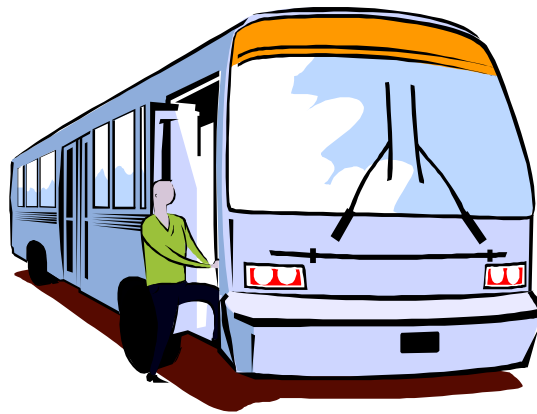


**CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY**  
**AIR RESOURCES BOARD**

**STAFF REPORT: INITIAL STATEMENT OF REASONS**

**PROPOSED REGULATION FOR A PUBLIC TRANSIT BUS FLEET RULE AND  
EMISSION STANDARDS FOR NEW URBAN BUSES**



This report has been reviewed by the staff of the California Air Resources Board and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Air Resources Board, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

Date of Release: December 10, 1999  
Scheduled for Consideration: January 27, 2000

## TABLE OF CONTENTS

|                                                                                         |    |
|-----------------------------------------------------------------------------------------|----|
| EXECUTIVE SUMMARY.....                                                                  | 1  |
| I. INTRODUCTION.....                                                                    | 5  |
| II. BACKGROUND.....                                                                     | 6  |
| A. California’s Air Quality Status.....                                                 | 6  |
| B. Urban Buses and Emission Standards.....                                              | 6  |
| C. Federal Urban Bus Retrofit/Rebuild Program.....                                      | 8  |
| D. Regulatory Focus on Urban Buses.....                                                 | 9  |
| E. Definitions.....                                                                     | 10 |
| III. NEED FOR CONTROL.....                                                              | 11 |
| A. Ozone.....                                                                           | 11 |
| B. Particulate Matter.....                                                              | 12 |
| IV. SUMMARY OF PROPOSED REGULATIONS.....                                                | 12 |
| A. Applicability.....                                                                   | 13 |
| B. Emission Standards.....                                                              | 13 |
| C. Transit Bus Fleet Rule.....                                                          | 16 |
| V. TECHNOLOGICAL FEASIBILITY.....                                                       | 24 |
| A. Currently-Available Technology.....                                                  | 24 |
| B. Retrofit Technology.....                                                             | 27 |
| C. New Technology.....                                                                  | 28 |
| VI. ISSUES.....                                                                         | 32 |
| A. Compressed Natural Gas Urban Bus Fleets.....                                         | 32 |
| B. Funding Sources.....                                                                 | 33 |
| C. School Buses.....                                                                    | 34 |
| D. Long-Term Viability of Natural Gas Fleets.....                                       | 35 |
| E. Natural Gas Availability.....                                                        | 35 |
| F. Safety Issues.....                                                                   | 35 |
| G. Ridership Issues.....                                                                | 36 |
| H. Statement of Principles.....                                                         | 36 |
| I. Settlement Agreements.....                                                           | 36 |
| J. Buses Designated as Alternative-Fuel Buses.....                                      | 37 |
| K. Zero-emission Bus Demonstration Projects.....                                        | 37 |
| L. Composite Buses.....                                                                 | 38 |
| VII. REGULATORY ALTERNATIVES.....                                                       | 38 |
| A. Do Not Adopt Transit Bus Fleet Rule and Amend<br>California Urban Bus Standards..... | 38 |

|       |                                                                          |    |
|-------|--------------------------------------------------------------------------|----|
| B.    | Adopt Low-Emission Standards Requiring<br>Alternative-Fuel Use.....      | 38 |
| C.    | Adopt A Fleet Average Rule.....                                          | 39 |
| D.    | Adopt Public Workshop Proposal Dated September 23, 1999.....             | 39 |
| VIII. | ECONOMIC IMPACTS.....                                                    | 40 |
| A.    | Legal Requirement.....                                                   | 40 |
| B.    | Affected Businesses.....                                                 | 40 |
| C.    | Potential Impacts on Business.....                                       | 40 |
| D.    | Potential Impact on Business Competitiveness.....                        | 41 |
| E.    | Potential Impact on Employment.....                                      | 41 |
| F.    | Potential Impact on Business Creation, Elimination,<br>or Expansion..... | 41 |
| G.    | Potential Costs to Local and State Agencies.....                         | 41 |
| IX.   | ENVIRONMENTAL IMPACTS.....                                               | 45 |
| X.    | COST-EFFECTIVENESS.....                                                  | 47 |
| XI.   | SUMMARY AND STAFF RECOMMENDATION.....                                    | 48 |
| A.    | Summary of Staff's Proposal.....                                         | 48 |
| B.    | Staff Recommendation.....                                                | 49 |
| XII.  | References.....                                                          | 50 |

APPENDIX A:       REGULATION

## TABLES

|          |                                                                                                       |    |
|----------|-------------------------------------------------------------------------------------------------------|----|
| Table 1  | California and Federal Urban Bus Engine NOx<br>Emission Standards.....                                | 7  |
| Table 2  | California and Federal Urban Bus Engine PM<br>Emission Standards.....                                 | 8  |
| Table 3  | Proposed Emission Standards for 2007 and Subsequent<br>Model Year Urban Bus Engines.....              | 14 |
| Table 4  | Proposed Emission Standards for 2004-2006 Model<br>Year Diesel or Dual-Fuel Urban Bus Engines.....    | 15 |
| Table 5  | Existing California Required and Optional,<br>Reduced-Emission Standards.....                         | 15 |
| Table 6  | Proposed Emission Standards for Urban Buses.....                                                      | 16 |
| Table 7  | Comparison of Fleet Rule Requirements .....                                                           | 21 |
| Table 8  | Proposed Fleet Rule Reporting Requirements .....                                                      | 22 |
| Table 9  | 1999 Model Year Urban Bus Engines Certified to<br>ARB's Optional, Reduced-Emission NOx Standards..... | 26 |
| Table 10 | Funding Scenario for Alternative-fuel Buses<br>and Infrastructure.....                                | 34 |
| Table 11 | Average Annual Cost of PM Retrofit Requirements.....                                                  | 43 |
| Table 12 | Estimated Incremental Costs to Transit Agencies<br>Of New Buses.....                                  | 44 |
| Table 13 | Emission Benefits of Proposed Regulation.....                                                         | 47 |
| Table 14 | Estimated Cost-Effectiveness of Proposed Regulation .....                                             | 48 |

## EXECUTIVE SUMMARY

The Air Resources Board's (ARB) major goal is to provide clean, healthful air to all the citizens of California. The staff's proposal for clean public transportation is an important step in achieving this goal. Public transportation provides important societal benefits. It provides access to work and education, reduces congestion, and meets the mobility needs of the public, including the elderly and disabled. It also has the potential to positively impact air quality. To do so, however, transit agencies must use the lowest-emission technology available to reduce ozone-forming emissions and reduce the public's exposure to cancer-causing pollutants, such as diesel particulate matter (PM). The ARB identified PM from diesel-fueled engines as a toxic air contaminant in August 1998. Current diesel urban buses usually emit more emissions of oxides of nitrogen (NOx) and PM than if all bus riders were driving separately. However, significant improvements in heavy-duty vehicle technology can result in clean public transportation and help reduce the public's exposure to harmful PM emissions. By taking advantage of engine improvements and new aftertreatment technologies, transit agencies and the ARB can be partners in achieving new air quality benefits from public transportation.

In September 1998, the ARB adopted Resolution 98-49 to encourage public agencies to purchase cleaner, alternative-fuel buses to reduce emissions and decrease the public's exposure to toxic air contaminants. Compared to conventional diesel technology, natural gas technology has already shown in-use emission reductions in the range of 50 percent for NOx and 90 percent for PM. Further advances in alternative-fuel technology, including hybrid-electric, battery-electric, and fuel cell technology, will provide even more opportunities for emission reductions from urban transit buses. Many transit agencies have been active in implementing the goals set forth in the resolution; others have not. As a result, additional strategies, in the form of this regulatory proposal, are necessary to achieve emission reductions from urban buses.

### Summary of Proposal

This regulatory proposal contains two elements to reduce emissions from urban buses: 1) a multi-component transit bus fleet rule applicable to transit agencies; and 2) more stringent emission standards for engines used in urban buses, applicable to engine manufacturers. The fleet rule is designed to achieve nearer-term emission benefits while the engine standards are designed to achieve long-term emission benefits resulting from new bus engines with ultra-low, near-zero, and zero-emissions.

The staff's proposal is structured to encourage transit agencies to voluntarily purchase cleaner alternative-fuel buses in order to reduce emissions of NOx and PM. To provide transit agencies with flexibility in determining their optimal fleet mix, the proposed rule allows transit agencies to choose between two compliance paths, either the diesel path or the alternative-fuel path.

The two-path system provides flexibility to transit agencies in making independent decisions for their region, while ensuring that maximum emission benefits are achieved. The alternative-fuel path provides immediate NOx and PM emissions benefits, although the two paths have been structured to provide approximately equivalent NOx emissions

over the lifetime of the requirements. The alternative-fuel path will provide greater PM emission benefits due to inherently low in-use PM emissions from alternative-fuel buses. Transit agencies on the diesel path would be responsible for being the first to implement low-emission and zero-emission buses.

Within the two paths, the staff is proposing a comprehensive transit bus program that encompasses a combination of different requirements. In total, these requirements will ensure low-emission public transportation within California. These requirements include: 1) an in-use NO<sub>x</sub> fleet average requirement that will encourage the retirement of the oldest, dirtiest diesel buses (1987 and earlier model year urban buses); 2) a PM retrofit requirement, with an emphasis on the dirtiest buses, to reduce public exposure to toxic diesel PM emissions; 3) a low-sulfur diesel fuel requirement; 4) low-emission bus purchase requirements, based on new urban bus emission standards; 5) a zero-emission bus demonstration project; and 6) zero-emission bus purchase requirements. A brief summary of each of these proposed requirements is presented below.

#### In-use NO<sub>x</sub> fleet average

In order to reduce NO<sub>x</sub> emissions from the in-use urban bus fleet, the ARB staff proposes that transit agencies on both the diesel and alternative-fuel paths must meet and maintain a minimum fleet average NO<sub>x</sub> standard of 4.8 grams per brake horsepower-hour (g/bhp-hr) by October 2002.

#### PM Retrofit Requirements

The PM retrofit requirements, applicable to transit agencies on both the diesel and alternative-fuel path, are intended to reduce PM emissions from existing diesel buses and those model year buses up to the year 2004. The ARB staff's proposal provides for a phase-in of the requirements from 2003 through 2009, with an emphasis on requiring retrofits for the oldest, dirtiest diesel buses first.

#### Low-sulfur Diesel Fuel Requirement

Low-sulfur diesel fuel is necessary for most aftertreatment technologies to function more efficiently and reliably. Therefore, the ARB staff's proposal includes requirements for transit agencies to purchase low-sulfur diesel fuel with a cap of 15 parts per million (ppm) sulfur beginning July 1, 2002. This requirement is timed to coincide with the PM retrofit requirements.

#### Low-emission Bus Purchase Requirements

The ARB staff's proposal includes new emission standards for NO<sub>x</sub>, PM, non-methane hydrocarbons, carbon monoxide, and formaldehyde for 2004 and subsequent model year diesel and dual-fuel urban bus engines, and for 2007 and subsequent model year urban bus engines, regardless of fuel type. Under the proposed transit fleet rule, the 2004 model year requirements for transit agencies purchasing diesel and dual-fuel engines include a 0.5 g/bhp-hr NO<sub>x</sub> standard and 0.01 g/bhp-hr PM standard. These levels represent approximately a 75 percent NO<sub>x</sub> reduction and an 80 percent PM

reduction from existing standards. The 2007 model year standards for all new bus purchases include a 0.2 g/bhp-hr NOx standard and a 0.01 g/bhp-hr PM standard, representing an additional 60 percent NOx reduction.

### Zero-emission Bus Demonstration Project

The ARB staff's proposal requires large transit agencies (an active fleet of more than 200 urban buses) on the diesel path to participate in zero-emission bus demonstration projects beginning in July 2003. At that time, each participating agency would be required to place at least three urban buses producing zero exhaust emissions in revenue service. Bus technologies qualifying as zero-emission include battery-electric buses, electric trolley buses, and fuel cell buses.

### Zero-emission Bus Purchase Requirements

The ARB staff's proposal also includes zero-emission bus purchase requirements for large transit agencies on both the diesel and alternative-fuel paths. For large transit agencies on the diesel path, a minimum 15 percent of all new urban bus purchases must be zero-emission buses beginning in 2008. For large transit agencies on the alternative-fuel path, the same purchase requirement applies beginning in 2010.

### **Environmental Impacts**

The ARB staff estimates that the proposed fleet average NOx requirement will reduce NOx emissions statewide by about 2 tons per day (tpd) in 2002. Although the staff's proposal ensures this reduction, it will mostly occur as a result of normal fleet turnover. Therefore, the staff does not assume any NOx benefit (or cost) due to the fleet average requirement. For the PM retrofit requirements, the ARB staff estimates that PM emissions will be reduced statewide by about 300 pounds per day (lbs/day) in 2005 and by about 100 lbs/day in 2010. The ARB staff estimates that the proposed low-emission bus purchase requirements, based on the new urban bus engine standards, together with the zero-emission bus purchase requirements, will reduce NOx emissions statewide in 2010 by about 5 tpd and PM emissions by about 50 lbs/day. In 2020, these emission reductions will increase to about 7 tpd of NOx and about 67 lbs/day of PM. All of these emission reduction estimates are based on the emission inventory model EMFAC 2000, which has not yet been adopted by the Board.

The estimated cost-effectiveness of the proposed low-emission bus purchase requirements, based on the new urban bus engine standards, together with the zero-emission bus purchase requirements, is \$1.80 per pound of NOx reduced in 2010. In 2020, the cost-effectiveness is \$1.50 per pound of NOx reduced. This cost-effectiveness compares favorably with that of other mobile source and motor vehicle fuel regulations adopted over the past decade.

The estimated cost-effectiveness of the proposed PM retrofit requirements is \$17.90 per pound of PM reduced annually from 2003 to 2009. This includes the costs associated with the requirement to purchase low-sulfur diesel fuel. The PM retrofit requirement

cost-effectiveness does not include the value of health benefits associated with a reduction in exposure to a toxic air contaminant.

### **Recommendations**

The ARB staff recommends that the Board adopt this regulatory proposal. It will provide for significant reductions of NO<sub>x</sub> and toxic PM emissions, especially in highly-populated urban environments. This proposal will ensure that the emissions of both new and in-use urban transit buses are significantly reduced while protecting the viability of transit operations.



## I. INTRODUCTION

Despite significant improvements in California's air quality over the last thirty years, there is still more work to do to achieve our air quality goals and provide healthful air for all Californians. California currently has eight major areas that are not in attainment with the one-hour federal ambient ozone standard. These areas are: the South Coast Air Basin, the Sacramento Metropolitan area, San Diego Air Basin, San Joaquin Valley Air Basin, Southeast Desert Air Basin, the San Francisco Bay Area, Santa Barbara County, and Ventura County. In addition, four of the six serious national nonattainment areas for particulate matter (PM) are located in California.

Mobile source controls are vital to the attainment of air quality standards. Mobile sources account for about 60 percent of ozone precursors and about 40 percent of combustion particulate emissions, statewide. Of the combustion particulate emissions, mobile source diesel engines account for about 30 percent. The Air Resources Board (ARB) identified particulate emissions from diesel exhaust as a toxic air contaminant in August 1998. Thus the control of particulate matter from diesel-fueled engines is critical.

The ARB's major goal is to provide clean, healthful air to all the citizens of California. The staff's proposal for clean public transportation is an important step in achieving this goal. Public transportation in California provides significant societal benefits. It provides mobility for those without cars, and reduces congestion when those with cars ride the bus. It also has the potential to positively impact air quality. Although current diesel urban buses usually emit more emissions of oxides of nitrogen (NOx) and PM than if all bus riders were driving separately, significant improvements in bus engine technology can result in clean public transportation and help reduce public exposure to harmful emissions. By taking advantage of these engine improvements, transit agencies and ARB can be partners in achieving new air quality benefits from congestion relief.

This proposal contains two components to reduce emissions from urban buses: 1) a fleet rule applicable to transit agencies; and 2) more stringent emission standards for engines used in urban buses, applicable to engine manufacturers. The fleet rule is designed to achieve nearer-term emission reductions, either through low-emission new bus purchases or through retrofitting or repowering older, higher-emitting urban bus engines to lower-emitting configurations. The engine standards are designed to achieve long-term emission benefits resulting from new bus engines with ultra-low, near-zero, and zero-emissions.

In September 1998, the ARB adopted Resolution 98-49 encouraging public agencies to purchase low-emission, alternative-fuel urban buses and school buses to achieve emission reductions and reduce the public's exposure risk to toxic air contaminants. While diesel engine technology may meet the staff's proposed engine standards in the future, this regulatory proposal is designed to increase low-emission, alternative-fuel engine use, including advanced battery and fuel cell technology use. Low-emission, alternative-fuel technology is already available today to achieve significant emission reductions. The ARB staff has identified at least 18 transit agencies throughout

California that are already using or have committed to purchasing significant numbers of low-emission, alternative-fuel urban buses. Other transit agencies are also purchasing smaller numbers of low-emission, alternative-fuel urban buses. Further improvements in low-emission, alternative-fuel technology, including advances in battery and fuel cell technology, will ensure its place as a key component in California's long-term clean air strategy.

## **II. BACKGROUND**

This chapter provides a brief overview of California's current air quality status; urban buses and applicable emission standards; and defines key terms used throughout the report. California is the only state that has the authority to establish motor vehicle emission standards different from federal standards. California's standards must be equivalent to or more stringent than the federal standards.

### **A. California's Air Quality Status**

Over the past three decades, there has been dramatic progress toward cleaner air in California, largely as a result of California's leadership in developing unique pollution control programs to reduce emissions from both vehicular and non-vehicular sources. For example, the peak one-hour ozone concentrations in southern California, the area in California with the most serious air quality problems, were as high as 0.65 parts per million during the 1960s. Peak ozone concentrations in southern California today are about one-third of the values in the 1960s, despite significant increases in population and the number of motor vehicles. In addition, the number of days exceeding both the federal and state one-hour ambient ozone standards has steadily declined. Since 1980, the number of days exceeding the federal and state standards has decreased by about 60 percent and 50 percent, respectively.

Despite this progress, including significant improvements resulting from the implementation of every feasible measure in the 1994 State Implementation Plan for Ozone, many areas of the state still fail to meet federal and state health-based air quality standards. This proposal is but one of several necessary measures to further California's progress in meeting its clean air challenges. Other measures to be considered in the near future include enhanced vapor recovery, more stringent emission standards for medium and heavy-duty gasoline vehicles, additional reductions from consumer products, and a suggested control measure for architectural coatings.

### **B. Urban Buses and Emission Standards**

In general, urban buses operate in heavily populated areas with a typical route consisting of stops and starts as passengers are routinely picked up and delivered to their destinations. Urban buses are typically 40 feet long, although they do vary in length; are normally powered by a heavy-duty diesel engine; and fall within the heavy-duty vehicle classification of greater than 33,000 pounds gross vehicle weight (GVW). These buses are owned (or leased) by public transit agencies that receive federal, state, and local funds to subsidize new bus purchases and to operate and maintain their bus fleets and facilities. The ARB staff estimates that there about 8,500

full-size transit buses operating in California. Of these, approximately 80 percent are operated by 16 large-sized transit fleets with more than 100 buses in their fleet. The remaining buses are spread among more than 60 other transit agencies operating throughout California.

Urban buses have relatively high emissions (on a per vehicle basis) of NOx and PM. Based on the emission inventory model EMFAC 2000, which has not yet been adopted by the Board, urban buses will emit approximately 24 tons per day of NOx, and 1,000 pounds per day of PM in the year 2000. NOx is critical because it is one of the two major components in ozone formation. Particulates are critical because of their adverse effect on respiratory health and because they are a significant toxic air contaminant. Diesel engines have relatively low emissions of carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), and hydrocarbons (HC). CO emissions create “hot spots” that affect public health, although nearly all areas of California are in attainment for CO. CO<sub>2</sub> is a greenhouse gas that contributes to global warming. Emissions of HC are important because in combination with NOx emissions, they create ozone.

In contrast, a natural gas bus engine will have significantly lower NOx and PM emissions than a comparable diesel bus engine, but it will likely have higher CO and CO<sub>2</sub> emissions and slightly higher HC emissions. However, the increase in these emissions is small compared to the decrease in NOx and PM emissions.

Tables 1 and 2 below present a recent history of both California and federal NOx and PM emission standards for urban bus engines. The heavy-duty emissions certification cycle is an engine-based test. This engine certification test determines emissions in units of grams per brake horsepower-hour (g/bhp-hr) or, in other words, emissions per unit of work performed.

**TABLE 1**

| <b>California and Federal Urban Bus Engine NOx Emission Standards (g/bhp-hr)</b> |                       |                       |
|----------------------------------------------------------------------------------|-----------------------|-----------------------|
|                                                                                  | <b>California</b>     | <b>Federal</b>        |
| 1988                                                                             | 6.0                   | 10.7                  |
| 1990                                                                             | 6.0                   | 6.0                   |
| 1991                                                                             | 5.0                   | 5.0                   |
| 1996                                                                             | 4.0                   | 5.0                   |
| 1998                                                                             | 4.0                   | 4.0                   |
| October 2002                                                                     | 2.0 <sub>(1)(2)</sub> | 2.0 <sub>(1)(2)</sub> |

1. Nominal NOx level based on U.S. EPA and ARB emission standards of 2.4 g/bhp-hr NOx plus non-methane hydrocarbons (NMHC) or 2.5 g/bhp-hr NOx plus NMHC with 0.5 g/bhp-hr NMHC cap to take effect in October 2002.
2. For those engines subject to the Settlement Agreements between the heavy-duty engine manufacturers, the U.S. Environmental Protection Agency, and ARB. As part of the Settlement Agreements, the federal and state heavy-duty engine emission standards adopted for 2004 are to take effect in October 2002.

**TABLE 2**

| <b>California and Federal Urban Bus Engine PM Emission Standards<br/>(g/bhp-hr)</b> |                     |                     |
|-------------------------------------------------------------------------------------|---------------------|---------------------|
|                                                                                     | <b>California</b>   | <b>Federal</b>      |
| 1988                                                                                | 0.6                 | 0.6                 |
| 1991                                                                                | 0.1                 | 0.25                |
| 1993                                                                                | 0.1                 | 0.1                 |
| 1994                                                                                | 0.07                | 0.07                |
| 1996                                                                                | 0.05 <sup>(1)</sup> | 0.05 <sup>(1)</sup> |
| October 2002                                                                        | 0.05                | 0.05                |

(1) In-use standard of 0.07 g/bhp-hr.

In addition to the mandatory emission standards shown above, the ARB also has optional, reduced-emission standards, which are integrated into the fleet rule component of the proposed regulation. A table presenting the optional, reduced-emission standards is presented in Chapter IV of this report.

### **C. Federal Urban Bus Retrofit/Rebuild Program**

The United States Environmental Protection Agency (U.S. EPA) has adopted requirements for an urban bus retrofit/rebuild program as required by the Clean Air Act Amendments of 1990. The program applies to 1993 and earlier model year urban buses whose engines are rebuilt or replaced after January 1, 1995. The program is limited to urban buses operating in metropolitan areas with 1980 populations of 750,000 more.

The U.S. EPA's rule, which became effective on January 2, 1995, includes two options for reducing PM emissions from in-use urban buses, implicitly based on particulate trap or oxidation catalyst technology. It also includes cost ceilings that limit the cost a transit operator must pay in order to comply with the regulation.

Option 1 requires the transit operator to retrofit each applicable engine to achieve compliance with a PM emission standard of 0.1 g/bhp-hr or less, assuming it can be done for an incremental life-cycle cost maximum of \$7,490 per engine. If no equipment is available that meets these requirements, then each engine must be rebuilt to achieve a 25 percent reduction in PM emissions for an incremental life-cycle cost of \$2,000 or less. If there is no equipment available that meets either of these options, then each engine must be rebuilt to its original new engine configuration or, at the transit operator's choice, to a configuration with PM emissions lower than the original engine configuration. Formulae for calculating the life-cycle costs are included in the U.S. EPA's regulation. New facility costs and incremental fuel costs are included in the incremental cost calculations.

Option 2 is an averaging program set up to yield overall emission reductions equivalent to those expected under Option 1. This option provides a transit operator with enhanced flexibility to reduce PM emissions while minimizing costs. The averaging calculations included in the regulation provide guidance for determining the target level

for an applicable fleet (TLF, the average PM emission value the fleet is expected to meet) and the fleet level attained (FLA, the actual average PM emission value after retrofits have been conducted). The TLF calculation indirectly takes into account the cost limits developed for Option 1.

The ARB staff's proposed regulation also includes retrofit requirements for PM control from the older, in-use diesel urban bus fleet. However, because California required new urban bus engines to meet a 0.10 g/bhp-hr standard in 1991, two years prior to the federal 0.10 b/bhp-hr PM standard went into effect, the federal retrofit requirements only apply to 1990 and earlier urban bus engines in California. While the ARB staff's proposal does include a retrofit requirement for urban bus engines certified to 0.60 g/bhp-hr PM, which are 1990 and earlier model year engines in California, it is expected that the proposed requirement would be met by retiring most of the 0.60 g/bhp-hr PM engines, rather than retrofitting them.

#### **D. Regulatory Focus on Urban Buses**

Diesel urban buses are ideally suited for improved controls due to relatively high NOx and PM emissions (on a per bus basis) and other factors described below. The ARB and the local air pollution control districts and air quality management districts have already adopted control measures for nearly all sources----mobile, stationary, consumer products, and pesticides----to ensure California's continued progress in attaining federal and state air quality standards. However, more work needs to be done to achieve our air quality goals. Therefore, those sectors that still have opportunities for emission reductions, such as the heavy-duty vehicle sector, must be proactive in reducing emissions. This proposal focuses strictly on urban buses. The ARB will consider a separate proposal to reduce emissions from school buses at a later date. In addition, other heavy-duty vehicles will be required to comply with new emission standards in late 2002, and both the ARB and the U.S. EPA will be considering even more stringent emission standards for heavy-duty vehicles for beyond the 2004 time frame.

In September 1998, the ARB adopted Resolution 98-49 to encourage public agencies to purchase cleaner, alternative-fuel buses to reduce emissions and decrease the public's exposure to toxic air contaminants. While the staff recognizes that the primary responsibility of transit agencies is to provide efficient, convenient transportation, we also believe transit agencies, as publicly funded entities, should bear some of the responsibility for providing the people they serve with clean, less polluting transportation. Many transit agencies have been active in implementing the goals set forth in the resolution; others have not. As a result, additional strategies, in the form of this proposal, are necessary to achieve emission reductions from urban buses. In addition to requiring clean, low-emitting and zero-emitting new bus purchases, this proposal relies on retrofit strategies, a NOx fleet average system, and requirements to purchase low-sulfur diesel fuel to achieve emission reductions from the diesel urban bus fleet.

As stated above, diesel urban buses contribute relatively high NOx and PM emissions on a per bus basis. However, there are other contributing factors that make the diesel urban bus sector an ideal candidate for achieving emission reductions. First, many of

these buses operate in the most heavily congested urban areas where air quality is critical and direct exposure to toxic diesel particulates occurs for large numbers of people, thus making toxic particulate emissions an even greater public health concern. Second, they are centrally-fueled with known, fixed-routes, which allows for a cleaner, alternative fuel to be utilized more efficiently. Third, the entire cost of a new bus is not borne by the local transit agency. Transit agencies do not rely entirely on local funding for new bus purchases; the federal government subsidizes 83 percent of the purchase price of a new, low-emission alternative-fuel bus and 80 percent of the purchase price of a new diesel bus (funding issues are discussed in Chapter VI of this report). Finally, cost-effective emission reductions can be immediately achieved as cleaner, alternative-fuel engine technology is already available. Current natural gas bus engines emit about 50 percent less NOx and PM than comparable diesel bus engines based on engine certification levels. For PM, in-use test data also show that PM emissions from diesel buses are significantly higher than PM emissions from natural gas buses.

## **E. Definitions**

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

(Note: A diesel-powered urban bus refers to a bus powered by a diesel-cycle engine, which includes alternative-fuel engines such as natural gas, propane, and methanol.)

Zero-emission Bus (ZEB) - "Zero-emission bus" means an urban bus, certified by the ARB Executive Officer, that produces zero exhaust emissions of any criteria pollutant (or ozone precursor pollutant) under any and all possible operational modes and conditions. The following provisions are applicable in defining a zero-emission bus:

- (a) A hydrogen fuel cell bus shall qualify as a zero-emission bus.
- (b) An electric trolley bus with overhead twin-wire power supply shall qualify as a zero-emission bus.
- (c) A battery-electric bus shall qualify as a zero-emission bus.
- (d) The incorporation of a fuel-fired heater shall not preclude an urban bus from being certified as a zero-emission bus provided that the fuel-fired heater cannot be operated at ambient temperatures above 40°F, and that

the heater has zero evaporative emissions under any and all possible operational modes and conditions.

Alternative-fuel - “Alternative-fuel “ means compressed and liquefied natural gas, propane, methanol, electricity, fuel cells, or other advanced technologies that do not rely on diesel fuel. For the purpose of this regulatory proposal, hybrid-electric and dual-fuel technologies that use diesel fuel are not considered alternative-fuel technologies.

Fleet Size - “Fleet size” means the total active fleet of urban buses, including spare buses, but not contingency vehicles (e.g., for emergencies) or non-revenue producing vehicles. This definition is consistent with that used by the Federal Transit Administration.

Transit Agency – “Transit agency” means a public entity responsible for administering and managing transit activities and services. Public transit agencies can directly operate transit service or contract out for all or part of the total transit service provided. This definition is consistent with that used by the Federal Transit Administration.

### **III. NEED FOR CONTROL**

The proposed emission standards for urban bus engines and the proposed fleet rule represent an important step in further reducing the human health and environmental impacts of ground-level ozone and the toxic impacts of PM emissions from diesel-fueled engines. This chapter summarizes the air quality rationale for the staff’s proposal.

#### **A. Ozone**

California has a serious, statewide ozone air pollution problem, which until very recently, included the worst air quality in the nation in the South Coast Air Basin (Houston, Texas recently acquired the distinction of having the worst air quality in the nation). Ozone, created by the photochemical reaction of NO<sub>x</sub> and HC, causes harmful health effects ranging from eye irritation, sore throats and coughing, to lung damage, cancer, and premature death. People with compromised respiratory systems and children are the most severely affected; however, even healthy children and adults who play or exercise outdoors are also at risk. Beyond their human health effects, other negative environmental effects are also associated with ozone and NO<sub>x</sub>. Ozone has been shown to injure plants and materials; NO<sub>x</sub> contributes to the secondary formation of PM (nitrates), and acid deposition.

California has made significant progress in controlling ozone. Statewide exposure to unhealthy ozone concentrations has been cut in half since 1980. The frequency and severity of pollution episodes is declining, and emissions are on a downward trend. However, as stated earlier, more needs to be done. California still has eight major areas that are designated as nonattainment with the one-hour federal ambient ozone standard. These are: the South Coast Air Basin (Los Angeles, San Bernardino, Riverside, and Orange counties), the Sacramento Metropolitan Area, San Diego Air Basin, San Joaquin Valley Air Basin, Southeast Desert Air Basin, the San Francisco

Bay Area, Santa Barbara County, and Ventura County. In addition, many more areas of the state violate our more stringent state ambient air quality standard for ozone.

The staff estimates that this proposal, once adopted, will reduce NOx emissions statewide by about seven tons per day (tpd) in 2020.

## **B. Particulate Matter**

In addition to California's serious ozone challenges, many areas of California violate the federal and state PM emission standards. This proposal, when adopted, will provide dual PM emission benefits: 1) it will help in the effort to attain the federal and state PM standards throughout California; and 2) it will reduce the public's direct exposure to toxic particulate emissions.

Particulate matter, like ozone, has been linked to a range of serious health problems. Particles are deposited deep in the lungs and can result in increased hospital admissions and emergency room visits; increased respiratory symptoms and disease; decreased lung function, particularly in children and individuals with asthma; alterations in lung tissue and respiratory tract defense mechanisms; and premature death.

In August 1998, the ARB identified particulate emissions from diesel-fueled engines as a toxic air contaminant, one that causes cancer. Preliminary estimates indicate that the particulate emissions from diesel-fueled engines are by far the most significant toxic risk faced by the citizens of California. Diesel buses operating in heavily congested urban areas cause direct exposure for the public to toxic diesel particulates. It is the ARB's goal to protect public health by reducing exposure to diesel particulate emissions.

This proposal, once adopted, will reduce PM emissions from urban buses by requiring new buses to meet more stringent PM standards and by requiring retrofits to reduce PM from certain portions of the older, diesel urban bus fleet. The staff estimates the PM reduction in 2005 as a result of the PM retrofit requirements is 300 pounds per day statewide. As a result of the proposed new emission standards, staff estimates the PM reduction will be 67 pounds per day in 2020 statewide.

## **IV. SUMMARY OF THE PROPOSED REGULATIONS**

The staff recommends that the Board adopt sections 1956.1, 1956.2, 1956.3 and 1956.4, and amend section 1956.8, Title 13, California Code of Regulations, and the incorporated "California Exhaust Emission Standards and Test Procedures for 1985 and Subsequent Model Year Heavy-duty Engines and Vehicles," as set forth in Appendix A. All the provisions in the proposed regulation apply to engines and vehicles produced for sale in California. There are two components to this proposal: 1) a transit bus fleet rule applicable to transit agencies; and 2) more stringent emission standards for new urban bus engines applicable to urban bus engine manufacturers. The transit bus rule would require fleet operators to choose between operating a diesel bus fleet (the diesel path) or an alternative-fuel bus fleet (the alternative-fuel path). The fleet rule contains different requirements for each path. For both paths, there is a requirement to achieve reductions from the older in-use fleet through a minimum NOx fleet average system and



through requirements for retrofits for PM control. The alternative-fuel path achieves equivalent NOx reductions and greater PM reductions than the diesel path due to inherently low in-use PM emissions from alternative-fuel buses. PM emissions from alternative-fuel buses are on the order of 20 to 100 times lower than diesel buses. The fleet rule also contains requirements for larger fleets on the diesel path to undertake a zero-emission bus demonstration project, and for larger fleets on both paths to purchase a required percentage of zero-emission buses. The fleet rule would be in effect from the date of adoption of this regulation in 2000 through 2015. The proposed emission standards are applicable to urban bus engine manufacturers and begin in model year 2004 for diesel and dual-fuel urban bus engines and in the model year 2007 for all urban bus engines. The following sections discuss the major provisions of the proposed regulation in detail.

## **A. Applicability**

The current urban bus definition, as specified in Section 86.094-2 of Subpart N, Part 86, Title 40, CFR, is a passenger-carrying vehicle (+33,000 pound GVW) powered by a heavy heavy-duty diesel-powered engine with a load capacity of fifteen or more passengers and intended primarily for intra-city operation. Equipment on urban buses usually includes quick-opening exit and entrance doors and fare collection equipment. Urban buses are of various lengths, and include articulated buses, but are usually at least 25 feet long.

The proposed regulation does not apply to buses used in shuttle services, airport shuttle services, paratransit services, school transportation services and commuter services unless urban buses are used to provide those services. Buses used to provide long-distance service, that are generally equipped with luggage compartments, rest rooms, and overhead storage, are not included.

Smaller transit buses (14,001 to 33,000 pounds GVW) have historically been regulated as heavy-duty trucks. Both the U.S. EPA and the ARB will be evaluating the need for more stringent standards for heavy-duty trucks, including school buses and smaller transit buses.

The proposed fleet rule applies to those public transit fleets operated by government agencies or operated by private entities under contract to government agencies.

## **B. Emission Standards**

### **1. Advancement of the 2004 Heavy-duty Engine Standards to 2002**

The ARB and the U.S. EPA have already adopted heavy-duty engine emission standards to take effect in 2004. In addition, as a result of the Heavy-duty Diesel Settlement Agreements between the U.S. EPA, the ARB, and seven engine manufacturers, the engine manufacturers will introduce engines produced for sale in California meeting the 2004 heavy-duty engine emission standards beginning in October 2002. The Settlement Agreements are the result of engine manufacturers using alternative emission control strategies that increased emissions of NOx beyond

what would be expected on the Federal Test Procedure. Similar agreements, referred to collectively as the federal Consent Decree, are applicable to engines produced for sale outside of California. In October 2002, engine manufacturers subject to the Settlement Agreements must certify new urban bus and other heavy-duty engines to either a 2.4 g/bhp-hr NOx + NMHC standard, or a 2.5 g/bhp-hr NOx + NMHC standard with a cap of 0.5 g/bhp-hr of NMHC. The NOx emission level is assumed to be 2.0 g/bhp-hr in California's State Implementation Plan for Ozone and in calculating the ARB's emission inventory. Therefore, in discussing the standards to take effect in October 2002, the term "nominal 2.0 g/bhp-hr NOx" is sometimes used. The Settlement Agreements do not affect PM emission standards.

## 2. Proposed Emission Standards

Under this proposal, engine manufacturers can continue to certify urban bus engines to one of two sets of existing NOx emission standards until 2007: 1) the ARB's mandatory standards (either the current 4.0 g/bhp-hr NOx standard or the NOx + NMHC standard taking effect in October 2002); or 2) the ARB's optional, reduced-emission NOx standards. Currently, there are no heavy-duty diesel engines certified to the ARB's reduced-emission optional NOx standards. However, as discussed in Chapter V, some natural gas engines are certified to the optional standards. All new urban bus engines must currently certify to the 0.05 g/bhp-hr PM standard.

The staff is proposing that the Board adopt new mandatory emission standards for 2007 and subsequent model year urban bus engines for NOx, PM, NMHC, and formaldehyde. Urban bus engines would be required to certify to the standards for each pollutant as shown in Table 3 below. The staff is in the process of developing a certification procedure for zero-emission buses required under the fleet rule.

**TABLE 3**

| <b>Proposed Emission Standards for 2007 and Subsequent Model Year Urban Bus Engines (g/bhp-hr)</b> |           |             |                     |           |
|----------------------------------------------------------------------------------------------------|-----------|-------------|---------------------|-----------|
| <b>NOx</b>                                                                                         | <b>PM</b> | <b>NMHC</b> | <b>Formaldehyde</b> | <b>CO</b> |
| 0.2                                                                                                | 0.01      | 0.05        | 0.01                | 5.0       |

Prior to implementation of the mandatory emission standards proposed for 2007 and subsequent model year urban bus engines, the NOx and PM standards discussed below would apply, based on fleet rule requirements (specific fleet rule requirements are discussed later in this chapter).

### a. Urban Buses on the Diesel Path

For the 2000 to October 2002 model years, diesel engines must be certified to current emission standards. From October 2002 through 2003, diesel engines made by all but one manufacturer subject to the Settlement Agreement must be certified to the existing 2.4/2.5 g/bhp-hr NOx + NMHC standard and the existing PM standard of 0.05 g/bhp-hr.

For 2004 through 2006 model year diesel and dual-fuel engines, the staff proposes that the Board adopt the emission standards shown in Table 4 below.

**TABLE 4**

| <b>Proposed Emission Standards for 2004 - 2006 Model Year Diesel or Dual-Fuel Urban Bus Engines (g/bhp-hr)</b> |           |             |                     |           |
|----------------------------------------------------------------------------------------------------------------|-----------|-------------|---------------------|-----------|
| <b>NOx</b>                                                                                                     | <b>PM</b> | <b>NMHC</b> | <b>Formaldehyde</b> | <b>CO</b> |
| 0.5                                                                                                            | 0.01      | 0.05        | 0.01                | 5.0       |

Engine manufacturers can choose to meet these standards with an engine certified at the 2.5 g/bhp-hr standard and an applied aftertreatment system that together demonstrate NOx at 0.5 g/bhp-hr and PM at 0.01 g/bhp-hr. Manufacturers are responsible for full certification of the base engine; durability, testing, in-use compliance, and emissions warranty requirements. For the aftertreatment, the ARB is proposing that manufacturers have reduced certification requirements but full functional warranty requirements.

For 2007 and subsequent model year urban bus engines, the staff proposes that the Board adopt the emission standards shown in Table 6 below. The proposed standards for 2007 and subsequent model year urban bus engines are applicable to diesel and alternative-fuel engines.

b. Urban Buses on the Alternative-Fuel Path

From the adoption of the regulation through the 2015 model year, for transit agencies on the alternative fuel path, at least 85 percent of all new bus purchases must be alternative-fuel bus buses. Although transit agencies are not required to purchase alternative fuel buses that are certified to one of the ARB's existing reduced-emission optional NOx standards (at 2.5 g/bhp-hr NOx or lower), those are the only alternative fuel bus engines currently available. In addition, bus engines certified to an optional NOx standard could qualify for incentive funding. Existing California standards for NOx and NOx plus NMHC, (both required and optional standards) are shown in Table 5. The applicable PM standard from now until October 2002 would be the existing 0.05 g/bhp-hr standard.

**TABLE 5**

| <b>Existing California Required and Optional, Reduced-Emission Standards for Urban Buses (g/bhp-hr)</b> |                                                         |                           |                  |
|---------------------------------------------------------------------------------------------------------|---------------------------------------------------------|---------------------------|------------------|
| <b>Model Year</b>                                                                                       | <b>Primary Standard</b>                                 | <b>Optional Standards</b> | <b>Increment</b> |
| 2000 to 10/2002                                                                                         | 4.0 (NOx)                                               | 2.5 – 0.5                 | 0.5              |
| 10/2002 through 2006                                                                                    | 2.4 NOx+NMHC<br>or<br>2.5 NOx+NMHC with<br>0.5 NMHC cap | 1.8-0.3                   | 0.3              |

For October 2002 through 2006 model years, urban bus engines, in buses purchased by transit agencies on the alternative fuel path, must be certified to either the 2.4/2.5 NOx + NMHC standard that takes effect in October 2002, or to one of the ARB's existing reduced-emission optional NOx + NMHC standards beginning at 1.8 g/bhp-hr. Only those engines certified to one of the ARB's optional, reduced NOx + NMHC standards would generally be eligible to receive incentive money to assist with the incremental purchase price. In either case, the engines must be certified to a new, proposed optional PM standard of 0.03 g/bhp-hr. This proposed new standard, plus the proposed 2004 NOx and PM standards for the diesel path, and the proposed new NOx and PM standards for 2007, applicable to both paths, are summarized in Table 6.

**TABLE 6**

| <b>Proposed Emission Standards for Urban Buses<br/>(g/bhp-hr)</b> |                       |                      |                                |                      |
|-------------------------------------------------------------------|-----------------------|----------------------|--------------------------------|----------------------|
| <b>Model<br/>Year</b>                                             | <b>"Diesel" Path</b>  |                      | <b>"Alternative Fuel" Path</b> |                      |
|                                                                   | <b>NOx (g/bhp-hr)</b> | <b>PM (g/bhp-hr)</b> | <b>NOx (g/bhp-hr)</b>          | <b>PM (g/bhp-hr)</b> |
| 2004                                                              | 0.5                   | 0.01                 | (1)                            | 0.03                 |
| 2007                                                              | 0.2                   | 0.01                 | 0.2                            | 0.01                 |

Dates shown indicate bus model years.

(1) No new standard is proposed for NOx on the alternative fuel path. The existing standard for 2004 is 2.4 g/bhp-hr NOx plus NMHC. Although transit agencies on the alternative-fuel path are not required to purchase engines certified to optional lower-NOx plus NMHC standard (1.8 g/bhp-hr NOx + NMHC or below), the staff expects that they will in order to qualify for incentive funding. At present, the only alternative-fuel engines available are certified to optional, lower-emission NOx standards.

Engines certified to the optional standards may not participate in any averaging, banking or trading program. However, the purchase of the buses with optional lower-NOx engines may be eligible for certain California mobile source emission reduction credit programs, or for low-emission vehicle incentive funding programs

### **C. Transit Bus Fleet Rule**

The ARB staff is proposing specific fleet requirements for transit agencies. First, transit agencies and other bus purchasers (e.g., bus leasing companies) would be required to buy buses that comply with the emission standards shown in Tables 3 and 4 above when making new bus purchases. Second, transit agencies would be required to choose between operating diesel bus fleets or low-emission, alternative-fuel bus fleets. Such a choice would put a transit agency on either the "diesel path" or the "alternative fuel path" of the proposed transit bus fleet rule. The proposed regulation contains different requirements for each path. The alternative fuel path achieves equivalent NOx and greater PM reductions than the diesel path. It would provide transit agencies incentives to continue implementing low-emission, alternative-fuel bus technology, or to start doing so immediately. Provisions of the fleet rule extend from the effective date of the proposed regulation in 2000 through 2015.

For the purpose of the fleet rule, low-emission, alternative-fuel buses are buses powered by natural gas, propane, ethanol, or a combination of those fuels and other

non-diesel fuels, and electricity and fuel cells. Buses powered by diesel fuel or a combination of fuels that includes diesel fuel (such as a diesel hybrid-electric) are not considered low-emission, alternative-fuel buses for the purpose of the proposed regulation.

The diesel and alternative-fuel paths differ primarily with respect to requirements for:

- New bus purchases and leases, emission standards, and fuel type.
- Zero-emission bus demonstration programs.
- Timing of zero-emission bus purchases.

## **1. Requirements for Transit Agencies on the Diesel Path**

### **a. New Bus Purchases and/or Leases**

New diesel urban buses would be required to use diesel engines certified to the applicable existing and proposed NO<sub>x</sub>, PM, NMHC, and formaldehyde emission standards or to the ARB's optional, reduced emission standards discussed in the previous section.

Some transit agencies on the diesel path may also want to purchase low-emission alternative-fuel buses, but not in quantities sufficient to qualify for the alternative-fuel path. Any model year 2004 through 2006 low-emission, alternative-fuel buses purchased by a diesel path transit agency must meet the 2004 proposed emission standards of 0.5 g/bhp-hr NO<sub>x</sub> and 0.01 g/bhp-hr PM. This is to prevent transit agencies on the diesel path from purchasing an alternative-fuel bus with higher NO<sub>x</sub> and PM emissions than a comparable diesel bus meeting the proposed emission standards of 0.5 g/bhp-hr NO<sub>x</sub> and a 0.01 g/bhp-hr PM. Fuel cell buses, electric trolley buses, and battery-electric buses would meet or exceed the proposed 2004 standards. Hybrid-electric buses may also meet these proposed emission standards. The proposed 2007 NO<sub>x</sub> and PM emission standards are applicable to all bus engines, whether diesel or low-emission, alternative-fuel.

### **b. Fleet Averaging for NO<sub>x</sub> Emissions**

The staff proposes that transit agencies meet a minimum active fleet average standard of 4.8 g/bhp-hr NO<sub>x</sub> by October 2002. The fleet average for each transit agency's fleet would be based on the NO<sub>x</sub> engine certification standard (new or repowered engine) for each urban bus, and all heavy-duty zero-emission buses, in the active fleet, whether owned or leased, of all fuel types. To achieve the proposed fleet average 4.8 g/bhp-hr NO<sub>x</sub> standard, transit agencies or their bus leasing companies may have to repower or retire older, high-emitting buses. It is possible to repower existing diesel urban buses with engines certified to 5.0 and 6.0 g/bhp-hr NO<sub>x</sub> standards with new 4.0 g/bhp-hr NO<sub>x</sub> engines. However, staff assumes that all but a few transit agencies on the diesel path would be able to meet and maintain the minimum required fleet average standard through normal bus retirement rates.

The staff also proposes that transit agencies have the option of retiring all 1987 and earlier model year diesel urban buses as a way to comply with the NOx fleet average requirement. This retirement option is intended to provide transit agencies flexibility in achieving fleet turnover, while maintaining the benefits of the NOx fleet average requirement.

### c. PM Retrofit Requirements

The ARB staff proposes that transit agencies could only operate buses in their active fleets that are in compliance with the PM retrofit requirements discussed here. The PM retrofit requirements would start in 2003 and extend to 2009. Diesel buses with the highest PM emissions would be given priority and would be the first buses to be retrofitted. A retrofit device that demonstrates 85 percent conversion efficiency would have to be installed. All low-sulfur fuel would have to be purchased beginning in July 1, 2002, to assure the durability of the retrofit devices. These requirements apply to transit agencies on both paths, but only diesel buses would have to be retrofitted. As discussed earlier, in-use emissions data show significant particulate benefits from CNG buses compared to diesel buses. Even with the bus retrofits, PM emissions would be lower for those agencies on the alternative-fuel path utilizing natural gas buses.

The staff has proposed that transit agencies with active fleets consisting of less than 20 buses operating in federal ozone attainment areas be allowed a delay in the Tier 1 and Tier 2 PM retrofit requirements, as described below, until 2007. This is primarily due to the projected cost and difficulty of securing delivery of low-sulfur diesel in outlying rural areas before 2007. By 2007, many of the buses subject to the Tier 1 and Tier 2 requirements would be retired and would not have to be retrofitted; this would be a cost savings for the smaller districts. These smaller transit agencies would be required to comply with the Tier 3 requirements as shown below.

Several types of buses would be exempt from the proposed PM retrofit requirements:

- Model year 2004 and newer buses certified at 0.01 g/bhp-hr PM.
- Buses scheduled for retirement within two years would be exempt from the 100 percent retrofit requirement, except as discussed below for 0.6 g/bhp-hr PM engines. Documentation of planned retirement schedules would be required.
- All alternative-fuel buses owned or leased by a transit agency.

The proposed PM retrofit requirements for fleets on the diesel path are shown below.

#### TIER 1

All 0.6 g/bhp-hr PM buses would require retrofits by January 1, 2003. The ARB staff assumes that most 1990 and older buses with 0.6 g/bhp-hr PM engines would be retired by 2003, so most transit agencies would be retiring, not retrofitting, their oldest buses. Only buses that have already been retrofitted to 0.10 g/bhp-hr PM with an ARB-certified retrofit device meeting the requirements of the U.S.EPA urban bus rebuild and retrofit program would be eligible for the two-year retirement exemption; buses retrofitted to 0.45 g/bhp-hr PM would not be eligible.

## TIER 2

- 1/1/03 -- 20 percent of 0.10 and 0.07 g/bhp-hr PM engines would have to be retrofitted
- 1/1/04 -- 75 percent of 0.10 and 0.07 g/bhp-hr PM engines would have to be retrofitted
- 1/1/05 -- 100 percent of 0.10 and 0.07 g/bhp-hr PM engines would have to be retrofitted

## TIER 3

- 1/1/07 -- 20 percent of 0.05 g/bhp-hr PM engines would have to be retrofitted
- 1/1/08 -- 75 percent of 0.05 g/bhp-hr PM engines would have to be retrofitted
- 1/1/09 -- 100 percent of 0.05 g/bhp-hr PM engines would have to be retrofitted

### d. Zero-emission Bus Demonstration Project

The ARB staff proposes that transit agencies with over 200 urban buses in their active fleets, either owned or leased, on January 31, 2001, would be required to buy or lease three zero-emission buses (ZEBs) and operate them in service for a minimum of a year, starting no later than July 1, 2003. The transit agencies would be required to secure refueling infrastructure and take any other actions necessary for implementation of the project. To qualify as a ZEB, a bus would have to be certified by the ARB Executive Officer. ZEB engines could be powered by fuel cells or electricity.

Transit agencies could petition the Executive Officer for approval to undertake a joint zero-emission bus demonstration project. At a minimum, transit agencies that want to participate in a joint project would have to designate the host agency and jointly fund the project. Electric trolley buses would not qualify as ZEBs for purposes of a joint demonstration project. To assure market penetration, staff proposes that no more than three transit agencies can participate in any one joint project.

### e. Zero-emission Bus Purchases and/or Leases

The ARB staff proposes that transit agencies with over 200 urban buses in their active fleets, either owned or leased on January 1, 2007, would be required to purchase and/or lease ZEBs in 2008. A minimum of 15 percent per year, from model year 2008 through model year 2015, of a transit agency's urban bus purchases and/or leases would have to be ZEBs. If flexibility is needed in scheduling bus purchases, a transit agency could apply to the Executive Officer for approval to deviate from the required purchase schedule. To qualify as a ZEB, an urban bus would have to be certified by the ARB Executive Officer. ZEB engines could be powered by fuel cells, electricity, or fuels that result in zero-emission exhaust levels.

This requirement does not apply if a transit agency's active urban bus fleet is composed of 15 percent or more zero-emission buses on January 1, 2008, or at any time thereafter.

## **2. Requirements for Transit Agencies on the Alternative-Fuel Path**

### **a. New Bus Purchases and/or Leases:**

In order for a transit agency to qualify for the alternative-fuel path, the ARB staff is proposing that at least 85 percent of all new urban bus purchases or leases must be low-emission, alternative-fuel buses, beginning with the adoption of the proposed regulation through model year 2015. If flexibility is needed in scheduling bus purchases, a transit agency could apply to the Executive Officer for approval to deviate from the proposed purchase schedule.

The staff is not proposing a 100 percent purchase or lease requirement as some types of urban buses used by transit agencies, such as articulated buses, may not be immediately available with low-emission, alternative-fuel engines. Additionally, there may not be an adequate number of alternative-fuel buses immediately available for lease.

One advantage to being on the alternative-fuel path is that transit agencies could buy or lease low-emission, alternative-fuel buses meeting the 2.5 g/bhp-hr NO<sub>x</sub> + NMHC standard through the model year 2006. However, in order for transit agencies to be eligible for state and local air quality incentive monies after October 2002, buses would have to be certified to one of the ARB's reduced-emission optional NO<sub>x</sub> + NMHC standards beginning at 1.8 g/bhp-hr NO<sub>x</sub> + NMHC.

### **b. Fleet Averaging for NO<sub>x</sub> Emissions**

The staff proposes that transit agencies meet a minimum fleet average emission standard of 4.8 g/bhp-hr NO<sub>x</sub> by October 2002. The fleet average for each transit agency's fleet would be based on the NO<sub>x</sub> engine certification standard (new or repowered engine) for each urban bus in the active fleet, whether owned or leased, of all fuel types. This is the same as the NO<sub>x</sub> fleet average requirement proposed for transit agencies on the diesel path. However, the ARB staff expects those transit agencies on the alternative-fuel path will be able to achieve and maintain the fleet average requirement fairly easily due to the low emissions of their alternative-fuel buses.

### **c. PM Retrofit Requirements**

The ARB staff is proposing identical PM retrofit requirements for transit agencies on the diesel and alternative-fuel paths as well as purchase of low sulfur diesel fuel, if any diesel fuel is required. However, since alternative-fuel buses already have significantly lower in-use PM emissions and are exempt from the PM bus retrofit requirements, transit districts on the alternative-fuel path would have a smaller percentage of their buses to retrofit. Transit agencies that have phased out their diesel buses, or do so by 2003, will not be required to do any PM retrofits.



d. Zero-emission Bus Demonstration Project

No demonstration program is required for transit agencies on the alternative-fuel path.

e. Zero-emission Bus Purchases and/or Leases

The ARB staff proposes that transit agencies with over 200 urban buses in their active fleets, either owned or leased on January 1, 2009, would be required to purchase or lease ZEBs beginning in 2010 (two years later than transit agencies on the diesel path). Transit agencies on the alternative-fuel path are allowed more time to comply with the ZEB purchase requirements because they have lower NOx fleet average emission levels and have already made investments in alternative-fuel infrastructure. From model year 2010 through model year 2015, a minimum of 15 percent per year of a transit agency's urban bus purchases and/or leases would have to be ZEBs. If flexibility is needed in scheduling bus purchases, a transit agency could apply to the Executive Officer for approval to deviate from the required purchase schedule. To qualify as a ZEB, an urban bus would have to be certified by the ARB Executive Officer. ZEB engines could be powered by fuel cells, electricity, or fuels that result in zero-emission exhaust levels.

This requirement does not apply if a transit agency's active urban bus fleet is composed of 15 percent or more zero-emission buses on January 1, 2010, or at any time thereafter.

**3. Comparison of Fleet Rule Requirements**

Table 7 below provides a comparison of the fleet rule components discussed above for transit agencies on the diesel path and on the alternative fuel path.

**TABLE 7**

| <b>Comparison of Fleet Rule Requirements</b> |                                                   |                                                   |
|----------------------------------------------|---------------------------------------------------|---------------------------------------------------|
| <b>Year</b>                                  | <b>Diesel Path</b>                                | <b>Alternative-Fuel Path</b>                      |
| 10/2002                                      | NOx fleet average requirement                     | NOx fleet average requirement                     |
| 2003-09                                      | PM retrofit requirement                           | PM retrofit requirement                           |
| 7/2003                                       | 3 bus demo of ZEBs for large fleets (>200)        |                                                   |
| 1/2008                                       | 15% of new buses are ZEBs for large fleets (>200) |                                                   |
| 1/2010                                       |                                                   | 15% of new buses are ZEBs for large fleets (>200) |

Although the NOx emission average and the diesel bus retrofit requirements are identical for the two paths, they are likely to have a significantly greater impact on those transit agencies on the diesel path. This is because the low NOx emissions of the alternative-fuel buses would allow for easier attainment of the fleet average standard. Also, natural gas buses, with their inherently low in-use PM emission are exempt from the retrofit requirements.

#### 4. Requirements for Low-sulfur Diesel Fuel

Low-sulfur diesel fuel is necessary for most aftertreatment technologies to function more efficiently and reliably. Low-sulfur fuel enables catalysts and particulate filters to operate more efficiently and with increased durability. With higher sulfur fuel, trap plugging and catalyst fouling can occur. Therefore, the proposed transit fleet rule requires most transit agencies (on both the diesel and alternative-fuel paths) using diesel fuel to purchase and use diesel fuel with a sulfur limit of 15 parts per million (ppm) or less. This requirement is effective beginning July 1, 2002, in order to be consistent with the proposed PM retrofit requirements. However, transit agencies with less than 20 buses in their active fleets that operate in federal ozone attainment areas would not be subject to this requirement until July 1, 2006, since the staff has proposed that these fleets be allowed a delay in the Tier 1 and Tier 2 PM retrofit requirements until January 1, 2007, due to the projected cost and difficulty of securing delivery of low-sulfur diesel fuel in outlying rural areas before 2007.

#### 5. Reporting Requirements

To assure compliance with the fleet rule, the ARB staff proposes that transit agencies submit reports shown below. Table 8 presents an overview of the proposed applicable reporting requirements and the dates on which they must be met.

- New bus purchases and/or leases by transit agencies on the alternative-fuel path.
- Fleet averaging for NOx emissions.
- Compliance with PM retrofit requirements for Tiers 1, 2, and 3.
- Zero-emission bus demonstrations.
- Zero-emission bus purchases and/or leases.

**TABLE 8**

| <b>Proposed Fleet Rule Reporting Requirements</b> |                         |             |                        |             |                     |
|---------------------------------------------------|-------------------------|-------------|------------------------|-------------|---------------------|
| <b>Requirement</b>                                | <b>Applicable Dates</b> | <b>Path</b> | <b>Initial Reports</b> | <b>Date</b> | <b>Final Report</b> |
| Bus purchase                                      | 2000-15                 | AF          | Intent; Records        | 1/2001      | No                  |
| Fleet average                                     | 10/02                   | Both        | Schedule               | 1/2001      | 1/2003              |
| PM retrofits Tier 1                               | 1/00-03                 | Both        | Schedule; Records      | 1/2002      | No                  |
| PM retrofits Tier 2                               | 1/03-05                 | Both        | Schedule; Records      | 1/2002      | No                  |
| PM retrofits Tier 3                               | 1/07-09                 | Both        | Schedule; Records      | 1/2005      | No                  |
| ZEB demo                                          | 7/03                    | D           | Purchase/demo plan     | 1/2003      | 1/2005              |
| ZEB purchase                                      | 2008-15                 | D           | Plan; Records          | 1/2007      | No                  |
| ZEB purchase                                      | 2010-15                 | AF          | Plan; Records          | 1/2009      | No                  |

Notes: AF indicates alternative-fuel; D indicates diesel  
Some requirements and a delayed compliance date are based on fleet size.

a. New Bus Purchases and/or Leases by Transit Agencies on the Alternative Fuel Path

Transit agencies that intend to qualify for the alternative-fuel path would be required to report such intent by letter to the ARB by January 31, 2001. The responsible transit district would maintain and produce on request records of the number, model year, and fuel used for engines in transit buses they currently own or operate, bus purchases and/or leases beginning in January 1, 2000, fuel types, and annual average percentage of total bus purchases and/or leases that were alternative-fuel buses. Any requests for deviation from the requirement that 85 percent of buses purchased per year must be alternative-fuel buses would be submitted to the Executive Officer.

b. Fleet Averaging for NOx Emissions:

The ARB staff is proposing that all transit agencies calculate their current urban bus NOx fleet average and submit that information to the ARB by January 31, 2001. If the fleet average exceeds 4.8 g/bhp-hr NOx, a schedule adopted by their governing board for meeting the 4.8 g/bhp-hr NOx fleet average standard by October 1, 2002, would be included in the submittal. Agencies planning on complying with the requirement by retiring all model year 1987 and earlier buses would submit that information instead. By January 1, 2003, a final report demonstrating compliance with the NOx fleet average requirement would be submitted to the ARB.

c. PM Retrofit Requirements

The ARB staff is proposing that affected transit agencies submit to the ARB a report showing their schedule for Tier 1 and Tier 2 retrofits (or retirements, as applicable), and the number and type of exempt buses, by January 31, 2002. For Tier 3 retrofits, a similar report would be due January 31, 2005. The transit agencies would maintain and produce on request, records of the number and model year of buses retrofitted, types of retrofit devices used and number of buses exempt.

d. Zero-emission Bus Demonstration

The applicable transportation agency and/or the transit district governing board would submit by January 1, 2003 plans for the purchase and/or lease and demonstration of at least three ZEBs. The plan would indicate planned expenditures for buses, the projected bus order and delivery schedule, fuel type and facilities, plus information about how the buses will be demonstrated. A final report on the demonstration project would be due on January 31, 2005.

e. Zero-emission Bus Purchases

The responsible transportation agency and/or the transit district governing board would submit a report giving a description of the zero-emission technology to be utilized and overall plans for implementation of the purchase requirement, and any request for exemption from the purchase requirement based on existing zero-emission bus fleet

composition, by January 1, 2007, for transit agencies on the diesel path and by January 1, 2009, for transit agencies on the alternative-fuel path.

The responsible transit agency would maintain and produce on request, records on the the number, model year and fuel used for engines they currently own or operate, bus purchases and/or leases beginning in 2008 or 2010, fuel types, and annual average percentage of total bus purchases and/or leases that were ZEBs. Any requests for deviation from the requirement that 15 percent of buses purchased per year must be zero-emission buses would be submitted to the Executive Officer.

## **6. Future Feasibility Review**

The ARB staff proposes that the Board provide for review of zero-emission bus technology, and the feasibility of implementing the proposed requirements. The ARB would conduct its review no later than January 2006. This review would reassess the need for the requirements and their technical and economical feasibility, based on information available in 2005 from the ZEB demonstration projects. If the technical feasibility of the zero-emission bus requirements are confirmed, the staff would recommend to the Board the implementation of the 2008 and 2010 zero-emission bus purchase requirements.

## **V. TECHNOLOGICAL FEASIBILITY**

Diesel engines have long been the engines of choice for use in urban buses. This is due to the efficiency and durability of diesel engines, as well as the operators' familiarity with diesel engine technology. Historically, this preference is also due to the lack of viable alternative-fuel engine technology for use in heavy-duty vehicle applications. This is no longer the case. Recent advances have enabled alternative-fuel engines to close the performance and reliability gaps with diesel engines and, at the same time, clearly outperform diesel engines in terms of emissions. This chapter focuses on the technologies that make the proposed standards technologically feasible. Included here are discussions of currently-available technologies, retrofit technologies for reducing NO<sub>x</sub> and toxic PM emissions from the older diesel urban bus fleet, and emerging diesel and advanced, alternative-fuel technologies.

### **A. Currently-Available Technology**

#### **1. Diesel Technology**

Diesel engines operate by compression ignition that causes the fuel to ignite upon injection into highly compressed air at elevated temperatures. NO<sub>x</sub> formation is directly dependent on the flame temperature. As combustion temperatures increase, NO<sub>x</sub> emissions also increase. Therefore, NO<sub>x</sub> control technologies generally focus on reducing the combustion temperatures and the duration of these high temperatures within the cylinder. In general, however, emission control strategies that reduce NO<sub>x</sub> tend to increase PM. Current emission control technologies such as combustion chamber modifications, advanced induction systems, and fuel injection strategies have

resulted in diesel engines that emit about 30 percent less NO<sub>x</sub> than diesel engines manufactured a decade earlier, while still allowing for decreases in PM emissions.

#### a. Combustion Chamber Modifications

Manufacturers have made significant progress in the area of combustion chamber modifications. If the fuel/air mixing rates and the shape of the flame in the combustion chamber are sufficiently controlled, they can be optimized over the range of engine operating conditions to control and minimize the formation of pollutants. This involves careful attention to combustion chamber geometry to optimize air flow parameters.

Proper air flow in the combustion chamber is also important to allow proper fuel injection penetration. If injected too far, the fuel spray will wet the cylinder wall leading to increased unburned HC emissions and increased wear. If the fuel spray is not injected far enough, inadequate mixing will lead to increased HC and PM emissions.

#### b. Advanced Induction Systems

Manufacturers have incorporated advanced turbochargers/aftercoolers in current diesel engines to provide better air/fuel management and lower intake air temperatures to meet lower emission standards. Turbocharging has a positive influence on the pumping losses of an engine and on the combustion efficiency through control of the air/fuel ratio. Aftercoolers cool the intake charge to reduce peak combustion temperatures, thus reducing NO<sub>x</sub> emissions.

#### c. Injection Timing/High Pressure Fuel Injection

Retarding injection timing (starting combustion later) reduces NO<sub>x</sub> through a reduction in the peak combustion temperature. However, this tends to increase PM emissions and fuel consumption. Manufacturers have developed higher pressure injection systems as one approach to reduce fuel economy impacts and PM emission increases. Higher injection pressures result in better atomization, better air utilization, more complete combustion, and consequently reduce PM emission, while improving fuel efficiency.

## **2. Alternative-Fuel Technology**

#### a. CNG and LNG

Alternative fuels such as methanol, ethanol, propane, compressed natural gas (CNG), and liquefied natural gas (LNG) have provided manufacturers with new options in meeting increasingly stringent emission standards. Currently, only natural gas technology has developed sufficiently for commercial heavy-duty vehicle applications. Compared to conventional diesel technology, natural gas technology has already shown emission reductions in the range of 50 percent for NO<sub>x</sub> and PM. As discussed earlier, PM in-use emissions are inherently lower, from 20 to 100 times lower.

Unlike diesel engines, which ignite by compression, natural gas engines are spark-ignited. In this respect, they are similar to gasoline engines, which also use the electrical energy provided by spark plugs to initiate the combustion process. Spark-ignition engines are slightly less efficient than compression-ignition engines (i.e., diesel engines). However, current heavy-duty natural gas engine technology, such as lean-burn, closed-loop, electronic fuel management, has enabled natural gas engines to approach diesel-like fuel economy and performance, while emitting 50 percent less NOx and PM than comparable diesel engines.

Both CNG and LNG engines are currently available for heavy-duty vehicle applications. CNG engines have traditionally been used in urban buses, although LNG engines have also been ordered. Some transit agencies, in fact, prefer LNG since its higher energy density provides for longer vehicle range, reduced weight and lower capital costs than CNG. However, LNG is not readily available in California today, therefore the incremental fuel cost is higher. Ongoing demonstration programs could allow for LNG availability in the future at significantly lower costs.

Most heavy-duty engine manufacturers sell both natural gas and diesel fuel engines. Some engine manufacturers have certified their natural gas engines to the ARB's optional, reduced-emission NOx standards, which start at approximately 40 percent less than the current 4.0 g/bhp-hr NOx standard. Table 9 below shows the 1999 model year urban bus engines certified to the ARB's optional, reduced-emission NOx standards.

**TABLE 9**

| <b>1999 Model Year Urban Bus Engines Certified to ARB's Optional, Reduced-Emission NOx Standards<br/>(Emission Levels for NOx, PM, and NMHC are in g/bhp-hr)</b> |                           |                     |                  |                     |            |           |             |                          |             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|---------------------|------------------|---------------------|------------|-----------|-------------|--------------------------|-------------|
| <b>MY</b>                                                                                                                                                        | <b>Manuf.<sup>a</sup></b> | <b>Service Type</b> | <b>Fuel Type</b> | <b>Displ. (ltr)</b> | <b>NOx</b> | <b>PM</b> | <b>NMHC</b> | <b>Cert. Std. NOx/PM</b> | <b>HP</b>   |
| 1999                                                                                                                                                             | DDC                       | UB/HHD              | CNG              | 12.7                | 2.0        | 0.02      | 0.8         | 2.5/0.05                 | 330         |
| 1999                                                                                                                                                             | DDC                       | UB/HHD              | CNG              | 8.5                 | 2.2        | 0.01      | 0.6         | 2.5/0.05                 | 275         |
| 1999                                                                                                                                                             | Cummins                   | UB/HHD              | L/CNG            | 10.0                | 1.4        | 0.02      | 0.03        | 2.0/0.05                 | 280/<br>300 |
| 1999                                                                                                                                                             | Cummins                   | UB/HHD              | L/CNG            | 8.3                 | 1.7        | 0.01      | 0.2         | 2.5/0.05                 | 250/<br>275 |

<sup>a</sup>Service Type: UB(Urban Bus); HHD(Heavy Heavy-Duty)

**b. Electric Trolley Buses**

Trackless electric trolley systems have been operated in North America and Europe for decades. Electric trolley buses are commercially available and in regular use in several transit districts nationwide. In California, the San Francisco Municipal Railway's transit fleet includes over 340 electric trolley buses.<sup>1</sup> Electric trolley buses are rubber-tired urban buses with electric motors powered by electricity distributed through an overhead twin-wire power supply. The electric power from the utility is converted to 750 volts DC at substations located at approximately one mile intervals and is fed from the substation

through underground cable to the overhead twin-wire. Onboard batteries provide electric trolley buses with limited emergency propulsion capabilities.

While electric trolley buses do not produce exhaust emissions, there are emissions associated with the generation of electricity used to power the buses. These emissions depend on the mix of power plants supplying the electricity. While this technology provides opportunities for significant emission reductions from conventional urban buses, it provides transit agencies with less flexibility due to the extensive and expensive public infrastructure and fixed routes.

## **B. Retrofit Technology**

Retrofit technologies are available to reduce emissions from the older urban bus fleet. A retrofit involves a hardware modification to an existing engine to reduce its emissions from the standards to which it was originally certified. This section discusses only NO<sub>x</sub> and PM retrofit technologies, although other pollutants may also be reduced through retrofits.

### **1. PM Retrofit Technology**

#### **a. Diesel Particulate Trap Oxidizer**

A trap oxidizer system consists of a filter positioned in the exhaust stream designed to collect a significant fraction of the particulate emissions while allowing the exhaust gases to pass through the system. Since the volume of particulate matter generated by a diesel engine is sufficient to fill up and plug a reasonably sized filter over time, a means of disposing of the trapped particulate must be provided. The most promising means of disposal is to oxidize the particulate in the trap, thus regenerating the filter. Different techniques are available to facilitate trap regeneration since the exhaust temperature of diesels is not always sufficient to initiate regeneration. Trap systems do not appear to cause any additional engine wear or affect vehicle maintenance.<sup>2</sup>

Several promising particulate trap technologies are Johnson Matthey's Continuously Regenerating Technology (CRT<sup>TM</sup>) diesel particulate filter and Engelhard's DPX<sup>TM</sup> catalytic soot filter. The CRT<sup>TM</sup> combines a platinum-based catalyst with a filter element. The catalyst oxidizes NO to NO<sub>2</sub> and uses the produced NO<sub>2</sub> as an oxidant to remove the PM trapped in the filter material following the catalyst. The CRT<sup>TM</sup> does require the use of low-sulfur diesel fuel (< 50 parts per million sulfur). Engelhard manufactures different DPX<sup>TM</sup> PM systems that can work at different fuel sulfur levels, including current California fuel. Programs are underway to evaluate appropriate levels of sulfur for future diesel fuel. In one such program in southern California, Detroit Diesel Corporation, Johnson Matthey, and Engelhard will demonstrate ARCO's new diesel fuel containing virtually no sulfur, thus enabling catalysts and particulate filters to operate more efficiently and with increased durability.<sup>3</sup> The CRT<sup>TM</sup> has demonstrated reductions in PM emissions by greater than 90 percent.

## b. Diesel Oxidation Catalyst

An oxidation catalyst transforms pollutants into harmless gases by means of oxidation. The catalyst oxidizes CO, gaseous HC, and the liquid HCs adsorbed on the carbon particles present in diesel exhaust gases. The liquid HCs are referred to as the soluble organic fraction (SOF) and make up part of the total PM. Oxidation catalysts can reduce the SOF of particulate by 90 percent under certain operating conditions<sup>4</sup>, and according to staff estimates, could reduce total particulate emissions by greater than 30 percent.

Oxidation catalysts have proven effective in achieving modest PM emission reductions on older buses. Under the U.S. EPA's urban bus rebuild/retrofit program, five manufacturers have certified diesel oxidation catalysts as providing at least a 25 percent reduction in PM emissions.

## **2. NOx Retrofit Technology**

### a. Selective Catalytic Reduction

Selective catalytic reduction (SCR) systems use a reductant, usually ammonia or urea, to convert NOx to nitrogen and oxygen. These systems are common in stationary sources and are also used on some mobile sources in Europe. In this system, the reductant is injected into the exhaust upstream of the catalyst. As the exhaust gases, along with the reductant, pass over a catalyst applied to either a ceramic or metallic substrate, NOx emissions can be reduced by more than 70 percent<sup>5</sup>. The staff estimates PM emissions could be reduced by 25 percent and HC emissions by 50 to 90 percent. SCR retrofit systems are expected to be available for urban bus applications within two to three years.

## **C. New Technology**

To comply with future, more stringent NOx emission standards, diesel engine manufacturers are researching several promising technologies for diesel engines, such as cooled exhaust gas recirculation (EGR) and aftertreatment technologies. Incorporation of these technologies into natural gas engines will also lower their emissions significantly from current levels, continuing to make them lower-emitting than even the best available diesel technology.

Other technologies capable of reducing emissions to near-zero or zero levels, such as hybrid-electric, battery-electric, and fuel cell technologies, are rapidly emerging. However, few of these technologies are at a commercial stage for urban buses today. The proposed regulation's aggressive time frame for longer-term engine standards is necessary to move near-zero and zero-emission urban buses from the developmental stage to commercial production. The proposed regulation requires the ARB staff to perform a technology assessment of zero-emission technology for urban transit buses no later than January 2006.



## **1. Future Diesel Technology**

### **a. Exhaust Gas Recirculation**

Exhaust gas recirculation is one of the most effective engine control methods for reducing NOx emissions. Spent combustion gases recirculated back into the intake system serve as a diluent to lower the oxygen concentration and to also increase the heat capacity of the air/fuel charge. Cooled EGR (cooled through the aftercooler) is used to minimize combustion temperatures. This reduces peak combustion temperature and the rate of combustion, thus reducing NOx emissions. However, PM emissions may increase and fuel economy may decrease. The proper balance of EGR and temperature may provide the proper characteristics necessary for decreasing NOx emissions without increasing PM emissions. It is anticipated cooled EGR would be an integral part of the engine manufacturers' effort to meet the lower NOx emission requirements in October 2002.

### **b. Aftertreatment Technologies**

Heavy-duty engine exhaust aftertreatment for NOx is currently limited by the lean environment (excess oxygen) of diesel engines. Automotive catalysts rely on a nearly perfect balance of oxygen in the exhaust stream to maximize catalytic converter efficiency. One solution for heavy-duty vehicles, including urban buses, is the use of SCR systems described above in the Retrofit Technology section. The estimated cost of an SCR system appears reasonable and NOx emissions are reduced by more than 70 percent. Most of the challenges to SCR use appear to be pragmatic (e.g., packaging, communication of the SCR system with the engine's computer controls, etc.). SCR systems are expected to be commercially available on new buses within two to three years.

For the 2004 time frame, NOx adsorbers are expected to be available. NOx adsorbers do not require an additional reductant to be added. Again, the cost is expected to be reasonable and NOx emissions are expected to be reduced by more than 70 percent. However, a critical element of this technology and other aftertreatment technologies is the necessity to have low-sulfur fuels. Although an SCR system may not need low-sulfur fuel, most other heavy-duty aftertreatment technologies will not function efficiently and reliably in an exhaust environment with a significant quantity of sulfates present, which cause trap plugging and catalyst fouling. As mentioned previously, programs are underway to evaluate appropriate levels of sulfur for future diesel fuel.

As discussed in the retrofit section, several particulate trap systems are available to reduce PM emission levels by more than 90 percent. It is expected that to meet the proposed 2004 requirements particulate trap systems will be used in conjunction with a NOx aftertreatment (SCR or adsorbers). Low-sulfur fuel (less than 30 ppm sulfur) will be necessary with this technology.

### c. Diesel Hybrid-Electric

Bus manufacturers and transit agencies have expressed interest in diesel hybrid-electric technology because of their familiarity with diesel technology and its compatibility with current fueling infrastructure. Diesel hybrid-electric technology utilizes electric traction drive motors, batteries, and a diesel engine/generator set combination, rather than the conventional engine/transmission combination. The batteries can be charged by the engine/generator set and through regenerative braking. On site "plug-in" charging may also be used to recharge batteries

Several demonstration projects with diesel hybrid-electric buses are underway with promising results. Preliminary reports indicate that the higher efficiencies associated with diesel hybrid-electric technology, compared to conventional diesel technology, can reduce fuel consumption by 25 percent, and reduce emissions of NOx and PM by 30 percent and 80 percent, respectively. In addition, an engine operating in a hybrid vehicle generally operates in a limited operating range. Therefore, without the severe transient parameters that typically accompany urban bus operation, exhaust aftertreatment can be designed far more efficiently. Significant emphasis is being placed on cost reductions for future hybrid-electric buses.

### d. Additional Controls

In order to reach the 0.2 g/bhp-hr NOx levels in 2007, additional engine controls and refined aftertreatment are expected to be necessary. It is anticipated that significantly lower NOx levels can be achieved through increased and optimized exhaust gas recirculation rates under all operating conditions. Relatively high PM emissions resulting from increased exhaust gas recirculation usage can be significantly reduced with a particulate filter, as discussed earlier. The ARB staff has attempted to harmonize the proposed 2007 model year urban bus engine standards (0.2g/bhp-hr NOx and 0.01 g/bhp-hr PM) with the heavy-duty engine standards under consideration by the U.S. EPA for the 2007 time frame.

## **2. Alternative-Fuel Technology**

### a. Natural Gas

The engine and aftertreatment technologies discussed above in the Diesel Technology section are generally applicable to lean-burn natural gas engines. Because natural gas engines operate at higher temperatures, which can improve the efficiency of aftertreatment technologies, higher aftertreatment efficiencies could be achieved than from comparable diesel engines. In addition, natural gas contains little or no sulfur so aftertreatment systems would not have the efficiency and durability issues associated with sulfur poisoning from diesel fuel.

### b. Hybrid-electric (non diesel)

In the developmental and early demonstration stage, hybrid-electric buses have been designed with power systems integrating battery-electric motors with internal

combustion engines (or fuel cells). Hybrid-electric bus designs can incorporate internal combustion engines fueled by alternative-fuels, such as LPG and CNG, in addition to diesel fuel, as discussed above in the Diesel Technology section. These buses can operate in pure electric mode or in hybrid mode. A bus operating in pure electric mode does not have emissions. A bus operating in hybrid mode will have emissions, which will vary depending on fuel type, but will have the potential for significantly lower emissions than a conventional diesel urban bus.

#### c. Battery-electric

Battery electric motor propulsion systems offer quiet, exhaust free, and odorless bus operation without the fixed route constraints of electric trolley buses. Batteries are devices that store electrochemical energy, without the polluting byproducts of combustion. When the stored energy is depleted, the batteries must be recharged (refueled) by the process of passing electricity into the battery. The current practice is to connect the buses to an electricity generation grid overnight. As noted in the previous discussion on electric trolley buses, emissions from power plants supplying electricity are a consideration.

An electric powertrain can process stored energy more than five times as efficiently as a diesel engine and can be further enhanced with the presence of regenerative braking. However, compared to diesel buses, the range of battery-electric buses is severely limited by the energy storage capacity of the various chemical battery technologies. For example, diesel #2 fuel has nearly 300 times by weight and 90 times by volume the stored energy of a lead-acid battery. Utilization of advanced lead-acid or nickel cadmium batteries will provide buses with more range -- up to 120 miles. While the passenger capacity of battery-electric buses is also reduced by the weight and volume of current batteries, these buses are suitable for the many short-range duty cycles typical of urban bus operations. Furthermore, range can be extended with opportunity charging (with fast or rapid charging), battery-exchange, or on-board auxiliary power units.

Commercial battery-electric bus technology is currently limited to smaller buses, known as electric shuttles, that do not meet the gross vehicle weight rating classification for conventional urban buses (>33,000 pounds). These electric shuttles are in regular service in many transit districts nationwide. In California, about 30 percent of the Santa Barbara Municipal Transit District fleet is battery-electric shuttles, which are used primarily on waterfront and downtown routes. Electric shuttle utilization is constrained by range requirements, terrain, and climate. Current development efforts are focusing on battery and recharging technology. Larger electric buses that would meet the definition of an urban bus are still in the developmental stage.

#### d. Fuel Cells

Fuel cell vehicles operate quietly, efficiently, and have the potential for zero or near-zero exhaust emissions. Fuel cells generate electric power through an electrochemical reaction in the same manner as batteries. While batteries must be recharged when the

stored reactants (fuels) are depleted, fuel cells can produce power as long as hydrogen and oxygen fuels are continuously supplied.

Each cell of a fuel cell stack contains two electrodes (usually containing platinum to catalyze the anodic and cathodic reactions) separated by an electrolyte (either aqueous or nonaqueous). Hydrogen (H<sub>2</sub>) is supplied to the anode, and oxygen (O<sub>2</sub>) to the cathode. The anodic oxidation of hydrogen results in protons (H<sup>+</sup>) and electrons (e<sup>-</sup>). Protons migrate through the electrolyte membrane to the cathode. The electrons flow through an external circuit to the cathode. The external circuit can power a load while the protons, electrons, and oxygen recombine at the cathode to produce water.

The choice of fuel will impact emissions, overall fuel efficiency, and cost of the fuel cell bus. The type of fuel supplied to a fuel cell bus will determine the exhaust emissions. If onboard hydrogen (either delivered or produced at a transit agency's central fueling station) is the fuel source, the exhaust emissions will be zero. On-site production of hydrogen would be primarily by electrolysis of water or reforming of hydrogen-containing fuels. If fuels such as natural gas, methanol, diesel, or gasoline are reformed onboard the bus (to produce hydrogen for the fuel cell), then some level of controlled emissions will occur, although at lower amounts than those emitted by internal combustion engines. Onboard fuel reforming reduces fuel efficiency because a percentage of the energy content of the original fuel is lost in the conversion. Onboard reforming also increases the purchase cost of the bus.

Proton exchange membrane (PEM) fuel cell and phosphoric acid fuel cell (PAFC) technologies have proven to be reliable. PAFCs are currently used worldwide to produce heat and electricity. They are particularly suited for hospitals and high technology facilities where a highly reliable source of energy is needed. The two most prominent types of fuel cells currently under development for transit applications are PEM fuel cells and PAFCs. In particular, the PEM fuel cell technology has emerged as the prime candidate in the transportation market. Ballard Power Systems has employed the PEM technology in demonstration fuel cell bus programs in Chicago, Illinois, and Vancouver, Canada. Additionally, dbb fuel cell engines, inc. expects to commercially produce fuel cell bus engines by 2002.<sup>6</sup> Fuel cell buses using the PAFC technology with onboard methanol reforming have been built under a Department of Energy/Federal Transit Administration contract and demonstrated by Georgetown University.

## **VI. ISSUES**

The following sections discuss issues and topics pertaining to the proposed regulation.

### **A. Compressed Natural Gas Urban Bus Fleets**

Several transit agencies have indicated that CNG bus operating costs are higher than diesel bus operating costs. However, some transit agencies have reported lower operating costs for CNG buses than for diesel buses. As natural gas fleets are relatively new, a comprehensive long-term comparison of operating costs of CNG buses to diesel buses is difficult to do at this time. Operating costs include both maintenance and fuel costs. While maintaining diesel fleets can currently cost less than for CNG

fleets, the requirements for diesel engines to meet more stringent emission standards, along with the availability of more reliable natural gas engines, should close that gap and equalize the costs. Fuel costs per mile for natural gas buses, including natural gas compression or liquefaction, is less than for diesel buses. The increased price of low-sulfur diesel fuel needed in the future should increase this difference. Future operating costs for natural gas fleets and diesel fleets are expected to be comparable. Transit agencies can project local costs for operating different types of fleets and consider that information when choosing the diesel path or the alternative-fuel path.

## **B. Funding Sources**

Funding constraints have been raised by many transit agencies as a concern associated with this proposal, and the ARB staff has looked into the urban bus funding process. The Federal Transit Administration (FTA) pays 80-83 percent of the purchase cost of a new urban bus. The remaining cost is made up from local and state transportation funds. Local and regional transportation planning agencies control the allocation of federal, state and local transportation funding in urban areas; the State Department of Transportation allocates some funds in rural areas.

The transportation planning agencies prioritize project categories and assign funding to each category. Transportation projects can include planning projects, streets and highways, bridges, public transit, rail projects, ferry operation, pedestrian and bicycle facilities, and other services and projects. Without additional transit funding in some regions, any additional cost of buying and operating transit buses meeting lower emission standards could result in service cut-backs or fare increases. In order to adequately fund transit operations, some transportation planning agencies would have to re-prioritize their project categories. The ARB staff and some local air districts are encouraging transportation planning agencies to provide more funding for transit agencies.

Various incentive programs to assist with new bus purchases are also available in most areas of the state. These incentive programs include the federal TEA-21 Congestion Mitigation and Air Quality Improvement Program (CMAQ), the state Carl Moyer Memorial Program, grants from the California Energy Commission (CEC), and air districts' motor vehicle registration fee (MV) programs. Additional funding should become available from other TEA-21 programs, as well as from state transportation accounts.

Projected statewide funding for new alternative-fuel buses is shown below in Table 10. In addition to new alternative-fuel bus purchases, some programs can also fund infrastructure costs.

**TABLE 10**

| <b>Funding Scenario for Alternative-Fuel Buses and Infrastructure</b> |                                  |                                     |
|-----------------------------------------------------------------------|----------------------------------|-------------------------------------|
| <b>Funding Program</b>                                                | <b>\$M for New Bus Purchases</b> | <b>Infrastructure Costs Covered</b> |
| FHWA CMAQ <sub>2</sub>                                                | 60                               | Yes                                 |
| FTA Formula 5307 <sub>1</sub>                                         | 102                              | Yes                                 |
| FTA Clean Fuels Formula Grants <sub>2</sub>                           | 10                               | Yes                                 |
| FTA Transit Capital 5309 <sub>2</sub>                                 | 11                               | Yes                                 |
|                                                                       |                                  |                                     |
| Moyer Incentive <sub>3</sub>                                          | 4.0                              | No                                  |
| State, local <sub>1</sub>                                             | 34                               | Yes                                 |
| MV Projects <sub>1</sub>                                              | 12                               | Yes                                 |
| CEC grants                                                            | 0                                | Yes (\$2M)                          |

1. Based on historical funding.
2. Best case scenario in California
3. Estimated amount as statewide data not yet available

The incentive programs generally co-fund the cost of an alternative-fuel bus and, in some cases, the cost of the infrastructure. In general, the staff found that adequate funding -- from transportation, air quality and energy-related sources -- is available to subsidize the incremental cost of alternative-fuel buses in urban areas, assuming a normal bus turnover rate. However, enough transportation or incentive funding has not been identified to cover the entire cost of the required infrastructure. The ARB staff is working with other agencies to assist in securing additional funding from federal, state, and local sources.

Only the purchase of buses with engines meeting the ARB's optional, reduced-emission standards or other low-emission standards (as defined by the air districts) meet the eligibility criteria for air quality incentive funds. Only the incremental cost of buses meeting the lower standards is generally funded. The ARB expects alternative-fuel buses that certify to the ARB's optional 2.5 g/bhp-hr NOx standard from 2000 to October 2002 to be eligible for grant funding. After October 2002 when a more stringent NOx + NMHC engine standard is in effect, only buses with engines meeting the 1.8 g/bhp-hr optional NOx + NMHC standard (or a lower reduced-emission optional standard) are expected to be eligible for incentive funding. Air quality incentive funds may also be used for technology advancement. Therefore, emerging zero-emitting technologies, such as fuel cell buses, would be eligible for co-funding with air quality incentive funds.

### **C. School Buses**

The ARB staff has received numerous comments that school buses should be included in this proposal, and, in fact, ARB sets a high priority on reducing student exposure to toxic particulate emissions from diesel-powered school buses. Originally, a school bus fleet rule was included in this proposal. However, the ARB staff has found barriers to including school districts in the fleet rule. The most significant barrier is the lack of available funding for new bus purchases and infrastructure for the approximately 900

school districts in the state that provide school bus service. The ARB will consider a separate proposal to reduce emissions from school buses at a later date. In the interim, the ARB staff will assist and encourage transportation agencies, air districts, state agencies, environmental groups, school districts and others to identify funding opportunities and regulatory methods that would reduce student exposure to toxic PM emissions from diesel-fueled engines.

#### **D. Long-term Viability of Natural Gas Fleets**

One of the concerns expressed to the ARB staff during the development of this proposal was the possibility of stranding transit agencies' investments in natural gas infrastructure as fleet operators acquire zero-emission buses. The ARB encourages and supports the purchase of clean natural gas buses and believes this technology has long-term viability. The staff proposal for transit agencies on the alternative fuel path requires that 85 percent of new bus purchases be alternative-fuel through model year 2015. Therefore, 85 percent of new bus purchases for transit agencies on the alternative-fuel path would likely be natural gas or, eventually, for large fleets, zero-emission buses. An option for producing hydrogen is to reform CNG on site. In this case, the existing natural gas infrastructure will be transferable to the operation of fuel cell buses and could substantially reduce the infrastructure cost for fuel cell bus fleets.

#### **E. Natural Gas Availability**

Pipeline natural gas is not available in some areas, including the Lake Tahoe area and some rural counties. In those areas, transit districts have little opportunity to operate natural gas buses. The ARB staff expects that in areas of the state where natural gas is unavailable, transit fleets will continue to purchase and/or lease diesel buses, thus participating in the diesel path of the transit bus fleet rule. Diesel bus purchases or leases will be required to meet the emission standards for the years 2002, 2004, and 2007, as proposed in this regulation.

#### **F. Safety Issues**

The safety of all motor vehicle technologies is a concern. Compressed natural gas tanks, which are under high pressure, have the potential to rupture. A rupture of a CNG tank can cause severe damage. One such rupture occurred several years ago at the Los Angeles County Metropolitan Transit Authority. To help ensure safety, operators with natural gas buses have instituted rigorous inspection procedures and provided safety training, in addition to other safeguards. Since CNG is more volatile than diesel fuel, modifications to existing maintenance facilities are generally necessary. The modifications usually consist of a methane detection system, an improved ventilation system, new lighting, employee training, and containment procedures.

Safety issues for battery-electric buses (and passenger vehicles) have been addressed by codes, standards or recommended guidelines for battery recharging stations, by onboard systems, and by training programs for emergency response personnel. One California transit district reports no battery-related incidents after 25,000 duty cycles.

The ARB staff is aware of only two emergency incidents, both of which occurred on the East Coast.

For fuel cell buses, safety concerns vary according to the fuel feedstock, but frequently focus on hydrogen handling and use. Hydrogen and natural gas, as flammable substances, have similar safety issues. Gaseous fuels have been used in transit applications for several years. This existing base of information can be fairly easily extrapolated to hydrogen. Some work has gone into the preparation and publication of guidelines for hydrogen systems and equipment.

## **G. Ridership Issues**

Transit agencies that operate low-emission, alternative-fuel buses advertise the clean air benefits of their buses. Some studies show a definite increase in ridership attributable to reduced air pollution and smoke-free exhaust. However, a lack of transportation funding due to increased capital and operating costs of alternative-fuel buses could cause delays in replacing older, less reliable diesel buses or increases in fares, thus decreasing ridership. This could adversely impact emission reduction opportunities and those who depend on public transit. Adequate availability of incentive funding can help avoid such impacts.

## **H. Statement of Principles**

The Statement of Principles (SOP), an agreement signed by the ARB, U.S. EPA, and heavy-duty engine manufacturers in 1995, provides a fixed schedule for the introduction of new heavy-duty engine standards. It is intended to result in consistency nationwide, where possible, in heavy-duty engine standards, including urban bus engine standards. The adoption of a transit bus fleet rule is not in conflict with the SOP agreement. In lieu of adopting new mandatory urban bus engine standards effective in the short term, the ARB staff is proposing a transit bus fleet rule to achieve near term emission reductions. For the long term, the ARB staff has attempted to harmonize the new urban bus engine standards in this proposal (0.2g/bhp-hr NO<sub>x</sub> and 0.01 g/bhp-hr PM) with the heavy-duty engine standards under consideration by the U.S. EPA for the 2007 time frame. If the proposed levels are not the emission levels ultimately adopted by the U.S. EPA, staff would consider modifications to the proposed long-term emission standards.

## **I. Settlement Agreements**

The ARB and the U.S. EPA have already adopted heavy-duty engine emission standards to take effect in 2004. As a result of the Heavy-duty Diesel Settlement Agreements between the U.S. EPA, the ARB, and seven engine manufacturers, signed in 1998, the engine manufacturers will "pull-ahead" the introduction of new engines, i.e., they will introduce engines meeting the 2004 heavy-duty engine emission standards into California buses beginning in October 2002. However, there is an issue related to one engine manufacturer not subject to the pull-ahead requirement that is producing urban bus engines being marketed and sold by a second engine manufacturer that is subject to this requirement. The ARB staff believes that if these engines were indeed marketed by the second manufacturer beginning in October 2002, this would jeopardize the



emission benefits of this proposal and would be a circumvention of the Settlement Agreements and a violation of its applicable requirements.

#### **J. Buses Designated as Alternative-fuel Buses**

For the purposes of the fleet rule, ARB staff proposes that buses designated as alternative-fuel buses are: natural gas, propane, ethanol buses, battery-powered buses, electric trolley buses, hybrid-electric CNG buses, fuel cell buses and other advanced technologies that do not rely on diesel fuel. Diesel, diesel hybrid-electric, dual-fuel buses, and other buses that use diesel fuel would not be considered alternative-fuel buses.

The purchase of diesel hybrid-electric buses is allowed on the alternative-fuel path, as 15 percent of new purchases can be something other than alternative-fuel buses. However, engine manufacturers have expressed concern that purchase of diesel-hybrid-electric buses would not count towards the 85 percent alternative-fuel purchase requirement. Engine manufacturers maintain that emissions from diesel hybrid-electric buses, and from newer technology diesel buses from 2004 to 2007, could be lower than those of natural gas buses.

The ARB staff agrees that, at a particular point in time, NO<sub>x</sub> emissions from a new diesel hybrid-electric or newer technology diesel bus could be lower than NO<sub>x</sub> emissions from a new CNG bus (though not as low as emissions from electric-powered buses, hybrid-electric CNG buses, or hydrogen fuel cell buses). However, ARB staff does not believe lower NO<sub>x</sub> emissions for some model years is sufficient justification to allow diesel buses or diesel hybrid-electric buses to qualify toward the 85 percent alternative-fuel purchase requirement.

One of the main purposes of the alternative-fuel path is to encourage transit agencies to make a firm commitment to operating an alternative-fuel fleet. In the long-term, this helps engine manufacturers justify continued reliability and emission reduction improvements to their alternative-fuel engines. Second, staff estimates, based on existing in-use test data, that PM in-use emissions would be 30 to 50 percent lower for a natural gas bus engine certified to the proposed 0.03 g/bhp-hr PM standard than for a diesel bus engine certified to the proposed 0.01 g/bhp-hr PM standard.

#### **K. Zero-emission Bus Demonstration Projects**

The ARB staff is proposing that transit agencies that are required to undertake a zero-emission bus demonstration project could conduct a joint project with a limit of no more than three agencies per project. A joint demonstration project would mean significant cost-savings for those transit agencies involved because the cost of management, training, infrastructure, any new facilities or modifications, and other costs would be shared. In the proposal, a demonstration project would include three zero-emission buses. A request has been made to allow fewer than the required three buses per agency in a joint project. In light of the cost-savings already achieved, and the need to provide a broad-based demonstration that includes mechanic and driver training, public visibility, revenue service over a large area, passenger reaction, and overall experience

with this new technology, the staff believes its proposal requiring three buses per agency is also appropriate for joint zero-emission bus demonstration projects.

## **L. Composite Buses**

The possible exemption of lightweight composite buses from urban bus standards is an issue. Urban buses are defined by several characteristics including a gross vehicle weight of more than 33,000 pounds. Innovative bus manufacturers are proposing development of diesel, hybrid-electric and alternative-fuel buses made of lightweight composite materials with a nominal curb weight as low as 22,000 pounds. Even when fully loaded, such buses may weigh less than 33,000 pounds GVW. Staff proposes that lightweight buses that are powered with heavy-duty diesel engines, diesel-derived engines, or zero-emission engines, carry comparable passenger loads in urban bus service, and meet other definitions of urban buses, would be considered urban buses for the purposes of this proposal.

## **VII. REGULATORY ALTERNATIVES**

### **A. Do Not Adopt Transit Agency Fleet Rule and Amend California Urban Bus Standards**

One alternative to this proposal would be to continue using the current heavy-duty diesel engine standards. In addition to being less stringent than the proposed emission standards for urban bus engines, the current standards do not include a transit bus fleet rule component to increase low-emission, alternative-fuel use in the new fleet and to reduce NOx and PM emissions from the in-use fleet. Low-emission, alternative-fuel technology can provide significant emission reductions over conventional diesel technology, and can reduce the public's exposure to toxic PM emissions. Retrofit technologies can provide additional emission reductions and also reduce the public's exposure to toxic PM emissions. While some transit agencies have voluntarily taken steps to reduce emissions immediately, others have not. Many areas of California are still in violation of health-based state and federal air quality standards and therefore emission reductions are necessary from those sources with the ability to provide them. The staff recommends the Board adopt the regulation, as proposed, presented in this report.

### **B. Adopt Low-Emission Standards Requiring Alternative-Fuel Use**

Another alternative to the current proposal would be to adopt emission standards that would immediately require all new bus purchases to be low-emission, alternative-fuel buses. Alternative-fuel technology has the ability to meet low-emission NOx and PM levels now. Furthermore, this technology is well established and many transit agencies already have practical experience with converting their fleets to low-emission, alternative-fuels.

However, during the development of this regulatory proposal, many transit districts and transportation agencies expressed the need for greater flexibility. As such, the staff's proposal incorporates provisions to allow diesel technology as an alternative for

reducing emissions, yet includes mechanisms to remove the most polluting diesel engines from service and to introduce advanced, alternative-fuel technologies (e.g., battery-electric buses and fuel cell buses). The staff believes the current proposal will provide more flexibility to transit districts than emission standards requiring the use of low-emission, alternative fuel only.

### **C. Adopt A Fleet Average Rule**

An additional alternative to the current proposal would be to adopt a fleet average rule, in lieu of new emission standards, that takes into account new bus purchases and buses already in-use. However, in analyzing the fleet average concept, the staff discovered that fleet characteristics differed so significantly between transit agencies that an effective fleet average system could not be established unless the baseline emission rate started so low as to challenge even the most proactive transit agencies. Alternatively, the baseline emission rate could be set higher to accommodate the transit fleets with large numbers of older buses, but this would drastically reduce achievable emission benefits.

Instead, the ARB staff is proposing a modified fleet average rule that is just one component of the overall transit bus fleet rule. The modified fleet average component reduces the challenges associated with the “fleet average rule only” alternative.

### **D. Adopt Public Workshop Proposal Dated September 23, 1999**

On October 18 and 20, 1999, the staff held two public workshops to discuss a publicly released proposal dated September 23, 1999. Like the current proposal, the September 23, 1999, proposal contained two paths for transit agencies to choose from in reducing emissions from their urban bus fleets. It was clear from the workshops, however, that the proposed paths, both of which allowed the use of diesel technology, did not adequately induce an increased penetration in low-emission, alternative-fuel technology, or an investment in advanced, alternative-fuel technologies that are zero-emitting. Additionally, the September 23, 1999, proposal did not contain any retrofit or repower provisions to reduce NO<sub>x</sub> and toxic PM emissions from the in-use urban bus fleet.

In the current proposal, one of the two paths that transit agencies must choose requires the use of low-emission, alternative-fuel technology, while the other path allows the use of diesel technology. Structured this way, the staff’s current proposal provides for increased penetration of low-emission, alternative-fuel technology, including investment in advanced, alternative-fuel technologies, yet it still provides flexibility to transit agencies. It is intended that the emission standards in the proposal harmonize with the standards that U.S. EPA is expected to adopt in 2000. Furthermore, the current proposal contains a modified fleet average component for NO<sub>x</sub> control, as well as retrofit requirements to achieve both NO<sub>x</sub> and PM emission reductions.

## **VIII. ECONOMIC IMPACTS**

### **A. Legal Requirement**

Sections 11346.3 and 11346.54 of the Government Code require state agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include consideration of the impact of the proposed regulation on California jobs, business, expansion, elimination, or creation, and the ability of California businesses to compete.

State agencies are also required to estimate the cost or savings to any state or local agency and school districts in accordance with instruction adopted by the Department of Finance. This estimate is to include any nondiscretionary costs or savings to local agencies and the costs or savings in federal funding to the state.

### **B. Affected Businesses**

Businesses that may be affected as a result of the proposed regulation include heavy heavy-duty diesel or alternative-fuel urban bus engine manufacturers, urban bus manufacturers, engine retrofit kit manufacturers, exhaust aftertreatment emission control manufacturers, and manufacturers of advanced, alternative-fuel technologies, such as batteries and fuel cells. Since there are no urban bus engine manufacturers located in California and only one urban bus manufacturer in California, most impacts to business, both positive and negative, will occur in other states.

### **C. Potential Impacts on Business**

The proposed regulation is projected to have some cost impact on companies involved in the manufacture and production of engines and transit buses by creating the need for new engines and buses. Currently, there are no urban bus engine manufacturers located in California and only one urban bus manufacturer. The staff estimates that the cost of the proposed regulation to engine and bus manufacturers would be less than \$10,000 per bus. The total impact on businesses in California will be determined by the extent to which these companies choose to expand production in California, as well as the extent to which any increases in costs could be passed on to the final purchasers of engines and buses. As an example, ddb fuel cell engines, inc. has recently opened a research and development site near San Diego, California, to promote the use of fuel cell technology in passenger cars and urban transit buses. Specific to the retrofit requirements, California businesses capable of performing engine retrofits will be positively affected with increased workload.

The proposed regulation will also have a financial impact on transportation agencies and commissions statewide by requiring these entities to fund retrofits of existing engines to low-emission configurations and purchase new clean buses. For new bus purchases, federal funds are available to cover 80 percent of the total cost of a diesel urban bus, and 83 percent of a low-emission alternative-fuel bus. The remaining percent of new bus purchase costs not covered by federal funds, as well as costs for

retrofits, will have to be covered by other funding sources, which include transportation, air quality, and energy funds.

#### **D. Potential Impact on Business Competitiveness**

The proposed regulation is not expected to impact the ability of California businesses to compete with businesses in other states. As indicated above, most businesses that produce the products needed to meet the proposal are located in other states. By requiring new, clean technology, this proposal may actually provide new opportunities for California businesses engaged in advanced technology.

#### **E. Potential Impact on Employment**

The proposed regulation will likely create a market for manufacturers of heavy-duty diesel or natural gas urban bus engines, urban buses, and exhaust aftertreatment devices. For those businesses located in California, the creation of new jobs is expected to meet this demand. Services to retrofit existing buses are expected to take place in California creating new opportunities for existing businesses.

#### **F. Potential Impact on Business Creation, Elimination, or Expansion**

The proposed regulation could impact any California companies involved in the manufacture and production of engines and transit buses. Currently, there are no engine manufacturers and only one bus manufacturer located in California. Requiring new, cleaner engines and buses, could create new business opportunities for manufacturers of heavy-duty diesel or natural gas bus engines, urban buses, and exhaust aftertreatment control devices. While most businesses that could benefit from the increased business are located outside of California, the total impact on California business will be determined by the extent to which these companies choose to expand in California. As an example, ddb fuel cell engines, inc. has recently opened a research and development site near San Diego, California, to promote the use of fuel cell technology in passenger cars and transit buses. This expansion is a result of the expected new business opportunities created by the need for cleaner transportation technologies.

#### **G. Potential Costs to Local and State Agencies**

The proposed regulation is expected to have an impact on transportation planning agencies and commissions (the entities that fund transit agencies), and transit agencies statewide. This is due to the proposed requirements for a NOx fleet average standard, low-sulfur diesel fuel, new bus purchases, and PM retrofits. The following provides a summary of the costs to agencies for complying with the proposed regulation.

## 1. Fleet NOx Average Emission Requirements

The ARB staff projects that most transit agencies will comply with the fleet average NOx emission standard by retiring 1987 and earlier buses and then replacing them with new buses meeting more stringent emission standards. The ARB staff anticipates that in most cases, transit agencies will be able to obtain sufficient funding from available state and federal sources to purchase the new buses. As a result, no significant additional costs to transit agencies are expected for compliance with the fleet average NOx emission standard in 2002. There may be, however, instances where a transit agency is not able to obtain sufficient funds to purchase the new buses necessary for compliance with the fleet average NOx emission standard. Reasons for insufficient funding could include gaps in a particular funding cycle or the requirement for an inordinately large number of pre-1988 buses that need to be replaced. In these cases, there will be some cost to the transit agency to comply with the fleet average NOx emission standard.

This cost cannot be determined accurately since it would be based on specific fleet composition and internal bus replacement policy of each transit agency and their local transportation commission. An alternative available to transit agencies is to repower or retrofit a certain number of existing buses to lower emission configurations. The cost of an engine repower or retrofit kit is several times less expensive than the cost of a new bus, although the remaining useful life of a repowered or retrofitted bus will likely be less than that of a new bus. The ARB staff estimates that an engine repower or a retrofit kit will have an incremental cost of less than \$10,000, including installation. This may be done instead of, or in addition to, buying new buses. A transit agency will need to evaluate the most cost-effective method for its specific fleet to comply with this requirement.

## 2. PM Retrofit Requirements

Under the proposed PM retrofit requirements, transit agencies are responsible for installing PM retrofit devices that are certified with a conversion efficiency of at least 85 percent. To provide the time necessary to accomplish this program and to focus on the most serious problems first, the PM retrofit requirements are divided in three Tiers. Table 11 provides estimated costs for a "typical" 200-bus fleet, as well as statewide costs.

**Tier 1:** Tier 1 requires that buses certified to a PM standard of 0.6 g/bhp-hr be retrofitted by January 1, 2003. These are 1990 and earlier model-year buses and have extremely high emission levels of toxic particulates. On-road emissions of these buses are estimated as greater than 1.7 g/mile, compared to 0.02 g/mile for a natural gas bus. The ARB estimated that there are currently over 4,300 of these buses statewide. Many of these older buses are expected to be retired by 2003 a part of normal fleet turnover and because of the proposed NOx fleet average requirement. A conservative estimate would be that 12 and 13 year old buses are still within the fleet, but that all buses 14 year old and older have been retired. Therefore, given the current in-use fleet distribution, staff estimates that approximately 800 buses would be affected by this requirement. For a "typical" evenly distributed 200-bus fleet, this would represent

approximately 16 buses. At a cost of \$3,000 per bus, the total cost for a typical 200-bus fleet would be \$50,000. Larger fleets would obviously have greater costs and smaller fleets would have lower costs. Total statewide costs are estimated at \$2,400,000.

**Tier 2:** Tier 2 requires that buses certified to 0.10 g/bhp-hr PM and 0.07 g/bhp-hr PM be retrofitted in the 2003 to 2005 time frame. These are 1991 to 1995 model-year buses. On-road emissions of these buses are estimated as greater than 1.0 g/mile of PM. The ARB staff currently estimates that there are about 2,000 of these buses. The staff estimates that most of the 1991 model year buses are likely to be normally retired prior to requiring retrofits. Therefore, based on the current in-use fleet, the Tier 2 requirements are likely to affect approximately 1,500 buses total. For a typical 200-bus fleet, approximately 70 buses would require retrofits, for a cost of \$200,000. Total costs statewide are estimated at \$4,500,000.

**Tier 3:** Tier 3 requires that buses certified to 0.05 g/bhp-hr PM be retrofitted in the 2007 to 2009 time frame. These are 1996-2003 model-year buses, although it is likely that new buses delivered to transit districts in 2002 and 2003 could already be equipped with the "retrofit" installed. If the particulate aftertreatment were marketed by the engine or bus manufacturer as part of a new bus, it is likely that the cost could be reduced substantially. In addition, staff is assuming that by the time Tier 3 requirements are needed, at least modest cost reductions of 25 percent would have occurred. Therefore, staff is assuming a retrofit cost of \$2,250. ARB staff estimates that there are a total of about 3,800 of these 1996-2003 model year buses, but only about 2,200 of these buses will be required to retrofit. This is because the retrofit requirements do not apply to alternative-fuel buses. For a "typical" 200-bus fleet on the diesel path, 130 vehicles would require retrofit systems at a total cost of \$300,000. A transit agency on the alternative-fuel path would have retired most of their diesel buses and is expected to have a cost of no more than \$70,000. Total statewide costs, assuming half of the transit districts are on the alternative-fuel path, are \$5,000,000.

**TABLE 11**

| <b>Average Annual Cost of PM Retrofit Requirements<br/>(2003-2009)</b> |                                |                                |
|------------------------------------------------------------------------|--------------------------------|--------------------------------|
|                                                                        | <b>"Typical" 200-bus fleet</b> | <b>Statewide Transit Costs</b> |
| Tier 1 (by 1/1/03)                                                     | \$50,000                       | \$2,400,000                    |
| Tier 2 (by 1/1/05)                                                     | \$200,000                      | \$4,500,000                    |
| Tier 3 (by 1/1/09)                                                     | \$300,000                      | \$5,000,000                    |
| Total (average annual cost 2002-2008)                                  | \$80,000                       | \$1,700,000                    |

### **3. Low-Sulfur Diesel Fuel**

ARB staff is proposing that by July 1, 2002, all diesel fuel used by transit districts must have a sulfur content no greater than 15 parts per million (ppm). The incremental cost of the lower sulfur diesel fuel is estimated to be five cents per gallon. However, some fuel providers have quoted lower incremental costs for lower sulfur diesel fuel, while other fuel providers have quoted incremental costs as high as 15 cents per gallon. For a 200-bus diesel fleet, the estimated cost would be \$120,000 per year. Transit districts

are assumed to have modest savings with the fuel due to increased engine durability. This should be especially significant with engines produced after October 1, 2002, which are likely to incorporate EGR in order to meet lower emission standards. The savings, however, are not quantifiable at this time. For transit districts on the alternative-fuel path, the incremental fuel cost will be directly proportional to the percentage of diesel buses remaining. Total statewide annual costs are expected to be approximately \$3,000,000 in 2003, dropping to \$2,000,000 by 2010.

#### 4. New Bus Purchase Requirements

The ARB staff projects that a total of about 420 diesel buses will be purchased annually that would meet the proposed 2004 emission standards of 0.5 g/bhp-hr NOx and 0.01 g/bhp-hr PM. In 2007, staff projects that about 440 diesel buses will be purchased annually that would meet the proposed emission standards of 0.2 g/bhp-hr NOx and 0.01 g/bhp-hr PM. For large transit fleets, the ARB staff estimates that 18 demonstration ZEBs will be purchased in 2003, 30 commercial ZEBs will be purchased in 2008, and 80 ZEBs in 2010.

The incremental costs for the low-emission buses required are estimated at \$8,000 to meet the proposed 2004 standards, and an additional \$1,000 to meet the lower standards in 2007. For ZEB technology, staff estimates incremental costs at \$275,000 in 2002, \$50,000 in 2007, and nominal incremental cost in 2010.

Combining the total number of buses needed with the incremental cost allows the ARB staff to calculate the total annual cost of the requirement. In 2004-2006, the total cost of the program is \$5,900,000 per year, including the cost of zero-emission bus demonstration program. In 2007-2009, this total becomes \$5,300,000 per year. This total is reduced by 80 percent due to Federal Transit Administration (FTA) grants and results in a cost to transit agencies of \$1,200,000 per year in years 2004-2006 and \$1,300,000 per year in 2007-2009. The estimated statewide incremental cost to transit agencies in 2010 of \$800,000 is attributable to the expected reductions in costs of zero-emission buses in that time frame. Table 12 provides a summary of the costs associated with the new bus purchase requirements.

**TABLE 12**

| <b>Estimated Incremental Costs To Transit Agencies of New Buses</b> |                                |                                 |                              |
|---------------------------------------------------------------------|--------------------------------|---------------------------------|------------------------------|
| <b>Year</b>                                                         | <b>"Typical" 200-bus fleet</b> |                                 | <b>Statewide<sup>2</sup></b> |
|                                                                     | <b>Conventional</b>            | <b>ZEB purchase<sup>1</sup></b> |                              |
| 2004                                                                | \$27,000                       | \$35,000                        | \$1,200,000                  |
| 2005                                                                | \$27,000                       | \$35,000                        | \$1,200,000                  |
| 2006                                                                | \$27,000                       | \$35,000                        | \$1,200,000                  |
| 2007                                                                | \$30,000                       | \$35,000                        | \$1,300,000                  |
| 2008                                                                | \$30,000                       | \$25,000                        | \$1,300,000                  |
| 2009                                                                | \$30,000                       | \$25,000                        | \$1,300,000                  |
| 2010                                                                | \$30,000                       | \$25,000                        | \$800,000                    |

<sup>1</sup> State and local incentives for advanced technologies may be available to offset a significant portion of the remaining incremental costs after FTA funding

<sup>2</sup> Federal funding covers 80 percent of new bus purchases and is not included in the costs shown in this table.



## **5. Alternative-Fuel Buses**

Under the proposed regulation, no transit agencies are required to buy natural gas buses if they want to continue buying conventional diesel buses. This section provides estimates of the costs that could be incurred if a transit agency elects to go on the alternative-fuel path as a means of compliance with the proposed regulation. Based on current fleet composition of transit agencies that have a significant presence of alternative-fuel buses, ARB staff estimates that about 300 alternative-fuel buses would be purchased annually, which could increase to 320 buses in 2007. Thus, the total incremental bus purchase cost to transit agencies, based on an incremental cost of \$40,000 per bus and an 83 percent fund match from FTA grants, is about \$2,200,000 per year. This cost is based on current purchasing trends from transit agencies that already have a significant number of alternative-fuel buses in their fleets. These transit agencies would be expected to continue to purchase alternative-fuel buses in the absence of this proposed regulation. Incentive funding by state and local air quality agencies has been available in the past to offset the incremental bus purchase cost not covered by FTA grants. It is not clear whether sufficient funding will continue to be available to offset the entire incremental purchase and infrastructure costs. Based on information obtained from transit agencies that already have significant numbers of alternative-fuel buses, operating costs vary significantly from one transit agency to another. Some transit agencies have shown cost savings.

## **IX. ENVIRONMENTAL IMPACTS**

This chapter presents the air quality benefits resulting from the implementation of the proposed public transit bus fleet rule and new urban bus engine emission standards. Adoption of the proposed regulation would benefit California's environment and would reduce the public's exposure to toxic diesel particulate emissions. The air quality benefits presented here are based on the mobile source inventory, EMFAC 2000, which has not yet been adopted by the Board.

In developing this regulation, the ARB staff has attempted to strike a balance between the need to reduce emissions as much as technologically feasible, and the desire to minimize the economic impact on affected businesses and transit organizations. A cost-effective approach is to reduce the emissions from the oldest buses in operation in fleets throughout the state. Under the proposed regulation, this could be accomplished by retrofitting an existing engine in a bus to a lower-emitting configuration, replacing an existing engine with a new lower-emitting engine, or retiring an old bus and replacing it with a new bus.

The useful life of an urban bus is twelve years. This is the minimum life required for buses purchased with FTA funds. However, many transit agencies are typically keeping at least a portion of their buses several years beyond the twelve-year useful life. These older buses are sometimes kept as reserve buses, but in actual practice, many of them are being placed in revenue service on a regular basis. Currently, a number of transit agencies in California have a significant number of pre-1988 buses in their fleets. Some agencies are operating 1984 and older buses. Based on information obtained by the ARB staff, pre-1988 buses comprise about 25 percent of the total number of buses in

California. These older buses emit more than one-and a half times the NO<sub>x</sub> emissions and twelve times the PM emissions of diesel buses meeting current emission standards. Significant emission benefits would be achieved if these older buses are retired and new buses are purchased to replace them. However, some transit agencies may be unable to obtain sufficient funding to replace all those older buses in their fleets in the time frame specified by the proposed fleet average NO<sub>x</sub> emission requirement. Significant emission benefits could also be achieved, particularly for PM emissions, by retrofitting these older engines to lower- emission configurations.

The proposed fleet average NO<sub>x</sub> emission level of 4.8 g/bhp-hr in 2002 could be easily achieved by most transit agencies simply by retiring their pre-1988 buses and replacing them with new buses. Depending on the actual fleet composition for each transit agency, staff believes that this is the most cost-effective way for many transit agencies to achieve the proposed fleet average emission level. In addition to retiring older buses, transit agencies could also repower or retrofit their existing buses to lower NO<sub>x</sub> emission levels. Engine repowering options are now available that can reduce emissions of engines from 6.0 g/bhp-hr to 4.0 g/bhp-hr and from 5.0 g/bhp-hr to 4.0 g/bhp-hr. In addition, engine manufacturers may make available a retrofit kit for urban bus engines that would reduce NO<sub>x</sub> emissions from 4.0 g/bhp-hr to 2.5 g/bhp-hr in the time frame of this regulation. Based on the fleet average emission level of existing buses, staff estimates that NO<sub>x</sub> emissions from urban buses would be reduced by about two tpd statewide in 2002. Although the staff's proposal ensures these two tpd are reduced, most of the reductions will be occurring through normal fleet turnover. Therefore, staff will not be assuming any NO<sub>x</sub> benefit (or cost) due to the fleet average requirement.

The proposed PM retrofit requirements are intended to reduce toxic diesel particulate emissions from existing diesel buses and those model year buses up to the year 2004. As discussed above, the PM emission standard for pre-1988 buses is about twelve times higher than the PM emission standard for current buses. The PM emission standards for pre-1996 buses are up to two times higher than the PM emission standard for current buses and model year buses up to the year 2004. As significant as these numbers are, in-use emissions data from chassis dynamometer tests show greater differences of PM emissions from diesel buses and CNG buses than would be predicted from the engine emission certification standards. Available chassis dynamometer data for urban buses operated on a Central Business District (CBD) test cycle show that for 1988 to 1990 buses, the average in-use PM emission level is about 1.7 grams per mile (g/mi). For 1991 to 1997 model year buses, the CBD data show the average in-use PM emission level to be about 1.0 g/mi. Even the current diesel buses have in-use particulate emissions of about 0.23 g/mi. By comparison, CNG bus emissions average 0.02 g/mi, regardless of their age. For these reasons, the ARB staff is proposing PM retrofit requirements for diesel buses. The ARB staff estimates that the retrofit requirements will reduce toxic PM emissions by about 300 pounds per day (lbs/day) statewide in 2005, and by about 100 lbs/day in statewide 2010, based on in-use CBD data.

While retrofit technology can yield immediate emission reductions from the existing bus fleet, future emission reductions from the urban bus sector can only be sustained

through more stringent emission requirements for new urban buses. Therefore, the proposed regulation contains new emission standards for buses, as well as requirements for larger transit agencies (fleets >200) to purchase zero-emission buses. As discussed previously, the ARB staff is proposing a 0.5 g/bhp-hr NOx standard and a 0.01 g/bhp-hr PM standard for diesel and dual-fuel urban bus engines effective in 2004. In 2007, all heavy-duty urban bus engines, diesel and alternative-fuel, will have to meet NOx and PM emission standards of 0.02 g/bhp-hr and 0.01 g/bhp-hr, respectively. To encourage the early introduction of zero-emission technologies for urban bus applications, the ARB staff is proposing a zero-emission bus purchase requirement for larger transit fleets. Transit fleets with more than 200 buses in their active fleets that are on the diesel path of the fleet rule will be subject to a zero-emission purchase requirement applicable to 15 percent of their new bus purchases starting in 2008. This same zero-emission purchase requirement will apply in 2010 for transit fleets with more than 200 buses in their active fleets that are on the alternative-fuel path of the fleet rule.

The ARB staff estimates the proposed new engine emission standards and the zero-emission bus purchase requirements will cumulatively reduce emissions statewide in 2010 by about 5.4 tpd of NOx and about 0.04 tpd (50 lbs/day) of PM. The emission benefits for the proposed regulation are summarized in Table 13 below.

**TABLE 13**

| <b>Emission Benefits of Proposed Regulation</b> |                  |                  |                  |                 |                  |                 |
|-------------------------------------------------|------------------|------------------|------------------|-----------------|------------------|-----------------|
|                                                 | <b>2005</b>      | <b>2007</b>      | <b>2010</b>      |                 | <b>2020</b>      |                 |
| <b>Proposed Regulation Component</b>            | PM (lbs/day)     | PM (lbs/day)     | NOx (tpd)        | PM (lbs/day)    | NOx (tpd)        | PM (lbs/day)    |
| PM Retrofit                                     | 300 <sup>1</sup> | 100 <sup>1</sup> |                  |                 |                  |                 |
| New Low-Emission and Zero-Emission Requirements |                  |                  | 5.4 <sub>2</sub> | 50 <sub>2</sub> | 7.2 <sub>2</sub> | 67 <sub>2</sub> |

(1) Based on in-use CBD emission data from chassis tests.

(2) Based on combined benefits of 2004 and 2007 emission standards.

## **X. COST-EFFECTIVENESS**

The estimated cost-effectiveness of the proposed regulation is given in Table 14. The cost-effectiveness of engine emission standards and zero-emission bus purchase requirements is estimated to be about \$1.80/lb of NOx in 2010. The cost-effectiveness for these requirements is estimated to be reduced to \$1.50/lb by 2020. The cost-effectiveness of the proposed requirements compares favorably with the cost-effectiveness of mobile source and motor vehicle fuels regulations adopted over the past decade. Those adopted measures had cost-effectiveness values from \$0.17 to \$2.55 per pound of ozone precursors reduced.

As shown in Table 14, the cost-effectiveness for the PM retrofit requirements averages about \$17.90 per pound (\$/lb) annually from 2003 to 2009. This cost-effectiveness includes the cost associated with the requirement to purchase low-sulfur diesel fuel. In comparison, the cost-effectiveness of previously adopted PM control measures ranges from \$1.44/lb to \$3.20/lb. The cost-effectiveness of the PM retrofit requirement under this proposal does not include the value of health benefits associated with a reduction in exposure to a toxic air contaminant. The risk management process for the control of toxic PM emissions from diesel-fueled engines is ongoing. Any PM control measures resulting from the risk management process will produce additional PM reductions and health benefits that are not included in this regulatory proposal and that are not part of this cost-effectiveness determination.

**TABLE 14**

| <b>Estimated Cost-Effectiveness of Proposed Regulation</b> |                             |                         |                         |
|------------------------------------------------------------|-----------------------------|-------------------------|-------------------------|
| <b>Proposed Requirement</b>                                | <b>Cost-Effectiveness</b>   |                         |                         |
|                                                            | <b>2003-2009 (\$/lb PM)</b> | <b>2010 (\$/lb NOx)</b> | <b>2020 (\$/lb NOx)</b> |
| PM Retrofit                                                | 17.90                       |                         |                         |
| Engine Standards                                           |                             | 1.80 <sub>1</sub>       | 1.50 <sub>1</sub>       |

(1) Estimated cost-effectiveness of engine standards includes federal contribution to bus purchase costs.

## **XI. SUMMARY AND STAFF RECOMMENDATION**

### **A. Summary of Staff's Proposal**

As presented in the previous chapters, the ARB staff's proposal is designed to reduce ozone precursor emissions, particularly NOx, and toxic air contaminants (diesel PM) by encouraging transit agencies to purchase or lease low-emission, alternative-fuel urban buses. The staff's proposal includes the following:

- A public transit fleet rule with two paths for compliance – a diesel path and an alternative-fuel path.
- A 4.8 g/bhp-hr NOx fleet average requirement for transit agencies.
- PM retrofit requirements for 2003 and earlier model year diesel urban buses.
- Zero-emission bus demonstration project requirements in 2003 for large transit agencies on the diesel path.
- Zero-emission bus purchase requirements beginning in 2008 for large transit agencies on the diesel path and in 2010 for large transit agencies on the alternative-fuel path.
- Requirements for transit agencies using diesel fuel to use low-sulfur fuel (15 ppm or less) beginning July 1, 2002.

- Reporting requirements as a means to determine a transit agency's compliance with the public transit fleet rule.
- More stringent emission standards, including a 0.5 g/bhp-hr NO<sub>x</sub> standard and 0.01 PM g/bhp-hr PM standard, for 2004 and subsequent model year diesel and dual-fuel urban bus engines.
- More stringent emission standards, including a 0.2 g/bhp-hr NO<sub>x</sub> standards and a 0.01 g/bhp-hr PM standard, for all 2007 and subsequent model year engines.

## **B. Staff Recommendation**

The ARB staff recommends that the Board adopt new sections 1956.1, 1956.2, 1956.3, and 1956.4, Title 13, California Code of Regulations, and amend section 1956.8, Title 13, California Code of Regulations, and the incorporated "California Exhaust Emission Standards and Test Procedures for 1985 and Subsequent Model Year Heavy-duty Engines and Vehicles." The regulation is set forth in the proposed Regulation Order in Appendix A.

## **XII. References**

1. Magary, Kerstin Fraser, San Francisco Municipal Railway, Information Provided on November 15, 1999.
2. Manufacturers of Emissions Controls Association (MECA), Emission Control Retrofit of Diesel-Fueled Vehicles, March 1998.
3. Detroit Diesel Corporation, Press Release, October 7, 1999.
4. MECA, Emission Control Retrofit of Diesel-Fueled Vehicles, March 1998.
5. MECA, Emission Control Retrofit of Diesel-Fueled Vehicles, March 1998.
6. Rothwell, Bruce, Marketing Manager, dbb fuel cell engines, inc., Information Provided on December 2, 1999