## SUMMARY OF BOARD ITEM

**ITEM # 02-8-2:** Public Hearing to Consider Amendments to the Public Transit Bus Fleet Rule and Emissions Standards for New Urban Buses.

**STAFF RECOMMENDATION:** The staff recommends that the Board approve the proposed amendments to the Public Transit Bus Fleet Rule and Emission Standards for New Urban Buses.

**DISCUSSION:** In February 2000, the Board adopted the Public Transit Fleet Rule and Emission Standards for New Urban Buses. The multifaceted transit bus regulations set fleet requirements applicable to transit agencies and set more stringent mid and long-term oxides of nitrogen (NOx) and particulate matter (PM) emission standards for new urban bus engines, applicable to engine manufacturers. Transit agencies were required to choose either a diesel or alternative fuel compliance path. The fuel path selected determines the compliance schedule and reporting requirements applicable to each transit agency. The fleet rule was designed to provide transit agencies with flexibility in meeting the NOx standard while achieving near-term PM reductions and promoting advancement of PM control technology. The PM standard requires that transit agencies retrofit progressively newer model-year buses with devices capable of reducing PM emissions by 85 percent. In addition, the Board required staff to report regularly on the progress for implementing the regulatory requirements and to consider developing a test procedure to certify hybrid-electric urban transit buses.

Staff worked with manufacturers of urban transit buses, control technologies, and engines, in addition to transit agencies, to gather information and provided progress reports to the Board on September 20, 2001 and March 21, 2002. Staff's key findings indicated that the majority of the transit agencies will meet the NOx fleet reduction requirements through the retirement and repowering of older higher-emitting buses and through the

purchase of lower-emitting buses. However, PM retrofit technology capable of reducing PM emissions by 85 percent or more is not available for 1993 model year and older engines. As a result, the Board directed staff to consider another approach for reducing PM emissions. The Board also directed staff to consider a method for allowing transit agencies to change from the diesel path to the alternative fuel path. Finally, the Board directed staff to present a procedure for evaluating emissions from hybrid-electric urban transit buses. For this item staff is also proposing modifications to the current Public Transit Bus fleet rule that would provide transit agencies with additional flexibility in complying with the urban transit bus regulations.

**SUMMARY AND IMPACTS:** The proposed amendments to the February 2000 urban transit bus regulations include modifying the current model-year-specific diesel PM retrofit requirement. In order to continue to aggressively reduce PM emissions, staff proposes that transit agencies reduce their diesel PM emissions by 85 percent in January 2007 (diesel path) or January 2009 (alternative-fuel path). Each transit agency would be required to estimate PM emission reductions from its entire diesel fleet as of January 1, 2002 (January 1, 2002 diesel PM emissions baseline). Beginning on January 1, 2004, the 85 percent reduction would be phased-in based on the selected fuel path. If approved, this modification would provide transit agencies with a more flexible approach for achieving the much needed PM emission reduction as anticipated in the original transit bus rulemaking.

A second modification would allow transit agencies in the South Coast Air Quality Management District (SCAQMD) that have selected to follow the "diesel" path a one time option of changing to the "alternative-fuel" path. Staff requested comments regarding a fuel path change from all transit agencies. Only transit agencies from the SCAQMD indicated a desire to change. Because transit agencies in the SCAQMD have already been purchasing alternative-fuel buses in accordance with local District rules, allowing these transit agencies to

change would have little or no impact on anticipated emission reductions.

A third modification includes changing the alternative-fuel provision for transit agencies on the diesel fuel path. The current regulations require that engines sold during 2004 through 2006, to transit agencies on the diesel path, meet a 0.5 grams per brake horse-power hour (g/bhp-hr) NOx standard. This standard applies whether the engine is a diesel-fueled, dual-fueled, bi-fueled, or alternative-fueled engine. Staff does not expect any full sized alternative-fueled or diesel-fueled urban bus engines certified to 0.5 g/bhp-hr NOx emissions to be available through 2006. To encourage and facilitate transit agencies on the diesel path to purchase alternative-fueled engines, staff proposes to remove the 0.5 g/bhp-hr NOx emission standard requirement for alternative-fueled engines during 2004 to 2006. Transit agencies would be permitted to purchase alternative-fuel buses that are certified at 2.5 g/bhp-hr NOx plus non-methane hydrocarbons.

Other minor modifications include authorizing the Executive Officer to grant a financial hardship implementation delay, upon evaluation of an application, for small transit agencies (agencies with fewer than 20 buses); modifying and including additional definitions for clarification of the urban transit bus fleet rule; and repealing certification procedures for PM retrofit devices adopted November 2000. If approved, these modifications would provide transit agencies with additional flexibility in meeting the public transit bus fleet rule.

Heavy-duty hybrid-electric vehicles, including transit buses, are currently certified using ARB-approved engine certification test procedures. Current engine certification procedures do not enable the quantification of emission reductions resulting from the use of a smaller engine operating more efficiently in a hybrid-electric drive system. Part of this rulemaking includes a proposed interim certification procedure for hybrid-electric buses. If approved the new voluntary procedures would

provide manufacturers and transit agencies with representative emission values that would allow quantification of emissions from different engine/drive system combinations and would facilitate the comparison of hybrid-electric bus emissions with other technologies.

If approved, the proposed amendments would achieve close to the same emission reductions beginning in 2005, as the original regulations. Prior to 2005, the benefits will be less than the original regulations. Two factors account for the lower emission reductions in the early years: the lack of technology to retrofit older engines now and the need to provide transit agencies additional time to obtain funding to replace older engines. The proposed amendments will reduce PM emissions statewide in 2010 by approximately 180 lbs./day (33 tons per year).

Estimated costs to transportation planning agencies, commissions, and transit agencies would remain the same (about $2.5 million) as those estimated in the February 2000 rulemaking. The cost-effectiveness during 2003 to 2009 would range from $11 to $45 per pound of PM, with an average expected cost effectiveness of $25 per pound of PM reduced. The original regulation cost-effectiveness was reported as $18 per pound of PM reduced, which is within the range calculated for the proposed amendments.

## TITLE 13 CALIFORNIA AIR RESOURCES BOARD

## NOTICE OF PUBLIC HEARING TO CONSIDER AMENDMENTS TO THE PUBLIC TRANSIT BUS FLEET RULE AND EMISSION STANDARDS FOR NEW URBAN BUSES

The California Air Resources Board (Board or ARB) will conduct a public hearing at the time and place noted below to consider amendments to the public transit bus fleet regulations. The amendments modify the current transit bus fleet rule and provide additional emission test procedures for specific urban buses, but do not affect new engine emission standards. This notice summarizes the significant amendments. The staff report presents all proposed amendments in greater detail.

| | |
|---|---|
| DATE: | October 24, 2002 |
| TIME: | 9:30 a.m. |
| PLACE: | Air Resources Board<br>Auditorium<br>9530 Telstar Avenue<br>El Monte, CA 91731 |

This item will be considered at a two-day meeting of the Board, which will commence at 9:30 a.m., on October 24, 2002 and may continue at 8:30 a.m., October 25, 2002. This item may not be considered until October 25, 2002. Please consult the agenda for the meeting which will be available at least 10 days before October 24, 2002, to determine when this item will be considered.

This facility is accessible to persons with disabilities. If accommodation is needed, please contact ARB's Clerk of the Board at (916) 322-5594 by October 10, 2002, to ensure accommodation. Persons with hearing or speech impairments can contact us by using our Telephone Device for the Deaf (TDD) at (916) 324-9531, or (800) 700-8326 for TDD calls from outside the Sacramento area.

## INFORMATIVE DIGEST OF PROPOSED ACTION

**Sections Affected:** Proposed amendments to sections 1956.1, 1956.2, 1956.4, 1956.8, and 2112, title 13, California Code of Regulations (CCR), and the incorporated document titled "California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric Vehicles, in the Urban Bus and Heavy-duty Vehicle Classes."

**Background:** In February 2000 the Board approved the Public Transit Fleet Rule and Emission Standards For New Urban Buses. The multifaceted transit bus regulations set

fleet requirements, applicable to transit agencies, and set more stringent mid- and long-term oxides of nitrogen (NOx) and particulate matter (PM) emission standards for new urban bus engines, applicable to engine manufacturers. Transit agencies were required to choose either a diesel or alternative fuel compliance path. The fuel path selected determines the compliance schedule and reporting requirements. The fleet rule was designed to provide transit agencies with flexibility in meeting the NOx standard while achieving near-term PM reductions and promoting advancement of PM control technology. The adopted PM fleet rule requirements are listed in Table 1. The PM standard requires transit agencies to retrofit progressively newer model-year (MY) buses with devices capable of reducing PM emissions by 85 percent. In addition to the fleet rule requirements, the Board adopted engine NOx emission standards designed to achieve long-term emission benefits from new bus engines.

**Table 1**

| Transit Bus PM Fleet Retrofit Requirements – By Fuel Path<br>Percentage of Model-Year Buses Required to Demonstrate a Minimum of 85% Reduction of PM | |
|---|---|
| **Diesel Path** | **Alternative Fuel Path** |
| Tier 1 (pre 1991-MY)<br>100% by January 1, 2003 | Tier 1 (pre 1991-MY)<br>100% by January 1, 2003 |
| Tier 2 (1991 – 1995-MYs)<br>50% by 1/1/03<br>100% by 1/1/04 | Tier 2 (1991 – 1995-MYs)<br>20% by 1/1/03<br>75% by 1/1/04<br>100% by 1/1/05 |
| Tier 3 (1996 – pre-Oct. 2002-MYs)<br>20% by 1/1/05<br>75% by 1/1/06<br>100% by 1/107 | Tier 3 (1996 – pre-Oct. 2002-MYs)<br>20% by 1/1/07<br>75% by 1/1/08<br>100% by 1/1/09 |

Recognizing the progressive nature of the fleet rule and emission standards, the Board directed staff to report back on the progress of implementing the regulatory requirements. Staff worked closely with transit agencies, urban transit bus manufacturers, and engine and drive system manufacturers to gather information. Staff reported back to the Board in September 2001 and March 2002. Based on the evaluation of available information, staff determined that most transit agencies would be able to meet the fleet rule requirements pertaining to NOx emissions. However, PM retrofit technology capable of reducing PM emissions by 85 percent or more is not available for 1993 model year and older engines.

**Proposed Actions:** These proposed regulatory amendments are designed to provide transit agencies with greater flexibility in complying with the required emission standards. The proposed amendments include: modifying the current, model year based, PM retrofit requirements to establish a total PM reduction requirement; allowing transit agencies in the South Coast Air Quality Management District (SCAQMD) that

have elected to follow the "diesel" path a one time option of changing to the "alternative fuel" path; modifying the alternative fuel provision for transit agencies on the diesel fuel path; authorizing the Executive Officer to grant small transit agencies a delay in implementation of the regulation; modifying and including additional definitions for clarification of the urban transit bus fleet rule; repealing the current certification procedure for PM retrofit devices adopted November 2000; and providing interim procedures for certification of hybrid-electric urban transit buses.

## A. Amendments to the Fleet Rule

### 1. PM Emission Reduction Proposal

As directed by the Board in March 2002, staff reviewed the technology available to achieve the current PM retrofit requirements. Staff concluded that PM retrofit technology capable of reducing in-use PM emissions by 85 percent or more is not currently available for 1993 model year and older engines. In order to enable transit agencies to comply with feasible PM emission reduction requirements, yet still aggressively reduce in-use PM emissions, staff proposes to amend the current rule which requires transit agencies to retrofit a percent of its overall fleet for each model year. The proposed amendments would require transit agencies to reduce PM by a specified percentage based on total diesel PM emissions. The proposed schedule to achieve the required percent of PM emission reductions is based on the implementation dates of the original regulation's implementation schedule and on the fuel path selected.

The proposed amendments will require a transit agency to reduce its overall diesel fleet PM emissions by a specified percentage. Total certified diesel fleet PM emissions as of January 1, 2002 will serve as the baseline value for calculating the required reduced emission level. The proposed implementation schedule and the percent reduction of PM from the baseline PM emission levels are provided in Table 2, below. For example, in 2004, transit agencies that selected the diesel fuel path would be allowed to emit up to 60 percent of their January 1, 2002 total diesel PM emissions, a 40 percent diesel PM emission reduction; and transit agencies that selected the alternative fuel path would be allowed to emit up to 80 percent of their January 1, 2002 total diesel PM emissions, which is a 20 percent diesel PM emission reduction.

The total diesel PM emission reduction proposal applies only to diesel-fueled, dual-fueled, bi-fueled, and diesel HEBs; in other words, any engine that uses diesel fuel and has diesel PM emissions. A transit agency with alternative-fueled buses and diesel-fueled buses would be required to reduce PM emissions from its diesel buses only. In this case, a PM emissions baseline would be based on the transit agency's diesel bus population. This proposal is designed to ensure that every diesel fleet will have its in-use PM emissions significantly reduced by 2007 or 2009, depending on fuel path.

Transit agencies may use a variety of methods to reduce their diesel PM emissions to comply with the proposed diesel PM emission reduction requirement, including bus

retirement, engine repower, purchase of new low-emission buses, and installation of a verfied diesel emission control strategy. Transit agencies may retire older buses or repower engines certified to higher emissions levels and replace them with newer diesel, dual fuel, bi-fuel, or diesel hybrid-electric buses certified to 0.01 g/bhp-hr, or with alternative fuel buses. Replacement of a diesel bus with an alternative-fuel bus also reduces the total diesel PM emissions.

**Table 2**

| Proposed Compliance Schedule for Total Diesel PM Emissions | | |
|---|---|---|
| **Compliance Year (as of January 1st)** | **Diesel Fuel Path Percent Reduction** | **Alternative Fuel Path Percent Reduction** |
| 2004 | 40 | 20 |
| 2005 | 60 | 40 |
| 2007 | 85 | 60 |
| 2009 | 85 | 85 |

## 2. Fuel Path Change

In order to determine which, if any, transit agencies would consider making a fuel path change, staff notified transit agencies and asked for comments. The only transit agencies that responded to the request for comment were in the SCAQMD. Therefore, the proposed amendments include a one-time opportunity for a transit agency in the SCAQMD to change its fuel path selection from diesel to alternative fuel. In establishing the fleet rule, the implementation dates for transit agencies on each fuel path were determined in order to ensure that emission reductions were essentially equivalent over the life of the rule. Transit agencies on the diesel path have earlier implementation dates for reducing emissions when compared to those set for the alternative fuel path.

Because transit agencies in the SCAQMD have already been purchasing alternative-fuel buses in accordance with District rules, allowing these agencies to change to the alternative fuel path would have little or no impact on the benefits expected from the regulation. Staff therefore proposes to limit the scope of the fuel path change only to transit agencies in the SCAQMD, and to require that any transit agency that wishes to change its fuel path declare its intention by January 31, 2004. This date would allow transit agencies sufficient time to bring the question before their management or Board, and would allow them to combine required reports on compliance with the annual report due each January 31.

## 3. Alternative Fuel Bus Purchase Provision for Diesel Path Transit Agencies

The required certified emission level of an engine that a transit agency wishes to purchase during 2004 through 2006 is dependent on the agency's selected fuel path. The current regulations prohibit transit agencies on the diesel path from purchasing

diesel-fueled, dual-fueled, bi-fueled, or alternative-fueled engines with certified NOx emissions greater than 0.5 g/bhp-hr. This requirement would also apply to diesel-fueled, dual-fueled, bi-fueled engines purchased by transit agencies on the alternative fuel path. This requirement would not apply, however, to alternative-fueled engines purchased by transit agencies on the alternative fuel path. Staff does not expect any full-sized alternative-fueled or diesel-fueled urban bus engines certified to 0.5 g/bhp-hr NOx emissions to be available through 2006.

To encourage and facilitate transit agencies on the diesel path to purchase alternative-fueled engines, staff proposes to remove the 0.5 g/bhp-hr NOx emission standard for certain transit agencies. That is, staff proposes to remove the restriction that prohibits transit agencies on the diesel path from purchasing model year 2004 to 2006 alternative-fueled urban bus engines with NOx emissions in excess of 0.5 g/bhp-hr.

### 4. Transit Agency Request for Delay

Staff has been asked by a number of transit agencies to allow them to deviate from the retrofit and fuel implementation schedules because of financial hardship. Staff believes this request is meritorious. Staff proposes adding a general provision that would allow a transit agency, with fewer than 20 buses, to request an implementation delay based on a convincing demonstration of financial hardship. Staff's proposal provides a mechanism to allow the Executive Officer to hear and decide on the merits of exceptional requests for an implementation delay.

### 5. Definitions

To clarify the intent and facilitate implementation of the transit bus regulation, staff proposes to modify the definitions of "active fleet" and "alternative fuel", and to add definitions for "emergency contingency vehicle" and "spare bus".

The most significant change pertains to the definition for alternative fuel. Previously the definition precluded all use of diesel fuel. The proposed revision will allow the use of small amount of diesel as a pilot ignition source.

### 6. Repeal Certification Procedures for PM Retrofit Devices

The proposed amendments require that any device installed on urban buses to meet the diesel PM reduction requirement be verified under the procedures adopted therein. Currently, there are two procedures available to manufacturers of diesel emission control strategies to certify technology. To ensure that all manufacturers follow the same procedures, have the same warranty and in-use compliance requirements, it is necessary to repeal "California Certification Procedures for PM Retrofit Devices for On-Road Heavy-Duty Diesel Vehicles," adopted November 22, 2000 and incorporated by reference in CCR title 13, section 1956.2 (f) (7). These procedures would be replaced with those adopted by the Board in May 2002: "Diesel Emission Control

Strategy Verification Procedure, Warranty and In-Use Compliance Requirements for On-Road, Off-Road, and Stationary Diesel-Fueled Vehicles and Equipment." This modification would have no impact on transit agencies or businesses because no manufacturer has followed the certification procedures that were adopted November 22, 2000.

**7. Hybrid-Electric Bus Certification Procedure**

Heavy-duty hybrid-electric vehicles, including transit buses, are currently certified using ARB- approved engine certification test procedures. Current engine certification procedures do not enable the quantification of emission reductions resulting from the use of a smaller engine operating more efficiently in a hybrid-electric drive system. A specific hybrid-electric certification procedure would provide manufacturers and transit agencies with representative emission values that would allow quantification of emissions from different engine/drive system combinations and would facilitate the comparison of hybrid-electric bus emissions with other technologies.

The proposed interim certification procedure for determining compliance with the urban transit bus emission standards, applicable to 2004 and subsequent model year hybrid-electric buses, is based on a modified version of the Society of Automotive Engineers (SAE) Recommended Practices, SAE J2711 (April 2002). SAE J2711 was developed to test the emissions of heavy-duty hybrid-electric vehicles using chassis dynamometer tests. The HEB's certification value is determined through calculations using chassis dynamometer tests and engine certification values for both the HEB and a conventional drivetrain urban transit bus. The ARB proposed procedures include a provision for chassis dynamometer testing of conventional drivetrain urban transit buses to determine baseline emissions.

To provide flexibility and facilitate sales of HEBs, up to two parties (i.e. the engine/turbine/fuel cell manufacturer and the electric drive component manufacturer) may apply for an Executive Order identifying the certified emission standard, for model years 2004 through 2006. Starting with model year 2007, only one party may apply for an Executive Order identifying the emission standard achieved by the HEB. HEBs could still be certified using current engine-based certification procedures on a case-by-case basis, if approved by ARB's Executive Officer.

## AVAILABILITY OF DOCUMENTS AND AGENCY CONTACT PERSON

The Board staff has prepared a Staff Report, which includes the Initial Statement of Reasons for Rulemaking and a summary of the environmental impacts of the proposed action, titled "Proposed Modifications to the Public Transit Bus Fleet Rule and Interim Certification Procedures for Hybrid-Electric Urban Transit Buses." Copies of the Staff Report and the full text of the proposed regulatory language may be accessed on the ARB's web site listed below, or may be obtained from the Board's Public Information Office, 1001 "I" Street, Sacramento, California 95814, (916) 322-2990 at least 45 days

prior to the scheduled hearing. Upon its completion, the Final Statement of Reasons (FSOR) will be available and copies may be requested from the agency contact person in this notice, or may be accessed on the ARB's web site listed below. In addition, the Board Staff has compiled a record that includes all information upon which the proposal is based. The material is available for inspection upon request to the contact person identified below.

To obtain these documents in an alternate format, please contact the Air Resources Board Americans with Disability Act (ADA) Coordinator at (916) 323-4916, TDD (916) 324-9531, or (800) 700-8326 for TDD calls from outside the Sacramento area.

Further inquiries concerning the substance of the proposed regulation may be directed to the designated agency contact persons, Mr. Juan Osborn, at (626) 575-6998 or josborn@arb.ca.gov, or Ms. Lucina Negrete, at (916) 327-2938 or lnegrete@arb.ca.gov.

Further, the agency representative and designated back-up contact persons to whom procedural inquiries concerning the proposed administrative action may be directed are Artavia Edwards, Manager, Board Administration & Regulatory Coordination Unit, (916) 322-6070, or Alexa Malik, Assistant, Board Administration & Regulatory Coordination Unit, (916) 322-4001.

This notice, the ISOR and all subsequent regulatory documents, including the FSOR when completed, will be available on the ARB Internet site for this rulemaking at www.arb.ca.gov/regact/bus02/bus02.htm or www.arb.ca.gov/msprog/bus/bus.htm.

## COST TO PUBLIC AGENCIES AND TO BUSINESSES AND PERSONS AFFECTED

The determinations of the Board's Executive Officer concerning the costs or savings necessarily incurred in reasonable compliance with the proposed regulations are presented below.

Pursuant to Government Code sections 11346.5(a)(5) and 11346.5(a)(6), the Executive Officer has determined that the proposed regulatory action will not create costs or savings to any state agency or in federal funding to the state, costs or mandate to any local agency or school district whether or not reimbursable by the State pursuant to part 7 (commencing with section 17500), division 4, title 2 of the Government Code, or other non-discretionary savings to State or local agencies.

In developing this regulatory proposal, the ARB staff evaluated the potential economic impacts on representative private persons or businesses. The Executive Officer has determined that there will be no, or an insignificant, potential cost impact, as defined in Government Code section 11346.5(a)(9), on private persons or businesses directly affected resulting from the proposed action, including the ability of California businesses to compete with businesses in other states, or on representative private persons. The proposed amendments will provide transit agencies with greater flexibility to comply with the required standards. Staff believes that the proposed amendments would cause

no adverse impacts in California employment, business status, or measured competitiveness or increase costs above those estimated for the Public Transit Bus Fleet Rule and Emission Standards for Urban Buses regulations adopted February 2000.

The proposed amendments would provide a mechanism that allows some transit agencies to change from the diesel path to the alternative-fuel path; establish a fleet average PM retrofit requirement; and establish an new interim certification procedure for hybrid-electric urban transit buses. Since the proposed amendments provide transit agencies with greater flexibility to comply with the required emission standards they are not expected to impose costs above those already estimated. Most impacts to business, both positive and negative, will likely occur in other states. Most manufacturers of engines and control technology are located outside of California.

Certification testing of hybrid-electric buses could increase the cost of purchasing a hybrid-electric bus. Manufacturer costs for testing a family of hybrid electric buses, according to proposed interim procedure, would range from $70,000 to $120,000 per certification. However, testing would provide manufacturers with a method for demonstrating the full emission reductions achievable from using a hybrid-electric drive system. Testing costs may be transferred to the purchase price of a hybrid-electric bus and transferred to agencies selecting this control option. Since it is not certain how many hybrid-electric buses will be purchased, the proportional increased cost of a hybrid-electric bus cannot be determined at this time.

A transit agency does not typically pay the full cost of purchasing a new bus. Federal funds are available to cover 80 percent of the total cost of a new urban diesel bus and 83 percent of new low emission alternative fuel bus. Since transit agencies can make the choice among emission control options, based on their individual transportation planning and operational needs, the increased cost of purchasing a hybrid-electric bus is not considered a significant cost impact.

In accordance with Government Code section 11346.3, the Executive Officer has determined that the proposed regulatory action will not affect the creation or elimination of jobs within the State of California, the creation of new businesses or elimination of existing businesses within the State of California, or the expansion of businesses currently doing business within the State of California.

The Executive Officer has also determined, pursuant to Government Code section 11346.5(a)(3)(B), that the proposed regulatory action will not affect small businesses because this is a change to a regulation that is voluntary with respect to small businesses and there are no mandated requirements and no associated impacts.

**ENVIRONMENTAL IMPACTS**

The proposed amendments provide greater flexibility to transit agencies to meet current regulations and do not set new emission standards. It is anticipated that after 2004 the proposed amendments would achieve close to the same emission reductions, as

anticipated from the February 2000 Public Transit Bus Fleet Rule. Two factors account for lower emission reductions prior to 2004: the lack of technology to retrofit older engines, and the need to provide transit agencies additional time to obtain funding to replace older engines. HEB's have the potential to provide emission reductions beyond those required in the regulations. However, there is no quantifiable method for determining how many HEBs with NOx emissions below those required will be purchased and therefore, it is not possible to quantify at this time any additional emission benefit.

The proposed amendments regulate all transit agencies throughout the state to ensure that emission benefits are achieved for all Californians. In addition, urban transit buses transport people every day to destinations in various communities throughout California; hence, environmental impacts resulting from the proposed amendments would affect all communities where urban transit buses travel.

## SUBMITTAL OF COMMENTS

The public may present comments relating to this matter orally or in writing at the hearing, and in writing or by e-mail before the hearing. To be considered by the Board, written submissions not physically submitted at the hearing must be received **no later than 12:00 noon, October 23, 2002**, and addressed to the following:

Postal mail is to be sent to:

Clerk of the Board
Air Resources Board
1001 "I" Street, 23rd Floor
Sacramento, California 95814

Electronic mail is to be sent to: bus02@listserv.arb.ca.gov
and received at the ARB **no later than 12:00 noon, October 23, 2002.**

Facsimile transmissions are to be transmitted to the Clerk of the Board at (916) 322-3928 and received at the ARB **no later than 12:00 noon October 23, 2002.**

The Board requests but does not require that 30 copies of any written statement be submitted and that all written statements be filed at least 10 days prior to the hearing so that ARB staff and Board Members have time to fully consider each comment. The ARB encourages members of the public to bring to the attention of staff in advance of the hearing any suggestions for modification of the proposed regulatory action.

## STATUTORY AUTHORITY AND HEARING PROCEDURES

This regulatory action is proposed under the authority provided in Health and Safety Code sections 39600, 39601, 43013, 43018, 43101, 43102, 43104, 43105, 43200, 43806, and Vehicle Code section 28114. This action is proposed to implement, interpret, and make specific California Health and Safety Code sections, 39002, 39003, 43000, 43009.5, 43012, 43018, 43100, 43101.5, 43102, 43104, 43105, 43106, 43200, 43204, 43205.5, and 43806. Before taking final action on the proposed regulatory action, the Board must determine that no alternative considered by the agency would be more effective in carrying out the purpose for which the action is proposed or would be as effective and less burdensome to affected private persons than the proposed action.

The public hearing will be conducted in accordance with the California Administrative Procedure Act, Title 2, Division 3, Part 1, Chapter 3.5 (commencing with section 11340) of the Government Code.

Following the public hearing, the Board may adopt the regulatory amendments as originally proposed, or with nonsubstantial or grammatical modifications. The Board may also adopt the proposed regulatory language with other modifications if the text as modified is sufficiently related to the originally proposed text that the public was adequately placed on notice that the regulatory language as modified could result from the proposed regulatory action; in such event the full regulatory text, with the modifications clearly indicated, will be made available to the public, for written comment, at least 15 days before it is adopted. The public may request a copy of the modified regulatory text from the Board's Public Information Office, 1001 "I" Street, Sacramento, California, 95814, (916) 322-2990.

CALIFORNIA AIR RESOURCES BOARD

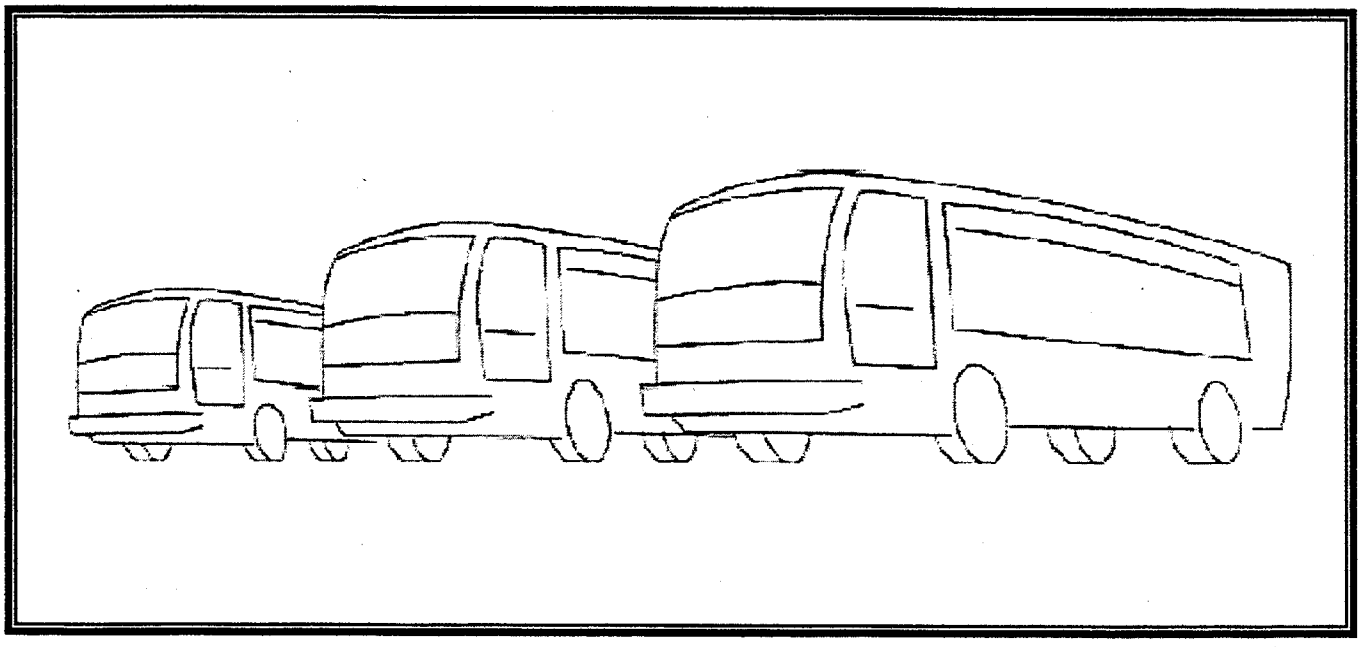
Michael P. Kenny
Executive Officer

Date: August 27, 2002

# CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
## AIR RESOURCES BOARD

## STAFF REPORT: INITIAL STATEMENT OF REASONS

## PROPOSED MODIFICATIONS TO THE PUBLIC TRANSIT BUS FLEET RULE AND INTERIM CERTIFICATION PROCEDURES FOR HYBRID-ELECTRIC URBAN TRANSIT 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: September 6, 2002
Scheduled for Consideration: October 24, 2002

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# STAFF REPORT: INITIAL STATEMENT OF REASONS PROPOSED MODIFICATIONS TO THE PUBLIC TRANSIT BUS FLEET RULE AND INTERIM CERTIFICATION PROCEDURES FOR HYBRID-ELECTRIC URBAN BUSES

## EXECUTIVE SUMMARY

A major goal of the Air Resources Board (ARB or "the Board") is to provide clean, healthful air to all the citizens of California. California's commitment to providing clean public transportation is an important part of 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 physically challenged. However, urban transit buses, one of California's modes of public transportation, are also a source of oxides of nitrogen (NOx) and diesel particulate matter (PM). NOx contributes to the atmospheric formation of ozone and fine particles. Diesel PM has been identified as a toxic air contaminant – a cancer-causing pollutant. These emissions often occur within California's most populated urban areas. It is vital to all Californians that the ARB continue its efforts to reduce NOx and PM emissions from all sources, specifically transit vehicles which transport California citizens every day.

In February 2000 the Board confirmed its continued commitment toward improving emissions from public transportation by approving the "Public Transit Bus Fleet Rule and Emission Standards for New Urban Buses." The multi-faceted transit bus regulations set fleet requirements applicable to transit agencies, and set more stringent mid- and long-term emission standards for new urban bus engines, applicable to manufacturers. Transit agencies were required to choose between diesel or alternative fuel compliance paths. The fuel path selected would determine the compliance schedule and reporting requirements. The fleet rule was designed to provide transit agencies with flexibility in meeting the NOx standard while achieving near-term PM reductions and promoting advancement of PM control technology. The PM standard required transit agencies to retrofit progressively newer model-year buses in their fleets with devices capable of reducing PM emissions by 85 percent.

Recognizing the progressive nature of the fleet rule and emission standards, the Board required staff to report back on the progress made by transit agencies toward implementing the regulatory requirements. Since adoption of the rule, staff has worked closely with transit agencies, urban transit bus and engine manufacturers, and control technology manufacturers. Staff conducted three workshops and several stakeholder's meetings, attended industry meetings, and issued written memoranda and advisories to the transit agencies. Staff gave progress reports to the Board on September 20, 2001, and March 21, 2002. Working together we have ensured that the vast majority of transit agencies will be in compliance with the NOx fleet average requirements. Staff reported,

however, that PM retrofit technology capable of reducing PM emissions by the mandated 85 percent or more would not be available for the 1993 model-year and older engines in time to meet the first implementation deadlines.

Understanding the importance of maintaining the PM emission reductions anticipated in the February 2000 public transit bus rulemaking and recognizing the lack of PM retrofit technology for older buses, the Board directed staff through Resolution 02-16, to consider another approach for requiring PM retrofits. The Board's objective was to provide transit agencies with additional flexibility while obtaining as close to the same reductions in diesel PM as would have been achieved had the existing regulations been fully implemented. This report describes staff's proposed amendments to the February 2000 public transit bus rule to implement the Board's directive, along with the environmental and cost impacts associated with the proposed modifications.

Staff also reported that a testing and certification protocol needed to be developed and adopted to accurately assess the emissions from hybrid-electric urban transit buses (HEBs). HEBs are a relatively new but promising technology for urban transit buses that would provide transit agencies with another option for reducing both NOx and PM emissions. Current heavy-duty certification and test procedures are based on engine testing and do not accurately reflect, without modifications, the vehicle emissions of a hybrid-electric drive system. This report presents staff's proposed interim certification procedures for HEBs.

**Summary of the Amendments**

PM Emission Reduction Proposal

As directed by the Board in March 2002, staff reviewed the technology available to achieve the current PM retrofit requirements. Staff concluded that PM retrofit technology capable of reducing PM emissions by 85 percent or more is not currently available for 1993 model-year and older engines. The 85 percent requirement was to go into effect during 2002 with 100 percent of pre-1991 urban bus engines retrofitted by January 1, 2003. In order to provide transit agencies with maximum flexibility in reducing PM emissions, yet still aggressively reduce in-use PM emissions, staff proposes to amend the current rule which requires transit agencies to retrofit a percent of its overall fleet for each model year. The proposed amendments would require transit agencies to reduce PM by a specified percentage based on total diesel PM emissions. The proposed schedule to achieve a required percent of PM emission reductions is based on the implementation dates of the original regulation's implementation schedule and on the fuel path selected.

The proposed amendments would require that a transit agency on the diesel path reduce its overall diesel fleet PM emissions by 40 percent of its January 1, 2002 total diesel PM emissions baseline by January 1, 2004, with increasing

reductions through 2007. Transit agencies that selected the alternative fuel path would also be required to reduce PM emissions from diesel-fueled buses remaining in their fleets. Those agencies would be required to reduce PM emissions by 20 percent by 2004, with increasing reductions through 2009. This new proposal provides transit agencies with the flexibility to choose the control methodology for achieving the required percentage reduction, rather than the use of retrofit control technology. A transit agency may choose to reduce in-use PM emissions by replacing buses with new buses, repowering buses with new engines, purchasing alternative-fueled engines that are not required under current requirements, or installing ARB-verified PM emission reduction technology.

Fuel Path Change

The proposed amendments include a one-time allowance for a transit agency to change its fuel path selection from diesel to alternative fuel, in response to the Board's request that staff consider allowing this change. After surveying transit agencies and examining potential impacts of the proposed modification, staff determined that minimal impact would result from allowing transit agencies on the diesel path located in the South Coast Air Quality Management District (SCAQMD) to make the change to the alternative fuel path. Some of these transit agencies chose the diesel path, although SCAQMD Rule 1192 requires them to purchase alternative fuel buses. Because these transit agencies are already required to purchase alternative-fueled buses, allowing any of them to change fuel path would not have an impact on the emission reductions anticipated from the current regulation. Staff's proposal is to limit the scope of the fuel path change only to transit agencies in the SCAQMD. Based on the transit agencies' response to staff's solicitation to declare a fuel path change from diesel to alternative fuel, only transit agencies in the SCAQMD replied and expressed interest in the change. A transit agency that wishes to change fuel path must make a declaration of its intention by January 31, 2004, at the same time as it makes its regular annual report.

Alternative Fuel Bus Purchase Provision for Diesel Path Transit Agencies

The certified emission level of an engine that a transit agency wishes to purchase during 2004 through 2006 is dependent on the agency's selected fuel path. The current regulations require engines sold to transit agencies on the diesel path to meet a 0.5 g/bhp-hr NOx standard. This standard applies whether the engine is a diesel-fueled, dual-fueled, bi-fueled, or alternative-fueled engine. Staff does not expect any full-sized alternative-fueled or diesel-fueled urban bus engines certified to 0.5 g/bhp-hr NOx emissions to be available through 2006. Transit agencies on the alternative fuel path are currently allowed to purchase alternative-fueled engines meeting a 2.5 g/bhp-hr NMHC + NOx standard through 2006.

To encourage and facilitate transit agencies on the diesel path to purchase alternative-fueled engines, and to ensure that transit buses are available to be purchased in the 2004 through 2006 time period, some flexibility is needed for transit agencies on the diesel path. Staff proposes to have consistent emission standards for all alternative-fueled buses in the 2004 through 2006 model years, regardless of the fuel path chosen by the transit agency. Thus, all transit agencies may purchase any certified alternative-fueled engines from 2004 through 2006.

Transit Agency Request for Delay

On occasion, transit agencies have requested delays to allow them to deviate from the schedule because of financial hardship. Small transit agencies may face unique situations and lack the ability to utilize some of the flexibility within the regulations. In order to provide a mechanism whereby the Executive Officer can hear exceptional requests and decide on the merits whether an implementation delay is warranted, staff proposes adding a general provision that would allow a transit agency with fewer than 20 buses to request an implementation delay based on demonstrated financial hardship.

Modifications to Definitions

To clarify and update the transit bus regulation in response to stakeholder inquiries, staff proposes to modify the definitions of "active fleet" and "alternative fuel", and to add definitions for "emergency contingency vehicle" and "spare bus". The most significant modification pertains to alternative-fueled engines. Previously the definition precluded any use of diesel fuel. The proposed revision will allow the use of a small quantity of diesel as a pilot ignition source only.

Repeal Certification Procedures for PM Retrofit Devices

The proposed amendments require that any device installed on urban buses to meet the diesel PM reduction requirement be verified under the procedures adopted therein. Currently, there are two procedures available to manufacturers of diesel emission control strategies to certify technology. To ensure that all manufacturers follow the same procedures and have the same warranty and in-use compliance requirements, it is necessary to repeal "California Certification Procedures for PM Retrofit Devices for On-Road Heavy-Duty Diesel Vehicles", adopted November 22, 2000 and incorporated by reference in CCR title 13, section 1956.2 (f) (7). These procedures would be replaced with those adopted by the Board in May 2002: "Diesel Emission Control Strategy Verification Procedure, Warranty and In-Use Compliance Requirements for On-Road, Off-Road, and Stationary Diesel-Fueled Vehicles and Equipment." This modification would have no impact on transit agencies or businesses because no manufacturer has followed the certification procedures that were adopted November 22, 2000.

Hybrid-Electric Bus (HEB) Certification Procedure

Hybrid-electric drive systems are emerging in the marketplace, offering lower energy use and lower emissions. Part of the challenge in developing a certification procedure for buses that use hybrid electric drive systems is designing a method that quantifies the emission benefits of the drive system in various HEB platforms.

Currently, manufacturers have one option for certifying an HEB – apply for certification to ARB on a case-by-case basis. Current procedures are engine-based and an HEB would be certified at a level that does not represent actual emission benefits of the HEB. Current engine-based certification test procedures do not have a method of quantifying the amount of power provided by the electric drive system incorporated into the HEB. Although recent ARB tests of HEBs being demonstrated in California indicate substantial emission reductions, these conclusions have been based on a few results and are not representative of all of the types of HEB platforms that are available for commercialization. Hence, staff believes it is appropriate to propose an interim certification procedure that better represents HEB emissions, to be effective for three years. This would allow ARB to work closely with manufacturers to determine whether modifications or more appropriate requirements are warranted in future years.

The proposed interim certification procedure for determining compliance with the urban transit bus emission standards, applicable to 2004 and subsequent model-year hybrid-electric buses, is based on a modified version of the Society of Automotive Engineers (SAE) Recommended Practice SAE J2711. This protocol was developed to test the emissions of heavy-duty hybrid-electric vehicles using a chassis dynamometer. The HEB's certification value is determined through calculations using chassis dynamometer test results and engine certification values for both the HEB and a conventional drivetrain urban transit bus. ARB's procedures include a provision for chassis dynamometer testing of conventional drivetrain urban transit buses to determine baseline emissions.

**Environmental Impacts and Cost-Effectiveness**

The proposed amendments achieve close to the same emissions reductions, beginning in 2005, as the original regulations. Prior to 2005, the benefits will be less than the original regulations. Two factors account for the rule relaxation in the early years: the lack of technology to retrofit older engines now and the need to provide transit agencies additional time to obtain funding to replace older engines.

If approved, the proposed amendments will reduce PM emissions statewide in 2010 by approximately 180 lbs/day (33.4 tons per year). Estimated costs to transportation planning agencies, commissions, and transit agencies would

remain similar (about $2.5 million) to the estimate in the February 2000 rulemaking. The cost-effectiveness during 2003 to 2009 would range from $10.91 to $44.51 per pound of PM, with an average expected cost effectiveness of $25.23 per pound reduced. The original regulation cost-effectiveness was reported as $17.90 per pound of PM reduced, which is within the range calculated for the proposed amendments.

The proposed amendments seek to balance the need to reduce diesel PM emissions to the extent technologically feasible with the need of the regulated entities for flexibility in achieving those reductions. The calculated benefits do not include the value of health benefits associated with a reduction in exposure the diesel PM, a toxic air contaminant.

**Recommendations**

The ARB staff recommends that the Board adopt the proposed amendments and incorporated test procedures. The new amended provisions will continue to require that PM emissions from urban transit buses be reduced, while providing transit agencies with additional flexibility. This proposal continues California's commitment to provide reductions of NOx and PM emissions from urban transit buses.

# I. INTRODUCTION

California's air quality has improved significantly over the last thirty years, yet there is a need to continue establishing and implementing regulatory and incentive programs that are designed to achieve future air quality goals and provide healthful air to all Californians. Over 90 percent of Californians still breathe air that violates one or more health-based air quality standards.

Mobile source control and incentive programs have been innovative and progressive and 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 matter (PM) emissions, statewide. Mobile source diesel engines account for 30 percent of the particulate emissions. ARB identified diesel PM as a toxic air contaminant in 1998. Hence, the control of PM for diesel-fueled engines is critical.

With this in mind, in February 2000 ARB adopted new regulations establishing a public transit bus fleet rule and emission standards for new urban buses. These regulations promote advanced technology for urban buses that will result in significant reductions in NOx and PM emissions. The requirements were designed to reduce NOx, an ozone precursor, and PM by encouraging transit agencies to voluntarily purchase cleaner alternative fuel buses and to incorporate ARB-certified PM retrofit traps on urban bus engines.

Recognizing the progressive nature of these regulations, the Board required staff to report back regularly on the progress for implementing the regulatory requirements and to consider developing a test procedure to certify hybrid-electric urban transit buses (HEBs) – an evolving propulsion system for urban transit buses. As such, staff worked closely with transit agencies to encourage compliance with the requirements and reported back to the Board at its September 20, 2001 and March 21, 2002 meetings. Based on staff's reports, the vast majority of the transit agencies will meet the NOx fleet average requirements. However, PM retrofit technology for early model-year urban transit buses would not be available for transit agencies to comply with the PM requirements.

Understanding the importance of reducing PM, the Board directed staff through Resolution 02-16 to consider another approach for reducing diesel PM while still obtaining similar PM benefits as achieved in the current adopted urban transit bus regulations. The Board also directed staff to consider an approach for allowing transit agencies that selected the diesel fuel path to change to the alternative fuel path, thus encouraging more PM reductions. The Board directed staff to present the proposed modifications to the urban transit bus fleet rule

requirements in the fall of 2002, while also presenting proposed recommendations for certifying HEBs.

This proposal contains ARB's proposed amendments to the Public Transit Bus Fleet Rule and Emission Standards for Urban Buses. The proposed amendments are designed to provide transit agencies with greater flexibility to comply with the required emission standards while recapturing the PM emission reductions lost because of the lack of verified technology to meet the mandated 85 percent reduction. The most significant modifications include proposed amendments that require transit agencies to reduce overall diesel PM emissions through use of a variety of mechanisms, rather than through the use of one method, a retrofit with a diesel particulate filter. Other proposed amendments include: a method for allowing transit agencies in the South Coast Air Basin to change from the "diesel" path to the "alternative fuel" path; a mechanism for a transit agency to request a delay with compliance due to financial hardship; and modifications to definitions for clarification of current regulations. This proposal also includes proposed procedures for interim certification of HEBs.

# II. BACKGROUND

This chapter provides a brief overview of California's current regulations designed to reduce emissions from urban transit bus engines. The chapter also presents a brief overview of implementation and the need to modify current regulations to ensure PM reductions, as anticipated from adoption of the February 2000 Public Transit Bus Fleet Rule, are achieved.

## A. Urban Buses and Emission Standards

In general, urban 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. Urban buses usually 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. Commuter bus operation within metropolitan areas (such as the Yolo-Sacramento metropolitan area) that consists of more than a few pick-up and drop-off stops is considered to fall within the definition of urban bus operation.

Urban buses are generally 35 to 40 feet long, are normally powered by a heavy heavy-duty diesel engine; and fall within the heavy heavy-duty vehicle classification of greater than 33,000 pounds gross vehicle weight (GVW). The ARB staff estimates that there are about 9,100 full-size transit buses operating in California in 2002. Of these, approximately 80 percent are operated by the 18 largest transit fleets with more than 100 buses in their fleet. The remaining buses are spread among 50 other transit agencies that operate urban buses throughout California.

Urban buses have relatively high emissions (on a per vehicle basis) of NOx and PM. Based on ARB's most current emission inventory model, urban buses will emit 8 tons per day of NOx and a half ton per day of PM in 2005. NOx is critical because it is one of the major components of ozone formation. Diesel particulate matter has been identified as a toxic air contaminant because it increases the risk of lung cancer, increases the onset and severity of respiratory and cardiac diseases, and increases mortality. Diesel engines emit relatively low levels of other pollutants, such as hydrocarbons (HC), and carbon monoxide (CO). Tables 1 and 2 below list both California and federal NOx and PM emission standards for urban bus engines.

## Table 1

| California and Federal NOx Emission Standards for Urban Bus Engines (g/bhp-hr) | | |
|---|---|---|
| **Model Year** | **California** | **Federal** |
| 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(1)(2) | 2.0(1)(2) |
| 2004 | 0.5(3) | -- |
| 2007 | 0.2 | 0.2 |

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.

3. Standard applies to urban buses for fleets that have selected the diesel path, whether equipped with diesel-fuel, dual fuel, bi-fuel, or alternative fuel engines.

## Table 2

| California and Federal PM Emission Standards for Urban Bus Engines (g/bhp-hr) | | |
|---|---|---|
| **Model Year** | **California** | **Federal** |
| 1988 | 0.6 | 0.6 |
| 1991 | 0.1 | 0.25 |
| 1993 | 0.1 | 0.1 |
| 1994 | 0.07 | 0.07 |
| 1996 | 0.05(1) | 0.05(1) |
| October 2002 | 0.01 | 0.05 |
| 2007 | 0.01 | 0.01 |

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

In addition to the mandatory emission standards listed above, the ARB also has optional, reduced-emission standards, which were integrated into the February 2000 urban transit bus fleet rule. The optional reduced-emission standards for NOx are listed in Table 3, below.

**Table 3**

**Existing California Required and Optional, Reduced-Emission Standards for Urban Buses (g/bhp-hr)**

| Model Year | Primary Standard | Optional Standards | Increment |
|---|---|---|---|
| 2000 - 10/2002 | 4.0 (NOx) | 2.5 – 0.5 | 0.5 |
| 10/2002 – 2003 | 2.4 NOx+NMHC or 2.5 NOx+NMHC with 0.5 NMHC cap | 1.8-0.3 | 0.3 |
| 2004 – 2006[a] | 2.4 NOx+NMHC or 2.5 NOx+NMHC with 0.5 NMHC cap | 1.8-0.3 | 0.3 |

Notes: a. Emission standards apply to alternative fueled engines on the alternative fuel path.

## B. February 2000 Urban Transit Bus Regulations

Urban Transit Bus regulations were approved by the Board in February 2000. This regulation contains two elements to reduce emissions from urban buses: 1) a multi-component transit bus fleet rule applicable to transit agencies that ultimately requires zero-emission bus (ZEB) purchases beginning in 2008; and 2) more stringent emission standards for engines used in urban buses, applicable to engine manufacturers.

The fleet rule was designed to provide transit agencies with flexibility in meeting the NOx standard while also achieving very near-term PM benefits and progressively promoting advanced PM control technology for California's urban transit buses. The engine standards were designed to achieve long-term emission benefits resulting from new bus engines. In order to provide agencies with flexibility in complying with the standards, transit agencies were required to choose between two fleet rule compliance paths -- the "diesel" path or the "alternative fuel" path.

## 1. Requirements for PM

Based on the need for PM emission reductions, California set technology-forcing PM emission standards for new engines. Beginning with engines produced after October 1, 2002, new engines used in urban transit buses must meet a 0.01 g/bhp-hr PM standard. In order to comply with these standards by the end of 2002, however, staff was aware that advanced fuel and control technology, such as ultra low sulfur (<15 ppm) fuel, and diesel particulate filters (DPFs) would be necessary.

Staff's approach was to include requirements that reduce in-use PM emissions from older diesel engines used in urban transit buses. In order to enable the use of PM-reducing technology and also obtain some reductions in diesel PM immediately, transit agencies on both paths were required to use ultra low-sulfur fuel as of July 1, 2002. Use of ultra low-sulfur fuel would facilitate use of DPFs, a technology likely needed to meet future PM standards. In addition, by January 1, 2003, and through 2009, transit agencies must retrofit their in-use diesel fuel, dual fuel, bi-fuel and diesel HEB engines produced through October 1, 2002, with ARB-verfied devices that reduce PM by 85 percent or more. The only current technology that can achieve this level of control is the DPF. The compliance path selected would determine the model years affected, percent of the fleet retrofitted, and the date for compliance. Table 4 lists the compliance schedule for PM retrofits that is in the original rule.

**Table 4**

| PM Retrofit Requirements By Fuel Path | |
|---|---|
| **Diesel Path** | **Alternative Fuel Path** |
| Tier 1 (pre 1991)<br>100% by January 1, 2003 | Tier 1 (pre 1991)<br>100% by January 1, 2003 |
| Tier 2 (1991 - 1995)<br>50% by 1/1/03<br>100% by 1/1/04 | Tier 2 (1991-1995)<br>20% by 1/1/03<br>75% by 1/1/04<br>100% by 1/1/05 |
| Tier 3 (1996 - pre-Oct. 2002)<br>20% by 1/1/05<br>75% by 1/1/06<br>100% by 1/107 | Tier 3 (1996 – pre-Oct. 2002)<br>20% by 1/1/07<br>75% by 1/1/08<br>100% by 1/1/09 |

### 2. Anticipated Emission Reductions

Staff estimated that the new low-emission standard and ZEB requirements would result in about 5.4 tons per day (tpd) NOx and 0.04 tpd (50 lbs/day) PM emissions reductions in 2010. The PM retrofit component of the February 2000 fleet rule would provide California with a PM emissions benefit of about 300 lbs/day in 2005, and 100 lbs/day in 2010. Requiring PM retrofits for older model-year engines is important in order to achieve significant and much needed PM emission reductions early.

## C. Implementation of the Urban Transit Bus Regulations

Staff has reported back to the Board on a regular basis on implementation progress by transit agencies. The Board asked staff to report: (1) on the transit agency program; (2) on implementation of NOx emission reduction strategies as an alternative to compliance with the 2004 standards along with an analysis of the first exemption application and a recommendation; (3) on the status of the advanced aftertreatment systems; and (4) on progress and development of a test procedure for HEBs. ARB staff has presented the Board with its first and second updates on September 20, 2001, and March 21, 2002. Staff has also worked with industry to develop the appropriate test procedure for certification of a hybrid-electric urban transit bus. This section provides a brief overview of the status on implementation and compliance with the February 2000 rulemaking for urban transit buses.

### 1. PM Retrofit Requirements

The approach for reducing PM relied heavily on the availability of DPFs for the older model-year urban transit bus engines beginning in 2003. At the time the public transit bus fleet rule was adopted, experience with DPFs was limited but promising. Demonstration programs using DPFs on a variety of engines showed promise for incorporation of this technology on all vehicles -- including older vehicles. Hence the 2000 Urban Transit Bus Fleet Rule required that 100 percent of pre-1991 diesel engines used in urban transit buses be retrofitted with ARB certified PM retrofits by January 1, 2003. Furthermore, the PM retrofit must reduce PM emissions by a minimum of 85 percent. Staff focused the original regulations on retrofitting the oldest engines first, even though they were more technologically challenging, because these were the engines with the highest PM emissions.

After the rules were adopted, staff worked closely with transit agencies and manufacturers to determine compliance with the approved PM retrofit requirements. Staff analyzed the status of PM retrofit technology and, by

March 2002, concluded that it was unlikely that retrofit technology for the oldest engines would be made available by manufacturers within the next year, or even in the near future. The only technology that will reduce PM emissions by 85 percent or more, as required, is the DPF. ARB staff had verified two DPF systems for use in 1994 and newer engines, but the DPF manufacturers had indicated that they would not be verifying technology in the near future for pre-1994 and any two-stroke engines.

The major issues preventing the use of this technology include very high in-use PM emissions from the older transit bus engines, which clogs diesel particulate filters rapidly, and low exhaust emission temperatures from two-stroke engines, which inhibit regeneration of DPFs. Another major issue that may prevent development of a new technology for these older engines is the small and declining number of older, two-stroke engines remaining in the transit bus fleet, which makes it less likely that manufacturers will invest in research and development to bring feasible technology to market. Indeed, the major manufacturers have shown little interest in developing technology for the oldest engines.

Based on these findings, staff reported to the Board on March 21, 2002, that currently there are no ARB-verified PM retrofits available for pre-1994 engines that would reduce PM by 85 percent. Hence, transit agencies would not be able to comply with current requirements by January 2003. The Board responded by directing staff, in Resolution 02-16 (March 21, 2002), to make the necessary changes to the diesel PM retrofit implementation schedule to recapture the diesel PM emission reductions lost because of the unavailability of technology. The ultimate goal for a new proposal would be to achieve as close to the same reductions in diesel PM as feasible, when compared to the PM reductions that would have been achieved had the existing regulation been fully implemented.

## 2. Selecting a Fuel Path

Under the current Public Transit Bus Fleet Rule, transit agencies were also required to declare an irrevocable fuel path – alternative fuel or diesel fuel – by January 31, 2001. The fuel path selected would determine the fraction of new bus purchases required to be alternative-fueled, and the compliance dates for incorporating PM retrofits and purchasing ZEBs. For example, for a transit agency on the alternative fuel path 85 percent of all new purchases must be alternative fuel buses. However, under this path transit agencies are provided with two years additional time to meet the PM retrofit, and ZEB purchase requirements.

During the March 2002 update to the Board, witnesses testified in favor of allowing transit agencies to change their fuel path selection from diesel to alternative fuel. Recognizing the benefits of alternative fuel technology, the

Board directed staff to evaluate the impact of allowing a transit agency to change its fuel path selection and make a recommendation.

### 3. HEB Test Procedures

Staff has also been working with industry to develop an interim certification procedure for hybrid-electric buses. Without a certification procedure in place, transit agencies planning to purchase HEBs as part of their fleet would not have a method for determining full emission benefits from the hybrid-electric technology. To allow transit agencies to receive emission reduction credit from the use of hybrid-electric buses, prior to the adoption of a certification procedure, ARB's Executive Officer established that HEBs would receive emission certification values 25 percent below the urban bus engine certification standard. A brief description of the proposed interim certification procedures for hybrid-electric urban buses is presented in Chapter III. The detailed interim certification procedure is provided in Appendix B of this document.

## D. The Role of HEBs in California

Hybrid-electric propulsion systems combine two motive power sources: an energy storage system such as a battery pack, and an internal combustion engine, turbine or fuel cell functioning as an auxiliary power unit (APU). An electric motor provides partial or complete power to the wheels. In addition, energy otherwise lost as heat during braking is captured through regenerative braking to charge the energy storage system. Since the engine/turbine/fuel cell is not the sole power source in hybrid-electric drivetrains, a smaller engine can be used and is operated at high efficiency and low emissions. Transit buses and delivery trucks with frequent stop-and-go drive cycles are ideal for hybrid-electric applications. The energy storage system is used during periods of initial acceleration which are usually high emission episodes, and regenerative braking during frequent stops will charge the energy storage system.

Current requirements under the Public Transit Bus Fleet Rule and future urban bus emission standards in California have been designed to encourage advanced technology in buses. Hybrid-electric drive systems provide another viable option to reduce NOx and PM emissions from urban transit buses and heavy-duty vehicles operating in California. Emissions testing results from HEBs (presented in section 3) indicate that these buses can potentially meet the future more stringent urban bus standards. If certified to full emission benefits, HEBs may be purchased to meet upcoming regulatory requirements, and potentially future more stringent requirements.

## 1. HEB Available Technology

Hybrid-electric drive systems for urban transit buses have been available commercially for five years. Within this time, a number of engine and turbine configurations have been developed. HEBs are available with internal combustion engines fueled with diesel, CNG, propane, or gasoline. Turbines fueled with diesel, CNG or liquefied petroleum gas (LPG) are also used in urban buses equipped with hybrid-electric drive systems. Fuel cell HEBs will be available in the near future.

Current hybrid-electric drive systems for urban transit buses use battery packs for energy storage. Energy storage systems using ultracapacitors or flywheels are under development. It is anticipated that hybrid-electric drive system technology will continue to advance at a rapid rate.

## 2. HEB Demonstration Programs

New York City Transit was the first North American transit agency to demonstrate full-size HEBs in revenue service. The program started in 1998 with four diesel HEBs; an additional six diesel HEBs were added in 2000. The favorable results from this initial study resulted in plans for delivery of an additional 375 diesel HEBs over the next four years.

A number of transit agencies are conducting small HEB demonstration projects in California. HEBs are in operation in Fresno, Los Angeles, Orange County, San Bernadino, San Francisco, and Torrance. Additional transit agencies in California have indicated an interest in purchasing HEBs for their fleets in the future.

## 3. Development of Heavy-Duty Hybrid-Electric Vehicle Test Procedures

Heavy-duty vehicles are currently certified using an engine test procedure, which cannot reflect the emission benefits provided by a hybrid-electric drive system. A new testing method for exhaust emissions from heavy-duty hybrid-electric vehicles needed to be developed. ARB staff participated with members from industry, academia, and government in the Northeast Advanced Vehicle Consortium (NAVC) Heavy-Duty Hybrid Certification Work Group to establish draft heavy-duty hybrid-electric vehicle test procedures. SAE, collaborating with the Heavy-Duty Hybrid Certification Work Group, developed a heavy-duty hybrid-electric chassis testing protocol, SAE J2711, based on the light-duty hybrid-electric chassis testing protocol J1711. This proposed recommended practice has received final approval by SAE through a balloting process in April 2002.

## 4. Emissions Testing of HEBs

The proposed (now approved by SAE as a recommended practice) chassis test procedure has been used for emission testing of a limited number of HEBs and conventional drivetrain buses. The test results illustrated in Figures 1 and 2, on the following page, were compiled from studies conducted in four testing facilities over the past three years. The model year of each bus is listed with manufacturer and fuel for each HEB, model years are indicated for the conventional drivetrain buses. All buses are 40-foot platforms except for the E-bus turbine LPG hybrid. Currently, the only data available for buses that utilize turbines pertains to a 22-foot platform and is included in these figures. Examples of older and newer diesel hybrid technology are provided for two manufacturers, Allison Electric Drives and BAE SYSTEMS. The diesel HEBs all utilize diesel particulate filters; the gasoline HEB has a catalytic converter.

**Figure 1: NOx Emission Results from HEBs**

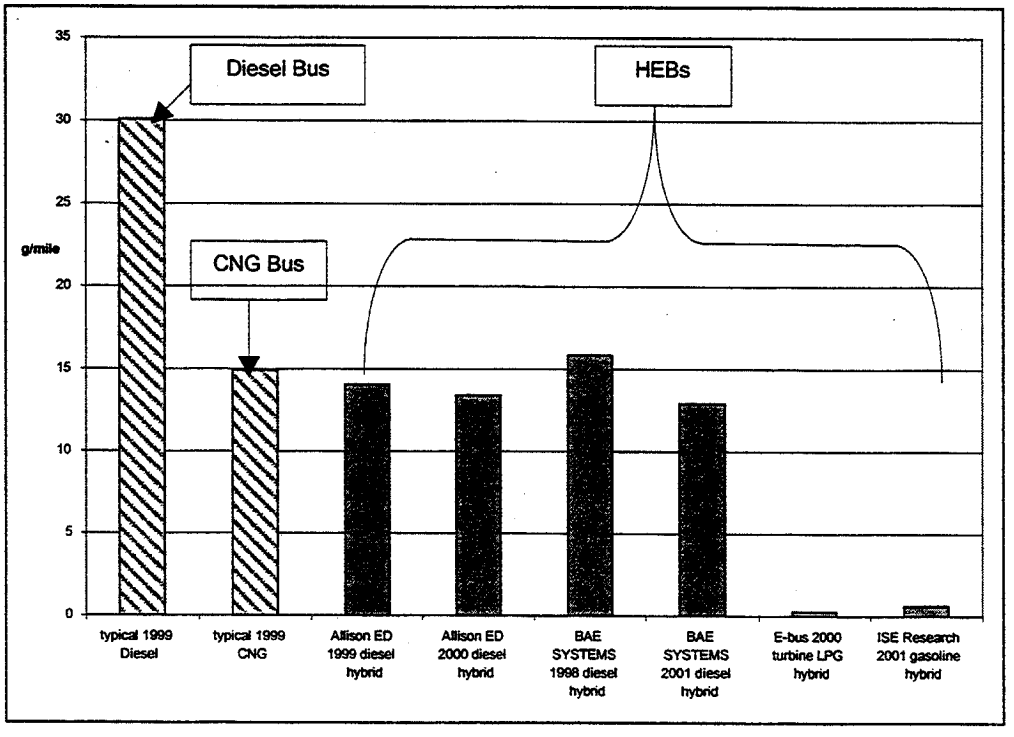
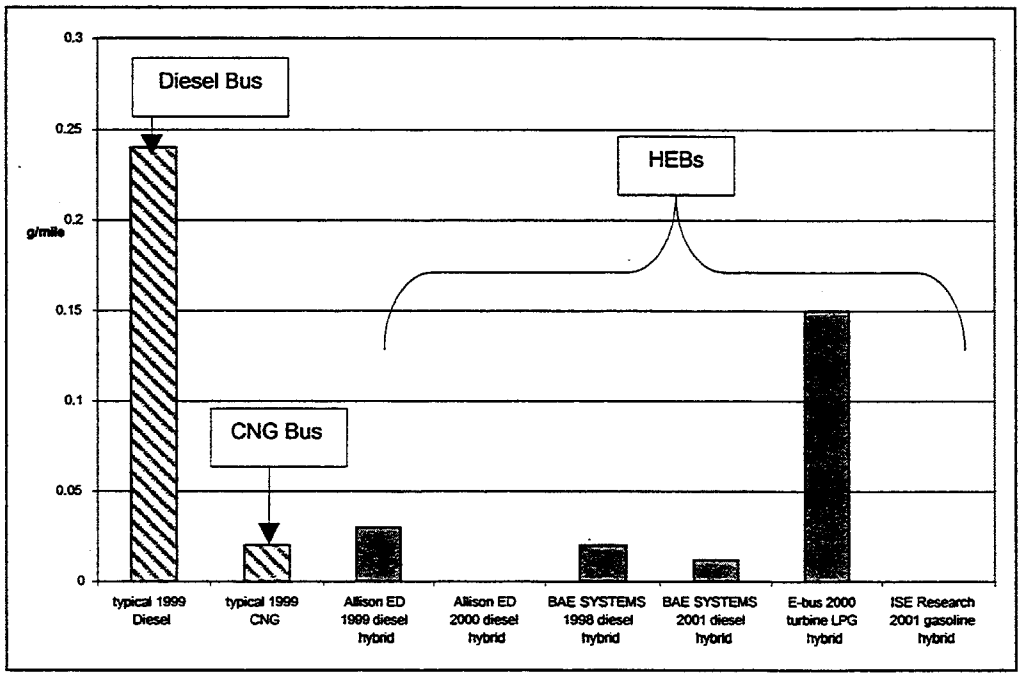


**Figure 2: PM Emission Results from HEBs**




It is important to understand that chassis testing provides results in units of grams per mile instead of g/bhp-hr used for engine certification. However, NOx emissions results for the diesel HEBs indicate about a 50 percent reduction over emissions from the conventional diesel bus. Furthermore, the turbine LPG hybrid and gasoline hybrid indicate a potential for much lower NOx emissions over the diesel hybrids.

While limited test data is available to make statistical significant evaluations, HEBs are considered a viable technology for reducing emissions from urban transit buses. However, HEBs are rapidly changing, there are many configurations and designs, and the available test data does not represent every type of HEB available. For these reasons, staff is proposing an interim certification procedure. The interim certification procedure would follow a modified SAE J2711 in conjunction with a supplemental formula that would calculate an emission factor ratio to determine a certification value in units of g/bhp-hr. An interim test procedure would provide a method for testing HEBs through which ARB staff would perform complete and comparable evaluations.

## E. Need for Modifications

### 1. PM Retrofit

During the March 2002 status update on the public transit bus rule making, staff informed the Board that there were no DPFs verified for 1993 and older model-year urban transit bus engines that would reduce PM emissions by 85 percent or more. This is a problem because the rule requires transit agencies to retrofit 100 percent of their pre-1991 model-year engines by January 1, 2003, and differing percentages of their 1991-1995 model-year engines, based on fuel path, also by January 1, 2003, using devices that reduce diesel PM by 85 percent or more.

The regulation allows ARB's Executive Officer to grant one-year delays for retrofitting because of unavailability of a retrofit device. After evaluating the status of technology development, however, staff determined that technology to reduce diesel PM by 85 percent or more from pre-1994 and two-stroke engines is unlikely to be available even after one year, by January 1, 2004. Transit agencies, therefore would be unable to comply with the PM retrofit requirements. The Board directed staff to revise the current PM retrofit requirements and consider another approach that would achieve as close to the same reductions in diesel PM as feasible, when compared to PM reductions anticipated from full implementation of the 2000 urban transit bus rule making.

### 2. Fuel Path Change from Diesel Path to Alternative Fuel Path

At its March 21, 2002 meeting, the Board heard testimony regarding the fuel path selection by transit agencies. Under the regulation, transit agencies elected a fuel path as of January 31, 2001, which may not be changed for the life of the rule. Some transit agencies located in the SCAQMD have asked staff in the past if they could change their fuel path, but the rule does not allow any change. Witnesses at the March 21, 2002, meeting asked the Board to allow transit agencies on the diesel path the option of changing to the alternative fuel path, and the Board directed staff to analyze the impact of and need for such a change.

### 3. Alternative Fuel Bus Purchase Provision for Diesel Path Transit Agencies

The certified emission level of an engine that a transit agency wishes to purchase, during 2004 through 2006, is dependent on the agency's selected fuel path. The current regulations require engines sold to transit agencies on the diesel path to meet a 0.5 g/bhp-hr NOx standard, unless the transit agency has an approved alternative NOx strategy exemption. This standard applies whether the engine is a diesel-fueled, dual-fueled, bi-fueled, or alternative-fueled engine.

Staff does not expect, however, any full-sized alternative-fueled or diesel-fueled urban bus engines certified to 0.5 g/bhp-hr NOx emissions to be available through 2006. Transit agencies on the alternative fuel path are currently allowed to purchase alternative-fueled engines meeting a 2.5 g/bhp-hr NOx+NMHC standard through 2006.

To encourage and facilitate transit agencies on the diesel path to purchase alternative-fueled engines, and to ensure transit buses are available to be purchased in the 2004 through 2006 time period, some flexibility is needed. Staff proposes to have consistent emission standards for all alternative fuel buses in the 2004 through 2006 model years, regardless of transit agency fuel path.

### 4. Transit Agency Request for Delay

Staff has been asked periodically by transit agencies to allow them to deviate from the schedule and delay implementation because of financial hardship. Specifically, a small number of transit agencies, two or three, have requested a compliance delay in meeting the July 1, 2002 ultra low sulfur (<15 ppm) fuel requirement. One transit agency, for example, has two transit buses operating on diesel fuel, which it plans to replace with natural gas buses in two years. This transit agency does not have ultra low sulfur fuel available locally and would have to build infrastructure (storage tanks), which it would use for only two years while it is converting all of its fleet to alternative fuels. They have requested, therefore, a two-year delay in complying with the ultra low sulfur diesel fuel mandate, after which they will no longer have any buses operating on diesel fuel.

In some cases, staff has viewed the request for a delay favorably, yet is unable to consider these requests because of the lack of any provision in the regulation for dealing with variations from implementation. Staff has therefore proposed adding a general provision that would allow a transit agency to request an implementation delay because of financial hardship, and a mechanism by which the Executive Officer could grant or deny the request.

### 5. Amended Definitions

Staff has determined that two modifications and two additions are needed to the list of definitions. Staff proposes to modify the definition of "active fleet" and define terms that are used in that definition. The modification is necessary to improve clarity and to assure that terms agree more closely to the Federal Transit Administration (FTA 2001) definitions. The two terms that must be defined are "emergency contingency vehicles" and "spare buses." Defining these two terms is important because the term "active fleet" is used several times in the rule to determine how many buses must be included when calculating, for example, the NOx fleet average and which buses must be retrofitted to reduce PM emissions.

In addition, staff has determined that the definition of "alternative fuel" needs to be modified to clarify the classification of a new-technology engine which uses a very small amount of diesel fuel for pilot ignition, but otherwise uses alternative fuel for operation.

### 6. Repeal California Certification Procedures for PM Retrofit Devices

In the February 2000 rulemaking, the Board adopted "California Certification Procedures for PM Retrofit Devices for On-Road Heavy-Duty Diesel Vehicles." These procedures were adopted to enable this technology to enter into California's market and transit agencies would have technology available to comply with the PM retrofit requirements. In May 2002 the Board adopted the "Diesel Emission Control Strategy Verification Procedure, Warranty and In-Use Compliance Requirements for On-Road, Off-Road, and Stationary Diesel-Fueled Vehicles and Equipment." The proposed amendments require that any device installed on urban buses to meet the diesel PM reduction requirement be verified under the procedures adopted therein. Currently, there are two procedures available to manufacturers of diesel emission control strategies to certify technology. To ensure that all manufacturers follow the same procedures and have the same warranty and in-use compliance requirements, it is necessary to repeal "California Certification Procedures for PM Retrofit Devices for On-Road Heavy-Duty Diesel Vehicles", adopted November 22, 2000 and incorporated by reference in CCR title 13, section 1956.2 (f) (7). This modification would have no impact on transit agencies or businesses because no manufacturer has followed the certification procedures that were adopted November 22, 2000.

### 7. Hybrid-Electric Bus Test Procedures

For heavy-duty engines, the U.S. EPA and ARB ensure maximum emission reductions by adopting engine test procedures that measure emissions occurring during typical in-use driving conditions. In order to sell an engine in California, manufacturers must follow the federal/ARB regulatory test procedure and certify engines to the appropriate regulatory standard or optional standard. Typically, owners of heavy-duty vehicles powered by engines certified to the optional standards are also eligible to receive either incentive funds or emission reduction credits for operating vehicles that are cleaner than required.

Standards implemented beginning this month require NOx emissions from heavy-duty vehicles and urban transit buses to be nearly 50 percent lower than previous standards. Hybrid-electric drive systems have the potential to allow urban transit buses to meet the already adopted urban transit bus standards and future more stringent standards. This technology can also be used in other heavy-duty vehicles to meet the future 2007 standards. However, test procedures are needed to certify these systems in heavy-duty vehicles for sale in California. At this time, there is not an approved certification procedure available to certify full emission benefits of hybrid-electric drive systems. Current heavy-

duty vehicle certification is conducted using engine-based test procedures. As hybrid-electric vehicles utilize both an electric motor and an internal combustion engine, engine testing alone will not reflect the contribution of the electric motor, or the emission benefits associated with it. Hence, there is need to develop a methodology for determining the actual emission benefits provided by heavy-duty hybrid-electric drive systems, specifically urban transit buses.

## III. SUMMARY OF PROPOSED REGULATIONS

Staff recommends that the Board adopt proposed amendments to sections 1956.1, 1956.2, 1956.4, 1956.8, and 2112, title 13, California Code of Regulations, and the incorporated "California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric Vehicles, in the Urban Bus and Heavy-duty Vehicle Classes", as set forth in Appendix A. All the provisions in the proposed amendments and new test procedures apply to engines and vehicles produced for sale in California. There are two components to this proposal 1) to the urban transit fleet rule and 2) incorporation of the exhaust emission test procedures for HEBs. The proposed amendments to the urban transit fleet rule would provide transit agencies with additional flexibility in meeting the PM retrofit requirement. The proposed amendments also include a one-time allowance for a transit agency in the SCAQMD to change its fuel path selection from diesel to alternative fuel and a method for ARB's Executive Officer to grant transit agencies a delay in compliance with the Public Transit Bus Fleet Rule. Finally, staff is proposing modifications to clarify the definitions of an "active fleet" and "alternative fuel bus"; and adding two new definitions -- "emergency contingency vehicle", and "spare bus."

With this proposal, staff is proposing to incorporate exhaust emission test procedures to certify HEBs for an interim period of three years. Since the technology for HEBs is fairly new and rapidly evolving, staff will use the interim period to determine the appropriateness of the proposed test procedures. Staff proposes to present modifications to the Board after two years, if necessary.

### 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, or operation within a metropolitan area. 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 amendments to the fleet rule apply to those public transit fleets operated by government agencies or operated by private entities under contract to government agencies. The proposed amendments to the fleet rule only apply to urban transit buses. The proposed amendments would not apply to buses used in shuttle services, airport shuttle services, paratransit services, and school

transportation services. Buses used to provide long-distance charter service, that are generally equipped with luggage compartments, rest rooms, and overhead storage, are not included.

The proposed interim certification procedures for heavy-duty hybrid-electric vehicles apply to urban transit buses as incorporated during a 3-year interim period. All other heavy-duty hybrid-electric vehicles would follow incorporated procedures on a case-by-case basis as approved by ARB's Executive Officer.

## B. Amendments to the Fleet Rule, 1956.2

### 1. PM Emission Reduction Proposal

Staff analyzed several alternatives to the current PM retrofit implementation schedule that could achieve as close to the same reductions in diesel PM as feasible. This section describes staff's proposal for PM emission reductions. The alternatives to this proposal are presented in Chapter IV.

In order to provide transit agencies with maximum flexibility in reducing PM emissions, yet still aggressively reduce in-use PM emissions, staff proposes to amend the rule and replace the PM retrofit program with a program that requires that transit agencies reduce their total diesel PM emissions through 2009. The proposed schedule is based on the implementation dates set in the original regulation's implementation schedule based on the fuel path selected by the transit agency. The proposed new schedule is provided in Table 5, below.

As listed in the table, beginning in 2004 each transit agency would be required to achieve a percent reduction of their January 1, 2002, total diesel PM emissions baseline. For example, in 2004 transit agencies that selected the diesel fuel path would be required to reduce their January 1, 2002, total diesel PM emissions baseline by 40 percent. Transit agencies that selected the alternative fuel path, however, would be required to reduce their January 1, 2002, total diesel PM emissions baseline by 20 percent. By 2007, transit agencies on the diesel path would be required to achieve an 85 percent emission reduction of their PM emissions baseline. This is two years earlier than transit agencies that have selected the alternative fuel path.

**Table 5**

| Proposed Compliance Schedule for Total Diesel PM Emission | | |
|---|---|---|
| **Compliance Year (as of January 1st)** | **Diesel Fuel Path Percent Reduction** | **Alternative Fuel Path Percent Reduction** |
| 2004 | 40 | 20 |
| 2005 | 60 | 40 |
| 2007 | 85 | 60 |
| 2009 | 85 | 85 |

The diesel PM emission reduction proposal applies only to diesel-fueled, dual-fueled, bi-fueled, and diesel HEBs, in other words, any engine that uses diesel fuel and has diesel PM emissions. A transit agency with only alternative-fueled buses does not have to reduce its total diesel PM emissions, because alternative-fueled buses emit zero diesel PM emissions. However, a transit agency with mostly alternative-fueled buses and some diesel-fueled buses would be required to reduce PM emissions from its diesel buses only. In this case a PM emissions baseline would only be calculated for the transit agency's diesel buses. This proposal is designed to ensure that every diesel fleet will have its in-use PM emissions significantly reduced by 2007 or 2009, depending on fuel path.

Staff is proposing additional modifications to the rule to allow transit agencies to apply for delays under special circumstances. In the first case, a transit agency that cannot comply with the percentage reductions because technology is not available may apply for an implementation delay of up to one year for each of the compliance deadlines. The transit agency must justify its request by providing the Executive Officer with information on why technology is unavailable, for example, either the technology is not being sold yet or it is being sold but all units have already been purchased by others. Additional required information includes why the transit agency cannot comply by retiring older buses, a plan for compliance, and when the transit agency can comply. In the case where technology is on the market but sold out, the transit agency should supply correspondence with the manufacturer that states when the units would be available.

In the second case, a transit agency that operates fewer than 20 buses and is located in a federal one hour ozone attainment area may delay complying with

the intermediate deadlines of January 1, 2004, 2005, and 2007[1] so long as the transit agency complies with the 85 percent reduction requirement by either January 1, 2007 (diesel path) or January 1, 2009 (alternative fuel path). In this case, the transit agency does not need to make an application for delay, but should include information regarding its intent in its annual reports.

Two other new sections describe how transit agencies are to reduce diesel PM emissions through the use of aftertreatment or other add-on devices. In the first section, staff proposes that transit agencies be required to use only diesel emission control strategies that are verified by the ARB under section 2700 et seq., title 13, CCR, or an urban bus retrofit kit certified and exempted from Vehicle Code section 27156 as an engine rebuild kit. The engine rebuild kits that are currently certified for use in California may be applied to engines of model 6V92 TA DDEC for various specified model years and reduce diesel PM emissions to 0.1 g/bhp-hr.

Additionally, staff provides guidance to transit agencies as to the allowable percentage reductions when using a diesel emission control strategy. The verification procedure categorizes a strategy into Level 1, which is a minimum of 25 percent reduction, Level 2, which is a minimum of 50 percent reduction, or Level 3, which is a minimum of 85 percent reduction. It is these values that staff proposes be used by transit agencies when calculating their diesel PM emission reductions.

Finally, section 1956.2 (f)(6) (formerly 1956.2 (f)(5)), which requires that transit agencies use only diesel fuel with a sulfur content of less than 15 parts per million by weight as of July 1, 2002, in their diesel buses, has been modified to allow the use of a fuel that is verified by the Executive Officer as a diesel emission control strategy (i.e. emulsified fuels). This is necessary because a verified fuel may be something other than a ultra low sulfur diesel fuel, and yet be verified to reduce diesel PM emissions.

## 2. Fuel Path Change

Staff has analyzed the impact of allowing a transit agency to change its fuel path three years into the implementation of what is a fifteen year rule. In establishing the fleet rule, the implementation dates for transit agencies on each fuel path were determined in order to ensure that emission reductions were essentially equivalent over the life of the rule. A transit agency on the alternative fuel path has been required to make 85 percent of its annual purchases or leases of alternative fuel buses since the January 31, 2001, fuel path selection date. Transit agencies that selected the diesel path have been purchasing only diesel-fueled buses, which are less expensive than alternative-fueled buses. Thus, a transit agency that changes now from the diesel path to the alternative fuel path

[1] The 2007 delay only applies to a transit agency on the alternative fuel path. A transit agency on the diesel path would be required to comply in 2007 as this is the full compliance deadline.

would have a higher proportion of diesel buses and lower proportion of alternative fuel buses over the life of the rule (through 2015).

As stated in the Staff Report for the regulation, the alternative fuel path was designed to achieve equivalent NOx and greater PM reductions than the diesel path. The rule also includes incentives for transit agencies on the alternative fuel path in terms of timing of the PM retrofit schedule, ZEB demonstration program, and timing of ZEB purchases (ARB 1999). An argument for not allowing transit agencies to switch paths, some three years into the regulation, is that such a change could affect the overall emission reductions achieved and the ZEB program.

The transit agencies located in the SCAQMD, however, are subject to Rule 1192, Clean On-Road Transit Buses, which was adopted June 16, 2000. The rule specifies that all purchases or leases of heavy-duty vehicles must be alternative-fueled, as of the date of adoption for transit agencies with 100 or more urban buses and as of July 1, 2001, for transit agencies with 15 or more urban buses. Seven transit agencies in the SCAQMD elected the diesel fuel path under the ARB's rule (Table 6). All but one of these transit agencies[2] must follow the SCAQMD rule where it is more stringent, i.e., they must purchase alternative fuel buses.

**Table 6**

| Transit Agencies in the SCAQMD on the Diesel Fuel Path | |
|---|---|
| **Transit Agency** | **Size of Fleet** |
| Commerce Municipal Bus Line[3] | 12 |
| Gardena Municipal Bus Line | 35 |
| Long Beach Transit | 190 |
| Montebello Bus Line | 78 |
| Norwalk Transit | 24 |
| Santa Clarita Transit | 60 |
| Torrance Transit | 33 |

None of the transit agencies in the SCAQMD are mandated to participate in the ZEB demonstration project, which only applies to transit agencies on the diesel path with more than 200 urban buses in their fleet as of January 31, 2001. The schedule for ZEB purchases is dependent both on fleet size and fuel path, but is

[2] Commerce is not subject to Rule 1192 because it has fewer than 15 buses.
[3] With only 12 urban buses in its fleet, Commerce is not subject to Rule 1192 and may purchase diesel buses.

determined based on fleet size as of either January 1, 2007, for diesel path agencies or January 1, 2009, for alternative fuel path agencies.

In order to determine which, if any, transit agencies would consider making a fuel path change, staff notified transit agencies and asked for comment on the proposal at workshops in Sacramento on May 3 and El Monte on May 9. Staff then sent electronic mail (e-mail) to the California Transit Association, again requesting comments from members, and finally sent e-mails to the transit agencies on the diesel path in the SCAQMD. In response, staff received one positive response (would change), one negative response (would not change), and one response that the transit agency would consider making the switch if the regulation was changed. The only transit agencies that responded to the request for comment were in the SCAQMD.

Staff concludes, therefore, that there is little interest in transit agencies making a fuel path change, and that the only transit agencies that would likely change are located in the SCAQMD. Allowing any transit agencies in the SCAQMD to change fuel path would have little or no impact on the benefits expected from the current regulation. Transit agencies in the SCAQMD have already been purchasing alternative fuel buses, because of the requirements set forth in South Coast's Rule 1196 pertaining to large heavy-duty fleets operating in the SCAQMD. Staff therefore proposes to limit the scope of the fuel path change only to transit agencies in the SCAQMD, and to require that any transit agency that wishes to change fuel path make a declaration of its intention by January 31, 2004. This date would allow transit agencies sufficient time to bring the question before their management or Board, and would allow them to combine reporting with the annual report due each January 31st.

### 3. Alternative Fuel Bus Purchase Provision for Diesel Path Transit Agencies

Staff proposes to delete the language "alternative-fueled" from section 1956.2 (d)(4) to remove the restriction on transit agencies on the diesel path from purchasing model year 2004 to 2006 alternative-fueled urban bus engines with NOx exhaust emission standards in excess of 0.5 bhp-hr. The intended effect of this change is to encourage transit agencies on the both paths to purchase alternative-fueled bus engines during this time period when staff expects there to be no complying diesel-fueled engines available.

### 4. Transit Agency Request for Delay

Staff is proposing that a new section be added to the existing regulation allowing transit agencies with fewer than 20 buses to request an implementation delay based on financial hardship. Current regulations have significant flexibility incorporated for the larger transit agencies ($\geq$ 20 buses) to comply with the

requirements. For very small transit agencies, financial hardship is a valid reason to consider in granting a delay for compliance.

The new provision is designed to provide a mechanism whereby ARB's Executive Officer can hear and decide on the merits of exceptional requests for an implementation delay. The transit agency would be required to provide evidence of financial hardship. Evidence must include an analysis of the cost of compliance, the source of funds available for complying with the regulation, the shortfall between funds available and the cost of compliance, and the data by which the transit agency would achieve compliance. The Executive Officer would then consider the transit agency's request along with the emission reductions forgone by delayed compliance before issuing a decision.

The new section allows a transit agency to apply for the delay within 30 days of the implementation deadline. Until a decision is made, a transit agency would be responsible for compliance. As the Executive Officer may take up to 90 days to render a decision, however, the transit agency should apply earlier to avoid the assessment of noncompliance penalties.

**5. Amended Definitions**

Staff proposes to modify the definition of "active fleet" to the following: "Active fleet means the total number of urban buses operated by a transit agency or under contract to a transit agency, including spare buses, but not emergency contingency vehicles or non-revenue producing vehicles."

Staff proposes to add two definitions, for "emergency contingency vehicle" and "spare bus," which are used in the definition of "active fleet." The proposed definitions are modeled on those published by the Federal Transit Administration National Transit Database (http://www.ntdprogram.com, 2001).

"Emergency contingency vehicle" would be defined as an urban bus placed in an inactive contingency fleet for energy or other local emergencies, after the urban bus has reached the end of its normal minimum useful life.

"Spare bus" would be defined as an urban bus that is used to accommodate routine maintenance and repair operations, and to replace a bus in scheduled service that breaks down or is involved in an accident.

There should be no impact from these changes, as staff has referred transit agencies to these already-existing definitions for "emergency contingency vehicle" and "spare bus" when a transit agency is determining the composition of its active fleet.

Staff proposes to modify the definition of "alternative fuel" as follows:

"Alternative fuel" means natural gas, propane, ethanol, methanol, electricity, fuel cells, or advanced technologies that do not rely on diesel fuel except as a pilot ignition source at an average ratio of less than 1 part diesel fuel to 10 parts total fuel on an energy equivalent basis. Alternative fuel also means any of these fuels used in combination with each other or in combination with other non-diesel fuels. Urban bus engines operating on alternative fuel may not have the capability to idle or operate solely on diesel fuel at any time.

The definition of alternative fuel is changed to include an engine that uses diesel fuel only as a pilot ignition source at less than 10 percent of the total fuel usage. The energy equivalent basis is in terms of Btus per gallon. In this case, natural gas is the primary fuel and the use of diesel fuel is limited to the small pilot quantity required to initiate combustion, precluding engine operation or idling solely on diesel fuel. Because natural gas is the primary fuel, allowing this small usage of diesel fuel in a system otherwise alternative-fueled is appropriate. Prohibiting such an engine from operating or idling solely on diesel fuel ensures that an engine with multiple operating modes, which may include operation on diesel fuel, does not come under this definition.

### 6. Repeal California Certification Procedures for PM Retrofit Devices

Staff proposes to repeal the "California Certification Procedures for PM Retrofit Devices for On-Road Heavy-Duty Diesel Vehicles," adopted November 22, 2000, that are incorporated by reference in 1956.2 (f)(7). In its place, the Board adopted in May 2002, the "Diesel Emission Control Strategy Verification Procedure, Warranty and In-Use Compliance Requirements for On-Road, Off-Road, and Stationary Diesel-Fueled Vehicles and Equipment," new sections 2700-2710, chapter 14, title 13, CCR. The proposed amendments require that any device installed on urban buses to meet the diesel PM reduction requirement be verified under the procedures adopted therein.

This change is necessary so manufacturers of all diesel emission control strategies follow the same procedures and have the same warranty and in-use compliance requirements for verification. As no manufacturer has followed the certification procedures that staff proposes to repeal, this change has no impact on transit agencies or businesses. This change will have a beneficial impact on transit agencies because the newly adopted verification procedures provide greater assurance of efficacy and reliability of the device.

## C. HEB Interim Certification

Based on preliminary results from HEBs tested following a chassis-based procedure, staff considers HEBs to be a viable technology for reducing emissions from urban transit buses. Full market penetration of the hybrid-electric drive

systems in urban buses, and eventually heavy-duty vehicles, will continue to be a challenge until a niche market is realized. The technology is rapidly changing with improvements in diesel HEBs to an expanded market for gasoline, natural gas, and fuel cell HEBs. In order for these systems to enter into the market smoothly and provide California with substantial emission reductions, recognition of full emission benefits is necessary. Staff proposes manufacturers to certify buses following a chassis-based test procedure and a calculation of emission reductions from the hybrid-electric drive system. Exhaust emissions would be verified following the HEB test procedures briefly described in section 9, below, (full detailed description in Appendix B). In lieu of testing, manufacturers would also have the choice to claim a 25 percent reduction from the engine's NOx certification value. Manufacturers may also continue to follow existing engine test procedures. Other types of heavy-duty hybrid-electric vehicles would also be eligible for certification on a case-by-case basis through the approval of ARB's Executive Officer.

Initially, flexibility is needed so manufacturers could sustain a market in the urban bus arena allowing the technology ample time to flourish from the urban bus into the heavy-duty vehicle market. To facilitate the introduction of this promising new technology in California, and to provide staff with a period of further evaluation of the technology, staff proposes interim certification procedures for a period of three years. To allow for additional flexibility staff proposes an approach that allows engine manufacturers to remain responsible for emissions from the engine during the interim period, while the hybrid-electric drive system manufacturer would be responsible for the emission reductions it provides for the HEB ("dual party" or "single party certification"). This approach would provide hybrid-electric drive system and engine manufacturers a period to develop a working relationship, collaborate efforts, and determine who would remain responsible for emissions beyond the interim period. Recognizing the merits and the age of the technology staff is also proposing relaxed useful life requirements during the interim period. In addition, proposed durability and emission testing requirements during the interim period would be based on the quantity of HEBs sold for a particular HEB family.

## 1. Definitions

Staff is defining various terms related to HEBs that are equivalent to those defined in the approved SAE J2711. These definitions are provided in Appendix B. The interim certification procedure includes using an emissions ratio factor to calculate a certification standard for the HEB. The ratio is determined by comparing emissions from a baseline certified heavy-duty engine and a baseline urban transit bus with emissions resulting from a chassis tested HEB.

ARB's Executive Officer would select the "baseline engine" that best represents the engine used in a family of HEBs as part of the hybrid-electric drive system.

Certified emissions for the selected engine would be used in calculating an emission factor for a particular hybrid-electric drive system. The "baseline urban transit bus" would also be selected by the Executive Officer to represent a conventional drivetrain (non-hybrid-electric) urban transit bus. Exhaust emissions for the "baseline urban transit bus", as determined by the chassis dynamometer test procedure, would be used with the certified emissions for the engine incorporated into that urban transit bus to calculate a non-HEB emission factor. The ratio of the hybrid emission factor to the non-HEB emission factor will then be used to calculate the appropriate emission reduction for a hybrid-electric drive system.

## 2. Test Procedures

The procedures for determining compliance with the urban transit bus emission standards applicable for 2004 and subsequent hybrid-electric urban buses are based on a chassis dynamometer test procedure and calculation of emissions attributed to the hybrid-electric drive system. The chassis dynamometer test procedure is a modified version of a SAE Recommended Practice, SAE J2711, developed for heavy-duty hybrid-electric vehicles. An emissions factor is calculated from the chassis dynamometer test results and the engine certification value for both an HEB and baseline urban transit bus. The ratio of the two emissions factors is then applied to the engine certification value of the engine used in the HEB, resulting in a hybrid-electric drive system certification value. Staff proposes that the Board adopt the modified chassis dynamometer test procedure with the emission factor ratio calculation and application as the method for determining exhaust emissions from hybrid-electric drive systems during the interim period.

SAE J2711, "Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy-Duty Vehicles", was formally approved in April 2002, and is considered a starting point for standardizing heavy-duty hybrid-electric vehicle testing. Staff has modified this comprehensive document for use as a chassis dynamometer test procedure for HEBs. SAE J2711 recommends the use of three driving cycles for exhaust emissions testing. Staff's proposed test procedure requires two heavy-duty vehicle driving cycles, the Orange County Bus Cycle and the Urban Dynamometer Driving Schedule (d) cycle, as well as the option of substituting a different driving cycle upon approval of ARB's Executive Officer. The SAE procedure includes a method for correcting the state of charge (SOC) for a series of test runs, resulting in emissions or fuel economy determination at zero net energy change (NEC). The test procedure proposed by staff does not use a SOC correction but instead requires each test run have a NEC variance of less than two percent. In addition, staff's proposed test procedure includes a provision for chassis dynamometer testing of conventional drivetrain urban transit buses, which is necessary for calculating the emission factor ratio.

Chassis level certification standards do not exist for heavy-duty vehicles and current engine certification methods do not reflect any emission reductions attributable to a hybrid-electric drive system. Staff proposes using an emission factor ratio for calculating a hybrid-electric drive system certification value from an engine certification value. An emissions factor is calculated by dividing the chassis test procedure result by the engine certification value. Emissions factors are calculated for both a hybrid-electric drive system and a baseline (conventional) urban transit bus. An emission factor ratio is then determined by dividing the emissions factor for the hybrid-electric drive system by the emissions factor for the baseline urban transit bus. The emission factor ratio is a number less than one and is indicative of the emission reduction benefit of the hybrid-electric drive system. The engine certification value is multiplied by the emission factor ratio to determine a certification value for the hybrid-electric drive system. Emission factors can be calculated for any mass emission or particulate emission species. Staff proposes to use the emission factor method for calculating NOx certification values for hybrid-electric drive systems. An example of applying an emission factor ratio for hybrid-electric drive system certification is provided in Figure 3.

**Figure 3: Example of Emission Factor Ratio Calculations**

Hybrid-electric Bus NOx = 8 g/mi
Engine (Hybrid-electric Bus) NOx = 2.5 g/bhp-hr

$$EF_{hybrid} = \frac{8\ g/mi}{2.5\ g/bhp\text{-}hr} = 3.2\ bhp\text{-}hr/mi$$

Baseline Bus NOx = 15 g/mi
Engine (Baseline Bus) NOx = 2.5 g/bhp-hr

$$EF_{baseline} = \frac{15\ g/mi}{2.5\ g/bhp\text{-}hr} = 6.0\ bhp\text{-}hr/mi$$

$$EFR = \frac{3.2\ bhp\text{-}hr/mi}{6.0\ bhp\text{-}hr/mi} = 0.53$$

Hybrid-electric $Bus_{cert}$ NOx = 2.5 g/bhp-hr x 0.53 = 1.3 g/bhp-hr

Where,

| | |
|---|---|
| g/mi | = grams per mile |
| g/bhp-hr | = grams per brake horsepower-hour |
| EF | = emissions factor |
| EFR | = emission factor ratio |
| Hybrid-electric $Bus_{cert}$ | = certification value for hybrid-electric drive system |

In the example provided above, NOx emission values for a hybrid-electric drive system and a baseline urban transit bus were obtained by chassis dynamometer testing. The NOx emission value for the engine used in either the hybrid-electric drive system or baseline urban transit bus was provided by engine certification. In this example, an emission factor ratio of 0.53 is calculated. The certification value of 1.3 g/bhp-hr for the hybrid-electric drive system reflects a 47 percent emission reduction attributed to the hybrid electric drive system.

If a single party assumed sole responsibility of emissions for the HEB in the above example, the certification value on the Executive Order would be as low as 1.3 g/bhp-hr, where as the certification standard would be the optional standard of 1.5 g/bhp-hr. If two parties (i.e. the engine manufacturer and the HEB system manufacturer) assumed responsibility for emissions, two Executive Orders would be granted. The engine manufacturer would be responsible for the emissions from the engine that is incorporated into the hybrid-electric drive system, 2.5 g/bhp-hr. The Hybrid-electric Bus manufacturer would be responsible for the hybrid-electric system that reduces emissions to the optional emission standard of 1.5 g/bhp-hr.

### 3. Certification

Staff is proposing an approach for interim certification that provides manufacturers with flexibility in introducing this viable technology into California's market, while still providing staff with ample time to evaluate technology for proper enforcement. With new technology, the conventional approach would be to allow the technology to be demonstrated through experimental permit. Under that approach, however, once the permit expires the technology would be removed from operation until certified. Under staff's proposal, during the interim period dual party or a single party certification would be granted through the 2006 model year. This approach provides manufacturers with an extended window of opportunity to develop technology to meet the more stringent enforcement requirements of a fully certified engine.

Under dual party certification two Executive Orders would be granted. One Executive Order would be for the baseline engine/turbine/fuel cell that is used as a source of motive energy (auxiliary power unit). The Executive Order for the baseline engine/turbine/fuel cell must contain certification levels that meet California's most current emission standards for heavy-duty on-road or urban transit bus engines. For PM, the engines must be certified to meet the PM emission standards for urban bus engines. Exhaust emission standards would be tested following "California Exhaust Emissions Standards and Test Procedures for 1985 and subsequent Heavy-Duty Diesel Engines and Vehicles," or "California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Year heavy Duty Otto-Cycle Engines." Optional test procedures for the turbine or fuel cell would be used at the approval of ARB's Executive Officer.

The second Executive Order would be for the electric drive components listing overall emission standard for the hybrid-electric drive system. Overall emissions would be determined by multiplying the engine certification by an emission factor ratio determined for the hybrid electric drive components. The end result would be a certification value in units of g/bhp-hr. The HEB must meet California's most current emission standards for Urban Transit Buses following "California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric Vehicles, In the Urban Bus and Heavy-Duty Vehicle Classes."

Beginning with the 2007 model year, one party would be granted an Executive Order. The Executive Order must contain certification levels that meet California's most current emission or optional emission standards for urban transit bus engines. Exhaust emission standards would be tested following "California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric Vehicles, In the Urban Bus and Heavy-Duty Vehicle Classes."

On a case-by-case basis, a heavy-duty hybrid-electric vehicle may be certified with the approval of ARB's Executive Officer.

### 4. 25 Percent Reduction Claim

During the interim period, hybrid-electric drive system manufacturers have the option of claiming a 25 percent reduction from the certification standard of any on-road certified heavy-duty engine incorporated as part of the hybrid-electric drive system. During this period, ARB's Executive Officer also has the authority to chassis test any HEB that incorporates a hybrid-electric drive system selecting this option. If the resulting emission reduction is smaller, the entire HEB family incorporating the system in its platform would be required to claim the smaller percent emission reduction.

After the interim period, this option is not available. Hybrid-electric drive system manufacturers must follow the proposed "California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric Vehicles, In the Urban Bus and Heavy-Duty Vehicle Classes," for testing and emission standards certification.

### 5. Useful Life, Warranties, Testing, and Emissions Related Maintenance

In order to provide flexibility and allow HEBs to enter into the market place more quickly, staff is proposing that for the interim period (model years 2004 through 2006) the useful life of the hybrid electric drive system would be 5 years or 150,000 miles, which ever occurs first. After the interim period the useful life requirement would remain consistent with already adopted urban transit bus regulations, 10 years, 435,000 miles or 22,000 hours, which ever occurs first. The emissions defect and performance warranties would be five years,

100,000 miles, or 3,000 hours of operation, whichever occurs first. An alternative useful life would be acceptable as approved by ARB's Executive Officer.

For 2004 and subsequent model years the HEB and its engine (diesel or otto-cycle), turbine, or fuel cell, and the electric drive components, by model year, would meet the requirements as listed in title 13, CCR sections 2035 and 2036: "Defects Warranty Requirements for 1979 through 1989 Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles; 1979 and Subsequent Model Motorcycles and Heavy-Duty Vehicles; and Motor Vehicle Engines Used in Such Vehicles."

During the interim period, staff proposes durability and emission testing requirements for an HEB family similar to what is already approved for urban transit buses. While durability and emissions testing would remain the same, during the interim period testing would be conducted only when a certain quantity of HEBs are sold per HEB family. Staff proposes that HEB families with less than 50 HEBs sold for the 2004 through 2006 model years be exempt from durability-data vehicle and emission-data vehicle testing. An HEB family in California with 50 or more HEBs sold, and any HEB families (regardless of the quantity of HEBs sold) 2007 and later would meet the durability-data vehicle and emission-data vehicle testing as required in title 13, CCR, sections 2111, 2112, and Appendix A as adopted and last amended.

Staff proposes that emission related maintenance intervals for the HEBs emission related components would be the same as already approved for heavy-duty urban bus engines.

### 6. Labeling Requirements

The applicant shall label each hybrid-electric drive system with a permanent, non-destructible label or stamp identifying the manufacturer, the model number, the month and year of manufacture, and the Executive Order number issued by the ARB. Labeling must conform with title 13, CCR, section 1965. Specific details on labeling are listed in Appendix B, "California Test Procedures for 2004 and Subsequent Model Hybrid-Electric Vehicles, in the Urban Bus and Heavy-duty Vehicle Classes." The label or stamp shall be easily visible after installation of the system according to the applicant's written instructions for proper maintenance and use. Each applicant shall submit a sample of its label or stamp to the ARB for review and approval, prior to selling the hybrid-electric drive system. Staff will propose modifications to the current labeling requirements for all heavy-duty vehicles in a regulatory item next month. Those modifications may also apply to HEBs.

## 7. Engine Service Manuals

Staff proposes that the Board adopt the same manufacturer requirements for service manuals as already approved for urban transit buses. The manufacturers of HEBs would provide owners with manuals specifying maintenance needed to ensure proper hybrid-electric drive system operation. The manual would also identify maintenance that may be needed for emissions-related components after the end of the regulatory useful life of any components, including mileage/hour intervals, and procedures for determining whether maintenance or repair is needed. Manufacturers are not required to incorporate additional on-board systems beyond what they already have. However, the maintenance manual must include instructions for access and responding to any emissions-related diagnostic codes that may be stored in any existing on-board monitoring systems.

The recommended maintenance practices may be based on engineering analysis or other sound technical rationale. In the event that an emission-related component is designed not to need maintenance during the full life of the engine or electric drive system, the manual would need to contain, at a minimum, a description of the component, noting its purpose, and a statement that the component is expected to last the life of the engine and electric drive system without maintenance or repair. In addition, the manual would include the rebuild provisions described in item 9 below, to ensure that owners and rebuilders are aware of the requirements.

## 8. Equipment Maintenance Signals

According to Health and Safety Code section 43009 manufacturers must ensure that critical emissions-related scheduled maintenance has a reasonable likelihood of being performed in-use. Manufacturers may chose a form of on-board driver notification that would be triggered based either on mileage intervals or component failure. Staff proposes that regulatory requirements already approved for equipment maintenance signals used in heavy-duty vehicles also be set for HEBs. Specifically, manufacturers of 2004 and subsequent model-year hybrid-electric drive systems must use equipment maintenance signals designed to function at or beyond the end of the regulatory useful life of the HEB. Recall liability is limited to failures during the regulatory useful life.

## 9. Rebuild Provisions and Record Keeping Requirements

Section 27156 of the California Vehicle code prohibits tampering, when rebuilding engines or at any other times. Currently, for 2004 and subsequent model-year heavy-duty diesel and Otto-cycle engines no one may remove or render inoperative any device or element of design installed on or in a heavy-duty vehicle or engine in compliance with current regulations. Furthermore, a

remanufactured engine must be rebuilt equivalently from an emissions standpoint, to the original certified engines. Staff proposes the Board adopt rebuild requirements for HEBs and hybrid-electric drive systems incorporated into HEBs. The proposed rebuild requirements would be the same as those already approved for heavy-duty vehicles and engines and would apply to the hybrid-electric drive system at the time of rebuild.

Staff also proposes that the Board adopt record keeping requirements for HEB rebuilds that are consistent with those already adopted for heavy-duty vehicles and engines. These requirements include the following

- Mileage and/or hours at the time of hybrid-electric drive system rebuild;
- A list of the work performed on the hybrid-electric drive system (engine/turbine/fuel cell and electric drive components);
- Any repair of emission control systems, including a list of replacement parts used, hybrid-electric drive system parameter adjustments, and design element changers;
- Emissions-related codes and equipment monitoring signals that are responded to and reset; and
- Responses to such signals and codes, and work performed.

Staff proposes records be kept for two years after the hybrid-electric drive system is rebuilt. For single party responsibility, maintaining records for HEB families rather than specific engines is allowed. However, under dual party responsibility, records would be maintained for the engine/turbine/fuel cell family separate from those for the electric drive components.

**10. Information Requirements**

When applying for certification, the application except as noted below, must follow Part I (40 CFR §86.1843-01(c)):

- Identification and description of the vehicle(s) covered by the application.

- Identification of the heavy-duty vehicle weight category to which the vehicle is certifying: light heavy-duty, medium heavy-duty, heavy-heavy duty, urban transit bus, and the curb weight and gross vehicle weight rating of the vehicle.

- Identification and description of the propulsion system for the vehicle.

- Identification and description of the climate control system used on the vehicle.

- Projected number of vehicles produced and delivered for sale in California, and projected California sales.

- All information necessary for proper and safe operation of the vehicle, including information on the safe handling of the battery system, emergency procedures to follow in the event of battery leakage or other malfunctions that may affect the safety of the vehicle operator or laboratory personnel.

- Method for determining battery state-of-charge, and any other relevant information as determined by the Executive Officer.

# IV. TECHNOLOGICAL FEASIBILITY

There have been major advances in heavy-duty diesel engine technology over the last several years to meet current and future PM and NOx standards for heavy-duty and urban bus engines. Retrofit manufacturers continue to improve PM retrofit technology that could be used in urban transit buses to meet future PM standards. Part of the challenge in meeting current PM requirements for urban buses will be having retrofit technology available for older buses.

Hybrid-electric drive system manufacturers have developed innovative technology to provide urban transit agencies with another method for meeting the current and future standards. Although considered a viable solution, entering into the production stage in California is a challenge for HEB manufacturers.

Staff's proposal for PM retrofits and hybrid-electric buses was designed considering the progress of PM retrofits and the fairly young and rapid development of hybrid-electric drive technology. This chapter discusses the feasibility of staff's proposal for PM retrofits and HEB certification.

## A. PM Emission Reduction Technology

Transit agencies may use a variety of methods to reduce their diesel PM emissions to comply with the proposed diesel PM emission reduction requirement, including bus retirement, engine repower, purchase of new low-emission buses, and installation of a verified diesel emission control strategy. Transit agencies may retire older buses or repower engines certified to higher emissions levels and replace them with newer diesel, dual-fuel, bi-fuel, or diesel hybrid-electric buses certified to 0.01 g/bhp-hr, or with alternative fuel buses. Replacement of a diesel bus with an alternative fuel bus also reduces the total diesel PM emissions.

A transit agency may comply with this proposal by installing a diesel emission control strategy that has been verified by ARB's Executive Officer to reduce diesel PM. There are several different options verified at Level 3, which is a verified 85 percent or greater reduction, and one option verified at Level 1, which is a verified 25 percent or greater reduction. Staff expects that additional technologies at all Levels will be verified for urban bus engines as a result of this proposal. Removal of the requirement to use only 85 percent reduction technologies will open the market to more innovative technologies for urban buses. Thus, a transit agency can use a variety of technologies and strategies to comply with this proposal.

Staff has reviewed retrofit technology for diesel PM reduction in the September 2001 and March 2002 status reports for the transit bus fleet rule (ARB 2001, ARB 2002). Staff's review of these technologies is provided in Appendix D. Other possible strategies that have been discussed with staff include alternative diesel fuels, such as a fuel-water emulsion; fuel additives, used with or without a diesel particulate filter; a fuel delivery optimization mechanism; a diesel oxidation catalyst used alone or in combination with a diesel fuel-water emulsion; cam modifications; and catalytic coatings inside the cylinder.

Some of these strategies are newly developed, while others have been in use for years, especially in Europe or in other industries such as mining. Verification by ARB proves to the consumer and to the State that the diesel emission control strategy is effective and durable, and provides a standard warranty that provides the user with some protection. Thus, any technology that has been verified is both feasible and effective.

## B. Availability of Ultra Low Sulfur Diesel Fuel

Beginning July 1, 2002, public transit agencies were required to operate their diesel buses on diesel fuel with a sulfur content of 15 parts per million by weight. To ensure availability of ultra low sulfur diesel fuel, staff surveyed each transit agency to determine availability in and around their area for heavy-duty buses in their fleets. Eight of the transit agencies operate fleets of only alternative fuel urban buses and, therefore, were excluded from the survey.

The regulation allows a transit agency that has fewer than 20 buses and operates in a one-hour ozone attainment area to delay implementation of the ultra low sulfur fuel requirement to July 1, 2006. Nine transit agencies are located in a one-hour ozone attainment area and have fewer than 20 buses (Table 7), and can therefore delay implementation of the requirement. Of these nine, two transit agencies – Monterey-Salinas Transit and Santa Cruz Metropolitan Transit – began using the fuel by July 1, 2002:

**Table 7**

| Transit Agencies Eligible for Fuel Delay | | |
|---|---|---|
| **Transit Agency** | **Implement by 07/01/02** | **Delay to 07/01/06** |
| Arcata & Mad River Transit | | X |
| Eureka Transit Service | | X |
| Humboldt Transit Authority | | X |
| Mendocino Transit Authority | | X |
| Monterey - Salinas Transit | X | |
| Redding Area Bus Authority | | X |
| San Luis Obispo | | X |
| San Luis Obispo Regional Transit Authority | | X |
| Santa Cruz Metropolitan Transit District | X | |
| Siskiyou County STAGE | | X |
| South County Area Transit | | X |

The majority of the remaining 50 transit agencies have the fuel readily available to them with a cost differential ranging from $0.05 to $0.12 per gallon relative to regular diesel fuel. Approximately 62 percent of these transit agencies contract to purchase the ultra low sulfur diesel fuel and the remaining 38 percent purchase fuel weekly on the open commercial market.

Four transit agencies with fewer than 20 buses, but that operate in one-hour ozone non-attainment areas have requested relief from the rule because of cost impacts: Stanislaus Regional Transit in San Joaquin Valley Unified (4 buses), Santa Maria Area Transit in Santa Barbara County (7 buses), El Dorado County Transit Authority in the El Dorado County (12 buses), and Chico Transit in Butte County (10 buses). All of these very small transit agencies have discussed with staff their claims of financial hardship because they would have to install infrastructure (storage tanks) that would be used for only four years, or in the case of Stanislaus, only two years. Two of the transit agencies are in air districts that either have not been formally designated attainment (Butte) or have been redesignated (Santa Barbara). In each case, the transit agency is claiming that the local commercial facilities are unwilling to carry the ultra low sulfur diesel fuel because there is not enough demand in advance of the national standard deadline of July 1, 2006. In the absence of any delay in the rule, staff is unable to evaluate the claims of financial hardship by transit agencies.

Thus, although ultra low sulfur diesel fuel is available in most areas of the state, the high cost of installing infrastructure to bring in a fuel prior to its mandated availability throughout the nation may render this requirement financially infeasible for a small number of transit agencies. Section 1956.2 (g) is proposed for addition to the regulation to allow the Executive Officer to consider applications for delay based on financial hardship, which would allow staff to evaluate the claims by these transit agencies. Allowing these transit agencies to delay adopting ultra low sulfur fuel should have little or no effect on their ability to reduce diesel PM emissions as these transit agencies could meet the requirements by retiring buses or installing diesel emission reduction technology that does not require ultra low sulfur fuel. In addition, staff expects the availability of ultra low sulfur fuel to grow throughout the state. Already, ARCO stations that carry diesel fuel now carry ultra low sulfur diesel.

## C. HEBs and Interim Certification

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, typically lead acid (PbA) or nickel metal hydride (NiMH), can be charged by the engine/generator set and through regenerative braking. On site "plug-in" charging may also be used to recharge batteries in some cases.

HEBs have been developed within the last decade and have been commercialized in the last 5 years. Over this period, hybrid-electric drive systems for urban transit buses most commonly included series or parallel platforms. Hybrid-electric drive systems are designed in many different configurations, incorporating compressed natural gas, liquid natural gas, gasoline, or propane engines, as well as turbines and fuel cells into the overall HEB platform. HEB platforms are designed so that the system achieves maximum fuel economy and emission benefits. This is done by typically incorporating smaller, medium-heavy duty engines (Cummins ISB 5.9 liter, Detroit Diesel Series 30, etc.) into the hybrid-electric drive system assisted by the power generated from the batteries. In general a HEB can achieve top speed, range, and acceleration equal to or better than a conventional diesel bus.

Several demonstration projects with hybrid-electric buses are underway with promising results. Preliminary reports indicate that the higher efficiencies associated with hybrid-electric technology, compared to conventional diesel technology, can reduce fuel consumption by 25 percent, and reduce emissions of NOx by about 50 percent. In addition, an engine operating in a hybrid-electric vehicle generally operates in a limited operating range. Therefore, without the severe transient parameters that typically accompany urban bus operation,

exhaust aftertreatment could be designed far more efficiently. Significant emphasis is being placed on cost reductions for future hybrid-electric buses.

Hybrid-electric drive systems are rapidly changing to improve energy management -- storage, regeneration and fuel economy, which will translate to greater emission reductions. Part of the challenge in developing a certification procedure is designing a method that quantifies full emission benefits of the technology that are comparable with the various HEB platforms and are fully enforceable, while considering rapid modifications and improvements in the technology. Currently, manufacturers have one option for certifying an HEB – apply for certification to ARB on a case-by-case basis. Current procedures are engine-based and an HEB would be certified at a level that does not represent actual emission benefits of the HEB. Although recent ARB tests of HEBs being demonstrated in California indicate substantial emission reductions, these conclusions have been based on a few results and do not include all types of HEB platforms available for commercialization. Hence, staff believes it is appropriate to propose an interim certification procedure for three years. This would allow ARB to work closely with manufacturers to determine whether modifications or more appropriate requirements are warranted.

# V. ISSUES

Staff held three public workshops to discuss proposals for amending the Public Transit Bus Fleet Rule and one workshop with two stakeholders meetings to discuss the proposed interim certification procedures for HEBs. This chapter describes the issues that remain after consideration of public comments.

## A. Buses that Should be Included in the Total Diesel PM Emissions Calculation

The original regulation included a provision that exempted transit agencies from retrofitting buses within one year (alternative fuel path) or two years (diesel path) of retirement. This provision has been removed from the proposed amendments, because the total diesel PM emission reduction approach allows maximum flexibility in choosing how to comply. Some transit agencies have argued that buses within one year of retirement should not be included in the calculations of diesel PM. In addition, some transit agencies have argued that new buses, on order but not yet in operation, should be figured in the diesel PM calculation, instead of the old buses those will replace. Finally, others have argued that PM emissions from alternative fuel buses should be included in the calculations.

Staff has considered these requests and does not feel that they are necessary or wise. Allowing a transit agency to remove certain buses from its calculations of total diesel PM emissions, based on an anticipated bus retirement date, would be contrary to the goal of reducing diesel PM emissions from each transit agency's fleet, as the transit agency would be able to continue to operate certain buses, without counting them in its total diesel PM emissions, for up to one year. In addition, allowing a transit agency to include a bus that has not yet been received, but not count a bus that is being operated in anticipation that it will be replaced, would not make sense. Bus delivery schedules change, and thus a bus anticipated to be delivered by one date may not arrive for several months, and may not be fully operational for several more months.

Finally, alternative fuel buses do not emit diesel PM, thus it is not appropriate to include their PM emissions in the calculation of diesel PM emissions. Staff has considered including alternative fuel buses in the calculation of total diesel PM emissions with "zero" diesel PM emissions, to provide an additional incentive to transit agencies to purchase alternative fuel buses. This approach, however, could encourage transit agencies with alternative fuel buses to keep the oldest, highest emitting diesel buses in their fleets because those emissions would be offset by the "zero" emissions from alternative fuel buses. A regulation that allows transit agencies to offset high-emitting diesel buses with alternative fuel

buses would have the negative effect of allowing people who ride on those diesel buses to continue to be exposed to the health impacts of breathing higher levels of diesel PM. Staff is already providing a different implementation schedule for transit agencies on the alternative fuel path, thus retaining the incentive to those agencies provided in the original rule.

## B. Baseline Emission Year that Should be Used

Staff proposed that the baseline year, against which reductions are measured, be January 1, 2002. Staff chose this year because it was prior to the mandated retrofit date of January 1, 2003, for all Tier 1 and some Tier 2 buses. Staff requested comments from transit agencies if another year, such as January 1, 2001, would be better for calculating a baseline. Staff specifically requested that transit agencies "do the calculations" and tell us if one date would be more advantageous than another for their agency.

Staff received two comments that an earlier year, before January 1, 2002, might be a better date for determining a total PM emissions baseline for transit agencies. However, no analysis was provided to ARB to back up this assertion. Furthermore, no specific examples of any transit agency for which a different baseline year might be better were provided. Out of the eight comment letters received, no transit agency provided evidence that a more appropriate date was better for its agency or any other transit agency.

Staff, however, did analyze the impact of a baseline date of January 1, 2001, on the emissions benefits. Based on the analysis conducted, staff determined that there would be a small negative impact on the ultimate diesel PM reductions if we use this date as a baseline instead of January 1, 2002. Staff, therefore, concluded that the January 1, 2002, baseline date for total PM emissions is the most appropriate date, was acceptable to transit agencies, and provides a small additional benefit over the January 1, 2001 baseline.

## C. Request for Allowing Credit for Buses Rebuilt/Retrofitted Using a Certified Kit Under the U.S. EPA Mandated Program

In a related comment, some transit agencies requested that ARB allow credit for bus engines that have had their PM reduced through installation of a rebuild/retrofit kit, perhaps by removing these buses from the total diesel PM calculation. These kits were mandated by the U. S. EPA urban bus retrofit/rebuild program, which in California applies to 1990[4] and earlier model-

[4] The U.S. EPA requires retrofit kits for 1994 and earlier model year urban bus engines whose engines are rebuilt or replaced after January 1, 1995.

year urban bus engines. In California urban bus engines are required to meet a 0.10 g/hb-hr standard in 1991, two years earlier than the federally-adopted 0.10 g/bhp-hr standard went into effect. Many transit agencies have already complied with this program by installing retrofit/rebuild kits on their bus engines. The original regulation included a provision that such a bus, which had its PM emissions reduced to 0.10 g/bhp-hr from 0.60 g/bhp-hr, did not need to be further retrofitted.

Staff does not believe it is wise to allow what would be retroactive credit for these buses for several reasons. First, the U. S. EPA rule applies in California to 1993 and earlier model-year bus engines. Over the life of this program, from 2004 through 2009, these buses will reach the end of their useful lifetimes and should be removed from transit bus fleets or the engines should be repowered. The second reason pertains to which baseline year and buses should be included in the calculations. Since the goal is to reduce diesel PM from transit bus fleets, staff believes that these buses should remain in the calculation of diesel PM emissions. Furthermore, if necessary to achieve the overall program goals, transit agencies may have to retire the buses or repower the engines to reduce the overall total diesel PM emissions from their fleets.

## D. Allow All Transit Agencies the Option of Switching to the Alternative Fuel Path

Several comments requested that all transit agencies be given the option of changing fuel paths. The option should remain the same as currently required. Staff has examined all available options (including the option in the proposed amendments), and concluded that providing only the SCAQMD with the option of changing from the diesel fuel path to the alternative fuel path would have the least negative impact on the anticipated benefits of the current regulation.

The current regulation has a schedule that requires the purchase and demonstration of ZEBs in transit fleets depending on the fuel path selected. Allowing all transit agencies the option of changing to the alternative fuel path could have the negative effect of slowing the ZEB demonstration by reducing the number of transit agencies required to participate and delaying purchase requirements. Providing the six transit agencies in the SCQMD the option to switch to the alternative fuel path would have no effect on the ZEB demonstration and purchase provisions, with little effect on the reduction of diesel PM emissions.

Furthermore, transit agencies in the SCAQMD requested that they be allowed to change their fuel path because of the timing of adoption of SCAQMD Rule 1192 and ARB's Public Transit Bus Fleet Rule. Rule 1192 was adopted June 16, 2000, six months before transit agencies had to choose their fuel path under ARB's Public Transit Bus Fleet Rule. Thus, some of those transit agencies

believe there was insufficient time to consider the dual impacts of Rule 1192 and ARB's rule. In addition, the six SCAQMD transit agencies that chose the diesel path and are subject to Rule 1192 have been required to purchase alternative fuel buses – Long Beach Transit since June 16, 2000, and the other five transit agencies since July 1, 2001. Thus, these transit agencies are already making current and future purchase decisions in line with the alternative fuel path requirements.

## E. Proposed Useful Life, Durability, and Emissions Warranty Are Too Stringent to Allow the HEB Technology Into the Market Place

The conventional approach for certification would be to require manufacturers to certify with full useful life, durability and emission warranty requirements. Staff worked closely with manufacturers and determined that a different approach was necessary in order to introduce this viable technology into California's market.

Staff understands that reliability is critical to transit agencies and that market flexibility is critical to manufacturers. As such, staff's proposal is designed to provide manufacturers with flexibility, while providing urban transit agencies with reliability. In the first 3 years (the interim period), staff's proposal allows manufacturers to meet a shorter useful life (when compared to conventional useful life requirements for an urban bus): 150,000 miles or 5 years. Recognizing that HEBs are new, limited in quantity, and have not been in operation long enough to determine durability, staff's proposal allows manufacturers with less than 50 HEBs sold in California during the interim period to be exempt from durability requirements. After the interim period, manufacturers are expected to meet the full certification requirements already adopted for urban bus engines.

## F. HEBs Should Be Verified Following Retrofit Procedures

One manufacturer requested that ARB allow HEBs to be certified following the Regulation for the Verification Procedure for In-Use Strategies to Control Emissions from Diesel Engines approved by the Board May 16, 2002. The, verification procedures were designed with the intent to certify both PM and NOx retrofit devices. While the hybrid-electric drive system may be both a PM and a NOx reduction device, issues associated with hybrid systems can be significantly different than those related with aftermarket retrofits, such as DPFs. The current verification procedures may not be the appropriate avenue for verifying emissions from HEBs. Staff, is willing to work with manufacturers to determine a more appropriate method, outside of this proposal and within the context of another protocol.

## G. Chassis Testing May Be too Costly for Measuring Exhaust Emission Standards from HEBs

Since typically, heavy-duty and urban bus engines are certified following an engine dynamometer test procedure resulting in engine-based standards (measured in g/bhp-hr), and have not been correlated to chassis dynamometer tests, some manufacturers believe that it may be too costly to follow chassis-based test procedures. Although chassis test results have not been correlated to engine-based test standards, HEBs incorporate a technology by which actual emission benefits could not be measured following engine-based procedures.

Several options are available to manufacturers, however. Currently, manufacturers have the option of certifying HEBs following already adopted engine-based procedure, as long as the engine is certified to meet the urban transit bus regulations. Furthermore, a technology that may not fall in the category of an engine, i.e. a fuel cell or a turbine, may also certify to the urban bus standards on a case-by-case basis, as approved by ARB's Executive Officer. While less costly, testing the engine used in an HEB solely following an engine-based test procedure would result in values that may not account for full emission benefits provided by the hybrid-electric drive system. An engine certification may not account for the power provided by the electric drive components, which offsets some of the load on the engine, thus reducing emissions. Recognizing the emission reduction potential of hybrid-electric drive system technology, ARB has provided manufacturers with the option of claiming a 25 percent emission reduction from the engine certification standard for a certified engine used in the HEB. To provide manufacturers with additional flexibility, staff has proposed to extend the 25 percent reduction claim through the interim period (3 years). This would relieve some of the costs associated with conducting a chassis-based test during the interim.

It has been a challenge to design a chassis-based test procedure that could be correlated to engine-based certification standards, considering the costs. Staff worked closely with manufacturers to develop a protocol that would balance economics, yet best represent actual benefits of the technology. One manufacturer recommended the use of an emission factor ratio in conjunction with the engine certification and chassis test results as a method for determining actual emissions. Recognizing the lack of data available to correlate chassis-based emission results with engine-based emission standards for HEBs, and the rapid change in technology, staff's proposal incorporates the manufacturer's recommendation with the goal of achieving enough data to develop a correlation. These data are necessary for staff to make a determination on the appropriateness of the certification procedure and the need for future modifications. It is important to recognize that this proposal is considered voluntary, since manufacturers currently have other options available to certify the technology on a case-by-case basis.

# VI. REGULATORY ALTERNATIVES

## A. Change PM Retrofit Schedule

Staff initially considered modifying the existing PM retrofit schedule to match its best predictions on when technology would be available for the older, pre-1994, engines. At this time, no PM retrofit device that reduces diesel PM by 85 percent or more is available and verified for engines older than 1994 or for any two-stroke engines. In addition, no technology is verified at any level, although that may change, for engines older than 1994. Staff rejected this alternative because it does not address the problem of reducing emissions from the oldest, dirtiest engines, and it relies completely on retrofit technology. This alternative would not be as effective, therefore, as the proposal.

## B. Declining PM Fleet Average

Staff also considered and rejected a declining PM fleet average based on setting a PM fleet average that every transit agency must meet or a percentage reduction from baseline. This alternative was rejected because neither approach obtained as much reductions in diesel PM as the preferred alternative.

For example, setting the first maximum fleet average of 0.2 g/bhp-hr to be met in 2004 would require only 10 transit agencies to reduce their PM fleet average, some of which currently have a PM fleet average of 0.6 g/bhp-hr or more. Since those fleets with a fleet average of 0.6 g/bhp-hr or more are made up of the oldest engines, the only option available to the transit agency would be purchase of new engines or complete buses. Thus, the ten dirtiest transit agencies would have to reduce their diesel PM but no other transit agency would have to take any action, and the cost of reducing emissions, using the methods open to those transit agencies, would be very high.

Setting a maximum fleet average of 0.1 g/bhp-hr to be met, for example in 2006 (with a declining PM fleet average over time), would require an additional 13 transit agencies to take action. Again, the options open to these transit agencies would be limited to replacement of the oldest engines with new engines, a very costly proposal.

Thus, the effect of this type of a declining PM fleet average is that a transit agency that already has relatively low average PM emissions would not have to take any action for several years. Following the same schedule, the next cut-point would be set at 0.05 g/bhp-hr, which would require 24 transit agencies to reduce emissions. Within this group, large numbers of engines can be retrofitted

with verified diesel particulate filters, allowing these transit agencies to utilize verified diesel emission control technologies.

Another approach, the declining PM fleet average based on percentage reductions, was rejected because some transit agencies would be unable to comply with the intermediate compliance deadlines. These transit agencies made the decision to purchase alternative fuel buses some years ago but maintain a small number (relative to the size of the fleet) of older diesel buses. Because most or all of these buses are in the same age class, the diesel PM fleet average does not change until all of the buses are gone from the fleet. Therefore, to meet even the first requirement would mean the transit agency would have to retire and replace every one of these buses. This approach is therefore infeasible.

In conclusion, staff did not select this approach because it would be very costly for many transit agencies. It would also allow most transit agencies to delay action for many years, placing the burden of reducing emissions mainly on the smaller transit agencies with the oldest engines. Finally, communities and individuals would be impacted unequally.

### C. Interim Certification for HEBs Following Chassis Test Procedure Without Emission Factor Ratio

Staff considered allowing interim certification for HEBs following a chassis-based test procedure, without using the proposed emission factor ratio. Following this approach would yield test results in grams/mile. Currently emission standards for urban transit buses are engine-based standards and measured in units of g/bhp-hr. With emission standards changing and technology evolving rapidly, insufficient data is available that accurately correlates engine-based standards with chassis-based test results.

To provide leniency, staff has provided manufacturers with an option of claiming a 25 percent reduction in lieu of testing during a 3-year interim period. In order to allow manufacturers to claim a larger emission reduction, however, ARB must validate emissions to ensure emission benefits are real and enforceable. Hence, staff selected an approach that incorporates an emission factor ratio. The emission factor ratio is designed to use both an engine dynamometer test and a chassis dynamometer test. The engine factor ratio correlates the overall chassis dynamometer results to certification levels in units of g/bhp-hr (engine certification result). Staff believes that the proposed interim certification procedure would provide data to correlate both types of emissions tests. Furthermore, in the interim the procedure would allow staff to gather more data to determine whether the correlation is appropriate or modification is necessary.

## D. Continue Allowing 25 Percent Emission Reduction Claim Without Interim Certification

Staff also considered allowing manufacturers to claim the 25 percent reduction, as granted by the Executive Officer, instead of interim certification. While this approach would cost less, and seems simple compared with staff's proposal, it would not account for the true benefit of the HEB. Preliminary test data indicates that many HEBs could reduce NOx emissions from diesel engines by about 50 percent.

Secondly, HEBs typically incorporate medium-duty diesel engines as part of the hybrid-electric drive system. These engines are not certified to the urban transit bus standard. Allowing a 25 percent emission reduction would not be enough for HEBs to meet future more stringent standards. Although a 25 percent emission reduction claim in the interim may be sufficient to encourage sale of HEBs, in the long term enforceability would be a challenge. Solely allowing a percent emission reduction claim does not include durability, useful life, in-use testing, and warranty requirements as those typically written into an interim certification procedure.

# VII. ECONOMIC IMPACTS

The proposed amendments to the Public Transit Fleet Rule and Emission Standards For New Urban Buses regulation will provide transit agencies with greater flexibility to comply with the required emission standards. Staff believes that the proposed amendments would cause no noticeable adverse impacts in California employment, business status, competitiveness or increase costs above those estimated for the Public Transit Bus Fleet Rule and Emission Standards for Urban Buses regulations adopted February 2000.

## A. Legal Requirement

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

State agencies are also required to estimate the cost or savings to any state or local agency and school district in accordance with instructions adopted by the Department of Finance. This estimate is to include 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 results of the proposed regulatory amendments include manufacturers of heavy-duty diesel or alternative fuel bus engines, urban buses, hybrid-electric buses, micro turbines, fuel cells, electric drives, engine retrofit kits, and exhaust aftertreatment devices. Most manufacturers of urban bus engines, hybrid-electric urban transit buses, and aftertreatment devices are located outside of California. There are only three hybrid-electric bus manufacturers and one urban bus manufacturer located in California.

## C. Potential Impact on Businesses

The proposed amendments include a modification to allow some transit agencies to change from the "diesel" path to the "alternative fuel" path, establish a new PM

emission reduction requirement, and include an interim certification procedure for hybrid-electric urban transit buses. Since the proposed amendments provide transit agencies with greater flexibility to comply with the required emission standards they are not expected to impose costs above those already estimated for the Public Transit Bus Fleet Rule and Emission Standards for Urban Buses regulations approved February 2000. The proposed amendments could provide cost savings in some cases. (The February 2000 estimated cost per bus ranged from $3,000 to $10,000.) Most impacts to business, both positive and negative, will likely occur in other states.

Testing of hybrid-electric buses could increase the cost of purchasing a hybrid-electric bus. Manufacturer costs for testing a family of hybrid-electric buses, according to the proposed interim procedure, would range from $70,000 to $120,000 per certification. However, the proposed interim certification procedure would provide manufacturers with a method for demonstrating the full emission benefits achieved by using a hybrid-electric drive system. Manufacturers could opt to certify their hybrid system using current engine-based certification procedures, depending on approval on a case-by-case basis by ARB's Executive Officer.

Since it is not certain how many hybrid-electric buses will be purchased the proportional increased cost of a hybrid bus cannot be determined. A transit agency does not typically cover the total cost of purchasing a new bus. Federal funds are available to cover 80 percent of the total cost of a new diesel urban bus and 83 percent of a new low emission alternative fuel bus. The remaining cost would have to be covered by other funding sources such as state or local incentive programs, transportation planning agencies, transit agencies, and air quality and energy funds. Since transit agencies can make the choice among emission control options, based on their individual transportation planning and operational needs, the increased cost of purchasing a hybrid bus is not considered a significant cost impact.

## D. Potential Impact on Business Competitiveness

The proposed amendments are not expected to impact the ability of California businesses to compete with businesses in other states. As indicated above, most businesses that produce products needed to meet the proposed amendments are located in other states. By providing additional options to transit agencies, this proposal may actually provide new opportunities for California business engaged in manufacturing HEBs, hybrid-electric drive systems and respective components, and exhaust aftertreatment devices.

## E. Potential Impact on Employment

Manufacturers of HEBs, hybrid-electric drive systems and respective components, and exhaust after treatment devices located in California may increase their production and thus result in the creation of new jobs.

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

The proposed amendments could impact any companies involved in the manufacture and production of heavy-duty alternative fuel urban bus engines, urban buses, HEBs, fuel cells, micro turbines, hybrid-electric drive systems and respective components, and exhaust aftertreatment devices that sell in California. Most manufacturers that could benefit from the potential increase in business created by requiring cleaner engines and buses are located outside of California. There are only three HEB manufacturers and one urban bus manufacturer located in California. To the extent that those business choose to locate in California, or in state business increase production, the amendments could lead to the creation or expansion of businesses in California.

## G. Potential Cost to Local and State Agencies

The proposed amendments are not expected to impose additional fiscal impacts on transportation planning agencies, commissions, transit agencies, or the ARB, above those estimated for the implementation or enforcement of the February 2000, Public Transit Bus Fleet Rule and Emission Standards for Urban Buses regulations.

# VIII. ENVIRONMENTAL IMPACTS, ENVIRONMENTAL JUSTICE, AND COST-EFFECTIVENESS

This chapter presents the air quality benefits and cost-effectiveness resulting from the implementation of the proposed amendments to the Public Transit Bus Fleet Rule and the interim-certification procedures – "California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Hybrid-Electric Vehicles, in the Urban Bus and Heavy-duty Vehicle Classes." Adoption of the proposed amendments would continue to provide PM emission reductions close to those anticipated in the original rule, while providing additional flexibility in meeting the requirements. There are no direct air quality benefits resulting from approval of the proposed interim-certification procedure for HEBs. Instead there is a benefit to transit agencies that another control option would be available to comply or potentially go beyond the already approved urban transit bus standards.

## A. Air Quality Benefits

### 1. PM Emission Reduction Proposal

The proposed modifications provide close to the same air quality benefits as anticipated in the original regulation adopted in February 2000. The amendments will reduce the public's exposure to toxic diesel particulate emissions and benefit California's environment. Since February 2000, staff has gained more information about California's transit bus fleet, and ARB's mobile source inventory and modeling capabilities have been further refined. The air quality benefits presented here have been modeled based on the January 31, 2001 and 2002 reports from transit agencies regarding composition of their fleets and the updated mobile source inventory, EMFAC 2001, which has been adopted by the Board.

The original transit bus rule was written to achieve maximum PM and NOx emissions benefits with available technology, while minimizing the economic impact on affected businesses and transit agencies. The proposed amendments were written to maintain that same goal. Each transit agency has the flexibility under the proposed amendments to reduce their total diesel PM emissions by retrofitting, retiring, or replacing the bus engines. Staff assumes that transit agencies will retrofit newer engines, retire older buses, and repower older buses with new engines under this proposal.

In the original rule, retrofit devices that reduce diesel PM by 85 percent or more were to be installed on engines beginning in 2002. By January 1, 2003, all pre-

1991 MY engines (Tier 1) were to be retrofitted. Tier 2 engines, comprising 1991 to 1995 MYs, were to be retrofitted in phases (Chapter II, Table 4), with the first phase implemented as of January 1, 2003. The rule allowed for a one year delay in retrofitting if no technology was available within six months of the applicable compliance dates.

When no technology achieving an 85 percent PM reduction was verified by ARB staff by January 1, 2002 for any pre-1994 MY or two-stroke engine, staff concluded that the benefits of the rule would be less than expected. Staff evaluated the status of the technology and, at the March 21, 2002 meeting of the Board, staff reported that it did not expect to see any 85 percent diesel PM reduction technology verified for these older engines in 2002, and possibly not in the near future. The Board directed staff to revise the rule to recapture the diesel PM reductions that were not going to be achieved because of the lack of verified PM reduction technology for older bus engines.

The proposed amendments achieve slightly more emissions reductions after 2005, compared to the original regulations. Prior to 2005, the benefits will be less than the original regulation. Two factors account for the smaller emission reductions prior to 2005: the lack of technology to retrofit older engines now, and the need to provide transit agencies additional time to obtain funding to replace older engines.

The proposed amendments seek to balance the need to reduce diesel PM emissions as much as technologically feasible with the need for flexibility in achieving those reductions. A mandatory progressive reduction in total diesel PM emissions will require transit agencies to use a variety of approaches to strike a balance between retiring the oldest buses, repowering buses that have remaining useful life, and retrofitting the newer buses (1994 MY and newer engines) for which there are verified diesel emission reduction devices. Although the minimum useful life for a transit bus is twelve years, transit agencies report that many of the oldest buses are kept much longer. Providing for a flexible implementation schedule will allow transit agencies the time necessary to replace these older buses, or repower them.

The ARB staff estimates that the proposed amendments will reduce PM emissions statewide in 2010 by approximately 180 lbs/day (33.4 tons per year). Staff recalculated the baseline emissions from transit buses using an improved model and better data. New information received from transit agencies in 2001 and 2002 showed that the transit bus population was significantly lower than assumed for the original staff report. In addition, emission factors and annual mileage have changed, based on research into emissions and reports from transit agencies. Finally, EMFAC 2001 has been approved thus staff took this opportunity to recalculate an improved baseline inventory on which to base the analysis for these proposed amendments (see Appendix E).

With no PM retrofit and only emission reductions from new transit bus engine standards, the total statewide PM emissions would be 300 lbs/day in 2005 and 239 lbs/day in 2010 (Baseline, Figure 4, Table 8). With full implementation of the original rule, the statewide PM emissions would drop to 125 lbs/day in 2005 and 68 lb/day in 2010 (Current, Figure 4). With the proposed amendments, PM emissions are 15 lbs/day higher in 2005 than was expected with the current rule, and 12 lbs/day lower by 2010 (Proposed, Figure 4). In devising the scenario for this comparison, staff assumed a ten percent allowance for delays and exemptions from rule implementation.

**Figure 4: Comparison of PM Emissions Scenarios**

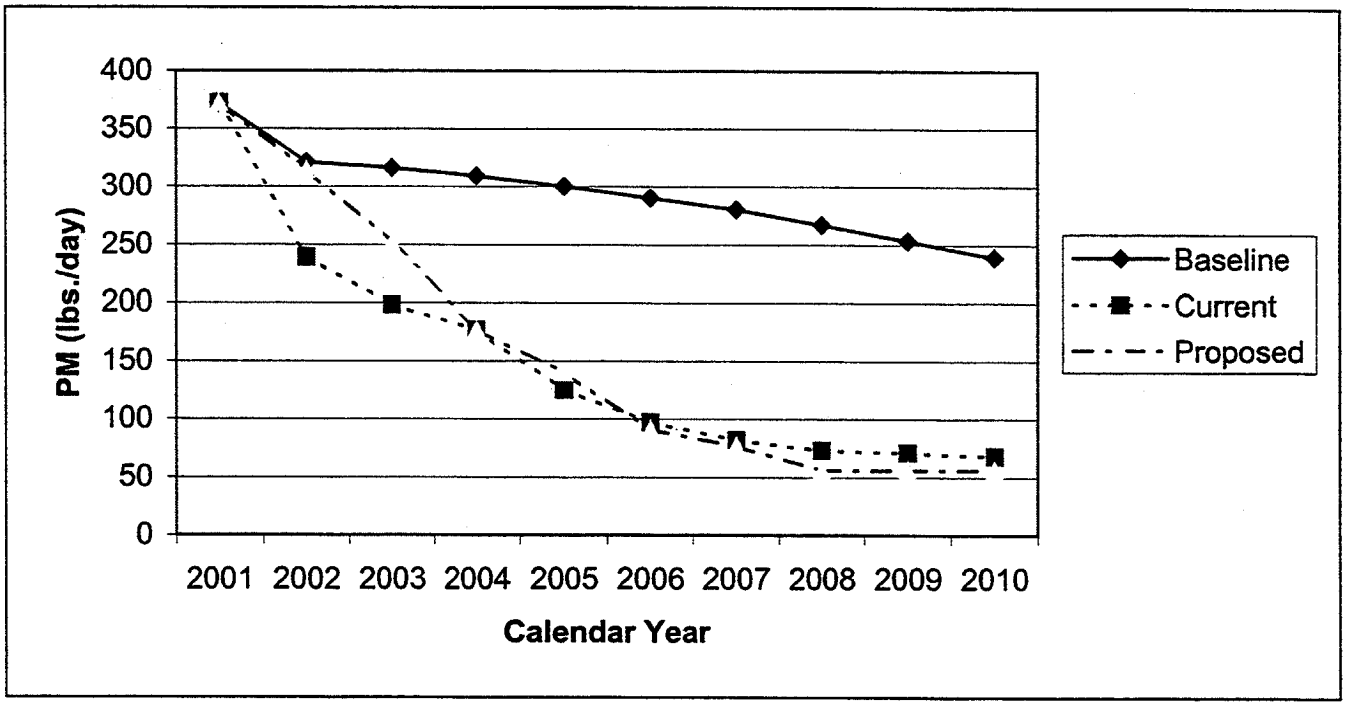



**Table 8**

| Statewide Transit Bus PM Inventory Scenarios (pounds per day) | | | |
|---|---|---|---|
| **Calendar Year** | **Baseline Inventory, No Retrofit** | **Current Regulation, Fully Implemented** | **Proposed Amendment** |
| 2005 | 300 | 125 | 140 |
| 2010 | 239 | 68 | 56 |

The original rule included further emission reductions through the demonstration and implementation of zero-emission bus programs beginning in 2003. Combining the zero-emission bus requirement with more stringent NOx and PM emission standards over the next several years, the original transit bus fleet rule was expected to ensure a long-term solution to continued reduction in toxic air contaminants. The proposed modifications will not change the long-term requirements of the original rule or the benefits from the zero-emission bus program. The zero-emission bus requirements will remain the same as adopted in 2000.

### 2. HEB Interim Certification Procedure

HEBs are one technology that is available for transit agencies to purchase to comply with the Public Transit Bus Fleet Rule. The procedure that certifies HEBs does not itself produce emission benefits. Instead, certification is the method for determining compliance with emission standards. Hence, no air quality benefits have been calculated or considered to be associated with approval of staff's proposed interim certification procedure for HEBs.

## B. Environmental Justice

The proposed amendments provide urban transit agencies with greater flexibility to meet current regulations and were designed to achieve PM emission reductions similar to those anticipated in the February 2000 rulemaking. The proposed amendments regulate all transit agencies throughout the state to ensure that emission benefits are achieved for all Californians. In addition, urban transit buses transport people every day to destinations in various communities throughout California; hence, environmental impacts resulting from the proposed amendments would affect all communities where urban transit buses travel.

## C. Cost-Effectiveness

### 1. PM Emission Reduction Proposal

The goal of the proposed amendments is to achieve benefits that are as close as possible to those anticipated in the February 2000 rulemaking. The estimated costs to transportation planning agencies, commissions, and transit agencies would be about $2.5 million per year to comply with the requirements in the February 2000 rulemaking. Total estimated costs per bus ranges from about $3,000 to $10,000 dollars. Furthermore, the cost-effectiveness for the PM retrofit requirements average about $17.90 per pound of PM reduced annually from 2003 to 2009.

Staff has determined that while costs per bus would remain within the same range for implementation of the proposed amendments, the cost per pound of PM reduced (cost-effectiveness) may increase. The cost-effectiveness each year from 2003 to 2009, based on the median cost option (Appendix F), would range from $13.67 to 32.77 per pound of PM reduced, with an average cost-effectiveness of $25.23 per pound (Table 9). Staff also calculated a low cost scenario, which resulted in an average cost-effectiveness of $10.91 per pound, and a high cost scenario, which resulted in an average cost-effectiveness of $44.51 per pound of PM reduced.

**Table 9**

| Average Cost-Effectiveness 2003 - 2009 | | | |
|---|---|---|---|
| | **Low Cost** | **Median Cost** | **High Cost** |
| Cost per Pound | $10.91 | $25.23 | $44.51 |

The original cost-effectiveness of $17.90 per pound is within the range of the recalculated cost-effectiveness range for these amendments. The slightly higher estimated cost-effectiveness for these amendments is caused by a combination of revised assumptions regarding emission benefits and costs (for example the lifetime of the DPF, the number of buses that would be retrofitted each year, and the cost of maintenance of the DPF). In determining the revised cost-effectiveness, staff used the updated EMFAC 2001 model and the updated transit bus inventory, which are based on reports from transit agencies.

Staff assumed that the current cost of a DPF is $5,500 and the future cost could be as low as $1,100. A median cost of $3,000 was used as an average of current and future costs to calculate the median average cost-effectiveness over the life of the rule. Staff also assumed that only model year 1994 through 2002 engines would be retrofitted, as these are the only engines from which verified technology is available. Staff has determined that it is unlikely that a DPF would be available for older buses. While older buses could be retrofitted with oxidation catalysts, most older transit buses have already been retrofitted under the U.S. EPA Urban Bus Retrofit/Rebuild Program. Those that have not yet been retrofitted with an oxidation catalyst represent a small portion of the urban buses. Newer buses would also not be retrofitted. Bus engines produced after October 1, 2002, are required to meet an engine standard for PM of 0.01 g/bhp-hr which requires use of a particulate filter.

Transit agencies may also retire their oldest buses, and replace engines in buses with remaining useful life with newer engines (repower). An engine repower may also extend the useful life of a bus if additional improvements are made at the

same time as the engine repower. Staff did not count the cost of bus retirement in this cost-effectiveness calculation as staff anticipates that those buses retired will have already exceeded their useful Federal minimum lifetime. Transit agencies have access to Federal funds for 80 to 83 percent of the cost of new buses, with State and local funding making up the balance of the cost. Likewise, a repower can qualify for Federal, State, and local funds, with 50 to 100 percent of the cost being covered (Appendix F, Table 1). In either bus retirement or engine repower the transit agency realizes significant savings in fuel economy and maintenance. Over the life of the engine, these savings often pay for the portion of the cost that is not covered by Federal funding. Consequently, staff did not include the cost of bus retirement or engine repower in calculating cost-effectiveness.

As with the original regulation, the cost-effectiveness of the proposed modifications does not include the value of health benefits associated with a reduction in exposure to a toxic air contaminant. While assessing the health benefits of PM control continues to be an important part of the ARB's risk management process, the benefits of the proposed transit rule modifications are not part of this cost-effectiveness determination.

### 2. HEB Interim Certification Procedure

When staff proposes rules that set new technology enforcing standards, costs associated with compliance of the standards are typically calculated. In February 2000, when staff proposed the rules setting future more stringent standards for urban transit buses and the fleet rule for public transit agencies, HEBs were considered a future control technology available for transit agencies to achieve the standards. However, no certification procedures were available to certify HEBs at the time the rule was approved.

The proposed interim certification for HEBs is voluntary. Staff's proposal provides manufacturers with an approach for certifying full emission benefits of HEBs. Furthermore, certified HEBs provide transit agencies with another control option for complying with the already approved Public Transit Bus Fleet Rule. Because the interim certification procedure is not setting new emission standards and thus no direct emissions benefits are associated with the proposal, no traditional cost-effectiveness can be calculated. Since staff's proposal for certifying HEBs is considered voluntary, there will be no economic impacts associated with reasonable compliance with interim certification of HEBs.

# IX. SUMMARY AND STAFF RECOMMENDATION

## A. Summary of Staff's Proposal

As presented in the previous chapters, ARB staff's proposed modifications to the Public Transit Fleet Rule are designed to reduce PM emissions to a level as close as possible as those anticipated from the already approved February 2000 Public Transit Fleet Rule. Furthermore, they are designed to provide transit agencies with additional flexibility in meeting PM retrofit requirements by allowing transit districts to achieve a PM emission reduction from its January 1, 2002, total PM emission baseline. The proposed amendments allow transit agencies in the South Coast the opportunity to switch from the diesel path to the alternative fuel path. Lastly, the proposed modifications introduce new definitions for clarification of already adopted fleet rule, and an interim certification procedure for HEBs.

## B. Staff Recommendation

The ARB staff recommends that the Board adopt modifications to 1956.1, 1956.2, 1956.4, 1956.8, and 2112, title 13, California Code of Regulations, and the new incorporated "California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric Vehicles, in the Urban and Heavy-duty Vehicle Classes." The modifications to the regulations are set forth in the proposed regulation Order in Appendix A. The proposed incorporated test procedures for HEBs are set forth in Appendix B.

# X. REFERENCES

ARB 1999. Proposed regulation for a public transit bus fleet rule and emission standards for new urban buses. Staff Report: Initial Statement of Reasons. December 10, 1999.

ARB 2000. Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles. Final. October 2000.

ARB 2001. The public transit bus fleet rule status report. September 20, 2001.

ARB 2002. Status report: public transit bus fleet rule. March 2002.

Federal Transit Administration. 2001. National Transit Database: Glossary of transit terminology as defined for NTD reporting – 2001. (Internet 11/19/2001).

SAE. J2711, Recommended Practice for Measuring Fuel Economy And Emissions Of Hybrid-Electric And Conventional Heavy-Duty Vehicles, April 2002.

# APPENDIX A

## PROPOSED REGULATION ORDER

# FINAL REGULATION ORDER

Amend the following sections of title 13, California Code of Regulations, to read as set forth on the following pages:

| | |
|---|---|
| Section 1956.1 | Exhaust Emission Standards and Test Procedures – 1985 and Subsequent Model Heavy Duty Urban Bus Engines and Vehicles. |
| Section 1956.2 | Fleet Rule for Transit Agencies |
| Section 1956.4 | Reporting Requirements for all Urban Bus Transit Agencies |
| Section 1956.8 | Exhaust Emission Standards and Test Procedures for 1985 and Subsequent Model Year Heavy-Duty Engines and Vehicles |
| Sections 2112 | Procedures for In-Use Vehicle Voluntary and Influenced Recalls, Definitions |

Notes:

a) Paragraphs within these sections that are not proposed for amendment in this rulemaking are indicated by "[No Change]".

b) The proposed regulatory amendments are shown in <u>underline</u> to indicate additions to the text and ~~strikeout~~ to indicate deletions.

c) [ ] in the proposed sections indicates text that can be finalized only upon Board adoption.

**Amend section 1956.1 to read as follows:**

1956.1 Exhaust Emission Standards and Test Procedures - 1985 and Subsequent Model Heavy Duty Urban Bus Engines and Vehicles

(a) [No Change]

(1) [No Change]

(2) [No Change

(3) [No Change]

(4) [No Change]

(5) [No Change]

(6) [No Change]

(7) [No Change]

(8) [No Change]

(9) [No Change]

(10) [No Change]

(11) [No Change]

(12) [No Change]

(b) The test procedures for determining compliance with standards applicable to 1985 and subsequent heavy-duty diesel cycle urban bus engines and vehicles and the requirements for participation in the averaging, banking and trading programs, are set forth in the "California Exhaust Emission Standards and Test Procedures for 1985 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles," adopted April 8, 1985, as last amended November 22, 2000, and the "California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric Vehicles, in the Urban Bus and Heavy-Duty Vehicle Classes", adopted [insert adopted date],which ~~is~~ are incorporated by reference herein.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43100, 43101, 43104, and 43806 Health and Safety Code and section 28114 Vehicle Code

Reference: Sections 39002, 39003, 39017, 39033, 39500, 39650, 39657, 39667, 39701, 40000, 43000, 43000.5, 43009, 43013, 43018, 43102, 43806, Health and Safety Code, and section 28114 Vehicle Code.

**Amend section 1956.2 to read as follows:**

1956.2 Fleet Rule for Transit Agencies

(a) To encourage transit agencies that operate urban bus fleets to purchase or lease lower emission alternative-fuel buses, while also providing flexibility to such fleet operators to determine their optimal fleet mix in consideration of such factors as air quality benefits, service availability, cost, efficiency, safety, and convenience, two paths to compliance with this fleet rule are available: the alternative-fuel path and the diesel path.

(1) Transit agencies must choose their compliance path, and shall notify ARB of their intent to follow either the diesel or the alternative-fuel path, by January 31, 2001. Reporting requirements for that notification are set forth in subdivisions (a) and (b) of section 1956.4, Title 13, CCR.

(2) A transit agency within the jurisdiction of the South Coast Air Quality Management District may elect to change its compliance path from the diesel path to the alternative-fuel path, provided that the transit agency notifies the Executive Officer of the change by January 31, 2004, and provided that the transit agency is in compliance with all requirements of this rule, including specific requirements of the diesel path, on or before January 1, 2004. Reporting requirements for this notification are set forth in paragraph (b)(3) of section 1956.4, title 13, CCR.

(b) For ~~the~~ purposes of the fleet rule specified in this section, the following definitions apply:

(1) "Alternative fuel" means natural gas, propane, ethanol, methanol, electricity, fuel cells, or advanced technologies that do not rely on diesel fuel except as a pilot ignition source at an average ratio of less than 1 part diesel fuel to 10 parts total fuel on an energy equivalent basis. Alternative fuel also means any of these fuels used in combination with each other or in combination with other non-diesel fuels. Urban bus engines operating on alternative fuel shall not have the capability to idle or operate solely on diesel fuel at any time.

(2) "Active fleet" means the ~~a transit agency's~~ total ~~active fleet~~ number of urban buses operated by a transit agency or under contract to a transit agency, including spare buses,

but not emergency contingency vehicles ~~(e.g.; for emergencies)~~ or non-revenue producing vehicles.

(3) "Emergency contingency vehicle" means an urban bus placed in an inactive contingency fleet for energy or other local emergencies, after the urban bus has reached the end of its normal minimum useful life.

(4) "Spare bus" means an urban bus that is used to accommodate routine maintenance and repair operations, and to replace a bus in scheduled service that breaks down or is involved in an accident.

(~~3~~5) "Transit agency" means a public entity responsible for administering and managing transit services. Public transit agencies can directly operate transit service or contract out for all or part of the total transit service provided.

(~~4~~6) "Urban bus" means a passenger-carrying vehicle powered by a heavy heavy-duty diesel engine, or of a type normally powered by a heavy heavy-duty diesel engine, with a load capacity of fifteen (15) or more passengers and 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 would normally be installed. Since fares are usually paid in cash or token, rather than purchased in advance in the form of tickets, urban buses would normally have equipment installed for the collection of fares. Urban buses are also typically characterized by the absence of equipment and facilities for long distance travel, e.g., restrooms, large luggage compartments, and facilities for stowing carry-on luggage.

(c) Transit agencies on the alternative-fuel path shall meet the following requirements:

(1) Upon approval of the regulation, and through Model Year 2015, at least 85 percent of all urban buses purchased or leased each year must be alternative-fuel buses.
(2) NOx fleet average requirements as set forth in subdivision (e), below.
(3) Beginning October 1, 2002, only engines certified to an optional PM standard of 0.03 g/bhp-hr or lower shall be purchased when making new bus purchases.

(4) Total diesel PM ~~retrofit~~ emission reduction requirements and use of low-sulfur or other allowed fuel as set forth in subdivision (f), below.

(5) Transit agencies on the alternative-fuel path shall not purchase any diesel-fueled, dual-fuel, or bi-fuel buses with 2004 – 2006 model year engines certified to emissions levels in excess of those specified in paragraph (a)(11) of section 1956.1, Title 13, CCR, except as provided in paragraph (c)(8) of this section.

(6) Zero-emission bus purchase requirements beginning in model year 2010, in accordance with the requirements set forth in subdivision (c) of section 1956.3, Title 13, CCR.

(7) Reporting requirements as set forth in section 1956.4, Title 13, CCR.

(8) The Executive Officer may exempt transit agencies on the alternative-fuel path from the requirements of paragraph (c)(5) of section 1956.2, Title 13, CCR, provided that:

(A) A transit agency applies to the Executive Officer for such exemption by June 30, 2001;

(B) A transit agency demonstrates to the Executive Officer that it will achieve NOx emissions benefits through 2015 greater than what would have been achieved through compliance with paragraph (c)(5); and

(C) The Executive Officer finds that transit agencies, after consulting with the Engine Manufacturers Association, have demonstrated, or are contractually committed to demonstrate, advanced NOx aftertreatment technology.

(d) Transit agencies on the diesel path shall meet the following requirements:

(1) NOx fleet average requirements as set forth in subdivision (e), below.

(2) Total diesel PM ~~retrofit~~ emission reduction requirements and use of low-sulfur or other allowed fuel as set forth in subdivision (f), below.

(3) Zero-emission bus demonstration in 2003-2004, as required in subdivision (b) of section 1956.3, Title 13, CCR.

(4) Transit agencies on the diesel path shall not purchase any diesel-fueled, dual-fuel, or bi-fuel~~, or alternative-fuel~~ buses with 2004 – 2006 model year engines certified to emissions

levels in excess of those specified in paragraph (a)(11) of section 1956.1, Title 13, CCR, except as provided in paragraph (d)(7) of this section. Beginning July 1, 2003, a transit agency may not purchase alternative fuel buses certified to a PM emission level in excess of the optional standard of 0.03 g/bhp-hr when making new bus purchases.

(5) Zero-emission bus purchase requirements beginning in model year 2008, in accordance with the requirements set forth in subdivision (c) of section 1956.3, Title 13, CCR.

(6) Reporting requirements as set forth in section 1956.4, Title 13, CCR.

(7) The Executive Officer may exempt transit agencies on the diesel path from the requirements of paragraph (d)(4) of section 1956.2, Title 13, CCR, provided that:

(A) A transit agency applies to the Executive Officer for such exemption by June 30, 2001;

(B) A transit agency demonstrates to the Executive Officer that it will achieve NOx emissions benefits through 2015 greater than what would have been achieved through compliance with paragraph (d)(4); and

(C) The Executive Officer finds that transit agencies, after consulting with the Engine Manufacturers Association, have demonstrated, or are contractually committed to demonstrate, advanced NOx aftertreatment technology.

(e) Beginning October 1, 2002, no transit agency shall own, operate, or lease an active fleet of urban buses with average NOx emissions in excess of 4.8 g/bhp-hr, based on the engine certification standards of the engines in the active fleet.

(1) This active fleet average requirement shall be based on urban buses owned, operated, or leased by the transit agency, including diesel buses, alternative-fuel buses, all heavy-duty zero-emission buses, electric trolley buses, and articulated buses, in each transit agency's active fleet. The Executive Officer may allow zero-emission buses that do not meet the definition of an urban bus to be included in the calculation of the fleet average standard upon written request to the ARB by January 31, 2002, and upon approval by the Executive Officer. The request shall include a description of the zero-emission buses, the zero-emission

technology utilized, and the number of zero-emission buses to be used in calculating the NOx fleet average standard. Zero-emission buses not meeting the definition of an urban bus may not be used to satisfy the requirements of the Zero-emission Bus Demonstration Project set forth in subdivision (b) of section 1956.3, Title 13, CCR.

(2) Transit agencies may use ARB-certified NOx retrofit systems to comply with the fleet average requirement (in addition to bus purchases, repowerings, and retirements).

(3) Transit agencies have the option of retiring all 1987 and earlier model year diesel urban buses by October 1, 2002, to comply with the fleet average standard requirement.

(f) To reduce public exposure to diesel particulate matter, each transit agency ~~agencies and companies that lease buses to transit agencies shall retrofit~~ shall reduce the total diesel PM emissions of the diesel buses in ~~their~~ its active fleet~~s~~ relative to its total diesel PM emissions as of January 1, 2002, according to the schedule below, and shall operate ~~their~~ its diesel buses on diesel fuel with a maximum sulfur content of 15 parts per million by weight. A transit agency shall calculate its diesel PM emission total by summing the PM exhaust emission values specified in section 1956.1(a) for each diesel-fueled, dual-fuel, bi-fuel, and diesel hybrid-electric engine in its active fleet in grams per brake horsepower-hour (g/bhp-hr). For 1987 and earlier engines, the PM exhaust emission value shall be presumed to be 1.0 g/bhp-hr. Documentation of compliance with these requirements must be provided in accordance with the provisions of subdivision (d) of section 1956.4, Title 13, CCR.

(1) ~~Tier 1 – Except as provided in (B) below, by January 1, 2003, transit agencies shall not own, operate or lease diesel-fueled, dual-fuel, bi-fuel, or diesel hybrid buses in their active fleets with 1990 and earlier model year engines, unless those engines have been retrofitted as provided in paragraph (A), below. Transit agencies with fewer than 20 buses in their active fleets, and that operate in federal one-hour ozone attainment areas, are not required to comply with this requirement until January 1, 2007; provided that in areas redesignated as one-hour ozone non-attainment areas prior to January 1, 2007, transit agencies initially eligible for delayed compliance shall submit a plan to the Executive Officer within 30 days of redesignation for achieving compliance with this retrofit requirement.~~No later than January 1, 2004:

(A) ~~The retrofit device must be certified by the Executive Officer of the ARB in accordance with the procedures set forth in the "California Certification Procedures for PM Retrofit Devices for On-Road Heavy-Duty Diesel Engines" incorporated by reference in paragraph (f)(7) below.~~ The diesel PM emission total for a transit agency on the diesel path shall be no more than 60 percent of its diesel PM emission total on January 1, 2002.

(B) ~~1990 and earlier engines were originally certified to a PM standard of 0.60 grams per brake horsepower-hour. Only those 1990 and earlier engines that have been retrofitted to 0.10 grams per brake horsepower-hour PM with an ARB-certified retrofit device (to meet the requirements of the U.S. EPA urban transit bus rebuild and retrofit program, 40 CFR 85.1401 - 1415) are exempt from further retrofit requirements under this section.~~ The diesel PM emission total for a transit agency on the alternative fuel path shall be no more than 80 percent of its diesel PM emission total on January 1, 2002.

(2) ~~Tier 2 — Transit agencies shall not own, operate or lease diesel-fueled, dual-fuel, bi-fuel, or diesel hybrid transit buses in their active fleets with 1991 through 1995 model year engines, unless the engines have been retrofitted with a device that has been certified by the Executive Officer in accordance with the procedures set forth in the "California Certification Procedures for PM Retrofit Devices for On-Road Heavy-Duty Diesel Engines" incorporated by reference in paragraph (f)(7) below, and in accordance with the following schedule. Transit agencies with fewer than 20 buses in their active fleets, and that operate in federal one-hour ozone attainment areas shall comply with the 100 percent retrofit requirement by January 1, 2007, and are exempt from the interim requirements described in (A) and (B) below that apply before that date. In areas redesignated as one-hour ozone non-attainment areas prior to January 1, 2007, transit agencies initially exempt from the interim requirements shall submit a plan to the Executive Officer within 30 days of redesignation for achieving compliance with this retrofit requirement.~~ No later than January 1, 2005:

(A) ~~Alternative fuel path: 20 percent of these buses shall be retrofitted by January 1, 2003; 75 percent of these buses shall be retrofitted by January 1, 2004; and 100 percent of these buses shall be retrofitted by January 1, 2005, except for those buses eligible for the retirement exemption set forth in paragraph (f)(4), below.~~ The diesel PM emission total for a transit agency on the diesel path shall be no more than 40 percent of its diesel PM emission total on January 1, 2002.

(B) ~~Diesel path: 50 percent of these buses shall be retrofitted by January 1, 2003; and 100 percent of these buses shall be retrofitted by January 1, 2004, except for those buses eligible for the retirement exemption set forth in paragraph (f)(4), below.~~ The diesel PM emission total for a transit agency on the alternative fuel path shall be no more than 60 percent of its diesel PM emission total on January 1, 2002.

(3) ~~Tier 3 — Transit agencies shall not own or operate diesel-fueled, dual-fuel, bi-fuel, or diesel hybrid buses in their active fleets with 1996 through 2002 model year engines produced before October 1, 2002, unless the engines have been retrofitted with a device that has been certified by the Executive Officer in accordance with the procedures set forth in the "California Certification Procedures for PM Retrofit Devices for On-Road Heavy-Duty Diesel Engines" incorporated by reference in paragraph (f)(7) below, and in accordance with the following schedule.~~ No later than January 1, 2007:

(A) ~~Alternative fuel path: 20 percent of these buses shall be retrofitted by January 1, 2007; 75 percent of these buses shall be retrofitted by January 1, 2008; and 100 percent of these buses shall be retrofitted by January 1, 2009, except for those buses eligible for the retirement exemption set forth in paragraph (f)(4), below.~~ The diesel PM emission total for a transit agency on the diesel path shall be no more than 15 percent of its diesel PM emission total on January 1, 2002.

(B) ~~Diesel path: 20 percent of these buses shall be retrofitted by January 1, 2005; 75 percent of these buses shall be retrofitted by January 1, 2006; and~~

~~100 percent of these buses shall be retrofitted by January 1, 2007.~~ The diesel PM emission total for a transit agency on the alternative fuel path shall be no more than 40 percent of its diesel PM fleet average on January 1, 2002.

(4) ~~For transit agencies on the alternative fuel path, those buses that are within two years of retirement are exempt from the 100 percent retrofit requirement set forth in paragraphs (2)(A) and (3)(A), above, provided documentation of retirement is supplied to the Executive Officer in accordance with the requirements set forth in paragraph (d)(2) of section 1956.4, Title 13, CCR.~~ No later than January 1, 2009, the diesel PM emission total for a transit agency on the alternative fuel path shall be no more than 15 percent of its diesel PM emission total on January 1, 2002.

~~For transit agencies on the diesel path, those buses that are within one year of retirement are exempt from the 100 percent retrofit requirement set forth in paragraph (2)(B), above, provided documentation of retirement is supplied to the Executive Officer in accordance with the requirements set forth in paragraph (d)(2) of section 1956.4, Title 13, CCR.~~

(5) A transit agency that is unable to comply with an implementation deadline specified in paragraph (f)(1), (2), (3), or (4) because of the unavailability of technology may apply in writing to the Executive Officer for an extension to comply no later than ninety days prior to the applicable implementation deadline, for a time of up to, but not to exceed, one year. The applicant must demonstrate that the technology is unavailable; shall explain why the transit agency cannot comply by retiring older buses; and shall provide a schedule for compliance.

~~(5)~~(6) Beginning July 1, 2002, a transit ~~agencies~~ agency shall not operate its diesel buses on diesel fuel with a sulfur content in excess of 15 parts per million by weight, except that a transit agency may operate its diesel buses on a fuel that is verified by the Executive Officer as a diesel emission control strategy that reduces PM in accordance with section 2700 et seq., title 13, CCR. A t~~T~~ransit ~~agencies~~ agency with fewer than 20 buses in ~~their~~ its active fleet~~s~~, and that operates in a federal one-hour ozone attainment area~~s~~, ~~are~~ is not subject to this low-sulfur fuel requirement until July 1, 2006. In areas redesignated as one-hour ozone non-attainment areas prior

to July 1, 2006, a transit ~~agencies~~ agency initially exempt from the low-sulfur fuel requirement shall submit a plan to the Executive Officer within 30 days of redesignation for achieving compliance with this requirement.

~~(6)~~(7) A t~~T~~ransit ~~agencies~~ agency that owns, operates, or leases ~~a~~ fewer than 20 diesel-fueled, dual-fuel, bi-fuel, or diesel hybrid-electric buses in its active fleet and that operates in a federal one-hour ozone attainment area may delay implementation of the intermediate total diesel PM emission reduction requirements provided the transit agency complies with the implementation deadlines set forth in paragraphs (f)(3)(A) or (f)(4). ~~with an engine for which a retrofit device is not, or will not be, available to meet the retrofit requirements within 6 months of the dates specified in paragraphs (f)(1) through (f)(3) shall be eligible for a one-year delay in complying with the retrofit requirements, upon submittal of documentation of device unavailability to the ARB in writing at least 30 days before the retrofit requirement becomes applicable and upon approval of the delay by the Executive Officer of the ARB.~~

~~(7)~~(8) ~~The retrofit certification procedures for use in complying with the PM retrofit requirements for 2002 model year diesel-fueled, dual-fuel and bi-fuel urban bus engines produced before October 1, 2002, and earlier model year urban bus engines (including engines used in diesel hybrid buses) are set forth in the "California Certification Procedures for PM Retrofit Devices for On-Road Heavy-Duty Diesel Engines" adopted November 22, 2000, which are incorporated herein by reference.~~A transit agency that installs a diesel emission control strategy to reduce diesel PM shall use a diesel emission control strategy that is verified by the Executive Officer in accordance with section 2700 et seq., title 13, CCR, or an urban bus retrofit device that has been exempted under Vehicle Code section 27156 as an engine rebuild kit and that reduces PM to 0.10 g/bhp-hr when used on an engine model 6V92TA DDEC for the model years specified for that engine.

(9) A transit agency that installs a diesel emission control strategy on an urban bus engine shall use the following percentage reductions from the engine certification standard value when calculating its total diesel PM emissions: 25

percent for a Level 1, 50 percent for a Level 2, and 85 percent for a Level 3 diesel emission control strategy.

(g) A transit agency with fewer than 20 buses in its active fleet may apply for an extension to comply with the provisions of section 1956.2 by submitting documentation of financial hardship to the Executive Officer, in writing, at least 30 days before the requirement becomes applicable for approval by the Executive Officer. Documentation of financial hardship shall include, but is not limited to, an analysis of the cost of compliance, the sources of available funds, and the shortfall between funds available and the cost of compliance. The transit agency must also specify the date and means by which compliance will be achieved in the request for a delay.

NOTE: Authority cited: Sections 39600, 39601, 39667, 43013, 43018, 43701(b) Health and Safety Code. Reference: Sections 39002, 39003, 39017, 39500, 39650, 39667, 40000, 43000, 43000.5, 43013, 43018, 43701(b), 43801, 43806 Health and Safety Code, and sections 233, 28114, Vehicle Code.

**Amend section 1956.4 to read as follows:**

1956.4 Reporting Requirements for all Urban Bus Transit Agencies

(a) The following reports on new bus purchases and/or leases by transit operators on the alternative-fuel path shall be submitted as described below:

(1) The initial report shall be submitted by January 31, 2001, and shall state the transit agency's intent to follow the alternative-fuel path.

(2) Any requests for deviation from the requirement that 85 percent of buses purchased per year must be alternative-fuel buses must be submitted in writing and approved by the Executive Officer of the Air Resources Board 90 days prior to purchase. The written request must include the reason for requesting the deviation from the 85 percent annual purchase requirement and the transit agency's future planned alternative-fuel bus purchases.

(3) Each t~~T~~ransit agency~~ies~~ shall submit an annual report~~s~~ containing: the number, manufacturer, make, and model year of engines, and fuel used ~~for engines in~~ for each transit bus~~es~~ it ~~they~~ currently owns or operates, bus purchases and/or leases beginning January 1, 2000, and annual average percentage of total bus purchases and/or leases that were alternative-fuel buses. The first report shall be submitted by January 31, 2001. Subsequent reports shall be submitted annually by January 31 through the year 2016.

(b) The following reports on new bus purchases and/or leases by transit operators on the diesel path shall be submitted as described below:

(1) The initial report shall be submitted by January 31, 2001, and shall state the transit agency's intent to follow the diesel path.

(2) Each t~~T~~ransit agency~~ies~~ shall submit an annual report~~s~~ containing the number, manufacturer, make, and model year of engines, and fuel used ~~for engines in~~ for each transit bus~~es~~ it ~~they~~ currently owns or operates, and bus purchases and/or leases beginning January 1, 2000. The first report shall be submitted by January 31, 2001. Subsequent reports

shall be submitted annually by January 31 through the year 2016.

(3) A transit agency within the jurisdiction the South Coast Air Quality Management District that chooses to change from the diesel path to the alternative fuel path in accordance with paragraph (a) (2) of section 1956.2, title 13, CCR, must submit to the Executive Officer a letter of intent to follow the alternative fuel path no later than January 31, 2004. The letter of intent shall contain a statement certifying that the transit agency is in compliance with all provisions of the fleet rule for transit agencies on or before January 1, 2004.

(c) Each transit agency shall submit t~~T~~he following reports on the NOx fleet average requirement~~ shall be submitted as described below~~:

(1) Initial documentation shall be submitted by January 31, 2001, and contain, at a minimum, the active urban bus fleet NOx emission average, and if that number exceeds the average required in subdivision (e), section 1956.2, Title 13, CCR, a schedule of actions planned to achieve that average by October 1, 2002, including numbers and model years of bus purchases, retirements, retrofits, and/or repowerings, or shall indicate the intent of the transit agency to retire all model year 1987 and earlier buses in its active fleet by October 1, 2002.

(2) A final report shall be submitted by January 31, 2003, detailing the active urban bus fleet NOx emission average as of October 1, 2002, and actions, if any were needed, taken to achieve that standard, including numbers and model years of bus purchases, retirements, retrofits, and/or repowerings, or documenting the retirement of all model year 1987 and earlier buses.

(d) Each transit agency shall submit t~~T~~he following reports on the total diesel PM ~~bus retrofit~~ emission reduction requirements~~ shall be submitted as described below~~:

(1) An i~~I~~nitial annual reports shall be submitted by January 31, 2003, ~~the dates shown below~~ and shall contain, at a minimum, the following information:

(A) number, manufacturer, make, and model year of diesel-fueled, dual-fuel, bi-fuel, and diesel hybrid-electric engines in urban buses in the active fleet; the

PM engine certification value of each of those bus engines; the diesel PM emission total for the diesel buses in the active fleet; and the diesel PM emission total for the baseline date of January 1, 2002. ~~projected number and model year of buses to be retrofitted annually, projected number and model year of exempt buses, if any, and basis for exemption~~.

(B) ~~for transit agencies on the alternative-fuel path, a report for Tier 1 and Tier 2 requirements shall be submitted by January 31, 2002; a report for Tier 3 requirements shall be submitted by January 31, 2005~~ For each urban bus, for which a diesel emission control strategy has been applied, the device's product serial number; its Diesel Emission Control Strategy Family Name in accordance with the requirements of section 2705 (g)(2), title 13, CCR; and the date of installation.

(C) ~~for transit agencies on the diesel path, a report for Tier 1 and Tier 2 requirements shall be submitted by January 31, 2002; a report for Tier 3 requirements shall be submitted by January 31, 2003~~.

(2) ~~Transit agencies shall submit annual reports, in accordance with the schedules in paragraphs (A) and (B) below, containing records of number and model year of diesel-fueled, dual-fuel, bi-fuel, and diesel hybrid buses in the active fleet, number and model year of buses retrofitted per year, retrofit devices used, number and model year of exempt buses, if any, and basis for exemption, and number and model year of buses retired, if any.~~ Annual reports shall be submitted each year beginning January 31, 2004 and each January 31 thereafter, through 2009, and shall contain the information required in sections (d)(1)(A) and (B) above plus the total percentage reduction of PM achieved from the baseline diesel PM emission total as of January 1 of each applicable year.

~~(A) for transit agencies on the alternative-fuel path, a report on compliance with Tier 1 requirements shall be submitted by January 31, 2003. For Tier 2, annual compliance reports shall be submitted by January 31, beginning in 2003 and ending in 2005. For Tier 3, annual compliance reports shall be submitted by January 31, beginning in 2007 and ending in 2009.~~

~~(B) for transit agencies on the diesel path, a report on compliance with Tier 1 requirements shall be submitted by January 31, 2003. For Tier 2, annual compliance reports shall be submitted by January 31, beginning in 2003 and ending in 2004. For Tier 3, annual compliance reports shall be submitted by January 31, beginning in 2005 and ending in 2007.~~

(e) The following reports on the zero-emission bus demonstration program shall be submitted by those transit agencies required to conduct such demonstrations, as described below:

(1) Initial documentation shall be submitted by January 31, 2003, and contain, at a minimum, the bus order and delivery schedule, fuel type, type of refueling station, any planned facility modifications, and a revenue service demonstration plan;

(2) A financial plan shall be submitted by January 31, 2003, and contain, at a minimum, projected expenditures for capital costs for purchasing and/or leasing buses, refueling stations, any facility modifications, and projected annual operating costs;

(3) A final report shall be submitted by January 31, 2005, and contain, at a minimum, the following information:

(A) a brief description of the zero-emission technology utilized, identification of bus manufacturer and product specifications,

(B) miles driven per bus in revenue service, safety incidents, driver and mechanic training conducted, and maintenance (both scheduled and unscheduled),

(C) qualitative transit personnel and passenger experience, and

(D) a financial summary of capital costs of demonstration program, including bus purchases and/or leases, fueling infrastructure, any new facilities or modifications, and annual operating costs.

(f) The following reports on new zero-emission bus purchases and/or leases shall be submitted by transit agencies required to purchase zero-emission buses as described below:

(1) Initial report shall be submitted 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 initial report shall contain, at a minimum, the following information:

(A) a brief description of the zero-emission technology to be utilized and a plan for the implementation of the requirement,

(B) for an exemption from the purchase requirement, documentation that 15 percent or more of the transit agency's active urban bus fleet is composed of zero-emission buses.

(2) Any requests for deviation from the requirement that 15 percent of buses purchased per year must be zero-emission buses must be submitted in writing and approved by the Executive Officer of the Air Resources Board 90 days prior to a transit agency submitting a purchase order(s) reflecting the purchase deviation. The written request shall include the reason for requesting the deviation and the transit agency's future planned zero-emission bus purchases.

(3) Transit agencies on the diesel path shall include in the annual reports required in paragraph (b)(2): zero-emission bus purchases and/or leases beginning with model year 2008 and through model year 2015, and the annual average percentage of total bus purchases and/or leases that were zero-emission buses.

(4) Transit agencies on the alternative-fuel path shall include in the annual reports required in paragraph (a)(3): zero-emission bus purchases and/or leases beginning with model year 2010 and through model year 2015, and the annual average percentage of total bus purchases and/or leases that were zero-emission buses.

(g) Transit agencies exempted from the requirements of paragraphs (c)(5) and (d)(4), section 1956.2, Title 13, CCR, shall submit annual reports demonstrating that they are achieving NOx emission benefits required in paragraphs (c)(8)(B) and (d)(7)(B), section 1956.2, Title 13, CCR. The

first report shall be submitted by January 31, 2005. Subsequent reports shall be submitted annually by January 31 through the year 2016.

NOTE: Authority cited: Sections 39600, 39601, 39659, 39667, 39701, 43018, 41511 Health and Safety Code. Reference: Sections 39667, 39700, 39701, 41510, 41511, 43000, 43000.5, 43013, 43018, 43801, 43806 Health and Safety Code.

**Amend title 13, California Code of Regulations, section 1956.8, to read as follows:**

1956.8. Exhaust Emissions Standards and Test Procedures - 1985 and Subsequent Model Heavy-Duty Engines and Vehicles.

(a) (1) [No Change]

(2) [No Change]

(3) [No Change]

(4) [No Change]

(b) The test procedures for determining compliance with standards applicable to 1985 and subsequent heavy-duty diesel engines and vehicles and the requirements for participation in the averaging, banking and trading programs, are set forth in the "California Exhaust Emission Standards and Test Procedures for 1985 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles" adopted April 8, 1985, as last amended December 8, 2000, and the "California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric Vehicles, in the Urban Bus and Heavy-Duty Vehicle Classes" adopted [insert adopted date], which ~~is~~ are incorporated by reference herein.

(c) [No Change]

(d) The test procedures for determining compliance with standards applicable to 1987 and subsequent heavy-duty Otto-cycle engines and vehicles are set forth in the "California Exhaust Emission Standards and Test Procedures for 1987 through 2003 Model Heavy-Duty Diesel Engines and Vehicles" adopted April 25, 1986, as last amended December 27, 2000, ~~and~~ the "California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy Duty Otto-Cycle Engines," adopted December 27, 2000, and the "California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric Vehicles, in the Urban Bus and Heavy-Duty Vehicle Classes" adopted [insert adopted date], which ~~is~~ are incorporated by reference herein.

(e) [No Change]

(f) [No Change]

(g) [No Change]

(h) [No Change]

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43100, 43101, 43104, and 43806, Health and Safety Code; and Section 28114, Vehicle Code. Reference: Sections 39002, 39003, 39500, 43000, 43013, 43018, 43100, 43101, ~~43101.5,~~ 43102, 43104, 43106, 43202, 43204, 43206, 43210-43213, and 43806, Health and Safety Code; 43105 and Section 28114, Vehicle Code.

**Amend title 13, California Code of Regulations, section 2112, to read as follows:**

2112. Definitions.

(a) [No Change]

(b) [No Change]

(c) [No Change]

(d) [No Change]

(e) [No Change]

(f) [No Change]

(g) [No Change]

(h) [No Change]

(i) [No Change]

(j) [No Change]

(k) [No Change]

(l) [No Change]

(1) [No Change]
(2) [No Change]
(3) [No Change]
(4) [No Change]
(5) [No Change]
(6) [No Change]
(7) [No Change]
(8) [No Change]
(9) [No Change]
(10) [No Change]
(11) [No Change]
(12) [No Change]
(13) [No Change]
(14) [No Change]
(15) [No Change]

(16) [No Change]
(17) [No Change]
(18) [No Change]
(19) [No Change]
(20) For 2004 and subsequent model-year heavy heavy-duty diesel engines, 2004 and subsequent model-year heavy-duty diesel urban buses, 2004 and subsequent model-year heavy-duty diesel engines to be used in urban buses, and 2004 and subsequent model year hybrid-electric urban buses for carbon monoxide, particulate, and oxides of nitrogen plus non-methane hydrocarbon emissions standards, a period of use of 10 years or 435,000 miles, or 22,000 hours, whichever first occurs, or any alternative useful life period approved by the Executive Officer, except as provided in paragraphs (19)(i) and (19)(ii).

(i) [No Change]
(ii) [No Change]

(20) [No Change]
(21) [No Change]

(m) [No Change]
(n) [No Change]

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43104, 43105 and 43806, Health and Safety Code; and Section 28114, Vehicle Code. Reference: Sections 39002, 39003, 39500, 43000, 43013, 43018, 43100, 43101, 43101.5, 43102, 43104, 43106, 43202, 43204, 43206, 43210-43213, and 43806, Health and Safety Code; and Section 28114, Vehicle Code.

State of California
AIR RESOURCES BOARD

# ~~CALIFORNIA CERTIFICATION PROCEDURES FOR PM RETROFIT DEVICES FOR ON-ROAD HEAVY-DUTY DIESEL ENGINES~~

~~Adopted: November 22, 2000~~

~~Note: The entire text of this document, which is incorporated by reference in section 1956.2, Title 13, CCR, is new language.~~

~~(a) **Applicability:** These procedures apply to applicants for certification of retrofit devices to reduce particulate matter (PM) emissions from on-road heavy-duty diesel engines, when PM retrofit is required or permitted for an affected engine family. Certification compliance shall be demonstrated as set forth in subdivisions (b) through (h), below.~~

~~(b) **Test procedure:** The applicant shall use the heavy-duty engine Federal Test Procedures as set forth in "California Exhaust Emission Standards and Test Procedures for 1985 and Subsequent Model Heavy-duty Diesel Engines and Vehicles" adopted April 8, 1985, as last amended November 22, 2000. Alternatively, the applicant, with written approval of the Executive Officer, may use a chassis test cycle for certification compliance. The Executive Officer shall approve the chassis test cycle if he determines that it represents normal driving conditions of the vehicle application(s) for which the device is warranted for use by the applicant. For each engine selected for testing, the applicant shall complete at least two emission tests using the same retrofit device.~~

~~(c) **Emission results:** In order for the retrofit device to be certified by the Executive Officer, the test results must demonstrate that the retrofit device reduces engine-out PM emissions by at least 85 percent, or, alternatively, reduces PM emissions to 0.01 g/bhp-hr or less. For retrofit devices tested with an Executive Officer-approved chassis test cycle, certification compliance shall be demonstrated by compliance with the 85 percent emission reduction requirement. The retrofit device shall not cause the engine to fail to meet any California emission standard or other requirement for the heavy-duty application for which the retrofit device is certified.~~

~~Pursuant to subdivision (h) of section 27156 of the Vehicle Code, an original equipment pollution control device may be removed from the test engine provided that the certification emission test results demonstrate an 85 percent conversion efficiency, or, alternatively, that PM emissions have been reduced to 0.01 g/bhp-hr or less, and that the engine does not fail to meet any California emission standard or other requirement applicable to that engine. No deterioration factors shall be applied to the measured results.~~

~~(d) **Emissions test engine selection:** The applicant shall select separate test engines to represent four-stroke engine families and two-stroke engine families. In each case, the test engine used must represent the "worst case" with respect to particulate emission control for each engine family for which the retrofit device is being certified. Engine families may be aggregated if the applicant can demonstrate to the Executive Officer that emissions and retrofit device performance do not vary significantly between aggregated engine families. For retrofit devices being certified to reduce PM emissions by 85 percent, the worst case test engine shall represent the engine family with the lowest PM emissions when originally certified by the ARB. For retrofit devices being certified to reduce PM emissions to a level of 0.01 g/bhp-hr or less, the~~

~~worst case test engine shall represent the engine family with the highest PM emissions when originally certified by the ARB.~~

~~(e) **Diesel test fuels:** The test fuel required for the baseline test and the test with the retrofit device in place shall meet the specifications contained in 40 CFR 86.1313-94(b)(2)(Federal Register, Vol.62, No. 172, September 5, 1997, page 47125), with the exception that the sulfur content must not exceed 15 parts per million by weight, and shall be representative of fuel used in-use.~~

~~(f) **Emissions warranty:** As a condition of certification, the applicant shall warrant that the certified retrofit device, when properly installed and maintained as stated in the applicant's written instructions for proper maintenance and use, will not cause the heavy-duty diesel engine for which the retrofit device is certified to exceed the applicable emission standards set forth in Title 13, CCR, for a period of at least 150,000 miles from the date when the retrofit device is installed. The applicant shall also warrant that the certified retrofit device will not cause damage to the engine, when properly installed and maintained, for this same mileage interval.~~

~~The applicant shall provide an emissions defect warranty stating that if the certified retrofit device is properly installed and maintained as stated in the applicant's written instructions for proper maintenance and use, the applicant will replace all defective parts, free of charge, for a period of at least 100,000 miles from the date when the retrofit device is installed.~~

~~The applicant shall provide a written statement to the purchaser that the certified retrofit device will not result in any unsafe condition endangering the motor vehicle or its occupants in any operational mode, including malfunction.~~

~~(g) **Durability requirements:** The applicant shall demonstrate device durability through field testing representing a mileage interval of at least 150,000 miles. Mileage accumulation shall be performed on a vehicle application representative of the vehicle application for which the applicant warrants the use of the retrofit device. The applicant may propose to shorten the durability testing requirements, with prior approval by the Executive Officer, if sufficient data, such as durability bench testing data, are available to determine durability to at least 150,000 miles. Any durability testing shall use diesel fuel meeting the specifications in subdivision (e), above.~~

~~(h) **Labeling requirements**: The applicant shall label each retrofit device with a permanent, non-destructible label or stamp identifying the manufacturer, the model number, the month and year of manufacture, and the Executive Order number issued by the ARB. The label or stamp shall be easily visible after installation of the retrofit device according to the applicant's written instructions for proper maintenance and use. Each applicant shall submit a sample of its~~

~~label or stamp to the ARB for review and approval, prior to selling the retrofit device.~~

# APPENDIX B

## CALIFORNIA INTERIM CERTIFICATION PROCEDURES FOR 2004 AND SUBSEQUENT MODEL HYBRID-ELECTRIC VEHICLES, IN THE URBAN BUS AND HEAVY-DUTY VEHICLE CLASSES

**Adopted: [insert date of adoption]**

## A. Applicability

The certification procedures in this document are applicable to 2004 and subsequent model year heavy-duty hybrid-electric vehicles and urban transit buses (HEBs).

General procedures and requirements necessary to certify a heavy-duty engine for sale in California are set forth in "California Exhaust Emission Standards and Test Procedures for 1985 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles" (hereinafter "HDD TPs"), as incorporated in title 13, CCR, section 1956.8(b), and "California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Otto-Cycle Engines," (hereinafter "HDO TPs"), as incorporated in title 13, CCR, section 1956.8(d), for testing and compliance of heavy-duty diesel and Otto-cycle engines with exhaust emission standards.

The interim certification procedures are optional for the 2004 through 2006 model years. The Executive Officer shall review test results and in-use data gathered from the 2004 through 2006 model years and make recommendations to the Board in 2006 for modifying certification procedures for 2007 and subsequent model year HEBs and heavy-duty hybrid-electric vehicles.

## B. Definitions

These certification procedures incorporate by reference the definitions and abbreviations set forth in 40 CFR §86.001-2 (October 22, 1996) and §86.004-2 (January 18, 2001), the definitions and abbreviations set forth in the HDD TPs, the definitions set forth in the HDO TPs, and the definitions set forth in title 13, CCR sections 1956.1 through 1956.8, unless otherwise amended below.

1. **"Auxiliary power unit (APU)"** means a device that converts consumable fuel energy into mechanical or electrical energy. Examples of auxiliary power units are internal combustion engines, turbines, and fuel cells.

2. **"Baseline HEB engine"** means the most representative heavy-duty engine in a specific heavy-duty engine family certified by the Executive Officer that will be used in a hybrid-electric drive system for a specific HEB family. Certified emissions from the selected engine will be used in calculating an emission factor to determine the appropriate emission reduction for a particular hybrid-electric drive system.

3. **"Baseline urban transit bus"** means a representative, non-hybrid-electric urban transit bus selected by the Executive Officer for chassis dynamometer testing. Exhaust emissions from the selected urban transit bus, as determined by the chassis dynamometer test procedure, will be used in

conjunction with the certified emissions from the engine incorporated into the baseline urban transit bus to calculate a baseline emission factor.

4. **"Battery"** means a device that stores chemical energy and releases electrical energy.

5. **"Battery rated Ampere-hour capacity"** means the manufacturer-rated capacity of a battery in Ampere-hours obtained from a battery discharged at the manufacturer's recommended discharge rate (C/1 – C/6) such that a specified minimum cut-off terminal voltage is reached.

6. **"Battery State of Charge (SOC)"** means the quantity of electric energy remaining in the battery relative to the maximum rated Ampere hour (Ah) capacity of the battery expressed in percent.

7. **"Capacitor"** means a device that stores energy electrostatically and releases electrical energy.

8. **"Capacitor SOC"** means the actual measured energy content of a capacitor and expressed as a percentage of the capacitor's maximum rated voltage squared ($V^2$).

9. **"CCR"** means California Code of Regulations.

10. **"CFR"** means Code of Federal Regulations.

11. **"Charge-depleting HEB"** means an HEB that is designed to be recharged off-board under normal conditions. Under conditions of continuous operation, the RESS of a charge-depleting HEB ultimately fully discharges and impairs vehicle operation when no off-board charging is performed and the consumable fuel is regularly replenished.

12. **"Charge-sustaining HEB"** means an HEB that derives all of its energy from on-board fuel under normal usage. Under conditions of continuous operation, the RESS of a charge-sustaining HEB does not fully discharge and impair vehicle operation when no off-board charging is performed and the consumable fuel is regularly replenished.

13. **"Electric drive components"** means the electric motor, system controller, generator, and energy storage system (batteries, capacitors, and flywheels).

14. **"Electromechanical flywheel"** means a device that stores rotational kinetic energy and releases that kinetic energy to an electric motor-generator system, thereby producing electrical energy.

15. **"Electromechanical flywheel SOC"** means a percentage of the flywheel's maximum-rated revolutions per minute squared ($rpm^2$), which is based on the actual measured energy content of an electromechanical flywheel.

16. **"Emission factor"** means the number calculated from exhaust emissions chassis dynamometer test results and engine dynamometer test results for a HEB or conventional urban transit bus. The number, expressed in units of bhp-hr/mi, is used to calculate an emission factor ratio.

17. **"Emission Factor Ratio"** means the number resulting from dividing the emission factor for a HEB by the emission factor for a baseline urban transit bus, and reflects the emission reduction capability of a hybrid-electric drive system.

18. **"Hybrid-electric drive system"** means the propulsion system comprised of the APU and the corresponding electric drive components connected with that APU.

19. **"Hybrid-electric urban transit bus (HEB)"** means an urban bus equipped with at least two sources of energy stored on board; this energy is converted to motive power using an electric drive motor and an APU. The electric drive motor must be used partially or fully to drive the vehicle's wheels.

20. **"HEB Family"** means the basic classification unit of a manufacturer's product line used for the purpose of test fleet selection, based on gross vehicle weight (either 24,000 lbs to 44,000 lbs, or greater than 44,000 lbs). A family may include any engine that certifies to the same standard as the HEB test vehicle.

21. **"Net Energy Change (NEC)"** means the net change in energy level of a RESS expressed in Joules (watt-seconds).

22. **"Propulsion energy"** means energy that is derived from the vehicle's consumable fuel and/or RESS to drive the wheels. If an energy source is supplying energy only to vehicle accessories (e.g., a 12-volt battery on a conventional vehicle), it is not acting as a source of propulsion energy.

23. **"Propulsion system"** means a system that, when started, provides propulsion for the vehicle in an amount proportional to what the driver commands.

24. **"Regenerative braking"** means deceleration of the bus caused by operating an electric motor-generator system. This act returns energy to the vehicle propulsion system and provides charge to the RESS or to operate on-board accessories.

25. **"Rechargeable Energy Storage System (RESS)"** means a component, or system of components, that stores energy and for which the supply of energy

is rechargeable by an electric motor-generator system, an off-vehicle electric energy source, or both. Examples of RESS for HEBs include batteries, capacitors, and electromechanical flywheels.

**26.** **"SOC"** See "Battery SOC".

**27.** **"SOC $_{delta}$"** means delta ampere-hours measured during a test.

**28.** **"SOC $_{final}$"** means SOC at the end of a test run (Ah, $V^2$, or $rpm^2$).

**29.** **"SOC $_{initial}$"** means SOC at the beginning of a test run (Ah, $V^2$, or $rpm^2$).

**30.** **"Total Fuel Energy"** means the total energy content of the fuel, in British Thermal Units (Btu) or kWh, consumed during a test as determined by carbon balance or other standard method and calculated based on the lower heating value of the fuel.

## C. Heavy-duty Hybrid-Electric Drive System Certification Requirements

Compliance with the heavy-duty hybrid-electric vehicle standards requires the development of an emission factor ratio for a heavy-duty hybrid-electric drive system with a certified baseline engine and comparison of the corresponding emissions with the applicable (e.g., urban bus or heavy-duty diesel or Otto-cycle engine) exhaust emission standards for a given engine by model year.

For model years 2004 through 2006, no more than two parties (i.e. the engine/turbine/fuel cell manufacturer and the hybrid-electric drive manufacturer) shall be granted an individual Executive Order identifying the emission standard achieved by the engine/turbine/fuel cell and the hybrid-electric drive system. For 2007 and subsequent model years, only one Executive Order shall be granted identifying the emission standard achieved by the hybrid-electric drive system.

**1. One Party Responsibility.** Where one party is responsible for emissions, an Executive Order shall be granted identifying the emission standard achieved by the HEB.

**1.1 Certification Standards.** All 2004 and subsequent model year HEBs shall, by model year, meet the exhaust emission standards or optional emission standards set forth in title 13, CCR, section 1956.1. The exhaust emissions for the hybrid-electric drive system of the HEB shall be determined in accordance with section D of this document. The certification standard for the hybrid-electric drive system shall be determined in accordance with section E of this document.

**2. Two Party Responsibility.** Where two parties are responsible for emissions, two Executive Orders shall be granted. One Executive Order shall be

granted to the engine/turbine/fuel cell manufacturer identifying the emission standard achieved and one Executive Order shall be granted to a second party identifying the emission standard of the hybrid-electric drive system.

**2.1 Certification Standards.** For model years 2004 through 2006, the heavy-duty engine, turbine, or fuel cell used as a motive source in a HEB shall, by model year and size, meet the exhaust emission standards or optional emission standards set forth in title 13, CCR, section 1956, 1956.1, 1956.7, or 1956.8. All 2004 and subsequent model year hybrid-electric drive systems shall, by model year, meet the exhaust emission standards or optional emission standards set forth in title 13, CCR, section 1956.1. The exhaust emissions for a hybrid-electric drive system shall be determined in accordance with section D of this document. The certification standard for the hybrid-electric drive system shall be determined in accordance with section E of this document.

**3. 25 Percent Reduction Claim.** For the 2004 through 2006 model years, hybrid-electric drive system manufacturers may claim a 25 percent reduction from the NOx certification standard of the engine or turbine incorporated as part of the hybrid-electric drive system in lieu of following the test procedures set forth in sections E and F. During that period, the Executive Officer may request the manufacturer to perform chassis testing of a HEB selecting this option in accordance with the test procedures in sections D and E. If testing data indicate a reduction of exhaust emissions of less than 25 percent, the HEB family shall receive that smaller reduction.

**4. Useful Life.** For the 2004 through 2006 model years, the useful life of the hybrid-electric drive system shall be 5 years or 150,000 miles, whichever comes first. After that time, the useful life of the hybrid-electric drive system shall meet the useful life requirements for urban transit buses as set forth in title 13, CCR, section 2112(20), as last amended October 24, 2002.

**5. Emissions Warranty.** For the 2004 and subsequent model years, the hybrid-electric drive system shall, by model year, meet the warranty requirements listed in title 13, CCR, sections 2035 and 2036, as last amended December 26, 1990 and May 15, 1999, respectively.

**6. Durability and Emission Testing.** An HEB family with less than 50 HEBs sold for the 2004 through 2006 model years shall be exempt from durability-data vehicle and emission-data vehicle testing. An HEB family in California with 50 or more HEBs sold, and any 2007 and subsequent model year HEB families shall meet the durability-data vehicle and emission-data vehicle testing as required in title 13, CCR, section 2111 et seq, as last amended December 28, 2000.

**7. Labeling Requirements.** The hybrid-electric drive system shall meet labeling requirements as set forth in title 13, CCR, section 1965, as

amended by the HDD TPs and the HDO TPs. In addition to the information required by those labeling requirements, the hybrid-electric drive system manufacturer shall also include the following information on the hybrid-electric drive system label:

**7.1** An unconditional statement of compliance with the appropriate model year California regulations; for example:

> "This vehicle (engine or hybrid-electric drive system, as applicable) conforms to California regulations applicable to [insert MY date] model year new, ___ (for 2004 and subsequent model years, specify heavy-duty Otto-cycle engines, heavy-duty diesel engines, or urban transit bus engine, as applicable)."

For federally certified vehicles certified for sale in California, the statement must include the phrase "conforms to U.S. EPA regulations and is certified for sale in California."

For 2004 and later model year hybrid-electric drive systems to be used in urban buses that incorporate an on-road heavy-duty diesel engine and are certified to the optional reduced-emission standards, the label shall contain the following statement in lieu of the above:

> "This hybrid-electric drive system conforms to California regulations applicable to [insert MY date] model year new urban bus engines and is certified to a NOx plus NMHC optional reduced-emission standard of [insert appropriate number] g/bhp-hr (for optional reduced-emission standards specify between 0.3 and 1.8, inclusive, at 0.3 g/bhp-hr increments), and a particulate matter standard of [insert appropriate number] g/bhp-hr (specify 0.03 g/bhp-hr, 0.02 g/bhp-hr, or 0.01 g/bhp-hr)."

**7.2** For 2004 and subsequent model year hybrid-electric drive systems used in urban transit buses, if the manufacturer is assigned an alternative useful life period by the Executive Officer, the label shall contain the statement:

> "This engine has been certified to meet California standards for a useful life period of [specify] years or [specify] miles of operation, whichever occurs first. This hybrid-electric drive system's actual life may vary depending on its service application."

The manufacturer may alter this statement only to express the assigned alternate useful life in terms other than years or miles (e.g., hours or miles only).

**7.3** For 2004 and subsequent model year hybrid-electric drive systems used in urban transit buses, the label shall contain the statement:

> "This hybrid-electric drive system has a primary intended service application as an urban transit bus engine. It is certified to the emission standards applicable to an urban transit bus."

**8. Engine Service Manuals and Equipment Maintenance Signals.** The hybrid-electric drive system manufacturer shall meet service manual and maintenance signal requirements as set forth in 40 CFR §86.004-38 (October 21, 1997) and §86.007-38 (January 18, 2001) as amended by the HDD TPs and the HDO TPs.

**9. Rebuild Provisions and Recordkeeping Requirement.** The heavy-duty engine rebuilding practices set forth in 40 CFR §86.004-40 (October 21, 1997) as amended in the HDD TPs and HDO TPs shall also apply to the hybrid-electric drive system.

**10. Information Requirements.** In addition to the requirements set forth in the HDD TPs and the HDO TPs, the certification application shall include the following:

**10.1** Identification and description of the hybrid-electric drive system covered by the application.

**10.2** Identification of the heavy-duty vehicle weight category to which the vehicle is certifying: light heavy-duty, medium heavy-duty, heavy-heavy duty, or urban transit bus; and the curb weight and gross vehicle weight rating of the vehicle.

**10.3** Identification and description of the propulsion system for the vehicle.

**10.4** Identification and description of the climate control system used on the vehicle.

**10.5** Projected number of heavy-duty hybrid-electric vehicles produced and delivered for sale in California.

**10.6** All information necessary for the proper and safe operation of the vehicle, including information on the safe handling of the battery system, emergency procedures to follow in the event of battery leakage, or other malfunctions that may affect the safety of the vehicle operator or laboratory personnel.

**10.7** Method for determining battery state-of-charge and any other relevant information as determined by the Executive Officer.

**11. Safety Procedures.** For 2004 and subsequent model years, a manufacturer shall conform to the requirements specified in title 13, CCR, division 2, chapter 6.5, articles 1, 3, and 8, inclusive.

## D. Hybrid-Electric Drive System Test Procedures

These test procedures incorporate by reference SAE J2711, "Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy-Duty Vehicles" (April 2002), as modified in these test procedures to apply to HEBs sold in California. For the 2004 through 2006 model years, heavy-duty hybrid-electric vehicles may follow these or equivalent procedures provided the manufacturer obtains prior written approval from the Executive Officer (EO).

The test procedure for determining compliance with standards applicable to the turbine or fuel cell used as the motive power in a hybrid-electric bus shall be determined by the Executive Officer on a case-by-case basis.

### 1. Chassis Dynamometer Test Preparations

**1.1 Test Site.** The ambient temperature levels encountered by the test vehicle shall be no less than 20 °C (68 °F) and no greater than 30 °C (86 °F). Ambient temperatures shall be recorded at the beginning and end of the test period. Adequate test site capabilities for safe venting and cooling of batteries, protection from exposure to high voltage, and any other necessary precaution shall be provided during testing. A fixed-speed fan shall direct cooling air to the vehicle to maintain the engine operating temperature as specified by the manufacturer during testing, and shall be operated only when the vehicle is in operation. Fans for brake cooling may be utilized during testing.

**1.2 Pre-Test Data Collection.** Vehicle demographics shall be recorded prior to testing including the vehicle identification number, gross vehicle weight (from vehicle data plate), curb weight (from vehicle data plate or by weighing), engine manufacturer, model year and type, engine serial number, engine displacement and number of cylinders, engine rated power and speed, tire size, transmission type, number of speeds, presence or absence of retarder, exhaust gas aftertreatment type, and rear axle ratio. Pre-test data shall also include details of the type, power, and speed of the electric motor(s); and type and capacity of the RESS.

**1.3 Fuel Specifications.** The test fuel shall meet the certification specifications set forth in the HDD TPs and HDO TPs.

**1.4 Vehicle Preparation.** Vehicle preparation and preconditioning shall be conducted in accordance with 40 CFR §86.1231-90 (April 11, 1989) and 40 CFR §86.1232-90 (April 11, 1989).

**1.4.1** Prior to testing, the vehicle shall be stabilized to a manufacturer-determined distance or to 4,000 miles.

**1.4.2** Vehicles shall be tested at curb weight plus driver weight and one half seated passenger load using a weight of 150 lbs per passenger.

**1.4.3** Manufacturer's recommended tires shall be used. Tire pressures shall be set at the beginning of the test at the pressure used to establish the dynamometer road-load coefficients and shall not exceed levels necessary for safe operation. Tires shall be conditioned as recommended by the vehicle manufacturer and shall be the same size as would be used in service.

**1.4.4** The vehicle lubricants normally specified by the manufacturer shall be used.

**1.4.5** The vehicle shall be driven with appropriate accelerator pedal movement to achieve the time-versus-speed relationship prescribed by the driving cycle. If test vehicles are equipped with manual transmission, the transmission shall be shifted in accordance with procedures that are representative of shift patterns that may reasonably be expected to be followed by vehicles in use.

**1.4.6** If the vehicle has a regenerative braking system, the vehicle shall be tested on the dynamometer with the identical control strategy as used in service. Vehicles equipped with an antilock braking system or traction control system may require modifications (i.e. defeat) to those systems during dynamometer testing to achieve normal operation of the regenerative braking system.

**1.4.7** If necessary, vehicles with air suspension may be aired up from an external source prior to testing. After the vehicle has reached sufficient air pressure to achieve proper suspension leveling and service brake operation, external air shall be disconnected from the vehicle and shall not be reconnected during emissions testing or between testing events during the key-off period.

**1.4.8** Off-vehicle charging shall be allowed only for the battery conditioning of charge-sustaining HEVs.

**1.5 Chassis Dynamometer Specifications.** The chassis dynamometer shall be capable of mimicking the transient inertial load, aerodynamic drag and rolling resistance associated with normal operations of heavy-duty vehicles. The transient inertial load shall be simulated using

appropriately sized flywheels or electronically controlled power absorbers. The driver shall be provided a visual display of the desired and actual vehicle speed to allow the driver to operate the vehicle on the prescribed cycle.

**1.5.1. Coastdown analysis.** The drag and rolling resistance shall be established as a function of vehicle speed as referenced in 40 CFR §1229-85 (October 6, 2000) or another appropriate method approved by the Executive Officer. The vehicle weight for the on-road coastdown shall be the same as the anticipated vehicle testing weight as simulated on the dynamometer. Vehicles equipped with regenerative braking systems that are activated at least in part when the brake pedal is not depressed shall have their regenerative braking systems disabled during the deceleration portion of coastdown testing, preferably through temporary software changes in the vehicle's control system

**1.6 Test Instrumentation.** Equipment referenced in 40 CFR §86.1301-90 (April 11, 1989) to 40 CFR §86.1326-90 (April 11, 1989) (including exhaust emissions sampling and analytical systems) shall be required for emissions measurements. All instrumentation shall be NIST-traceable (National Institute of Standards and Technology). The following instruments shall be required for as-needed usage: a DC wideband Ampere-hour meter with an integration period of less than 0.05 seconds if an integration technique is used; an instrument to measure a capacitor's voltage; an instrument to measure an electromechanical flywheel's rotational speed; an AC Watt-hour meter to measure AC Recharge Energy; and a voltmeter and ammeter. Tunnel flow volume shall be set at the minimum level possible for vehicles such that a carbon balance for fuel efficiency and a hydrocarbon balance for tunnel integrity can be performed accurately and the lowest possible detection limits can be determined. Emission levels that are determined to be below detection limit shall be cited as less than the detection limit value.

## 2. Chassis Dynamometer Test Procedure

**2.1 Vehicle Propulsion System Starting and Restarting.** The vehicle's propulsion system shall be started according to the manufacturer's recommended starting procedures in the owner's manual. Only equipment necessary to the primary propulsion of the vehicle during normal service shall be operated.

**2.2 Driving cycles.** Chassis testing shall include two separate test cycles as follows: one cold start and three hot start tests using the Orange County bus cycle (Appendix C); and one cold start and three hot start tests using the Urban Dynamometer Driving Schedule (UDDS) (40 CFR §86 Appendix I(d)) (April 29, 1998).

**2.2.1** During the interim certification period, the Executive Officer may request data from one cold start and three hot starts using the Central Business District (CBD) cycle which will not be used for certification.

**2.2.2** The applicant may request a substitution of one test cycle with one representative of specific transit fleet operation for approval of the Executive Officer.

**2.2.3** The test vehicle shall be operated through at least one preliminary run of the desired test cycles to familiarize the driver with vehicle operation and verify function of laboratory instrumentation.

**2.2.4** A cycle length of approximately 30 minutes shall be used for all chassis tests. For driving cycles less than 30 minutes in duration, repetitions of the cycle shall be run back-to-back for a total cycle length of approximately 30 minutes. Chassis tests shall also consist of a normalized condition prior to the test, including either a 12-hour cold soak or a warm-up followed by a 20- to 30-minute key-off period.

**2.2.5** If at any point during the test vehicle propulsion is not possible or the driver is warned by the vehicle to discontinue driving because the RESS energy supply is too low, the test shall be considered invalid.

### 2.3 Cold and Hot Emission Tests

**2.3.1** Cold start test cycles shall include all emission data from the moment the vehicle is started, including the actual start event. The vehicle shall be cold soaked for a minimum of 12 hours to ensure that all components are at ambient temperature. The vehicle shall remain in the key-off position for 30 minutes until testing begins. A separate vehicle or other equipment (e.g. electric heaters) as necessary shall be utilized to bring the dynamometer to operating temperature. The vehicle shall be started and idled for one minute, after which time the 30-minute test cycle shall commence. Emission measurements shall be taken from one minute before the vehicle is started through test cycle completion. At the end of the test cycle the vehicle shall be returned to the key-off condition.

**2.3.2** Hot test cycles shall include all emission data from the moment the vehicle is started, excluding the actual start event. The vehicle shall be started and warmed to operating temperature utilizing the same test cycle that will be used for emission characterization. Multiple back-to-back hot test events must include a 20- to 30- minute key-off condition in between each test event. Once the vehicle is at operating temperature the vehicle shall be turned off and will remain in the key-off position for approximately 20 to 30 minutes. The vehicle shall be restarted and idled for one minute, at which time the 30-minute test cycle

shall begin and emission measurements will be taken. At the end of the test cycle the vehicle shall be returned to the key-off condition.

**2.4 Intra-test Pauses.** Between two test events, the vehicle shall remain with the key switch in the key-off position for 20 to 30 minutes, with the engine enclosure closed and the brake pedal not depressed.

**2.5 Test Termination.** The test shall be terminated at the conclusion of the test run. If necessary, a one-minute idle may be added at the end of the test cycle before termination for collection of emissions remaining in the sampling train.

**2.6 Data Recording.**

**2.6.1** The emissions from the vehicle exhaust shall be ducted to a full-scale dilution tunnel where the gaseous emissions of hydrocarbons, carbon monoxide, oxides of nitrogen (both nitric oxide and nitrogen dioxide) and carbon dioxide shall be measured on a continual basis at a frequency of 5 Hz or greater. An integrated bag sample of the dilution tunnel may be collected and analyzed for carbon monoxide and carbon dioxide levels, and these may be compared to the continuous measurements for carbon monoxide and carbon dioxide as a quality assurance check. Modal results must be within five percent of bag sample results for modal results to be used. Alternatively, the measured values for carbon monoxide and carbon dioxide may be obtained from the integrated bag sample. Particulate matter shall be measured gravimetrically using fluorocarbon-coated glass fiber filters by weighing the filters before and after testing. Filters shall be conditioned to temperature and humidity conditions as specified in 40 CFR §86.1312-88 (September 5, 1997).

**2.6.2** For each constituent, a background sample using the same sampling train as used during the emission testing shall be measured before and after the emission test, and the background correction shall be performed as specified by 40 CFR §86.1343-88 (September 5, 1997). For a compressed natural gas-fueled vehicle, and in cases where non-methane hydrocarbons are a species of interest, the integrated methane and non-methane content of hydrocarbons shall be measured, using gas chromatography analysis of integrated bag samples for each run. If necessary, the tunnel inlet may be filtered for PM with a HEPA filter to aid in lowering the detection limits.

**2.6.3** Fuel consumed shall be determined by carbon balance from the analytical instruments, and the number of dynamometer roll revolutions shall be used to determine the distance traveled during the driving cycles.

**2.6.4** SOC of the vehicle shall be measured continuously (at a rate of 1Hz or greater) and recorded throughout the entire test. Recorded data shall then be time integrated against the emission measurement data at the beginning

and end of the test to coincide with the emission measurement portion of the chassis test. Provided the SOC is measured, time sequenced and integrated in accordance with the procedures in this document, only the beginning and ending SOC values are necessary in the final test report. Both Ah and system voltage shall be recorded during the test, as outlined in the method for determining NEC.

**3. Final Report.**

**3.1 Exhaust Emissions and FE.** The exhaust emissions and fuel economy of the vehicle shall be reported in grams per mile and miles per diesel equivalent gallon, respectively. Total fuel energy shall be reported in British Thermal Units (Btu).

**3.1.1** Calculations for exhaust emissions are referenced in 40 CFR §86.1342-90 (September 5, 1997) with the following revision to paragraph (a):

$$A_{WM} = (1/7)(Y_C/D_C) + (6/7)(Y_H/D_H)$$

Where:

$A_{WM}$ = Weighted mass emission level in grams per vehicle mile

$Y_C$ = Mass emissions from the cold start test in grams

$Y_H$ = Averaged mass emissions from the hot start tests in grams

$D_C$ = Measured driving distance from the cold start test in miles

$D_H$ = Averaged measured driving distance from the hot start tests in miles

**3.2 SOC Difference.** The state of charge difference of the RESS shall be measured during the test and reported along with the RESS NEC.

**3.3 Net Energy Change (NEC).** NEC calculations for batteries, capacitors, and electromechanical flywheels are listed below.

**3.3.1 Batteries.** Either of two equations may be used to calculate the NEC for batteries:

(1) $$\mathbf{NEC = [SOC_{final} - SOC_{initial}] * V_{system} * K_1}$$

where

SOC = Battery SOC at the beginning and end of the test run, in Ampere-hours (Ah). If the $SOC_{final}$ and $SOC_{initial}$ values are in amp-seconds, the conversion factor is not used.

$V_{system}$ = Battery's DC nominal system voltage as specified by the manufacturer, in volts (V)

K1 = Conversion factor = 3600 (seconds/hour; not used if $SOC_{final}$ and $SOC_{initial}$ values are in seconds)

or,

(2) $\mathbf{NEC = SOC_{delta} * V_{system} * K_1}$

where

$SOC_{delta}$ = Delta Ampere-hours during a test

$V_{system}$ = Battery's DC nominal system voltage as specified by the manufacturer, in volts (V)

$K_1$ = Conversion factor = 3600 (seconds/hour; not used if $SOC_{final}$ and $SOC_{initial}$ values are in seconds)

**3.3.2 Capacitors.** The following equation calculates NEC for capacitors:

$$\mathbf{NEC = (C/2) * [SOC_{final} - SOC_{initial}]}$$

where

SOC = The capacitor SOC at the beginning and end of the test run, in $(V)^2$

C = Rated capacitance of the capacitor as specified by the manufacturer, in Farads (F)

**3.3.3 Electromechanical Flywheels.** The following equation shall be used to calculate NEC for electromechanical flywheels:

$$\mathbf{NEC = (1/2) * I * [SOC_{final} - SOC_{initial}] * K_2}$$

where

SOC = Flywheel state-of-charge at the beginning and end of the test run, in $(rpm)^2$

I = Rated moment of inertia of the flywheel system, in kilogram-meter$^2$ (kg-m$^2$)

$K_2$= Conversion factor = $4\pi^2/3600$ (rad$^2$/sec$^2$/rpm$^2$)

**3.4 NEC Variance Determination.**

**3.4.1 Total Fuel Energy.** Total fuel energy is the energy value of the fuel consumed by the internal combustion engine, turbine, or fuel cell during the test and shall be calculated using the following equation:

**Total Fuel Energy = $NHV_{fuel}$ * $m_{fuel}$**

where

$NHV_{fuel}$ = Net heating value (per consumable fuel analysis as specified by ASTM) in Joules per kilogram (J/kg)

$M_{fuel}$ = Total mass of fuel consumed over test, in kilograms (kg)

**3.4.2 Total Cycle Energy.** The total cycle energy shall be reported in watt-seconds or converted to kWh.

**Total Cycle Energy = Total Fuel Energy – NEC**

**3.4.3 Determination Procedure.** To determine if a test run has an acceptable NEC, divide NEC by total cycle energy. If the absolute value of the calculation yields a number less than or equal to 2%, as shown in the equation below, the NEC variance is within tolerance levels.

**(NEC/total cycle energy) * 100% $\leq$ 2%**

Test runs with NEC variance greater than +/- 2% shall be considered invalid.

**3.5 Final Test Report.** The final test report shall include all measured parameters, including vehicle configuration, vehicle statistics, test cycles, measured parameters and calculated test results.

**4. Charge-Depleting Hybrid-Electric Vehicles.**
Modifications to this procedure for measuring fuel economy and emissions of charge-depleting heavy-duty hybrid-electric vehicles may be made upon approval of the Executive Officer.

**5. Conventional Drivetrain Urban Transit Buses.** Modifications to this hybrid-electric drive system procedure for measuring fuel economy and emissions of conventional drivetrain urban transit buses may be made upon approval of the Executive Officer.

## E. Certification by Emission Factor Ratio Application

The applicant shall provide both engine and vehicle test results when using the following procedure. Engine test results shall be obtained from an engine manufacturer who has complied with the HDD TPs, HDO TPs, or alternative procedures approved by the Executive Officer. Vehicle test results shall be obtained from the party certifying the hybrid-electric drive system in accordance with the procedures set forth in Section D of this document. An emission factor shall be calculated from the two results to determine the emissions reduction achieved by the hybrid-electric drive system.

**1. Emission Factor.** An emissions factor shall be calculated by following equation:

$$\mathbf{EF} = \frac{\textbf{Vehicle NOx (g/mi)}}{\textbf{Engine NOx (g/bhp-hr)}}$$

where

EF = emission factor of the vehicle in bhp-hr/mi

Vehicle NOx = weighted mass emissions level of NOx determined from chassis dynamometer testing in g/mi

Engine NOx = weighted mass emissions level of NOx determined from engine dynamometer testing in g/bhp-hr

Emission factors shall be calculated for HEBs and for baseline urban transit buses. The baseline urban transit bus shall be selected by the Executive Officer and tested by the Air Resources Board. The resulting data will be available for use by manufacturers applying for certification.

**2. Emission Factor Ratio.** An emission factor ratio shall be calculated by the following equation:

$$\mathbf{EFR} = \frac{\mathbf{EF_{hybrid}}}{\mathbf{EF_{baseline}}}$$

where

EFR = emission factor ratio

$EF_{hybrid}$ = emission factor calculated for a hybrid-electric urban transit bus

$EF_{baseline}$ = emission factor calculated for a baseline urban transit bus

**3. Application of Emission Factor Ratio for Hybrid-Electric Bus Certification.** The NOx certification value for a hybrid-electric bus shall be calculated by applying the following equation:

$$\mathbf{HEB_{cert} = EFR * Engine\ NOx}$$

where

$HEB_{cert}$ = hybrid-electric bus NOx certification value in g/bhp-hr

EFR = emission factor ratio

Engine NOx = weighted mass emissions level of NOx determined from engine dynamometer testing in g/bhp-hr

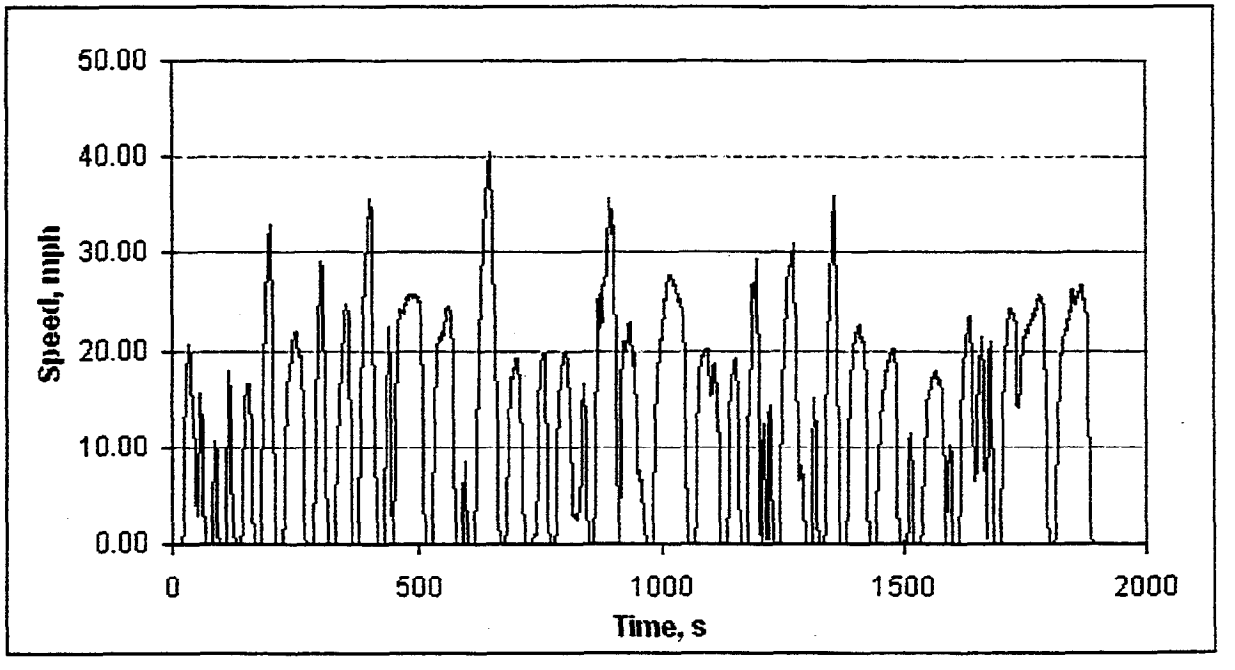
# APPENDIX C

## ORANGE COUNTY BUS CYCLE

The Orange County Bus Cycle is a chassis dynamometer test for heavy-duty vehicles. The driving cycle was developed by West Virginia University based on real bus operating data from the Orange County Transportation Authority. It is an intermediate speed test cycle consisting of accelerations, decelerations and cruise operations reflective of transit bus use.

Variable speed over the duration of the cycle is illustrated in Figure 1. A speed versus time sequence is also provided.

**Figure 1. Orange County Bus Cycle**



| Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) |
|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 46 | 10.72 | 91 | 2.24 | 136 | 0.00 |
| 2 | 0.00 | 47 | 9.87 | 92 | 1.28 | 137 | 0.00 |
| 3 | 0.00 | 48 | 8.63 | 93 | 0.53 | 138 | 0.00 |
| 4 | 0.00 | 49 | 6.00 | 94 | 0.13 | 139 | 0.00 |
| 5 | 0.00 | 50 | 3.19 | 95 | 0.00 | 140 | 0.19 |
| 6 | 0.00 | 51 | 2.91 | 96 | 0.00 | 141 | 1.25 |
| 7 | 0.00 | 52 | 4.25 | 97 | 0.00 | 142 | 3.29 |
| 8 | 0.00 | 53 | 5.96 | 98 | 0.00 | 143 | 5.97 |
| 9 | 0.00 | 54 | 7.92 | 99 | 0.00 | 144 | 8.57 |
| 10 | 0.00 | 55 | 10.06 | 100 | 0.00 | 145 | 10.25 |
| 11 | 0.00 | 56 | 12.32 | 101 | 0.00 | 146 | 11.70 |
| 12 | 0.00 | 57 | 14.65 | 102 | 0.00 | 147 | 12.95 |
| 13 | 0.00 | 58 | 15.54 | 103 | 0.00 | 148 | 14.05 |
| 14 | 0.00 | 59 | 14.56 | 104 | 0.00 | 149 | 15.04 |
| 15 | 0.00 | 60 | 13.20 | 105 | 0.00 | 150 | 15.50 |
| 16 | 0.00 | 61 | 11.98 | 106 | 0.00 | 151 | 15.55 |
| 17 | 0.00 | 62 | 9.60 | 107 | 0.00 | 152 | 15.57 |
| 18 | 0.00 | 63 | 7.10 | 108 | 0.30 | 153 | 15.98 |
| 19 | 0.00 | 64 | 4.64 | 109 | 1.95 | 154 | 16.32 |
| 20 | 0.00 | 65 | 1.77 | 110 | 5.05 | 155 | 16.47 |
| 21 | 0.24 | 66 | 0.46 | 111 | 8.07 | 156 | 16.23 |
| 22 | 1.25 | 67 | 0.12 | 112 | 10.95 | 157 | 15.70 |
| 23 | 3.56 | 68 | 0.00 | 113 | 13.52 | 158 | 14.69 |
| 24 | 6.20 | 69 | 0.00 | 114 | 15.81 | 159 | 13.89 |
| 25 | 8.81 | 70 | 0.00 | 115 | 17.83 | 160 | 13.04 |
| 26 | 11.40 | 71 | 0.00 | 116 | 17.84 | 161 | 10.81 |
| 27 | 13.74 | 72 | 0.00 | 117 | 15.86 | 162 | 7.43 |
| 28 | 15.89 | 73 | 0.00 | 118 | 13.43 | 163 | 3.53 |
| 29 | 17.26 | 74 | 0.00 | 119 | 10.92 | 164 | 1.59 |
| 30 | 18.15 | 75 | 0.00 | 120 | 8.66 | 165 | 0.54 |
| 31 | 19.06 | 76 | 0.00 | 121 | 6.70 | 166 | 0.00 |
| 32 | 19.94 | 77 | 0.00 | 122 | 4.61 | 167 | 0.00 |
| 33 | 20.59 | 78 | 0.00 | 123 | 3.01 | 168 | 0.00 |
| 34 | 20.59 | 79 | 0.00 | 124 | 2.02 | 169 | 0.00 |
| 35 | 20.08 | 80 | 0.00 | 125 | 1.29 | 170 | 0.00 |
| 36 | 19.44 | 81 | 0.59 | 126 | 0.56 | 171 | 0.00 |
| 37 | 18.70 | 82 | 2.37 | 127 | 0.00 | 172 | 0.00 |
| 38 | 17.82 | 83 | 4.85 | 128 | 0.00 | 173 | 0.00 |
| 39 | 16.92 | 84 | 7.09 | 129 | 0.00 | 174 | 0.00 |
| 40 | 15.99 | 85 | 8.88 | 130 | 0.00 | 175 | 0.00 |
| 41 | 15.15 | 86 | 10.35 | 131 | 0.00 | 176 | 0.00 |
| 42 | 14.27 | 87 | 10.77 | 132 | 0.00 | 177 | 0.00 |
| 43 | 13.39 | 88 | 9.25 | 133 | 0.00 | 178 | 0.00 |
| 44 | 12.46 | 89 | 6.14 | 134 | 0.00 | 179 | 0.10 |
| 45 | 11.58 | 90 | 3.74 | 135 | 0.00 | 180 | 0.97 |

| Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) |
|---|---|---|---|---|---|---|---|
| 181 | 4.10 | 226 | 1.88 | 271 | 0.00 | 316 | 0.00 |
| 182 | 7.67 | 227 | 4.14 | 272 | 0.00 | 317 | 0.00 |
| 183 | 10.50 | 228 | 6.64 | 273 | 0.00 | 318 | 0.00 |
| 184 | 13.15 | 229 | 9.10 | 274 | 0.00 | 319 | 0.00 |
| 185 | 15.57 | 230 | 11.29 | 275 | 0.00 | 320 | 0.00 |
| 186 | 17.64 | 231 | 12.56 | 276 | 0.00 | 321 | 0.00 |
| 187 | 19.46 | 232 | 13.63 | 277 | 0.00 | 322 | 0.00 |
| 188 | 21.048 | 233 | 14.76 | 278 | 0.00 | 323 | 0.00 |
| 189 | 22.45 | 234 | 15.75 | 279 | 0.00 | 324 | 0.00 |
| 190 | 23.82 | 235 | 16.43 | 280 | 0.00 | 325 | 0.00 |
| 191 | 25.03 | 236 | 17.03 | 281 | 0.00 | 326 | 0.00 |
| 192 | 26.23 | 237 | 17.59 | 282 | 0.00 | 327 | 0.00 |
| 193 | 27.47 | 238 | 18.06 | 283 | 0.17 | 328 | 0.15 |
| 194 | 28.58 | 239 | 18.43 | 284 | 0.49 | 329 | 1.30 |
| 195 | 29.64 | 240 | 18.97 | 285 | 1.01 | 330 | 4.11 |
| 196 | 30.61 | 241 | 19.61 | 286 | 1.76 | 331 | 6.81 |
| 197 | 31.62 | 242 | 20.06 | 287 | 2.73 | 332 | 8.63 |
| 198 | 32.59 | 243 | 20.60 | 288 | 4.75 | 333 | 10.15 |
| 199 | 33.03 | 244 | 20.99 | 289 | 7.43 | 334 | 11.53 |
| 200 | 31.78 | 245 | 21.24 | 290 | 10.08 | 335 | 12.73 |
| 201 | 29.22 | 246 | 21.42 | 291 | 12.75 | 336 | 13.70 |
| 202 | 26.44 | 247 | 21.68 | 292 | 15.43 | 337 | 14.42 |
| 203 | 23.16 | 248 | 21.80 | 293 | 17.79 | 338 | 15.17 |
| 204 | 19.30 | 249 | 21.81 | 294 | 19.89 | 339 | 16.06 |
| 205 | 15.80 | 250 | 21.77 | 295 | 21.82 | 340 | 16.98 |
| 206 | 12.55 | 251 | 21.58 | 296 | 23.46 | 341 | 17.80 |
| 207 | 8.14 | 252 | 21.17 | 297 | 25.10 | 342 | 18.62 |
| 208 | 4.51 | 253 | 20.77 | 298 | 26.59 | 343 | 19.41 |
| 209 | 1.95 | 254 | 20.33 | 299 | 27.92 | 344 | 20.15 |
| 210 | 0.42 | 255 | 20.06 | 300 | 28.77 | 345 | 20.97 |
| 211 | 0.14 | 256 | 19.78 | 301 | 29.08 | 346 | 21.70 |
| 212 | 0.00 | 257 | 19.55 | 302 | 28.66 | 347 | 22.43 |
| 213 | 0.00 | 258 | 19.48 | 303 | 26.98 | 348 | 23.15 |
| 214 | 0.00 | 259 | 19.40 | 304 | 25.19 | 349 | 23.78 |
| 215 | 0.00 | 260 | 19.16 | 305 | 23.35 | 350 | 24.29 |
| 216 | 0.00 | 261 | 18.77 | 306 | 21.44 | 351 | 24.71 |
| 217 | 0.00 | 262 | 18.20 | 307 | 19.34 | 352 | 24.86 |
| 218 | 0.00 | 263 | 17.00 | 308 | 16.64 | 353 | 24.58 |
| 219 | 0.00 | 264 | 15.63 | 309 | 13.18 | 354 | 24.01 |
| 220 | 0.00 | 265 | 13.45 | 310 | 9.97 | 355 | 23.57 |
| 221 | 0.00 | 266 | 9.86 | 311 | 6.82 | 356 | 23.00 |
| 222 | 0.00 | 267 | 6.06 | 312 | 4.08 | 357 | 20.96 |
| 223 | 0.00 | 268 | 1.76 | 313 | 1.60 | 358 | 17.55 |
| 224 | 0.00 | 269 | 0.10 | 314 | 0.25 | 359 | 13.88 |
| 225 | 0.51 | 270 | 0.00 | 315 | 0.10 | 360 | 9.77 |

| Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) |
|---|---|---|---|---|---|---|---|
| 361 | 4.83 | 406 | 21.06 | 451 | 10.43 | 496 | 25.53 |
| 362 | 1.11 | 407 | 17.75 | 452 | 12.87 | 497 | 25.51 |
| 363 | 0.10 | 408 | 14.31 | 453 | 15.18 | 498 | 25.41 |
| 364 | 0.00 | 409 | 11.47 | 454 | 17.25 | 499 | 25.31 |
| 365 | 0.00 | 410 | 8.69 | 455 | 19.24 | 500 | 25.21 |
| 366 | 0.00 | 411 | 6.05 | 456 | 20.95 | 501 | 25.07 |
| 367 | 0.00 | 412 | 3.25 | 457 | 22.18 | 502 | 24.89 |
| 368 | 0.00 | 413 | 1.05 | 458 | 22.78 | 503 | 24.44 |
| 369 | 0.00 | 414 | 0.10 | 459 | 23.18 | 504 | 23.27 |
| 370 | 0.00 | 415 | 0.00 | 460 | 23.45 | 505 | 20.81 |
| 371 | 0.00 | 416 | 0.00 | 461 | 23.78 | 506 | 17.79 |
| 372 | 0.00 | 417 | 0.00 | 462 | 24.06 | 507 | 14.56 |
| 373 | 0.00 | 418 | 0.00 | 463 | 24.23 | 508 | 11.63 |
| 374 | 0.00 | 419 | 0.00 | 464 | 24.14 | 509 | 8.63 |
| 375 | 0.00 | 420 | 0.00 | 465 | 24.01 | 510 | 5.17 |
| 376 | 0.98 | 421 | 0.00 | 466 | 23.97 | 511 | 2.32 |
| 377 | 4.21 | 422 | 0.00 | 467 | 23.94 | 512 | 0.88 |
| 378 | 7.76 | 423 | 0.00 | 468 | 23.91 | 513 | 0.18 |
| 379 | 10.46 | 424 | 0.00 | 469 | 23.86 | 514 | 0.00 |
| 380 | 12.82 | 425 | 0.00 | 470 | 24.00 | 515 | 0.00 |
| 381 | 14.99 | 426 | 0.00 | 471 | 24.31 | 516 | 0.00 |
| 382 | 16.95 | 427 | 0.22 | 472 | 24.46 | 517 | 0.00 |
| 383 | 18.83 | 428 | 1.54 | 473 | 24.75 | 518 | 0.00 |
| 384 | 20.66 | 429 | 5.20 | 474 | 24.97 | 519 | 0.00 |
| 385 | 22.18 | 430 | 8.85 | 475 | 25.21 | 520 | 0.00 |
| 386 | 23.58 | 431 | 11.89 | 476 | 25.30 | 521 | 0.00 |
| 387 | 24.76 | 432 | 14.23 | 477 | 25.37 | 522 | 0.00 |
| 388 | 25.93 | 433 | 15.64 | 478 | 25.38 | 523 | 0.00 |
| 389 | 27.11 | 434 | 16.72 | 479 | 25.35 | 524 | 0.00 |
| 390 | 28.19 | 435 | 18.02 | 480 | 25.22 | 525 | 0.00 |
| 391 | 29.30 | 436 | 19.39 | 481 | 25.25 | 526 | 0.13 |
| 392 | 30.35 | 437 | 21.08 | 482 | 25.42 | 527 | 0.98 |
| 393 | 31.25 | 438 | 22.44 | 483 | 25.63 | 528 | 3.09 |
| 394 | 32.14 | 439 | 21.47 | 484 | 25.82 | 529 | 5.66 |
| 395 | 32.97 | 440 | 19.17 | 485 | 25.68 | 530 | 8.35 |
| 396 | 33.54 | 441 | 15.77 | 486 | 25.65 | 531 | 10.93 |
| 397 | 33.73 | 442 | 11.90 | 487 | 25.59 | 532 | 13.38 |
| 398 | 34.12 | 443 | 7.88 | 488 | 25.54 | 533 | 15.09 |
| 399 | 34.77 | 444 | 4.77 | 489 | 25.67 | 534 | 15.82 |
| 400 | 35.52 | 445 | 1.84 | 490 | 25.70 | 535 | 16.56 |
| 401 | 35.67 | 446 | 0.28 | 491 | 25.66 | 536 | 17.45 |
| 402 | 34.38 | 447 | 0.67 | 492 | 25.62 | 537 | 18.41 |
| 403 | 31.49 | 448 | 2.68 | 493 | 25.58 | 538 | 19.32 |
| 404 | 28.21 | 449 | 5.26 | 494 | 25.58 | 539 | 20.20 |
| 405 | 24.55 | 450 | 7.85 | 495 | 25.58 | 540 | 20.85 |

| Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) |
|---|---|---|---|---|---|---|---|
| 541 | 21.10 | 586 | 0.00 | 631 | 30.21 | 676 | 0.23 |
| 542 | 21.27 | 587 | 0.00 | 632 | 31.26 | 677 | 1.15 |
| 543 | 21.18 | 588 | 0.10 | 633 | 32.15 | 678 | 2.40 |
| 544 | 21.05 | 589 | 0.69 | 634 | 33.05 | 679 | 3.70 |
| 545 | 21.09 | 590 | 3.05 | 635 | 33.82 | 680 | 4.77 |
| 546 | 21.39 | 591 | 4.99 | 636 | 34.61 | 681 | 5.87 |
| 547 | 21.69 | 592 | 7.09 | 637 | 35.42 | 682 | 7.47 |
| 548 | 21.79 | 593 | 8.45 | 638 | 36.09 | 683 | 9.14 |
| 549 | 21.65 | 594 | 7.24 | 639 | 36.80 | 684 | 10.76 |
| 550 | 21.65 | 595 | 5.60 | 640 | 37.38 | 685 | 12.15 |
| 551 | 21.90 | 596 | 4.43 | 641 | 38.05 | 686 | 13.41 |
| 552 | 22.23 | 597 | 3.20 | 642 | 38.68 | 687 | 14.41 |
| 553 | 22.59 | 598 | 1.72 | 643 | 39.34 | 688 | 15.42 |
| 554 | 22.94 | 599 | 0.49 | 644 | 39.86 | 689 | 16.09 |
| 555 | 23.42 | 600 | 0.15 | 645 | 40.41 | 690 | 16.48 |
| 556 | 23.75 | 601 | 0.00 | 646 | 40.63 | 691 | 16.89 |
| 557 | 24.02 | 602 | 0.00 | 647 | 39.81 | 692 | 17.21 |
| 558 | 24.17 | 603 | 0.00 | 648 | 37.98 | 693 | 17.51 |
| 559 | 24.36 | 604 | 0.00 | 649 | 35.89 | 694 | 17.79 |
| 560 | 24.42 | 605 | 0.00 | 650 | 33.71 | 695 | 18.00 |
| 561 | 24.39 | 606 | 0.00 | 651 | 31.62 | 696 | 18.26 |
| 562 | 24.27 | 607 | 0.00 | 652 | 29.47 | 697 | 18.47 |
| 563 | 23.93 | 608 | 0.00 | 653 | 28.02 | 698 | 18.66 |
| 564 | 23.50 | 609 | 0.00 | 654 | 26.56 | 699 | 18.86 |
| 565 | 22.84 | 610 | 0.00 | 655 | 24.67 | 700 | 19.03 |
| 566 | 22.15 | 611 | 0.00 | 656 | 22.02 | 701 | 19.16 |
| 567 | 21.59 | 612 | 0.00 | 657 | 19.47 | 702 | 19.29 |
| 568 | 20.98 | 613 | 0.23 | 658 | 16.04 | 703 | 18.98 |
| 569 | 19.71 | 614 | 0.54 | 659 | 12.49 | 704 | 18.40 |
| 570 | 16.83 | 615 | 1.76 | 660 | 8.90 | 705 | 17.91 |
| 571 | 12.46 | 616 | 4.18 | 661 | 5.63 | 706 | 17.48 |
| 572 | 8.45 | 617 | 7.07 | 662 | 2.86 | 707 | 17.14 |
| 573 | 4.85 | 618 | 9.64 | 663 | 0.73 | 708 | 16.77 |
| 574 | 1.82 | 619 | 12.10 | 664 | 0.00 | 709 | 16.13 |
| 575 | 0.51 | 620 | 14.59 | 665 | 0.00 | 710 | 14.16 |
| 576 | 0.00 | 621 | 16.80 | 666 | 0.00 | 711 | 11.96 |
| 577 | 0.00 | 622 | 18.71 | 667 | 0.00 | 712 | 9.78 |
| 578 | 0.00 | 623 | 20.45 | 668 | 0.00 | 713 | 7.44 |
| 579 | 0.00 | 624 | 22.03 | 669 | 0.00 | 714 | 4.90 |
| 580 | 0.00 | 625 | 23.45 | 670 | 0.00 | 715 | 2.52 |
| 581 | 0.00 | 626 | 24.75 | 671 | 0.00 | 716 | 0.89 |
| 582 | 0.00 | 627 | 25.97 | 672 | 0.00 | 717 | 0.13 |
| 583 | 0.00 | 628 | 27.01 | 673 | 0.00 | 718 | 0.10 |
| 584 | 0.00 | 629 | 28.09 | 674 | 0.00 | 719 | 0.00 |
| 585 | 0.00 | 630 | 29.16 | 675 | 0.00 | 720 | 0.00 |

| Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) |
|---|---|---|---|---|---|---|---|
| 721 | 0.00 | 766 | 3.80 | 811 | 13.80 | 856 | 0.00 |
| 722 | 0.00 | 767 | 2.48 | 812 | 12.31 | 857 | 0.00 |
| 723 | 0.00 | 768 | 0.75 | 813 | 10.67 | 858 | 0.00 |
| 724 | 0.00 | 769 | 0.00 | 814 | 9.42 | 859 | 0.00 |
| 725 | 0.00 | 770 | 0.00 | 815 | 8.09 | 860 | 0.00 |
| 726 | 0.00 | 771 | 0.00 | 816 | 6.60 | 861 | 0.00 |
| 727 | 0.00 | 772 | 0.00 | 817 | 4.86 | 862 | 0.54 |
| 728 | 0.00 | 773 | 0.00 | 818 | 3.61 | 863 | 3.28 |
| 729 | 0.00 | 774 | 0.00 | 819 | 3.14 | 864 | 7.30 |
| 730 | 0.00 | 775 | 0.00 | 820 | 2.88 | 865 | 10.56 |
| 731 | 0.12 | 776 | 0.00 | 821 | 2.68 | 866 | 13.49 |
| 732 | 0.25 | 777 | 0.00 | 822 | 2.69 | 867 | 16.27 |
| 733 | 0.35 | 778 | 0.00 | 823 | 2.63 | 868 | 18.74 |
| 734 | 0.64 | 779 | 0.00 | 824 | 2.60 | 869 | 20.88 |
| 735 | 0.84 | 780 | 0.00 | 825 | 2.53 | 870 | 22.68 |
| 736 | 0.90 | 781 | 0.20 | 826 | 2.50 | 871 | 24.44 |
| 737 | 0.90 | 782 | 1.17 | 827 | 2.50 | 872 | 25.78 |
| 738 | 0.97 | 783 | 3.18 | 828 | 2.68 | 873 | 25.65 |
| 739 | 1.00 | 784 | 5.67 | 829 | 3.56 | 874 | 23.71 |
| 740 | 1.00 | 785 | 8.18 | 830 | 4.35 | 875 | 22.31 |
| 741 | 0.90 | 786 | 10.53 | 831 | 4.18 | 876 | 22.38 |
| 742 | 1.25 | 787 | 12.74 | 832 | 3.90 | 877 | 22.83 |
| 743 | 2.75 | 788 | 13.65 | 833 | 4.78 | 878 | 23.59 |
| 744 | 4.99 | 789 | 14.22 | 834 | 6.24 | 879 | 24.69 |
| 745 | 7.46 | 790 | 15.16 | 835 | 8.05 | 880 | 26.00 |
| 746 | 9.89 | 791 | 16.25 | 836 | 10.04 | 881 | 26.52 |
| 747 | 12.32 | 792 | 17.30 | 837 | 12.05 | 882 | 26.83 |
| 748 | 14.63 | 793 | 17.78 | 838 | 13.79 | 883 | 26.76 |
| 749 | 16.26 | 794 | 18.13 | 839 | 15.31 | 884 | 26.94 |
| 750 | 17.26 | 795 | 18.28 | 840 | 16.28 | 885 | 27.28 |
| 751 | 18.12 | 796 | 18.60 | 841 | 16.43 | 886 | 27.91 |
| 752 | 18.65 | 797 | 18.76 | 842 | 15.75 | 887 | 28.83 |
| 753 | 19.08 | 798 | 18.97 | 843 | 14.64 | 888 | 29.94 |
| 754 | 19.41 | 799 | 19.18 | 844 | 13.99 | 889 | 30.98 |
| 755 | 19.40 | 800 | 19.41 | 845 | 12.32 | 890 | 31.95 |
| 756 | 19.45 | 801 | 19.59 | 846 | 9.35 | 891 | 32.94 |
| 757 | 19.72 | 802 | 19.82 | 847 | 5.15 | 892 | 33.94 |
| 758 | 19.58 | 803 | 19.90 | 848 | 1.08 | 893 | 34.88 |
| 759 | 19.16 | 804 | 19.78 | 849 | 0.15 | 894 | 35.68 |
| 760 | 17.98 | 805 | 19.55 | 850 | 0.00 | 895 | 35.46 |
| 761 | 16.57 | 806 | 19.16 | 851 | 0.00 | 896 | 34.15 |
| 762 | 15.00 | 807 | 18.69 | 852 | 0.00 | 897 | 32.48 |
| 763 | 11.56 | 808 | 18.43 | 853 | 0.00 | 898 | 31.94 |
| 764 | 8.14 | 809 | 17.38 | 854 | 0.00 | 899 | 32.13 |
| 765 | 5.22 | 810 | 15.50 | 855 | 0.00 | 900 | 32.51 |

| Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) |
|---|---|---|---|---|---|---|---|
| 901 | 32.83 | 946 | 18.80 | 991 | 14.91 | 1036 | 25.22 |
| 902 | 31.85 | 947 | 16.84 | 992 | 16.04 | 1037 | 25.07 |
| 903 | 29.25 | 948 | 14.77 | 993 | 17.05 | 1038 | 25.13 |
| 904 | 26.18 | 949 | 12.63 | 994 | 17.84 | 1039 | 25.14 |
| 905 | 22.75 | 950 | 10.51 | 995 | 18.37 | 1040 | 24.94 |
| 906 | 19.47 | 951 | 8.47 | 996 | 18.98 | 1041 | 24.73 |
| 907 | 16.14 | 952 | 7.22 | 997 | 19.61 | 1042 | 24.49 |
| 908 | 12.37 | 953 | 7.35 | 998 | 20.25 | 1043 | 24.23 |
| 909 | 8.44 | 954 | 7.57 | 999 | 20.82 | 1044 | 23.82 |
| 910 | 5.04 | 955 | 7.59 | 1000 | 21.13 | 1045 | 23.19 |
| 911 | 2.12 | 956 | 7.25 | 1001 | 21.40 | 1046 | 22.60 |
| 912 | 0.33 | 957 | 6.50 | 1002 | 21.78 | 1047 | 21.78 |
| 913 | 0.36 | 958 | 6.48 | 1003 | 22.31 | 1048 | 20.49 |
| 914 | 2.46 | 959 | 6.12 | 1004 | 22.87 | 1049 | 17.80 |
| 915 | 6.28 | 960 | 5.26 | 1005 | 23.38 | 1050 | 15.09 |
| 916 | 9.40 | 961 | 4.55 | 1006 | 23.79 | 1051 | 12.18 |
| 917 | 12.00 | 962 | 4.04 | 1007 | 24.25 | 1052 | 8.33 |
| 918 | 14.52 | 963 | 3.53 | 1008 | 24.71 | 1053 | 4.87 |
| 919 | 16.68 | 964 | 3.12 | 1009 | 25.00 | 1054 | 2.48 |
| 920 | 18.36 | 965 | 2.11 | 1010 | 25.17 | 1055 | 1.28 |
| 921 | 19.35 | 966 | 1.35 | 1011 | 25.37 | 1056 | 0.42 |
| 922 | 20.32 | 967 | 0.73 | 1012 | 25.84 | 1057 | 0.10 |
| 923 | 20.96 | 968 | 0.23 | 1013 | 26.35 | 1058 | 0.00 |
| 924 | 20.58 | 969 | 0.00 | 1014 | 26.79 | 1059 | 0.00 |
| 925 | 19.93 | 970 | 0.00 | 1015 | 27.14 | 1060 | 0.00 |
| 926 | 19.97 | 971 | 0.00 | 1016 | 27.40 | 1061 | 0.00 |
| 927 | 20.29 | 972 | 0.00 | 1017 | 27.51 | 1062 | 0.00 |
| 928 | 20.68 | 973 | 0.00 | 1018 | 27.61 | 1063 | 0.00 |
| 929 | 20.95 | 974 | 0.00 | 1019 | 27.69 | 1064 | 0.00 |
| 930 | 21.15 | 975 | 0.00 | 1020 | 27.64 | 1065 | 0.00 |
| 931 | 21.39 | 976 | 0.00 | 1021 | 27.50 | 1066 | 0.00 |
| 932 | 21.81 | 977 | 0.00 | 1022 | 27.35 | 1067 | 0.00 |
| 933 | 22.26 | 978 | 0.00 | 1023 | 27.32 | 1068 | 0.00 |
| 934 | 22.64 | 979 | 0.00 | 1024 | 27.23 | 1069 | 0.00 |
| 935 | 22.71 | 980 | 0.00 | 1025 | 27.15 | 1070 | 0.10 |
| 936 | 22.58 | 981 | 0.22 | 1026 | 27.10 | 1071 | 0.46 |
| 937 | 22.28 | 982 | 0.96 | 1027 | 27.10 | 1072 | 1.91 |
| 938 | 21.41 | 983 | 2.24 | 1028 | 26.95 | 1073 | 4.21 |
| 939 | 20.20 | 984 | 3.98 | 1029 | 26.81 | 1074 | 6.78 |
| 940 | 19.06 | 985 | 5.95 | 1030 | 26.66 | 1075 | 9.43 |
| 941 | 18.39 | 986 | 7.71 | 1031 | 26.41 | 1076 | 11.96 |
| 942 | 18.43 | 987 | 9.27 | 1032 | 26.25 | 1077 | 14.04 |
| 943 | 18.78 | 988 | 10.78 | 1033 | 25.86 | 1078 | 15.82 |
| 944 | 19.36 | 989 | 12.22 | 1034 | 25.61 | 1079 | 17.07 |
| 945 | 19.65 | 990 | 13.60 | 1035 | 25.45 | 1080 | 17.90 |

| Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) |
|---|---|---|---|---|---|---|---|
| 1081 | 18.36 | 1126 | 0.00 | 1171 | 0.00 | 1216 | 3.22 |
| 1082 | 18.67 | 1127 | 0.00 | 1172 | 0.00 | 1217 | 1.52 |
| 1083 | 18.92 | 1128 | 0.00 | 1173 | 0.00 | 1218 | 0.37 |
| 1084 | 19.07 | 1129 | 0.00 | 1174 | 0.00 | 1219 | 0.45 |
| 1085 | 19.25 | 1130 | 0.00 | 1175 | 0.00 | 1220 | 2.79 |
| 1086 | 19.33 | 1131 | 0.00 | 1176 | 0.18 | 1221 | 6.47 |
| 1087 | 19.46 | 1132 | 0.00 | 1177 | 1.65 | 1222 | 9.47 |
| 1088 | 19.57 | 1133 | 0.00 | 1178 | 5.71 | 1223 | 12.09 |
| 1089 | 19.63 | 1134 | 0.00 | 1179 | 9.38 | 1224 | 14.41 |
| 1090 | 19.68 | 1135 | 0.00 | 1180 | 12.42 | 1225 | 13.91 |
| 1091 | 19.79 | 1136 | 0.26 | 1181 | 13.56 | 1226 | 11.78 |
| 1092 | 19.96 | 1137 | 1.18 | 1182 | 13.74 | 1227 | 8.82 |
| 1093 | 19.98 | 1138 | 3.06 | 1183 | 14.51 | 1228 | 6.23 |
| 1094 | 19.99 | 1139 | 5.60 | 1184 | 15.32 | 1229 | 3.54 |
| 1095 | 20.04 | 1140 | 8.23 | 1185 | 16.76 | 1230 | 1.04 |
| 1096 | 20.05 | 1141 | 10.87 | 1186 | 18.72 | 1231 | 0.10 |
| 1097 | 19.64 | 1142 | 13.34 | 1187 | 20.78 | 1232 | 0.00 |
| 1098 | 18.85 | 1143 | 15.30 | 1188 | 22.74 | 1233 | 0.00 |
| 1099 | 17.94 | 1144 | 15.99 | 1189 | 24.52 | 1234 | 0.00 |
| 1100 | 17.17 | 1145 | 16.36 | 1190 | 26.30 | 1235 | 0.00 |
| 1101 | 16.68 | 1146 | 16.85 | 1191 | 26.81 | 1236 | 0.00 |
| 1102 | 16.23 | 1147 | 17.34 | 1192 | 25.48 | 1237 | 0.00 |
| 1103 | 15.70 | 1148 | 17.70 | 1193 | 25.46 | 1238 | 0.00 |
| 1104 | 15.33 | 1149 | 18.01 | 1194 | 26.24 | 1239 | 0.00 |
| 1105 | 15.64 | 1150 | 18.29 | 1195 | 27.37 | 1240 | 0.00 |
| 1106 | 16.35 | 1151 | 18.52 | 1196 | 28.73 | 1241 | 0.00 |
| 1107 | 17.14 | 1152 | 18.70 | 1197 | 29.36 | 1242 | 0.00 |
| 1108 | 17.68 | 1153 | 18.89 | 1198 | 27.82 | 1243 | 0.00 |
| 1109 | 18.22 | 1154 | 19.06 | 1199 | 24.38 | 1244 | 0.22 |
| 1110 | 18.51 | 1155 | 18.77 | 1200 | 20.99 | 1245 | 1.63 |
| 1111 | 18.58 | 1156 | 17.65 | 1201 | 16.35 | 1246 | 5.13 |
| 1112 | 18.54 | 1157 | 16.59 | 1202 | 11.31 | 1247 | 8.45 |
| 1113 | 18.31 | 1158 | 14.68 | 1203 | 6.18 | 1248 | 10.86 |
| 1114 | 17.29 | 1159 | 11.97 | 1204 | 2.52 | 1249 | 13.01 |
| 1115 | 16.24 | 1160 | 9.04 | 1205 | 0.55 | 1250 | 14.99 |
| 1116 | 15.67 | 1161 | 5.88 | 1206 | 0.34 | 1251 | 16.85 |
| 1117 | 14.99 | 1162 | 2.76 | 1207 | 2.28 | 1252 | 18.42 |
| 1118 | 13.38 | 1163 | 0.60 | 1208 | 5.91 | 1253 | 19.17 |
| 1119 | 10.91 | 1164 | 0.00 | 1209 | 8.97 | 1254 | 20.07 |
| 1120 | 7.84 | 1165 | 0.00 | 1210 | 11.59 | 1255 | 21.18 |
| 1121 | 3.86 | 1166 | 0.00 | 1211 | 12.43 | 1256 | 22.52 |
| 1122 | 0.75 | 1167 | 0.00 | 1212 | 10.60 | 1257 | 23.54 |
| 1123 | 0.10 | 1168 | 0.00 | 1213 | 8.23 | 1258 | 24.70 |
| 1124 | 0.00 | 1169 | 0.00 | 1214 | 5.91 | 1259 | 25.50 |
| 1125 | 0.00 | 1170 | 0.00 | 1215 | 4.74 | 1260 | 26.21 |

| Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) |
|---|---|---|---|---|---|---|---|
| 1261 | 27.02 | 1306 | 0.00 | 1351 | 28.34 | 1396 | 18.82 |
| 1262 | 27.93 | 1307 | 0.00 | 1352 | 29.44 | 1397 | 19.35 |
| 1263 | 28.50 | 1308 | 0.00 | 1353 | 30.59 | 1398 | 19.85 |
| 1264 | 28.54 | 1309 | 0.00 | 1354 | 31.66 | 1399 | 20.32 |
| 1265 | 28.75 | 1310 | 0.75 | 1355 | 32.66 | 1400 | 20.83 |
| 1266 | 28.72 | 1311 | 3.89 | 1356 | 33.62 | 1401 | 21.28 |
| 1267 | 28.72 | 1312 | 7.33 | 1357 | 34.57 | 1402 | 21.58 |
| 1268 | 28.78 | 1313 | 10.04 | 1358 | 35.45 | 1403 | 21.72 |
| 1269 | 29.10 | 1314 | 12.59 | 1359 | 36.03 | 1404 | 21.78 |
| 1270 | 29.65 | 1315 | 14.88 | 1360 | 34.66 | 1405 | 21.74 |
| 1271 | 30.51 | 1316 | 15.07 | 1361 | 31.01 | 1406 | 21.76 |
| 1272 | 31.12 | 1317 | 14.56 | 1362 | 27.98 | 1407 | 21.98 |
| 1273 | 30.33 | 1318 | 14.20 | 1363 | 24.96 | 1408 | 22.22 |
| 1274 | 28.31 | 1319 | 12.13 | 1364 | 21.03 | 1409 | 22.40 |
| 1275 | 26.37 | 1320 | 9.67 | 1365 | 17.20 | 1410 | 22.51 |
| 1276 | 24.39 | 1321 | 7.38 | 1366 | 13.00 | 1411 | 22.33 |
| 1277 | 22.38 | 1322 | 5.20 | 1367 | 8.36 | 1412 | 21.97 |
| 1278 | 20.40 | 1323 | 2.79 | 1368 | 4.44 | 1413 | 21.56 |
| 1279 | 18.30 | 1324 | 0.74 | 1369 | 1.73 | 1414 | 21.31 |
| 1280 | 16.19 | 1325 | 0.00 | 1370 | 0.33 | 1415 | 21.21 |
| 1281 | 14.01 | 1326 | 0.00 | 1371 | 0.00 | 1416 | 21.17 |
| 1282 | 11.80 | 1327 | 0.00 | 1372 | 0.00 | 1417 | 21.08 |
| 1283 | 9.63 | 1328 | 0.00 | 1373 | 0.00 | 1418 | 20.89 |
| 1284 | 7.58 | 1329 | 0.00 | 1374 | 0.00 | 1419 | 20.81 |
| 1285 | 6.53 | 1330 | 0.00 | 1375 | 0.00 | 1420 | 20.37 |
| 1286 | 6.79 | 1331 | 0.00 | 1376 | 0.00 | 1421 | 19.77 |
| 1287 | 7.19 | 1332 | 0.00 | 1377 | 0.00 | 1422 | 19.38 |
| 1288 | 7.70 | 1333 | 0.00 | 1378 | 0.00 | 1423 | 17.39 |
| 1289 | 7.95 | 1334 | 0.00 | 1379 | 0.00 | 1424 | 14.27 |
| 1290 | 6.80 | 1335 | 0.00 | 1380 | 0.00 | 1425 | 10.34 |
| 1291 | 5.56 | 1336 | 0.00 | 1381 | 0.00 | 1426 | 6.46 |
| 1292 | 4.67 | 1337 | 0.15 | 1382 | 0.00 | 1427 | 3.56 |
| 1293 | 3.98 | 1338 | 1.13 | 1383 | 0.10 | 1428 | 1.75 |
| 1294 | 3.22 | 1339 | 4.47 | 1384 | 0.83 | 1429 | 0.45 |
| 1295 | 2.03 | 1340 | 8.03 | 1385 | 3.01 | 1430 | 0.00 |
| 1296 | 0.72 | 1341 | 10.88 | 1386 | 5.61 | 1431 | 0.00 |
| 1297 | 0.13 | 1342 | 13.51 | 1387 | 8.25 | 1432 | 0.00 |
| 1298 | 0.00 | 1343 | 15.98 | 1388 | 10.47 | 1433 | 0.00 |
| 1299 | 0.00 | 1344 | 18.10 | 1389 | 12.04 | 1434 | 0.00 |
| 1300 | 0.00 | 1345 | 19.96 | 1390 | 13.39 | 1435 | 0.00 |
| 1301 | 0.00 | 1346 | 21.69 | 1391 | 14.60 | 1436 | 0.00 |
| 1302 | 0.00 | 1347 | 23.21 | 1392 | 15.70 | 1437 | 0.00 |
| 1303 | 0.00 | 1348 | 24.66 | 1393 | 16.67 | 1438 | 0.00 |
| 1304 | 0.00 | 1349 | 25.97 | 1394 | 17.56 | 1439 | 0.00 |
| 1305 | 0.00 | 1350 | 27.20 | 1395 | 18.21 | 1440 | 0.00 |

| Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) |
|---|---|---|---|---|---|---|---|
| 1441 | 0.00 | 1486 | 17.09 | 1531 | 0.00 | 1576 | 16.99 |
| 1442 | 0.23 | 1487 | 13.42 | 1532 | 0.00 | 1577 | 16.79 |
| 1443 | 0.88 | 1488 | 9.12 | 1533 | 0.00 | 1578 | 16.62 |
| 1444 | 1.82 | 1489 | 4.98 | 1534 | 0.00 | 1579 | 16.35 |
| 1445 | 2.83 | 1490 | 1.22 | 1535 | 0.17 | 1580 | 16.01 |
| 1446 | 4.25 | 1491 | 0.10 | 1536 | 0.40 | 1581 | 15.31 |
| 1447 | 5.76 | 1492 | 0.00 | 1537 | 1.01 | 1582 | 15.05 |
| 1448 | 6.99 | 1493 | 0.00 | 1538 | 1.89 | 1583 | 13.83 |
| 1449 | 7.92 | 1494 | 0.00 | 1539 | 2.87 | 1584 | 10.88 |
| 1450 | 8.86 | 1495 | 0.00 | 1540 | 3.95 | 1585 | 8.28 |
| 1451 | 9.77 | 1496 | 0.00 | 1541 | 5.15 | 1586 | 5.36 |
| 1452 | 10.57 | 1497 | 0.00 | 1542 | 6.31 | 1587 | 1.65 |
| 1453 | 11.28 | 1498 | 0.00 | 1543 | 7.41 | 1588 | 0.25 |
| 1454 | 12.01 | 1499 | 0.00 | 1544 | 8.53 | 1589 | 1.47 |
| 1455 | 12.61 | 1500 | 0.00 | 1545 | 9.51 | 1590 | 4.11 |
| 1456 | 13.15 | 1501 | 0.00 | 1546 | 10.42 | 1591 | 6.94 |
| 1457 | 13.76 | 1502 | 0.00 | 1547 | 11.22 | 1592 | 8.51 |
| 1458 | 14.40 | 1503 | 0.00 | 1548 | 11.92 | 1593 | 8.57 |
| 1459 | 15.05 | 1504 | 0.13 | 1549 | 12.65 | 1594 | 8.54 |
| 1460 | 15.60 | 1505 | 0.20 | 1550 | 13.50 | 1595 | 9.21 |
| 1461 | 16.06 | 1506 | 0.31 | 1551 | 14.29 | 1596 | 9.94 |
| 1462 | 16.53 | 1507 | 0.43 | 1552 | 14.98 | 1597 | 10.31 |
| 1463 | 16.94 | 1508 | 0.55 | 1553 | 15.50 | 1598 | 10.02 |
| 1464 | 17.38 | 1509 | 1.54 | 1554 | 15.68 | 1599 | 9.11 |
| 1465 | 17.66 | 1510 | 3.46 | 1555 | 15.80 | 1600 | 7.69 |
| 1466 | 17.92 | 1511 | 5.77 | 1556 | 16.06 | 1601 | 5.98 |
| 1467 | 18.19 | 1512 | 7.98 | 1557 | 16.43 | 1602 | 2.97 |
| 1468 | 18.39 | 1513 | 10.12 | 1558 | 16.74 | 1603 | 0.60 |
| 1469 | 18.55 | 1514 | 11.35 | 1559 | 16.90 | 1604 | 0.00 |
| 1470 | 18.65 | 1515 | 11.05 | 1560 | 17.11 | 1605 | 0.00 |
| 1471 | 18.82 | 1516 | 10.19 | 1561 | 17.26 | 1606 | 0.00 |
| 1472 | 19.00 | 1517 | 9.59 | 1562 | 17.23 | 1607 | 0.00 |
| 1473 | 19.18 | 1518 | 8.26 | 1563 | 17.30 | 1608 | 0.00 |
| 1474 | 19.36 | 1519 | 5.97 | 1564 | 17.29 | 1609 | 0.00 |
| 1475 | 19.58 | 1520 | 4.03 | 1565 | 17.57 | 1610 | 0.00 |
| 1476 | 19.70 | 1521 | 1.31 | 1566 | 17.85 | 1611 | 0.00 |
| 1477 | 19.88 | 1522 | 0.13 | 1567 | 18.04 | 1612 | 0.00 |
| 1478 | 20.01 | 1523 | 0.00 | 1568 | 18.01 | 1613 | 0.00 |
| 1479 | 20.22 | 1524 | 0.00 | 1569 | 17.86 | 1614 | 0.00 |
| 1480 | 20.24 | 1525 | 0.00 | 1570 | 17.48 | 1615 | 0.00 |
| 1481 | 20.07 | 1526 | 0.00 | 1571 | 17.17 | 1616 | 0.16 |
| 1482 | 19.63 | 1527 | 0.00 | 1572 | 16.90 | 1617 | 1.25 |
| 1483 | 19.38 | 1528 | 0.00 | 1573 | 16.58 | 1618 | 3.46 |
| 1484 | 18.98 | 1529 | 0.00 | 1574 | 16.65 | 1619 | 6.08 |
| 1485 | 18.59 | 1530 | 0.00 | 1575 | 16.97 | 1620 | 8.79 |

| Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) |
|---|---|---|---|---|---|---|---|
| 1621 | 11.36 | 1666 | 18.68 | 1711 | 19.34 | 1756 | 21.99 |
| 1622 | 13.70 | 1667 | 16.35 | 1712 | 20.04 | 1757 | 21.92 |
| 1623 | 15.25 | 1668 | 13.31 | 1713 | 20.64 | 1758 | 22.04 |
| 1624 | 16.23 | 1669 | 10.06 | 1714 | 21.23 | 1759 | 22.24 |
| 1625 | 17.14 | 1670 | 6.34 | 1715 | 21.79 | 1760 | 22.40 |
| 1626 | 17.99 | 1671 | 1.74 | 1716 | 22.34 | 1761 | 22.52 |
| 1627 | 18.77 | 1672 | 0.45 | 1717 | 22.75 | 1762 | 22.63 |
| 1628 | 19.43 | 1673 | 2.93 | 1718 | 23.26 | 1763 | 22.77 |
| 1629 | 20.06 | 1674 | 6.63 | 1719 | 23.65 | 1764 | 22.90 |
| 1630 | 20.65 | 1675 | 9.72 | 1720 | 24.07 | 1765 | 22.99 |
| 1631 | 21.22 | 1676 | 12.47 | 1721 | 24.37 | 1766 | 23.17 |
| 1632 | 21.79 | 1677 | 15.07 | 1722 | 24.37 | 1767 | 23.43 |
| 1633 | 22.18 | 1678 | 17.29 | 1723 | 24.20 | 1768 | 23.69 |
| 1634 | 22.54 | 1679 | 19.06 | 1724 | 24.05 | 1769 | 23.68 |
| 1635 | 22.85 | 1680 | 20.59 | 1725 | 23.91 | 1770 | 23.65 |
| 1636 | 23.15 | 1681 | 20.80 | 1726 | 23.88 | 1771 | 23.62 |
| 1637 | 23.40 | 1682 | 18.46 | 1727 | 23.81 | 1772 | 23.73 |
| 1638 | 23.59 | 1683 | 15.56 | 1728 | 23.74 | 1773 | 23.92 |
| 1639 | 23.29 | 1684 | 12.47 | 1729 | 23.59 | 1774 | 24.08 |
| 1640 | 22.34 | 1685 | 8.84 | 1730 | 23.41 | 1775 | 24.20 |
| 1641 | 21.37 | 1686 | 5.57 | 1731 | 23.32 | 1776 | 24.39 |
| 1642 | 20.65 | 1687 | 2.71 | 1732 | 22.78 | 1777 | 24.57 |
| 1643 | 19.82 | 1688 | 0.60 | 1733 | 21.64 | 1778 | 24.72 |
| 1644 | 17.07 | 1689 | 0.00 | 1734 | 20.73 | 1779 | 24.90 |
| 1645 | 13.53 | 1690 | 0.00 | 1735 | 18.14 | 1780 | 25.17 |
| 1646 | 11.36 | 1691 | 0.00 | 1736 | 14.96 | 1781 | 25.43 |
| 1647 | 9.65 | 1692 | 0.00 | 1737 | 13.98 | 1782 | 25.61 |
| 1648 | 7.88 | 1693 | 0.00 | 1738 | 14.01 | 1783 | 25.60 |
| 1649 | 6.46 | 1694 | 0.00 | 1739 | 14.57 | 1784 | 25.55 |
| 1650 | 6.55 | 1695 | 0.00 | 1740 | 15.00 | 1785 | 25.44 |
| 1651 | 7.56 | 1696 | 0.00 | 1741 | 15.06 | 1786 | 25.38 |
| 1652 | 9.01 | 1697 | 0.00 | 1742 | 15.86 | 1787 | 25.27 |
| 1653 | 10.80 | 1698 | 0.00 | 1743 | 16.96 | 1788 | 25.18 |
| 1654 | 12.63 | 1699 | 0.00 | 1744 | 18.20 | 1789 | 24.67 |
| 1655 | 14.25 | 1700 | 0.00 | 1745 | 19.17 | 1790 | 24.29 |
| 1656 | 15.80 | 1701 | 0.24 | 1746 | 19.65 | 1791 | 23.94 |
| 1657 | 16.99 | 1702 | 1.60 | 1747 | 19.86 | 1792 | 22.08 |
| 1658 | 17.77 | 1703 | 3.96 | 1748 | 20.40 | 1793 | 20.04 |
| 1659 | 18.67 | 1704 | 6.67 | 1749 | 21.08 | 1794 | 17.26 |
| 1660 | 19.26 | 1705 | 9.33 | 1750 | 21.28 | 1795 | 13.73 |
| 1661 | 19.97 | 1706 | 12.01 | 1751 | 21.25 | 1796 | 9.70 |
| 1662 | 20.79 | 1707 | 14.38 | 1752 | 21.52 | 1797 | 6.77 |
| 1663 | 21.40 | 1708 | 16.13 | 1753 | 21.75 | 1798 | 3.46 |
| 1664 | 20.87 | 1709 | 17.43 | 1754 | 21.80 | 1799 | 0.66 |
| 1665 | 19.66 | 1710 | 18.54 | 1755 | 21.86 | 1800 | 0.10 |

| Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) | Time (s) | Speed (mph) |
|---|---|---|---|---|---|---|---|
| 1801 | 0.00 | 1846 | 24.09 | 1891 | 0.00 | | |
| 1802 | 0.00 | 1847 | 24.37 | 1892 | 0.00 | | |
| 1803 | 0.00 | 1848 | 24.62 | 1893 | 0.00 | | |
| 1804 | 0.00 | 1849 | 25.22 | 1894 | 0.00 | | |
| 1805 | 0.00 | 1850 | 26.08 | 1895 | 0.00 | | |
| 1806 | 0.00 | 1851 | 26.30 | 1896 | 0.00 | | |
| 1807 | 0.00 | 1852 | 25.89 | 1897 | 0.00 | | |
| 1808 | 0.00 | 1853 | 25.56 | 1898 | 0.00 | | |
| 1809 | 0.00 | 1854 | 25.16 | 1899 | 0.00 | | |
| 1810 | 0.00 | 1855 | 24.92 | 1900 | 0.00 | | |
| 1811 | 0.00 | 1856 | 24.97 | 1901 | 0.00 | | |
| 1812 | 0.00 | 1857 | 24.85 | 1902 | 0.00 | | |
| 1813 | 0.42 | 1858 | 24.99 | 1903 | 0.00 | | |
| 1814 | 1.70 | 1859 | 25.25 | 1904 | 0.00 | | |
| 1815 | 3.20 | 1860 | 25.47 | 1905 | 0.00 | | |
| 1816 | 4.84 | 1861 | 25.43 | 1906 | 0.00 | | |
| 1817 | 6.78 | 1862 | 25.46 | 1907 | 0.00 | | |
| 1818 | 8.67 | 1863 | 25.59 | 1908 | 0.00 | | |
| 1819 | 10.52 | 1864 | 25.85 | 1909 | 0.00 | | |
| 1820 | 12.18 | 1865 | 26.04 | | | | |
| 1821 | 13.62 | 1866 | 26.21 | | | | |
| 1822 | 15.04 | 1867 | 26.40 | | | | |
| 1823 | 16.42 | 1868 | 26.52 | | | | |
| 1824 | 17.57 | 1869 | 26.63 | | | | |
| 1825 | 18.59 | 1870 | 26.58 | | | | |
| 1826 | 19.44 | 1871 | 26.38 | | | | |
| 1827 | 19.78 | 1872 | 26.17 | | | | |
| 1828 | 20.05 | 1873 | 25.91 | | | | |
| 1829 | 20.49 | 1874 | 25.59 | | | | |
| 1830 | 20.86 | 1875 | 25.31 | | | | |
| 1831 | 21.05 | 1876 | 25.04 | | | | |
| 1832 | 21.51 | 1877 | 24.61 | | | | |
| 1833 | 21.92 | 1878 | 24.25 | | | | |
| 1834 | 22.03 | 1879 | 23.84 | | | | |
| 1835 | 22.16 | 1880 | 22.15 | | | | |
| 1836 | 22.16 | 1881 | 19.70 | | | | |
| 1837 | 22.16 | 1882 | 17.01 | | | | |
| 1838 | 22.24 | 1883 | 13.69 | | | | |
| 1839 | 22.44 | 1884 | 10.22 | | | | |
| 1840 | 22.81 | 1885 | 6.80 | | | | |
| 1841 | 23.03 | 1886 | 4.38 | | | | |
| 1842 | 23.42 | 1887 | 2.90 | | | | |
| 1843 | 23.81 | 1888 | 1.07 | | | | |
| 1844 | 24.10 | 1889 | 0.13 | | | | |
| 1845 | 24.03 | 1890 | 0.00 | | | | |

# APPENDIX D

## REVIEW OF PM EMISSION REDUCTION TECHNOLOGY

In September 2001 and March 2002, staff updated the Board on the status of advanced aftertreatment technology for particulate matter (PM) and oxides of nitrogen (NOx). In this Appendix, staff summarizes and discusses the status of these technologies. The discussion pertains specifically to availability and how retrofit technologies reduce NOx and PM, although other pollutants such as carbon monoxide (CO) and HC may also be significantly reduced through these emission control systems.

## AFTERTREATMENT TECHNOLOGY STATUS UPDATE

### A. Advanced PM Aftertreatment Technology

There are several available emission control technologies, including engine modifications, that can reduce diesel PM emissions from diesel-fueled engines. Many of these emission control technologies are already being used today in a variety of engine applications to reduce diesel PM emissions. Below is a summary of the emission control technologies that will play a key role in reducing exposures to diesel PM.

#### 1. Diesel Particulate Filter

A diesel particulate filter (DPF) is positioned in the exhaust stream to trap or 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 ("regeneration") must be provided. The most common means of disposal is to oxidize or burn the particulate in the filter. To facilitate filter regeneration on diesel engines in real operations, the exhaust gas temperature has to be increased or the soot ignition temperature has to be lowered using a catalyst.

DPFs can incorporate either passive or active regeneration techniques. Passive systems rely on the heat of the exhaust, usually with the aid of a catalyst, to combust the PM at a higher average rate than the rate at which the PM is accumulated. Thus, the applicability of passively regenerating diesel particulate filters may be limited to applications with moderate to low engine-out PM emissions and higher exhaust temperatures. The use of low sulfur fuel (15 parts per million) with DPFs minimizes sulfate formation and in some cases is necessary for proper catalytic operation.

Programs are underway to evaluate the correlation between levels of sulfur in diesel fuels and the effectiveness of retrofit (both PM and NOx) devices. In one demonstration program, BP/ARCO is testing its low sulfur diesel fuel, ECD-1, on catalysts and particulate filters made by Johnson Matthey and Engelhard. ECD-1 contains a maximum of 15 ppm sulfur. The first round of emission results from the BP/ARCO demonstration program indicate that PM, HC, and CO are

reduced by greater than 90 percent (LeTavec 2001). A second round of emission tests one year later supports the same conclusion.

The Clean Diesel Demonstration Program conducted by New York City Transit (NYCT) tested the results of using PM retrofits on urban buses (MTA NYCT 2001). The program was designed to test the emissions using these systems: (1) original equipment manufacturer (OEM) diesel oxidation catalyst (DOC) using 350 ppm sulfur diesel fuel; (2) OEM DOC using 30 ppm sulfur diesel fuel; and (3) Johnson Matthey's Continuously Regenerating Technology (CRT™) particulate filter using 30 ppm sulfur diesel fuel.

The conclusions drawn from this study were: (1) the use of the ultra-low sulfur diesel fuel alone resulted in a 76 percent average reduction in the total HC, 29 percent average reduction in CO, and 29 percent average reduction in PM; and (2) the CRT™ resulted in 93-98 percent reductions in total HC, CO, and PM, using the New York Bus Cycle. The CRT™ testing continued until November 2001. Confident in the results of this program, NYCT has contracted for ultra low sulfur diesel fuel for its entire fleet for three years starting from September 2000. NYCT has also committed to retrofitting 100 percent of its fleet of 3500 buses by the end of 2003 (MTA NYCT 2001). Diesel particulate filters have been retrofitted onto 1150 buses as of August 2002. All buses retrofit so far have had 1994 or later model year engines; all remaining buses with pre-1994 engines are expected to be retired by the end of 2003 (Dana Lowell, personal communication, 2002).

Another issue that has arisen with regards to passive DPFs is that in these systems, the catalyst oxidizes NO to $NO_2$ and uses the produced $NO_2$ as an oxidant to remove the PM trapped in the filter material. Measurements of $NO_X$ emissions (NO and $NO_2$) from heavy-duty diesel vehicles equipped with passive catalyzed filters have shown an increase in the $NO_2$ fraction, though total $NO_X$ emissions remain approximately the same. Passive catalyzed filters oxidize NO to $NO_2$, which burns soot captured in the filter. More $NO_2$ is created than is actually used in the regeneration process; and the excess is emitted. In fact, the $NO_2$ to $NO_X$ ratios could range from 20 to 70 percent, depending on factors such as the diesel particulate filter systems, sulfur level in diesel fuel, and the duty cycle (DaMassa, 2002). To minimize the possible effects on population exposure to ozone and $NO_2$, the ARB has established a cap of 20 percent of $NO_2$ to NOx emission ratio for all diesel emission control technologies. To ensure that the cap does not penalize retrofit strategies that reduce total NOx emissions, the 20 percent cap is determined from the baseline (pre-control) emissions.

The applicability of passively regenerating diesel particulate filters may be limited to applications with moderate to low engine-out PM emissions and higher exhaust temperatures, because passive DPF systems rely on the heat of the exhaust, to combust the PM at a higher average rate than the rate at which the PM is accumulated. Thus, although these conditions typically encompass late-

model buses, they do not include all buses. For example, older two-stroke engines are likely to require different control strategies. For those and other applications in which the engine-out PM level is relatively high and the exhaust temperatures are relatively cool, actively regenerating systems are more appropriate. Active systems typically use an external source of heat to oxidize the particulate matter. The most common methods involve electrical regeneration by passing current through a heating element, injecting fuel to provide additional heat for particle oxidation, or the use of a fuel-borne catalyst or other reagent to initiate regeneration. Off-road applications of these active systems have been implemented in Europe since the early 1990's (Mayer and Wyser 2001). However, it should be recognized that passive systems are more attractive from a user's standpoint as they are expected to require less maintenance and to be less expensive.

### 2. Diesel Oxidation Catalyst

A diesel oxidation catalyst (DOC) converts pollutants into harmless gases by promoting chemical oxidation. The catalyst, which is similar in design to catalysts used on passenger cars, oxidizes CO, gaseous HC, and the liquid HCs adsorbed on the carbon particles present in diesel exhaust gases. The liquid and gas phase HCs are referred to as the soluble organic fraction (SOF). The SOF is one component of the total PM in exhaust emissions. Oxidation catalysts can reduce the SOF by 90 percent under certain operating conditions (MECA 1998), and according to staff estimates, could reduce total particulate emissions by greater than 30 percent.

Additional benefits of the DOC include oxidation of several HC-derived emissions, such as aldehydes or polynuclear aromatic hydrocarbons (PAHs), as well as reduction or elimination of the diesel exhaust odor. The DOC also oxidizes sulfur dioxide ($SO_2$), which is present in diesel exhaust from the combustion of sulfur containing fuels, generating sulfate particles and may increase total particulate emissions. Reducing the sulfur content of the fuel will reduce the sulfate particles formed. 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 (Detroit Diesel Corporation, Engelhard, Johnson Matthey, Twin Rivers Technologies, and Engine Control Systems) have certified diesel oxidation catalysts as providing at least a 25 percent reduction in PM emissions (U.S. EPA 2001; MECA 1998).

The Diesel Emission Control – Sulfur Effects (DECSE) Program is a joint government/industry program created to investigate the effects of diesel fuel sulfur levels on emission control systems such as diesel oxidation catalysts. Two DOCs (low and high temperature catalysts) were tested before, during, and after a 250-hour aging cycle using four different sulfur level diesel fuels (DECSE 2001). The reduction efficiencies for HC, CO, and PM were evaluated. Results from this study indicated that fuel sulfur level does not significantly affect

performance degradation. Some performance loss, however, was noted as early as 250 hours after initial installation. Other results from the same study showed that low sulfur diesel fuel is needed if a DOC is to be used as an efficient emission control device.

Some potential adverse environmental impacts of DOCs have been identified. First, as is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and sulfur content of the fuel, the increase in sulfate particles may offset the reductions in SOF emissions. Using low sulfur (15 parts per million) diesel fuel can minimize this effect. Second, a DOC could be considered a "hazardous waste" at the end of its useful life depending on the material(s) used in the catalytic coating. However, DOCs can be manufactured with catalytic coatings such that the product would not be considered a hazardous waste. Finally, because the oxidation process converts NO to $NO_2$,, the emissions of $NO_2$ could increase. However, these concerns are relatively minor, and DOCs have been successfully used as original equipment in numerous diesel engines for many years.

### 3. Fuel Additives

Fuel additives are substances added to the fuel to reduce the total mass of PM, with variable effects on CO, NOx and HC production. When additives are used alone, the PM reduction range from 15 percent to 50 percent, although reduction as high as 99 percent can be seen when additives are used with a DPF. Some additive-based systems reduce polynuclear aromatic hydrocarbons by around 80 percent.

Fuel-borne catalysts (FBCs) are fuel additives added to diesel fuel to aid in soot removal in diesel particulate filters by decreasing the ignition temperature of the carbonaceous exhaust. Additionally, FBC can improve fuel economy, aid other retrofit systems, and decrease mass PM emissions. FBC/DPF systems are widely used in Europe for on-road and off-road, mobile and stationary applications. Typical FBC materials include cerium, platinum, iron, strontium, and sodium. Most additives act to reduce soot combustion temperature, thereby facilitating filter regeneration and potentially preventing excessive filter loading and/or uncontrolled regeneration. Additives can be used with both passive and active systems.

The additive is added to the fuel in one of three methods: dosing the bulk fuel, incorporating an on-board dosing system in the vehicle, or allowing consumers to add the additive directly. The last method is least attractive due to high likelihood of user error, thus allowing for situations where the vehicle may run with an inappropriate additive dose. The formulation concentration of the additive, as well as the actual base constituent of the additive, will profoundly affect the behavior of the FBC. When used with a DPF, approximately 1% of metal

consumed is emitted in the tailpipe exhaust. Although some similarities exist among FBCs, it is inappropriate to draw generalizations between additives. Additionally, additives with similar active ingredients can have significant differences.

A question left unanswered about FBCs is the potential long-term health effect of metals used in FBCs. When FBCs are used at high treatment rates without filters, there is a potential for high levels of metal emissions and an increase in ultra-fine particles. Other concerns associated with the use of FBCs include incompatibility with other applications and interference with normal engine functioning. Further investigations are needed to address these potential concerns.

### 4. Alternative Diesel Fuels

Alternative diesel fuels, such as biodiesel, synthetic diesel, and water emulsions, have also shown to reduce diesel PM emissions. Biodiesel fuel, a renewable energy source, is derived from vegetable oils or animal fats. Biodiesel can be used for combustion in a diesel engine either in the pure state or blended with diesel fuel. Biodiesel fuel blends that include oxygenate additives can decrease PM emissions, but can also increase NOx emissions. In addition, in some cases biodiesel may not be compatible with alloys and elastomers commonly used in diesel engines necessitating special engine material design considerations.

Synthetic diesel fuels are manufactured using carbon-containing feedstocks, such as natural gas or coal. The most widely known synthetic diesel fuel technology is the Fischer-Tropsch process. Synthetic diesel fuels are attractive because they do not require modifications to existing diesel engines. The fuels can be designed to provide both good engine performance and emission reductions. The high cetane numbers and low sulfur content of synthetic fuels promote emission reductions of several diesel exhaust pollutants. Significant reductions in diesel emissions, including NOx and PM, have been reported when using synthetic fuel. Because the sulfur content is very low, synthetic fuels are compatible with a range of sulfur-sensitive aftertreatment technologies, such as lean NOx catalysts or passive filters.

Water-fuel emulsions are a third type of alternative diesel fuel. The various emulsifying technologies being developed utilize chemical additives (surfactants), high pressures, or electrical phenomena and have 20-30% water in their formulations. NOx and PM emissions have been reduced 40-50% using water-fuel emulsions. One drawback to this method is the increase of HC and CO emissions. However, this increase can be mitigated by the use of a DOC. Although water emulsions appear to be a promising diesel emission control technology, they have been known to alter the fuel lubricity and corrosion properties. The stratification of the emulsified fuel during storage is another

problem associated with technology. Further development is needed to eliminate these undesirable properties of the fuels.

## B. Technology Evaluation

### 1. Retrofit Requirements

Following is the summary of the urban transit bus fleet rule requirements for retrofitting diesel bus engines to reduce diesel PM emissions in use, which are being proposed for modification. Title 13, CCR, section 1956.2 (f) requires that older engines be retrofitted to reduce diesel PM earlier than newer engines. Specifically, 100 percent of pre-1991 MY (Tier 1) diesel engines must be retrofitted with technology that will reduce diesel PM by 85 percent by January 1, 2003. The same requirement applies to a lower percentage of MY 1991 through 1995 (Tier 2) engines by January 1, 2003, under a phase-in period. The deadline for full compliance for all 1995 and older models is January 1, 2004, for transit agencies on the diesel path and January 1, 2005, for transit agencies on the alternative-fuel path.

For Tier 3, or 1996 through 2002 MY, engines, the rule specifies that these be retrofitted under a phase in schedule as follows: for diesel path transit agencies, 20 percent by January 1, 2005; 75 percent by January 1, 2006; and 100 percent by January 1, 2007. Transit agencies on the alternative-fuel path have two additional years to begin and conclude retrofits, as follows: 20 percent by January 1, 2007; 75 percent by January 1, 2008; and 100 percent by January 1, 2009. Included in the retrofit requirements are the following exemptions:

(1) MY 1990 and earlier engines that were originally certified to 0.6 g/bhp-hr PM and have been retrofitted to 0.1 g/bhp-hr PM with an ARB certified retrofit device are exempt from further retrofits;

(2) Tier 2 and 3 buses, operated by transit agencies on the alternative fuel path, that are within two years of retirement are exempt from the retrofit requirements; and

(3) Tier 2 and 3 buses, operated by transit agencies on the diesel path, that are within one year of retirement are exempt from the retrofit requirements.

### 2. Requirements for Technology Verification

Prior to its use in any transit bus, ARB requires that a retrofit device be verified to reduce diesel particulate matter emissions by 85 percent or, alternatively, to levels of 0.01 g/bhp-hr or below (title 13, CCR, section 1956.2(f)(7)). The ARB staff is developing regulations regarding the evaluation of retrofit devices. In recognition of the major role that retrofit technologies must play in the reduction

of public exposure to diesel PM, the Board has adopted a verification procedure to verify emission reductions.

The verification process is intended to ensure that retrofit devices provide the necessary reductions while remaining durable. Prior to a device being verified, the manufacturer must provide a general description of the emission control system, including the principles of operation; effects on engine performance and fuel consumption; any fuel requirements (e.g., diesel fuel with a sulfur level of 15 ppm or less); and maintenance requirements. In addition, the manufacturer must provide emissions test data (including $NO_2$ measurements), and durability data. Devices intended for heavy-duty engines, such as those used in transit buses, must show a durability of 50,000 miles or 1,000 hours.

Installation of emission control equipment in the exhaust system of a vehicle may result in increases in backpressure. The manufacturer must therefore demonstrate that the resulting backpressure is within the engine manufacturer's specified limits, or will not result in any damage to the engine. Acknowledging this, the verification procedure requires that a backpressure monitor be installed for all filter-based systems.

To ensure acceptability to the user, the manufacturer must provide a warranty that covers defects and damage to the vehicle. In addition, the manufacturer must clearly specify in the owner's manual the following information:

- Warranty statement including the warranty period over which the manufacturer is liable for any defects;
- Installation and maintenance requirements;
- Fuel consumption penalty, if any;
- Fuel limitations, if any (e.g., sulfur content);
- Contact information for the manufacturer of replacement components and maintenance supplies.
- Safety considerations.

### 3. Verified Technologies

As of August, 2002, the ARB staff has verified the following particulate control strategies for retrofit use:

Level 3 - 85 percent or greater PM reduction

- Clean Air Partners - diesel particulate filter for use with specific Power Systems Associates natural gas/diesel bi-fuel engines and Caterpillar engines which have been converted to bi-fuel operation using the Power Systems Associates and Clean Air Partners bi-fuel retrofit systems.

- Engelhard - DPX™ diesel particulate filters for use with most 1994-2002 model year diesel engines in on-road applications using 15 ppm or less sulfur fuel. All of these engines are four-stroke, turbocharged, and were certified in California to the 0.1 gram per brake horsepower-hour (g/bhp-hr) PM emission standard when new.

- Johnson Matthey - CRT™ diesel particulate filters for use with most 1994-2002 model year diesel engines in on-road applications using 15 ppm or less sulfur fuel. All of these engines are four-stroke, turbocharged, and were certified in California to the 0.1 gram per brake horsepower-hour (g/bhp-hr) PM emission standard when new.

Level 3 - 85 percent or greater PM reduction with 25 percent NOx reduction

- Cleaire - Flash and Catch™ system for use with specific 1994 through 1998 model year Cummins M11 engines, for steady state application (long haul truck), operating on low-sulfur fuel in on-road applications. The nature of the control place additional restrictions on the calibrations for which the controls will function. These other restrictions are detailed in the verification letters, which may be found on the ARB web site at http://www.arb.ca.gov/diesel/verifieddevices/verdev.htm.

Level 1 - 25 percent or greater PM reduction with 25 percent NOx reduction

- Cleaire - Flash and Match™ oxidation catalyst system for use with specific 1994 through 1998 model year Cummins M11 engines, for steady state application (long haul truck), in on-road applications. The nature of the control place additional restrictions on the calibrations for which the controls will function. These other restrictions are detailed in the verification letters, which may be found on the ARB web site at http://www.arb.ca.gov/diesel/verifieddevices/verdev.htm.

### 4. Availability of PM Emission Reduction Technology

At this time, two particulate control devices that achieve 85 percent control are available and ARB-verified for urban bus use (the Engelhard DPX™ and the Johnson Matthey CRT™). Those devices are verified only for 1994 and newer four-stroke engines. The devices are passive diesel particulate filters that utilize exhaust gas heat and a catalyst to regenerate. No system has been verified as of August 1, 2002, to reduce diesel PM emissions from older and two-stroke bus engines, at any level of PM reduction. In general, two-stroke bus engines are more technologically challenging to retrofit with a passive DPF because PM emissions tend to be higher than four-stroke engines. Furthermore, the exhaust gas temperature may not meet the minimum temperature required for

spontaneous regeneration. Perhaps as importantly, the number of engines that are available to be retrofitted is relatively small and unlikely to grow, thus providing a disincentive for manufacturers to bring such a technologically challenging product to market.

Staff reported to the Board in March 2002 that the technology to reduce diesel PM emissions by 85 percent would not be available for pre-1994 MY engines in time to meet the January 2003, regulatory deadline. As a result, staff's proposal in this report revises the current PM retrofit requirement to allow transit agencies more flexibility to reduce in-use diesel PM emissions to the same level as envisioned by the original regulation. Transit agencies would use the funds already earmarked for the retrofit of the Tier 1 and Tier 2 engines to reduce their diesel PM emissions.

# APPENDIX E

## URBAN DIESEL TRANSIT BUS EMISSIONS INVENTORY

The EMFAC model used by the Air Resource Board (ARB) to obtain on-road motor vehicle emissions also calculates an emissions inventory for urban buses. However, for two reasons staff believes that the urban diesel bus inventory in EMFAC may not be suitable, without modification, for developing regulations that address only urban diesel transit buses. First, the population of the urban diesel bus vehicle class in EMFAC is derived from the Department of Motor Vehicles (DMV) registration database and contains urban transit buses as well as other categories of non-public transit buses, such as Greyhound and tour buses. The population reported by transit bus agencies is smaller than that used in the EMFAC model. Second, the urban bus fleet in EMFAC consists of 45 model years of vehicles, and buses of all ages are assumed to accrue 37,700 miles per year on average. Data reported for the years 2000-2002 by transit agencies show that the transit bus fleet consists of only 22 model years and buses of different ages accrue different mileage as a function of the age of the buses.

In support of the ARB transit bus fleet rule regulation amendments, staff has constructed an inventory model specifically for diesel-powered transit buses that uses the population and activity data reported by transit agencies and emission rates from the EMFAC model. The following sections discuss the transit bus activity and emission rate estimate and present a revised urban diesel transit bus inventory.

**Urban Diesel Transit Bus Activity Data**

The following urban diesel transit bus activity data were obtained and analyzed:

- Annual mileage accrual rate;
- Population (POP) and age distribution;
- Total vehicle miles traveled (VMT).

The annual mileage accrual rate for diesel transit buses was estimated from the annual mileage data provided by transit agencies. The average annual mileage data by model year was statistically fit to obtain a relationship between annual mileage accrual rate and vehicle age.

A statewide diesel transit bus population (POP) of 6,303 vehicles was reported for 2002 by transit bus agencies. The age distribution (the number of vehicles by age) for diesel transit buses was calculated from the 2002 population data.

Population for future years was projected based the following assumptions:

- No growth in 2003;
- Forty new diesel buses each year for 2004, 2005, and 2006;
- One percent growth for 2007, 2008, 2009, and 2010.

The population of diesel transit buses for 2002+ was estimated using 2002 population as the base year. The projected population for each future year was adjusted with the survival rate (the fraction of the new vehicles that remains in the fleet after certain years) used for urban diesel buses in the EMFAC model.

The diesel transit bus accrual rate, survival rate, and population distribution for years 2002 and 2010 are given in Table 1.

**Table 1. Diesel Transit Bus Accrual Rate, Survival Rate, and Population Distribution**

| Age | Accrual Rate (mi/year) | Survival Rate | Year 2002 Population* | Year 2010 Population** |
|---|---|---|---|---|
| 0 | 30,868 | 1.0000 | 467 | 107 |
| 1 | 31,679 | 1.0000 | 945 | 160 |
| 2 | 32,332 | 1.0000 | 539 | 144 |
| 3 | 32,824 | 0.9930 | 269 | 96 |
| 4 | 33,158 | 0.9930 | 400 | 40 |
| 5 | 33,332 | 0.9930 | 506 | 40 |
| 6 | 33,346 | 0.9930 | 230 | 40 |
| 7 | 33,201 | 0.9894 | 188 | 52 |
| 8 | 32,897 | 0.9894 | 144 | 462 |
| 9 | 32,434 | 0.9878 | 326 | 933 |
| 10 | 31,811 | 0.9877 | 496 | 532 |
| 11 | 31,028 | 0.9840 | 462 | 267 |
| 12 | 30,087 | 0.9840 | 412 | 396 |
| 13 | 28,986 | 0.9791 | 362 | 499 |
| 14 | 27,725 | 0.9791 | 340 | 227 |
| 15 | 26,305 | 0.9746 | 18 | 185 |
| 16 | 24,726 | 0.9329 | 69 | 136 |
| 17 | 22,987 | 0.9329 | 45 | 308 |
| 18 | 21,089 | 0.9329 | 2 | 468 |
| 19 | 19,032 | 0.9251 | 10 | 434 |
| 20 | 16,815 | 0.9151 | 23 | 383 |
| 21 | 14,439 | 0.9099 | 9 | 336 |
| 22 | 11,904 | 0.9032 | 41 | 314 |

* Reported by transit bus agencies.

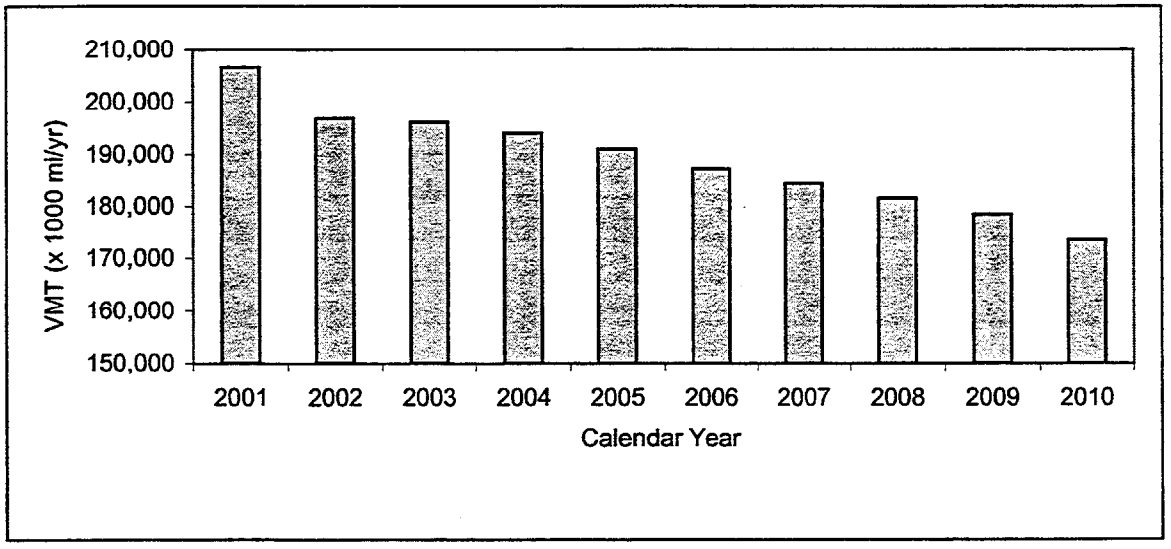
** Projected from year 2002 population and growth rate.

The diesel transit bus annual VMT for any given year was estimated from the population (POP) and accrual rate using the following equation:

$$VMT = \Sigma\ (POP_{age} \times \text{Accrual Rate}_i), \quad age = 1 \text{ to } 22. \qquad (1)$$

Figure 1 shows the estimated diesel transit bus fleet annual VMT for 2001 to 2010.

**Figure 1. Urban Diesel Transient Bus Annual Mileage VMT**




The diesel transit bus fleet shows a decline in VMT from 2001 to 2010. According to transit agency reporting, the population of diesel transit buses decreases from 6,738 vehicles in 2001 to 6,303 in 2002. From 2003 to 2006, the population is projected to remain essentially constant at 2002 level and then grow slightly each year from 2007 to 2010. However, from 2002 to 2010, the average transit bus fleet is projected to transform from mostly newer buses to mostly older buses (see Table 1). Since the annual mileage data shows that newer buses accrue more mileage than older buses, the annual VMT is projected to decline from 2001 to 2010.

It is believed that this decline in diesel transit bus fleet VMT should be compensated by buses powered by alternative fuels and therefore the total VMT of the transit bus fleet should remain essentially constant or show an overall increase.

## Transit Bus Emission Rates

The transit bus emission rates used for this analysis are the same as those used in EMFAC2001 version 2.08. Table 2 shows the speed-corrected NOx and PM emission rates obtained from EMFAC2001.

**Table 2. EMFAC2001 Diesel Urban Bus Emission Rates (g/mi)**

| Model Year Group | NOx | PM |
|---|---|---|
| Pre 1987 | 23.2 | 0.310 |
| 1987-1990 | 20.3 | 0.294 |
| 1991-93 | 12.9 | 0.278 |
| 1994-95 | 15.1 | 0.339 |
| 1996-98 | 19.8 | 0.407 |
| 1999-02 | 10.3 | 0.139 |
| 2003 | 5.15 | 0.028 |
| 2004-06 | 1.2 | 0.024 |
| 2007 | 0.478 | 0.037 |
| 2008+ | 0.426 | 0.032 |

## Transit Bus Emission Inventory

Table 3 shows the diesel transit bus baseline inventories for selected calendar years.

**Table 3. Statewide Transit Bus Baseline Emissions Inventory**

| | 2001 | 2002 | 2004 | 2006 | 2008 | 2010 |
|---|---|---|---|---|---|---|
| NOx (ton/day) | 10.3 | 8.82 | 8.49 | 7.98 | 7.31 | 6.49 |
| PM (lb/day) | 372 | 321 | 309 | 290 | 267 | 239 |

The inventory given in the table does not include the ARB's 2002 low sulfur diesel fuel and adopted retrofit regulations for transit buses and the U.S. EPA 2006 low sulfur diesel fuel regulation.

# APPENDIX F

## STAFF ANALYSIS OF PM EMISSION REDUCTIONS AND COST-EFFECTIVENESS

ARB's methodology for determining cost-effectiveness of a regulation is to determine what costs are involved to comply with the proposed regulation over the life of the controls and to compare those costs to the emission reduction benefits to the public. Staff summarizes this cost-effectiveness as cost (in $) per pound or ton of air pollutant reduced, in this case diesel PM. The benefit to the public in terms of health expenses avoided and lost productivity are not included in the cost-effectiveness calculation, although the value of those benefits is substantial.

The proposed implementation schedule dictates a phase-in by calendar year, with the full 85 percent reduction in diesel PM by 2007 for transit agencies on the diesel path and by 2009 for transit agencies on the alternative-fuel path. Staff assumed that retrofit diesel particulate filters (DPF) would only be available for 1994 through 2002 model year engines, and that transit agencies would retire or repower older pre-1994 engines to achieve the PM reduction targets. Some transit agencies keep buses beyond the twelve year Federal minimum useful life, and therefore could comply with this regulation by retiring old buses that are past their useful life. Another strategy a transit agency could employ to reduce diesel PM emissions would be to fuel its fleet with a diesel-water emulsion, such as PuriNOx™.

Staff is only considering the cost of retrofitting buses (1994 to 2002 MY) in calculating the cost of this regulation. The Federal Transit Administration (FTA) pays 80 to 83 percent of the purchase cost of a new 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 ARB staff and some local air districts have encouraged transportation planning agencies to provide more funding for transit agencies that need to comply with this Fleet Rule and funding has been made available, in most cases, during the first two years of implementation of this rule. Staff expects funding to continue to be available to cover the costs of new buses.

The cost of repowering, i.e., replacing an existing engine with a new engine, may also be covered by Federal, State, and local funds. Federal funding is available for 50 to 100 percent of the cost of repower, based on an informal survey by staff. In addition, transit agencies that repower from older engines to new engines realize significant savings in fuel, from improved fuel economy, and in maintenance costs. Therefore, staff believes that the cost share of the repower is off-set over the life of the new engine by reduced fuel costs and maintenance. For example, in the case where Federal funds pay for 80 percent of the cost of a repower, over the six year lifetime of the new engine a transit agency could recoup all of its costs through avoided engine rebuild, and fuel economy and maintenance savings (Table 1).

**Table 1. Example of Costs Recovered by Engine Repower, 2-Stroke to 4-Stroke**

| | | |
|---|---|---|
| Average Cost to Repower with New Engine and Rebuilt Transmission | $80,000 | |
| Credit Federal Cost Share 80% (50-100% Range) | | -$64,000 |
| Credit Avoided Cost of Rebuild | | -$6,000 |
| Credit Annual Fuel Savings for 6 yr Engine Life | | -$12,000 |
| (Maintenance Savings Not Quantified) | | |
| Net Cost of Repower | | -$2,000 |

In general, two types of costs were accounted for in the cost-effectiveness analysis, capital and operation and maintenance (O&M) costs. It is important to note that since most of these costs are predictive, they could vary significantly depending on the state of the economy, demand, competition, and unknown factors. The costs of technology typically decline over time. These costs have been obtained from the U.S. EPA, the Manufacturers of Emission Controls Association (MECA), and from actual quoted costs to transit agencies.

Capital costs for a passive DPF include the cost of the device, an engine backpressure monitor, and its installation. In general, the horsepower of the engine determines a DPF's cost. Transit bus engines covered by this rule are heavy heavy-duty engines, so the DPF cost is on the high side. The current cost to retrofit heavy heavy-duty on-road engines and vehicles with catalyst-based DPFs is estimated to range from $4,750 to $9,500. This assumes a cost of $10 to $20 per horsepower, as reported by MECA in "Emission Control Retrofit of Diesel-Fueled Vehicles" (March 2000). The current average cost to purchase a DPF for an urban bus engine is approximately $5,500.

In contrast to the current retrofit costs, the U.S. EPA's estimate of the future (2007) costs of applying DPFs to new on-road heavy heavy-duty engines shows a significantly lower cost, about $1,100. The U.S. EPA estimate is based on higher production volumes, and is similar to the future cost projections presented by manufacturers (MECA, March 2000). Therefore the estimated DPF capital cost ranges from $1,100 to $9,500 over the implementation of this rule (2003 to 2009). Based on current bids for retrofitting, however, staff believes a 2003 DPF cost of approximately $5,500 is a reasonable current estimate for an urban bus engine. For this rulemaking, staff has used a median cost of $3,000 as an average of current and future costs for urban bus engines (Table 2).

**Table 2. Capital Costs Associated with a Passive DPF Retrofit of Urban Bus Engines**

| Cost Categories | Median Cost | Range |
|---|---|---|
| Capital Cost, inc. Installation | $3,000 | $1,100 - $5,500 |
| Annual Maintenance | $80 | $0-$190 |

O&M costs considered by staff included the cost for maintenance, for example, periodic cleaning of the trap. Based on conversations with the manufacturers and demonstration program experience, staff determined the number of cleanings would be on average once a year or less, dependent on the device and other vehicle variables, such as oil consumption. The incremental cost of low sulfur diesel fuel is not included in this calculation, as low sulfur diesel was required to be implemented as of July 1, 2002, and its cost was figured in the original rulemaking. The cost of DPF inspection and cleanings is estimated to range from zero cost to $190 per year, with an average cost of $80. Total O&M costs per urban bus for maintenance are, therefore, an average of $80 per year.

Another option available to control diesel PM emissions, which may be verified in the future to Level 2 (50% reduction), is an emulsified fuel, Lubrizol's PuriNOx™. PuriNOx™ costs approximately 25 cents per gallon over conventional diesel fuel, based solely on incremental operation and maintenance costs. This option is not considered in the cost-effectiveness calculation because the technology is not yet verified for use as a diesel emission control strategy.

Staff determined the amount of PM, in tons, reduced per year based on the implementation of this proposed regulation (Table 3). Utilizing the EMFAC modeling program, implementation of these proposed rule changes is expected to result in a reduction of 24.1 tons of PM in 2004. For 2006, the total PM reduced is estimated to be 36.3 tons. By 2008, the proposed regulation would realize an estimated 38.5 tons of PM reduction.

In order to arrive at the discounted capital costs for the regulation, staff multiplied the capital costs by the capital recovery factor[1], and assumed a lifetime of the DPF based on the minimum warranty period of five years with an annual interest rate of seven percent[2]. It is quite likely a DPF will last much longer than five years in a well-maintained vehicle, as some DPFs have been operating for over five years in Europe.

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[1] Capital Recovery Rate Factor: 480r(1+r)^N/[(1+r)^N-1], where r = the annual interest rate, and N = lifetime of project (in years) (Linsley, 1977).
[2] USEPA uses the factor to calculate costs of environmental programs.

Five years was used in an effort to make a conservative estimate. Clearly, the cost effectiveness would be lower if the DPF has a longer lifetime.

The average costs of implementing the program from 2003 to 2009 were included in the cost effectiveness calculation (Table 3). Based on the median cost scenario, the cost effectiveness would be approximately $50,460 per ton ($25.23/lb) diesel PM reduced. Staff also calculated a low cost scenario, based on the future cost of $1,100 per DPF, of $21,824 per ton diesel PM reduced and a high cost scenario, based on the current cost of $5,500 per DPF, of $89,021 per ton reduced. The staff predicts the cost will fall toward the low to average end of the cost effectiveness scale, based on past experience and because engine manufacturers already are required to install DPFs on new urban bus engines produced after October 1, 2002 to comply with the PM emission standard of 0.01 g/bhp-hr. The federal PM emission standard declines to 0.01 g/bhp-hr for all heavy-duty diesel engines beginning with the 2007 MY.

**Table 3. Average Cost Effectiveness of Proposed Regulation**

| Year | Diesel PM Reduced (tons/year) | Total Annual Cost ($) | Total Cost ($) per Ton PM Reduced |
|---|---|---|---|
| 2003 | 24.1 | 658,800 | 27,347 |
| 2004 | 29.2 | 1,133,400 | 38,815 |
| 2005 | 36.3 | 1,580,000 | 43,502 |
| 2006 | 37.1 | 2,026,600 | 54,699 |
| 2007 | 38.5 | 2,445,200 | 63,495 |
| 2008 | 36.0 | 2,356,460 | 65,548 |
| 2009 | 33.4 | 1,997,860 | 59,816 |
| **TOTAL:** | **234.6** | **12,198,320** | **50,460** |

The costs accounted for above do not include administrative costs. Reporting and additional administrative costs are not expected to result in any significant cost to transit agencies. Under the existing rule, transit agencies must already make annual reports, and the reporting required by this proposed amendment substitutes for reporting that has been deleted from the original rule.

The cost of maintenance training is not included in the analysis. From discussions with trap manufacturers, ARB staff concluded that the DPF manufacturer would provide maintenance training at no additional charge.

Staff assumed no fuel economy penalty would exist from the use of a DPF. This is based on staff experience with the verification procedure and the inability of studies to determine a consistently significant impact, either positive or negative. It is possible a slight penalty or benefit might exist, but until more conclusive data are available, staff assumed either would be negligible.

Waste ash generated by cleaning a DPF may be a hazardous waste in California because of high zinc content. The source of the zinc is the lubricating oil. Staff assumed the fee for disposal of ash from a DPF would be negligible, based on the following analysis. From experience gained during demonstration and testing programs, ARB staff estimated the weight of ash generated per DPF to be approximately 10 to 20 grams, which is dependent upon oil consumption. The quantity of ash would be greater with more than average oil consumption. Based on conversations with the manufacturers and demonstration program experience, staff determined the number of cleanings would be on the average once a year or less, dependent on the device and other vehicle variables, such as oil consumption. Using these values staff determined the quantity of ash that might be generated by a fleet of ten, 100, or 1000 transit buses (Table 4).

**Table 4. Ash Disposal Analysis**

| Number of Buses | Ash Accumulation (kilograms per year) | | Years to Accumulate 100 kg of Ash |
|---|---|---|---|
| | Low | High | |
| 10 | 0.1 | 0.2 | 500-1000 |
| 100 | 1 | 2 | 50-100 |
| 1000 | 10 | 20 | 5-10 |

Considering only waste ash generation, a transit agency could qualify as a small quantity generator. According to the Department for Toxic Substances Control, a hazardous waste may be stored on-site for 180 days or less, after the site has accumulated 100 kilograms of waste. Staff did not include the cost of ash disposal in the cost effectiveness analysis because of the long length of time to accumulate sufficient ash for disposal, the uncertainty that ash will be a hazardous waste in all fleets, and the variability in ash quantity generated per vehicle and fleet.