State of California
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS

PUBLIC HEARING TO CONSIDER AMENDMENTS TO ADOPT NOT-TO-EXCEED AND EURO III EUROPEAN STATIONARY CYCLE EMISSION TEST PROCEDURES FOR THE 2005 AND SUBSEQUENT MODEL YEAR HEAVY-DUTY DIESEL ENGINES

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EXECUTIVE SUMMARY

In the 1990s, seven large manufacturers of heavy-duty diesel engines (HDDEs) violated certification regulations by turning off, or defeating, emissions control equipment during in-use highway driving. To address this violation, the Department of Justice, the United States Environmental Protection Agency (U.S. EPA) and the Air Resources Board (ARB) signed consent decrees with the seven engine manufacturers. A consent decree is a judicial decree that recognizes a mutual settlement between the parties — in this case, between the government and the engine manufacturers (herein referred to as the "settling manufacturers").

In the consent decrees, the settling manufacturers are required, among other things, to produce HDDEs that comply with prescribed emission standards that are lower than those required in current state and federal regulations, as measured by the Federal Test Procedure (FTP).[1] Specifically, these engines must meet a 2.5 gram per brake horsepower (g/bhp-hr) hour standard for non-methane hydrocarbons (NMHC) plus oxides of nitrogen (NOx) emissions no later than October 1, 2002 (about 50 percent cleaner than current engines). In addition, because it was found that the FTP was not adequate to ensure that exhaust emissions were controlled during all in-use driving, it was agreed that compliance with supplemental test procedures would be necessary. Thus, the majority of the settling manufacturers agreed to produce engines by October 1, 2002, that would meet supplemental test procedures including the Not-To-Exceed (NTE) test and the EURO III European Stationary Cycle (ESC) test. The consent decrees state that these requirements must be met for a period of two years. Together with the FTP test, the supplemental test procedures will require control of emissions during the majority of real world operating conditions, ensuring that in the future defeat devices will no longer be employed.

Recognizing the effectiveness of the supplemental tests, the U.S. EPA published a Notice of Proposed Rulemaking (Vol. 64, Federal Register, pp. 58472- 58566, October 29, 1999) proposing to adopt similar supplemental test procedures for 2004 and subsequent model year HDDEs. However, because of federal timing constraints, the NTE and ESC test procedures will not be required until the 2007 model year for federally certified HDDEs (65 FR 59896, October 6, 2000). Therefore, once the consent decree requirements expire in 2004, the settling manufacturers will not be obligated to comply with the supplemental test procedures in 2005 or 2006. Not until the 2007 model year, when the federal rule comes into effect, will HDDE manufacturers be required to comply with similar supplemental test procedures federally.

In order to assure continued compliance during model years 2005 and 2006 by the settling manufacturers and to begin compliance by all other manufacturers in 2005, staff proposes the inclusion of the NTE and ESC tests in the required California

[1] During the FTP, an engine operates through a narrowly defined test cycle.

certification process for 2005 and subsequent model year HDDEs. The proposed supplemental test procedures parallel those in the consent decrees and the U.S. EPA's Final Rule for 2007 and subsequent model year HDDEs,[2] but differ by adding options for flexibility and by exempting "ultra-small volume manufacturers"[3] and "urban buses"[4] until the 2007 model year in order to allow additional lead time for compliance.

The proposal closes the two-year span, after the termination of the consent decrees, from which time engine manufacturers need only satisfy the FTP test procedure under current state and federal regulations. By adopting the proposed additional test procedures, which cover wider ranges of engine operating conditions, potential excess NOx emissions greater than 17 tons per day and 13 tons per day in 2006 and 2010, respectively, can be eliminated from California registered heavy-duty vehicles. Additional emission reductions could also be realized when other states adopt these procedures under the authority granted in section 177 of the federal Clean Air Act.[5] When other states support the proposal by adopting California's proposed supplemental test procedures, the success and effectiveness of the proposal is maximized. Adoption of the proposal by other states ensures that manufacturers produce "clean" HDDEs on a national basis. Additional emission reductions would be realized from "clean" out-of-state HDDE vehicles travelling in California.

Lifetime excess emissions have been calculated at approximately 1 ton per engine from medium heavy-duty diesel engines and approximately 5 tons per engine from heavy heavy-duty diesel engines if the engines are required only to comply with the existing FTP test procedure. Based on an aggregate lifetime net present value cost ranging from $717 to $915 per heavy-duty diesel vehicle, the cost effectiveness of the proposed supplemental test procedures ranges from $0.09 to $0.63 per pound of excess NOx emissions eliminated.

[2] U.S. EPA Final Rule on the Control of Emissions of Air Pollution from 2004 and Later Model Year Heavy-Duty Highway Engines and Vehicles; Revision of Light-Duty On-Board Diagnostics Requirements (65 FR 59896, October 6, 2000).

[3] An "ultra-small volume manufacturer" is defined as any manufacturer with California sales less than or equal to 300 new passenger cars, light-duty trucks, medium-duty vehicles, heavy-duty vehicles, and heavy-duty engines per model year based on the average number of vehicles and engines sold by the manufacturer in the previous three consecutive model years.

[4] An "urban bus" is defined in proposed Title 13, California Code of Regulations, Section 1956.2.

[5] Section 177 allows the adoption of California standards under specified circumstances.

I. INTRODUCTION

Despite significant improvements in California's air quality over the last forty years, more must be done to improve air quality and protect the health of those living in California. California does not attain the one-hour federal ambient ozone standard in many areas of the state. Mobile source controls are vital to attaining air quality standards statewide because mobile sources account for about 60 percent of ozone precursors. Thus, the need for emission reductions from mobile sources is great. Diesel engines, in particular, can be targeted for major reductions from the mobile source sector. California's plan for attaining the federal ozone ambient air quality standard, as set out in the 1994 Ozone State Implementation Plan (SIP), calls for more exhaust emission reductions from diesel engines.

The current certification requirements for new heavy-duty diesel engines produced for sale in California are based on compliance with emission standards under conditions specified by the Federal Test Procedure (FTP). The FTP is a prescribed engine test cycle conducted in the laboratory that represents the typical operation of a vehicle in-use. In the 1990s, it was found that seven of the largest heavy-duty diesel engine (HDDE) manufacturers violated certification regulations by turning off, or defeating, emission control devices during in-use highway driving. Consequently, the Department of Justice, the United States Environmental Protection Agency (U.S. EPA) and the Air Resources Board (ARB or "Board") signed consent decrees with the seven engine manufacturers. A consent decree is a judicial decree that recognizes a mutual settlement between the parties — in this case, between the government and the engine manufacturers (herein referred to as the "settling manufacturers").

In these consent decrees, the settling manufacturers are required, among other things, to produce HDDEs that meet a 2.5 gram per brake horsepower-hour (g/bhp-hr) FTP limit on non-methane hydrocarbons (NMHC) plus oxides of nitrogen (NOx) emissions no later than October 1, 2002 (about 50 percent cleaner than current engines on the FTP). The majority of these settling manufacturers, herein referred to as the "signing manufacturers" (Caterpillar, Cummins, Detroit Diesel, Mack Trucks, Renault (RVI), and Volvo Trucks), have also agreed to produce engines by October 1, 2002 that meet supplemental certification procedures including the Not-To-Exceed (NTE) test and the EURO III European Stationary Cycle (ESC) test. The consent decrees stipulate that these requirements must be met for a period of two years. Together with the FTP test, these supplemental procedures will require control of emissions over the majority of real world conditions.

Recognizing the effectiveness of the supplemental tests, the U.S. EPA published a Notice of Proposed Rulemaking proposing to adopt the supplemental test procedures

for 2004 and subsequent model year HDDEs.[6] However, because of federal timing constraints imposed on the U.S. EPA, the NTE and ESC test procedures will not be required nationally until the 2007 model year. Therefore, once the consent decree requirements expire in 2004, the signing manufacturers will not be obligated to comply with the supplemental test procedures in 2005 or 2006. Not until the 2007 model year, when the federal rule comes into effect, will HDDE manufacturers be required to comply with similar supplemental test procedures federally.

The balance of the Staff Report provides greater detail on the proposal, including the supplemental test procedures themselves, the feasibility of the supplemental test procedures, and the preliminary emission benefit calculations for the excess emissions reduced. The proposal is designed to be consistent with the consent decrees so that engines produced by the signing manufacturers will not have to make any design changes in 2005. Several features contained in the U.S. EPA's Final Rule are provided as options that increase the flexibility of this proposal.[7] Staff believes that complying with the proposed test procedures in 2005 and subsequent model years is feasible. Staff is not proposing any changes to the existing emissions standards. It should be noted that support and adoption of the proposal by other states under the authority granted in section 177 of the federal Clean Air Act is important in ensuring that manufacturers produce "clean" heavy-duty diesel engines nationwide. The adoption of the proposal by other states is integral to maximizing the success and effectiveness of the proposal.

Sections I and II of the Staff Report contain the introduction and background, respectively. Section III contains a discussion on the need for the proposed supplemental test procedures. Section IV is a summary of the proposed requirements, while Section V describes the areas in which the proposal differs from the federal requirements. The technological feasibility of the proposed program is addressed in Section VI. Section VII discusses remaining issues that have arisen during the development of the requirements, and discusses how the issues are addressed by the proposal. Section VIII describes the regulatory alternatives that were considered, while Section IX discusses the economic impacts. The environmental impacts and cost-effectiveness of the proposal follow in Section X, along with the cost-effectiveness analysis for the proposed requirements. Finally, Section XI summarizes the staff's findings and recommendations, followed by a list of references in Section XII.

[6] See 64 FR 58472, October 29, 1999.
[7] See 65 FR 59896, October 6, 2000.

II. BACKGROUND

This section provides an overview of the exhaust emissions from heavy-duty diesel engines, the current regulations and the SIP commitments for heavy-duty engines.

A. HEAVY-DUTY DIESEL ENGINE EMISSIONS

Heavy-duty diesel engines are used in vehicles with a gross vehicle weight rating of 14,001 pounds and greater.[8] Diesel engines are compression ignited, which means that the fuel and air mixture is ignited by high pressure in the combustion chamber instead of by spark plugs as used in gasoline-fueled vehicles. Regulating the amount of fuel injected into the combustion chamber controls the power output. The primary pollutants of concern from diesel engines are oxides of nitrogen (NOx) and particulate matter (PM). The high temperatures and excess air cause the nitrogen in the air to combine with available oxygen to form NOx. Because of the presence of excess air (and thus oxygen), hydrocarbons (HC) evaporating in the combustion chamber tend to be mostly burned, and HC and carbon monoxide (CO) are not emitted at high levels. Evaporative emissions from diesel engines are insignificant due to the low evaporation rate of diesel fuel. However, PM emissions result from fuel droplets that have not completely combusted. Lubrication oil that enters the cylinder also contributes to PM emissions.

B. EMISSIONS INVENTORY

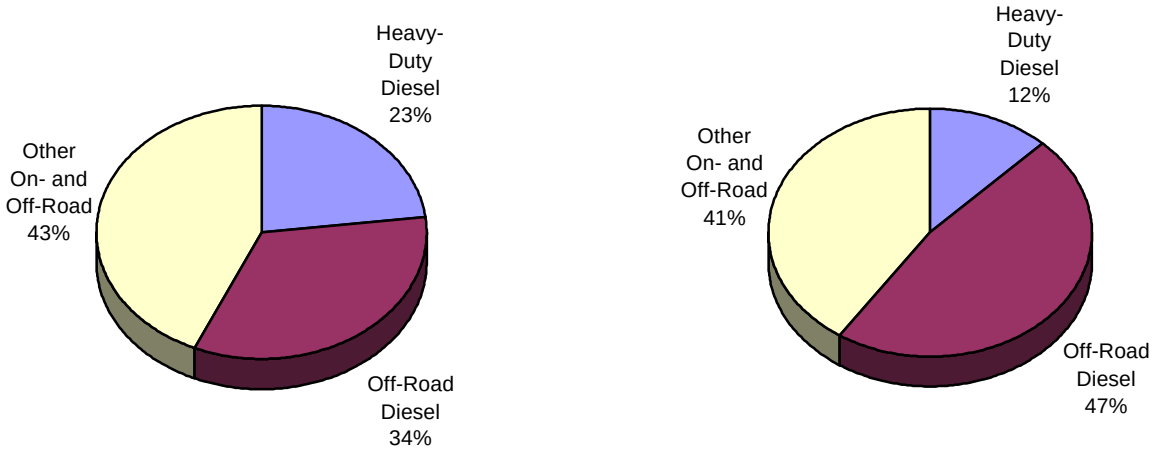
The California emissions inventory for HDDEs has recently been updated. The updated inventory, called EMFAC2000, was adopted by the Board in May 2000. The emissions information in this report is based on the updated emissions inventory from EMFAC2000 Version 2.0.

As shown in Figures 1, the projected statewide NOx and PM emissions from on-road heavy-duty diesel engines in 2010 will contribute approximately 23 percent of the mobile source NOx emissions and 12 percent of the diesel PM exhaust emissions, in the State of California.

[8] The proposed supplemental test procedures are optional for engines used in medium-duty vehicles 8,501 pounds and greater, up to 14,000 pounds gross vehicle weight rating, pursuant to the LEV II requirements in Title 13, California Code of Regulations, Section 1956.8(h).

Figure 1

Statewide Mobile Source Emissions in 2010



Oxides of Nitrogen (NOx) Particulate Matter (PM)

C. EXISTING EMISSION STANDARDS

California is the only state that has the authority to establish new mobile source emission standards and/or test procedures that differ from federal standards and test procedures (Federal Clean Air Act Section 209(b)). Section 177 of the Clean Air Act, however, allows other states to adopt standards and test procedures identical to California's. California standards and test procedures must be, in the aggregate, at least as protective of public health and welfare as applicable federal standards and test procedures.

In October 1997, the U.S. EPA adopted new emission standards for model year 2004 and subsequent model year HDDEs. In February 1998, the ARB subsequently adopted parallel new HDDE standards for the same model years to harmonize the heavy-duty vehicle regulations between the ARB and the U.S. EPA. The standards reflect the provisions of the Statement of Principles signed in 1995 by the U.S. EPA, ARB, and the leading manufacturers of heavy-duty diesel engines. For 2004 and subsequent model year engines, manufacturers will have the flexibility to certify their engines to one of the two options given in Table 1.

Table 1 - U.S. EPA Emission Standards for MY 2004 and Subsequent Heavy-Duty Diesel Engines

Option	NMHC plus NOx	NMHC
1	2.4	n/a
2	2.5	0.5

D. STATE IMPLEMENTATION PLAN (SIP)

In November 1994, the ARB approved the State Implementation Plan (SIP) for ozone, which outlines the measures to be taken to bring the state's air quality into attainment with the federal ambient air quality standards for ozone. During the SIP's development, it became clear that reducing emissions of NOx from on-road HDDEs operating within the state is imperative for cleaning California's air.

A SIP measure (M6) calls for the adoption of a 2.5 g/bhp-hr NMHC plus NOx emission standard for new on-road HDDEs beginning in 2004. This would represent a 50 percent decrease of NOx emissions from the existing federal standard. The SIP assumes that a 50 percent decrease would not only result during driving as measured by the FTP, but during all driving.

III. NEED FOR CONTROL

The NTE and ESC test procedures that staff proposes to the Board for adoption will ensure that original emission benefits associated with the State Implementation Plan M6 are achieved. This section summarizes the air quality benefits that justify the proposed supplemental test procedures.

Ozone is created from the photochemical reaction of primarily NOx and HC. Growing evidence shows that ozone is the cause of harmful respiratory effects, including chest pain, coughing, and shortness of breath. Those who may be severely affected include children, the elderly, and people with poor respiratory systems. Even healthy people may be affected by the elevated ozone levels if they are active outdoors during smoggy days. NOx alone can also directly harm human health by aggravating common respiratory illnesses, such as asthma and bronchitis, and contributes to the premature aging of lung tissue and various other chronic lung diseases. In addition to their human health effects, negative environmental effects are also associated with ozone and NOx. Ozone has been shown to adversely impact plants and many man-made materials, while NOx contributes to the secondary formation of PM (nitrates), acid deposition, and the overgrowth of algae in coastal estuaries.

Prior to entering the consent decrees, the U.S. EPA discovered that many engine manufacturers were optimizing their engines to run at peak fuel efficiency. This optimization resulted in NOx emissions greater than certified levels and greater than regulatory limits, at steady state conditions. Facing federal and California enforcement action, engine manufacturers signed consent decrees that required the reduction of NOx emissions by meeting a 2.5 g/bhp-hr limit on NOx plus NMHC, by October 1, 2002. Additionally, these engines must also be certified using the NTE and ESC test procedures. The supplemental test procedures, when used with the FTP test cycle, will cover a broader range of actual operating conditions. As a result, there will be a reduction of the excess NOx emissions which are not accounted for when certification is completed solely with the FTP test cycle. However, the consent decree requirements are valid for only two years, and will not include 2005 and subsequent model year engines. The current proposal will bridge the NTE and ESC requirements for those two model years and reduce any excess NOx emissions that may be emitted during that time frame.

IV. SUMMARY OF PROPOSED TEST PROCEDURES

The staff recommends that the Board amend section 1956.8, Title 13, California Code of Regulations, and the incorporated "California Exhaust Emission Standards and Test Procedures for 1985 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles", as set forth in Appendices 1 and 2. The proposed regulatory language for the supplemental test procedures duplicates the technical requirements in the consent decrees. They also include several options to conform with portions of the federal regulations adopted in July 2000.[9] Staff proposes to adopt the NTE and ESC test procedures beginning in the 2005 model year.

A. APPLICABILITY

The provisions in this proposal apply to all heavy-duty diesel engines produced for sale in California in the 2005 and subsequent model years. Heavy-duty diesel engines are used in vehicles with a Gross Vehicle Weight Rating of 14,001 pounds and greater. The proposed supplemental test procedures would be optional for medium-duty diesel engines with a Gross Vehicle Weight Rating from 8,501 pounds to 14,000 pounds. Additionally, "ultra-small volume manufacturers"[10] and "urban buses"[11] are exempted from the proposed supplemental test procedures until the 2007 model year in order to allow additional lead time for compliance.

Specific provisions of this proposal include the:

- NTE test procedure with associated emission caps for NMHC plus NOx, CO, and PM from 2005 and subsequent model year heavy-duty diesel engines,

[9] The federal regulations are published at 65 FR 59896, October 6, 2000.

[10] An "ultra-small volume manufacturer" is defined as any manufacturer with California sales less than or equal to 300 new passenger cars, light-duty trucks, medium-duty vehicles, heavy-duty vehicles, and heavy-duty engines per model year based on the average number of vehicles and engines sold by the manufacturer in the previous three consecutive model years.

[11] "Urban bus" is defined in proposed Title 13, California Code of Regulations, Section 1956.2, and 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.

- Euro III ESC test procedure with associated emission caps for NMHC plus NOx, CO, and PM from 2005 and subsequent model year heavy-duty diesel engines, and

- MAEL test procedure with associated emission caps for NMHC plus NOx, and CO from 2005 and subsequent model year heavy-duty diesel engines.

B. EMISSION CAPS

There are three sets of proposed emission caps in the test procedures, which are identical to those contained in the consent decrees. Two of these emission caps are based on the existing emission limits determined by the FTP test cycle. The first proposed emission cap is for the NTE test. This cap is set at 1.25 times the emission limit. The second proposed emission cap is for the Euro III ESC test. This cap is equivalent to the FTP emission limit, although the test procedure for measuring the limit is different. The third proposed emission cap is for the MAEL test. This cap is derived from the Euro III ESC test by using the emission results from the 12 non-idle modes. Emissions from any of these modes may not exceed the Euro III ESC test results at the corresponding modes of operation. The cap at intermediate points between the 12 basic modes are calculated by interpolation, which assumes a linear relationship between the 12 basic modes.

C. TEST PROCEDURES

1. Not-to-Exceed Test Procedure

The NTE test, as defined in CFR 86.1370-2007, establishes an area (NTE control area) under the torque curve of an engine where emissions must not exceed a specified emission cap for a given pollutant. The NTE cap is set at 1.25 times the FTP emission limit as described in the subsection above. For 2005 model year heavy-duty engines, the NTE emission cap for NMHC plus NOx is 1.25 times 2.5 grams per brake horsepower-hour, or 3.125 grams per brake horsepower-hour. The basic NTE control area for diesel engines has three basic boundaries on the engine's torque and speed map. The first is the upper boundary that is represented by an engine's maximum torque at a given speed. The second boundary is 30 percent of maximum torque. Only operation above this boundary is included in the NTE control area. The third boundary is determined based on the lowest engine speed at 50 percent of maximum power

and highest engine speed at 70 percent of maximum power. This engine speed is considered the “15 percent operational engine speed”. Only engine operation above the engine speed calculated with Equation 1 is included in the NTE control area.

$$\text{15\% Operational Engine Speed} = n_{lo} + [\, 0.15 \times (n_{hi} - n_{lo}) \,]$$

Equation 1 : Minimum engine speed for NTE control area

Where,

n_{lo} = Point on engine map at 50 percent of maximum power and lowest engine speed

n_{hi} = Point on engine map at 70 percent of maximum power and highest engine speed

As in the consent decrees, there are two areas which are “carved out” of the basic NTE control area. The first carve out area applies to emissions of all air contaminants. All engine operation less than 30 percent of maximum power is removed from the basic NTE control area on the engine’s torque and speed map, since excess emissions are unlikely to occur in this operating region. Excess emissions are more likely to occur under higher torque and speed conditions, as when a truck is carrying a load up a grade. The second carve out area applies solely to PM emissions. This carve out area depends upon the “75 percent operational engine speed” as calculated in Equation 2 below.

$$\text{75\% Operational Engine Speed} = n_{lo} + [\, 0.75 \times (n_{hi} - n_{lo}) \,]$$

Equation 2 : 75% Operational engine speed

If the “75 percent operational engine speed” is less than 2400 revolutions per minute, the PM carve out area of the NTE control area is determined as described below. The carve out area begins at 30 percent of maximum torque or 30 percent of maximum power, whichever is greater at the “50 percent operational engine speed” (shown in Equation 3 below). The carve out extends linearly to a point at 70 percent of maximum power and the highest engine speed (this is also defined as n_{hi} or the “100 percent operational engine speed”). Operation of the engine within the area below and to the right of this line and within the basic NTE control area is excluded from the NTE requirements for PM.

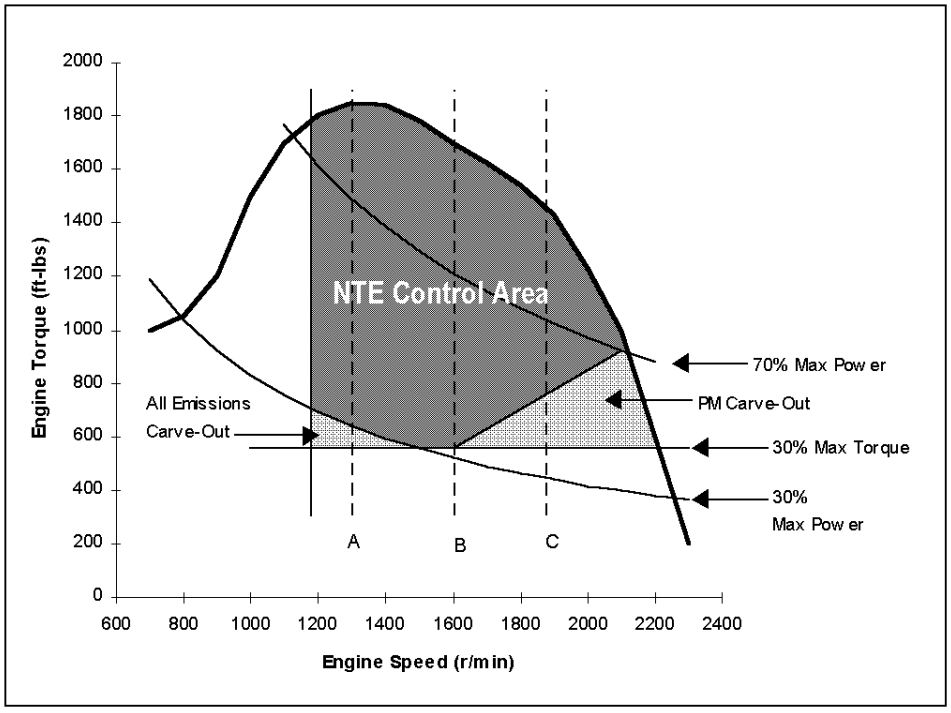
$$\text{50\% Operational Engine Speed} = n_{lo} + [\, 0.50 \times (n_{hi} - n_{lo}) \,]$$

Equation 3 : 50% Operational engine speed

In the U.S. EPA's Final Rule and consent decrees, the U.S. EPA has plotted a sample engine map for a heavy-duty diesel engine with a 100% operational engine speed less than 2400 rpm, shown below in Figure 2.

Figure 2

Example NTE Control Area for Heavy-Duty Diesel Engine With 100% Operational Engine Speed Less Than 2400 rpm



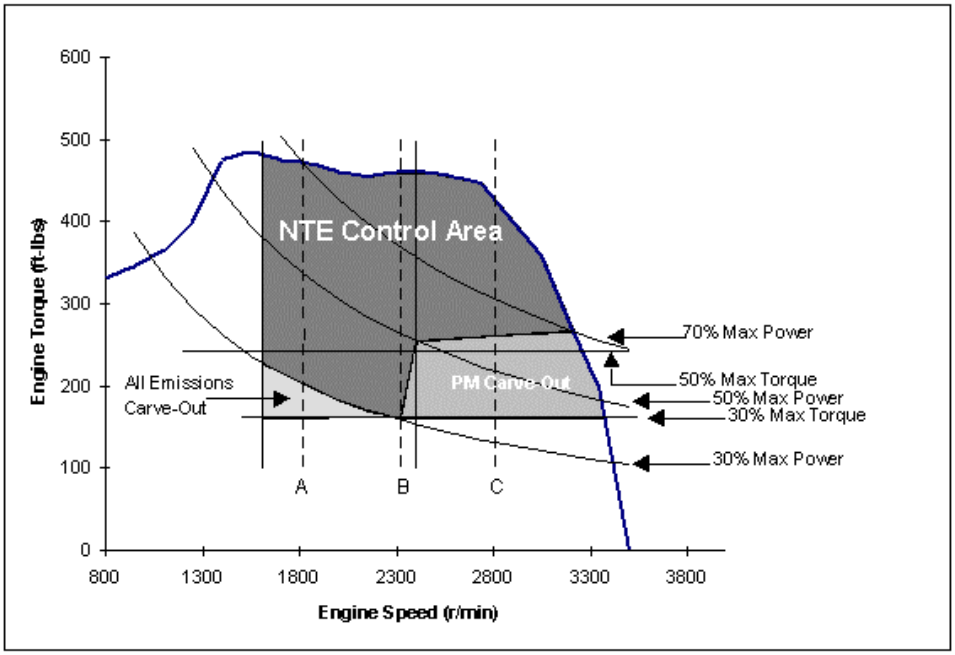
If the "75 percent operational engine speed" is greater than 2400 revolutions per minute, the PM carve out area of the NTE control area is determined as described below. The carve out area begins at 30 percent of maximum torque or 30 percent of maximum power, whichever is greater at the "50 percent operational engine speed" (shown in Equation 3 above). The carve out extends linearly to a point at 50 percent of maximum power and 2400 revolutions per minute. The carve out then extends linearly to a point at 70 percent of maximum power and the highest engine speed. Operation of the engine within area below and to the right of this line and within the basic NTE control area is excluded from the NTE requirements for PM.

In the U.S. EPA's Final Rule and consent decrees, the U.S. EPA has plotted a sample engine map for a heavy-duty diesel engine with a 100% operational

engine speed greater than 2400 rpm, shown below in Figure 3.

Figure 3

Example NTE Control Area for Heavy Duty Diesel Engine With 100% Operational Engine Speed Greater Than 2400 rpm



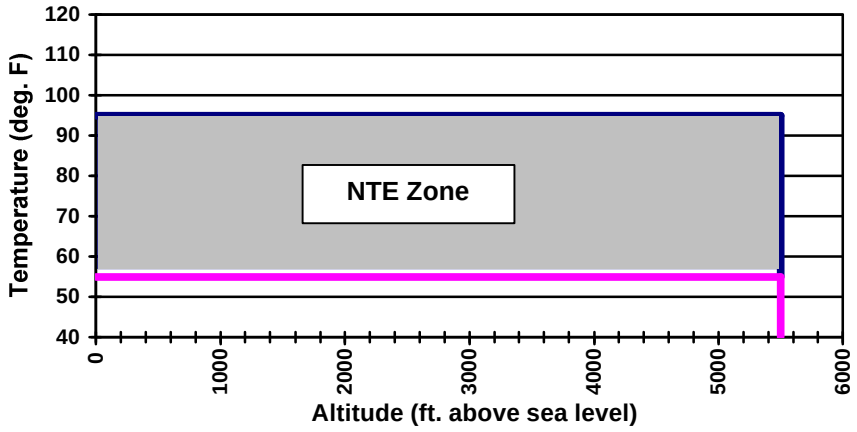
The NTE requirement would apply under any engine operating condition that could reasonably be expected in normal vehicle use. A vehicle can be tested over the NTE procedure either on the road or in an emission testing laboratory using an engine or chassis dynamometer. Instead of using a specific driving cycle such as the FTP, it can involve driving of any type which could reasonably be expected to occur in normal vehicle operation within the boundaries of the NTE control area, including operation under steady-state or transient conditions and under varying ambient conditions. Measured emissions are averaged over a minimum of thirty seconds and compared to the NTE test limit. These requirements would apply to new 2005 and 2006 engines throughout their useful life.

In addition, the NTE test procedures are applicable in a wide range of ambient conditions. For example, NTE ambient temperature coverage can range from 55^{o} to 95^{o}F compared to the FTP ambient conditions of 68^{o} to 86^{o}F. The proposal, however, includes two options related to temperature and altitude that will be available for manufacturers to comply with the NTE requirements. Under option one, which is contained in the consent decrees, manufacturers must comply with the NTE requirements within the ambient temperature range of 55

°F to 95 °F, and an altitude range of up to 5,500 feet above sea level. Within the NTE zone shown in the chart below, the engine must meet the NTE requirements. For testing at a given altitude outside of this zone, NOx and PM emission results may be corrected for temperature. This is shown in Figure 4.

Figure 4

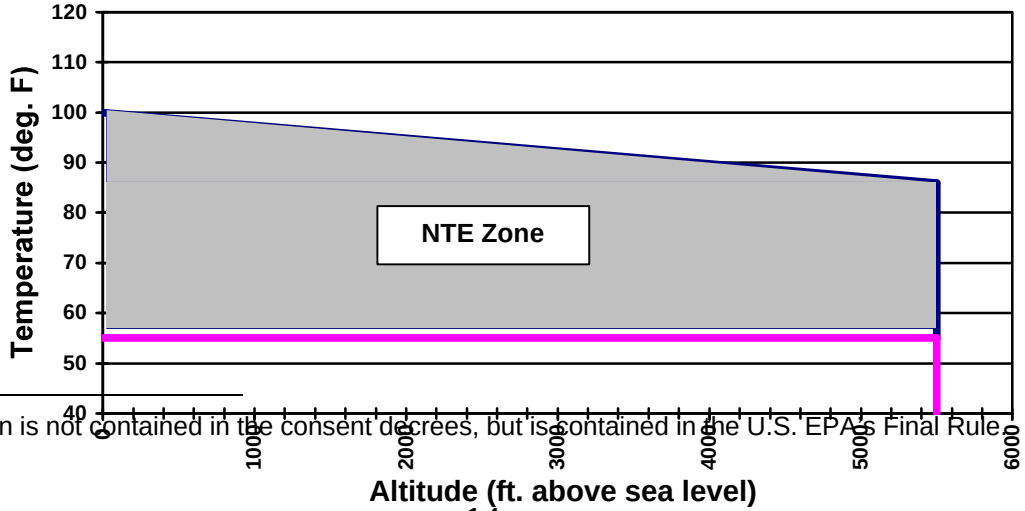
NTE Zone of Option 1



Under option two,[12] manufacturers must comply with the NTE requirements between 55 °F and 100 °F at sea-level and between 55 °F and 86 °F at 5,500 feet above sea-level. The NTE zone described is shown in Figure 5. The maximum temperatures for the corresponding altitudes between those points are determined linearly. At temperatures above the NTE zone, NTE requirements do not apply. In addition, existing requirements, which prohibit defeat devices, apply during operation in the temperatures above the NTE zone.

Figure 5

NTE Zone of Option 2



[12] This option is not contained in the consent decrees, but is contained in the U.S. EPA's Final Rule.

Option one is included in this proposal to ensure consistency between this proposal and the consent decree requirements so that consent decree engines would comply with the proposed test procedure without additional technological changes. However, in 2001 staff may propose that for 2007 and beyond, the NTE zone include ambient temperatures up to 105 °F to ensure control of emissions during virtually all California temperatures during the "ozone season." In California, temperatures over 95 °F are often experienced during periods of ozone non-attainment. Because the ambient conditions substantially contribute to National Ambient Air Quality Standard exceedances, proper emission control is critically needed at the higher ambient temperatures. At this time, however, for consistency with the consent decrees, the proposal includes the option for the same ambient temperature range for NTE control as required in the consent decrees.

Similar to the approach taken in the U.S. EPA's Final Rule, the proposal includes a provision for NTE deficiency in 2005 through 2007 model years. The deficiency provision provides manufacturers additional flexibility through a relief mechanism for failing to comply with some of the NTE requirements. This provision, however, is not contained in the consent decrees. Although the NTE control area and test procedures in the proposed regulation are identical to the NTE requirements in the consent decrees for model years 2003 and 2004, only the settling manufacturers will be in compliance with proposed NTE requirements prior to the implementation date of this proposal. Additionally, the proposal recommends a technology review in 2003, in the event engine manufacturers are unable to demonstrate that they can comply with the proposed test procedures.

2. Euro III European Stationary Cycle Test Procedure

The Euro III European Stationary Cycle (ESC) test cycle, defined in CFR §86.1360-2007 as the "supplemental steady state test", consists of 13 modes at specified speed and power conditions, primarily representing the typical highway cruise operating conditions of heavy-duty diesel vehicles. The ESC test cycle is identical to that in the consent decrees, and also identified as the "Supplemental Steady State Test Cycle" in the U.S. EPA's Final Rule.

During the test cycle, the engine is initially operated at idle, then through a defined sequence of 12 modes at various speeds and engine loads. The test modes are at three different operational engine speeds and at 25%, 50%, 75%, and 100% of maximum load. The engine is operated for two minutes at each mode, except idle. The emission results at each mode are then weighted and averaged. Table 2 details the various modes of operation and associated weighting factors.

Table 2 - Euro III ESC Testing Modes

Mode Number	Operational Engine Speed	Percent Load	Weighting Factor	Mode Length (minutes)
1	Idle	--	0.15	4
2	A	100	0.08	2
3	B	50	0.10	2
4	B	75	0.10	2
5	A	50	0.05	2
6	A	75	0.05	2
7	A	25	0.05	2
8	B	100	0.09	2
9	B	25	0.10	2
10	C	100	0.08	2
11	C	25	0.05	2
12	C	75	0.05	2
13	C	50	0.05	2

The operational engine speeds are calculated for the ESC test by a method that is similar to the NTE control area definition.

$$\text{Operational Engine Speed A} = 25\% \text{ Operational Engine Speed} = n_{lo} + [\, 0.25 \times (n_{hi} - n_{lo}) \,]$$

Equation 4 : Operational engine speed A

$$\text{Operational Engine Speed B} = 50\% \text{ Operational Engine Speed} = n_{lo} + [\, 0.50 \times (n_{hi} - n_{lo}) \,]$$

Equation 5 : Operational engine speed B

$$\text{Operational Engine Speed C} = 75\% \text{ Operational Engine Speed} = n_{lo} + [\, 0.75 \times (n_{hi} - n_{lo}) \,]$$

Equation 6 : Operational engine speed C

Manufacturers would be required to show compliance with the following:

Average Allowable Emission Caps

At each mode of operation of the ESC test, the concentration of the gaseous pollutants is measured. The weighted average emissions for each pollutant, must not be greater than the existing Federal Test Procedure emission standard which is currently 2.5 g/bhp-hr for NMHC plus NOx for 2005 and subsequent model year engines. A single, particulate matter measurement is made of the entire 13 modes at the end of the test.

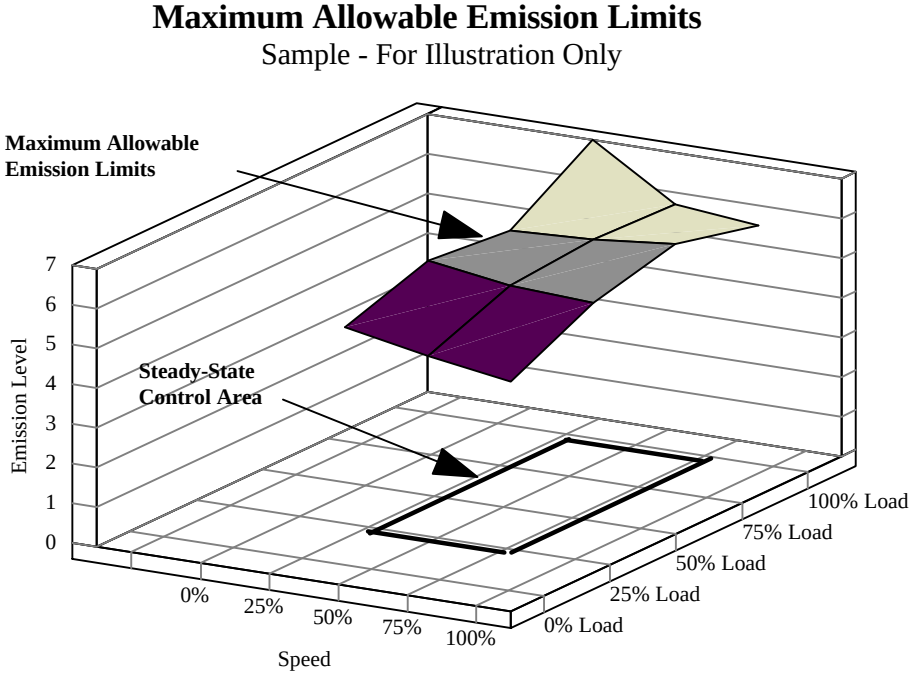
The ARB may select an additional 3 test points between the 12 non-idle test modes. The additional test points are for gaseous pollutants only. Results from each test point are compared to the interpolated emissions from the nearest four test modes. Interpolation is completed using a four-point interpolation procedure. The purpose of these tests is to ensure that the engines are not optimized for the specific test modes.

Maximum Allowable Emission Limits

Maximum allowable emission limits are determined from the 12 non-idle test points of the ESC tests. A 10 percent interpolation allowance is added to the results of each of the 12 test points. The 10 percent allowance is added to provide additional allowance for possible errors in interpolation. This is similar to the U.S. EPA's Final Rule, but differs from the consent decrees, which have a 5 percent interpolation allowance. The maximum allowable emission limit at any set of speed and load conditions between the test points can be determined by using a four-point interpolation procedure. If a test point exceeds the NTE cap, the NTE cap will be used for the point, in addition to determining the map of limit points, described below. Emissions of gaseous pollutants at any point within the maximum allowable emission limit operational zone must not exceed the cap as determined by interpolation. Maximum allowable emission limits only apply to gaseous pollutants and do not apply to particulate matter. The following plot in Figure 6 is a sample of the steady-state control area for a heavy-duty diesel engine. The figure is taken from the U.S. EPA's Final Rule.

Figure 6

Sample Map in the Steady State Control Area for a Heavy-Duty Diesel Engine



3. Measuring Smoke Emissions Within the NTE Zone

Similar to the consent decree requirements, within the NTE control area, an engine must meet either a filter smoke cap or an opacity cap. The filter smoke cap is 1.0 on the Bosch number scale, a measure of smoke opacity. There are two alternatives for the smoke opacity cap. The first opacity cap is 4 percent averaged over 30 seconds using a 5 inch path. This cap is for transient testing. The second opacity cap is also 4 percent, but averaged over 10 seconds using a 5 inch path. This cap is for steady state testing (ESC test). Both caps are at levels where smoke would not be visible to an observer.

D. FLEXIBILITY PROVISIONS – 2003 TECHNOLOGY REVIEW

As mentioned previously, settling manufacturers are required to comply with these requirements by October of 2002 because of the consent decrees. For other engine manufacturers, the proposal provides sufficient time to develop complying engines technologies, if necessary. Many of the approaches to compliance presented in this proposal are identical to those presented by the U.S. EPA in their Final Rule. However, in the event that settling manufacturers have difficulty with full compliance before 2004, staff is proposing a 2003 technology review to determine the state of progress in complying with the proposed supplemental test procedures.

V. DIFFERENCES AND SIMILARITIES BETWEEN FEDERAL AND CALIFORNIA REGULATIONS

The proposed supplemental test procedures are intended to be identical in stringency to the testing provisions in the consent decrees. This would allow a continuation of lower emitting consent decree engines beyond 2004 and to prevent unnecessary, redundant work for settling manufacturers. Additionally, the proposed test procedures prevent the potential excess emissions that would have occurred in model years 2005 and 2006, after the consent decree requirements expire and before the Federal program begins in 2007.

Therefore, most of the requirements in the proposed supplemental tests are identical to those in the consent decrees. The identical requirements between the proposed test procedures and the consent decrees are shown in Table 3. For example, the proposed supplemental steady state test procedure is identical to that in the consent decrees.

Similar to the U.S. EPA's Final Rule, some additional provisions are incorporated in the proposed rule to allow flexibility for manufacturers to comply with the requirements and to increase control of emissions under the typical ambient conditions in California. The differences among the proposed test procedures, the consent decrees, and the U.S. EPA's Final Rule are described below and summarized in Table 4.

1. NTE Deficiency Provision

Recently, settling manufacturers have indicated that under certain temperatures and altitudes it would be difficult to comply with the NTE requirements. Negotiations are underway to determine whether these exemptions are permissible in the consent decrees. In the U.S. EPA's Final Rule, deficiency provisions for NTE were provided in order to allow manufacturers a relief mechanism for some of the NTE requirements if compliance would not be feasible due to the technological difficulties and/or need for more lead time. NTE deficiencies will only be granted on an engine family basis and under limited operating conditions. The proposed supplemental test procedures provide manufacturers the flexibility to apply for NTE deficiencies, as in the U.S. EPA's Final Rule.

Table 3 - Comparison of Consent Decrees, U.S. EPA Final Rule, and ARB Proposal - Identical Consent Decrees and ARB Provisions

Items	Consent Decrees	U.S. EPA 2004 Final Rule	ARB Proposed Test Procedures
NTE Test:			
NTE test procedure	Defined	Identical to consent decrees	Identical to consent decrees
NTE emission cap	1.25 times the standard for each regulated pollutant	Identical to consent decrees	Identical to consent decrees
Temperature and altitude of the NTE control zone (55 °F – 95 °F from sea level and higher)	Defined	Identical to consent decrees (plus 1 additional option)	Identical to consent decrees (plus 1 additional option)
NTE cold temperature exclusion for EGR equipped engines	Not included	Stated	Identical to consent decrees
Euro III ESC Test			
Euro III ESC test procedure	Defined	Identical to consent decrees	Identical to consent decrees
ESC emission cap	1 times the emission standard	Identical to consent decrees	Identical to consent decrees
MAEL test procedure	Defined	Identical to consent decrees	Identical to consent decrees
In-use Compliance			
Calculation of emission threshold for failure	Threshold is equivalent to emission cap plus 0.5 g/bhp-hr.	Threshold is equivalent to emission cap	Identical to consent decrees for 2005 and 2006 MY; otherwise at emission cap.
Option of engine or chassis dynamometer or ROVER	Available	Identical to consent decrees	Identical to consent decrees
Primary set of engines tested	“Population“ of engines tested	Typically ten engines	Identical to consent decrees for 2005 and 2006 MY; otherwise 10 engines tested.
Test at least nine more times under same conditions per each exceedance found in original testing “population”.	Available	Typically one test per engine	Identical to consent decrees for 2005 and 2006 MY; otherwise one test per engine.
Defeat Device Definition	Defined to cover operation in FTP test cycle	Similar to Consent Decree with additional coverage in NTE and ESC test cycles.	Identical to consent decrees

Table 4 - Comparison of Consent Decrees, U.S. EPA Final Rule, and ARB Proposal - Different Consent Decrees and ARB Provisions

Items	Consent Decrees	U.S. EPA 2004 Final Rule	ARB Proposed Test Procedures
Implementation of NTE/EURO III ESC requirements	2002 through 2004 calendar years	2007 and subsequent model years	2005 and subsequent model years
NTE Test:			
NTE Deficiency Provision	None	Allowed	Identical to U.S. EPA's Final Rule
Apply to altitudes less than or equal to 5,500 ft. at ambient conditions	Not Stated	Stated	Identical to U.S. EPA's Final Rule
Optional temperature and altitude NTE control zone (55 °F – 100 °F @ sea level to 55 °F – 86 °F @ 5,500 ft. elevation).	None	Allowed	Identical to U.S. EPA's Final Rule
MAEL Test. Interpolation calculation allowance to allow for variability between operating modes	5%	10%	Identical to U.S. EPA's Final Rule

2. Temperature and Altitude of the NTE Control Zone

In the consent decrees, the NTE control zone parameters for temperature and altitude are defined as the ambient temperature range of 55 °F to 95 °F, and any altitude above sea level. For testing at a given altitude outside of this temperature zone, NOx and PM emission results may be corrected for temperature.

In addition to the single control range required in the consent decrees, the proposed NTE test procedure allows a second option included in the U.S. EPA's Final Rule. In the second option, the temperature in the NTE control zone ranges 55 °F and 100 °F at sea level and between 55 °F and 86 °F at 5,500 feet above sea level. The maximum temperatures for the corresponding altitudes between those points are determined linearly. At temperatures and altitudes above the NTE zone, NTE requirements do not apply. Flexibility is provided by allowing manufacturers to choose between either option for NTE compliance. Unlike the consent decrees, the proposal has an altitude upper limit of 5,500 feet elevation for which NTE requirements apply.

As with the U.S. EPA's Final Rule, the staff's proposal includes both the consent decree NTE control zone and an optional second ambient temperature and altitude range. The optional second NTE control zone more closely represents the ambient conditions in California and would result in better control of emissions under typical conditions in California.

3. MAEL

Maximum allowable emission limit (MAEL) controls the emission during steady state operation of engines. The limit is calculated based on the collection of emission data from 12 steady state points, the four interpolation points and the margin. The allowed margin for the limit is 5 percent in the consent decrees whereas the allowance is 10 percent in the U.S. EPA's Final Rule. The proposal utilizes the higher margin of 10 percent, similar to the U.S. EPA's Final Rule to allow more flexibility in compliance.

4. EGR Cold Temperature Exclusion

Responding to the U.S. EPA's 2004 Notice of Proposed Rulemaking, manufacturers expressed concern regarding operation of exhaust gas recirculation technologies during cold temperatures. Specifically, sulfuric acid is formed from the mixture of cold ambient air and hot engine exhaust (i.e., a mixture containing small amounts of water vapor and SO2). When this mixture is recirculated through the intake system, corrosion problems reportedly occur. Consequently, in the U.S. EPA's Final Rule, an exclusion is included to allow EGR to be turned off in cold ambient temperature conditions, as shown in Table 3. As in the consent decrees, however, this exclusion is not included in the proposal since manufacturers may use more corrosion resistant materials. Additionally, the proposed NTE deficiency provision will give manufacturers a relief mechanism if the technologies have not developed sufficiently to allow EGR use during cold temperature conditions.

VI. TECHNOLOGICAL FEASIBILITY

A. GENERAL REVIEW

As described in the U.S. EPA's Final Rule, significant technological progress has been made in the last few years to achieve emission reductions from heavy-duty diesel engines. The examples of technologies described below have been demonstrated to effectively lower emissions: advanced fuel injection systems, cooled exhaust gas recirculation, advanced turbocharging systems (such as variable geometry and multiple turbochargers), and advanced electronic control systems. These systems have proven to be technically feasible and effective in numerous demonstrations and have been documented in scientific and engineering publications. These emission control technologies can produce substantial emission reductions in NOx, particulate matter and hydrocarbons, over a broad range of engine operating conditions. Emission reductions of approximately 50 to 90 percent from current generation heavy-duty diesel engines, have been demonstrated by combining these technologies.

In response to U.S. EPA's 1999 Notice of Proposed Rulemaking to adopt supplemental test procedures, several manufacturers provided U.S. EPA and ARB with information and data regarding the testing and development work they have already performed. The data show that under some extreme ambient and operating conditions, some engine technologies are challenged to meet the NTE and ESC requirements without sacrificing performance. Overall, however, under typical operating conditions, the data demonstrate that engines are capable of fully complying with the NTE and ESC requirements. Additionally, the signing manufacturers are required to meet the supplemental test procedures beginning October 1, 2002, pursuant to the consent decrees. Thus, the proposed supplemental test procedures, which mirror those in the consent decrees, will be technically feasible for the 2005 model year, about two years after the first consent decree engines have been manufactured.

Overall, the U.S. EPA's review of technology offers sufficient evidence that the proposed requirements in this report are technologically feasible. The following section will, therefore, briefly discuss some of the likely control strategies. Much of the information listed here is derived from the U.S. EPA's Final Rule and its Regulatory Impact Analysis. It should be noted that in the U.S. EPA's Final Rule, the rule reaffirmed the reduced FTP emission standard from 4.0 g/bhp-hr of NOx to 2.5 g/bhp-hr of NMHC plus NOx (for 2004 and subsequent model year HDDEs), and adopted similar supplemental test procedures (for 2007 and subsequent model year HDDEs). Consequently, the U.S. EPA's Final Rule described the combined technologies required for compliance with both the

reduced FTP standard and the supplemental test procedures. In this proposal, ARB staff is not proposing any change to the existing ARB 2.4/2.5 g/bhp-hr emission standard, but is proposing to adopt similar supplemental test procedures. Therefore, technology requirements and associated costs to comply with only the supplemental test procedures are expected to be significantly less than the costs presented by the U.S. EPA. Additionally, as mentioned previously in Section IV, staff is proposing a 2003 Technology Review to determine the state of technological progress to achieve compliance with the proposed supplemental test procedures.

B. EXAMPLES OF TECHNOLOGY

1. *Exhaust Gas Recirculation*

Exhaust gas recirculation (EGR) reduces peak combustion chamber temperatures by feeding exhaust gas back into the cylinder. This slows reaction rates and absorbs some of the heat, resulting in lower NOx emissions. Unfortunately, EGR also tends to negatively impact combustion efficiency, which tends to increase PM. However, PM increases can be minimized by reducing the amount of EGR during high-load operation. Another concern is that soot from the exhaust is added to the intake air, which could increase engine wear, damage a turbocharger or reduce the efficiency of an aftercooler. Researchers are evaluating ways to reduce the soot fed back into the engine.

2. *Turbocharging and Aftercooling*

Turbocharging is used to generate increased power from a given engine displacement. A turbocharger uses the waste energy in the exhaust gas to drive a turbine, which then boosts the pressure of the incoming air charge. By forcing more air into the combustion chamber, more fuel can be added, resulting in higher power while still inhibiting large particulate formation. Increasing power from a given engine, increases the denominator in the grams per brake horsepower-hour calculation, thereby reducing the emissions per unit of engine work.

Aftercooling was initially developed to improve the specific power output of an engine by increasing the density of air entering the combustion chamber, but aftercooling also reduces NOx emissions, by reducing the temperature of the charge air after it has been heated during compression. There are two kinds of aftercooling strategies: air-to-water, which releases the absorbed heat to the engine coolant system; and air-to-air, which releases the heat directly to the ambient air.

3. *Timing Retard*

Retarding the timing when fuel is injected into the engine cylinder, reduces NOx emissions by shortening the time available for combustion and lowering cylinder temperature and pressure. Conversely, timing retard increases HC, CO, PM, and fuel consumption, for the same reasons. In most cases, timing retard will be used in conjunction with other strategies to counteract any emission increases.

4. *Advanced Fuel Injection Controls*

Improved fuel injection is a major part of virtually any approach to reduce emissions from compression-ignition engines. High injection pressures offer better fuel atomization and mixing of the fuel and air, achieving more complete combustion. Timing retard can be used in conjunction with this strategy to inhibit NOx formation, resulting in overall reductions in NOx, HC, and PM simultaneously. Fuel injection rate shaping is another technique that helps reduce NOx. In a rate shaping system, the fuel is injected in several different injection events. Especially with electronic controls, this results in more carefully-controlled combustion. Thus, rapid increases in temperature and pressure can be minimized, reducing NOx formation. Staff expects most manufacturers can achieve significant NOx reductions by optimizing injection.

5. *Aftertreatment*

Aftertreatment strategies are not expected to be necessary to comply with the supplemental test procedures being proposed. However, aftertreatment remains a likely option for the future. Further reductions in emissions from diesel exhaust sources will be needed, particularly since diesel PM has been identified as a toxic air contaminant.

There are a number of aftertreatment technologies being researched for use on diesel-fueled vehicles and equipment that show a potential to control greater than 75 percent of engine-out NOx emissions. Some of these include DeNOx or “Lean-NOx” catalysts, NOx Adsorbers or NOx “traps,” selective catalytic reduction (SCR) technology, and non-thermal plasma. For advanced particulate emissions control, diesel particulate filters have been applied commercially in Europe and to provide reductions in excess of 85 percent for PM, HC, and CO emissions. These technologies are strong candidates for both new engines and retrofit applications.

All catalyst-based technologies are sensitive, to some extent, to the sulfur content in fuels. Sulfur impacts the emissions reduction capability of the aftertreatment device by attaching to the chemical sites that are needed for the catalytic reaction that reduces the emissions. NOx reduction catalysts are very susceptible to sulfur poisoning. Similarly, for catalyzed particulate traps, a high sulfur content directly leads to high levels of sulfate-based PM, rendering very low PM levels infeasible with high-sulfur fuel. Therefore, it is desirable to use the lowest sulfur diesel fuel available. Currently, California limits the sulfur level of diesel fuel used on-road to 500 parts per million (ppm). Actual sulfur levels are about 120 ppm, well below the maximum limit. The U.S. EPA also limits sulfur levels of diesel fuel for on-road vehicles to 500 ppm; in-use sulfur levels average 350 ppm. In order for manufacturers to take advantage of the emissions reduction potential of these advanced aftertreatment technologies, adoption of a nationwide sulfur limit of 15 ppm or less will be necessary.

VII. REMAINING ISSUES

Although the proposed supplemental test procedures were first required in 1998, through the consent decrees, and adopted in July 2000 by the U.S. EPA, several issues remain. These remaining issues are the technical feasibility of the proposed test procedures and concerns regarding ARB's authority to adopt the test procedures.

In early 2000, manufacturers raised several technological concerns with achieving full compliance with NTE test procedures. The concerns include the performance of emission control components at high ambient operating conditions (e.g., high ambient temperatures and high altitudes) and the durability of available materials for components. Manufacturers argue that without turning off emission control devices under these conditions, the engine turbochargers would overheat.

The NTE test procedure's range of applicability is restricted in the consent decrees, with respect to the engine operating map, humidity, and temperature. The restrictions were designed to ensure that the requirements would be feasible, and we anticipate that settling manufacturers will be able to meet these limits in 2002. If NTE compliance at these operating conditions continues to pose a problem, a solution is to limit power generated by the engines under these conditions of concern. While manufacturers do not favor this option, it is certainly feasible. In addition, staff has included an NTE deficiency allowance in the proposal to provide relief for technical problems that are of a limited nature. Finally, to ensure that manufacturers can comply with the proposed test procedures, staff is proposing a 2003 technology review to determine the state of technological progress to achieve compliance with the proposed supplemental test procedures.

In addition, manufacturers have expressed concern with the proposal to implement the NTE and ESC test procedures in 2005 and subsequent model years. The final federal rulemaking for the NTE and ESC test procedures (65 FR 59896, October 6, 2000), delayed the implementation of the test procedures to 2007. The delay was attributed to timing constraints imposed on the U.S. EPA by the federal Clean Air Act Amendments of 1990 (CAA; Public Law 101-549; Title 42, United States Code, § 7401 et seq.). Some believe that California's proposed implementation of the supplemental test procedures should be similarly delayed. The federal timing constraints, however, do not apply to California's rulemaking: California has authority to adopt a separate state program of emission controls for new motor vehicles and new motor vehicle engines under CAA § 209(b). California's authority includes the authority to adopt test procedures that ensure that new motor vehicles and new motor vehicle engines meet California's state emission control standards.

VIII. REGULATORY ALTERNATIVES

The staff evaluated various alternatives to the proposed amendments. A brief description of the alternatives and the staff's reasoning for rejecting them follows.

A. DO NOT AMEND CURRENT CALIFORNIA REGULATIONS

One alternative to this proposal would be to continue to use the current on-road heavy-duty diesel test procedures for 2005 and subsequent model years. The current certification method uses the FTP test cycle. However, this test cycle does not completely represent actual, in-use driving. As a result, engine manufacturers may employ less efficient emission control strategies in order to achieve higher fuel efficiency during driving patterns not represented on the FTP test cycle.

Additionally, many engine manufacturers are required to satisfy the proposed NTE and ESC requirements for a two-year period beginning in October 2002. If the proposed amendments are not approved, the marketplace in 2005 may prompt the settling manufacturers to use less efficient emission control strategies to boost fuel economy. If this occurs, the potential resulting emissions in California from HDDEs are in excess of 20 tons per day of NOx in 2006 and 18 tons per day of NOx in 2010. Because of these potential excess emissions, and because the technologies needed to achieve the reductions will be in use by the time the proposed regulations are implemented, staff rejected this alternative.

B. ADOPT MORE STRINGENT TESTING STANDARDS

The staff recognizes that more stringent standards for the control of emissions from heavy-duty diesel engines will be necessary to cover all types of driving and attain federal ambient air quality standard for ozone. Emission benefits of this proposal are discussed in Section X. For 2007 and subsequent model year HDDEs, both the U.S. EPA and ARB are examining further emission reductions through more stringent testing standards. At this time, however, the staff is not recommending more stringent requirements compared to those required for the settling manufacturers in the consent decrees.

IX. ECONOMIC IMPACTS

The proposed amendments fill the regulatory gap between consent decree requirements for the settling manufacturers and the federal regulations for 2007 and subsequent model year heavy-duty diesel engines. Adoption of the proposed test procedures would not impose additional costs above the costs to comply with the requirements set forth in the consent decrees for the settling manufacturers.

Only those engine manufacturers who are not subject to consent decree requirements are expected to incur additional costs for engine design modifications. Currently, the non-settling engine manufacturers and settling manufacturers who are not required to comply with the supplemental test requirements of the consent decrees account for approximately 40 percent of engine sales. Under the proposed regulations, the non-settling manufacturers are required to satisfy the NTE and ESC requirements two years earlier than they would under the U.S. EPA's Final Rule. Staff believes that the proposed supplemental test procedures will not impose significant costs on these manufacturers given that they will nonetheless have to meet the NTE and ESC requirements in 2007. The proposed adoption of the supplemental test procedures is expected to have no noticeable impact on California business competitiveness, employment, or on business creation, elimination, and expansion for 2005 and 2006. A detailed discussion of the potential cost and economic impacts of the proposed amendments follows; it is primarily based on the U.S. EPA's Final Rule.

A. LEGAL REQUIREMENT

Sections 11346.3 and 11346.5 of the Government Code require State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment includes a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination, or creation, and the ability of California business to compete.

State agencies are required to estimate the cost or savings to any state or local agency, and school districts. The estimate is to include any non-discretionary cost or savings to local agencies and the cost or savings in federal funding to the State.

B. AFFECTED BUSINESSES

Any business that is involved in manufacturing on-road heavy-duty diesel engines may be affected by the proposed supplemental test procedures. ARB has identified 21 major engine manufacturers worldwide. Based on California's emission inventory model, EMFAC2000 Version 2.0, a projected total of 300,000 on-road heavy-duty diesel engines will be operating in California in 2005 and 2006. Projections indicate that 36,000 new, heavy-duty diesel vehicles may be affected during this two-year period.

The proposed supplemental test procedures may require additional or upgraded engine accessories. As a result, the HDDEs may be more costly to manufacture, and hence heavy-duty vehicles may cost more. Due to the potential price increase for HDDEs, transportation companies may be affected. The baseline average costs for a heavy-duty diesel engine, vehicle, and the operating costs based on a 30-year lifetime are shown in Table 5, with potential increases shown in Table 6.

Table 5 - Baseline Heavy-Duty Engine and Vehicle Costs

Heavy-Duty Class	Engine Cost	Vehicle Cost	Operating Cost
Medium Heavy-Duty	$ 13,938.00	$ 51,852.00	$ 35,116.00
Heavy Heavy-Duty	$ 24,391.00	$108,455.00	$121,422.00

Source: U.S. EPA's Final Regulatory Impact Analysis: Control of Emissions of Air Pollution from Highway Heavy-Duty Engines, July 2000. Costs are in year 2000 dollars.

Table 6 - Potential Cost Increases for Transportation Businesses

Heavy-Duty Class	Increased Engine and Vehicle Cost (2005)	Increased Annual Operating Cost	Total Annualized Cost (20 year)
Medium Heavy-Duty	$ 674.00	$ 4.03	$ 67.65
Heavy Heavy-Duty	$ 824.00	$ 8.62	$ 86.40

Source: U.S. EPA's Final Regulatory Impact Analysis: Control of Emissions of Air Pollution from Highway Heavy-Duty Engines, July 2000. Costs are in year 2000 dollars.

The net impact of increasing vehicle and operating costs may be greater competition from transportation companies that register their vehicles outside of California. Medium heavy-duty vehicles are assumed (from the EMFAC 2000 emissions inventory model) to only operate within the State. Therefore, only businesses that use heavy heavy-duty vehicles may encounter increased competition. Since the emissions inventory model that assumes only 24.6% of heavy heavy-duty vehicle activity is not registered in California, and the annualized increased costs are less than 1% of total annualized vehicle and

operating costs, the detrimental effects of this proposal are expected to be minimal.

C. ESTIMATED COSTS TO ENGINE MANUFACTURERS

The costs of the proposed supplemental test procedures have been estimated and are based on U.S. EPA's analysis for their Final Rule. The U.S. EPA's analysis not only includes costs to comply with similar supplemental test procedures, but also costs to reduce NOx emissions from 4.0 g/bhp-hr to NOx plus NMHC emissions of 2.5 g/bhp-hr. Because U.S. EPA's analysis includes costs for requirements in addition to the supplemental test procedures, the costs are considered a conservative, worst case estimate and actual costs for compliance with the supplemental test procedures will be markedly less. All engine manufacturers are assumed to utilize multiple technologies to satisfy the test procedure requirements for 2005 and subsequent model year medium and heavy heavy-duty engines. To estimate the incremental effect of the federal FTP standards and supplemental test procedures on engine costs, the U.S. EPA determined the most likely combination of technologies necessary to meet the requirements. The technologies which are expected to be used, include combustion optimization, electronic controls, improved fuel injection, cooled exhaust gas recirculation, and variable and multiple geometry turbochargers. The only non-emission parameters affected were engine performance, fuel consumption, and life of the engine. The net result of the non-emission benefits was a slight increase in annual costs associated with these effects. Assuming that engine manufacturers pass on the entire costs of the new test procedures to the end users, the incremental increase in per-engine price and overall lifetime operating costs have been estimated. These cost estimates are presented in Table 7 and are identical to those determined by the U.S. EPA.

Table 7 - Projected Unit Costs per Engine

Medium Heavy-Duty (14,001 – 33,000 lbs. GVWR)		
Item	Fixed Cost	Variable Cost
Cooled EGR (high-flow)	$106.00	$249.00
EGR durability	$ 28.00	$ 0.00
Combustion optimization	$ 57.00	$ 0.00
Improved fuel injection	$ 10.00	$ 65.00
Variable geometry turbochargers	$ 18.00	$127.00
Emission map testing	$ 5.00	$ 0.00
Certification	$ 9.00	$ 0.00
TOTAL	**$233.00**	**$441.00**

*(Table 7 continues on next page)

Heavy Heavy-Duty (33,000 lbs. and greater GVWR)		
Item	Fixed Cost	Variable Cost
Cooled EGR (high-flow)	$106.00	$345.00
EGR durability	$28.00	$0.00
Combustion optimization	$57.00	$0.00
Improved fuel injection	$10.00	$72.00
Variable geometry turbochargers	$18.00	$174.00
Emission map testing	$5.00	$0.00
Certification	$9.00	$0.00
TOTAL	**$233.00**	**$591.00**

Source: U.S. EPA's Final Regulatory Impact Analysis: Control of Emissions of Air Pollution from Highway Heavy-Duty Engines, July 2000. Costs are in year 2000 dollars.

The estimated costs are separated into incremental engine purchase price and annual operating costs. The incremental engine purchase price for new engines includes the fixed and variable costs. Fixed costs are costs associated with research and development, retooling, and certification. Variable costs are costs associated with hardware and assembly. Annual operating costs include any expected increases in maintenance and/or fuel consumption. U.S. EPA relied on a study of the economic impacts on heavy-duty highway engines by Accurex Environmental Corporation.[13] All costs in the Accurex study were presented in year 1995 dollars, although the costs shown in the table above are in year 2000 dollars.

Although hardware costs generally decline over time, the proposed test procedures will only affect model year 2005 and 2006 engines. Therefore, the resulting costs per engine per model year are as detailed in Table 8.

Table 8 - Projected Lifetime Net Present Value Cost per Engine

	Lifetime NPV Cost	
Medium Heavy-Duty	$	716.69
Heavy Heavy-Duty	$	915.35
Weighted Average of All Heavy-Duty	*$*	*797.04*

[13] "Benefits of Reducing Mobile Source NOx Emissions," prepared by Accurex Environmental Corporation for U.S. EPA, March 31, 1997. The Acurex Environmental Corporation has since changed its name to Arcadis Geraghty & Miller.

Additionally, many of the settling manufacturers are required to comply with the supplemental test procedures for the two-year period beginning in 2002. Since this accounts for approximately 60 percent of the current engines sold, the fixed costs associated with the supplemental test procedures will not be realized by the settling manufacturers, or HDDE purchasers, for model years 2005 and 2006.

D. POTENTIAL COSTS TO VEHICLE MANUFACTURERS

In addition to the costs directly associated with the manufacturing of engines which comply with the proposed test procedures, there may be costs associated with the re-design of vehicle chassis. However, in the U.S. EPA's Final Rule, no increased cost was attributed to vehicle manufacturers.

E. POTENTIAL IMPACTS ON BUSINESS

There are no potential impacts on businesses other than the additional costs for the engines and the additional annual operating costs, both described above. These costs summarized by vehicle class and model year are detailed in Table 9.

Table 9 - Estimated Prices for New On-Road Diesel Vehicles (per vehicle)

	2005 MY	2006 MY	Operating Costs NPV (20 yr)	Annualized Total Cost
Medium Heavy-Duty	$ 674.00	$ 441.00	$ 42.69	$ 67.65
Heavy Heavy-Duty	$ 824.00	$ 591.00	$ 91.35	$ 86.40
Weighted Average of All Heavy-Duty	*$ 734.05*	*$ 502.28*	*$ 62.37*	*$ 75.23*

Based on: U.S. EPA's Final Regulatory Impact Analysis: Control of Emissions of Air Pollution from Highway Heavy-Duty Engines, July 2000. Costs are in year 2000 dollars.

There are only two model years that would expect an increased cost due to the proposed supplemental test procedures since similar requirements have been finalized by the U.S. EPA for 2007 and subsequent model year heavy-duty diesel engines. The difference in vehicle prices for 2005 and 2006 model years is due to the assumption that fixed costs are only applied to the 2005 model year.

F. POTENTIAL IMPACT ON BUSINESS COMPETITIVENESS

The proposed amendments would have no significant impact on the ability of California businesses to compete with businesses in other states. This is

because all manufacturers that manufacture diesel engines for sale in California are subject to the proposed amendments regardless of where they are located. Most manufacturers of diesel engine have no major manufacturing facilities in California although they have some presence here. In addition, California's adoption of the proposed amendments would not impose additional costs above the costs to comply with the requirements set forth in the consent decrees for the signing manufacturers. These manufacturers supply approximately 60 percent of diesel engines used in California.

California trucking companies who use heavy-duty diesel engines may experience a slight increase in the price of a new truck relative to those in other states. We estimated the proposed amendments would increase the price of a new truck by about 1 to 2 percent compared to the estimated vehicle price of $52,000 for a medium heavy-duty vehicle and $108,000 for a heavy heavy-duty vehicle. This is not expected to significantly dampen the demand for heavy-duty trucks in California. In addition, this price disadvantage would last only for two years until the U.S. EPA's Final Rule became effective in 2007. If other states will adopt the supplemental test procedures pursuant to their authority to adopt California test procedures, California trucking companies would not have any increased costs for new heavy-duty diesel vehicles compared to costs in other states.

G. POTENTIAL IMPACT ON EMPLOYMENT

California accounts only for a small share of manufacturing employment for diesel engine production. According to the U.S. Department of Commerce, California employment in the internal combustion engines industry (NAICS 333618), which includes manufacturers of diesel engines, was 1,635 persons in 1998 or less than 0.1 percent of total manufacturing jobs in California. These employees work in 28 businesses across the state. One business employed over 500 people, two employed between 100 and 500, and the rest had less than 100 employees. Employment in these businesses is unlikely to be affected adversely because a small price increase is not expected to dampen the demand for diesel engines in California. Thus, the proposed regulations are not expected to cause a noticeable adverse impact on the California employment. However, some jobs may be created in research and development to enhance the design of current engine models. Some jobs may also be created in businesses manufacturing and distributing parts.

H. POTENTIAL IMPACT ON BUSINESS CREATION, ELIMINATION OR EXPANSION

The proposed amendments would have no noticeable impact on the status of California businesses. The amendments would not impose additional costs on major HDDE manufacturers that supply approximately 60 percent of engines. Non-consent decree manufacturers may experience a small increase in their manufacturing costs two years earlier than required in the U.S. EPA's Final Rule. We estimate the cost increase would range from about $674 to $824 per engine in 2005 model year and $441 to $591 per engine in 2006 model year. As noted above, the difference in vehicle prices for the 2005 and 2006 model years is due to the assumption that fixed costs are only applied to the 2005 model year. A cost increase of this magnitude is not expected to significantly alter the status of California businesses.

I. POTENTIAL COSTS TO LOCAL AND STATE AGENCIES

There would be no additional costs for local and state agencies associated with adopting the proposed test procedures. There may be a net health benefit as heavy-duty diesel engines must certify using more stringent test procedures. Health benefits, however, were not quantifiable in monetary terms.

X. ENVIRONMENTAL IMPACTS AND COST-EFFECTIVENESS

The air quality benefits and the cost-effectiveness of the proposed supplemental test procedures are presented in this section. The analysis, though based on U.S. EPA's Regulatory Impact Analysis, is adjusted to reflect costs in California and excess emissions reduced in California. The U.S. EPA's analysis includes increases in costs due to the costs of technologies needed to reduce engine emissions from 4.0 g/bhp-hr of NOx to 2.5 g/bhp-hr of NMHC plus NOx (for 2004 and subsequent model year HDDEs), as well as the costs associated with similar supplemental test procedures (for 2007 and subsequent model year HDDEs). Because of these premises, the presented cost-effectiveness for the proposed supplemental test procedures is very conservative. Yet, because the proposed supplemental test procedures would apply statewide, they would provide significant cost-effective emission reductions throughout California.

A. AIR QUALITY BENEFITS

1. Statewide Benefits

Using the methodology described below, Table 10 shows the statewide excess NOx emissions reduced by the staff's proposal for the 2005, 2006, and 2010 calendar years. Over the lifetime of the vehicles from the 2005 and 2006 model years, the amount of excess NOx emissions reduced is 0.6 tons per medium heavy-duty vehicle and 5.1 tons per heavy heavy-duty vehicle.

Table 10 - 2005, 2006, and 2010 Statewide Excess NOx Emissions Reduced by the Proposal (in tons per day)

	CY 2005	CY 2006	CY 2010
California Registered Vehicles Only	8.4	17.3	13.8
California and Out-of-State Registered Vehicles	10.8	22.2	18.3

In the adoption of the 2.5 g/bhp-hr NMHC plus NOx standard (SIP Measure M6), it was assumed that the 50 percent reduction of the federal NOx standard would also result in a 50 percent reduction in emissions for all driving. The ARB's emission inventory reflected this assumption. When the HDDE certification violations in the 1990s were discovered, it was found that operation outside the scope of the FTP test cycle could result in significant emission increases. The proposed supplemental test procedures ensure that the original emission benefit

assumptions under SIP Measure M6 are valid.

The 1994 Ozone SIP is California's plan for achieving the federal ozone standard in all areas of the state by the federally required date. The 1994 Ozone SIP includes state measures to control motor vehicles and pesticides, local measures for stationary and area sources, and federal measures for sources under exclusive or practical federal control. The U.S. EPA approved the 1994 Ozone SIP in September 1996 (62 Federal Register 1150, January 8, 1997).

The proposed test procedures will not affect the SIP since the excess emissions are not included in the inventory. Reductions from this proposal are not valid for SIP purposes. However, failure to adopt these test procedures could increase the NOx emission inventory and thus require further control in a future SIP. At this point, no further SIP analysis is necessary. Table 11 shows excess emissions that would be eliminated in several California air basins which have not yet achieved National Ambient Air Quality Standards. The excess emissions are calculated for California registered vehicles only.

Table 11 - Excess Emissions Eliminated by Air Basin in 2005, 2006 and 2010 (tons per day)

	2005	2006	2010
Sacramento Air Basin	0.8	1.6	1.3
San Joaquin Valley Air Basin	1.6	3.4	2.8
South Coast Air Basin	3.4	7.0	6.0
Statewide	8.4	17.3	14.3

2. Methodology to Calculate Excess Emissions

The equation used to calculate the excess NOx emissions, if the NTE and ESC standards were not required, for the 2005 and 2006 model years is as follows:

$$\text{Excess Emissions (tons/day)} = \frac{\text{EF x CF x (Daily\_VMT) x (Percent\_steady\_state)}}{909{,}091}$$

Equation 7 : Excess Emissions Formula

Where:

EF = The incremental NOx emission factor in grams per brake horsepower-hour (2.5 g/bhp-hr). This number was obtained by subtracting the FTP standard from the emission rate at steady-state mode. The emission rate at steady-state was provided, by one manufacturer of heavy-duty engines,

as confidential information.

CF = The conversion factor from gram per bhp-hr to grams per mile
= 2.3 for medium heavy-duty diesel engines or
= 2.6 for heavy heavy-duty diesel engines
(both are from California's previous Motor Vehicle Emission Factor Model – MVEI7G).

Daily VMT = Total daily vehicle miles traveled (from EMFAC2000)

Percent_steady_state
= The percent of VMT under steady-state mode. The split between the steady-state mode and the urban or transient mode of driving were obtained from two sources. One source of steady state driving mode information is based on confidential information from an engine manufacturer. The second source is the U.S. EPA's Defeat Device Spreadsheet model. Estimation from this model resulted in a 72% steady-state mode for heavy-heavy duty vehicles and 25% steady-state mode for medium-heavy duty vehicles. In this rulemaking, results from the Defeat Device spreadsheet model were used to calculate the excess emissions since the data in the model were derived from individual engine family defeat device response data provided to the U.S. EPA by engine manufacturers as a confidential and proprietary information and thus would be more representative than data obtained from a single manufacturer.

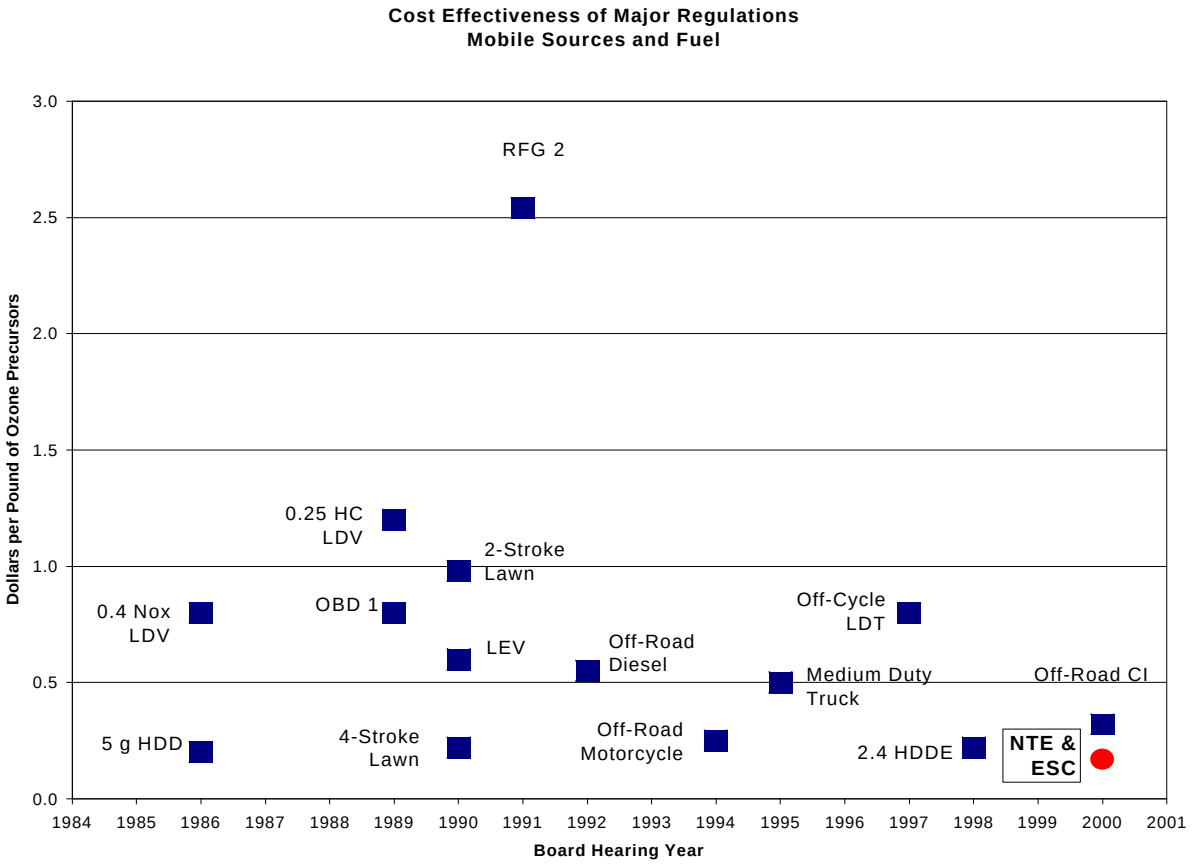
909,091 = Conversion factor from grams per day to tons per day

B. COST-EFFECTIVENESS

This proposal contains the most conservative cost estimates, as described in the sections above. The estimated cost of complying with the test procedures will vary depending on the gross vehicle weight rating class.

As shown in Figure 7, the cost-effectiveness of California mobile source and motor vehicle fuels regulations adopted over the past decade range from $0.17 to $2.55 per pound of ozone precursors reduced. The cost-effectiveness of the proposed test procedures by weight class is $0.63 per pound of NOx reduced for medium heavy-duty vehicles and $0.09 per pound of NOx reduced for heavy heavy-duty vehicles. Combining the cost-effectiveness for all heavy-duty vehicles based on predicted sales, results in $0.17 per pound of NOx reduced for all heavy-duty vehicles (identified with a round marker on Figure 7).

Figure 7


Cost Effectiveness of Major Regulations
Mobile Sources and Fuel
Dollars per Pound of Ozone Precursors
3.0
2.5
2.0
1.5
1.0
0.5
0.0
RFG 2
0.25 HC LDV
2-Stroke Lawn
0.4 Nox LDV
OBD 1
LEV
Off-Road Diesel
Off-Cycle LDT
Medium Duty Truck
Off-Road CI
5 g HDD
4-Stroke Lawn
Off-Road Motorcycle
2.4 HDDE
NTE & ESC
1984
1985
1986
1987
1988
1989
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2000
2001
Board Hearing Year

XI. SUMMARY AND STAFF RECOMMENDATION

The supplemental test procedures included in the proposed amendments are essential to ensure in-use compliance with ARB's standards over various operation conditions. These supplemental test procedures will be effective measures to prevent excess emissions that are not detected when certifying only to the FTP test cycle. Since these emissions were not included in the SIP, they are "excess". However, due to their potential negative effects on human health, reduction of these excess emissions is important.

When the consent decree requirements expire in 2004, the engines produced by the settling manufacturers will likely revert to engine control strategies that are more fuel efficient, but also emit more NOx during in-use driving, to enhance competitiveness in the marketplace. Adopting the proposed test procedures will require settling manufacturers to continue producing clean engines during the 2005 and 2006 calendar year period, and require non-settling manufacturers to produce similarly clean engines beginning in 2005.

The technologies that would allow manufacturers to comply with the proposed test procedures are available. Furthermore, the HDDE settling manufacturers will start producing engines that are compliant with the proposed test procedures by October 1, 2002 under the consent decrees. These engine manufacturers will have at least two years of experience with the various technologies by 2005. Therefore, it will be technologically feasible for model year 2005 heavy-duty diesel engines to comply with the supplemental test procedures.

Estimates of statewide reductions of excess emissions resulting from the proposal are 8 tons per day and 17 tons per day of NOx in 2005 and 2006, respectively, for California registered vehicles (i.e., not including out-of-state vehicles). However, if enough States adopt California's requirements, under the authority granted in section 177 of the federal Clean Air Act, engine manufacturers will decide to produce clean heavy-duty diesel engines on a national basis. Consequently, the reduction of excess emissions (including emissions from out-of-state vehicles) would be 11 tons per day and 22 tons per day of NOx in 2005 and 2006, respectively. The additional emission reductions would be realized from "clean" out-of-state vehicles travelling in California. This makes the support, and adoption, of the proposed test procedures by other states an important component in maximizing the success and effectiveness of the proposal.

The estimated California cost-effectiveness with adoption of the staff's proposal ranges from approximately $0.09 to $0.63 per pound of NOx reduced. The staff recommends that the Board adopt the proposed supplemental test procedures.

XII. REFERENCES

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ARB, 1998. Proposed Amendments to Heavy-Duty Vehicle Regulations: 2004 Emission Standards; Averaging, Banking and Trading; Optional Reduced Emission Standards; Certification Test Fuel; Labeling; Maintenance Requirements and Warranties, March 6, 1998 (Staff Report).

U.S. EPA, 2000. Notice of Final Rulemaking, Control of Emissions of Air Pollution From 2004 and Later Model Year Heavy-Duty Highway Engines and Vehicles; Revision of Light-Duty On-Board Diagnostics Requirements, Signed by Carol Browner, United States Environmental Protection Agency Administrator, July 31, 2000; 65 Federal Register 59896, October 6, 2000.

U.S. EPA, 2000. Regulatory Impact Analysis: Control of Emissions of Air Pollution from Highway Heavy-Duty Engines, July 2000 (EPA420-R-00-010).

APPENDIX A – PROPOSED AMENDMENTS TO TITLE 13, CALIFORNIA CODE OF REGULATIONS, CHAPTER 1, ARTICLE 2; EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 1985 AND SUBSEQUENT MODEL YEAR HEAVY-DUTY ENGINES AND VEHICLES.

APPENDIX B — PROPOSED AMENDMENTS TO CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 1985 AND SUBSEQUENT MODEL HEAVY-DUTY DIESEL ENGINES AND VEHICLES