California Environmental Protection Agency

Air Resources Board

Proposed Amendments to the California Diesel Fuel Regulations

STAFF REPORT: INITIAL STATEMENT OF REASONS

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State of California
California Environmental Protection Agency
AIR RESOURCES BOARD
Stationary Source Division

STAFF REPORT: INITIAL STATEMENT OF REASONS
PROPOSED AMENDMENTS TO THE CALIFORNIA
DIESEL FUEL REGULATIONS

Public Hearing to Consider Amendments to the California Diesel Fuel Regulations Including Reduction of the Maximum Permissible Sulfur Content of Motor Vehicle Diesel Fuel

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I. INTRODUCTION AND SUMMARY

A. Introduction

In November 1988, the Air Resources Board (ARB) approved regulations limiting the allowable sulfur content of motor vehicle diesel fuel to 500 parts per million by weight (ppmw) statewide and the aromatic hydrocarbon content to 10 percent with a 20 percent limit for small refiners. These diesel fuel regulations, which became effective in 1993, are a necessary part of the state's strategy to reduce air pollution through the use of clean fuels and lower emitting motor vehicles and off-road equipment. The regulation limiting the aromatic hydrocarbon content of diesel fuel has included provisions that enable diesel fuel producers and importers to comply through alternative diesel formulations that may cost less. The alternative specifications must result in the same emission benefits as the 10 percent aromatic standard (or in the case of small refiners, the 20 percent standard).

The California diesel fuel regulations have resulted in significant reductions in emissions from diesel powered vehicles and equipment: greater than 80 percent for sulfur dioxide (SO_2), 25 percent for particulate matter, and 7 percent for oxides of nitrogen (NOx). California diesel fuel also results in reductions of emissions of several toxic substances, other than diesel particulate matter, including benzene and polynuclear aromatic hydrocarbons.

This report is the initial statement of reasons to support proposed amendments to the California diesel fuel regulations. One of the proposed amendments would reduce the sulfur content limit from 500 ppmw to 15 ppmw for diesel fuel sold for use in California in on-road and off-road motor vehicles starting in mid-2006. The lower sulfur limit would align the California requirement with the on-road diesel sulfur limit adopted by the United States Environmental Protection Agency (U.S. EPA). However, the California sulfur requirement would apply to on and off-road motor vehicle diesel fuel. The new sulfur standard will enable the use of the emissions control technology required to ensure compliance with the new emissions standards adopted by the U.S. EPA for 2007 and subsequent model-year heavy-duty engines and vehicles. We are also proposing establishment of another compliance option to the aromatics regulation to provide further flexibility to fuel producers. Under the proposed option, producers could choose to meet a set of specific diesel fuel properties that would achieve emissions benefits equivalent to those provided by the original specification for aromatic hydrocarbons approved by the Board 15 years ago. Staff is also proposing improved procedures for certifying emission-equivalent alternative formulations. In addition, we are proposing adoption of standards for diesel fuel lubricity. Also, to implement requirements of ARB's risk reduction plan for diesel PM emissions, staff is proposing the adoption of an airborne toxic control measure (ATCM) making the diesel fuel requirements applicable to nonvehicular diesel fuel.

B. What is California Diesel Fuel?

California diesel fuel used in motor vehicles must meet specifications adopted by the ARB in 1988 limiting sulfur and aromatic contents. The requirements for "CARB diesel," which became applicable in 1993, consists of two basic elements:

- A limit of 500 ppmw on sulfur content to reduce emissions of both sulfur dioxide and directly emitted particulate matter.
- A limit on aromatic hydrocarbon content of 10 percent for large refiners and 20 percent for small refiners to reduce emissions of both particulate matter and NOx.

The regulation limiting aromatic hydrocarbons also includes a provision that enables producers and importers to comply with the regulation by qualifying a set of alternative specifications of their own choosing. The alternative formulation must be shown, through emissions testing, to provide emission benefits equivalent to that obtained with a 10 percent aromatic standard (or in the case of small refiners, the 20 percent standard). Most refiners have taken advantage of the regulation's flexibility to produce alternative diesel formulations that provide the required emission reduction benefits at a lower cost.

C. Why are Amendments to the California Diesel Fuel Regulations Necessary?

1. Lower Sulfur Limit

A lower sulfur limit is needed to ensure the emissions performance of heavy-duty diesel engines and vehicles designed to meet 2007 model-year federal and California exhaust emission standards and to help reduce the exposure and risk from diesel particulate matter emissions as required by the ARB Diesel Risk Reduction Plan.

a) 2007 Model-Year Emission Standards for Heavy-Duty Diesel Engines

In January 2001, the U.S. EPA adopted emission standards for 2007 and subsequent model-year heavy-duty diesel engines. These emission standards represent a 90% reduction of NOx emissions, 72% reduction of non-methane hydrocarbon (NMHC) emissions, and 90% reduction of particulate matter (PM) emissions compared to the 2004 emission standards. In October 2001, the ARB approved amendments that aligned the California exhaust emission standards for heavy-duty diesel engines with those promulgated by the U.S. EPA.

The U.S. EPA's Final Rule sets heavy-duty engine emissions standards that will necessitate the use of catalyzed diesel particulate filters, NOx after-treatment and other advanced after-treatment based technologies. However, current commercial diesel fuel sulfur levels would inhibit the performance of these technologies. In the same January 2001 rulemaking, the U.S. EPA adopted new diesel fuel quality standards limiting the sulfur content of on-road diesel fuel to no more than 15 ppmw to enable the effective performance of the advanced engine emission control technologies. The average sulfur content of California diesel is about 140 ppmw with about 20 percent of production already meeting the proposed 15-ppmw limit.

b) The Diesel Risk Reduction Plan

Diesel-powered vehicles (on-road and off-road) account for a disproportionate amount of pollutants emitted by motor vehicles. They represent about 4 percent of California motor vehicles but produce about 40 percent of the NOx and 60 percent of directly emitted particulate matter from California on- and off-road vehicles.

In August 1998, the ARB identified particulate matter emitted from diesel engines (diesel PM) as a Toxic Air Contaminant (TAC). Because of the considerable potential health risks posed by exposure to diesel PM, ARB staff recommended a comprehensive plan, the diesel RRP, to further reduce diesel PM emissions and the health risks associated with such emissions. This plan seeks to reduce Californians' exposure to diesel particulate matter and associated cancer risks from baseline levels in 2000 by 85 percent by 2020.

In October 2000, the diesel RRP was approved by the ARB. The plan identified air toxic control measures and regulations that will set more stringent emissions standards for new diesel-fueled engines and vehicles, establish retrofit requirements for existing engines and vehicles where determined to be technically feasible and cost-effective, and require the sulfur content of diesel fuel to be reduced to no more than 15 ppmw.

The proposed maximum fuel sulfur standard of 15 ppmw is needed for the effective performance of the emissions control technologies proposed in the diesel RRP for new and retrofitted engines. At diesel sulfur concentrations higher than 15 ppmw, the effectiveness of the emissions control systems is sufficiently reduced that the desired emissions reductions for NOx and particulate matter cannot be achieved. These reductions in hydrocarbons, NOx, carbon monoxide (CO), and particulate matter are essential to the achievement of California's air quality goals.

2. New Equivalent Limits for Diesel Fuel Properties

Staff is proposing a new option for compliance with the aromatic hydrocarbon specification. The proposed option is a set of specified limits that provide an alternative formulation that would provide equivalent environmental benefits to the 10 percent aromatic hydrocarbon limit. The proposed new equivalent limits are based upon the average properties of existing certified formulations to preserve the actual emission benefits of California diesel fuel.

This proposal provides producers or importers of diesel fuel another compliance option that should facilitate the importation of diesel fuel into California.

3. Diesel Fuel Lubricity Standard

Staff is proposing a diesel fuel lubricity standard to ensure that California diesel fuel provides adequate lubrication for fuel systems of existing and future diesel engines. Diesel fuel lubricity can be defined as the ability of diesel fuel to provide surface contact lubrication. Adequate levels of fuel lubricity are necessary to protect the internal contact points in fuel pumps and injection systems to maintain reliable performance.

The levels of natural lubricity agents in diesel fuel are expected to be reduced by the more severe hydrotreating needed to lower the sulfur content of diesel fuel to meet the proposed 15-ppmw sulfur limit. Lubricity additives are available to increase the lubricity of fuels that have had their natural lubricity agents depleted.

Several types of diesel fuel injection equipment rely on the fuel for lubrication of the moving parts. Fuels of low lubricity do not provide adequate lubrication and will contribute to excessive wear resulting in reduced equipment life and performance. New fuel injector systems, developed to further reduce exhaust emissions, use extremely high pressures and require even higher levels of fuel lubricity than conventional systems. Excessive wear in these systems is expected to increase emissions due to compromised pump performance.

The American Society for Testing and Materials (ASTM) has been working to develop lubricity standards for its D-975 diesel fuel specifications since the introduction of low sulfur diesel fuel in 1993. To date, ASTM has not been successful in adopting a lubricity standard. As diesel fuel sulfur levels continue to be reduced, equipment manufacturers and consumers have expressed concern regarding the lack of a lubricity standard.

Staff believes that a lubricity standard is necessary due to the reduction of natural diesel fuel lubricity that is expected to occur with the implementation of the proposed 15-ppmw sulfur limit. Adequate diesel fuel lubricity must be maintained to protect both existing and future diesel engine fuel systems from excessive wear that would reduce engine life and increase exhaust emissions.

4. Certified Alternative Diesel Fuel Formulations

Staff is proposing several technical amendments to the portion of the regulation addressing certification of alternative formulations – Title 13, California Code of Regulations (CCR), Section 2282 (g).

a) Consistency With the Proposed Sulfur limit

For consistency with the proposed new sulfur content limits in section 2281, we are proposing that the Board amend section 2282(g) to require that both the candidate fuels and the reference fuels meet a sulfur limitation of 15 ppmw. Also, fuel produced under the existing certified formulations will independently have to meet the 15-ppmw sulfur limit when it becomes effective in 2006.

b) Emission Equivalency of Candidate Fuels to In-Use Fuels

Studies have shown that emissions from diesel engines are affected by fuel properties other than the five minimum specifications of certified alternative formulations. The effects of other properties on emissions do not change the applicability of section 2282(g) for certifying emission-equivalent California diesel fuel formulations. However, if there are large differences in properties between a reference fuel and a candidate fuel and between the candidate fuel and the fuel produced under the certification, the emission equivalency of the fuel produced for sale is in doubt. To eliminate doubts about the emission equivalency of fuel produced for sale, we are proposing that section 2282(g)(2) be amended by adding additional required specification ranges for candidate fuels, applicable for all new alternative formulations certified on or after August 1, 2004.

c) Emission Equivalency of Candidate Fuels to Reference Fuels

To determine whether the average emissions of NOx, particulate matter, and the soluble organic fraction (SOF) during testing with the candidate fuel do not exceed the average emissions of the comparable compounds during testing with the reference fuel, an arithmetic criterion is applied to the average emissions of each pollutant. The arithmetic criterion includes a margin of safety, based on the pooled standard deviation of the emissions, as well as a tolerance to ensure that truly emission-equivalent fuels will qualify. We have evaluated the results of the test programs for sixteen 10-percent equivalent formulations and have determined that the allowable tolerances for each pollutant are too large. Therefore, we are recommending that the tolerances for each pollutant be reduced by half.

d) Elimination of Sulfate Credit.

The provisions on certifying alternative formulations currently allow a sulfate credit for the candidate fuel when calculating particulate matter emissions. The sulfate credit was provided to encourage refiners to reduce sulfur in diesel fuel below the 500-ppmw limit, since fuel-originated secondary sulfates in the environment would significantly outweigh the sulfate portion in the primary PM emissions. Because ARB staff did not want an unlimited credit to be provided, the sulfate credit was capped at the primary sulfate level. For future certifications, the staff proposes to eliminate the sulfate credit, because the proposed sulfur level of 15 ppmw practically eliminates the possibility of a sulfate credit for future applicants.

D. What are the Proposed Amendments?

1. Reduce the Maximum Allowable Sulfur Content of Diesel Fuel

Staff is proposing that the Board amend the California diesel fuel regulations to reduce the maximum sulfur content of motor vehicle diesel fuel from 500 ppm by weight to 15 ppm by weight. Staff is proposing that the new sulfur limit for diesel fuel become effective at the refinery June 1, 2006 – the same effective date as the U.S. EPA's 15 ppmw sulfur limit for diesel fuel. The proposed change is expected to reduce the sulfur level in California diesel fuel from its current average of 140 ppmw to about 10 ppmw.

2. Change the Allowable Sulfur Content of Diesel Engine Certification Fuel

Staff is proposing an amendment that would change the sulfur content specification for certification fuel used to certify diesel vehicles and engines. Staff is proposing a range of sulfur content of 7 to 15 ppmw to replace the current range of 100 to 500 ppmw. This change is necessary to be consistent with the maximum permissible sulfur content of 15 ppmw being proposed for commercial diesel fuel in this rulemaking. The proposed sulfur content of the certification fuel will not exceed levels compatible with the effective operation of diesel engines and vehicles equipped with sulfur sensitive emissions control technologies.

3. Adopt New Alternative Equivalent Limits for California Diesel

We are proposing that the Board approve new equivalent limits which can be used by diesel fuel producers and marketers as an alternative means of complying with the 10-percent aromatic standard. Table I-1 presents the proposed new equivalent limits.

Table I-1: Proposed New Equivalent Limits for California Diesel Fuel

Property	Equivalent Limit[1]	Test Method
Aromatic Content (% by wt.)	≤ 21.0	ASTM D5186-96
PAH Content (% by wt.)	≤ 3.5	ASTM D5186-96
API Gravity	≥ 36.9	ASTM D287-82
Cetane Number	≥ 53	ASTM D613-84
Nitrogen Content (ppmw)	≤ 500	ASTM D4629-96
Sulfur (ppmw)	≤ 160[2]	ASTM D2622-94

[1] ≤ means "less than or equal to"
≥ means "greater than or equal to"
[2] Becomes ≤ 15 ppmw beginning June 1, 2006.

4. Adopt a Diesel Fuel Lubricity Standard

Staff is proposing that the Board approve a two phase plan to institute a fuel lubricity standard that will apply to all diesel fuel sold or supplied in California.

The proposed initial phase will be to immediately adopt a standard that is at least as protective as the current voluntary standard to protect current in-use engines. The proposed standard is a High Frequency Reciprocating Rig (HFRR) maximum wear scar diameter (WSD) of 520 microns. The HFRR ASTM test method, D6079-02, would be incorporated by reference. Staff is proposing that this standard be implemented on a 90-day phase-in schedule, commencing August 1, 2004.

The proposed second phase would be to determine a 2006 lubricity standard protective of advanced technology fuel systems via a technology assessment. Staff proposes that a place holder be included in the regulation for the 2006 standard and that the Board's resolution direct staff to conduct a technical assessment, to be completed in 2005, to determine an appropriate 2006 standard. The Board's resolution would further direct staff to return to the Board in 2005 with a proposed 2006 lubricity standard if the technology assessment determines that a HFRR maximum WSD of 460 microns at 60 degrees C, or a more appropriate standard, should be implemented on the same schedule as the proposed 15-ppmw sulfur limit for diesel fuel.

5. Revise the Requirements for Certifying Alternative Diesel Formulations.

We are proposing four types of technical amendments to subsection 2282(g): 1) for consistency with section 2281; 2) to ensure equivalent emissions performance of fuels sold as certified formulations to candidate fuels; 3) to ensure equivalent emissions performance of candidate fuels to reference fuels; and, 4) to eliminate a provision for sulfate credit in determining equivalency of the candidate fuel.

a) Consistency With the Sulfur Standard in Section 2281

Since we are proposing under section 2281 that all California diesel fuel meet a 15-ppmw sulfur limitation starting in mid-2006, for consistency and to improve the effectiveness of subsection 2282(g) we are also proposing that reference and candidate fuels also meet the 15-ppmw sulfur limitation for all alternative formulations certified after July 31, 2004. In addition, fuels produced under existing certified formulations will have to meet the 15 ppmw limit when it becomes applicable.

b) Emission Equivalency of Candidate Fuels to In-Use Fuels

To ensure that future candidate fuels tested in the laboratory are fully characterized, we are proposing that the reporting requirements for candidate fuel properties be expanded to include all the properties that must be reported for reference fuels. We are also proposing that the Board require that the same property limitations and ranges apply to candidate fuels as reference fuels, except for the four specified certified-formulation properties, and that candidate fuel properties be within half the range of reference fuel properties. For new formulations, a candidate fuel property will be permitted to be outside applicable ranges only if the property is specified in the formulation in the Executive Order certifying the formulation. This would prevent the applicant from changing other candidate fuel properties that could affect emissions unless the applicant is willing to accept that specifications for those properties be included in the certified formulation.

c) Emission Equivalency of Candidate Fuels to Reference Fuels

For a candidate fuel to qualify an alternative formulation, the average emissions of NOx, PM, and SOF during testing with the candidate fuel cannot exceed the average emissions of NOx, PM, and SOF during testing with the reference fuel. A statistical margin of safety, based on the pooled standard deviation of the tests with the candidate and reference fuels, is required for each pollutant. Tolerances are allowed for each pollutant to make sure that a truly emission-equivalent fuel will always pass. Based on sixteen fuels qualified in the same laboratory, we have found that the standard deviations and calculated safety margins warrant that the tolerances be lowered. Therefore, we are proposing that the tolerances be lowered from 2, 4, and 12 percent to 1, 2, and 6 percent of the average emissions of NOx, PM, and SOF, respectively, during testing with the reference fuel.

d) Elimination of Sulfate Credit

In the interest of updating the certified alternative formulation provisions of subsection 2282(g) to be applicable to fuels with the proposed 15-ppmw sulfur content limitation, we are proposing that the Board amend the regulation to eliminate the two provisions for sulfate credit under subsection 2282(g)(5)(B) for all new certified formulations. The proposed limit for sulfur content of 15 ppmw makes this provision obsolete as there could not practically be any significant difference between the sulfur levels in the reference and candidate fuels. Existing formulations would not be affected.

6. Adopt Diesel Fuel Standards for Nonvehicular Diesel Engine Applications

Staff is proposing that the Board adopt, as a new section of title 17 of the California Code of Regulations, an Airborne Toxic Control Measure (ATCM) for nonvehicular diesel fuel standards. The new diesel fuel requirements would be identical to the California Diesel Fuel Regulations except that the applicability would be to fuel used in nonvehicular diesel engines, other than those powering locomotives or marine vessels. The proposed ATCM would facilitate the implementation of the Diesel Risk Reduction Plan for nonvehicular diesel engines.

7. Other Amendments

The staff is proposing the following amendments to clarify the requirements of the regulations and to ensure that the regulations work effectively.

The sulfur regulation currently requires that sulfur in diesel fuel be determined by x-ray spectrometry using ASTM D2622-94. The detection limit and repeatability for this method are not acceptable for determining sulfur at the levels expected in diesel fuels produced to comply with the proposed sulfur limit of 15 ppmw. Therefore, staff is proposing to replace this method with ASTM D5453-93, an ultraviolet fluorescence method that will provide a more suitable detection limit and better precision than the current method, when the new sulfur standard becomes applicable.

Staff is proposing a revision of the definition of “diesel fuel” to clarify the applicability of the diesel fuel regulations and make the definition consistent with the definition for fuel for internal combustion, spark ignition engines. The revised definition will include any predominantly hydrocarbon, liquid fuel that is used or intended for use or represented for use in internal combustion, compression ignition (diesel cycle) engines.

Staff is also proposing a conforming amendment to the definition of diesel fuel in the verification procedure and in-use compliance requirements for in-use strategies to control emissions from diesel engines. This amendment would assure that the current effect of the requirements for the verification procedure regulation will not be changed by the expansion of the definition of diesel fuel.

Also, staff is proposing that an exemption from the diesel fuel requirements be established for diesel fuel used in qualifying military vehicles, closely paralleling provisions in the U.S. EPA regulations.

E. What Alternatives Were Considered?

Staff evaluated alternatives to the proposed new sulfur standard and concluded that there were no alternative means of complying with the emission standards for 2007 and subsequent model year diesel engines. Staff also found that there were also no alternative means of facilitating the implementation of the Diesel Risk Reduction Plan. Discussions of the alternatives considered by staff are contained in the chapters of this report that describe the individual proposed amendments.

F. Do the Proposed Amendments Satisfy the Commitments in the State Implementation Plan?

The proposed amendment to reduce the sulfur content of diesel fuel will have a direct benefit for the State Implementation Plan (SIP) by reducing particulate sulfate PM_{10} emissions. Most importantly, the proposed diesel fuel sulfur standard is central to the success of the 2007 heavy-duty diesel vehicle emission standards in providing benefits that help the state meet SIP emission reduction obligations. The lower sulfur diesel fuel will be an enabling fuel for the advanced emission control technologies needed to achieve the emissions reductions required by the 2007 heavy-duty diesel engine emission standards.

G. What Are the Emission Impacts of the Proposed Amendments?

Sulfur oxides and particulate sulfate are emitted in direct proportion to the sulfur content of diesel fuel. Reducing the sulfur content of diesel fuel from the statewide average of 140 ppmw to less than 10 ppmw would reduce sulfur oxide emissions by about 90 percent or by about 6.4 tons per day from 2000 levels. Direct diesel particulate matter emissions would be reduced by about 4 percent, or about 0.6 tons per year in 2010 for engines not equipped with advanced particulate emissions control technologies. These emissions reductions would be obtained with low sulfur diesel used in mobile on-road and off-road engines, portable engines, and those stationary engines required by district regulations to use CARB diesel. In addition, NOx emissions would be reduced by 7 percent or about 80 tons per year for those engines not currently using CARB diesel, assumed to be about 10 percent of the stationary engine inventory.

The lower sulfur diesel makes much more significant emissions reductions possible by enabling the effective use of advanced emission control technologies on new and retrofitted diesel engines. With these new technologies, emissions of diesel particulate matter and NOx can be reduced by 90 percent. Significant reductions of non-methane hydrocarbons and carbon monoxide can also be achieved with these control devices.

H. What are the Environmental Impacts of the Proposed Amendments?

1. Air Quality

Sulfur in diesel fuel contributes to ambient levels of fine particulate matter through the formation of sulfates both in the exhaust stream of the diesel engine and later in the atmosphere. Therefore, reducing the sulfur limit of California diesel to 15 ppmw will have a positive air quality impact by reducing ambient levels of particulate matter. The proposed diesel sulfur limit of 15 ppmw will also help to improve air quality by enabling the effective performance of advanced diesel exhaust emissions control technologies that reduce emissions of ozone precursors (NOx and NMHC) and diesel PM. As ozone precursor emissions are reduced, ozone levels will also be reduced. In addition, reducing ozone precursor emissions will help to reduce secondary particulate matter formation – whether nitrate or organic compound aerosols. Reductions in emissions of diesel PM mean reduced ambient levels of the toxic air contaminants found in diesel exhaust and reduced public exposure to those TACs.

2. Water Quality.

The proposed amendment to lower the sulfur content limit of California diesel fuel to 15 ppmw should have no significant adverse impacts on water quality. With a lower sulfur content, emitted sulfur oxides and sulfates would be lower and consequently there would be a reduction of atmospheric deposition of sulfuric acid and sulfates in water bodies. The low sulfur diesel will enable the use of emissions control devices to reduce NOx and diesel PM emissions. As a result, there should be a decrease in atmospheric deposition of nitrogen compounds such as nitrates and airborne diesel particles as well as the associated heavy metals, PAHs, dioxins, and other toxic compounds typically found in diesel exhaust.

The release of diesel fuel to surface water and groundwater can occur during production, storage, distribution or use. The refining process to reduce the sulfur content of diesel to 15 ppmw is not expected to result in a significant change in the chemical composition of the fuel. There should also be no significant change in the physical or chemical properties that affect the activity of the fuel in soil and water. Therefore, any release of low sulfur diesel fuel to the environment should have no additional impact on water quality compared to the current diesel fuel.

The other proposed amendments to the California diesel regulation should not have any significant adverse impacts on water quality.

3. Greenhouse Gas Emissions

Implementation of the proposed amendment to reduce the sulfur content of diesel fuel could have a small effect on global warming. The production of low sulfur diesel is expected to increase emissions of greenhouse gases. Emissions of CO_2 from refineries will increase due to the increased demand for energy for additional hydrogen production and additional processing to produce low sulfur diesel. Emissions from refineries of other greenhouse gases like methane and nitrous oxide will be very small compared to the additional carbon dioxide emissions.

4. Refinery Modifications

Implementation of the proposed amendment to the diesel fuel sulfur standard will require changes in processing that could affect emissions from the refinery.

Refiners have indicated that they will meet the proposed sulfur limit by increasing their hydrotreating capability. The additional energy needs for this additional processing could mean increases in combustion derived emissions such as NOx, PM, CO, and SO_2 from sources such as heaters and boilers that must increase their operation to meet the additional energy demands. The impact of these process changes on air quality will be limited by the requirements of the California Environmental Quality Act (CEQA) and by new source review or BACT requirements of the air quality management districts.

I. What is the Cost of the Proposed Amendments?

The staff's estimates of the costs of the proposed amendments are based on information provided by California refiners, the major California common carrier pipeline operator, specialty fuel suppliers, California Energy Commission (CEC) staff, and documents prepared by the U.S. EPA, U.S. DOE, and the SCAQMD.

1. Overall Costs.

The ARB staff estimates that the costs of reducing the sulfur content of diesel fuel and requiring the fuel to meet minimum lubricity specifications will be about 2 to 4 cents per gallon of diesel. The cost estimates include: capital expenditures of about $170 to $250 million; operating and maintenance costs of $50 to $60 million per year; distribution system costs of about $8 million due to downgrading of transmix to federal off-road diesel standards; a fuel economy penalty of about 0.5 cents per gallon; and the cost of the proposed lubricity standard which could range from 0.2 to 0.6 cents per gallon of diesel.

Most of these costs to refiners to reduce diesel fuel sulfur levels will be incurred as a result of the U.S. EPA and the SCAQMD regulations[a] that have already been adopted. Staff's proposed amendments would extend the applicability of these regulations to the 25 percent of state's total diesel fuel consumed by California off-road diesel vehicles outside the SCAQMD.

The U.S. EPA estimated the cost of its national program to be between 4 cents and 5 cents per gallon. The cost of the national program is expected to be higher than the estimated cost of 2 to 4 cents for California's because the California refining industry is already producing a lower sulfur on-road diesel fuel than most refineries in other regions of the country, and is therefore better positioned to produce low-sulfur diesel fuel. About 20 percent of the diesel fuel produced in California has sulfur levels below 15 ppmw.

2. Fuel Supply and Price.

With respect to diesel prices, it is very difficult to predict what will occur in the marketplace. California diesel prices are heavily influenced by supply and demand, crude oil prices, and competitive market considerations. However, it is reasonable to assume that over time, the refiners will recover the increased costs of production in the marketplace. With this assumption and the staff's estimate that the long-term production cost of low-sulfur diesel fuel will be from 2 to 4 cents per gallon, it is reasonable to assume that this increase in production cost will, on average, be reflected in diesel fuel prices.

It is very difficult to predict the stability of diesel prices. However, the proposed amendments regulation should not affect the ability of California refiners to supply sufficient quantities of diesel fuel to the California market. The recent ARB refinery survey suggests that sufficient diesel refinery capacity already exists. In addition, the implementation of the federal on-road low sulfur diesel regulations, adoption of the California diesel fuel regulations by the state of Texas, and the ability of out-of-state refiners to produce diesel fuel meeting California standards should provide even greater assurance of diesel fuel availability to the State. Further, the flexibility provided by the proposed equivalent limits should enhance the ability of producers

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[a] SCAQMD Rule 431.2. Sulfur Content of Liquid Fuels limits the sulfur content in diesel to 15 ppm by weight. The limit applies to diesel produced for both stationary and motor vehicle sources but excluding ships and trains. The rule is described in Section VI.C below.

outside California to provide fuel to California. Therefore, the overall diesel production system – consisting of California refineries and imports – should not be impacted after the implementation of the proposed amendments.

J. What are the Economic Impacts?

The proposed amendments should have only a very small relative economic impact on the California economy or the diesel fuel consuming sectors of the economy investigated by staff. Staff estimated potential impacts for the petroleum industry, the agricultural sector, and the transportation sector using a computable general equilibrium (CGE) model of the California economy. This model is a modified version of the California Department of Finance's Dynamic Revenue Analysis Model (DRAM) developed by researchers at the University of California, Berkeley. The ARB model called E-DRAM describes the economic relationships between California producers, consumers, government, and rest of the world. The analysis predicted very minor changes in various economic outputs. Staff also found that there should be no significant additional adverse effect on small businesses because of the cost impacts of the regulations.

K. What Future Activities Are Planned?

The staff will continue its investigation of a statistical regression model that enables users to predict how diesel emissions are affected by changes in fuel properties. If successful, such a model could be used by refiners and importers to certify alternative formulations, like the California Predictive Model is used for gasoline, and could provide the same type of flexibility for diesel fuel production. Such a model would allow refiners and importers to quickly certify alternative formulations for sale in California without having to conduct engine emissions tests. This should also allow more diesel fuel outside of California to qualify for sale in California.

This effort will involve working with the U.S. EPA's staff and other stakeholders to conduct a comprehensive review and analysis of available data to quantify the exhaust emission effects of diesel fuel parameters including cetane number, aromatic content, 90 percent distillation temperature, sulfur content, and fuel density. The adequacy of available test data to construct a model will be an important consideration.

Also, staff will participate in the Coordinating Research Council (CRC) Diesel Performance Group lubricity panel and the associated lubricity testing of advanced technology fuel injection systems. Staff will conduct a technology assessment of the lubricity level required by advanced technology fuel injection systems in 2005, considering the CRC research results as well as additional data as it becomes available. If necessary, staff will propose a 2006 lubricity standard of a HFRR maximum WSD of 460 microns, or a more appropriate value as determined by the technology assessment.

II. RECOMMENDATIONS

The staff recommends that the Board adopt the proposed amendments to the California diesel regulations as contained in Appendix A. These amendments will do the following:

1. Reduce the maximum permissible sulfur content in vehicular diesel fuel from 500 ppmw to 15 ppmw;
2. Adopt an Air Toxics Control Measure to require the use of vehicular diesel fuel in all nonvehicular diesel engines;
3. Revise the sulfur specifications for diesel certification fuel used to determine whether diesel engines comply with California's emission standards for heavy-duty diesel engines;
4. Revise the requirements for certification of alternative diesel formulations to require that both the candidate and reference fuels used in the certification procedure meet a sulfur limit of 15 ppmw;
5. Establish additional requirements for certification of alternative diesel formulations to ensure that the diesel fuel produced commercially under the alternative formulation has comparable emissions performance to the candidate fuel used to certify the formulation;
6. Adopt new specifications for equivalency to the aromatic hydrocarbon limit for California diesel fuel to provide another compliance option while maintaining the benefits of the existing regulations;
7. Adopt standards for diesel fuel lubricity to ensure that California diesel fuel provides adequate lubrication for the fuel systems of existing and future diesel engines; and
8. Make other changes, including improvements to the sulfur test method and a revision of the definition of "diesel fuel," to ensure that the regulation works effectively.

III. BACKGROUND

This chapter contains general information about the source of the air pollution problems being addressed in this rulemaking and the current air pollution impacts of diesel fuel use.

A. Sources of Diesel Sulfur

The primary sources of sulfur in diesel fuel are the sulfur-containing compounds which occur naturally in crude oil. The sulfur content can vary widely depending on the source of the crude oil. For crude oil refined in the U.S. outside of California, the sulfur content can range from 0.4 percent to 2.8 percent with an average content of about 1.3 percent.[1] The range for crude oil refined in California is 0.4 percent to 3.3 percent while the average is about 1.3 percent.[1]

Most of the sulfur in crude oil is in the heaviest boiling fractions. Since most of the refinery blendstocks used to manufacture diesel fuel come from the heavier boiling components of crude oil, they contain substantial amounts of sulfur.

B. Current Levels of Sulfur in California Diesel Fuel

Almost all of the diesel fuel sold to final users in California is Grade Low Sulfur No. 2-D [2] which complies with the requirements of the Clean Air Act and 40 CFR section 80.29 regarding sulfur content. About 90 percent of the diesel fuel sold or supplied in California meets the "CARB diesel" requirements for sulfur and aromatic hydrocarbons which apply to diesel fuel used in on-road and off-road vehicular sources and are described later in the report. Only stationary sources, marine vessels and locomotives are currently exempt from the CARB diesel requirements.[a]

Table III-1 shows average values for sulfur and four other fuel properties for motor vehicle fuel sold in California before and after the current diesel fuel regulation became effective in 1993. Before 1993, the average fuel sulfur content of 400 ppm for the Los Angeles area was considerably lower than the 3000-ppmw average for the rest of the state. This difference was due to the ARB's 500-ppmw limit on diesel fuel sulfur that had been in effect in the South Coast Air Basin since 1985. The corresponding national averages are shown for the same properties for on-road diesel only since the U.S. EPA sulfur standard does not apply to off-road or nonvehicular diesel fuel.

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[a] Most stationary engines use CARB diesel because of the state's single fuel distribution network and because of districts' BACT requirements that specify CARB diesel. Also, South Coast Air Quality Management District's rule 431.2 will require CARB diesel for all stationary engines in 2004, excluding engines in locomotives and ships.

Table III-1: Average Properties of Reformulated Diesel Fuel

Property	California		U.S.[1]
	Pre-1993	1999	1999
Sulfur, ppmw	440[2]	140[3]	360
Aromatics, vol.%	35	19	35
Cetane No.	43	50	45
PNA, wt.%	NA	3	NA
Nitrogen, ppmw	NA	150	110

1 AAMA National Surveys for on-road vehicles only.
2 For Los Angeles area only, greater than 3000 ppmw in rest of California.
3 About 20 % of total California volume is less than 15 ppmw.

C. Diesel-Fueled Engines

A diesel-fueled engine is defined as any internal combustion, compression-ignition (diesel-cycle) engine. The benefits of the proposed amendment to lower the California diesel sulfur limit will result from the use of diesel fuel in the categories of engines listed in Table III-2.

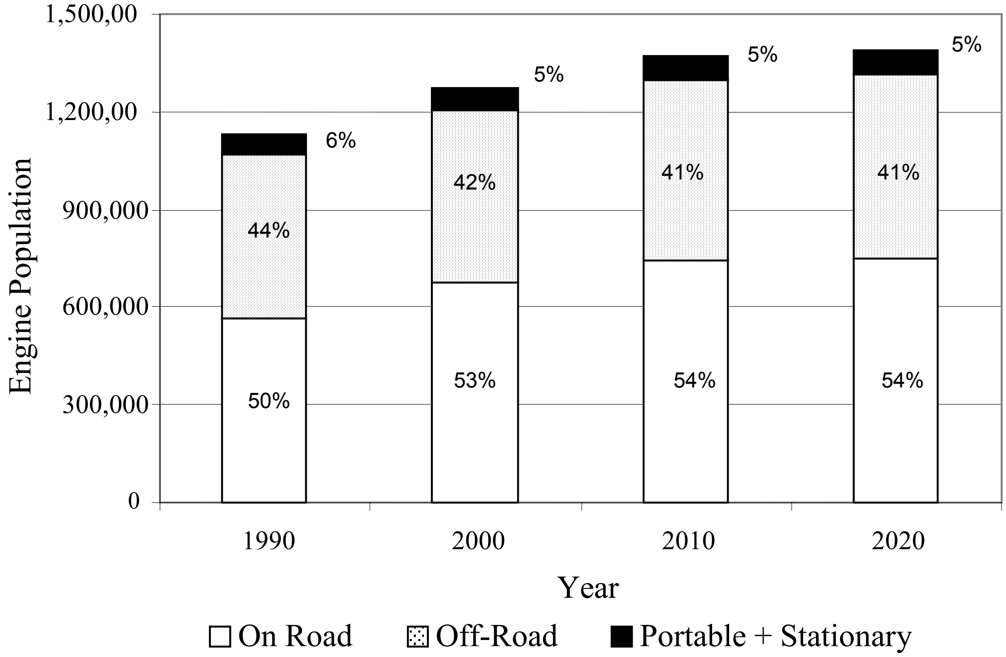
Table III-2 and Figure III-1 present population estimates for the different categories of diesel-fueled engines in California. An increase in the engine population is predicted for all of the diesel engine categories. The statewide population of on-road engines is predicted to increase by about 9 percent between 2000 and 2010 and by about 1 percent between 2010 and 2020. In 2000, 54 percent of the on-road diesel-fueled vehicles fell into one of the heavy-duty classes. There were approximately 700,000 on-road diesel-fueled vehicles in use in the state with the majority in the heavy-duty vehicle class with a gross vehicle weight rating greater than 14,000 pounds. This population is predicted to increase by about 12 percent between 2000 and 2010.[3]

Table III-2: Estimates of Statewide Diesel Engine Population[1]

Engine Category	Engine population			
	1990	2000	2010	2020
On-road	567,000	679,000	742,000	751,000
Off-road	504,000	528,000	556,000	563,000
Portable	48,000	49,000	54,000	55,000
Stationary	15,000	16,000	17,000	18,000
Total	1,134,000	1,272,000	1,369,000	1,387,000

1 From ARB's Risk Reduction Plan[3,4,] except for on-road and off-road estimates which were revised based on EMFAC 2002, version 2.2.

Figure III-1: Statewide Diesel Engine Population in California



D. Pollutants Emitted From Diesel Engines

Diesel exhaust is a complex mixture of inorganic and organic compounds that exist in gaseous, liquid, and solid phases. The composition of this mixture will vary depending on engine type, operating conditions, fuel, lubricating oil, and whether or not an emission control system is present. Many of the individual exhaust constituents remain unidentified.

The primary gas or vapor phase components of diesel exhaust include typical combustion gases and vapors such as carbon monoxide (CO), carbon dioxide (CO_2), oxides of sulfur (SO_X), oxides of nitrogen (NOx), reactive organic gases (ROG), water vapor, and excess air (nitrogen and oxygen). Table III-3 shows the contributions of emissions of PM_{10}, NOx, SOx, and reactive organic gases (ROG) from diesel engines to the statewide total emissions of those pollutants in 2000. Diesel engines contributed 3 percent to the statewide total PM_{10} , of which 85 percent is attributed to area sources. Diesel engines are significant sources of SOx, and NOx, accounting for 44 percent and 43 percent respectively of total statewide emissions. They account for 24 percent of the statewide total emissions of ozone precursors (NOx+ROG). A later chapter discusses the need for further reductions of these emissions to reach attainment of the federal ambient air quality standards for ozone.

The emissions from diesel-fueled engines also contain potential cancer-causing substances such as arsenic, nickel, benzene, formaldehyde, and polycyclic aromatic hydrocarbons. Diesel exhaust includes over 40 substances that are listed by the U.S. EPA as hazardous air pollutants (HAPS) and by the ARB as toxic air contaminants (TACs).

Table III-3: Contribution of Diesel Engines to Statewide Emissions of PM_{10}, NOx, SOx, and ROG in 2000

Pollutant	Emissions (tons per year)		Percent of Statewide total
	Diesel engines	Statewide total[1]	
PM_{10}	28,000	878,000	3.2%
SOx	52,000	117,000	44%
NOx	570,000	1,340,000	43%
ROG	44,000	1,210,000	4%
NOx+ROG	614,000	2,550,000	24%

[1] Data from California Emissions Forecasting System, year 2000.
(run date: 5/14/01)

E. Particulate Matter Emissions from Diesel-Fueled Engines

In 1998, the ARB identified diesel particulate matter as a toxic air contaminant. Approximately 98 percent of the particles emitted from diesel engines are smaller than 10 microns in diameter.[4] Diesel particulate matter consists of both solid and liquid material and can be divided into three primary constituents: the elemental carbon fraction; the soluble organic fraction (SOF), and the sulfate fraction. The elemental carbon fraction, which makes up the largest portion of the total DPM, is the result of incomplete combustion in locally fuel-rich regions. The SOF consists of unburned organic compounds in the small fraction of the fuel and atomized and evaporated lube oil that escape oxidation. These compounds condense into liquid droplets or are adsorbed onto the surfaces of the elemental carbon particles. Several components of the SOF have been identified as individual toxic air contaminants. The sulfates with associated water are the result of oxidation of fuel-borne sulfur in the engine's exhaust.

Table III-4 and Figure III-2 present estimates of the statewide inventory for diesel PM emissions for 1990, 2000, 2010, and 2020. These estimates take into account growth in the engine population due to population and economic growth and emission reductions due to both federal and state regulations in effect at the time of the inventory estimate.

As shown in Table III-4 and Figure III-2, mobile diesel-fueled engines (on-road and off-road) are responsible for the majority of the diesel PM emissions in California. These two categories contribute approximately 94 percent of the total diesel PM emissions (Figure III-2). The estimated statewide PM emissions from on-road diesel motor vehicles was 7,600 tons in 2000 while the off-road estimate was 18,600 tons for the year. Emissions from off-road mobile sources far exceed emissions from all other categories. In 2000, off-road mobile sources accounted for 66% of the total diesel PM emissions, on-road sources for 27 percent, portable equipment for 5 percent and stationary sources the remaining 2 percent.

Emissions from stationary engines are expected to remain relatively stable while emissions from portable engines show a significant decrease. This reduction is due to replacement of older engines with new low emission engines.[4]

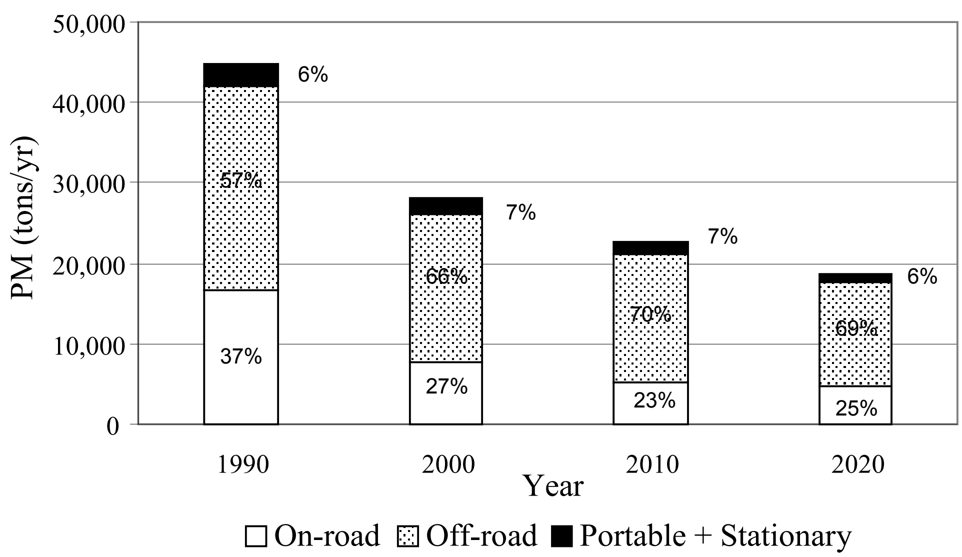
Figure III-2 shows a downward trend in PM emissions from mobile diesel engines even as the number of diesel engines increases (Table III-2 and Figure III-1). These reductions are due to improvements in engine design and emission control technology, currently adopted on-road standards, fleet turn-over as new vehicles with controls replace older vehicles with less effective controls, and the use of reformulated diesel fuels. However, without further controls, the effect of these emissions reduction measures will be to some extent offset by continued growth in vehicle use.

Table III-4: Statewide Diesel PM Emissions (tons per year)[1]

Engine Category	PM emissions (tons per year)			
	1990	2000	2010	2020
On-road	17,000	7,600	5,100	4,700
Off-road	25,000	18,600	16,000	12,800
Portable	2,200	1,400	1,100	660
Stationary	500	600	500	500
Total	44,700	28,200	22,700	18,660

[1] From ARB's Risk Reduction Plan, except for the on-road estimates that were revised based on EMFAC 2.02.

Figure III-2: Statewide Diesel PM Emissions



F. Effect of California Diesel Fuel Regulations on Emissions from Diesel Engines

In the 1988-1989 rulemaking establishing the California diesel fuel regulations, ARB staff estimated the emissions impacts based on transient-cycle testing of two engines and the results of earlier studies. The staff estimated that the diesel fuel specifications in the California diesel fuel regulations result in significant reductions in emissions from diesel powered vehicles and equipment: greater than 80 percent for sulfur dioxide (SO_2), 25 percent for particulate matter, and 7 percent for NOx. California diesel fuel also reduces emissions of several toxic substances other than diesel particulate matter, including benzene and polynuclear aromatic hydrocarbons. Appendix C contains a discussion of how diesel fuel aromatics content affects the emissions of PAHs and PAH derivatives in diesel exhaust.

ARB staff has analyzed the results of 35 different emission studies, involving 300 fuels and 73 engines, which have been conducted since the original estimates of the emission benefits were made in 1988. The staff's analysis show that ARB's original estimates continue to be valid, and are in close agreement with the estimates from the currently available emission studies.

In each study and for every engine configuration analyzed, emissions were predicted to decrease when fuel complying with the California diesel fuel regulations was used instead of conventional diesel fuel. These studies indicate that reducing sulfur content, aromatic hydrocarbon content, and specific gravity and increasing cetane number reduces PM emissions. They also show that reducing aromatic hydrocarbon content and specific gravity and increasing cetane number reduces NOx emissions from diesel engines.

The California diesel fuel regulations reduce emissions of PM and NOx because they limit the sulfur and aromatic hydrocarbons content of diesel or require changes to other properties that produce equivalent emission benefits. The studies reviewed confirm that this flexibility is possible because emission benefits accrue not only from the reduction in the content of sulfur and aromatic hydrocarbons in diesel fuel, but also from the lower specific gravity and higher cetane number of complying alternative diesel fuel formulations. This interrelationship of multiple diesel fuel properties that affect emissions enables fuel producers to employ considerable flexibility in formulating California diesel fuel, so long as their alternative formulations provide the same environmental benefits as defined reference fuels. Appendix D contains a draft report on the current emissions benefits of California's diesel fuel program while Appendix E supplements this report with an analysis of how future emissions benefits will be affected by fleet turnover.

IV. Need for Emissions Reductions

California's mobile source and fuels programs, more than any other pollution control effort, have helped to move the state's nonattainment areas closer to meeting federal and state air quality standards. The combination of fuels and vehicle emissions regulations provide significant statewide reductions in emissions of CO, PM_{10}, SOx, and ozone precursors - NOx and reactive organic gases or ROG (also called volatile organic compounds or VOCs). Nevertheless, significant additional reductions in mobile source emissions are essential if the state is to attain the state and national ambient air quality standards.

The ARB has published a series of new measures in a proposed new control strategy to reduce emissions of VOC, NOx, and particulate matter statewide.[5] The measures were initially proposed in the draft state and federal element of the South Coast Implementation Plan, but appropriate measures from the list will be incorporated where they are needed in regional ozone and PM_{10} attainment SIPs.

U.S. EPA regulations are needed to effectively reduce emissions from locomotives, aircraft, heavy –duty vehicles used in interstate commerce, and other sources such as off-road engines that are either preempted from state control or best regulated at the national level. Therefore, the reduction of PM_{10} and ozone precursor emissions will require cooperation with the U.S. EPA.

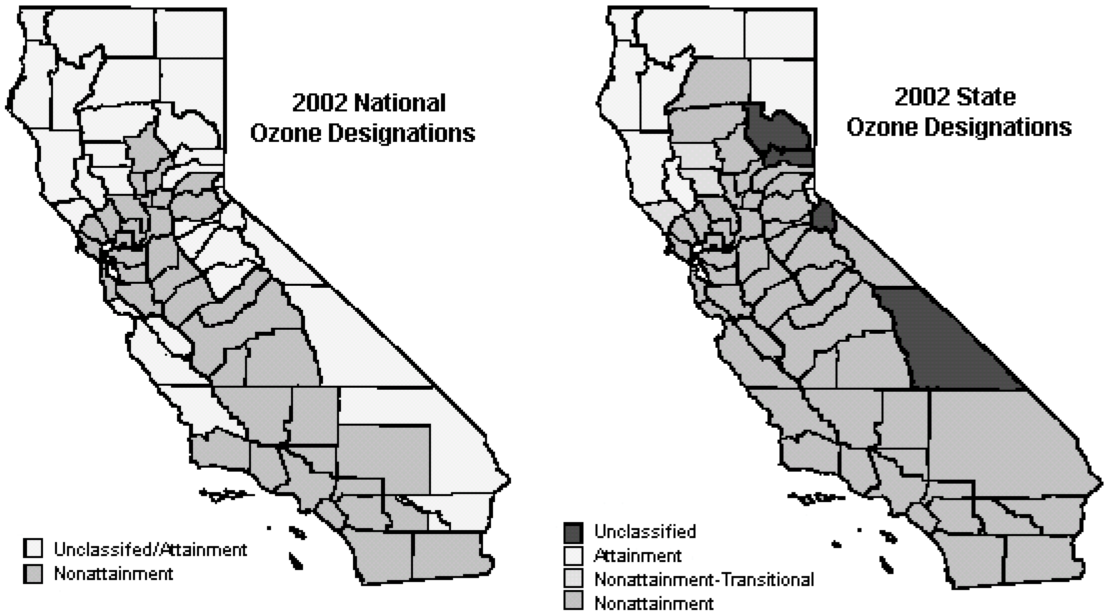
A. Criteria Pollutants

1. Ozone

As shown in Figure IV-1, most of the state does not meet the state or federal ozone standards. The areas that violate the national ozone standard are pursuing a strategy that reduces the emissions of precursors of ozone. Lowering ozone precursor emissions will also help reduce secondary particulate matter formation.

California's plan for achieving the federal ozone standard is contained in the California State Implementation Plan (SIP) that was approved by the Board in 1994. A significant part of the emission reductions in the SIP is achieved by controlling vehicles and their fuels. Mobile source emissions, both on-road and off-road, account for about 70 percent of ozone precursor emissions in California with diesel engines contributing 24 percent to the statewide total in 2000, as shown in Table III-3. Further reductions from the current emissions levels of NOx and ROG are essential if California is to reach attainment for ozone. ARB's strategy for obtaining further mobile source emissions reductions include improved technology measures. The largest new emissions reductions are expected from on-road and off-road diesel engines equipped with technology developed to meet emissions standards for on-road heavy-duty diesel trucks.

Figure IV-1: Federal and State Area Designations for Ozone



The greatest reductions are needed in the South Coast Air Basin. The South Coast Air Quality Management District (SCAQMD) revised its part of the Ozone SIP in 1997 and again in 1999. The U.S. EPA approved the South Coast's 1999 Ozone SIP revision in 2000. The SCAQMD has proposed a 2003 revision to the ozone SIP because of the need for additional reductions beyond those incorporated in the 1997/1999 plan. These additional reductions are need to offset increased emissions from mobile sources and meet all federal criteria pollutant standards within the time frames allowed under the Clean Air Act. The South Coast Air Basin is required to demonstrate attainment of the federal 1-hour ozone standard by 2010.

Significant reductions will also be needed in the San Joaquin Valley Air Basin (SJVAB) which has been classified as severe nonattainment for ozone effective December 10, 2001. The SJVAB is required to attain the ozone standards as expeditiously as possible, but no later than November 15, 2005. The SJVAB cannot attain the one-standard by the required date but the District must reduce emissions by 3 percent per year on average and must continue to make progress toward attainment.[6] Heavy –duty engines are a major source of NOx emissions in the SJVAB. The benefits of low sulfur fuel diesel as an enabling fuel for advanced diesel engine aftertreatment technologies will not come in time for the required timeframe for the SJVAB plan. However the District is developing fleet rules comparable the SCAQMD rules that could require the use of low sulfur diesel in retrofitted engines.[6]

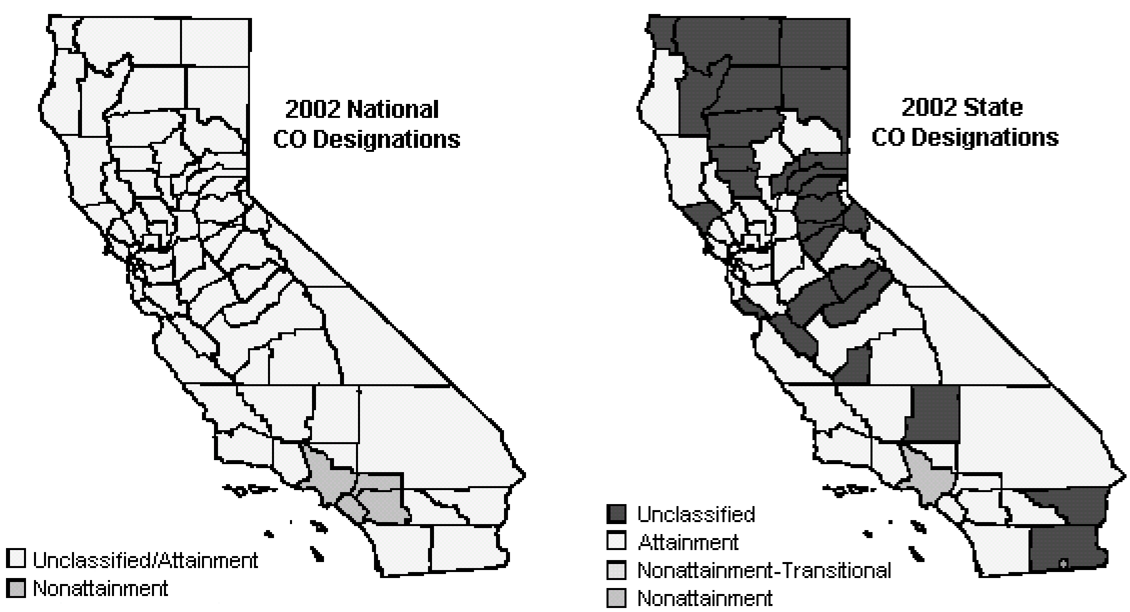
2. Carbon Monoxide

All of California, with the exception of the South Coast Air Basin, has attained the state and federal CO standards. Violations of these standards are now limited to a small region in the Los

Angeles area and Calexico in Imperial county. Based on projected emissions, the South Coast Air Quality Management District predicts Los Angeles County will attain the national CO standards sometime after the year 2005.

Reductions in CO levels are largely the result of the implementation of ARB mobile source and clean fuels regulations. These reductions have been achieved despite significant increases in the number of vehicle miles traveled each day. California's on-going mobile source programs will continue to provide new reductions in CO emissions to keep pace with the increases in population and vehicle usage. The aftertreatment technology that would be used to meet the 2007 heavy-duty diesel vehicle emissions standards for NOx and PM would result in a per-vehicle reduction in excess of 90 percent CO from baseline levels.[7] Additional emission reductions will come from continued fleet turnover, expanded use of low emission vehicles, and measures to promote less polluting modes of transportation. In addition, the introduction of zero and near zero emission vehicles will play an increasingly important role in the coming years.

Figure IV-2: Federal and State Area Designations for Carbon Monoxide

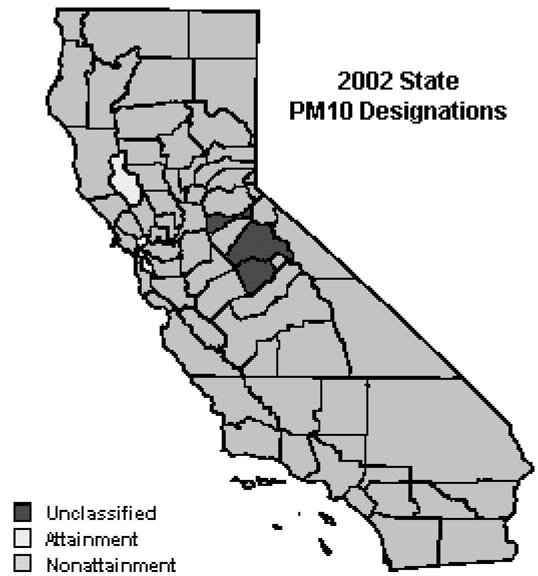


3. Particulate Matter

Particulate pollution is a problem affecting much of California. The majority of California is designated as non-attainment for the state and federal PM_{10} standards as shown in Figure IV-3. Only the Lake County Air Basin is designated as attainment in California and three counties in the northern half of the state remain unclassified. The nonattainment areas with serious problems will require substantial reductions of directly emitted PM_{10} pollutants and PM_{10} precursors. Also control of the emissions of ozone precursors may provide some small benefit due to the reduction in condensible PM_{10} emissions from the organic ozone precursors. Control of oxides of nitrogen would also be effective in controlling ambient nitrate concentrations.

Motor vehicles and equipment under state and federal jurisdiction are responsible for a considerable amount of PM_{10} air pollution but they also contribute the majority of the emissions reductions needed for attainment. As indicated above, appropriate measures from the list proposed in the ARB's control strategy will be incorporated where they are needed in regional PM_{10} attainment SIPs. Included in the list are measures to clean up existing and new truck and bus fleets by reducing PM emissions.

Figure IV-3: Federal and State Area Designations for PM_{10}.



B. Toxic Air Contaminants

1. Components of Diesel Exhaust

Diesel exhaust is a complex mixture of inorganic and organic compounds that exist in gaseous, liquid, and solid phases. The composition of this mixture will vary depending on engine type, operating conditions, fuel, lubricating oil, and whether an emission control system is present.

Diesel engines operate with excess air (around 25-30 parts air to 1 part fuel). Consequently, the primary gas or vapor phase components of whole diesel exhaust are nitrogen (N_2), oxygen (O_2), carbon dioxide (CO_2), and water vapor (H_2O). Diesel exhaust also contains substances such as carbon monoxide, oxides of nitrogen, sulfur dioxide, hydrocarbons, particulate matter, aldehydes, ketones, sulfates, cyanides, phenols, metals, and ammonia. These substances are unburned fuel and lubricant components, products of combustion, or are a result of engine wear or trace contaminants in the fuel and lubricating oil.[8] Other gas phase components of diesel exhaust, are low-molecular mass PAH and nitro-PAH derivatives. Atmospheric reactions of these gas phase PAH and nitro-PAH derivatives may lead to the formation of several mutagenic nitro-PAH, and nitro-PAH compounds, including nitrodibenzopyranones, 2-nitroflouranthene and 2-nitropyrene.[9, 10]

Diesel exhaust contains over 40 substances that have been listed as TACs by the state of California and as hazardous air pollutants by the U.S. EPA. Fifteen of these substances are listed by the International Agency for Research on Cancer (IARC) as carcinogenic to humans, or as a probable or possible human carcinogen. The list includes the following substances: formaldehyde, acetaldehyde, 1,3-butadiene, antimony compounds, arsenic, benzene, beryllium compounds, bis(2-ethylhexyl)phthalate, dioxins and dibenzofurans, inorganic lead, mercury compounds, nickel, POM (including PAHs); and styrene.[11]

Almost all of the diesel particle mass is in the fine particle (PM_{10}) fraction. Approximately 95 percent of the mass of these particles is less than 2.5 microns in diameter. The particles have a very large surface area per unit mass which makes them excellent carriers for many of the organic compounds and metals found in diesel exhaust.

2. Potential Cancer Risk

In 1990, ARB staff[12] reported the statewide population-weighted annual outdoor average diesel PM concentration as 3.0 $\mu g/m^3$. Using this 1990 value for ambient concentrations, and assuming that the ratio of ambient concentration to statewide emissions remained constant, ARB staff[13] calculated ambient diesel PM concentrations for 2000, 2010, and 2020. Estimates of statewide annual average ambient PM concentration are presented in Table IV-1 along with the corresponding percent reduction from the 1990 ambient concentration. Table IV-1 also shows estimates of the risks of contracting cancer from exposure to the indicated ambient diesel PM concentrations. The methodology for estimating these cancer risks is described in the ARB's diesel Risk Reduction Plan.[13]

Diesel PM is a major contributor to potential ambient risk levels. In 2000, the average potential cancer risk associated with diesel PM emissions was estimated at over 500 potential cases per million. This diesel PM cancer risk accounted for approximately 70 percent of the ambient air toxics cancer risk (Figure IV-4).

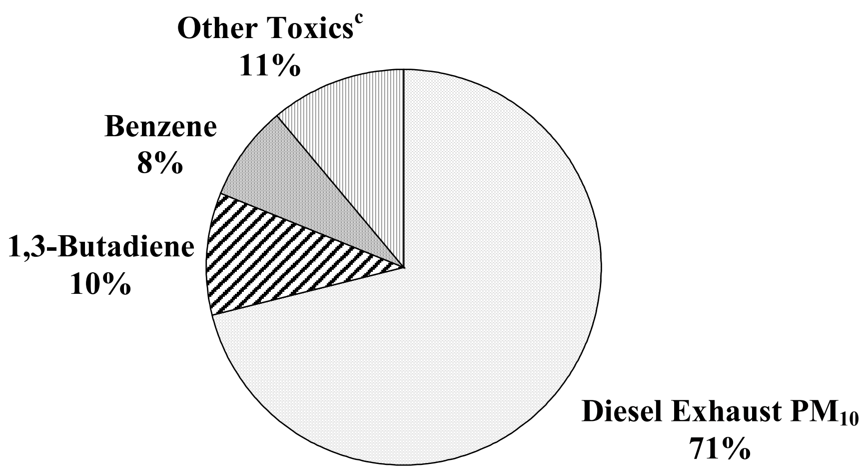
The SCAQMD Multiple Air Toxics Exposure Study II (MATES II) estimated that the average potential cancer risk in the South Coast Air Basin from diesel PM was about 1000 excess cancers per million people, or 71 percent of the average cancer risk from all air toxics in the South Coast Air Basin. Localized or near-source exposures to diesel exhaust, such as might occur near busy roads and intersections, will present much higher potential risks.

Reducing the risk from diesel PM is essential to reducing overall public exposure to air toxics. The control measures proposed in the diesel Risk Reduction Plan will result in an overall 85 percent reduction in the diesel PM inventory and the associated cancer risk by 2020.

Table IV-1: Statewide Population-Weighted Annual Outdoor Average Diesel PM Concentration for 1990, 2000, 2010, and 2020[13]

	1990	2000	2010	2020
Outdoor Ambient Concentration ($\mu g/m^3$)	3.0	1.8	1.5	1.2
Percent Reduction in Diesel PM from 1990 Concentration	N/A	40%	50%	60%
Risk (cancers/million)	900	540	450	360

Figure IV-4:
State Average Potential Cancer Risk from Outdoor Ambient Levels of Toxic Pollutants for the Year 2000[a,b]



a. ARB Risk Reduction Plan[14] .

b. Diesel exhaust PM_{10} potential cancer risk based on 2000 emission inventory estimates. All other potential cancer risks based on air toxics network data. Used 1997 data for para-dichlorobenzene. Used 1998 monitoring data for all others.

Assumes measured concentrations are equivalent to annual average concentrations and duration of exposure is 70 years, inhalation pathway only.

c. Includes carbon tetrachloride (4%), formaldehyde (2..5%), hexavalent chromium (2.2%), para-dichlorobenzene (1.2%), acetaldehyde (0.7%), perchloroethylene (0.7%), and methylene chloride (0.3%).

V. HEALTH BENEFITS OF DIESEL EMISSIONS REDUCTIONS

This chapter discusses the health effects of the pollutants emitted by diesel engines and the health benefits of the emissions reductions that would result from the use of low sulfur diesel fuel in diesel engines. There would be health benefits from the sulfate PM emissions reductions that result from the lowering of the sulfur limit of California diesel to 15 ppmw. In addition, there would be major health benefits from the reductions of emissions of ozone precursors (NOx and NMHC), diesel PM and other toxic air contaminants through the use of low sulfur fuel in diesel engines equipped with exhaust aftertreatment systems.

A. Diesel Exhaust

Diesel exhaust is a complex mixture of inorganic and organic compounds that exist in gaseous, liquid, and solid phases. The composition of this mixture will vary depending on engine type, operating conditions, fuel, lubricating oil, and whether or not an emission control system is present. The primary gas or vapor phase components of diesel exhaust include typical combustion gases and vapors such as carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (CO_2), oxides of nitrogen (NOx), reactive organic gases (ROG), water vapor, and excess air (nitrogen and oxygen). The emissions from diesel-fueled engines also contain potential cancer-causing substances such as arsenic, nickel, benzene, formaldehyde, and polycyclic aromatic hydrocarbons. Diesel exhaust includes over 40 substances that are listed by the U.S. EPA as hazardous air pollutants (HAPS) and by the ARB as TACs. Fifteen of these substances are listed by the International Agency for Research (IARC) as carcinogenic to humans, or as a probable or possible human carcinogen. The list includes the following substances: formaldehyde, acetaldehyde, 1,3-butadiene, antimony compounds, arsenic, benzene, beryllium compounds, bis(2-ethylhexyl)phthalate, dioxins and dibenzofurans, inorganic lead, mercury compounds, nickel, POM (including PAHs), and styrene.

1. Diesel Particulate Matter

Diesel particulate matter is either directly emitted from diesel-powered engines (primary particulate matter) or is formed from the gaseous compounds emitted by a diesel engine (secondary particulate matter). Diesel particulate matter consists of both solid and liquid material and can be divided into three primary constituents: the elemental carbon fraction (ECF); the soluble organic fraction (SOF), and the sulfate fraction.

Many of the diesel particles exist in the atmosphere as a carbon core with a coating of organic carbon compounds, or as sulfuric acid and ash, sulfuric acid aerosols, or sulfate particles associated with organic carbon.[15] The organic fraction of the diesel particle contains compounds such as aldehydes, alkanes and alkenes, and high-molecular weight PAH and PAH-derivatives. Many of these PAHs and PAH-derivatives, especially nitro-PAHs, have been found to be potent mutagens and carcinogens. Nitro-PAH compounds can also be formed during transport through the atmosphere by reactions of adsorbed PAH with nitric acid and by gas-phase radical-initiated reactions in the presence of oxides of nitrogen.[11] Fine particles may also be formed secondarily from gaseous precursors such as SO2, NOx, or organic compounds. Fine particles can remain in the atmosphere for days to weeks and travel through the atmosphere for hundreds to thousands of kilometers, while coarse particles deposit to the earth within minutes to hours and within tens of kilometers from the emission source.

Almost all of the diesel particle mass is in the fine particle range of 10 microns or less in diameter (PM_{10}). Approximately 94 percent of the mass of these particles are less than 2.5 microns in diameter ($PM_{2.5}$). Because of their small size, the particles are readily respirable and can effectively reach the lowest airways of the lung along with the adsorbed compounds, many of which are known or suspected mutagens and carcinogens.[16] They are easily distinguished from noncombustion sources of $PM_{2.5}$ by the high content of elemental carbon with the adsorbed organic compounds and the high number of ultrafine particles (organic carbon and sulfate).

The soluble organic fraction (SOF) consists of unburned organic compounds in the small fraction of the fuel and atomized and evaporated lubricating oil that escape oxidation. These compounds condense into liquid droplets or are adsorbed onto the surfaces of the elemental carbon particles. Several components of the SOF have been identified as individual toxic air contaminants.

B. Health Impacts of Exposure to Diesel Exhaust

In addition to its contribution to ambient PM inventories, diesel exhaust is of specific concern because it poses a lung cancer hazard for humans as well as a hazard from noncancer respiratory effects such as pulmonary inflammation.[17] More than 30 human epidemiological studies have investigated the potential carcinogenicity of diesel exhaust. On average, these studies found that long-term occupational exposures to diesel exhaust were associated with a 40% increase in the relative risk of lung cancer.[18] However, there is limited specific information that addresses the variable susceptibilities to the carcinogenicity of diesel exhaust within the general human population and vulnerable subgroups, such as infants and children and people with pre-existing health conditions. The carcinogenic potential of diesel exhaust was also demonstrated in numerous genotoxic and mutagenic studies on some of the organic compounds typically detected in diesel exhaust.[18] Diesel exhaust was recently listed as a TAC by ARB after an extensive review and evaluation of the scientific literature by OEHHA[19] and subsequent review by the Scientific Research Panel (SRP). Using the cancer unit risk factor developed by OEHHA for the TAC program, it was estimated that for the year 2000, exposure to ambient concentrations of diesel (1.8 $\mu g/m^3$) could be associated with a health risk of 540 excess cancer cases per million people exposed over a 70-year lifetime. This estimated risk is equivalent to about 270 excess cases of cancer per year for the entire State, which is several times higher than the risk from all other identified TACs combined. Another highly significant health effect of diesel exhaust exposure is its apparent ability to act as an adjuvant in allergic responses and possibly asthma.[20, 21, 22] However, additional research is needed at diesel exhaust concentrations that more closely approximate current ambient levels before the role of diesel exhaust exposure in the increasing allergy and asthma rates is established.

C. Health Impacts of Exposure to Diesel PM

The U.S. EPA discussed the epidemiological and toxicological evidence of the health effects of ambient PM and diesel PM in the regulatory impact analyses for on-road and nonroad diesel engine emission standards.[17] The key health effects categories associated with ambient particulate matter include premature mortality, aggravation of respiratory and cardiovascular disease (as indicated by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days), aggravated asthma, acute respiratory symptoms, including aggravated coughing and difficult or painful breathing, chronic bronchitis, and decreased lung function that can be experienced as shortness of breath.

Health impacts from exposure to the fine particulate matter ($PM_{2.5}$) component of diesel exhaust have been calculated for California, using concentration-response equations from several epidemiologic studies. Both mortality and morbidity effects could be associated with exposure to either direct diesel $PM_{2.5}$ or indirect diesel $PM_{2.5}$, the latter of which arises from the conversion of diesel NOx emissions to $PM_{2.5}$ nitrates. It was estimated that 2000 and 900 premature deaths resulted from long-term exposure to either 1.8 $\mu g/m^3$ of direct $PM_{2.5}$ or 0.81 $\mu g/m^3$ of indirect $PM_{2.5}$, respectively, for the year 2000.[23] The mortality estimates are likely to exclude cancer cases, but may include some premature deaths due to cancer, because the epidemiologic studies did not identify the cause of death. Exposure to fine particulate matter, including diesel $PM_{2.5}$ can also be linked to a number of heart and lung diseases. For example, it was estimated that 5400 hospital admissions for chronic obstructive pulmonary disease, pneumonia, cardiovascular disease and asthma were due to exposure to direct diesel $PM_{2.5}$. An additional 2400 admissions were linked to exposure to indirect diesel PM.[23]

D. Health Impacts of Exposure to Ozone

Ozone is formed by the reaction of VOCs and NOx in the atmosphere in the presence of heat and sunlight. The highest levels of ozone are produced when both VOC and NOx emissions are present in significant quantities on clear summer days. This pollutant is a powerful oxidant that can damage the respiratory tract, causing inflammation and irritation, which can result in breathing difficulties. Currently there are no quantitative data available regarding the health impacts associated with ozone.

Studies have shown that there are impacts on public health and welfare from ozone at moderate levels that do not exceed the 1-hour ozone standard. Short-term exposure to high ambient ozone concentrations have been linked to increased hospital admissions and emergency visits for respiratory problems.[24] Repeated exposure to ozone can make people more susceptible to respiratory infection and lung inflammation and can aggravate pre-existing respiratory diseases, such as asthma. Prolonged (6 to 8 hours), repeated exposure to ozone can cause inflammation of the lung, impairment of lung defense mechanisms, and possibly irreversible changes in lung structure, which over time could lead to premature aging of the lungs and/or chronic respiratory illnesses such as emphysema and chronic bronchitis.

The subgroups most susceptible to ozone health effects include individuals exercising outdoors, children and people with pre-existing lung disease such as asthma, and chronic pulmonary lung disease. Children are more at risk from ozone exposure because they typically are active outside, during the summer when ozone levels are highest. Also, children are more at risk than adults from ozone exposure because their respiratory systems are still developing. Adults who are outdoors and moderately active during the summer months, such as construction workers and other outdoor workers, also are among those most at risk. These individuals, as well as people with respiratory illnesses such as asthma, especially asthmatic children, can experience reduced lung function and increased respiratory symptoms, such as chest pain and cough, when exposed to relatively low ozone levels during prolonged periods of moderate exertion.

E. Health Benefits of Reductions of Diesel Exhaust Emissions

1. Reduced Ambient PM Levels

Studies have shown that there are public health and welfare effects from PM at concentrations that do not constitute a violation of the National Ambient Air Quality Standard (NAAQS) for PM. The emission reductions obtained with low sulfur diesel and diesel engines equipped with aftertreatment systems will result in lower ambient PM levels and significant reductions of exposure to primary and secondary diesel PM. In contrast to ozone, which is a product of complex photochemical reactions and therefore difficult to directly relate to precursor emissions, ambient PM_{10} concentrations are more directly influenced by emissions of particulate matter and can therefore be correlated more meaningfully with emissions inventories. Lower ambient PM levels and reduced exposure mean reduction of the prevalence of the diseases attributed to diesel PM, reduced incidences of hospitalizations, and prevention of premature deaths.

2. Reduced Ambient Ozone Levels

Emissions of NOx and VOC are precursors to the formation of ozone in the lower atmosphere. Ozone can have adverse health impacts at concentrations that do not exceed the 1-hour NAAQS.. Heavy-duty vehicles contribute a substantial fraction of ozone precursors in any metropolitan area. Therefore, reduction of heavy-duty diesel vehicle emissions of NOx and VOCs through the use of low sulfur diesel fuel and exhaust aftertreatment systems would make a considerable contribution to reducing exposures to ambient ozone. Controlling emissions of ozone precursors would reduce the prevalence of the types of respiratory problems associated with ozone exposure and would reduce hospital admissions and emergency visits for respiratory problems.

VI. EXISTING DIESEL FUEL REGULATIONS

This chapter presents a summary of state, federal, and local diesel fuel regulations that affect the quality of diesel fuel consumed by diesel engines in California.

A. California Diesel Fuel Regulations

"CARB diesel" is diesel fuel that meets the Air Resources Board's regulations controlling the sulfur and aromatic contents of diesel fuels used in motor vehicles. The California Division of Measurement Standards requires that motor vehicle diesel fuel meet ASTM D-975 specifications and have a minimum cetane number of 40. About 90 percent of the diesel fuel sold or supplied in California meets "CARB Diesel" requirements. Only diesel fuel for stationary engines, locomotives, and marine vessels is currently exempt from the California diesel fuel regulations. The requirements of the CARB diesel fuel regulations are summarized in Table VI-1 along with the EPA diesel fuel requirements.

1. Sulfur Standard

Section 2281 of Title 13, CCR regulates the sulfur content of vehicular diesel fuel sold or supplied in California. The regulation was approved by the ARB in 1988 originally as section 2255 and was implemented in 1993 statewide. All diesel fuel sold or supplied in California for motor-vehicle use must have a sulfur content no greater than 500 ppmw. The sulfur content of motor vehicle fuel in the South Coast Air Basin and Ventura County had been limited to 500 ppmw since 1985 for large refiners and 1989 for small refiners.

2. Aromatic Hydrocarbon Standard

Section 2282 of Title 13, CCR regulates the aromatic hydrocarbon content of vehicular diesel fuel sold or supplied in California. The regulation was approved by the ARB about 15 years ago in 1988 originally as section 2256 and was implemented in 1993. The aromatic hydrocarbon content of vehicular diesel sold or supplied in California must not exceed 10 percent by volume for large refiners. Small refiners are allowed to meet a less stringent 20 percent limit on aromatic hydrocarbons. The regulation allows alternatives to the aromatic hydrogen concentration if a refiner can demonstrate that the alternative formulation provides emission reductions equivalent to that obtained with specified 10- or 20-percent aromatic reference fuels, as determined through a series of engine emission tests. In 1990, the ARB adopted amendments to the aromatic hydrocarbon fuel regulation to provide more reasonable safeguards that an inferior performing alternative fuel would not be certified as equivalent to a 10- or 20-percent aromatic diesel fuel.

Most refiners have taken advantage of the regulation's flexibility to produce alternative diesel formulations. The ARB has certified a total of 25 alternative formulations. Five have been authorized for full public disclosure. Under the provisions for alternative formulations, the ARB has certified CARB diesel fuel for use in California that typically has a lower sulfur content than 500 ppmw and a higher aromatic content than 10 percent. The average sulfur content of California diesel fuel sold in California has been about 140 ppmw (Table III-1). Excluding the small refiners' fuel production, the average has been about 120 ppmw. About 20 percent of the motor vehicle diesel fuel currently produced in California has a sulfur content of 15 ppmw or less.

Table VI-1: Requirements of Motor Vehicle Diesel Fuel Regulations

	EPA	CARB
1. Applicability	On-road	On-and Off-road
2. Specifications		
a) Maximum Sulfur Content[1] (ppm by weight)	500	500
b) Maximum Aromatic Hydrocarbon Content[2] (% by volume)		
– Independent and Large Refiners	35% or Cetane No. ≥40	10%
– Small Refiners		20%
3. Allows for Certification of Alternative Formulations	NO	YES[3]

≥ means "greater than or equal to"

[1] Required in South Coast Air Basin and Ventura County for large refiners since 1985, for small refiners since 1989.

[2] Averaging of aromatic hydrocarbon content allowed over a period of 90 days.

[3] Requires demonstration of equivalency to the appropriate 10% or 20% aromatic reference fuel.

3. Diesel Engine Certification Fuel Quality Standards

In 1994, the Board adopted regulations pertaining to the composition of diesel fuel used in the certification of diesel engines to ensure that the certification fuel represents California commercial diesel fuel. In order to ensure repeatable and reliable engine test results, the fuel was set to more narrow specifications than commercial fuel. The current regulation specifies an allowable range of sulfur content from 100 ppmw to 500 ppmw and limits or allowable ranges for other fuel properties as indicated in Table VI-2. Manufacturers may also certify diesel engines using certification fuel meeting the federally established certification fuel specifications. In addition, manufacturers have the option to use an alternative certification test fuel provided they can demonstrate that this test fuel will be the predominant in-use fuel.

Table VI-2: Current Diesel Certification Fuel Specifications

Fuel Property	Units	Fuel Specifications
Cetane Number		47-55
Cetane Index		
Distillation Range IBP	^oF	340-420
10% point	^oF	400-490
50% point	^oF	470-560
90% point	^oF	550-610
EP	^oF	580-660
API Gravity	-	33-39
Total Sulfur	% (wt.)	0.01-0.05
Nitrogen Content (maximum)	ppmw	100-500
Hydrocarbon Composition Total Aromatics	% (vol.)	8-12
Polycyclic Aromatic Hydrocarbons (maximum)	% (wt.)	1.4
Flash Point (minimum)	^oF	130
Viscocity @ 40^oF	centistokes	2.0-4.1

B. Federal Fuel Regulations

Current federal U.S.EPA regulations establish fuel registration and formulation requirements.

1. Registration of Fuels and Fuel Additives

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

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

2. *Federal Diesel Fuel Quality Standards*

a) *On-Road Diesel Fuel*

The current U.S. EPA diesel fuel standards have been applicable since 1993. The U.S. EPA regulation – 40 CFR §80.29 – prohibits the sale or supply of diesel fuel for use in on-road motor vehicles, unless the diesel fuel has a sulfur content no greater than 500 ppmw. In addition, the regulation requires on-road motor-vehicle diesel fuel to have a cetane index of at least 40 or have an aromatic hydrocarbon content of no greater than 35 percent by volume (vol. %). All on-road motor-vehicle diesel fuel sold or supplied in the United States, except in Alaska, must comply with these requirements. Diesel fuel, not intended for on-road motor-vehicle use, must contain dye solvent red 164.

On January 18, 2001,[25] the U.S. EPA published a final rule which specifies that, beginning June 1, 2006, refiners must begin producing highway diesel fuel that meets a maximum sulfur standard of 15 ppmw. All 2007 and later model year diesel-fueled vehicles must be fueled with this new low sulfur diesel. The requirements are contained in 40 CFR §§80,500 et seq.

The U.S. EPA's regulations contain temporary compliance options and flexibility provisions not offered in the ARB's proposed amendments. The EPA's temporary compliance option including an averaging, banking and trading component, begins in June 2006 and lasts through 2009, with credit given for early compliance before June 2006. Under this temporary compliance option, up to 20 percent of highway diesel fuel may continue to be produced at the existing 500 ppmw sulfur maximum standard. Highway diesel fuel marketed as complying with the 500-ppmw sulfur standard must be segregated from 15-ppmw fuel in the distribution system, and may only be used in pre-2007 model year heavy-duty vehicles.

The U.S. EPA's regulations also provide additional hardship provisions that the EPA believes will minimize the economic burden of the small refiners in complying with the 15-ppmw sulfur standard. These provisions include the following:

500 ppm Option
A small refiner may continue to produce and sell diesel fuel meeting the current 500-ppmw sulfur standard for four additional years, until May 31, 2010, provided that it reasonably ensures the existence of sufficient volumes of 15-ppmw fuel in the marketing area(s) that it serves.

Small Refiner Credit Option
A small refiner that chooses to produce 15 ppmw fuel prior to June 1, 2010 may generate and sell credits under the broader temporary compliance option. Since a small refiner has no requirement to produce 15 ppmw fuel under this option, any fuel it produces at or below 15-ppmw sulfur will qualify for generating credits.

Diesel/Gasoline Compliance Option
For small refiners that are also subject to the Tier 2/Gasoline sulfur program (40 CFR part 80, subpart H), the refiner may choose to extend by three years the duration of its applicable interim gasoline standards, provided that it also produces all its highway diesel fuel at 15-ppmw sulfur beginning June 1, 2006.

Geographic Phase-in Area (GPA) Provisions
The EPA is providing additional flexibility to refiners subject to the Geographic Phase-in Area (GPA) provisions of the Tier 2 gasoline sulfur program. The additional provisions will allow refiners the option of staggering their gasoline and diesel investments.

General Hardship Provisions
Under the general hardship provisions, any refiner may apply on a case-by-case basis under certain conditions. These hardship provisions, coupled with the temporary compliance option, will provide a "safety valve" allowing up to 25 percent of highway diesel fuel produced to remain at 500 ppmw for these transitional years to minimize any potential for highway diesel fuel supply problems.

b) Nonroad Diesel Fuel

On May 23, 2003, the U.S. EPA published a proposed rulemaking for the control of emissions from nonroad diesel engines and fuel.[26] The U.S. EPA is proposing that sulfur levels for nonroad diesel fuel be reduced from current uncontrolled levels ultimately to 15 ppmw, though they are proposing an interim cap of 500 ppmw. Beginning June 1, 2007, refiners would be required to produce nonroad, locomotive, and marine diesel fuel that meets a maximum sulfur level of 500 ppmw. This does not include diesel fuel for stationary sources. Beginning June 1, 2010, the proposed maximum sulfur level would be 15 ppmw for fuel used for nonroad diesel applications (excluding locomotive and marine engines) since all 2011 and later model year nonroad diesel fueled engines are expected to be equipped with aftertreatment systems to meet the new standards and will require this low sulfur fuel. The U.S. EPA is also asking for comments on reducing sulfur levels for locomotive and marine fuel to 15 ppmw in 2010.

C. SCAQMD Fuel Regulation – Rule 431.2

Health and Safety Code Section 40447.6 authorizes the South Coast AQMD to adopt regulations that specify the composition of diesel fuel manufactured for sale in the District, subject to ARB approval.

In September 2000, SCAQMD amended Rule 431.2 to define low sulfur diesel fuel as having a sulfur content no higher than 15 ppmw. This is applicable to fuel for stationary engines on or after June 1, 2004. In addition, on or after January 1, 2005, the amended regulation will prohibit refiners and importers from selling diesel fuel for use in the District that exceeds the new low sulfur diesel standard of 15 ppm by weight. The rule also allows for extension of the effective date to match a later compliance date adopted by the California Air Resources Board, but no later than June 1, 2006, applicable to refiners and importers in the South Coast District. The adopted amendments apply to diesel fuel produced for both stationary and mobile sources, including RECLAIM sources but excluding ships and locomotives.

VII. PM RISK REDUCTION ACTIVITIES

This chapter describes state and local activities to reduce the adverse impacts of diesel PM emissions. It includes descriptions of measures that identify the risk associated with diesel fuel use and provide recommendations for control. The chapter also includes descriptions of regulations that will require the use of low sulfur diesel fuel to be effective in reducing diesel PM emissions, exposure, and risk.

A. State Activities

1. Identification of Diesel Exhaust as a Toxic Air Contaminant

In 1998, the ARB identified particulate matter from diesel-fueled engines as a toxic air contaminant.[27] Section 39655 of California's Health and Safety Code defines a toxic air contaminant as an air pollutant which may cause or contribute to an increase in mortality or an increase in serious illness, or which may pose a present or potential hazard to human health. Further, Assembly Bill (AB) 2728 (Tanner, 1992; Health and Safety Code Section 39656) requires all federally listed hazardous air pollutants to be defined by the ARB as toxic air contaminants. The TAC designation was based on research studies which showed that exposures to diesel PM resulted in an increased risk of cancer and an increase in chronic non-cancer health effects including a greater incidence of coughing, labored breathing, chest tightness, wheezing, and bronchitis.

Once the Board approved the identification of diesel PM as a TAC, it directed staff to begin the risk management process. The Board directed staff to form a diesel risk-management working-group to advise staff during its development of a risk management guidance document and a risk reduction plan.

2. ARB's Risk Reduction Plan

In September 2000 the ARB approved a Diesel Risk Reduction Plan developed by its staff following an extensive public process.[28] The staff's proposed plan contained the following three components:

- New regulatory standards for all new on-road, off-road, and stationary diesel-fueled engines and vehicles to reduce diesel PM emissions by about 90 percent overall from current levels;
- New retrofit requirements for existing on-road, off-road, and stationary diesel-fueled engines and vehicles where determined to be technically feasible and cost-effective; and
- New diesel fuel regulations to reduce the sulfur content levels of diesel fuel to no more than 15 ppmw to provide the quality of diesel fuel needed by the advanced diesel PM emission controls.

With the Board's approval of the risk reduction plan, staff can now develop the specific statewide regulations proposed in the plan. The goal of each regulation will be to make diesel engines as clean as possible by establishing state-of-the-art technology.

The diesel Risk Reduction Plan is not in itself a regulatory action, but a blueprint for future action. The proposed measures comprise a comprehensive program to be implemented over the next decade in California to control emissions and reduce risk from exposure to diesel PM over the complete lifetime of diesel-fueled engines. The measures recommended in the risk reduction plan will also reduce the localized risks associated with activities that expose nearby individuals to diesel PM emissions.

ARB staff estimates that full implementation of the recommended measures, including retrofit of locomotives and commercial marine vessels, will result in an overall 85 percent reduction in the diesel PM inventory and the associated potential cancer risk by 2020 compared to today's diesel PM inventory and risk. These reductions will occur through the combined actions of both California and the U.S. EPA to adopt and implement rules that reduce diesel PM.

Many of the proposed measures will also control and reduce emissions of NOx and other criteria and toxic air pollutants from compression-ignition engines. During the actual rulemaking process for each recommended measure the cost-effectiveness and technological feasibility of each recommended measure will be fully assessed. Each recommended measure will be developed, through a public process, with full opportunity for stakeholders to participate before a rule is finalized.

Appendix III of the RRP report also provides expected emission reductions, and expected cost for implementation of the proposed measures. Non-regulatory strategies such as retrofit programs for locomotives and marine vessels are also discussed.

3. Public Transit Fleet

In February of 2000, the ARB approved a Fleet Rule for Urban Transit Bus Operators (13 CCR section 1956.2) that was intended to reduce emissions of both ozone precursors (NOx and NMHC) and toxic air contaminants (diesel PM). Transit agencies and leasing companies must participate in a program to retrofit diesel buses in their fleets, and to operate their diesel buses on very low-sulfur diesel fuel. Beginning July 1, 2002, medium and larger transit agencies and companies that lease buses to these transit agencies must use diesel fuel with a sulfur content no greater than 15 ppmw in all diesel buses.

This program is meant to encourage the use of clean alternative fuels and high-efficiency diesel emission control technologies. It includes requirements for zero-emissions buses, fleet average NO_X levels, and retrofits for PM control, as well as model year 2007 NO_X and PM standards levels of 0.2 and 0.01 g/bhp-hr, respectively (equal to the levels finalized in this rule). It also requires that all diesel fuel used by transit agencies after July 1, 2002 must meet a cap of 15-ppmw sulfur.

4. Portable Engines

Pursuant to State law, the ARB has established the Portable Equipment Registration Program (PERP) which is a voluntary program for the registration and regulation of portable engines and associated equipment. Portable engines registered under ARB's Statewide Portable Equipment

Registration Program are also required to use CARB diesel (13 CCR 2456(e)(2)). Several Districts have implemented similar registration programs. Portable equipment not registered through the ARB or a local district may be subject to District stationary source permit requirements depending on the size of the engine. In addition, the U.S. EPA and ARB have established engine certification standards for new off-road engines of which portable engines are a subset.

The ARB staff is investigating the development of regulations to reduce diesel particulate emissions from portable diesel-fueled equipment. The staff is proposing to develop an air toxic control measure for portable equipment that is subject to local air districts' permitting programs. In addition, staff is proposing to develop amendments to the Portable Equipment Registration Program regulation to include diesel particulate air toxic control measures and to clarify specific provisions in the regulation. The staff expects to present the regulations to the Board at the end of 2003.[29]

5. Airborne Toxic Control Measures (ATCM)

An ATCM restricting school bus idling has already been adopted and should become effective later this year. Several proposed ATCMs for diesel engines are in development.[30] They include the following:

- Proposed ATCM for New and In-Use Stationary Compression Ignition Engines Greater Than 50 Horsepower
- Proposed ATCM for New and In-Use Stationary Compression Ignition Engines Less Than or Equal to 50 Horsepower
- Draft Transport Refrigeration Unit ATCM

Staff is working on several other diesel-PM control-measure proposals to bring before the Board in 2003 and 2004. These activities are directed towards:

- Garbage trucks
- Fuel delivery trucks
- On-road public fleets
- Off-road public fleets
- Truck idling
- M17 Measures to obtain additional emission reductions from on-road heavy-duty vehicles
- Adoption of proposed federal off-road Tier 4 standards for new off-road engines

B. Local Activities

1. Stationary Engines

Stationary engines are not required by state regulations to use fuel that meets CARB diesel formulation requirements, but most use complying fuel because of California's single fuel distribution network. Also, under state law, local air pollution control and air quality management districts (Districts) have the authority to establish formulation requirements for fuels to be used in stationary engines. To date, several districts have established best available control technology requirements for diesel-fueled engines that specify the use of CARB diesel.

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

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

The South Coast Air Quality Management District's Rule 431.2 specifies the sulfur content of diesel and other liquid fuels to be used for any stationary source application in the District. Currently, the sulfur content cannot exceed 500 ppmw. The District has adopted an amendment to the rule, which will change the sulfur limit to 15 ppmw for stationary-engine use, beginning June 1, 2004, and for other applications, no later than June 1, 2006.

2. South Coast AQMD: Clean On-Road Vehicles for Captive Fleets

Under California Health & Safety Code section 40447.5 the SCAQMD is given the authority to require public and private fleet operators with 15 or more vehicles to purchase clean-fueled vehicles at the time the operators are purchasing or replacing vehicles in their fleets. Under that authority, the SCAQMD is implementing several rules [Rule 1190 series] to reduce diesel PM in the South Coast Air Basin. These rules are summarized in Appendix III of the ARB's Risk Reduction Plan.[3]

VIII. PROPOSED AMENDMENTS TO SULFUR STANDARD FOR CALIFORNIA DIESEL FUEL

This chapter describes the staff's proposed amendments to Title 13, CCR, section 2281, "Sulfur Content of Diesel Fuel." The proposed amendments to the regulatory standard for sulfur would reduce the sulfur content of commercial motor vehicle fuel.

The text of the proposed amendments is presented in Appendix A.

A. Background

The statewide sulfur limits in Title 13, CCR, section 2281, "Sulfur Content of Diesel Fuel," were approved by the Board in 1988, originally as section 2255, and were implemented in October 1993. Section 2281 limited the sulfur content of motor vehicle fuel for use in California to 500 ppmw. The purpose of the sulfur standard is to reduce sulfur dioxide (SO_2) emissions and directly emitted sulfate which affect ambient concentrations of SO_2 and sulfate and contribute to ambient levels of fine particulate matter.

Almost all motor vehicle diesel fuel sold in California today is produced under the alternative diesel formulation provision to comply with the aromatic hydrocarbon standard (section 2282) of the California diesel fuel regulations. Under this provision, the ARB has certified diesel fuel for use in California that typically has a lower sulfur content than 500 ppmw and a higher maximum aromatics content than 10 percent. The average sulfur content of California diesel is estimated to be about 140 ppmw (see Table III-1).

About 90 percent of the diesel fuel sold or supplied in California meets the "CARB Diesel" requirements for sulfur and aromatic hydrocarbons prescribed by the California diesel fuel regulations. Only stationary sources, marine vessels and locomotives are currently exempt from the CARB diesel requirements.

B. Proposed Amendment to Reduce the Sulfur Limit for California Diesel

Staff is proposing that the specification for the maximum sulfur content of motor vehicle diesel fuel be reduced from 500 ppm by weight to 15 ppm by weight. This fuel sulfur requirement will apply to both on-road and-off-road vehicle use. The 15-ppmw sulfur limit will apply to all diesel supplied from production and import facilities starting June 1, 2006. The limit would apply 45 days later – starting July 15, 2006 – to all downstream facilities except bulk plants, retail outlets, and bulk purchaser-consumer facilities. After another 45 days – starting September 1, 2006 – the 15-ppmw sulfur limit will apply throughout the distribution system. This proposed amendment does not affect the aromatic hydrocarbon standard.

C. Rationale for Proposed Reduction of the Sulfur Limit for California Diesel

The amendment to the sulfur limit for California vehicular diesel fuel is being proposed because it is needed to enable the effective performance of sulfur-sensitive exhaust gas treatment technologies. However, the lower sulfur content can also have a direct effect by decreasing direct sulfate PM and other sulfur derived emissions.

1. Enabling Diesel Exhaust Aftertreatment Systems

The proposed 15-ppmw limit for the sulfur content of diesel fuel is needed for two primary reasons: to enable the effective use of the emissions control technology that will be required by heavy-duty diesel vehicles and engines that must meet the new PM and NOx emission standards adopted by the U.S EPA and ARB; and to enable the use of the exhaust gas treatment technologies that will be required by new and retrofitted diesel engines to meet the diesel PM reduction targets proposed in the diesel risk reduction plan. Current sulfur levels in diesel fuel will prevent effective operation of both the NOx and PM control technologies.

Heavy-Duty and Medium-Duty Diesel Emission Standards

In October 2001, the ARB approved amendments to section 1956.8, Title 13, California Code of Regulations and the incorporated "California Exhaust Emission Standards and Test Procedures for 1985 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles" to adopt requirements adopted by the U.S. EPA in their 2007 Rule. The emissions standards will apply to all medium duty diesel engines (MDDE) and heavy-duty diesel engines (HDDE) produced for sale in California in the 2007 and subsequent model years. Specific requirements include more stringent emission standards for NOx emissions at 0.2 grams per brake horsepower-hour, NMHC emissions at 0.14 grams per brake horsepower-hour, and PM emissions at 0.01 grams per brake horsepower-hour. These emission standards represent a 90% reduction of NOx emissions, 72% reduction of NMHC emissions, and 90% reduction of PM emissions compared to the 2004 emission standards.

The EPA and the ARB have identified catalyzed diesel particulate filter (CDPF) and NOx adsorber technologies as the most likely candidates to be used to meet the emissions standards. However, neither of these technologies will be effective enough on diesel engines and vehicles unless low sulfur diesel fuel is available. Both the PM and NOx technologies have the potential to make significant amounts of sulfate PM under operating conditions typical of heavy-duty vehicles. The U.S. EPA's position is that the sulfate PM formed in this manner will result in total PM emissions in excess of the total PM standard unless diesel fuel sulfur levels are at or below 15 ppmw.

Diesel Risk Reduction Plan

In September 2000 the ARB approved a diesel Risk Reduction Plan to reduce public exposure to diesel exhaust PM.[28] The measures recommended in the plan would require high efficiency diesel particulate filters for new stationary engines and retrofitting of on-road and off-road diesel engines with high efficiency diesel particulate filters. Low sulfur diesel is required to enable the effective use of these diesel particulate emission control systems.

Emissions Control Technologies

(a) Catalyzed Diesel Particulate Filters

Advanced CDPFs with precious metal catalysts are able to provide more than 90 percent control of diesel PM, provided they are operated on diesel fuel with sulfur levels at or below 15 ppmw. The CDPF works by mechanical filtration of solid and liquid PM from the exhaust through a ceramic or metallic filter and then oxidation of the stored PM (filter regeneration). The collected

PM, mostly elemental carbon particles, is oxidized to CO_2 which is released to the atmosphere. Catalyzed diesel particulate filters also reduce hydrocarbon emissions.

Current sulfur levels in diesel fuel can limit the effectiveness of the CDPFs in two ways: first, the catalyst is poisoned by the current sulfur levels thereby preventing proper regeneration of the CDPF; second, there is a loss of PM control effectiveness due to the high rate of SO_2 oxidation to SO_3 by the CDPF and the eventual formation of hydrated sulfuric acid or sulfate PM downstream of the filter.

(b) NOx Adsorbers

The U.S. EPA is projecting that NOx adsorbers will be the technology used to meet the NOx emissions standards.[31, 32] NOx adsorbers have been demonstrated to reduce NOx emissions by over 90%,[33] but this control efficiency is directly affected by the sulfur content of the diesel fuel. There still remains some engineering development to be done but the U.S. EPA expects significant development in the years before implementation of the new standards. The NOx adsorber technology has the potential to significantly lower hydrocarbon and carbon monoxide emissions from diesel exhaust. Because a NOx adsorber contains high levels of precious metals, it may also be effective in oxidizing the soluble organic fraction of diesel particulate matter.

The NOx adsorber technology requires the diesel engine to cycle between fuel lean and fuel rich conditions to reduce NOx emissions. The catalyst oxidizes nitric oxide (NO) in the exhaust to NO_2 and then stores it as inorganic nitrate on the surface of the catalyst or adsorber (storage) bed during the fuel lean conditions typical of diesel engine operation. Before the NOx adsorbent becomes fully saturated, engine operating conditions and fueling rates are adjusted to produce a fuel-rich exhaust. Under these rich conditions, the stored nitrate compounds are reduced to nitrogen over precious metal adsorber catalyst sites.

NOx adsorbers are extremely sensitive to to the sulfur content of the diesel fuel. Current sulfur levels in diesel fuel can limit the effectiveness of NOx adsorbers by poisoning the NOx storage bed and by increasing sulfate PM emissions. NOx adsorbers are very effective at oxidizing SO_2 and storing it in the adsorber bed as sulfate. This deactivates the catalyst and makes it less efficient over time for storing NOx. Further, the sulfate compounds are more stable than nitrate compounds on the catalyst, making the sulfate compounds more difficult to remove during regeneration of the catalyst. Improved NOx adsorber desulfurization systems, active catalyst layers that are more sulfur-resistant, and other methods are under development to maintain the NOx adsorber's high efficiency for the useful life of the engine.[34,35]

2. Reduction of Emissions of Sulfur Compounds

Nearly all of the sulfur in diesel fuel reacts with oxygen during combustion to form SO_2 which can react with oxidizing agents and water vapor to form hydrated sulfuric acid (H_2SO_4) or sulfate aerosols. Typically 1 percent to 3 percent of the fuel sulfur is converted to sulfate through the diesel combustion process.[36] Reducing the sulfur content of diesel fuel will reduce emissions of sulfur dioxide and particulate sulfate thus lowering the overall mass of PM emitted from diesel engines.

Once the low sulfur diesel fuel requirements become effective, pre-2007 model year heavy-duty engines will be using low sulfur fuel, as will engines using new PM control technology. Because these pre-2007 engines will have been certified with a higher sulfur fuel, they will achieve reductions in PM beyond their certification levels. A U.S. EPA on-road emission model predicts that reducing the sulfur content of diesel fuel from the current statewide average of 140 ppmw to 15 ppmw would reduce diesel PM emissions by about 4 percent from engines with FTP-cycle specific emissions rates of 0.1 grams per brake horsepower-hour.

D. Alternatives

Staff considered the following alternatives to the proposed amendment:

- Do not amend the current regulation
- Adopt a more stringent standard.

Do not amend the current regulation: The current sulfur standard would not be acceptable. The sulfur content permitted by the current regulation would reduce the efficiency of exhaust after-treatment systems that are essential to meet the PM and NOx emissions standards adopted by the U.S. EPA and ARB for 2007 and subsequent model year heavy-duty diesel engines. Also, the sulfur contents would be too high for the effective performance of the PM control technologies for new and retrofitted engines that will have to meet the PM reduction targets proposed in the risk reduction plan.

If the ARB did not amend the current regulation, the sulfur content of diesel in California would be limited by the requirements of the U.S. EPA's 2007 Final Rule and the SCAQMD's Rule 431.2. The SCAQMD's 15-ppmw sulfur limit applies to diesel used in on-road, off-road, and stationary engines, but the federal 15-ppmw sulfur limit applies only to on-road diesel fuel use. These two regulations could ensure that low sulfur diesel is available for on-road use regardless of California action. However, the SCAQMD rule is not sufficient to ensure the statewide availability of low-sulfur diesel needed for effective implementation of the proposed control measures to reduce diesel PM emissions.

Low sulfur diesel is a critical component of the diesel Risk Reduction Plan which recommends measures for diesel-fueled off-road engines and stationary engines that include retrofitting of older engines with exhaust treatment technologies as well as stringent diesel PM emission standards for new engines that would require exhaust treatment technologies. Without low sulfur diesel available for use in off-road and stationary engines, the exhaust treatment systems could not be effective. Emissions reductions from off-road and stationary engines are also needed to meet the commitment in the State Implementation Plans for ozone and PM_{10} and to make further progress towards attainment of both the State and federal ambient air quality standards.

Adopt a more stringent requirement: A lower sulfur limit is not necessary as the emissions reductions required by the new heavy-duty diesel engines emission standards for PM can be achieved with diesel sulfur levels up to 15 ppmw. The proposed limit for sulfur is also low enough to enable the use of NOx adsorbers – the most advanced emissions control technologies available for reducing NOx emissions. This technology is extremely sensitive to sulfur and there still remains engineering development to be done, but the EPA expects significant development before the implementation of the new NOx standards. We also expect that commercial fuel produced to comply with the proposed limit would have sulfur contents in the range of 5 to 10 ppmw. The additional investments and operating costs for additional processing required to reduce the fuel sulfur content even further cannot be justified at this time in light of the small additional air quality benefit of a lower sulfur fuel. Therefore, staff is not recommending a lower sulfur limit than that adopted by the U.S. EPA and the SCAQMD.

IX. PROPOSED AMENDMENTS TO THE DIESEL ENGINE CERTIFICATION FUEL REGULATION

This chapter describes the staff's proposal for amendments to the following sections of CCR Title 13 and incorporated test procedures. These amendments would revise the sulfur specification for diesel engine certification fuel to make it consistent with the proposed amendment to the sulfur specification for commercial diesel fuel.

- Section 1956.8(b) and the incorporated test procedures for determining compliance with the standards as set forth in the "California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Diesel Engines."
- Sections 1961(d) and 1962 and the incorporated test procedures for determining compliance with the standards as set forth in the "California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles."

The text of the proposed amendments is presented in Appendix A and the test procedures are given in Appendix B.

A. Background

Certification fuel is used to test motor vehicles to determine whether or not the vehicles comply with emission standards established by the ARB. The current specifications for California diesel engine certification fuel were approved by the ARB in 1994 and adopted in 1995. They represent the average composition expected for commercial diesel fuel if all diesel fuel produced in California met the 10 volume percent aromatic hydrocarbon limit. The current California diesel engine certification fuel specifications were presented earlier in Table VI-2. The regulation sets an allowable range of 100 to 500 ppm by weight for the sulfur content of the certification fuel. Manufacturers may also certify diesel engines using certification fuel meeting the federally established certification fuel specifications. In addition, manufacturers have the option to use an alternative certification test fuel provided they can demonstrate that this test fuel will be the predominant in-use fuel.

B. Proposed Amendment to the Diesel Engine Certification Fuel Sulfur Specification

Staff is proposing that the Board adopt a range of 7 to 15 ppm by weight for the allowable sulfur content of the optional California diesel engine certification fuel, for exhaust emissions testing, starting with the 2007 model year. As shown in Table IX-1, staff is proposing an allowable range for sulfur content that is the same as that promulgated by the U.S. EPA in its revised specifications for fuel for diesel engine exhaust emissions testing. The specifications for the remaining fuel properties shown in Table IX-1 would be unchanged from the values for current California diesel certification fuel

C. Rationale for Proposed Amendments to the Certification Fuel Specifications

The proposed change to the allowable sulfur content of certification fuel is necessary for consistency with the proposed amendment to lower the upper limit for the sulfur content of commercial California diesel to 15 ppm by weight starting June 2006. The proposed allowable range of 7 to 15 ppm by weight for sulfur in certification fuel will be more representative of the fuel that will be used in heavy-duty diesel engines to comply with the exhaust emission standards promulgated by the U.S. EPA in January 2001 and adopted by the ARB at a hearing in October 2001. Also, because exhaust emissions are affected by the properties of the fuel used during certification testing, a lower sulfur content in certification fuel is necessary to help manufacturers meet the more stringent exhaust emissions standards that will apply to 2007 and subsequent model-year diesel engines. The lower sulfur level in diesel fuel is needed for effective operation of both the NOx and PM aftertreatment technologies that manufacturers are expected to use to help them meet the standards.

D. Alternatives

A higher maximum sulfur content was not considered an acceptable alternative as this would not be typical of in-use fuels subject to the 15-ppmw sulfur limit that is being proposed in this rulemaking. Also, a higher sulfur limit would not provide manufacturers a low enough sulfur content for effective performance of the aftertreatment technologies that are essential to meet the new PM and NOx emissions standards. Another alternative to the proposed amendment would be a sulfur content range with a lower maximum than the 15-ppmw limit being proposed for certification diesel fuel. A lower sulfur limit is not necessary as the proposed allowable range for the certification fuel includes sulfur contents that would be typical of commercial diesel produced to comply with the 15-ppmw maximum allowed for in-use diesel. The U.S. EPA expects that refineries will typically produce diesel fuel with about 7 ppmw sulfur and that this fuel could have a slightly higher sulfur content after distribution.[37] Based on this, the U.S. EPA expects to use fuel having a sulfur content between 7 and 10 ppmw sulfur for their emission testing. The current range allows them to adjust the target sulfur content upward if in-use fuel is determined to have higher levels than expected.

Table IX-1: Specifications for Diesel Engine Certification Fuel for 2007 and Subsequent Model Year Vehicles

Fuel Property	Units	Federal Specifications		ARB Specifications
		D-1[a]	D-2	
Cetane Number		40-54	40-50	47-55
Cetane Index		40-54	40-50	
Distillation Range				
IBP	°F	330-390	340-400	340-420
10% point	°F	370-430	400-460	400-490
50% point	°F	410-480	470-540	470-560
90% point	°F	460-520	560-630	550-610
EP	°F	500-560	610-690	580-660
API Gravity	-	40-44	32-37	33-39
Total Sulfur	ppmw	7-15	7-15	7-15
Nitrogen Content (maximum)	ppmw	—	—	100-500
Hydrocarbon Composition				
Total Aromatics	% (vol.)	8[b]	27[b]	8-12
Polycyclic Aromatic Hydrocarbons (maximum)	% (wt.)	—	—	1.4
Flash Point (minimum)	°F	120	130	130
Viscocity @ 40°F	centistokes	2.0-4.1		2.0-4.1

[a] Type 1-D grade diesel is allowed only if the engine manufacturer demonstrates that this fuel will be the predominant in-use fuel.
[b] Minimum, the remainder shall be paraffins, naphtnenes, and olefins.

X. PROPOSED AMENDMENTS TO REGULATORY PROVISIONS ON CERTIFIED ALTERNATIVE DIESEL FUEL FORMULATIONS

This chapter describes proposed amendments to Title 13, CCR, subsection 2282(g), "Certified Diesel Fuel Formulations Resulting in Equivalent Emissions Reductions." The amendments are proposed to maintain consistency with the sulfur content requirements of section 2281, to further ensure that alternative-formulation diesel fuel sold in California results in emissions that are equivalent to the emissions achieved with diesel fuel that complies with the 10-percent aromatic hydrocarbon standard, and to eliminate an unneeded provision for sulfate credit.

A. Background

1. Section 2282

Title 13, CCR, section 2282, "Aromatic Hydrocarbon Content of Diesel Fuel" was approved by the ARB in 1988, originally as section 2256, and was implemented in 1993. Along with the certified alternative formulation option described below, section 2282 requires that the aromatic hydrocarbon content of vehicular diesel fuel sold, offered for sale or supplied in California not exceed 10 percent by volume, 20 percent for small-refiner fuel, or a designated alternative limit (DAL). A DAL blend of greater than 10 percent aromatic hydrocarbons must be offset by the producer or importer with an equal or greater volume of DAL blend less than 10 percent within 90 days before or after the start of transfer. The DAL of the offsetting blend must have sufficiently low aromatic hydrocarbons that the excess aromatics in the high-DAL blend are fully offset. Analogous requirements apply to small-refiner DAL blends, with the substitution of 20 percent for 10 percent. There is an annual limit on the volume of a small refiner's vehicular diesel fuel that is subject to the 20 percent aromatic hydrocarbon standard.

Many studies completed both before and since the adoption of section 2282 have shown the emission benefits of reducing the total aromatic hydrocarbon content of diesel fuel. Reducing the aromatic hydrocarbon content of diesel fuel reduces emissions from diesel engines, including NOx, particulate matter, CO, and hydrocarbons (HCs), as well as toxic compounds in both vapor and condensed phases.

As an alternative means of compliance with 10- or 20-percent aromatic fuel, subsection 2282(g) establishes procedures for certifying alternative emission-equivalent formulations of diesel fuel that have greater than 10- or 20-percent aromatic hydrocarbon content. Formulations that have been certified under 2282(g) as equivalent to 10-percent aromatic fuel generally have aromatic hydrocarbon contents of about 20 percent and cetane numbers above 50.

2. Subsection 2282(g)

Subsection 2282(g) prescribes the procedures for submitting, testing, evaluating, and specifying fuel formulations for ARB certification. "Candidate fuel" formulations are tested in a laboratory engine for emission equivalency against a defined "reference fuel."

a) Candidate Fuel Specifications

Subsection 2282(g)(2) requires candidate fuels to meet the specifications for No. 1 or No. 2 diesel fuel set forth in ASTM D975-81. The sulfur content, total aromatic hydrocarbon content, poly-cyclic aromatic hydrocarbon content, nitrogen content, and cetane number of each candidate fuel must be determined as the average of three tests conducted in accordance with referenced test methods. The sulfur content of a candidate fuel cannot exceed 500 ppmw. In addition, the identity and concentration of each additive must be determined.

b) Reference Fuel Specifications

Reference fuels must be produced from straight-run California diesel fuel by a hydrodearomatization process. General reference fuels have a maximum aromatic hydrocarbon content of 10 percent, and small-refiner reference fuels have a maximum aromatic hydrocarbon content of 20 percent. Other composition and property limitations also apply to reference fuels (see Table X-1).

Table X-1: Reference Fuel Specifications

Property	Unit	ASTM	Limit	General	Small Refiner
Sulfur Content	ppmw	D2622-94	maximum	500	500
Aromatic Hydrocarbon Content	vol. %	D5186-96	maximum	10	20
Poly-cyclic Aromatic Content	wt. %	D5186-96	maximum	1.4	4
Nitrogen Content	ppmw	D4629-96	maximum	10	90
Natural Cetane Number		D613-84	minimum	48	47
API Gravity		D287-82	min – max	33 – 39	33 – 39
Kinematic Viscosity at 40 °C	cSt	D445-83	min – max	2.0 – 4.1	2.0 – 4.1
Flash Point	°F	D93-80	minimum	130	130
Distillation Temperatures		D86-96			
Initial Boiling Point	°F		min – max	340 – 420	340 – 420
10 % Volume Recovered	°F		min – max	400 – 490	400 – 490
50 % Volume Recovered	°F		min – max	470 – 560	470 – 560
90 % Volume Recovered	°F		min – max	550 – 610	550 – 610
End Point	°F		min – max	580 – 660	580 – 660

c) Testing and Evaluation

Candidate fuel formulations must be shown to be equivalent or better than reference fuels for NOx, sulfate-corrected PM, and PM soluble organic fraction (SOF) emissions. Each fuel must be tested at least 20 times according to one of several specified test sequences. A statistical margin of safety and an allowable tolerance are included in the emission-equivalency determinations. The allowable tolerances are 2 percent, 4 percent, and 12 percent of the mean emissions with the reference fuel for NOx, sulfate-corrected PM, and SOF, respectively. The sulfate correction is a reduction, which is applied only to the candidate fuel's PM emissions. It is the lesser of the calculated specific secondary-sulfate emission difference between 500 ppmw and the actual sulfur content of the candidate fuel or the actual measured specific sulfate emissions with the candidate fuel.

d) Specifications for Certified Formulations

Alternative formulations are certified by Executive Orders issued by the Executive Officer of the ARB. The Executive Order must impose at a minimum the five property specifications shown in Table X-2. In addition, the Executive Order must specify the presence and concentration of all additives that were contained in the candidate fuel, except for an additive demonstrated by the applicant to have the sole effect of increasing cetane number.

Table X-2: Specifications for Certified Formulations

Property	Specification
Sulfur Content	Shall not exceed that of the candidate fuel
Total Aromatic Hydrocarbon Content	Shall not exceed that of the candidate fuel
Poly-cyclic Aromatic Hydrocarbon Content	Shall not exceed that of the candidate fuel
Nitrogen Content	Shall not exceed that of the candidate fuel
Cetane Number	Shall not be less than that of the candidate fuel

3. 2282(g)(9)(A) – Modification of Specifications for a Certified Formulation Based on Subsequent Emissions Testing

Based on additional emissions testing following the protocol in the regulations, the Executive Officer may determine that a commercially available diesel fuel blend meets all of the specifications of a certified diesel fuel formulation set forth in an Executive Order, but does not meet the emission criteria for a candidate fuel to be certified. In that case, the Executive Officer must modify the Executive Order as is necessary to assure that diesel fuel blends sold commercially pursuant to the certification will meet the emission criteria set forth in subsection 2282(g)(5). The modifications to the order may include additional specifications or conditions, or a provision making the order inapplicable to diesel fuel produced by the producer of the commercially available diesel fuel blend found not to meet the criteria.

B. Proposed Changes to Subsection 2282(g)

We are proposing four types of changes to subsection 2282(g): 1) for consistency with section 2281; 2) to ensure emission equivalency of fuels sold as a certified formulations to candidate fuels; 3) to ensure emission equivalency of candidate fuels to reference fuels; and, 4) to eliminate a provision for sulfate credit in determining equivalency of the candidate fuel.

1. Consistency With Section 2281

Since we are proposing under section 2281 that all California diesel fuel meet a 15-ppmw sulfur limitation, for consistency and to improve the effectiveness of subsection 2282(g) we are also proposing that all reference and candidate fuels meet the 15-ppmw sulfur limitation. The new limitation would be applied to reference and candidate fuels beginning August 1, 2004 instead of

June 1, 2006, when producers of California diesel fuel must meet the new sulfur limitation. Fuels produced under existing certified formulations will have to meet the 15-ppmw limit beginning June 1, 2006.

2. Emission Equivalency of In-Use Fuels to Candidate Fuels

To ensure emission equivalency of certified formulations produced for sale to the candidate fuels that had been tested in the laboratory, we are proposing that the reporting requirements for candidate fuel properties be expanded to include all the properties that must be reported for reference fuels. We are also proposing a requirement that the same property limitations and ranges apply to candidate fuels as currently apply to reference fuels, except for the five properties that are always designated in the Executive Order. Moreover, the API gravity, viscosity, flash point and distillation temperatures of the candidate fuel could not differ from the corresponding values of the reference fuel used in testing by more than half the range of reference fuel properties. For example, if the reference fuel used in testing has an API gravity of 34.1, the candidate fuel could not have an API gravity of less than 33.0, the bottom of the absolute property range, or greater than 37.1, the top of the relative property range. For new formulations when candidate fuel properties are outside applicable ranges, if the applicant agrees, additional specifications for those properties may be identified in the formulation by executive order. Otherwise, the formulation would not be certified. An additional requirement would be that if a candidate fuel property were outside of the reference fuel property range, then the reference fuel property value could not lie beyond the midpoint of the range away from the candidate fuel property. For example, if a candidate fuel were to have an API gravity of 40.1, then the API gravity of the reference fuel would have to be no less than 36.0 – the midpoint of the property range. These new requirements would be applied to all candidate and reference fuels for all formulations certified after July 31, 2004.

3. Emission Equivalency of Candidate Fuels to Reference Fuels

For a candidate fuel to qualify as an alternative formulation, the average emissions of NOx, PM, and SOF during testing with the candidate fuel each have to not exceed the average emissions of NOx, PM, and SOF, respectively, during testing with the reference fuel. A statistical margin of safety, based on the pooled standard deviation of the tests with the candidate and reference fuels, is specified for each pollutant. Tolerances are allowed for each pollutant to make sure that a truly emission-equivalent fuel will always pass. Based on the testing of the sixteen fuels that by now have all been qualified in the same laboratory, we have found that the standard deviations and calculated safety margins warrant that the tolerances be lowered. Therefore, we are proposing that the tolerances be lowered from 2, 4, and 12 percent to 1, 2, and 6 percent of the average emissions of NOx, PM, and SOF, respectively, during testing with the reference fuel.

4. Elimination of Sulfate Credit

In the interest of updating subsection 2282(g) to be applicable to fuels with the proposed future 15-ppmw sulfur content limitation, we are proposing that the two provisions for sulfate credit under subsection 2282(g)(5)(B) be eliminated. Effectively, the average PM emissions during testing with the candidate could not exceed the average PM emissions during testing with the reference fuel. In the case of a formulation tested under subsection 2282(g)(9)(A), the average

PM emissions during testing with the formulation produced for sale could not exceed the average PM emissions during testing with the reference fuel.

C. Rationale for Proposed Changes to Subsection 2282(g)

1. Consistency With Sulfur Standard in Section 2281

For consistency with the proposed amendments to section 2281, we are proposing that subsection 2282(g) be amended to require that both the candidate fuels and the reference fuels meet a sulfur limitation of 15 ppmw, effective for all fuels certified on or after August 1, 2004. Certification of new formulations based on the higher sulfur content currently allowed for reference fuels could result in higher PM emissions for future alternative formulation fuels. We are also proposing that the required sulfur content test method be changed to ASTM D5453-93 for improved precision. Fuel produced under the existing certified formulations will have to meet the 15-ppmw-sulfur limit when it becomes effective.

2. Ensuring Emission Equivalency of Candidate Fuels to In-Use Fuels

Studies have shown that emissions from diesel engines are affected by fuel properties other than the five properties that always must be covered by the specifications for a certified formulation.[38, 39] Emissions are especially influenced by fuel density (or API gravity), but also are influenced by backend volatility (or distillation temperature at 90 percent volume recovered, T90) and other properties. The effects of these and other properties on emissions do not change the applicability of subsection 2282(g) for certifying emission-equivalent California diesel fuel formulations. Candidate fuels produced by the same process that is, or would be, used to commercially produce the certified formulation for sale should not reduce the effectiveness of the certified formulation. The unspecified properties normally are expected to not vary greatly among fuels which are equivalent in the specified properties and which are produced the same way. However, if there are large differences in properties between a reference fuel and a candidate fuel and between the candidate fuel and the fuel produced under the certification, the emission equivalency of the fuel produced for sale is in doubt. Appendix F provides further discussion of the effect of diesel fuel properties on emissions from diesel engines.

To eliminate doubts about the emission equivalency between candidate fuels and fuels produced commercially for sale, we are proposing that subsection 2282(g)(2) be amended to require that candidate fuels meet the specifications for No. 2 as set forth in ASTM D975. This would prohibit the testing of a No. 1 diesel as the basis for the production of No. 2 diesel. The testing of No. 1 diesel as the basis of emission equivalency must be excluded, since No. 1 diesel has improved emission performance over No. 2 diesel, and certified-formulation diesel fuel is sold in California as No. 2 diesel fuel. We are further proposing, for candidate fuels, determination and reporting of all fuel properties specified in subsection 2282(g)(3) for reference fuels. A candidate fuel would be subject to the same specifications and ranges required of the reference fuel, except for properties (other than sulfur content) specified by executive order for the resultant certified formulation.

We are also proposing a requirement that candidate fuel properties be within half the allowable reference fuel property ranges of the actual reference fuel properties (Table X-3). A candidate fuel outside of an allowable property range or limit could still be allowed as the basis of a certified formulation, if the applicant agrees that the certified formulation include additional specifications based on the candidate fuel properties. This would prevent the applicant from changing other candidate fuel properties that could affect emissions unless the applicant is willing to accept that specifications for those properties be included in the certified formulation. An additional requirement would be that if a candidate fuel property were outside of its required absolute range, then the reference fuel property value could not lie beyond the midpoint of the range away from the candidate fuel property. This additional requirement would help to eliminate the production of reference fuels with properties at the far ends of the ranges and candidate fuels with properties outside of the ranges to qualify formulations that are not truly equivalent.

Table X-3: Proposed Candidate Fuel Requirements

Property	Unit	ASTM	Limit	Absolute	Relative*
Sulfur Content	ppmw	D5453-93	maximum	15	None
API Gravity		D287-82	min – max	33 – 39	R-3.0 – R+3.0
Kinematic Viscosity at 40 °C	cSt	D445-83	min – max	2.0 – 4.1	R-1.0 – R+1.0
Flash Point	°F	D93-80	minimum	130	None
Distillation Temperatures		D86-96			
Initial Boiling Point	°F		min – max	340 – 420	R-40 – R+40
10 % Volume Recovered	°F		min – max	400 – 490	R-45 – R+45
50 % Volume Recovered	°F		min – max	470 – 560	R-45 – R+45
90 % Volume Recovered	°F		min – max	550 – 610	R-30 – R+30
End Point	°F		min – max	580 – 660	R-40 – R+40

*Relative to reference fuel property value (R)

3. Ensuring Emission Equivalency of Candidate Fuels to Reference Fuels

To determine whether the average specific emissions $\bar{x}_C$ of NOx, PM, and SOF, during testing with the candidate fuel, do not exceed the average specific emissions $\bar{x}_R$ during testing with the reference fuel, an arithmetic criterion is applied the average emissions of each pollutant. The criterion that must be satisfied for each pollutant is

$$\bar{x}_C < \bar{x}_R + \delta - S_p \sqrt{\frac{2}{n}}\ t$$

where S_p is the pooled standard deviation of the emissions over the total number n of valid tests run for each fuel, and t is the value of the one-sided Student's t distribution for a=0.15 and $2n$-2 degrees of freedom (same as for the two-sided distribution with a=0.30). The total number of valid tests must always be the same for the candidate fuel as the reference fuel, so the pooled standard deviation is just the square root of the mean of the squares of the standard deviations for each fuel separately. The δ is a tolerance which is a percentage of $\bar{x}_R$ specific to each pollutant. The original objectives of the standard deviation and tolerance terms were to provide a margin of safety in determining equivalency, while assuring that a fuel tested against itself would be able to satisfy the equivalency criteria. The tolerances were established by estimating the value of the standard deviation term based on data from previous emission test programs.

To determine whether the tolerances allowed by the existing regulation are still appropriate, we looked at the test programs for sixteen large-refiner certified formulations. The sixteen were chosen because all of the test programs were run in the same laboratory. The total number of valid tests run on candidate fuels and on reference fuels was 335 each. We calculated $\bar{x}_R$ for each pollutant over the 335 tests with the reference fuels, and we calculated the pooled standard deviations of specific emissions for each pollutant from the 670 individual tests. Then, we set n=20, since 20 is the minimum number of tests required and requires the greatest margin of safety, and we calculated the standard deviation term as a percentage of $\bar{x}_R$ for each pollutant. Table X-4 shows the results of $\bar{x}_R$, S_p, and the relative safety margins calculated for each pollutant with t=1.05077. Table X-5 shows the tolerances allowed now and the proposed new tolerances, as percentages of $\bar{x}_R$. Based on the newly calculated safety margins, we are proposing that the allowable tolerances be reduced by one half to 1, 2, and 6 percent for NOx, PM, and SOF emissions, respectively. By reducing the allowable tolerances, we will preserve almost all of the benefits of the 10-percent aromatic standard, making the regulation more effective. The new tolerances will apply to all future testing of existing certified formulations under subsection 2282(g)(9)(A), and future candidate fuel formulations.

Table X-4: Average Emissions, Pooled Standard Deviations, and Relative Safety Margins

Pollutant	$\bar{x}_R$ (g/hp-hr)	S_p (g/hp-hr)	$S_p(2/n)^{1/2}t$ / $\bar{x}_R$
NOx	4.101	0.0553	0.45 %
PM	0.1749	0.0062	1.2 %
Sulfate-Corrected PM	0.1749*	0.0062	1.2 %
SOF	0.0370	0.0058	5.2 %

*The sulfate correction is not applied to the emissions with the reference fuels.

Table X-5: Current Tolerances and Proposed Tolerances

Pollutant	**Current Tolerance**	**Proposed Tolerance**
NOx	2 %	1 %
PM	Inapplicable	2 %
Sulfate-Corrected PM	4 %	See Section B.4
SOF	12 %	6 %

4. Eliminate Sulfate Credit in Determining Equivalency of the Candidate Fuel.

Title 13, CCR, section 2282(g)(5)(B) currently allows a sulfate credit for the candidate fuel when calculating PM emissions. The sulfate credit was provided to encourage reducing sulfur in diesel fuel, since fuel-originated secondary sulfates in the environment would significantly outweigh the sulfate portion in the primary PM emissions. Because ARB staff did not want to provide unlimited credit, the sulfate credit was capped at the primary sulfate level. A comparable sulfur credit is not given to the reference fuel. What actually happened was the opposite of the intent, and candidate fuels with high sulfur contents received more credit due to their higher actual sulfate emissions. In most cases, it was as easy to pass a high sulfur formulation as a low sulfur formulation.

The staff proposes that the sulfate credit be eliminated, because the proposed sulfur level of 15 ppmw reduces the allowable sulfate credit for future applicants to almost nothing. Almost all past applicants of certified diesel fuel formulations have received the actual candidate fuel sulfate emissions as a reduction to the candidate fuel PM emissions. Most successful formulations have not needed the credit to pass equivalency for PM emissions.

D. Alternatives Considered

1. Consistency With Section 2281

The only practical alternative to amending the certification procedure to be consistent with section 2281 would be to maintain those aspects of section 2282 which are inconsistent with the proposed amendments to 2281. Preserving the 500-ppmw sulfur content limitation for the reference fuel would allow a higher PM-emitting fuel to be used as the reference for equivalency testing. Staff recommends against allowing a higher-emitting fuel to be used as a reference than commercially produced fuel, which would comply with the 15-ppmw sulfur and 10-percent aromatic standards. Furthermore, the best way to assure that certified formulations in use are equivalent to the fuels tested in the laboratory is to require that the candidate fuels be as much as possible like fuel produced for sale. This means that the candidate fuels should be required to meet the 15-ppmw-sulfur limit. There would be no advantage to a fuel producer to test a candidate fuel with a higher sulfur content, since it would be more difficult to qualify the fuel for PM emission equivalency.

2. Emission Equivalency to Candidate Fuels

The alternatives to the proposed amendments to ensure emission equivalency would be to adopt no changes or to require that the values of all fuel properties be specified for certified formulations as equal or better than the candidate fuel property values. We are proposing a middle ground, which we believe will eliminate most of the uncertainty with regard to the emission performance of formulations produced for market.

If no changes are made, then it is possible that a fuel with some properties significantly different than the formulation that would be commercially produced could be tested as the basis of the formulation. Since it is known that other properties such as density can affect emissions, there would be no way to know whether the proposed alternative formulation would be protective of the benefits of the aromatic hydrocarbon content regulation.

We have found that, on average, the properties of California diesel fuel are similar to what was expected when the California diesel fuel regulations were originally adopted. Requiring that many more properties be specified for all certified formulations would significantly reduce producer flexibility and could impact the supply and availability of diesel fuel for California consumers. In cases where not all of the candidate fuel properties are known for existing formulations, either the formulations would have to be decertified or fuel property values would have to be assigned. The staff recommends against retroactive application of these proposed new amendments, since the regulation still provides the option under subsection 2282(g)(9)(A) to make a determination of emission equivalency on a commercially available diesel fuel blend.

3. Emission Equivalency to Reference Fuels

The alternatives to the proposed new tolerances would be to maintain the existing tolerances, lower the tolerances even more than proposed, or eliminate the tolerances and safety margin.

We think that our proposal is a good compromise in that it provides further assurance that the benefits of the 10 percent aromatic fuel will be maintained, while assuring that a truly equivalent would have a high probability of being certified. Since the test-to-test variation is less than what was expected when the regulations were amended in 1990, the tolerances do not need to be as large. Maintaining the existing tolerances could reduce emission benefits by allowing candidate fuels to pass even though they were not as close to being emission-equivalent as practicable.

Reducing the tolerances beyond the proposed levels would make it difficult to certify a truly equivalent fuel, therefore defeating the intention of a procedure for certifying equivalent alternative formulations of California diesel fuel.

Another alternative would be to apply the proposed new tolerances retroactively to previous test programs, which have qualified existing formulations. The staff recommends against the application of the proposed new tolerances retroactively. However, the staff reserves the option of applying the proposed new tolerances to future testing of commercially available diesel fuel blends for the purpose of making a determination under subsection 2282(g)(9)(A).

4. Elimination of Sulfate Credit

The alternatives to eliminating the sulfate credit would be to maintain the provision for sulfate credit or amend the provision to be consistent with section 2281. Since the provision was not needed for successful equivalency determination of most of the existing formulations – and either maintained or amended, it should be even less useful in the future – we think that it would be best to delete the provision. In the future, either alternative will essentially become useless, since we have proposed that all formulations of California diesel fuel meet a 15-ppmw sulfur limit and that all reference and candidate fuels meet the 15-ppmw limit. Whether for testing of formulations produced for sale or for testing of candidate fuels to qualify a formulation, the sulfate credit will diminish to negligibility. Therefore, in the interest of cleaning up the regulation, we recommend that the proposal to eliminate the sulfate credit provision be adopted.

XI. PROPOSED NEW FUEL SPECIFICATIONS FOR EQUIVALENCY TO THE AROMATIC HYDROCARBON LIMIT

This chapter describes proposed alternative equivalent property limits to the 10-percent aromatic hydrocarbon limit of California diesel fuel. We are proposing the alternative equivalent limits to provide additional flexibility for refiners and to make it easier to market diesel fuel in California. A means of compliance other than by 10-percent aromatic content or by certified formulation would be available to fuel producers or importers for marketing diesel fuel in California.

A. Background

1. Section 2282

Title 13, CCR, section 2282, "Aromatic Hydrocarbon Content of Diesel Fuel," requires specifically that the aromatic hydrocarbon content of vehicular diesel fuel sold, offered for sale or supplied in California not exceed 10 percent by volume (20 percent for small-refiner fuel) or a designated alternative limit (DAL). A DAL blend of greater than the aromatic limit must be offset by the producer or importer with an equal or greater volume of DAL blend less than the aromatic limit within 90 days before or after the start of transfer. Small-refiner specification production volumes of California diesel fuel are limited by the regulation or by Executive Orders. The actual small refiner production is less than 5 percent of the statewide California diesel fuel production at this time.

2. Subsection 2282(g)

As an alternative means of compliance with the 10-percent aromatic requirement, subsection 2282(g) provides procedures for certifying alternative emission-equivalent formulations of diesel fuel that have greater than 10-percent aromatic hydrocarbon content. The same procedures with different reference fuel properties are provided for certifying small-refiner fuels that have greater than 20-percent aromatic hydrocarbon content. Formulations certified under 2282(g) as equivalent to 10-percent aromatic fuel generally have aromatic hydrocarbon contents of about 20 percent and cetane numbers above 50.

3. Average Properties of Certified Formulations

Table XI-1 presents the fuel properties of the candidate fuels for five certified formulations along with the averages of properties for the five candidate fuels. The companies that qualified the five formulations shown in the table have allowed their disclosure. Also shown in the table are averages of properties for the candidate fuels of eleven other 10-percent-aromatic equivalent formulations, and for all sixteen candidate fuels together. The other individual formulations cannot be disclosed because the companies that qualified them have requested that the formulations be kept confidential.

Table XI-2 presents average California diesel fuel properties from actual field samples. The Alliance of Automobile Manufacturers (AAM) averages are taken from EPA's "Staff Discussion Document," *Strategies and Issues in Correlating Diesel Fuel Properties with Emissions*[38], and cover years 1995 through 2000 for the Los Angeles area. The British Petroleum (BP) averages are from three Emission Control Diesel (EC-D) test programs conducted by ARCO Products Company (now BP), each of which used three-fuel blends of major oil company fuels from the Los Angeles area between 1998 and 2001. The ARB averages are from enforcement samples taken statewide from July 1999 to March 2002, excluding fuels meeting the 10-percent aromatic standard and high aromatic fuels. Effectively, all of the averages represent blends of large-refiner certified California diesel formulations.

Table XI-1: Properties of Candidate Fuels for Certified Formulations[1]

Executive Order Number	API Gravity	Aromatic HC (% by vol.)	PAH (% by wt.)	Cetane No.	Sulfur (ppmw)	Nitrogen (ppmw)
G-714-001	37.2	18.7	2.2	58	54	484
G-714-003	37.2	18.7	4.7	59	196	466
G-714-006	38.9	15.1	3.6	55	200	340
G-714-007	36.3	21.7	4.6	55.2	33	20
G-714-008	36.4	24.7	4.0	56.2	42	40
Five-Fuel Average	37.2	19.8	3.8	56.7	105	270
Eleven-Fuel Average	36.9	22.0	4.2	52.5	314	630
Sixteen-Fuel Average	37.0	21.3	4.0	53.8	249	520

[1] API gravities are not currently included in executive orders specifying certified formulations. Sulfur contents are shown in the table but would become obsolete when the proposed 15-ppmw sulfur limit under section 2281 becomes effective.

Table XI-2: Average California Diesel Fuel Properties

Property	AAM in LA	BP in LA	ARB Statewide	Averaged
Aromatic Content (% by vol.)	21.9	19.0	19.9	20.3
PAH Content (% by wt.)	Not Measured	3.3	3.2	3.3
API Gravity	37.6	36.1	Not Measured	36.9
Cetane Number	52.3	52.9	Not Measured	52.6
Sulfur Content (ppmw)	130	119	132	128
Nitrogen Content (ppmw)	120*	98**	Not Measured	110

* Data taken directly from AAMA/AAM summary reports, available for summer surveys only
** Measured for only one test fuel blend

B. Proposed Equivalent Limits

We are proposing new equivalent limits that could be used by diesel fuel producers, importers, and marketers as an alternative means of complying with the 10-percent aromatic standard. The new limits would be set forth in a new subsection of 13 CCR 2282. To comply with the proposed limits, a diesel fuel must meet each fuel property standard. The new limits, except for nitrogen content, were derived as averages of the average fuel property values tabulated in

Table XI-1 and Table XI-2 above. The sixteen-fuel average from Table XI-1 was averaged with the available fuel property averages shown in Table XI-2 for aromatic content, PAH content, API gravity, cetane number, and sulfur content. The proposed new limit for sulfur content would become obsolete when the proposed 15-ppmw sulfur limit under section 2281 becomes effective. Data on nitrogen content of California diesel fuel outside of Los Angeles are not readily available. The publicly available formulations have nitrogen limitations less than 500 ppmw, and the average limitation of the sixteen formulations is about 500 ppmw, so we have set the equivalent limit for nitrogen content at 500 ppmw. The 500-ppmw level is adequate to curb significant fuel NOx contribution, while allowing the use of cetane-improving nitrates.
Table XI-3 presents the proposed new equivalent limits. The aromatic hydrocarbon limit is expressed as percent by weight (% by wt.) to be consistent with the specified method of determination. The value expressed as percent by volume (% by vol.) would be about a half a percent less.

Table XI-3: Proposed New Equivalent Limits for California Diesel Fuel

Property	Equivalent Limit[1]	Test Method
Aromatic Content (% by wt.)	≤ 21.0	ASTM D5186-96
PAH Content (% by wt.)	≤ 3.5	ASTM D5186-96
API Gravity	≥ 36.9	ASTM D287-82
Cetane Number	≥ 53	ASTM D613-84
Nitrogen Content (ppmw)	≤ 500	ASTM D4629-96
Sulfur (ppmw)[2]	≤ 160	ASTM D2622-94
	≤ 15	ASTM D5453-93

[1] ≤ means "less than or equal to"
≥ means "greater than or equal to"
[2] ≤ 160 ppmw before June 1, 2006
≤ 15 ppmw starting June 1, 2006

C. Rationale for Proposed New Equivalent Limits

The rationale for proposing equivalent limits as an alternative to the 10-percent aromatic standard, or to compliance with a certified formulation, is to provide another compliance option while maintaining the benefits that the existing regulations are achieving. Having another compliance option will help to bring more diesel fuel to the California market. Since different California diesel fuels are blended in the distribution process, basing the proposed new equivalent limits on the average properties of certified formulations would preserve the actual emission benefits of California diesel fuel. We have included API gravity as an equivalent limit property to eliminate the potential for production of nonequivalent higher-emitting fuels. Studies have shown that emissions from diesel engines are affected independently by the API gravity (or specific gravity or density) of the fuel. See Chapter X for more discussion on diesel fuel property specifications and emissions.

The proposed equivalent property limits, if used, would preserve the emission benefits of California's diesel fuel program. The proposed limits are similar to the properties of three candidate fuels that qualified as emission-equivalent formulations to the 10-percent aromatic reference fuels. Overall, the emission performance of an equivalent limit fuel is expected to be a little better than the three similar candidate fuels. This is because at least three of the proposed property limits provide some extra emission benefit compared to the candidate fuel properties.

D. Alternatives Considered to Proposed New Equivalent Limits

One alternative to the new equivalent limits would be to allow only the existing options for complying with section 2282. If the proposed equivalent limits are not adopted, there would be no net economic benefit to the state. If the proposed equivalent limits are adopted, there may be a net economic benefit to the state, since the overall costs of producing and supplying diesel fuel to California could be less. Either way, there should be no difference in emission benefits. Therefore, we recommend that the Board adopt the proposed new equivalent limits for California diesel fuel.

Another alternative would be to develop a mathematical model to relate diesel fuel properties to engine exhaust emissions. Producers of diesel fuel could use such as model to evaluate potential alternative formulations that could provide equivalent emissions as a 10-percent aromatic hydrocarbon reference fuel. Staff is pursuing this option but have not yet developed an acceptable model.

XII. PROPOSED REGULATION ESTABLISHING A DIESEL FUEL LUBRICITY STANDARD

This chapter discusses the staff's proposed new regulation (Title 13, CCR, section 2284) establishing a minimum lubricity standard for commercial motor vehicle diesel fuel.

A. Introduction

Diesel fuel lubricity can be defined as the ability of diesel fuel to provide surface contact lubrication. Adequate levels of fuel lubricity are necessary to protect the internal contact points in fuel pumps and injection systems to maintain reliable performance. Natural lubricity of diesel fuel is provided by trace levels of oxygen- and nitrogen-containing compounds, and certain classes of aromatic and high molecular weight hydrocarbons in diesel fuels.[40,41]

Fuel lubricity levels are expected to be reduced as a result of the severe hydrotreating refiners are anticipated to use to meet the proposed 15-ppm sulfur limit, as discussed in Chapter XIV. Hydrotreating, a process used to reduce fuel sulfur levels, also depletes the levels of natural fuel lubricity agents. Lubricity additives have and continue to be used to increase the lubricity of fuels that have had their natural lubricity agents depleted. It has been found that fuels that contain more of these natural lubricity agents require less additive to bring the fuel lubricity up to acceptable levels.[40] Consequently, it is expected that increased levels of lubricity additives will be required as the sulfur contents of diesel fuels are lowered.

Diesel fuel lubricity is dependent on the presence of trace components that provide surface-active molecules that adhere to or combine with metallic surfaces to produce a protective film that reduces wear.[42] Rotary or distributor type injection pumps commonly used in light and medium-duty diesel engines, including most agricultural equipment, rely on the fuel for lubrication of the moving parts and are therefore very sensitive to fuel lubricity. This is in contrast to in-line pumps, commonly used in heavy-duty applications, in which some of the components are lubricated by engine oil. New fuel injector systems, including common rail systems, developed to more accurately tailor fuel injection to reduce exhaust emissions, use extremely high pressures and require higher levels of fuel lubricity than older systems. The high injection pressures provide finer fuel atomization that results in improved fuel air mixing, more complete combustion, and lower exhaust emissions.[40,43]

B. Lubricity Evaluation Tests

Various laboratory scale bench tests have been developed for evaluating the lubricity of diesel fuels.[44,45] These bench tests have been compared to diesel fuel injection pump tests to evaluate their accuracy in predicting lubricity levels.[46] One advantage of the bench tests is that they can be completed in a few hours whereas pump tests require hundreds of hours. However, pump wear due to low lubricity involves a variety of wear mechanisms of which each bench test can only simulate one or two. In spite of this limitation, good correlation has been shown between some bench tests and pump tests for unadditized fuels.[40,46] However, these tests appear to be significantly less accurate in discriminating the beneficial effects of lubricity additives in additized fuels.

ASTM has adopted test methods for two of the lubricity evaluation bench tests. These two test methods are the Scuffing Load Ball-on-Cylinder Lubricity Evaluator (SLBOCLE) test method[47] and the High-Frequency Reciprocating Rig (HFRR) test method.[48] These two test methods have not shown good correlation with each other and show differing degrees of sensitivity to additives depending on both the base fuel and the additive chemistry.

1. SLBOCLE

The SLBOCLE test consists of a cylinder that rotates with its lower portion immersed in 77°F (25°C) temperature fuel and a stationary ball pressed onto the upper portion of the rotating cylinder for a duration of 60 seconds. The friction force between ball and cylinder is measured for different applied loads. The load at which the friction coefficient exceeds a specified value is determined as the scuffing load, reported in total grams. Higher lubricity fuels will result in higher scuffing loads. The wear mechanism measured by the SLBOCLE test is an adhesive wear called scuffing.[44] The complete SLBOCLE test method is contained in ASTM standard D6078-99.[47]

2. HFRR

In the HFRR test, a steel disk is submerged in 140°F (60°C) temperature fuel and a steel ball, loaded with a 200 gram mass, is rubbed on the disk using a 1 mm stroke at a frequency of 50 Hz for 75 minutes. The lubricity of the fuel is determined from the measurement of the resulting wear scar on the ball. The wear mechanism measured by the HFRR test is an oxidation/adhesive wear.[44] While the HFRR test is relatively insensitive to acidic type lubricity additives, it has been shown to be more sensitive to non-acidic additives.[49] The complete HFRR test method is contained in ASTM standard D6079-02.[48]

C. Hardware Lubricity Requirements

The lubricity requirements for different types of hardware vary with the technology employed. The more stringent emissions requirements placed on light duty vehicles have driven manufacturers to more sophisticated fuel injection systems. Heavy-duty vehicles predominately use more conventional systems, however, this may change in the future.

a) Heavy-Duty Engines

Heavy-duty engines primarily use in-line pumps in which critical parts are fuel lubricated.[40] The Engine Manufacturers Association (EMA), which represents manufacturers of heavy-duty engines, supports both a SLBOCLE standard of 3,100 grams, similar to the California voluntary lubricity standard, and an HFRR standard of 460 microns.[50] However, as discussed in sections below, these two standards are not equivalent. Pump wear data for conventional pumps are shown in Appendix G.

b) Light-Duty Engines

High pressure common rail fuel injection systems are being developed to meet the increasingly stringent emissions requirements for light duty diesel vehicles. The extreme high pressures (on the order of 24,000 pounds per square inch, psi) required to achieve the fine atomization and improved fuel/air mixing, result in excessively harsh wear conditions. These harsh conditions, in combination with the demanding life requirement (over 100,000 miles), result in greater fuel lubricity demands. Consequently, the Alliance of Automobile Manufacturers, which represents the light duty vehicle manufacturers, supports a more stringent diesel fuel lubricity requirement of an HFRR WSD of 450 microns. Wear data for high pressure common rail fuel injection systems are shown in Appendix G.

c) Agricultural Equipment

Agricultural equipment primarily use all fuel lubricated rotary pumps to which fuel lubricity is of major importance. These pumps, while heavily dependent on fuel lubricity, operate at more moderate pressures (between 8,000 and 14,000 psi) than the newest light duty technology. Pump manufacturers for these types of equipment recommend the more stringent lubricity requirement of an HFRR WSD of 450 microns.

D. Lubricity Standards

There is currently no government or industry standard controlling diesel fuel lubricity in the United States. However, in California, industry has maintained a voluntary minimum lubricity level consistent with the recommendation of a 1994 Governor's Task Force[51] that was created during the introduction of 500-ppmw sulfur California reformulated diesel. This voluntary level is a SLBOCLE scuffing load of 3,000 grams or higher. The American Society for Testing and Materials (ASTM) has been working since 1993 to develop a lubricity specification for its D-975 specifications for diesel fuel but at this time has failed to come to a consensus. There is significant controversy over which lubricity evaluation test is most representative of the equipment requirements and what level of lubricity is required to adequately protect hardware.

Europe, where 40 percent[52] of new cars are diesel vehicles, has included a lubricity specification in their diesel fuel specification EN 590. Additionally, the World Wide Fuels Charter, a document produced cooperatively by a coalition of vehicle and engine manufacturers throughout the world, also includes a diesel fuel lubricity specification.

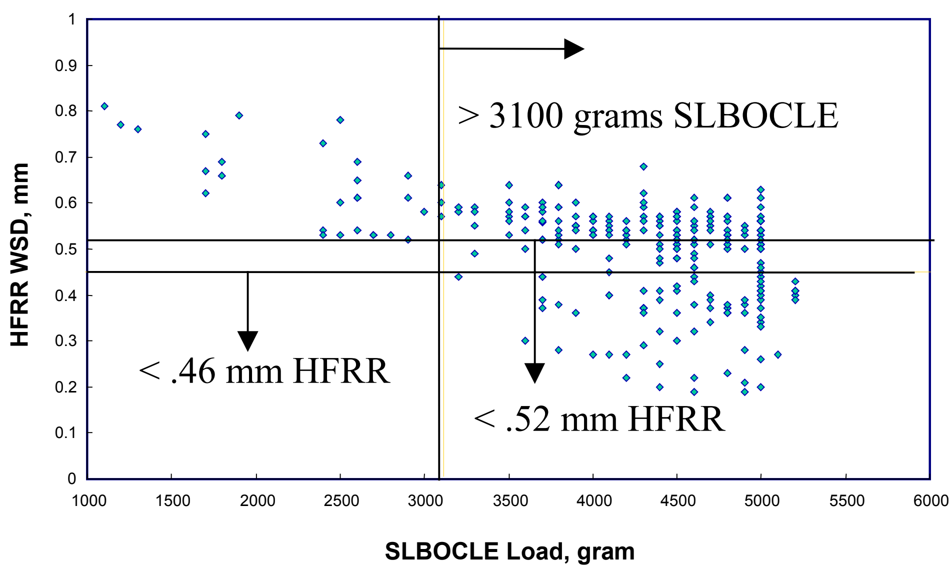
The various specifications and efforts are discussed in the following paragraphs.

1. ASTM Specification Efforts

Fuel system producers, engine and vehicle manufacturers, and the military have been working with ASTM since 1993 to develop protocols and standards for diesel fuel lubricity in its D-975 specifications for diesel fuel. Currently, this ASTM standard includes a section on lubricity (X3. Diesel Fuel Lubricity)[42], that is included as one of the "non-mandatory information" appendices. The ASTM lubricity section gives a range of values for both the SLBOCLE and the HFRR tests. The guideline states that for SLBOCLE lubricity values below 2,000 grams or HFFR with fuels at 60°C with values above 600 microns, the lubricity might not prevent excessive wear. However, fuels with SLBOCLE lubricity values above 3,100 grams or HFFR with fuels at 60°C with values below 450 microns wear scar diameter (WSD) should provide sufficient lubricity in all cases. The guideline cites references as the basis for these values.[49, 53, 46] Additionally, this guideline states that industry-accepted long-term durability pump tests, such as the ones used on a test stand or in a vehicle, can be used to evaluate the lubricity more accurately.

ASTM has balloted two different lubricity standards without success in their effort to replace the non-mandatory appendix with a lubricity standard. These ballots have included both the SLBOCLE minimum 3,100 grams and the HFRR maximum WSD of 460 microns. However, it should be noted that these two standards are not equivalent. The HFRR maximum 460 micron WSD standard provides a higher level of lubricity than the SLBOCLE minimum 3,100 grams. As shown in Figure XII-1 below, all of the fuels that meet the HFRR 460 micron maximum WSD resulted in measured scuffing loads greater than 3,500 grams. The lubricity levels of these fuels exceed the SLBOCLE 3,100 gram standard. Conversely, there are a large number of fuels that meet the minimum 3,100 grams SLBOCLE standard that produced WSDs significantly greater than 460 microns, indicating a lower lubricity level than the HFRR maximum 460 micron WSD standard.

Figure XII-1 Comparison of Lubricity Levels of Diesel Fuels[54]



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The latest ASTM ballot currently in progress proposes an HFRR standard of a maximum WSD of 520 microns. As indicated by data in Figure XII-1, this standard is at least as protective as the SLBOCLE 3,100 grams standard, while disallowing fuels that produce WSDs greater than 520 microns.

2. *World Wide Fuels Charter*

The World Wide Fuels Charter is a document produced cooperatively by a coalition of vehicle and engine manufacturers throughout the world that attempts to establish world wide recommendations for quality fuels. The World Wide Fuels Charter recommends a diesel fuel lubricity standard of a HFRR maximum WSD of 400 microns. This standard is significantly more stringent than the SLBOCLE minimum 3,100 gram standard balloted by ASTM.

3. *European Specifications*

The European diesel fuel specification, EN590, issued by CEN - European Committee for Standardization, includes a lubricity specification based on the HFRR test.[45] This standard specifies a maximum WSD of 460 microns and states that the fuel may contain lubricity agent in order to achieve this result.

4. *Canadian Specification*

The Canadian General Standards Board has developed diesel fuel lubricity standards which require that base fuels with cloud point operability temperatures of -20°C or lower be additized for lubricity.[45] Low cloud point diesel fuels, necessary for operation in extreme cold weather, are a lighter distillate with lower viscosity and density, which are known to have poor lubricity. Acceptable additization, based on a representative fuel sample, may be determined based on several optional criteria. These criteria include pump wear in either a vehicle fleet test, with a Bosch pump or with a Stanadyne pump, or meeting the following standards in a bench test: an HFRR maximum WSD of 460 microns or a SLBOCLE scuffing load of greater than 2800 grams.

E. Increasing Fuel Lubricity

1. *Options*

There are three options for increasing the fuel lubricity when it does not meet the recommended lubricity level: 1) modify refinery process operations and crude feed to maximize the trace species that provide natural lubricity properties in diesel fuel, 2) blend in either a biodiesel or refinery stream that is high in lubricity providing species, or 3) treat the diesel fuel with a lubricity additive.[55] When the first two options are not feasible, lubricity additives are used.

Lubricity additives are available in today's market, are effective, and are in widespread use around the world. California refineries report that the additive suppliers have sufficient experience with the effects of the additives to determine how much additive is required to bring the fuel up to the required lubricity without over-additizing. Other examples include Sweden, Canada, and the U.S. military. Since 1991, the use of lubricity additives in Sweden's 10 ppmw sulfur Class I diesel fuel and 50 ppmw sulfur Class II diesel fuel has resulted in acceptable equipment durability.[56] Since 1997, Canadian fuel standards have dictated that diesel fuels with low operability temperature limits be treated with lubricity additives.

2. *Lubricity Additives*

A variety of lubricity additives have been developed. These additives incorporate surface active chemicals that bond to metal surfaces, preventing metal to metal contact and the resulting wear.[57] Additives vary in effectiveness, treat rates, and costs, and can have harm effects depending on the additive type. Some common types of additives are fatty acids, fatty amides, and fatty esters. These additive types can be categorized as either acidic, mono-acid, or non-acidic. Fatty acids can be categorized as either acidic or mono-acidic. Fatty amides and fatty esters are non-acidic.

a) Additive Types

The first lubricity additives to be used were traditional corrosion inhibitors, which are mild fatty acids used in jet fuels at extremely low treat rates. However, it became necessary to increase treat rates by five to 15 times when used in diesel fuel as a lubricity additive. These increased treat rates resulted in engine harm effects, described in the section below. Other types of lubricity additives have since been developed which minimize engine harm effects. These types are mono-acids and non-acids.

The cost and treat rate required for effectiveness vary with additive chemistry. While acidic lubricity additives are the least expensive additives, they have the most significant harm effects. Mono-acidic additives and non-acidic additives do not have the engine harm effects that may be experienced with acidic additives, however they are more expensive than the acidic additives.

<u>Acidic Additives</u>

Acidic lubricity additives are the earliest lubricity additive technology and the least expensive. These additives are fatty acids with multiple replaceable hydrogen atoms. Acidic lubricity additives are primarily divalent acids, or acids with two replaceable hydrogen atoms. These additives generally have a total acid number (TAN) greater 200.[58] The SLBOCLE test tends to show response to acidic additives at lower treat rates than with other types of additives.[59] However, with the HFRR test, the measured lubricity level at times plateaus with acidic additives and lower wear scar diameters may not be achievable. Additionally, at higher treat rates, engine harm effects, as discussed below, are a risk.

<u>Mono-acidic Additives</u>

Mono-acidic lubricity additives are fatty acids with a single replaceable hydrogen. These additives generally have a TAN between 50 and 100.[58] These additives are generally successful in attaining HFRR WSDs down to 460 microns. Mono-acidic lubricity additives are generally more expensive than acidic additives but less expensive than non-acidic.

<u>Non-Acidic Additives</u>

Non-acidic may be either fatty esters or fatty amines. Of the three additive types, non-acidic lubricity additives generate the best response with the HFRR test.[60] However they are also the most expensive additives.

b) Harm Effects

There are lubricity additive harm effects associated with engines and with common carrier pipelines.

<u>Engine</u>

Acidic additives can interact with lubrication oil additives and form salts. These salts can precipitate out of solution in the fuel system, plugging filters, causing plungers to stick, and contaminating surfaces. This interaction results only with specific types of divalent acidic additives.[61] The mono-acidic and non-acidic additives are not known to cause engine harm effects.

Pipeline

Common carrier pipeline harm effects can be a result of surface active species in the lubricity additives that plate out on pipeline walls. Other fuels following diesel fuel treated with lubricity additive through the pipeline can become contaminated with these surface active species. Jet fuel contaminated with these species can have an increased affinity for water. This can result in the jet fuel being out-of-specification for moisture content.

Pipeline contamination of jet fuel can be addressed by pipeline protocol. In Western Canada, jet fuel pipeline contamination is avoided by additizing at the rack or fuel terminal.[62] Another option would be to follow shipments of diesel fuel with gasoline prior to running jet fuel. Since gasoline shipments are approximately three times the amount of diesel shipped, and approximately five times the amount of jet fuel shipped through California pipelines,[58] this protocol could be feasible for California.

F. Regulatory Actions

1. U.S. EPA's Action on Lubricity

The U.S. EPA decided not to establish a lubricity standard in their current action to require 15 ppmw maximum sulfur nationally for on-road motor vehicle diesel fuel. The U.S. EPA's position is that the best approach is to allow the industry and the market to address the lubricity issue in the most economical manner. This approach allows for the continuation of current industry practices for diesel fuel produced to meet the current federal and California 500-ppmw-sulfur diesel fuel specifications, which draws from the considerable experience gained since 1993. This approach offers flexibility to recognize any new specifications and test procedures that might be developed and adopted by the ASTM, regarding lubricity of highway diesel fuel.[56]

2. California's Action on Lubricity

California's implementation of the low-aromatic and statewide 500-ppmw sulfur diesel regulations initiated an evaluation of diesel fuel lubricity in 1993. In 1994, the California Governor's Diesel Fuel Task Force recommended that the lubricity of diesel fuel be maintained at pre-regulation lubricity levels as defined by a SLBOCLE scuffing load of not less than 3,000 grams.[51] The refineries agreed to comply with this recommendation for minimum lubricity and have been maintaining this level as part of their present specification for diesel production.

From October 1993 through the end of 1996, the ARB Monitoring Laboratory Division staff monitored the lubricity of California diesel for five different months.[63] The production weighted mean lubricity SLBOCLE values for November 1993 and August 1994 were 2,700 grams, which is slightly below the recommended SLBOCLE value of 3,000 grams. However, the 95% confidence level for the data for December 1994, June 1995 and December 1996 were at or above the 3,000 grams recommendation. No lubricity-related fuel pump damage had been documented for California vehicles for that time period.[63] It appears that maintaining the Task Force recommendation precludes damage to California's historical hardware due to changes in lubricity. Consequently, lubricity levels with low sulfur (<15 ppmw) diesel should not be an issue for current California equipment as long as the current guideline (a SLBOCLE scuffing load of not less than 3,000 grams) is maintained. However, light duty vehicle and injection hardware manufacturers warn that new advanced technology fuel systems presently being introduced into California require a higher lubricity level than the existing voluntary level.

G. Proposed Action for Instituting a Lubricity Standard

Staff is proposing a two phase strategy to institute a fuel lubricity standard that will apply to all diesel fuel marketed in California.

The proposed initial phase will be to immediately adopt a standard that is at least as protective as the current voluntary standard in place in order to protect existing engines in use today. This proposed standard is a HFRR maximum WSD of 520 microns. The HFRR ASTM test method, D6079-02,[48] would be incorporated by reference. Staff is proposing that this standard be implemented on a phase-in schedule, similar to that proposed for the 15-ppmw maximum sulfur diesel standard. The HFRR maximum WSD of 520 microns standard will apply to all diesel fuel supplied from production and import facilities starting no later than August 1, 2004 unless the Executive Officer has been notified that arrangements have been made to additize the diesel fuel at the terminal. In this case the terminal operator would be required to comply on August 1, 2004. In all other cases, this standard would apply 45 days after applicability at the production and import facilities, starting September 15, 2004, to all downstream facilities except bulk plants, retail outlets, and bulk purchaser-consumer facilities. After another 45 days, starting November 1, 2006, the standard will apply throughout the distribution system.

The proposed second phase would be to determine a 2006 lubricity standard protective of advanced technology fuel systems via a technology assessment. Staff proposes that a place holder be included in the regulation for the 2006 standard and that the Board's resolution direct staff to conduct a technical assessment, to be completed in 2005, to determine an appropriate 2006 standard. The Board's resolution would further direct staff to return to the Board in 2005 with a proposed 2006 lubricity standard if the technology assessment determines that a HFRR maximum WSD of 460 microns at 60 degrees C, or a more appropriate standard, should be implemented on the same schedule as the proposed 15-ppmw sulfur limit for diesel fuel.

Staff proposes that a provision be included in the regulation that would sunset the 2004 lubricity standard if ASTM adopts a lubricity specification to be included in D-975 diesel fuel specifications and the California Department of Food and Agriculture, Division of Measurement Standards (DMS) adopts and enforces it. Staff proposes that this provision also sunset the 2006 lubricity standard if ASTM adopts a lubricity specification that is shown to be protective of advanced technology fuel systems based on the Coordinating Research Council (CRC) Diesel Performance Workgroup lubricity test program.

H. Rationale

The proposed diesel fuel lubricity standard is needed to ensure that California diesel fuel has adequate lubricity to protect fuel systems of existing and future diesel engines. Diesel fuel lubricity is the characteristic of diesel fuel that provides sufficient lubrication to protect each of the many types of contact points within fuel pumps and injection systems for reliable performance.

The levels of natural lubricity agents in diesel fuel are expected to be reduced by the more severe hydrotreating needed to lower the sulfur content of diesel fuel to meet the proposed 15-ppmw sulfur limit. Lubricity additives can be used to increase the lubricity of fuels that have had their natural lubricity agents depleted.

Several types of diesel fuel injection equipment rely on the fuel for lubrication of the moving parts.[40] Historically, a minimum lubricity level of SLBOCLE scuffing load of 3,000 grams has been adequate in California to protect hardware. However, advanced technology fuel injection systems will be required in the future to meet more stringent heavy-duty emissions requirements and to expand the use of diesel technology into the light-duty market. Such systems, including common rail, are currently being introduced in medium-duty vehicles. These systems, which utilize extremely high operating pressures, require a higher level of fuel lubricity. While a minimum lubricity level consistent with current refinery practice may be adequate for the short term, this level is not adequate for enabling and maintaining future low emissions technology. Consequently, staff is proposing a two phase strategy to protect both existing and future hardware.

The first phase of the proposed strategy is to implement an HFRR standard of a maximum WSD of 520 microns. The HFRR standard is the level presently supported by the vast majority of the stakeholders as being appropriate for the preponderance of diesel fuel systems currently in use in California. Data show that an HFRR maximum WSD of 520 microns is at least as protective as the current California voluntary level being practiced by California refiners (minimum SLBOCLE 3,000 grams) and the recommendation of EMA (minimum SLBOCLE 3,100 grams).[49, 64] Additionally, statistical pump data[64] are available to support these levels as being protective of conventional pump technology. Pump wear data are included in Appendix G. The HFRR test was chosen because the HFRR test wear mechanisms better represents the wear mechanisms present in the advanced technology fuel systems, such as common rail.

The second phase of the proposed lubricity standard strategy is to conduct a technology assessment to determine an adequate diesel fuel lubricity level for advanced technology fuel injection systems. Fuels with insufficient lubricity contribute to excessive wear that results in reduced equipment life and performance. Excessive wear in these systems is also expected to increase emissions due to compromised pump performance. In Europe, where the technology was first introduced, the HFRR maximum WSD of 460 microns standard has proven to be protective of advanced technology fuel injection systems. Additionally there are pump wear data to support this level, as shown in Appendix G.[52] However, many in industry believe that there may be a less stringent fuel lubricity level that may be similarly protective of this equipment. Consequently, the CRC Diesel Performance Workgroup has begun planning a test program to determine the correlation between diesel fuel lubricity levels and wear in advanced technology fuel injection systems in the U.S. This test program is scheduled to be initiated by the third quarter of 2003 and will be completed in 2004.

ASTM is currently balloting a lubricity standard of a HFRR maximum WSD of 520 microns at 60 degree C for inclusion in their D-975 diesel fuel specifications. This ballot is a compromise between stakeholders and includes a commitment to form a lubricity panel within the CRC Diesel Performance Group and conduct a research program to determine the level of lubricity required for protection of advanced technology fuel injection systems. The CRC lubricity panel has been formed and the planing of the research test program initiated. ASTM adoption of the lubricity specification in this ballot and the subsequent adoption by DMS would preclude the necessity for the ARB 2004 lubricity specification. Upon completion of the CRC lubricity testing, ASTM may propose to adjust the lubricity specification level based on the research results. A deferral of the ARB 2006 lubricity specification would be warranted by either the determination that the HFRR maximum WSD of 520 microns is adequately protective of advanced technology fuel injection systems or the ASTM adoption of a lubricity standard based on the CRC research results.

The first phase of the proposed strategy would become effective in 2004 in order to protect equipment in the field today, since some advanced technology diesel fuel systems have entered the market as well as some 15-ppmw maximum sulfur fuel. There is currently no industry or government lubricity standard in place and as diesel fuel sulfur levels continue to be reduced, equipment manufacturers and consumers have expressed concern regarding the lack of a lubricity standard. ASTM has been working to develop lubricity standards for its D-975 diesel fuel specifications since the introduction of low sulfur diesel fuel in 1993. Currently, ASTM has not been successful in adopting a lubricity standard.

The technology assessment of the second phase of the proposed strategy would be conducted and completed in 2005. The timing allows for the CRC Diesel Performance Workgroup to initiate and complete testing to generate statistical data for the determination of lubricity levels required for the protection of advanced technology fuel injection systems. A minimum lubricity level consistent with these findings would then be proposed to the Board for implementation in 2006. It is expected that advanced technology fuel injection systems will be introduced on a larger scale at that time.

I. Alternatives

An alternative to the proposed lubricity standard is to continue to rely on the current California refinery voluntary standard based on the 1994 Governor's Diesel Task Force recommendation. However, this voluntary standard does not address imported fuel and is not enforceable by DMS. Additionally, this standard is not adequate for the protection of advanced high pressure fuel injections systems that will become more prevalent within the next few years.

A second alternative to the proposed lubricity standard is to defer to ASTM to adopt a standard. DMS would then be required to adopt and enforce the ASTM lubricity standard. However, ASTM has been sharply divided on this issue, and, until recently, has not shown promise in this effort. The latest ASTM ballot currently in progress involves a compromise between the different factions and may be successful.

J. Future Work

Staff will participate in the CRC Diesel Performance Group lubricity panel and the associated lubricity testing of advanced technology fuel injection systems. Staff will conduct a technology assessment of the lubricity level required by advanced technology fuel injection systems in 2005, considering the CRC research results as well as additional data as it becomes available. If necessary, staff will propose a 2006 lubricity standard of a HFRR maximum WSD of 460 microns, or a more appropriate value as determined by the technology assessment.

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XIII. Other Proposed Amendments to the Diesel Fuel Regulations

This chapter describes amendments proposed by staff to clarify requirements of the regulations and to ensure that the regulations work effectively.

A. Amendments to Test Method for Sulfur

Staff is proposing a change to improve the test method for determining the sulfur content of diesel fuel. Currently CCR, Title 13, subsection 2281(c) requires that sulfur in diesel fuel be determined by ASTM D2622-94, which is a x-ray spectrometry method.[65]

Staff is proposing that the Board amend the regulation to replace ASTM D2622-94 with ASTM D5453-93, an ultraviolet fluorescence method, for determining compliance with the 15-ppmw sulfur standard. Staff is proposing that ASTM D5453-93 be incorporated by reference as the specified method for determining the sulfur level in diesel fuel.

The reported detection limit for the current method (ASTM D2622-94) is 10 ppm and the repeatability for sulfur in the range of 10 ppm to 49 ppm is 60 percent of the sulfur level.[66] For a diesel fuel with 15 ppmw sulfur, the repeatability of the method is plus or minus 9 ppm, which provides a range of 6 ppm to 24 ppm for a single measurement. This range is not acceptable for determining sulfur content of diesel fuel that must comply with a permissible maximum sulfur content of 15 ppm. The proposed method will provide a more suitable detection limit and better precision for determining sulfur at the levels expected in diesel fuels produced to comply with the proposed limit of 15 ppm on the sulfur content.

The ARB staff has already determined that the proposed test method, D 5453-93 is equivalent to the current method D2622-94 for diesel fuels. This method has a detection limit of 1 ppm and a precision of plus or minus 2.8 ppm for determination of a sulfur content of 15 ppm. In a study conducted by Nadkarni,[67] the precision of D5453-93 and D2622-94 were compared for analyses of motor gasoline, jet fuel, and reformulated gasoline fuel samples containing between 2.5 and 8.7 ppm sulfur. The precision of D2622-94 ranged from 5.7 ppm to 13.3 ppm, while the precision of D5453-93 ranged from 0.9 ppm to 1.8 ppm. The lower detection limit and better precision of D5453-93 makes this method more suitable than D2622-94 for determining sulfur levels of 15 ppm and less.

B. Definition of "Diesel Fuel"

Staff is proposing a revision of the definition of "diesel fuel" that will clarify the applicability of the diesel fuel regulations and make the definition consistent with the definition for fuel for internal combustion, spark ignition engines. The revised definition will include any liquid fuel that is predominantly a mixture of hydrocarbons that is used or intended for use or represented for use in internal combustion, compression ignition (diesel cycle) engines.

Staff is also proposing a conforming amendment to the definition of diesel fuel in the verification procedure and in-use compliance requirements for in-use strategies to control emissions from diesel engines, in Title 13, CCR, subsection 2701(a). This amendment would assure that the current effect of the requirements for the verification procedure regulation will not be changed by the expansion of the definition of diesel fuel.

Also, staff is proposing that an exemption from the diesel fuel requirements be established for diesel fuel used in qualifying military vehicles, closely paralleling provisions in the U.S. EPA regulations. This would be combined in a new section 2285 of Title 13, CCR.

XIV. FEASIBILITY OF REFINING LOW SULFUR DIESEL FUEL

This chapter presents ARB staff's assessment of the feasibility of refining and distributing diesel fuel with a sulfur content of no more than 15 ppmw. The staff's evaluation incorporates the findings of the U.S.EPA's feasibility study and the results of two surveys: one conducted by ARB staff and the other conducted by staff of the South Coast Air Quality Management District.[68] Also presented is a brief discussion of the desulfurization technologies that the staff expects refiners to use. Appendix H contains more information on the desulfurization technologies as well as the other refinery processes affected by the changes in refinery desulfurization operations.

A. Diesel Production in the United States

The diesel fuel produced by a given refinery is composed of one or more blendstocks from the crude oil fractionation and conversion units at the refinery. Refinery configuration and equipment, and the range and relative volumes of products manufactured (the product slate) can significantly affect the sulfur content of diesel fuel.

In their regulatory impact analysis for the new federal diesel fuel regulation adopted in January, 2001, the U.S. EPA reported that most of the highway diesel fuel volume manufactured in the U.S. is produced from the crude fractionation tower (called straight-run diesel).[69] Most of the remainder comes from the fluid catalytic cracker (FCC) conversion unit (called light cycle oil). The remaining small fraction of diesel fuel volume comes from a coker conversion unit (called light coker gas oil), or from the hydrocracker conversion unit (called hydrocrackate). The blendstock streams from these process units are typically further processed to reduce their sulfur content to comply with the current federal 500-ppmw cap for the sulfur content of highway diesel fuel.

A survey conducted by the American Petroleum Institute (API) and National Petroleum Refiners Association (NPRA) in 1996 examined the typical blendstock properties for the U.S. highway diesel pool as a whole.[1] The U.S. EPA summarized the results for the various Petroleum Administrative Districts for Defense (PADD) excluding California. Approximately 80 percent of all blendstocks used to manufacture highway diesel fuel outside of California are hydrotreated to reduce their sulfur content. Hydrocrackate is desulfurized to a substantial extent as a necessary element of the hydrocracking process and is not further processed in a hydrotreater. The EPA's summary also showed that approximately 16 percent of highway diesel fuel comes from nonhydrotreated blendstocks. Production of 15-ppmw sulfur fuel is expected to require severe hydrotreating of all components to be acceptable for blending for on-road uses.[70,71]

B. Diesel Production in California

Diesel fuel is produced in California at 12 large refineries and two small refineries. The blendstocks used to manufacture CARB diesel fuel differ from the rest of the nation. Only hydrotreated or hydrocracked blendstocks are used in the manufacture of CARB diesel fuel. The results of the NPRA/API survey[1] indicated that CARB diesel fuel is made primarily from hydrotreated and hydrocracked distillates in roughly equal proportions (48 and 47 percent, respectively) with small fractions of hydrotreated cracked stock (2 percent) and hydrotreated coker gas oil (3 percent).

Data from the State Board of Equalization indicates that the total volume of diesel fuel sold in California during 2002 was approximately 2.8 billion gallons. The average sulfur content is about 140 ppmw, with about 20 percent of the California production already meeting the proposed 15-ppmw sulfur limit.

C. Technology Options for Low Sulfur Fuel Production

Refineries can, to a limited extent, reduce the sulfur content of their diesel fuel by using more crude oil with lower sulfur concentration. However, this change alone would not satisfy future needs for low sulfur diesel fuel. All surveys indicate that the sulfur requirement will be achieved through chemical removal of sulfur from distillate by reaction with hydrogen.

1. EPA's Conclusions

The U.S. EPA projects that all refiners will be technically capable of meeting the 15-ppmw sulfur cap with extensions of the same conventional diesel desulfurization technologies which they are using to meet the current highway diesel fuel standard of 500 ppmw sulfur.[69] Improvements to current hydrotreaters alone do not appear to be sufficient to provide compliance with the proposed 15-ppmw cap. Past commercial experience suggests that it is possible to incorporate current distillate hydrotreaters into designs that can provide compliance with the proposed 15-ppmw cap. Thus, the equipment added to meet the 500-ppmw standard in the early 1990s will continue to be useful in meeting a more stringent standard.

The U.S. EPA reports that existing commercial hydrotreaters are already producing distillate with average sulfur levels below 10 ppmw, which should be more than sufficient to meet a 15-ppmw cap. These hydrotreaters process distillate with typical breakdowns of straight run light gas oil (SRLGO),light cycle oil (LCO), and light cycle gas oil (LCGO). Therefore, the proposed 15-ppmw cap appears to be feasible with today's distillate processing technology. These commercial demonstrations were designed to reduce aromatics content, or improve cetane, as well as reduce sulfur. Therefore, the hydrogen consumption and its associated cost are higher than that needed for simple sulfur removal. This combination of sulfur and aromatics reduction has been encouraged by fuel tax incentives in Europe. The incentive to reduce sulfur by itself to such low levels has not existed, so refiners have generally had no incentive to produce such a product commercially.

The primary changes to refiners' current distillate hydrotreating systems would be the following:

1. the use of a second reactor to increase residence time, possibly incorporating counter-current flow characteristics, or the addition of a completely new second stage hydrotreater,
2. the use of more active catalysts, including those specially designed to desulfurize sterically hindered sulfur containing material,
3. greater hydrogen purity and less hydrogen sulfide in the recycle gas, and
4. possible use of higher pressure in the reactor.

The U.S.EPA also projects that all refiners will use recently developed high activity catalysts which increase the amount of sulfur that can be removed relative to the catalysts which were available when the current desulfurization units were designed and built. Changing to a more active catalyst can by itself reduce sulfur moderately. This will help to reduce the reactor size needed, but by itself would not appear to be sufficient for most refiners to meet a 15-ppmw limit.

The U.S.EPA also anticipates that some refiners (roughly 20 percent of current production volume) will decide to invest in a completely new two-stage hydrotreater rather than revamp their current unit. This could occur because the current hydrotreater is too old or designed to operate at too low a pressure, or because the refiner desires to expand production of highway diesel fuel.

2. ARB Survey

The ARB staff conducted a statewide survey of refineries to obtain information on current and future diesel fuel production. A copy of the survey questionnaire is included in Appendix L. Among other questions, refiners were asked to indicate what new equipment, modifications to existing equipment and changes in refinery operations would be needed to produce diesel fuel to meet the proposed sulfur limit. The responses to the survey did not contradict the EPA's conclusions listed above.

Refiners in California have had about ten years of experience with hydrodesulfurization technology in producing low sulfur diesel fuel. Most refiners will meet the requirements for increased sulfur removal by modifying existing units to increase their hydrodesulfurization capability. Eight refiners expect that modifications will be minimal with process modifications that could include additional reactors in series with existing reactors. Three refiners have reported that new hydrotreating units would likely be needed to comply with the proposed 15-ppmw sulfur limit

One other option for increasing the desulfurization capability is the use of more effective catalysts, such as double density catalysts, in the reactor of the hydrotreater. The double density catalyst increases reactor yield by increasing the amount of metal, in this case nickel, cobalt, and/or molybdenum, on the catalyst pellets.

The increase in desulfurization means an increase in demand for hydrogen and an increase in generation of hydrogen sulfide if refiners are to maintain current CARB diesel production levels for the lower fuel sulfur limit. Some refiners may need to upgrade the hydrogen production and amine scrubbing capacity. Increased demands for hydrogen may be met by modifying existing hydrogen plants or by new construction. Another option is to purchase hydrogen from a producer thereby incurring an operational cost as opposed to a capital investment.

3. SCAQMD Survey

The South Coast Air Quality Management District (AQMD) conducted a survey of the eight area refiners that the AQMD considered potential suppliers of low sulfur fuel to the district.[68]

According to the District, the information supplied by the refineries indicated that the proposed reduction in diesel sulfur would require modifications to refinery desulfurization units.

A number of refineries in the SCAQMD currently produce low-sulfur ($\leq$ 15 ppmw) fuel in their hydrocrackers. A portion of this volume is sold, while the remainder is used for blending with higher sulfur hydrotreated blendstock, and this has been adequate to meet current regulatory requirements. With the proposed regulation, the sulfur content of the hydrotreated distillate will have to be reduced significantly. Most refiners will enhance or expand their current distillate hydrotreating capability to meet the sulfur cap. The methods that they will use to achieve this goal include all of the options identified above in the summary of EPA's conclusions and in the results of the ARB survey.

D. Hydrodesulfurization

One method to reduce diesel fuel sulfur is to chemically remove sulfur from the hydrocarbon compounds which comprise diesel fuel. This is usually accomplished through reaction with hydrogen at moderate to high temperature and pressure. Specific examples of this process are hydrotreating and hydrocracking. Hydrogen for these processes is produced by catalytic reformers or hydrogen generation units and is distributed to the hydrotreaters through a refinery-wide network. Hydrotreating for sulfur removal is called hydrodesulfurization.

In the hydrotreating process, liquid distillate from the crude unit is combined with hydrogen and brought to the reaction temperatures and pressures prior to entering the reactor. The reaction occurs in the presence of a solid catalyst. Hydrogen reacts with the sulfur and nitrogen compounds in the distillate, forming hydrogen sulfide and ammonia. The resulting vapor is then separated from the desulfurized distillate, which is usually mixed with other distillate streams in the refinery.

The vapor still contains valuable hydrogen, because the reaction requires a significant amount of excess hydrogen to operate effectively and practically. However, the vapor also contains a significant amount of hydrogen sulfide and ammonia, which inhibit the desulfurization and denitrogenation reactions and which must be removed from the system. To avoid a build-up of hydrogen sulfide and ammonia in the system, the hydrogen sulfide and ammonia are usually chemically scrubbed from the hydrogen recycle. The hydrogen recycle is then usually mixed with fresh hydrogen and recycled to the front of the reactor for reaction with fresh distillate feed.

Hydrocracking is a two-stage process combining catalytic cracking and hydrogenation, wherein heavier feedstocks are cracked in the presence of hydrogen to produce more desirable products. The process employs high pressure, high temperature, a catalyst, and hydrogen. Hydrocracking is used for feedstocks that are difficult to process by either catalytic cracking or reforming, since these feedstocks are characterized usually by high polycyclic aromatic contents or by high concentrations of the two principal catalyst poisons, sulfur and nitrogen compounds, or by both.

E. Effect of Hydrodesulfurization on Fuel Volume

Conventional desulfurization processes employ hydrotreating to remove sulfur. The processes lead to a decrease in fuel density and decrease in fuel energy density as well. To make up the loss in energy density, and to meet fuel demand, refiners' fuel production volumes must increase by approximately the same amount. Since conventional desulfurization is not very efficient, we expect that additional hydrotreating well beyond the theoretical minimum required for desulfurization will occur, resulting in additional fuel production mass. The additional production mass combined with the higher mass-based energy content of the hydrotreated fuel means that, once refiners are equipped to process their feedstocks to produce the low-sulfur diesel fuel, they should be able to produce more than enough fuel to meet demand. Overall, to provide the same amount of work, diesel engines will burn slightly more volume of the low-sulfur diesel fuel, but slightly less mass.

F. Recovery of Sulfur from Hydrotreating

During the hydrotreating process, hydrogen reacts with sulfur-containing compounds in the distillate to form hydrogen sulfide (H_2S). The desulfurized distillate is separated from the mixed stream leaving the reactor to yield a gaseous stream containing the H_2S by-product. The H_2S is removed from this gaseous stream by an amine solution scrubber and the solution is sent to a sulfur recovery unit where the H_2S is separated and then converted to elemental sulfur. State and federal regulations now require recovery of more than 99% of the sulfur in refinery gas. The most widely used recovery system is the Claus process, which uses both thermal and catalytic-conversion reactions. In a typical process, hydrogen sulfide is burned under controlled conditions to produce SO_2, H_2O, and saleable elemental sulfur which may be used by a number of industries including fertilizer production, and the chemical industry.

G. Other Desulfurization Processes

There are other low temperature and pressure processes being developed, such as biodesulfurization, and chemical oxidation. Sulfur can be removed by these processes early in the refining process; for example, from crude oil, before being processed into diesel fuel. These processes can also be used to remove sulfur from those refinery streams, which are to be blended directly into diesel fuel. Another process was announced recently which uses a moving bed catalyst to both remove and adsorb the sulfur using hydrogen at moderate temperature and pressure. Finally, another method to reduce diesel fuel sulfur is to shift sulfur-containing hydrocarbon compounds to other fuels produced by the refinery.

In cases where they are cost effective, these other methods may be used by refiners to complement the primary sulfur reduction achieved through hydrotreating. The following is a summary of four alternatives to conventional distillate hydrotreating discussed in the EPA's regulatory impact analysis.[72]

1. Biodesulfurization

Biodesulfurization involves the removal of sulfur-containing hydrocarbon compounds from distillate or naphtha streams using bacteria. Enzymes in the bacteria first oxidize the sulfur atoms and then cleave some of the sulfur-carbon bonds. The sulfur leaves the process in the form of hydroxyphenyl benzene sulfonate, which can be used commercially as a feedstock to produce surfactants. In pilot plant studies biodesulfurization was combined with conventional hydrotreating to produce diesel fuel containing 50 ppmw sulfur.

2. Chemical Oxidation and Extraction

Two oxidative desulfurization processes were described in the EPA document. In one process, a water emulsion is first formed with the diesel fuel. The diesel sulfur atom is then oxidized to a sulfone using peroxyacetic acid. With an oxygen atom attached to the sulfur atom, the sulfur-containing hydrocarbon molecule becomes polar and hydrophilic and then moves into the aqueous phase. Like biodesulfurization, some of the sulfones can be converted to surfactants.

The other oxidative desulfurization process differed from the first in the sulfur product of the oxidation reaction. This process does not create a sulfonate. Instead, the oxidized sulfur atom is separated from the hydrocarbon immediately after the oxidation reaction and the resulting sulfate is then easily separable from the petroleum.

3. Sulfur Adsorption

In this process, highway diesel fuel (typically with about 350 ppmw sulfur) reacts with hydrogen and a catalyst in a reactor at relatively low pressures and temperatures. The sulfur atom of the sulfur-containing compounds adsorbs onto the catalyst, which then cleaves the sulfur atom from the sulfur-containing hydrocarbon. The catalyst is continually removed from the reactor and regenerated in a separate regeneration vessel. Here the sulfur is burned off before being sent to the sulfur plant. The regenerated catalyst is then recycled back to the reactor for removing more sulfur. This process would likely be used to treat distillate containing 500 ppmw sulfur or less as the sulfur in untreated distillate can overwhelm the catalyst.

4. FCC Feed Hydrotreating

The FCC unit primarily produces gasoline, but it also produces a significant quantity of distillate, called light cycle oil (LCO). LCO is high in aromatics and sulfur and contains a relatively high fraction of the sterically hindered sulfur compounds found in diesel fuel. Hydrotreating feed to the FCC unit requires higher temperatures and pressures than hydrotreating distillate streams because FCC feed contains much larger and heavier molecules. Because of this, FCC feed hydrotreating is more expensive than distillate hydrotreating.

The LCO produced at refineries with a FCC feed hydrotreating unit should contain a much lower concentration of sterically hindered compounds than refineries that do not hydrotreat their FCC feed. FCC feed hydrotreating is much more costly than distillate hydrotreating. FCC feed hydrotreating by itself is generally not capable of reducing diesel fuel sulfur to the levels required by the proposed amendment to the regulation. The decision to use FCC feed hydrotreating is based on both environmental and economic benefits. FCC feed hydrotreating decreases the sulfur content of gasoline significantly, as well as reduces sulfur oxide emissions from the FCC unit. Economically, it increases the yield of relatively high value gasoline and LPG from the FCC unit and reduces the formation of coke on the FCC catalyst. For individual refiners, these additional benefits may offset enough of the cost of FCC hydrotreating to make it more economical than distillate hydrotreating.

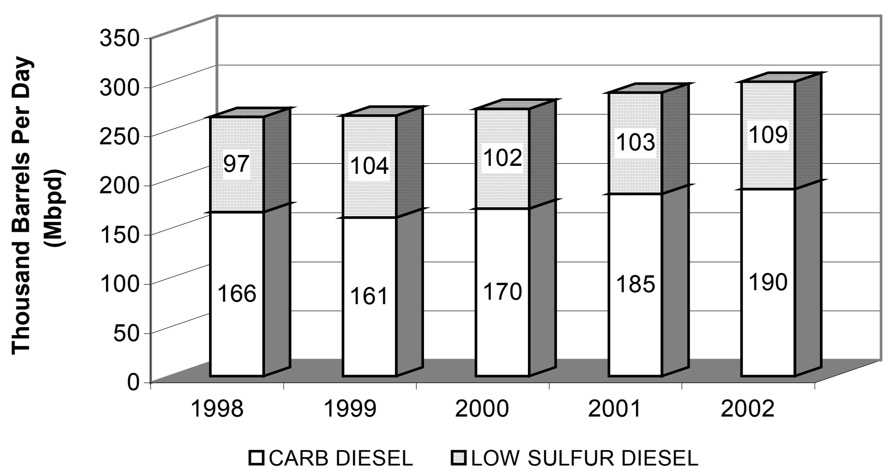
XV. POTENTIAL IMPACTS OF THE PROPOSED SPECIFICATION ON THE PRODUCTION OF DIESEL FUEL BY CALIFORNIA REFINERIES

This chapter presents a summary of the potential impacts of the proposed amendments on diesel production by California refineries and diesel production capacity of California refineries.

A. Diesel Production in California Refineries

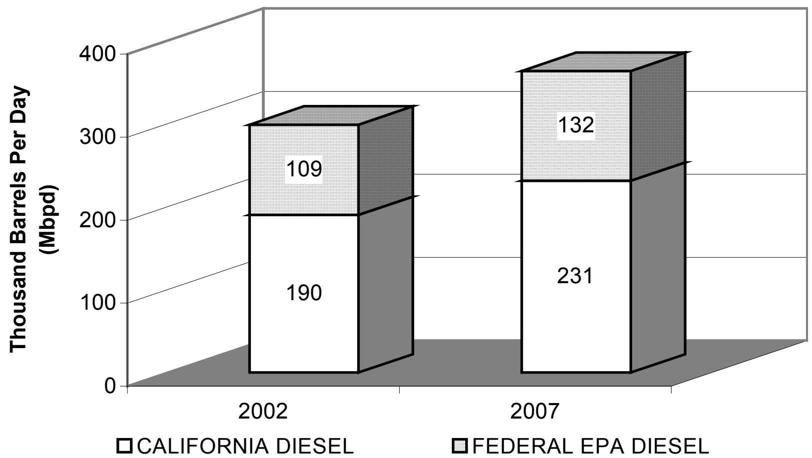
The proposed requirements for California low sulfur diesel fuel are not expected to have any impact on the ability of California to produce and supply adequate volumes of California diesel fuel. In California, on-road diesel fuel (either California or U.S. EPA) is produced at 12 large refineries and two small refineries. Based on information from the CEC, in 2001, these refineries produced 190 Mbpd of California diesel fuel, and nearly 110 Mbpd of U.S. EPA on-road diesel fuel. This is an increase in California diesel fuel production of over 14 percent, and an increase of over 12 percent for U.S. EPA on-road diesel fuel over 1998 levels. Figure XV-1 shows the annual diesel fuel production from California refineries from 1998 through 2002.

Figure XV-1
California Refinery Diesel Production (1998 – 2002)



Based on recent diesel fuel consumption trends showing increases of nearly four percent per year, staff estimates that in 2007, nearly 231 Mbpd of California low sulfur diesel fuel will need to be produced to meet anticipated California demand. Also, over 130 Mbpd of U.S. EPA on-road diesel fuel will be needed to meet diesel demands in neighboring states. These diesel fuel production demand estimates are shown in Figure XV-2.

Figure XV-2
Anticipated 2007 On-Road Diesel Production Compared to 2002 Actual Diesel Production

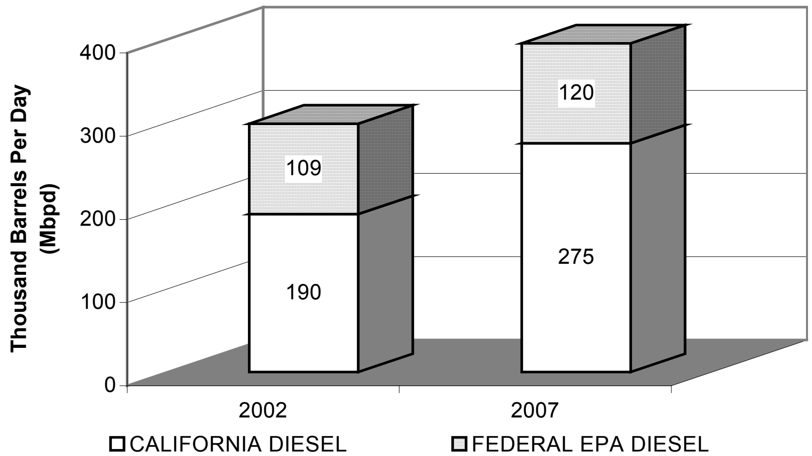


Based on survey responses, California diesel capacity is approximately 275,000 barrels per day. As can be seen, there is still a wide margin between projected estimates for diesel production in 2007 and the estimated diesel capacity, as reported by the refineries.

B. Diesel Capacity of California Refineries

Currently, California refineries have the capacity to produce about 190 Mbpd of California diesel fuel, and about 110 Mbpd of capacity to produce U.S. EPA on-road diesel fuel. Based on information provided by refiners, the requirements to produce low sulfur diesel fuel will not have any impact on the ability of California refiners to produce adequate volumes of low sulfur diesel fuel. Because several refiners indicated that they will expand their ability to produce volumes of California diesel fuel, it is expected that California refining capacity to produce California diesel fuel will increase to 275 Mbpd by 2007. In addition, the capacity of California refiners to produce U.S. EPA on-road diesel fuel will increase to about 120 Mbpd by 2007. This is shown in Figure XV-3.

Figure XV-3
California Refiners' Diesel Fuel Production Capacity
(2002 Versus 2007)



In comparing Figure XV-2 to Figure XV-3, it can be seen that there should be more than adequate refining capacity by California refineries to increase their production of California diesel fuel to meet projected demand estimates. However, it appears the situation may be more constrained for the production of U.S. EPA diesel fuel. Staff does not believe that this should be significant for two reasons. First, the ability of refiners to import U.S. EPA diesel from other parts of the country fuel to supply to neighboring states will be available. Also, since there appears to be excess California diesel fuel production capacity available to California refiners, they have the ability to supply California diesel fuel to neighboring states as demand and market conditions allow.

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XVI. OTHER ISSUES

A. Small Refiners

Currently, the California diesel regulations contain provisions for small refineries. A "small refiner" is defined in CCR, Title 13, Section 2260 as a refiner who owns or operates a refinery in California that satisfies the following:

- Has and at all times had since January 1, 1978, a crude oil capacity of not more than 55,000 barrels per stream day;
- Has not been at any time since September 1, 1988, owned or controlled by any refiner that at the same time owned or controlled refineries in California with a total combined crude oil capacity of more than 55,000 barrels per stream day; and
- Has not been at any time since September 1, 1988, owned or controlled by any refiner that has the same time owned or controlled refineries in the United States with a total combined crude oil capacity of more than 137,00 barrels per stream day.

Small refiners are allowed to produce diesel fuel meeting a 20 volume percent aromatic hydrocarbon content limit while large refiners are required to meet a 10 volume, percent aromatic hydrocarbon content standard. Both large and small refiners can certify alternative diesel formulations that are shown to be equivalent to their respective standards. The production of small refiner diesel fuel is limited to a specific volume determined by the capacity and operating characteristic for each refinery. A small refiner may produce an unlimited quantity of large refiner California diesel fuel. At this time the staff is not proposing any specific amendments to the California diesel fuel regulation for small refiners.

Some small refiners have indicated that they will have greater difficulty than large refiners in complying with the proposed 15-ppmw sulfur standard due to such factors as limited operation flexibility, lack of access to blendstocks, poorer economies of scale, or difficulties in raising capital. Staff recognizes that small refiners could experience a "significant and disproportionate financial hardship in reaching the objectives of the diesel fuel sulfur program," as stated in the EPA's final rule. The ARB staff will continue to monitor California's refining industry to evaluate the issues and consider possible actions that could provide some relief to disproportionately affected parties without compromising the benefits of the diesel fuel program.

B. Diesel Engine Lubricating Oils

Diesel engine lubricating oils are a source of sulfur and other compounds that could potentially poison emissions control systems that will likely be used to comply with new heavy-duty diesel emissions standards. Lubricating oils also have the potential to contribute to engine-out sulfur and particulate emissions. The significance of these two effects is not known but current research efforts should establish whether or not these effects should be of concern. Appendix I provides more detailed information.

1. Lubricant Formulation

Diesel engine lubricating oils are comprised of approximately 80 to 85% base oil, with the remainder made up of additives that modify or enhance the properties of the base oil. Base oils may be synthetic oils, which contribute essentially no sulfur to the lubricant, or petroleum-derived base oils. Petroleum-derived base oils can contribute significantly to sulfur content if they are not highly refined and hydrotreated. The EPA[73] reported that the sulfur content of current engine lubricating oils can range from 2,500 ppmw to as high as 8,000 ppmw by weight with the base oil contributing up to half of the sulfur.

Except for the sulfur contribution from high-sulfur base oils, performance additives are the major source of sulfur and ash in lubricating oils. The sulfur containing compounds, in the form of sulfonates, phenol sulfide salts and thiophosphonates, are vital to the performance of the additives that function as anti-wear agents, detergents, corrosion inhibitors, friction modifiers, and anti-oxidants.[74, 75] Anti-wear agents, primarily zinc diakyl dithiophosphates (ZDDP), are the main source of sulfur in the additives. Proven substitutes for all sulfur-containing additives are not available.

The following two sections briefly describe current efforts to determine whether there is a need for sulfur-free low ash substitutes for performance additives.

2. Lubricant Contribution to Sulfur in Exhaust

Under proper operation, only a small percentage of the oil consumed by open-crankcase ventilation heavy-duty diesel engines travels past piston rings and valves and burns in the combustion chamber. In both open-crankcase ventilation systems and closed-crankcase filtration systems, the magnitude of the contribution of engine oil sulfur to the exhaust is unknown. Estimates made for the magnitude of the equivalent fuel sulfur level contributed by engine oil range from nearly zero to seven ppmw. The EPA concluded that, while some sulfur from lubricating oils is almost certainly present in diesel engine exhaust, the amount may not be significant, even for after treatment systems requiring fuel sulfur levels of 15 ppmw or less.[73]

3. Research

There are currently two major research groups working to determine the effects of sulfur and other chemical compounds in diesel engine lubricating oils on diesel engine emissions and the performance of emission control devices.

The two research groups are the lubricants work group of the Advanced Petroleum-Based Fuels Program Diesel Emission Control - Sulfur Effects (APBF-DEC) program and a Southwest Research Institute (SwRI) private consortium called Diesel Aftertreatment Sensitivity to Lubricant/Non-Thermal Catalyst Deactivation (DASL/N-TCD).

The APBF-DEC lubricants workgroup has completed its first phase of testing. The first phase investigated the effect of lubricant formulations on engine out emissions. The second phase will explore the effect of oil formulations on after treatment performance.

The DASL/N-TCD consortium plans to conduct both parametric and research studies, including both gasoline and diesel engines, complementing the APBF-DEC lubricants work.

The results from these research efforts are expected to give engine and emission control system manufacturers insight into the magnitude of the potential problems and to help oil additive/component makers in formulating future additive packages.[76]

4. ASTM Proposed Engine Oil Category

An ASTM Heavy-Duty Engine Oil Classification Panel has been formed to develop a new engine oil classification, called Proposed Category 10, for use with advanced after treatment technology. This effort will be exploring the performance of oil formulations with reduced sulfur, phosphorous and sulfated ash. Oil licensing for this new classification is scheduled for mid 2006.

5. Ash Content of Lubricating Oils

The ability of the lubricating oil to control acidification (the total base number (TBN) of the oil) is a function of the lubricating oil ash content. Lubricating oil acidification is primarily due to the sulfur content of the fuel and the sulfuric acid that it forms. The proposed lowering of sulfur in diesel fuel will decrease the need for TBN control, requiring less ash content in the lubricating oils.[56] A decrease in ash content will result in a reduced particulate load on the particulate matter filter.

C. Alternative Diesel Fuels

Reformulated and alternative diesel fuels have shown promise for achieving significant reductions in PM and NO_x emissions. In addition to very low sulfur contents, all of these fuels have relatively low density, with low aromatic and PAH contents. The ARB's Interim Procedure for Verification of Emission Reductions for Alternative Diesel Fuels may be used to demonstrate emissions reductions with alternative diesel fuels.

Alternative diesel fuels generally contain more than trace amounts of oxygenated fuel constituents or are emulsified with water. Synthetic diesel fuel, with nearly zero sulfur and aromatic contents, is the cleanest burning of the reformulated diesel fuels. The fuel is produced by the gas-to-liquid chemical conversion process known as Fischer Tropsch (FT). Laboratory engine and truck chassis dynamometer emission testing have demonstrated average emission reductions of 26% and 24% for PM, 4% and 12% for NO_x, 20% and 40% for HC, and 36% and 18% for CO, respectively, for FT diesel over ARB Diesel.[2]

Microemulsions of water or ethanol in diesel fuel have been shown to reduce both PM and NO_x emissions through rapid vaporization of the emulsified droplets. These microexplosions break fuel droplets into smaller droplets, resulting in more complete vaporization and turbulent mixing and consequently more complete combustion of the fuel. The vaporization of the emulsified droplets also lowers peak combustion temperatures, thereby reducing NO_x formation. Enhanced fuel atomization also reduces soot formation. Appendix IV of the Risk Reduction Plan reports the results of testing of a water microemulsion where emission reductions of 62.9% for PM and

14% for NO_x were verified relative to the performance of a 10% aromatic ARB Diesel reference fuel.[2]

Biodiesel is defined as the mono alkyl esters of long chain fatty acids derived from vegetable oil or animal fats. It contains 11% oxygen by weight and nearly zero sulfur and no aromatic compounds. Otherwise, it has properties similar to petroleum-based diesel fuel and can be blended into conventional diesel fuel at any ratio. Neat biodiesel (B100) has been classified as an alternative fuel by the U.S. Department of Energy and the U.S. Department of Transportation. Biodiesel is most commonly blended into petroleum-based diesel fuel at 20 percent by volume – a mixture commonly referred to as "B20."

The use of B100 may reduce heavy-duty diesel engine emissions of PM by 47%, HC by 67%, and CO by 48% over conventional diesel fuel; however, its use tends to increase NOx emissions by 10%.[77] Compared to conventional diesel fuel, B20 can reduce emissions of PM by 10%, HC by 20%, and CO by 10%, but it can increase NOx emissions by 2%.[77]

Biodiesel reduces the health risks associated with conventional diesel fuel: emissions of PAH and nitro-PAHs are significantly reduced. The toxic emissions differences are likely to be smaller when compared to CARB diesel fuel but data comparing the two fuels are not available. Testing has been conducted to satisfy Tier2 requirements for the registration of biodiesel as a fuel and fuel additive. In an inhalation study in which rats were exposed to dilute biodiesel exhaust, no significant emissions exposure effects were observed.[78]

D. Actions in Other States

Other states with difficult air pollution problems have emulated California's strategy to achieve clean air benefits through clean diesel fuel. On December 6, 2000, the Texas Natural Resource Conservative Commission approved a low sulfur diesel fuel program patterned after the diesel fuel regulations adopted by California in 1988. Beginning May 1, 2002, diesel fuel produced for sale must not exceed 500 ppmw sulfur, must contain less than 10% by volume of aromatic hydrocarbons, and must have a cetane number of 48 or greater. The regulation also contains provisions for alternative formulations similar to the provisions in the California regulation. Low Emission Diesel Fuel will be required for all on-road motor vehicle use and for off-road use in several areas that are required to distribute federal reformulated gasoline and Texas' low Reid vapor pressure gasoline. These include the eight counties in the Houston/Galveston ozone nonattainment area, the four counties of the Dallas/Fort Worth ozone nonattainment area, the three counties of the Beaumont/Port Arthur ozone nonattainment area; and 95 additional central and eastern Texas counties. Beginning June 1, 2006, the Low Diesel Fuel rules will require the sulfur content in the diesel fuel supplied to the Houston/Galveston area, the Dallas/Fort Worth ozone area, and 95 additional counties covering central and eastern Texas, be reduced to 15 ppmw sulfur.

E. Actions in Other Countries

Diesel fuel is widely used in other countries. In fact, about 40 percent of new cars sold in Europe are powered by a diesel engine.[52] As a result of this large market share enjoyed by diesel passenger cars and the effect of their considerable emissions on air quality, diesel fuel quality programs are assuming a more important role in environmental policies. By 2005, the sulfur content of diesel fuel throughout the European Union (EU) will contain no more than 50 ppm by weight sulfur and perhaps as little as 10 ppm.

The United Kingdom made a rapid conversion to 50 ppmw maximum sulfur diesel fuel in 1999 by offering tax incentives to offset higher production costs. Some refinery production in that country is at levels well below 50 ppmw. Germany is moving forward with plans to introduce a 10 ppmw sulfur cap for diesel fuel by 2003, also with tax incentives, and is trying to get the 50 ppmw specification that was adopted by the European Commission revised downward to the 10 ppmw

Sweden has had extensive experience with low sulfur diesel fuel. With the help of a large tax incentive, Sweden introduced 10 ppmw sulfur fuel (Class I Swedish Diesel) into city areas in 1991. By 1999, over 90% of the highway diesel fuel sold in Sweden met the 10 ppmw sulfur maximum and other specifications (including a 5% by volume aromatics maximum) of the Class I Swedish Diesel.

Canada has harmonized its fuel regulations with the new U.S. 15 ppmw sulfur specification for 2006.[79] This would accommodate the operation of new-technology vehicles that cross the U.S-Canada border. The government is also looking to establish lower off-road sulfur standards. Japan, which currently has a 500 ppmw standard, is scheduled to implement 50-ppmw sulfur diesel by 2005 and has proposed 10-ppmw sulfur diesel for 2008.[80] Western Australia adopted 500-ppmw sulfur fuel for 2000, with a 50-ppmw standard to follow in 2006. In the meantime, the government has granted diesel tax breaks starting in 2003 for early introduction of the 50-ppmw sulfur fuel. will shortly introduce a tax incentive to reduce sulfur in diesel from the national average of 1300 ppmw.

Table XVI-1[81] is a summary of programs in various countries that will reduce the sulfur content of diesel fuel,

F. World Wide Fuel Charter

The international community of vehicle and engine manufacturers has established the World-Wide Fuel Charter "to promote greater understanding of the fuel quality needs of motor vehicle technologies and to harmonize fuel quality world-wide in accordance with vehicle needs." Four different categories of fuel quality have been established by the World-Wide Fuel Charter. They are described in Table 2. Category 4 fuel quality standards are proposed for markets with requirements for advanced PM and NO_x emissions control technologies and would therefore apply to the USA. The Category 4 standards include a minimum cetane number of 55, maximum sulfur content of 5 to 10 ppmw, and maximum total aromatics and polyaromatics contents of 15% and 2% respectively. Fuels meeting these specifications should provide emissions benefits equal to or greater than current ARB diesel requirements.

Table XVI-1: Summary of Diesel Fuel Regulations and Incentive Programs for Selected Countries

Country	Regulation or Incentive	Max S limit	Conventional Fuel limit (and typical content)	Introduced
EU	EURO2 98/70/EC EURO3 98/70/EC EURO4		500 ppm (450) 350 ppm 50 ppm	1 Jan 1997 1 Jan. 2000 1 Jan 2005
Belgium	National incentive	50 ppm	350 ppm	1 Oct. 2001
Denmark[1]	National incentive	50 ppm	500 ppm	June 1999
Finland[2]	National incentive Neste/Fortum Initiative	50 ppm 10 ppm	350 ppm	2002
Germany[3]	National incentive	50 ppm 10 ppm	350 ppm	1 Nov 2001 Jan 2003
Netherlands	National incentive	50 ppm	350 ppm	Jan 2001
Sweden	National incentive[4] National incentive[5]	10 ppm 10 ppm 50 ppm	2000 ppm 350 ppm 350 ppm	1991 2001 2001
Switzerland	National incentive Agrola initiative BP initiative	50/10 ppm[6] 10 ppm[7] 10 ppm[8]	350 ppm 350 ppm 350 ppm	2003 2000 2000
UK	National incentive National incentive	50 ppm 50 ppm	500 ppm 350 ppm	March 1999 7 Mar 2001
Australia	National regulation BP initiative[9]	50 ppm 50 ppm	1300 ppm 500 ppm	Jan 2006 End 2000
Hong Kong[10]	"Ultra low sulphur" national incentive	50 ppm	500 ppm	July 2000
Japan[11]	National regulatory proposal	50 ppm	500 ppm	Before 2005

Selected from Report to Committee of Deputies, European Conference of Ministers of Transport. March 2001

1 100 % penetration by July 1999
2 100 % penetration
3 From 2003, the incentive will shift from 50 ppm fuels to 10 ppm fuels
4 City diesel
5 Current incentive, last adjusted 1 Jan. 2001.
6 Proposal before parliament
7 Small market share
8 Supply to public transport and army
9 Capacity to supply 12% of national market
10 Replaced regular diesel at all filling stations but high sulfur fuel still used by bus fleets as tax free
11 Japan Air Quality Committee has recommended further reduction in the future

Table XVI-2: World-Wide Fuel Charter Fuel Quality Categories[82]

Categories	Basis of Fuel Quality Recommendations
1	Markets with no or first level of emission control; based primarily on fundamental vehicle/engine performance and protection of emission control systems.
2	Markets with stringent requirements for emission control or other market demands. *For example, U.S. Tier 0 or Tier 1, EURO 1 and 2, or equivalent emission standards.*
3	Markets with advanced requirements for emission control or other market demands. *For example, markets requiring US California LEV, ULEV and EURO 3 and 4, or equivalent emission standards.*
4	Markets with further advanced requirements for emission control, to enable sophisticated NO_x and particulate matter after treatment technologies. *For example, markets requiring US California LEV-II, US EPA Tier 2, EURO 4 in conjunction with increased fuel efficiency constraints or equivalent emission standards.*

Table XVI-3: Proposed Diesel Fuel Specifications[83]

Specification	EY Year 2000	Fuel Charter
Cetane Number	≥ 51	≥ 55
Cetane Index	NA	≥ 52
Density @ 15°C, (kg/m^3)	< 845	< 840
<u>Distillation</u> 90% Boiling Point, °C	NA	< 320
95% Boiling Point, °C	< 360	< 340
Final Boiling point, °C	NA	< 350
Polyaromatic Hydrocarbons, wt%	< 11	< 2.0
Total Aromatics Content, wt%	NA	< 15
Sulfur Content, ppmw	< 350*	Zero**

* From Year 2005, the European Union has adopted a sulfur content of 50 ppmw.
** Zero has yet to be defined as either <5 ppmw or <10 ppmw.

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XVII. ENVIRONMENTAL EFFECTS OF THE PROPOSED AMENDMENTS TO THE DIESEL FUEL REGULATIONS

This chapter discusses the environmental impacts of the proposed amendments to the California diesel fuel regulations. The proposed amendments would reduce the limit on sulfur in California diesel from 500 ppmw to 15 ppmw; revise the allowable range for the sulfur content of diesel engine certification fuel to be consistent with the proposed limit on commercial fuel; revise the certification requirements for alternative diesel formulations; adopt new standards for lubricity of diesel fuel, and adopt a new airborne toxic control measure which would extend the applicability of the diesel fuel regulations to nonvehicular diesel engines.

A. Legal Requirements Applicable to Analysis

The California Environmental Quality Act (CEQA) and ARB policy require an analysis to determine the potential adverse environmental impacts of the proposed standards. Because the ARB's program involving the adoption of regulations has been approved by the Secretary of Resources (see Public Resources Code, section 21080.5), the CEQA environmental analysis requirements are to be included in the ARB's Staff Report in lieu of preparing an environmental impact report or negative declaration. In addition, the ARB will respond in writing to all significant environmental issues raise by the public during the public review period or the public Board hearing. These responses are to be contained in the Final Statement of Reasons for the proposed amendments.

Public Resources Code section 21159 requires that the environmental impact analysis conducted by the ARB include the following:

- An analysis of the reasonably foreseeable environmental impacts of the methods of compliance;
- An analysis of reasonably foreseeable mitigation measures; and
- An analysis of reasonably foreseeable alternative means of compliance with the standard.

Compliance with the proposed amendments is expected to directly affect air quality and indirectly affect other environmental media as a consequence of the air quality impact. Our analysis of the reasonable forseeable environmental impacts of the methods of compliance is presented in sections C to H below. Regarding mitigation measures, CEQA requires the lead agency to identify and adopt any feasible mitigation measures that would minimize any significant adverse environmental impacts described in the environmental analysis.

The proposed diesel fuel regulation is needed to ensure compliance with the 2007 exhaust emission standards for new heavy-duty diesel engines and vehicles and to reduce the risk from diesel PM emissions as required by the 2000 California Risk Reduction Plan (RRP). Alternatives to the proposed amendments have been discussed in earlier chapters (VIII to XIII) of this report. ARB staff has concluded that at this time, there is no alternative means of complying with the 2007 emission standards. Other alternatives have been evaluated in the RRP.

B. California Environmental Policy Council

Health and Safety Code section 43830.8, enacted in 1999 (Stats. 1999, ch. 813; S.B. 529, Bowen) generally prohibits the ARB from adopting a regulation establishing a specification for motor vehicle fuel unless the regulation is subject to a multimedia evaluation by the California Environmental Policy Council (CEPC). The CEPC is a seven-member body comprised of the Secretary for Environmental Protection, the Chairpersons of the ARB, State Water Resources Control Board, and Integrated Waste Management Board, and the Directors of the Office of Environmental Health Hazard Assessment, the Department of Toxic Substances Control, and the Department of Pesticide Regulation. Key components of the evaluation process are the identification and evaluation of significant adverse impacts on public health or the environment and the use of best available scientific data.

Multimedia evaluation means the identification and evaluation of any significant adverse impact on public health or the environment, including air, water, or soil, that may result from the production, use, or disposal of the motor vehicle fuel that may be used to meet the state board's motor vehicle fuel specifications.

The statute provides that the ARB may adopt a regulation that establishes a specification for motor vehicle fuel without the proposed regulation being subject to a multimedia evaluation if the CEPC, following an initial evaluation of the proposed regulation, conclusively determines that the regulation will not have any significant adverse impact on public health or the environment.

It is the staff's intention that the proposed regulatory amendments will be reviewed by the CEPC prior to final adoption. The proposed changes include new vehicular diesel fuel specifications of a 15-ppmw limit for sulfur content and a lubricity standard.

C. Effects on Air Quality

Sulfur in diesel fuel contributes to ambient levels of fine particulate matter through the formation of sulfates both in the exhaust stream of the diesel engine and later in the atmosphere. Therefore, reducing the sulfur limit of California diesel to 15 ppmw will have a positive air quality impact by reducing ambient levels of particulate matter. Significant additional air quality benefits will be achieved from reductions of emissions of ozone precursors (NOx and NMHC) and toxic air contaminants (diesel PM) through the use of low sulfur diesel in diesel engines and vehicles equipped with advanced aftertreatment devices.

Implementation of the proposed amendment to the diesel fuel sulfur standard will require changes in processing that could affect emissions from the refinery. The impact of these process changes on air quality will be limited by the requirements of the California Environmental Quality Act (CEQA) and permit requirements of the air pollution control districts. These impacts are discussed in Section K of this chapter.

1. Emissions from Stationary Engines and Portable Engines

Stationary engines are not required to use fuel that meets California Air Resources Board diesel (CARB diesel) formulation requirements but virtually all use complying fuel because of California's single fuel distribution network. Also, several districts have established best available control technology requirements for diesel-fueled stationary engines that specify the use of CARB diesel. Portable engines registered under ARB's Statewide Portable Equipment Registration program are required to use CARB diesel. Therefore, the proposal to reduce the sulfur content of CARB diesel will result in lower sulfur dioxide and particulate sulfate emissions from stationary engines and off-road portable engines.

Low-sulfur diesel will also help provide added emissions benefits by enabling the implementation of measures recommended in the Diesel Risk Reduction Plan to reduce diesel PM emissions from new and existing stationary and off-road portable diesel-fueled engines. The recommended measures will benefit California's environment and reduce the public's exposure to air pollutants, particularly the toxic air contaminant diesel PM. Reductions of diesel PM emission from new stationary diesel-fueled engines would be accomplished through specific technology requirements, such as stringent diesel PM engine certification levels, use of low-sulfur diesel fuel, and application of catalyst-based DPFs, or an equally stringent performance standard.

The proposed amendment will enable the retrofitting of existing off-road portable and stationary diesel engines with sulfur sensitive catalytic after-treatment control technologies to control diesel PM emissions.

2. Emissions from Mobile Sources

The proposed amendment to lower the sulfur content limit of California diesel will provide modest reductions in emissions of sulfate particulate matter from diesel vehicles already in the fleet. A U.S. EPA on-road emission model predicts that reducing the sulfur content of California diesel from the current average of 141 ppmw to 15 ppmw would reduce sulfur oxide emissions (as SO_2) by 0.11 grams per pound (g/lb) of fuel, and sulfate PM emissions (as $H_2SO_4 : 7H_2O$) by 0.0080 g/lb of fuel. The sulfur oxide emission reductions would reduce atmospheric sulfate formation (as half NH_2SO_4 and half NH_4HSO_4) by 0.026 g/lb of fuel. Diesel PM emissions would be reduced by about 4 percent from engines with FTP cycle-specific emission rates of 0.1 grams per brake horsepower-hour.[2]

The proposed diesel sulfur limit of 15 ppmw will help generate significant air quality benefits by enabling the effective performance of advanced diesel exhaust emissions control technologies that reduce emissions of ozone precursors (NOx and NMHC) and diesel PM. These control technologies are needed to achieve the emissions reductions required for compliance with the stringent diesel engine emission standards adopted by the ARB in October 2001 for 2007 and subsequent model year medium-duty and heavy-duty diesel engines. The new emission standards represent a 90% reduction of NOx emissions, 72% reduction of NMHC, and 90% reduction of PM emissions compared to the 2004 emission standards. These standards will significantly reduce emissions of NOx, NMHC, SO_2 and PM, which will in turn result in reductions of ozone levels and ambient PM levels. Reductions in emissions of diesel PM mean reduced ambient levels of the toxic air contaminants (TAC) found in diesel exhaust and reduced public exposure to those TACs.

The proposed lubricity standard for the low sulfur diesel fuel will provide an emissions benefit. Fuels of inadequate lubricity do not provide sufficient fuel system lubrication and will contribute to excessive wear resulting in reduced equipment life and performance. New fuel injector systems, called common rail systems, use extremely high pressures and require higher levels of fuel lubricity than conventional systems. These high pressure injection systems have been developed to more accurately tailor fuel injection, provide finer fuel atomization, and improve fuel/air mixing to reduce exhaust emissions. Excessive wear in these high pressure fuel injection systems is expected to increase emissions due to compromised pump performance. These systems are vital to the success of vehicle manufacturers' efforts to produce diesel engines that meet the California light duty vehicle emissions standards.

D. Effects on Greenhouse Gas Emissions

Greenhouse gases (GHG) are predominantly comprised of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The gases differ in their atmospheric warming potential and as a result, the contribution of each gas is determined as equivalent CO_2 emissions using conversion factors approved by the Intergovernmental Panel on Climate Change; for example, methane has 21 times the warming potential of carbon dioxide.

Transportation is a large source of greenhouse gas emissions around the world. Table XVII-1 reports greenhouse gas emissions as million metric tons of carbon dioxide equivalent (MMTCO_2 Eq.) for diesel and gasoline consumption in the transportation sector in California. The CO_2 emissions estimates for diesel consumption include non-highway vehicles, ships, and trains which together are a small proportion of the total emissions. The estimates of CH_4 and N_2O emissions are only for highway vehicles.

Table XVII-1: Greenhouse Gas Emissions from Diesel and Gasoline Consumption in the Transportation Sector in 1999

Greenhouse Gas	Global Warming Potential	GHG Emissions (MMTCO_2 Eq.)	
		Diesel	Gasoline
CO_2	1	27.0	126.8
CH_4	21	+	0.4
N_2O	310	0.2	5.6

Source: California Energy Commission[84]
+ Does not exceed 0.05

Implementation of the proposed amendments could have a small net effect on global warming. The production of low sulfur diesel is expected to increase emissions of greenhouse gases, but the greenhouse effect from diesel production is expected to be substantially offset by the effect of a reduction in CO_2 emissions from use of the low sulfur fuel in diesel engines.

Emissions of CO_2 from refineries will increase due to the increased demand for energy for additional hydrogen production and additional processing to produce low sulfur diesel. Methane emissions are expected to increase due to natural gas production and distribution losses but these methane losses will be small compared to the additional carbon dioxide emissions. A smaller amount of methane and nitrous oxide will be emitted in the natural gas combustion process. Some of the extra hydrogen and the energy it represents will be in the fuel, increasing the hydrogen to carbon ratio and reducing CO_2 exhaust emissions. Appendix J provides a detailed discussion of the staff's evaluation of the greenhouse effects.

E. Impact on the State Implementation Plan

The 1994 SIP for ozone is California's master plan for achieving the federal ozone standard in six areas of the state by the federally required date. For the South Coast Air Basin, the 1994 SIP requires that the federal ozone standard be met by 2010. The SIP includes state measures to control emissions from motor vehicles and fuels, consumer products and pesticide usage, local measures for stationary and area sources, and federal measures for sources under exclusive or practical federal control. U.S. EPA approved the 1994 SIP in September 1996. The South Coast Air Quality Management District revised its part of the Ozone SIP in 1997 and again in 1999. U.S. EPA approved the South Coast's 1999 Ozone SIP revision in 2000.

Once the U.S. EPA approved the 1994 SIP and the 1999 update for the South Coast, the emissions inventories and assumptions used in the SIP are frozen. Evaluations of the impacts on the SIP of new measures or modifications to existing measures must use the same emissions inventories and assumptions used in developing the SIP.

As ARB has implemented the SIP over the last eight years, some measures have delivered more reductions than anticipated, while other measures have delivered fewer reductions due to technical or economic concerns. In some cases, measures not originally envisioned in the 1994 SIP are providing benefits that help meet the SIP emission reduction obligations. The 2007 heavy-duty diesel vehicle emission standards is one of the measures not originally included in the 1994 SIP that will provide emission reductions needed to help the state meet its SIP obligations. In the Initial Statement of Reasons[85] for the amendments to the diesel truck standards, the ARB staff quantified the benefits of these emission reductions for the South Coast which is currently the only area with a post-2007 attainment date.

The proposed diesel fuel sulfur standard is central to the success of the diesel truck standards in achieving the emissions reductions estimated for the SIP. The lower fuel sulfur content is needed to ensure the effectiveness and durability of advanced emission control technology. Without the low sulfur fuel, the control devices could not perform effectively enough to meet the new diesel truck standards.

F. Diesel Particulate Matter Emissions, Exposure, and Risk

The proposed amendment to the diesel sulfur specification is critical to the attainment of the emission and risk reduction targets in the Diesel Risk Reduction Plan. The plan would reduce public exposure to toxic air contaminants associated with diesel exhaust PM through various measures. The measures would require the retrofitting of older off-road and stationary engines with CDPFs and would establish stringent diesel PM emissions standards for new engines that would require exhaust treatment with CDPFs. Low sulfur diesel will be needed for the effective performance of these filters.

ARB staff estimated that full implementation of the recommended measures, including retrofit of locomotives and commercial marine vessels would result in an overall 85 percent reduction by 2020 of the diesel PM inventory and the associated potential cancer risk compared to baseline levels in 2000.[86] These reductions would require the combined actions of both California and the U.S. EPA to adopt and implement rules that reduce diesel PM.

The measures recommended in the Diesel Risk Reduction Plan address on-road vehicles, off-road equipment and vehicles, and stationary and portable engines. These measures include the emissions standards adopted by the U.S. EPA and the ARB for 2007 and subsequent model year new heavy-duty diesel engines and vehicles and the proposed low sulfur limit for California diesel fuel.

G. Additional Benefits of the Proposed Amendments

Full implementation of the measures in the Diesel Risk Reduction plan will result in significant reductions in diesel PM emissions and the associated risk. There are additional benefits associated with reducing diesel PM emissions. These include:

- Improved visibility with reduction of both primary and secondary particles;
- Less soiling and material damage as a result of decreased deposition of airborne diesel PM; and
- Decreased noncancer health effects associated with diesel PM.

H. Effects on Water Quality

The proposed amendment to lower the sulfur content limit of California diesel fuel to 15 ppmw should have no significant adverse impacts on water quality. One direct benefit of lowering the sulfur content limit is a reduction of emitted sulfur oxides, and particulate sulfate and consequently a reduction of atmospheric deposition of sulfuric acid and sulfates in water bodies. The low sulfur diesel will enable the use of high-efficiency aftertreatment devices to reduce NOx and diesel PM emissions from 2007 and subsequent model year vehicles and from retrofitted engines. As a result, there should be a decrease in atmospheric deposition of nitrogen and airborne diesel particles as well as the associated heavy metals, PAHs, dioxins, and other toxic compounds typically found in diesel exhaust.

The release of diesel fuel to surface water and groundwater can occur during production, storage, distribution or use. The potential sources of such releases, which include underground storage tanks, above-ground storage tanks, refineries, pipelines, and service stations, will be the same as with the current diesel fuel. Also, the mechanisms by which the diesel fuel enters surface water or migrates in the subsurface at a site will be unchanged. The factors that control the behavior of diesel in soil and water are not expected to be significantly different with the low sulfur fuel. As discussed in Appendix K, the refining process to reduce the sulfur content of diesel fuel to 15 ppmw is not expected to result in a significant change in the chemical composition of the fuel.

Also, the expected increase in additives to meet the proposed lubricity standard should not significantly change the chemical composition of the diesel fuel. Therefore, there should be no significant change in the physical or chemical properties that affect the activity of the fuel in soil and water, and any release of low sulfur diesel fuel to the environment should have no additional impact on water quality compared to the current diesel fuel.

The other proposed amendments to the diesel regulation should not have any significant adverse impacts on water quality.

I. California Environmental Quality Act Review of Refinery Modifications

Every project which is not exempt from CEQA must be analyzed by a lead agency to determine the potential environmental impacts. The lead agency is the single agency responsible for determining the type of environmental analysis CEQA requires. In addition, the lead agency must prepare the environmental review document required by CEQA. Once the lead agency is identified, all other involved agencies, whether state or local, become responsible or trustee agencies. In the case of refiners in the South Coast Air Basin and San Joaquin Valley, historically the air districts have assumed lead agency responsibility for refiner's fuels projects. In the case of the Bay Area, this responsibility has been assumed by local government agencies (city and county).

The lead agency prepares an initial study to determine whether proposed projects may have a significant adverse impact on the environment. If a project is found to have no significant impact, the lead agency prepares a negative declaration document. A mitigated negative declaration is prepared for a project with potential significant effects that can be avoided or rendered insignificant with modifications of the project.

If the initial study shows that the project may have one or more significant effects, the lead agency must circulate a notice of preparation (NOP) in anticipation of preparing an Environmental Impact Report (EIR) and must consult with responsible and trustee agencies as to the content of the environmental analysis. The lead agency first prepares a draft EIR that must include detailed information on the potentially significant environmental effects which the proposed project is likely to have, list ways which the significant environmental effects may be minimized, and indicate alternatives to the project.

A Final EIR is prepared and certified by the lead agency. If the lead agency approves the project, it must find that each significant impact will be mitigated below the level of significance where feasible, and that overriding social or economic concerns merit the approval of the project in the face of unavoidable effects. For example, in the case of refinery modifications for California Phase 2 Reformulated Gasoline, lead agencies approved these projects with a statement of overriding consideration because the regional air toxic and air quality benefits from CaRFG2 far exceeded the local air quality impacts.

J. Air District Permit Requirements

California’s programs for permitting new construction or modification of stationary sources which may emit pollutants are referred to as New Source Review (NSR) programs. Each District has its own NSR program and issues its own permits to construct and operate, but the district program must incorporate California and federal requirements for NSR. The California Clean Air Act (CCAA) mandates that there must be no increase in emissions from the permitting of new and modified sources. If potential emissions increases are above specified levels, the district requires the source to install Best Available Control Technology (BACT) to control those emissions. In addition, depending on the type and quantity of pollutants emitted, new or modified sources in California may be required to mitigate or offset any emission increases remaining after BACT has been applied.

The Federal Clean Air Act Amendments of 1990 provides state and local agencies in extreme ozone non-attainment area with the authority to exempt projects from offset requirements for emissions increases resulting from compliance with federal, state, and local air quality mandates. Under this authority, the SCAQMD in a federal extreme ozone non-attainment area chose to exempt CaRFG3 modifications from their offset requirements. The BAAQMD did not allow offset exemptions. As a result, except for CO, refineries in the BAAQMD offset all of the criteria pollutant emissions associated with their CaRFG3 projects.

K. Environmental Justice and Neighborhood Impacts

The primary environmental justice and neighborhood impacts of the proposed action would be potential additional emissions from changes in refinery operation. Refineries are expected to modify their operation to varying extents to comply with the proposed amendment to lower the limit on the sulfur content of diesel fuel. Several of the refiners responding to the staff's survey indicated that process adjustments would be minimal while others could not provide any detail until after the planning process has started. Until then, it will not be possible to determine the impact of refinery modifications on communities near refineries.

The proposed amendment to the diesel sulfur standard would be a benefit to communities as the low sulfur diesel enables the use of control systems on diesel powered vehicles to greatly reduce the exposure to diesel particulate matter and the associated cancer risks.

1. Refinery Modifications

Refinery modifications will be subject to the requirements of CEQA and air pollution control district permit requirements. CEQA requires state and local agencies to identify the significant environmental impacts of their actions and to avoid or mitigate those impacts, where feasible.

The results of an ARB staff survey suggest that refiners will most likely meet the proposed sulfur limit by increasing their hydrotreating capability. The additional energy needs for this additional processing could mean increases in combustion derived emissions such as NOx, PM, CO, and SO_2 from sources such as heaters and boilers that must increase their operation to meet the additional energy demands.

Increased energy demands could be met by adding new process heaters or by operating existing heaters at higher rates. Demands on power plants are also expected to increase. The increased fuel consumption will result in increased emissions of NOx, CO, and SO_2. The efficiency of new process units and improvements to existing units will also determine whether or not pollutant emissions increase. Also, the impact of additional hydrotreating could be reduced with the use of more selective hydrotreating catalysts that require less hydrogen. Any increases in emissions would be limited under new source review or BACT requirements of the air quality management districts.

Equipment leaks are the main source of VOC emissions from refinery equipment. Leaks typically occur at valves, pumps, compressors, flanges and connectors, pressure relief devices, open-end lines, and sampling connections. The addition of new process units and modification of existing units increase the potential for new equipment leaks. VOC emissions from a new process unit depend on the number and type of components in the unit. However, emissions from new equipment subject to BACT requirements could be lower than emissions from older equipment.

The removal of additional sulfur from diesel fuel will result in higher levels of sulfur in the sour gas stream from the hydrotreater. There is the potential for increases in SO_2 emissions from the combustion of the refinery fuel gas and the discharge of the sulfur recovery tail gas to the atmosphere.

2. SCAQMD's Environmental Assessment

The South Coast AQMD has completed a final Program Environmental Assessment (PEA) to address the potential adverse environmental impacts of the implementation of their fleet vehicle rules and the amendments to Rule 431.2 to reduce the maximum permissible sulfur content of diesel to 15 ppmw.[87] The PEA included an analysis of the impacts of refinery modifications to produce low sulfur fuel.

A "worst case" analysis was conducted because there was insufficient detailed information on the type and extent of refinery process changes required to produce 15-ppmw diesel fuel. It was assumed that all refineries would modify their processes at the same time and to the same extent and that refinery modifications would take up to two years to complete.

The conclusion from this analysis was that there would be significant adverse short-term construction-related air quality impacts from refinery modifications to implement the amendments to Rule 431.2. This would occur despite implementing all feasible mitigation measures. The SCAQMD analysis identified three main sources of emissions from refinery construction activities: 1) grading, 2) off-road mobile source equipment, and 3) on-road motor vehicles for construction worker trips. Once construction is complete, construction air quality impacts would cease while the permanent long-term TAC benefits and criteria pollutant reductions associated with the use of the low sulfur fuel would remain.

Existing sources that could be affected by the implementation of the proposed regulation have already had their permitted maximum potential to emit set by district regulations or programs such as RECLAIM. Incremental emissions from existing sources would not be considered a significant air quality impact if the emissions increases do not exceed maximum permitted levels.

New permitted sources are subject to the district's NSR regulations which require that new, modified, and relocated stationary sources install BACT. If emissions from the stationary sources in the SCAQMD's jurisdiction are greater than one pound, the source must conduct ambient air modeling and provide emission offsets. If a new source complies will all applicable SCAQMD rules or regulations, the district presumes that no significant adverse air quality impacts will result from the project.

3. Diesel Use by On-road, Off-road and Stationary Sources

Since its implementation in 1993, CARB diesel has provided significant reductions in emissions of SOx, NOx, and PM from diesel engines. Communities that are affected by emissions from diesel engines would benefit even further from the proposed amendment to reduce the sulfur content limit of CARB diesel to 15 ppmw. The proposed amendment, which would become effective in 2006, would ensure the availability of the low sulfur diesel fuel required for the effective performance of control devices needed to comply with stringent new exhaust emissions standards that will provide further emissions reductions and air quality benefits. The new emission standards represent a 90% reduction of NOx emissions, 72% reduction of NMHC emissions, and 90% reduction of PM emissions compared to the 2004 emission standards. They will apply to all medium-duty and heavy-duty diesel engines produced for sale in California in the 2007 and subsequent model years. Additional benefits will accrue through early availability of low sulfur diesel for vehicle fleets and stationary engines that are required through state or local rules to install catalytic add-on controls prior to 2006.

The proposed amendment would also enable the retrofitting of existing diesel engines with control devices that reduce PM emissions. ARB staff estimates the full implementation of the measures recommended by the RRP, including retrofit of locomotives and commercial marine vessels, will result in an overall 85 percent reduction in the diesel PM inventory and the associated potential cancer risk for 2020, when compared to today's diesel PM inventory and risk. These reductions will occur through the combined actions of both California and the U.S. EPA to adopt and implement rules that reduce diesel PM.

XVIII. Costs to Produce Low Sulfur Diesel Fuel

This chapter presents a summary of the analysis of the costs to produce low sulfur diesel fuel and of the other proposed amendments.

A. Background

The new requirements for low sulfur diesel fuel will necessitate changes in the way diesel fuel is produced. Refiners will need to perform modifications to their facilities that will ensure that they are capable of producing sufficient and consistent quantities of California diesel fuel below 15 ppmw sulfur. To accomplish this, refiners must increase their flexibility to reduce the concentration of sulfur in various diesel blendstocks. In addition, pipeline operators face new challenges in resequencing the shipping of low sulfur petroleum products (both gasoline and diesel fuel) with jet fuel, which is a high sulfur product.

In developing the cost estimates to produce low sulfur diesel fuel, staff utilized two methodologies. One method was to take a conservative approach and allocate the full economic effect of these various programs to the proposed amendments as though the proposed amendments are the only requirements to produce low sulfur diesel fuel in California. However, since both the U.S. EPA and the SCAQMD have adopted requirements for the use of this fuel, which means that virtually all of the diesel fuel produced by California refineries (both for consumption in and out of California) will have to meet the new low sulfur requirement regardless of new ARB requirements. Staff's alternative method considers this.

In addition to the use of low sulfur diesel fuel in California, staff’s proposal also consists of requirements for minimum lubricity standards for California diesel fuel, modifications to the procedures for certifying diesel alternative formulations, and modifications to the ARB’s new diesel engine and diesel vehicle certification fuel. The costs for these amendments are also discussed.

In developing the cost estimates for this chapter, staff relied on information provided by California refiners and the major California common carrier pipeline operator, documents prepared by the U.S. EPA, U.S. DOE, and the SCAQMD, specialty fuel suppliers, and conversations with the CEC staff.

B. Effect of U.S. EPA and SCAQMD Low Sulfur Diesel Fuel Regulations in California

As discussed in previous chapters, both the SCAQMD and the U.S.EPA have adopted regulations requiring the use of low sulfur diesel fuel. In California, these two regulations will effectively apply to about 75 percent of the diesel fuel used in the State. As a result, the proposed amendments will extend the requirements for the use of low sulfur diesel fuel to the remaining approximately 25 percent of the diesel fuel market.

While the two pre-existing regulations will apply to 75 percent of the California diesel fuel market, as a practical matter these existing regulations will shift a much greater portion of the California diesel market to low sulfur diesel fuel. This is because many of the modifications required to comply with the SCAQMD and the U.S. EPA low sulfur diesel regulations will, as a side benefit, also reduce the sulfur content of much of the remaining 25 percent of the California diesel fuel production. Because of this, for the low sulfur diesel fuel cost estimates provided later in this chapter, staff estimates that as much as 90 percent of these costs to produce low sulfur diesel can be attributed to the requirements of the U.S. EPA and SCAQMD regulations, and accordingly are not directly a result of the proposed amendments. However, while the majority of the costs associated with the production of low sulfur diesel fuel are not a result of the proposed amendments, staff believes it is appropriate to estimate the overall costs of all of the requirements for low sulfur diesel fuel (U.S. EPA, SCAQMD and the proposed amendments) to California.

C. Costs to Produce Low Sulfur Diesel in California

The development of cost estimates has been divided into two sections, one which describes the cost impacts of producing low sulfur diesel fuel, and a second section which describes the cost impacts of staff's remaining amendments.

In determining the overall cost estimate to produce low sulfur diesel fuel, staff has estimated that first year costs will be 2 to 5 cents per gallon. These costs are summarized in Table XVIII-1. Costs during the second year and beyond are expected to be about 2 to 4 cents per gallon, due to stability and optimization in production, with the most likely cost to be closer to 2 or 3 cents per gallon. The costs of staff's other proposed amendments are not expected to be significant.

Table XVIII-1: Overall Costs of Low Sulfur Diesel Fuel

Expenditure	1st Year (¢/gallon)	Subsequent Years (¢/gallon)
Capital Investment (including O&M)	2.2 – 2.7	2.2 – 2.7
Distribution System	0.0 – 0.2	0.0 – 0.2
Lubricity Additives	0.2 – 0.4	0.2 – 0.4
Fuel Economy Penalty	0.0 – 0.5	0.0 – 0.5
Price Sensitivity	0.0 – 1.0	--
Overall Costs	2 – 5	2 – 4

To develop the cost estimates for the proposed amendments, staff sent out two surveys to California refineries producing California diesel fuel. The first survey was sent in April of 2001 and a second survey was sent out in March of 2003. The purpose of the second survey was to allow refineries to update any changes to the status of their low sulfur diesel production plans since the submission of their original survey. Copies of the two survey forms are provided in Appendix L.

1. Methodology Used to Estimate Annualized Capital Costs

Currently, the California on- and off-road motor vehicle diesel pool has an average sulfur content of about 140 ppmw. It is expected that with the proposed limit of 15 ppmw, the average sulfur content in the California diesel pool will be reduced to about 10 ppmw. This will necessitate changes in the production and distribution of diesel fuel in California. The compliance costs calculated for this section are based on projected increases in capital expenditures and operating and maintenance (O&M) costs for California refineries and the petroleum pipeline distribution system.

Staff analyzed the responses submitted by refiners and compiled two separate capital cost estimates. One estimate is for the cost to produce California low sulfur diesel for both on- and off-road motor vehicle and stationary source applications within California. This takes a conservative approach which presumes that the proposed amendments are the only requirements to produce low sulfur diesel, and that refiners can only recover their production costs over their California production volume.

However, as previously described, since there are already existing federal requirements to produce low sulfur diesel, California refiners have the ability to recover their production costs not just over their California production but over their federal on-road diesel production as well. As such, the second cost estimate consists of the production of both California low sulfur diesel and U.S. EPA low sulfur diesel (for out-of-state consumption) by California refiners. This recognizes the larger diesel pool over which refiners will actually be able to recover their increased capital and production costs.

It is important to recognize that any changes in production costs will not necessarily be reflected in retail prices. Retail prices reflect not only production costs, but also other market conditions (supply/demand, crude oil prices, competitive market considerations, etc.) not associated with the proposed amendments, all of which will influence the final price. However, it is reasonable to assume that over time, refiners will recover the increased costs of production in the marketplace.

2. Refinery Capital Costs to Produce California Diesel Fuel

The capital costs associated with staff's proposed amendments are based on the refinery modifications proposed by refiners, as described in Chapter XIV. It is anticipated that these modifications will occur on existing equipment, which generally results in a lower net increase in costs as opposed to the installation of new process equipment.

To determine the costs associated with the production of California and also U.S. EPA low sulfur diesel fuel, staff analyzed survey responses and information supplied by California refiners, as well as documents from the U.S. EPA and the SCAQMD. Most refiners provided their cost estimates in ranges. Therefore, staff's cost analysis provides a range of cost estimates. The cumulative capital costs include estimates from the refiners surveyed, and eight of the 12 large refineries reported that capital expenditures to produce low sulfur diesel fuel should be minimal. Three refineries reported significant costs involving the installation of new hydro-desulfurization units. The refinery cost estimates were given as total capital investment for the purchase, installation, associated engineering, permitting, and start-up costs for necessary equipment.

3. Annualized Capital Costs to Produce California Diesel Fuel

Based on survey responses, refiners will incur capital expenditures of approximately $170 to about $250 million to comply with the proposed amendments and produce California low sulfur diesel. These capital expenditures are considered one-time costs that will most likely be recovered over a period of time which staff has assumed at 10 years, and at an interest rate of seven percent per year. Thus, the associated annualized capital recovery cost of the proposed amendments can be determined according to the following equation:

Capital Recovery Cost = (*Capital Cost*) x (*Capital Recovery Factor*)

Where:

Capital Cost - $170 million to $250 million
Capital Recovery Factor – 14.2% (7% per year over 10 years)

This value, calculated to range from $24 to $36 million, represents the annualized capital cost to refiners to upgrade refineries to comply with the proposed amendments.

4. Annual Operating Costs to Produce California Diesel Fuel

Along with the initial capital investment, annual O&M costs must also be considered. Most of the survey responses included annual O&M costs. Usually, these are costs associated with labor, material (such as catalysts, etc.), sulfur disposal, maintenance, insurance, and repairs associated with the new or modified equipment. When O&M costs were provided by the refiner, these numbers was used in staff's preparation of the cost estimates. However, when information for O&M costs were not included, staff conservatively estimated, based on available data from the U.S. EPA and the SCAQMD, that annual O&M costs would range from 10% to 20% of the capital expenditure.[88, 68] The O&M costs are estimated to range from $50 to $60 million per year for all California refineries.

Total annualized statewide refinery costs can be determined according to the following equation:

Annualized Statewide Refinery Cost = (*Capital Recovery Cost*) + (*Annual O&M Cost*)

Using this equation, the annualized statewide refinery costs of the proposed amendments are estimated to range from about $74 to $96 million.

5. Total Annualized Costs to Produce California Diesel Fuel

To determine the per gallon annualized statewide refinery costs, staff used the 2002 California on-and-off-road diesel fuel production[89] of approximately 2.9 billion gallons and an annual growth factor of 4 percent to grow California diesel production to a 2007 level of about 3.5 billion gallons (about 230 mbpd). Based on refiners' total annualized costs spread over 2007 diesel production, staff estimates that the annualized statewide refinery costs will be about 2.2 to 2.7 cents per gallon. These costs are shown in Table XVIII-2.

Table XVIII-2: Annualized Statewide Refinery Production Costs
(Based on California Diesel Fuel Production Only) [a,b]

Scenario	Capital Recovery Cost (cents/gallon)	O&M Cost (cents/gallon)	Total Cost (cents/gallon)
Low-Range	0.7	1.5	**2.2**
Mid-Range	0.9	1.7	**2.5**
High-Range	1.0	1.7	**2.7**

[a] Numbers may not be additive due to rounding.
[b] Based on California in-state production of 230 mbpd in 2007.

While the 2.2 to 2.7 cents per gallon is the average statewide refinery capital cost increase, individual costs to refiners will vary depending on the level of capital investment needed. A separate analysis of each refinery suggests that individual refiners may experience capital cost increases ranging from 0 to 11 cents per gallon to produce low sulfur diesel.

6. Production Costs to Produce Both California & Federal Low Sulfur Diesel Fuel

In considering the potential capital and O&M costs on a per gallon basis, it is relevant to note that while California refineries will incur costs to comply with the proposed amendments, a significant amount of these costs will be incurred even without the proposed amendments. This is because California refiners, like refiners across the country, will have to produce on-road diesel fuel and meet a 15-ppmw sulfur limit.[88] Since California refiners have to change the on-road diesel fuel production that they export (predominately to nearby states such as Nevada and Arizona), these increased capital costs will in reality be recovered over this volume of exported fuel as well as the California production. As such, it is also appropriate to estimate California annualized refinery costs estimates using this volume as well.

Staff estimates that capital expenditures to comply with both the California and federal low sulfur diesel standards are expected to be about $215 to $300 million ($45 to $50 million more than California-only capital costs). Again, using the capital recovery factor of approximately 14 percent, the annualized capital costs to refiners to produce both U.S. EPA on-road and California low sulfur diesel fuel is estimated to be between $31 to $43 million. The annual O&M costs are expected to be in the range of $60 to $70 million. Summing these costs yields annualized refinery capital costs of $90 to $115 to produce both U.S. EPA and California low sulfur diesel. Using similar methodologies to grow diesel production, an annual growth factor of 4 percent was applied to the 2002 California and U.S. EPA diesel production of approximately 4.6 billion gallons (approximately 300 thousand barrels per day or 300 mbpd). Staff estimated total diesel production in 2007 of about 5.6 billion gallons (370 mbpd). Based on these numbers, it is estimated that annualized refinery capital costs will be between 1.7 to 1.9 cents per gallon. These costs are summarized below in Table XVIII-3.

Table XVIII-3: Annualized Statewide Refinery Production Costs
(Based on California and U.S. EPA On-Road Diesel Fuel Production) [a,b]

Scenario	Capital Recovery Cost (cents/gallon)	O&M Cost (cents/gallon)	Total Cost (cents/gallon)
Low-Range	0.5	1.1	**1.7**
Mid-Range	0.6	1.2	**1.8**
High-Range	0.8	1.2	**1.9**

[a] Numbers may not be additive due to rounding.
[b] Based on California in-state production of 370 mbpd in 2007.

On an individual basis, the estimated cost increase to large refiners ranges from zero to 6 cents per gallon. As can be seen, because of the larger volume of fuel produced, and with only minor increases in the capital costs involved, the per gallon cost, both average and overall diesel production as well as refinery specific, is less than the analysis based on California diesel fuel only.

7. California Distribution System Cost Estimates

Common carrier pipelines ship over 60% of the diesel fuel distributed in California. In addition to shipping diesel fuel (both California and U.S. EPA grades), pipeline operators also ship other petroleum products such as gasoline and jet fuel. Because the pipeline must be full of petroleum products at all times, these various products are shipped next to each other, resulting in a mixing of the interfaces of the two products which creates "transmix." Transmix generally cannot be blended back into either of its products of origin, and must be either downgraded into another product, or reprocessed into another product. Much of the transmix generated (both in California and the rest of the nation) can be downgraded into U.S. EPA off-road diesel fuel.

To minimize the amount of transmix generated during the shipping of petroleum products, pipeline operators attempt to carefully select the order in which they sequence the fuels in the pipeline, based on various fuel quality specifications and fuel properties of the products. While the shipping order of fuels is often left to the customer based on shipping needs, pipeline operators usually attempt to ship products with similar sulfur contents sequentially. This serves to minimize the amount of downgrading or reprocessing of transmix.

Based on industry estimates, no capital expenditures will be needed on pipeline distribution systems in California as a result of low sulfur diesel fuel. However, based on figures generated by the U.S. EPA, current practices by pipeline operators' result in approximately 2.2% of highway diesel fuel shipments to become transmix,[88] which is usually downgraded to lower grade products (such as U.S. EPA off-road diesel). As a result of their on-road low sulfur rulemaking, U.S. EPA estimates that the amount of transmix generated from on-road diesel fuel shipments and downgraded into lower grade off-road diesel will increase to 4.4% of highway diesel fuel shipments. Staff believes that in California, because both on- and off-road diesel fuels must meet the same diesel fuel standards, this value is conservative and that the percentage of transmix will most likely be lower. This is because the amount of low sulfur diesel fuel that will be shipped as a percentage of total diesel fuel shipped within the State represents a much larger percentage in California (approaching 100%). For comparison, this number is about 40 to

50 percent outside of California. However, staff has used U.S. EPA's figure to calculate the anticipated cost increase that could be expected from the increase in transmix generated and downgraded into U.S. EPA off-road diesel fuel. Based on about 160 million gallons of transmix assumed to be generated in 2007, this cost is estimated to be about $8 million annually and represents a cost of about 0.2 cents per gallon. Again, this is a worst case estimate.

8. Lubricity Additive Impacts

As discussed in Chapter XII, California refiners voluntarily additize their current on- and off-road diesel fuel to meet suggested requirements for proper lubrication. Currently, most refiners have been using the Scuffing Load Ball On Cylinder Lubricity Evaluator (SLBOCLE) test to determine if lubricity levels are adequate. As mentioned, since there are currently no government or industry standards, the costs associated with lubricity additives can vary. Based on survey responses, refiners indicated that the current costs to additize to suggested levels of lubricity ranged from 0.1 to 0.2 cents per gallon.

With the proposed amendments of a higher lubricity standard of 520 HFRR, refiners indicated that the cost for lubricity could double because of the need for increased additive use. Staff has conservatively estimated that lubricity costs could range up to 0.2 to 0.4 cents per gallon based on this information.

9. Fuel Economy Impacts

While hydro-desulfurization of diesel fuel tends to reduce the energy content of the fuel, existing vehicle test programs comparing California produced low sulfur diesel fuel to current "typical" California on-road diesel fuel demonstrated no loss in energy density or an associated vehicle fuel economy penalty. The "typical" fuel evaluated was a blend of commercially available California diesel fuels purchased from retail suppliers in volumes that approximated their particular market-share in the State. However, because fuel economy is directly proportional to energy density, more diesel fuel may be consumed on a per mile basis with low sulfur diesel fuel as compared to current diesel formulations. Staff estimates, based on figures developed by the U.S. EIA, that the fuel economy penalty of low sulfur diesel fuel could be as high as 0.5%, resulting in an energy penalty cost of up to 0.5 cents per gallon.[90]

10. Price Sensitivity

Based on past experience, and in consultation with CEC staff, staff has estimated that certain non-recurring costs may occur in the short-term (likely the first year of implementation). These costs could result from temporary limitations on supply and production. Staff estimates that these factors could result in potential first year costs of up to 1 cent per gallon.

11. Overall Cost Estimate

As shown previously in Table XVIII-1, in determining the overall cost estimate of the staff's proposal, the staff has estimated that first year costs of the proposed amendments will be 2 to 5 cents per gallon. However, after the first year, stability in the production of low sulfur diesel fuel, as well as optimization of the new and modified equipment installed by refiners, should result in lower costs. Based on this information, costs during the second year and beyond are expected to be about 2 to 4 cents per gallon, with the most likely cost to be closer to 2 to 3 cents per gallon (based on inclusion of federal on-road diesel fuel in staff's analysis). These costs are also summarized in Table XVIII-1.

D. Impacts of the Proposed Amendments on Small Refiners

To comply with regulatory changes that require the investment of capital at refineries, small refiners are typically impacted differently than large refiners. This is because small refiners have a much smaller economy of scale due to smaller volumes of finished product over which to amortize their installed capital costs and increased O&M costs. Also, the cost to borrow capital may be higher for small refiners as compared to large refiners. This is due to the smaller refiners' generally higher operating costs, lower rates of return, smaller company diversity, and the size of total assets.

Based on information provided by small refiners currently producing California on- and off-road diesel fuel, the anticipated capital costs for California small refiners to produce low sulfur diesel fuel are estimated to be about $40 million. In addition, these refineries could incur an increase in annual O&M costs of approximately $10 million. Assuming the other non-capital costs identified previously also apply equally to small refiners, the per gallon cost to produce low sulfur diesel fuel for small refiners is estimated to be about 11 cents per gallon. This is at the high end of the range of the anticipated costs for large refiners, estimated to be from 0 to 11 cents per gallon.

E. Other Studies on the Costs to Produce Low Sulfur Diesel Fuel

In developing the production cost estimates contained in this chapter, staff also evaluated several other existing studies on the cost impacts of producing low sulfur diesel fuel. These studies included evaluations by: Mathpro, the U.S. EPA, the SCAQMD, the National Petroleum Council (NPC), Charles River and Associates and Baker and O'Brien (CRA/BOB), EnSys Energy & Systems, Inc. (EnSys), and recently, by the Energy Information Administration (EIA), an agency within the US Department of Energy. A summary of these studies is presented in Table XVIII-4.

Table XVIII-4: Summary Of Existing Studies Evaluating Production Costs Of Low Sulfur Diesel

Study	Projected Cost (¢/gallon)	Date Released	Includes California?
Mathpro[91]	4.2 – 6.1	10/99 & 08/00	No
U.S. EPA[88]	4.3 – 5.1	12/00	Yes (PADD V [a])
SCAQMD[68]	1.3 – 3.5 [b]	09/00	Yes
NPC [92]	5.8	06/00	No
CRA/BOB[70]	6.2	08/00	Yes (results are national average)
EnSys[93]	4.2 – 4.4	08/00	No
EIA[90]	5.4 – 6.8	05/01	No
Mathpro[94]	5 – 8	02/02	No

[a] Petroleum Administrative District for Defense 5, which includes California.
[b] Capital costs recalculated using methodology described in Section C.1.

With the exception of the SCAQMD study, the other studies do not directly apply to California refineries for several reasons. These include the assumptions used for current on-road sulfur levels which are higher than in California, differences in existing refinery configurations (and the necessary refinery modifications to produce low sulfur diesel fuel) between California refiners and refiners in the rest of the country, and differences in the diesel volumes over which to amortize the necessary capital costs. The U.S. EPA study does include an analysis of Petroleum Administrative District for Defense (PADD) V, which includes California. The estimated costs for PADD V to produce on-road low sulfur diesel fuel ranged from 4.3 – 5.1 cents per gallon, which is slightly higher than staff's estimate. However, this is likely a result of the other PADD V refiners requiring additional desulfurization capacity, having higher average on-road sulfur levels, and also due to a lesser volume of fuel (which includes off-road and stationary engine uses) over which to amortize capital costs as compared to California. Also, while the CRA/BOB study included California refiners, the analysis of the impacts of low sulfur diesel fuel is on the impacts on the U.S. refining industry as a whole, and is not necessarily applicable to California refiners for the reasons just discussed.

The most applicable analysis of the potential impacts of low sulfur diesel fuel to California refiners has been developed by the SCAQMD in association with the development of their amendments to Rule 431.2. In their analysis, the SCAQMD estimated capital cost numbers of $70 to $315 million, and identified a projected volume of about 1.9 billion gallons of diesel fuel sold within the SCAQMD in 2006. However, in evaluating the cost numbers provided in the SCAQMD's analysis, it is necessary to recalculate the annual costs based on the methodology used in section C.1 of this chapter. When these costs are amortized according the ARB's methodology, and using the O&M costs developed by the SCAQMD, the costs to produce low sulfur diesel fuel in the SCAQMD are 1.3 – 3.5 cents per gallon, which is consistent with the anticipated capital costs identified in this report.

F. Effects of the Staff Proposal on Fuel Prices

With respect to retail diesel prices, it is very difficult to predict what will occur in the marketplace. Supply/demand, crude oil prices, competitive market considerations, etc. predominately influence diesel prices. However, it is reasonable to assume that over time, refiners will recover the increased costs of production in the marketplace. With this assumption, and the staff's estimate that the long-term increased production cost of low sulfur diesel fuel will be from two to three cents per gallon, it is reasonable to assume that this increase in production cost will, on average, be reflected in retail diesel prices. This assumption does not attempt to predict changes in fuel taxes and refinery product markup. In reality, since both the U.S. EPA and the SCAQMD have adopted requirements for the use of this fuel, most of the costs identified in this chapter will be incurred by refiners regardless of staff's proposal. However, this chapter assumes a conservative approach and has allocated the full economic effect of these various programs to the proposed amendments. Refiners will recover cost through increased diesel fuel markup if competitive conditions allow it. However, predictions of 2006 and beyond petroleum product markup and pricing are beyond the scope of this document.

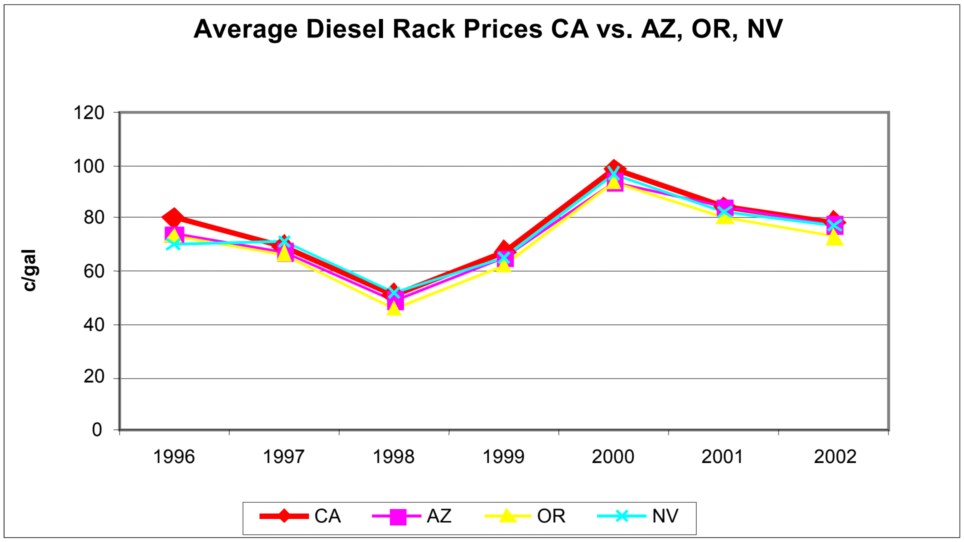
It is very difficult to predict the market for diesel pricing and volatility. However, the proposed amendments should not impact the ability of California refiners to supply sufficient quantities of diesel fuel to the California market. The ARB recent refinery survey suggests that sufficient diesel refinery capacity already exists. In addition, the implementation of the federal on-road low sulfur diesel regulations, adoption of the California diesel fuel regulations by the state of Texas, and the ability of out-of-state refiners to produce diesel fuel meeting California standards should provide even greater diesel fuel availability to the State. As a result, the overall diesel production system - consisting of California refineries and imports - should be no more subject to supply disruptions than today. In fact 2006 market conditions may be better able to readily adjust to any California diesel production requirements that occur in the future.

1. Evaluation of Fuel Prices Between California and Other States

a) Wholesale & Spot Prices

In comparing diesel fuel prices between states or regions, the best indicator of price is the wholesale diesel price. The wholesale price is the price of fuel before taxes and transportation charges have been applied. As can be seen in Figure XVIII-1, California wholesale diesel prices in California and surrounding states (Arizona, Nevada and Oregon,) have generally closely tracked one another.[95] In general, there is very little difference in wholesale diesel prices between California and surrounding states. This would suggest that there is very little difference in the market between California diesel fuel and U.S. EPA on-road diesel fuel between California and the surrounding states.

Figure XVIII-1
Diesel Wholesale Prices Between California and Surrounding States
(1996 through 2002)



Source – Oil Price Information Service (OPIS)

As shown in Table XVIII-5, over this same period, the average California wholesale diesel price was about 69 cents per gallon. This compares with an average wholesale diesel price of 67 cents per gallon in Arizona and Nevada, and an average wholesale diesel price of 65 cents per gallon in Oregon over this same period.

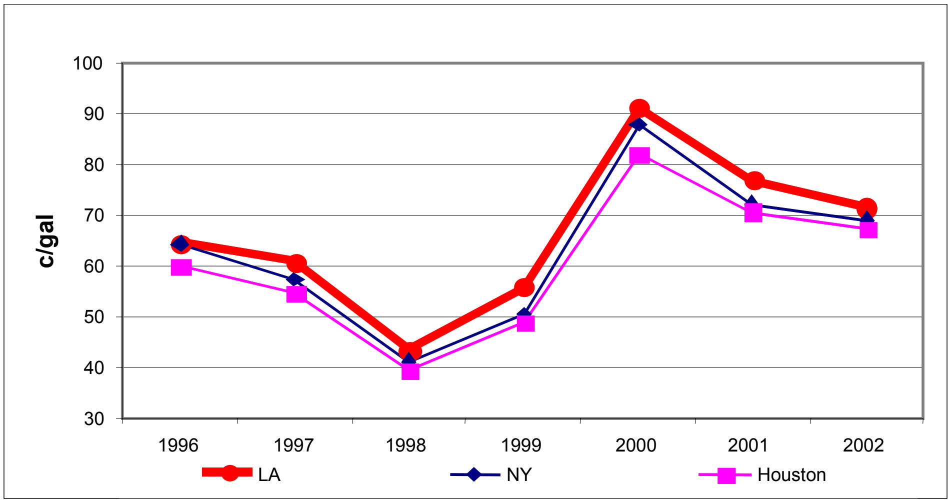
Table XVIII-5: Average Diesel Wholesale Price in California and Surrounding States (1996 through 2002)

Year	Average Wholesale Price (cents/gallon)			
	CA – Avg.	AZ – Phoenix	NV – Reno	OR – Portland
1996	77.75	72.19	70.26	71.33
1997	67.51	65.63	69.58	64.65
1998	49.35	47.22	50.03	44.13
1999	65.57	62.75	63.33	60.12
2000	96.43	92.06	94.90	91.64
2001	81.94	82.38	80.46	78.32
2002	76.57	75.73	75.35	70.81
1996 - 2002	**68.75**	**66.80**	**67.49**	**64.78**

Source – Oil Price Information Service (OPIS)

In evaluating prices between California and the rest of the nation, this same trend also applies. As can be seen in Figure XVIII-2, diesel spot prices in California have been comparable when compared to those around the nation (based on prices in New York Harbor and the Gulf Coast), and these prices have tracked consistently nationwide over this period.[96] Spot prices are similar to wholesale prices, where the spot price is usually the commodity price paid on any given day for "a one-time open market transaction" of fuel.

Figure XVIII-2
Diesel Spot Prices LA vs. NY and Houston (1996-2002)



Sources: EIA - DOE

As shown in Table XVIII-6, the differences in spot prices between Los Angeles and New York, for the period 1996 to 2002, was about 3 cents per gallon. Differences in diesel spot prices between Los Angeles and Houston (Gulf Area) for this same period were about 6 cents per gallon. Similar to the comparison between California and surrounding states, this would suggest that there is very little difference in the market between California diesel fuel and U.S. EPA on-road diesel fuel between California and the rest of the nation.

Table XVIII-6: Average Diesel Spot Price in California, New York, and Gulf Coast (1996 through 2002)

Year	Average Diesel Spot Price (cents/gallon)					
	LA	NY	Difference	LA	Gulf	Difference
1996	64.7	64.6	0.1	64.7	60.2	4.4
1997	61.1	57.5	3.6	61.1	54.9	6.2
1998	43.6	41.4	2.1	43.6	39.4	4.1
1999	56.1	50.6	5.5	56.1	48.9	7.2
2000	91.4	87.9	3.4	91.4	82.1	9.3
2001	77.2	72.5	4.7	77.2	70.9	6.4
2002	71.7	69.3	2.4	71.7	67.5	4.2
Average 1996-2002	**66.5**	**63.4**	**3.1**	**66.5**	**60.6**	**6.0**

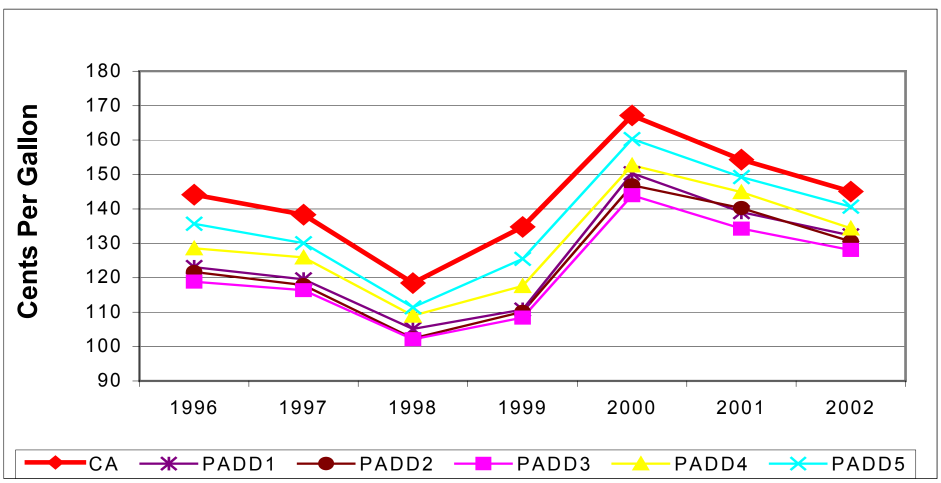
Sources: EIA - DOE

As can be seen by the above graphs, historically, diesel prices (excluding taxes and transportation charges) have remained relatively similar across the nation. As low sulfur diesel is implemented nationwide, staff believes that the price differentials discussed above may be mitigated as low sulfur diesel production costs in the rest of the country increase more significantly than in California (U.S. EPA estimated production costs estimates of 4 to 5 cents per gallon).[88] As a result, California wholesale prices in comparison with other States should remain consistent or even perhaps lower than they have been historically.

b) Retail Prices

Unlike diesel wholesale prices, retail prices also include both federal and state excise taxes, transportation costs, and the retailer's operating costs which likely include a percentage for profit. Aside from state and other government taxes, which are fixed, the transportation costs and retailer's operating costs, along with supply and demand and other competitive market considerations, create a market environment that has a large influence on the retail price. As shown in Figure XVIII-3 and Table XVIII-7, retail diesel prices vary significantly between Petroleum Administration Defense Districts (PADD).[96] In general, PADD 3 (representing the Gulf Coast region) diesel retail prices were the lowest while California, a part of PADD 5 (representing the Western United States), had consistently higher prices compared to the other regions.

Figure XVIII-3
Average Diesel Retail Prices in PADD I - V and California (1996-2002)



Source – Energy Information Administration

As shown in the bottom of Table XVIII-7, the average retail price from 1996 to 2002 for PADD 3 was about $1.21 cents per gallon while in PADD 5 the average retail price was about $1.36 cents per gallon, a 15 cent difference. During this same period, the average retail price in California was $1.43 cent per gallon, a 7 cent difference between California and the rest of PADD 5.

Table XVIII-7: Average Diesel Retail Prices in PADD's I Through V (1996 through 2002)

Date	PADD1	PADD2	PADD3	PADD4	PADD5	CA
1996	123.1	121.6	118.9	128.5	135.7	144.1
1997	119.5	117.9	116.3	125.9	130.0	138.3
1998	105.1	102.3	102.1	109.0	111.4	118.4
1999	110.7	110.1	108.4	117.6	125.5	134.8
2000	150.3	146.8	144.0	152.7	160.3	167.2
2001	139.0	140.2	134.2	144.9	149.3	154.3
2002	132.2	130.5	128.0	134.3	140.7	145.0
Avg. 1996 - 2002	125.7	124.2	121.7	130.4	136.1	143.2

Source – Energy Information Administration

c) Cost Benefits of the Proposed Low Sulfur Diesel Requirements

Staff has identified several cost benefits to the proposed amendments that have not been quantified in the above production cost estimates. These benefits will be felt both initially, and over the course of the life of the program.

Initially, diesel fuel users are expected to see a decrease in engine wear as a result of low sulfur diesel fuel. This is because fuel sulfur tends to produce acidic compounds that increases the corrosion wear of engine components. In addition, lower sulfur fuels should increase the life of diesel engine lubrication oil, as fuel sulfur tends to increase the acidification of engine lubricating oils resulting in loss of pH control. By reducing the diesel fuel sulfur content, it is expected that the interval between oil changes can be extended, leading to a cost saving to diesel engine operators. While it is difficult to quantify these benefits, we expect these benefits to be realized immediately upon implementation of the proposed amendments.

In addition, with the implementation of both new diesel engine certification standards as well as the retrofit of existing diesel engines, the use of emission control equipment will become much more commonplace in diesel powered vehicles and equipment than is the case today. The effects of low sulfur diesel fuel should improve not only the efficiency of this equipment, but also its durability. This should result in longer useful equipment life and decreased maintenance and replacement costs. These benefits are also difficult to quantify, and likely will not be realized until the new standards and retrofit requirements become applicable.

G. Cost of the Other Proposed Amendments

In addition to the use of low sulfur diesel fuel in California, staff's proposal also consists of requirements for minimum lubricity standards for current California diesel fuel, modifications to the procedures for certifying alternative diesel formulations, and modifications to the ARB's new diesel engine and diesel vehicle certification fuel.

1. Proposed Lubricity Standards for Current California Diesel Fuel

As discussed previously, California refiners voluntarily additize their current on- and off-road diesel fuel production to meet industry standards (meeting a minimum lubricity standard of about

3000 SLBOCLE). Based on information provided to the ARB by refiners, this cost is typically about 0.1 to 0.2 cents per gallon. This is consistent with the U.S. EPA's estimate of about 0.2 cents per gallon to additize on-road low sulfur diesel fuel nationwide.

Staff's proposed amendments would require that all California diesel fuel be additized to this level. While the proposed amendment would result in an additional regulatory requirement on the production of California diesel fuel, in practice there should be no additional costs associated with the proposed amendment since refiners are currently additizing to this level on a voluntary basis, and the proposed amendment will not impose any additional requirements above this level on refiners.

2. Proposed Modifications to the Procedures for Certifying Alternative Diesel Formulations

Staff expects that the costs associated with the changes to the procedures for certifying alternative formulations will be minimal. This is because the proposed amendments simply require that the reference fuel be better defined in terms of the properties of the commercial fuels that the refinery produces. This amendment should not require the refiner to perform any additional testing or formulating on the reference fuels during the certification process, nor does it establish any new criteria for certifying alternative formulations.

3. Proposed Modifications to the Certification Fuel for Diesel Engines and Vehicles

Staff also expects that the costs associated with the proposed amendments to the diesel engine and diesel vehicle certification fuel will also be minimal. This is because certification fuels are almost exclusively produced from specialty fuel providers, who blend fuels from a variety of petroleum blendstocks with precisely known properties. The change to the sulfur content range in the certification fuel should not hinder the ability of these specialty fuel providers to continue to produce certification fuels for costs that are similar to the costs already associated with these fuels. They will simply have to use blendstocks with lower sulfur contents. In conversations with specialty fuel providers, they have indicated that they do not expect the costs to produce diesel certification fuels will change significantly with the proposed amendments, as the U.S. EPA has also changed their diesel engine and vehicle certification fuel to require a lower sulfur content. However, even if there were slight increases in the cost to produce and supply diesel certification fuels, fuel costs as a percentage of total new engine or vehicle certification costs are minor.

H. Costs of Other Alternative Proposals Considered

In developing the proposed amendments, staff considered two alternative proposals. One would have not changed the existing California diesel fuel standard, and the other would have proposed a lower fuel sulfur content limit than is contained in staff's present proposal.

The first alternative, not changing the existing California diesel fuel standard, would not provide any significant cost savings to refiners, but would come at the expense of significant environmental benefits that the existing proposal provides. This is because, as stated previously, both the U.S. EPA and the SCAQMD have established rules for the sulfur content of diesel fuel. The U.S. EPA rule applies to all on-road diesel fuel sold in California, and the SCAQMD rule further applies to off-road and stationary source fuel sold in the South Coast Air Basin. These two rules apply to about 75% of the diesel fuel sold in California, and have the same costs associated with them as described in section C.1 of this Chapter. Since most refiners have indicated that they would convert all of their production over to low sulfur to comply with these regulations, the actual incremental cost of staff's proposal is very small. However, nearly 2 tpd of SOx and PM emission benefits from off-road and stationary sources, as well as the potential to retrofit these sources for additional PM and NOx control, would not be realized.

The second alternative considered would have further reduced the fuel sulfur limit below staff's current proposal. Staff's evaluation of this proposal concluded that reductions in fuel sulfur levels below 15 ppmw would result in a significant cost increase with little or no increase in benefits. The increased cost is associated with the difficulty in removing and maintaining sulfur levels as the concentration of sulfur approaches zero. Reductions in diesel sulfur levels below 15 ppmw would require the installation of duplicate refinery desulfurization capacity with no increase in diesel fuel capacity over which to amortize the additional costs. This would mean that the capital costs to comply with a lower sulfur level would likely be in excess of $600 million, and would likely increase diesel fuel production costs by about 8 cents per gallon. This is consistent with a Mathpro analysis that concluded that the cost to produce 2 ppmw sulfur diesel fuel would be 9 cents per gallon[91]. The reason that staff would expect the production costs to be near the upper bound is that refiners would not be able use additional desulfurization capacity on a regular basis. In addition, this additional desulfurization capacity would not translate into increased refinery capacity, and would likely require additional hydrogen production to supplement any new desulfurization capacity. Altogether, with these additional refinery costs incurred, the diesel particulate reduction efficiency of Diesel Particulate Filters (DPFs) would not appreciably increase.

I. Cost-Effectiveness

Most of staff's proposed amendments and associated costs occur in order to enable the application of diesel exhaust after-treatment technology to existing diesel powered engines and vehicles to provide significant future reductions in PM and NOx emissions. As such, it is not feasible to estimate the cost-effectiveness of staff's proposed amendments of these expenditures by using traditional methods commonly used in assessing air quality regulations.

XIX. ECONOMIC IMPACTS OF THE PROPOSED AMENDMENTS TO THE DIESEL FUEL REGULATIONS

This section describes the economic impacts of the production and use of low sulfur diesel fuel on the economy of the State, petroleum, agricultural, and transportation sectors, and operators of stationary diesel engines. In evaluating the economic impacts, staff used, where possible, both an estimate of the direct costs on a typical business, as well as the combined effects on the entire economic sector.

A. Potential Impacts on the California Economy

As discussed in the previous chapter, the proposed statewide requirements for the use of low sulfur diesel fuel are expected to have a minimal impact on the production costs of diesel fuel in California. This is due to existing requirements of the U.S. EPA and the SCAQMD, which apply to approximately 75 percent of the diesel fuel consumed in the state. Based on staff's analysis, the cumulative impact of these regulations could be expected to increase fuel costs to diesel end users in California by up to about $110 million per year in 2007. This is not expected to have a significant impact on the overall California economy.

The economy-wide impacts of the production of low sulfur diesel fuel were estimated using a computable general equilibrium (CGE) model of the California economy. This model is a modified version of the California Department of Finance's Dynamic Revenue Analysis Model (DRAM) developed by researchers at the University of California, Berkeley. The ARB model called E-DRAM describes the economic relationships between California producers, consumers, government, and rest of the world. The model uses the capital requirements of $70 to $250 million, and a worst case diesel fuel production cost increase of 4 cents per gallon to estimate economic impacts.

1. Potential Impacts on Petroleum Sector

As discussed in Chapter XVIII, diesel refiners are expected to recover their compliance expenditures in the long run. These expenditures include capital investments of $170 to $250 million dollars for equipment and hardware modifications, and annual O&M costs of $54 to $60 million per year.

Staff conducted an overall economic impact of the production of low sulfur diesel fuel on the California petroleum industry assuming that the industry is unable to pass on the compliance costs initially using E-DRAM. The model projects a minor contractionary impact on the industry. The industry output would fall by about $52 million or 0.2 percent and employment by about 61 jobs, or 0.3 percent.

2. Potential Impacts on Agricultural Sector

Diesel fuel is used in agriculture to power a variety of equipment, including irrigation pumps, tractors and combines, light-duty trucks, electrical generators, and refrigeration equipment. As such, diesel fuel is an integral part of the operation of a modern farm.

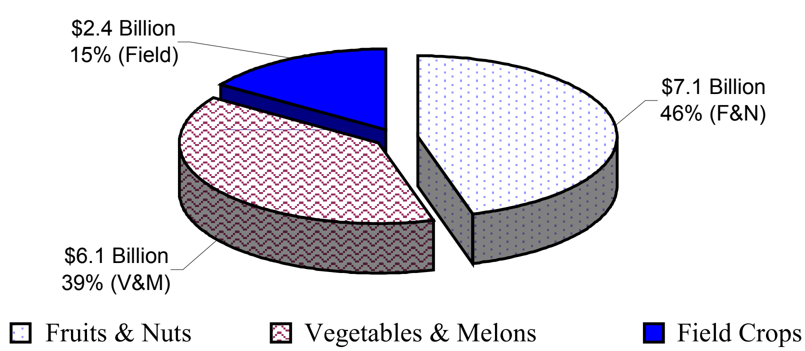
It is estimated that the total impact of the requirement to use low sulfur diesel fuel on the agricultural sector will increase diesel fuel costs by about $23 million annually. This represents a decline of about 0.05 percent in the value of the California agricultural production, and a 0.08 percent increase in agricultural operating costs.

In estimating the potential economic impacts of low sulfur diesel fuel on the agricultural sector, staff first identified the principal harvested commodities of the State, based on both the numbers of harvested acres as well as total commodity values. For the purposes of this analysis, harvested commodities are considered crops that are grown and either picked or harvested by hand or machine. Staff also identified principal livestock commodities, based on their commodity values, to estimate the potential economic impacts of low sulfur diesel to this category within the agricultural sector.

a) Harvested Commodities

Based on data from the California Department of Food and Agriculture (CDFA) California's total production value from agricultural commodities was $27.6 billion in 2001.[97] Of that, $15.7 billion, or approximately 60 percent, was attributable to harvested commodities. As shown in Figure XIX-1, harvested commodities can be broken down into three categories. Figure XIX-1 shows the gross product income from each category in 2001. Harvested commodities include fruits & nuts, such as almonds, strawberries, and grapes; vegetables & melons, including cantaloupe, tomatoes, and lettuce; and field crops, such as cotton, wheat, and hay. These designations are based on a categorization scheme used by the University of California, Davis (UCD) Cooperative Extension. While these commodities are grown all over the state, they are predominately grown in the Central Valley.

Figure XIX-1 California 2001 Gross Harvested Agricultural Income



Source: CDFA 2002 Resource Directory

As part of staff's analysis, ARB staff obtained and evaluated information from studies developed by the UCD Cooperative Extension Department. These studies contained information on typical fuel costs for each of the studied commodities on a per acre basis and total operational costs to produce each of the commodities.[98] With this data, the percentage of costs attributable to both diesel and gasoline, as a portion of the total operating costs, for each commodity was determined.

Because many of the commodities had specific data from several different years, data was normalized and adjusted for inflation to year 2001 dollars based on inflationary factors from the Consumer Price Index (CPI).[99] In developing the potential impacts of the use of California low sulfur diesel on farmers, staff estimated that a 3 cent increase would be felt. Please refer to Appendix M for a more detailed explanation and complete breakdown of the commodities studied.

As can be seen in Table XIX-1, the three evaluated harvested commodity categories have a value of greater than 80% ($12.6 billion) of the total 2001 agricultural harvested commodities total of $15.7 billion. For each commodity category, the average diesel use, diesel fuel costs, total operational costs on a per acre basis, and impact of a 3 cent increase in diesel fuel cost are shown.

As shown in Table XIX-1, staff estimates that a 3 cent increase in diesel fuel will result in an overall average increase in total operating costs for harvested commodities of 0.05 percent. Specific agricultural impacts for each harvested commodity category are also shown in this table.

Table XIX-1: Impacts of a Four Cent Increase in Diesel Fuel Prices on Various Agricultural Commodities (2001 Values)

Crop Type	Value of Crop Sector Analyzed (Billions)	Average Diesel Use (gal/acre)	Average Diesel Fuel Costs[2] (per acre)	Average Total Operating Cost (per acre)	Average Diesel Cost Increase[3] (per acre)	Average Increase in Operating Costs (per acre)
Field	$ 1.7	23.2	$ 19.3	$ 511	$ 0.70	0.15%
Fruits/Nuts	$ 6.2	30.2	$ 25.1	$ 5,578	$ 0.91	0.02%
Vegs/Melons	$ 4.7	41.9	$ 34.8	$ 4,518	$ 1.26	0.04%
Total[1]	$ 12.6	33.1	$ 27.5	$ 4,176	$ 0.99	0.05%

[1] Total 2001 agricultural harvested commodity value of $15.7 billion dollars.
[2] Assumes 2001 average diesel wholesale costs of $0.83 per gallon.
[3] Assumes average diesel wholesale cost increase of 3 cents per gallon.

Because of differences in the manner and processes in which various types of crops are grown, diesel use ranges considerably from about 11 gallons per acre for prunes to about 81 gallons per acre for strawberries. Farmers growing commodities that use a higher amount of diesel per acre will have correspondingly higher diesel fuel costs on a per acre basis. Similarly, diesel costs as a percentage of total operating costs also varied widely from 0.3 percent (strawberries) to almost 7 percent for wheat. As can be seen from the example of strawberries, while diesel use on a per acre basis can be substantial for a particular crop, an increase in diesel fuel costs does not necessarily translate into a significant cost increase as a function of total operating costs. For strawberries, a 3 cent increase in diesel fuel costs represents only a 0.01 percent increase in total operating costs for strawberry growers. Similar results for other high diesel use crops such as nectarines and tomatoes used for processing were also observed.

In terms of each of the harvested commodity categories, fruit and nut growers have the highest product value of the three categories, valued at $7.14 billion. As can be seen in Table XIX-1, staff was able to capture 87 percent of that value, or $6.2 billion. When compared to the other categories, fruits and nuts had the highest average operating cost, on a per acre basis. At approximately $5,600 per acre, staff's analysis shows that operating costs can vary significantly between commodities, from $9,737 to $24,729, for nectarines and strawberries on a per acre basis. Staff estimates that a 3 cent increase in diesel fuel costs will result in a 0.02 percent increase in total production costs.

As can be seen in Table XIX-1, staff was able to capture 77 percent, or $4.7 billion of the vegetable and melon category total of $6.1 billion. Compared to fruit and nut growers, vegetable and melon growers have a slightly lower average operating cost of approximately $4,500 per acre. On a per acre basis, the cost impacts of diesel will be greater for vegetable and melon producers because of a higher volume of diesel usage (almost 42 gallons per acre). On average, staff estimates that a 3 cent increase in diesel fuel will effect average total operating costs by 0.04 percent for the vegetable and melon category.

Within the field crop category, staff was able to capture $1.7 billion of $2.4 billion, or 70 percent of the category total. Among the three harvested commodities categories, field crops generally will feel the largest economic impact and percentage increase in total due to a 3 cent increase in diesel fuel prices. Because of tillage practices, soil types, and irrigation practices common with field crops, fuel costs as a percentage of total operating costs are significantly higher for field crops than for either fruits and nuts or vegetables and melons, even though the amount of diesel fuel used is only about 23 gallons per acre. Staff estimates total average operational cost increases of 0.15 percent for field crops.

b) Livestock Commodities

In California, livestock commodities total $7.3 billion of the total $27.6 billion state agricultural value. Of the livestock products and commodities, staff evaluated dairy milk and cow/calf beef production which accounts for approximately $6 billion of the livestock commodity total of $7.3 billion. This represents over 82 percent of the livestock sector. Data for milk production was obtained from the California branch of the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS).[100] However, no information was available from the California Agricultural Statistics Service (CASS) for the costs of cow/calf beef production in the state. As such, staff utilized source studies on beef production from the Oregon State University Extension Agricultural and Resource Economics Department in their analysis.[101]

ARB staff evaluated information from studies developed by CASS on typical fuel costs for the production of dairy milk. Studies developed by the Oregon State University Extension were used to analyze the typical fuel costs of cow/calf beef production. Staff has assumed that the costs of production of beef are similar in both California and Oregon. From these studies, staff was able to obtain the total operational costs to produce each of the commodities. From the operational cost, the percentage of costs attributable to diesel fuel use as a portion of the total operating costs for each commodity was derived. It should be noted that none of the source studies for dairy milk and cattle production neither defined nor categorized fuel costs (i.e. gasoline and diesel). Therefore, staff conservatively assumed that all fuel, lube, tractor, and truck costs were directly attributable to diesel fuel use.

Because most of the studies on cow/calf beef production had specific data from several different years, data was normalized and adjusted to reflect inflation to year 2001 dollars based on inflationary factors from the CPI.[99] Dairy milk data obtained from CASS already represented information for 2001. In further developing the potential impacts of the use of California low sulfur diesel on dairy milk and cattle producers, staff conservatively estimated a 3 cent increase would be experienced. Appendix M provides a more detailed explanation and complete breakdown of the commodities studied.

Based on available data, the average total operating cost for dairy farmers is $49 per cow per month, or $584 per cow per year. The cost impacts of diesel fuel use on dairy production as a percentage of total operating costs ranged from about two to almost eight percent with an average of nearly 6 percent. These impacts on dairy operations are similar to some commodities in the field crop sector such, as wheat. Assuming a 3 cent increase in diesel costs, the average percentage increase associated to total operating costs is less than 0.2 percent.

For beef producers, data analyzed from the Oregon University Extension studies also showed minimal production cost increases associated with a 3 cent increase in diesel fuel costs. The average impact on total operating costs was 0.14 percent. It should be noted that the method of reporting for cow/calf beef producers showed that operators with smaller numbers of cows (i.e. 50 cows) had relatively higher average costs when compared to operators that had much larger operations (i.e. 500 cows). While the average impact on total operating costs was about 0.14 percent, the costs for cow/calf beef operations ranged from about 0.04 percent for larger operations to 0.37 percent for smaller operators. Appendix M provides additional information about staff's analysis of these commodities.

c) Statewide Agricultural Sector Impact

The overall economic impacts of the production of low sulfur diesel fuel on the California agricultural sector were also estimated using E-DRAM. Since the agricultural sector uses significant quantities of diesel fuel in its operations, the increased costs associated with the use of low sulfur diesel fuel are expected to have a contractionary impact on the sector. The E-DRAM model projects that the use of low sulfur diesel fuel could reduce output in the California agricultural sector by an average of about $27 million and employment by 170 jobs. This represents a decline of about 0.05 percent in the value of the California agricultural production and a decline of 0.04% in employment.

3. Potential Impacts on Transportation Sector

Staff also estimated the costs of the use of low sulfur diesel fuel on a heavy-duty truck operator. This analysis was based on information in the ARB's EMFAC 2002 emissions model data.[102] These costs were based on an average daily fuel use of about 32 gallons per day for a heavy-duty diesel truck used in ARB's emission model EMFAC2002, operating 7 days per week and traveling about 70,000 miles annually. Using this data, staff estimates that a 3 cent per gallon price increase in diesel fuel could result in additional annual cost to the operators of heavy-duty trucks of about $350 per truck. It should be noted that as discussed earlier, this cost for on-road diesel fuel would be incurred even without any action by the Board because of the existing federal requirement for low sulfur on-road diesel fuel.

In addition, while the numbers derived using the data in EMFAC 2002, staff also estimated the costs to a heavy-duty truck owner/operator who drives longer distances than those used in the previous example. For this analysis, it is estimated an owner/operator drives 400 miles per day, at 4.6 miles per gallon, and operates their vehicle 5 days a week, 52 weeks per year. Under this scenario, annual costs of a 3 cent increase in diesel fuel prices would result in additional fuel costs of about $680 per year. Based on information from the American Trucking Association (ATA), fuel, equipment, and other costs, account for nearly 63% of total operating costs based on a typical heavy-duty 18 wheel tractor-trailer traveling 100,000 miles per year and earning $110,000 per year for a typical trucking company.[103] Using these figures for operating cost estimates, staff estimates that the use of low sulfur diesel fuel could impact total operating costs for a typical truck driver by 0.6 percent, based on a 3 cent increase in diesel prices.

It is important to note that while the requirements for low sulfur diesel fuel may result in likely diesel fuel production cost increases of 2 to 3 cents per gallon, these are not necessarily the cost increases that will be reflected in retail diesel prices. As described earlier, retail prices are a function of many different factors, and the impacts on retail prices is difficult to predict. However, as a result of the U.S. EPA's development of nationwide low sulfur diesel fuel standards, staff believe that the nationwide costs of producing on-road diesel fuel will increase more significantly outside of California, thereby "leveling the playing field" for California trucking and transportation companies as their fuel costs are compared to the rest of the nation. In addition, staff also believes that the ability of refiners and distributors to import diesel fuel during times of tight supply will be increased both with the nationwide availability of low sulfur diesel fuel and the other flexibility provisions contained in staff's proposal.

A macroeconomic impact analysis of the use of low sulfur diesel fuel on the California transportation sector was also conducted using E-DRAM. The model projects that the use of low sulfur diesel fuel would reduce output in the California transportation sector by approximately $26 million and employment by 258 jobs. This translates into a decline of less than 0.06 percent in the output value of the California transportation sector and its employment.

4. Stationary Engines Retrofitted with Diesel Particulate Traps

Because the Board has identified stationary diesel engines as a category of engines to be retrofitted with diesel particulate traps as part of the DRRP, staff has estimated the impacts of the use of low sulfur diesel fuel on the operators of these engines.

While there are some stationary diesel engines permitted to use high sulfur (greater than 500 ppmw sulfur) U.S. EPA off-road diesel fuel, in reality most stationary diesel engines in the state are currently using fuel meeting the California on-road diesel fuel standards. This is because very limited quantities of U.S. EPA off-road diesel fuel are distributed and available for use within California. For stationary diesel engine operators who are currently using California on-road diesel fuel, the cost impact from the use of low sulfur diesel fuel is expected be 2 to 3 cents per gallon.

5. Taxable Diesel Fuel Sales

The requirements for the use of ultra low sulfur diesel fuel in California are also not expected to have any impact on taxable diesel fuel sales in California, nor are they expected to shift future taxable sales of diesel fuel to neighboring states.

As discussed in Appendix N, while there are incentives due to different excise tax rates between states for diesel fuel users to purchase out of state fuel, this does not appear to have had much impact on taxable diesel fuel sales in California. As can be seen in Figure XIX-2 and shown in Table XIX-2, taxable sales in California steadily increased over the period 1995 through 2001[104] from a daily average of 138 Mbpd in 1995 to an average of 173 Mbpd in 2001, an increase of 35 Mbpd or an annual increase of 3.9 percent. Similarly, Arizona, Nevada and Oregon also saw increases in taxable diesel sales during this same period, with Arizona's average taxable diesel sales increasing by 12 Mbpd (6.6 percent annually), Nevada's by 6 Mbpd (7.5 percent annually), and Oregon's by 4 Mbpd (2.7 percent annually).

Figure XIX-2
Taxable Diesel Fuel Sales from 1995 - 2001

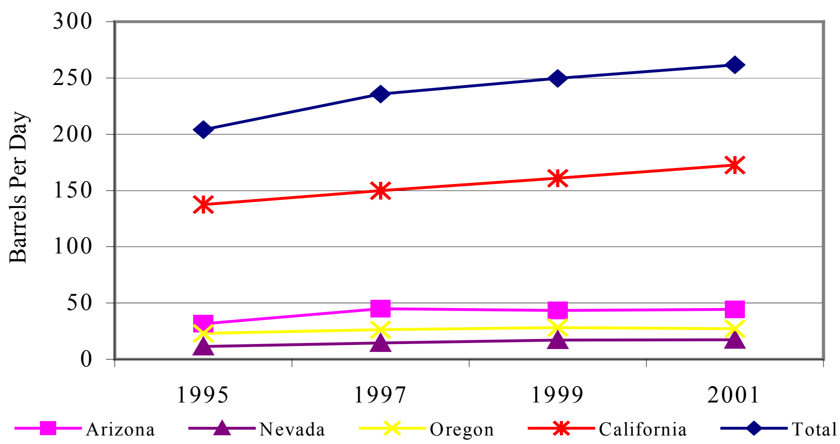


Table XIX-2: Taxable Diesel Fuel Sales in California and Nearby States from 1995 – 2001
(Thousands of Barrels)

State	1995		1997		1999		2001	
	MBPD	% of total	MBPD	% of total	MBPD	% of total	MBPD	% of total
Arizona	32	15.5%	45	19.1%	43	17.4%	44	16.9%
Nevada	12	5.7%	15	6.2%	17	6.9%	18	6.7%
Oregon	23	11.4%	26	11.1%	28	11.3%	27	10.4%
California	138	67.5%	150	63.6%	161	64.5%	173	66.0%
Total	204	100.0%	236	100.0%	250	100.0%	262	100.0%

* Numbers may not be additive due to rounding.

However, while as an annual percentage, the increase in taxable diesel sales were greater in Arizona and Nevada than in California, their relative proportions of the total taxable diesel sales in the four states as shown in Table XIX-2 changed less significantly. This indicates that no large shift in diesel sales is occurring from California to other states.

In considering these numbers, it is important to recognize several factors that could lead to the higher rate of increased taxable sales in Nevada and Arizona compared to California. Based on data provided by the US Census Bureau[105] for the periods 1990 to 2000, and shown in Table XIX-3, population increases in Nevada and Arizona have been significantly higher than California. Over this period, Nevada exhibited the largest increase in population at 6.6 percent, and Arizona saw an increase of 4 percent in its population. By comparison, California only saw a 1.4 percent increase in its population over this same period. This increase in population corresponds very closely with the increased taxable diesel fuel sales observed, as the larger populations living in Arizona and Nevada increase the demand for goods, commodities and services resulting in an increased use of diesel trucks to meet this demand.

Table XIX-3: Average Annual Percent Change in Taxable Diesel Fuel Sales versus Population in California and Nearby States

State	Average Annual % Change In:	
	Taxable Diesel Sales*	Population**
Arizona	6.6%	4.0%
Nevada	7.5%	6.6%
Oregon	2.7%	2.0%
California	3.9%	1.4%

* 1995 - 2001, US DOT - Federal Highway Administration
** 1990 - 2000, US Census Bureau

B. Economic Effects on Small Businesses

Government Code sections 11342 et. Seq. requires the ARB to consider any adverse effects on small businesses that would have to comply with a proposed regulation. In defining small business, Government Code section 11342 explicitly excludes refiners from the definition of "small business." Also, the definition includes only businesses that are independently owned and, if in retail trade, gross less than $2,000,000 per year. Thus, our analysis of the economic effects on small business is limited to the costs to diesel retailers and jobbers, farmers, and transportation companies. A jobber is an individual or business that purchases wholesale diesel and delivers and sells it to another party, usually a retailer or other end-user.

1. Jobbers and Retailers

If the wholesale price of diesel rose as a result of additional costs to refiners to comply with the production of low sulfur diesel fuel, retailers and jobbers would pay more for every gallon of diesel that they resell in the State. Any adverse impacts on retailers and jobbers would occur only if their profits decreased as a result of the higher wholesale prices. The decrease in profits would likely only occur if retail prices did not increase by the corresponding increase in wholesale prices, or if the demand for diesel declined as a result of higher retail prices. Historically, small changes in wholesale fuel prices have not had substantial impacts on diesel purchases. Also, over time, changes in wholesale prices have been passed on to consumers through changes in retail prices.

While the magnitude of any potential reduction in profits is difficult to estimate reliably for any particular wholesale price increase, large swings in price commonly occur in the current wholesale and retail diesel markets and are part of the current business situation faced by jobbers and retailers. While there may be a short-term delay in passing these costs on to consumers, even large swings in wholesale prices are reflected in retail prices in a fairly rapid timeframe.

2. Diesel Fuel End-Users

The potential economic effects of low sulfur diesel fuel requirements are not limited to jobbers and diesel retailers. End users, such as transportation companies and farmers, could be impacted. This is because these two economic sectors are large consumers of diesel fuel, and would likely be impacted by any increase in the costs to produce low sulfur diesel fuel.

As previously discussed, staff considered a likely scenario of a 3 cent increase in diesel fuel prices in the analysis of the potential economic impacts from staff's proposal and analyzed the impact on the agricultural and transportation sectors, and other diesel fuel end-users. Staff reviewed and analyzed a majority of the representative crops in the agricultural sector based on their economic worth. Staff estimated the economic impact on total operating costs to the agricultural sector to range from 0.02 percent to 0.15 percent, with the average impact to the sector of 0.05 percent. For the transportation sector, staff estimated the economic impact on operating costs for a typical truck operator could be about 0.6 percent, based on a 3 cent increase in diesel prices.

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XX. NEED FOR NONVEHICULAR DIESEL-ENGINE FUEL REGULATION

This chapter addresses the need for regulating nonvehicular diesel-engine fuel to accommodate high-efficiency after-treatment of stationary, portable, and transportation refrigeration unit (TRU) diesel engines. We are proposing that the Board adopt an Airborne Toxicant Control Measure (ATCM) requiring the use of low-sulfur and otherwise complying CARB diesel in all nonvehicular diesel engines subject to ATCM's implemented as part of California's Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles, other than engines used to power locomotives and marine vessels.

A. Introduction and Background

In 1998, diesel PM was identified by the Board as a TAC in accordance with Division 26, Part 2, Chapter 3.5, Article 3 (section 39660 et seq.) of the California Health and Safety Code (H&SC). Board Resolution 98-35 identifies an estimated range of lifetime excess lung-cancer risk associated with diesel PM inhalation of 1.3×10^{-4} to 2.4×10^{-3} per microgram diesel PM per cubic meter of air exposure (1.3 to $24 \times 10^{-4}\ \mu g^{-1}\text{-}m^{3}$). Resolution 98-35 also directed ARB staff to begin the risk management process for diesel PM and other potentially harmful pollutants from diesel engines.

In the South Coast Air Basin about 70 percent of the lifetime cancer risk due to TAC exposure is attributable to diesel PM. Statewide diesel PM exposure has the potential to cause more than 500 cancer cases per million persons.

In September of 2000 the ARB approved California's Risk Reduction Plan (RRP) to reduce diesel PM emissions 75 percent by 2010 and 85 percent by 2020. A necessary element of the plan is the adoption of a diesel fuel sulfur limitation of 15 parts per million by weight (ppmw) to enable the use of sulfur-sensitive, after-treatment, emission-control devices on all diesel engines operating in California.

H&SC section 39665 directs the Executive Officer of the ARB to prepare a report on the need and appropriate degree of regulation for each substance determined to be a TAC. This chapter addresses the need for and appropriate degree of regulation of nonvehicular diesel-engine fuel for the control of diesel PM.

All diesel fuel sold or supplied in California for motor-vehicle use must have a sulfur content of 500 ppmw or less (13 CCR §2281). The actual sulfur content of California diesel fuel averages about 120 to 140 ppmw. In addition, the average aromatic hydrocarbon content of CARB diesel, except that produced by California small refiners, must not exceed 10 percent by volume, unless the fuel is produced as an ARB-certified alternative formulation (13 CCR §2282). Most California diesel fuel is produced as alternative formulation, averaging about 21 percent in aromatic content.

Some stationary engines are required by district rule or by permit to use California vehicular diesel fuel. Portable equipment registered under the state's portable equipment registration program (PERP) is also required to use California vehicular diesel fuel. In practice, TRU diesel engines, fueled in California, are normally fueled with California vehicular diesel fuel, but existing law does not require the use of the California fuel in TRUs. Locomotive and most marine diesel engines are examples of other applications that are not required to use California vehicular diesel fuel. Locomotive diesel engines fueled in California primarily burn diesel fuel complying with the U.S. EPA's sulfur content regulation (≤ 500 ppmw) for diesel fuel used in on-road engines. Passenger-fleet, marine diesel engines are required by statute to use California vehicular diesel fuel. It is believed that high-sulfur (≤ 5000 ppmw) diesel fuel is burned in most of the rest of the marine diesel engines fueled in California.

Reducing the sulfur level of California diesel fuel from an average of about 140 ppmw to 15 ppmw, in the absence of exhaust after-treatment, would have an expected impact on diesel PM emissions equal to a FTP-cycle specific emission reduction of about 0.004 g/bhp-hr. For nonvehicular diesel engines burning high-sulfur fuel, direct PM emission reductions before after-treatment would be about 0.1 g/bhp-hr. More importantly, improved after-treatment control efficiency (to over 90 percent control of diesel PM emissions) has been consistently demonstrated with low-sulfur (≤ 15 ppmw) diesel fuel. Low-sulfur fuel would allow after-treatment manufacturers to use more highly active catalysts, which operate effectively at lower temperatures and have a broader range of engine applications.

The U.S. EPA has published regulations which require that all diesel fuel sold for use in on-road vehicles have a sulfur content no greater than 15 ppmw, beginning June 1, 2006. U.S. EPA estimates that the overall cost, associated with lowering the sulfur cap from the current level of 500 ppmw to the proposed level of 15 ppmw, will be approximately $0.03 to $0.04 per gallon. U.S. EPA has proposed that diesel fuel for non-road engines meet the 15-ppmw-sulfur standard by 2010. The incremental cost for producing the low-sulfur fuel instead of high-sulfur (≤ 5000 ppmw) fuel was estimated to be about $0.05 per gallon.

The SCAQMD has amended its Rule 431.2, "Sulfur Content of Liquid Fuels," to require that all stationary source applications use low-sulfur (15 ppmw) diesel fuel, beginning June 1, 2004. All other diesel-engine applications must comply with the low-sulfur requirement by January 1, 2005, unless the ARB adopts the low-sulfur diesel fuel requirement, in which case the effective date becomes the same as that adopted by the ARB, but no later than June 1, 2006. Diesel fuel used in marine vessels and locomotives is exempted.

B. Proposed New ATCM for Nonvehicular Diesel-Engine Fuel

The ARB staff recommends that the Board adopt, as new section 93114 of title 17 of the California Code of Regulations, an ATCM for nonvehicular diesel fuel standards. The new regulation would provide that California nonvehicular diesel fuel is subject to all of the requirements of the ARB regulations governing the sulfur content, aromatic hydrocarbon content, and lubricity of motor vehicle diesel fuel, as if it were vehicular diesel fuel. There would be an exception for diesel fuel offered, sold, or supplied solely for use in locomotives or marine vessels. In accordance with H&SC section 39666(d), the regulation would provide that, no later than 120 days after its approval by the California Office of Administrative Law, each air quality district and air quality management district would be required either to implement and enforce the requirements of the proposed ATCM or propose its own qualifying ATCM to reduce particulate emissions from diesel-fueled vehicles. As described in the ARB's RRP for diesel

PM, when implemented, the new fuel standards would complement and enable the use of high-efficiency, PM emission-control devices for nonvehicular diesel engines.

C. Rationale for ATCM for Nonvehicular Diesel-Engine Fuel

The rationale for adopting regulations for nonvehicular diesel-engine fuel is that it is a necessary element for implementing the RRP. The RRP represents the staff's proposal for a comprehensive plan to significantly reduce diesel PM emissions. The basic premise behind the staff proposal is simple: to require all new diesel-fueled vehicles and engines to use state-of-the-art catalyzed diesel particulate filters (DPFs) and very low-sulfur diesel fuel. Further, all existing vehicles and engines should be evaluated, and wherever technically feasible and cost-effective, retrofitted with DPFs. As with new engines, very low-sulfur diesel fuel should be used by retrofitted vehicles and engines. In short, RRP contains the following three components:

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

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

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

For convenience, we briefly review the statewide diesel PM emission inventories. As presented in Table XX-1, PM emissions from nonvehicular diesel engines represent an increasingly significant portion of the total statewide diesel PM emissions. By 2010 diesel PM emissions from nonvehicular sources could compose about 40 percent of the total diesel PM emissions.

Table XX-1: Estimated Statewide Diesel PM Emission Inventories[106, a]

Year 2000		
Diesel Engine Category	Emissions (tons/year)	Percent of Total
Vehicular	19400	69
Nonvehicular[b]	8600	31
Total	28000	100
Year 2010		
Diesel Engine Category	Emissions (tons/year)	Percent of Total
Vehicular	13900	61
Nonvehicular[b]	8800	39
Total	22700	100
Year 2020		
Diesel Engine Category	Emissions (tons/year)	Percent of Total
Vehicular	10000	53
Nonvehicular[b]	8900	47
Total	18900	100

D. Alternatives to ATCM for Nonvehicular Diesel-Engine Fuel

There are two basic alternatives to the proposed amendment, leave the standard as is, or lower proposed standard.

Leaving the standard as is would seriously limit the implementation of the DRRP. As can be seen from table above, the emissions from nonvehicular sources is significant and is increasing as a proportion of diesel particulate matter emissions. Without low-sulfur diesel fuel, many of the control measure likely to be developed to implement the DRRP would not be technically feasible.

Adopting a lower standard is unnecessary, the DRRP clearly states that going beyond a 15-ppmw limit for the sulfur content of diesel fuel would not be cost effective. Going to a lower level would also, create a standard that is different that that which was adopted by the U.S. EPA for on-road diesel fuel.

[a] Inventories do not include impacts of control measured adopted since October 2000.

[b] Stationary, portable, transportation-refrigeration-unit, locomotive, and marine diesel PM emissions

APPENDIX O

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