Appendix II

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

October 2000

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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 percent 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 70 percent 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 BACT 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 percent) 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 percent) 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.

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[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 A*ll 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 inventories of certain substances that 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. Each facility must be prioritized to determine whether a risk assessment must be conducted. The risk assessments must be conducted according to methods developed by the Office of Environmental Health Hazard Assessment (OEHHA). The public must be notified of significant risks posed by nearby facilities. The emissions which result in a significant risk must 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 six 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-fueled 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 percent 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 percent 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 percent 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 percent are located within four air basins: San Francisco, San Diego, San Joaquin Valley and South Coast.

Prime engines account for 75 percent 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 percent of the total number of engines used in prime applications (and 57 percent of all diesel PM emissions from stationary engines).

For prime engines not used in agricultural irrigation operations, more than 70 percent 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 percent 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 percent of the emissions are emitted from high use engines. For non-agricultural prime engines, the high use engines represent less than 25 percent of the total number of non-agricultural prime engines, but emit in excess of 80 percent of the total emissions from these engines. High use agricultural engines account for more than 90 percent of the total number of agricultural engines and 98 percent 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 percent), San Diego (7 percent), San Francisco Bay Area (23 percent), San Joaquin Valley (14 percent) and South Coast (32 percent) air basins. Approximately 85 percent 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 percent of the total number of portable engines, but emit less than 10 percent of the total diesel PM from portable engines. For engines greater than 50 horsepower, 62 percent are rated between 51 and 175 horsepower and the remaining 11 percent are greater than 175 horsepower. Engines rated between 51 and

175 horsepower account for approximately 57 percent 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 75 percent 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 percent), oil and gas well drilling and servicing (3 percent), and military TSE (5 percent).

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 percent by the year 2010. Although the number of engines is expected to increase, diesel PM emissions are expected to decrease by about 25 percent 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 percent 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-fueled 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

	Stationary – Prime		Stationary – Backup		Portable	
Year	**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 percent) 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].

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[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 (SO_2). A small percentage of SO_2 is further oxidized to form sulfur trioxide (SO_3^{-1}) 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 SO_2 to SO_3^{-1} 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 expects 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-fueled 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 percent 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 percent 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 percent. A technology is ranked as a moderately efficient technology where the available emission test information demonstrates a control efficiency of more than 30 percent, but less than 70 percent. A technology is ranked as a low efficiency technology if the available emission test information demonstrates a control efficiency of 30 percent 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.

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[5] The comparative annualized costs assume 500 hours per year of operation, a maximum economic life of 10 years and a 9 percent 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-fueled engines, and can be retrofitted to existing diesel-fueled engines. CCTS has been installed in more than 300 portable diesel-fueled 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-fueled 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 percent 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 percent.

ITG Bi-Fuel Conversion Kit

The technology 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 percent gaseous/20 percent diesel and 50 percent gaseous/50 percent 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-fueled engines, and can be retrofitted to existing diesel-fueled engines. The technology has been installed on over 200 diesel-fueled 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 percent and 37 percent. 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

<u>Diesel Oxidation Catalyst</u>

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-fueled 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-fueled engines.

2. Particulate Emission Reduction Efficiency

Based on the available emission test information, the technology reduces diesel PM by 16 percent to 30 percent. 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 NO_2, which is a strong oxidant. The NO_2 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-fueled engines. The technology can be retrofitted to many existing diesel-fueled 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-fueled engines[6] and on a few stationary diesel-fueled 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 percent to 97 percent 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.

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

i. Applicability

The technology can be applied to stationary, portable, and mobile diesel-fueled 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-fueled 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 percent 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-fueled engines rated at between 25 and 200 horsepower. Multiple filter elements can be used together for larger engine applications.

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[7] "Available particulate trap systems for diesel-fueled 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 percent. 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-fueled engines, and can be retrofitted to existing diesel-fueled 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 percent. 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-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 percent 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-fueled engines rated from 200 horsepower to more than 10,000 horsepower, and has been installed on 125 diesel-fueled engines worldwide.

2. Particulate Emission Reduction Efficiency

Based on the available emission test information, the technology has reduced diesel PM by 28 percent. 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 percent. 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-fueled 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 percent, 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 percent. 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 percent 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-fueled 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-fueled 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-fueled 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-fueled engines are used in a variety of applications, and there are situations where multiple diesel-fueled 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.

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[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 percent 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 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-fueled 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

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

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-fueled 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 percent 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 percent over an uncontrolled engine in a specific application, the reduction in exposure and risk will also be 90 percent.

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-fueled 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-fueled engines. Staff recommends the development of an ATCM that specifies retrofit control requirements for existing prime-use diesel-fueled 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-fueled 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-fueled 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.

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[10] "Available particulate trap systems for diesel-fueled 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 percent reduction in diesel PM emissions from at least 90 percent 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 percent in a specific application, the reduction in exposure and risk will also be 85 percent.

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 percent 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-fueled 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-fueled 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 percent reduction applied to 90 percent 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 percent 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-fueled engines. Specifically, the Statewide Portable Equipment Registration Program Regulation should be amended to include requirements for reducing diesel PM emissions from registered portable diesel-fueled 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-fueled 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 percent reduction of diesel PM emissions from 90 percent 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 percent 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

Currently, there are well over 7,000 agricultural irrigation pump engines in California, and they represent about 11 percent 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-fueled 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 percent 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 percent of the engines in this category will be equipped with emission control technologies capable of achieving 85 percent 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 percent 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

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. 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.

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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-fueled engines.” 1998

Appendix II-A

California Air Districts and Counties

Air Districts are Delineated by Bold Black Text Labels and Yellow Boundary Lines.

Counties are Delineated by Smaller Text Labels and Black Boundary Lines.

California Environmental Protection Agency
Air Resources Board

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 percent 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 includes 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

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[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 cost 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 percent 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 percent)
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.

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[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.

Table B-1: Equivalent Uniform Annual Cost

Control Technology	HP	Annual Hours	Equipment/Economic Life Min	Equipment/Economic Life Max	Equipment/Economic Life NTE	Interest Rate	Capital Cost Min	Capital Cost Max	Installation Cost Min	Installation Cost Max	Operating Cost Min	Operating Cost Max	Maintenance Cost Min	Maintenance Cost Max	Total Annual Cost Min	Total Annual Cost Max
	(hp)	(hr)	(hr)	(hr)	(yr)	(%)	($)	($)	($)	($)	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)	($/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%	$ 6,960	$ 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	$ 2,413	$ 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-fueled engines, amending the Statewide Portable Equipment Registration Program regulation for portable diesel-fueled 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		Control Measure Cost	
			Low	High	Low	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.