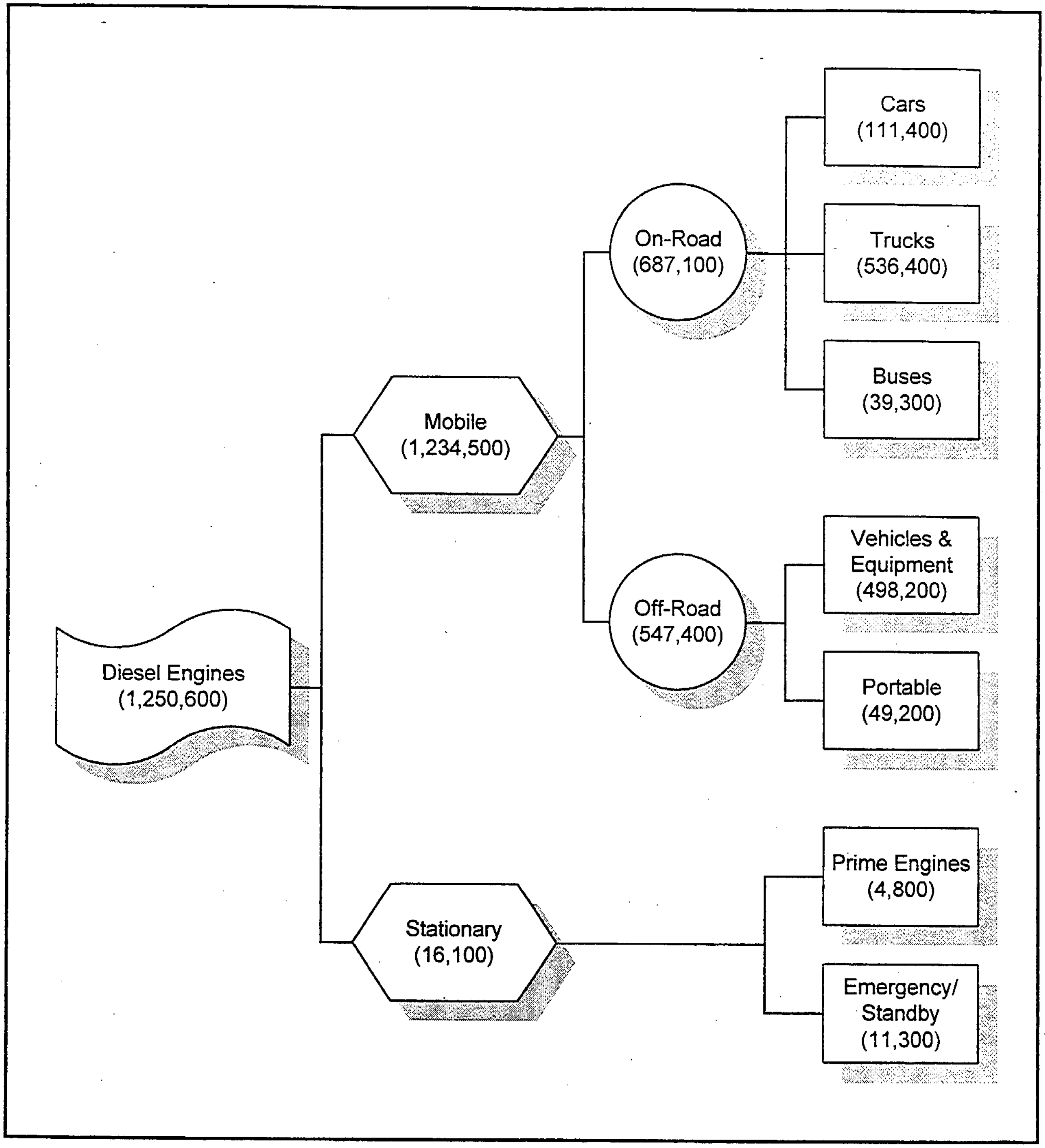
For purposes of this report, a diesel-fueled engine is defined as any internal combustion, compression-ignition (diesel-cycle) engine. It is generally assumed that the engine will be using diesel fuel. However, diesel-cycle engines using alternative fuels or fuel reformulation (e.g., jet fuel, biodiesel, CNG, and diesel/water mixtures) will also be addressed during the development of each specific ATCM or regulation.

B. What categories of diesel-fueled engines and vehicles were evaluated in this report?

Staff's goal in this plan was to address all diesel-fueled engines in California. Figure 1 identifies the specific categories and the current population of diesel-fueled engines and vehicles evaluated in this report.[1] The following paragraphs provide a brief description of each category. Detailed descriptions can be found in Appendix II for Stationary Engines and in Appendix III for Mobile Engines.

[1] The off-road vehicle population estimate does not include locomotives, but does include military tactical support equipment. The heavy-duty trucks and motor homes category includes approximately 36,000 vehicles not registered in California.

Figure 1: Diesel-Fueled Engines and Vehicle Categories



C. What are mobile engines?

Mobile engines can be divided into two categories: on-road vehicles and off-road engines and vehicles.

On-Road Vehicles: Diesel-fueled engines are used in every category of on-road vehicles except motorcycles, and include light to heavy-duty trucks; school buses, urban buses, and passengers vehicles. In California, the majority of on-road diesel-fueled engines are found in the heavy-duty vehicles with a gross vehicle weight rating (GVWR) ranging from 14,000 pounds to 33,000 pounds. There are approximately 700,000 on-road diesel-fueled vehicles currently in use in California.

Off-Road Engines and vehicles: Diesel-fueled off-road engines comprise over 100 individual off-road vehicle and equipment types classified into 17 equipment categories. Engine sizes range from under 15 horsepower to over 10,000 horsepower. These equipment categories include agriculture, airport ground support, construction and mining, commercial, industrial, logging, transportation-refrigeration units, lawn and garden, commercial marine vessels, pleasure craft, and locomotives. Many of the off-road categories contain equipment types that are classified as portable (equipment of 25 horsepower or greater that is designed and capable of being carried or moved from one location to another). There are approximately 550,000 off-road diesel-fueled engines and vehicles currently in use in California. A more detailed breakdown is presented in Appendix III.

D. What are stationary engines?

Stationary engines can be divided into two categories: emergency/standby engines and prime engines.

Emergency/standby engine: Emergency standby engines are typically used for emergency back-up electric power generation or the emergency pumping of water. Sizes range from 50 to 6,000 horsepower, depending on the needs of the user. There are over 10,000 diesel-fueled emergency/standby engines in use in California. Emergency standby engines make up about 70 percent of the total number of stationary engines throughout the State. Several local air pollution control and air quality management districts (districts) have rules that regulate NOx and CO emissions, but not PM from internal combustion engines. However, some districts currently exempt emergency standby engines from complying with these requirements.

Prime Engines: Prime engines are stationary engines that are not used in an emergency back-up or standby mode. There are approximately 5,000 diesel-fueled prime engines currently in use in California. Examples include diesel-fueled engines that are used to power compressors, cranes, generators, pumps, and grinders. Prime engines make up about 30 percent of the total stationary engine inventory throughout the State.

Of the prime engines operating throughout the State, about 70 percent are agricultural irrigation pump engines.

IV. SUMMARY OF EXISTING AND PROPOSED REGULATIONS

The ARB has the responsibility for control of emissions from mobile sources. The local air districts have the primary responsibility for control of air pollution for all sources, other than emissions for mobile sources. State law provides the South Coast AQMD with the authority to require fleets of 15 or more vehicles to purchase alternative-fuel vehicles when adding or replacing vehicles. They have recently exercised this authority through the adoption of Rules 1191, 1192, 1193, and 1194.

The federal Clean Air Act Amendments of 1990 (CAA) preempt state and local authorities from the control of emissions from new farm and construction equipment under 175 horsepower and from new locomotives or locomotive engines (CAA Section 209(e)(1)(A)); only the U.S. EPA has the authority to establish emission standards for those engines. In addition, heavy-duty diesel vehicles that travel in California but are registered in other states are subject only to federal emission certification standards; these vehicles contribute approximately 25 percent of the heavy heavy-duty vehicle-miles-traveled in California. As a result of the preemption and out-of-state vehicles, emission reductions of diesel PM in these categories are beyond the ARB's authority to regulate.

The CAA also requires California to receive authorization from the U.S. EPA for controls over on-road (CAA Section 209(b)(1)) and the non-preempted off-road sources (CAA section 209(e)(2)(A)). Overall these provisions make the U.S. EPA an important partner in control of emissions from diesel engines.

The following sections briefly describe the existing federal, state, and local programs that currently apply to diesel-fueled engines and vehicles operating in California. A more detailed summary of the statutes and regulations may be found in the tables in Appendix V.

A. What current federal, state, or local regulations address diesel PM emissions from mobile diesel-fueled engines?

Virtually all new diesel-fueled on-road and off-road motor engines and vehicles sold in California are required to meet both federal and state emission certification requirements. Preempted engines, as noted above, must meet only the federal requirements. In most cases, California's motor vehicle and diesel-fueled engine programs are designed to be consistent with the federal programs. To ensure the engines continue to have functional controls and proper maintenance, California has implemented Heavy-Duty Vehicle Inspection and Periodic Smoke Inspection Programs to reduce excessive smoke emissions and tampering with on-road diesel-fueled vehicles over 6,000 pounds gross vehicular weight for both in-state and out-of-state registered heavy-duty diesel vehicles. In addition to certification standard non-regulatory strategies, which include incentives and voluntary agreements with vehicle and engine manufacturers, have also been implemented in California to accelerate reductions in certain criteria pollutants.

B. What current federal, state, or local regulations address diesel PM emissions from stationary and portable diesel-fueled engines?

In California, the local air pollution control and air quality management districts (Districts) establish rules and regulations for controlling emissions from new and existing stationary sources of air contaminants. These rules and regulations address both criteria and toxic air contaminant emissions.

District preconstruction and operating permit programs implement the local, State, and federal air pollution control requirements applicable to new or modified sources of air pollution. Larger new or modified sources located in a nonattainment area must apply the Lowest Achievable Emission Rate control technology to minimize emissions, and they must "offset" the remaining emissions with reductions from other sources when appropriate. A new or modifying source located in an attainment or unclassified area must apply the Best Available Control Technology and meet additional requirements aimed at maintaining the region's clean air. In addition, "major sources" of air pollution must obtain federal Title V operating permits that govern continuing operation.

Many Districts have also adopted, pursuant to the California Health and Safety Code, Reasonably Available Control Technology/Best Available Retrofit Control Technology requirements that apply to existing sources located in nonattainment, attainment, and unclassified areas. These requirements are also implemented through the district's permit program.

Pursuant to State law, the ARB has established the Portable Equipment Registration Program (PERP) which is a voluntary program for the registration and regulation of portable engines and associated equipment. Several Districts have implemented similar registration programs. Portable equipment not registered through the ARB or a local district may be subject to District stationary source permit requirements, depending on the size of the engine. In addition, the U.S. EPA and ARB have established engine certification standards for new off-road engines (of which portable engines are a subset). These engines are available for use in portable equipment.

C. What current federal, state or local regulations address diesel fuel formulation?

Current federal U.S. EPA regulations establish fuel registration and formulation requirements. All diesel fuels and all additives for on-road motor vehicles are required to be registered with the U.S. EPA. The ARB has established California fuel formulation requirements, applicable to all motor vehicles, that either meet or exceed existing federal formulation requirements. In addition, ASTM D 975 specifies standards which diesel fuels should meet to ensure safety, reliability, and performance. Generally, alternative diesel fuels do not meet all of the ASTM specifications.

Since 1993, the sulfur content limit of California diesel (as well as diesel fuel sold to on-road vehicles nationwide) has been set at a maximum 500 parts per million by weight (ppmw). However, the average sulfur content of complying fuel formulations currently being sold in California is about 140 ppmw.[2] Further, California's diesel fuel specifications include an aromatics limit and the fuel specifications apply to both on-road and off-road vehicles (EPA's fuel sulfur requirements only apply to on-road vehicles). Although stationary engines are not required to use fuel that meets California Air Resources Board diesel (CARB diesel) formulation requirements, virtually all use complying fuel because of California's single fuel distribution network. Also, under state law, districts have the authority to establish formulation requirements for fuels to be used in stationary engines. To date, several districts have established diesel-fueled engine best available control technology requirements specifying the use of CARB diesel. Portable engines registered under ARB's Statewide Portable Equipment Registration program are required to use CARB diesel. Beginning July 1, 2002, medium and larger transit agencies must use diesel fuel with a sulfur content no greater than 15 ppmw in all diesel buses.

V. EMISSION INVENTORY AND RISK

This section summarizes the statewide diesel PM emissions inventory from diesel-fueled engines and provides ambient and near-source potential cancer risk estimates for those emissions. A detailed description of how the inventory, ambient concentration, and ambient risk values listed in Tables 1 through 5 of this chapter were determined is presented in Appendix VI.

A. What are the estimated diesel particulate matter emissions for 1990, 2000, 2010, and 2020?

Table 1 lists the estimates for the statewide diesel PM emissions inventory from diesel-fueled engines and vehicles for 1990. Tables 2, 3, and 4 provide similar estimates for 2000, 2010, and 2020. The relative contribution of the major subcategories of engines and vehicles that comprise the stationary and mobile categories are also shown. All tables take into account growth in engines due to population and economic growth and emission reductions due to both federal and state regulations in effect at the time of the inventory estimate. These estimates do not include proposed recommended measures discussed in Chapter VIII, including the recently proposed 2007 federal on-road and diesel fuel standards.

---

[2] 141 ppmw is the volume-weighted average determined by the California Energy Commission's 1997 California refiner survey. (See Appendix IV.)

Table 1: Estimated Statewide Diesel PM Emissions Inventory – Diesel-Fueled Engines and Vehicles (1990)

Category	Engine Population	Diesel PM (tons per year)	% of Total Diesel PM Emissions
STATIONARY			
Prime	4,600	400	0.9
Emergency Stand-by	10,200	124	0.3
MOBILE			
On-road	606,700	18,400	39.7
Off-road (Excluding Portable Equipment)	476,300	25,300	54.5
Portable	47,600	2,200	4.7
TOTAL	**1,145,300**	**46,400**	**100.0**

Table 2: Estimated Statewide Diesel PM Emissions Inventory – Diesel-Fueled Engines and Vehicles (2000)

Category	Engine Population	Diesel PM (tons per year)	% of Total Diesel PM Emissions
STATIONARY			
Prime	4,800	420	1.5
Emergency Stand-by	11,300	138	0.5
MOBILE			
On-road	687,200	7,500	26.7
Off-road (Excluding Portable Equipment)	498,200	18,600	66.4
Portable	49,200	1,400	5.0
TOTAL	**1,250,700**	**28,000**	**100.0**

Table 3: Estimated Statewide Diesel PM Emissions Inventory – Diesel-Fueled Engines and Vehicles (2010)

Category	Engine Population	Diesel PM (tons per year)	% of Total Diesel PM Emissions
STATIONARY			
Prime	4,400	360	1.6
Emergency/Standby	12,300	143	0.6
MOBILE			
On-road	643,900	5,200	22.9
Off-road (Excluding Portable Equipment)	521,300	15,900	69.7
Portable	53,600	1,100	4.8
TOTAL	**1,235,500**	**22,700**	**100.0**

Table 4: Estimated Statewide Diesel PM Emissions Inventory – Diesel-Fueled Engines and Vehicles (2020)

Category	Engine Population	Diesel PM. (tons per year)	% of Total Diesel PM Emissions
STATIONARY			
Prime	4,400	350	1.9
Emergency/Standby	13,200	149	0.8
MOBILE			
On-road	610,200	4,900	25.9
Off-road (Excluding Portable Equipment)	527,800	12,800	67.7
Portable	55,200	660	3.5
TOTAL	**1,210,800**	**18,900**	**100.0**

The current inventory of diesel PM emissions in Table 2 shows that there are about 28,000 tons per year of diesel PM that can potentially be reduced from a variety of sources. The inventory also shows that the sources are numerous, with over 1.25 million diesel-fueled engines operating statewide. Comparing the statewide diesel PM emissions in Table 1 (1990) and Table 2 (2000), shows that significant progress has been made to reduce diesel PM emissions in California.

The bulk of the 30 percent decrease in diesel PM emissions from 2000 to 2020 is due to currently adopted on-road standards and fleet turn-over as new vehicles with controls replace older vehicles with little or far less effective controls. Proposed federal standards for diesel-fueled engines are not considered in this inventory, but would reduce total diesel PM by approximately 3,500 tons per year (or an additional 15 percent when compared to year 2000 emissions) by 2020. Some reduction in diesel PM emissions is due to a slight decrease in engine population.

B. What are the estimated statewide potential cancer risks associated with diesel PM emissions?

Table 5 lists the estimates for the statewide population-weighted annual outdoor average diesel PM concentrations and corresponding percent change in the concentration for the years 1990, 2000, 2010, and 2020 resulting from diesel PM emissions. These estimates are based on the emission inventory estimates presented in Tables 1 through 4.

The Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant, Appendix III, Part A, Exposure Assessment[3] (ID Report) reported the statewide population-weighted annual outdoor average diesel PM concentration as 3.0 $\mu g/m^3$ for 1990. The ARB staff reviewed studies conducted in the San Joaquin Valley, South

[3] As approved by the Scientific Review Panel on April 22, 1998.

Coast, and San Jose to obtain more complete PM_{10} ambient data. This information, along with routinely collected ambient PM_{10} monitoring network data and the 1990 PM_{10} emissions inventory, were used in a receptor model to estimate the statewide outdoor concentration of diesel PM in 1990.

We estimated the statewide outdoor concentration of diesel PM for 1990, 2000, 2010, and 2020 by assuming that the ambient concentration is proportional (linearly) to the statewide emissions. The ratio of the ambient concentration to statewide emissions was assumed to remain constant for the years 1990, 2000, 2010, and 2020. For 1990, this ratio was determined by using the ambient concentration from the ID report (3.0 $\mu g/m^3$) and the statewide emission estimate for 1990 from Table 1 (46,400 TPY). Using the 1990 ratio and the statewide emissions estimates for 2000, 2010, and 2020 from Tables 2, 3, and 4, the ambient concentration estimates for 2000, 2010, and 2020 were estimated. These are presented in Table 5.

Table 5: Statewide Population-Weighted Annual Outdoor Average Diesel PM Concentration for 1990, 2000, 2010, and 2020

	1990	2000	2010	2020
Concentration ($\mu g/m^3$)	3.0	1.8	1.5	1.2
Percent Reduction in Diesel PM from 1990 Concentration	N/A	40%	50%	60%

The ID Report provided estimates of indoor and total exposure to diesel PM. Applying the 1990 ratio to the estimated population-weighted annual outdoor average diesel PM concentrations for 2000, 2010, and 2020 results in the following indoor exposure estimates, respectively: 1.2 μ/m^3, 1.0 μ/m^3, and 0.8 μ/m^3. Total exposure estimates for 2000, 2010, and 2020 are 1.3 μ/m^3, 1.1 μ/m^3, and 0.84 μ/m^3. The potential risk was estimated by multiplying the statewide ambient concentration by the unit risk factor of 300 excess cancers per million per microgram per cubic meter of diesel PM.[4] This information, along with the estimated potential cancer risk values, is summarized in Table 6.

[4] The full range of unit risk factors identified by the SRP is 130 to 2400 excess cancers per million per microgram per cubic meter of diesel particulate matter. The 300 value was recommended by the SRP for use as a point estimate of the unit risk.

Table 6: Estimated Exposure of Californians to Diesel PM for 2000, 2010 and 2020

-	Estimated Average Air Exposure Concentration – 1990 μg/m³	1990 Ratio	Estimated Average Air Exposure Concentration (μg/m³) and Potential Risk (excess cancers/million)					
			2000		2010		2020	
			Conc.	Risk	Conc.	Risk	Conc.	Risk
Outdoor Ambient Estimate	3.0		1.8	540	1.5	450	1.2	360
Total Indoor Exposure Estimate	2.0	2.0/3.0	1.2	360	1.0	300	0.8	240
Total Exposure Estimate	2.1	2.1/3.0	1.3	390	1.1	315	0.84	252

C. How much of the estimated statewide potential cancer risk level from air toxics is due to diesel PM?

To provide a perspective on the contribution that diesel PM has on the overall statewide average ambient air toxics potential cancer risk, ARB staff evaluated risks from other compounds using data from ARB's ambient monitoring network. ARB maintains a 21 site air toxics monitoring network which measures outdoor ambient concentration levels for approximately 60 air toxics.

Table 7 shows the potential cancer risk from the top ten inhalation risk contributors that the State of California has identified as TACs and routinely monitors. The diesel PM values are calculated based on the procedure discussed in the previous section. The risk values for the other compounds are based on the annual average concentration (determined from ambient monitoring) multiplied by the unit risk factor for each compound. Table 7 also shows that for the top ten risk contributors, diesel PM contributes over 70 percent of the state estimated potential cancer risk levels.

Table 7: Estimated Statewide Average Potential Cancer Risk from Outdoor Ambient Levels of Air Toxics for the year 2000

Compound	Potential Cancer Risk[1,2] Excess Cancers/Million	Percent Contribution to Total Risk
Diesel Exhaust PM_{10}	540	71.2
1,3-Butadiene	74	9.8
Benzene	57	7.5
Carbon Tetrachloride	30	4.0
Formaldehyde	19	2.5
Hexavalent Chromium	17	2.2
para-Dichlorobenzene	9	1.2
Acetaldehyde	5	0.7
Perchloroethylene	5	0.7
Methylene Chloride	2	0.3
TOTAL	**758**	**100**

1. Diesel exhaust PM_{10} potential cancer risk based on 2000 emission inventory estimates presented in Table 5. All other potential cancer risks based on air toxics network data. Used 1997 data for para-Dichlorobenzene. Used 1998 monitoring data for all others.
2. Assumes measured concentrations are equivalent to annual average concentrations and duration of exposure is 70 years, inhalation pathway only.

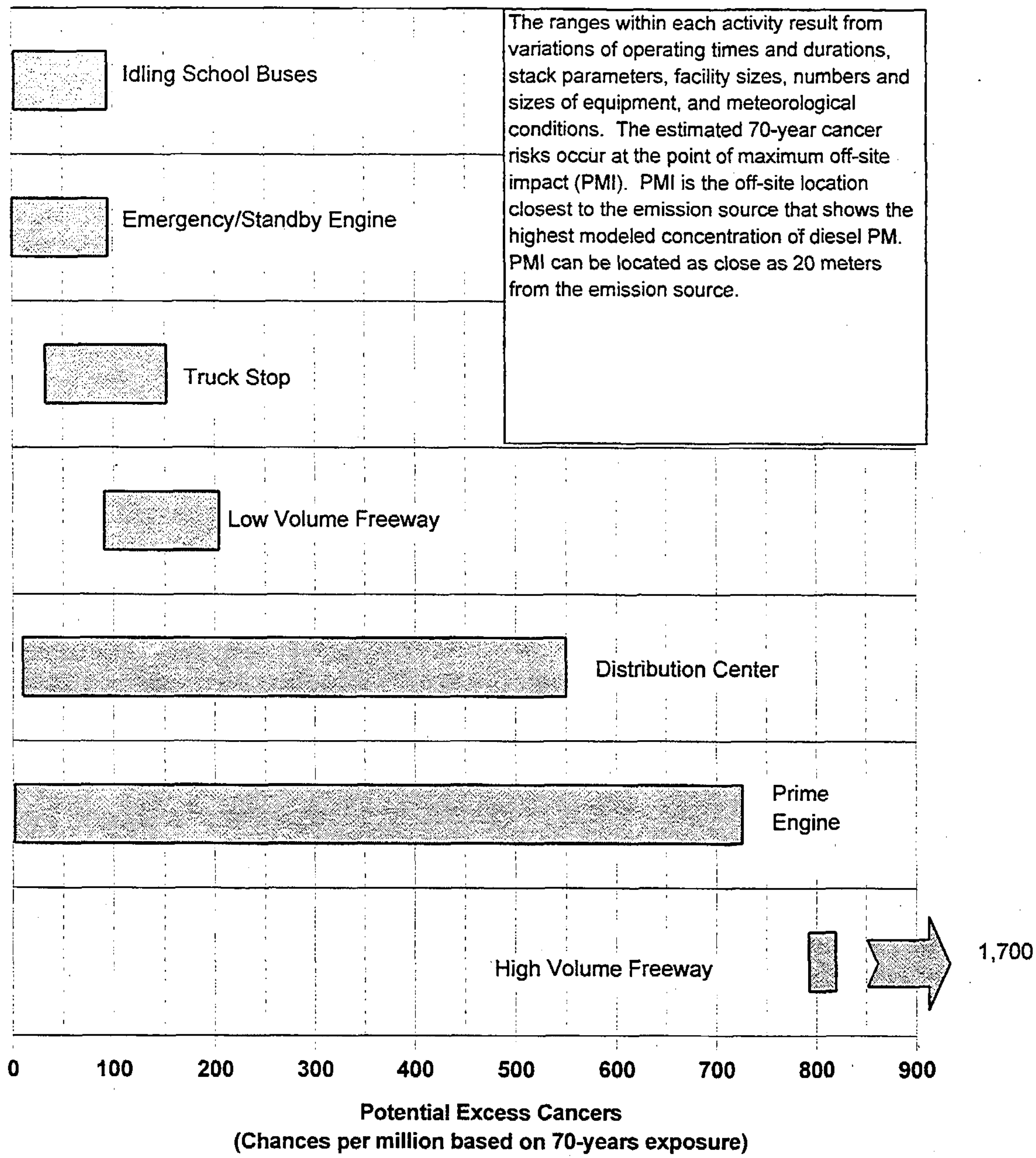
The South Coast Air Quality Management District also conducted a study of air toxics in the South Coast Air Basin (Multiple Air Toxics Exposure Study II (MATES-II)) in 1998 and 1999. The MATES-II study estimated that the average basin wide potential cancer risk from diesel PM was about 1,000 excess cancers per million, or 71 percent of the 1,400 potential excess cancers per million people exposed to air toxics that are measured in the South Coast Air Basin.

ARB staff's findings are consistent with the MATES-II study in that diesel PM is a major contributor to potential ambient risk levels and accounts for approximately 70 percent of the ambient air toxics risk. Our analysis also indicates that average ambient concentrations of air toxics are higher in the South Coast Air Basin then elsewhere, resulting in higher estimates of risk for residents of that air basin. Staff concludes that reducing the risk from diesel PM is an essential element in reducing the public's overall ambient exposure to air toxics.

D. What are the potential cancer risks associated with some typical activities where diesel-fueled engines are used?

ARB staff estimated the range of potential cancer risks from seven common activities or situations to determine if the concentrated operation of diesel-fueled engines could expose nearby individuals to locally elevated diesel PM concentrations higher than average regional concentrations. The specific situations investigated included idling school buses, truck stops, freeways, emergency and standby diesel engine operations, prime engine operations, and warehouse distribution center operations. Figure 2 shows the range of potential cancer risk, above background levels, estimated for each type of activity. The risk estimate for each activity does not account for the risk from any other diesel-fueled engines or vehicles. For more detailed information regarding each activity, see Appendix VII.

Figure 2: Potential Cancer Risk Range of Activities Using Diesel-Fueled Engines



Risk is a function of the lifetime average daily dose and the carcinogenic potency of the compound. The potential risks reported here were estimated by multiplying the modeled concentration of a toxic compound by the carcinogenic potency value, also known as the unit risk factor. The unit risk factor is defined as the estimated probability of a person contracting cancer as a result of constant exposure to an ambient concentration of 1 $\mu g/m^3$ over a 70-year lifetime. This approach and the use of a 70-year lifetime is consistent with the OEHHA/ARB methodology for evaluating the potential risk from exposure to air toxics.

We expect the estimated 70-year potential cancer risk range for each of these activities will fall within the ranges in Figure 2. Each range assumes a 70-year exposure to diesel PM emissions at current levels, and uses SRP's diesel PM unit risk factor point estimate of 300 excess cancers per million per microgram per cubic meter of diesel PM. The ranges within each activity result from variations in assumptions of operating times and durations, stack parameters, facility sizes, numbers and sizes of equipment, and meteorological conditions. For example, in the Idling School Buses scenario the activity ranged from five buses idling two minutes each twice per day to 20 buses idling 15 minutes each twice per day for 180 days per year.

The estimated 70-year potential cancer risks in Figure 2 are based on the modeled diesel PM concentrations at the point of maximum impact (PMI). PMI is the off-site location closest to the emission source that shows the highest modeled concentration of diesel PM. The PMI can be located as close as 20 meters from the emission point. The diesel PM concentrations and associated potential risk decreases as one moves away from the point of maximum impact. For example, the potential cancer risk at the point of maximum impact for the Low-Volume Freeway scenario is estimated to be 200 excess cancers per million if a residence were located 20 meters away. For a residence located 500 meters away, the estimated potential cancer risk drops to 30 excess cancers per million.

The estimated risks presented in Figure 2, and the assumptions used to determine these risks, are not based on a specific source of diesel PM. Instead, general assumptions bracketing a fairly broad range of possible operating scenarios were used. The estimated risks are based on the diesel PM concentration at the point of maximum impact as determined using air dispersion modeling. The estimated risk ranges are used to provide a "qualitative" assessment of potential risk levels near sources of diesel PM. These estimates are based on the risk assessment methodology and assumptions identified in Appendix 7. Actual risk levels from these types of sources at any individual site will vary due to site specific parameters, including equipment technologies and emission rates, fuel properties, operating schedules, meteorology, and the actual location of off-site receptors.

Figure 2 shows that each of the investigated activities has the potential of significant increases in potential cancer risk under certain circumstances. The potential cancer risk associated with these activities, combined with the high statewide ambient risk levels reported earlier, provide additional evidence that all categories of diesel-fueled engines should be subject to further control requirements.

VI. CONTROL TECHNOLOGY AND FUEL OPTIONS

A. Has ARB identified control technology options that can further reduce diesel PM emissions from diesel-fueled engines and vehicles?

Yes. The ARB has evaluated various types of control options identifying the control efficiency, description of technology, cost, and source test data. Technical evaluations of the control technologies, including summaries of the available emission test information, are included in Appendix IX. Because emission test information was deemed essential for a thorough evaluation of diesel PM control technologies, detailed technical evaluations were not performed where the technology proponent did not provide adequate emission test information. The most effective control technologies evaluated by ARB staff are catalyst-based diesel particulate filters (catalyst-based DPFs).

Catalyst-based DPFs use catalyst materials to reduce the temperature at which collected diesel PM oxidizes. The catalyst material can either be directly incorporated into the filter system, or can be added to the fuel as a fuel-borne catalyst (FBC-DPF). Although catalyst-based DPFs can be used with diesel fuels of varying sulfur content, the greatest reductions come from using very low-sulfur fuels. Used with very low-sulfur (<15 ppmw sulfur) diesel fuel, catalyst-based DPFs can reduce diesel PM emissions by over 90 percent.

Table 8 provides a description and range of control efficiencies catalyst-based DPFs and new diesel-fueled engines. The control efficiency information is based on available test information summarized in Appendix IX. As shown, the range of control efficiencies for catalyst-based DPFs is 85 to 97 percent.

Table 8: Control Technology Efficiencies

Control Technology	Diesel PM Control Efficiency	Description
Catalyst-Based DPFs / Very low-sulfur Fuel	85% - 97%	Particulate filter system where the catalyst material is either incorporated into the filter or added to the fuel; Diesel fuel with a sulfur content ≤ 15 ppmw.
New Engine	Up to 85%	Replaces existing engines with engines certified to meet ARB/U.S. EPA off-road engine emission standards.

For existing diesel engine applications, catalyst-based DPFs have been shown to be effective in reducing diesel PM emissions. Worldwide, DPFs have been used in over 20,000 applications. In several European countries, catalyst-based DPFs have been installed on more than 6,500 buses, heavy-duty trucks, and municipal vehicles. In the United States, the application of catalyst-based DPF's is less prevalent, but several demonstration projects have been initiated. In California, diesel-fueled school buses and tanker trucks have been retrofitted with catalyzed DPFs as part of a program to evaluate the effectiveness of a refiner's low-sulfur diesel formulation. In New York, the New York City transit authority's fleet demonstration program will test the effectiveness of catalyzed DPF's on 50 diesel-fueled buses.

For new diesel engine applications, catalyst-based DPF technology is playing a key role in both establishing and complying with new more stringent diesel PM standards. The U.S. EPA recently announced its proposed regulation for heavy-duty engine and vehicle standards and highway diesel fuel sulfur control requirements. A diesel PM emission standard of 0.01 g/bhp/hr is proposed. This proposed standard is based on the anticipated emission reductions from low-sulfur diesel fuel and the use of a catalyst-based diesel particulate filter. To comply with a 2005 European Union (EU) emission standard for diesel fueled vehicles, the French automaker, Peugeot Citroen, recently unveiled a diesel PM catalyst-based DPF system which is expected to go into production in the year 2000.

B. What are the costs associated with these control technology options?

Tables 9a through 9d present information on the costs associated with applying catalyst-based DPFs[5] to stationary, off-road, and on-road diesel engines, including both retrofit and new engine applications. Table 9a provides information on the capital costs associated with retrofitting stationary diesel engines with catalyst-based DPFs. This information was obtained from representative catalyst-based DPF manufacturers and is intended to represent the range in the retail costs at this time. These cost estimates are mostly consistent with the $30 to $50 per horsepower range reported by the Manufacturers of Emission Controls Association (MECA) in "Emission Control Technology for Stationary Internal Combustion Engines" dated July 1997.

Table 9a: Stationary Engines - Current Catalyst-Based DPF Retrofit Costs

Technology	40 hp	100 hp	275 hp	400 hp	1,400 hp
Capital Cost	$1,300 - $5,000	$2,000 - $7,500	$3,500 - $9,000	$7,000 – $10,500	$30,000 - $44,000

[5] Some Catalyst-Based DPFs require, and all Catalyst-Based DPF's will benefit from, the use of very low-sulfur fuel. The incremental cost of this fuel is projected to be less than $ 0.05 per gallon and is discussed further in Appendix IV.

The costs associated with retrofitting off-road engines with catalyst-based DPFs are presented in Table 9b. This information also assumes a cost of $30 to $50 per horsepower, as reported by MECA representatives in "Exhaust Controls Available to Reduce Emissions from Non-road Heavy-Duty Engines."

Table 9b: Off-Road Engines - Current Catalyst-Based DPF Retrofit Costs

Technology	190 hp[6]	275 hp	475 hp
Catalyst-Based DPF	$5,700-9,500	$8,250-13,750	$13,500- 23,750

Table 9c provides an estimate of the current cost to retrofit on-road engines and vehicles with catalyst-based DPFs. This information assumes a cost of $10 to $20 per horsepower, as reported by MECA in "Emission Control Retrofit of Diesel-Fueled Vehicles" dated March 2000.

Table 9c: On-Road Engines - Current Catalyst-Based DPF Retrofit Costs

Vehicle Class	LHD	MHD	HHD
Average Horsepower[7]	**190 hp**	**250 hp**	**475 hp**
Capital Cost	$1,900 - $3,800	$2,500 - $5,000	$4,750 - $9,500

In contrast to the retrofit costs presented in Tables 9a – 9c, Table 9d presents the U.S. EPA's estimate of the future (2007) costs of applying catalyst-based DPFs to new on-road engines and vehicles. The U.S. EPA estimates are based on higher production volumes, and they are similar to the future cost projections presented by MECA in "Emission Control Retrofit of Diesel-Fueled Vehicles."

Table 9d: On-Road Engines - Future (2007) Catalyst-Based DPF Costs

Vehicle Class	LHD	MHD	HHD
Average Horsepower[8]	**190 hp**	**250 hp**	**475 hp**
Catalyst-Based DPF Costs[9]	$670	$890	$1,100

6 The power range noted has been selected to facilitate comparison with on-road costs.

7 The average horsepower was derived from the U.S. EPA's engine certification database for LHDD, MHDD, and HHDD engines for model years 1999 and 2000.

8 The engine horsepower ranges were derived from the U.S. EPA's engine certification database for LHDD, MHDD, and HHDD engines for model years 1999 and 2000.

9 The U.S. EPA Catalyst Based-DPF cost estimates include both fixed costs (e.g., tooling, research and development, and certification) and variable costs (e.g., hardware, assembly and markup).

There is a stark difference between the current costs associated with retrofitting existing engines and the future costs associated with applying catalyst-based DPFs to new engines and vehicles. However, we expect these costs to decline as production volumes and experience increase. ARB staff expects that, over the next few years, the retrofit costs presented in Tables 9a- 9c will approach the new engine costs presented in Table 9d.

Detailed cost and cost-effectiveness analyses will be completed during the preparation of each control measure. However, staff expects that the costs associated with carrying out this plan will be significant and will be on the order of the costs associated with other major ARB programs. In addition, ARB staff recognize that there may be unique situations that require a special evaluation of the feasibility and/or cost-effectiveness of applying catalyst-based DPF technology. These issues will be fully investigated and considered during the development of the specific control measures.

VII. ALTERNATIVE TECHNOLOGIES

A. What alternatives to diesel-fueled engines and vehicles exist today that would result in lower diesel PM emissions?

Diesel-fueled engines are extensively used throughout California in equipment and vehicles that provide for the transportation of goods, construction of homes, and emergency power generation. (See Chapter III for more information on the uses of diesel-fueled engines.) Diesels are the engines of choice for most "heavy-duty" applications. However, for a significant number of applications, lower PM emitting alternatives to existing diesel-fueled engines exist. As ARB staff develops the control measure recommended in this report, the feasibility and cost of these alternatives will be evaluated and considered. In most cases, it is expected that well controlled diesel engines using very low-sulfur fuel will have equivalent PM emissions as benchmark gasoline or CNG fueled engines. Where this is true, it is envisioned that regulations would be structured to provide a choice of fuels. In cases where alternatively-fueled engines offer emission performance that cannot be matched by diesel-fueled engines, the feasibility and costs of setting standards based the capability of alternatively fueled engines will be assessed.

Current alternatives to diesel-fueled vehicles and equipment include:

- natural gas fueled vehicles and equipment;
- gasoline-fueled vehicles and equipment;
- dual-fueled vehicles and equipment;
- electrically-powered vehicles and equipment;
- fuel cell technology; and
- other alternatively fueled (e.g., Bio-diesel) vehicles and equipment.

The next step in the AB 1807 process, following approval of this report, is the development of the specific ATCMs and regulations designed to reduce diesel PM emissions from diesel-fueled engines and vehicles. Chapter VIII identifies the specific control measures we currently recommend be developed. As part of the process in developing these recommended measures, where appropriate, the ARB staff will thoroughly evaluate available alternatives to diesel-fueled engines and diesel fuel. Criteria evaluated by the ARB staff when considering the recommendation of alternative technologies include:

- reduction in emissions of air toxics;
- the availability and quality of source test information;
- cost and cost-effectiveness of the alternative technology; and
- operation or design constraints associated with the alternative

In summary, diesel-fueled engines have established themselves for a variety of reasons as the preferred power source for many functions in our industrial society. However, cleaner alternatives do exist which ARB staff will consider when developing the measures recommended in this report.

ARB staff will develop the ATCMs and regulations in an open and public process. Draft versions of ATCMs and regulations will be presented to the public for review and comment, and a final draft version will be presented to the Board for approval. Public outreach is an essential element in the development of any ATCM or regulation to ensure that all affected and interested parties have full opportunity to provide input and shape rules that are both effective and workable.

VIII. STAFF'S RECOMMENDATION

In August 1998, the ARB identified particulate matter emissions from diesel fueled engines as a TAC, and staff was directed to begin the risk management process. A working group was convened to advise the staff with its risk management efforts. Since October 1998, staff has been working with the advisory committee to develop this report on the need for further control of particulate emissions from diesel engines. Staff finds that:

1. The current inventory of diesel PM emissions, as presented in Chapter V of this report, demonstrate that stationary and mobile diesel engines currently emit over 28,000 tons per year of diesel PM in California;
2. The current statewide population-weighted annual outdoor and indoor risk from exposure to diesel PM emissions, as presented in Chapter V of this report, is estimated at over 500 and 350 potential excess cancers in a million, respectively; and
3. The evaluation of available diesel PM control technologies and strategies, as presented in Appendix II and Appendix IX to this report, demonstrates that

technically and economically feasible diesel PM control measures are available for diesel-fueled engines and vehicles.

Therefore, we recommend that the Board direct staff to develop measures to reduce diesel PM emissions from all diesel-fueled engines and vehicles. Measures that we recommend to be developed are presented below. None of the recommended measures will result in an increase in NOx emissions above applicable NOx emission certification levels.

The recommended measures for regulation development are discussed in sections A, B, and C below. Section D discusses the actions we believe the U.S. EPA needs to pursue to support our recommendations and to reduce diesel PM emissions in California. Section E discusses possible adverse impacts associated with the recommended measures. A more detailed description of each recommended measure and the associated emission reduction, risk reduction, cost analysis, and proposed implementation date for each measure can be found in Appendices II, III, and IV.

A. What measures does ARB recommend be developed to further reduce diesel PM emissions from mobile diesel-fueled engines and vehicles?

Table 10 summarizes the recommended measures for all mobile sources except for retrofit of off-road portable equipment, which is discussed in the next section. Together, these measures comprise a comprehensive program to be implemented in California to control and reduce potential cancer risk from exposure to diesel particulate matter from mobile sources. These measures are further subcategorized for on-road and off-road applications. Alternative strategy applications, which are non-regulatory, are also part of the comprehensive program. They are discussed later in this section.

As discussed in Chapter II, the recommended measures will be developed in accordance with the requirements of AB 1807. The specific control requirements of each measure will be developed in an open and public process. Details concerning each specific recommended measure, which include the cost and cost-effectiveness of controls and the availability of alternative technologies, will be explored as each recommended measure is developed.

Table 10: Recommended Measures to Reduce Diesel PM from Mobile Sources

Measures	Proposed Board Adoption Date	Proposed Implementation Date	Est. PM Reduction, tons per year	Est. PM Reduction, tons per year	Est. Cost per Unit, $
On-Road Measures			**2010**	**2020**	
Supplemental test procedures HDV certification	2000	2005	n/a	n/a	to be determined
Lower emission standards for new HDV engines	2001	2007	1,600	3,500	670-1,100
Control of emissions from existing engines (retrofit)	2002	2002-2008	1,870	280	1,900-9,500
Solid waste collection vehicles		2002			
Other public HDV fleets		2002			
Other public & private HDV fleets		2003-2008			
Control of HDV in-use emissions	2003	2005	n/a	n/a	130-150
Off-Road Measures					
Lower emission standards for new engines	2002	2006-2008	910	3,600	1,300-1,800
Control of emissions from existing engines (retrofit)	2002	2002-2008	10,800	6,800	5,700-23,800
Public fleets		2002-2003			
Other off-road fleets		2006-2008			
Control of in-use emissions	2003	2006-2008	n/a	n/a	to be determined
PM standards for new diesel pleasure craft engines	2002	2005	9	24	to be determined

On-Road

The recommended measures for diesel-fueled on-road mobile vehicles listed in Table 10 address both new and existing vehicles. The proposed implementation dates listed in Table 10 are tentative. The actual implementation dates may vary based on engine type or service and on the availability of very low-sulfur fuel. For new vehicles, ARB staff is proposing that new engine diesel PM standards that will reduce diesel PM emission by at least 90 percent from the current on-road standards. This proposal is based upon the U.S. EPA's proposed heavy-duty engine and vehicle standards and highway diesel fuel sulfur control requirements rule, and the expected engine, fuel, and control technology development needed to meet the proposed standards. For existing vehicles, ARB staff is proposing diesel PM emissions be reduced, for almost all (90 percent) engines, by at least 85 percent. This equates to an overall diesel PM emission reduction of 75 percent from existing vehicles. This reduction will be achieved through the addition of after-treatment technology, replacement of existing engines with new technology or alternatively fueled engines, or restrictions placed on the operation of existing equipment. The details of each of the recommended measures will be addressed during the actual regulation development process. In-use compliance programs will be implemented or enhanced to maintain the diesel PM emission reductions achieved through cleaner new engine standards and retrofits.

Off-Road

The recommended measures for diesel-fueled off-road engines are similar to those for on-road vehicles: more stringent diesel PM standards, after-treatment control retrofit requirements, and in-use compliance programs. In contrast, to on-road vehicles, off-road engines are not registered by the State, with the exception of portable engines that are permitted and/or registered by local districts or the State. Therefore, to ensure the application of recommended measures such as inspection and maintenance programs, in-use compliance testing, or mandatory retrofitting of older equipment, the ARB and district staff must rely on mechanisms such as warranty registration and local operating permits.

Non-Regulatory Strategies

Non-regulatory strategies for mobile sources include guideline development, voluntary memoranda of understanding, and non-regulatory incentive programs. A variety of voluntary and incentive programs are being proposed to achieve reductions beyond those California can achieve through regulatory action. Some involve programs adopted and implemented by local air districts, others are activities for which the ARB does not currently have the authority to regulate. While pursuing these non-regulatory strategies, ARB staff will work with the appropriate regulatory agencies to support their development of regulations consistent with what we are proposing for on-road and off-road sources under our jurisdiction. The non-regulatory strategies being considered by the ARB staff include:

- the voluntary application of diesel particulate filters for locomotives;
- the voluntary application of diesel particulate filters for commercial marine vessels;
- developing a memorandum of understanding (MOU) for the retrofit of airport ground support equipment;
- the voluntary retrofit of emergency vehicles; and
- implementing transportation control measures – idling restrictions;

B. What measures does ARB recommend be developed to further reduce diesel PM emissions from stationary and off-road portable diesel-fueled engines?

Table 11 summarizes the recommended measures designed to reduce diesel PM emissions from stationary and off-road portable diesel-fueled engines. The proposed implementation dates listed in Table 11 are tentative. The actual implementation dates may vary based on engine type or service and on the availability of very low-sulfur fuel. The measures identified in this section are discussed in more detail in Appendix II. For new engines, the recommended control measures presented in Table 11 require the application of catalyst-based DPFs or a similar technology that will reduce diesel PM emissions by at least 90 percent from uncontrolled levels. For existing vehicles, ARB staff is proposing diesel PM emissions be reduced, for almost all (90 percent) engines, by at least 85 percent. This equates to an overall diesel PM emission reduction of 75 percent from existing vehicles. This reduction will be achieved through the addition of after-treatment technology, replacement of older technology engines with new technology or alternatively fueled engines, or restrictions placed on the operation of existing equipment. The details of each of the recommended measures will be addressed during the development of each of the air toxic control measures and regulations. Because of the variety of existing engines, as well as the multitude of applications, staff expects that no single control technology will be universally applicable to all retrofit applications.

Tables 9a and 9b presented information on the costs associated with applying catalyst-based DPFs on both new and retrofit stationary and portable engines. The preliminary cost-effectiveness for the control measures identified in Table 11 ranges from 5 to 200 dollars per pound of diesel PM reduced. The cost per pound of diesel PM reduced reflects the predicted costs associated with purchasing, installing, and maintaining a catalyst-based DPF on each of the diesel-fueled engines addressed by the recommended measures. We believe these cost-effectiveness estimates similar to the cost-effectiveness estimates for regulations developed to reduce other particulate compounds that have been identified as toxic air contaminants (e.g., hexavalent chromium and lead).

Table 11: Recommended Measures to Reduce Diesel PM from Stationary and Off-Road Portable Sources

Control Measure	Proposed Board Adoption Date	Proposed Implementation Date	Estimated PM Reduction 2010 (TPY)	Estimated PM Reduction 2020 (TPY)
Stationary Engine				
New Engines	2002	2002	33	21
Prime Engine Retrofit	2002	2003	70	66
Emergency Standby Retrofit	2002	2003	105	105
Off-Road Portable Engine Retrofit	2002	2003-2005	712	252
Agricultural Engine Retrofit	2002	2003-2005	297	197

Stationary

The recommended measures for stationary diesel-fueled engines listed in Table 11 address both new and existing engines. For new engines, the ARB staff recommends an ATCM be developed based on the requirements of the ARB's permitting guidance document, Risk Management Guidance for the Permitting of New Stationary Diesel-fueled Engines, (September 2000). (See Appendix II for a more detailed description of Guidance requirements.) Diesel PM emission reductions from new stationary diesel-fueled engines will be accomplished by requiring these engines to meet either specific technology requirements (i.e., stringent diesel PM engine certification levels, usage of low-sulfur diesel fuel, and application of catalyst-based DPFs); or an equally stringent performance standard.

For existing prime (non-emergency) engines and emergency standby engines, ARB staff recommends the development of ATCMs that define retrofit control requirements. As shown in Table 11, ARB staff predicts the implementation of the prime engine and emergency standby engine ATCMs by 2003 will result in diesel PM reductions of up to 70 tons and 105 tons in 2010, respectively. To achieve this reduction, ARB staff is proposing diesel PM emissions be reduced, for almost all (90 percent) engines by at least 85 percent. This represents a 75 percent reduction in diesel PM emissions from engines in these categories. The details of each of the recommended measures will be addressed during the development of the regulations. Although catalyst-based DPFs are available, for these sources, this technology may not prove to be cost-effective for all engines especially smaller engines with limited hours of operation. During the ATCM development process, the ARB staff will conduct a more detailed cost-effectiveness analysis to help in determining the appropriateness of these controls. It is anticipated that both of these ATCMs would be fully implemented prior to 2010.

There are over 7,000 agricultural irrigation pump engines in California, representing about 11 percent of the total stationary and portable engine inventory. Because of the high use of these engines, they are a significant source of diesel PM and contribute half of the diesel PM emissions from the entire stationary engine category. In addition, agricultural irrigation pumps tend to be concentrated in specific regions of the State, contributing proportionally higher emissions within these regions.

H & SC section 42310(e) prohibits districts from requiring a permit for most equipment used in agricultural operations. However, the State and districts may establish emission control requirements for stationary agricultural equipment. Further, although districts are preempted from regulating portable agricultural equipment, the State can regulate this equipment if granted a waiver by the U.S. EPA. Therefore, ARB staff recommends working with the agricultural community to develop a comprehensive program to reduce emissions from engines used in agricultural operations. This program should evaluate both the substitution of diesel engines with electrically driven equipment and a comprehensive retrofit element.

ARB staff predicts a reduction of diesel PM from agricultural irrigation pumps of up to 297 TPY by 2010 and 197 TPY by 2020. To achieve this reduction, ARB staff is proposing diesel PM emissions be reduced, for almost all (90 percent) engines, by at least 85 percent. This represents a 75 percent reduction in diesel PM emissions from the engines in this category. This reduction will be achieved through the addition of after-treatment technology, replacement of older technology engines with new technology engines, use of alternative-fueled engines, or electrification. The details of each of the recommended measures will be addressed during the development of each of the regulations.

Off-Road Portable

Staff recommends that the ARB develop regulations to reduce diesel PM emissions from existing off-road portable diesel engines. New engines for off-road portable equipment will be regulated by the off-road rules discussed above. The ARB currently administers the Statewide Portable Equipment Registration Program (Statewide Registration Program) Regulation (Title 13 California Code of Regulation §2450 - 2466), which is a voluntary program for the statewide registration and regulation of off-road portable engines. To date, approximately 12,000 off-road portable engines have been registered. The staff recommends that the Statewide Registration Program Regulation be amended to include requirements for reducing diesel PM emissions from portable diesel engines through the application of catalyst-based DPFs, electrification where feasible, and consideration of alternate fuels. In addition, staff recommends the development of an ATCM, for implementation by local districts, consistent with amendments to the PERP regulation. Staff predicts compliance with the ATCM would reduce diesel PM emissions up to 712 tons per year in 2010 and up to 252 tons per year by 2020. To achieve this reduction, ARB staff is proposing diesel PM emissions be reduced, for almost all (90 percent) engines, by at least 85 percent. This represents a 75 percent reduction in diesel PM emissions the engines in this category. This reduction will be achieved through the addition of after-treatment technology, replacement of existing engines with new technology or alternatively fueled engines, or restrictions placed on the operation of existing equipment. The details of each of the recommended measures will be addressed during the development of the regulations.

C. What measures does ARB recommend regarding diesel fuel reformulation?

Table 12 summarizes the recommended measures regarding diesel fuel reformulation. The measures identified in this section are discussed in more detail in Appendix IV.

Table 12: Summary of Recommendations

Recommendation	Emission Reduction (%)	Incremental Cost ($/gal)	Implementation or Issue Date
	Diesel PM		
Very low-sulfur CARB diesel (≤ 15 ppmw S)	> 90 *	< 0.05	2005-2006
Guidance on alternative "diesel" fuels	20 **	< 0.18 **	2001

* Emission reductions with after-treatment.

** Estimated for emulsions of water in CARB diesel.

ARB staff recommends that a regulation be adopted in 2001 that requires very low-sulfur CARB diesel for all on-road, off-road, and stationary engines statewide, effective in 2006. ARB also recommends that programs be developed to ensure the adequate supply of very low-sulfur diesel fuel for vehicle fleets and stationary engines that are required through state or local rules to install catalytic add-on controls prior to 2006. The U.S. EPA has published proposed regulations which would require that all diesel fuel sold for use in on-road vehicles have a sulfur content no greater than 15 ppmw, beginning June 1, 2006. It is envisioned that the ARB regulation would apply to on-road and off-road sources but would otherwise be consistent with the U.S. EPA's efforts and enable the retrofit of off-road and stationary diesel engines with catalyst-based after-treatment control technologies.

ARB staff is also proposing to develop guidance on synthetic or alternative diesel fuel options. Synthetic or alternative diesel fuels may cost more than reformulated very low-sulfur CARB diesel, but should be considered if shown to be cost-effective for reducing diesel PM. These alternatives may result in significant benefits for higher-emitting categories, such as off-road engines. Synthetic or alternative diesel fuels may also prove to be part of the preferred control strategy for diesel-fueled engines or vehicles that result in relatively high risk, or where control retrofit options are very expensive or difficult to implement.

The guidance will identify alternative diesel fuels and provide information on associated emission reductions and cost. The guidance would assist local districts in their permitting of fleets and equipment, and may be especially useful in cases where control equipment retrofits are impractical.

D. What impact will the recommended measures have on diesel PM emissions and risk?

As illustrated in Figures 3 and 4, ARB staff estimates the full implementation of the recommended measures will result in an overall 75 percent reduction in the diesel PM inventory and the associated potential cancer risk for 2010, and an 85 percent reduction for 2020, when compared to today's diesel PM inventory and risk. These reductions will occur through the combined actions of both California and the U.S. EPA to adopt and implement rules that reduce diesel PM.

From 2000 to 2010, ARB staff predicts diesel PM emissions and risk would decrease by only about 20 percent if the recommended measures are not implemented. This reduction would result from the implementation of existing federal and state regulations and the attrition of older diesel-fueled passenger cars and light-duty trucks from the on-road fleet. The U.S. EPA has proposed new, lower emission standards for heavy-duty trucks for 2007 and lower sulfur limits for diesel fuel (on-road vehicles only) in 2006. The benefits of these proposed rules are not included as existing measures because they have not been adopted as of the date of this Plan.

The recommended measures can be grouped as follows: measures addressing on-road vehicles; measures addressing off-road equipment and vehicles, and measures addressing stationary and portable engines. These measures include the U.S. EPA proposed 2007 new heavy-duty truck standards and the proposed 2006 low-sulfur fuel limits. Figure 4 illustrates the impact of each of these groups of measures on projected diesel PM emission levels for 2010 and 2020. As shown, off-road recommended measures have the largest impact. Of the off-road recommended measures, the retrofit measures (see Figure 4) result in over 90 percent of the diesel PM reductions associated with all of the off-road measures.

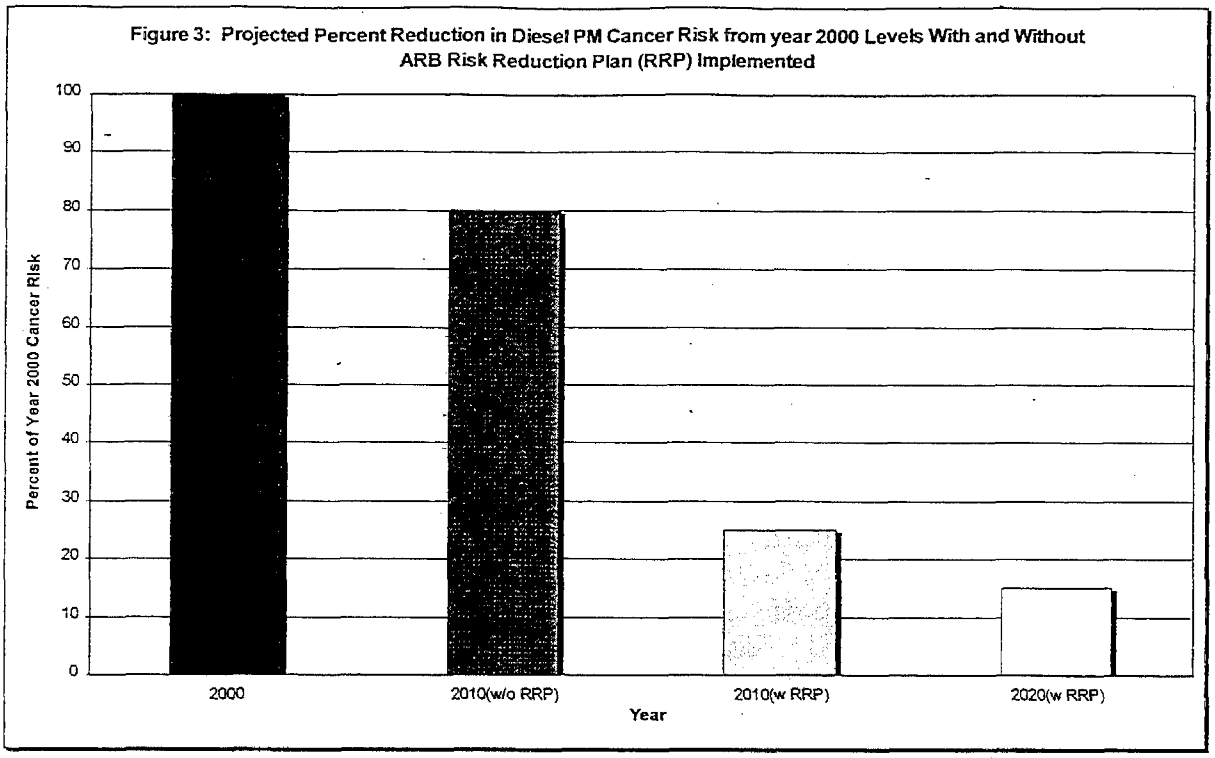


Figure 3: Projected Percent Reduction in Diesel PM Cancer Risk from year 2000 Levels With and Without ARB Risk Reduction Plan (RRP) Implemented
Percent of Year 2000 Cancer Risk
100
90
80
70
60
50
40
30
20
10
0
2000
2010(w/o RRP)
2010(w RRP)
2020(w RRP)
Year

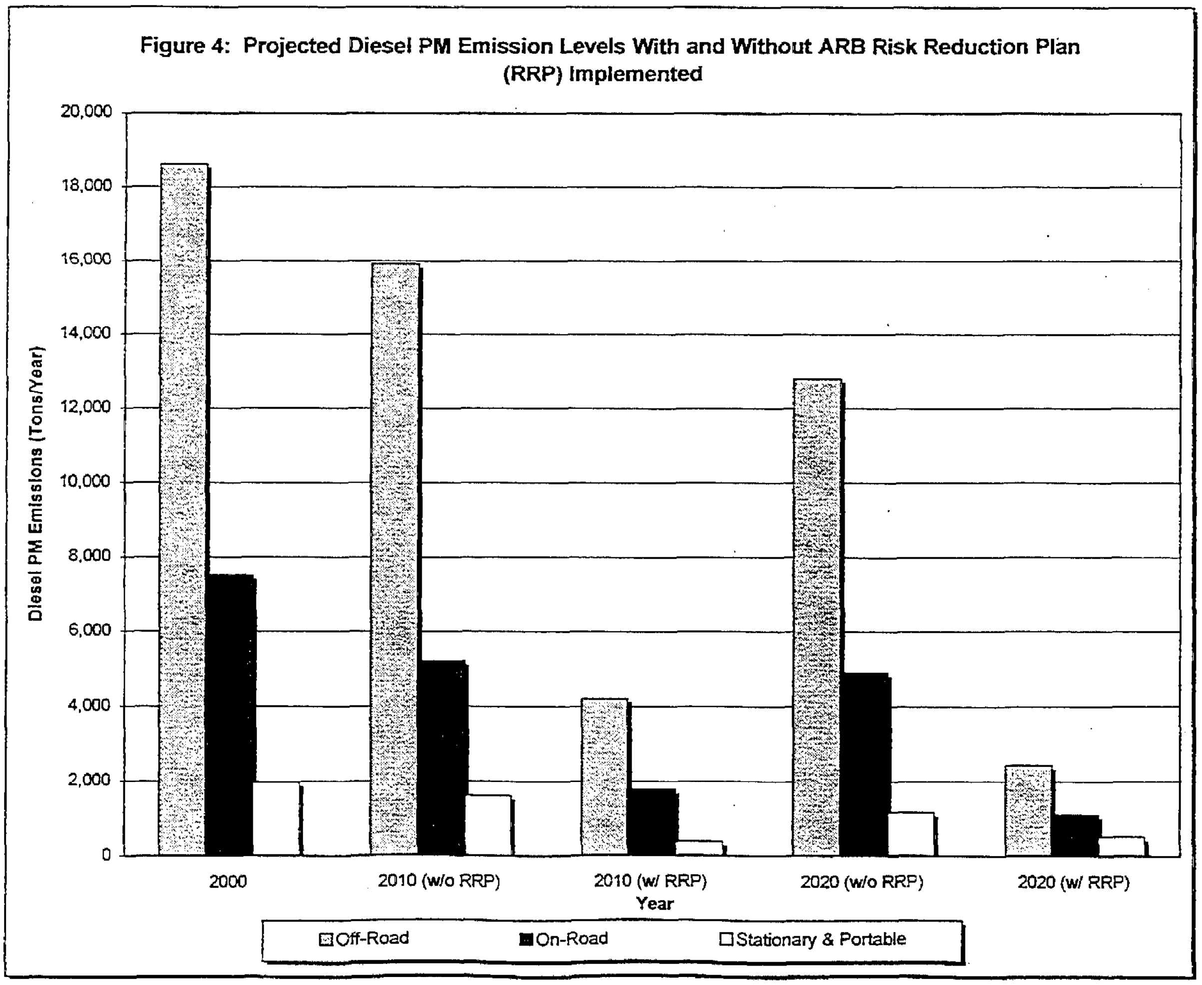


Figure 4: Projected Diesel PM Emission Levels With and Without ARB Risk Reduction Plan (RRP) Implemented
Diesel PM Emissions (Tons/Year)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
2000
2010 (w/o RRP)
2010 (w/ RRP)
2020 (w/o RRP)
2020 (w/ RRP)
Year
Off-Road
On-Road
Stationary & Portable

E. What other expected benefits are associated with implementing the recommended measures?

As discussed in the previous two sections, full implementation of the measures in this plan will result in significant reductions in diesel PM emissions and associated risk. There are additional benefits associated with reducing diesel PM emissions. These include:

- Increased visibility;
- Less material damage due to "soiling" of surfaces with diesel PM;
- Decreased noncancer health effects associated with diesel PM; and
- Decreased deposits of diesel PM and toxic chemicals on to surface water.

F. What possible adverse impacts may be associated with the recommended measures?

Most recommended measures require the use of add-on control devices, engine modifications, catalysts, low-sulfur diesel fuel and/or alternative fuel formulations. ARB staff has identified possible adverse environmental and safety impacts associated with the recommended measures. Each of these impacts will be fully investigated and addressed during the rulemaking process. Possible adverse impacts are identified below.

- Potential for decrease in fuel economy;
- Potential for increases in emissions of hydrocarbons (HC), oxides of nitrogen (NOx), and carbon monoxide (CO);
- Potential for changes in composition of diesel exhaust that could result in an increase in emissions of other toxic air pollutants.
- Potential for contamination of ground and surface waters;
- Potential safety issues due to use and handling of gaseous-fuels; and
- Potential increase in hazardous waste from the disposal of spent catalyst material.

G. What actions should the U.S. EPA pursue to support the ARB staff's recommended measures?

ARB staff recommends that the U.S. EPA adopt standards and regulations applicable to all 50 states that are similar in both scope and stringency to the measures in this plan. Further, ARB staff recommends the U.S. EPA take the following actions to support the measures in this plan and to reduce diesel PM emissions nationwide.

- *The U.S. EPA should implement more stringent emission standards for diesel PM in the Tier 3 rulemaking than are currently envisioned in the Off-Road Statement of Principles.*

Currently, the federal Clean Air Act preempts California from regulating new construction and farm equipment below 175 horsepower, new locomotives and locomotive engines, and commercial marine engines. Preempted off-road vehicles and equipment generate approximately 60 percent of the diesel PM emissions from off-road sources, thus limiting California's ability to achieve significant emission reductions on its own. Recent developments suggest that off-road engine control can move directly to after-treatment technology-based standards with higher emission reductions, on a cost-effective per engine basis. The U.S. EPA should, therefore, consider accelerating the implementation of emission standards based on after-treatment technologies with the goal of reducing diesel PM emissions by 90 percent from engines in these categories.

- *Require all diesel-fueled on-road and off-road engines and vehicles to use very low-sulfur diesel fuel (≤15 ppm).*
  The U.S. EPA has proposed regulations that would require all very low-sulfur diesel fuel to be sold for use in on-road vehicles beginning June 1, 2006, but has not proposed to extend this requirement to off-road sources. ARB staff's recommended measures for off-road engines are based on the use of very low-sulfur diesel fuel and the use of exhaust after-treatment devices which would require low-sulfur fuel. It is critical that very low-sulfur diesel fuel be required to be sold nationwide for use in both on-road and off-road engines and vehicles. If not, California-only off-road regulations should be developed, but issues concerning the cost-effectiveness of developing California-only engine/after treatment systems and the compatibility of those systems with a higher sulfur national off-road diesel fuel need to be explored.

- *The U.S. EPA should require more stringent control of PM emissions from commercial marine vessels through retrofit of existing engines.*
  Emissions from commercial marine vessels, which includes ocean-going vessels, tugboats, fishing boats, cruise ships, and other large ships, are a major source of diesel PM which is expected to grow from 2000 to 2010. A program to retrofit existing engines could provide significant benefits over the adopted controls for new engines recently adopted by the U.S. EPA. The U.S. EPA should, therefore, develop standards to reduce diesel PM emissions from these engines.

- *The U.S. EPA should require the implementation of a retrofit program to reduce diesel PM from locomotives.*
  The current national rule only affects particulate matter emissions from model year 2005 and later locomotives and does not reduce PM emissions from older locomotives. Recent developments in diesel particulate filter technology suggest that a locomotive retrofit program may be feasible and cost-effective. The U.S. EPA should, therefore, develop retrofit standards to reduce diesel PM emissions from engines in these categories.

Appendix I

Glossary of Terms and Acronyms

September 13, 2000

Air Basin [Glossary][1] – means a land area with generally similar meteorological and geographic conditions throughout. To the extent possible, air basin boundaries are defined along political boundary lines and include both the source and receptor areas. California is currently divided into 15 air basins. See section 39012 of the California Health and Safety Code.

Air Dispersion Model – A mathematical model or computer simulation used to estimate the concentration of toxic air pollutants at specific locations as a result of mixing in the atmosphere.

Alternate Fuels [13 CCR § 2421 (a)(1)] – means any fuel that will reduce non-methane hydrocarbons (on a reactivity-adjusted basis), NOx, CO, and the potential risk associated with toxic air contaminants as compared to gasoline or diesel fuel and would not result in increased deterioration of the engine. Alternate fuels include, but are not limited to, methanol, ethanol, liquefied petroleum gas, compressed natural gas, and electricity.

Ambient Risk – The background risk level from all the sources of air toxics pollutants within a certain specific area or location.

Annual Average Concentration – The concentration of an air toxics pollutant based on an annual average calculation for a full year of meteorological data.

Area Source [Glossary] – Those sources for which a methodology is used to estimate emissions. This can include area-wide, mobile and natural sources, and also groups of stationary sources (such as dry cleaners and gas stations). The California Clean Air Act requires air districts to include area sources in the development and implementation of the AQMP. In the California emission inventory all sources which are not reported as individual point sources are included as area sources. The federal air toxics program defines a source that emits less than 10 tons per year of a single hazardous air pollutant (HAP) or 25 tons per year of all HAPs as an area source, but shall not include motor vehicle or nonroad vehicles subject to regulation under Title II. .

Area-Wide Sources [Glossary] - Sources of pollution where the emissions are spread over a wide area, such as consumer products, fireplaces, road dust and farming operations. Area-wide sources do not include mobile sources or stationary sources.

Best Available Control Technology (BACT) [Glossary] – The most up-to-date methods, systems, techniques, and production processes available to achieve the greatest feasible emission reductions for given regulated air pollutants and processes. BACT is a requirement of NSR (New Source Review) and PSD (Prevention of Significant Deterioration).

[1] From the Air Resources Board's Glossary for Air Pollution Terms, available online at http://www.arb.ca.gov/html/gloss.htm.

Best Available Retrofit Control Technology (BARCT) [Glossary] – An air emission limitation that applies to existing sources and is based on the maximum degree of reduction achievable, taking into account environmental, energy, and economic impacts by each class or category of source.

California Ambient Air Quality Standard (CAAQS) [Glossary – A legal limit that specifies the maximum level and time of exposure in the outdoor air for a given air pollutant and which is protective of human health and public welfare (Health and Safety Code 39606b). CAAQSs are recommended by the California Office of Environmental Health Hazard Assessment and adopted into regulation by the CARB. CAAQSs are the standards which must be met per the requirements of the California Clean Air Act (CCAA).

Cancer Risk – The theoretical probability of contracting cancer when exposed for a lifetime to a given concentration of a substance usually calculated as an upper confidence limit. The maximum estimate risk may be presented as the number of chances in a million of contracting cancer.

Compression-ignition engine [13 CCR §2410 (a)(10)] - A type of engine with operating characteristics significantly similar to the theoretical diesel combustion cycle. The non-use of a throttle to regulate intake flow for controlling power during normal operation is indicative of a compression-ignition engine. A compression-ignition engine may be petroleum-fueled (i.e., diesel-fueled) or alternate-fueled. All engines and equipment that fall within the scope of the preemption of Section 209(e)(1)(A) of the Federal Clean Air Act (42 U.S.C. 7543(e)(1)(A) and as defined by regulation of the Environmental Protection Agency, are specifically not included within this category.

Construction Equipment [40 CFR Part 85, Subpart Q, § 85.1602]– Any internal combustion engine-powered machine primarily used in construction and located on commercial construction sites.

Criteria Pollutant [Glossary – An air pollutant for which acceptable levels of exposure can be determined and for which an ambient air quality standard has been set. Examples include ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, and PM10 and PM2.5. The term "criteria air pollutants" derives from the requirement that the U.S. EPA must describe the characteristics and potential health and welfare effects of these pollutants The U.S. EPA and CARB periodically review new scientific data and may propose revisions to the standards as a result.

Diesel Cycle Engine [13 CCR § 2421 (a)(16)] – A type of engine with operating characteristics significantly similar to the theoretical diesel combustion cycle. The primary means of controlling power output in a diesel cycle engine is by limiting the amount of fuel that is injected into the combustion chambers of the engine. A diesel cycle engine may be petroleum-fueled (i.e., diesel-fueled) or alternate-fueled.

Diesel Fuel – Fuel meeting the following specification

> ASTM D975 – 98, Standard Specification for Diesel Fuel Oil; includes No. 1-D, No. 1-D low sulfur, No. 2-D, No. 2-D low sulfur, and No. 4-D.

Diesel Fueled Engine – Any internal combustion, compression-ignition (diesel-cycle) engine that is fueled by diesel fuel or jet fuel.

Diesel Oxidation Catalyst (DOC) – An exhaust treatment device that reduces carbon monoxide emissions, hydrocarbon emissions and the soluble organic fraction of diesel particulate matter through catalytic oxidation. Typical diesel PM control efficiencies range from 16% to 30%.

Diesel Particulate Filter (DPF) – An exhaust treatment device that reduces diesel particulate matter through filtration. DPFs must be periodically "regenerated" to remove the collected particulate matter. DPFs can incorporate passive regeneration techniques, such as the catalyzed particulate filter, or they can incorporate active regeneration techniques, such as the electrically regenerated particulate filter. Typical diesel PM control efficiencies range from 62% to 97%.

Diesel Particulate Matter (diesel PM) – That portion of the exhaust from a diesel fueled compression ignition engine which is collected via a particulate matter sampling method. Diesel PM consists of several constituents, including: an elemental carbon fraction, a soluble organic fraction and a sulfate fraction. The majority of diesel PM (i.e., 98%) is smaller than 10 microns in diameter.

District [Glossary] – An air pollution control district or an air quality management district. Currently, there are 35 air districts in California.

Elemental Carbon Fraction – For diesel particulate matter (a.k.a. the carbonaceous fraction or soot), the solid, non-volatile component of diesel particulate matter which is formed during the combustion process. The sponge-like structure of elemental carbon particles allow them to be carriers for low-volatility organic compounds, including the soluble organic fraction of diesel particulate matter. Elemental carbon particles are very small (0.01 to 0.08 μm in diameter) and can be easily inhaled into the deep areas of the respiratory tract.

Emergency Standby Engine – An engine which operates as a temporary replacement for primary mechanical or electrical power during an unscheduled outage. An engine is not considered an emergency standby engine if it is used for purposes other than: periodic maintenance, periodic readiness testing, unscheduled outages, or to supply power while maintenance is performed or repairs are made to the primary power supply.

Emission Factor [Glossary] – For stationary sources, an emission factor is the relationship between the amount of pollution produced and the amount of raw material processed or burned. For mobile sources, an emission factor is the relationship between the amount of pollution produced and the number of vehicle miles traveled. By using an emission factor for a pollutant and specific source activity data, it is possible to compute emissions from a source. This approach is used in preparing emissions inventories.

Emission Inventory [Glossary] – An estimate of the amount of pollutants emitted into the atmosphere from major mobile, stationary, area-wide, and natural-source categories over a specific time period such as a day or year.

Farm Equipment or Vehicle [40 CFR Part 85, Subpart Q § 85.1602] – Any internal combustion engine-powered machine primarily used in the commercial production and or commercial harvesting of food, fiber, wood, or commercial organic products, or for the processing of such products for further use on a farm. This includes

Fuel Borne Catalyst (FBC) – A fuel additive containing one or more fuel-soluble metals that acts as a catalyst to lower the temperature at which regeneration occurs within a diesel particulate filter.

Heavy-duty vehicle [EMFAC2000 Technical Support Document] – The EMFAC2000 inventory model classifies heavy-duty vehicles by gross vehicle weight rating (GVWR). Light heavy-duty vehicles have a vehicle weight of 8,501 to 14,000 lbs. GVWR, medium heavy-duty vehicles are 14,001 to 33,000 lbs. GVWR, and heavy heavy-duty vehicles are greater than 33,000 lbs. GVWR.

ISCST3 – Industrial Source Complex Short Term.

Light-duty truck [13 CCR § 1900 (a)(8)] – Any 2000 and subsequent model motor vehicle certified to the standards in section 1961(a)(1) rated at 8,500 pounds gross vehicle weight or less; and any other motor vehicle, rated at 6,000 pounds gross vehicle weight or less, which is designed primarily for the purposes of transportation of property or is a derivative of such a vehicle, or is available with special features enabling off-street or off-highway operation and use.

Marine diesel engine [13 CCR § 2421 (a)(28)] – A compression-ignition engine that is intended to be installed on a vessel.

Medium-duty vehicle [13 CCR § 1900 (a)(9)] – Any pre-1995 model year heavy-duty vehicle having a manufacturer's gross vehicle weight rating of 8,500 pounds or less; any 1992 through 2006 model-year heavy-duty low-emission, ultra-low-emission, super-ultra-low emission or zero-emission vehicle certified to standards in section 1960.1(h)(2) having a manufacturer's gross vehicle weight rating of 14,000 pounds or less; any 1995 through 2003 model year heavy-duty vehicle certified to the standards in section 1960.1(h)(1) having a manufacturer's gross vehicle weight rating of 14,000 pounds or less; and any 2000 and subsequent model heavy-duty low-emission, ultra-low-emission, super-ultra-low emission or zero-emission vehicle certified to the standards in Section 1961(a)(1) or 1962 having a manufacturer's gross vehicle weight rating between 8,500 and 14,000 pounds.

Multiple Air Toxics Exposure Study II (MATES II) - The Multiple Air Toxics Exposure Study (MATES-II) is an urban toxics monitoring and evaluation study conducted for the South Coast Air Basin.

New Source Risk – Cancer risk resulted from toxic air contaminants due to the construction and operation of new stationary sources.

New Source Review (NSR) [Glossary] – A Clean Air Act requirement that State Implementation Plans must include a permit review, which applies to the construction and operation of new and modified stationary sources in nonattainment areas, to ensure attainment of national ambient air quality standards. The two major requirements of NSR are Best Available Control Technology and emission offsets.

Non-road Engine [13 CCR § 2452 (v)] – Any engine that is in or on a piece of equipment that is self-propelled or serves a dual purpose by both propelling itself and performing another function, such as lawnmowers and string trimmers; or is in or on a piece of equipment that is intended to be propelled while performing its function, such as lawnmowers and string trimmers; or that, by itself or in a piece of equipment, is portable or transportable.

Off-road compression-ignition engine [13 CCR § 2421 (a)(31)] -

(A) Except as specified in paragraph (B) of this definition, an off-road compression-ignition engine is any internal combustion engine:

i. in or on a piece of equipment that is self-propelled or serves a dual purpose by both propelling itself and performing another function and is primarily used off the highways (such as garden tractors, off-highway mobile cranes and bulldozers); or
ii. in or on a piece of equipment that is intended to be propelled while performing its function (such as lawnmowers and string trimmers); or
iii. that, by itself or in or on a piece of equipment, is portable or transportable, meaning designed to be and capable of being carried or moved from one location to another. Indicia of transportability include, but are not limited to wheels, skids, carrying handles, dolly, trailer, or platform.

(B) An internal combustion engine is not an off-road compression-ignition engine if:

i. the engine is used to propel a vehicle subject to the emissions standards contained in Title 13, California Code of Regulations, Sections 1950 - 1978, or a vehicle used solely for competition, or is subject to standards promulgated under section 202 of the federal Clean Air Act (42 U.S.C. 7521); or
ii. the engine is regulated by a federal New Source Performance Standard promulgated under section 111 of the federal Clean Air Act (42 U.S.C. 7511); or

iii. the engine otherwise included in paragraph (a)(iii) of this definition remains or will remain at a location for more than 12 consecutive months or a shorter period of time for an engine located at a seasonal source. A location is any single site at a building, structure, facility, or installation. Any engine (or engines) that replaces an engine at a location and that is intended to perform the same or similar function as the engine replaced will be included in calculating the consecutive period. An engine located at a seasonal source is an engine that remains at a seasonal source during the full operating period of the seasonal source. A seasonal source is a stationary source that remains in a single location on a permanent basis (i.e., at least two years) and that operates at a single location approximately three months (or more) each year. This paragraph does not apply to an engine after the engine is removed from the location.

Off-Road Vehicle or Off-Road Equipment [13 CCR § 2421 (a)(32)] – A vehicle or equipment that is powered by an off-road compression-ignition engine.

Particulate Matter (PM) [Glossary] - Any material, except pure water, that exists in the solid or liquid state in the atmosphere. The size of particulate matter can vary from coarse, wind-blown dust particles to fine particle combustion products.

Passenger car [13 CCR § 1900 (a)(12)] – Any motor vehicle designed primarily for transportation of persons and having a design capacity of twelve persons or less.

PM_{10} [Glossary]– A criteria air pollutant consisting of small particles with an aerodynamic diameter less than or equal to a nominal 10 microns (about 1/7 the diameter of a single human hair). Their small size allows them to make their way to the air sacs deep within the lungs where they may be deposited and result in adverse health effects . PM10 also causes visibility reduction. For the purposes of this report, PM_{10} has the same meaning as Diesel Particulate Matter.

Point Source [Glossary]– Specific points of origin where pollutants are emitted into the atmosphere such as factory smokestacks.

Portable [13 CCR § 2452 (x)] – Designed and capable of being carried or moved from one location to another. Indicia of portability include, but are not limited to, wheels, skids, carrying handles, dolly, trailer, or platform. For the purposes of the portable engine and equipment program, dredge engines on a boat or barge are considered portable. The engine or equipment unit is not portable if any of the following are true:

(1) the engine or equipment unit or its replacement is attached to a foundation, or if not so attached, will reside at the same location for more than 12 consecutive months. Any engine or equipment unit such as back-up or stand-by engines or equipment units, that replace engines(s) or equipment unit(s) at a location, and is intended to perform the same or similar function as the engine(s) or equipment unit(s) being replaced, will be included in calculating the consecutive time period. In that case, the cumulative time of all engines or equipment units, including the time between the removal of the replacement engine(s) or equipment unit(s), will

be counted toward the consecutive time period; or the engine or equipment unit remains or will reside at a location for less than 12 consecutive months, if the engine or equipment unit is located at a seasonal source and operates during the full annual operating period of the seasonal source, where a seasonal source is a stationary source that remains in a single location on a permanent basis (at least two years) and that operates at that single location at least three months each year; or

(2) the engine or equipment unit is moved from one location to another in an attempt to circumvent the portable residence time requirements.

The period during which the engine or equipment unit is maintained at a storage facility is excluded from the residency time determination.

Portable Equipment Registration Program (PERP) – A statewide program for the registration and regulation of portable engines and engine-associated equipment units. See 13 CCR § 2450 – 2466.

Prime Engine – An engine that is not an emergency standby engine.

Reasonable Available Control Technology (RACT) – a control technique for limiting emissions from existing sources in certain nonattainment areas. RACT determinations are developed to aid districts in developing regulations to attain and maintain the state ambient air quality standards. RACT determinations help promote consistency among control requirements for similar emission sources among districts with the same air quality attainment designations.

Receptor – A resident or offsite worker that is exposed to a air toxic pollutant sources emissions.

Sac Volume – On a fuel injector, the Sac Volume is the space between needle valve and the tip of a fuel injector.

SCREEN3 Meteorological Data – A set of datum chosen to represent the most unfavorable meteorological conditions (i.e., those resulting in the highest concentration estimates) to simulate the worst case scenario.

Site-Specific Meteorological Data – A minimum of 3 to 5 years collection of meteorological data for a specific area as input data for the air dispersion model.

Soluble Organic Fraction (SOF) – The soluble organic fraction of diesel particulate matter is that portion of diesel PM that consists of the unburned portions of diesel fuel and lubricating oil which condense and adsorb on to the sponge-like elemental carbon particles. The soluble organic fraction includes extractable compounds such as aldehydes, alkanes, alkenes, aliphatic hydrocarbons, and polycyclic aromatic hydrocarbons and their derivatives.

Source Specific Rule – An air pollution control regulation that applies to one category or class of air pollution sources (e.g. boilers). An Airborne Toxic Control Measure (ATCM) is an example of a Source Specific Rule.

State Implementation Plan (SIP) [Glossary] – A plan prepared by states and submitted to U. S. EPA describing how each area will attain and maintain the national ambient air quality standards. SIPs include the technical foundation for understanding the air quality (e.g. emission inventories and air quality monitoring), control measures and strategies, and enforcement mechanisms.

Stationary Engine – A stationary engine is an engine which is neither portable nor self-propelled and is operated at a single facility.

Sulfate Fraction – The sulfate fraction of diesel particulate matter is that portion of diesel PM formed when sulfur dioxide in an engine's exhaust stream oxidizes to form sulfur trioxide which then combines with available moisture to form sulfates.

Total Suspended Particulate (TSP) [Glossary] – Particles of solid or liquid matter -- such as soot, dust, aerosols, fumes, and mist -- up to approximately 30 microns in size. For the purposes of this report, TSP has the same meaning as diesel PM.

Toxic Air Contaminant (TAC) [Glossary] – An air pollutant, identified in regulation by the ARB, which may cause or contribute to an increase in deaths or in serious illness, or which may pose a present or potential hazard to human health. TACs are considered under a different regulatory process (California Health and Safety Code Section 39650 et seq.) than pollutants subject to CAAQSs. Health effects to TACs may occur at extremely low levels, and it is typically difficult to identify levels of exposure which do not produce adverse health effects.

Transit Agency – A public entity responsible for administering and managing transit activities and services. Public transit agencies can directly operate transit service or contract out for all or part of the total transit service provided. The definition is consistent with that used by the Federal Transit Administration (Staff Report: Proposed regulation for a public transit bus fleet rule and emission standards for new urban buses, December 10, 1999).

Transportation Control Measure (TCM) [Glossary] - Any control measure to reduce vehicle trips, vehicle use, vehicle miles traveled, vehicle idling, or traffic congestion for the purpose of reducing motor vehicle emissions. TCMs can include encouraging the use of carpools and mass transit.

Unit Risk Number [Glossary] - The number of potential excess cancer cases from a lifetime exposure to one microgram per cubic meter (μ/m3) of a given substance. For example; a unit risk value of 5.5x10-6 would indicate an estimated 5.5 cancer cases per million people exposed to an average concentration of 1 μ/m3 of a specific carcinogen for 70 years.

Urban Bus – Current California regulations, by reference to the Code of Federal Regulations (CFR), Section 86.091-2, define an urban bus as a heavy heavy-duty diesel-powered passenger-carrying vehicle (+33,000 pounds GVW) with a load capacity of 15 or more passengers intended primarily for intra-city operation, i.e., within the confines of a city or greater metropolitan area. Urban bus operation is characterized by short rides and frequent stops. To facilitate this type of operation, more than one set of quick-operating entrance and exit doors are normally present. Since fares are usually paid in cash or tokens, rather than purchased in advance in the form of tickets, urban buses normally have equipment installed for collection of fares. Urban buses are also typically characterized by the absence of equipment and facilities for long distance travel, e.g., rest rooms, large luggage compartments, and facilities for stowing carry-on luggage (Staff Report: Proposed regulation for a public transit bus fleet rule and emission standards for new urban buses, December 10, 1999).

Volatile Organic Fraction (VOF) – The volatile organic fraction of diesel particulate matter is that portion of diesel PM that consists of the unburned portions of diesel fuel and lubricating oil which condense and adsorb on to the sponge-like elemental carbon particles. While similar to the Soluble Organic Fraction, the VOF is determined by a different test method.

Volume Source – Volume source is one of the Industrial Source Complex algorithms which is being used to model releases from a variety of industrial sources, such as building roof monitors, multiple vents, and conveyor belts.

Appendix II

Stationary and Portable Diesel-Fueled Engines: Appendix to the Diesel Risk Reduction Plan

September 13, 2000

TABLE OF CONTENTS

Contents Page

TABLE OF CONTENTS (cont.)

Contents Page

TABLE OF CONTENTS (cont.)

Contents | Page

I. PURPOSE

This report summarizes the need for further regulation of stationary and portable diesel-fueled engines.

II. ENGINE CATEGORIES

A. Stationary Engines

Stationary diesel-fueled engines were split into two categories: emergency standby and prime engines.

1. Emergency Standby

Emergency standby engines represent the majority of all stationary engines. For all stationary engines, emergency standby applications represent about 70% of the total stationary engines.

The most common use of emergency standby engines is in conjunction with generator sets to provide back-up electrical power during emergencies or unscheduled power outages. The emergency standby category does not include generators that are operated to displace or supplement utility grid power for economic reasons. Engines used in this capacity are considered prime engines and are discussed in the next section. Emergency generator engines can range from less than 50 horsepower to over 6,000 horsepower, depending on the end user's needs. Emergency standby engines are also used with fire pumps as part of fire suppression systems. Engines used in fire pump applications are seldom larger than 200 horsepower.

Typical operation of emergency standby applications average 50 hours annually, with most of the hours run for maintenance operations.

2. Prime Engines

Prime engines are used in a wide variety of applications, including: compressors, cranes, generators, pumps (includes agricultural irrigation pumps), and grinders/screening units.

The size and operation of prime engines are highly variable, depending on the specific application. Prime engines can range in size from about 50 horsepower for an engine used with a screening plant used to sort wood waste, to 2,000 horsepower or more for an engine generator set that is the main source of power for a facility. Annual operation can be as low as 100 hours a year for a prime engine driving a compressor to several thousand hours a year for an irrigation pump.

Engines used in agricultural irrigation operations represent about 2/3 of the engines used in prime applications. Agricultural operations, including irrigation pump engines are exempt from district permit requirements and are not currently subject to air quality requirements. Agricultural irrigation pump engines can be either stationary or portable. For stationary applications, these engines are typically around 160 horsepower and normally operate between 1,500 to 2,000 hours a year.

B. Portable Engines

Portable engines are a subset of the off-road engine category. Portable engines are engines that move from location to location, but are not used to propel mobile equipment or motor vehicles.

Portable engines are used in a wide variety of applications. Examples of the use of portable engines include: agricultural irrigation pumps; compressors; cranes; dredging equipment; ground support equipment at airports; military tactical support equipment (TSE); oil well drilling, servicing and workover rigs; pile-driving hammers; power generators; rock crushing and screening equipment; welding equipment; and woodchippers. The engines used in these activities can range in size from less than 50 horsepower to in excess of 2,000 horsepower. Similarly, the annual hours of operation vary from several hundred hours to several thousand hours. In the case of portable agricultural irrigation pump engines, the average horsepower is less than 100 horsepower and the engines normally operate about 750 hours a year.

III. SUMMARY OF EXISTING REGULATIONS

A. Stationary Engines

This section discusses the air pollution control laws that apply to stationary and portable diesel-fueled engines. Health and Safety Code Division 26, Section 40000 specifies that the Air Resources Board (ARB) has direct responsibility for controlling emissions from motor vehicles, and that districts have the responsibility of controlling air pollution from all sources other than motor vehicles.

The discussion of existing regulations in this section covers regulations that are currently in effect or control measures committed to in the 1994 State Implementation Plan (SIP). Only one measure in the SIP has not been fully implemented. This measure affects off-road industrial equipment and targets oxides of nitrogen (NOx) emissions. This commitment will be satisfied with the implementation of the Tier IV standards for off-road engines. Future revisions to the SIP are likely to result in additional control measures being implemented by both districts and ARB, some of which may affect diesel-fueled engines.

New Source Review Rules

A new or modified stationary source may be subject to one or more federal, State or local air pollution control laws. The federal Clean Air Act established two distinct preconstruction permit programs (termed New Source Review (NSR)) governing the construction of major new and modifying stationary sources. NSR is intended to ensure these sources do not prevent the attainment or interfere with the maintenance of the ambient air quality standards. Sources constructing in nonattainment areas are required to apply the Lowest Achievable Emission Rate (LAER) control technology to minimize emissions and to "offset" the remaining emissions with reductions from other sources. Sources constructing in attainment or unclassified areas are required by the Prevention of Significant Deterioration (PSD) program to apply the Best Available Control Technology (BACT) and meet additional requirements aimed at maintaining the region's clean air. In addition, the Federal Clean Air Act requires all major sources subject to federal NSR to obtain federal Title V operating permits governing continuing operations.

The State Health and Safety Code requires districts with nonattainment areas for CO, NOx, VOC, and SOx to design permit programs for new and modified stationary sources with the potential to emit above specified levels to achieve no net increase in emissions. In these areas, districts must also require Best Available Control Technology on new and modified stationary sources above specified emission levels.

The state Health and Safety Code allows local districts to establish a permit system that requires any person who builds, erects, alters, replaces or operates equipment or machinery which may cause the issuance of air contaminants to obtain a permit from the district. All districts in California have adopted permit programs. Generally, the local districts incorporate the State and federal permitting requirements into their preconstruction and operating permit programs. Some districts issue separate federal permits. Most of the emission control requirements that have been established for diesel-fueled engines have been set through the district permitting programs. In addition, for particulate matter, nothing restricts the authority of a district to adopt regulations to control suspended particulate matter or visibility reducing particles.

IC Engine Regulations

While most districts require some level of control to reduce NOx emissions from new and modified stationary and portable diesel-fueled engines, only twelve districts have adopted source specific regulations affecting emissions from existing stationary and portable diesel-fueled engines. Engines used in agricultural operations, emergency standby applications, and low capacity engines are typically exempt from these regulations. All twelve regulations set NOx and carbon monoxide (CO) standards (three districts also have hydrocarbon (HC) standards). These regulations do not set limits for diesel PM emissions. However, South Coast Air Quality Management District (SCAQMD) Regulation 1110.2 is projected by SCAQMD staff to result in a number of diesel-fueled engines being taken out of service because of the cost of satisfying the

Regulation's NOx standard. Consequently, SCAQMD staff expects overall diesel PM emissions will be lower in the SCAQMD by the end of 2004.

Ventura County air pollution control district (APCD) is the only district that has adopted a source specific regulation that targets portable engines. Ventura County APCD Rule 74.16 affects only portable engines used in oilfield drilling operations and requires, for some drilling activities, the use of electrified drilling equipment.

Emergency Standby Requirements

In addition to local district regulation of emergency standby engines, there are other laws and regulations that affect the use of these engines. Certain types of facilities are required by either California law or local regulations to provide for emergency lighting and power. Examples of affected facilities include medical facilities, prisons, and certain office complexes. For medical facilities, State law requires that the equipment providing the emergency lighting and power must be tested at load for 30 minutes every 7 to 10 days.

Toxic New Source Review

Currently, four districts have adopted Toxic New Source Review rules and approximately 15 districts have policies. A rule is a set of criteria that has been formally adopted. A policy is a set of guiding principles that has not been codified into a rule. None of these rules or policies was designed to facilitate the permitting of diesel-fueled engines. Most of these rules and policies use an approach that incorporates risk levels that trigger the installation of Toxic Best Available Control Technology (T-BACT) and permit denial. This approach doesn't work well with diesel-fueled engines, since relatively small engines (100 hp) operated for relatively short periods of time (400 hours per year) can pose significant cancer risks. As a result, the ARB; working with districts, industry, and environmental groups; has developed a risk management guidance document for the permitting of new stationary diesel-fueled engines.

The *Risk Management Guidance for the Permitting of New Stationary Diesel-Fueled Engines. September 2000,* (Guidance) is the ARB staff's guidance to assist local air pollution control districts and air quality management districts (districts) in making risk management decisions associated with the permitting of new stationary diesel-fueled engines that are greater than 50 horsepower. The Guidance identifies minimum technology requirements and performance standards for reducing particulate matter emissions from new stationary diesel-fueled engines. It identifies engine categories that may be approved without a site-specific health risk assessment (HRA), provided either the minimum technology requirements or performance standards are met. The Guidance also discusses diesel-specific adjustments that may be used when a site-specific HRA is required

The key recommendations in the Guidance are:

- Approve permits for Group 1 diesel-fueled engines if they meet the appropriate performance standards or minimum technology requirements (see Table 1). We anticipate most (90%) new stationary diesel-fueled engines will fall in Group 1 based on the current inventory and average hours of operation of stationary diesel-fueled engines (See Chapter IV). This excludes agricultural engines which are exempt from permitting requirements. Meeting the appropriate minimum technology requirements or performance standards will result in the application of the best available control technologies (BACT) and the lowest achievable risk levels, in consideration of costs, uncertainty in the emissions and exposure estimates, and uncertainties in the approved health values. For these engines, a site-specific HRA is not required.

- Emergency standby engines are not required to meet add-on control or very-low sulfur fuel requirements until March 2002, or until the analysis supporting the Emergency Standby Retrofit ATCM (see section VI) is complete, whichever is sooner. ARB staff will use the additional time to determine if there are any technical issues that may limit the application of catalyst-based control technologies on emergency standby engines.

- Require a site-specific HRA prior to approval of diesel-fueled engines that fall within the Group 2 category; basically engines operated over 400 hours per year (see Table 1). We anticipate relatively few (10%) new non-agricultural stationary diesel-fueled engines will fall in Group 2 based on the current inventory and average hours of operation of stationary diesel-fueled engines (See Chapter IV). Because of the potential elevated risk associated with Group 2 engines, we believe a site-specific health risk analysis (HRA) is appropriate prior to making a permitting decision. If the HRA estimates a potential cancer risk greater than or equal to of 10 chances in a million, we suggest the district review additional site-specific information; e.g., site specific design considerations, location of sensitive receptors, and alternative technologies or fuels; before making a permitting decision. This information should be summarized in a Specific Findings (SF) Report. We further recommend the public be provided the opportunity to review and comment on the proposed permit action. The APCO would consider the public's comments in making the final permitting decision. We believe an upper level risk level would be too restrictive, not allowing for the approval of sources with well-controlled diesel-fueled engines that perform critical functions (i.e., emergency power generation) or for which there is no economically or technically feasible substitute.

- For Group 2 engines, conduct risk assessments consistent with the *California Air Pollution Control Officers Association (CAPCOA), Air Toxics "Hot Spots" Program, Revised 1992 Risk Assessment Guidelines* (Risk Assessment Guidelines), dated October 1993[1], and the risk assessment guidance presented in the Guidance. Use diesel PM as a surrogate for all toxic air contaminant emissions from diesel-fueled engines when determining the potential cancer risk and the noncancer chronic hazard index for the inhalation pathway.

- Estimate risk using the Scientific Review Panel's (SRP) recommended unit risk factor of 300 excess cancers per million per microgram per cubic meter of diesel PM [$3 \times 10^{-4} (\mu g/m^3)^{-1}$] based on 70 years of exposure.[2]

- Consider the need for the project in addition to the uncertainty in the risk assessment information when making risk management decisions.

---

1 The Office of Environmental Health Hazard Assessment (OEHHA) is currently revising the CAPCOA Risk Assessment Guidelines. It is expected that districts will use the OEHHA risk assessment guidelines when completed later this year (2000).

2 For Group 2 engines, the Specific Findings Report should also report the full range of potential cancer risk using the range of unit risk factors (URF) identified by the SRP; 130 to 2400 excess cancers per million per microgram per cubic meter of diesel particulate matter. The URF of $3 \times 10^{-4} (\mu g/m^3)^{-1}$ is commonly expressed as 300 excess cancers per million per microgram per cubic meter of diesel particulate matter.

Table 1: Permitting Requirements for New Stationary Diesel-Fueled Engines

Engine Category	Annual Hours of Operation	Group	Performance Standard[1] (g/bhp-hr)	Minimum Technology Requirements			Additional Requirements	
				New Engine PM Emission Levels[1] (g/bhp-hr)	Fuel Technology Requirements	Add-On Control	HRA Required	SF Report
Emergency/ Standby > 50 hp[2]	≤ 100 hours[3]	1	0.1	0.1	CARB Diesel or Equivalent	No	No	No
All Other Engines > 50 hp	≤ 400 hours	1	0.02	0.1	Very low-sulfur CARB Diesel or equivalent[4]	Catalyst-based DPF or equivalent	No	No
	> 400 hours	2	0.02	0.1	Very low-sulfur CARB Diesel or equivalent[4]	Catalyst-based DPF or equivalent	Yes	If HRA shows risk > 10/million

HRA - Health Risk Assessment; SF - Specific Findings; DPF - Diesel Particulate Filter

1. ISO 8178 test procedure IAW *California Exhaust Emission Standards and Test Procedures for New 1996 and Later Off-Road Compression–Ignition Engines, May12, 1993.*
2. The emergency standby engine category is valid until March 2002, or until the analysis supporting the Emergency Standby Retrofit ATCM is complete, whichever is sooner. At that time, emergency standby engines will be required to meet the *All Other Engine >50 hp* requirements. New emergency standby engines must be "plumbed" to facilitate the installation of a catalyst-based DPF at a later date.
3. The annual hours of operation for emergency standby engines include the hours of operation for maintenance and testing runs only, and do not include emergency operation hours.
4. Very low sulfur (≤ 15 ppmw) CARB diesel or equivalent is only required in areas where the district determines it is available in sufficient quantities and economically feasible to purchase. CARB diesel is required to be used in all other areas.

AB 2588 "Hot Spots" Information and Assessment Act

The Air Toxics "Hot Spots" Information and Assessment Act (Assembly Bill (AB) 2588) was enacted in September 1987 (Health and Safety Code 44300-44394). AB 2588 requires and quantities of certain substances their facilities routinely release into the air. Emissions of interest are those that result from the routine operation of a facility or that are predictable, including but not limited to continuous and intermittent releases and process upsets or leaks.

The goals of the Air Toxics "Hot Spots" Act are to collect emissions data, to identify facilities having localized impacts, to ascertain health risks, and to notify nearby residents of significant risks. In September 1992, the "Hot Spots" Act was amended by Senate Bill (SB) 1731 to address the reduction of significant risks. The bill requires owners of significant-risk facilities to reduce their risks below the level of significance.

AB 2588 requires that toxic air emissions from stationary sources (facilities) be quantified and compiled into an inventory according to criteria and guidelines developed by the ARB, that each facility be prioritized to determine whether a risk assessment must be conducted, that the risk assessments be conducted according to methods developed by the Office of Environmental Health Hazard Assessment (OEHHA), that the public be notified of significant risks posed by nearby facilities, and that emissions which result in a significant risk be reduced. Since the amendment of the statute in 1992 by enactment of SB 1731, facilities that pose a potentially significant health risks to the public are required to reduce their risks, thereby reducing the near-source exposure of Californians to toxic air pollutants. Owners of facilities found to pose significant risks by a district must prepare and implement risk reduction audit and plans within 6 months of the determination.

AB 2588 requires the ARB to compile and maintain a list of substances posing chronic or acute health threats when present in the air. The Air Toxics "Hot Spots" Act currently identifies by reference over 600 substances which are required to be subject to the program. The ARB may remove substances from the list if criteria outlined in the law are met. A facility is subject to AB 2588 if it: (1) manufactures, formulates, uses, or releases a substance subject to the Act (or substance which reacts to form such a substance) and emits 10 tons or more per year of total organic gases, particulate matter, nitrogen oxides or sulfur oxides; (2) is listed in any district's existing toxics use or toxics air emission survey, inventory or report released or compiled by a district; or (3) manufactures, formulates, uses, or releases a substance subject to the Act (or substance which reacts to form such a substance) and emits less than 10 tons per year of criteria pollutants and is subject to emission inventory requirements.

Guidance documents are currently available for conducting emission inventories, facility prioritizations, risk assessments, and public notifications. ARB developed the Emission Inventory Criteria And Guidelines for conducting emission inventories, while CAPCOA developed the Facility Prioritization Guidelines, Risk Assessment Guidelines, and the Public Notification Guidelines. In August 1998, the ARB approved the listing of diesel PM as a Toxic Air Contaminant (TAC) and the SRP conclusion that a value of 3×10^{-4} $(ug/m^3)^{-1}$ is a reasonable estimate of unit risk from diesel-fueled engines. Now that a unit risk factor has been approved, districts are required to reevaluate the classification of facilities subject to the "Hot Spots" program, specified in Health & Safety Code section 44320, operating stationary diesel-fueled engines.

After reevaluating the AB 2588 program as it pertains to diesel-fueled engines, ARB identified four main issues with the current program. ARB has also committed to reevaluate the current guidance documents and create a separate AB 2588 guidance document for diesel-fueled engines.

The first issue with the current AB 2588 program is reevaluating the 3,000 gallon per year exemption. AB 2588 currently exempts diesel-fueled engines that burn less than 3,000 gallons per year. ARB intends to evaluate the impact of that exemption level in light of the new unit risk factor for diesel PM emissions.

The second issue with the current AB 2588 program is the inventory of prime diesel-fueled engines.

Another issue includes requiring emergency standby engines to be inventoried.

The final issue regarding the current AB 2588 program, is whether or not agricultural engines should be inventoried.

In summary, the Air Toxics "Hot Spots" Act establishes a formal air toxics emission inventory risk quantification program for districts to manage. The goal of the Air Toxics "Hot Spots" Act is to collect emissions data indicative of routine predictable releases of toxic substances to the air, to identify facilities having localized impacts, to evaluate health risks from exposure to the emissions, to notify nearby residents of significant risks, and, due to SB 1731, reduce risk below the determined level of significance. Information gathered from this program has complemented the ARB's existing toxic air contaminant program by locating sources of substances that were not under evaluation and by providing exposure data needed to develop regulations for control of toxic pollutants. Additionally, the program has been a motivating factor for facility owners to voluntarily reduce their facility's toxic emissions.

B. Portable Engines

A portable engine undergoing permit review by a local district is subject to the same NSR requirements discussed in the previous section. In addition, there are two other programs affecting portable engines. These programs include emission standards for newly manufactured off-road engines and the Statewide Portable Equipment Registration Program. These programs are important components of district and ARB efforts to attain the State and federal ozone standards. Consequently, the focus of both programs has been to reduce emissions of NOx, and to a lesser extent reduce emissions of CO, HC, and PM.

1. ARB /U.S. EPA Off-Road Standards

As discussed previously, portable engines are a subset of the off-road engine category. As such, newly manufactured portable engines are subject to the ARB / U.S. EPA standards for newly manufactured off-road engines. Any regulation affecting off-road engines is also subject to certain federal prohibitions and regulatory requirements, including limitations on the ability of the State and local districts to adopt standards or other requirements relating to the control of emissions from off-road engines. These issues are discussed in greater detail in Appendix III.

2. Statewide Portable Equipment Program

The Statewide Portable Equipment Registration Program allows for the registration and regulation by ARB of portable engines and portable equipment units. Once registered, such engines and equipment may operate throughout California without the need to obtain individual permits from local air pollution control districts. For most portable engines and portable equipment units, the Statewide Registration Program is voluntary. The owner of the portable equipment has the choice of either participating in the Statewide Registration Program or getting permits from the local air districts. About 12,000 registrations have been issued by ARB, including about 5,000 pieces of military TSE. Districts are preempted from permitting, registering, or otherwise regulating portable engines and portable equipment units registered with the ARB. However, districts are responsible for enforcing the requirements of the Statewide Registration Program.

To be registered in the Statewide Registration Program, engines must meet certain emission standards or have specific emission control equipment installed. A major element of the Statewide Registration Program is the reduction and eventual elimination of high-emission engines. After January 1, 2010, all existing portable engines not previously meeting post-1996 California or federal standards must meet the applicable California or federal emission standard.

C. Agricultural Irrigation Pump Engines

Section 42310(e) of the Health and Safety Code prohibits districts from requiring a permit for any equipment used in agricultural operations in the growing of crops or the raising of fowl or animals. Consequently, irrigation pump engines have never been subject to district permitting programs.

IV. EMISSION INVENTORY

This section characterizes, in detail, current and year 2010-projected diesel PM emissions from stationary and portable diesel-fueled engines. The last portion of the section discusses the trend in diesel PM emissions from 1990 through 2020.

A. Stationary Engines

In its report on the proposed identification of diesel PM as a TAC, ARB staff used information from the ARB 1993 emissions inventory as the basis for estimating the emissions of diesel PM from diesel-fueled engines. To develop information for the Risk Management Plan, we have performed a more detailed inventory of diesel engines. We began our effort using the most current inventory, which was the ARB 1996 emissions inventory.

For stationary engines, the 1996 emissions inventory includes estimates for engines located at stationary sources and area-wide estimates for engines not otherwise identified with a stationary source. The 1996 inventory identified about 2,000 engines operated at stationary sources. Area-wide estimates were based upon methods that are not engine specific, such as total fuel usage for a geographical area.

By comparison, recent staff estimates, based largely on the number of engines permitted by districts, suggest there are over 16,000 stationary engines Statewide. For discussion purposes, if we assume that area-wide estimates account for two to three times the number of engines identified at stationary sources, then the number of stationary engines appears to be underrepresented in the 1996 emissions inventory. In the case of agricultural irrigation pump engines, the 1996 inventory contained estimates for only two districts Statewide.

For the above reasons, staff is not basing estimates for stationary engines on the information contained in the 1996 ARB emissions inventory. The following methodologies were used to develop inventory estimates for stationary engines.

1. Emission Inventory Methodology

a. Current Emissions

Estimates of emissions for stationary engines are based on average engine characteristics for each category or sub-category of diesel-fueled engine and the number of these engines, by category, within each district. Stationary source emission estimates for engines rated at less than 50 horsepower are not included because staff assumes that the majority of engines in this size range are used in portable applications.

The population of engines was estimated using a number of data sources, depending upon the category or sub-category. For emergency standby engines, where available, the population estimate is based on information provided by local districts. Where this information was not available (some districts do not permit emergency standby engines), the number of engines was extrapolated using the engine population estimates provided by districts that permit emergency standby engines and 1998 Census Bureau population estimates. Except for agricultural irrigation pump engines, a similar procedure was used for estimating the number of prime engines. Population estimates for agricultural irrigation pump engines are based largely upon the National Agricultural Statistics Service (NASS) 1994 Farm And Ranch Irrigation Survey. The NASS estimate is based on a statistical sampling of farms nationally, including farms in California.

Engine characteristics such as horsepower ranges, annual hours of operation, and average operating load also vary depending on the category or sub-category of stationary engine. For both emergency standby and prime engines, these characteristics are based on information provided by local districts. For stationary agricultural irrigation pump engines, estimates for average horsepower size and annual hours of operation are based upon applications filed with the Carl Moyer Program for the repowering of agricultural irrigation pump engines.

In developing emission factors for engines used in stationary applications, staff used the diesel PM emission factors used for the off-road engine emissions inventory. There should not be a significant difference in emissions from an engine based on its application. These emission factors are identified in the ARB staff report: Public Meeting to Consider Approval of California's Emission Inventory for Off-Road Large Compression-Ignited Engines (>25 horsepower) (January 2000). Emission factors used in the off-road inventory vary depending on the date of engine manufacture and the horsepower rating of the engine. Staff assumed that all existing stationary diesel-fueled engines emit diesel PM at levels consistent with engines manufactured prior to 1988.

b. 2010 Emissions

Emission estimates for the year 2010 were developed using growth/reduction factors and the diesel PM emission rates for new off-road engines.

In general, engines used in prime and emergency standby applications are expected to increase in total number consistent with the expected increase in the general population. One exception is for prime engines operated within the SCAQMD. For these engines, staff anticipates a reduction in the total number of stationary engines due to the implementation of SCAQMD Regulation 1110.2, Emissions from Gaseous- and Liquid-Fueled Internal Combustion Engines.

In the case of agricultural irrigation pump engines, irrigated acreage is expected to decrease over time. The last three Census of Agriculture Reports, prepared by United States Department of Agriculture (the census is conducted every five years, with the most recent census prepared for the year 1997), indicate a general trend of declining number of acres being farmed. To account for this trend of declining farmland, staff is assuming that the number of agricultural irrigation pump engines decrease at a rate of 0.5% annually.

To estimate emissions from the 2010 engine population, staff assumed that new and replacement stationary engines would emit at levels at least as low as those required of newly manufactured off-road engines meeting Tier I California emission standards.

c. Statewide Diesel PM Emissions: 1990 and 2020

The methodology used to estimate 1990 and 2020 diesel PM emissions is consistent with the methodology used to estimate the diesel PM emissions for 2000 and 2010. The 1990 emission inventory was backcast from the 2000 inventory, and the 2020 emission inventory was forecast from the 2010 inventory.

2. Estimates for Current Emissions

Estimates for current NOx and diesel PM emissions from all stationary diesel-fueled engines are presented in Table 2. The table lists, for each air basin, the number of emergency standby, prime and total stationary engines that are rated at 50 horsepower and greater and the associated annual NOx and diesel PM emissions

Table 2:
Stationary Diesel-Fueled Engines
Current NOx and Diesel PM Emission Estimates

	Emergency Standby			Prime			Total		
Air Basin	number	NOx Emissions (tpy)	Diesel PM Emissions (tpy)	number	NOx Emissions (tpy)	Diesel PM Emissions (tpy)	number	NOx Emissions (tpy)	Diesel PM Emissions (tpy)
Great Basin Valleys	9	2.2	0.1	69	98.9	4.7	78	101.1	4.8
Lake County	32	3.5	0.2	9	19.8	1	41	23.3	1.2
Lake Tahoe	44	10.7	0.5	0	0	0	44	10.7	0.5
Mountain Counties	197	47.8	2.4	101	179	8.7	298	226.8	11.1
North Central Coast	207	50.2	2.5	171	241.9	11.4	378	292.1	13.9
North Coast	95	23.1	1.1	13	21	1	108	44.1	2.1
Northeast Plateau	28	6.8	0.3	270	367.1	16.8	298	373.9	17.1
Sacramento Valley	544	148.8	7.5	1294	1,698	79	1,838	1,846.8	86.5
San Diego	877	214.2	10.7	101	176.1	9	978	390.3	19.7
San Francisco	2,021	490.2	24.5	313	500.7	25.5	2,334	990.9	50
San Joaquin Valley	964	233.8	11.7	1436	4,154.7	192.1	2,400	4,388.5	203.8
South Central Coast	428	103.7	5.2	49	71.4	3.5	477	175.1	8.7
South Coast	5,350	1,297.6	64.8	367	593.2	30.5	5,717	1,890.8	95.3
Southeast Desert	548	125.0	6.2	611	836.4	39.4	1,159	961.4	45.6
Totals	**11,344**	**2,757.6**	**137.7**	**4,804**	**8,958.2**	**422.6**	**16,148**	**11,716**	**560.3**

(tons per year) for each category. A map showing the air basin boundaries and the districts within each air basin is included in Appendix II-A.

About 70% of the stationary diesel-fueled engines are used in emergency standby applications. Because of the low operating hours for emergency standby engines, this category only accounts for approximately 25% of the total diesel PM emissions from all diesel-fueled stationary engines. However, most of these emissions are concentrated in air basins with large urban areas. For example, approximately half of the total emergency standby engines are located within the South Coast air basin and 80% are located within four air basins: San Francisco, San Diego, San Joaquin Valley and South Coast.

Prime engines account for 75% of the total diesel PM emissions from all diesel-fueled stationary engines. Nearly half of the emissions originate within the San Joaquin Valley air basin and two thirds of the total emissions originate within San Joaquin Valley and Sacramento Valley air basins. Both air basins have large areas of farmland irrigated with agricultural irrigation pump engines. Overall, engines used in agricultural irrigation operations represent about 70% of the total number of engines used in prime applications (and 50% of all diesel PM emissions from stationary engines).

For prime engines not used in agricultural irrigation operations, more than 70% are located within the San Francisco, San Diego, San Joaquin Valley and South Coast air basins. In terms of horsepower rating, 60 percent of the total non-agricultural engines used in prime applications are less than 175 horsepower, and over 90% of the total non-agricultural engines are less than 750 horsepower.

Table 3 provides a breakdown of the emissions from engines used in prime applications that would fall into low use or high use. High use is defined as an engine operating in excess of 500 hours annually. The table indicates that in excess of 90% of the emissions are emitted from high use engines. For non-agricultural prime engines, the high use engines represent less than 25% of the total number of non-agricultural prime engines, but emit in excess of 80% of the total emissions from these engines. High use agricultural engines account for more than 90% of the total number of agricultural engines and 98% of the total emissions for this sub-category.

Table 3:
Diesel PM Emissions for Stationary Prime Engines, Based on Annual Usage

	Number of Engines	Emissions (TPY)
All Prime Engines		
Low Use	1,318	26
High Use	3,486	396.6
Non-agricultural Prime Engines		
Low Use	1,037	19.6
High Use*	325	85.1
Agricultural Engines		
Low Use	281	6.4
High Use	3,161	311.5

*High use operate in excess of 500 hours annually

3. Estimates for 2010 Emissions

Table 4 provides inventory estimates for NOx and diesel PM emissions from stationary engines, by category, for the year 2010. The overall diesel PM emissions in the year 2010 from stationary engines is expected to be 10 percent lower, even though the total number of engines increases by about 3 percent. This is due to an anticipated decrease in the number of agricultural irrigation pumps and engines subject to SCAQMD Regulation 1110.2 for reasons noted earlier, and the replacement of older engines with new cleaner engines.

Table 4:
Stationary Diesel-Fueled Engines Diesel PM and NOx Emission Estimates for 2010

	Emergency Standby			Prime			Total		
Air Basin	number	NOx Emissions (tpy)	Diesel PM Emissions (tpy)	number	NOx Emissions (tpy)	Diesel PM Emissions (tpy)	number	NOx Emissions (tpy)	Diesel PM Emissions (tpy)
Great Basin Valleys	10	2.3	0.1	67	86.3	4.1	77	88.6	4.2
Lake County	35	3.9	0.2	9	17.9	0.9	44	21.8	1.1
Lake Tahoe	48	11.5	0.6	0	0	0	48	11.5	0.6
Mountain Counties	213	50	2.5	101	159.4	7.9	314	209.4	10.4
North Central Coast	224	52.6	2.6	166	210.3	9.9	390	262.9	12.5
North Coast	102	24.1	1.1	13	18.9	0.9	115	43.0	2
Northeast Plateau	30	7.2	0.3	255	311.7	14.3	285	318.9	14.6
Sacramento Valley	588	154.6	7.7	1239	1,460.30	68.2	1,827	1,614.9	75.9
San Diego	949	224.1	11.1	109	164.2	8.4	1,058	388.3	19.5
San Francisco	2,188	513.1	25.5	333	462.6	23.8	2,521	975.7	49.3
San Joaquin Valley	1,044	244.8	12.2	1379	3,551	164.3	2,423	3,795.8	176.5
South Central Coast	463	108.7	5.4	48	62.7	3	511	171.4	8.4
South Coast	5,792	1,358.40	67.5	86	65.8	18.7	5,878	1,424.2	86.2
Southeast Desert	593	131.2	6.6	590	722.4	34.1	1,183	853.6	40.7
Totals	**12,279**	**2,886.5**	**143.4**	**4,395**	**7,293.5**	**358.5**	**16,674**	**10,180.0**	**501.9**

B. Portable Engines

On January 28, 2000, the ARB Board approved a revised emissions inventory for large off-road compression-ignited engines using the Off-Road Emissions Model. Staff's inventory, as approved by the Board, is presented in the ARB staff report, Public Meeting to Consider Approval of California's Emission Inventory for Off-Road Large Compression-Ignited Engines (>25 horsepower) (January 2000). This report establishes emission estimates for engines rated at 25 horsepower and larger used in off-road applications. Portable engine estimates are included in the report for agricultural irrigation, commercial, construction, dredging, drilling, and military tactical support activities. Portable engine emission estimates for years 2000 and 2010 are summarized in the following sections.

1. Current Emissions

Table 5 summarizes both current (2000) and future year (2010) population and emission estimates for NOx and Diesel PM from portable diesel-fueled engines. The estimates for 2010 are discussed in the next section.

**Table 5:
Portable Diesel-Fueled Engines Diesel PM
Emission Estimates for 2000 and 2010**

	2000			2010		
Air Basin	number	NOx Emissions (tpy)	Diesel PM Emissions (tpy)	number	NOx Emissions (tpy)	Diesel PM Emissions (tpy)
Great Basin Valleys	63	19.5	1.4	69	15.9	1.3
Lake County	72	30.4	2.1	79	22.6	1.8
Lake Tahoe	59	18.8	1.3	73	16.4	1.3
Mountain Counties	605	242.8	15.9	708	183.4	13
North Central Coast	935	331.5	24	981	234.6	19
North Coast	599	204.3	14.5	610	143.8	11.7
Northeast Plateau	238	92.7	6.8	233	64.5	5.3
Sacramento Valley	4,085	2,078.0	135	4,450	1,479.5	101.1
San Diego	4,950	1,890.2	117.8	5,388	1,364.6	90.3
San Francisco	11,309	4,130.4	273.2	12,583	3,038.4	219.8
San Joaquin Valley	6,304	4,883.4	306.3	6,412	3,301.6	203.6
South Central Coast	2,170	1,155.4	73.7	2,339	806.0	53.3
South Coast	16,435	6,285.6	418.1	18,003	4,629.4	338.7
Southeast Desert	1,410	975.1	51.6	1,665	715.6	38.5
Totals	**49,234**	**22,338.1**	**1,441.7**	**53,593**	**16,016.3**	**1,098.7**

Staff estimates that there are currently 49,234 portable diesel-fueled engines operating Statewide with emissions of approximately 1,442 tons per year of diesel PM. Included in the count of portable engines are engines associated with cranes and bore/drilling equipment (drilling equipment that is not associated with oil and gas field activities).

Table 5 lists engine population and emission estimates by air basin. Because of the movement of portable engines between districts, the estimates given for the number of engines per air basin represent an average number of engines at any given time. By location, most of the State's portable diesel-fueled engines operate within the Sacramento Valley (9%), San Diego (7%), San Francisco Bay Area (23%), San Joaquin Valley (14%), and South Coast (32%) air basins. Approximately 85% of the diesel PM emissions from portable diesel-fueled engines originate in these five air basins.

Unlike the population estimates for stationary engines, the 49,234 portable engines also include engines rated between 25 and 50 horsepower. Engines in this size range represent about 27% of the total number of portable engines, but emit less than 10% of the total diesel PM from portable engines. For engines greater than 50 horsepower, 62% are rated between 51 and 175 horsepower and the remaining 11% are greater than 175 horsepower. Engines rated between 51 and 175 horsepower account for approximately 57% of the total emissions from portable diesel-fueled engines.

By type of equipment, engines used to drive compressors, generate power, drive pumps, and power welding equipment account for over 75% of the total number of portable diesel-fueled engines. This type of equipment is a mainstay for the construction and rental equipment industry, but is used in most industries. Other major categories using portable engines include agricultural irrigation (8%), oil and gas well drilling and servicing (3%), and military TSE (5%).

Most portable engine applications involve engines used for short-term activities that occur at various locations. However, certain types of facilities have regular activity involving portable equipment driven by diesel-fueled engines. Examples of such facilities and the type of equipment include: aircraft ground support equipment at major airports, dredging equipment at harbors and other navigable waterways, dedicated sorting and waste reduction equipment (crushers and grinders) at landfills, TSE associated with military bases, and oil and gas well drilling and servicing at oil and gas fields.

2. 2010 Emissions

Population and diesel PM emission estimates shown in Table 5 indicate that the overall population of portable diesel-fueled engines will increase by 9% by the year 2010. Although the number of engines is expected to increase, diesel PM emissions are expected to decrease by about 25% during this period. This reduction in emissions is due to older higher emitting engines being replaced with new lower emitting engines.

The greatest reduction in diesel PM emissions is expected from engines larger than 175 horsepower. Emissions from engines larger than 175 horsepower are expected to be reduced by 50% between 2000 and 2010 due to engine replacement or retrofit.

C. Statewide Diesel PM Emissions: 1990 to 2020

Table 6 provides an estimate of the diesel PM emissions from prime, emergency standby, and portable engines for the period 1990 through 2020 based upon full implementation of all existing regulations. In general, emissions from stationary diesel-fueled engines remain relatively steady while emissions from portable diesel engines exhibit a significant decrease. This reduction is due to the lifecycle replacement of older engines with new, low emission engines.

Table 6: Statewide Estimates of Diesel PM Emissions for 1990 Through 2020

Year	Stationary – Prime		Stationary – Backup		Portable	
	Engine Population	Diesel PM (tpy)	Engine Population	Diesel PM (tpy)	Engine Population	Diesel PM (tpy)
1990	4,600	400	10,200	124	47,563	2,150
2000	4,804	423	11,344	138	49,234	1,442
2010	4,395	359	12,279	143	53,593	1,099
2020	4,400	350	13,200	149	55,225	665

V. CONTROL TECHNOLOGY OPTIONS AND ASSOCIATED IMPACTS

This chapter addresses the composition and formation of diesel PM, and provides a general discussion of the options that are available to reduce these emissions. Included are staff's evaluations of the available control options, including a discussion of the applicability, potential emission reduction, costs, and any environmental impacts.

A. Diesel PM Emissions

To understand the applicability and efficiency of the various control options available for diesel-fueled engines, an understanding of the constituents of diesel PM is necessary. Diesel PM consists of both solid and liquid material and can be divided into three main components: the elemental carbon fraction; the soluble organic fraction; and the sulfate fraction. The majority of diesel PM (i.e., 98%) is smaller than 10 microns in diameter, and therefore, references to total suspended particulate (TSP), diesel PM, and particulate matter less than 10 micron (PM_{10}) should be considered synonymous.

The elemental carbon fraction (ECF), also known as the carbonaceous fraction or soot, is formed within the combustion chamber and consists of the carbon residue resulting from the incomplete combustion of the individual atomized fuel particles

The soluble organic fraction (SOF) consists of unburned portions of diesel fuel and lubricating oil which condense and adsorb onto the ECF. Both constituents are included in the determination of diesel PM mass. In addition, several components of the SOF have been identified as individual toxic air contaminants, including: dibenzofurans[3] and naphthalene[4].

[3] Mills, G.A. Ph.D. Thesis, University of Southamption, 1983

[4] "Demonstration of Advanced Emission Control Technologies Enabling Diesel Powered Heavy-Duty Engines to Achieve Low Emission Levels – Final Report" Manufacturers of Emission Controls Association, 1999

Finally, sulfate particles are formed from sulfur in the diesel fuel. Nearly all of the diesel fuel sulfur reacts with oxygen within the engine to form sulfur dioxide (SO2). A small percentage of SO2 is further oxidized to form sulfur trioxide ($SO3^-$) which then combines with available moisture to form sulfuric acid that ultimately reacts to form sulfates. These sulfate particles are included in the determination of diesel PM mass. (As discussed later, catalyst-based control technologies increase the oxidation of SO2 to $SO3^-$ and thus increase the formation of sulfate particles.)

B. Control Techniques

1. Introduction

There are a number of technologies that are available to reduce diesel PM from diesel-fueled engines. These technologies can be categorized as engine design changes, exhaust treatments, or fuel additives. There are also alternative strategies for reducing diesel PM, such as replacing an existing diesel engine with a newer, cleaner burning diesel engine, an alternative fuel engine, or via electrification. Finally, while the focus of this chapter is the evaluation of control options to reduce diesel PM, the impact on other regulated pollutants, such as NOx emissions, will also be addressed. Diesel-fueled engines are a major source for NOx emissions, and for many districts, they are a category targeted for NOx emission reductions.

Staff expect that many of the technologies described in the following sections can be combined to achieve higher diesel PM control efficiencies or reductions of other air pollutants.

a. Engine Design Changes

The formation of diesel PM can be minimized by improving the mixing of air and fuel within the combustion chamber. This can be accomplished by increasing fuel injection pressures, by using fuel injectors with low sac volumes and by improving the design of the combustion chamber itself. Higher fuel injection pressures increase the atomization of the fuel droplets and encourage better mixing within the combustion chamber. Low sac volume fuel injectors limit the amount of fuel that drips into the combustion chamber at the end of the fuel injectors injection cycle, thereby minimizing the amount of unatomized fuel within the combustion chamber. Examples of improvements to combustion chamber design include a reentrant bowl on top of the piston, or modifications to improve air swirl and air to fuel mixing within the chamber. Because of the limited amount of information available on these technologies, they will not be addressed further in this report. We will, however, continue to collect information on these technologies.

In addition to the engine design changes referenced above, there are several engine retrofit technologies which reduce diesel PM by other means. One engine retrofit technology helps reduce diesel PM and NOx emissions by reducing peak combustion temperatures. Another retrofit technology converts a diesel-fueled engine to operate on a mixture of diesel and a variety of gaseous fuels, such as natural gas. The latter two technologies will be discussed further in Section V.B.2.a.

Finally, injection timing retard is being used as a cost effective measure to reduce NOx emissions. However, there is considerable anecdotal information on increased particulate emissions and reduced performance when timing retard has been applied. While ARB staff have not received emission test data that support these claims, staff recognizes that this strategy likely increases diesel PM emissions, and the impact of this strategy needs to be considered in efforts to develop airborne toxic control measures (ATCM).

b. Exhaust Treatment

Exhaust treatment devices include diesel oxidation catalysts (DOC) and diesel particulate filters (DPF). DOCs oxidize carbon monoxide and hydrocarbon emissions, including the SOF, to form carbon dioxide and water. DPFs physically trap and collect diesel PM with high efficiency, but must be periodically "cleaned" to remove the collected diesel PM. This cleaning process is referred to as regeneration. DPFs can incorporate either active or passive regeneration techniques.

The NOxTECH emission control system and the SINOx system reduce CO, NOx, PM, and HC. The NOxTECH emission control system achieves the emission reduction through non-catalytic oxidation, and it has been used on stationary diesel-fueled engines primarily for NOx emission reduction. The SINOx selective catalytic reduction (SCR) system employs a proprietary base metal catalyst designed specifically for diesel engines and has been used on mobile, portable, and stationary engines.

Each of these exhaust treatment technologies is discussed further in Section V.B.2.b.

c. Fuels

In addition to applying a catalyst material directly to a substrate or filter element, the catalyst material can be introduced into the fuel, and is known as a fuel-borne catalyst (FBC). Examples of typical FBC material include platinum, cerium, and iron. FBCs may inhibit the formation of diesel PM by increasing the combustion efficiency of the engine or they can reduce the temperature at which diesel PM oxidizes. While FBCs can be used alone, FBCs are more effective at reducing diesel PM when combined with other exhaust treatment devices, especially DPFs. FBCs must receive U.S. EPA approval when introduced to diesel fuel intended for on-highway applications. FBCs are also discussed in Appendix IV.

d. Alternative Strategies

There are alternatives to engine modification and control techniques that are viable strategies for reducing diesel PM. These alternatives include repowering and electrification. Repowering involves replacing an older engine with either a new, cleaner burning diesel engine or an engine using an alternative fuel such as natural gas or propane. Electrification refers to replacing the power provided by diesel-fueled engines with electricity provided by a utility. Because most of the power obtained by utilities is either hydroelectric or based on the use of natural gas (with minimal PM emissions), this option would eliminate diesel-fueled PM emissions and lead to an overall reduction in diesel PM.

2. Evaluation of Control Technologies

This section summarizes information for many diesel PM control technologies. (See Appendix IX for a list of the technologies reviewed.) Because emission test information was deemed essential for a thorough evaluation of the diesel PM control technologies, no evaluation was performed where the technology proponent did not provide adequate emission test information. Consequently, a number of potentially viable technologies are not included in the following discussion. A detailed technical evaluation of each diesel PM control technology, including a summary of the available emission test information, is also included in Appendix IX.

Table 7 provides a summary of basic information on the control efficiency and annualized costs for each technology evaluated. The control efficiency is based on the available emission test information. The annualized costs, which are presented for comparative purposes only, are estimated based on a manufacturer survey of the current retail price, 500 hours per year operation, a maximum economic life of 10 years and a 9% interest rate. Staff anticipates that the costs will decline over the next few years as production volumes increase.

For example, the Manufacturers of Emission Controls Association (MECA) projects that with a production volume of 200,000 units per year, the cost of a DPF system will range from $625 to $2,250 for an engine with a displacement of between 7 and 13 liters. This represents an 80% decrease from the average current retail costs presented by particulate filter system manufacturers. Detailed cost calculations are presented in Appendix II-B.

The technologies are also categorized into one of three ranks depending on their diesel PM control efficiency. A technology is ranked as a high efficiency technology where the available emission test information demonstrates a control efficiency of at least 70%. A technology is ranked as a moderately efficient technology where the available emission test information demonstrates a control efficiency of more than 30%, but less than 70%. A technology is ranked as a low efficiency technology if the available emission test information demonstrates a control efficiency of 30% or less.

Table 7:
Comparative Annualized Costs of Diesel PM Control Technologies[5]

Control Technology	Control Efficiency	40 hp	100 hp	275 hp	400 hp	1,400 hp
CCTS	Low to Moderate	N/A	$490 - $590	$930 - $1,210	$1,290 - $1,680	$4,020 - $4,890
Ecotip Injector	Low	N/A	$(70) - $(75)	$(240) - $(260)	$(350) - $(375)	$(1340) - $(1420)
ITG Bi-Fuel	Low to Moderate	$750 - $820	$880 - $950	N/A	$1,120 - $1,190	$1,520 - $$1,590
DOC	Low	$150 - $850	$200 - $990	$420 - $1,210	$530 - $1,410	$1,650 - $4,360
Catalyzed DPF	High*	$720 - $1200	$1,030 - $1,630	$1,430 - $1,970	$2,070 - $2,280	$6,060 - $8,140
CDT FBC+DPF	High*	$440 - $1,240	$620 - $1,560	$1,090 - $2,480	$1,790 - $3,500	$6,670 - $10,980
Electric DPF	High	$890 - $1,220	$1,090 - $1,420	$2,000 - $2,330	$2,410 - $2,740	$6,930 - $7,260
NOxTECH	Moderate	$1150 - $2580	$1370 - $3050	$2,010 - $4,460	$2,460 - $5,460	$6,140 - $13,520
SINOx	Low	N/A	N/A	$2,940 - $4,070	$3,990 - $5,319	$12,390 - $15,270
Repower	Variable	$ 1,040	$1,770 - $3,620	$2,480 - $5,970	$4,910 - $8,850	$ 32,800

* When combined with very low sulfur diesel fuel.

[5] The comparative annualized costs assume 500 hours per year of operation, a maximum economic life of 10 years and a 9% rate of return. The values in () represent cost savings.

a. Engine Design Changes

Cam Shaft Cylinder Reengineering Kit

The Clean Cam Technology Systems (CCTS) technology consists of specific engine retrofit components, including a proprietary cam shaft, and reduces NOx emissions by increasing the volume of exhaust gas that remains in the combustion chamber after the power stroke. Within the combustion chamber, the residual exhaust gas absorbs heat and reduces the peak combustion temperature, which results in lower NOx emissions. The injection timing can then be adjusted (i.e. advanced) on some engines to maximize PM emission reductions, or it can be varied to achieve the desired balance of NOx vs. PM. The technology has been certified through the ARB's Equipment and Process Certification Program.

1. Applicability

The CCTS technology is commercially available for certain Detroit Diesel Corporation two stroke engines. The technology can be applied to stationary, portable and mobile diesel engines, and can be retrofitted to existing diesel engines. CCTS has been installed in more than 300 portable diesel engines used in oil well drilling and in more than 1,250 urban bus engines as part of the federal Urban Bus Retrofit / Rebuild Program.

2. Particulate Emission Reduction Efficiency

Based on a review of the available emission test information, the installation of the Cam Shaft Cylinder Reengineering Kit results in a diesel PM reduction of 25 to 66 percent, although the specific reduction efficiency depends on the engine being retrofitted. These results qualify the technology as a low to moderate efficiency diesel PM control technology.

3. Environmental Impacts

In addition to reducing diesel PM, the technology also reduces NOx and CO emissions, and it may reduce HC emissions. Engines retrofitted with this technology may incur a fuel penalty of between zero and twelve percent depending on the engine model and rebuild configuration.

ECOTIP Superstack Fuel Injectors

The Ecotip Superstack fuel injector, in comparison to a standard injector, has a reduced sac volume and a more consistent fuel injection pressure. The replacement of existing injectors with the ECOTIP product should improve combustion and reduce diesel PM emissions by minimizing the amount of unatomized fuel that drips into the combustion chamber at the end of the chamber's fuel injection cycle.

1. Applicability

The technology is commercially available for stationary, portable and mobile diesel engines manufactured by General Motors Electro-Motive Division (EMD) and Detroit Diesel Corporation (DDC). For EMD engines, mechanical fuel injectors are available as Original Equipment Manufacturer (OEM) products and electronic fuel injectors are available as replacement products. For DDC engines, both mechanical and electronic fuel injectors are available as replacement products. The technology has been installed in about 2,000 engines primarily in the locomotive service.

2. Particulate Emission Reduction Efficiency

Based on the available emission test information, the product reduces diesel PM by 7% for DDC Engines. These results qualify the technology as a low efficiency diesel PM control technology. The ARB has not received emission test information for EMD engines.

3. Environmental Impacts

One series of steady-state emission tests show that the fuel injectors increase hydrocarbon emissions by up to 15%.

ITG Bi-Fuel Conversion Kit

The technology involves retrofitting existing diesel engines to operate on a mixture of diesel fuel and a variety of gaseous fuels, such as pipeline quality natural gas, liquefied natural gas, compressed natural gas, digester gas, etc. The supplemental gaseous fuel is mixed with combustion air before being introduced into the engine's charge air system. This process is referred to as fumigation. Within the combustion chamber, the diesel fuel serves as a pilot ignition source for the gaseous fuel. The gaseous fuel / diesel mixture typically varies between 80% gaseous / 20% diesel and 50% gaseous / 50% diesel. The engine retrofit mainly involves the integration of a gaseous fuel control system with an engine's charge air system. There are no changes to the engine block, cylinder heads, or pistons, and an engine equipped with the bi-fuel retrofit kit remains a compression-ignition engine.

1. Applicability

The technology is commercially available for stationary, portable and mobile diesel engines, and can be retrofitted to existing diesel engines. The technology has been installed on over 200 diesel engines, including a backup generator within the Mojave Desert Air Quality Management District and a locomotive in the Napa Valley.

2. Particulate Emission Reduction Efficiency

Based on the available emission test information, the product reduces diesel PM by between 28% and 37%. These results qualify the technology as a low to moderate efficiency diesel PM control technology.

3. Environmental Impacts

There are no known adverse environmental impacts.

b. Exhaust Treatment

Diesel Oxidation Catalyst

The technology reduces CO, HC and SOF emissions through catalytic oxidation. In the presence of a catalyst material and oxygen, CO, HC & SOF undergo a chemical reaction and are converted into carbon dioxide and water. Hydrocarbon traps can enhance the HC reduction efficiency of DOCs at lower exhaust temperatures and sulfate suppressants can minimize the generation of sulfates at higher exhaust temperatures. The availability and use of a very low-sulfur content diesel fuel will improve the particulate reduction efficiency of DOCs. Several models of DOCs have been certified under the U.S. EPA's Urban Bus Retrofit/Rebuild Program.

1. Applicability

The technology is commercially available for stationary, portable and mobile diesel engines less than 5,000 horsepower, and can be retrofitted to most existing engines. The technology has been installed on tens of thousands of mobile diesel engines.

2. Particulate Emission Reduction Efficiency

Based on the available emission test information, the technology reduces diesel PM by 16% to 30%. This qualifies the technology as a low efficiency diesel PM control technology.

3. Environmental Impacts

In addition to reducing the SOF component of diesel PM, DOCs also reduce CO and HC emissions. However, two potential adverse environmental impacts have been identified. First, as is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reductions in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

In addition, the determination of whether or not a used DOC would be considered a "hazardous waste" at the end of its useful life depends on the material(s) used in the catalytic coating. DOCs can be manufactured with catalytic coatings such that the product would not be considered a hazardous waste at the end of its useful life.

DOCs are similar to automotive catalytic converters, and the California Department of Toxic Substances Control currently regulates used automotive catalytic converters as scrap metal as long as the catalyst material is left in the converter shell during collection and transport and the converters are going for recycling. The ash residue associated with cleaning a DOC would need to be tested before a hazardous waste determination could be made.

Particulate Filters

Diesel Particulate Filters refer to a variety of technologies that physically trap and collect diesel PM. The main differences between the various types of DPFs are the filtration method and the technique used to regenerate the filter. DPFs typically use either a ceramic wall-flow monolith that captures diesel PM via surface filtration, or a woven ceramic-fiber element that captures diesel PM via depth filtration.

DPFs can incorporate either passive or active regeneration techniques. Passively regenerated DPFs use catalyst materials to reduce the temperature at which the collected particulate matter oxidizes, and rely on an engine's exhaust temperature to regenerate the DPF. The catalyst material can be incorporated into the filter system, or can be added to the fuel as a fuel-borne catalyst. Actively regenerated DPFs incorporate electric heating elements or fuel burners that increase the temperature within the filter and oxidize the collected particulate matter. Microwaves are also being used to regenerate DPFs.

1. Catalyzed Particulate Filters

A catalyzed DPF is a particulate filter system where the catalyst material is incorporated into the filter. Currently, two main types of catalyzed DPFs are commercially available. In one system, the catalytic coating is applied directly to the filter media, and relies on oxygen within the engine's exhaust stream to oxidize the collected diesel PM and regenerate the filter. The catalyst allows this oxidation reaction to occur at a lower temperature. The second type of catalyzed DPF, referred to as a continuously regenerating DPF, incorporates a precious metal oxidation catalyst upstream of an uncatalyzed particulate filter. The precious metal catalyst oxidizes NO to NO2, which is a strong oxidant. The NO2 then oxidizes the collected diesel PM and regenerates the filter.

Fuel sulfur levels have a significant impact on the viability of catalyst-based diesel PM control technologies. As previously mentioned, catalyst-based control technologies tend to convert an engine's sulfur emissions into sulfates. Higher fuel sulfur levels result in higher sulfate formation and increased overall diesel PM emission rates. Recent studies by the Department of Energy suggest that both catalyzed and continuously regenerating DPFs significantly reduce the ECF and the SOF of diesel PM. However, at 150 ppm sulfur concentration in the fuel, the ECF and SOF reductions may be offset by increases in sulfate particle emissions. At higher fuel sulfur concentrations, this study suggests that catalyzed DPFs may actually increase diesel PM emission rates. As such, the use of very low-sulfur fuel, which is discussed in Appendix IV, increases the emission reduction efficiency of DPFs.

i. Applicability

Catalyzed DPFs are commercially available for stationary, portable, and mobile diesel engines. The technology can be retrofitted to many existing diesel engines, depending on the respective engine's emission levels, exhaust temperature profile, and duty cycle. Catalyzed DPFs have been installed on several thousand mobile diesel engines[6] and on a few stationary diesel engines, including two standby generators in Chico, California.

ii. Particulate Emission Reduction Efficiency

Based on the available emission test information, catalyzed DPF control efficiencies can be as high as 85% to 97% when combined with very low-sulfur diesel fuel. This qualifies the technology as a high efficiency diesel PM control technology.

iii. Environmental Impacts

In addition to high diesel PM reduction efficiencies, catalyzed DPFs also reduce CO and HC emissions. However, the same issues identified for DOCs (i.e., conversion of fuel sulfur to sulfates and disposal of the spent catalyst) are applicable to catalyzed DPFs.

2. Fuel Borne Catalyst-Based Particulate Filters

Some DPF systems rely on FBCs for regeneration. This technology involves combining the use of an uncatalyzed or lightly catalyzed DPF with an FBC, and reduces diesel PM, CO, and HC emissions through catalytic oxidation and filtration. The FBC typically contains fuel-soluble metal that acts as a catalyst, which lowers the temperature at which regeneration occurs within a DPF, similar to a catalyzed particulate filter. However, an FBC enhances regeneration by encouraging better contact between the diesel PM and the catalyst material. An FBC is also reported to reduce engine-out particulate emissions, including both the carbonaceous fraction and the soluble organic fraction.

[6] "Available particulate trap systems for diesel engines" VERT: Suva, AUVA, TBG, BUWAL, 1998

i. Applicability

The technology can be applied to stationary, portable, and mobile diesel engines, and can be retrofitted to many existing engines depending on the respective engine's emission levels, exhaust temperature profile, and duty cycle. The technology has been applied to several thousand mobile diesel engines[7]. In addition, PSA Peugeot Citroën is introducing an integrated particulate filter system on one of its 2000 model year luxury vehicles.

ii. Particulate Emission Reduction Efficiency

Based on the available emission test information, the FBC+DPF combination reduces diesel PM by 78% when used with very low sulfur diesel fuel. This qualifies the technology as a high efficiency diesel PM control technology.

iii. Environmental Impacts

In addition to reducing the particulate oxidation temperature within a DPF, FBCs may alter the composition of diesel engine exhaust either by reducing or by increasing the emission rate of specific compounds. Some of the emission changes may be undesirable. For example, the use of copper as an FBC has been linked to increased dioxin formation[7]. As such, for any future regulatory action, the potential impacts from the use of fuel borne catalysts in conjunction with particulate filters should be fully investigated, and the potential impacts considered in the rulemaking process.

3. Actively Regenerated Particulate Filters

Actively regenerated particulate filters incorporate active regeneration techniques to clean the filter, prevent clogging of the filter media, and minimize backpressure. Where catalyzed particulate filter systems incorporate catalyst material to lower the temperature at which the collected particulate matter oxidizes, actively regenerated particulate filter systems employ various techniques to raise the temperature of the collected particulate matter to the point of oxidation. These techniques include electrical regeneration, fuel-based regeneration and microwave regeneration. Due to the limited availability of information on fuel-based and microwave regeneration, the evaluation of this technology focuses on electrically regenerated DPFs.

i. Applicability

Individual electrically regenerated particulate filter systems are available for diesel engines rated at between 25 and 200 horsepower. Multiple filter elements can be used together for larger engine applications.

---

[7] "Available particulate trap systems for diesel engines" VERT: Suva, AUVA, TBG, BUWAL, 1998

ii. Particulate Emission Reduction

Based on available emission test information, the diesel PM reduction efficiency of electrically regenerated DPFs is approximately 80%. This qualifies the technology as a high efficiency diesel PM control technology.

iii. Environmental Impacts

There are no known adverse environmental impacts.

NOxTECH Emission Control System

The technology consists of a muffler-sized reactor that reduces carbon monoxide, hydrocarbons, and particulate matter through non-catalytic oxidation, similar to an afterburner. The engine exhaust is heated to between 1,400 to 1,550°F in the reactor by introducing fuel to the exhaust stream. The high temperature environment oxidizes the PM, CO, and HC emissions. A urea injection system can be added to reduce NOx emissions. Systems for engines operating over 2,000 hours per year include a heat exchanger that uses the reactor effluent to preheat the engine exhaust to enhance fuel auto-ignition.

1. Applicability

The technology is commercially available for stationary and portable diesel engines, and can be retrofitted to existing diesel engines, although it must be designed for each specific application. The technology has been installed and operated on two stationary diesel generator sets, and one of the units has been in operation for more than three years.

2. Particulate Emission Reduction Efficiency

Based on the available emission test information, this technology can reduce diesel PM by 50-60%. This qualifies the technology as a moderate efficiency diesel PM control technology.

3 Environmental Impacts

Where a urea injection system is used to reduce NOx, any unreacted urea will be emitted as ammonia. While ammonia is not a federal hazardous air pollutant or a State identified toxic air contaminant, it does have acute and chronic non-cancer health effects. Source tests have shown ammonia slip levels controlled to below 2 ppm. The federal Occupational Safety and Health Administration (OSHA) 15-minute short-term exposure limit for ammonia is 35 ppm.

SINOx System

The technology is an SCR system consisting of a proprietary base metal catalyst designed specifically for diesel engines, and an integrated predictive emissions monitoring system. According to the manufacturer, the product reduces the volatile organic fraction (VOF) of diesel particulate matter and hydrocarbon/air toxics emissions through catalytic oxidation, and concurrently reduces NOx emissions using a reducing agent, such as a 32% aqueous urea solution. The product also allows the injection timing of some engines to be adjusted for maximum fuel efficiency, which may result in further reductions of particulate matter and hydrocarbon/air toxic emissions.

1. Applicability

The technology can be applied to stationary, portable, and mobile diesel engines rated from 200 horsepower to more than 10,000 horsepower, and has been installed on 125 diesel engines worldwide.

2. Particulate Emission Reduction Efficiency

Based on the available emission test information, the technology has reduced diesel PM by 28%. This qualifies the technology as a low efficiency diesel PM control technology.

3. Environmental Impacts

The technology reduces NOx emission by as much as 90%. However, aqueous urea is used to reduce NOx emissions, and any unreacted urea will be emitted as ammonia (a.k.a., ammonia slip). Source tests have shown ammonia slip levels controlled to 4.4 ppm, with spikes reaching 30 ppm, based on the federal test procedure (FTP) for heavy-duty vehicle engines. As discussed above, there are acute and chronic non-cancer health effects for ammonia as well as a federal OSHA 15-minute short-term exposure limit.

c. Alternative Strategies

Repower with Tier 2 or Tier 3 Certified Non-road Engines

The strategy involves replacing existing older diesel engines with engines certified to meet ARB/U.S. EPA off-road engine emission standards. Tier 2 standards have already been promulgated by both the ARB and the U.S. EPA. The Tier 3 diesel PM standards will be established upon completion of a technical feasibility review, which is scheduled for 2001.

1. Applicability

This strategy can be implemented immediately. Cleaner engines are readily available, although the lowest emitting engines will not be available for all horsepower sizes until the end of this decade or early 2010's.

2. Particulate Emission Reduction Efficiency

Replacing an existing engine with a new engine meeting ARB/U.S. EPA off-road engine Tier 3 standards may result in an emission reduction of up to 85%, depending upon the emission rate of the engine being replaced.

3. Environmental Impacts

In addition to reductions in diesel PM, there may be significant reductions in NOx emissions when an older engine is replaced with a Tier 2 / Tier 3 certified engine.

Repower with an Alternative Fuel Engine

This strategy involves replacing an existing older diesel engine with an engine that operates on an alternative fuel, such as natural gas or propane. This strategy can be differentiated from dual fuel or bi-fuel engines in that the latter uses a mixture of both diesel fuel and a gaseous fuel. An alternative fuel engine operates completely on the alternative fuel.

1. Applicability

Engines using alternative fuels are available for stationary, portable and mobile applications. However, alternative fuel engines have not made a significant impact on the diesel engine market because these engines are typically more expensive than a similarly rated diesel engine. Beyond economic factors, other limiting factors include the availability of the alternative fuels at a particular location and the re-fueling of mobile applications. The ARB has developed NOx, CO, and HC emission standards and test procedures for new 2001 and later model year off-road large spark-ignited engines. However, due to the future effective date, alternative-fueled engines certified to meet the ARB standards are not widely available at this time.

2. Particulate Emission Reduction Efficiency

Because diesel fuel would not be used in the alternative fuel engine, the reduction in diesel PM would be 100%. This qualifies the strategy as a high efficiency diesel PM control measure.

3. Environmental Impacts

Depending upon the engine being replaced and the replacement engine, there may be minor increases in emissions of NOx, CO, or HC.

Electrification

This strategy involves replacing an existing diesel engine with an electric motor.

1. Applicability

This strategy can be applied to most prime stationary engines and some portable engines that are near an electric power grid.

2. Particulate Emission Reduction Efficiency

Staff expects that the reduction in diesel PM would be nearly 100% as most of California's electrical power is generated by hydroelectric plants or via natural gas-fueled boilers or turbines. Diesel fuel is not typically used to generate power in California. As such, this strategy qualifies as a high efficiency diesel PM control measure.

3. Environmental Impacts

Implementing this option would result in additional reductions of NOx, CO, and HC for all engines replaced with electric motors.

VI. RECOMMENDED MEASURES FOR REGULATORY ACTION

A. Stationary and Portable Engines

ARB staff recommends that the Board direct staff to develop regulations to reduce diesel PM emissions from new and existing stationary diesel-fueled engines and portable diesel-fueled engines. The current and anticipated future inventories of diesel PM emissions, as presented in section IV of this appendix, demonstrate that existing stationary and portable diesel engines contribute diesel PM in California. The evaluation of available diesel PM control technologies and strategies, as presented in section V of this appendix, demonstrates that feasible diesel PM control measures are available for both stationary and portable diesel engines. The specific details of staff's recommendations and suggested measures to control diesel PM emissions are presented in the following sections. Table 8 summarizes, for each proposed measure, the proposed implementation date, estimated PM reductions, and cost.

Table 8:
Recommended Measures to Reduce Diesel PM From Stationary and Portable Engines

Control Measure	Proposed Board Adoption Date	Proposed Implementation Date	Estimated PM Reduction by 2010 (TPY)	Estimated PM Reduction by 2020 (TPY)	Estimated Cost[8] (Millions/yr)
Stationary Engine					
New Engine	2002	2002	33	21	$2.4 - $4.7
Prime Engine Retrofit	2002	2003	70	66	$2.0 - $3.8
Emergency Standby Retrofit	2002	2003	105	105	$24.8 - $47.2
Portable Engine Retrofit	2002	2003 – 2005	712	252	$29.2 - $75.1
Agricultural Engine Retrofit	2002	2003 – 2005	297	197	$3.9 - $9.9

1. Stationary Engines

Staff recommends that ATCMs be developed to reduce diesel PM emissions from existing stationary diesel engines designated for prime-use and emergency standby operations. The ATCMs should reduce diesel PM emissions to the lowest level achievable through the application of the best available control technology or a more effective control method, consistent with section 39666(c) of the California Health and Safety Code.

Stationary diesel engines are used in a variety of applications, and there are situations where multiple diesel engines are operated at one location. In addition, some sectors of the population may be more sensitive to diesel PM than others (e.g., schools and hospitals). As such, the ATCMs should incorporate flexibility to allow districts to consider more stringent control strategies or other mitigation measures where site-specific issues warrant such an approach.

Because district new source review regulations vary widely throughout the State, many districts may need to modify existing new source review rules to ensure consistency with the ATCMs.

[8] The estimated cost is calculated based on the application of catalyst-based DPFs and represents the maximum expected cost associated with retrofitting existing engines with diesel PM control technologies. (Catalyst-based DPFs include both catalyzed diesel particulate filters and fuel borne catalyst regenerated particulate filters.) However, ARB staff recognize that one or more of the available diesel PM control technologies can be combined to achieve similar emission reductions. For example, an electrically regenerated DPF combined with a downstream DOC can achieve a 95% reduction in diesel PM over the ISO 8-mode test cycle.

a. New Stationary Diesel-Fueled Engine Rule

Description of the Proposed Measure

Staff recommends that an ATCM be developed that is similar to the ARB's permitting guidance document, *Risk Management Guidance for the Permitting of New Stationary Diesel-fueled Engines, September 2000,* (Guidance). The new engine ATCM will differ from the Guidance in that it will address all new engines, including those currently exempted from district permitting programs, e.g. agricultural engines. Diesel PM emission reductions from new stationary diesel-fueled engines will be accomplished by requiring these engines to meet either minimum technology requirements; engine certification, fuel, and add-on control requirements; or a performance standard which is based on the anticipated PM reductions associated with meeting the minimum technology requirements. See Chapter III for a more detailed description of the requirements of the Guidance. The ARB should begin the ATCM regulatory development as soon as possible with the goal of Board adoption in 2002.

Feasibility

The ATCM will be based on the Guidance, which recommends the use of very low-sulfur (<15 ppmw) fuel and the use of an exhaust treatment device, a catalyst-based DPF or equivalent.

There is some question as to whether very low-sulfur diesel fuel will be readily available by the 2003. To be consistent with the U.S. EPA, the ARB is planning on adopting a regulation in 2001 that would require very low-sulfur diesel-fuel to be sold and supplied in California for on-road, off-road, and stationary engines, statewide, effective 2006. Currently, there is no existing regulation requiring very low-sulfur diesel fuel be sold in California. However, in-field compliance sampling and analysis indicates that CARB diesel fuel meeting the 15 ppmw sulfur content requirement has already been marketed in California. In addition, ARB has recently adopted a regulation requiring transit agencies to use very low-sulfur diesel fuel beginning July 1, 2002. As a result, ARB staff believes relatively small batches of very low-sulfur fuel will be available to owners/operators of stationary diesel fueled engines, however, there is uncertainty as to the cost and availability of this fuel prior to 2006. The ARB anticipates that the ATCM will address this issue by allowing districts to make case-by-case decisions regarding the required use of very low-sulfur diesel fuel prior to 2006.

Catalyst-based DPFs are commercially available and have been installed on several thousand mobile diesel engines[9]. In several European countries, catalyst-based DPFs have been installed on more than 6,500 buses, heavy-duty trucks, and municipal vehicles. In the United States, the application of catalyst-based DPF's is less prevalent, but several demonstration projects have been initiated. In California, diesel-fueled school buses and tanker trucks have been retrofitted with catalyzed DPFs as part of a

[9] "Available particulate trap systems for diesel engines" VERT: Suva, AUVA, TBG, BUWAL, 1998

program to evaluate the effectiveness of a refiner's low-sulfur diesel formulation. In New York, the New York City transit authority's fleet demonstration program will test the effectiveness of catalyzed DPF's on 50 diesel-fueled buses.

For new diesel engine applications, catalyst-based DPF technology is playing a key role in both establishing and complying with new more stringent diesel PM standards. The U.S. EPA recently announced its proposed regulation for heavy-duty engine and vehicle standards and highway diesel fuel sulfur control requirements. A diesel PM emission standard of 0.01 g/bhp/hr is proposed. This proposed standard is based on the anticipated emission reductions from low-sulfur diesel fuel and the use of a catalyst-based diesel particulate filter. To comply with a 2005 European Union (EU) emission standard for diesel fueled vehicles, the French automaker, Peugeot Citroen, recently unveiled a diesel PM catalyst-based DPF system which is expected to go into production in the year 2000.

Experience with DPFs on stationary sources is limited. However, DPFs have recently been installed on two emergency standby engines in Chico, California. ARB staff has source tested these engines and is currently analyzing the results to determine the effectiveness of the DPFs in reducing diesel PM emissions. ARB staff believes that, when coupled with very low-sulfur diesel fuel, DPFs will result in reduced emissions of diesel PM.

Estimated Emission Reduction

Assuming implementation by 2002, this control measure will result in diesel PM reductions of 33 tons per year by calendar year 2010. This represents a 90% reduction in diesel PM emissions this category.

Reduction in Exposure /Risk

The reduction in exposure and risk will be consistent with the efficiency of the control technology. For example, if a particulate filter reduces diesel PM by 90% over an uncontrolled engine in a specific application, the reduction in exposure and risk will also be 90%.

Approximate Cost to Businesses, State and Local Agencies

Fuel Technology Requirements: The incremental cost of producing very low-sulfur diesel fuel is estimated at less than $0.05 per gallon. However, additional costs are associated with producing relatively small batches (before the anticipated 2006 Statewide very low-sulfur requirement goes into effect) and transporting the fuel to the stationary engine's fuel storage tanks.

Add-on Control Requirements: The costs associated with purchasing, installing, and maintaining a DPF varies with the size of the engine. For example, the current capital cost of a catalyst-based DPF ranges from $1,300 - $5,000 for a 40 horsepower engine to $32,000 - $44,000 for a 1,400 horsepower engine.

Potential Adverse Environmental and Safety Impacts

The potential adverse environmental and safety impacts associated with the available control technologies are discussed in Section V. Depending on the control technology applied, these impacts may include: 1) the formation of sulfates; 2) increases in emissions of other pollutants; and 3) problems associated with waste disposal.

b. Prime-Use Engine Retrofit Requirement

Description of the Proposed Measure

Diesel engines are rugged, reliable and fuel efficient, and are the power source of choice for many stationary source applications. Because of this durability, the retirement of older engines coupled with the integration of newer (i.e., lower emitting) engines cannot be relied upon as an effective measure to achieve near-term diesel PM reductions. However, many diesel PM control technologies can be retrofitted to existing diesel engines. Staff recommends the development of an ATCM that specifies retrofit control requirements for existing prime-use diesel engines. The ATCM should require the application of catalyst-based DPFs where feasible.

However, while catalyst-based DPFs represent the most effective control technology, because of the variety of existing engines and the multitude of applications, staff recognizes that this technology may not be universally applicable to all retrofit applications. Therefore, a variety of control technologies should be evaluated during the development of the ATCM. The ARB should begin the ATCM regulatory development as soon as possible with the goal of Board adoption in 2002 and implementation in 2003.

Feasibility

As discussed previously in this report, there are a variety of technologies that are available to reduce diesel PM from diesel engines. Some of the technologies available include new fuel injectors, engine rebuild kits, and exhaust control technologies such as particulate filters. While much of the experience with these technologies has been obtained from application to mobile sources, some of the technologies have also been applied to, and demonstrated on, stationary engines. For example, particulate filters have been installed on several thousand mobile diesel engines[10], primarily in Europe, and were recently applied to two emergency standby engines in Chico, California. Staff expects that many of the technologies demonstrated on mobile sources can be applied to stationary engines.

[10] "Available particulate trap systems for diesel engines" VERT: Suva, AUVA, TBG, BUWAL, 1998

Estimated Emission Reduction

Assuming full implementation by 2003, this control measure will result in diesel PM reductions of 70 tons per year by calendar year 2010. This represents an 85% reduction in diesel PM emissions from at least 90% of the engines in this category.

Reduction in Exposure/Risk

The reduction in exposure and risk will be consistent with the efficiency of the control technology. For example, if a particulate filter reduces diesel PM by 85% in a specific application, the reduction in exposure and risk will also be 85%.

Approximate Cost to Businesses, State and Local Agencies

The cost of applying a particular control technology to a prime-use engine typically varies based on the size of the engine. For example, the current capital cost of catalyst-based particulate filters ranges from $1,300 - $5,000 for a 40 horsepower engine to $32,000 - $44,000 for a 1,400 horsepower engine. The annualized cost of catalyst-based particulate filters is projected to vary between $440 - $1,240 per year for a 40 horsepower engine and $6,060 - $10,980 per year for a 1,400 horsepower engine. The capital and annualized costs of other diesel PM control technologies, such as oxidation catalysts and low emission retrofit kits, also vary by engine size.

The range in consumer costs associated with the control measure is not expected to exceed $2.0 million to $3.8 million per year. The cost estimates assume that 90% of the projected 2010 prime-use engine inventory will be equipped with catalyst-based DPFs. This represents the maximum anticipated cost of the control measure. State and local agencies can expect to incur similar costs. The detailed cost calculations are presented in Appendix II-B.

Potential Adverse Environmental and Safety Impacts

The potential adverse environmental and safety impacts associated with the available control technologies are discussed in Section V. Depending on the control technology applied, these impacts may include: 1) the formation of sulfates; 2) increases in emissions of other pollutants; and 3) problems associated with waste disposal.

c. Emergency Standby Engine Retrofit Requirement

Description of the Proposed Measure

In addition to the development of an ATCM for prime-use engines, staff recommends that an ATCM be developed that specifies retrofit control requirements for existing emergency standby engines. The ATCM should require the application of catalyst-based DPFs where feasible. However, while catalyst based DPFs represent the most effective control technology, because of the variety of existing engines, staff recognizes that this technology may not be universally applicable to all retrofit applications. Therefore, a variety of control technologies should be evaluated during the development of the ATCM. The ARB should begin the ATCM regulatory development as soon as possible with the goal of Board adoption in 2002 and implementation in 2003. Additionally, this ATCM should be developed concurrently with the prime-use engine ATCM.

Feasibility

As discussed above, there are a variety of technologies that are available to reduce diesel PM from diesel engines. While many of these technologies have been applied primarily to mobile sources, some of the technologies have also been applied to stationary engines. For example, oxidation catalysts, which are in common use in urban transit buses, have also been applied to several stationary diesel engines. In addition, a diesel/natural gas bi-fuel retrofit kit has been installed on locomotive engines.

Estimated Emission Reduction

Assuming full implementation by 2003, this control measure will result in a diesel PM reduction of 105 tons per year by calendar year 2010. This represents an 85% reduction applied to 90% of the engines in this category.

Reduction in Exposure/Risk

The reduction in exposure and risk will be consistent with the efficiency of the control technology.

Approximate Cost to Businesses, State and Local Agencies

The cost of applying a particular control technology to an emergency standby engine typically varies based on the size of the engine. For example, the current capital cost of an oxidation catalyst ranges from $400 for a 40 horsepower engine to $20,000 for a 1,400 horsepower engine. The annualized cost for an oxidation catalyst is projected to vary between $150 - $850 per year for a 40 horsepower engine to $1,650 - $4,360 per year for a 1,400 horsepower engine. The capital and annualized costs of other diesel PM control technologies, such as particulate filters and bi-fuel retrofit kits, also vary by engine size. These costs will need to be evaluated further during the development of the ATCM.

The range in consumer costs associated with this control measure are not expected to exceed $24.8 million to $47.2 million per year. The cost estimates assume that 90% of the projected 2010 emergency standby engine inventory will be equipped with catalyst-based DPFs. This represents the maximum anticipated cost of the control measure. State and local agencies can expect to incur similar costs. The detailed cost calculations are presented in Appendix II-B.

Potential Adverse Environmental and Safety Impacts

The impacts associated with an ATCM for emergency standby engines will be similar to the impacts for the prime-use engine ATCM.

2. Retrofit of Existing Portable Engines

Staff recommends that regulations be developed to reduce diesel PM emissions from existing portable diesel engines. Specifically, the Statewide Portable Equipment Registration Program Regulation should be amended to include requirements for reducing diesel PM emissions from registered portable diesel engines. The new diesel PM control requirements should reduce diesel PM emissions to the lowest level achievable through the application of the best available control technology or a more effective control method, consistent with Section 39666(c) of the Health and Safety Code. In addition, an ATCM should be developed, for implementation by local districts, that is consistent with the amended Statewide Registration Program requirements.

Staff also recommends that ARB work with U.S. EPA on measures to reduce diesel PM emissions from non-road engines rated at less than 175 horsepower and used primarily in farm and construction operations. Specifically, the U.S. EPA should be encouraged to set standards that reduce diesel PM emissions from new non-road engines rated at less than 175 horsepower and used primarily in farm and construction operations to the lowest level achievable through the application of the best available control technology or a more effective control method. In addition, staff should work with U.S. EPA to clarify for preempted engine categories the time period after which a new off-road engine can be considered "non-new" and eligible for control by ARB.

Description of the Proposed Measure

The Statewide Registration Program amendments and the portable engine ATCM should include requirements for reducing diesel PM emissions through the application of catalyst-based DPFs, electrification where feasible, and in consideration of alternate fuels. Staff anticipates that the revisions to the Statewide Registration Program could be adopted by the Board in 2002 with implementation beginning in 2003.

Feasibility

Staff expects that operators of portable engines will meet the revised diesel PM emission standards by either: 1) replacing existing engines with electric motors; or 2) retrofitting existing engines with either catalyst-based DPFs where feasible or with one of the control technology options identified in Chapter V where catalyst-based DPFs are not feasible. As discussed in Chapter V, there are several technologies that can be used to reduce diesel PM emissions. While some of the technologies that could be used in retrofit applications have not been demonstrated on portable applications, they have been demonstrated on mobile and/or stationary diesel engines. ARB staff expect that many of these technologies can be successfully applied to portable engines.

Estimated Emission Reduction

The proposed measure is estimated to reduce diesel PM emissions by 712 TPY by 2010. This represents an 85% reduction of diesel PM emissions from 90% of the engines in this category.

Reduction in Exposure/Risk

The reduction in exposure and risk is expected to be consistent with the control efficiency achieved.

Approximate Cost to Businesses, State and Local Agencies

The cost of applying a particular control technology varies based on the size of the engine. For example, the current capital cost of the CCTS retrofit kit ranges from $1,500 for a 100 horsepower engine to $6,000 for a 1,400 horsepower engine. The annualized cost for CCTS retrofit kits is projected to vary between $490 - $590 per year for a 100 horsepower engine to $4,020 - $4,890 per year for a 1,400 horsepower engine. The capital and annualized costs of other diesel PM control technologies, such as particulate filters and bi-fuel retrofit kits, also vary by engine size. These costs will need to be evaluated further during the development of the ATCM.

The range in consumer costs associated with this control measure are not expected to exceed $29.2 million to $75.1 million per year. The cost estimates assume that 90% of the projected 2010 portable engine inventory will be equipped with catalyst-based DPFs. This represents the maximum anticipated cost of the control measure. State and local agencies can expect to incur similar costs. The detailed cost calculations are presented in Appendix II-B.

Potential Adverse Environmental Impacts

There may be a range of potential adverse environmental impacts depending upon the control technique used, including formation of sulfates, disposal of waste, or minor emissions of various contaminants.

3. Retrofit of Agricultural Irrigation Pump Engines

There are well over 7,000 agricultural irrigation pump engines in California, and they represent about 11% of the total stationary and portable engine inventory. Because of their high use, they are a significant source of diesel PM, contributing half of the diesel PM emissions from the entire stationary engine category. In addition, agricultural irrigation pumps tend to be concentrated in specific regions of the State, and their contribution to the ambient levels of diesel PM is expected to be proportionally higher within these regions.

Description of the Proposed Measure

While H&SC § 42310(e) prohibits districts from requiring a permit for most equipment used in agricultural operations, districts can establish emission control requirements for engines in this category. Therefore, ARB staff recommend working with the agricultural community to develop a comprehensive program to reduce emissions from engines used in agricultural operations. This agricultural engine emission reduction program should include: 1) the substitution of diesel engines with electrically driven equipment where feasible; and 2) a comprehensive retrofit element where electrical substitution is not feasible. Incentive programs may be considered to facilitate implementation of this control measure.

Feasibility

Over 90% of the agricultural irrigation pumps used in California are electrically driven, and ARB staff have observed diesel-fired agricultural irrigation pumps located directly adjacent to electrical service poles. As such, electrification appears to be a viable alternative to diesel engine use in many agricultural pumping activities. In addition, there are a variety of technologies that are available for retrofit applications, including catalyst-based DPFs. Staff expect that many of these technologies can be applied to engines used in agricultural operations.

Estimated Emission Reduction

Assuming full implementation of this control measure by 2005, ARB staff anticipates that diesel PM emissions from agricultural irrigation pumps will be reduced by 297 TPY in 2010. These emission reduction estimates assume that 90% of the engines in this category will be equipped with emission control technologies capable of achieving 85% control

Reduction in Exposure/Risk

The reduction in exposure and risk is expected to be consistent with the control efficiency achieved

Approximate Cost to Businesses, State and Local Agencies

The cost of applying a particular control technology to an engine used in agricultural irrigation operations depends on the size of the engine and / or the pumping requirements. For example, Pacific Gas and Electric (PG&E) staff estimate that the cost of purchasing and installing a new irrigation pump motor and the associated equipment (e.g. service pole, service panel, transformer, etc…) would be approximately $10,000 for a 100 horsepower motor and $46,500 for a 400 horsepower motor. ARB staff estimate that the costs associated with the purchase and installation of a catalyst-based DPFs are between $5,200 and $8,000 for a 100 horsepower engine and $10,700 to $11,000 for a 400 horsepower engine. However, these costs need to be evaluated further.

The range in consumer costs associated with this control measure are not expected to exceed $3.9 million to $9.9 million per year. The cost estimates assume that 90% of the engines in this category will be equipped with catalyst-based DPFs. State and local agencies can expect to incur similar costs. The detailed cost calculations are presented in Appendix II-B.

Potential Adverse Environmental Impacts

There are no known adverse environmental impacts associated with the electrification aspect of the proposed control measure. However, there may be adverse environmental impacts associated with the retrofit element of the proposed measure. These impacts may include: sulfate particle formation, waste disposal, and/or emissions of other air pollutants.

VII. REFERENCES

Air Resources Board, Mobile Source Control Division, Public Meeting to Consider Approval of California's Emissions Inventory for Off-Road Large Compression-ignited (CI) Engines (>25 HP), January 2000

Challen, Bernard and Rodica Baranescu, eds. Diesel Engine Reference Book. 2nd ed. Warrendale, PA: SAE International, 1999

Majewski, W. Addy. DieselNet Technology Guide. Toronto, Ontario: Ecopoint, Inc.

Manufacturers of Emission Controls Association. "Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Low Emission Levels." Washington, D.C. 1999.

Mills, G.A. Ph.D. Thesis, University of Southamption, 1983

National Agricultural Statistics Service, 1994 Farm and Ranch Irrigation Survey.

The Office of Environmental Health Hazard Assessment (OEHHA) is currently revising the CAPCOA Risk Assessment Guidelines. It is expected that districts will use the OEHHA risk assessment guidelines when completed later this year (2000).

For Group 2 engines, the Specific Findings Report should also report the full range of risk identified by the SRP; 1.3×10^{-4} to 2.4×10^{-3} chances per microgram per cubic meter of diesel particulate matter. The unit risk factor of 3×10^{-4} $(\mu g/m^3)^{-1}$ is commonly expressed as 300 chances per microgram per meter cubed of diesel particulate matter.

U.S. Department of Energy, et al. "Diesel Emission Control – Sulfur Effects (DECSE) Program Phase I Interim Data Report No. 4: Diesel Particulate Filters – Final Report." January 2000.

VERT: Suva, et al. "Available particulate trap systems for diesel engines." 1998

Appendix II-A

California Air Districts and Counties

Appendix II-B

Analysis of Control Technology Costs

The California Health and Safety code requires the Air Resources Board (ARB) to evaluate the approximate cost of each airborne toxic control measure (ATCM). To address this requirement for the range in diesel particulate matter (Diesel PM) control options, staff collected detailed cost and durability (i.e., equipment life) information from the manufacturers of the technologies evaluated in the Risk Reduction Plan (RRP). Using this information, the Total Annual Cost[1] was determined for each technology. The Total Annual Cost and the equipment inventories, as discussed in Section IV of Appendix II, were then used to estimate the range of costs associated with potential ATCMs.

The information collected from each vendor included: the current retail cost of each technology (a.k.a. capital cost); the installation cost; and the operating and maintenance costs. The current retail cost was requested for five diesel engine "ratings," including: a 40 horsepower engine, a 100 horsepower engine, a 275 horsepower engine, a 400 horsepower engine, and a 1,400 horsepower engine[2].

The current retail costs, as opposed to future costs assuming higher production volumes, were selected so that an operator who is considering the near term purchase of one of the control technologies evaluated in the RRP would have the latest cost information available. However, staff anticipates that the current retail costs will decline over the next few years as production volumes increase. For example, the Manufacturers of Emission Controls Association (MECA) projects that with a production volume of 200,000 units per year, the cost of a diesel particulate filter system will range from $625 to $2,250 for an engine with a displacement of between 7 and 13 liters. This represents an 80% decrease from the average current retail costs identified by several particulate filter system manufacturers.

The control technology manufacturers were also requested to provide estimates of the installation costs, operating costs and maintenance costs for their respective products. The installation cost is a one-time cost that include both the time and materials associated with installing a product in a specific application. Installation costs tend to vary depending on the technology and the specific type of application.

The operating cost is an annual cost associated with operating a specific technology, such as the cost of supplemental fuel, if required. Operating costs can also be negative, which represent a cost savings (e.g., improved fuel economy). The

[1] The Total Annual Cost is also known as the Annualized Cost or the Equivalent Uniform Annual Cost.

[2] These engine size ranges were selected earlier in the control technology evaluation process when it appeared that the engines would be categorized via engine size similar to the non-road engine regulations (i.e., < 50 hp, 50 – 175 hp, 175 - 750 hp, and > 750 hp). The five engine sizes (i.e., 40 hp, 100 hp, 275 hp, 400 hp and 1,400 hp) represented an early estimate of the average size of stationary and portable engines used in California within the respective horsepower ranges (i.e., < 50 hp, 50 - 175 hp, 175 - 750 hp, and > 750 hp).

maintenance cost is also an annual costs and includes items such as periodic cleaning. Similar to operating costs, some technologies may have negative maintenance costs. For example, some technologies may allow less frequent engine oil changes.

The control technology manufacturers provided estimates of the "equipment life" or durability of each technology. Recognizing that the equipment life may be different than its economic life, the "life" considered in the Total Annual Cost calculations is computed as the lessor of the equipment life or the maximum economic life. The maximum economic life is assumed to be 10 years, which is consistent with ARB cost effectiveness guidance[3]. Since product vendors tended to estimate the equipment life based on the number of hours the product can operate, the equipment life (in years) was calculated based on an assumption of 500 hours per year of operation. Five hundred hours per year represents the threshold between low use engines and high use engines presented in Section IV of Appendix II. An interest rate of 9% was selected after consulting with staff in the ARB's Economic Studies Section.

The cost information provided by the product vendors showed a range in costs and equipment life. Therefore, both a high and a low Total Annual Cost were computed for each technology.

The following formula was used to determine the Total Annual Cost:

$$TotalAnnualCost = \left[\frac{I(1+I)^{n}}{(1+I)^{n}-1} * (CC + IC) \right] + OC + MC$$

Where,

I = Interest Rate (9%)
n = the lessor of:
- Equipment Life (hr) ÷ Annual Operating Time (500 hr/yr)
- Economic Life (10 yr)

CC = Capital Cost ($)
IC = Installation Cost ($)
OC = Operating Cost ($/yr)
MC = Maintenance Cost ($/yr)

The Total Annual Cost calculations are presented in Table B-1. This information is also summarized in Table 7 of Appendix II

[3] "Cost-Effectiveness: District Options for Satisfying the Requirements of the California Clean Air Act," September, 1990, Air Resources Board Office of Air Quality Planning & Liaison.

DRAFT – DO NOT CITE OR QUOTE

Table B-1: Equivalent Uniform Annual Cost

Control Technology	HP (hp)	Annual Hours (hr)	Equipment/Economic Life Min (hr)	Equipment/Economic Life Max (hr)	NTE (yr)	Interest Rate (%)	Capital Cost Min ($)	Capital Cost Max ($)	Installation Cost Min ($)	Installation Cost Max ($)	Operating Cost Min ($/yr)	Operating Cost Max ($/yr)	Maintenance Cost Min ($/yr)	Maintenance Cost Max ($/yr)	Total Annual Cost Min ($/yr)	Total Annual Cost Max ($/yr)
DOC	40	500	4,000	10,000	10	9.00%	$ 400	$ 600	$ 167	$ 167	$ -	$ -	$ 64	$ 712	$ 152	$ 851
DOC	100	500	4,000	10,000	10	9.00%	$ 680	$ 1,356	$ 167	$ 167	$ -	$ -	$ 64	$ 712	$ 196	$ 987
DOC	275	500	4,000	10,000	10	9.00%	$ 2,100	$ 2,600	$ 167	$ 167	$ -	$ -	$ 64	$ 712	$ 417	$ 1,212
DOC	400	500	4,000	10,000	10	9.00%	$ 2,800	$ 3,700	$ 167	$ 167	$ -	$ -	$ 64	$ 712	$ 526	$ 1,411
DOC	1400	500	4,000	10,000	10	9.00%	$ 10,000	$ 20,000	$ 167	$ 167	$ -	$ -	$ 64	$ 712	$ 1,648	$ 4,356
DPF	40	500	8,000	12,000	10	9.00%	$ 3,300	$ 5,000	$ 167	$ 518	$ 28	$ 28	$ 156	$ 312	$ 724	$ 1,200
DPF	100	500	8,000	12,000	10	9.00%	$ 5,000	$ 7,500	$ 167	$ 518	$ 64	$ 64	$ 156	$ 312	$ 1,025	$ 1,625
DPF	275	500	8,000	12,000	10	9.00%	$ 6,900	$ 9,000	$ 167	$ 518	$ 175	$ 175	$ 156	$ 312	$ 1,432	$ 1,970
DPF	400	500	8,000	12,000	10	9.00%	$ 10,500	$ 10,500	$ 167	$ 518	$ 253	$ 253	$ 156	$ 312	$ 2,071	$ 2,282
DPF	1400	500	8,000	12,000	10	9.00%	$ 32,000	$ 44,000	$ 167	$ 518	$ 888	$ 888	$ 156	$ 312	$ 6,056	$ 8,136
ECOTIP	40	Not available for engines in this size category.														
ECOTIP	100	500	4,000	6,000	10	9.00%	$ 200	$ 200	$ -	$ -	$ (106)	$ (106)	$ -	$ -	$ (75)	$ (70)
ECOTIP	275	500	4,000	6,000	10	9.00%	$ 200	$ 300	$ -	$ -	$ (291)	$ (291)	$ -	$ -	$ (260)	$ (237)
ECOTIP	400	500	4,000	6,000	10	9.00%	$ 300	$ 400	$ -	$ -	$ (422)	$ (422)	$ -	$ -	$ (375)	$ (349)
ECOTIP	1400	500	4,000	6,000	10	9.00%	$ 400	$ 800	$ -	$ -	$ (1,479)	$ (1,479)	$ -	$ -	$ (1,417)	$ (1,335)
CCTS	40	Not available for engines in this size category.														
CCTS	100	500	3,000	8,000	10	9.00%	$ 1,500	$ 1,500	$ -	$ -	$ 254	$ 254	$ -	$ -	$ 488	$ 589
CCTS	275	500	3,000	8,000	10	9.00%	$ 1,500	$ 2,300	$ -	$ -	$ 699	$ 699	$ -	$ -	$ 933	$ 1,212
CCTS	400	500	3,000	8,000	10	9.00%	$ 1,800	$ 3,000	$ -	$ -	$ 1,012	$ 1,012	$ -	$ -	$ 1,293	$ 1,681
CCTS	1400	500	3,000	8,000	10	9.00%	$ 3,000	$ 6,000	$ -	$ -	$ 3,550	$ 3,550	$ -	$ -	$ 4,018	$ 4,888
Repower - Tier 2	40	500	8,000	8,000	10	9.00%	$ 4,290	$ 4,290	$ 2,380	$ 2,380	$ -	$ -	$ -	$ -	$ 1,039	$ 1,039
Repower - Tier 2	100	500	8,000	8,000	10	9.00%	$ 8,960	$ 18,840	$ 4,390	$ 4,390	$ -	$ -	$ -	$ -	$ 1,769	$ 3,620
Repower - Tier 2	275	500	8,000	8,000	10	9.00%	$ 12,440	$ 32,150	$ 3,450	$ 6,190	$ -	$ -	$ -	$ -	$ 2,476	$ 5,974
Repower - Tier 2	400	500	8,000	8,000	10	9.00%	$ 23,100	$ 48,370	$ 8,430	$ 8,430	$ -	$ -	$ -	$ -	$ 4,913	$ 8,851
Repower - Tier 2	1400	500	8,000	8,000	10	9.00%	$ 186,890	$ 186,890	$ 23,630	$ 23,630	$ -	$ -	$ -	$ -	$ 32,803	$ 32,803
NOxTECH	40	500	8,000	8,000	10	9.00%	$ 400	$ 1,200	$ 6,400	$ 14,400	$ 94	$ 150	$ -	$ -	$ 1,153	$ 2,581
NOxTECH	100	500	8,000	8,000	10	9.00%	$ 1,000	$ 3,000	$ 6,400	$ 14,400	$ 212	$ 339	$ -	$ -	$ 1,365	$ 3,050
NOxTECH	275	500	8,000	8,000	10	9.00%	$ 2,750	$ 8,250	$ 6,400	$ 14,400	$ 583	$ 932	$ -	$ -	$ 2,008	$ 4,462
NOxTECH	400	500	8,000	8,000	10	9.00%	$ 4,000	$ 12,000	$ 6,400	$ 14,400	$ 844	$ 1,350	$ -	$ -	$ 2,464	$ 5,463
NOxTECH	1400	500	8,000	8,000	10	9.00%	$ 14,000	$ 42,000	$ 6,400	$ 14,400	$ 2,958	$ 4,734	$ -	$ -	$ 6,137	$ 13,522
SINOx	40	Not available for engines in this size category.														
SINOx	100	Not available for engines in this size category.														
SINOx	275	500	20,000	20,000	10	9.00%	$ 13,750	$ 16,500	$ 500	$ 5,000	$ -	$ -	$ 715	$ 715	$ 2,935	$ 4,065
SINOx	400	500	20,000	20,000	10	9.00%	$ 20,000	$ 24,000	$ 500	$ 5,000	$ -	$ -	$ 800	$ 800	$ 3,994	$ 5,319
SINOx	1400	500	20,000	20,000	10	9.00%	$ 70,000	$ 84,000	$ 500	$ 5,000	$ -	$ -	$ 1,400	$ 1,400	$ 12,385	$ 15,268
ITG Bi-Fuel	40	500	8,000	8,000	10	9.00%	$ 4,000	$ 4,000	$ 1,800	$ 2,250	$ (150)	$ (150)	$ -	$ -	$ 754	$ 824
ITG Bi-Fuel	100	500	8,000	8,000	10	9.00%	$ 6,000	$ 6,000	$ 1,800	$ 2,250	$ (340)	$ (340)	$ -	$ -	$ 875	$ 946
ITG Bi-Fuel	275	Information not provided by the manufacturer.														
ITG Bi-Fuel	400	500	8,000	8,000	10	9.00%	$ 14,000	$ 14,000	$ 1,800	$ 2,250	$ (1,340)	$ (1,340)	$ -	$ -	$ 1,122	$ 1,192
ITG Bi-Fuel	1400	500	8,000	8,000	10	9.00%	$ 38,000	$ 38,000	$ 1,800	$ 2,250	$ (4,680)	$ (4,680)	$ -	$ -	$ 1,522	$ 1,592
FBC + DPF	40	500	8,000	8,000	10	9.00%	$ 1,300	$ 4,300	$ 167	$ 518	$ 58	$ 173	$ 156	$ 312	$ 442	$ 1,235
FBC + DPF	100	500	8,000	8,000	10	9.00%	$ 2,000	$ 5,000	$ 167	$ 518	$ 130	$ 390	$ 156	$ 312	$ 624	$ 1,562
FBC + DPF	275	500	8,000	8,000	10	9.00%	$ 3,500	$ 6,500	$ 167	$ 518	$ 358	$ 1,073	$ 156	$ 312	$ 1,085	$ 2,478
FBC + DPF	400	500	8,000	8,000	10	9.00%	$ 7,000	$ 10,000	$ 167	$ 518	$ 518	$ 1,553	$ 156	$ 312	$ 1,790	$ 3,503
FBC + DPF	1400	500	8,000	8,000	10	9.00%	$ 30,000	$ 33,000	$ 167	$ 518	$ 1,815	$ 5,445	$ 156	$ 312	$ 6,672	$ 10,980
Electric DPF	40	500	8,000	8,000	10	9.00%	$ 4,450	$ 4,450	$ 206	$ 518	$ 131	$ 131	$ 31	$ 312	$ 888	$ 1,217
Electric DPF	100	500	8,000	8,000	10	9.00%	$ 5,780	$ 5,780	$ 206	$ 518	$ 127	$ 127	$ 31	$ 312	$ 1,091	$ 1,420
Electric DPF	275	500	8,000	8,000	10	9.00%	$ 11,690	$ 11,690	$ 206	$ 518	$ 117	$ 117	$ 31	$ 312	$ 2,001	$ 2,331
Electric DPF	400	500	8,000	8,000	10	9.00%	$ 14,000	$ 14,000	$ 206	$ 518	$ 169	$ 169	$ 31	$ 312	$ 2,410	$ 2,743
Electric DPF	1400	500	8,000	8,000	10	9.00%	$ 40,250	$ 40,250	$ 206	$ 518	$ 592	$ 592	$ 31	$ 312	$ 6,927	$ 7,256
Electrification	50	500	10,000	30,000	10	9.00%	$ 5,241	$ 5,241	$ 1,230	$ 1,230	$ -	$ -	$ -	$ -	$ 1,008	$ 1,008
Electrification	100	500	10,000	30,000	10	9.00%	$ 8,790	$ 8,790	$ 1,230	$ 1,230	$ -	$ -	$ -	$ -	$ 1,561	$ 1,561
Electrification	125	500	10,000	30,000	10	9.00%	$ 10,919	$ 10,919	$ 1,415	$ 1,415	$ -	$ -	$ -	$ -	$ 1,922	$ 1,922
Electrification	400	500	10,000	30,000	10	9.00%	$ 40,470	$ 40,470	$ 6,065	$ 6,065	$ -	$ -	$ -	$ -	$ 7,251	$ 7,251

Notes:

1. Diesel Fuel Cost: $1.63 Statewide average as of March 31, 2000.
2. () represents a savings.
3. The Total Annual Cost is also known as the Annualized Cost or the Equivalent Uniform Annual Cost.
4. The analysis of the Total Annual Cost of electrification does not include the differential costs associated with operating and maintaining the electric motor and associated equipment.

The cost of each control measure, not just the cost of each control technology, must be evaluated to satisfy the requirements of the California Health and Safety Code. The control measures recommended by staff include promulgating ATCMs for stationary diesel engines, amending the Statewide Portable Equipment Registration Program regulation for portable diesel engines, and establishing an electrification / retrofit program for engines used in agricultural operations. The range of costs for these control measures can be determined by multiplying the cost of the control technologies by the inventory of sources over which the technologies are expected to be applied.

As is discussed in Section V of Appendix II, there is a wide range in effectiveness of the various control technologies, as well as a wide range in costs. To determine the costs for the available control measures, staff evaluated the range of costs associated with catalyst-based diesel particulate filters (DPF), which represent the highest efficiency diesel PM control technology.

Because the cost of catalyst-based DPFs vary by engine size, specific engine sizes are needed to determine the cost of these control technologies. The average horsepower for stationary engines (backup and prime), portable engines and agricultural engines was determined from information collected by the local districts and from the *Emission Inventory of Off-Road Large Compression-Ignited Engines (>25 HP) Using the New Offroad Emissions Model*, respectively. The new engine category assume 93 stationary backup engines, 10 new stationary prime engines and 6 new replacement stationary prime engines and 60 replacement agricultural engines are permitted each year. The average horsepower of engines in these categories (i.e., stationary backup, stationary prime, portable and agricultural) is presented in Table B-2. The costs associated with applying catalyst-based DPFs to these four engine categories were then interpolated from the Total Annual Cost data presented in Table B-1.

The Total Annual Cost of each control technology was then multiplied by the respective engine inventory, as presented in Section IV of Appendix II, to determine the cost range for the available control measures. This information is presented in Table B-2.

Table B-2: Control Measure Cost Analysis

Engine Category	Average Horsepower	2010 Inventory	Annualized Costs Low	Annualized Costs High	Control Measure Cost Low	Control Measure Cost High
New Engine	400	1352	$1,790	$3,503.00	$2,420,080	$4,736,056
Stationary - Backup*	550	11,344	$ 2,430	$ 4,625	$ 24,809,328	$47,219,400
Stationary - Prime*	480	1,025	$ 2,131	$ 4,101	$ 1,965,848	$ 3,783,173
Portable Engines*	110	49,860	$ 650	$ 1,674	$ 29,168,100	$75,119,076
Agricultural*	120	6,380	$ 677	$ 1,722	$ 3,887,334	$ 9,887,724

* Percent of engine population controlled: 90%

The estimates presented above represent the anticipated range of costs associated with applying high efficiency control measures to stationary, portable and agricultural diesel-fueled engines.

Appendix III

Mobile Diesel-Fueled Engines: Report on the Need for Further Regulation of Particulate Matter Emissions

September 13, 2000

Table of Contents

Tables

I. PURPOSE

This report summarizes the need for further regulation of on- and off-road mobile diesel-fueled engines to reduce ambient diesel particulate matter (diesel PM) and the associated health risk. Proposed control measures to achieve those reductions are described, along with estimated emission reductions and costs per vehicle. Suggested non-regulatory strategies that may achieve additional reductions in emissions are also described.

II. ENGINE CATEGORIES

A. On-Road Engines

There are approximately 700,000 on-road diesel-fueled vehicles currently in use in California. Diesel-fueled, or compression-ignition, engines are used in every on-road vehicle category except for motorcycles, and include light- to heavy-duty trucks, school buses, urban buses, and passenger vehicles (Table 1). The majority of on-road diesel-fueled engines, however, are found in heavy-duty vehicles with a gross vehicle weight rating (GVWR) from 14,000 pounds GVWR and up. The reported heavy-duty vehicle population includes an adjustment to account for mileage by out-of-state registered vehicles that travel in California.

The federal definition of a heavy-duty vehicle is any vehicle with a GVWR greater than 8,500 pounds. California's lower GVWR limit for heavy-duty vehicles is either greater than 8,500 pounds or greater than 14,000 pounds, depending on the model year [13 CCR § 1900(a)(9)]. For the purpose of this report, "heavy-duty vehicle" is used to refer to any vehicle with a GVWR greater than 8,500 pounds. The two categories of light heavy-duty trucks, from 8,501 to 14,000 pounds GVWR, comprise vehicles currently covered by emission standards for medium-duty vehicles. For the weight classes above 14,000 pounds GVWR, heavy-duty vehicles are further subdivided into medium heavy-duty and heavy heavy-duty. The additional heavy-duty categories are school buses and urban transit buses. Larger motor homes would also be considered "heavy-duty."

The population of heavy-duty vehicles is predicted to increase on average by approximately 12 percent from 2000 to 2010 (Table 1). Medium heavy-duty vehicles are projected to increase by about 16 percent and heavy heavy-duty vehicles by about 10 percent. The proportionate increase is greater in the South Coast Air Basin, where the expected increase from 2000 to 2010 in heavy-duty vehicles is about 23 percent. Again, medium heavy-duty trucks are expected to increase faster than heavy heavy-duty trucks (27% versus 19%, respectively) in the South Coast Air Basin. Interestingly, the greatest population increase for any category, on a percentage basis, is expected to occur in diesel-fueled motor homes, which will almost double by 2010, from 1.2 to 2.4 percent of the diesel-fueled vehicle population statewide.

Table 1
On-Road: Categories and Population of Diesel-Fueled Vehicles (EMFAC2000)

		Statewide Population		SoCAB Population	
Category	**GVWR (lb.)**	**2000**	**2010**	**2000**	**2010**
Passenger Cars	all	111,430	41,630	43,050	16,160
Light-Duty Truck 1	up to 3,750	19,160	8,220	4,820	2,140
Light-Duty Truck 2	3,751-5,750	12,250	7,990	3,270	2,350
Medium-Duty Vehicle	5,751-8,500	134,870	117,230	28,050	25,960
MDV/Light Heavy-Duty Truck 1	8,501-10,000	24,380	28,450	8,040	10,620
MDV/Light Heavy-Duty Truck 2	10,001-14,000	34,190	35,170	12,000	13,670
Medium Heavy-Duty Truck	14,001-33,000	163,100	189,220	66,080	83,680
Heavy Heavy-Duty Truck	33,001 +	148,480	162,780	58,170	69,120
School Bus	all	21,250	25,950	7,820	9,500
Urban Bus	all	9,940	11,760	4,360	5,260
Motor Home	all	8,150	15,500	2,580	4,980
	Totals	**687,200**	**643,900**	**238,240**	**243,440**

"SoCAB" – South Coast Air Basin

Although the majority of diesel-fueled vehicles fall into one of the heavy-duty categories (54% in 2000), Californians today drive considerable numbers of diesel-fueled passenger cars, light-duty trucks, and medium-duty vehicles. The majority of the diesel passenger cars and light-duty trucks, however, are greater than 15 years old and ARB staff expects that most of these will be removed from service over the next decade to be replaced with other, non-diesel vehicles. Thus, the statewide population of diesel-fueled passenger cars and light duty trucks is expected to decline by about 60 percent over the next decade. The population of medium-duty diesel-fueled vehicles is also expected to decline statewide, but by only about 13 percent over the next ten years.

B. Off-Road Vehicles and Equipment

There are approximately 550,000 off-road diesel-fueled vehicles and equipment currently in use in California (Table 2), two-thirds of which are categorized as agricultural or construction equipment. Many equipment types are classified as "portable," or equipment of 25 horsepower or greater that is designed to be carried or moved from one location to another. For the purpose of this report, "motive" is use to designate the bulk of off-road equipment and vehicles that are not otherwise classified as portable.

Diesel-fueled off-road engines comprise 138 individual off-road vehicle and equipment types aggregated into 17 categories. Engine sizes range from under 15 horsepower to over 10,000 horsepower. These equipment categories include aircraft, agriculture, airport ground support, construction and mining, commercial, industrial, logging, transportation refrigeration units, lawn and garden, pleasure craft, locomotives, and others (Table 2). For this report, however, aircraft engines are not included. This report only addresses internal combustion, diesel-cycle engines.

Aircraft, in addition, are fueled by either aviation gasoline or jet fuel, neither of which meets the definition of diesel fuel.

Table 2
Off-Road: Categories and Population of Diesel-Fueled Equipment

Category		Population 2000	Population 2010
Agricultural	Total	199860	199860
	Motive	*195940*	*186330*
	Portable	*3920*	*3730*
Airport Ground Support	Total	1970	2440
	Motive	*1480*	*1830*
	Portable	*490*	*610*
Commercial	Total	53710	59460
	Motive	*17470*	*19330*
	Portable	*36240*	*40130*
Commercial Marine Vessel	Total	n/a	n/a
	Motive	*n/a*	*n/a*
	Portable	*n/a*	*n/a*
Construction & Mining	Total	168450	188110
	Motive	*164020*	*183160*
	Portable	*4430*	*4960*
Dredging	Total	130	130
	Motive	*0*	*0*
	Portable	*130*	*130*
Drilling	Total	1500	1500
	Motive	*0*	*0*
	Portable	*1500*	*1500*
Industrial	Total	12160	13360
	Motive	*12160*	*13360*
	Portable	*0*	*0*
Lawn & Garden	Total	44200	50650
	Motive	*44070*	*50500*
	Portable	*130*	*150*
Locomotive	Total	n/a	n/a
	Motive	*n/a*	*n/a*
	Portable	*n/a*	*n/a*
Logging	Total	2780	2780
	Motive	*2780*	*2780*
	Portable	*0*	*0*
Military Tactical Support	Total	2300	2300
	Motive	*0*	*0*
	Portable	*2300*	*2300*
Misc. Portable	Total	90	90
	Motive	*0*	*0*
	Portable	*90*	*90*
Pleasure Craft	Total	19700	19860
	Motive	*19700*	*19860*
	Portable	*0*	*0*
Transportation Refrigeration	Total	40610	44150
	Motive	*40610*	*44150*
	Portable	*0*	*0*
TOTALS	**GRAND TOTAL**	**547460**	**574900**
	MOTIVE	*498230*	*521300*
	PORTABLE	*49230*	*53600*

For all categories, except for commercial marine vessels and locomotives, engines are further classified by the following horsepower groups: ≤15, 16-25, 26-50, 51-120, 121-175, 176-250, 251-500, 501-750, 751-9999, >9999 hp. The statewide population of these off-road vehicle and equipment types is expected to increase by approximately five percent from 2000 to 2010 (Table 2).

Staff count activity rather than pieces of equipment to determine emissions for commercial marine vessels and locomotive operations, thus Table 2 does not include population figures for these two categories. The commercial marine vessel category includes U.S. and foreign registered ships, tugboats, crew and supply boats, fishing boats, ferries, and other commercial vessels. Yachts and other recreational boats are categorized as pleasure craft.

About nine percent of off-road equipment types are classified as portable equipment for the purposes of permitting. Portable engines are granted permits to operate either under local air district rules or through the ARB under the Portable Equipment Registration Program. Portable engines are therefore subject to permitting requirements for in-use engines in addition to the rules that apply to new off-road engines. Portable equipment is discussed in more detail in Appendix II.

III. EMISSION INVENTORY

The development of an emission inventory is a multi-agency effort, conducted through a public process in which input is solicited from various agencies, air quality management districts, engine manufacturers, and technical consultants. The Air Resources Board is responsible for the final statewide emissions inventory, which is maintained in an electronic database. The California Health and Safety Code (HSC) [§§ 39607 (b) & 39607.3] requires the Board to approve, at a public meeting, the emission inventory for criteria pollutants, including emissions from mobile, stationary, area-wide, and non-anthropogenic sources. The Board's initial approval, under HSC § 39607.3, was required no later than January 1, 1998 and subsequent updates are required at least every three years.

Table 3 provides a summary of diesel PM emissions from mobile engines for the decades from 1990 to 2020 based on the EMFAC2000 1.99f inventory model.[1] The model includes the effects of implementation of existing regulations, which are discussed in Section IV. In general, emissions decline over the four decades because of the effects of these regulations. New engines are subject to more stringent PM standards, and thus emissions decline as older engines are replaced with new, complying engines. Additional details regarding the emission inventories for on- and off-road engines are provided in Sections A and B following.

[1] EMFAC2000 1.99f was the approved and public inventory model version at the time this report was prepared.

Table 3
Statewide Estimates of Diesel PM Emissions for 1990 through 2020

Year	On-Road Engines		Off-Road Engines[1]	
	Population	Diesel PM (tpy)	Population	Diesel PM (tpy)
1990	606,700	18,360	476,300	25,310
2000	687,200	7,500	498,200	18,545
2010	643,900	5,190	521,300	15,910
2020	610,200	4865	527,800	12,830

[1] Does not include portable engines, which are discussed in Appendix II.

A. On-Road Engines

Methodology. California's emission inventory for on-road vehicles is an estimate of the amounts and types of emitted pollutants. The current on-road motor vehicle emission inventory, EMFAC2000, represents more than ten years of effort on the part of ARB staff to refine and improve the accuracy of the inventory, as well as to resolve observed discrepancies between measured ambient emissions, modeled air quality estimates, and estimated emissions.

Details regarding the scientific basis for the model can be found in the document entitled "Public meeting to consider approval of revisions to the State's on-road motor vehicle emissions inventory," dated May 2000, and in the accompanying Technical Support Document. In short, data were collected from all relevant sources and analyzed, the model was developed and tested, and the public had the opportunity to interact with staff regarding the model. As with the previous model, EMFAC2000 has an adjustment to the emission inventory for on-road vehicles to account for mileage traveled within California by heavy-duty trucks registered out-of-state. The outcome is a much improved model that more accurately describes emissions from on-road motor vehicles in California.

1. Current Emissions

The estimated statewide 2000 diesel PM exhaust emissions from on-road diesel-fueled motor vehicles are about 7,500 tons per year (Table 4). The majority of the emissions are generated by two categories of vehicles, medium heavy-duty trucks (21%) and heavy heavy-duty trucks (66%). The next largest categories are passenger cars (3%) and medium-duty vehicles (3%). The remaining emissions (7%) are from light-duty trucks, light heavy-duty trucks, school buses, urban buses, and motor homes. The same pattern occurs for NOx emissions from diesel-fueled vehicles, with medium heavy-duty trucks and heavy heavy-duty trucks generating 89 percent of the NOx emissions from on-road diesel-fueled vehicles, except that the next two largest categories for NOx emissions are light heavy-duty trucks (2%) and medium-duty vehicles (1%). On-road diesel-fueled vehicle emissions in the South Coast Air Basin are 38 percent of the statewide total for diesel PM and 40 percent of the statewide total for NOx emissions from diesel-fueled vehicles.

2. 2010 Emissions

The estimated statewide 2010 diesel PM exhaust emissions from on-road diesel-fueled motor vehicles are about 5,200 tons per year, which is an overall 30 percent decline from 2000 (Table 4). For passenger cars, light-duty trucks, and medium-duty vehicles, the average decline in diesel PM emissions is 60 percent and is accounted for by the predicted population decrease in these categories over the decade and by the effects of existing regulations. For the heavy-duty vehicle categories, existing regulations will cause a 30 percent decline in diesel PM emissions even though vehicle population is expected to increase by about 12 percent. A slightly smaller overall decline in diesel PM emissions, 27 percent, is predicted for the South Coast Air Basin. Diesel PM emissions from buses and motor homes, however, are not predicted to decline over the next decade. Diesel PM emissions from motor homes are expected to increase by one-third from 2000 to 2010, corresponding to a 90 percent increase in the predicted motor home vehicle population.

Emissions of NOx from diesel-fueled vehicles are also expected to decline over the next decade by 34 percent statewide and 29 percent for the South Coast Air Basin. Again, emissions from motor homes are expected to increase, corresponding to an almost doubling of the predicted population (Tables 1 and 4).

Table 4
On-Road Inventory – Diesel-Fueled Vehicles

Category		PM (tons per year) 2000	PM (tons per year) 2010	NOx (tons per year) 2000	NOx (tons per year) 2010
Passenger Car	Statewide	241	66	2,484	877
n/a	*SoCAB*	*106*	*29*	*1,169*	*435*
Light-Duty Truck 1	Statewide	44	15	457	190
Up to 3,750 lbs. GVWR	*SoCAB*	*15*	*4*	*135*	*62*
Light-Duty Truck 2	Statewide	22	11	263	175
3,751-5,750 lbs. GVWR	*SoCAB*	*7*	*4*	*77*	*58*
Medium-Duty Vehicle	Statewide	219	124	3,152	2,597
5,751-8,500 lbs. GVWR	*SoCAB*	*47*	*29*	*694*	*636*
Light Heavy-Duty Truck 1	Statewide	37	26	1,903	1,289
8,501-10,000 lbs. GVWR	*SoCAB*	*11*	*7*	*636*	*478*
Light Heavy-Duty Truck 2	Statewide	58	33	3,021	1,702
10,001-14,000 lbs. GVWR	*SoCAB*	*18*	*11*	*1,048*	*650*
Medium Heavy-Duty Truck	Statewide	1,607	1,428	49,754	32,975
14,001-33,000 lbs. GVWR	*SoCAB*	*646*	*617*	*20,355*	*14,592*
Heavy Heavy-Duty Truck	Statewide	4,927	3,127	177,928	113,041
33,001 + lbs. GVWR	*SoCAB*	*1,881*	*1,267*	*68,956*	*47,515*
School Bus	Statewide	153	157	4,810	4,529
n/a	*SoCAB*	*40*	*40*	*2,520*	*2,400*
Urban Bus	Statewide	179	179	10,085	9,599
n/a	*SoCAB*	*91*	*80*	*4,752*	*4,639*
Motor Home	Statewide	15	22	562	588
n/a	*SoCAB*	*4*	*7*	*172*	*183*
TOTALS	**Total Statewide**	**7,502**	**5,188**	**254,419**	**167,562**
	Total SoCAB	*2,866*	*2,095*	*100,514*	*71,648*

"SoCAB" – South Coast Air Basin

B. Off-Road Vehicles and Equipment

Methodology: California's emission inventory for off-road engines and associated vehicles is an estimate of the amounts and types of pollutants emitted from the thousands of pieces of equipment types used in various applications, all of which are characterized as "off-road." The Board approved an initial statewide off-road inventory in December 1997. The new computer model for the estimation of off-road emissions inventory (OFFROAD) was not completed at that time, however, and the staff made the commitment to bring revised estimates before the Board for approval.

Staff has since provided updated emissions inventories for most of the categories of off-road engines or equipment. Updated population and other input data were obtained from a variety of authoritative sources and provided to the public for comment, along with the updated model. Further modifications to input data and the model were made based on input from interested persons before the inventories were presented to the Board for approval. Diesel-fueled engines and equipment were included in three of the recently approved inventories: (1) the small off-road engine (<25 hp) emission inventory, which was approved March 26, 1998 (ARB, March 1998); (2) the pleasure craft exhaust emission inventory, which was approved December 10, 1998 (ARB, November 1998); and (3) the off-road large compression-ignited engine emission (≥25 hp) inventory, which was approved January 27, 2000 (ARB, January 2000). Details on the methodology used to derive the off-road inventory can be found in each of the associated reports.

The off-road inventory and model represent the most up-to-date data available to the ARB and are a significant improvement over the inventory of diesel exhaust PM10 presented in the "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant" Part A, Exposure Assessment (Table IV-1) (ARB, April 1998). For example, the OFFROAD model contains a more comprehensive list of equipment from a wider range of categories. Several other parameters, such as emission factors, growth, deterioration, and seasonal use, were modified, resulting in a higher inventory of emissions.

Emissions. Most off-road equipment categories include both gasoline- and diesel-fueled engines, with exhaust emissions from diesel-fueled engines dominating. Over the next decade, existing regulations will result in a decline in diesel PM from off-road mobile sources statewide at the same time that the population is growing. The total statewide population of off-road equipment, not including locomotives and commercial marine vessels, is expected to grow by 5 percent from 2000 to 2010, from about 547,000 to 575,000 pieces of equipment. Over the same time period, emissions of diesel PM are expected to decline by about 15 percent, from 20,000 tons per year in 2000 to 17,000 tons per year in 2010 (Table 5). The decline in diesel PM emissions will take place as older, dirtier equipment is retired and replaced with newer, cleaner equipment required by existing regulations.

The following section provides additional detail on the emissions from motive off-road diesel-fueled engines and equipment, excluding portable equipment. Motive off-road diesel-fueled engines contribute about 92 percent of the off-road diesel PM. Appendix II provides information on the inventory for equipment defined as "portable" and regulated either by the local air districts or the ARB under the Portable Engine and Equipment Registration program, which generate about eight percent of the off-road diesel PM.

Table 5
Off-Road Inventory – Diesel-Fueled Vehicles & Equipment

Category		PM (tons per year) 2000	PM (tons per year) 2010	NOx (tons per year) 2000	NOx (tons per year) 2010
Agricultural	Total	3,547	2,575	54,579	37,091
	SoCAB	*212*	*153*	*3,276*	*2,224*
Airport Ground Support	Total	113	102	1,479	1,319
	SoCAB	*58*	*51*	*785*	*698*
Commercial	Total	749	646	9,957	7,791
	SoCAB	*292*	*252*	*3,883*	*3,039*
Commercial Marine Vessel	Total	4,522	5,157	30,060	33,493
	SoCAB	*2,531*	*3,130*	*14,460*	*17,247*
Construction & Mining	Total	7,721	5,658	121,048	83,876
	SoCAB	*2,856*	*2,093*	*44,787*	*31,035*
Dredging	Total	18	11	380	259
	SoCAB	*1*	*0.4*	*15*	*10*
Drilling	Total	234	135	4,339	2,929
	SoCAB	*29*	*18*	*562*	*380*
Industrial	Total	573	497	6,699	4,986
	SoCAB	*281*	*245*	*3,284*	*2,444*
Lawn & Garden	Total	113	40	1,278	500
	SoCAB	*47*	*18*	*526*	*205*
Locomotive	Total	1,151	1,129	53,327	28,720
	SoCAB	*215*	*208*	*10,943*	*3,561*
Logging	Total	244	150	4,069	2,378
	SoCAB	*0*	*0*	*0*	*0*
Military Tactical Support	Total	29	22	519	243
	SoCAB	*4*	*4*	*66*	*44*
Misc. Portable	Total	3	3	47	33
	SoCAB	*1*	*1*	*11*	*7*
Pleasure Craft	Total	26	33	968	1,205
	SoCAB	*7*	*11*	*292*	*365*
Transportation Refrigeration	Total	946	851	9,336	7,210
	SoCAB	*351*	*314*	*3,455*	*2,666*
TOTALS	**Total Statewide**	**19,988**	**17,009**	**298,085**	**211,583**
	SoCAB	*6,885*	*6,498*	*86,345*	*64,017*

1. Current emissions: Motive Off-Road

Staff estimates there are currently almost 500,000 pieces of motive off-road diesel-fueled equipment in California, plus commercial marine vessels and locomotives, generating about 18,500 tons per year of diesel PM (Table 6). Four off-road categories, dredging, drilling, military tactical support, and miscellaneous portable, contain only equipment classified as portable. Diesel PM emissions in 2000 from all portable engines, as discussed further in Appendix II, are about 1,400 tons per year.

As discussed in the next section on existing regulations, the Clean Air Act prohibits California and other states from regulating emissions from new engines used in construction and farming equipment of less than 175 horsepower and in new locomotives. These equipment types are termed "preempted." Statewide, diesel PM emissions from motive diesel-fueled equipment in preempted categories, and including commercial marine vessels, are about 10,400 tons per year in 2000, which is 56 percent of the motive off-road inventory (Table 6). Although not preempted from regulating commercial marine vessels, California has worked with the U.S. EPA on nationwide regulations because of the difficulty of enforcement and ease with which many of these vessels can move to different ports to avoid regulation. ARB is also not preempted from regulating off-road engines that are not new, but the inventory does not distinguish between new and not-new engines at this time.

2. 2010 Emissions: Motive Off-Road

Over the next ten years, total diesel PM emissions from motive off-road diesel-fueled sources are predicted to decline by about 14 percent, from 18,500 tons per year in 2000 to 16,000 tons per year in 2010 statewide (Table 6). Existing regulations lead to these emission decreases as old engines are replaced with new, cleaner engines. Emission declines occur in every category except for the commercial marine vessel and pleasure craft categories, for which the model predicts diesel PM emissions to increase by about 14 percent over the decade, from about 4,500 tons per year in 2000 to 5,200 tons per year in 2010. Diesel PM emissions decline at a somewhat higher rate over the ten years from federally preempted equipment (17%) than from the nonpreempted equipment (12%). If the increasing emissions from commercial marine vessels and pleasure craft are excluded, however, the remaining nonpreempted equipment diesel PM emissions are predicted to decline by 40 percent as of 2010.

Table 6
Off-Road: Diesel PM Emissions
By Preempt and Non-Preempt Categories

2000	Particulate Matter Emissions (tons per year)					
	Preempt			Nonpreempt		
Category	**Portable**	**Motive**	**Total**	**Portable**	**Motive**	**Total**
Agricultural	160	2,654	2,814	3	730	733
Airport GSE	-	-	-	33	80	113
Commercial	452	26	478	252	18	270
Comm. Marine	-	-	-	-	4,522	4,522
Construction	132	5,392	5,524	119	2,078	2,197
Dredging	-	-	-	18	-	18
Drilling	42	-	42	192	-	192
Industrial	4	240	244	-	329	329
Lawn & Garden	-	-	-	4	109	113
Locomotive	-	1,151	1,151	-	-	-
Logging	-	178	178	-	66	66
Military	22	-	22	7	-	7
Misc. Portable	2	-	2	1	-	1
Pleasure Craft	-	-	-	-	26	26
Trans. Refer	-	789	789	-	157	157
Totals	**814**	**10,430**	**11,244**	**629**	**8,115**	**8,744**
2010						
	Preempt			Nonpreempt		
Category	**Portable**	**Motive**	**Total**	**Portable**	**Motive**	**Total**
Agricultural	124	2,075	2,199	-	376	376
Airport GSE	-	-	-	29	73	102
Commercial	413	29	442	197	7	204
Comm. Marine	-	-	-	-	5,157	5,157
Construction	106	4,321	4,427	62	1,169	1,231
Dredging	-	-	-	11	-	11
Drilling	33	-	33	102	-	102
Industrial	-	212	212	-	285	285
Lawn & Garden	-	-	-	-	40	40
Locomotive	-	1,129	1,129	-	-	-
Logging	-	117	117	-	33	33
Military	18	-	18	4	-	4
Misc. Portable	2	-	2	1	-	1
Pleasure Craft	-	-	-	-	33	33
Trans. Refer	-	705	705	-	146	146
Totals	**696**	**8,588**	**9,284**	**406**	**7,319**	**7,725**

IV. SUMMARY OF EXISTING REGULATIONS

California law grants the Air Resources Board authority to adopt statewide regulations affecting mobile sources. Local and regional authorities may regulate all other sources of air pollution. In addition, the Health & Safety Code section 40447.5(a) grants the South Coast Air Quality Management District authority to require fleets of 15 or more vehicles to purchase clean vehicles[2] when adding or replacing vehicles, authority which they have recently exercised.

The federal Clean Air Act grants California the ability to adopt and enforce rules for the control of emissions from mobile sources as long as the State standards are at least as protective as the applicable federal standards. In the Clean Air Act Amendments of 1990, however, California and other states are prohibited from adopting and enforcing emission control standards for two categories of new off-road engines or vehicles: (1) engines used in construction and farm equipment of less than 175 horsepower and (2) locomotives or locomotive engines.

The following existing measures that control diesel PM emissions are divided into federal measures, California measures, and local measures adopted by the South Coast Air Quality Management District. In addition to measures adopted as regulations, this section also lists and describes existing alternative strategies, which include incentives and voluntary agreements. The summaries are provided herein for informational purposes only; agency staff and the regulations should be consulted for more specific information and for compliance purposes.

A. Federal Measures

Federal rules that are the same as or less stringent than California rules are not discussed in detail here but are covered in the next section on state measures. For certain categories, such as large marine vessels and locomotives, national rules are required to fully control what is a national or international fleet. These categories are discussed below.

Commercial Marine Diesel [40 CFR Part 94]: The standards apply to new marine compression-ignition engines at or above 50 horsepower in commercial vessels. The engines are used for propulsion and auxiliary power in a variety of applications, including fishing boats, tug and towboats, dredgers, cargo vessels, and ocean-going ships. The standards are similar to the Tier 2 standards for land-based off-road compression-ignition engines and locomotives and vary with engine cylinder displacement and rated power (Table 7). Class 1 engines are generally derived from off-road configurations. Class 2 engines are similar to those used in locomotives. Standards for these engines are phased in from 2004 through 2007. These standards apply only to engines used in commercial vessels, not to engines used in recreational boats or pleasure craft. The U.S. EPA expects the marine CI engine standards to result

2 ". . . methanol or other equivalently clean burning alternative fuel . . ."

in a 24 percent reduction in NOx emissions and a 12 percent reduction in PM emissions nationwide in 2030.

The large international cargo ships that berth in California harbors and travel long distances close and parallel to the coast emit the majority of air pollutants from commercial marine vessels in California, about 60 percent. The federal rule does not cover Class 3 engines used in these ships but defers their control to international treaty through the International Maritime Organization, known as MARPOL Annex VI. The MARPOL Annex VI international emission standards for NOx are based on rated engine speed.

Table 7
Federal Marine Diesel Exhaust Emission Standards

Engine Category	Displacement (liters/cylinder)	Starting Date	NOx+HC g/bhp-hr	PM g/bhp-hr
1	Power □50 hp, displacement <0.9	2005	5.6	0.3
	0.9 □ displacement <1.2	2004	5.4	0.22
	1.2 □ displacement <2.5	2004	5.4	0.15
	2.5 □ displacement <5.0	2007	5.4	0.15
2	5.0 □ displacement <15	2007	5.8	0.2
	15 □ displacement <20, power < 4425 hp	2007	6.5	0.37
	15 □ displacement <20, power □4425 hp	2007	7.3	0.37
	20 □ displacement <25	2007	7.3	0.37
	25 □ displacement <30	2007	8.2	0.37

Locomotives and Locomotive Engines [40 CFR Part 92]: U.S. EPA adopted emission standards for NOx, hydrocarbons (HC), carbon monoxide, particulate matter, and smoke for newly manufactured and remanufactured locomotives and locomotive engines to take effect beginning in 2001 (Table 8). The first set of standards, Tier 0, apply to locomotives and engines originally manufactured from 1973 through 2001, whenever they are remanufactured in 2001 or later. The Tier 1 and 2 standards apply to locomotives and engines originally manufactured on or after January 1, 2002 and January 1, 2005, respectively. Tier 2 locomotives will be required to meet the applicable standards at the time of original manufacture and each subsequent remanufacture. All locomotives are required to comply with both line-haul and switch duty cycle standards, regardless of intended usage. U.S. EPA estimates that in 2040 PM emissions will be reduced by 46 percent compared to 1995 baseline emissions and NOx emissions will be reduced by almost 60 percent nationwide.

Table 8
Federal Locomotive Exhaust and Smoke Emission Standards

Tier and Duty-Cycle	NOx (g/bhp-hr)		PM (g/bhp-hr)		Smoke (Percent Opacity – Normalized)		
	Line-haul duty-cycle	Switch duty-cycle	Line-haul duty-cycle	Switch duty-cycle	Steady-State	30-sec Peak	3-sec Peak
Tier 0 1973-2001	9.5	14	0.6	0.72	30	40	50
Tier 1 2002-2004	7.4	11	0.45	0.54	25	40	50
Tier 2 2005 and later	5.5	8.1	0.2	0.24	20	40	50

Urban Bus Retrofit Rebuild Program [40 CFR Part 85]: The U.S. EPA's retrofit/rebuild program for urban buses was intended to reduce ambient levels of PM in urban areas. Retrofit and rebuild requirements apply to 1993 and earlier model year buses operating in metropolitan areas with 1980 populations of 750,000 or more when their engines are rebuilt or replaced. The requirements took effect nationwide as of January 2, 1995. California required new urban buses to meet a 0.10 g/bhp-hr standard in 1991, prior to the effective date of the federal 0.10 g/bhp-hr standard, thus the federal retrofit requirements only apply to 1990 and earlier model year engines in California.

Heavy-Duty Highway Engine and Vehicle Standards [40 CFR Part 86]: The U.S. EPA has adopted standards for on-highway heavy duty vehicles beginning in 1974. The most recent rulemaking, which is described in section B below, adopted more stringent standards that take effect beginning with the 2004 model year, and is based on a negotiated Statement of Principles between the U.S. EPA, ARB, and heavy-duty engine manufacturers.

Nonroad[3] Diesel Engine Standards [40 CFR Part 89]: Following negotiations with stakeholders, the U.S. EPA, ARB, and members of the off-road diesel engine industry signed a Statement of Principles calling for significantly more stringent standards for emissions of NOx, hydrocarbons, and diesel PM emissions from compression-ignition engines used in most land-based off-road equipment and some marine applications. The final rule, with which California's rule harmonizes, is discussed in more detail in section B below.

B. California Measures

Heavy-Duty Vehicle Inspection and Periodic Smoke Inspection Programs [HSC §§ 44011.6, 43701; 13 CCR §§ 2180 et seq.]: The Heavy-Duty Vehicle Inspection Program reduces excessive smoke emissions and tampering on gasoline- and diesel-fueled vehicles above 6000 pounds GVWR through inspections at California Highway Patrol inspection facilities and scales, at fleet yards, and in random roadside stops. Violators receive citations and are required to perform corrective

[3] California uses the term "off-road."

actions. The ARB resumed the Heavy-Duty Vehicle Inspection Program on June 1, 1998, after a hiatus of four and one-half years, with a revised snap acceleration test procedure.

The Periodic Smoke Inspection program, implemented in 1999, focuses on self-inspections of heavy-duty diesel vehicles by fleet owners (fleet being two or more vehicles). Owners are required to conduct annual inspections of their California-registered vehicles with engines over four years old for smoke opacity and make repairs to comply with the smoke opacity standards. Owners maintain records for two years, which ARB inspectors may review. The projected statewide combined emission benefits for the two inspection programs are reductions in diesel PM of 5.24 tpd statewide in 1999, declining to 3.19 tpd by 2010 as new engines result in fewer smoking engines on the road.

Heavy-Duty On-Road Vehicles [13 CCR §§ 1956.8 et seq., 1965, 2036, 2122]: Heavy-duty vehicle gaseous emissions were first regulated by California in 1969 and by the U.S. EPA in 1974. Over the years, more stringent emission standards have paralleled improvements in control technology. In summer 1995, the ARB, the U.S. EPA, and heavy-duty engine manufacturers signed an agreement for harmonized emission standards nationwide, and to review those standards in 1999. In October 1997, U.S. EPA adopted those national standards for engines, along with changes to the existing federal averaging, banking, and trading program, and to useful life and maintenance requirements for heavy-duty diesel engines. California amended its heavy-duty vehicle regulations to harmonize with the federal amendments in 1998 for implementation with the 2004 model year.

The amendments to existing California emission standards and test procedures were designed to harmonize as closely as possible with the federal program. As with the adopted federal requirements, the amendments include a NOx plus nonmethane hydrocarbon (NMHC) emission standard of 2.4 g/bhp-hr; or 2.5 g/bhp-hr with a 0.5 g/bhp-hr NMHC cap. Particulate matter standards, however, have not changed since the 1994 model year, as shown in Table 9. The federal and California rules also include voluntary standards, to which manufacturers may opt to certify engines. Engines certified to these voluntary standards would be eligible for marketable credit programs. The manufacturer must declare at the time of certification whether it is certifying an engine family to an optional reduced-emission standard that could subsequently be used in a marketable credits program.

Table 9
California Heavy-Duty Vehicle Engine Emission Standards, Beginning with the 1988 Model Year(1)
(grams per brake horsepower-hour)

Model Year	Gross Vehicle Weight (pounds)	Non-methane Hydrocarbons	Total HC	Carbon Monoxide	NOx	HC + NOx	PM
1988-1989	over 14,000	n/a	1.3	15.5	6.0	n/a	0.60
1990	over 14,000	1.2	1.3	15.5	6.0	n/a	0.60
1991-1993	over 14,000	1.2	1.3	15.5	5.0	n/a	0.25
1994-1997	over 14,000	1.2	1.3	15.5	5.0	n/a	0.10
1998-2003	over 14,000	1.2	1.3	15.5	4.0	n/a	0.10
2004-later	over 14,000	n/a	n/a	15.5	n/a	2.4 or 2.5 w/ 0.5 NMHC cap	0.10

(1) Does not include optional standards applicable to heavy-duty vehicles or urban bus engine standards.

Low Emission Vehicles [13 CCR § 1960.1 and others]: The ARB first adopted low emission vehicle (LEV) regulations in 1990 to cover the 1994 through 2003 model year light- and medium-duty vehicles. LEV II regulations, running from 2004 through 2010, were adopted in 1998. The major elements that impact diesel-fueled vehicles include extension of passenger car emission standards to heavier sport utility vehicles and pick-up trucks with GVWR up to 8,500 pounds, which formerly has been regulated under less stringent emission standards; and new cleaner standards for a new medium-duty class, for vehicles with GVWR from 8,501 to 14,000 pounds. Vehicles in this category, which overlaps with the light heavy-duty vehicle category, will be subject to emission standards nearly as stringent as passenger car standards, although manufacturers have the option of certifying to the less stringent heavy-duty engine standards. Diesel-fueled vehicles up to 8,500 pounds GVWR are unlikely to be able to meet these lower chassis standards, thus preventing their sale in California.

Urban Buses and Public Transit Bus Fleets [13 CCR §§ 1956.1-1956.4, 1956.8]: California's public transit bus fleet rule was approved by the Air Resources Board on February 24, 2000. In this rule, diesel PM and NOx emissions from urban buses will be reduced through progressively more stringent standards and a program that encourages transit agencies to purchase or lease low-emission, alternative fuel buses (Table 10). Transit agencies are given the flexibility to choose between two compliance paths, either the diesel path or the alternative fuel path. Both paths include a PM retrofit phase-in requirement beginning in 2003, and includes a 0.01 g/bhp-hr PM standard, beginning in October 2002. Continued use of diesel fuel mandates that the operator uses ultra-low-sulfur fuel beginning July 1, 2002. In addition, transit agencies are required to purchase zero emission buses on a mandated schedule. The low emission bus engine standards, together with the zero emission bus purchase requirements, will reduce diesel PM emissions by 67 pounds per day and NOx by seven tons per day statewide by 2020.

Table 10
California Urban Transit Bus Fleet Rule Requirements and Emission Standards

Model Year	"Diesel" Path		"Alternative-Fuel" Path	
	NOx (g/bhp-hr)	PM (g/bhp-hr)	NOx (g/bhp-hr)	PM (g/bhp-hr)
2000	4[1]	0.05	2.5 optional[2]	0.05
Oct. 2002	2.5 (NOx+NMHC)	0.01	1.8 (NOx+NMHC) optional[2]	0.03
Oct. 2002	4.8 NOx fleet average		4.8 NOx fleet average	
2003-2009	Accelerated PM retrofit requirements[3] ☐ 15 ppm sulfur diesel fuel		PM retrofit requirements ☐ 15 ppm sulfur diesel fuel	
Jul. 2003	3 bus demos of ZEBs[4] (large fleets)			
2004[5]	0.50	0.01		
2007	0.20	0.01	0.2	0.01
2008	ZEBs:15% of new purchases (large fleets)			
2010	n/a		ZEBs:15% of new purchases (large fleets)	

(1) Shaded areas show existing requirements and optional emission standards
(2) Although transit agencies on the alternative-fuel path are not required to purchase engines certified to these optional standards, the staff expects that they will do so in order to qualify for incentive funding. At present, the only alternative-fuel engines available are certified to optional, lower-emission NOx standards.
(3) Transit agencies on the diesel path must meet the PM retrofit requirements at an accelerated rate and must complete all retrofits by 2007.
(4) Zero Emission Bus. A large fleet includes over 200 vehicles.
(5) In lieu of purchasing buses meeting the 2004 – 2006 emission standards, transit agencies on the diesel path may implement an alternative strategy that achieves greater NOx emission reductions. The alternative strategy must be approved by the ARB's Executive Officer.

Off-Road Compression-Ignition Engines [13 CCR §§ 2420 et seq.]: Exhaust emission standards for off-road heavy-duty compression-ignition engines become increasingly more stringent, based on the power produced by the engine and model year (Table 11). The off-road compression-ignition rule was the result of a negotiated process that resulted in the Off-Road Statement of Principles (SOP). California is preempted by federal statute from adopting emission standards for new off-road construction and agricultural equipment with engines less than 175 horsepower, thus a national rule was necessary to achieve emission reductions from that subset of engines. California's rule harmonizes with the federal program. Statewide diesel PM emission benefits, in conjunction with the federal rule, are 8.5 tons per day in 2010, of which 0.9 tons per day is from non-preempted equipment and 7.6 tons per day is from preempted equipment. In 2001, ARB and U.S. EPA plan to review the feasibility of the Tier 3 standards, and of the Tier 2 standards for engines rated under 37 kW (50 hp), after which Tier 3 PM standards would be proposed.

Table 11
Emission Standards for Off-Road Compression-Ignition Engines
(grams per brake horsepower-hour)

Maximum Rated Power	Tier	Model Year	NOx	NMHC+NOx	PM	Smoke (%)
hp<11	1	2000-2004		7.8	0.75	20/15/50*
	2	2005 +		5.6	0.60	
11□hp<25	1	2000-2004		7.1	0.60	
	2	2005 +		5.6	0.60	
25□hp<50	1	2000-2003		7.1	0.60	
	2	2004 +		5.6	0.45	
50□hp<100	1	2000-2003	6.9			
	2	2004-2007		5.6	0.30	
	3	2008 +		3.5	tbd**	
100□hp<175	1	2000-2002	6.9			
	2	2003-2006		4.9	0.22	
	3	2007 +		3	tbd	
175□hp<300	1	1996-2002	6.9		0.40	
	2	2003-2005		4.9	0.15	
	3	2006 +		3	tbd	
300□hp<600	1	1996-2000	6.9		0.40	
	2	2001-2005		4.8	0.15	
	3	2006 +		3	tbd	
600□hp<750	1	1996-2001	6.9		0.40	
	2	2002-2005		4.8	0.15	
	3	2006 +		3	tbd	
hp>750	1	2000-2005	6.9		0.40	
	2	2006 +		4.8	0.15	

*Percentages apply to smoke opacity at acceleration/lug/peak modes; smoke opacity limits apply to all engines except: (1) single cylinder engines, (2) propulsion marine engines, and (3) constant speed engines.
**Tier 3 PM standards will be determined after the technology feasibility review in 2001.

The federal and California rules also include voluntary standards, to which manufacturers may opt to certify engines, earning the designation of "Blue Sky Series" low-emitting engines. Tier 3 emission levels, where applicable, were chosen as the best level for defining Blue Sky Series engines. This represents a reduction of approximately 40 percent beyond the Tier 2 NMHC + NOx levels. For PM emissions and for engines with no Tier 3 standards, a calculated level corresponding to a 40 percent reduction beyond Tier 2 levels will be used to qualify as a Blue Sky Series engine. Engines certified to these voluntary standards would be eligible for marketable credit programs. The manufacturer must declare at the time of certification whether it is certifying an engine family to an optional reduced-emission standard that could subsequently be used in a marketable credits program.

Small Off-Road Engines (<25 hp) and Equipment [13 CCR §§ 2400 et seq.]: Beginning with the 1995 model year, California has applied progressively more stringent particulate matter emission standards to small off-road engines, including those that are diesel-fueled (Table 12). According to the small off-road engine inventory, 36% of the particulate matter emissions and 62% of the NOx emissions from small off-road engines come from diesel-fueled engines. With the signing and implementation of the compression-ignition off-road Statement of Principles, standards for small off-road engines have been folded into the heavy-duty CI standards such that future rulemaking will be coordinated along the entire range of off-road diesel-fueled engines.

Table 12
Comparison of Particulate Standards for Small Off-Road Engines
(grams per brake horsepower-hour)

Model Year	Applicability	PM	Applicability
1995-1999	all	0.90	Calendar year
2000-2004	<11 hp	0.75	Model year
2000-2004	11□hp<25	0.60	Model year
2005 +	all	0.60	Model year

C. Local Measures (South Coast Air Quality Management District)

Clean On-Road Vehicles for Captive Fleets [Rule 1190 series]: Under California Health & Safety Code section 40447.5 the South Coast Air Quality Management District is given the authority to require public and private fleet operators with 15 or more vehicles to purchase clean-fueled vehicles at the time the operators are purchasing or replacing vehicles in their fleets. The SCAQMD is, therefore, implementing several rules to reduce diesel PM in the South Coast Air Basin:[4]

Rule 1191 - Light and Medium-Duty Public Fleet Vehicles, adopted June 16, 2000, applies to all government agencies located in the District, including federal, state, regional, county and city government departments and agencies, and any special districts such as water, air, sanitation, transit, and school districts, with 15 or more vehicles. Exempted are exempting emergency vehicles operated by local, state, or local law enforcement agencies; fire departments; paramedic and rescue vehicles; or heavy-duty on-road vehicles. Beginning January 1, 2001, public fleet operators of 15 or more vehicles may only procure vehicles that are certified by the ARB as equivalent low-emitting gasoline or alternative-fuel vehicles, when adding or replacing vehicles to their vehicle fleet.

Rule 1192 - Clean On-Road Transit Buses, adopted June 16, 2000, applies to those public transit fleets with 15 or more public transit vehicles or urban buses, operated by government agencies or by private entities under contract to government agencies, that provide passenger transportation services, including intra- and inter-city

4 Potential emission benefits from these rules have not been calculated and are not reflected in the inventory.

shuttle services. The rule does not apply to school transportation services, long-distance services, paratransit vehicles, and transit vehicles used for non-public transportation. Beginning upon adoption of the rule, public transit operators with 100 or more vehicles are required to purchase alternative fuel transit vehicles when adding or replacing buses in the vehicle fleet. Public transit operators with 15 to 99 transit vehicles are required to comply beginning July 1, 2001.

Rule 1193 - Clean On-Road Residential and Commercial Refuse Collection Vehicles, adopted June 16, 2000, applies to refuse collection fleets with 15 or more curbside refuse collection vehicles, operated by government agencies or private entities. Fleet operators with 50 or more solid waste collection vehicles are required to purchase or lease only alternative-fuel heavy-duty vehicles when adding to or replacing curbside refuse collection or transfer vehicles to their fleet, beginning July 1, 2001. Refuse collection operators with 15-49 solid waste collection vehicles must comply beginning July 1, 2002. Exempted are test and evaluation vehicles and vehicles not used for the purpose of collecting or transferring waste.

Rule 1194 - Commercial Airport Ground Access, adopted August 18, 2000, applies to public and private airport fleet operators that operate 15 or more vehicles used to pick up passengers from commercial airport terminals. Beginning July 1, 2001, operators must purchase or lease ultra-low emission (ULEV) or cleaner light- or medium-duty vehicles or alternative fueled heavy-duty vehicles when adding or replacing vehicles in their fleets. For shuttle van services that provide multiple-party passenger transportation and generally do not operate on fixed, scheduled routes such as Supershuttle, PR 1194 would require that at least 50 percent of new purchases or leases be ULEV or cleaner beginning July 1, 2001 and 100 percent beginning July 1, 2002. PR 1194 exempts transit buses, commonly termed motorcoaches, that travel in and out of the District, and other heavy-duty vehicles that are covered by other fleet rules. In addition, if a demonstration is made that an alternative fuel engine/chassis configuration is not commercially available or could be used, then a conventionally fueled vehicle may be purchased. The portion of the rule applying to taxi cab fleets has been delayed for consideration at the October 20, 2000 hearing.

Proposed Rule 1195 - Clean On-Road School Buses *Rule on hold.*

Proposed Rule 1196 - Clean On-Road Heavy-Duty Public Fleet Vehicles, not yet set for hearing, would apply to for public fleet operators with 15 or more heavy-duty vehicles, with certain exemptions. Beginning July 1, 2002, all new additions to an existing fleet, or formation of a new fleet, of heavy-duty vehicles would be by purchase or lease of alternative-fuel heavy-duty engine or vehicles or dual-fuel heavy-duty vehicles. Prior to July 1, 2004, if the fleet operator has an approved Technical Infeasibility Certification for a purchase or lease, the operator could instead purchase a diesel-powered heavy-duty engine or vehicle with an approved control device and so long as the approved control device is maintained per manufacturer's specifications.

Rule 1186.1 – Street Sweeping Operations, adopted August 18, 2000, will require public and private fleet operators that provide sweeping services to governmental jurisdictions and agencies with greater than 15 vehicles to purchase alternative-fuel sweepers or otherwise less-polluting sweepers when adding or replacing vehicles in their fleet after July 1, 2002. A fleet operator can delay the procurement of an individual alternative-fuel sweeper purchase before July 1, 2005, if the District approves a Technical Infeasibility Certification, which would be based on a demonstration that an alternative-fueling station is not within five miles of the applicable maintenance yard or that, on solely technical reasons, there are no commercially available alternative-fuel sweepers for the specific sweeping operations conducted by the fleet operator. If the District approves a Technical Infeasibility Certification for an individual sweeper purchase, the fleet operator must purchase a Rule 1186-certifed sweeper powered by ultra-low-sulfur diesel with all exhaust vented through a CARB-approved control device(s).

Proposed Amended Rule 431.2 –Sulfur Content of Liquid Fuels would prohibit the sale of any diesel fuel with a sulfur content in excess of 15 ppm by weight on or after July 1, 2003, in the South Coast Air District. South Coast Air Quality Management District staff is proposing that the Executive Officer report to the Governing Board as to progress toward rule implementation by July 2002. This rule will require approval from ARB before it can be implemented by the South Coast AQMD. *Set for adoption September 15, 2000.*

D. Non-Regulatory Strategies for Mobile Sources

Non-regulatory strategies include ARB programs that fall within its authority but are not implemented through regulation. These programs are usually accomplished through legislative action or voluntary agreement. Non-regulatory strategies include guidelines, memoranda of agreement (or understanding), and incentive programs that result in emission reductions beyond what is required by law, or at a faster pace than is required.

Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program) [HSC §§ 44275 et seq.]: The Carl Moyer Program, established in the 1998/1999 fiscal year, pays for the incremental cost of repower, retrofit, and purchase of cleaner engines that meet a specified cost-effectiveness level for NOx reduction. The Program has received funding for three years and has significantly reduced NOx and PM emissions from heavy-duty vehicles and equipment traditionally powered by diesel engines. The Carl Moyer Program Advisory Board (Advisory Board) has reviewed the program and recommended to the Legislature and the Governor that funding be continued for a multi-year program.

As originally established, the Carl Moyer Program was primarily intended as a NOx reduction program. The Advisory Board acknowledged that cancer-causing particulate matter emissions are a serious health concern throughout the state, and through its report to the Legislature and the Governor, recommended that the ARB staff address this public health issue within the Carl Moyer Program Guidelines.

With the first year's funding, the Carl Moyer Program reduced NOx emissions by approximately four tons per day. Additionally, it reduced particulate matter emissions statewide by approximately 100 pounds per day. These reductions were achieved even without specific program criteria to reduce particulate matter. These benefits have come from diesel engine to diesel engine repowers where older, less efficient diesel engines are replaced with new, more efficient, lower emitting diesel engines. Particulate matter benefits have also been achieved through alternative-fuel conversion projects. These projects generally provide the greatest emission reductions per engine and have the potential for longer-term emission reductions. The types of projects being funded include: purchase of new natural gas transit and school buses; purchase of new natural gas and dual-fuel trucks; purchase of electric forklifts instead of internal combustion forklifts; and replacement of old diesel engines with newer diesel engines in marine vessels, agricultural pumps, and other off-road equipment.

Locomotive Memorandum Of Understanding (MOU): Federal law preempts California from setting standards for new locomotives and new locomotive engines. In April 1998, as discussed previously, U.S. EPA adopted national emission standards applicable to remanufactured and new locomotives. Measure M14 of the California State Implementation Plan (SIP) for ozone called for a 67 percent reduction in NOx emissions within the South Coast Air Basin by 2010. In order to gain additional reductions over the federal rule and meet this obligation, California and the railroads negotiated a Memorandum of Understanding, which was signed in July 1998.

The MOU for locomotive emissions is a voluntary agreement between ARB, the Burlington Northern and Santa Fe Railway Company, and the Union Pacific Railroad, which operate Class I freight railroads within the boundaries of the South Coast Air Basin non-attainment area. The agreement accelerates the introduction and use of cleaner, lower-emitting locomotives within the South Coast Air Basin.

Lower-Emission School Bus Program: The California State budget for 2000/2001 includes $50 million for replacement and retrofit of older diesel school buses. The primary goal of the program is to reduce the exposure of school children to both cancer-causing and smog-forming pollution. The focus is on reduction of PM through replacement and retrofit of 1986 and older buses. Guidelines for expenditure of the funds will be adopted by the ARB in late 2000, and funds will be distributed to school districts in early 2001. The funds will be made available, based on population, to all school districts in the State. The ARB is working on this program in cooperation with the California Energy Commission, the State Board of Education, and the local air districts.

There are over 21,000 school buses in California; about 5,000 of those were built before 1987 and 1,900 prior to 1977. Engines in these buses do not meet current heavy-duty engine standards. Older buses thus emit as much as ten times more diesel

PM and three times more NOx than current low-emission natural gas buses. Only new buses with engines certified to low PM and NOx levels will be eligible for funding. Emission control retrofit devices approved for use will be required to have been verified that they achieve an 85 percent reduction efficiency. These requirements are similar to the recently adopted urban transit bus rule. Because school districts have limited funds for school bus purchase and maintenance, staff expects that the program will be designed to cover all of the cost of retrofit and the majority of the cost of new buses.

V. RECOMMENDED MEASURES FOR REGULATORY ACTION

Diesel-fueled engines overwhelmingly dominate the large truck, bus, and off-road equipment markets, and have been growing in market share of the medium-duty and light heavy-duty vehicle market over the last decade. Manufacturers also plan to increase sales of diesel-fueled light-duty trucks and passenger cars nationwide over the next several years, although California's LEV II standards will slow diesel growth in these sectors in this state because of the stringency of the standards. Finally, some of the hybrid-electric vehicles in the research and development phase use diesel-fueled engines for power. Based on these market trends, lower new engine standards, along with low sulfur diesel fuel, are necessary to reduce exposure to diesel particulate emissions in California.

In addition to further tightening emission standards for new engines, emissions from existing compression-ignition engines must be lowered. Compression-ignition engines typically have useful lifetimes of 400,000 miles and longer. An engine is rebuilt, rather than replaced, when it reaches the end of its useful lifetime. Current regulations, except those applying to urban transit buses, allow the engine to be rebuilt to standards in effect at the time of original manufacture. Until recently, programs designed to ensure compliance with emissions in-use, such as on-board diagnostics, in-use compliance, and inspection and maintenance, have been primarily focused on gasoline-powered light- and medium-duty trucks and passenger vehicles. To reduce exposures to diesel PM, then, California needs to reduce emissions from existing vehicles and equipment, not just from new engines.

The Diesel Risk Reduction Plan is not in itself a regulatory action, but a blueprint for future action. The measures proposed here comprise a comprehensive program to be implemented over the next decade in California to control emissions and reduce risk from exposure to diesel PM over the complete lifetime of diesel-fueled engines. At the same time, many of the proposed measures will also control and reduce emissions of NOx and other criteria and toxic air pollutants from compression-ignition engines. During the actual rulemaking process for each recommended measure the cost-effectiveness and technological feasibility of each recommended measure will be fully assessed. Each recommended measure will be developed, through a public process, with full opportunity for stakeholders to participate before a rule is finalized.

Table 13 provides a summary of the measures, expected emission reductions, and expected cost per unit for implementation. Most non-regulatory strategies are not included in Table 13 but are discussed in the text.

Table 13
Recommended Measures to Reduce Diesel PM from Mobile Sources

Measures	Proposed Board Adoption Date	Proposed Implementation Date	Est. PM Reduction, tons per year		Est. NOx Reduction, tons per year		Est. Cost per Engine $
On-Road Measures			**2010**	**2020**	**2010**	**2020**	
Supplemental test procedures for HDV certification	2000	2005	tbd	tbd	tbd	tbd	tbd
Lower emission standards for new HDV engines	2001	2007	1,565* (646)	3,519 (1,592)	23,105 (9,578)	72,664 (32,880)	674-1,117
Control of emissions from existing engines (retrofit)	2002	2002-2008	1,865 (770)	280 (128)	–**	–	1,900-9,500
Solid waste collection vehicles		2002					
Other public HDV fleets		2002					
Other public & private HDV fleets		2003-2008					
Control of HDV in-use emissions	2003	2005	tbd		tbd		130-150
Off-Road Measures							
Lower emission standards for new engines	2002	2006-2008	913 (292)	3,579 (1,132)	–#	–	1,327-1,770
Control of emissions from existing engines (retrofit)	2002	2002-2008	5,968 (1,786)	1,505 (435)	–**	–	5,700-23,750
Public fleets		2002-2003					
Other off-road fleets		2006-2008					
Control of in-use emissions	2003	2006-2008	tbd		tbd		tbd
PM standards for new diesel pleasure craft engines	2002	2005	9 (3)	24 (8)	**	**	tbd
Non-Regulatory Strategies							
Federal locomotive retrofit program		2005	862 (161)	763 (150)	**	**	tbd
Federal commercial marine vessel retrofit program		2005	3,945 (2,396)	4,504 (2,955)	**	**	tbd

* Statewide emission reductions (South Coast Air Basin emission reductions)
**Retrofit measures specifically target PM reductions and not NOx
#Future NOx controls were adopted in January 2000, thus staff assumed no NOx reductions would be included with this measure.
tbd: to be determined; data not available

A. On-Road Vehicles

The Air Resources Board has over 30 years of experience in regulating emissions from on-road mobile sources. The proposed measures described in this section reflect both past experience with regulating on-road mobile sources of air pollution and informed future expectations for technological solutions. New engines standards would be tightened to reduce emissions in the future. In the present time-frame, diesel PM emissions from existing vehicles would be reduced by the addition of aftertreatment technology to reduce diesel PM directly and through in-use compliance programs that will maintain the improvements achieved through cleaner new engine standards and retrofits.

Supplemental Test Procedures for Heavy-Duty Vehicle Certification

Description of the Proposed Measure

As a part of a required technology assessment of the 1997 heavy-duty vehicle standards, the U.S. EPA announced in an October 1999 notice of proposed rulemaking, supplemental strategies to ensure lower emissions from heavy-duty vehicles beginning with the 2004 model year. The supplemental strategies include additional emission test procedures designed to ensure that engine exhaust emissions are controlled over the range of operating conditions. The strategies were modeled on the "pull-ahead" provisions of the heavy-duty diesel emissions consent decree between U.S. EPA and heavy-duty engine manufacturers[5] that had incorporated illegal emission control defeat algorithms into their engine control systems. The final rule, however, was not promulgated by U.S. EPA in time for a 2004 implementation and it is not clear that the relevant provisions of the consent decree will remain effective through the 2006 model year.

The "pull-ahead" provisions of the consent decree require manufacturers to produce engines that comply with the 2004 model year Federal Test Procedure Standards and the supplemental strategies beginning in October 2002 for 24 months of full compliance. Recently, the settling manufacturers have indicated that under certain circumstances the emission limits for the supplemental strategies cannot be met. The pull-ahead provisions allow extension of these requirements until 24 months of full compliance is attained. The U.S EPA is therefore seeking to extend the pull-ahead provisions until the 2006 model year, after which more stringent new engine standards are proposed to take effect.

Staff believes that these supplemental strategies for model year 2005 and later heavy-duty diesel engines are feasible and should be implemented in California, if necessary because of changes to the consent decree. Together with the transient Federal Test Procedure, the goal of the proposed supplemental test requirements is to more closely model real world operations and conditions. The relevant test procedures include a supplemental steady-state test consistent with the European Union's "EURO III ESC Test" with accompanying standards and Not-To-Exceed emission limits. The new standards would apply to certification, production line testing, and vehicles in actual use. This combination of tests is designed to ensure that engine emissions achieve the expected level of in-use emissions control over all expected operation regimes.

Feasibility

Seven of the largest heavy-duty diesel engine manufacturers will be implementing measures to reduce emissions beginning October 1, 2002, to meet the requirements of the heavy-duty diesel emissions consent decree.[6] The agreement

5 A parallel settlement agreement was negotiated by ARB and the engine manufacturers.

6 The Heavy-Duty Diesel Emissions Settlement settled lawsuits brought by U.S. EPA and ARB alleging excess in-use emissions from defeat devices and algorithms.

requires those manufacturers to meet a 1.25 Not-To-Exceed limit, a 1.0 Euro III ESC limit, and to test engines over, and ultimately comply with, a load response test and limit. Given that the manufacturers have agreed to meet these standards in 2002, staff believes that this proposal is feasible for the industry as a whole by the 2005 model year. Should U.S. EPA identify an enforceable mechanism to assure compliance with these additional standards and procedures beyond 2005, adoption by California of this measure would not be required.

Probable emission control strategies include exhaust gas recirculation (EGR) and fuel injection rate-shaping. EGR is the recirculation of exhaust gas from a point in the engine's exhaust system to a point in the intake system. EGR reduces NOx emissions by up to 90 percent at light load and up to 60 percent at full load. EGR tends, however, to increase diesel PM emissions, a problem that can be controlled through proper system design. Fuel injection rate-shaping refers to precisely controlling the rate of fuel injected into the cylinder on a crank-angle by crank-angle resolution. It has been shown to simultaneously reduce NOx by 20 percent and PM by 50 percent under some conditions. Several manufacturers and fuel system suppliers have demonstrated fuel injection systems that can achieve effective rate shaping, and fuel injection rate-shaping is used to a limited extent today (U.S. EPA, October 1999).

Estimated Emission Reduction

The proposal is expected to reduce diesel PM emissions through the reduction of secondary PM formed when NOx reacts with ammonia in the atmosphere to yield ammonium nitrate particulate and directly through the NTE limits. According to the U.S. EPA's draft Regulatory Impact Analysis (U.S. EPA, August 1999) for every 25 tons of NOx reduced, one ton of secondary PM is reduced. The emission benefit for California is unknown at this time.

Estimated Costs to Businesses, State and Local Agencies

Six of the largest diesel engine manufacturers, representing about 90% of the market, however, have already agreed to comply with similar emission standards as of October 1, 2002, under the consent decree, and thus would incur no additional costs from a California rule. For non-consent decree manufacturers, additional information and data are required to calculate the cost of compliance, including the cost of additional hardware and of research and development. State and local agencies would be expected to incur the additional costs, as passed on by manufacturers, to purchase vehicles. The ARB would have increased costs for monitoring compliance.

Lower Emission Standards for New Heavy-Duty Engines

Description of the Proposed Measure

Staff has determined that a PM emission standard of 0.01 g/bhp-hr for new heavy-duty engines to take effect for the 2007 model year is feasible. In addition, other emission standards could be reduced: NOx to 0.20 g/bhp-hr, and NMHC to 0.14 g/bhp-hr. The proposed PM standard represents a 90 percent reduction from the current PM standard of 0.10 g/bhp-hr, which has been in effect since the 1994 model year. Achieving the proposed PM standard will require the use of a highly efficient diesel particulate filter in conjunction with ultra-low-sulfur diesel fuel.

Feasibility

On May 17, 2000, the U.S. EPA released a Notice of Proposed Rulemaking that would adopt these proposed emission standards nationwide, judging them feasible beginning in 2007. The proposed standards have already been adopted by California for public transit buses. High-efficiency PM aftertreatment technology has been available for several years and has been applied with success in Europe and Asia. The proposed standard, along with more stringent standards proposed and being implemented in European and Asian countries, will spur additional research and development. In addition, research and development trends indicate that systems to significantly reduce both PM and NOx emissions will be commercially available and cost-effective within the proposed timeframe. Finally, ultra-low-sulfur fuel (15 ppm cap), which will be required to protect the aftertreatment devices, should be available nationwide before 2007.

Estimated Emission Reductions

The estimated emission reductions from the proposed standards depend on projected population growth of heavy-duty vehicles and vehicle-miles-traveled, PM emission factors, and engine deterioration rates. To model emission reductions, staff assumed that all new 2007 and subsequent model year engines conform to the 0.01 g/bhp-hr PM standard. The NOx standard (0.2 g/bhp-hr) is assumed to phase in as follows: 25 percent of new 2007 model year engines, 50 percent of new 2008 model year engines; 75 percent of new 2009 model year engines; and 100 percent of new 2010 and subsequent model year engines. This follows the U.S. EPA-proposed phase in schedule. A more rapid phase in period for NOx would reap greater emission reduction benefits.

In California, approximately 25 percent of the heavy heavy-duty diesel vehicle-miles-traveled are driven by vehicles registered out-of-state that are subject only to the federal emission standards. As a result, both a California and a Federal action to adopt lower emission standards based on aftertreatment are necessary to maximize emission reductions in California. Based on the modeled assumptions and on both a California and a Federal rule, staff estimates diesel PM will be reduced 1,565 tons per year in 2010 statewide, increasing to 3,519 tons per year in 2020 statewide when a greater proportion of the fleet will have turned over. Expected reductions in NOx emissions are 23,105 tons per year statewide in 2010, increasing to 72,664 tons per year statewide in 2020.

Estimated Costs to Businesses, State and Local Agencies

The costs of meeting the proposed 2007 model year emission standards estimated by U.S. EPA are summarized in Table 14 (U.S. EPA, May 2000). The cost of a catalyzed diesel particulate filter, the most effective current option for PM control, is compared to new engine cost for each heavy-duty vehicle category. The cost of the diesel particulate filter includes both fixed costs, i.e., retooling, research and development, and certification; and variable costs, i.e., hardware, assembly, and markup. The average engine horsepowers in Table 14 were derived from the U.S. EPA certification database for the years 1999 and 2000. Diesel particulate filter operation requires the use of ultra-low-sulfur fuel. The incremental cost of this fuel is expected to be less than $0.05 per gallon and is discussed further in Appendix IV. Each of these estimated incremental cost increases is expected to be less for 2012 and subsequent model year engines.

Table 14
On-Road Engines: Future (2007) Costs of Catalyzed Diesel Particulate Filter per Vehicle, Based on High Volume Production

Vehicle Class	Light Heavy-Duty	Medium Heavy-Duty	Heavy Heavy-Duty
Average Horsepower	**190**	**250**	**475**
Catalyzed DPF Cost	$674	$894	$1,117
New Engine Cost (comparison)	$8,527	$13,555	$23,722

Staff expect that manufacturers will pass along these costs to purchasers, which will increase costs to business owners and state and local agencies that purchase these vehicles. ARB will incur additional costs of monitoring compliance.

Control of Emissions From Existing On-Road Engines - Retrofit

Description of the Proposed Measure

While new engine standards can provide significant, long-term reductions in emissions as the fleet turns over, near-term emission reductions can only occur through programs that target the in-use fleet. These near-term emission reductions do not rely on vehicle turnover, a slow process within the heavy-duty truck fleet, but will improve the air quality in the near-term. The air quality and health benefits will last until each retrofitted truck is removed permanently from service, to be replaced with a new, lower emitting truck. A retrofit program that requires owners, especially of heavy-duty trucks, to retrofit their existing vehicles to reduce diesel PM could achieve significant diesel PM reductions and result in significant health benefits as the air quality improves in the near-term. At the same time vehicles are retrofitted for diesel PM reduction, they could also be retrofitted for NOx emission reduction, also providing near-term health benefits.

Staff believes that requiring existing heavy-duty vehicle owners to install aftertreatment devices would effectively reduce diesel PM, while simultaneously reducing NOx emissions, in the in-use fleet. The retrofit requirement could allow for different implementation dates, from 2002 through 2008, for different types of fleets. Retrofit requirements would be phased-in by vehicle application type and ownership of fleet vehicles. A PM retrofit requirement beginning January 1, 2003, has already been adopted for transit buses. The California 2000/2001 budget includes $50 million for a program aimed at replacing or retrofitting old school buses.

Fleets that ARB will address in the future include solid waste collection trucks, operated by cities, counties, special districts, and private contractors; other on-road heavy-duty publicly-owned fleets; and privately-owned heavy-duty fleets, including rental motorhome fleets. Heavy-duty trucks not in fleets will also be retrofitted. The inventory of diesel-fueled passenger cars, light-duty trucks, medium-duty vehicles, and motor homes will be examined in more detail to determine if retrofits for these vehicles would be a cost-effective diesel PM reduction strategy.

Certain types of heavy-duty diesel-fueled vehicles could be exempted from the proposed PM retrofit requirements, such as heavy-duty trucks scheduled for retirement within two years of implementation and all alternative-fueled heavy-duty vehicles. Vehicles exempted by statute include publicly-owned emergency vehicles, including those operated by peace officers and fire fighters; vehicles owned by mosquito abatement, vector control, and pest abatement districts or agencies; and ambulances operated by private entities under contract to public agencies.

<u>Feasibility</u>

Several types of retrofit emission control technologies are available with varying levels of demonstrated effectiveness at reducing PM and NOx emissions. The list of available retrofit technologies includes diesel oxidation catalysts, diesel particulate filter systems, selective catalytic reduction, air enhancement technologies, such as electronic superchargers, and thermal management technologies, such as heat recuperators combined with oxidation catalysts. In some applications, two or more of these technologies can be combined to provide even greater emission control (MECA, March 2000). Technologies are discussed in more detail in Appendix IX.

The type of technology currently closest to commercialization with the maximum ability to reduce particulates to near zero is the diesel particulate filter. Diesel particulate filters have been demonstrated to reduce diesel PM by over 85%, depending on the operating cycle. Retrofit demonstration programs with diesel particulate filters began in the 1980s. In Europe, original equipment diesel vehicles with particulate filters are being offered commercially by Daimler-Benz and MAN on buses and Liebherr and Deutz on construction engines. Over 3,000 systems are in use in England, Scandinavia, and Germany. Oberland-Mangold had over 1000 systems in use on forklifts, construction site engines, stationary engines, passenger cars, and trucks. The company Linde + Still installs about 1,500 diesel particulate filters annually in forklifts.

Finally, since 1990 the city of Zurich has operated 150 city buses and the city of Munich has operated 400 city buses with diesel particulate filter systems (Mayer 1998).

Pilot retrofit programs are currently in process in South Korea and Taiwan. In Taiwan, hundreds of buses have been equipped with different emission control technologies including catalysts and filters. In Korea, over 200 filter systems were evaluated on trucks and buses. In addition, Japan has recently stated its plan to require all diesel-fueled vehicles entering Tokyo to be equipped with diesel particulate filters (DieselNet 2000; Anonymous 2000). In the United States, the New York Metropolitan Transportation Authority has recently announced that it will install diesel particulate filters on every diesel bus in its fleet, over 3000 buses, by 2003, and will begin using ultra-low-sulfur fuel.

Estimated Emission Reduction

To estimate the emission impact for each phase, staff requires information on publicly- and privately-owned fleets and individually-owned vehicles, including the heavy-duty diesel vehicle population by category, model year distribution, and vehicle-miles-traveled distribution for each retrofit phase. Easily obtainable registration data from the Department of Motor Vehicles does not identify heavy-duty vehicles by public or private ownership, and thus additional data collection will be required. For the purpose of this report, however, estimated emission reductions have been calculated for the population of existing heavy-duty engines for the years 2010 and 2020. Retrofitting with diesel particulate filters would not reduce NOx emissions, but a retrofit rule will require that NOx emissions not be allowed to increase.

Staff assumed that 90 percent of medium heavy-duty trucks are retrofitted by 2010, using emission control devices that remove 85 percent of diesel PM. For heavy heavy-duty trucks, staff assumed that a lesser percentage, 75 percent, of the engines would be retrofitted, adjusting for the vehicle-miles-traveled of out-of-state trucks. Staff, therefore, estimate emission reductions of 1,865 tons per year statewide in 2010, declining to 280 tons per year statewide in 2020, as retrofitted vehicles are removed from the fleet and replaced with new engines. Higher emission benefits, of course, would be realized if out-of-state trucks that operate in California are retrofitted.

Approximate Cost To Businesses, State and Local Agencies

Businesses, State and local agencies will incur costs of retrofitting existing vehicles. While additional information must be collected prior to a formal rulemaking, the costs reported herein represent staff's best current estimate based on surveys of emission control equipment manufacturers, and assume low volume production and purchasing in the near term (Table 15). While vehicle owners may choose to use differing technologies to meet the retrofit requirement, this analysis will only cover the minimum technology requirement to reduce the maximum amount of PM emissions, i.e., the diesel particulate filter. The costs reported in Table 15 are based on $10 to $20 per horsepower for a catalyzed diesel particulate filter, as reported by the Manufacturers of

Emission Controls Association (MECA, March 2000). Staff expects the actual cost as of the implementation date of this proposal to be somewhere in between these high and low estimates. The cost of ultra-low-sulfur fuel is discussed in detail in Appendix IV.

Table 15
On-Road Engines: Diesel Particulate Filter Costs for Retrofitting Current Vehicles

Vehicle Class	**Light Heavy-Duty**	**Medium Heavy-Duty**	**Heavy Heavy-Duty**
Average Horsepower	**190**	**250**	**475**
Capital Cost, DPF	$1,900-3,800	$2,500-5,000	$4,750-9,500

Because this proposal is expected to impact small business owners such as individual truck operators, staff recognizes that there is a benefit in establishing funding to assist those parties in order to implement the retrofit program smoothly. Public agencies will also incur costs, which would need to be borne by the state and local agencies. In addition, the ARB will have additional costs associated with certification of aftertreatment devices, compliance, and public outreach and education.

Control of In-Use Emissions for Heavy-Duty Vehicles

As new engine emission standards decline, manufacturers will need to adopt increasingly complex strategies to comply with the regulations. Electronic engine control, with associated sensors, engine design changes, and exhaust aftertreatment are all used to reduce emissions. With this increase in engine design complexity will come a corresponding increase in opportunities for malfunctions and premature failure of the emission control system. Staff therefore recommends adoption of a comprehensive program to control emissions from existing engines in-use. The following describes three strategies, in-use compliance testing, on-board diagnostics system, and an inspection and maintenance program that staff believes can be adopted for on-road heavy-duty diesel vehicles.

<u>Description of the Proposed Measures</u>

In-Use Compliance Testing. In-use testing programs are designed to monitor the emission levels of vehicles over their lifetime and to ensure that engines do not exceed their applicable certification emission standards. Under the current light-duty vehicle program, vehicles are selected and procured for testing. Emissions are measured and compared to certification levels. If enough vehicles of an engine family fail the testing, ARB can order a recall and the manufacturer must fix the problem that caused the failure. Although ARB has authority for an in-use program for heavy-duty vehicles, currently it is not being implemented. Heavy-duty engines are certified separate from the vehicle, and thus in-use testing requires removal of the engine from the vehicle for testing on an engine dynamometer.

Staff believes, however, that the implementation of an in-use compliance program for heavy-duty diesel vehicles patterned after the light-duty compliance program could ensure low in-use diesel PM emissions. An in-use testing and recall program for heavy-duty vehicles that is based on chassis testing, rather than engine testing, would reduce the time and cost of conducting an in-use program.[7] A chassis test is an emission test conducted while the engine is in-place, on the vehicle, as received by the testing facility. ARB is currently investigating development and feasibility of a chassis test program, which would include determining chassis test cycles and failure levels, taking into account the certification test and emission standards.

Current in-use testing programs for light-duty vehicles have proved highly effective at reducing excess emissions from the fleet. When ARB first began testing passenger vehicle engine families for in-use compliance, the staff recorded close to a 90 percent failure rate. The in-use testing program and associated recalls have provided manufacturers with the incentive to develop more robust emission control systems. As a result, manufacturers have reduced the in-use failure rate to less than 15 percent, even though staff select engine families for testing that are expected to experience failures. This dramatic improvement is evidence that a properly run in-use compliance program will dramatically reduce in-use emissions.

On-Board Diagnostics System. On-board diagnostics (OBD) systems are designed to reduce emissions throughout the life of an engine through monitoring emission-related parts and sensor outputs. Staff believes that expansion of OBD for heavy-duty vehicles could reduce in-use emissions. In passenger cars, light-duty trucks, and medium duty vehicles OBD systems monitor the components of the emission control system of the vehicle and notify the operator or an inspector of any malfunction through the use of a malfunction indicator light and stored computer codes (fault codes). This information not only informs the operator when there is a problem but also assists mechanics in identifying the cause of the problem.

ARB is taking the lead and is working closely with the U.S. EPA on the development and implementation of this program. Staff expects a heavy-duty OBD program to be structured closely after the current light- and medium-duty vehicle program. The heavy-duty program, which could be coordinated with implementation of the existing 2004 standards, will monitor emission-related parts such as the fuel metering system, aftertreatment devices, sensors, turbocharger, EGR, and misfire detection. Advances in technology and failure detection may also make it possible to reduce inspection and maintenance testing (discussed below) by combining the OBD system with a transponder. Such a system could not only notify the driver of an emission-related problem, but also be capable of sending this information to a centralized location.

---

7 In the State Implementation Plan, Measure M-17 recommends heavy-duty vehicle in-use testing based on a chassis test.

Inspection and Maintenance Program. The ARB has had authority to perform tests and enforce limits on smoke opacity from diesel engines since the late 1980's. These in-use exhaust tests measure the opacity of the exhaust plume and are credited with PM reductions of approximately 39 percent by 2010. Since these tests are unable to measure NOx, the mass of fine particulates, and other air toxic compounds, however, a cost-effective alternate method of measurement needs to be developed.

Measure M-17 of the State Implementation Plan calls for incorporation of NOx screening as a part of the Heavy-Duty Vehicle Inspection and Periodic Smoke Inspection Programs. At the same time, staff believes that heavy-duty vehicles could be held to lower diesel PM standards, including a standard of no-detectable visible smoke emissions for newer engines. Currently, owners are subject to enforcement action when visible smoke meets or exceeds 70 percent opacity for pre-1991 engines and 40 percent or greater opacity for 1991 and newer engines. Since June 1998, the monthly average failure rate has varied between four and nine percent, with an overall average of 7.8 percent (ARB, May 2000).

A new test procedure for heavy-duty diesel vehicles could be similar to an in-use compliance test discussed above. The vehicle would be placed on a chassis dynamometer and emission levels would be measured directly from the exhaust stack or tailpipe. A smog check-type program could be operated similarly to smog check for passenger cars or tied through a voluntary program to the on-board diagnostics (OBD) system. With OBD-equipped vehicles, the system could be configured to send out a low power signal indicating the system status. California Highway Patrol-operated weigh stations, which already are used for safety and smoke opacity inspection, could receive the low-power signal. If the signal indicates a properly functioning pollution-control system, the test would be waived. If the signal indicates a malfunction, the vehicle would be stopped for a chassis-based inspection. Vehicles not equipped with the ability to send the system status to the receiver, or vehicles on which the transponder is not activated, would be subject to annual or biannual pollution control system inspections.

Feasibility

In-Use Compliance Testing. A heavy-duty in-use compliance program would likely be structured after the current light- and medium-duty programs, which utilize chassis-based test procedures, allowing staff to rapidly determine compliance with applicable standards. Currently, heavy-duty diesel vehicle engines are certified using an engine test. In order to verify the emission levels of these engines in-use, the engine must be removed from the vehicle and installed on a stationary engine dynamometer. An owner would need to be provided a monetary incentive to compensate for the loss of vehicle usage during in-use testing or a new engine provided to replace the one that is removed. Staff estimates that testing an engine family (ten engines) could cost $300,000 to $700,000. A chassis-based test procedure, therefore, will be necessary in order to implement a large-scale, cost-effective in-use compliance program.

On-Board Diagnostics System. On-board diagnostic systems have been successfully used in light- and medium-duty applications. Medium-duty diesel-fueled vehicles have been required to use on-board diagnostics since the 1997 model year in California. Staff anticipates the same approach used for light- and medium-duty vehicles will be directly transferable to heavy-duty applications.

One of the key components of gasoline vehicle OBD systems is the oxygen sensor, which monitors and controls conditions for the catalyst. The analogous component for a diesel engine would be a NOx sensor. A NOx sensor with the necessary sensitivity and durability is not yet currently commercially available. There are, however, at least two manufacturers currently working on this issue that may bring commercially viable products to the market in the necessary timeframe. Given the available lead time and technology concerns, implementation of OBD for heavy-duty vehicles is expected to be feasible and effective.

Inspection and Maintenance Program. As with in-use compliance testing, the feasibility of an inspection and maintenance program is tied to the development and adoption of a chassis-based test that can be done in an acceptable amount of time, such as 15-25 minutes. An acceptable program would be quick, relatively inexpensive, and not require a huge new infrastructure for implementation. Staff will be exploring these issues but believes that these conditions can be met.

Estimated Emission Reduction

In-use emissions control programs are designed to ensure that the emission reductions expected from new engine and retrofit measures are realized, thus staff has not estimated emission reductions specifically from the programs proposed herein.

Approximate Cost To Businesses, State and Local Agencies

A provision for an in-use compliance program for heavy-duty diesel engines is currently included in the present regulations. The ARB anticipates developing a chassis test to allow for lower cost in-use compliance testing. This would reduce the overall cost of an in-use test program by eliminating the expense of removing the engine from the vehicle to perform an engine-based test. Testing costs may be borne by the State, and the cost of recall would be borne by manufacturers and passed on to consumers through higher vehicle or engine costs.

Because most new diesel engines on the market are currently equipped with most of the required sensors and computer controls necessary for an OBD system, staff estimates the cost of upgrading their present control package to include an OBD system should be approximately $30 - $50 per engine. This includes the cost of upgrading the current capacity of their present systems as well as the programming costs associated with OBD and is similar to that estimated for converting light-duty OBD vehicles to OBD II systems. Staff does recognize that the cost of adding an OBD system will be higher for those manufacturers who do not presently employ advanced computer-controlled systems. Staff has not yet determined the exact cost to monitor heavy-duty diesel aftertreatment devices, or to measure NOx directly. The necessary equipment to monitor NOx emissions and aftertreatment devices, however, should cost less than $100, for a total per vehicle cost of $130 to $150 (Table 16).

Table 16
On-Road Engines: Heavy-Duty OBD Estimated Costs

Item	Cost
CPU upgrade and necessary programming	$30-50
Additional sensors (NOx + Aftertreatment)	$100
Total estimated costs	***$130 -$150***

The cost for inspection and maintenance programs varies considerably depending on the scenario or test procedure used. For vehicle owners who are part of a voluntary transponder-equipped OBD system, the cost could be a minimal annual fee. For older vehicles and those that are not participating in the voluntary transponder program, the cost of "smog-check-type" testing could be as high as $100 - $200 per vehicle per test. Staff requires additional data, however, to more accurately estimate costs. State and local agencies would be subject to the same costs as businesses. The ARB would incur additional costs to administer the program, which may be offset by the elimination of the Periodic Smoke Inspection Program.

B. Off-Road Vehicles and Equipment

Virtually all technologies or control strategies that can be applied to on-road diesel engines can also be applied to off-road diesel engines, although the effectiveness of those strategies may vary considerably because of the different nature of off-road operation. From an administrative standpoint, the most significant difference from on-road vehicles is that, with the exception of engines registered under the portable engine registration program, pleasure craft, and off-road motorcycles, off-road engines and vehicles are not registered by the state. Thus, there are only limited mechanisms, such as warranty registration and local permits, with which to ensure the application of various in-use strategies, such as inspection and maintenance programs, in-use compliance testing or mandatory retrofitting of older equipment.

Functionally, off-road vehicles and equipment vary widely in application, from chainsaws to road graders, and in size, from less than one hp to over 10,000 hp. Measures to reduce engine emissions, therefore, require more research and time for implementation. The ARB staff are currently involved in a technology review that will provide additional information regarding feasibility of emission controls for off-road vehicles and equipment. As with on-road vehicles, the following measures proposed for off-road equipment and vehicles range from new engine standards to retrofits and in-use compliance strategies and reflect both past experience with regulating off-road mobile sources of air pollution and informed future expectations for technological solutions.

Lower Emission Standards for New Off-Road Engines

Description of the Proposed Measure

The recent national emissions standards for Off-Road Compression-Ignition[8] Engines that were adopted by both the U.S. EPA and the ARB consist of a tiered structure of emission limits based on engine power. The Tier 1 standards were implemented in 1996, while the Tier 2 standards are being implemented at the present or in the extreme near term. Both the Tier 1 and Tier 2 standards include limits on PM. The development of Tier 3 PM standards for engines between 50 hp and 750 hp is a task that ARB and U.S. EPA committed to as part of the Off-Road Statement of Principles (SOP). The two agencies are currently funding a contract with Southwest Research Institute to assess the capabilities of Tier 3 technology. That work will be used to support the 2001 technology review, also required under the SOP.

Although the work mentioned above does not include consideration of the use of aftertreatment devices, the staff believes that the Tier 3 PM standards should be based on the use of ultra-low-sulfur diesel fuel and a highly-effective diesel particulate filter along with on-board diagnostics systems to ensure proper operation. These strategies are projected to result in approximately 85 to 90 percent reduction of engine-out PM emissions. At this time, staff estimates that new engines greater than 50 horsepower could be certified at a PM level of 0.02 g/bhp-hr (0.02 g/bhp-hr) (Table 17). Smaller engines and equipment will require additional work to develop and package an effective aftertreatment device that can fit within the space constraints.

Table 17
Off-Road Engines: Proposed Standards Based on Aftertreatment

Maximum Rated Power (hp)	Implementation (model year)	PM grams/brake horsepower-hour
hp<11	2008 and later	0.30
11□hp<25	2008 and later	0.30
25□hp<50	2007 and later	0.22
50□hp<100	2007 and later	0.02
100□hp<175	2007 and later	0.02
175□hp<300	2006 and later	0.02
300□hp<600	2006 and later	0.02
600□hp□750	2006 and later	0.02
hp>750	2006 and later	0.02

8 Compression-ignition engines use diesel fuel.

Feasibility

The feasibility of this measure is dependent mostly on the availability of ultra-low-sulfur diesel for off-road equipment and vehicles. A confounding factor is the federal preemption of authority to regulate new construction and farm equipment below 175 horsepower and new locomotives. These factors make it vital for the ARB to convince the U.S. EPA to set standards equivalent to the California standards and to similarly adopt ultra-low-sulfur diesel nationwide. The majority of larger off-road engines are equipped with electronic controls, so implementation of an on-board diagnostics requirement would be relatively easy, particularly for those engines with on-road counterparts.

If the U.S. EPA does not pursue the use of aftertreatment for the national Tier 3 standard, two courses of action present themselves. The first would be unilateral California implementation of aftertreatment-based Tier 3 standards. Unfortunately, because only the U.S. EPA may control emissions from new construction and farm equipment below 175 horsepower, a California-only regulation would cover a relatively smaller percentage of the new vehicles and equipment. A California-only regulation, therefore, is likely to prove more expensive on a per-engine basis and result in much lower emission reduction benefits than if the U.S. EPA also requires such standards.

The second course of action would be for ARB to adopt an aggressive aftertreatment retrofit program to ensure that an equal level of control is achieved from the engines not subject to the preemption. A retrofit program primarily targeted at publicly-owned and -leased off-road vehicles is discussed below.

Estimated Emission Reduction

The emission inventories for 2010 and 2020 were estimated using the assumptions that all previously adopted emission standards remain in effect and durability requirements remain the same as adopted, and that NOx levels would not be affected by this measure. The already adopted Tier 3 off-road standards contain NOx standards, which are reflected in the emissions inventory baseline. Using these assumptions, staff calculated the emissions benefit from this proposal to be a reduction in diesel PM of 913 tons per year statewide in 2010, increasing to 3,579 tons per year statewide in 2020.

Approximate Cost To Businesses, State and Local Agencies

The major costs to businesses would include the increased costs of new hardware, maintenance, and ultra-low-sulfur diesel. Because the use of diesel particulate filters would allow engine manufacturers to calibrate engines with less concern about engine-out emissions, staff expects better performance with no fuel consumption increase. The cost estimates are based on the same sources as noted for on-road engines, and assume that those of-road engines would be equipped in the same time-frame. The on- and off-road engines are substantially similar, so both sets of engines should be able to take advantage of the high production volume. Off-road applications, however, would require extra research and development resources for possible equipment modification. Staff has estimated the equipment modification costs using the information contained in the regulatory impact analysis conducted by U.S. EPA for their off-road diesel rule (U.S. EPA, August 1998). The engine power ranges shown in Table 18 were selected to facilitate comparison with on-road costs. For on-road engines, the cost of an on-board diagnostics system is approximately $130-$150. Thus, staff has assumed the same cost for a comparable OBD system for off-road equipment and vehicles.

Table 18
Off-Road Engines: Future Diesel Particulate Filter and OBD Costs Based on High Volume Production

Average Horsepower	**190**	**250**	**475**
Diesel particulate filter	$1,177	$1,397	$1,620
OBD System	$150	$150	$150
New Engine Costs (comparison)	$8,527	$13,555	$23,722

In addition to these costs, vehicle owners will incur incremental costs for ultra-low-sulfur fuel and maintenance costs of the new hardware. Staff requires additional information to determine these life-cycle operating costs for off-road equipment and vehicles. The costs to State and local agencies would be the same as those experienced by businesses: increased costs for new hardware, maintenance, and ultra-low-sulfur fuel. The ARB will incur additional costs for regulatory development and ensuring compliance.

Control of Emissions from Existing Off-Road Engines - Retrofit

Description of the Proposed Measure

The long lifetime of diesel engines, particularly at the higher power ratings, requires a comprehensive control strategy to control existing engines to complement the development of new engine controls. A retrofit requirement is an obvious strategy, but one that must be carefully crafted to minimize any effect on the engine or on the equipment's ability to carry out its task. The most effective aftertreatment device for PM reduction is the diesel particulate filter, which is presently applicable to engines above 50 horsepower, unless technology becomes available that could package a diesel particulate filter for the smaller equipment and engines. A likely timeframe for privately-owned vehicles would be concurrent with the availability of ultra-low-sulfur fuel in 2006. For publicly-owned or -contracted fleets, however, a phased-in implementation beginning in 2002 would be feasible.

Feasibility

Diesel particulate filters have been commercially retrofitted to off-road equipment since 1986. The types of equipment that have been retrofitted include mining equipment, material handling equipment, forklifts, street sweepers, and utility vehicles (MECA 2000). Over 2,500 diesel particulate filter systems are in operation worldwide; some of the systems have been operated for over 15,000 hours or over five years and are still in use. Existing off-road engines that are retrofitted with diesel particulate filters could achieve the same percentage reduction as new engines, approximately 85 percent assuming ultra-low-sulfur fuel is available, although from a higher initial level of emissions.

Retrofit programs could be implemented using a variety of approaches, such as requiring local permitting agencies to ensure that retrofits are performed prior to the granting of permits. Another approach could require large state construction contracts to include a retrofit requirement as a contract condition. Finally, a retrofit rule for off-road could apply specifically to publicly-owned and -contracted fleets. While an off-road retrofit program is certainly feasible, its effectiveness may be less than optimum without a statewide registration program. This is because it would be difficult to track certain types of retrofitted off-road equipment, thereby hampering ARB's ability to directly enforce the retrofit installation. It may make sense, therefore, to propose a registration requirement in California for off-road equipment.

Estimated Emission Reduction

Almost all engines greater than 50 horsepower, other than portable engines, which would be subject to separate conditions, would be rebuilt or retrofitted to achieve an 85 percent reduction in diesel PM emissions. In order to calculate emission benefits, staff assumed that 90 percent of all eligible engines,[9] are retrofitted by 2010, using emission control devices that remove 85 percent of diesel PM. Staff estimate diesel PM would be reduced by 5,968 tons per year statewide in 2010, and by 1,505 tons per year statewide in 2020. These figures do not include the potential emission benefits of retrofitting locomotives and commercial marine vessels, which are discussed under non-regulatory strategies below.

Approximate Cost To Businesses, State and Local Agencies

The costs to vehicle owners of retrofit would consist of the hardware and installation costs at rebuild, subsequent maintenance costs, and the incremental cost of ultra-low-sulfur fuel, which is required to maintain aftertreatment device operation. Ultra-low-sulfur fuel is expected to cost 5 cents per gallon more than the present fuel. The cost to retrofit the diesel particulate filters is expected to be higher than the cost of incorporating the same equipment on new engines. Retrofitting with aftertreatment devices will not have been included in initial engine designs, nor will most owners be able to take advantage of high volume purchasing. The estimate given here does not

[9] Excluding portable equipment engines, which are covered in Appendix II.

assume any savings from retrofit systems sharing any components, such as the muffler, with the systems intended for new engines (Table 19).

Table 19
Off-Road Engines: Current Cost for Retrofit

Horsepower	**190**	***250***	**475**
Diesel Particulate Filter	$5,700-9,500	$8,250-13,750	$13,500-23,750

In addition to these costs, vehicle owners will incur incremental costs of ultra-low-sulfur fuel and maintenance costs of the new hardware. Staff requires additional information to determine these life-cycle operating costs for off-road equipment and vehicles. Costs to State and local agencies would be similar to those incurred by businesses, consisting of the cost of retrofitting existing equipment at rebuild, subsequent maintenance costs, and the increased cost of ultra-low-sulfur fuel. If the State creates a registration program, there would be administrative costs that could be offset by registration fees. ARB will incur costs from rule development, equipment certification, program management, and enforcement.

Control of In-Use Emissions for Off-Road Vehicles and Equipment

Description of Proposed Control Measure

For off-road vehicles and equipment, staff proposes to modify the off-road in-use compliance testing program. Although in-use compliance testing is currently in place for off-road diesel engines, the existing program is limited to engine testing, rather than chassis or equipment testing. This hampers testing greatly by increasing the cost. Staff proposes that a simplified compliance assessment test be developed. The compliance assessment test should be an on-site test that can be correlated in some way to the certification test. Ideally, such a test should take 30 minutes to less than half a day to conduct to minimize the costs of taking a vehicle or piece of equipment out of service.

Feasibility

An in-use compliance program is not, strictly speaking, a control strategy, as much as it is a means of ensuring that the chosen control strategies remain effective over the lifetime of the engine or equipment. Typically, the ARB sends a letter to a vehicle owner notifying them that their vehicle has been selected for a voluntary testing program. If the vehicle owner chooses to participate, he or she is provided with a substitute vehicle while their vehicle is being tested. The difficulty involved in implementing this strategy for off-road engines includes the fact that off-road equipment tends to be specialized. For example, it would be difficult and expensive to provide a substitute for earth-moving equipment to an end-user in order to test his equipment, which is in constant use. Without a replacement piece of equipment, the down time encountered would provide a serious disincentive for owners or operators to participate in the program, hindering the ARB's ability to test a representative sample of similar equipment.

The current regulations for off-road compression-ignition engines include provisions for in-use compliance testing on an engine, not equipment, basis. The program allows for the identification in advance of purchase of the engines and applications that will be tested. This allows the engine manufacturer to retain an unused engine to be installed when the in-use engine is removed for testing. This approach, while providing some enforcement capability, is lacking in the element of surprise, and would allow a manufacturer to cut corners on the engine families that have not been selected. Full effectiveness of an in-use compliance program can be achieved if registration is required and engine manufacturers are assigned recall responsibility, as they are with on-road engines. A compliance test could possibly be developed based on the power take-off or hydraulic systems of many off-road vehicles or equipment.

Estimated Emission Reduction

In-use compliance programs are a means of ensuring that the chosen control strategies remain effective over the lifetime of the engine or equipment. Thus the emissions reductions attributable to this program can be divided into (a) direct reductions due to detection of failing systems, which will be similar to those experienced in on-road testing, and (b) indirect reductions due to the deterrent effect of the program, for which the changes in compliance margin will be similar to those experienced in on-road certification. Staff have not estimated separate emission benefits from an off-road in-use program. Although those benefits could be substantial, they are presently assumed to be included in the estimated benefits from new engine standards and the retrofit measure.

Approximate Cost To Businesses, State and Local Agencies

Staff does not have an estimate of the cost of an in-use compliance assessment program to the end user, but expects that the cost will be small relative to the cost of the engine. Staff requires additional data to determine these costs. Manufacturers could incur additional costs of corrective action (i.e., recall) if an engine family failed testing.

The ARB would incur costs to implement the program. Staff estimates a per engine cost of $33,000 to $70,000, which includes the costs for engine replacement, an incentive to the owner, removal of the engine, installation and set-up of the engine for testing, the emission tests, and shipping. If ARB implements a simplified compliance assessment test, as described above, staff expects that per engine costs could be greatly reduced. Owners would not need to be provided with a new engine, and installation and shipping costs would therefore be eliminated. The cost of an incentive for testing could also be drastically reduced, provided the time necessary for the test is reduced to less than a full day.

Particulate Matter Standards for New Diesel Pleasure Craft Engines

Description of the Proposed Control Measure

In 1999, the Air Resources Board adopted regulations for emission standards and test procedures for new 2001 and later spark-ignition marine outboard and personal watercraft engines. The rule did not cover diesel-fueled, or compression-ignition, inboard or auxiliary engines used in pleasure craft. Furthermore, the 1999 standards did not set PM emissions, but focused on hydrocarbon and oxides of nitrogen emissions. The adopted off-road compression-ignition rule, however, does cover marine engines less than 50 horsepower.

Staff suggests, therefore, that a diesel PM standard for new pleasure craft compression-ignition engines is necessary. The proposed implementation date would be 2005, with an initial target reduction of diesel PM by 25 percent overall or more by 2010. A NOx standard would also be proposed, and will be a part of any proposed rulemaking for recreational marine engines. Engines to which the rule would apply are inboards and auxiliary engines used for power generation and propulsion in recreational marine vessels, such as yachts and sailboats. The inventory of diesel PM emissions from this category, while small, is expected to increase by about 28 percent from 2000 to 2010, and 57 percent from 2000 to 2020, mainly due to expected growth in the population of inboard engines and simultaneous expected decline in auxiliary engines. Inboard engines are larger (horsepower) and are used more hours (activity) than the auxiliary engines, thus there is a correspondingly large increase expected in diesel PM emissions.

Feasibility

Control technology is expected to be available and feasible as the diesel-fueled engines used in pleasure craft are similar to on-road engines. These PM standards do not envision aftertreatment technology. Manufacturers would, therefore, be able to use the same control technology as has been developed and demonstrated for on-road engines, although the off-road retrofit program, discussed earlier, may be applied to existing pleasure craft engines.

Estimated Emission Reduction

Staff estimates the diesel PM emissions could be reduced, statewide, by 25 percent in 2010 by reducing the per engine emissions by approximately 65 percent beginning in 2005. As there is presently no diesel PM standard for these engines, the reduction was calculated based on the present exhaust emission factor of 0.34 grams per brake-horsepower hour. Staff estimates that a diesel PM standard between 0.1 and 0.15 grams per brake-horsepower hour would be necessary to achieve a 25 percent reduction in 2010. Maintaining the same engine emission standard for the next decade would result in a 60 percent reduction in 2020 emissions. Since most of the emissions are generated on summer weekends, the emissions benefit would be greater on a per day basis when adjusted by usage. The expected diesel PM emission reductions are 9 tons per year in 2010 and 24 tons per year in 2020.

Approximate Cost To Businesses, State and Local Agencies

Although staff expects that the costs of implementation of this measure to be similar to those for on-road engines, staff requires additional data to calculate costs. A diesel PM standard alone is unlikely to increase engine costs significantly as manufacturers could reduce diesel PM by engine retuning. A standard that reduces NOx simultaneously with diesel PM, however, is likely to increase the cost of the engine. As with on-road engines, the costs would include costs of engine redesign, hardware, operating and maintenance costs. ARB does not expect that implementation of a diesel PM standard alone will require aftertreatment devices, thus the incremental cost of ultra-low-sulfur fuel may not be incurred.

C. Non-Regulatory Strategies for Mobile Sources

Non-regulatory strategies are those actions for which ARB has authority to adopt guidelines, voluntary memoranda of understanding (or agreement), or incentive programs that are not regulations. An example of this would be the Carl Moyer Program Guidelines, which were developed through a public process and approved by the Board, but which were not adopted into regulation. A non-regulatory strategy, as discussed herein, could also be an activity for which ARB does not presently have authority, but which it may seek authority through legislative action. In addition, non-regulatory strategies could involve programs adopted and implemented by local air districts. No estimated emission reductions and costs have been calculated for these strategies for this report, although this information is discussed. Emission reductions and costs, however, would be estimated before any particular strategy is implemented.

Diesel Particulate Filters for Locomotives

Description of the Proposed Measure

The recently adopted U.S. EPA locomotive rule will result in significant reductions in diesel PM emissions from locomotives beginning with model year 2005. The national rule only affects PM emissions from model year 2005 and later locomotives and does not reduce PM emissions from older locomotives. Control of PM is expected to occur through improvements in air cooling, fuel management, combustion chamber configuration, and electronic controls. Diesel particulate filters, while mentioned in the regulatory support document accompanying the U.S. EPA rule, were not considered by the U.S. EPA for application by manufacturers to meet the standards. Because of recent developments in diesel particulate filter technology, however, retrofitting locomotive engines to further reduce diesel PM emissions could result in significant reductions in diesel PM emissions.

As discussed previously, the Clean Air Act preempts California from regulating emissions from new locomotives or new engines used in locomotive. Staff feels, however, that it would be valuable for locomotives to use aftertreatment technology to reduce particulate emissions. Staff suggests, therefore, exploring a voluntary program for locomotive retrofit with the railroads and working with the U.S. EPA to explore a future requirement that locomotives be retrofitted with diesel particulate filters achieving a minimum 85 percent efficiency.

Feasibility

Recent developments in diesel particulate filter technology suggest that a locomotive retrofit program may be feasible. Diesel particulate filters, along with other aftertreatment devices for reduction of PM and NOx emissions, require use of ultra-low-sulfur fuel for optimal efficiency. Any retrofit requirement, therefore, should be implemented along the same time frame as the availability of ultra-low-sulfur fuel. While diesel particulate filters are not currently used on locomotives, these technologies, which are being developed for use with on-road heavy-duty trucks, are expected to be applicable to locomotives.

Estimated Emission Reduction

Staff estimate the potential statewide emission reductions from retrofitting 90 percent of all locomotive engines operating in California by 2010 to be 862 tons per year, or a reduction of 75 percent of diesel PM, and 762 tons per year in 2020. Staff assumed that any emission control device would remove 85 percent of all diesel PM from exhaust.

Approximate Cost To Businesses, State and Local Agencies

A standard size for an older locomotive engine is approximately 3,500 horsepower. According to estimates by MECA (March 2000), the cost for retrofitting an engine of this size with a diesel particulate filter would range from $35,000 to $70,000. The costs of retrofitting could be offset by incentive funds, if available, such as the Carl Moyer Program.

Particulate Matter Controls for Commercial Marine Vessels

Description of the Proposed Measure

Emissions from commercial marine vessels, which include cargo ships, tug and tow boats, fishing boats, cruise ships, and other large ocean-going ships, are a major source of diesel PM particularly in the South Coast Air Basin. Engine standards adopted by the U.S. EPA, however, only apply to new engines and do not impact emissions from existing ship engines. As discussed earlier, engine standards for commercial marine vessels are best approached at the national level by the U.S. EPA with state input.

Staff believes that a combination of voluntary, incentive, and regulatory approaches would significantly reduce diesel PM emissions from commercial marine engines. The following strategies are proposed: first, a voluntary speed reduction control strategy for ocean-going ships operating in California; second, a federal incentive program to provide funds, beyond those already available through California's funding of the Carl Moyer Program, for repowering with cleaner engines and for retrofitting existing engines; and third, a federal regulation that applies the new commercial marine engine standards to existing vessels when their engines are rebuilt or repowered. In addition to these engine strategies, a mandatory reduction in fuel sulfur level would also reduce emissions.

Feasibility

The technology for reducing stack emissions from ships is well known and increasingly being applied to new engines. While repowering old, dirty engines with new, current technology engines is feasible and produces significant emission reductions (SCAQMD 1998), new technologies are being developed that will result in even cleaner engines. For example, gas-turbine engines are lighter in weight and provide more horsepower per ton than diesel engines, although the higher initial cost and fuel consumption have limited their use (Aichele 2000a). Another promising technology is a smokeless diesel-propulsion system using common rail technology and water-jet injection that will equal the low emissions of the gas-turbine engine which is being developed by Wartsila NSD and Carnival Corporation. In addition to repowering, aftertreatment, such as with selective catalytic reduction, has also been demonstrated in ships (Aichele 2000b).

Estimated Emission Reduction

Staff requires additional data on the mix of specific programs that would be adopted to calculate estimated emission reductions. Staff did estimate, however, the emission reductions that could be achieved if 90 percent of existing commercial marine engines were retrofitted with emission control devices that remove 85 percent of diesel PM. Under this scenario, diesel PM emissions would be reduced statewide by 3,945 tons per year in 2010 and 4,504 tons per year in 2020. As an example of the emission reductions that could be achieved by repowering an individual vessel, the South Coast AQMD reported reducing diesel PM by 0.81 tons per year from one tug boat by installing two new main engines and two new auxiliary engines (SCAQMD 1998).

Approximate Cost To Businesses, State and Local Agencies

In the above mentioned South Coast AQMD tug boat repower project, the cost was $390,000. In other projects completed with incentive funds costs ranged from $193,000 to 330,000 per boat. ARB staff have yet to estimate a cost per engine power for retrofitting boat engines. Incentive funds, if available, could be used to offset the costs of reducing diesel PM emissions.

Retrofit for Emergency Vehicles

Description of the Proposed Strategy

Publicly-owned emergency vehicles, including those operated by peace officers, fire fighters, and paramedics, are exempt from requirements for pollution control devices. Also exempt are vehicles owned by mosquito abatement districts, vector control, and pest abatement districts or agencies, and ambulances operated by private entities under contract to public agencies. Because many of these districts and agencies operate heavy-duty, diesel-fueled vehicles, staff proposes to negotiate voluntary agreements with public agencies and districts for retrofitting these vehicles with diesel particulate filters and to work with manufacturers to assure that new emergency vehicles are equipped with modern, state-of-the art pollution control equipment.

Feasibility

The major issue affecting feasibility would be the cost of retrofitting vehicles with pollution control devices. Staff would attempt to identify funds that could be used to retrofit engines wherever retrofit devices could be installed without impairing the life-saving function of the vehicles. Staff would also work with agencies and districts to identify incentive funds that could be used to pay the incremental costs above the cost of purchase of the uncontrolled technology.

A secondary feasibility issue concerns the impact of emission control technology on the performance of the vehicle. In the past this was a valid concern. Today, however, manufacturers have long since developed technologies that control pollution with little or no effect on engine performance. Staff would, however, review this issue with respect to the specialized vehicles used by the exempt categories.

Estimated Emission Reduction

Current diesel particulate filter technology achieves 85 percent or better control of diesel PM. Staff, however, lacks the data necessary at this time to calculate estimated emission reductions. Staff requires data on the number of emergency vehicles to which the program would apply or the amount of funding available, which would influence the number of vehicles that could be retrofitted. In addition, data would have to be collected to determine the emission inventory of emergency vehicles, which is not presently available.

Approximate Cost To Businesses, State and Local Agencies

This strategy assumes that funding can be secured through the state to off-set the costs of retrofitting equipment. A current program for reducing NOx emissions, the Carl Moyer Program, has been funded at $19 to 25 million per year, which may increase in the coming year. Carl Moyer Program funds could be used for this measure, especially if the program is expanded to include the goal of reducing diesel PM, as recommended by the Advisory Committee (Carl Moyer Program Advisory Board 2000).

Airport Ground Support Equipment Memorandum Of Understanding

Description of the Proposed Strategy

California has become one of the fastest growing air transportation links to the Pacific Rim, pushing California's average aviation growth even higher. As a result of this growth, airport-related activities account for an increasingly large component of the state's emissions inventory. Airport-related activities include aircraft engine emissions at landing and takeoff, on-road ground operations, such as taxis and shuttles, and airport ground support equipment, most of which consists of off-road equipment. A Memorandum of Understanding with airports and airlines operating in the South Coast Air Basin is currently being negotiated and will identify specific goals to achieve emission reductions from airport ground support equipment. The MOU is expected to significantly reduce emissions of hydrocarbons, oxides of nitrogen, and diesel PM.

The voluntary agreement negotiations were initiated through a public consultative process convened by the U.S. EPA to determine and evaluate opportunities for emission reductions specified for aircraft in the 1994 California Ozone State Implementation Plan (SIP). The consultative process identified airport ground support equipment (GSE) as one category that could achieve exhaust emissions below those required by regulation. Emission reductions are to be focused on the airports of the South Coast Air Basin. The primary stakeholders for the subcommittee on GSE are the U.S. EPA, Region IX, ARB, the South Coast Air Quality Management District, the Air Transport Association, the Federal Aviation Administration, the five major airports in the South Coast, and the major airlines serving those airports.

Feasibility

As a group, GSE largely comprise off-road types of equipment fueled by either gasoline or diesel. The negotiated voluntary agreement will focus on emission standards based on various strategies that can be applied to various pieces of equipment. One strategy for reducing emissions from GSE is to use alternative fuels that result in lower emissions operation. Alternatives to gasoline and diesel include liquefied petroleum gas (LPG or propane), compressed natural gas, and liquefied natural gas. Another strategy is to replace existing GSE with battery-powered or electric equipment. A third strategy is to repower GSE with new on-road engines which are currently certified to a more stringent emission standards than off-road engines. This allows the opportunity to generate additional emission reductions by using lower-emitting engines beyond what may be required for new purchase GSE. This opportunity will decrease, however, as new more stringent emission standards for off-road engines are phased-in.

Estimated Emission Reduction

Staff and the working group for the memorandum of understanding are in the process of calculating the estimated emission reduction from this measure.

Approximate Cost to Businesses, State and Local Agencies

Staff and the working group for the memorandum of understanding are in the process of determining the estimated costs of implementation.

Transportation Control Measures – Idling Restrictions

Description of the Proposed Strategy

A technical advisory group created by legislation (AB 2595, 1988), developed initial guidelines in 1990 for reducing emissions from truck operations. Many of the transportation control measure concepts in these guidelines are still feasible and viable today. The advisory group included ARB, other transportation and air quality related agencies, and trucking industry representatives. The advisory group recommended and ranked measures based on feasibility, ease of implementation, cost effectiveness, and air quality benefit. The guidelines include truck idling restrictions, freight consolidation centers, time-of-day restrictions, and pricing measures, in descending order of ranking. Of these, truck idling restrictions are proposed to be feasible at this time.

Idling restrictions limit the amount of time heavy-duty vehicle engines are allowed to operate while not performing useful work, e.g., moving the vehicle or operating essential equipment. Limiting idling would reduce ambient emissions and reduce public exposure (especially for truck and facility operators) to diesel toxics. It would also reduce fuel consumption and engine wear. An effective strategy must include compelling information to educate vehicle operators about the need to, and benefits of, limiting idling time.

Many heavy-duty truck operators allow their engines to remain idling while they are waiting to access facilities to make deliveries or pick-ups. Idling is common in areas of high truck activity, such as port facilities, rail yards, business parks, canneries, industrial parks, retail centers, construction sites, and truck stops. Many drivers allow their engines to idle out of habit or the misconception that heavy-duty diesel vehicles still require extended time to warm up and cool down. This, however, is no longer the case with modern engines.

Heavy-duty truck idling could be limited to a maximum time period, except under certain circumstances. The maximum time period would be set by start and idle emission analysis and practical trucking industry concerns. Stricter limits could be required in areas accessible to the general public, such as schools and shopping centers. Prohibiting school bus idling at school facilities could be an initial regulatory action. A companion measure would require, or incentivize, the installation of electrical outlets at truck and bus terminals to allow for sleeper berth use and cabin heating and air conditioning.

Options for implementation include a voluntary, education-based approach or a regulatory strategy that could involve: ARB adoption of a statewide truck idling regulation; local air district adoption of truck idling regulations, assisted by a model rule developed by ARB, or legislation amending the Health and Safety Code to restrict truck idling. Implementation should also include a program to gain the cooperation of facilities where truck idling occurs to support and better ensure compliance with idling restrictions.

Feasibility

The feasibility of implementing idling restrictions would be affected by costs and human nature. The costs to the state and local air districts of enforcing idling restrictions could be high, requiring additional staff to conduct inspections and monitor compliance at truck stops and by each truck owner. Alternately, if staff emphasizes the education approach, the cost would be somewhat lower. Gaining the cooperation of facilities where truck idling occurs to ensure compliance with the law will be challenging, requiring education and outreach activities at many locations throughout the state. Finally, ARB will have to extend its education and outreach activities into other states to notify out-of-state owners of vehicles that operate within California.

Estimated Emission Reduction

Potential emission reductions from this strategy could be estimated in-house through an analysis of current truck activity studies, with second-by-second geographic information system data, and truck idling and trip-end emission factors. Estimated emission reductions, however, were not calculated for this report.

Approximate Cost To Businesses, State and Local Agencies

The 1990 Advisory Group suggested that the savings to vehicle owners would offset the costs, and thus there would be no cost to businesses. Savings would accrue from reduced engine wear, increased engine life, and reduced fuel costs from decreased idling. The costs include an increased replacement frequency of the starter system and battery from increased starts, and the cost of electricity-adaptable air conditioning and heating units, if sleeper cab use is included in the idling restriction. In addition to costs to vehicle owners, owners of truck stops would incur the cost of installing electric outlets and implementing a procedure to charge truck owners for electricity used.

There are several categories of costs to state and local agencies. First, ARB and local air districts would incur additional costs for enforcement. Second, ARB and local air districts would incur costs associated with education for truck drivers, trucking facilities, and truck stops. Finally, the State of California could provide public funding to provide incentives for installing electrical outlets at truck stops.

D. Potential Associated Adverse Environmental Impacts

Every one of these recommended measures will benefit California's environment and reduce the public's exposure to air pollutants, particularly the toxic air contaminant diesel PM. The net benefit to the public, in the form of reduced health costs, is likely to be in the millions of dollars. Nevertheless, certain of the aftertreatment technologies may themselves have potential adverse environmental impacts on a much lesser scale.

One technology that could be used to meet lower NOx standards, selective catalytic reduction (SCR) requires the use of urea to achieve emission reductions. SCR has been used to control NOx emissions from stationary sources for over 15 years and has been applied more recently to trucks, marine vessels, and locomotives. If this method is used to meet these new standards, there will be issues related to the so-called "ammonia slip," which is the release of excess ammonia in the exhaust.

Ammonia slip could form secondary particulate (nitrates) when released into the atmosphere. In order to eliminate ammonia slip, an oxidation catalyst can be installed downstream of the SCR unit, which would reduce ammonia slip by oxidizing most of the ammonia into harmless compounds. A more detailed study will be necessary to evaluate potential impacts.

Another technology, catalyst-based diesel particulate filters (DPFs), may also have associated adverse environmental impacts, but additional information is needed. First, as is the case with most processes that incorporate catalytic oxidation, sulfate formation can occur during operation. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reductions in soluble organic fraction emissions. Using diesel fuel with very low sulfur content, as proposed in this report, would minimize this effect.

In addition, a spent DPF may be considered hazardous waste according to state or federal regulations. The determination of whether or not a used DPF would be considered a hazardous waste at the end of its useful life depends on the materials used in the catalytic coating. DPFs are somewhat similar to automotive catalytic converters, and thus a comparison may be useful. The California Department of Toxic Substances Control currently regulates used automotive catalytic converters as scrap metal, so long as the catalyst material is left in the converter shell during collection and transportation and the converters are going to be recycled. The ash residue associated with cleaning (regenerating) a DPF would also need to be tested to determine if it is a hazardous waste. If it is, there would be increased costs associated with maintenance of the DPF throughout its life.

VI. CITATIONS

Aichele, Richard O. Propulsion evolution: new technologies speed advances in engine systems. Professional Mariner #47: 50-57; April/May 2000a.

________. Technology cutting stack emissions. Professional Mariner #47: 58-63; April/May 2000b.

Air Resources Board (ARB). The California small off-road engine emissions inventory. Staff report, Mobile Source Control Division. Mail-out MSC#98-04. March 1998.

________. Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant" Part A, Exposure Assessment. As approved by the Scientific Review Panel, April 22, 1998.

________. California's pleasure craft exhaust emissions inventory. Staff report, Mobile Source Control Division. Mail-out MSC#98-34. November 1998.

________. California's emissions inventory for off-road large compression ignited (CI) engines (□25 HP). Staff report, Mobile Source Control Division. Mail-out MSC#99-32. January 2000.

________. April 2000 Mobile Source Enforcement Branch Monthly Status Report. May 12, 2000.

Anonymous. Draft of a program of measures for diesel vehicles (4/25/00), www.kankyo.metro.tokyo.hp/dno/ENG/pre04_2.htm.

Carl Moyer Program Advisory Board Report; March 31, 2000. Available on-line at: http://www.arb.ca.gov/msprog/moyer/cmpabfinal.pdf.

DieselNet (4/25/00), www.dieselnet.com/news/9910engelhard.html.

Mayer, A. Selection criteria for diesel particulate trap systems: VERT experience. DieselNet Technical Report; December 1998.

MECA. Emission control retrofit of diesel-fueled vehicles. March 22, 2000.

South Coast Air Quality Management District (SCAQMD). Final project assessment for repower of a tug boat with ultra-low emissions diesel engines. AQMD Contract #98021. 1998.

U.S. EPA. Final regulatory impact analysis: control of emissions from nonroad diesel engines. EPA420-R-98-016. August 1998.

U.S. EPA. Draft regulatory impact analysis: control of emissions of air pollution from highway heavy-duty engines," August 1999.

U.S. EPA. Notice of proposed rulemaking; control of emissions of air pollution from 2004 and later model year heavy-duty highway engines and vehicles; October 1999.

U.S. EPA. Draft regulatory impact analysis for the proposed heavy-duty engine and vehicle standards and highway diesel fuel sulfur control requirements rule. EPA420-D-00-001. May 2000.

Appendix IV

Fuels Report: Appendix to the Diesel Risk Reduction Plan

September 13, 2000

TABLE OF CONTENTS

Contents Page

TABLE OF CONTENTS (cont.)

Contents | Page

I. SUMMARY

This report addresses the need for and the appropriate degree of regulation of diesel-engine fuel for the control of particulate matter from diesel-fueled engines (diesel PM). Diesel PM was identified by the Air Resources Board (ARB or Board) as a toxic air contaminant (TAC) in 1998.

All diesel fuel sold or supplied in California for motor-vehicle use (CARB Diesel) must have a sulfur content of 500 ppmw or less (13 CCR 2281). In addition, the average aromatic hydrocarbon content of CARB Diesel, except that produced by California small refiners, must not exceed 10% by volume, unless the fuel is produced as an ARB-certified alternative formulation (13 CCR 2282). The ARB has certified a total of 25 alternative formulations.

Reducing sulfur levels from the CARB Diesel average sulfur content of 141 ppmw to 15 ppmw in the absence of exhaust after-treatment, is expected to have an impact on diesel PM emissions equal to a FTP-cycle specific emission reduction of about 0.004 g/bhp-hr. More importantly, improved after-treatment control efficiency (to over 90% control of diesel PM emissions) has been consistently demonstrated with very low-sulfur diesel fuel. Very low-sulfur fuel would allow after-treatment manufacturers to use more highly active catalysts, which operate effectively at lower temperatures and have a broader range of vehicle applications.

In February of 2000, the ARB approved a Fleet Rule for Urban Transit Bus Operators (13 CCR 1956.2). Beginning July 1, 2002, transit agencies shall not operate diesel buses on diesel fuel with a sulfur content in excess of 15 ppmw. ARB staff has estimated an incremental refining cost of less than $0.05-per-gallon to produce this fuel.

The United States Environmental Protection Agency (U.S. EPA) has published proposed regulations which would require that all diesel fuel sold for use in on-road vehicles have a sulfur content no greater than 15 ppmw, beginning June 1, 2006. U.S. EPA estimates that the overall cost, associated with lowering the sulfur cap from the current level of 500 ppmw to the proposed level of 15 ppmw, would be approximately $0.03 to $0.04 per gallon.

Alternative diesel fuels, such as water-in-fuel emulsions, have demonstrated great promise for reducing diesel PM and other emissions from diesel engines. While there is uncertainty in the emission-reduction potential of these fuels versus CARB Diesel, diesel PM emission reductions of over 20% have been demonstrated in comparison testing with other diesel fuels. An appropriately optimized emulsion of water in CARB Diesel should result in significant diesel PM and other emission reductions versus CARB Diesel alone. The use of alternative diesel fuels to achieve emission reductions is best suited for application to fleets, stationary engines, and equipment, which have access to a centralized fueling station.

To be consistent with U.S. EPA and to enable after-treatment control technologies for off-road and stationary diesel engines; the ARB should adopt a regulation in 2001, which would require very low-sulfur (≤ 15 ppmw S) CARB Diesel for all on-road, off-road, and stationary engines statewide, effective in 2006. In the regulatory development process, the ARB staff will investigate the feasibility of an earlier implementation date. Also, guidance on diesel fuel options and associated emission reductions should be developed to assist local districts in their permitting of fleets and equipment.

Summary of Recommendations

Recommendation	Emission Reduction (%)		Incremental Cost ($/gal)	Implementation or Issue Date
	Diesel PM	NOx		
Very low-sulfur (≤ 15 ppmw S)	> 90 *	> 80 *	< 0.05	2006 ***
Diesel Fuel Guidance	20 **	10 **	< 0.18 **	2001 ****

* Emission reductions with after-treatment.
** Estimated for emulsions of water in CARB Diesel.
*** Very low-sulfur CARB Diesel to be considered at ARB hearing in 2001.
**** Guidance for districts' use to be approved and issued by ARB in 2001.

II. INTRODUCTION

A. Purpose

In 1998, particulate matter (PM) from diesel-fueled engines (diesel PM) was identified by the ARB as a TAC in accordance with Division 26, Part 2, Chapter 3.5, Article 3 (section 39660 et seq.) of the California Health and Safety Code (H&SC). The ARB Resolution 98-35, August 27, 1998, identifies an estimated range of lifetime excess lung-cancer risk, associated with diesel PM inhalation, of 1.3 to 24 x 10^{-4} per microgram diesel PM per cubic meter of air (1.3 to 24 x 10^{-4} μg^{-1}-m^3). Resolution 98-35 also directs ARB staff to begin the risk management process for diesel PM and other potentially harmful pollutants from diesel-fueled engines.

Article 4 (H&SC section 39665) directs the executive officer of the ARB to prepare a report on the need and appropriate degree of regulation for each substance determined to be a TAC. H&SC section 39667 directs the ARB to consider the adoption of regulations specifying the content of motor vehicle fuel to achieve the maximum possible reduction in public exposure to TACs; and further provides that the regulations may include the modification, removal, or substitution of vehicle fuel or fuel additives. This report addresses the appropriate degree of regulation of diesel-engine fuel for the control of diesel PM.

B. Review of Adopted and Proposed Regulations

1. U.S. EPA Regulations

All diesel fuels, Grades 1-D and 2-D, and all fuel additives for on-road motor-vehicle use must be registered in accordance with 40 CFR Part 79 – Registration of Fuels and Fuel Additives. The registration requirements for diesel fuels apply to fuels composed of more than 50% diesel fuel by volume and their associated fuel additives. As provided in 40 CFR 79.56, manufacturers may enroll a fuel or fuel additive in a group of similar fuels and fuel additives through submission of jointly-sponsored testing and analysis, conducted on a product which is representative of all products in that group. The general grouping categories are baseline, non-baseline, and atypical.

The baseline diesel fuel category is comprised of a single group, represented by diesel base fuel specified in 40 CFR 79.55(c). Fuel additives are categorized as mixed with diesel base fuel. The baseline category is defined as fuels possessing the characteristics of diesel fuel as specified by ASTM D 975-93 and derived only from conventional petroleum, heavy oil deposits, coal, tar sands, or oil sands. Baseline category fuels may contain no elements other than carbon, hydrogen, oxygen, nitrogen, and sulfur; and the oxygen content must be less than 1.0% by weight. Fuels and fuel groups in the non-baseline diesel fuel category are derived from sources other than those listed for the baseline category or contain 1.0% or more oxygen by weight, or both. Fuels and fuel groups in the atypical diesel fuel category contain one or more elements other than carbon, hydrogen, oxygen, nitrogen, and sulfur.

U.S. EPA regulation (40 CFR 80.29) prohibits the sale or supply of diesel fuel for use in on-road motor vehicles, unless the diesel fuel has a sulfur content, by weight, no greater than 500 parts per million (ppmw). In addition, the regulation prohibits on-road motor-vehicle diesel fuel, unless the diesel fuel has a cetane index of at least 40 or has an aromatic hydrocarbon content of no greater than 35%, by volume (vol. %). All on-road motor-vehicle diesel fuel sold or supplied in the United States, except in Alaska, must comply with these requirements. Diesel fuel, not intended for on-road motor-vehicle use, must contain dye solvent red 164.

On May 13, 1999, in anticipation of Tier 2 emission standards for passenger cars and light trucks, U.S. EPA published its Advance Notice of Proposed Rulemaking (ANPRM) – Control of Diesel Fuel Quality (Federal Register pp. 26142-26158). The ANPRM solicited comment on all potentially beneficial diesel fuel quality changes, but pointed to fuel desulfurization for the purpose of enabling new engine and after-treatment technologies that are sensitive to sulfur compounds in the exhaust stream. For example, oxidation catalysts, which are a proven technology already in widespread use on diesel engines, promote the conversion of oxides of sulfur (SOx) to particulate sulfates. The recently developed continuously regenerating PM filter has shown considerable promise for light-duty diesel applications due to its ability to regenerate even at fairly low exhaust temperatures. However, these systems are fairly intolerant of fuel sulfur and are effectively limited to use with diesel fuel of less than 50-ppmw sulfur. Diesel-engine after-treatment control technologies for oxides of nitrogen (NOx) may require fuel sulfur levels of five ppmw or less.

Any emission control technologies that prove effective in light-duty, on-road diesel applications are likely to be effective with heavy-duty, on-road engines as well. Eventually, these advanced technologies could also find application in off-road equipment. U.S. EPA is considering regulating off-road diesel fuel temporarily to a quality similar to that of current, on-road motor-vehicle diesel fuel. This would provide for the transfer of advanced on-road engine technologies already under development for use with that fuel.

In its notice of Proposed Rulemaking (NPRM) – Control of Air Pollution from New Motor Vehicles: Proposed Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements (Federal Register pp. 35430-35559; June 2, 2000), U.S. EPA proposes regulations which would require that all diesel fuel sold for use in on-road vehicles have a sulfur content no greater than 15 ppmw, beginning June 1, 2006. U.S. EPA estimates that the overall cost, associated with lowering the sulfur cap from the current level of 500 ppmw to the proposed level of 15 ppmw, would be approximately $0.03 to $0.04 per gallon.

2. ARB Regulations

All diesel fuel sold or supplied in California for motor-vehicle use must have a sulfur content of 500 ppmw or less (13 CCR 2281). In addition, the average aromatic hydrocarbon content of motor-vehicle diesel fuel produced for sale in California, except that produced by California small refiners, must not exceed 10% by volume, unless the fuel is produced as an ARB-certified alternative formulation (13 CCR 2282). The average aromatic hydrocarbon limit for small refiners is 20% by volume. About 90% of the diesel fuel sold or supplied in California meets these "CARB Diesel" requirements. Only marine vessels and locomotives are currently totally exempt from the requirements. Stationary engines are exempt from the state requirements, but may be required under local district rules to use CARB Diesel. Portable engines registered under a Statewide Portable Equipment Registration Program are also required to use CARB Diesel (13 CCR 2456(e)(2)).

About seven million gallons of CARB Diesel are consumed in California each day. The fuel is produced at 12 California refineries, operated by five major refining companies, two large independent refiners, and two small refiners. The ARB has certified a total of 25 alternative formulations, including six for small refiners, 1 for a small refiner no longer in business. Five of the alternative formulations have been authorized for full public disclosure. The specifications of the five public alternative formulations are tabulated on the next page. Also shown are some of the specifications of the general reference fuel, against which the alternative formulations must be emission-tested in order to demonstrate equivalency. The small refiner reference fuel has different specification limits for aromatic (20 vol. %), polycyclic aromatic (4 wt. %), and nitrogen (90 ppmw) contents, as well as natural cetane number (47). The reference fuels are produced from straight-run California diesel fuel by a hydrodearomatization process and contain no additives for cetane boosting.

Summary of Public Alternative Formulation and General Reference Fuel Specifications

ARB Executive Order No.	Fuel Id. Number	Max. Aromatic Content	Maximum Polycyclic Aromatics	Minimum Cetane No. w/ Additives	Max. Nitrogen Content	Max. Sulfur Content
G-714-001	Chevron D4781	19 wt. %	2.2 wt. %	58	484 ppmw	54 ppmw
G-714-003	Chevron D4922	19 wt. %	4.68 wt. %	59	466 ppmw	196 ppmw
G-714-006	Chevron D4988	15 wt. %	3.6 wt. %	55	340 ppmw	200 ppmw
G-714-007	ARCO D-25	21.7 vol. %	4.6 wt. %	55.2	20 ppmw	33 ppmw
G-714-008	ARCO D-26	24.7 vol. %	4.0 wt. %	56.2	40 ppmw	42 ppmw
Reference		10 vol. %	1.4 wt. %	48 (natural)	10 ppmw	500 ppmw
Average[1]		15.8 vol. %	2.5 wt. %	54	156 ppmw	141

[1] Volume-weighted average properties from California refiner survey taken by the California Energy Commission (CEC) in summer 1997.

In February of 2000, the ARB approved a Fleet Rule for Urban Transit Bus Operators (13 CCR 1956.2). To reduce public exposure to diesel PM, transit agencies and companies that lease buses to transit agencies must participate in a program to retrofit diesel buses in their fleets, and to operate their diesel buses on very low-sulfur diesel fuel. Beginning July 1, 2002, transit agencies shall not operate diesel buses on diesel fuel with a sulfur content in excess of 15 ppmw. ARB staff has estimated an incremental refining cost of less than $0.05-per-gallon to produce this fuel. In fact, compliance sampling and analysis indicates that diesel fuel meeting this requirement has already been marketed in California for general use. Three of the major refining companies, which produce over 70% of the CARB diesel, have expressed support for the Fleet Rule and its requirement for very low-sulfur diesel fuel. About 20% of the motor-vehicle diesel fuel currently produced in California meets the 15-ppmw sulfur limit.

In a February 18, 2000 letter to Mr. Robert Perciasepe, U.S. EPA's Assistant Administrator for Air and Radiation; Chairman Alan Lloyd of the ARB urged U.S. EPA to "adopt a nationwide cap on sulfur in diesel fuel of no greater than 15 parts per million for on-road and off-road engines effective no later than 2006."

C. Other Diesel Fuel Specifications and Properties

ASTM D 975, Standard Specification for Diesel Fuel Oils, covers five grades of diesel fuel oils suitable for various types of diesel engines. Grade No. 2-D is a general-purpose, middle distillate fuel for automotive diesel engines, which is also suitable for use in non-automotive applications, especially in conditions of frequently varying speed and load. Grade No. 1-D is a light distillate fuel for automotive applications requiring higher volatility; and Grade No. 4-D is a heavy distillate fuel for low- and medium-speed, non-automotive applications, involving predominantly constant speed and load. ASTM D 975 also covers Grade Low Sulfur No. 1-D and Grade Low Sulfur No. 2-D. The low-sulfur grades comply with the Clean Air Act and 40 CFR Part 80 – Regulation of Fuels and Fuel Additives: Fuel Quality Regulations for Highway Diesel Fuel Sold in 1993 and Later Calendar Years.

About 100% of the diesel fuel sold in California is Grade Low Sulfur No. 2-D. An abbreviated table of ASTM requirements for Grade Low Sulfur No. 2-D is presented on the next page. Grade Low Sulfur No. 1-D may become more prevalent in the future if cleaner burning diesel fuel is required. The table shows the specifications of Grade Low Sulfur No. 1-D which differ from the specifications of Grade Low Sulfur No. 2-D.

Flash point is the lowest fuel temperature, corrected to standard barometric pressure, at which application of an ignition source causes the fuel vapors to ignite. The flash point is not directly related to engine performance, but is important for legal requirements and safety precautions involved in fuel handling and storage, and is normally specified to meet insurance and fire regulations.

Cloud point is of importance in that it defines the highest temperature at which a cloud or haze of wax crystals appears in the fuel under prescribed test conditions. The temperature generally relates to the temperature at which wax crystals begin to precipitate from the fuel in use. See table note 1.

The distillation temperature at which 90% of volume is recovered (T_{90}) is a measure of fuel volatility; the lower the T_{90}, the more volatile the fuel. For engines in services involving rapidly fluctuating loads and speeds, as in bus and truck operation, the more volatile fuels generally provide better performance, particularly with respect to smoke and odor. However, better volumetric fuel economy (VFE) is generally obtained from the less volatile types of fuels because of their higher densities and higher volumetric energy contents.

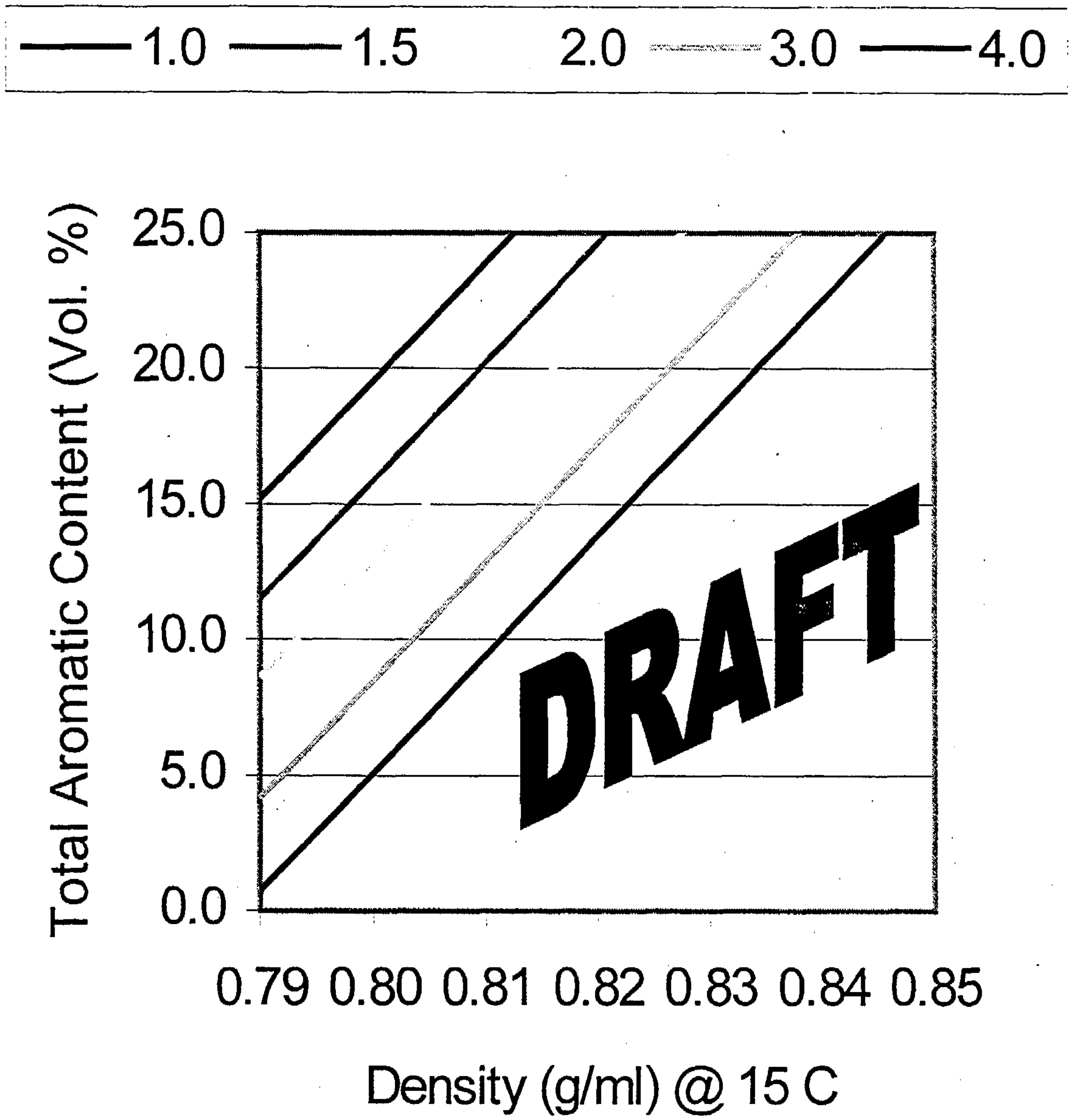
Abbreviated Table of ASTM D 975 Requirements for Grade Low Sulfur Fuels

Property	ASTM Test Method	Grade Low Sulfur No. 2-D	Grade Low Sulfur No. 1-D
Flash Point, Minimum	D 93	52 °C (126 °F)	38 °C (100 °F)
Cloud Point, Maximum	D 2500	[1]	[2]
Distillation Temperature at 90 % Volume Recovered, Minimum / Maximum	D 86	282 °C (540 °F) / 338 °C (640 °F)	No Minimum / 288 °C (550 °F)
Kinematic Viscosity At 40 °C (104 °F), Minimum / Maximum	D 445	1.9 cSt (11 in^2/hr) / 4.1 cSt (23 in^2/hr)	1.3 cSt (7 in^2/hr) / 2.4 cSt (13 in^2/hr)
Cetane Number, Minimum	D 613	40	[2]
Cetane Index, Minimum, or Aromatic Hydrocarbon Content, Maximum	D 976 or D 1319	40 or 35 vol. %	[2]
Sulfur Content, Maximum	D 2622	0.05 wt. % (500 ppmw)	[2]

[1] Satisfactory operation should be achieved in most cases if the cloud point (or wax appearance point) is specified at 6 °C (11 °F) above the tenth percentile minimum ambient temperature for the area and calendar month. When a cloud point less than -12 °C (10 °F) is specified, the minimum flash point shall be 38 °C (100 °F), the minimum viscosity at 40 °C (104 °F) shall be 1.7 cSt (9.5 in^2/hr), and the minimum T_{90} shall be waived.
[2] Same as Grade Low Sulfur No. 2-D specification.

Viscosity is a measure of flow resistance; the higher the viscosity, the greater the resistance to flow. Fuel viscosity is also related to fuel density, generally the lighter fuels being less viscous and the heavier fuels being more viscous. Based on the properties of 52 finished diesel fuels and blending components, a correlation of viscosity, density, and total aromatic hydrocarbon content has been described (see figure on next page)

Diesel Fuel Correlation of Total Aromatic Content, Density and Viscosity (cSt) @ 40 C



Fuel viscosity requirements are pertinent to the design of fuel-metering and fuel-injection equipment, which must accurately meter and precisely inject a small quantity of fuel. Since viscosity is temperature-dependent, the fuel tolerance band between maximum and minimum viscosity should be kept as small as practicable to avoid loss of performance under extreme conditions. At low temperature, viscosity reduces fuel flow rates; and a high-viscosity fuel may result in incomplete filling of the metering chamber and an inadequate volume of fuel being injected. A low-viscosity fuel in high-temperature, low-speed operation could result in unacceptable clearance leakage from the pumping elements; making "hot restarting" impossible until the fuel system has cooled down. Fuel viscosity also affects injector-spray penetration rate, cone angle, and drop-size distribution.

Cetane number is a measure of the ignition quality of the fuel and influences combustion roughness. The cetane number requirements depend on engine design, size, nature of speed and load variations, and on starting and atmospheric conditions. A cetane number too low can result in poor combustion and high emissions under transient cycle operation. Cetane number can be increased through the use of ignition improvement additives such as 2-ethyl hexyl nitrate. Cetane index is an estimate of the natural cetane number of the fuel, and is calculated based on the fuel's density and mid-boiling temperature (T_{50}) (an updated ASTM method additionally uses the T_{10} and T_{90}).

The aromatic hydrocarbon content (aromaticity) of diesel fuel has a great influence on fuel quality. Aromatic compounds have high liquid densities. Monocyclic compounds have relatively low boiling points; polycyclic compounds have relatively high boiling points. Aromatic compounds are also relatively refractory to combustion. High aromaticity generally means high volumetric energy content, high combustion temperatures, poor combustion (ergo, low natural cetane number), and high emissions.

Fuel sulfur content can affect engine wear, deposit formation, and emission performance. Fuel sulfur that is not deposited within the fuel system, engine, or exhaust system is emitted as sulfurous compounds, such as gaseous sulfur dioxide (SO_2) and particulate sulfates (SO_4^{2-}). Sulfur compounds in engine exhaust can also reduce the effectiveness of emission control equipment.

ASTM D 975 also addresses fuel lubricity, but does not currently include a standard for fuel lubricity. Two fuel characteristics, which affect fuel lubricity and equipment wear, are fuel viscosity and the amounts of trace fuel components which have an affinity for metal surfaces. Fuel lubricity is a concern when fuels with lower viscosities than what is specified for a particular engine are used, or when fuels are used which have been processed in a manner that results in the elimination of the surface active species, which act as lubricating agents. Fuels, which have been shown to have lubricity problems, are fuels, which have been severely hydro-treated to remove sulfur and reduce aromaticity. This effect can be counteracted with the use of lubricity improvement additives.

Work in the area of diesel fuel lubricity has been ongoing by several organizations, such as the International Standard Organization (ISO) and the ASTM Diesel Fuel Lubricity Task Force. The charge of the ASTM task force is the recommendation of lubricity test methods and a fuel lubricity specification for D 975. Test Methods D 6078, a scuffing load ball-on-cylinder lubricity evaluator (SLBOCLE) method, and D 6079, a high frequency reciprocating rig (HFRR) method, were proposed and approved by the task force. Both methods in their current forms do not apply to all fuel-additive combinations.

Further research is required before the task force can recommend a lubricity specification. SAE Technical Paper 952369 indicates that fuels with scuffing load values below 2000 g in Test Method D 6078 will probably cause accelerated wear in fuel-lubricated, rotary-type fuel injection pumps. Work at ISO, documented in SAE Technical Paper 952372, indicates that fuels with Test Method D 6079 wear-scar diameters of 450-micron, or less, at 60 °F (380-micron, or less, at 25 °C) should protect all fuel injection equipment.

Unspecified properties of No. 2 diesel fuel include density, lower heating value (LHV), and volumetric energy content. A summary of composition and property ranges is tabulated below for No. 2-D. The ranges may be narrower for Grade Low Sulfur or other cleaner burning No. 2-D fuels.

Summary of Composition and Property Ranges for No. 2-D

Molecular Formula	C_8 to C_{25}
Carbon Content (wt. %)	84 to 87
Hydrogen Content (wt. %)	13 to 16
Boiling Temperature (°F)	370 to 650
API Gravity	27 to 43
Specific Gravity @ 60 °F/ 60 °F	0.81 to 0.89
Density (lb/gal) @ 60 °F	6.7 to 7.4
Lower Heating Value (Btu/lb)	18,000 to 19,000
Volumetric Energy Content (Btu/gal)	126,000 to 130,800

Fuel Density (g/ml) @ 15 °C ≈ Specific Gravity @ 60 °F/ 60 °F = 141.5 ÷ (131.5 + API Gravity)

III. FUEL OPTIONS

A review of engine emission testing programs for fuel property effects on heavy-duty diesel (HDD) emissions, based on both transient-cycle and steady-state testing, indicates that six properties of diesel fuel have some influence on HDD emissions. The properties studied were sulfur content, aromatic hydrocarbon content, polycyclic (or polynuclear) aromatic hydrocarbon (PAH) content, cetane number, density, and volatility. Another property, which may influence HDD emissions, is oxygen content. In this report we discuss this property effect under "Alternative Diesel Fuels," as it may properly relate to the specific oxygenated component of the fuel.

A. Reformulated and Synthetic Diesel Fuels

Studies indicate generally that reducing sulfur, aromatic, and PAH contents; increasing cetane number and back-end volatility; and decreasing the density of diesel fuel causes reductions in diesel PM and NOx emissions. These property changes generally cause favorable or neutral behavior with respect to gaseous hydrocarbon (HC) and carbon monoxide (CO) emissions, with the exception that these emissions generally behave oppositely with respect to back-end volatility and fuel density. Overall, the fuel property effects on HDD emissions are generally more pronounced in higher-emitting engines. Also, the greatest absolute and relative emission reductions can of course be achieved relative to a fuel with high-emitting properties.

CARB diesel and its alternative formulations have low-emitting properties; except that volatility and density are essentially unregulated aspects of the basic property requirements or equivalency determinations. The T_{90} of the reference fuel may vary from 550 to 610°F (288 to 321°C) and the API gravity of the reference fuel may vary from 33 to 39 (0.83 to 0.86 g/ml). The specifications for alternative formulations are not required to include volatility or density specifications.

Swedish Urban Diesel and ARCO's Emission Control – Diesel (EC-D) are reformulated diesel fuels which are refined from crude. Syntroleum's ultra-low-aromatic synthetic diesel fuel is synthesized from natural gas by the Fischer-Tropsch (F-T) process. All of these fuels should perform similarly to ASTM Grade No. 1-D fuel. All of these fuels have properties which, when compared to CARB diesel, are consistent with the six property changes discussed previously, and which combined should reduce diesel PM, NOx, HC, and CO emissions overall.

Of the six fuel properties, which have been identified as influencing HDD emissions; only sulfur content, aromatic hydrocarbon and PAH contents, and fuel density significantly affect diesel PM emissions.

1. Very low-sulfur CARB Diesel

Sulfur in diesel fuel results in proportional amounts of engine-out SOx and particulate sulfate emissions. Reducing sulfur levels below the CARB Diesel average sulfur content of 141 ppmw in the absence of exhaust after-treatment, is expected to have an impact on diesel PM emissions. An U.S. EPA on-road emission model predicts that reducing sulfur content from 141 ppmw to 15 ppmw would reduce SOx emissions (as SO_2) by 0.11 grams per pound (g/lb) of fuel, and would reduce diesel PM emissions (as $H_2SO_4 : 7H_2O$) by 0.0080 g/lb of fuel. The SOx emission reductions would reduce atmospheric sulfate formation (as half NH_2SO_4 and half NH_4HSO_4) by 0.026 g/lb of fuel. These differences are approximately equal to FTP-cycle specific emission reductions of 0.016 grams per brake horsepower-hour (g/bhp-hr) for SOx, 0.0040 g/bhp-hr for diesel PM, and 0.013 g/bhp-hr for indirect sulfate. Based on the U.S. EPA model, reducing fuel sulfur from 141 ppmw to 15 ppmw would reduce diesel PM emissions by about 4% from engines with FTP-cycle specific emission rates of 0.1 g/bhp-hr. (A reduction from 500 ppmw to 5 ppmw would result in about a 16% reduction from 0.1 g/bhp-hr.) At 15-ppmw sulfur, the residual engine-out SOx and particulate sulfate emissions would be 0.013 g/lb of fuel and 0.0010 g/lb of fuel, respectively. These emission ratios are approximately equal to FTP-cycle specific emissions of 0.007 g/bhp-hr for SOx and 0.0005 g/bhp-hr for particulate sulfate (see table).

Fuel Sulfur Content, Predicted Engine-Out Sulfur Compound Emissions, and Predicted Atmospheric Sulfate Formation

Fuel Sulfur (ppmw)	SOx Emissions (g/lb)[1]	SOx Emissions (g/bhp-hr)[2]	Sulfate Emissions (g/lb)[1]	Sulfate Emissions (g/bhp-hr)[2]	Indirect Sulfate (g/lb)[1]	Indirect Sulfate (g/bhp-hr)[2]
500	0.44	0.22	0.032	0.016	0.10	0.051
368	0.33	0.16	0.023	0.012	0.075	0.038
141	0.13	0.063	0.0090	0.0045	0.029	0.014
54	0.048	0.024	0.0034	0.0017	0.011	0.0055
15	0.013	0.0067	0.0010	0.00048	0.0031	0.0015
5	0.0044	0.0022	0.0003	0.00016	0.0010	0.00051

[1] Predicted with U.S. EPA on-road emission model.
[2] FTP-cycle emissions if brake specific fuel consumption (BSFC) is 0.5 lb/bhp-hr.

2. Impact of Sulfur on After-Treatment Technology

a) MECA Demonstration Results

The impact of sulfur content on diesel PM emissions varies widely depending on whether exhaust after-treatment is used and what type of after-treatment is used. A 1999 report by the Manufacturer of Emission Controls Association (MECA), *Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Low Emission Levels*, compares emissions from a 1998-model, Detroit Diesel Corporation (DDC) series-60 engine with various after-treatments and for fuels with different sulfur contents. One of the fuels contained 368 ppmw sulfur and another contained 54 ppmw sulfur; other properties of the fuels were not the same. The lower-sulfur fuel yielded fuel-effect diesel PM emission reductions of approximately 14% with no after-treatment to 72% for after-treatment with a catalyst-coated diesel particulate filter (DPF-A). Some of the reduction in baseline (without after-treatment) emissions may have been due to other property differences of the fuels; however, the U.S. EPA on-road emission model predicts an emission difference of about 0.01 g/bhp-hr due to sulfur alone. Two medium-activity diesel oxidation catalysts (DOC-B and DOC-E) and one high-activity diesel oxidation catalyst (DOC-F) were also tested with the two fuels. Improved after-treatment control efficiency was consistently demonstrated with the lower-sulfur fuel (see table).

MECA Demonstration Results

After-Treatment	368 ppmw sulfur Fuel g/bhp-hr[1]	368 ppmw sulfur Fuel % Reduction[2]	54 ppmw sulfur Fuel g/bhp-hr[1]	54 ppmw sulfur Fuel % Reduction[2]	Fuel Effect % Reduction
Baseline	0.073	--	0.063	--	14
DOC-B	0.054	26	0.043	32	20
DOC-E	0.053	27	0.045	29	15
DOC-F	0.077	-5	0.053	16	31
DPF-A	0.022	70	0.0062	90	72

[1] Federal test procedure (FTP)-cycle diesel PM emissions.
[2] Reduction from baseline diesel PM emissions.

With catalytic after-treatment, SO_2 in the engine exhaust can be oxidized to SO_3, which condenses with water. The condensed SO_3 increases the particulate mass, offsetting the reduction of other particulate components. For this reason, reducing fuel sulfur improves after-treatment effectiveness and reduces diesel PM emissions. Very low-sulfur fuel would allow after-treatment manufacturers to use more highly active catalysts, which operate effectively at lower temperatures and have a broader range of vehicle applications.

b) DECSE Program's DPF Results

The United States Department of Energy (DOE), the Engine Manufacturers Association (EMA), and MECA have been conducting a joint test program to evaluate four levels of diesel sulfur (350, 151, 30, and 3.1 ppmw) with four types of after-treatment technologies. Tabulated below are some of the data from this Diesel Emission Control – Sulfur Effects (DECSE) Program's *Phase I Interim Data Report No. 4: Diesel Particulate Filters – Final Report.*

A Caterpillar 3126 engine rated at 205 kW (275 horsepower) and equipped with electronic controls was used for the DPF tests. The 3126 engines are typically used for applications that result in relatively low-temperature exhaust (e.g, below 300 °C (572 °F)). Because fuel sulfur level is expected to affect the filter regeneration temperature, these low-temperature applications are an excellent test of the effects of fuel sulfur level. Two different DPFs were tested; one catalyzed (catalyst-coated) DPF (CDPF) and one continuously regenerating DPF (CR-DPF). The CR-DPF has an upstream oxidation catalyst, which generates NO_2 to oxidize the filter-collected diesel PM. Emissions were sampled for Organisation Interntionale des Constructeurs d'Automobiles (OICA) 13- mode, peak-torque, and "road-load" steady-state engine tests.

DECSE Program's DPF Results

Steady-State Test	After-treatment Device	Diesel PM Emissions (g/bhp-hr)			Efficiency (% Reduction)		Sulfur Effect (% Reduction)	
		151 ppmw	30 ppmw	3.1 ppmw	30 ppmw	3.1 ppmw	30 ppmw	3.1 ppmw
OICA 13-Mode	Eng.-out	0.0708	0.063	0.0613	--	--	11	13
	CDPF	0.0707	0.0166	0.0031	74	95	77	96
	CR-DPF	0.0729	0.0176	0.0032	72	95	76	96
Peak-Torque Mode	Eng.-out	0.0563	0.0489	0.043	--	--	13	24
	CDPF	0.046	0.0137	0.0031	72	93	70	93
	CR-DPF	0.0456	0.0133	0.0039	73	91	71	91
Road-Load Mode	Eng.-out	0.0459	0.0414	0.041	--	--	10	11
	CDPF	0.0574	0.0082	0.0026	80	94	86	95
	CR-DPF	0.0637	0.008	0.0012	81	97	87	98

We have assumed the 151-ppmw-sulfur data as the baseline for sulfur effects on diesel PM emissions. The DPF data for the 350-ppmw-sulfur fuel indicate significant diesel PM increases due to catalytic sulfate generation. Carbon monoxide emission reductions of 90% or more, and hydrocarbon emission reductions of over 50%, were achieved for all fuel sulfur levels and engine tests with both DPFs.

3. Other Reformulation Options

Aromatic-hydrocarbon-content, PAH-content, and fuel-density limits should help to control diesel PM emissions; however, more data on emission effects on the various engines and run cycles are needed to determine what the limits should be.

4. Swedish Urban Diesel Fuels

In 1991, Sweden introduced new environmental classifications for diesel fuels, with tax incentives to encourage their use. The revised specifications for Swedish Urban Diesel Fuels, issued in 1992, are tabulated here.

Revised Specifications for Swedish Urban Diesel Fuels

Property	Limit	Swedish Class 1	Swedish Class 2
Sulfur (ppmw)	Maximum	10	50
Aromatic Content (vol. %)	Maximum	5.0	20
PAH Content (vol. %)	Maximum	0.02	0.1
Initial Boiling Point (°C)	Minimum	180	180
T_{95} (°C)	Maximum	285	295
Density (g/ml)	Range	0.800 to 0.820	0.800 to 0.820
Cetane Index	Minimum	50	47

A concern was identified that Swedish Class 1 and Class 2 fuels may cause premature injection-pump wear due to their low lubricity characteristics; however, testing has shown that Class 1 fuel, enhanced with a lubricity additive, performs without problems.

5. ARCO's Emission Control – Diesel

ARCO has developed diesel fuel called Emission Control – Diesel that results in substantially lower exhaust emissions compared to a CARB Diesel fuel blend. EC-D has a very low-sulfur content, low aromatic and PAH contents, a high natural cetane number, and low density. EC-D is produced from typical crude oil using a conventional refining process.

Three engines were tested in an emissions laboratory and six urban trucks and buses were tested on a heavy-duty vehicle chassis dynamometer. Initial test results indicate that EC-D reduces regulated emissions while maintaining fuel economy, compared to a CARB Diesel fuel blend. Averaged, the tests showed diesel PM and HC reductions of 13% each, a CO reduction of 6%, and a NOx reduction of 3%. The properties of the initial test fuels are tabulated below.

Averaged Results from Initial EC-D Test Program

Emission Reduction	
Diesel PM	13 %
HC	13 %
CO	6 %
NOx	3 %

Summary of Initial EC-D Test Program Fuel Properties

Property	**EC-D**	**CARB Blend**
Sulfur Content (ppmw)	<2	120
Aromatic Content (vol. %)	8.8	18.9
PAH Content (wt. %)	0.5	2
Natural Cetane Number	61.7	53.2
Nitrogen Content (ppmw)	1	98
API Gravity	41.5	36.3
Specific Gravity	0.818	0.843
Cloud Point (°F)	32	10.4
Initial Boiling Point (°F)	386	358

As discussed previously, very low-sulfur fuels such as EC-D will enable the use of sulfur-sensitive emission control devices for even greater exhaust emission reductions. A technology validation program evaluating EC-D and regenerative DPF technology on urban diesel vehicles has been initiated. The fuel's impacts on engine durability, vehicle performance, and emissions will be evaluated in eight truck and bus fleets. Currently, 184 trucks and buses are participating in the test program, 74 (40%) of which will be retrofitted with regenerative DPFs. So far, no significant maintenance issues have been reported for school bus, tanker truck, and grocery truck fleets, which have been participating in the program for over six months. Preliminary test results indicate that the EC-D with DPFs reduces diesel PM emissions by over 90%. The properties of the program test fuels are tabulated below.

Summary of Current EC-D Test Program Fuel Properties

Property	EC-D	CARB Blend
Sulfur Content (ppmw)	7.4	121.1
Aromatic Content (vol. %)	10.9	22.5
PAH Content (wt. %)	0.9	4.1
Natural Cetane Number	64.7	54.1
API Gravity	42.8	36
Density @ 15 °C (g/ml)	0.8119	0.8445
Energy Content (Btu/gal)	126,300	130,000
Cloud Point (°F)	27	16
Initial Boiling Point (°F)	412.8	351.7
T_{10} (°F)	445.4	409.0
T_{50} (°F)	526.1	525.4
T_{90} (°F)	610.9	622.7
Final Boiling Point (°F)	656.2	664.9

The averaged preliminary emission test results for two school buses and two tanker trucks are tabulated below. The vehicles were tested on a heavy-duty chassis dynamometer over a City-Suburban Heavy Vehicle Route (CSHVR) driving schedule. Averaged results of testing, prior to DPF installation, indicate NOx and diesel PM emission reductions, due to EC-D alone, of 10 and 15% for the buses and 11 and 3% for the trucks. The VFE decrease observed with EC-D, approximately 3%, was about equal to the difference in volumetric energy contents between the EC-D test fuel and the CARB blend.

Averaged Preliminary Results from Current EC-D Test Program

Vehicle Type	Fuel/ DPF	NOx		CO		HC		Diesel PM		VFE	
		g/mi	%Δ	g/mi	%Δ	g/mi	%Δ	g/mi	%Δ	mpg	%Δ
Bus	CARB	20.19	--	2.51	--	0.55	--	0.218	--	4.70	--
Bus	EC-D	18.12	-10	2.25	-10	0.48	-13	0.186	-15	4.57	-2.8
Bus	w/ DPF	16.25	-20	0.15	-94	0.00	-99>	0.000	-99>	4.79	1.9
Truck	CARB	16.46	--	3.13	--	1.35	--	0.581	--	5.55	--
Truck	EC-D	14.66	-11	2.89	-8	1.24	-8	0.562	-3	5.36	-3.4
Truck	w/ DPF	13.93	-15	0.32	-90	0.11	-92	0.026	-96	5.24	-5.6

6. Ultra-Low-Aromatic Synthetic Diesel Fuel

Fischer-Tropsch is a gas-to-liquid chemical conversion process that is being successfully used to produce high quality gasoline and diesel fuel products from coal, natural gas, and biomass feedstocks. The process originates from Franz Fischer and Hans Tropsch, who patented the synthesis of petroleum at normal pressure using metal catalysts in 1926. In the Syntroleum Process, sulfur is first removed from natural gas. Then, the natural gas is reformed with air, producing a nitrogen-diluted synthesis gas containing mostly CO and H_2. A cobalt-based F-T catalyst is used to reassemble the synthesis gas molecules into highly saturated synthetic oil and by-product water. The principal products are iso- and normal paraffins, along with minor amounts of simple olefins and primary alcohols. These few olefins and alcohols are removed by mild hydrosaturation, leaving very-low-aromatic, super-very low-sulfur synthetic diesel fuel. Fischer-Tropsch fuels may require a lubricity additive to prevent undue fuel-injection system wear. A commercially available lubricity additive has been found to be effective.

Three different F-T diesel fuels have been tested against a CARB Diesel fuel with properties of the general reference fuel, following a procedure similar to the CARB procedure for evaluation of alternative formulations. On average, the testing showed emission reductions, compared to the CARB fuel, of 4% for NOx, 36% for CO, 20% for HC, and 26% for diesel PM (see table). Averaged properties of the three F-T fuels and the properties of the CARB fuel are also shown below.

Averaged Emission Reductions Due to Three F-T Test Fuels

Emission Reduction	
NOx	4 %
CO	36 %
HC	20 %
Diesel PM	26 %

Averaged Properties of Three F-T Test Fuels and Properties of CARB Test Fuel

Property	F-T	CARB
Sulfur Content (ppmw)	0	345
Aromatic Content (vol. %)	0	10
Cetane Number	74	50
Specific Gravity @ 60 °F/ 60 °F	0.769	0.842
Kinematic Viscosity @ 40 °C (cSt)	1.58	2.79
Cloud Point (°F)	-9	4
Flash Point (°F)	144	180

Four trucks, White-GMC WG64T class-8 tractors (80,000-lb gross vehicle weight), with 1996- and 1997-model Caterpillar 3176B, 350-hp diesel engines were tested with a F-T fuel and a CARB Diesel fuel on a heavy-duty chassis dynamometer. Emission reductions with the F-T fuel averaged 12% for NOx, 18% for CO, 40% for HC, and 24% for diesel PM (see table on next page). Based on the volumetric energy contents of the two fuels, a VFE reduction of about 3.4% was predicted for the F-T fuel.

The test average reduction was 2.4%. Drivers could not detect a performance difference between trucks operating on the F-T fuel and the CARB Diesel. Properties of the two fuels are summarized below.

Summary of Chassis Dynamometer Emission Results for F-T and CARB Fuels

Average Values	CARB	F-T	% Reduction
NOx (g/mi)	13.4	11.7	12
CO (g/mi)	3.99	3.27	18
HC (g/mi)	0.67	0.40	40
Diesel PM (g/mi)	0.48	0.37	24
VFE (mpg)	5.95	5.81	2.4

Summary of F-T and CARB Test Fuel Properties

Property	**F-T**	**CARB**
Sulfur Content (ppmw)	< 5	100
Aromatic Content (vol. %)	0.1	17.9
Cetane Number (Index)	> 74	(53.7)
Specific Gravity @ 60 °F/ 60 °F	0.7845	0.8337
Volumetric Energy Content (Btu/gal)	123,600	127,900
Initial Boiling Point (°F)	410	347
T_{10} (°F)	500	415
T_{50} (°F)	572	514
T_{90} (°F)	628	630
Final Boiling Point (°F)	640	685

B. Alternative Diesel Fuels

The fuels discussed in this section contain oxygenated components or consist of oxygenated chemical compounds.

1. Fuel/water Emulsions

A-55, Incorporated, has patented diesel/water and naphtha/water emulsion fuels for use in compression ignition (CI or diesel) engines. The diesel/water fuel patented by A-55 consists of about 30% water and about 70% petroleum diesel. Small amounts (less than 1%) of a proprietary additive are included to maintain the emulsion, enhance the lubricity, inhibit corrosion, protect against freezing, and limit foaming potential. The diesel fraction of the emulsion can be either a naphtha cut or finished diesel fuel.

The presence of water in the emulsion reduces both diesel PM and NOx emissions in diesel engines. The water causes lower combustion temperatures, which reduces NOx emissions. The NOx emissions reductions increase as the water content of the emulsion increases. Also, for a given water content, the NOx reductions are greater for diesel/water emulsions than for diesel/naphtha emulsions. The water also produces a different combustion pattern, which causes the carbon in the fuel to burn more completely, producing lower diesel PM emissions. Tests in a transit bus showed

NOx reductions of 53% and diesel PM reductions of 20%. More recent tests on a 1999 diesel pickup showed NOx reductions of 26% and diesel PM reductions of 22%.

There does not appear to be any loss in engine power or degradation in performance from the use of diesel/water or naphtha/water emulsions. Testing has shown that power and torque curves with the emulsions are comparable to those of No. 2-D fuel. Peak cylinder pressures are also comparable. Diesel/water emulsions appear to result in slightly greater thermal efficiency. The presence of water decreases the volumetric energy content, which is translated into a reduction in VFE (miles per gallon). However, there appears to be little difference, or perhaps a slight increase, in the fuel economy, on a miles-per-BTU basis with the emulsion. Because of the reduced volumetric fuel economy, the range is reduced. Also, on some applications, the volumetric flow rate to the engine is increased, necessitating modifications to the fuel metering system. The need for these modifications is an obstacle that has to be overcome before diesel/water emulsions could be considered feasible on a widespread basis for all diesel vehicles.

The use of diesel/water and naphtha/water emulsions has been demonstrated in some bus fleet applications. The regional transit agency in Reno had three urban transit buses operating on diesel/water and naphtha/water emulsions, and the Washoe County School District became the first school district to approve the use of the fuels in four school buses. More recently, two para-transit buses in Sacramento were operated on A-55.

The Lubrizol Corporation has also been developing diesel/water emulsions for use in diesel engines. Lubrizol calls its fuel PuriNOx Performance Systems fuel (PuriNOx). PuriNOx is a diesel/water emulsion in which the diesel fuel is the continuous phase and the water is emulsified. The water content of PuriNOx is about 20% and the diesel fuel content is about 80%. Surfactants and other additives make up less than 1%. Lubrizol has reported a NOx reduction of 15%, and a diesel PM reduction of 51%, in eight-mode emission testing of PuriNOx in an eight cylinder, 34.5-liter diesel engine. The table below summarizes the reported emission reductions.

Emission Reductions from Engine Testing of PuriNOx

Pollutant	Reduction (%)
NOx	15
THC	14
CO	9
Diesel PM	51

Lubrizol has also conducted a chassis dynamometer test on a Euro II Olympian bus in which PuriNOx was used in combination with a diesel oxidation catalyst. Over the Millbrook London Transport Bus (MLTB) Cycle, the combined use of the diesel oxidation catalyst and PuriNOx achieved a NOx reduction of 21% and a diesel PM reduction of 70%. The baseline diesel fuel and the emulsion-base diesel fuel were the same, and had a sulfur content of less than 50 ppmw and a T_{95} of less than 345 °C. The table below summarizes the observed emission reductions.

Emissions and Emission Reductions from Chassis Testing of a Bus with Diesel Oxidation Catalyst and PuriNOx

Pollutant	Baseline Emissions (g/km)	Emissions w/ DOC+PuriNOx (g/km)	Emission Reduction (%)
NOx	14.0	11.1	21
THC	0.654	0.055	92
CO	1.516	0.046	97
Diesel PM	0.182	0.055	70

In summary, diesel/water and naphtha/water emulsions have promise for applications where central fueling facilities exist. Fleet applications such as transit buses and school buses are examples of such applications.

2. Ethanol-Diesel Micro-Emulsions

Emulsions between ethanol and diesel recently have shown promise as an emission reduction technology for diesel engines. In ethanol-diesel emulsions, globules of ethanol are dispersed within the diesel fuel. Most of the research to date has focused on formulations with aqueous ethanol, that is, solutions of water and ethanol. The aqueous ethanol content of the emulsions is typically 12 to 24% by weight. A stable emulsion is maintained with the presence of surfactants, which contain polar and non-polar ends. The polar ends point towards the interior of the globules where the ethanol molecules are found, while the non-polar ends point to the area between the globules where the diesel compounds are found. The globules in ethanol-diesel emulsions tend to be smaller than those found in fuel/water emulsions. Hence they are referred to as micro-emulsions, as opposed to macro-emulsions. Micro-emulsions are clear, temperature-stable formulations that can be handled the same way as diesel fuel.

Ethanol-diesel emulsions are being developed as a strategy for diesel PM and NOx emission reductions. NOx reductions are achieved as a result of lower combustion temperatures. The combustion temperatures are reduced as a result of the high heats of vaporization of ethanol and water. The diesel PM emissions are reduced as a result of a phenomenon referred to as steam explosion. Steam explosion refers to the sudden vaporization and expansion of the water within the globules. This vaporization better atomizes the fuel, which promotes complete combustion. The emission reduction effects of water and ethanol are proportional to their concentration. So-called "first generation" formulations of ethanol-diesel emulsions reduced diesel PM emissions by approximately 40% and NOx emissions by approximately 10%. "Second generation" formulations incorporating several refinements increased the NOx reduction somewhat, but decreased the diesel PM reductions. Further work is being done to obtain the optimum formulation for combined NOx and diesel PM reductions. Some tests have shown that the use of ethanol-diesel emulsions increases emissions of some pollutants. Exhaust hydrocarbon emission increases of

20 to 50% have been measured. The presence of ethanol in the emulsion causes both formaldehyde and acetaldehyde to increase. The table below summarizes the emissions reductions from the use of ethanol-diesel emulsions.

Potential Emission Benefits of Ethanol-Diesel Fuel Emulsions

Pollutant	% Reduction
Diesel PM	30 to 40
NOx	10 to 20
CO	0 to 20
HC	-20 to -50
Formaldehyde	-170
Acetaldehyde	-75

Ethanol-diesel emulsions appear to have little effect on diesel-engine fuel economy. The volumetric energy content of ethanol-diesel emulsions is lower than that of diesel fuel. This would tend to reduce the fuel economy of ethanol-diesel emulsions. However, the thermal efficiency of an engine fueled with an ethanol-diesel emulsion is somewhat higher than with diesel fuel, and this offsets the effect of lower energy content. Consequently, the net VFEwith ethanol-diesel emulsions is about the same as with diesel fuel.

A number of companies are working to commercialize the ethanol-diesel emulsion technology. Pure Fuels USA, Incorporated, is working to find the optimum mix of ethanol, water, and diesel. They are also working to optimize the amount and type of emulsifier. The use of other additives to increase cetane number, improve NOx reductions, and lower cost is also being explored. Pure Energy Corporation has developed an additive package that allows the emulsion to be maintained at temperatures as low as 20 °F below zero. Pure Energy Corporation participated in a demonstration program by the Chicago Transit Authority in which 15 buses were operated with an ethanol-diesel emulsion.

Further development work needs to be done before ethanol-diesel emulsions can be considered a viable alternative to conventional diesel. Currently, ethanol-diesel emulsions are not cost competitive with conventional diesel, costing about $0.07 to $0.15 more per gallon to produce. Ethanol-diesel emulsions require government subsidies in the form of tax breaks to approach cost competitiveness with conventional diesel. Further fleet testing is required to demonstrate the lack of adverse, long-term engine and fuel system effects. Specifically, more information is needed on long-term lubricity and corrosion effects. Also, further optimization of the emulsifier/additive package is required. In order to optimize the total emissions reductions from diesel engines, the integrated use of ethanol-diesel emulsions in engines using exhaust gas treatment technologies needs to be demonstrated.

3. Biodiesel and Blends

Biodiesel is a mono-alkyl ester-based oxygenated fuel, a fuel made from vegetable oil or animal fats. It can be produced from oilseed plants, such as soybeans and canola, or from used vegetable oil. It has similar properties to petroleum-based diesel fuel, and can be blended into petroleum-based diesel fuel at any ratio. It is most commonly blended into petroleum-based diesel fuel at 20%. This mixture is commonly referred to as "B20". Neat biodiesel is termed B100. The use of biodiesel, neat or in petroleum-based blends, does not require modifications to the engine or fuel system.

Biodiesel is registered as a fuel and fuel additive with the United States Environmental Protection Agency. It has gone through the U.S. EPA Tier I Health Effects Testing under section 211(b) of the Clean Air Act, which provides an inventory of environmental and human health effects attributes. Recently, B100 has been classified as an alternative fuel by the United States Department of Energy, and the United States Department of Transportation.

Biodiesel has similar properties to petroleum based diesel fuel; however, there are some significant differences. Biodiesel contains 11% oxygen by weight and contains no sulfur or aromatic hydrocarbons. On a transient test cycle, fuel economy and power are about 10% lower than conventional diesel fuel; with B20 the loss is about 2%. Biodiesel has favorable lubricity characteristics, but will soften and degrade certain types of elastomers and natural rubber compounds over time. Manufacturers recommend that natural or butyl rubbers not be allowed to come in contact with pure biodiesel. Biodiesel can be stored in the same tanks as petroleum based diesel, but it has a shorter shelf life, which makes it less suitable for use in emergency generators or engines that operate infrequently.

Emission data comparing biodiesel to CARB diesel are limited, but data comparing biodiesel to conventional diesel fuel are more readily available. Compared to CARB diesel or conventional diesel fuel, the use of B100 significantly reduces diesel PM, CO, and HC, but significantly increases NOx. Also, based on Ames mutagenicity studies, B100 may provide a 90-percent reduction in cancer risk compared to conventional diesel fuel. In comparing B20 to conventional diesel fuel, the changes in emissions are directionally the same, but smaller. The table on the next page provides a summary of emission test results from the use of B100 and B20 compared to conventional diesel fuel.

Potential Emission Benefits of Biodiesel and a 20-Percent Biodiesel Blend		
Pollutant	**B100**	**B20**
NOx	+13%	+2%
Carbon Monoxide	-50%	-20%
Hydrocarbons	-93%	-30%
Particulate Matter	-30%	-22%
Sulfates	-100%	-20%*
Polycyclic Aromatic Hydrocarbons**	-80%	-13%
Nitro-PAH's**	-90%	-50%***

* Estimated from B100 result
** Average reduction across all compounds measured
*** 2-nitroflourine results were within test method variability
Source: Biodiesel Emissions, Fact Sheet, National Biodiesel Board

Biodiesel reduces the health risks associated with conventional diesel fuel. Biodiesel emissions showed decreased levels of PAH and nitrited-PAH (nPAH) compounds, which have been identified as potential cancer causing compounds. In recent tests, PAH compounds were reduced by 75 to 85%, with the exception of benzo(a)anthracene, which was reduced by roughly 50%. Also nPAH compounds were reduced significantly. The 2-nitrofluorene and 1-nitropyrene emissions were reduced by 90%, and the rest of the nPAH compounds were reduced to only trace levels. These toxic emission differences are likely to be smaller when compared to CARB Diesel fuel, but may still be significant. More data comparing CARB Diesel to biodiesel are needed.

C. Diesel Fuel Additives

There are thousands of additives that have been registered with the U.S. EPA as injector cleaners, corrosion inhibitors, or lubricity enhancers; however, the focus of this section is to investigate existing additives and their effectiveness in reducing diesel PM emissions from diesel engines. Additive manufacturers have used different additives to improve combustion efficiency or to facilitate the post combustion reactions in a catalyst or particulate filter. However, in many cases very limited data is available regarding the use of these additives in California diesel fuels. The following is a description of information provided to the ARB staff with regard to additives and their potential ability to reduce diesel PM. Any additives with unsupported claims of emissions reductions were not included; however, the discussion of the following additives does not constitute an endorsement or confirmation of the results by the ARB staff.

1. Fuel-Borne Catalysts

Fuel-borne catalysts (FBCs) or regenerative additives can be used to improve the performance of diesel oxidation catalysts and particulate filters. A number of these types of additives have been registered with the U.S. EPA for on-highway use. In Europe certain FBCs have been approved for use with filters in mines, tunnels and construction vehicles; and Peugeot recently announced a new light-duty diesel vehicle using an on board reservoir of FBC and filter.

However, there is also growing concern about potential long-term health effect of the metals in these catalysts. In particular, concerns have been raised about the use of certain FBCs at high levels of treatment on vehicles not equipped with filters. This is generally related to the potential for high levels of metal emissions and an increase in ultra-fine particles when FBCs are used at high treatment rates without filters. Recently certain FBCs have demonstrated PM reductions at ultra-low levels of metal (4-8 ppm) with no increase in the number of ultra-fine particles emitted.

Limited emissions testing using fuel-borne metallic additives has shown varied emissions results. Diesel PM emissions increased slightly with some additives and decreased significantly with others. Diesel fuel tested in vehicles with and without diesel particulate filters, with metallic additives, showed from an 8% increase to a 30-percent reduction in diesel PM. HC emissions decreased, and CO emissions either did not change or decreased by about 10%. NOx emissions decreased from two to 10%, depending on the test additive. However, in combination with a four degree timing retard; some fuel-borne catalysts have been shown to reduce NOx by up to 30%, without affecting diesel PM emissions or increasing fuel consumption. Based on tests that were done to measure exhaust metal emissions, metal emissions do not appear to change substantially by using these metallic additives.

Additive manufacturers claim that the use of these additives also improves fuel efficiency, particularly at lower engine speeds, and can reduce the need for very low-sulfur diesel fuels.

In both 368-ppmw and 54-ppmw sulfur fuel, an EPA-registered FBC along with a low-activity DOC has been shown to reduce diesel PM emissions by about 43% in FTP testing of a 1998 DDC Series 60 engine. More recent testing of the bimetallic platinum/cerium fuel-borne catalyst, used alone at levels of 8 ppm in a CARB low-sulfur (50 ppm) market blend of diesel, demonstrated a 13% reduction in PM emissions. When FBC-treated CARB fuel was used with either an uncatalyzed DPF or lightly catalyzed DPF, PM emissions were reduced by over 80% to 0.01g/bhp-hr. Testing of this same FBC in a commercial grade of jet/kerosene fuel produced PM emissions 17% below the CARB blend with slightly lower NOx emissions. A combination of FBC-treated CARB fuel blended with 20% biodiesel, and used with engine timing changes and a lightly catalyzed filter, reduced PM by 82% to 0.011g/bhp-hr and lowered NOx by 8% versus the CARB fuel baseline.

1998 DDC SERIES 60-400hp CERTIFIED @ 0.1/4.0 PM/NOx
(Average of Triplicate Hot FTP Transient)

Fuel / Technology	PM (gbhp-hr)	NOx (gbhp-hr)
CARB Market Blend @ 50ppm /s	0.060	3.73
CARB + FBC	0.052	3.76
CARB + FBC + DPFA	0.010	3.76
CARB + FBC + DPFD	0.011	3.76
CARB + FBC +DPFA +2 °TR	0.011	3.61
CARB + FBC +DPFA +4 °TR	0.026	3.33
CARB + FBC + BIO +4° TR + DPFC	0.011	3.42
FBC + Jet/Kerosene @ 300ppm S	0.050	3.63

Testing in support of EPA registration and under the European VERT protocol has shown that at 8 ppm the level of metal emitted is 5% of that input to the engine and less than 1% is emitted after a filter. This is roughly equivalent to attrition from current autocatalysts. There is no increase in ultra-fine particle emissions with FBC-treated fuel at these low levels, and there was a 95% reduction in the number of ultra fines with the FBC and filter combination. Cost increases are estimated at $0.10/gal for the fuel borne catalyst alone and $0.15/gal for the FBC-jet/kerosene formulation over conventional highway diesel fuel.

2. Nonmetallic Additives

Chemecol developed a nonmetallic combustion-enhancing additive to reduce emissions. This additive technology is applicable to most diesel fuels and is comprised of mainly hydrocarbon species. It is not believed to be a health hazard because its combustion produces mainly carbon dioxide and water vapor. The additive is currently used in Europe and it has been used in variety of European vehicles for over 8 million miles with no compatibility problems.

The use of this additive has been shown to reduce diesel PM by ten to 20%, and to reduce other emissions, in both ECE15 + EUDC and R49 and FiGE transient test conditions. It also reduces PAH and nPAH levels and reduces the sub-2.5-micron particle numbers.

Additives containing esters have been shown to reduce opacity in snap idle tests, but data indicating particulate emission reductions are not available.

IV. RECOMMENDATIONS

A. Changes to Fuel Specifications and Applicability

Depending on technology, very low-sulfur (≤ 15 ppmw S) CARB Diesel may need to be required for all engines to be manufactured or retrofitted with diesel PM after-treatment. To be consistent with U.S. EPA and to enable after-treatment control technologies for off-road and stationary diesel engines; the ARB should adopt a regulation in 2001, which would require very low-sulfur CARB Diesel for all on-road, off-road, and stationary engines statewide, effective in 2006. In the regulatory development process the ARB staff should investigate the feasibility of earlier implementation.

Also, directionally, lower aromatic hydrocarbon and PAH contents and lower fuel-density may help to reduce engine-out diesel PM emissions. These fuel specifications should be evaluated for further control.

Synthetic or alternative diesel fuels may cost more than reformulated very low-sulfur CARB Diesel, but should be considered if shown to be cost-effective for diesel PM and other emission reductions. As these alternatives may result in significant benefits for higher-emitting operational categories, such as off-road engines; consideration may need to be given to operational applicability.

B. Diesel Fuel Guidance for Districts

Guidance on diesel fuel options and associated emission reductions should be developed to assist local districts in their permitting of fleets and equipment. The guidance may be especially useful in cases where control equipment retrofitting is impractical.

V. RESEARCH NEEDS

A. Fuels

More information is needed on the emission effects of the aromatic hydrocarbon and PAH contents, and the density, of very low-sulfur CARB Diesel for various engines and run cycles. Also, more information is needed on the emissions from synthetic and alternative diesel fuels versus very low-sulfur CARB Diesel.

VI. IMPACTS OF RECOMMENDED MEASURES

A. Particulate Matter Emission Reduction

For engines manufactured or retrofitted with after-treatment, the emission reductions with very low-sulfur CARB Diesel would be included as a result of the after-treatment. Reductions from fuel reformulation, synthetic and alternative diesel fuels, and additive-enhanced fuel are uncertain at this time; but would probably range from about 5 to 30% for diesel PM emissions.

B. Other Emissions

For engines manufactured or retrofitted with after-treatment, the emission reductions with very low-sulfur CARB Diesel would be included as a result of the after-treatment. Reductions from fuel reformulation, synthetic and alternative diesel fuels, and additive-enhanced fuel are uncertain at this time; but would be fuel and emission specific.

C. Cost

We estimate an incremental cost of less than $0.05-per-gallon for production of very low-sulfur CARB Diesel. This cost should be added to the cost of after-treatment in considering the overall cost and cost-effectiveness of after-treatment.

Synthetic or alternative diesel fuels may cost more than reformulated very low-sulfur CARB Diesel, but should be considered if shown to be cost-effective for diesel PM and other emission reductions. Additive-enhanced, reformulated very low-sulfur CARB Diesel should also be considered.

D. Other Environmental Impacts

Any changes in CARB Diesel fuel requirements would require increased refinery operations. Decreased fuel density would require an increase in fuel distribution if VFE decreases. These changes are not expected to cause significant negative environmental impacts.

Impacts of these and other potential fuel changes, if proposed as future regulations, should be evaluated as required under regulatory development. The potential environmental impacts of fuel alternatives, considered in the future for equivalency, should be addressed under the equivalency demonstration and certification application process.

VII. REFERENCES

1. ARB Staff; December 10, 1999. Staff Report: Initial Statement of Reasons – Proposed Regulation for a Public Transit Bus Fleet Rule and Emission Standards for New Urban Buses. California Environmental Protection Agency, Air Resources Board, Sacramento.

2. ASTM D 975-96a and -98a. "Standard Specification for Diesel Fuel Oils," American Society of Testing and Materials, Committee on Standards, West Conshohocken, Pennsylvania.

3. ASTM D 976-91. "Standard Test Methods for Calculated Cetane Index of Distillate Fuels," American Society of Testing and Materials, Committee on Standards, West Conshohocken, Pennsylvania.

4. ASTM D 4737-96a. "Standard Test Method for Calculated Cetane Index by Four Variable Equation," American Society of Testing and Materials, Committee on Standards, West Conshohocken, Pennsylvania.

5. Owen, K; Coley, T; and Weaver, C. S; 1995. Automotive Fuels Reference Book; Second Edition; Society of Automotive Engineers, Inc; Warrendale, Pennsylvania.

6. Obert, E. F; 1973. Internal Combustion Engines and Air Pollution; Harper & Row, Publishers, Inc; New York.

7. API, 1988. Alcohols and Ethers, A Technical Assessment of Their Application as Fuels and Fuel Components; Second Edition; American Petroleum Institute; Washington, D.C.

8. Lee, R; Pedley, J; and Hobbs, C; 1998. "Fuel Quality Impact on Heavy Duty Diesel Emissions: – A Literature Review;" SAE 982649; Society of Automotive Engineers, Inc; Warrendale, Pennsylvania.

9. MECA, 1999. *Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Low Emission Levels*, Final Report; Manufacturers of Emission Controls Association; Washington, D.C.

10. Darlington, T; and Kahlbaum, D; 1999. *Nationwide Emission Benefits of a Low Sulfur Diesel Fuel*; for Engine Manufacturers Association; Air Improvement Resource, Inc; Novi, Michigan.

11. DOE, EMA, and MECA; 2000. *Diesel Emission Control – Sulfur Effects (DECSE) Program; Phase I Interim Data Report No. 4: Diesel Particulate Filters – Final Report*; sponsored by the United States Department of Energy, the Engine Manufacturers Association, and the Manufacturers of Emission Controls Association.

12. U.S. EPA; May 2000. Draft Regulatory Impact Analysis for the Proposed Heavy-Duty Engine and Vehicle Standards and Highway Diesel fuel Sulfur Control Requirements Rule; EPA420-D-00-001; Assessment and Standards Division, Office of Transportation and Air Quality, United state Environmental Protection Agency; Washington, DC.

13. LeTavec, C; Uihlein, J; Segal, J; and Vertin, K; 2000. "EC-Diesel Technology Validation Program Interim Report;" SAE 2000-01-1854; Society of Automotive Engineers, Inc; Warrendale, Pennsylvania.

14. Snyder, P. V; Russell, B. J; and Schubert, P. F; 2000. "The Case for Synthetic Fuels: Enabling Technology for Advanced Engines;" Syntroleum Corporation; Tulsa, Oklahoma.

15. Snyder, P. V; 1999. "The Potential for GTL-Based Synthetic Fuels;" Syntroleum Corporation's Presentation to the Fuels Subcommittee; http://www.arb.ca.gov/toxics/diesel/fs/042999fsmeetsum.htm; California Air Resources Board; Sacramento, California.

16. Ryan, T. W. III; and Montalvo, D. A; 1997. "Emissions Performance of Fischer-Tropsch Diesel Fuels;" unpublished paper prepared for American Institute of Chemical Engineers' spring meeting; Southwest Research Institute; San Antonio, Texas.

17. Norton, P; Vertin, K; Bailey, B; Clark, N. N; Lyons, D. W; Goguen, S; and Eberhardt, J; 1998. "Emissions from Trucks Using Fischer-Tropsch Diesel Fuel;" SAE 982526; Society of Automotive Engineers, Inc; Warrendale, Pennsylvania.

18. Presentation of A-55 to ARB staff, March 7, 2000

19. Brown, K. F; Chadderton, J; Daly, D. T; Langer, D. A; and Duncan, D; 2000. "Opportunity for Diesel Emission Reductions Using Advanced Catalysts and Water Blend Fuel;" SAE 2000-01-0182; Society of Automotive Engineers, Inc; Warrendale, Pennsylvania.

20. "Diesel-Ethanol Fuel Cleans Up in Early Tests," Wall Street Journal, July 19, 1999.

21. Klausmeier, W. H; 1999. "Microemulsion Formulations for Reducing diesel PM and NOx Emissions;" Pure Fuels USA, Inc; Paper Distributed at Fuels Subcommittee Meeting; http://www.arb.ca.gov/toxics/diesel/fs/082599fsmeetsum.htm; California Air Resources Board; Sacramento.

22. Klausmeier, W.H.; August 19, 2000. E-mail to Mr. Jim Guthrie of ARB Staff.

23. Biodiesel Emissions, Fact Sheet; http://www.biodiesel.org/fuelfactsheets.htm#IS; National Biodiesel Board; Jefferson City, Missouri.

24. Sharp, C. A; 1998. *Characterization of Biodiesel Exhaust Emissions for EPA 211(b), Final Report, Cummins N14 Engine*; Southwest Research Institute; Prepared for National Biodiesel Board; Jefferson City, Missouri.

25. Hayat, S. O; February 18, 2000. "ChemEcol Ashless Diesel Combustion Enhancer Additive;" ChemEcol's Presentation to the Fuels Subcommittee; http://www.arb.ca.gov/toxics/diesel/fs/021800fsmeetsum.htm; California Air Resources Board; Sacramento.

26. Rogers, T; February 18, 2000.. "Diesel Particulate Filter/Regenerating Additive Combination - A Practical and Cost-Effective Solution to Removing Diesel Engine PM Emissions;" Associated Octel's Presentation to the Fuels Subcommittee; http://www.arb.ca.gov/toxics/diesel/fs/021800fsmeetsum.htm; California Air Resources Board; Sacramento.

27. Valentine, J. M; February 18, 2000. "Platinum Plus® DFX - A Bimetallic Fuel Borne Catalyst;" Clean Diesel Technologies' Presentation to the Fuels Subcommittee; http://www.arb.ca.gov/toxics/diesel/fs/021800fsmeetsum.htm; California Air Resources Board; Sacramento.

28. Valentine, J. M; March 13, 2000. Letter to Mr. Robert Hughes of ARB staff, and attachments; Clean Diesel Technologies, Inc; Stamford, Connecticut.

29. Valentine, J.M.; August 15, 2000. Letter to Mr. Daniel E. Donohoue, Chief, Emissions Assessment Branch, ARB; and attachments; Clean Diesel Technologies, Inc.; Stanford, Connecticut.

30. Carroll, R; February 18, 2000. "The Story of Might-Tron™ Catalyst;" Bio-Friendly Corporation's Presentation to the Fuels Subcommittee; http://www.arb.ca.gov/toxics/diesel/fs/021800fsmeetsum.htm; California Air Resources Board; Sacramento.

31. Mauro, J; and de Vilmorin, E; February 18, 2000. Omstar Today; Omstar Environmental Products International's Video Presentation to the Fuels Subcommittee http://www.omstarint.com or info@omstarint.com.

Appendix V

Summary of Existing Regulations

September 13, 2000

Table 1: Existing Regulations for Mobile Source Engines

Regulations	Description	Reference
Federal		
Commercial Marine Diesel Engines	The standards adopted by U.S. EPA for small- and medium-sized marine engines are similar to the Tier 2 HC + NOx standards for land-based off-road CI engines. The standards phase-in between 2004 and 2007. The federal rule does not cover large, international cargo ships, which emit the majority of air pollutants, but defers control to international treaty.	40 CFR Part 94
Aircraft Engines	The International Civil Aviation Organization and the U.S. EPA adopted standards for smoke emissions from aircraft engines.	40 CFR Part 87
Locomotive and Locomotive Engine Standards	The U.S. EPA adopted standards to be phased-in for NOx, hydrocarbons, CO, PM, and smoke for new locomotives and remanufactured locomotive and locomotive engines.	40 CFR Part 92
Urban Bus Retrofit /Rebuild Program	The U.S. EPA retrofit/rebuild program for urban buses applies to 1993 and earlier model year urban buses operating in metropolitan areas with 1980 populations of 750,000 or more.	40 CFR Part 85
Heavy-Duty Highway Engine and Vehicle Standards	The U.S. EPA has standards for on-highway heavy-duty vehicles. The standards apply to 1985 and later year engines. The most recently adopted standards will take affect in 2004. However, the SOP will be implemented in late 2002.	40 CFR Part 86
Off-road Diesel Engine Emissions Control Program	The U.S. EPA established a tiered progression to lower the emission standards for several categories of off-road engines. Each tier is phased in over several years by engine power category: Tier 1 2000-2004, Tier 2 2003-2006, Tier 3 2006+.	40 CFR Part 89
State		
Authority to Develop Mobile Source Regulations	CA law grants the ARB the responsibility for control of emissions from motor vehicles. [The federal CAA preempts CA from regulating new off-road construction and farm equipment with engines less than 175 hp and new locomotives.]	H&SC sections 39002, 39500, 43000 (c), 43101, and 43600
Heavy Duty Vehicle Inspection and Periodic Smoke Inspection Programs	This program reduces excessive smoke emissions and tampering with diesel-fueled vehicles over 6,000 pounds GVW.	HSC §§ 44011.6, 43701; 13 CCR §§ 2180 et seq.
Heavy Duty On-Road Vehicle Programs	For 1998, CA's emission standards and test procedures for heavy-duty on-road vehicles were designed to closely parallel the federal standards (see above).	13 CCR §§ 1956.8 et seq., 1965, 2036, 2112
Public Transit Bus Fleet Rule	This rule reduces diesel PM progressively with more stringent standards from 2002 – 2010 and aprogram that encourages transit agencies to purchase or lease low-emission, alternative fueled buses. Continued use of diesel buses mandates that the operator use ultra-low sulfur fuel.	13 CCR §§ 1956.1-1956.4, 1956.8

Table 1: Existing Regulations for Mobile Source Engines

Regulations	Description	Reference
Heavy Duty Off-Road CI Engine Program	Exhaust emission standards for off-road heavy-duty diesel engines become increasing more stringent, based on horsepower and the model year. CA's rule harmonizes with the federal program (see above).	13 CCR §§ 2420 et seq.
Small Off-Road Engine (<25 hp) and Equipment Program	This program, beginning with the 1995 model year, has applied progressively more stringent PM emission standards to small off-road engines. Future rulemaking will be coordinated along the entire range of off-road diesel-fueled engines.	13 CCR §§ 2400 et seq.
Alternative Strategies		
Carl Moyer Program established in 1998/1999 fiscal year	The Carl Moyer Memorial Air Quality Standards Attainment Program was primarily intended to be a NOx reduction program, but diesel PM has also been reduced. The Moyer program Advisory Committee has recommended diesel PM reductions as a goal of the program.	HSC § 44275 et seq. and ARB Guidelines
Locomotive Memorandum of Understanding (MOU)	This MOU is a voluntary agreement between the ARB, the Burlington, Northern, and Santa Fe Railway Company, and the Union Pacific Railroad to accelerate the introduction and use of cleaner, lower-emitting locomotives in the South Coast Air Basin. It was implemented in 1998.	Contact ARB
Local		
South Coast Air Quality Management District (SCAQMD)	The SCAQMD is in the process of adopting several rules to mandate purchase of clean vehicles when fleet owner are adding or replacing vehicles. Rules 1191, Light & Medium Duty Fleet Vehicles; 1192, Transit Buses; and 1193, Refuse Collection Vehicles, were adopted in June, 2000.	HSC section 40447.5; SCAQMD 1190 Series Rules

Table 2: Existing Regulations for Stationary Engines

Regulation	Description	Reference
Federal	The federal Clean Air Act established two distinct preconstruction permit programs (termed New Source Review) governing the construction of major new and modifying stationary sources. Sources constructing in nonattainment areas are required to apply the Lowest Achievable Emission Rate control technology to minimize emissions and to "offset" remaining emissions with reductions from other sources. Sources constructing in attainment or unclassified areas are required by the Prevention of Significant Deterioration requirements to apply the Best Available Control Technology and meet additional requirements aimed at maintaining the region's clean air.	Nonattainment: CAA Title I, Section 172 (b)(5) and 40 CFR 51.165 Attainment/Unclassified: CAA Title I, Section 165(a) and 40 CFR 51.166

Table 2: Existing Regulations for Stationary Engines

Regulation	Description	Reference
Federal (cont.)	In addition, the Federal Clean Air Act requires all major sources subject to federal NSR to obtain federal Title V operating permits governing continuing operation	Operating Permits: CAA Title V, Section 502(a) and 40 CFR Part 70
State	The state Health and Safety Code requires nonattainment areas for CO, NOx, VOC and SOx to design permit programs for new and modified stationary sources with the potential to emit above specified levels to achieve no net increase in emissions. Such areas must also require Best Available Control Technology on new and modified stationary sources.	H&S Code Sections 40918 – 40920.5
State (cont.) AB 2588 "Hot Spots" Requirements	The overall goal of the Air Toxics "Hot Spots" program is to develop a statewide inventory of toxic emissions, determine individual facilities health risk, and require the development and implementation of risk reduction and audit plans where significant health risks are identified. ARB works with local air districts and Cal/EPA's Office of Environmental Health Hazard Assessment to compile emissions data from individual facilities and assess health risks posed by those emissions. Owners/operators of diesel-fueled engines may be subject to some or all of these requirements.	H&SC Sections (44300-44394)
Local	The state Health and Safety Code allows local districts to establish a permit system that requires any person who builds, erects, alters, replaces or operates equipment or machinery which may cause the issuance of air contaminants to obtain a permit from the district. All districts in California have adopted permit programs. Generally, the local districts incorporate the state and federal permitting requirements into their preconstruction and operating permit programs. Some districts issue separate federal permits. In addition, for particulate matter, nothing restricts the authority of a district to adopt regulations to control suspended particulate matter or visibility reducing particles.	H&S Code Section 42300 H&S Code Section 40926
RACT/BARCT	Many air districts in California adopt source or category-specific rules to reduce emissions from existing stationary sources. The required levels of control (RACT or BARCT control technology) for existing stationary sources depends on each air district's nonattainment classification (i.e., moderate, serious, severe, or extreme).	H&SC sections 40918 (a)(2), 40919 (a)(3), 40920 (a), and 40920.5 (a).

Table 2: Existing Regulations for Stationary Engines

Regulation	Description	Reference
Internal Combustion (IC) Engine Regulations	Thirteen districts have established regulations for stationary diesel-fueled IC engines and one district has established a regulation for portable engines. All 13 set NOx and CO standards. These regulations do not set standards for diesel PM.	H&SC sections 40918 (a)(2), 40919 (a)(3), 40920 (a), and 40920.5 (a).

Table 3: Existing Regulations for Portable Engines

Regulation	Description	Reference
Federal and State		
See Table 1 above for new off-road engine regulations		
State/Local		
The statewide portable equipment registration program	A uniform, voluntary statewide program for registration and regulation of portable engines and equipment. Air districts are responsible for enforcing the statewide registration program.	H&SC sections 41750 - 41755
Local Registration Program	A program available in some districts in lieu of New Source Review.	

Table 4: Existing and Proposed Regulations for Diesel Fuel[1]

Regulation	*Description*	*Reference*
Federal		
Registration of Fuels and Fuel Additives	All on-road diesel fuels and additives must be registered.	40 CFR part 79
Sale or Supply of Diesel Fuel for use in On-road Motor Vehicles	Prohibits the sale or supply of diesel fuel for use in on-road motor vehicles, unless the diesel fuel meets or exceeds formulation requirements including a sulfur content, by weight, no greater than 500 parts per million (ppmw).	40 CFR 80.29
State		
CARB Diesel Requirements	All diesel fuel sold or supplied in California for motor-vehicle use must meet or exceed formulation requirements including a sulfur content no greater than 500 ppmw. The average sulfur content of CARB diesel is between 100 and 120 ppmw.	13 CCR 2281, 13 CCR 2282, 13 CCR 2456(e)2
Fleet Rule for Urban Transit Bus Operators	Beginning July 1, 2002, transit agencies and companies that lease buses to transit agencies must participate in a program to retrofit diesel buses in their fleets, and operate their diesel buses on ultra-low-sulfur diesel fuel (< 15 ppmw.)	13 CCR 1956.2

[1] Table does not include optional requirements applicable to federal and CARB diesel fuel formulation requirements. Refer to references for optional requirements.

Table 4: Existing and Proposed Regulations for Diesel Fuel[1]

Regulation	*Description*	*Reference*
The statewide portable equipment registration program	Portable engines registered under this regulation shall use only fuels meeting the standards for California motor vehicles fuel (e.g. CARB diesel.)	13 CFR 2456

Appendix VI

Methodology for Estimating the Ambient Concentrations of Particulate Matter from Diesel-Fueled Engines and Vehicles

September 13, 2000

I. PURPOSE

The purpose of this section is to present our methodology for updating the estimates for the statewide population-weighted annual outdoor average diesel PM concentration.

II. INTRODUCTION

The concentration of diesel PM that most Californians may be exposed to is estimated by the statewide population-weighted annual outdoor average diesel PM concentration. The Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant, Appendix III, Part A, Exposure Assessment[1] (ID Report) reported the statewide population-weighted annual outdoor average diesel PM concentration as 3.0 $\mu g/m^3$ for 1990. The ARB staff used studies from the San Joaquin Valley, South Coast, and San Jose to obtain speciated PM_{10} ambient data, along with ambient PM_{10} monitoring network data, and the 1990 PM_{10} emissions inventory, in a receptor model approach to estimate the statewide outdoor concentration of diesel PM.

III. METHODOLOGY

A. Basic Approach

We determined the ratio of the estimated statewide population-weighted annual outdoor average diesel PM concentration for 1990 from the ID Report and the most recent diesel PM emission inventory for the year 1990.

$$\frac{3.0\ \mu g/m^3 \text{ (year 1990 statewide diesel PM concentration)}}{46{,}400 \text{ TPY (1990 diesel PM emissions inventory)}}$$

We then established the following equation:

$$\frac{3.0\ \mu g/m^3 \quad (1990)}{46{,}400 \text{ TPY} \quad (1990)} = \frac{x\ \mu g/m^3 \quad (2000)}{28{,}000 \text{ TPY} \ (2000)}$$

We then multiplied the year 2000 updated emission inventory estimate by (3.0 $\mu g/m^3$/46,400 TPY) to obtain the year 2000 statewide population-weighted annual outdoor average diesel PM concentration.

B. The Baseline

As stated above, the ID Report reported the statewide population-weighted annual outdoor average diesel PM concentration as 3.0 $\mu g/m^3$ for 1990. This estimate

[1] As approved by the Scientific Review Panel on April 22, 1998.

was determined using receptor modeling techniques, including chemical mass balance model results from several studies, ambient 1990 PM_{10} monitoring network data, and 1990 PM_{10} emissions inventory data to estimate Californians' outdoor ambient exposures to diesel PM. The 1990 PM_{10} inventory and ambient monitoring data were used as the basis for calculating the statewide exposure to diesel PM because it better represented the emission sources in the years when the ambient data were collected for the studies used to estimate 1990 diesel PM outdoor concentrations.

C. Revised Estimates

The emissions inventory is updated continuously. The categories of the emissions inventory include: stationary source, area sources, and mobile sources. The emissions inventory also includes natural (non-anthropogenic) sources.

Originally, the emissions inventory did not include a complete inventory of off-road equipment. Recently, we have worked to update the off-road diesel engine inventory. Portable equipment has been included as a subset of the off-road emissions inventory. The methodology used to develop the inventory for off-road engines including portable engines is presented in Appendix III. Typical categories in the off-road emissions inventory include: agricultural engines, construction equipment, and military tactical support equipment.

In addition to underestimating emissions from off-road equipment, previous emission inventories underestimated emissions from diesel-fueled stationary engines by underrepresenting the number of stationary engines. Because of this concern, we have performed a more detailed inventory of stationary diesel engines along with better estimates of the stationary source contribution to diesel exhaust emissions. The methodology used to develop the inventory for stationary engines is presented in Appendix II.

As a result of the additional work to update the emissions inventory, the revised estimate for the total statewide diesel PM emissions inventory for 1990 is 46,400 TPY. The estimated emissions of diesel PM in California for the years 1990, 2000, 2010, and 2020 are as presented in Tables 1, 2, 3, and 4.

Table 1: Estimated Statewide Diesel PM Emissions Inventory – Diesel-Fueled Engines and Vehicles (1990)

Category	Engine Population	Diesel PM (tons per year)	% of Total Diesel PM Emissions
STATIONARY			
Prime	4,600	400	0.9
Emergency Stand-by	10,200	124	0.3
MOBILE			
On-road	606,700	18,400	39.7
Off-road (Excluding Portable Equipment)	476,300	25,300	54.5
Portable	47,600	2,200	4.7
TOTAL	**1,145,300**	**46,400**	**100.0***

* may not add to 100% due to rounding

Table 2: Estimated Statewide Diesel PM Emissions Inventory – Diesel-Fueled Equipment and Vehicles (2000)

Category	Engine Population	Diesel PM (tons per year)	% of Total Diesel PM Emissions
STATIONARY			
Prime	4,800	420	1.5
Emergency Stand-by	11,300	138	0.5
MOBILE			
On-road	687,200	7,500	26.7
Off-road (Excluding Potable Equipment)	498,200	18,600	66.4
Portable	49,200	1,400	5.0
TOTAL	**1,250,700**	**28,000**	**100.0 ***

* may not add to 100% due to rounding

Table 3: Estimated Statewide Diesel PM Emissions Inventory – Diesel-Fueled Equipment and Vehicles (2010)

Category	Engine Population	diesel PM (tons per year)	% of Total Diesel PM Emissions
STATIONARY			
Prime	4,400	360	1.6
Emergency/Standby	12,300	143	0.6
MOBILE			
On-road	643,900	5,200	22.9
Off-road (Excluding Potable Equipment)	521,300	15,900	70.0
Portable	53,600	1,100	4.8
TOTAL	**1,235,500**	**22,700**	**100.0 ***

* may not add to 100% due to rounding

Table 4: Estimated Statewide Diesel PM Emissions Inventory – Diesel-Fueled Equipment and Vehicles (2020)

Category	Engine Population	diesel PM (tons per year)	% of Total diesel PM Emissions
STATIONARY			
Prime	4,440	350	1.9
Emergency Stand-by	13,200	149	0.8
MOBILE			
On-road	610,200	4,900	25.9
Off-road (Excluding Potable Equipment)	527,800	12,800	67.7
Portable	55,200	660	3.5
TOTAL	**1,210,800**	**18,900**	**100.0 ***

* may not add to 100% due to rounding

The statewide population-weighted annual outdoor average diesel PM concentration was estimated at 3.0 $\mu g/m^3$ in 1990. We are assuming that the ratio between the statewide population-weighted annual outdoor average diesel PM concentration and statewide emissions remains constant.

Applying the ratio (3.0 μg/m³/46,400 TPY) to the updated year 2000 statewide emissions of 28,000 TPY yields an updated statewide population-weighted annual outdoor average diesel PM concentration of 1.8 μg/m³.

$$\frac{3.0\ \mu g/m^3\ (1990)}{46{,}400\,TPY\ (1990)} = \frac{x\ \mu g/m^3\ (2000)}{28{,}000\ TPY\ (2000)}$$

The same ratio can be applied to the updated statewide concentration estimates for the years 2010 and 2020 to estimate the statewide population-weighted annual outdoor average diesel PM concentrations for those years. (See Table 4.)

Table 4: Updated statewide population-weighted annual outdoor average diesel PM concentrations for 2000, 2010, and 2020

Year	2000	2010	2020
Emissions (TPY)	28,000	22,700	18,900
Concentration (μg/m³)	1.8	1.5	1.2
Risk (cancers/million)	540	450	360

D. Cancer Risk Associated with the Updated Statewide Population-Weighted Annual Outdoor Average Diesel PM Concentration

The Office of Environmental Health Hazard Assessment (OEHHA) reviewed and evaluated the potential for diesel exhaust to affect human health, and the associated scientific uncertainties. They considered acute and chronic noncancer health impacts, and potential cancer health impacts. The Scientific Review Panel (SRP) approved the OEHHA's health assessment at their April 22, 1998, meeting.

Based on available scientific evidence, a level of diesel PM exposure below which no carcinogenic effects are anticipated has not been identified. This finding was also approved by the SRP at their April 22, 1998 meeting.

The estimated range of lung cancer risk (upper 95% confidence interval) based on human epidemiological data is 1.3×10^{-4} to 2.4×10^{-3} $(\mu g/m^3)^{-1}$. After considering the results of human studies and detailed analysis of railroad workers, the SRP concluded that 3×10^{-4} $(\mu g/m^3)^{-1}$ is a reasonable estimate of unit risk expressed in terms of diesel PM

This reasonable estimate of 3 x 10^{-4} ($\mu g/m^3$)$^{-1}$ means that a person exposed to a concentration of 1 $\mu g/m^3$ of diesel PM has a 3 per 10,000 chance of contracting cancer in their lifetime. Three per 10,000 chances is the same as a 300 per million chances.

For Californians exposed to an annual outdoor average diesel PM concentration of 1.8 $\mu g/m^3$, the risk of contracting cancer from exposure to diesel PM is 540 chances per million during a lifetime. (See Table 5.)

Table 5:
Updated Statewide Outdoor Diesel PM Concentrations and Cancer Risk

Year	Statewide Diesel PM in California (TPY)	Statewide Population–Weighted Annual Outdoor Average Diesel PM Concentration ($\mu g/m^3$)	Statewide Cancer Risk (cancers/million)
1990	46,400	3.0	900
2000	28,000	1.8	540
2010	22,700	1.5	450
2020	18,900	1.2	360

E. Indoor and Total Air Exposure

The ID Report provided estimates of indoor and total exposure to diesel PM. ARB staff used estimates of population-weighted annual outdoor average diesel PM concentrations for 1990 in the California Population Indoor Exposure Model (CPIEM). The resulting indoor exposure estimate was approximately two-thirds of the population-weighted annual outdoor average diesel PM concentration. In the ID Report, the 1990 ratio was then applied to the estimated population-weighted annual outdoor average diesel PM concentrations for 1995, 2000, 2010 and 2020. In this report, we applied the same indoor/outdoor ratio to the updated statewide diesel PM concentrations. (See Table 6.)

Table 6:
Estimated Exposure of Californians to Diesel PM for 2000, 2010, and 2020

	Estimated Average Air Exposure Concentration – 1990 µg/m^3	1990 Ratio	Estimated Average Air Exposure Concentration (µg/m^3) and Risk (excess cancers/million)					
			2000		2010		2020	
			Conc.	Risk	Conc.	Risk	Conc.	Risk
Outdoor Ambient Estimate	3.0		1.8	540	1.5	450	1.2	360
Total Indoor Exposure Estimate	2.0	2.0/3.0	1.2	360	1.0	300	0.80	240
Total Exposure Estimate	2.1	2.1/3.0	1.3	390	1.1	315	0.84	252

Appendix VII

Risk Characterization Scenarios

September 13, 2000

DRAFT – DO NOT CITE OR QUOTE

TABLE OF CONTENTS

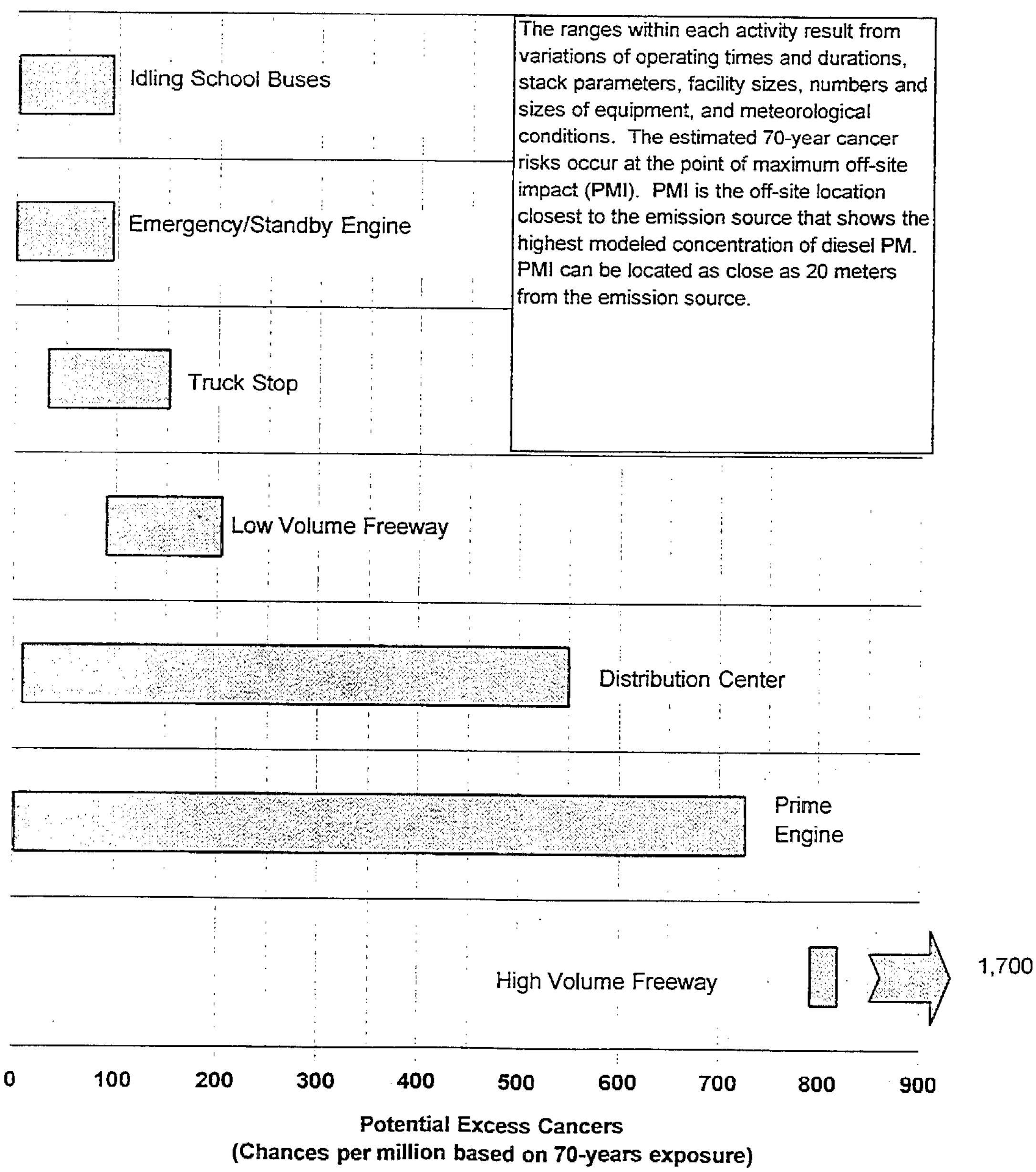
Contents | Page

Tables

I. INTRODUCTION

The purpose of the risk characterization scenarios is to estimate, through air dispersion modeling, the 70-year cancer risk associated with typical diesel-fueled engine or vehicle activities. The risk assessment methodologies followed by ARB staff in preparing the risk characterization scenarios are consistent with the California Air Pollution Control officers Association (CAPCOA) “Hot Spots” Program Revised 1992 Risk Assessment Guidelines, October 1993.

Figure 1: Potential Cancer Risk Range of Activities Using Diesel-Fueled Engines



The estimated risks presented in Figure 1, and the assumptions used to determine these risks, are not based on a specific source of diesel PM. Instead, general assumptions bracketing a fairly broad range of possible operating scenarios were used. The estimated risks are based on the diesel PM concentration at the point of maximum impact as determined using air dispersion modeling. The estimated risk ranges are used to provide a "qualitative" assessment of potential risk levels near sources of diesel PM. These estimates are based on the risk assessment methodology and assumptions identified below. Actual risk levels from these types of sources at any individual site will vary due to site specific parameters, including equipment technologies and emission rates, fuel properties, operating schedules, meteorology, and the actual location of off-site receptors.

We have chosen seven different operations or activities based on their prevalence throughout California, and their potential to increase Californians' exposure to diesel particulate matter (PM). These include idling school buses, truck stops, low volume freeways, high volume freeways, emergency/standby engines, prime engines, and distribution centers. Figure 1 shows the range of 70-year cancer risks associated with each of the seven scenarios. We chose the off-site point of maximum impact (PMI) as the location where our estimated 70-year potential cancer risks occur. PMI can be characterized as the off-site location closest to the emissions source that shows the highest modeled concentration of diesel PM.

Meteorological data are a site-specific parameter that is input to the air dispersion model to calculate concentrations and subsequent risk. It is important to indicate its variability in our analysis. For this initial effort, meteorological variability is addressed by performing the air dispersion modeling analysis with data from Anaheim and Concord. We recognize that there are over one hundred possible sources for meteorological data in California and more work may need to be performed to more completely determine the meteorological variability throughout California. However, we do not expect further refinements to significantly change our conclusions.

The modeling results of the completed scenarios are characterized as estimates of potential excess cancer risks in chances per million per microgram of diesel PM in a cubic meter of air over a 70-year lifetime. The estimated 70-year potential cancer risks in Figure 1 are based on the modeled diesel PM concentrations at the point of maximum impact (PMI). Potential cancer risk is calculated by multiplying the annual average concentration from inhalation exposure by the Unit Risk Factor (URF) for diesel PM (i.e., 300×10^{-6} $(\mu g/m^3)^{-1}$). We expect the potential cancer risks for the majority of these activities in California to fall within the ranges illustrated in Figure 1.

II. RISK CHARACTERIZATION SCENARIOS

In all but the freeway scenario, we used the Industrial Source Complex Short-Term (ISCST3) air dispersion model. In the freeway scenario, the California Line Source Dispersion (CALINE4) Model was used. The range of estimated 70-year cancer risks depicted in Figure 1 are considered to occur at the point of maximum offsite impact. PMI is the off-site location closest to the emission source that shows the highest modeled concentration of diesel PM. The PMI can be located as close as 20 meters from the emission point.

A. Idling School Buses

In this scenario, we evaluated diesel PM emissions resulting from the loading and unloading of school children in the designated loading zone. We modeled idling and running diesel PM emissions (both entering and leaving the loading zone) that only occurred in the designated loading zone. We assumed the buses were moving for 27 seconds per event, and we varied the idling times in each modeling run from two minutes to 15 minutes per bus. We assumed five, 78 passenger school buses (pre-1994 model years) delivered and picked-up students in a designated area at the school twice a day (i.e., between 8:00 a.m. - 9:00 a.m. and 2:00 p.m. - 3:00 p.m.). Five buses idling for two minutes per event represent the lower end of the risk range, and 20 buses idling for 15 minutes per event represent the upper end of the risk range. For more details, see Table 1.

B. Truck Stop

In this scenario, we evaluated the diesel PM emissions associated with a five-acre truck stop. We assumed an average of 5 diesel-fueled trucks per hour used this facility, 24 hours per day, 365 days per year. We assumed 10 percent of all the trucks have transport refrigeration units (TRUs) that cycle-on 10 percent of the time, while on-site. Cycling means the diesel engine of a TRU is running to achieve or maintain the temperature setting of the TRU. The temperature setting, and the allowable temperature range, is dependent on the product being transported. We increased the number of trucks and the size of the truck stop to 25 per hour in the 25-acre truck stop. The five-acre truck stop represents the lower end of the risk range, and the 25-acre truck stop represents the upper end of the risk range. Area one, the parking lot, is 30 percent of the entire surface area of the truck stop. Area two is the area around the diesel fuel pumps. The emissions generated in area two resulted from the refueling of trucks, and from the cycling of TRUs. For more details, see Table 2.

C. Low Volume Freeway

In this scenario, we evaluated diesel PM emissions resulting from heavy heavy-duty (HHD) diesel-fueled truck activity on a four-kilometer segment of freeway. A brief analysis of the composition of diesel-fueled vehicles on a freeway segment demonstrated that HHD diesel-fueled trucks predominated. The freeway has three lanes in each direction. Receptors were placed perpendicular to the freeway segment, and may be as close as 20 meters from the edge of the freeway. Sound walls and other obstructions were not considered in the evaluation. We modeled a truck traffic flow of 2,000 trucks per day.

Except for meteorological data, all inputs in our air dispersion modeling runs were the same (See Table 3). The low and high ends of the cancer risk range were generated as a result of the variability in Concord and Anaheim meteorological data. Concord meteorological data gave us the low end of the risk range, while Anaheim meteorological data gave us the high end of our risk range. For more details, see Table 3.

D. High Volume Freeway

This scenario is a similar approach to the low volume freeway scenario except a HHD diesel-fueled truck traffic flow of 20,000 trucks per day. The low and high ends of the cancer risk range were also generated as a result of the variability in Concord and Anaheim meteorological data, respectively. For more details, see Table 4.

E. Emergency/Standby Diesel Engines

In this scenario, we evaluated diesel PM emissions resulting from intermittent maintenance operations of emergency or standby diesel-fueled engines. We chose a 306 hp engine and a 1,109 HP engine, due to availability of PM emissions data at various loads. Based on data from operators of emergency standby engines, the engines were assumed to operate 12 to 100 hours per year from 10 to 100 percent load. A ISO 8178 composite diesel PM emission factor of 0.1 grams per brake horsepower-hour (g/bhp-hr) was used to represent the newest engines available, while a ISO 8178 composite diesel PM emission factor of 1.0 grams per brake horsepower-hour was used to represent the oldest existing engines.

To generate the low end of the cancer risk range, we used a 1,109 HP engine operating at 100% load for 12 hours per year with an emission factor of 0.0757 g/bhp-hr. Data provided by industry show engines operating at 100 percent load emit a slightly lower amount of diesel PM emissions on a g/bhp-hr basis. The ARB staff adjusted the ISO 8178 composite emission factor to account for this decrease in emissions. The high load and increased horsepower of the larger engine increase dispersion because of the higher exhaust temperature and flowrate, thereby decreasing the maximum risk of cancer. The lesser amount of time for the release also contributes to decreasing the maximum risk of cancer. We assumed the diesel PM emissions were released at the time of day with the best dispersion conditions (6:00 a.m.) using Concord meteorological data.

The high end of the cancer risk range was determined using a 306 HP engine operating at 10 percent load for 100 hours per year with an emission factor of 2.78173 g/bhp-hr. Data provided by industry show engines operating at 10 percent load emit a significantly larger amount of diesel PM emissions on a g/bhp-hr basis. The ARB staff adjusted the ISO 8178 composite emission factor to account for this increase in emissions. The low load and decreased horsepower of the smaller engine decrease dispersion because of the lower exhaust temperature and flowrate, thereby increasing the maximum risk of cancer. The greater amount of time for the release also contributes to increasing the maximum risk of cancer.

In addition to increased diesel PM emissions, the diesel PM emissions were modeled as if released during the time of the day with the worst dispersion conditions (3:00 p.m.) using Anaheim meteorological data. For more details, see Table 5.

F. Prime Engines

In this scenario, we evaluated diesel PM emissions from prime engines. Prime engines are used in a variety of applications, e.g., compressors, cranes, generators, pumps (including agricultural pumps), grinders, or screening units. Engines used in agricultural irrigation operations represent about two-thirds of the engines in prime applications. The size and operation of prime engines are highly variable; depending on the specific operation. Data provided by local air districts showed that high use engines have a wide range of horsepower ratings. We chose a 420 HP engine and a 1490 HP engine to generate, respectively, the high and low ends of the cancer risk range. We chose these engines due to availability of engine operating parameters at various loads.

To generate the lower end of the potential cancer risk range at the point of maximum impact, we used a 1,490 HP engine operating at 100% load for 100 hours per year with an emission factor of 0.1 g/bhp-hr. The high load and increased horsepower of the larger engine increase dispersion because of the higher exhaust temperature, thereby decreasing the maximum risk of cancer. The lesser amount of time for the release also contributes to decreasing the maximum risk of cancer. We assumed the diesel PM emissions were released at the time of day with the best dispersion conditions (6:00 a.m.) using Concord meteorological data.

To generate the higher end of the potential cancer risk range at the point of maximum impact, we used a 420 HP engine operating at 80 percent load for 2,080 hours per year with an emission factor of 1.0 g/bhp-hr. The lower load and decreased horsepower of the smaller engine decrease dispersion because of the lower exhaust temperature, thereby increasing the maximum risk of cancer. Decreasing the load to 10 percent was not practical for simulating an engine working for a lengthy amount of time. The greater amount of time for the release also contributes to increasing the maximum risk of cancer. We modeled the diesel PM emission as if they were released during the time of the day with the worst dispersion conditions (12:00 p.m. to 5:00 p.m.) using Anaheim meteorological data. For more details, see Table 6. The stack diameters for the low and high end risk ranges were taken from the table found in U.S. EPA guidance listed in 40 CFR PART 86.884-8 (c)(4).

G. Distribution Center

In this scenario, we evaluated diesel PM emissions associated with the shipping and receiving of goods at a distribution center. We modeled two facilities to create a range of risks. The following operating parameters occurred at both facilities: We assumed that the HHD diesel-fueled trucks idled for one minute at the refueling station (area 1), and the trucks idled for five minutes in the shipping or receiving areas (areas 2, 3, and 4). Area 5 is the facility, and the emissions rate specified in Table 7 represents traveling over this route. We also assumed the TRU's diesel-fueled engines run for 60 minutes to reach the desired temperature for the product being shipped.

To generate the low end of the cancer risk range, we modeled the diesel-emitting activities associated with the shipping and receiving of goods from 200 HHD diesel-fueled trucks. We assumed this distribution center did not use TRU's. We also assumed only 100 of the trucks refueled on-site every day.

To generate the high end of the cancer risk range, we modeled the diesel-emitting activities associated with the shipping and receiving of goods from 700 HHD diesel-fueled trucks (400 of the trucks have TRUs). We assumed all of the trucks refueled on-site every day. In addition to the time needed for a TRU to reach the desired temperature, we assumed the TRUs cycled 25 percent of the time for two hours (i.e., 15 minutes every hour for two hours). All diesel-emitting activities mentioned above occur over a 24-hour period. The distribution center operates 24 hours per day, 365 days per year. For more details, see Table 7.

III. CONCLUSIONS

While our risk characterization scenarios are hypothetical by design, we believe they represent the range of potential cancer risks that could occur at such an activity in California. Keep in mind that the potential ranges of risks characterized in the scenarios occur at the PMI, which is the off-site location closest to the emission source that shows the highest modeled concentration. We assumed in all the scenarios that a residence is located at the PMI, and the PMI can be located as close as 20 meters from the emission source. We conclude from the results of our analyses that all categories of diesel-fueled engines or vehicles may need to further reduce their emissions of diesel PM to adequately protect the health of all Californians.

However, many factors greatly influence the determination of whether a diesel PM emitting activity or operation poses a significant health risk, such as the size of an operation, the frequency of the activity, the age of the vehicles or engines, and the location of the sensitive receptors in relation to the diesel PM emitting sources. Other critical factors are the air dispersion model used to characterize the risk, emission factors, meteorological data, and modeling configuration such as area source, point source, and volume source. Because of these uncertainties, it must be recognized that the most accurate estimate of potential cancer risk of any diesel PM operation or activity should be based on site-specific information and meteorology.

Table 1: Idling School Buses Scenario				
Equipment Parameter	**Low Risk**		**High Risk**	
School Bus Throughput	5 buses		20 buses	
Idling Emission Factor Per Bus[a]	2.52 g/hour			
Running Emission Factor[b]	0.67 g/mile			
Stack Temperature	366 K			
Stack Height	0.6 meters			
Stack Diameter	0.1 meters			
Stack Exit Velocity	0.01 m/sec			
Activity	**Low Risk**		**High Risk**	
Idling Time Per School Bus.	2 minutes, twice a day, 180 days per year		15 minutes, twice a day, 180 days per year	
Traveling Distance Per School Bus.	60 meters		60 meters	
ISCST3 Input Parameters	**Low Risk**		**High Risk**	
	Idle	**Moving**	**Idle**	**Moving**
Source Type	Point Source	Area Source 60 m x 6.6 m	Staff assumed the cancer risk would be linear, with 20 buses in intervals of 5 buses with each bus idling 15 minutes. Therefore, staff multiplied the low end of the risk range by 4 to account for 20 buses, and then multiplied by 7.5 to account for 15 minutes of idling time.	
Emission Rate	0.0007 g/s	1.175 x 10^{-5} g/s-m^2		
Hourly Scalar Factor	0.01644	0.003678		
Model Option	Rural			
Time Emissions Are Being Emitted	8 a.m. & 2 p.m.			
Flagpole Height	1.2 meters			
Release Height	0.6 meters			
σ_{z0}	NA	1.39		
Stack Velocity	0.01 m/sec	NA		
Stack Temperature	366 K	NA		
MET Data	Anaheim		Concord	
Closest Receptor Location	20 m from source center		20 m from source center	

a. United States Environmental Protection Agency, Air and Radiation, Office of Mobile Sources, Emission Facts, April 1998, "Idling Vehicle Emissions" EPA420-F98-014.
b. California Air Resources Board, "Methodology For Estimating Emissions From On-Road Motor Vehicles" Volume II: EMFAC 7G, November 1996.
c. 0.01644 prorates from 1-hour to 2 minutes and 365 days to 180 days.
d. 0.003678 assumes the buses travel the 60 meters at 5 miles/hour and prorates 365 days to 180 days

<table>
<tr><th colspan="7">Table 2: Truck Stop Scenario</th></tr>
<tr><th colspan="3">Equipment Parameter</th><th colspan="2">Low Risk</th><th colspan="2">High Risk</th></tr>
<tr><td colspan="3">Truck Throughput</td><td colspan="2">5 trucks/hour (5-acre)</td><td colspan="2">25 trucks/hour (25-acre)</td></tr>
<tr><td colspan="3">Idling Emission Factor Per Truck[a]</td><td colspan="4">2.57 g/hour</td></tr>
<tr><td colspan="3">Running Emission Factor[b]</td><td colspan="4">0.67 g/mile</td></tr>
<tr><td colspan="3">50 HP TRU Emission Factor[c]</td><td colspan="4">0.76 g/bhp-hr</td></tr>
<tr><td colspan="3">50 HP TRU Load Factor[c]</td><td colspan="4">0.28</td></tr>
<tr><td colspan="3">TRU Emission Rate (35 HP)</td><td colspan="4">0.0021 g/sec</td></tr>
<tr><th colspan="3">Activity</th><th colspan="2">Low Risk</th><th colspan="2">High Risk</th></tr>
<tr><th colspan="2">Area 1</th><th>Area 2</th><th>Area 1</th><th>Area 2</th><th>Area 1</th><th>Area 2</th></tr>
<tr><td>Idling time</td><td rowspan="3">10 percent of all trucks</td><td>N/A</td><td>6 mins/hr</td><td>N/A</td><td>6 mins/hr</td><td>N/A</td></tr>
<tr><td>Travel distance</td><td rowspan="2">90 percent of all trucks</td><td>0.248 mi</td><td>0.124 mi</td><td>0.622 mi</td><td>0.311 mi</td></tr>
<tr><td>TRU cycling</td><td>6 mins/hr</td><td>1 min/hr</td><td>6 mins/hr</td><td>1 min/hr</td></tr>
<tr><td colspan="7">24 hours/day, 365 days/year</td></tr>
<tr><th colspan="3" rowspan="2">ISCST3 Input Parameters</th><th colspan="2">Low Risk</th><th colspan="2">High Risk</th></tr>
<tr><th>Area 1</th><th>Area 2</th><th>Area 1</th><th>Area 2</th></tr>
<tr><td colspan="3">Source Type</td><td colspan="2">Area Source</td><td colspan="2">Area Source</td></tr>
<tr><td colspan="3">Area Source Dimensions (meters)</td><td>39.6 x 132</td><td>92.4 x 132</td><td>92.4 x 308</td><td>215.6 x 308</td></tr>
<tr><td colspan="3">Emission Rate (g/s/m^2)</td><td>2.54E-8</td><td>7.74E-8</td><td>5.39E-8</td><td>7.37E-8</td></tr>
<tr><td colspan="3">Model Option</td><td colspan="2">Rural</td><td colspan="2">Rural</td></tr>
<tr><td colspan="3">Time Emissions Are Being Emitted</td><td colspan="2">24 hours/day</td><td colspan="2">24 hours/day</td></tr>
<tr><td colspan="3">Flagpole Height</td><td colspan="2">1.5 meters</td><td colspan="2">1.5 meters</td></tr>
<tr><td colspan="3">Release Height</td><td colspan="2">4.15 meters</td><td colspan="2">4.15 meters</td></tr>
<tr><td colspan="3">σ_{z0}</td><td colspan="2">1.39</td><td colspan="2">1.39</td></tr>
<tr><td colspan="3">MET Data</td><td colspan="2">Anaheim</td><td colspan="2">Anaheim</td></tr>
<tr><td colspan="3">Closest Receptor Location</td><td colspan="2">20 m from fence line</td><td colspan="2">20 m from fence line</td></tr>
</table>

a. United States Environmental Protection Agency, Air and Radiation, Office of Mobile Sources Emission Facts, April 1998, "Idling Vehicle Emissions" EPA420-F98-014.

b. California Air Resources Board, "Methodology For Estimating Emissions From On-Road Motor Vehicles" Volume II: EMFAC 7G, November 1996.

c. California Air Resources Board, "California's Emissions Inventory of Off-Road Large Compression-Ignited Engines (≥ 25 hp) Using the New OFFROAD Emissions Model," January 2000

Table 3: Low Volume Freeway Scenario		
Equipment Parameter	**Low Risk**	**High Risk**
Freeway Throughput	2,000 trucks per day (low volume freeway)	
Running Emission Factor[a]	0.67 g/mile	
Activity	**Low Risk**	**High Risk**
Diurnal Variation	Peak Hours 8am – 3pm Off-Peak Hours 10pm – 3am Off-Peak Throughput Approximately 10 percent of Peak Throughput Daily, 365 days per year	
Freeway segment analyzed .	4 kilometers segment length, 3 lanes in each direction	
CALINE-4 Additional Parameters	**Low Risk**	**High Risk**
Line Source	4,000 meters length by four links spaced 3.66 meters apart with center median. (0.0, 0.3, 0.7 of flow in lanes number one, two, and three, respectively)	
Flagpole Height	1.5 m	
σ_{z0}	Links normally 9.66 m wide are assigned widths of 11.7 m to account for initial dispersion of a truck compared to an automobile.	
Meteorological Data	Concord	Anaheim
Closest Receptor Location	20 m from edge of freeway	

a. California Air Resources Board, "Methodology For Estimating Emissions From On-Road Motor Vehicles" Volume II: EMFAC 7G, November 1996.

Table 4: High Volume Freeway Scenario		
Equipment Parameter	**Low Risk**	**High Risk**
Freeway Throughput	20,000 trucks per day (high volume freeway)	
Running Emission Factor[a]	0.67 g/mile	
Activity	**Low Risk**	**High Risk**
Diurnal Variation	Peak Hours 8 a.m. – 3 p.m. Off-Peak Hours 10 p.m. – 3 a.m. Off-Peak Throughput Approximately 10 percent of Peak Throughput Daily, 365 days per year	
Freeway segment analyzed .	4 kilometers segment length, 3 lanes in each direction	
CALINE-4 Additional Parameters	**Low Risk**	**High Risk**
Line Source	4,000 meters length by four links spaced 3.66 meters apart with center median. (0.0, 0.3, 0.7 of flow in lanes number one, two, and three, respectively)	
Flagpole Height	1.5 m	
σ_{z0}	Links normally 9.66 m wide are assigned widths of 11.7 m to account for initial dispersion of a truck compared to an automobile.	
Meteorological Data	Concord	Anaheim
Closest Receptor Location	20 m from edge of freeway	

a. California Air Resources Board, "Methodology For Estimating Emissions From On-Road Motor Vehicles" Volume II: EMFAC 7G, November 1996.

Table 5: Emergency Standby Engine Scenario

Engine Operating Parameter	Low Risk	High Risk
Maximum Engine Rating	1,109 HP (1,109 at 100 percent load)	306 HP (40.4 at 10 percent load)
ISO 8178 Composite Emission Factor	0.1 g/bhp-hr	1.0 g/bhp-hr
Emission Factor	0.075713 g/bhp-hr	2.78173 g/bhp-hr
Load	100 percent	10 percent
Emission Rate	0.02332 g/sec	0.031217 g/sec
Stack Temperature	787 K	536 K
Stack Height	3 m	3 m
Stack Diameter	0.254 m	0.127 m
Stack Exit Velocity	59.8 m/sec	19.5 m/sec

Note: Engine operating parameters based on engine specification sheets provided by engine manufacturers.

Activity	Low Risk	High Risk
Emergency Standby Diesel Engine	A 1,109 HP engine running 0.0329 hours/day x 365 days/year = 12 hours/year	A 306 HP engine running 0.274 hours/day x 365 days/year = 100 hours/year

ISCST3 Input Parameters	Low Risk	High Risk
Source Type	Point Source	Point Source
MET Data	Concord	Anaheim
Model Option	Urban	Urban
Time Emissions Emitted	6 a.m.	3 p.m.
Flagpole Height	1.5 m	1.5 m
Release Height	Same as stack height	Same as stack height
Closest Receptor Location	20 m	20 m

Table 6: Prime Engine Scenario		
Engine Operating Parameter	**Low Risk**	**High Risk**
Maximum Engine Rating	1,490 HP	420 HP
Emission Factor	0.1 g/bhp-hr*	1.0 g/bhp-hr**
Load	100 percent	80 percent
Emission Rate	0.04139 g/sec	0.0933 g/sec
Stack Temperature	769 K	739 K
Stack Height	3 m	3 m
Stack Diameter	0.330 m	0.127 m
Stack Exit Velocity	45.4 m/sec	90.8 m/sec
* Current on-road heavy-duty certification standard. ** United States Environmental Protection Agency, Air and Radiation, Office of Air Quality Planning & Standards, Emission Facts, April 1998, "Compilation of Air Pollutant Emission Factors AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources, Chapter 3, Section 3.3 Gasoline and Diesel Industrial Engines" EPA68-D2-0160. Note: Engine operating parameters based on engine specification sheets provided by engine manufacturers.		
Activity	**Low Risk**	**High Risk**
Prime Diesel Engine	A 1,490 HP engine running 0.274 hour/day x 365 days/year = 100 hours/year.	A 420 HP engine running 0.95 of 6 hours/day x 365 days/year = 2,080 hours/year.
ISCST3 Input Parameters	**Low Risk**	**High Risk**
Source Type	Point Source	Point Source
MET Data	Concord	Anaheim
Model Option	Urban	Urban
Time Emissions Emitted	6 a.m.	Noon - 5 p.m.
Flagpole Height	1.5 m	1.5 m
Release Height	Same as stack height	Same as stack height
Closest Receptor Location	20 m	20 m

Table 7: Distribution Center Scenario

Equipment Parameter		Low Risk		High Risk	
Trucks and transportation refrigeration units (TRUs)		200 trucks no TRUs		700 trucks and 400 TRUs	
Idling Emission Factor Per Truck[a]		2.57 g/hour			
Running Emission Factor[b]		0.67 g/mile			
50 HP TRU Emission Factor[c]		0.76 g/bhp-hr			
50 HP TRU Load Factor[c]		0.28			
TRU Emission Rate (34.8 HP)		0.0021 g/sec			
Activity		**Low Risk Number of Trucks**	**High Risk Number of Trucks/TRUs**	**Low Risk**	**High Risk**
Area 1	Trucks, idling time per truck	200	700	1 min/day	
	Traveling distance for trucks	N/A	N/A	N/A	N/A
	TRUs, cooling and cycling time	N/A	400	N/A	N/A
Area 2 & Area 3	Trucks, idling time per truck	75	250	5 mins/truck	
	Traveling distance per truck	N/A		N/A	
	TRUs, cooling and cycling time per TRU	N/A	150, 150	60 mins, 6 mins/hr for 2 hrs	60 mins, 15 mins/hr for 2 hrs
Area 4	Trucks, idling time per truck	50	200	5 mins/truck	
	Traveling distance per truck	N/A		N/A	
	TRUs, cooling and cycling time per TRU	N/A	100	60 mins, 6 mins/hr for 2 hrs	60 mins, 15 mins/hr for 2 hrs
Area 5	Traveling distance per Truck	200	700	0.44 mi/day	0.88 mi/day
24 hours/day, 365 days/year					

Table 7: Distribution Center Scenario (Cont.)								
ISCST3 Input Parameters	**Low Risk**				**High Risk**			
	Area 1	**Area 2 & Area 3**	**Area 4**	**Area 5**	**Area 1**	**Area 2 & Area 3**	**Area 4**	**Area 5**
Source Type	Area Source				Area Source			
Area Source Dimensions (meters^2)	50x20= 1,000	250x20= 5,000	125x20= 2,500	350x240= 84,000	50x40= 2,000	250x25= 6,250	140x25= 3,500	500x350= 175,000
Emission Rate (g/s/m^2)								
Idling trucks	9.92×10^{-8}	3.72×10^{-8}	4.96×10^{-8}	N/A	1.74×10^{-7}	9.92×10^{-8}	1.42×10^{-7}	N/A
TRUs Cooling	N/A	N/A	N/A	N/A	N/A	2.06×10^{-6}	2.45×10^{-6}	N/A
TRUs Cycling	N/A	N/A	N/A	N/A	N/A	1.03×10^{-6}	1.22×10^{-6}	N/A
Total	9.92×10^{-8}	3.72×10^{-8}	4.96×10^{-8}	N/A	1.74×10^{-7}	3.18×10^{-6}	3.82×10^{-6}	N/A
Traveling only	N/A	N/A	N/A	8.12×10^{-9}	N/A	N/A	N/A	2.73×10^{-8}
Model Option	Urban				Urban			
Time Emissions Are Being Emitted	24 hours/day				24 hours/day			
Flagpole Height	1.5							
Release Height	4.15							
σ_{z0}	1.93							
MET Data	Anaheim							
Closest Receptor Location	20 m from fence line				20 m from fence line			

a. United States Environmental Protection Agency, Air and Radiation, Office of Mobile Sources, Emission Facts, April 1998, "Idling Vehicle Emissions" EPA420-F98-014.

b. California Air Resources Board, "Methodology For Estimating Emissions From On-Road Motor Vehicles" Volume II: EMFAC 7G, November 1996.

c. California Air Resources Board, "California's Emissions Inventory of Off-Road Large Compression-Ignited Engines (≥ 25 hp) Using the New OFFROAD Emissions Model," January 2000

Appendix VIII

Health and Safety Code Section 39665

September 13, 2000

Health and Safety Code
Division 26. Air Resources
Part 2. State Air Resources Board
Chapter 3.5. Toxic Air Contaminants
Article 4. Control of Toxic Air Contaminants

H&S 39665 Report on Need for Regulation

39665. (a) Following adoption of the determinations pursuant to Section 39662, the executive officer of the state board shall, with the participation of the districts, and in consultation with affected sources and the interested public, prepare a report on the need and appropriate degree of regulation for each substance which the state board has determined to be a toxic air contaminant.
(b) The report shall address all of the following issues, to the extent data can reasonably be made available:
(1) The rate and extent of present and anticipated future emissions, the estimated levels of human exposure, and the risks associated with those levels.
(2) The stability, persistence, transformation products, dispersion potential, and other physical and chemical characteristics of the substance when present in the ambient air.
(3) The categories, numbers, and relative contribution of present or anticipated sources of the substance, including mobile, industrial, agricultural, and natural sources.
(4) The availability and technological feasibility of airborne toxic control measures to reduce or eliminate emissions, the anticipated effect of airborne toxic control measures on levels of exposure, and the degree to which proposed airborne toxic control measures are compatible with, or applicable to, recent technological improvements or other actions which emitting sources have implemented or taken in the recent past to reduce emissions.
(5) The approximate cost of each airborne toxic control measure, the magnitude of risks posed by the substances as reflected by the amount of emissions from the source or category of sources, and the reduction in risk which can be attributed to each airborne toxic control measure.
(6) The availability, suitability, and relative efficacy of substitute compounds of a less hazardous nature.
(7) The potential adverse health, safety, or environmental impacts that may occur as a result of implementation of an airborne toxic control measure.
(8) The basis for the finding required by paragraph (3) of subdivision (b) of Section 39658, if applicable.
(c) The staff report, and relevant comments received during consultation with the districts, affected sources, and the public, shall be made available for public review and comment at least 45 days prior to the public hearing required by Section 39666.
(Amended by Stats. 1992, Ch. 1161, Sec. 7.)

References at the time of publication (see page iii):
Regulations: 17, CCR, section 93108

Appendix IX

Diesel PM Control Technologies

September 13, 2000

INTRODUCTION

In preparation for the development of the Diesel RRP, ARB staff reviewed many products and technologies that were reported to reduce particulate emissions from diesel-fueled engines. The reviews consisted of two phases. In the first phase, ARB staff contacted manufacturers and collected basic information on the various diesel PM control technologies. Using this information, staff prepared short summaries of products that were reported to reduce diesel PM emissions. These "product summaries" are primarily based on information submitted by the control technology manufacturers, and they are intended to provide brief introductions of the various technologies. They are not intended to serve as comprehensive evaluations of the technologies. The product summaries are presented in Part A.

In the second phase of the technology review, staff worked with the Stationary Source Subcommittee to develop criteria for the evaluation of the various diesel PM control products. Specific criteria include commercial availability, emission reduction efficiency, costs, adverse impacts and other relevant factors. The evaluation criteria was then incorporated into a series of tables that have been completed for each of the diesel PM control products. Where multiple manufacturers provided information for similar technologies, a consolidated evaluation was prepared.

Because emission test information was deemed essential for a thorough evaluation, no evaluation was performed where the manufacturer did not provide adequate emission test data. Consequently, a number of the potentially viable technologies did not progress from the introductory first phase to the technical evaluations of the second phase. We are, however, continuing to collect and review information on these and other emerging diesel PM control technologies. The detailed technical evaluations are presented in Part B.

Staff will continue to update the ARB's Diesel RRP website (http://www.arb.ca.gov/toxics/diesel/diesel.htm) with new product summaries and detailed control technology evaluations as new information becomes available.

Note: Mention of specific products or trade names does not convey, and should not be interpreted as conveying, official ARB approval, endorsement, or recommendation. Unless otherwise noted, the ARB has not tested or evaluated any of the products to verify the claims of the manufacturer.

DRAFT - DO NOT CITE OR QUOTE

Part A: SUMMARY OF PRODUCTS THAT ARE REPORTED TO REDUCE PARTICULATE EMISSIONS FROM DIESEL-FUELED ENGINES

Particulate Filters

PRODUCT SUMMARIES

Alternative Fuels

Product Name: Biodiesel
Manufacturers: NOPEC, Proctor and Gamble, Ag Environmental Products, Griffin Industries, West Central Soya, Columbus Food, and Pacific Biodiesel
Category: Alternative Fuel / Fuel Additive

Description:

The product is a liquid fuel for stationary, portable, and mobile compression ignition engines that is manufactured from various feedstocks, including soy and waste restaurant grease (yellow grease). The product can be used in pure form, or it can be mixed with standard diesel fuel. One common mixture, referred to as B20, includes 20 percent Biodiesel and 80 percent standard diesel. The product reduces the carbonaceous fraction of diesel particulate matter (PM) through improved in-cylinder combustion which can be attributed primarily to Biodiesel's high oxygen content (11 percent $O2$ by weight). According to the National Renewable Energy Laboratory (NREL), pure Biodiesel reduces PM emissions by an average of 55 percent, and B20 reduces PM emissions by an average of 18 percent. The product has also been tested in combination with original engine manufacturer (OEM) diesel oxidation catalysts.

The results of one series of federal test procedure (FTP) transient emission tests show that pure Biodiesel reduced total PM emissions by 28 percent to 49 percent, and that B20 reduced PM emissions by 4 percent to 15 percent. When tested with an OEM diesel oxidation catalyst over the FTP test cycle, pure Biodiesel reduced PM emissions by 48 percent to 60 percent, and B20 reduced PM emissions by 10 percent to 21 percent. However, the use of Biodiesel may increase oxide of nitrogen (NOx) emissions by up to 4 percent when using B20 and by up to 14 percent when using pure Biodiesel, although this effect varies depending on the feedstock. The NREL, the U.S. Department of Agriculture and the National Biodiesel Board are currently researching Biodiesel formulations which will minimize or eliminate these increases in NOx emissions.

The product is commercially available and has been tested in more than 50 urban bus fleets in the United States over the past six years. B20 can be used without changes to existing diesel engines or the fuel distribution infrastructure. However, the use of pure Biodiesel may require changing some engine seals and fuel lines in older engines. The cost of Biodiesel depends on the feedstock. In California where yellow grease is the principal feedstock, the cost of pure Biodiesel is currently between \$2.00 to \$3.00 per gallon (pre-tax), although costs continue to decline. According to the NREL, a B20 Biodiesel/California Air Resources Board (ARB) diesel blend could be produced for an additional \$ 0.25 to \$ 0.45 per gallon above the cost of ARB diesel. Because the heat content of pure Biodiesel is only 120,000 Btu/gal, fuel economy may degrade slightly (although test data show that the decrease in fuel economy is less than 4 percent for B20 blends). Biodiesel generally contains no sulfur or aromatics, and it can be blended with California's existing diesel fuel formulations. A Biodiesel blend must meet the American Society for Testing and Materials (ASTM) and ARB diesel specifications when used in motor vehicles.

Product Name: Fumigation Natural Gas/Diesel Bi-Fuel Retrofit Kit
Manufacturers: Innovative Technologies Group
Category: Alternative Fuel

Description:

The product reduces diesel PM, hydrocarbon (HC), carbon monoxide (CO), and NOx emissions from stationary, portable, and mobile diesel-fueled engines. Specifically, the product includes the components necessary to convert a diesel-fueled engine to run on a mixture of diesel and a variety of gaseous fuels, such as pipeline quality natural gas, liquefied natural gas, compressed natural gas, digester gas, etc... The supplemental gaseous fuel is introduced into the engine's charge air system via a fumigation process. According to the manufacturer, there is no loss of power, diesel fuel consumption can be reduced by 50 percent to 80 percent, and NOx emissions can be reduced by 20 percent to 60 percent. The results of one transient emission test show that, over the cold start CVS Federal Test Procedure, the product reduced diesel PM emissions by 28 percent, NOx emissions by 38 percent, HC emissions by 38 percent, and CO emissions by 6 percent.

ARB's Mobile Source Operations Division (MSOD) evaluated the product in response to an application for certification of an alternative fuel delivery system under Health and Safety Code 43004 and 43006. MSOD staff concluded that use of the product "will not adversely affect exhaust emissions..."

The product is commercially available, can be applied to new engines, and it can be retrofitted to existing engines. The product has been installed on more than 200 diesel-fueled engines, including stationary generators, trucks, busses and locomotives. The manufacturer states that the product life is consistent with that of other engine components. The initial product cost, which varies with engine size, is approximately $35/kW for engines larger than 500 kW. This cost includes both hardware and installation. The manufacturer provides a one-year warranty which includes full replacement of the engine if damage is caused by the bi-fuel process. The product can be used with the existing California diesel fuel formulations.

Engine Design and Modifications

Product Name: Cam Shaft Cylinder Reengineering Kit
Manufacturer: Clean Cam Technology Systems
Category: Engine Design

Description:

The product reduces diesel PM and NOx emissions from eleven models of two-stroke diesel-fueled engines manufactured by Detroit Diesel Corporation (DDC) before 1993. The product consists of specific engine retrofit components, including a proprietary cam shaft. The product reduces NOx emissions by increasing the volume of exhaust gas that remains in the combustion chamber after the power stroke. Within the combustion chamber, the residual exhaust gas absorbs heat and reduces the peak combustion temperature which results in lower NOx emissions. The injection timing can then be adjusted (i.e. advanced) to maximize diesel PM emission reductions, or it can be varied to achieve the desired balance of NOx vs. PM.

The manufacturer states that engines retrofitted with the product will have emissions of no greater than 1.0 gram per brake horsepower-hour (g/bhp-hr) of hydrocarbons, 8.5 g/bhp-hr of carbon monoxide, 5.8 g/bhp-hr of nitrogen oxides, and 0.16 g/bhp-hr of diesel PM. ARB staff have verified this claim, and the product has been certified through the ARB's Equipment and Process Certification Program. In addition, the results of two 8-mode steady-state source tests show that the product can reduce diesel PM emissions by up to 55 percent.

The product is commercially available and has been installed on over 125 portable and 400 mobile diesel-fueled engines. The manufacturer states that the product's useful life is between 3,000 and 8,000 operating hours, and that the product life is consistent with the durability requirements for new nonroad engines. The initial product cost ranges from approximately $3,480 for a three cylinder engine to $15,680 for a sixteen cylinder engine. According to the manufacturer, there are no additional maintenance costs; however, the product can affect fuel economy. Although this effect can vary by engine, there may be a fuel penalty. The manufacturer provides a one-year / 3,000 engine hour warranty, and the product can be used with the existing California diesel fuel formulations.

Product Name: Diesel Emission Control System
Manufacturer: Clean Air Technology, a division of Applied Technology Solutions, Inc.
Category: Engine Modification

Description:

The product reduces diesel PM, HC, and NOx emissions from mobile, stationary, and portable diesel-fueled engines by introducing a combustion catalyst into the engine's air intake system. While the specific reactions are not known, the platinum oxide catalyst is believed to initiate combustion earlier such that the duration is longer which allows for more complete combustion. The manufacturer states that the product reduces both the elemental carbon and SOF of diesel PM, and that the overall diesel PM removal efficiency is between 30 percent and 60 percent. One steady-state source test shows that the product reduces diesel PM emissions by 48 percent, HC emissions by 65 percent, and NOx emissions by 51 percent.

MSOD evaluated an earlier version of the product in response to an application for exemption from the State's emission control system anti-tampering laws (Vehicle Code Section 27156). MSOD staff concluded that use of the product "will not have an adverse effect on exhaust emissions..."

The product is commercially available and has been installed on approximately 140 mobile diesel-fueled engines. The product has also been tested on at least one large portable diesel-fueled engine. The initial cost is $1,495, and it takes 2 hours to install. The maintenance cost, which consists of replacing the catalyst element, is $900 for every 1,200 hours of operation. The manufacturer warrants the product for 1,200 hours of operation. The product is also reported to improve fuel economy, and it can be used with the existing California diesel fuel formulations.

Product Name: ECOTIP Superstack Fuel Injectors
Manufacturer: Interstate Diesel
Category: Engine Design

Description:

The product reduces diesel PM emissions from stationary, portable, mobile, marine, and locomotive diesel-fueled engines manufactured by General Motors Electro-Motive Division (EMD) and DDC. The product consists of a fuel injector with a reduced sac volume and a more consistent fuel injection pressure, and it can be incorporated into either mechanical or electronic fuel injection systems. The product improves combustion and reduces diesel PM emissions by minimizing the amount of fuel that drips into the combustion chamber at the end of the chamber's fuel injection cycle. The manufacturer states that the overall diesel PM removal efficiency can be as high as 44 percent for EMD engines and as high as 7 percent for DDC engines.

The results of one 8-mode steady-state source test performed on a DDC engine equipped with the product show that it reduces diesel PM emissions by 7 percent, NOx emissions by 4 percent, and CO emissions by 19 percent, but that it increases HC emissions by 15 percent. (The ARB has not received emission test data for the EMD engines.) The product has also been tested with 2° injection timing retard, and the results of an 8-mode steady-state source test performed on a similar DDC engine show that the product can reduce diesel PM emissions by 3 percent, NOx emissions by 16 percent, CO emissions by 13 percent, and HC emissions by 1 percent.

The product is commercially available and has been installed on approximately 2,000 diesel-fueled engines. The manufacturer states that the product's useful life is typically between two and three years. For EMD engines, mechanical fuel injectors are available as OEM products and electronic fuel injectors are available as replacement products. For DDC engines, both mechanical and electronic fuel injectors are available as replacement products. The initial product cost for a DDC engine ranges from approximately $49 to $92 for each rebuilt fuel injector with core exchange, and between $250 and $300 for each new fuel injector. According to the manufacturer, there are no maintenance costs; however, fuel economy is reported to improve by 2 percent to 3 percent. The manufacturer provides a 12-month / 2,000 engine hour warranty, and the product can be used with the existing California diesel fuel formulations.

Product Name: IET 2000 Series Emission/Fuel Reduction System
Manufacturer: International Engine Technologies, Ltd.
Category: Engine Modification

Description:

The product reduces diesel PM emissions from mobile, stationary, and portable diesel-fueled engines by cleaning, heating, and mixing the fuel before it is delivered to the fuel injection system. The product includes: 1) a filter that cleans the fuel down to three to five microns; 2) a "homogenizer" that heats and mixes the fuel; and 3) a catalytic bed that imparts an electrical charge to the fuel. These components work together to improve fuel atomization and allow for more complete combustion. The manufacturer states that the product reduces both the elemental carbon and soluble organic fractions (SOF) of diesel PM, and that the overall diesel PM removal efficiency is between 20 percent and 50 percent. However, the ARB has not received emission test data that support this claim.

The product is commercially available and has been installed on eight mobile diesel-fueled engines. The manufacturer states that the product's useful life is 10 years or more. The initial cost varies with engine size and is $180 for 1.5 to 4 liter engines (catalytic bed only), $950 for 2 - 5 liter engines, $1,080 for 6 - 10 liter engines, and $1,250 for 11 - 15 liter engines. The product takes about one hour to install. The manufacturer states that fuel economy improves by 8 percent to 12 percent for engines with mechanical fuel injectors and by 3 percent to 5 percent for engines with electronic fuel injection. The manufacturer provides a one-year warranty, and the product can be used with the existing California diesel fuel formulations.

Fuel Borne Catalysts

Product Name: COMTEC Emission Control Device
Manufacturer: COMTEC Combustion Technologies, Inc.
Category: Fuel Borne Catalyst

Description:

The product is reported to reduce diesel PM, NOx, CO, and HC emissions from stationary, portable and mobile diesel-fueled engines. Specifically, the product is an in-line solid metal oxidation / fuel modification catalyst which changes the composition of diesel fuel immediately prior to its use in an engine. Subsequent combustion of the modified fuel results in a reduction of both the elemental carbon and SOF of diesel PM, as compared to untreated fuel. According to the manufacturer, the tin antimony-based catalyst converts some of the longer chain hydrocarbons into shorter chain hydrocarbons. Use of the product appears to increase the number of shorter chain hydrocarbons, particularly those in the C10 through C12 range, and slightly decrease the number of longer chain hydrocarbons. The manufacturer states that the product reduces diesel PM emissions by up to 40 percent, NOx emissions by up to 25 percent, CO emissions by up to 60 percent, and HC emissions by up to 60 percent. However, the ARB has not received emission test data that support this claim.

The product is commercially available and has been installed on several hundred diesel-fueled engines used primarily in marine vessels. These engines range in size from 150 horsepower to 10,000 horsepower. The product's useful life is 8,000 to 10,000 service hours and is guaranteed by the manufacturer. The initial product cost, which varies by engine size, ranges from $326 (US) for a 300 horsepower engine to $1,563 (US) for a 3,000 horsepower engine. The installation cost, which also varies by engine size, ranges from $150 to $500. The manufacturer reports an increase in fuel economy of between 3 percent and 7 percent. The product is covered by both a performance and a liability warranty, and it can be used with the existing California diesel fuel formulations.

Product Name: Platinum Plus® DFX diesel fuel combustion catalyst
Manufacturer: Clean Diesel Technologies, Inc.
Category: Fuel Additive

Description:

The product is a concentrated liquid fuel-borne catalyst (FBC) containing 4 to 8 parts per million (ppm) of fuel-soluble platinum and cerium metal that reduces diesel PM emissions from all stationary and portable diesel-fueled engine types. The product can be used alone or in conjunction with other control technologies such as diesel particulate filters (DPF) and diesel oxidation catalysts (DOC); and with NOx controls such as exhaust gas recirculation and injection timing retard. The FBC catalyzes the rate of soot oxidation and lowers the temperature at which soot oxidation takes place. The FBC is packaged as an aftermarket product, so fuel or bulk storage tanks can be dosed by the owner or operator. The product reduces the carbonaceous and SOF of diesel PM; however, the product appears most effective at reducing the dry carbonaceous fraction. The manufacturer states that the removal efficiency is dependent on the baseline emission level and chemical makeup of the diesel PM. Results from the heavy-duty engine transient FTP and a 13-mode steady-state source test shows that the product can reduce diesel PM emissions ranging from 15 percent to 30 percent for the FBC alone, 30 percent to 50 percent for a DOC+FBC, and 80 percent to 95 percent for a DPF+FBC combination.

The product is commercially available and has been applied to more than 60 heavy-duty trucks in the United States and to six large stationary diesel-fueled engines in Maine. FBC+DPF combinations have been applied to about 100 city buses in Taiwan. The initial cost to the end user varies based on the method of product distribution. Individually packaged products are expected to cost $0.10 to $0.12 per gallon of fuel treated; bulk treated fuel, or on-board additive is estimated to cost $0.05 to $0.10 per gallon of fuel treated. Additive cost is expected to be partially offset by fuel economy improvements in the range of 5 percent to 7 percent. Additional operation and maintenance costs are negligible for the FBC alone. If used with DOCs and DPFs, maintenance should be reduced owing to the reduced soot fouling and replenishment of catalytic activity with the FBC. The manufacturer states that the product's shelf life is about 24 months for individually packaged units and 12 to 18 months in fuel. The product works with diesel fuels containing up to 500 ppm sulfur at any operating temperature; when used with a DOC or catalyzed DPF, exhaust gas temperature should be maintained below 500 °C to avoid sulfation.

Other Exhaust Treatment Technologies

Product Name: NOxTECH Emission Control System
Manufacturer: NOxTECH, Inc.
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines and turbines through non-catalytic oxidation (i.e. similar to an afterburner). When used with an aqueous urea injection system, the product also reduces emissions of NOx. The product consists of a muffler-size reactor where the exhaust gases are heated to a temperature of 1,400°F - 1,550°F by introducing fuel to the exhaust stream. Within this high temperature environment, diesel PM, CO, and HC emissions are oxidized. When a urea injection system is used, NOx emissions are reduced in a reaction with the aqueous urea.

The manufacturer states that the overall diesel PM removal efficiency can be as high as 90 percent. Test results from a steady-state source test of a 1.5 megawatt (MW) generator in Southern California demonstrated diesel PM removal efficiencies between 43 percent and 71 percent.

The product is commercially available and can be retrofitted to existing engines; however, it must be designed for each application. The product is currently being used on two stationary diesel-fueled engine-powered generators in Southern California. The initial costs are: $10 - $30 per horsepower for installations without the urea injection system or the heat exchanger; $15 - $37 per horsepower for installations with the urea injection system but without the heat exchanger; and $52 - $75 per horsepower for installations with both the urea injection system and the heat exchanger. The operating costs include a fuel penalty of approximately 5 percent to 8 percent, and when used, the cost of the aqueous urea is approximately $300 per ton of NOx reduced. The manufacturer guarantees that the product will be free from defects for a period of 12 months. The product can be used with the existing California diesel fuel formulations.

Product Name: SINOx (Selective Catalytic Reduction) System
Manufacturer: Siemens Westinghouse Power Corporation
Category: Exhaust Treatment

Description:

The product reduces diesel PM, NOx, and HC / air toxics (including odor, formaldehyde and polyaromatics) emissions from mobile, stationary, and portable diesel-fueled engines using a proprietary base metal catalyst designed specifically for diesel-fueled engines. According to the manufacturer, the product reduces the volatile organic fraction (VOF) of diesel PM and HC / air toxics emissions through catalytic oxidation. The product concurrently reduces NOx emissions through selective catalytic reduction using a reducing agent, such as a 32 percent aqueous urea solution, as an integrated control system. The manufacturer states that the product's overall diesel PM removal efficiency can be between 20 percent and 50 percent depending on the engine timing, the type of controls, and the uncontrolled emission rate. In addition, the product's VOF of diesel PM removal efficiency can be more than 60 percent, its HC / air toxics removal efficiency can be more than 90 percent, and its NOx removal efficiency can be over 90 percent in stationary and portable applications and 65 percent to 85 percent in heavy-duty truck applications. The product can be used through an exhaust temperature range of 350°F to 1,020°F, and it allows the injection timing to be adjusted (on non-certified engines) for maximum fuel efficiency which may result in further reductions of diesel PM and HC /air toxics and fuel savings. One transient driving cycle emission test of a 1999 certified Detroit Diesel Corporation Series 60 heavy-duty diesel-fueled truck engine shows that, over the hot start portions of the FTP, the product reduces the VOF of diesel PM by more than 60 percent, total diesel PM emissions by more than 20 percent (to less than 0.07 g/bhp-hr), HC emissions by 90 percent, and NOx emissions by 73 percent (to less than 1.0 g/bhp-hr). In addition, according to the manufacturer, a NOx emission rate of 0.5 g/bhp-hr was recently achieved on an engine equipped with both the product and a supplemental exhaust gas recirculation system.

The product is commercially available for engines rated at 200 to 10,000 horsepower or more, and it has been installed on 125 stationary, portable, and mobile diesel-fueled engines worldwide. Specific applications include: stationary and portable generator sets, pump stations, on-highway heavy-duty trucks, offroad construction equipment, marine vessels, locomotives, and others. The cost of the product depends on the degree of custom engineering required, the size of the engine, the operating conditions, and other variables such as production volume. For a 367 horsepower portable diesel-fueled engine, the initial cost would be approximately $7,000 depending on production volume and assuming minimal custom engineering. The operating cost would be approximately $300 per ton of NOx reduced (primarily for the aqueous urea), and the maintenance cost would be approximately $800 per year depending on run time and other variables. The manufacturer provides a one-year standard equipment warranty for workmanship, parts and materials. The manufacturer also provides a process guarantee of up to 3-years / 20,000 service hours (whichever occurs first) for the emission reductions in stationary and portable applications. A 500,000 mile performance guarantee is provided for on-road applications. The product is resistant to fuel sulfur and can be used with the existing California diesel fuel formulations, as well as with high sulfur fuels such as bulk or crude oil used in coastal and ocean vessels.

Oxidation/Oxidation Catalysts

Product Name: CEM Catalytic Exhaust Muffler
Manufacturer: Johnson Matthey
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from mobile diesel engines through catalytic oxidation. Specifically, the product reduces the SOF of diesel PM by 50 percent to 60 percent. The product is certified under the U.S. Environmental Protection Agency's Urban Bus Retrofit/Rebuild Program, and the manufacturer guarantees that it will reduce overall diesel PM emissions by at least 25 percent. The manufacturer states that HC and CO emissions will be reduced by up to 50 percent or more. The results of one transient emission test show that, over the FTP, the product reduced diesel PM emissions by 51 percent, NOx emissions by 3 percent, HC emissions by 47 percent, and CO emissions by 40 percent.

MSOD evaluated the product in response to an application for exemption from the State's emission control system anti-tampering laws (Vehicle Code Section 27156). MSOD staff concluded that use of the product "...will not have any adverse effect on exhaust emissions of the engines for which the exemption is requested."

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. While the product has been formulated to minimize the formation of sulfates, depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available for urban transit bus applications, and has been installed on several thousand transit buses in the United States. The product's initial cost depends on the engine / coach configuration and varies between $1,600 and $2,300. Installation takes between two and four hours and, according to the manufacturer, periodic maintenance is not normally required. For urban transit bus applications, the manufacturer provides an emission performance warranty for 150,000 miles and will replace defective parts for a period of 100,000 miles. The manufacturer typically provides a one year unlimited mileage warranty for other applications. The product can be used with California's existing diesel fuel formulations.

Product Name: CleanDIESEL Converters
Manufacturer: Clean Air Systems
Category: Exhaust Treatment

Description:

The product reduces PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation. Specifically, the product reduces the SOF of diesel PM. The manufacturer states that the SOF removal efficiency can be as high as 80 percent at an exhaust temperature of 570°F, and that the overall diesel PM removal efficiency should be between 25 percent and 43 percent. However, ARB has not received emission test data that support these claims.

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available and has been installed on approximately 3,000 stationary, portable, and mobile diesel-fueled engines. The manufacturer states that the product's useful life should be approximately 10,000 engine hours. The initial cost ranges from $369 for a 150 cubic inch naturally aspirated engine to $4,079 for a 2,215 cubic inch turbocharged engine, and the product takes between one and six hours to install. The maintenance costs depend on the maintenance level of the engine: the catalyst may require periodic cleaning when installed on a poorly maintained engine or when the catalyst temperature does not regularly reach 570°F. The product carries a one-year / 2,000 engine hour warranty and it can be used with the existing California diesel fuel formulations.

Product Name: DCC Diesel Catalytic Converter
Manufacturer: Johnson Matthey
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from mobile and portable diesel-fueled engines through catalytic oxidation. Specifically, the product reduces the SOF of diesel PM by 50 percent to 60 percent. The manufacturer states that the overall diesel PM removal efficiency ranges from 20 percent to 50 percent depending on the engine size and model year, exhaust temperature and flow rate, duty cycle, and condition of the engine. However, ARB has not received emission test data that support this claim.

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. While the product incorporates sulfate suppressant technology, depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available for mobile diesel-fueled engines, and has been installed on more than three million engines worldwide. The initial product cost, which varies with engine size and emission reduction requirements, ranges from $500 to $3,000. The installation, operating, and maintenance costs also vary by application and engine size. The manufacturer typically provides a one year unlimited mileage warranty. The product can be used with the existing California diesel fuel formulations.

Product Name: Dieselytic SX Exhaust Gas Purifier
Manufacturer: Catalytic Exhaust Products Limited
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation. Specifically, the product reduces the SOF of diesel PM. The manufacturer states that the SOF removal efficiency ranges from 27 percent at an exhaust temperature of 275˚F to 91 percent at 600˚F. The overall diesel PM removal efficiency depends on the make-up of each engine's diesel PM emissions, but should be between 25 percent and 39 percent. One 8-mode steady-state source test shows that the product reduces diesel PM emissions by almost 16 percent, HC emissions by 39 percent, and CO emissions by 59 percent.

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available and has been installed on approximately 15,000 portable and mobile diesel-fueled engines. Several units have also been installed in stationary applications. The manufacturer states that the product's useful life ranges from approximately 4,000 to 6,000 engine hours in heavy-duty applications to 8,000 to 10,000 engine hours in light-duty applications. The initial product cost, which varies with engine size, ranges from approximately $2,000 for a 250 horsepower engine to approximately $5,000 for a 550 horsepower engine. The manufacturer recommends cleaning the product every 6 months or 2,000 engine hours (whichever occurs first) when it is installed on newer engines, and every 3 months or 1,000 engine hours (whichever occurs first) when it is installed on older engines. The catalyst can be cleaned by the engine operator by: applying a compressed air stream to the face of the catalyst; heat treating the catalyst core; or soaking the catalyst in an appropriate solvent. The maintenance costs include the time and materials associated with the cleaning activity. The product carries a one-year / 2,000 engine hour warranty. The product can be used with the existing California diesel fuel formulations; however, the manufacturer recommends a maximum aromatic content of 18 percent.

Product Name: Flameless Thermal Oxidizer
Manufacturer: Thermatrix, Inc.
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines and turbines through non-catalytic oxidation (i.e. similar to an afterburner). Exhaust gases are heated in a muffler-like enclosure where the organic gases are oxidized in the flameless, high temperature, environment. System temperature is maintained by introducing supplemental fuel to the exhaust stream which reacts within a proprietary inert ceramic matrix.

The product reduces the carbonaceous, soluble organic and sulfate fractions of diesel PM. The manufacturer states that the overall diesel PM removal efficiency should be greater than 90 percent, although emission test results will not be available until October 1999.

Although still under development, the product is expected to be available for commercial use within the next few years. The initial cost is projected at $3,000 for heavy-duty diesel engines. The operating costs consist primarily of the supplemental fuel use, which is between one and three percent. The product can be used with the existing California diesel fuel formulations.

Product Name:	Nett D-series Diesel Purifier
Manufacturer:	Nett Technologies, Inc.
Category:	Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation. The catalyst formulation can be customized for specific engine applications, and can be designed to suppress the formation of sulfate particles. To enhance low temperature conversion, the product incorporates a zeolite trap which captures and temporarily stores hydrocarbon emissions, including the SOF of diesel PM. Upon reaching the catalysts' minimum conversion temperature of about 360°F, the hydrocarbons are released from the zeolites and are oxidized by the catalyst. The zeolites can collect and store hydrocarbons for 15 to 30 minutes before becoming saturated. The manufacturer states that the product's SOF removal efficiency ranges from 40 percent at an exhaust temperature of 210°F to 90 percent at 840°F, and that the product's overall diesel PM removal efficiency can be as high as 10 percent to 50 percent. One 5-mode steady-state source test shows that the product reduces diesel PM emissions by 21 percent.

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. While the product incorporates sulfate suppressants, depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available and has been installed on approximately 15,000 mobile, portable, and stationary diesel-fueled engines. The initial product cost, which varies with engine size, ranges from $4 to $20 per horsepower, and it takes approximately 1½ hours to install. The operating costs depend on the maintenance level of the engine as the catalyst may require periodic cleaning when installed on a poorly maintained engine. The manufacturer states that the product's useful life ranges from 15,000 to 25,000 engine hours depending on the condition of the engine, type of fuel and maintenance practices. The manufacturer provides a 2,000 hour limited warranty on mechanical durability. The product can be used with the existing California diesel fuel formulations.

Product Name: Nett Standard Diesel Purifier
Manufacturer: Nett Technologies, Inc.
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation. Specifically, the product reduces the SOF of diesel PM. The manufacturer states that the SOF removal efficiency ranges from zero percent at an exhaust temperature of 210°F to 90 percent at 840°F. The overall diesel PM removal efficiency is estimated at between 10 percent and 50 percent, but this has not been confirmed through emission testing.

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available and has been installed on approximately 30,000 mobile, portable, and stationary diesel-fueled engines. The initial product cost, which varies with engine size, ranges from $3 to $14 per horsepower, and takes approximately 1½ hours to install. The operating costs depend on the maintenance level of the engine, because the catalyst may require periodic cleaning when installed on a poorly maintained engine. The manufacturer provides a 2,000 hour limited warranty on mechanical durability. The product can be used with the existing California diesel fuel formulations.

Product Name: PTX Oxidation Catalyst
Manufacturer: Engelhard Corporation
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from mobile, stationary, and portable diesel-fueled engines through catalytic oxidation. The product reduces both the carbonaceous fraction and the SOF of diesel PM. The manufacturer states that the SOF removal efficiency can be as high as 50 percent to 90 percent, and that the overall diesel PM removal efficiency can be as high as 25 percent to 50 percent. The results of one emission test of a bulldozer, which was tested over a specially designed transient cycle, show that the product reduces total diesel PM emissions by 24 percent.

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available and has been installed on several thousand mostly-mobile diesel-fueled engines. The manufacturer states that the product's useful life is consistent with the life of the associated diesel-fueled engine, and they recommend replacing the catalyst at the time an engine is rebuilt. The product's initial cost varies between $5 and $15 per horsepower. According to the manufacturer, periodic maintenance is not normally required. The product carries a mechanical durability warranty of between one and two years, depending on the application, and the product can be used with California's existing diesel fuel formulations.

Particulate Filters

Product Name: 3M Diesel Particulate Filter Cartridges
Manufacturer: Minnesota Mining and Manufacturing (3M)
Category: Exhaust Treatment

Description:

3M manufactures several ceramic fiber-based cartridges that are one component of particulate filter systems assembled by other companies. The cartridges can reduce the carbonaceous and soluble organic fractions of diesel PM by collecting the contaminants on ceramic fibers. They can be regenerated either electrically via internal heating elements or by external methods, such as fuel burners, fuel additives, catalysts, and microwaves. The manufacturer states that the overall diesel PM removal efficiency should be as high as 85 percent to 95 percent when used alone, and as high as 90 percent to 95 percent when combined with an oxidation catalyst, although emission test results will not be available until September 1999.

The product is commercially available and has been integrated into particulate filter systems that can be used on both portable and stationary engines and on turbines. The manufacturer states that the product has been used on 2,000+ vehicles with some preliminary testing in stationary applications. The manufacturer also states that some of the particulate filter systems have been in the field for 6 years and have logged 10,000+ hours of operation. The initial cost of a ceramic fiber cartridge is between $80 and $250. However, the initial cost of a particulate filter system depends on the builder and method of regeneration. The product can be used with the existing California diesel fuel formulations.

Product Name: CleanDIESEL Soot Filter
Manufacturer: Clean Air Systems
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation and filtration. The passive, self-regenerating catalyzed particulate filter system collects diesel PM and oxidizes it during hot duty cycle operations (i.e. exhaust temperatures above 700°F). The integrated catalyst reduces the particulate oxidation temperature, and it oxidizes the CO and HC emissions. For proper filter regeneration and to maintain an acceptable back pressure, the hot duty cycle must account for at least 20 percent of the engine operating time. The manufacturer states that reductions of both the SOF and the carbonaceous fraction of diesel PM can be as high as 85 percent. However, ARB has not received emission test data that support this claim.

The product is commercially available and has been installed on approximately 100 stationary, portable, and mobile diesel-fueled engines. The initial product cost ranges from $990 for a 122 cubic inch naturally aspirated engine to $20,025 for a 2,900 cubic inch turbocharged engine, and it takes between one and six hours to install. The manufacturer states that the product's useful life should be approximately 10,000 engine hours, however, the product's life may be limited on poorly maintained engines where soot can accumulate rapidly. (In this situation, the excessive soot can oxidize uncontrollably and destroy the filter.) The manufacturer recommends cleaning the product annually, and the maintenance costs include the time and materials associated with this activity. The product carries a one-year / 2,000 engine hour warranty on the filter packaging; however, no warranty is provided on the filter media. The product can be used with the existing California diesel fuel formulations.

Product Name: Combifilter
Manufacturer: Engine Control Systems
Category: Exhaust Treatment

Description:

The product reduces diesel PM through filtration and is actively regenerated with the periodic use of electric heating. The manufacturer states that the overall diesel PM removal efficiency is between 80 percent to 90 percent. Higher reductions can be achieved when an oxidation catalyst is used in conjunction with the product. The results of one transient emission test, based on a test procedure developed specifically for a backhoe, indicated that the product when used without an oxidation catalyst reduced diesel PM emissions by 81 percent. Another set of emission tests, based upon the ISO 8-mode test, indicated that the product used in conjunction with an oxidation catalyst achieved a 95 percent reduction in diesel PM emissions, 88 percent reduction in carbon monoxide, and 92 percent reduction in hydrocarbons.

The product is commercially available in Europe and Asia and has been employed on over 3,000 diesel-fueled engines including captive fleet vehicles, stationary and mining engines. The product will be marketed in the United States later this year. The product's initial cost depends on engine size, exhaust flow rate, exhaust temperature and duty cycle, and typically varies between $5,000 and $40,000 for engines rated from 40 horsepower up to 1,400 horsepower. The filter must be cleaned every 1,000-1,500 hours, depending upon oil consumption. The product is covered by a one-year warranty and it can be used with existing California diesel fuel formulations.

Product Name: CRT Particulate Filter
Manufacturer: Johnson Matthey
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, HC, and NOx emissions from mobile, stationary, and portable diesel-fueled engines through filtration and catalytic oxidation. The passive, self-regenerating filter system collects diesel PM and oxidizes it during hot duty cycle operations (i.e. exhaust temperatures above 530°F). A precious metal oxidation catalyst, installed upstream of a wall flow monolith filter element, converts nitrogen oxide in the exhaust stream to nitrogen dioxide, which is a strong oxidant. The product then relies on the nitrogen dioxide to oxidize the diesel PM collected on the filter element at temperatures typical for diesel-fueled engine exhaust. The catalyst also oxidizes the carbon monoxide and hydrocarbon emissions, including the SOF of diesel PM. For proper filter regeneration and operation, the hot duty cycle must account for at least 40 percent to 50 percent of the engine operating time. The manufacturer states that the overall diesel PM, CO, and HC removal efficiency can be more than 90 percent, and that the NOx removal efficiency can be as high as 10 percent. The results of one transient emission test of a 1986 2-stroke diesel-fueled transit bus engine show that, over the FTP, the product reduced diesel PM emissions by 93 percent, HC emissions by 86 percent, CO emissions by 90 percent, and NOx emissions by 2 percent.

As is the case with most processes that incorporate catalytic oxidation, the formation of sulfate particles increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in diesel PM emissions. Sulfur also inhibits the conversion of nitrogen oxide to nitrogen dioxide. Because of these effects, the manufacturer requires the use of ultra-low sulfur fuel. For proper regeneration, diesel with an average fuel sulfur content of 30 ppm (50 ppm max.) is required. A fuel sulfur content of less than 15 parts per million is recommend to achieve maximum diesel PM reductions.

The product is commercially available and has been installed on over 10,500 mobile diesel-fueled engines in Europe, and it is currently being demonstrated in eight heavy-duty vehicle fleets in southern California and at the New York Metropolitan Transportation Authority. The product's initial cost depends on engine size, exhaust flow rate, exhaust temperature, and duty cycle, and typically varies between $5,000 and $8,000 for engines rated up to 450 horsepower. Installation takes about four hours, and the operating costs include the incremental cost of using an ultra-low sulfur diesel fuel. The product should be cleaned every 12 months or 60,000 miles, whichever occurs first, according to the manufacturers maintenance instructions, and the maintenance costs include the time and materials associated with this cleaning activity. For urban transit bus applications, the manufacturer provides an emission performance warranty for 150,000 miles and will replace defective parts for a period of 100,000 miles.

Product Name: DPX Particulate Filter
Manufacturer: Engelhard Corporation
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation and filtration. The passive, self-regenerating catalyzed filter system collects diesel PM and oxidizes it under normal engine exhaust temperatures. The integrated catalyst reduces the particulate oxidation temperature, and oxidizes soluble organic, CO, and HC emissions. For proper filter regeneration and operation, the hot duty cycle must account for at least 20 percent of the engine operating time. The manufacturer states that the overall diesel PM removal efficiency can be as high as 70 percent to 95 percent. The results of one emission test of a Caterpillar wheel loader, which was tested over a specially designed transient cycle, show that the product can reduce diesel PM emissions by 96 percent.

The product is commercially available and has been installed on several stationary diesel-fueled engines as well as approximately 1,000 mobile diesel-fueled engines. The manufacturer states that the product's useful life can exceed 15,000 engine hours. The product's initial cost varies between $10 and $125 per horsepower. The product should be cleaned regularly according to the maintenance instructions because lube oil ash can accumulate and increases the system's back pressure. This maintenance activity is expected to take from 2 to 4 hours per year, and the maintenance costs include the time and materials associated with this cleaning activity. When the product is installed on standby engines, the periodic engine testing should include 45 minutes of operation under load to allow for proper filter regeneration. The product carries a mechanical durability warranty of between one and two years depending on the application, and it can be used with California's existing diesel fuel formulations.

Product Name: QuadCat Four-Way Catalytic Converter
Manufacturer: Ceryx, Inc.
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, HC, and NOx emissions from mobile, stationary, and portable diesel-fueled engines. The product consists of a lean NOx catalyst and a catalyzed diesel particulate filter (CDPF) integrated together with a heat exchanger. The lean NOx system reduces NOx, via a catalytic process, to nitrogen and water. The CDPF collects diesel PM and oxidizes the soluble organic portion of diesel PM, CO, and HC emissions. Diesel fuel is injected into the heat exchanger to ensure the catalyst is operating at the optimum temperature levels for diesel PM regeneration. The manufacturer indicates that the product is expected to achieve 90 percent reduction in CO, HC, and diesel PM emissions and 30 percent to 50 percent reduction in NOx emissions. Testing is currently being conducted by the manufacturer to verify the product's performance.

As is the case with most processes that incorporate catalytic oxidation, the formation of sulfate particles increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in particulate emissions. Lower fuel sulfur content is expected to enhance the performance of the product.

The product is expected to be commercially available in late 2000. Research units have been installed on a 7.3 L Navistar Powerstroke Ford F-250 and a school bus equipped with a Navistar 466 engine. The product's initial cost in mobile applications depends on engine size, exhaust flow rate, exhaust temperature, and duty cycle, and typically varies between $5,000 and $10,000 for engines rated up to 400 horsepower. Installation takes about 5 - 6 hours, and the operating costs include the cost of supplementary diesel fuel, which is typically 2 percent to 4 percent of engine fuel use at full load. The product can be used with the existing California diesel fuel formulations.

Product Name: "Trap-Muffler" System
Manufacturer: Doubletree Technologies, Inc.
Category: Exhaust Treatment

Description:

The product reduces diesel PM, HC, and NOx emissions from stationary, portable, and mobile diesel-fueled engines through filtration, exhaust gas recirculation (EGR) and oxidation. The system consists of twin particulate filters located such that the exhaust temperature remains relatively low (i.e. 100°C to 300°C) allowing gaseous hydrocarbons to condense on the collected diesel PM. One particulate filter is isolated and slowly regenerates while the engine's exhaust stream is directed to the second filter. Regeneration is accomplished using either an optimally located glow plug for ceramic fiber-type filters or an electric igniter coil for honeycomb-type filters. A pressure sensor-controlled diverter valve alternates between the two filters and ensures minimum exhaust backpressures.

A fuel borne catalyst is used to lower the oxidation temperature of the collected diesel PM. Alternatively, a catalyzed particulate filter can be used in place of the fuel borne catalyst when low sulfur fuel is available. In addition, a portion of the filtered and cooled exhaust stream is directed to the EGR system which further enhances hydrocarbon oxidation and minimizes the formation of NOx. The manufacturer states that the product reduces both the carbonaceous fraction and the soluble organic fraction of diesel PM, and they guarantee that the overall diesel PM removal efficiency will be at least 90 percent. However, ARB has not received emission test data that support this claim.

The product is expected to be available for commercial use in the near future. The product (absent the EGR component) has been installed on 1,100 mobile diesel-fueled engines in Seoul, Korea, although the catalyzed filters experienced durability problems related to level of sulfur in the diesel fuel. The manufacturer states that the product's useful life should be about two years, and that the individual filter elements can be easily serviced. The product's initial cost is: $1,500 for a 40 hp engine (with simplified controls); $1,700 for a 100 hp engine; $2,000 for a 275 hp engine; $2,500 for a 400 hp engine and $4,500 for a 1,400 hp engine. It takes approximately 3 - 6 hours to install the product, and the installation costs are expected to be between $300 and $600. The operating costs will include a 2 percent increase in fuel costs when a fuel borne catalyst is used. The maintenance costs are not known at this time, and the warranty has not been determined. The product can be used with California's existing diesel fuel formulations.

Product Name: Nett SF Soot Filter
Manufacturer: Nett Technologies, Inc.
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation and filtration. The passive, self-regenerating catalyzed filter system collects diesel PM and oxidizes it during hot duty cycle operations (i.e. exhaust temperatures between 700 °F and 750 °F). The integrated proprietary catalyst reduces the particulate oxidation temperature, and it oxidizes the soluble organic, CO, and HC emissions. For proper filter regeneration and operation, the hot duty cycle must account for at least 20 percent of the engine operating time. The manufacturer states that the overall diesel PM removal efficiency can be as high as 85 percent to 99 percent. One Central Business District transient driving cycle emission test of a hybrid diesel-electric bus shows that the product reduces diesel PM emissions by 92 percent, HC emissions by 41 percent, and CO emissions by 93 percent when compared to an OEM catalyst.

The product is commercially available and has been installed on approximately 200 stationary and portable diesel-fueled engines. The initial product cost, which varies with engine size, ranges from $25 to $75 per horsepower, and it takes approximately 1½ hours to install. The operating costs include a 1 percent - 1½ percent fuel penalty due to the increased backpressure, which can be as high as 20 to 40 inches of water. The manufacturer states that the product's useful life can extend from 8,000 to 12,000 engine hours, although this may be reduced in poorly maintained engines with leaking fuel injectors, dirty intake air cleaners, excessive oil consumption and/or lubricating oil in the exhaust. The manufacturer provides a 2,000 hour limited warranty on mechanical durability. The product can be used with the existing California diesel fuel formulations.

Part B: TECHNICAL EVALUATION OF TECHNOLOGIES THAT REDUCE PARTICULATE EMISSIONS FROM DIESEL-FUELED ENGINES

DRAFT Control Technology Evaluation

Item	Response
Technology:	Catalyzed Diesel Particulate Filter
Technology Description: (How does it work?)	The technology is a passive, self-regenerating catalyzed diesel particulate filter (C-DPF). The technology reduces particulate matter, carbon monoxide and hydrocarbon emissions through catalytic oxidation and filtration. The C-DPF collects diesel particulate matter and oxidizes it during hot duty cycle operations. (This process of cleaning the C-DPF is called regeneration.) Typically, the filter media consists of ceramic wall-flow monoliths which capture the diesel particulates. These ceramic monoliths are either coated with a catalyst material or a separate catalyst is installed upstream of the C-DPF. The catalyst reduces the temperature at which the collected particulate matter oxidizes, and it oxidizes the soluble organic, carbon monoxide and hydrocarbon emissions.
Applicability: (What types of engines can the product be installed on?)	The technology is available for stationary and portable diesel engines rated at 5,000 horsepower or less and can be retrofitted to existing equipment. C-DPFs are also available for mobile diesel engines. However, the technology is not appropriate for an application where an engine and its associated duty cycle do not generate enough heat to oxidize the collected particulate matter and regenerate the filter. For example, C-DPFs may not be appropriate for engines used in severe cyclic operations.
Achieved Emission Reductions:	<u>Product</u> / <u>Test Cycle</u> / <u>PM Reduction</u> Nett SF Soot Filter / CBD Transient / 92% Engelhard DPX / Special Transient / 97% CleanDiesel Soot Filter / ISO 8178 C1 / 85%
Emission Reduction Guarantee:	The emission reduction efficiency of this technology depends on the associated engine's baseline emissions, fuel sulfur content and emission test method / cycle. As such, diesel particulate filter manufacturers do not provide emission reduction guarantees.
Costs: **Initial Retail:**	The initial cost is: $3,300 - $5,000 for a 40 hp engine; $5,000 - $7,500 for a 100 hp engine; $6,900 - $9,000 for a 275 hp engine; $10,500 for a 400 hp engine; and $32,000 - $44,000 for a 1,400 hp engine.
Installation:	$167 - $518 (Assuming 1.5 - 6 hours x $78/hr + $50 in misc parts.)
Operating:	Fuel consumption may increase by one to one and a half percent due to additional backpressure.
Maintenance:	$156 - $312 (Assuming 2 - 4 hours labor per year.)
Comments:	Diesel particulate filters should be cleaned regularly. Because of their higher backpressures (e.g. 20 - 70+ in. wc.) and the potential for masking by lube oil ash, ARB staff expect that the periodic maintenance of DPFs will be more frequent and possibly more extensive than that of diesel oxidation catalysts. ARB staff expect that the maintenance costs listed above reflect the minimum.

Item	Response
Certifications:	
Durability: (How long can the technology be expected to function under normal operating conditions and still achieve the specified emission reductions?)	Manufacturers claim that the useful life of the technology can be as high as 8,000 to 12,000 service hours if properly maintained. However, this may be reduced when a C-DPF is installed on a poorly maintained engine with leaking fuel injectors, a dirty intake air cleaner, excessive oil consumption and/or lubricating oil in the exhaust. In addition, particulate matter can build up on a C-DPF when an engine does not achieve the proper regeneration temperature for the proper duration (i.e. soot overloading). With this build up, if the C-DPF subsequently begins to regenerate, the collected particulate can oxidize uncontrollably and destroy the particulate filter.
Warranty:	Diesel particulate filters typically carry a 2,000 service hour warranty.
Affect on Engine Warranty: (When possible, identify any impact the technology may have on an engine's warranty.)	The technology imposes additional exhaust flow restrictions of between 20" to 70" of water column or more. In some applications, such as severe cyclic operations, the engine may not generate enough heat to oxidize the collected particulate matter and regenerate the filter. This can lead to soot overloading and backpressures beyond the manufacturer's recommended limit. The specific impact on an OEM engine warranty is not known.
Adverse Impacts: **Environmental:**	See "Special Operating Requirements" section below.
Safety:	No known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	As is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset a portion of the C-DPF's particulate reductions. In addition, sulfur dioxide can counteract the effect of the catalyst material and increase the C-DPF's regeneration temperature. Diesel fuel with a very low sulfur content will maximize the emission reduction capability of this technology.
	C-DPFs must be selected for the specific engine and its associated duty cycle. All engines must be able to maintain the minimum regeneration temperature (which varies by product) for at least 20% - 50% of the engine's duty cycle.
Current Status: (Is the technology commercially available, or is it still under development? How many engines has the technology been installed on, and how long has the technology been in use?)	The technology is commercially available. According to the VERT study [1999], C-DPFs have been installed on several thousand mobile diesel-fueled engines. The technology has also been installed on a few stationary diesel-fueled engines.

DRAFT - DO NOT CITE OR QUOTE

<table>
<tr><th>Item</th><th>Response</th></tr>
<tr><td rowspan="3">Other:
(e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)</td><td>The size and weight of one manufacturer's C-DPFs are as follows:
<table>
<tr><th>HP</th><th></th><th>Diameter</th><th>Length</th><th>Weight</th></tr>
<tr><td>40</td><td></td><td>8.1"</td><td>18.5"</td><td>17 lb</td></tr>
<tr><td>100</td><td></td><td>9.6"</td><td>25.5"</td><td>34 lb</td></tr>
<tr><td>275</td><td></td><td>11.9"</td><td>30.6"</td><td>47 lb</td></tr>
<tr><td>400</td><td></td><td>15.7"</td><td>34.2"</td><td>87 lb</td></tr>
<tr><td>1,400</td><td>2@</td><td>20.7"</td><td>38.2"</td><td>151 lb</td></tr>
</table></td></tr>
<tr><td>The determination of whether or not a used C-DPF would be considered a "hazardous waste" depends on the material(s) used in the catalytic coating. C-DPFs can be manufactured with catalytic coatings such that the product would not be considered a hazardous waste at the end of its useful life. Further, the Department of Toxic Substances Control currently regulates used automotive catalytic converters as scrap metal as long as the catalyst is left in the converter shell during collection and transport and the converters are going for recycling.</td></tr>
<tr><td>The ash residue associated with cleaning and maintaining a C-DPF would need to be tested before a hazardous waste determination could be made.</td></tr>
<tr><td>Impacts of Lower Sulfur Diesel Fuel</td><td>Use of diesel fuel with a very low sulfur content will improve the technology's particulate reduction efficiency. A recent study sponsored by the U.S. Department of Energy (DOE) found that fuel sulfur levels have a significant impact on the ability of C-DPFs to reduce particulate emissions. The study also concluded that fuel sulfur levels of less than 150 ppm are necessary in order to achieve reductions in particulate emission from some C-DPFs.</td></tr>
<tr><td>Comments:
(Address other issues relevant to the use of this technology, including other advantages / disadvantages of using the technology.)</td><td>In addition to reducing particulate emissions, the technology also reduces carbon monoxide and hydrocarbon emissions.</td></tr>
</table>

List of Applications

Technology Name: Catalyzed Diesel Particulate Filter

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
Sierra Nevada Brewing Company, Inc. Chico, CA	Make: Caterpillar Model: 3412 Application: Generator Fuel Type: Shell Amber 363 DPF: Engelhard DPX	Authority to Construct No. SNB-99-09-AC Issued by Butte County AQMD	Two C-DPFs installed on each of two emergency backup generators.	Recent Installation	0.0584 lb/hr	Emission testing completed in March 2000. Results pending.
New York Metropolitan Transportation Authority[1]	Make: Detroit Diesel Model: Series 50 Application: Transit Bus Fuel Type: Reduced Sulfur Diesel (30 ppm S) DPF: Johnson Matthey CRT	n/a	22	Since February 2000	n/a	Pending
San Diego School District[2]	Make: International Model: 530E Application: School Bus Fuel Type: ARCO EC-D DPF: Engelhard DPX & Johnson Matthey CRT	n/a	5 w/ DPX 5 w/ CRT	Since December 1999	n/a	See List of Emission Test Results

[1] New York MTA Clean Diesel Demonstration Program. As part of this program, the New York MTA intends to evaluate the technology on twentyfive DDC Series 50 and twentyfive DDC 6V92 transit bus engines over a one year period.

[2] Fleet managed by Navistar as part of the ARCO EC-D Demonstration Program.

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
ARCO Distribution[3]	Make: Cummins Model: M11 Application: Tanker Truck Fuel Type: ARCO EC-D DPF: Engelhard DPX & Johnson Matthey CRT	n/a	5 w/ DPX 5 w/ CRT	Unknown	n/a	See List of Emission Test Results
Ralphs Grocery[4]	Make: Detroit Diesel Model: Series 60 Application: Grocery Truck Fuel Type: ARCO EC-D DPF: Engelhard DPX & Johnson Matthey CRT	n/a	5 w/ DPX 5 w/ CRT	Unknown	n/a	See SAE paper 2000-01-1854 for detailed emission test results.
Swedish Public Transportation Association	Make: Unknown Model: Unknown Application: Transit Bus Fuel Type: Low Sulfur Diesel DPF: Johnson Matthey CRT	n/a	1994: 10 Buses 1996: 1,000 Buses 1999: 2,000 Buses 1999: 1,000 Trucks		Unknown	Unknown

[3] Fleet managed by ARCO as part of the ARCO EC D-Demonstration Program.

[4] Fleet managed by the National Renewable Energy laboratory (NREL) as part of the ARCO EC-D Demonstration Program.

List of Emission Test Results

Technology Name: Catalyzed Diesel Particulate Filter

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Central Business District (CBD)	Environment Canada, Emission Research and Measurement Division, Report #97-26771-3 (Unpublished)	Nett SF Soot Filter Mfg. by Nett Technologies	Make: Navistar Model: T444 Diesel-Electric Year: Not known BHP: Not known Application: Hybrid Diesel-Electric Transit Bus Configuration: Not known Engine Hours: Not known Fuel Type: Certification Diesel D2 Fuel Use: Not known Exhaust Temp: Not known	 PM NOx CO HC	w/ oxidation catalyst 0.318 g/mile 10.66 g/mile 1.78 g/mile 0.22 g/mile	600 rpm Config. 0.036 g/mile 11.16 g/mile 0.12 g/mile 0.04 g/mile	 89% -5% 93% 82%
				  PM NOx CO HC	w/ oxidation catalyst 0.318 g/mile 10.66 g/mile 1.78 g/mile 0.22 g/mile	750 rpm Config. 0.027 g/mile 10.62 g/mile 0.13 g/mile 0.13 g/mile	 92% 0% 93% 41%
Special transient cycle designed for a specific wheel loader application.[5]	Emissions Research and Measurement Division, Environment Canada	DPX Particulate Filter Mfg. by Engelhard Corporation	Make: Caterpillar Model: 988 Year: Unknown BHP: 320 Application: Wheel loader Configuration: Unknown Engine Hours: Unknown Fuel Type: 530 ppm S Diesel Fuel Use: 15.8 kg/hr Exhaust Temp: Unknown	PM NOx CO HC	17.38 g/hr 290.72 g/hr 112.65 g/hr 9.32 g/hr	0.59 g/hr 224.96 g/hr 35.67 g/hr 2.96 g/hr	97% 23% 68% 68%

[5] Study reported in SAE Technical Paper #1999-01-0110 entitled "The Impact of Retrofit Exhaust Control Technologies on Emissions from heavy-Duty Diesel Construction Equipment."

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
ISO 8178 C1	AB Svensk Motor Test Center	CleanDiesel Soot Filter Mfg. by Clean Air Systems	Make: Volvo Model: TD61-G Year: Unknown BHP: 78 hp Application: Mobile Source Configuration: Unknown Engine Hours: Unknown Fuel Type: 50 ppm S MK-1 Diesel Fuel Use (lb/hp-hr): 0.376 / 0.380 Exhaust Temp: Unknown	PM NOx CO HC	0.14 g/bhp-hr 9.55 g/bhp-hr 2.33 g/bhp-hr 0.22 g/bhp-hr	0.02 g/bhp-hr 9.17 g/bhp-hr 0.02 g/bhp-hr 0.01 g/bhp-hr	85% 4% 99% 97%
European Stationary Cycle (OICA)[6]	Engineering Test Services, Charleston, SC	Catalyzed Diesel Particulate Filter	Make: Caterpillar Model: 3126 Year: 1998 or 1999 BHP: 275 horsepower Application: N/A Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: Diesel w/ varying fuel sulfur levels Fuel Use (lb/hp-hr): 0.35 - 0.36 Exhaust Temp: Not Reported	 PM NOx CO HC	<u>3 ppm Sulfur</u> 0.0613 g/hphr 4.94 g/hphr 0.98 g/hphr 0.0542 g/hphr	<u>3 ppm Sulfur</u> 0.0031 g/hphr 4.92 g/hphr 0.06 g/hphr 0.0228 g/hphr	 95% 0% 94% 58%
				 PM NOx CO HC	<u>30 ppm Sulfur</u> 0.063 g/hphr 4.98 g/hphr 0.96 g/hphr 0.056 g/hphr	<u>30 ppm Sulfur</u> 0.0166 g/hphr 4.8 g/hphr 0.02 g/hphr 0.0182 g/hphr	 74% 4% 98% 68%
				 PM NOx CO HC	<u>150 ppm S</u> 0.0708 g/hphr 4.85 g/hphr 1.04 g/hphr 0.0586 g/hphr	<u>150 ppm Sulfur</u> 0.0707 g/hphr 4.87 g/hphr 0.02 g/hphr 0.0105 g/hphr	 0% 0% 98% 82%

[6] Emission test results reported in "Diesel Emission Control - Sulfur Effects (DECSE) Program, Phase I Interim Data Report No. 4: Diesel Particulate Filters - Final Report," January 2000.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
					350 ppm S	350 ppm Sulfur	
				PM	0.0793 g/hphr	0.176 g/hphr	-122%
				NOx	4.91 g/hphr	4.69 g/hphr	4%
				CO	0.94 g/hphr	0.03 g/hphr	97%
				HC	0.0565 g/hphr	0.0194 g/hphr	66%
European Stationary Cycle (OICA)[7]	Engineering Test Services, Charleston, SC	Continuously Regenerating Diesel Particulate Filter	Make: Caterpillar Model: 3126 Year: 1998 or 1999 BHP: 275 horsepower Application: N/A Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: Diesel w/ varying fuel sulfur levels Fuel Use (lb/hp-hr): 0.35 - 0.36 Exhaust Temp: Not Reported		3 ppm Sulfur	3 ppm Sulfur	
				PM	0.0613 g/hphr	0.0032 g/hphr	95%
				NOx	4.94 g/hphr	4.96 g/hphr	0%
				CO	0.98 g/hphr	0.1 g/hphr	90%
				HC	0.0542 g/hphr	0.0136 g/hphr	75%
					30 ppm Sulfur	30 ppm Sulfur	
				PM	0.063 g/hphr	0.0176 g/hphr	72%
				NOx	4.98 g/hphr	4.84 g/hphr	3%
				CO	0.96 g/hphr	0.06 g/hphr	94%
				HC	0.056 g/hphr	0.0052 g/hphr	91%
					150 ppm S	150 ppm Sulfur	
				PM	0.0708 g/hphr	0.0729 g/hphr	-3%
				NOx	4.85 g/hphr	4.88 g/hphr	-1%
				CO	1.04 g/hphr	0.06 g/hphr	94%
				HC	0.0586 g/hphr	0.0189 g/hphr	68%
					350 ppm S	350 ppm Sulfur	
				PM	0.0793 g/hphr	0.2025 g/hphr	-155%
				NOx	4.91 g/hphr	4.81 g/hphr	2%
				CO	0.94 g/hphr	0.05 g/hphr	95%
				HC	0.0565 g/hphr	0.0064 g/hphr	89%

[7] Emission test results reported in "Diesel Emission Control - Sulfur Effects (DECSE) Program, Phase I Interim Data Report No. 4: Diesel Particulate Filters - Final Report," January 2000.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Federal Test Procedure[8]	Southwest Research Institute, Inc.	One Individual Diesel Particulate Filters	Make: Detroit Diesel Corporation Model: DDC 6067TK60 (DDC Series 60) Year:1998 BHP: 400 hp Application: Heavy Duty Vehicle Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: 368 ppm S Diesel Fuel Use (lb/bhp-hr): 0.393 - 0.401 Exhaust Temp: Approx 100-800°F	PM NOx CO HC	0.073 g/bhp-hr 3.991 g/bhp-hr 1.111 g/bhp-hr 0.115 g/bhp-hr	DPF "A" 0.022 g/bhp-hr 3.960 g/bhp-hr 0.403 g/bhp-hr 0.006 g/bhp-hr	70% 1% 64% 95%
Federal Test Procedure [8]	Southwest Research Institute, Inc.	Two Individual Diesel Particulate Filters	Make: Detroit Diesel Corporation Model: DDC 6067TK60 (DDC Series 60) Year:1998 BHP: 400 hp Application: Heavy Duty Vehicle Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: 54 ppm S Diesel Fuel Use (lb/bhp-hr): 0.396 - 0.402 Exhaust Temp: Approx 100-800°F	PM NOx CO HC	0.063 g/bhp-hr 3.836 g/bhp-hr 1.200 g/bhp-hr 0.109 g/bhp-hr	DPF "B" 0.008 g/bhp-hr 3.901 g/bhp-hr 0.077 g/bhp-hr 0.005 g/bhp-hr	87% -2% 94% 95%
				PM NOx CO HC	0.063 g/bhp-hr 3.836 g/bhp-hr 1.200 g/bhp-hr 0.109 g/bhp-hr	DPF "A" 0.006 g/bhp-hr 4.062 g/bhp-hr 0.267 g/bhp-hr 0.019 g/bhp-hr	90% -6% 78% 83%

[8] The FTP emission test information was presented in the May 1999 report "Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Very Low Emission Levels" prepared for the Manufacturers of Emission Controls Association by Southwest Research Institute, Inc.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Federal Test Procedure[9]	Southwest Research Institute, Inc.	Continuously Regenerating Trap (CRT) by Johnson Matthey	Make: Detroit Diesel Corporation Model: 6V92TA MUI Year: 1986 BHP: 253 hp Application: Transit Bus Configuration: Turbocharged & Aftercooled Engine Miles: Over 300,000 miles Fuel Type: 2-D Certification Diesel Fuel Use (lb/hr): 64.8 - 66.6 Exhaust Temp: Not Reported Note: Pre-Rebuild w/ CRT & Uninsulated	 PM NOx CO HC	<u>500 ppm S</u> 0.44 g/bhp-hr 10.5 g/bhp-hr 1.0 g/bhp-hr 0.7 g/bhp-hr	<u>100 ppm S</u> 0.03 g/bhp-hr 10.3 g/bhp-hr 0.1 g/bhp-hr 0.1 g/bhp-hr	 93% 2% 90% 86%
City-Suburban heavy Vehicle Route (CSHVR)[10]	West Virginia University	Engelhard DPX Particulate Filter	Make: International Model: 530E Year: 1988 BHP: 275 hp Application: School Bus Configuration: Not Reported Engine Miles: Not Reported Fuel Type: ARCO EC-D Fuel Use (mpg): 4.68/5.09 4.46/4.49 Exhaust Temp: Not Reported	 PM NOx CO HC PM NOx CO HC	<u>Bus 3</u> 0.180 g/mile 18.14 g/mile 2.06 g/mile 0.466 g/mile <u>Bus 4</u> 0.192 g/mile 18.11 g/mile 2.45 g/mile 0.487 g/mile	<u>Bus 3</u> 0.000 g/mile 16.05 g/mile 0.11 g/mile 0.000 g/mile <u>Bus 4</u> 0.000 g/mile 16.45 g/mile 0.18 g/mile 0.000 g/mile	<u>Bus 3</u> 100% 11% 95% 100% <u>Bus 4</u> 100% 9% 93% 100%

[9] The emission test information was submitted to support Johnson Matthey's application for certification of a Low Sulfur 0.1 g/bhp-hr PM Emissions Reduction Rebuild Kit for all transit engines.

[10] Emission test results reported in SAE paper 2000-01-1854 entitled "EC-Diesel Technology Validation Program Interim Report." (Unpublished)

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
City-Suburban heavy Vehicle Route (CSHVR)[11]	West Virginia University	Johnson Matthey CRT Particulate Filter	Make: Cummins Model: M11 Year: 1995-96 BHP: 330 hp Application: Tanker Truck Configuration: Not Reported Engine Miles: Not Reported Fuel Type: ARCO EC-D Fuel Use (mpg): 5.92/5.53 & 4.79/4.95 Exhaust Temp: Not Reported	 PM NOx CO HC PM NOx CO HC	Truck 3 0.510 g/mile 14.05 g/mile 3.25 g/mile 1.026 g/mile Truck 4 0.613 g/mile 15.26 g/mile 2.53 g/mile 1.456 g/mile	Truck 3 0.015 g/mile 12.49 g/mile 0.49 g/mile 0.068 g/mile Truck 4 0.037 g/mile 15.37 g/mile 0.15 g/mile 0.153 g/mile	Truck 3 97% 11% 85% 93% Truck 4 94% -1% 94% 89%

[11] Emission test results reported in SAE paper 2000-01-1854 entitled "EC-Diesel Technology Validation Program Interim Report." (Unpublished)

DRAFT Control Technology Evaluation

Item	Response
Product Name:	Platinum Plus® DFX Fuel Borne Catalyst + Diesel Particulate Filter
Product Vendor:	Clean Diesel Technologies, Inc.
Vendor Address:	300 Atlantic Street, Suite 702 Stamford, CT 06901-3522
Product Description: (What is the product, and how does it work?)	The technology involves combining the use of a concentrated liquid fuel-borne catalyst (FBC) with an uncatalyzed or lightly catalyzed Diesel Particulate Filter (DPF). The technology reduces particulate matter emissions through catalytic oxidation and filtration. The FBC contains low doses (i.e. 4 ppm - 8 ppm) of platinum and cerium that work together to improve particulate oxidation within the combustion chamber and to lower the temperature at which regeneration occurs within a DPF. While similar to a catalyzed DPF, an FBC enhances DPF regeneration by encouraging better contact between the particulate matter and the catalyst material. The FBC+DPF combination reduces both the carbonaceous and soluble organic fractions of diesel PM.
Applicability: (What types of engines can the product be installed on?)	The technology can be applied to all stationary and portable diesel-fueled engines rated at 5,000 horsepower or less, and can be retrofitted to existing equipment. However, the technology may not be appropriate for applications where an engine and its associated duty cycle do not generate enough heat to oxidize the collected particulate matter and regenerate the filter. For example, the FBC+DPF combination may not be appropriate for engines with exhaust temperatures routinely below 540°F. The FBC manufacturer recommends that an FBC+DPF equipped engine operate such that the exhaust gas temperatures reach 660°F for at least 20 minutes during each 8 hour period of operation.
Manufacturer's Emission Reduction Claim: (What level of emission reduction can be achieved?)	The manufacturer claims that the technology reduces particulate emissions by 70% - 95%.
Emission Reduction Guarantee:	The manufacturer's emission reduction guarantee depends on the engine's baseline emission level.
Certifications: (Identify certifications the product has received, and explain any limits on those certifications.)	Platinum Plus is registered by the U.S. Environmental Protection Agency as a diesel fuel additive.
Emission Test Results: (Summarize emission test results and describe in detail on the attached table.)	<u>Engine Make/Model</u> — <u>Test Cycle</u> — <u>PM Reduction</u> DDC Series 60 — FTP Transient — 57% - 96% Cummins 6BTA — FTP Transient — 95% Cummins N-14 — FTP Transient — 79%

Item	Response
Costs: **Initial Retail:**	The cost of uncatalyzed or lightly catalyzed particulate filters varies by engine size as follows: $1,300 for a 40 hp engine; $2,000 for a 100 hp engine; $3,500 for a 275 hp engine; $7,000 for a 400 hp engine; and $30,000 for a 1,400 hp engine. The cost of on-board dosing systems is approximately $1,500 - $3,000 for a field retrofit, and $500 - $1,000 if factory installed.
Installation:	$167 - $518 (Assuming 1.5 - 6 hours x $78/hr + $50 in misc parts.)
Operating:	The cost of the FBC is $0.05 - $0.10 per gallon of diesel for bulk treatment or on-board dosing, and $0.10 - $0.15 per gallon of diesel for individually packaged products (quart or gallon containers).
Maintenance:	$156 - $312 (Assuming 2 - 4 hours labor per year.)
Comments:	Diesel particulate filters should be cleaned regularly. Because of higher backpressures and the potential for masking by lube oil ash, ARB staff expects that the periodic maintenance of DPFs will be more frequent and possibly more extensive than that of diesel oxidation catalysts. ARB staff expects that the maintenance costs listed above reflect the minimum.
Durability / Product Life: (How long can the technology be expected to function under normal operating conditions and still achieve the specified emission reductions?)	The manufacturer states that the shelf life of Platinum Plus, when packaged individually, is 24 months, and that its shelf life is 12 - 18 months when mixed with diesel fuel. Manufacturers claim that the useful life of a DPF can be as high as 8,000 to 12,000 service hours if properly maintained. However, this may be reduced when a DPF is installed on a poorly maintained engine with leaking fuel injectors, a dirty intake air cleaner, excessive oil consumption and/or lubricating oil in the exhaust. In addition, particulate matter can build up on a DPF when an engine does not achieve the proper regeneration temperature for the proper duration (i.e. soot overloading). With this build up, if the DPF subsequently begins to regenerate, the collected particulate matter can oxidize uncontrollably and destroy the filter. Because the product lowers particulate oxidation temperatures, it can reduce the risk of plugging and uncontrolled regeneration.
Product Warranty:	DPFs typically carry a 2,000 service hour warranty.
Affect on Engine Warranty: (When possible, identify any impact the technology may have on an engine warranty.)	The engine manufacturer should be contacted to determine the specific impact of an FBC+DPF combination on an OEM engine warranty.
Adverse Impacts: **Environmental:**	One FTP emission test suggests that the application of the FBC+DPF combination on an engine equipped with exhaust gas recirculation (EGR) may increase hydrocarbon emissions. See Comments section.
Safety:	There are no known adverse safety impacts.

Item	Response
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	The FBC manufacturer recommends that an FBC+DPF equipped engine operate such that the exhaust gas temperatures reach 660°F for at least 20 minutes during each 8 hour period of engine operation. In addition, the exhaust temperature should be maintained below 930°F to avoid and/or minimize sulfation.
Current Status: (Is the technology commercially available, or is it still under development? How many engines has the technology been installed on, and how long has the technology been in use?)	The technology is commercially available and has been applied to over 100 city buses in Taiwan, six buses in Hong Kong, and twelve pieces of construction and mining equipment in Germany and Switzerland.
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	The available emission test data shows that fuel economy varies from an increase of 2% to a decrease of 3%.
Impacts of Lower Sulfur Diesel Fuel	Although the technology can be applied to existing California diesel fuel formulations with sulfur contents up to 500 ppm, the use of low sulfur diesel fuel should improve the emission reduction efficiency of this technology.
Comments: (Address other issues relevant to the use of this technology, including other advantages / disadvantages of using the technology.)	The FBC+DPF technology appears to have a variable effect on hydrocarbon emissions. When tested on a DDC Series 60 engine equipped with EGR, hydrocarbon emissions increased by approximately 150% although the emissions did not exceed the applicable NOx+HC standard. However, other tests on the same engine without EGR show hydrocarbon reductions of 57% - 82%. When tested on a Cummins N-14 engine, hydrocarbon emissions were reduced by 80%, and when tested on a Cummins 6BTA engine, they were reduced by 64%.
	The manufacturer suggests that, when used with a lightly catalyzed DPF, the FBC+DPF combination can dramatically reduce both hydrocarbon and carbon monoxide emissions. In addition to selecting a precatalyzed DPF, a filter can be lightly catalyzed by conditioning it for 20 hours on FBC treated fuel.

276

List of Stationary &/or Portable Applications

Technology Name: Platinum Plus Fuel Borne Catalyst + Diesel Particulate Filter

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
There are no known stationary or portable applications of this technology.	Make: Model: Application: Fuel Type:					

List of Emission Test Results

Technology Name: Platinum Plus Fuel Borne Catalyst + Diesel Particulate Filter

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
FTP Transient	Southwest Research Institute	Clean Diesel Technology Platinum Plus DFX + Diesel Particulate Filter	Make: Detroit Diesel Corporation Model: Series 60 Year: 1998 BHP: 400 Application: Heavy Duty Vehicle Configuration: Turbocharged, Aftercooled, EGR Engine Hours: Not Reported Fuel Type: No. 2 Diesel (368 ppm S) Fuel Use (lb/hp-hr): 0.408 / 0.400 Exhaust Temp: Not Reported	PM NOx CO HC	0.204 g/bhp-hr 2.492 g/bhp-hr 2.528 g/bhp-hr 0.063 g/bhp-hr	0.009 g/bhp-hr 2.312 g/bhp-hr 1.863 g/bhp-hr 0.156 g/bhp-hr	96% 7% 26% -148%
FTP Transient	Southwest Research Institute	Clean Diesel Technology Platinum Plus DFX + Diesel Particulate Filter	Make: Detroit Diesel Model: Series 60 Year: 1998 BHP: 400 Application: Heavy Duty Vehicle Configuration: Turbocharged Engine Hours: Not Reported Fuel Type: Diesel (350 ppm S) Fuel Use (lb/hp-hr): 0.403 / 0.409 Exhaust Temp: Not Reported	PM NOx CO HC	0.074 g/bhp-hr 4.051 g/bhp-hr 1.128 g/bhp-hr 0.146 g/bhp-hr	0.014 g/bhp-hr 4.048 g/bhp-hr 0.658 g/bhp-hr 0.049 g/bhp-hr	81% 0% 42% 66%

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
FTP Transient	Southwest Research Institute	Clean Diesel Technology Platinum Plus DFX + Diesel Particulate Filter	Make: Detroit Diesel Model: Series 60 Year: 1998 BHP: 400 Application: Heavy Duty Vehicle Configuration: Turbocharged Engine Hours: Not Reported Fuel Type: Diesel (350 ppm S) Fuel Use (lb/hp-hr): 0.403 / 0.416 Exhaust Temp: Not Reported	PM NOx CO HC	0.074 g/bhp-hr 4.051 g/bhp-hr 1.128 g/bhp-hr 0.146 g/bhp-hr	0.017 g/bhp-hr 3.969 g/bhp-hr 0.665 g/bhp-hr 0.071 g/bhp-hr	77% 2% 41% 51%
FTP Transient	Southwest Research Institute	Clean Diesel Technology Platinum Plus DFX + *Catalyzed* Diesel Particulate Filter	Make: Detroit Diesel Model: Series 60 Year: 1998 BHP: 400 Application: Heavy Duty Vehicle Configuration: Turbocharged Engine Hours: Not Reported Fuel Type: Diesel (350 ppm S) Fuel Use (lb/hp-hr): 0.403 / 0.400 Exhaust Temp: Not Reported	PM NOx CO HC	0.074 g/bhp-hr 4.051 g/bhp-hr 1.128 g/bhp-hr 0.146 g/bhp-hr	0.032 g/bhp-hr 3.953 g/bhp-hr 0.411 g/bhp-hr 0.032 g/bhp-hr	57% 2% 64% 78%
FTP Transient	Southwest Research Institute	Clean Diesel Technology Platinum Plus DFX + *Lightly Catalyzed* Diesel Particulate Filter	Make: Detroit Diesel Model: Series 60 Year: 1998 BHP: 400 Application: Heavy Duty Vehicle Configuration: Turbocharged Engine Hours: Not Reported Fuel Type: CARB Diesel (50 ppm S) Fuel Use (lb/hp-hr): 0.390 / 0.408 Exhaust Temp: Not Reported	PM NOx CO HC	0.060 g/bhp-hr 3.681 g/bhp-hr 0.927 g/bhp-hr 0.098 g/bhp-hr	0.013 g/bhp-hr 3.786 g/bhp-hr 0.342 g/bhp-hr 0.018 g/bhp-hr	78% 3% 63% 82%

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
FTP Transient	Cummins Engine Company	Clean Diesel Technology Platinum Plus 3100C & Rhone-Poulenc Eolys DPX9 + Diesel Particulate Filter	Make: Cummins Model: Encore 6BTA Year: 1996 BHP: 225 Application: Medium Duty Vehicle Configuration: EGR Engine Hours: 400 hrs Fuel Type: Diesel (350 ppm S) Fuel Use (lb/hp-hr): Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.231 g/bhp-hr 2.64 g/bhp-hr 1.44 g/bhp-hr 0.22 g/bhp-hr	0.011 g/bhp-hr 2.14 g/bhp-hr 1.39 g/bhp-hr 0.08 g/bhp-hr	95% 19% 3% 64%
FTP Transient (Hot Start Only)	Southwest Research Institute	Platinum Plus DFX + Diesel Particulate Filter	Make: Cummins Model: N-14 Year: 1998 BHP: 370 Application: Heavy Duty Vehicle Configuration: Not Reported Engine Hours: 1000 Fuel Type: Diesel Fuel Use (lb/hp-hr): 0.393 / 0.391 Exhaust Temp: Not Reported	PM NOx CO HC	0.100 g/bhp-hr 3.869 g/bhp-hr 0.505 g/bhp-hr 0.174 g/bhp-hr	0.021 g/bhp-hr 3.628 g/bhp-hr 0.487 g/bhp-hr 0.035 g/bhp-hr	79% 6% 4% 80%

DRAFT Control Technology Evaluation

Item	Response
Technology:	Diesel Oxidation Catalyst
Technology Description: (How does it work?)	The technology reduces carbon monoxide (CO), hydrocarbons (HC), and the soluble organic fraction (SOF) of diesel particulate matter through catalytic oxidation. In the presence of a catalyst material and oxygen, CO, HC, & SOF undergo a chemical reaction and are converted into carbon dioxide and water. Some manufacturers integrate hydrocarbon traps (zeolites) and sulfate suppressants into their oxidation catalysts. Hydrocarbon traps enhance HC reduction efficiency at lower exhaust temperatures and sulfate suppressants minimize the generation of sulfates at higher exhaust temperatures.
Applicability: (What types of engines can the product be installed on?)	The technology is available for stationary and portable diesel-fueled engines between four horsepower and 5,000 horsepower and can be retrofitted to existing equipment.
Achieved Emission Reductions: (Summarize emission test results and describe in detail on the attached table.)	**Product** / **Test Cycle** / **PM Reduction** Nett D-Series / 5-Mode Steady State / 21% CEP Dieselytic SX / 8-Mode Steady State / 16% Engelhard PTX / Special Transient / 24% Engelhard CMX / FTP Transient / 30%
Emission Reduction Guarantee:	The emission reduction efficiency of this technology depends on the associated engine's baseline emissions, fuel sulfur content and emission test method / cycle. As such, diesel oxidation catalyst (DOC) manufacturers do not provide emission reduction guarantees.
Certifications: (Identify certifications the technology has received, and explain any limits on the certifications.)	Several models have been certified under EPA's Urban Bus Retrofit/Rebuild program.
Product Costs: **Initial Retail:**	The initial cost range is: $400 - $600 for a 40 hp engine; $680 - $1,356 for a 100 hp engine; $2,100 - $2,600 for a 275 hp engine; $2,800 - $3,700 for a 400 hp engine; and $10,000 - $20,000 for a 1,400 hp engine.
Installation:	Approx. $167 (Assuming 1.5 hours x $78/hr + $50 in misc parts.)
Operating:	None
Maintenance:	$64/year - $712/year (Assumes $50 - $100 for thermal cleaning and 1 hour labor (at $78/hour): once every other year to 4 times per year, depending on manufacturer recommendations and application)
Comments:	The technology requires periodic maintenance which may include thermal cleaning. The frequency of the maintenance depends on the manufacturer and application and varies from biennially to four times per year. The maintenance costs above reflect this schedule.

Item	Response
Durability: (How long can the technology be expected to function under normal operating conditions and still achieve the specified emission reductions?)	Manufacturers claim that the useful life of the technology depends on the application, and that it varies between 4,000 and 10,000 service hours. However, the useful life generally appears to be consistent with the rebuild cycle of the associated engine: one manufacturer recommends replacing the catalyst at the time an engine is rebuilt. Another manufacturer claims that their product's useful life can extend to 25,000 service hours, but this depends on the condition of the engine, type of fuel and maintenance practices.
Product Warranty: (Identify the type of warranty and its duration.)	Diesel oxidation catalysts typically carry a 2,000 service hour warranty.
Affect on Engine Warranty: (When possible, identify any impact the technology may have on an engine's warranty.)	The technology imposes additional exhaust gas flow restrictions of between 4 - 11 inches of water column; however, the additional restriction is expected to be within the manufacturer's specifications. As such, the technology is not expected to have an impact on an OEM engine warranty.
Adverse Impacts: Environmental:	As is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reductions in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.
Safety:	There are no known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	One manufacturer recommends cleaning their product every 6 months or 2,000 service hours (whichever occurs first) when it is installed on newer engines, and every 3 months or 1,000 service hours (whichever occurs first) when it is installed on older engines. The catalyst can be cleaned by the engine operator by either: 1) applying a compressed air stream to the face of the catalyst; 2) heat treating the catalyst core; or 3) soaking the catalyst in an appropriate solvent.
Current Status: (Is the technology commercially available, or is it still under development? How many engines has the technology been installed on, and how long has the technology been in use?)	The technology is commercially available and has been installed on tens of thousands of mobile diesel-fueled engines. The technology has also been applied to several stationary diesel-fueled engines.

<table>
<tr><th>Item</th><th>Response</th></tr>
<tr><td>Other:
(e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)</td><td>The typical size and weight of DOCs vary as follows:
<table><tr><th><u>HP</u></th><th></th><th><u>Diameter</u></th><th><u>Length</u></th><th><u>Weight</u></th></tr><tr><td>40</td><td></td><td>3.6" - 4.6"</td><td>8.4" - 9.0"</td><td>1.8 lb - 6 lb</td></tr><tr><td>100</td><td></td><td>5.6" - 6.6"</td><td>10.2" - 10.5"</td><td>4 lb - 15 lb</td></tr><tr><td>275</td><td></td><td>8.8" - 8.9"</td><td>18"</td><td>14.8 lb - 32 lb</td></tr><tr><td>400</td><td></td><td>8.8" - 11.9"</td><td>18" - 20"</td><td>20.3 lb - 37 lb</td></tr><tr><td>1,400</td><td>2@</td><td>8.8" - 14.9"</td><td>20" - 20.8"</td><td>29.8 lb - 58.5 lb</td></tr></table>
The determination of whether or not a used DOC would be considered a "hazardous waste" depends on the material(s) used in the catalytic coating. DOCs can be manufactured with catalytic coatings such that the product would not be considered a hazardous waste at the end of its useful life. Further, the Department of Toxic Substances Control currently regulates used automotive catalytic converters as scrap metal as long as the catalyst is left in the converter shell during collection and transport and the converters are going for recycling.

The ash residue associated with cleaning and maintaining a DOC would need to be tested before a hazardous waste determination could be made.</td></tr>
<tr><td>Impacts of Lower Sulfur Diesel Fuel</td><td>Use of diesel fuel with a very low sulfur content will improve the technology's particulate reduction efficiency. One manufacturer recommends using diesel fuel with a maximum sulfur content of 500 ppm and an aromatics content of less than 18%. A second manufacturer suggests that using diesel fuel with a sulfur content of less than 500 ppm will enhance the durability and performance of their product.</td></tr>
<tr><td>Comments:
(Address other issues relevant to the use of this technology, including other advantages / disadvantages of using the technology.)</td><td>In addition to reducing the soluble organic fraction of diesel particulate matter, the product also reduces carbon monoxide and hydrocarbon emissions.</td></tr>
</table>

List of Applications

Technology Name: Diesel Oxidation Catalyst

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
New York City Metropolitan Transportation Authority	Make: Detroit Diesel Model: Series 50 & 6V92 Application: Transit Bus Fuel Type: No. 1 Diesel / Kerosene (350 ppm Sulfur)	N/A	All 4,400 Urban Transit Buses Operated by NYC MTA	Since 1993	0.05 g/bhp-hr to 0.1 g/bhp-hr	N/A
Golden Gate Transit, San Rafael, CA	Make: Detroit Diesel Model: 6V92 Application: Transit Bus Fuel Type: CARB Diesel	N/A	90 Urban Transit Buses	Since early 1990's	Unknown	N/A
Motorola - Oak Hill Site, Austin, Texas	Make: Caterpillar Model: 3516 Application: Backkup Generator Fuel Type: Diesel DOC: Johnson Matthey	N/A	1	6 Years (Installed April '94)	N/A	Unknown

List of Emission Test Results

Technology Name: Diesel Oxidation Catalyst

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
8-mode steady-state	Canada Center for Mining and Minerals Technology July 1998	Dieselytic SX Exhaust Gas Purifier Mfg. by: Catalytic Exhaust Products Limited	Make: Deutz Model: F6L-912W Year: 1979 BHP: 75.4 bhp Application: Underground mining Configuration: Naturally aspirated Engine Hours: Approx. 2,000 hours Fuel Type: 250 ppm Sulfur Diesel Fuel Use: 31.9 lb/hr Exhaust Temp: 146°F - 880°F	PM NOx CO HC	100.6 mg/m^3 835.3 ppm 291.2 ppm 130.1 ppm	84.9 mg/m^3 835.0 ppm 118.9 ppm 79.5 ppm	16% 0% 59% 39%
ISO 8178-D2 5-mode steady-state	Not Publicly Available[12]	Nett DH422 Diesel Purifier Mfg. by: Nett Technologies	Make: Ford Model: 5.0 liter Year: Unknown BHP: 150 Application: Generator Configuration: Unknown Engine Hours: Unknown Fuel Type: Diesel Fuel Use: Unknown Exhaust Temp: 933°F	PM NOx CO HC	0.5656 g/bhp-hr 6.468 g/bhp-hr 1.108 g/bhp-hr 0.489 g/bhp-hr	0.4475 g/bhp-hr 6.429 g/bhp-hr 0.214 g/bhp-hr 0.067 g/bhp-hr	21% 1% 81% 86%

[12] The manufacturer has requested that the name of the company that performed the emission tests be withheld from publication.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
ISO 8178-D2 5-mode steady-state	Not Publicly Available[13]	Nett DH312 Diesel Purifier Mfg. by: Nett Technologies Inc.	Make: Ford Model: 5.0 liter Year: Unknown BHP: 150 Application: Generator Configuration: Unknown Engine Hours: Unknown Fuel Use: Unknown Exhaust Temp: 948°F	PM NOx CO HC	0.5656 g/bhp-hr 6.468 g/bhp-hr 1.108 g/bhp-hr 0.489 g/bhp-hr	0.521 g/bhp-hr 6.943 g/bhp-hr 0.245 g/bhp-hr 0.121 g/bhp-hr	8% -7% 78% 75%
Transient cycle designed for a specific bulldozer application.[14]	Emissions Research and Measurement Division, Environment Canada	PTX Oxidation Catalyst Mfg. by: Engelhard Corporation	Make: Cummins Model: TD-25G Year: Unknown BHP: 450 Application: Bulldozer Configuration: Unknown Engine Hours: Unknown Fuel Type: 530 ppm S Diesel Fuel Use: 34.36 kg/hr Exhaust Temp: Unknown	PM NOx CO HC	62.54 g/hr 871.03 g/hr 302.37 g/hr 42.95 g/hr	47.40 g/hr 886.60 g/hr 214.15 g/hr 43.31 g/hr	24% -2% 29% -1%
Federal Test Procedure	Engine Research Center, Department of Mechanical & Aerospace Engineering, West Virginia University	CMX Diesel Oxidation Catalyst Mfg. by: Engelhard Corporation	Make: Cummins Model: L-10 Year: 1992 BHP: 280 Application: Urban Bus Configuration: Electronic Controls Engine Hours: Unknown Fuel Type: Diesel - 500 ppm S max Fuel Use (lb/bhp-hr): 0.373 / 0.368 Exhaust Temp: Unknown	PM NOx CO HC	0.105 g/bhp-hr 5.045 g/bhp-hr 1.467 g/bhp-hr 0.260 g/bhp-hr	0.073 g/bhp-hr 4.874 g/bhp-hr 0.759 g/bhp-hr 0.127 g/bhp-hr	30% 3% 48% 51%

[13] The manufacturer has requested that the name of the company that performed the emission tests be withheld from publication.

[14] Study reported in SAE Technical Paper # 1999-01-0110 entitled "The Impact of Retrofit Exhaust Control Technologies on Emissions from Heavy-Duty Diesel Construction Equipment."

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Federal Test Procedure[15]	Southwest Research Institute, Inc.	Five Individual Diesel Oxidation Catalysts	Make: Detroit Diesel Corporation Model: DDC 6067TK60 (DDC Series 60) Year:1998 BHP: 400 hp Application: Heavy Duty Vehicle Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: 368 ppm S Diesel Fuel Use (lb/bhp-hr): 0.395 - 0.406 Exhaust Temp: Approx 100-800°F			DOC "A"	
				PM	0.073 g/bhp-hr	0.056 g/bhp-hr	23%
				NOx	3.991 g/bhp-hr	3.995 g/bhp-hr	0%
				CO	1.111 g/bhp-hr	0.674 g/bhp-hr	39%
				HC	0.115 g/bhp-hr	0.050 g/bhp-hr	57%
						DOC "B"	
				PM		0.055 g/bhp-hr	25%
				NOx		4.085 g/bhp-hr	-2%
				CO		0.350 g/bhp-hr	68%
				HC		0.014 g/bhp-hr	88%
						DOC "C"	
				PM		0.069 g/bhp-hr	5%
				NOx		4.034 g/bhp-hr	-1%
				CO		0.202 g/bhp-hr	82%
				HC		0.003 g/bhp-hr	97%
						DOC "D"	
				PM		0.052 g/bhp-hr	29%
				NOx		3.996 g/bhp-hr	0%
				CO		0.964 g/bhp-hr	13%
				HC		0.055 g/bhp-hr	52%
						DOC "E"	
				PM		0.053 g/bhp-hr	27%
				NOx		3.922 g/bhp-hr	2%
				CO		0.479 g/bhp-hr	57%
				HC		0.014 g/bhp-hr	88%

[15] The FTP emission test information was presented in the May 1999 report "Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Very Low Emission Levels" prepared for the Manufacturers of Emission Controls Association by Southwest Research Institute, Inc.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Federal Test Procedure[16]	Southwest Research Institute, Inc.	One Individual Diesel Oxidation Catalysts	Make: Detroit Diesel Corporation Model: DDC 6067TK60 (DDC Series 60) Year:1998 BHP: 400 hp Application: Heavy Duty Vehicle Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: 368 ppm S Diesel Fuel Use (lb/bhp-hr): 0.401 - 0.403 Exhaust Temp: Approx 100-800°F	 PM NOx CO HC	None 0.073 g/bhp-hr 3.991 g/bhp-hr 1.111 g/bhp-hr 0.115 g/bhp-hr	DOC "F" 0.077 g/bhp-hr 4.004 g/bhp-hr 0.260 g/bhp-hr 0.004 g/bhp-hr	 -5% 0% 77% 97%
Federal Test Procedure [16]	Southwest Research Institute, Inc.	Three Individual Diesel Oxidation Catalysts	Make: Detroit Diesel Corporation Model: DDC 6067TK60 (DDC Series 60) Year:1998 BHP: 400 hp Application: Heavy Duty Vehicle Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: 54 ppm S Diesel Fuel Use (lb/bhp-hr): 0.397 - 0.403 Exhaust Temp: Approx 100-800°F	 PM NOx CO HC	 0.063 g/bhp-hr 3.836 g/bhp-hr 1.200 g/bhp-hr 0.109 g/bhp-hr	DOC "B" 0.043 g/bhp-hr 3.941 g/bhp-hr 0.347 g/bhp-hr 0.032 g/bhp-hr	 32% -3% 71% 71%
				 PM NOx CO HC		DOC "E" 0.046 g/bhp-hr 3.781 g/bhp-hr 0.522 g/bhp-hr 0.041 g/bhp-hr	 27% 1% 57% 62%
				 PM NOx CO HC		DOC "F" 0.053 g/bhp-hr 3.961 g/bhp-hr 0.194 g/bhp-hr 0.016 g/bhp-hr	 16% -3% 84% 85%

[16] The FTP emission test information was presented in the May 1999 report "Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Very Low Emission Levels" prepared for the Manufacturers of Emission Controls Association by Southwest Research Institute, Inc.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Federal Test Procedure	Southwest Research Institute, Inc.[17]	Catalytic Exhaust Muffler (CEM) Mfg. by Johnson Matthey, Inc.	Make: Detroit Diesel Corporation Model: 6V92TA MUI Year:1986 BHP: Not Reported Application: Heavy Duty Vehicle Configuration: Not Reported Engine Miles: 300,000 Fuel Type: Diesel Fuel Use (lb/bhp-hr): Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.443 g/bhp-hr 10.458 g/bhp-hr 1.007 g/bhp-hr 0.694 g/bhp-hr	0.218 g/bhp-hr 10.194 g/bhp-hr 0.607 g/bhp-hr 0.370 g/bhp-hr	51% 3% 40% 47%

[17] The emission test information was submitted to support Johnson Matthey's application for exemption from the State's emission control system anti-tampering law, Vehicle Code section 27156.

DRAFT Control Technology Evaluation

Item	Response
Product Name:	ECOTIP Superstack Fuel Injectors
Product Vendor:	Interstate Diesel
Vendor Address:	4901 Lakeside Avenue Cleveland, OH 44114
Product Description: (What is the product, and how does it work?)	The product consists of a fuel injector with a reduced sac volume and a more consistent fuel injection pressure. The product improves combustion and reduces particulate emissions by minimizing the amount of fuel that drips into the combustion chamber at the end of the chamber's fuel injection cycle.
Applicability: (What types of engines can the product be installed on?)	The product is available for diesel-fueled engines manufactured by General Motors Electro-Motive Division (EMD) and Detroit Diesel Corporation (DDC). The product can be incorporated into either mechanical or electronic fuel injection systems. For EMD engines, mechanical fuel injectors are available as OEM products and electronic fuel injectors are available as replacement products. For DDC engines, both mechanical and electronic fuel injectors are available as replacement products.
Emission Reduction Claim: (What level of emission reduction can be achieved? Address: EC, SOF, and SO_3?)	The manufacturer states that the overall particulate removal efficiency can be as high as 44% for EMD engines and as high as 7% for DDC engines. The manufacturer guarantees the emission reductions within standard testing errors.
Achieved Emission Reductions:	**Product** / **Test Cycle** / **PM Reduction** ECOTIP Standard / 8-Mode Steady State / 7% ECOTIP 2° ITR / 8-Mode Steady State / 3%
Certifications:	None.
Product Costs: **Initial Retail:**	The initial cost range for standard stationary and portable applications, assuming core exchange, is: $200 for a 100 hp engine; $200 - $300 for a 275 hp engine; $300 - $400 for a 400 hp engine; and $400 - $800 for a 1,400 hp engine. These costs may be higher for special applications.
Installation:	No installation costs beyond those associated with replacing standard fuel injectors.
Operating:	Fuel economy is reported to improve by 2% to 3%;
Maintenance:	None.
Durability / Product Life: (How long can the product be expected to function under normal operating conditions and still achieve the specified emission reductions?)	The manufacturer states that the product's useful life is typically between 4,000 and 6,000 service hours under normal operating conditions.

Item	Response
Product Warranty: (Identify the type of warranty and its duration.)	The manufacturer provides a 12 month / 2,000 engine hour warranty.
Affect on Engine Warranty: (When possible, identify any impact the product may have on an engine's warranty.)	When installed as an OEM component of EMD engines, the product does not impact the OEM engine warranty. When installed on DDC engines, use of the product may affect the OEM engine warranty if the product is determined to be the cause of a failure.
Adverse Impacts: **Environmental:** **Safety:**	One 8-mode steady-state emission test shows that the product increases hydrocarbon emissions by 15%. No known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	The product can be used with the existing California diesel fuel formulations.
Current Status: (Is the product commercially available, or is it still under development? How many engines has the product been installed on, and how long has the product been in use?)	The product is commercially available and has been installed on approximately 2,000 mostly locomotive diesel-fueled engines. The product has been in service in the locomotive market since 1995.
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	Fuel economy is reported to improve by 2% to 3%. In addition, the product reduces carbon monoxide and oxides of nitrogen emissions.
Impacts of Lower Sulfur Diesel Fuel:	Unknown. However, the product can be used with the existing California diesel fuel formulations.
Comments: (Address other issues relevant to the use of this product, including other advantages disadvantages of using the product.)	According to the manufacturer, particulate matter emissions from fuel injectors can increase over time. As such, the manufacturer anticipates that the particulate matter emission rate may increase over the life of the product but that this increase will be consistent with that of standard fuel injectors.

List of Stationary &/or Portable Applications

Product Name: ECOTIP Superstack Fuel Injectors

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
Information on the stationary &/or portable applications of this product is not known.	Make: Model: Application: Fuel Type:					

List of Emission Test Results

Product Name: ECOTIP Superstack Fuel Injectors

Method & Type of Test	Source Test Company	Engine Information	Pollutant	Baseline Emission Rate	Emission Rate w/ Controls	Control Efficiency
ISO 8178 8-mode steady-state	Southwest Research Institute July 1998	Make: Detroit Diesel Model: 4L-71N Year: Unknown BHP: 140 bhp Application: Unknown Configuration: Standard Timing Engine Hours: Unknown Fuel Use (lb/hp-hr)[18]: 0.440 / 0.432 Fuel Type: Diesel Exhaust Temp: Unknown	PM NOx CO HC	Standard Timing 0.357 g/hp-hr* 18.26 g/hp-hr* 11.30 g/hp-hr* 0.66 g/hp-hr* * Average of three test runs.	Standard Timing 0.331 g/hp-hr* 17.45 g/hp-hr* 9.13 g/hp-hr* 0.76 g/hp-hr* * Average of three test runs.	7% 4% 19% -15%
ISO 8178 8-mode steady-state	Southwest Research Institute July 1998	Make: Detroit Diesel Model: 4L-71N Year: Unknown BHP: 140 bhp Application: Unknown Configuration: 2° Timing Retard Engine Hours: Unknown Fuel Use (lb/hp-hr)[1]: 0.440 / 0.430 Fuel Type: Diesel Exhaust Temp: Unknown	PM NOx CO HC	Standard Timing 0.357 g/hp-hr* 18.26 g/hp-hr* 11.30 g/hp-hr* 0.66 g/hp-hr* * Average of three test runs.	2° Timing Retard 0.347 g/hp-hr* 15.41 g/hp-hr* 9.88 g/hp-hr* 0.66 g/hp-hr* * Average of three test runs.	3% 16% 13% 0%

[18] Baseline / Retrofit

DRAFT - DO NOT CITE OR QUOTE

DRAFT Control Technology Evaluation

Item	Response
Product Name:	Cam Shaft Cylinder Reengineering Kit (Version I and Version II)
Product Vendor:	Clean Cam Technology Systems
Vendor Address:	7001 Charity Avenue Bakersfield, CA 93308
Product Description: (What is the product, and how does it work?)	The products consist of specific engine retrofit components, including a proprietary cam shaft. The products reduce NOx emissions by increasing the volume of exhaust gas that remains in the combustion chamber after the power stroke. Within the combustion chamber, the residual exhaust gas absorbs heat and reduces the peak combustion temperature which results in lower NOx emissions. The injection timing can then be adjusted (i.e. advanced) to maximize particulate emission reductions, or it can be varied to achieve the desired balance of NOx vs. PM. In addition to Version I components, Version II includes modified pistons which allow the piston to remain near top dead center (TDC) for a longer duration.
Applicability: (What types of engines can the product be installed on?)	Version I of the product can be used on all Series 71 and Series 92 diesel-fueled engines manufactured by Detroit Diesel Corporation (DDC). Version II of the product can be used on all Series 92 DDC engines.
Manufacturer's Emission Reduction Claim: (What level of emission reduction can be achieved? Address: EC, SOF, and SO_3?)	The manufacturer states that engines retrofitted with Version I will have emissions of no greater than 1.0 g/bhp-hr of hydrocarbons, 8.5 g/bhp-hr of carbon monoxide, 5.8 g/bhp-hr of nitrogen oxides and 0.16 g/bhp-hr of diesel particulate matter. The manufacturer also states that engines retrofitted with Version II will have emissions of no greater than 0.3 g/bhp-hr of hydrocarbons, 2.6 g/bhp-hr of carbon monoxide, 4.5 g/bhp-hr of nitrogen oxides and 0.15 g/bhp-hr of diesel particulate matter.
Certifications: (Identify certifications the product has received, and explain any limits on the certifications.)	ARB staff have verified the Version I performance claims for eleven models of two-stroke diesel-fueled engines manufactured by DDC before 1993, including: DDC 6V92; 8V92, 12V92, 16V92, 3L71, 4L71, 6L71, 6V71, 8V71, 12V71 & 16V71 engines. ARB staff have also verified the Version II performance claims for four models of two-stroke DDC engines manufactured before 1993, including: DDC 6V92; 8V92, 12V92 & 16V92 engines.
Emission Test Results: (Summarize emission test results and describe in detail on the attached table.)	8-mode steady-state emission test data demonstrate that engines retrofitted with the products can meet the emission limits specified above.

Item	Response
Product Costs: **Initial:**	The incremental cost of the products vary with engine size and are approximately: $1,500 for a 100 hp engine; $1,500 - $2,300 for a 275 hp engine; $1,800 - $3,000 for a 400 hp engine; and $3,000 - $6,000 for a 1,400 hp engine. These costs must be added to the costs of standard rebuild components to determine the total initial cost of the products.
Standard Rebuild	The costs of standard engine rebuild components also vary by engine size and are approximately: $2,500 for a 100 hp engine; $2,500 - $3,800 for a 275 hp engine; $3,000 - $4,500 for a 400 hp engine; and $4,500 - $10,000 for a 1,400 hp engine.
Installation:	There are no installation costs beyond those associated with a standard engine rebuild.
Operating:	Engines retrofitted with the products may incur a fuel penalty of between zero and 12% depending on the engine model and rebuild configuration.
Maintenance:	No additional engine maintenance is required.
Durability / Product Life: (How long can the product be expected to function under normal operating conditions and still achieve the specified emission reductions?)	The manufacturer states that the useful life of the products is between 3,000 and 8,000 operating hours, and that the useful life is consistent with the durability requirements for new nonroad engines. Deterioration factor emission tests demonstrate conformance with the emission performance claim.
Product Warranty: (Identify the type of warranty and its duration.)	The manufacturer provides an emissions / mechanical durability warranty for one year or 3,000 engine hours, whichever occurs first.
Affect on Engine Warranty: (When possible, identify any impact the product may have on an engine's warranty.)	According to the manufacturer, use of the product does not impact the OEM engine warranty.
Adverse Impacts: (For example, does the product create a hazardous byproduct? Attach MSDS sheet if applicable.)	
Environmental:	The products can also reduce NOx emissions.
Safety:	No known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	The products can be used with the existing California diesel fuel formulations.

Item	Response
Current Status: (Is the product commercially available, or is it still under development? How many engines has the product been installed on, and how long has the product been in use?)	The products are commercially available and have been installed on approximately 300 stationary and portable diesel-fueled engines, including generators and pumps. The products have also been installed on approximately 1,250 mobile diesel-fueled engines as part of the federal Urban Bus Retrofit program, and they have been installed in military equipment, such as generators, loaders and hydraulic power units. Twenty-five engines retrofitted with the product have logged 20,000+ hours of operation.
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	Engines retrofitted with the products may incur a fuel penalty of between zero and 12% depending on the engine model and rebuild configuration.
Comments: (Address other issues relevant to the use of this product, including other advantages / disadvantages of using the product.)	The products are specifically designed to allow older 2-stroke DDC engines to meet State & federal new nonroad engine emission standards.

List of Stationary &/or Portable Applications

Product Name: CCTS Cam Shaft Cylinder Reengineering Kit (Version I)

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
Gary Drilling Co. 7001 Charity Ave Bakersfield, CA 93308	Make: Detroit Diesel Model: 4L71T Application: Generators Fuel Type: CARB Diesel	PERP Registration Nos. - 100223 - 100295	2	Since: - 12/16/98 - 11/27/97	0.16 g/bhp-hr	See following table.
Gary Drilling Co. 7001 Charity Ave Bakersfield, CA 93308	Make: Detroit Diesel Model: 8V92TA Application: Pumps Fuel Type: CARB Diesel	PERP Registration Nos. - 100124 - 100222	2	Since: - 11/27/97 - 1/28/99	0.16 g/bhp-hr	See following table.

List of Emission Test Results

Product Name: CCTS Cam Shaft Cylinder Reengineering Kit

Method & Type of Test	Source Test Company	Engine Information	Engine Hours	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
ISO 8178-C1 40 CFR 89 8-mode steady-state	Southwest Research Institute	Make: Detroit Diesel Corp Model: 6V-92TA Year: 1984 BHP: 310 hp Application: Not Reported Configuration: Turbo Fuel Type: 2-D Diesel Fuel Use[19](lb/hp-hr): 0.414/0.431/0.422/0.425 Exhaust Temp: 329°F - 697°F	Zero	PM NOx CO HC	0.299 g/bhp-hr 8.99 g/bhp-hr 0.88 g/bhp-hr 0.51 g/bhp-hr	0.099 g/bhp-hr[20] 4.52 g/bhp-hr[20] 0.5 g/bhp-hr[20] 0.32 g/bhp-hr[20]	67% 50% 43% 37%
			125	PM NOx CO HC	n/a	0.094 g/bhp-hr[21] 5.77 g/bhp-hr[21] 0.39 g/bhp-hr[21] 0.33 g/bhp-hr[21]	69% 36% 56% 35%
			1000	PM NOx CO HC	n/a	0.114 g/bhp-hr[21] 5.15 g/bhp-hr[21] 0.45 g/bhp-hr[21] 0.31 g/bhp-hr[21]	62% 43% 49% 39%

[19] Pre-/Post- Retrofit

[20] Version II

[21] Version I

Method & Type of Test	Source Test Company	Engine Information	Engine Hours	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
ISO 8178-C1 40 CFR 89 8-mode steady-state	Southwest Research Institute	Make: Detroit Diesel Corp Model: 6V-71TA Year: 1983 BHP: 250 Application: Not Reported Configuration: Turbo, Aftercooled Fuel Type: 2-D Diesel Fuel Use[1] (lb/hp-hr): 0.384/0.430/0.419 Exhaust Temp: 252°F - 798°F	Zero	PM NOx CO HC	0.201 g/bhp-hr 10.39 g/bhp-hr 1.2 g/bhp-hr 0.45 g/bhp-hr	0.098 g/bhp-hr[21] 5.26 g/bhp-hr[21] 0.7 g/bhp-hr[21] 0.36 g/bhp-hr[21]	51% 49% 42% 20%
			Zero	PM NOx CO HC	n/a	0.148 g/bhp-hr[21] 5.45 g/bhp-hr[21] 1.16 g/bhp-hr[21] 0.38 g/bhp-hr[21]	26% 48% 3% 16%

Method & Type of Test	Source Test Company	Engine Information	Engine Hours	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
ISO 8178-C1 40 CFR 89 8-mode steady-state	Southwest Research Institute	Make: Detroit Diesel Corp Model: 6L-71T Year: 1983 BHP: 250 Application: Not Reported Configuration: Turbo Fuel Type: 2-D Diesel Fuel Use[1] (lb/hp-hr): 0.399/0.438/0.450/0.449 Exhaust Temp: 270°F - 806°F	Zero	PM NOx CO HC	0.208 g/bhp-hr 12.58 g/bhp-hr 2.00 g/bhp-hr 0.47 g/bhp-hr	n/a	n/a
			125	PM NOx CO HC	n/a	0.151 g/bhp-hr[22] 5.56 g/bhp-hr[22] 0.62 g/bhp-hr[22] 0.48 g/bhp-hr[22]	25% 56% 69% -2%
			279	PM NOx CO HC	n/a	0.143 g/bhp-hr[22] 5.57 g/bhp-hr[22] 0.64 g/bhp-hr[22] 0.42 g/bhp-hr[22]	29% 56% 68% 11%
			500	PM NOx CO HC	n/a	0.147 g/bhp-hr[22] 5.54 g/bhp-hr[22] 0.59 g/bhp-hr[22] 0.39 g/bhp-hr[22]	27% 56% 71% 17%
ISO 8178-D2 40 CFR 89 5-mode steady-state	Southwest Research Institute	Make: Detroit Diesel Corp Model: 4L-71 Year: Unknown BHP: 150 hp Application: Generator Configuration: Turbo Fuel Type: Jet A Fuel Use[1] (lb/hp-hr): 0.481/0.480 Exhaust Temp:365°F - 971°F	Not Known	PM NOx CO HC	0.282 g/bhp-hr 18.74 g/bhp-hr 1.40 g/bhp-hr 0.90 g/bhp-hr DDC 4L-71N S/N: 4A246627	0.147 g/bhp-hr[22] 4.44 g/bhp-hr[22] 0.83 g/bhp-hr[22] 0.51 g/bhp-hr[22] DDC 4L-71T S/N: 4A26-8418	48% 76% 41% 43%

[22] Version I

DRAFT Control Technology Evaluation

Item	Response
Product Name:	NOxTECH Emission Control System
Product Vendor:	NOxTECH, Inc.
Vendor Address:	1939 Deere Ave. Irvine, CA 92606
Product Description: (What is the product, and how does it work?)	The product is a muffler-size reactor that reduces carbon monoxide, hydrocarbons, and diesel particulate matter through non-catalytic oxidation, similar to an afterburner. The engine exhaust is heated to between 1,400 to 1,550 °F in the reactor by introducing fuel to the exhaust stream. The high temperature environment oxidizes the diesel particulate matter, carbon monoxide, and hydrocarbon emissions. A urea injection system can be added for reduction of NOx emissions. Systems for engines operating over 2,000 hours per year include a heat exchanger that uses the reactor effluent to preheat the engine exhaust to enhance fuel autoignition.
Applicability: (What types of engines can the product be installed on?)	The product is available for use on stationary and portable internal combustion engines.
Manufacturer's Emission Reduction Claim: (What level of emission reduction can be achieved? Address: EC, SOF, and SO_3?)	90% to 95% NOx reduction. 50% to 90% CO reduction (depending on operating conditions). 50% to 90% Diesel PM reduction (depending on operating conditions). 60% to 95% ROG reduction (depending on operating conditions).
Certifications:	None.
Emission Test Results: (Summarize emission test results and describe in detail on the attached table.)	<u>Engine</u> — <u>Test Method</u> — <u>PM Reduction</u> EMD 16-567-D4 — SCAQMD Method 5.2 — 51% EMD 16-710G4B — SCAQMD Method 5.2 — 62%
Product Costs: **Initial:**	<u>Without urea injection</u>: \$400-\$1,200 for a 40 hp engine; \$1,000-\$3,000 for a 100 hp engine; \$2,750-\$8,250 for a 275 hp engine; \$4,000-\$12,000 for a 400 hp engine; \$14,000-\$42,000 for a 1,400 hp engine <u>With urea injection</u>: \$600-\$1,480 for a 40 hp engine; \$1,500-\$3,700 for a 100 hp engine; \$4125-\$10,175 for a 275 hp engine; \$6,000-\$14,800 for a 400 hp engine; \$21,000-\$51,800 for a 1,400 hp engine <u>With urea injection and heat exchanger</u>: \$2,080-\$3,000 for a 40 hp engine; \$5,200-\$7,500 for a 100 hp engine; \$14,300-\$20,625 for a 275 hp engine; \$20,800-\$30,000 for a 400 hp engine; \$72,800-\$105,000 for a 1,400 hp engine
Installation:	\$6,400 - \$14,400 (Assuming 2 - 3 weeks x 40 hours/week x \$80 - \$120/hour).

Item	Response
Product Costs: continued **Operating:**	Fuel penalty of 5% to 8%*. With urea injection system, $300/ton NOx reduced. *The attached summary of emission test results indicates a fuel penalty of 23%-24%. The manufacturer states that this system at Catalina Island is an older model using cyanuric acid. The 5%-8% fuel penalty refers to the new design using liquid urea, which is smaller and more compact.
Maintenance:	Manufacturer estimates maintenance costs will be minimal.
Durability / Product Life: (How long can the product be expected to function under normal operating conditions and still achieve the specified emission reductions?)	The manufacturer suggests that the product's useful life will be similar to that of the associated diesel engine.
Product Warranty: (Identify the type of warranty and its duration.)	The product carries a 12-month warranty. The product is guaranteed to be free from defects in material and workmanship and to maintain emissions compliance during normal operations.
Affect on Engine Warranty: (When possible, identify any impact the product may have on an engine's warranty.)	The manufacturer states that the product has no impact on the OEM engine warranty.
Adverse Impacts: (For example, does the product create a hazardous byproduct? Attach MSDS sheet if applicable.) **Environmental:**	Where a urea injection system is utilized to reduce NOx, any unreacted urea will be emitted as ammonia. Ammonia is not a federal hazardous air pollutant or a State identified toxic air contaminant. However, ammonia does have acute and chronic non-cancer health effects. Source tests have shown ammonia slip levels controlled to below 2 ppm.
Safety:	No known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature etc...)	None.
Current Status: (Is the product commercially available, or is it still under development. How many engines has the product been installed on, and how long has the product been in use?)	The product is commercially available and has been installed on two stationary diesel generator sets that provide primary commercial power for Catalina Island. One installation has been in operation for 3.5 years.

Item	Response
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	When the product is used without a heat exchanger, the fuel penalty depends on the engine exhaust temperature. The manufacturer estimates a fuel penalty of 5% to 8%. The size and weight of the product for various engine sizes is approximately 50% larger and heavier than their respective silencers.
Impacts of Lower Sulfur Diesel Fuel:	The product can be used with existing California diesel formulations. The manufacturer states that lower sulfur fuel should have no effect since the product can operate at higher sulfur levels in present fuels.
Comments: (Address other issues relevant to the use of this product, including other advantages / disadvantages of using the product.)	In addition to reducing diesel particulate matter, the manufacturer states that the product may also reduce carbon monoxide by 50%-90%, hydrocarbons by 60%-95%, and oxides of nitrogen emissions by 90%-95% (with urea injection).

List of Stationary &/or Portable Applications

Product Name: NOxTECH Emission Control System

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
Southern California Edison - Pebbly Beach Generating Station (Unit #8)	Make: EMD Model: 16-567-D4 Application: Generator Fuel Type: Diesel	SCAQMD RECLAIM Permit No. 4477; Engine ID No. D2, Control ID No. C27	1	Since:	0.1 gr/dscf	0.0172 gr/dscf
Southern California Edison - Pebbly Beach Generating Station (Unit #15)	Make: EMD Model: 16-710G4B Application: Generator Fuel Type: Diesel	SCAQMD RECLAIM Permit No. 4477; Engine ID No. D42, Control ID No. C43	1	Since: Issued 11/4/94	0.1 gr/dscf	0.006 gr/dscf

List of Emission Test Results

Product Name: NOxTECH Emission Control System

Method & Type of Test	Source Test Company	Engine Information	Engine Hours	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
<u>PM</u>: SCAQMD Method 5.2 <u>NOx, CO</u>: SCAQMD Method 100.1 <u>HC</u>: SCAQMD Method 25.1	SCEC Test dates: 9/15-17/93	Make: Electro-Motive Diesel (EMD) Model: 16-567-D4 Year: Not reported BHP: 2150 Application: 1.5 MW Generator Configuration: Two-cycle, lean burn with turbocharger Fuel Use (gal/hr): 87.6 (engine) + 21.4 (supplemental) Exhaust Temp (°F): 612 (prior to control device)	Not Reported	PM NOx CO HC	0.510 g/bhp-hr* 11.343 g/bhp-hr* 4.857 g/bhp-hr* 0.133 g/bhp-hr* *Average of 3 runs at low, mid, and high loads	0.251 g/bhp-hr* 1.163 g/bhp-hr* 0.205 g/bhp-hr* 0.034 g/bhp-hr* *Average of 3 runs at low, mid, and high loads	51% 90% 96% 74%
<u>PM</u>: SCAQMD Method 5.2 <u>NOx, CO</u>: SCAQMD Method 100.1 <u>HC</u>: Modified Method 25.2 (Baseline); Method 25.1 (Controlled)	SCEC Test dates: 5/10/95 (baseline) and 1/30-2/1/96 (controlled)	Make: Electro-Motive Diesel Model: 16-710G4B Year: Not reported BHP: 3900 Application: 2.8 MW Generator Configuration: Two-cycle, lean burn with turbocharger and aftercooler Fuel Use (gal/hr): 191.2 (engine) + 44.8 (supplemental) Exhaust Temp (°F): 599 (prior to control device)	Not Reported	PM NOx CO HC	0.215 g/bhp-hr* 6.225 g/bhp-hr*[23] 0.305 g/bhp-hr* 0.360 g/bhp-hr* *Average of 2 runs at high load	0.082 g/bhp-hr* 0.826 g/bhp-hr* 0.321 g/bhp-hr* 0.347 g/bhp-hr* *Average of 2 runs at high load	62% 87% -5%[24] 4%

[23] Engine is equipped with electronically controlled low NOx fuel injectors and the injection timing was retarded during the test.

[24] Manufacturer states that the number is a reflection of the operating requirements of this installation. As a whole, the manufacturer states that the product can reduce CO to below 50 ppm if required.

DRAFT Control Technology Evaluation

Item	Response
Product Name:	Fumigation Natural Gas/Diesel Bi-Fuel Retrofit Kit
Product Vendor:	Innovative Technologies Group, Corp.
Vendor Address:	2968 Ravenswood Road, Unit 109 Ft. Lauderdale, FL 33312
Product Description: (What is the product, and how does it work?)	The product is a bi-fuel conversion system for all diesel-fueled engines, and it involves retrofitting existing diesel-fueled engines to operate on a mixture of diesel fuel and a variety of gaseous fuels, such as pipeline quality natural gas, liquefied natural gas, compressed natural gas, digester gas, etc... The supplemental gaseous fuel is mixed with combustion air before being introduced into the engine's charge air system. This process is referred to as fumigation. Within the combustion chamber, the diesel fuel serves as a pilot ignition source for the gaseous fuel. The gaseous fuel / diesel mixture typically varies between 80% gaseous / 20% diesel to 50% gaseous / 50% diesel. The engine retrofit mainly involves the integration of a gaseous fuel control system with an engine's charge air system. There are no changes to the engine block, cylinder heads, pistons, etc..., and the engine remains a compression ignition engine.
Applicability: (What types of engines can the product be installed on?)	The product can be applied to all diesel-fueled engines, including stationary, portable, mobile, marine, and locomotive engines. The product can also be retrofitted to existing engines.
Manufacturer's Emission Reduction Claim: (What level of emission reduction can be achieved? Address: EC, SOF, and SO_3?)	The manufacturer claims that the product reduces oxides of nitrogen emissions by 20% to 60%. While the manufacturer does not specifically claim that the product reduces diesel particulate emissions, the emission test data suggests that the product reduces diesel particulate by up to 37%.
Certifications: (Identify certifications the product has received, and explain any limits on the certifications.)	The product has been certified as an alternative fuel delivery system in accordance with the provisions of Sections 43004 and 43006 of the California Health and Safety Code for use on 1993 and older model year four-stroke heavy-duty diesel-fueled engines, excluding those equipped with self-compensating fuel pumps.
Emission Test Results: (Summarize emission test results and describe in detail on the attached table.)	<u>Engine Make/Model</u> — <u>Test Cycle</u> — <u>PM Reduction</u> International Harvester 7.3 liter — CVS-75 — 28% Cummins 5.9 liter — CVS-72 — 37%

Item	Response
Product Costs: **Initial / Installation:**	The initial product cost is: $4,000 for a 40 hp engine, $6,000 for a 100 hp engine,$14,000 for a 400 hp engine, and $38,000 for a 1,400 hp engine. These costs do not include installation of gaseous fuel supply systems, which vary by application.
Installation:	Installation is typically performed by the manufacturer, or the manufacturer's representative, and usually takes between four and five days. At the manufacturer's rate of $450 per day, installation costs are expected to be between $1,800 and $2,250, not including travel.
Operating:	The operating costs depend on the specific application and the type of gaseous fuel used. However, a 13% -14% decrease in fuel costs is expected if an engine operates on a mixture of 40% diesel and 60% natural gas, assuming diesel costs $0.90/gal and natural gas costs $0.50 per therm.
Maintenance:	There are no additional maintenance requirements associated with the use of this product. However, according to the manufacturer, the engine oil will not need to be changed as frequently.
Durability / Product Life: (How long can the product be expected to function under normal operating conditions and still achieve the specified emission reductions?)	According to the manufacturer, the product life is consistent with that of other mechanical engine components.
Product Warranty: (Identify the type of warranty and its duration.)	The manufacturer provides a one year warranty on materials and workmanship which includes repair or replacement of an engine if damage is caused by the bi-fuel system.
Affect on Engine Warranty: (When possible, identify any impact the product may have on an engine's warranty.)	The product manufacturer does not expect the engine manufacturer's warranty to cover damage caused by the bi-fuel process. As noted above, the product manufacturer will repair or replace an engine damaged by the bi-fuel system.
Adverse Impacts: (For example, does the product create a hazardous byproduct? Attach MSDS sheet if applicable.) **Environmental:**	There are no known adverse environmental impacts.
Safety:	There are no known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	The product requires a gaseous fuel supply system, such as a natural gas supply system for stationary applications or a CNG storage system for portable and/or mobile applications.

Item	Response
Current Status: (Is the product commercially available, or is it still under development? How many engines has the product been installed on, and how long has the product been in use?)	The product is commercially available and has been installed on more than 200 diesel-fueled engines, including stationary generators, trucks, buses, and locomotives.
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	According to the manufacturer, engines retrofitted with this technology do not suffer a loss of power.
Impacts of Low Sulfur Fuel	The product can be used with California's existing diesel fuel formulations.
Comments: (Address other issues relevant to the use of this product, including other advantages / disadvantages of using the product.)	Representatives from one facility which operates a 1,490 hp engine equipped with the bi-fuel technology suggest that the product reduces NOx emissions by up to 20 lb/hr and that there is an overall fuel savings because the cost of natural gas is about one third of the cost of diesel fuel.

List of Stationary &/or Portable Applications

Product Name: Fumigation Natural Gas/Diesel Bi-Fuel Retrofit Kit

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
International Billing Services, El Dorado Hills, California	Make: Cummins Model: KTTA-50-G2 Horsepower: 2200 Application: Generator Fuel Type: Diesel / Natural Gas	Authority to Construct No. 13-903-01, Issued by the El Dorado County Air Pollution Control District on February 28, 2000	1	None	None	N/A
Chicago Landfill, Templeton, CA	Make: Komatsu Model: Unknown Horsepower: 227 hp Application: Generator Fuel Type: Landfill Gas + Low Sulfur Diesel Fuel	Permit to Operate No. 548-1 Issued by the San Luis Obispo County Air Pollution Control District	1	June 1998	None	N/A
Roche Diagnostics Corporation, Indianapolis, IN	Make: Caterpillar Model: 3516 Horsepower: 2615 hp Application: Generator Fuel Type: Diesel & Diesel/Natural Gas	Indianapolis Environmental Resources Management, Federally Enforceable State Operating Permit No. F097-11275-00338 Issued January 12, 2000	4	Units In Service Since December 1993	None	N/A
AFG Industries Victorville, CA	Make: Cummins Model: KTA-50-G1 Horsepower: 1,490 bhp Application: Emergency Backup Generator Fuel Type: Diesel / Natural Gas (40%:60%)	Permit No: E001729 Issued by the Mojave Desert Air Quality Management District	1	Approx. 3 Years	None	N/A

List of Emission Test Results

Product Name: Fumigation Natural Gas/Diesel Bi-Fuel Retrofit Kit

Method & Type of Test	Source Test Company	Engine Information	Test Procedure	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
Federal Test Procedure[25] (UDDS)	Air Testing Services, Inc. Landsdale, PA	Make: Cummins Model: 5.9 liter Year: 1992 BHP: Not Reported Application: Light Duty Truck Configuration: Not Reported Engine Hours: Not Reported Fuel Use: Not Reported Exhaust Temp: Not Reported	CVS-75	 PM NOx CO HC	100% Diesel 0.627 gm/mile 6.444 gm/mile 1.830 gm/mile 0.908 gm/mile	80% CNG / 20% Diesel 0.436 gm/mile 6.429 gm/mile 0.957 gm/mile 0.912 gm/mile	 30% 0% 48% 0%
			CVS-72 (Hot Start)	 PM NOx CO HC	100% Diesel 0.347 gm/mile 6.351 gm/mile 1.606 gm/mile 0.799 gm/mile	80% CNG / 20% Diesel 0.220 gm/mile 6.135 gm/mile 0.658 gm/mile 0.563 gm/mile	 37% 3% 59% 30%
Federal Test Procedure [25] (UDDS)	Air Testing Services, Inc. Landsdale, PA	Make: International Harvester Model: 7.3 liter Year: 1992 BHP: Not Reported Application: Light Duty Truck Configuration: Not Reported Engine Hours: Not Reported Fuel Use: Not Reported Exhaust Temp: Not Reported	CVS-75	 PM NOx CO HC	100% Diesel 0.199 gm/mile 9.151 gm/mile 1.149 gm/mile 0.560 gm/mile	80% CNG / 20% Diesel 0.144 gm/mile 5.717 gm/mile 1.080 gm/mile 0.348 gm/mile	 28% 38% 6% 38%
			CVS-72 (Hot Start)	 PM NOx CO HC	100% Diesel 0.146 gm/mile 7.992 gm/mile 0.773 gm/mile 0.245 gm/mile	80% CNG / 20% Diesel 0.121 gm/mile 6.683 gm/mile 0.764 gm/mile 0.167 gm/mile	 17% 16% 1% 32%

[25] The emission test results were provided by Carburetion Labs International, Inc. (CLI) in support of their application for certification of an alternative fuel delivery system in accordance with Sections 43004 and 43006 of the California Health and Safety Code. The ARB's Mobile Source Division reviewed the product and associated emission test data, and on December 22, 1992, the ARB issued Executive Order B-17 approving the use of this technology on all 1992 and older model year heavy-duty diesel engines excluding those with self-compensating fuel pumps. The Executive Order has been updated several times, and now applies to all 1993 and older model year four-stroke heavy-duty diesel engines excluding those with self-compensating fuel pumps (EO B-44 & B-44-1). Innovative Technologies Group now owns the rights to this technology.

DRAFT Control Technology Evaluation

Item	Response
Product Name:	SINOx System
Product Vendor:	Siemens Westinghouse Power Corporation
Vendor Address:	1345 Ridgeland Parkway, Suite 116 Alpharetta, GA 30004
Product Description: (What is the product, and how does it work?)	The product is a Selective Catalytic Reduction (SCR) system consisting of a proprietary base metal catalyst, designed specifically for diesel-fueled engines and an integrated predictive emissions monitoring system. According to the manufacturer, the product reduces the volatile organic fraction (VOF) of diesel particulate matter and hydrocarbon/air toxics emissions through catalytic oxidation, and concurrently reduces NOx emissions using a reducing agent, such as a 32% aqueous urea solution. The product also allows the injection timing of non-certified engines to be adjusted for maximum fuel efficiency which may result in further reductions of diesel particulate matter and hydrocarbon/air toxic emissions.
Applicability: (What types of engines can the product be installed on?)	The product can be used on stationary, portable and mobile diesel-fueled engines typically rated at 200 horsepower to 10,000 horsepower or more.
Manufacturer's Emission Reduction Claim: (What level of emission reduction can be achieved? Address: EC, SOF, and SO_3?)	The manufacturer states that the product's overall particulate removal efficiency can be between 20% and 50% depending on the engine timing, the type of controls and the uncontrolled emission rate. In addition, the product's VOF removal efficiency can be more than 60%, hydrocarbon/air toxics removal efficiency can be more than 90%, NOx removal efficiency can be over 90% in stationary and portable applications, and over 65% to 85% in on- and offroad applications.
Certifications: (Identify certifications the product has received, and explain any limits on the certifications.)	
Emission Test Results: (Summarize emission test results and describe in detail on the attached table.)	<u>**Engine Make/Model**</u> / <u>**Test Cycle**</u> / <u>**PM Reduction**</u> 1999 DDC Series 60 / FTP / 28% 1999 Mack E-Tech E7 / Cold Transient / 22% 1999 Mack E-Tech E7 / Hot Transient / 25% 1999 Mack E-Tech E7 / OICA / 0%

Item	Response
Product Costs: **Initial:**	The initial cost of the product depends on the degree of custom engineering required, the size of the engine, the operating conditions and other variables such as production volume, and ranges from approximately $50 to $60 per horsepower. For example, the initial cost typically ranges from $13,750 to $16,500 for a 275 hp engine, $20,000 to $24,000 for a 400 hp engine, and $70,000 to $84,000 for a 1,400 hp engine.
Installation:	Installation costs vary from $500 to $5,000 depending on the application.
Operating:	The operating costs include approximately $300 per ton of NOx reduced for the aqueous urea.
Maintenance:	The maintenance costs vary depending on engine size, run time and other variables. Approximate costs are $715 per year for a 275 hp engine, $800 per year for a 400 hp engine, and $1,500 per year for a 1,400 hp engine.
Durability / Product Life: (How long can the product be expected to function under normal operating conditions and still achieve the specified emission reductions?)	According to the manufacturer, operating periods of greater than 20,000 hours have been demonstrated, and some vehicles have accumulated over 500,000 miles.
Product Warranty: (Identify the type of warranty and its duration.)	The manufacturer provides a one year standard equipment warranty for workmanship, parts and materials. The manufacturer also provides a process guarantee of up to 3 years / 20,000 service hours (whichever occurs first) for the emission reductions in stationary and portable applications.
Affect on Engine Warranty:	According to the manufacturer, use of the product does not impact the OEM engine warranty.
Adverse Impacts: (For example, does the product create a hazardous byproduct? Attach MSDS sheet if applicable.) **Environmental:**	Aqueous urea is used to reduce NOx emissions, and any unreacted urea will be emitted as ammonia (a.k.a. ammonia slip). Although ammonia is not a state toxic air contaminant or federal hazardous air pollutant, ammonia does have acute and chronic non-cancer health effects. Source tests have shown ammonia slip levels controlled to 4.4 ppm averaged over the FTP test cycle, although spikes have reached 30 ppm. The federal OSHA 15-minute short term exposure limit for ammonia is 35 ppm.
	Several FTP transient emission tests show that the product increases carbon monoxide emissions by up to 89%; however, the applicable carbon monoxide emission limits were not exceeded.
Adverse Impacts: **Safety:**	Except as noted previously, there are no other known safety impacts when aqueous urea is used as the reducing agent.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	The typical engine exhaust temperature range is 350 °F to 1,020 °F.

Item	Response
Current Status: (Is the product commercially available, or is it still under development? How many engines has the product been installed on, and how long has the product been in use?)	The product is commercially available for stationary and mobile engines in Europe. In the US, it is commercially available for stationary engines and ready for commercialization for mobile engines. (For mobile applications, commercialization for a specific engine family depends on the development / availability of an emission map for the respective engine family - see the Comments section below.) The product has been installed on 125 stationary, portable, and mobile diesel-fueled engines worldwide. Specific applications include: stationary and portable generator sets, pump stations, marine vessels, on-highway heavy-duty trucks, offroad construction equipment, and locomotives.
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	The typical size and weight of demonstration and other stationary SINOx Systems are as follows: **HP** / **Length** / **Width** / **Height** / **Weight** 275 / 14 in / 18 in / 18 in / 150 lb 400 / 14 in / 18 in / 18 in / 150 lb 1,400 / 40 in / 35 in / 35 in / - - -
Impacts of Low Sulfur Fuel	According to manufacturer documentation, the catalyst is formulated for low SO_2/SO_3 conversion (i.e. < 1%). The product is resistant to fuel sulfur and can be used with the existing California diesel fuel formulations, as well as with high sulfur fuels such as bulk or crude oil used in coastal and ocean vessels.
Comments: (Address other issues relevant to the use of this product, including other advantages / disadvantages of using the product.)	In mobile applications, the product relies on an open loop control system to regulate urea injection. An emission "map" of each engine family is developed, and a predictive emission monitoring system evaluates multiple engine operating parameters. After comparing these parameters to the emission map, the control system regulates the quantity of urea introduced to the SCR catalyst ensuring optimum NOx reductions with minimal ammonia slip. According to the manufacturer, volume production of the SINOx system will begin in Europe for model year 2001 Class 8 heavy-duty diesel-fueled trucks (250 - 400 hp). This will allow the design to be standardized for particular engine families.

DRAFT - DO NOT CITE OR QUOTE

List of Stationary &/or Portable Applications

Product Name: SINOx System

Facility / Operator	Engine Information	Permit / Registration	Number of Engines	Time in Service	Emission Limitation	Emission Test Results
Yale University	Make: Mitsubishi Model: S16R-PTA Horsepower: 2,164 hp Application: Generator Fuel Type: Diesel	Permit # 117-0204 Issued by the Connecticut Department of Environmental Protection, Bureau of Air Management	3	Permit Issued 7/1/97	PM: 1.36 lb/hr NO_x: 5.3 lb/hr NH_3: 10 ppm	PM: Unknown NO_x: Unknown NH_3: Unknown
Highway Materials, Inc	Make: Caterpillar Model: 3412C Horsepower: 634 bhp Application: Portable Rock Plant Fuel Type: Not Reported	Plan Approval Permit No. PA-46-0069 Issued by Commonwealth of Pennsylvania, Bureau of Air Quality	2	Plan Approval Issued 5/11/98	PM: 0.33 lb/hr NO_x: 1.7 lb/hr NH_3: 10 ppm	PM: Unknown NO_x: 0.57 lb/hr NH_3: 0.044 ppmvd
	Make: Cummins Model: KTA-50-G3 Horsepower: 1850 bhp Application: Portable Rock Plant Fuel Type: Not Reported				PM: 0.33 lb/hr NO_x: 9.55 lb/hr NH_3: 10 ppm	PM: Unknown NO_x: 2.33 lb/hr NH_3: 0.048 ppmvd

List of Emission Test Results

Product Name: SINOx System

Method & Type of Test	Source Test Company	Engine Information	Engine Hours	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
Federal Test Procedure	UC Davis, Institute of Transportation Studies	Make: Detroit Diesel Corporation Model: Series 60 Year: 1999 BHP: Not Reported Application: On-highway Heavy Duty Diesel Truck Configuration: Turbocharged & Aftercooled Fuel Type: Certification Diesel Fuel Use: Not reported Exhaust Temp: Not Reported	Not Reported	PM NOx CO HC	0.096 g/bhp-hr[26] 3.761 g/bhp-hr[26] 0.723 g/bhp-hr[26] 0.134 g/bhp-hr[26]	N/A	N/A
			Not Reported	PM NOx CO HC	N/A	0.0693 g/bhp-hr[27] 0.980 g/bhp-hr[27] 1.37 g/bhp-hr[27] 0.0252 g/bhp-hr[27]	28% 74% -89% 81%
Federal Test Procedure (Cold Start & Hot Start)[28]	Southwest Research Institute	Make: Mack Model: E-Tech E7-350 Year: 1999 BHP: 350 bhp Application: Heavy Duty Truck Configuration: Turbocharged and Aftercooled Fuel Type: 2D Diesel Fuel Use: Not Reported Exhaust Temp:	Not Reported	PM NOx CO HC	Cold Transient 0.09 g/bhp-hr 6.24 g/bhp-hr 1.80 g/bhp-hr 0.06 g/bhp-hr	Cold Transient 0.07 g/bhp-hr 2.77 g/bhp-hr 2.31 g/bhp-hr 0.00 g/bhp-hr	22% 56% -28% 100%
				PM NOx CO HC	Hot Transient 0.08 g/bhp-hr 5.25 g/bhp-hr 1.12 g/bhp-hr 0.06 g/bhp-hr	Hot Transient 0.06 g/bhp-hr 1.55 g/bhp-hr 1.54 g/bhp-hr 0.00 g/bhp-hr	25% 70% -38% 100%

[26] U.S. EPA On-highway engine certification data.

[27] Emission test results reported in a U.C. Davis study entitled "Urea-SCR System Demonstration and Evaluation for Heavy-Duty Diesel Trucks: Phase I, Preliminary Emissions Test Results and Cost-Effectiveness Analysis."

[28] Emission test results reported in SAE Technical Paper # 2000-01-0190, "The Development of Urea-SCR Technology for US Heavy Duty Trucks."

Method & Type of Test	Source Test Company	Engine Information	Engine Hours	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
OICA[29]	Southwest Research Institute	Make: Mack Model: E-Tech E7-350 Year: 1999 BHP: 350 bhp Application: Heavy Duty Truck Configuration: Turbocharged and Aftercooled Fuel Type: 2D Diesel Fuel Use: Not Reported Exhaust Temp:	Not Reported	PM NOx CO HC	OICA 0.04 g/bhp-hr 4.86 g/bhp-hr 0.29 g/bhp-hr 0.01 g/bhp-hr	OICA 0.04 g/bhp-hr 0.70 g/bhp-hr 0.29 g/bhp-hr 0.00 g/bhp-hr	0% 86% 0% 100%

[29] Emission test results reported in SAE Technical Paper # 2000-01-0190, "The Development of Urea-SCR Technology for US Heavy Duty Trucks."

DRAFT Control Measure Evaluation

Item	Response
Technology:	Repower with Tier 2 or Tier 3 certified nonroad engines.
Technology Description: (How does it work?)	Replacement of existing diesel engines with engines certified to meet U.S. EPA nonroad engine emission standards. The current Tier 2 standards are as follows: **Horsepower** / **Model Year** / **PM Emission Limit** hp < 25 / 2005 / 0.60 g/bhp-hr 25≤ hp < 50 / 2004 / 0.45 g/bhp-hr 50≤ hp < 100 / 2004 / 0.30 g/bhp-hr 100≤ hp < 175 / 2003 / 0.22 g/bhp-hr 175≤ hp < 300 / 2003 / 0.15 g/bhp-hr 300≤ hp < 600 / 2001 / 0.15 g/bhp-hr 600≤ hp≤ 750 / 2002 / 0.15 g/bhp-hr hp > 750 / 2006 / 0.15 g/bhp-hr The ARB recently adopted emission standards comparable to the U.S. EPA Tier 2 standards described above. Tier 3 standards for particulate matter will be established upon completion of a technical feasibility review, which is scheduled for 2001.
Applicability: (What types of engines can the product be installed on?)	This control measure is applicable to all stationary and portable diesel-fueled engines. Currently, engines rated at 175 horsepower or larger and designated for nonroad applications must meet a particulate matter emission standard. By 2004, all engines designated for nonroad applications must meet a particulate matter emission standard. Certified nonroad engines can be used in stationary applications.
Achieved Emission Reductions:	The federal nonroad engine certification data presented below demonstrates that engines are currently available which meet the Tier 2 standards. **Engine Make & Model** / **Model Year** / **PM Emission Rate** Cummins 6CTAA8.3-G1 / 1999 / 0.132 g/bhp-hr Caterpillar 3306 / 1999 / 0.114 g/bhp-hr Daimler-Benz OM 501 LA / 1999 / 0.042 g/bhp-hr Caterpillar 3408 / 2000 / 0.084 g/bhp-hr Komatsu SA6D140E-2 / 2000 / 0.125 g/bhp-hr
Emission Reduction Guarantee:	Within the limitations of the applicable regulations, certified nonroad engines are required to meet the emission standards throughout their useful life. ARB and U.S. EPA in-use testing and recall programs ensure compliance with these requirements.
Costs: **Initial Retail:**	The initial costs of Tier 2 certified engines range from: $4,290 for a 40 hp engine; $6,960 to $18,840 for a 100 hp engine; $12,440 to $32,150 for a 275 hp engine; $23,100 to $48,370 for a 400 hp engine; and $186,890 for a 1,400 hp engine.
Installation:	The installation costs range from: $2,380 for a 40 hp engine; $4,390 for a 100 hp engine; $3,450 to $6,190 for a 275 hp engine; $8,430 for a 400 hp engine; and $23,630 for a 1,400 hp engine.

Item	Response
Operating:	Operating costs should be similar to a comparably rated non-certified engine.
Maintenance:	Engine maintenance requirements should be comparable to the existing engine.
Certifications:	As previously mentioned, the engines must be certified by the U.S. EPA or ARB to meet the applicable nonroad engine emission standard.
Durability: (How long can the technology be expected to function under normal operating conditions and still achieve the specified emission reductions?)	Federal nonroad engine regulations specify that the useful life of certified nonroad engines is at least: 10 years or 8,000 hours (whichever occurs first) for engines rated at or above 50 horsepower; 7 years or 5,000 hours (whichever occurs first) for engines rated at or above 25 horsepower but less than 50 horsepower; 5 years or 3,000 hours (whichever occurs first) for engines rated at less than 25 horsepower; and 5 years or 3,000 hours (whichever occurs first) for constant-speed engines rated at less than 50 horsepower with rated speeds of 3,000 rpm or more. The ARB recently adopted useful life requirements comparable to the federal requirements described above.
Warranty:	Federal nonroad engine regulations specify that the warranty period for certified nonroad engines is at least: 5 years or 3,000 hours (whichever occurs first) for engines rated at or above 25 horsepower; 2 years or 1,500 hours (whichever occurs first) for engines rated at less than 25 horsepower; and 2 years or 1,500 hours (whichever occurs first) for constant-speed engines rated at less than 50 horsepower with rated speeds of 3,000 rpm or more. The ARB recently adopted warranty requirements comparable to the federal requirements described above.
Affect on Engine Warranty: (When possible, identify any impact the technology may have on an engine's warranty.)	N/A
Adverse Impacts: **Environmental:**	No known adverse environmental impacts.
Safety:	No known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	None
Current Status: (Is the technology commercially available, or is it still under development? How many engines has the technology been installed on, and how long has the technology been in use?)	Engines are currently available which meet the Tier 2 nonroad engine emission standards. All new nonroad engines rated at or above 175 horsepower must meet the current Tier 1 particulate matter standard of 0.4 g/bhp-hr. Tier 2 standards will be phased in over a 5 year period beginning in 2001. Tier 3 standards are expected to be phased in between 2006 and 2008.

318

Item	Response
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	N/A
Impacts of Lower Sulfur Diesel Fuel	Although not required to implement this control measure, the use of ultra-low sulfur fuel should reduce the sulfate fraction of diesel particulate matter.
Comments: (Address other issues relevant to the use of this technology, including other advantages / disadvantages of using the technology.)	The disposition of surplus engines must be addressed.

List of Stationary &/or Portable Applications

Technology Name: Repower With Certified Nonroad Engines

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
Pool California Energy Services	Make: Caterpillar Model: 3406E DITA Horsepower: 582 hp Application: Generator Fuel Type: CARB Diesel	Statewide Portable Equipment Registration Program Regist. No: 103700	1	1 year	0.4 g/bhp-hr	N/A
Alturdyne Motion Picture Services	Make: John Deere Model: 6081AF Horsepower: 300 hp Application: Generator Fuel Type: CARB Diesel	Statewide Portable Equipment Registration Program Regist. No: 101807	1	2 years	0.4 g/bhp-hr	N/A
Johnson Power Systems	Make: Caterpillar Model: 3406 Horsepower: 519 Application: Unknown Fuel Type: CARB Diesel	Statewide Portable Equipment Registration Program Regist. No: 105006	1	1 year	0.4 g/bhp-hr	N/A
Prime Equipment	Make: Komatsu Model: SA6D108E Horsepower: 217 Application: Generator Fuel Type: CARB Diesel	Statewide Portable Equipment Registration Program Regist. No: 104797	1	1 year	0.4 g/bhp-hr	N/A
Nesco Leasing	Make: Komatsu Model: SA6D125E-2 Horsepower: 345 Application: Generator Fuel Type: CARB Diesel	Statewide Portable Equipment Registration Program Regist. No: 104026	1	2 years	0.4 g/bhp-hr	N/A

List of Emission Test Results

Technology Name: Repower With Certified Nonroad Engines

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Emission Rate w/ Controls	Control Efficiency
ISO 8178-D2 5-mode steady-state	U.S. EPA Nonroad Engine Certification Data	Certified Nonroad Engine	Make: Cummins Model: C8.3, 6CTAA8.3-G1 Year: 1999 BHP: 280 Application: Pump, Compressor, Generator Set, Crane, etc... Configuration: Turbo, Aftercooler Engine Hours: n/a Fuel Type: CARB Diesel Fuel Use: Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.132 g/bhp-hr 6.32 g/bhp-hr 0.62 g/bhp-hr 0.45 g/bhp-hr	N/A N/A N/A N/A
ISO 8178-C1 8-mode steady-state	U.S. EPA Nonroad Engine Certification Data	Certified Nonroad Engine	Make: Caterpillar Model: 3306 Year: 1999 BHP: 397 Application: Generator Set, Industrial, Excavator, etc... Configuration: Turbo, Aftercooler Engine Hours: n/a Fuel Type: CARB Diesel Fuel Use: Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.114 g/bhp-hr 4.65 g/bhp-hr 1.35 g/bhp-hr 0.19 g/bhp-hr	N/A N/A N/A N/A

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Emission Rate w/ Controls	Control Efficiency
ISO 8178-C1 8-mode steady-state	U.S. EPA Nonroad Engine Certification Data	Certified Nonroad Engine	Make: Daimler-Benz AG Model: OM 501 LA Year: 1999 BHP: 422 Application: Not Reported Configuration: Turbo, Aftercooler Engine Hours: n/a Fuel Type: CARB Diesel Fuel Use: Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.042 g/bhp-hr 4.97 g/bhp-hr 0.40 g/bhp-hr 0.15 g/bhp-hr	N/A N/A N/A N/A
ISO 8178-C1 8-mode steady-state	U.S. EPA Nonroad Engine Certification Data	Certified Nonroad Engine	Make: Caterpillar Model: 3408 Year: 2000 BHP: 750 Application: Industrial Configuration: Turbo, Aftercooler Engine Hours: n/a Fuel Type: CARB Diesel Fuel Use: Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.084 g/bhp-hr 5.84 g/bhp-hr 0.90 g/bhp-hr 0.07 g/bhp-hr	N/A N/A N/A N/A
ISO 8178-C1 8-mode steady-state	U.S. EPA Nonroad Engine Certification Data	Certified Nonroad Engine	Make: Komatsu Model: SA6D140E-2 Year: 2000 BHP: 375 Application: Generator Set, Dozer Configuration: Turbo, Aftercooler Engine Hours: n/a Fuel Type: CARB Diesel Fuel Use: Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.125 g/bhp-hr 5.722 g/bhp-hr 0.321 g/bhp-hr 0.221 g/bhp-hr	N/A N/A N/A N/A

DRAFT Control Technology Evaluation

Item	Response
Product Name:	Unikat Combifilter
Product Vendor:	Engine Control Systems
Vendor Address:	165 Pony Drive Newmarket, Ontario Canada, L3Y 7V1
Product Description: (How does it work?)	The product is a diesel particulate filter system which incorporates electrical regeneration. Typically, the particulate filter media consists of either a ceramic wall-flow monolith (e.g. cordierite or silicon carbide) or woven ceramic fibers. The ceramic wall-flow monoliths capture diesel particulate matter primarily through surface filtration, and the woven ceramic fibers capture diesel particulate matter though depth filtration. To prevent plugging of the filter media and to minimize system backpressure, particulate filters must be periodically cleaned. This process of cleaning a particulate filter, termed regeneration, involves the oxidation of the collected particulate matter. Where passive particulate filter systems incorporate catalyst material to lower the temperature at which the collected particulate matter oxidizes, this technology actively regenerates the particulate filter via an electrical heating element. The regeneration is electronically controlled and can be completed in either 30 minutes or 8 hours, depending upon the system chosen.
Applicability: (What types of engines can the product be installed on?)	Individual particulate filter systems are available for diesel-fueled engines rated at between 25 and approximately 200 horsepower. Multiple filter elements can be used together for larger applications.
Achieved Emission Reductions:	<u>Product</u> — <u>Test Cycle</u> — <u>PM Reduction</u> Unikat Combifilter — Special Transient — 81% Unikat Combifilter with oxidation catalyst — ISO 8178 — 95%
Emission Reduction Guarantee:	The manufacturer guarantees that their product will reduce diesel PM emissions by at least 80%.
Costs: **Initial Retail:**	The initial cost is approximately: \$4,450 for a 40 hp engine; \$5,780 for a 100 hp engine; \$11,690 for a 275 hp engine; \$14,000 for a 400 hp engine; and \$40,250 for a 1,400 hp engine.
Installation:	For single and dual filter systems: \$206 - \$518 (Assuming 2 - 6 hours x \$78/hr + \$50 in misc parts.)
Operating:	For a generator larger than 275 hp, the cost to regenerate the filter is about 1% of the energy produced. The regeneration cost is higher for smaller engine generator sets--up to 7% for a 40 hp engine. In addition, fuel consumption may increase by one to one and a half percent due to additional backpressure.

Item	Response
Maintenance:	$312 for prime engine (Assume 2 cleanings at 2 hours labor each— total of 4 hours labor per year.) and $156 for emergency backup engine every five years (Assume 2 hours labor).
Comments:	The particulate filter systems must be cleaned every 1,000 - 1,500 hours of service to remove accumulated ash. The exact interval is dependent on lube oil consumption.
Certifications:	**Product** / **Certification** / **Agency** Unikat Combifilter / 80% diesel PM Removal / Swiss VERT Program Unikat Combifilter / 80% diesel PM Removal / Sweden Environmental Zones--Off-road
Durability / Product Life: (How long can the technology be expected to function under normal operating conditions and still achieve the specified emission reductions?)	Some installations have been in operation over 20,000 hours. The manufacturer does not provide a guarantee for product life.
Product Warranty:	The manufacturer provides a twelve month limited warranty covering manufacturing defects and workmanship. Other warranties may be provided on a case by case basis.
Affect on Engine Warranty: (When possible, identify any impact the technology may have on an engine's warranty.)	The engine manufacturer should be contacted to determine the specific impact of the product on an OEM engine warranty. However, the technology is sized to stay within OEM backpressure limitations.
Adverse Impacts: **Environmental:**	There are no known adverse environmental impacts.
Safety:	There are no known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	230V or 400V electrical service is required.
Current Status: (Is the technology commercially available, or is it still under development? How many engines has the technology been installed on, and how long has the technology been in use?)	The technology is commercially available in Europe and Asia and has been employed on captive fleet vehicles such as fork lifts and front end loaders, stationary and mining engines with total installation base of 3,000. According to the manufacturer, the product will be marketed in the United States as of September 1, 2000.

<table>
<tr><th>Item</th><th>Response</th></tr>
<tr><td>Other:
(e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)</td><td>The size and weight of actively regenerated DPF's are as follows:
<table>
<tr><th><u>HP</u></th><th><u>Diameter</u></th><th><u>Length</u></th><th><u>Weight</u></th></tr>
<tr><td>40 hp</td><td>13.8" - 25.7"</td><td>7.4" - 10.8"</td><td>53 lb - 64 lb</td></tr>
<tr><td>100 hp</td><td>12.2" - 14.5"</td><td>14.6" - 28.4"</td><td>64 lb - 179 lb</td></tr>
<tr><td>275 hp</td><td>--</td><td>--</td><td>--</td></tr>
<tr><td>400 hp</td><td>2 @ 13.8"</td><td>2 @ 20"</td><td>2 @ 86 lb</td></tr>
</table></td></tr>
<tr><td>Impacts of Lower Sulfur Diesel Fuel:</td><td>The product can be used with California's existing diesel fuel formulations.</td></tr>
<tr><td>Comments:
(Address other issues relevant to the use of this technology, including other advantages / disadvantages of using the technology.)</td><td>The product regenerates independently of engine exhaust temperature and is suitable for any size engine working under any duty cycle including long idle or light load conditions.</td></tr>
</table>

List of Stationary &/or Portable Applications

Technology Name: Unikat Combifilter

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
There are no known portable or stationary applications Unikat Combifilter in US	Make: Model Application Fuel Type					
However, a Combifilter system is operational in Welland, Ontario, Canada.	Make: Cummins Model: B5.9 Application: Taylor lift truck Fuel Type: Diesel, unknown S concentration		1	27 Months		

List of Emission Test Results

Technology Name: Unikat Combifilter

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Special transient cycle designed for a specific backhoe application.	Emission Research and Measurement Division, Environment Canada[30]	Combifilter Mfg. by Engine Control Systems	Make: Caterpillar Model: 3054DIT Year: 1994 BHP: 84 Application: Backhoe Configuration: Unknown Engine Hours: Unknown Fuel Type: 530 ppm S Diesel Fuel Use: 4.66 kg/hr Exhaust Temp: Unknown	PM NOx CO HC	8.46 g/hr 93.79 g/hr 41.66 g/hr 5.47 g/hr	1.77 g/hr 98.70 g/hr 37.56 g/hr 5.17 g/hr	79% -5% 10% 5%
ISO 8178 C1	AB Svensk Bilprovning	Combifilter with oxidation catalyst Mfg. by Engine Control Systems	Make: Perkins Model: 1004T Year: Unknown BHP: about 44 (for 33.7 kw) Application: Unknown Configuration: Unknown Engine Hours: Unknown Fuel Type: 30 ppm S Diesel Fuel Use: 234-236 g/kwh Exhaust Temp: Unknown	PM NOx CO HC	0.59 g/kwh 13.1 g/kwh 4.71 g/kwh 0.48 g as $CH_{1.85}$/kwh	0.03 g/kwh unk 0.11 g/kwh 0.04 g as $CH_{1.85}$/kwh	95% NA 98% 92%

[30] Study reported in SAE Technical Paper #1999-01-0110 entitled "The Impact of Retrofit Exhaust Control Technologies on Emissions from Heavy-Duty Diesel Construction Equipment."

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
ISO 8178 C1	AB Svensk Bilprovning	Combifilter with oxidation catalyst Mfg. by Engine Control Systems	Make: Scania Model: Unknown Year: Unknown BHP: 150 (for 114.9 kw) Application: Unknown Configuration: Unknown Engine Hours: Unkown Fuel Type: 30 ppm S Diesel Fuel Use: 223-225 g/kwh Exhaust Temp: Unknown	PM NOx CO HC	0.21 g/kwh 9.65 g/kwh 0.98 g/kwh 0.89 g as $CH_{1.85}$/kwh	0.01 g/kwh 9.68 g/kwh 0.12 g/kwh 0.07 g as $CH_{1.85}$/kwh	95% -0.3% 88% 92%