State of California
California Environmental Protection Agency

AIR RESOURCES BOARD

STAFF REPORT

PUBLIC HEARING TO CONSIDER ADOPTION OF NEW CERTIFICATION TESTS AND STANDARDS TO CONTROL EXHAUST EMISSIONS FROM AGGRESSIVE DRIVING AND AIR-CONDITIONER USAGE FOR PASSENGER CARS, LIGHT-DUTY TRUCKS, AND MEDIUM-DUTY VEHICLES UNDER 8,501 POUNDS GROSS VEHICLE WEIGHT RATING

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Prepared by

Mobile Source Control Division

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EXECUTIVE SUMMARY

In this rulemaking, the Air Resources Board (ARB) staff is proposing new exhaust emission standards that will apply to vehicles during high-speed, high-acceleration operation, and driving with air-conditioner usage. Emission increases due to aggressive driving have not been regulated by existing standards, and emission increases associated with air-conditioner usage have been undercounted. The central standards being proposed, applicable to low-emission passenger cars, light-duty trucks and lighter medium-duty vehicles, reflect a consensus between staff and the motor vehicle industry based on a series of cooperative test programs conducted since 1995. It is expected that the standards, to be phased in starting with the 2001 model year, will effectively eliminate the significant emission increases associated with these operating modes.

Currently, both the California and Federal exhaust emission standards for motor vehicles apply to emissions that occur when the vehicle is operated through a series of narrowly defined operations, collectively known as the Federal Test Procedure, or FTP. Tests conducted in the past several years have shown that the FTP does not accurately reflect various operating conditions such as aggressive driving and use of the air-conditioner. During these operating conditions, emissions can be substantially higher than those measured during the normal FTP driving cycle. As a result, the ARB and the United States Environmental Protection Agency (U.S. EPA), in close coordination with motor vehicle manufacturers, initiated a joint effort to identify additional test cycles that effectively measure emissions during "off-cycle" operation. Staff from the two agencies ultimately agreed upon two supplemental test procedures (collectively the SFTP): a high-speed, high-acceleration test known as the US06 test, and the SC03 air-conditioner test.

In October 1996, U.S. EPA issued a Final Rule adopting the SFTP and established SFTP emission standards that apply to passenger cars, light-duty trucks, and heavy light-duty trucks, to be phased-in starting with the 2000 model year. Under the Federal Clean Air Act, the "Tier 1" emission standards -- equivalent to California's 1994 model-year standards -- must remain unchanged at the federal level until the 2004 model year. Thus U.S. EPA set 50,000 and 100,000 mile SFTP standards at levels appropriate for Tier 1 vehicles. U.S. EPA took a "composite" approach in which emissions from the US06 test, SC03 air-conditioner test and the FTP are combined on a weighted basis. The composite emissions of non-methane hydrocarbons (NMHC) and oxides of nitrogen (NOx) from passenger cars must meet a 50,000-mile combined standard of 0.65 grams per mile (g/mi). This standard is numerically identical to the sum of the Tier 1 FTP 50,000 mile standards for NMHC (0.25 g/mi) and NOx (0.4 g/mi). Vehicles certified to the SFTP standards must also separately comply with the preexisting FTP standards.

The ARB staff is proposing the adoption of the high-speed, high-acceleration and air-conditioner supplemental *test procedures* that are in all respects identical to the procedures adopted by U.S. EPA. The SFTP is sound and well-designed. The establishment of identical test procedures will continue to permit manufacturers to put a vehicle through one set of tests to demonstrate compliance with both the California and Federal standards.

The staff is also proposing that the Board adopt SFTP emission *standards*, phased-in starting with the 2001 model year, that overall are substantially more stringent than the Federal SFTP standards and will achieve very significant emission reductions. Under the California Low-Emission Vehicle and Clean Fuels Program, by the 2001 model year the vast majority of passenger cars and light-duty trucks will be certified to the low-emission vehicle (LEV) standards, which limit hydrocarbon emissions to only 30 percent of the Federal Tier 1 level, and NOx to 50 percent of the Tier 1 level. Thus, without any additional SFTP control strategies, an LEV would be expected to have substantially lower SFTP emissions than a Tier 1 vehicle. To comply with the proposed SFTP standards, there are also technologically feasible control strategies that can significantly further reduce SFTP emissions from LEVs.

Under staff's proposal, there would be one set of 4,000 mile SFTP standards, made up of a US06 and an SC03 element, that apply equally to LEVs, ultra-low-emission vehicles (ULEVs), and super-ultra-low-emission vehicles (SULEVs) in the same weight classifications. The California SFTP standards for Tier 1 vehicles and transitional low-emission vehicles (TLEVs) would be identical to the Federal SFTP Tier 1 standards; under the "non-methane organic gas fleet average" element of the Low-Emission Vehicle and Clean Fuels Program, manufacturers have the option to sell small numbers of Tier 1 vehicles and TLEVs by the 2001 model year when these proposed regulations are phased-in. As is the case with the ARB's FTP tailpipe emission standards, there would be a set of SFTP emission levels for passenger cars and lighter light-duty trucks, with greater emissions allowed for heavier weight classifications up to and including medium-duty vehicles having a gross vehicle weight rating of 8,500 pounds.

The proposed SFTP standards for LEVs, ULEVs and SULEVs are based on a series of test programs conducted by ARB staff and the motor vehicle industry from June 1995 to February 1997, and reflect a *consensus* between staff and industry. The vehicles tested were either LEV prototypes tested by the manufacturers or production vehicles certified to the Tier 1 or TLEV standards and considered to be representative of future LEVs; in both cases the emission control systems were initially aged to 50,000 miles. ARB staff also tested additional low-mileage (around 4000 miles) vehicles.

The objective of the test programs was to determine US06 and SC03 emission levels from vehicles under two distinct modes: first, in their original configuration, and second, with SFTP emission control optimized using engine calibration techniques. The main control strategy investigated for both the US06 and SC03 cycles was the use of air-fuel ratio "bias," in which slightly rich air-fuel ratios can reduce NMHC plus NOx by increasing catalyst NOx conversion efficiency. Ultimately, the lowest emission levels were achieved with optimized low-mileage vehicles. They had average NMHC plus NOx US06 emissions of 0.09 g/mi; this was a 68 percent reduction from the average unoptimized emissions. The low-mileage vehicles optimized for the air-conditioning test had average NMHC plus NOx SC03 emissions of 0.13 g/mi, a 64 percent reduction from the average unoptimized emissions.

The proposed 4,000 mile SFTP standards for LEV and ULEV passenger cars are shown in Table E-1. The NMHC plus NOx values approximate the average emissions of the optimized low-mileage test vehicles, with a 50 percent "headroom" allowance. The staff is recommending establishment of 4,000 mile standards because these standards can be appropriately based on the impressive emission performance of the low-mileage vehicles tested. Some deterioration in SFTP emissions will be expected over 50,000 and 100,000 miles. However, gross deterioration should be avoided by the existence of 50,000 and 100,000 mile FTP emission standards, and by the use of On-Board Diagnostics II systems.

Table E-1. Proposed US06 and SC03 Emission Standards for Passenger Cars

US06 (g/mi)		**SC03 (g/mi)**	
NMHC+NOx	**CO**	**NMHC+NOx**	**CO**
0.14	8.0	0.20	2.7

The proposed standards are technologically feasible. Strategies to reduce warmed-up FTP emissions from LEVs should also generally reduce SFTP emissions. Staff conservatively estimates that at least 70 percent of LEVs will comply with the US06 and SC03 standards with only software modifications, typically consisting of a rich-bias calibration. The remaining vehicles would require catalyst hardware modifications, generally either increased precious metal loading or increased catalyst volume.

In 2020, the proposal is estimated to reduce statewide emissions of NMHC plus NOx by 133 tons per day. The best estimate of the projected costs is $43.2 to 57.9 million annually, or $28.80 - 38.60 per vehicle. The estimated cost-effectiveness is $890 to $1,200 per ton, or $0.44 to $0.060 per pound. This compares favorably to $5 per pound, which is a typical cost-effectiveness value for an air pollution control measure.

I. INTRODUCTION

It is well known that, despite major improvements, California continues to experience the worst air pollution of any region in the United States. Violations of the National Ambient Air Quality Standards for both ozone and particulate matter continue to occur on a regular basis in the State and especially in the South Coast Air Basin. During 1996, the Federal and more stringent State ozone standards were violated, respectively, on 90 and 152 days in the South Coast Air Basin.

Ozone and particulate matter pollution are of primary concern because of their effects on human health. Ozone is a known respiratory irritant and is believed to harm lung tissue and breathing capacity. Its effects are most prominent in sensitive individuals such as asthmatics, the elderly, and children. Based on recent epidemiological studies[1], particulate matter pollution, while not considered to directly irritate lung tissues, has been increasingly implicated in premature mortalities. According to a recent Natural Resources Defense Council study[2], particulate matter pollution causes between 8,600 and 19,400 premature deaths in the State annually. In response to evidence concerning these and other health effects, the United States Environmental Protection Agency (U.S. EPA) is presently proposing to revise both the Federal ozone and particulate matter standards.

The above considerations and the 1994 State Implementation Plan for ozone require that current emissions of precursors to ozone and particulate matter be reduced to attain ambient air quality standards. Emissions from mobile sources are the primary cause of air pollution in many parts of the state. Mobile sources contribute up to 50 percent of the statewide reactive organic gases (hydrocarbons) and over 50 percent of the statewide oxides of nitrogen (NOx) emissions, both known to contribute to the formation of ozone and particulate matter pollution in the atmosphere. The Air Resources Board (ARB or Board) is directed by California Health and Safety Code Section 43108 to achieve the maximum degree of emission reductions from mobile sources that would allow attainment of state ambient air quality standards by the earliest practicable date.

On-road motor vehicle emissions are currently controlled through a process of certification of vehicles for sale in California and in-use compliance testing. In this process, motor vehicle manufacturers are required to demonstrate, both prior to selling new vehicles in the State and during subsequent in-use operation, that vehicles comply with all applicable exhaust and evaporative emission standards. The Board made major revisions to these standards during 1990 by adopting the Low-Emission Vehicle and Clean Fuels Program and the "Enhanced" Evaporative Emission Test Procedure, with standards for both categories of emissions reduced by over 70 percent. These revisions are expected to result in significant air-quality improvements in the State

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[1] Dockery, Douglas W. et al. "An Association Between Air Pollution and Mortality in Six U.S. Cities." New England Journal Of Medicine, Vol. 329, No. 24, pp. 1753-9.

[2] Shprentz, Deborah Sheiman, et al. Breath-Taking: Premature Mortality due to Particulate Air Pollution in 239 American Cities. Natural Resources Defense Council. May 1996.

by the year 2010, when the South Coast Air Basin is required by the Federal Clean Air Act to be in compliance with the current Federal ozone standard.

The current motor vehicle exhaust emission test procedure, known as the Federal Test Procedure (or FTP), was first used for motor vehicle certification in 1975. In recent studies, it was found to have several major shortcomings in representing conditions under which motor vehicles are driven. Consequently, actual in-use vehicle emissions are underestimated. The principal limitations of this test are as follows:

- Speeds greater than 57 miles per hour (mph) are not represented during the test;
- Accelerations greater than 3.3 mph/second are not included (at this constant acceleration rate, it would require 18 seconds to accelerate from 0 to 60 mph);
- Air-conditioner operation is not properly represented; and
- The twin-roll dynamometer currently required for testing does not adequately simulate the actual on-road effects of vehicle inertia or aerodynamic drag.

For these reasons, the U.S. EPA on October 22, 1996 promulgated a Final Rule (61 F.R. 54852) that establishes a Supplemental Federal Test Procedure (SFTP). These additional certification test procedures, designed to remedy the above shortcomings of the FTP, include the following elements:

- An additional high speed, high acceleration test, known as the US06 test, was added. This test contains a maximum speed of 80 mph and a maximum acceleration rate of 8.5 mph/second. This test and the current FTP assure emission control under virtually all driving modes.
- An additional test, known as the SC03 air-conditioner test, was added in order to directly measure and control emissions that occur with air-conditioner operation.
- The use of new dynamometers, known as "single-roll" dynamometers, was mandated in order to ensure that on-road vehicle load effects are properly represented during emission testing.

In its Final Rule, the U.S. EPA specified SFTP emission standards that would apply to the new tests outlined above. These new standards and test procedures apply to Federally-certified "Tier 1" vehicles with a phase-in schedule starting in the 2000 model year. While the Federal SFTP standards are appropriate for this category of vehicle, lower SFTP emission standards are more suitable for California low-emission vehicle (LEV), ultra-low-emission vehicle (ULEV), and super-ultra-low-emission vehicle (SULEV) emission categories. Tier 1 vehicles are required to meet FTP emission requirements significantly less stringent than the California Low-Emission Vehicle and Clean Fuels Program requirements. For example, at 50,000 miles, passenger cars certified to the LEV category are permitted to emit only about 30 percent of hydrocarbon (HC) emissions and 50 percent of NOx emissions compared to Tier 1 vehicles. For this reason, ARB staff is recommending that the Board adopt the more stringent SFTP standards proposed in Section III, Summary of Recommended Action, for LEVs, ULEVs, and SULEVs.

II. BACKGROUND

A. High-Speed, High-Load Driving

Concerns about the representativeness of the FTP were first investigated in an ARB test program conducted in 1990, where ten vehicles were tested over a computer-generated cycle consisting of accelerations significantly more aggressive than those contained on the FTP. The results of this program are discussed in the ARB Mobile Source Division Mail-Out 91-12. The vehicles showed extremely high emissions of HC and carbon monoxide (CO) over these modes. For some vehicles, the CO emitted during a single 10-second acceleration equaled the emissions produced during 20 minutes of typical driving. Although less significant, increases in NOx emissions were observed as well. The HC and CO emission increases are believed to be due to the use of “commanded enrichment.” During this process, the vehicle fuel-injection system is “commanded” by the vehicle computer to inject additional fuel into the engine beyond that required to maintain a “stoichiometric” air-fuel ratio. This generates a 3-5 percent increase in engine power. Commanded enrichment also cools the exhaust gas and catalyst in order to lessen catalyst thermal deterioration.

Following ARB’s 1990 test program, both the U.S. EPA and the ARB began in 1992 to study the driving patterns of in-use vehicles. Data were gathered on driving behavior in Los Angeles, Spokane, Baltimore, and Atlanta. In general, these data showed that a significant fraction of current driving conditions are not represented by the FTP; approximately 28 percent of the current light-duty vehicle miles recorded were traveled during speed or acceleration regimes not covered by the FTP. The majority of these miles were at high speed (approximately 60 - 70 mph), with an additional increment from low-speed acceleration rates higher than those in the FTP. Several driving cycles were developed using these data sets, in which two cycles of interest are the REPO5 and ARB01B test cycles (See Appendix 1, Figures A and B.) The REPO5 cycle was designed by the U.S. EPA to be representative of non-FTP driving. It contains high-speed and high-acceleration events in the same proportion as they were found to occur in real-world driving. The ARB01B cycle was designed by the ARB staff to cover the entire regime of high-speed, high-acceleration events, including the more extreme driving modes excluded by the REPO5 cycle. It was from these two cycles that the US06 test cycle was developed and later adopted by the U.S. EPA to represent aggressive driving.

Following development of these cycles, a cooperative ARB/U.S. EPA/Industry test program, involving some 60 Tier 0[3] and Tier 1 vehicles, was conducted in 1993 and 1994 over

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[3] Tier 0 refers to those emission standards in effect when the 1990 Amendments to the Federal Clean Air Act were enacted.

various driving cycles, including the REPO5 and ARB01B cycles. Using these cycles, HC, CO, and NOx emissions from production vehicles were compared to emissions observed during warmed-up driving on the FTP. Included were data generated in a stoichiometric configuration, in which commanded enrichment was removed. In the stoichiometric configuration, the data showed HC and CO emission decreases relative to the production configuration, but also generally showed NOx emission increases. Due to the higher temperatures involved in stoichiometric combustion, the engine produces more NOx in the stoichiometric configuration than in the commanded enrichment configuration, resulting in increased tailpipe NOx emissions. Subsequent ARB research suggests that the use of a proper "rich-bias," or a very slightly rich air-fuel ratio, will moderate these NOx increases on many vehicles.

The U.S. EPA conducted a test program to assess the high-speed, high-load emission increases. Based on eight Tier 1 low-mileage passenger cars, emissions from hot-stabilized, high-speed and high-load driving compared to hot-stabilized FTP in-use emissions increased by 0.014 grams per mile (g/mi) non-methane hydrocarbon (NMHC), 1.6 g/mi CO, and 0.025 g/mi NOx. Actual in-use emission increases for passenger cars are likely to be considerably higher due to vehicle deterioration. In addition, total Tier 1 vehicle fleet emission increases will likely be larger than these passenger car increases because of the likelihood of greater high-speed, high-load emission increases in light-duty trucks and medium-duty vehicles.

It is worth noting that the above absolute emission increases are not necessarily applicable to LEVs, which are expected to employ more advanced technologies (such as improved air-fuel ratio control and improved catalyst technology) to reduce FTP NMHC, CO and NOx emissions. The use of these technologies may result in a corresponding reduction in high-speed, high-load emissions. A discussion of the high-speed, high-load emission impact on LEVs is provided in Subsection D, which describes the ARB/Manufacturer standards-setting test program for the US06 test cycle. This was the only test program performed with vehicles considered to be reasonably representative of LEVs. Therefore, the ARB staff has used data from this program in its assessment of high-speed, high-load emissions from LEVs.

B. Air-Conditioner Operation

Due to the shortcomings in the FTP, the U.S. EPA also became concerned with the real-world emission impact of air-conditioner usage. Currently, use of the air-conditioner is simulated in the FTP by increasing the aerodynamic power absorption (also known as Road Load Horsepower) of the dynamometer load by 10 percent. Concern grew that this simulation vastly under-represented the effect of air-conditioner operation on emissions. For example, the fuel economy penalty commonly associated with air-conditioner operation is generally underestimated by the 10 percent dynamometer load increase. In addition, there are ongoing concerns that the FTP does not accurately represent current driving behavior in the first few minutes following the start of a trip and "micro-transient" driving in which many small variations in speed occur; the unrepresented parameters may lead to greater emission increases associated with air-conditioner usage than generally expected. For these reasons, in the spring of 1994 General Motors Corporation (GM), in cooperation with other vehicle manufacturers, conducted an 8-vehicle test program in the now GM-affiliated Delphi "environmental chamber" facility located in Rochester, New York. This facility was used rather than more standard emission facilities because of its ability to adequately represent high ambient temperature (95°F), humidity, air-flow over the vehicle, and solar load. All four of these parameters are believed to significantly affect the work performed by the air-conditioner, and hence the emission impact of actual air-conditioner operation.

The vehicles tested were generally Tier 1-certified vehicles at approximately 4,000 mile odometer readings, with two light-duty trucks and two transitional low-emission vehicles (TLEVs) included. The vehicles were tested over standard cold-start FTPs, as well as FTP tests in which the air-conditioner was used. Also included were hot-start tests over a U.S. EPA-designed, lower-speed "REM01" test cycle, and over the high-speed, high-load REPO5 test cycle. Data from this program are summarized in Table 1, which is taken from a U.S. EPA document.[4]

As indicated in Table 1, air-conditioner usage results in significant increases in NMHC, CO and NOx emissions, with the NOx increase being predominant. FTP NOx emissions increased by more than 90 percent, from 0.214 to 0.411 g/mi, or a total increase of 0.197 g/mi. FTP NMHC and CO emissions increased by 0.022 and 0.495 g/mi, respectively. Data from the REM01 start cycle generally confirm these increases, although they are numerically larger due to the shortness and relative severity of this cycle. Also shown in Table 1, a somewhat smaller percent increase in NOx emissions is observed during the high-speed, high-load REPO5 test cycle.

A second test program conducted by the automotive manufacturers in 1995 confirmed these results. This program was performed using vehicles with emission control hardware aged to the equivalent of 50,000 miles, and showed even larger NOx emission increases than did the first program.[5]

As with the high-speed, high-load driving test programs, the vehicles tested in these air-conditioner programs were not LEVs, so that the numerical g/mi increases observed are not representative of those that would be observed in LEVs. The percent increases are, however, in all likelihood comparable to those that would be experienced by LEVs. Actual data on vehicles having similar emission characteristics to LEVs are contained in Subsection E.

C. U.S. EPA Rulemaking

On October 22, 1996, the U.S. EPA promulgated regulations (61 F.R. 54852) designed to reduce the emission increases outlined above. These regulations added the US06 and SC03 test procedures to the existing testing requirements for manufacturers to certify motor vehicles for sale in the United States.

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[4] U.S. EPA. "Final Technical Report on Air Conditioning for the Federal Test Procedure Revisions, Notice of Proposed Rulemaking." January 31, 1995.

[5] Ibid.

Table 1. Vehicle Manufacturer Air-Conditioner Test Program Emission Summary

Test Cycle	A/C Usage	NMHC	CO	NOx
FTP	Off	0.088	0.965	0.214
	On	0.110	1.460	0.411
	Increases: g/mi	**0.022**	**0.495**	**0.197**
	Percent	**+25%**	**+25%**	**+92%**
REM01	Off	0.523	3.038	0.822
	On	0.505	3.866	1.569
	Increases: g/mi	**-0.018**	**0.828**	**0.747**
	Percent	**-3%**	**+27%**	**+91%**
REPO5 Test Cycle	Off	0.059	2.881	0.269
	On	0.076	5.026	0.371
	Increases: g/mi	**+0.017**	**+2.145**	**+0.102**
	Percent	**+29%**	**+74%**	**+38%**

Reference: U.S. EPA, "Final Technical Report on Air Conditioning for the Federal Test Procedure Revisions, Notice of Proposed Rulemaking." January 31, 1995.

The US06 test cycle was agreed upon by the ARB, U.S. EPA, and motor vehicle industry in June 1994 as an appropriate cycle for the control of high-speed, high-load emissions. Since high-speed, high-load conditions generally exhibit the greatest emission increases and are the most difficult to control, the cycle is intentionally designed to contain a greater frequency of these events than would occur in typical driving. A plot of the test cycle is included in Appendix 1, Figure C.

The SC03 test for air-conditioner emission control was designed to accurately represent driving behavior during the first few minutes following a hot trip-start, as well as provide a reasonably accurate representation of typical low- to moderate-speed driving. A plot of this cycle is included in Appendix 1, Figure D. High-speed driving was excluded because of the smaller air-conditioner related emission increases found in this regime during the air-conditioner test programs. Cold-start driving was excluded because it was believed that the only method to reduce these emissions was through increased cold-start emission control. Cold-start emissions are currently controlled through the FTP. However, the U.S. EPA is prohibited by Federal law[6] from increasing the stringency of the Tier 1 FTP standards until the 2004 model year.

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[6] Federal Clean Air Act, Section 202(b)(1)(C).

In its rulemaking, the U.S. EPA formulated NMHC plus NOx emission standards using a "composite" of the US06, SC03 air-conditioner test, and the FTP emissions. This was done with the intention of allowing manufacturers flexibility in meeting the emission levels specified, and also in an attempt to keep overall costs as low as possible. In its composite approach, the U.S. EPA used weighting factors of 35 percent, 37 percent, and 28 percent for the g/mi results of the FTP, SC03 air-conditioner test, and the US06, respectively. For compliance with the CO emission standards, manufacturers may elect to certify their vehicles to the stand-alone standards for the US06 and the SC03 tests, or the composite option. Table 2 shows the U.S. EPA's adopted emission standards for Tier 1 passenger cars and trucks. These standards would be implemented on a 40-80-100 percent phase-in basis, beginning in the model year 2000. These standards are "useful" life standards, with which manufacturers' vehicles must comply at 50,000 and 100,000 miles during both certification and in-use compliance testing.

D. ARB/Manufacturer US06 Standards-Setting Test Program

In December of 1994, the ARB staff and the motor vehicle industry began discussions for a joint test program aimed at developing technologically appropriate emission standards for LEVs over the US06 test cycle. This joint program was considered necessary because of the need to develop emission standards for the LEV class for which no production LEVs were available. For this reason, the ARB staff invited the motor vehicle industry to test prototype LEVs in support of an LEV US06 standard. After several months of discussions, the automotive industry agreed to a cooperative program at a March 31, 1995 meeting in El Monte, California.

As part of this agreement, twenty vehicles would be tested over the US06 test cycle. Ten of these would be prototype LEVs, tested at participating manufacturers' laboratories. The ARB would test the other ten vehicles certified to either the Tier 1 or TLEV emission standards. The ARB staff used considerable discretion in its vehicle selection such that the vehicles chosen would generally perform comparably to future LEVs in hot, stabilized emissions. (The US06 is a hot, stabilized emission test.) Vehicles believed likely to demonstrate low US06 emissions, based on highway NOx emission results, were included. In this way, approximately twenty vehicles considered to be comparable to or representative of future LEVs would be tested on the US06 cycle. These vehicles would be tested with emission control components (catalysts and oxygen sensors) provided by the automobile manufacturers and aged to the equivalent of 50,000 miles of usage. In this way, 50,000-mile emission standards could be developed.

Table 2. Federal US06 and SC03 Exhaust Emission Standards for 2000 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, and Heavy Light-Duty Trucks

Vehicle Type [A]	Loaded Vehicle Weight (lbs) [B]	Durability Vehicle Basis (mi)	Fuel Type	NMHC + NOx (g/mi) Composite	CO (g/mi)		
					SC03 Test	US06 Test	Composite Option

PC	All	50,000	Gasoline	0.65	3.0	9.0	3.4
			Diesel	1.48	NA	9.0	3.4
		100,000	Gasoline	0.91	3.7	11.1	4.2
			Diesel	2.07	NA	11.1	4.2
LDT	0-3750	50,000	Gasoline	0.65	3.0	9.0	3.4
			Diesel	1.48	NA	9.0	3.4
		100,000	Gasoline	0.91	3.7	11.1	4.2
			Diesel	2.07	NA	11.1	4.2
LDT	3751-5750	50,000	Gasoline	1.02	3.9	11.6	4.4
		100,000	Gasoline	1.37	4.9	14.6	5.5
HLDT [C]	3751-5750	50,000	Gasoline	1.02	3.9	11.6	4.4
		100,000	Gasoline	1.44	5.6	16.9	6.4
	5751-8500	50,000	Gasoline	1.49	4.4	13.2	5.0
		100,000	Gasoline	2.09	6.4	19.3	7.3

[A] "PC" means passenger car. "LDT" means light-duty truck. "HLDT" means heavy light-duty truck.
[B] "Loaded Vehicle Weight" is the vehicle's curb weight plus 300 pounds.
[C] For HLDTs, "Loaded Vehicle Weight" in this case means "Adjusted Loaded Vehicle Weight," which is the average of the vehicle's curb weight and gross vehicle weight rating.

The ARB/Industry agreement included a methodology to set the US06 emission standard once the testing was completed. The basic criterion for determining this emission standard was that the vehicle with the 4th lowest NMHC plus NOx emissions, or 20th percentile vehicle, would be used. An adjustment factor upwards would be allowed to provide manufacturers sufficient compliance margin or "headroom." This criterion was understood to be somewhat flexible, with standards potentially adjusted either up or down from this value depending upon the results of the test program. The main control strategy investigated in the test program was the use of air-fuel ratio "bias," in which slightly rich air-fuel ratios would be used for the US06 testing (this strategy is discussed in detail in Section V.B. and in staff's Technical Support Document.) Of the 19 vehicles ultimately tested in this program, 15 vehicles were tested with an air-fuel "bias" optimization for the US06 test. This optimization was expected to reduce NMHC plus NOx emissions by increasing catalyst NOx conversion efficiency, and showed such results on a significant portion of vehicles tested. Optimized US06 test results from this program are shown in Appendix 2 (Tables A and B.) A number of passenger cars performed at or under 0.15 g/mi NMHC plus NOx, with most performing at or below 0.2 g/mi.

During the test program, ARB staff observed that many of the manufacturer-provided emission control components used in the ARB testing appeared to produce unexpectedly large emission increases when compared to baseline, low-mileage emission results. ARB staff subsequently learned that many of the manufacturer components were not, in fact, aged to an average driver usage of 50,000 miles; rather, they had been aged to simulate the effect of a relatively aggressive driver (roughly a 90th percentile driver) over this mileage interval. ARB staff estimated that the catalysts used in this program had been effectively aged to between 75,000 and 100,000 miles of average use. Staff found that manufacturers typically use these additionally-aged components for their own research and development to provide additional assurance that after 50,000 miles of use, vehicles will still comply with the applicable emission standards. Although this is appropriate for the manufacturers' research and development testing, these overly-aged components would overstate the average real-world vehicular emissions at 50,000 miles of use and were not suitable for purposes of the US06 50,000-mile standard-setting.

Due to the above concerns, ARB staff began testing vehicles in their initial low-mileage condition, so that the effects of catalyst deterioration would not be an issue. Table C in Appendix 2 presents the optimized "rich-bias" results of this low-mileage testing. Twelve vehicles were tested, with average optimized US06 emissions of 0.09 g/mi NMHC plus NOx. The proposed passenger car emission standards for the US06 test was based solely on this data-set. A detailed discussion of the standard-setting process is provided in Section VI, Issues Addressed During Regulatory Development. Subsequent discussions with manufacturers resulted in the development of numerically higher standards for light-duty trucks in the 3751-5750 pound loaded vehicle weight range and medium-duty vehicles. As with the FTP, numerically higher standards for these vehicles are allowed given the relatively large engine displacement and vehicle weight compared to passenger cars.

E. ARB/Manufacturer Air-Conditioner Test Program

Following the US06 program described above, ARB staff conducted a passenger car test program to evaluate appropriate air-conditioner emission standards. This program was conducted from June 1996 to February 1997, with eight passenger cars, and eight light-duty trucks and medium-duty vehicles. Optimal air-fuel ratio strategies were used during the testing.

The SC03 test was used to determine emissions with the air-conditioner on. The "AC2" simulation (discussed in further detail in the staff's Technical Support Document) was used to simulate the air-conditioner emissions on a hot summer day. The AC2, conducted in a standard test cell with the air-conditioner on, simulates the environmental chamber conditions by adding a heat load to the passenger compartment. Although this simulation does not consistently correlate well with the environmental chamber, it is generally believed that AC2 emissions average approximately 80 to 85 percent of the environmental chamber emissions with the air-conditioner on. Optimized results from this program are summarized in Appendix 3.

Based on the test data, an SC03 standard of 0.20 g/mi NMHC plus NOx for passenger cars was considered appropriate for LEVs by the ARB and industry staff. Continued discussions led to the development of SC03 standards for light-duty trucks and medium-duty vehicles. The standard-setting process is discussed in more detail in Section VI, Issues Addressed During Regulatory Development.

F. Applicability of ARB's Requirements to Motor Vehicles Sold in Other States

Section 177 of the Federal Clean Air Act authorizes other states to adopt and enforce new motor vehicle emission standards that are identical to the California standards. New York and Massachusetts are currently administering the California light-duty motor vehicle emission standards pursuant to section 177. Connecticut, New Jersey and Rhode Island have also adopted the California LEV program (excluding the zero-emission vehicle (ZEV) mandate), becoming effective in the 1998 model year for Connecticut and in the 1999 model year for the other two states. In addition, Vermont has adopted the California LEV program for the 1999 model year subject to some conditions. After adoption, the California SFTP standards and requirements will apply to the California-certified passenger cars and light-duty trucks required to be sold in those states.

In addition, there are two other developments that may result in light-duty vehicles sold in other states being subject to the proposed California SFTP requirements. The first involves the Memoranda of Agreement agreed upon in the summer of 1996 between the ARB and each of the seven largest light-duty vehicle manufacturers to help ensure continued progress toward a successful launch of a sustainable ZEV market in California. Each of these manufacturers — General Motors, Ford, Chrysler, Toyota, Honda, Nissan and Mazda — agreed to participate in a voluntary program, beginning no later than the 2001 model year, in which the manufacturer will produce cleaner light-duty vehicles in states other than California and "section 177" states. Under the program, passenger cars and light-duty trucks would have to meet a fleet average non-methane organic gas (NMOG) standard that is equivalent to the average NMOG emissions of a 100 percent LEV fleet. Since the vehicles sold in other states would either be California-certified or be sold pursuant to the voluntary National LEV program described below, the vehicles would have to meet the ARB's SFTP standards.

Second, on May 2, 1997, the U.S. EPA Administrator signed regulations[7] for a voluntary "National LEV program" designed to achieve emission reductions in the 12 northeast-seaboard "Ozone Transport Commission" (OTC) states and the District of Columbia equivalent to the reductions resulting from adoption of the California light-duty LEV program by each of the states. Under the proposed National LEV program, beginning with the 2001 model year a participating manufacturer would have to meet a fleet average NMOG standard that is equivalent to the average NMOG emissions of a 100 percent LEV fleet. A manufacturer would have to meet the fleet average NMOG requirement both for its vehicles sold in the OTC states and for those sold in the 37 states excluding the OTC states and California. Section IV.B.5.a. of the Preamble to the final regulations states that the automotive manufacturers have concluded that the finalized ARB SFTP standards, if consistent with the staff's proposal agreed to by the manufacturers, are appropriate to extend to the National LEV program. Implementation of the National LEV program is dependent on whether the automotive manufacturers and the various OTC states can reach agreement on the treatment of advanced technology vehicles and OTC state commitment to the National LEV program.

III. SUMMARY OF RECOMMENDED ACTION

Staff recommends that the Board amend sections 1960.1 and 2101, Title 13, California Code of Regulations, and the incorporated "California Exhaust Emission Standards and Test Procedures for 1988 and Subsequent Model Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles," to adopt the new Supplemental Federal Test Procedure (SFTP) and appropriate emission standards. The SFTP consists of the aggressive driving US06 test procedure and the SC03 air-conditioner test procedure.

A. US06 and SC03 Test Procedures

Staff is proposing US06 and SC03 test procedure requirements that are identical to those promulgated by the U.S. EPA on October 22, 1996 (61 F.R. 54851). The establishment of identical test procedures will permit manufacturers to limit testing costs by allowing one set of tests to demonstrate compliance with both the California and Federal standards. As an addition to the current FTP requirements, the SFTP would be required as part of certification for new passenger cars, light-duty trucks, and medium-duty vehicles under 8,501 pounds gross vehicle weight rating. As described earlier, the new US06 cycle characterizes exhaust emissions from high-speed and high-acceleration driving. The air-conditioner test, based on the new hot-start SC03 driving schedule, is conducted in an environmental chamber to simulate real-world vehicle air-conditioner usage. The environmental chamber simulates the ambient conditions that a vehicle would experience on a hot summer day. A detailed description of the test procedures is provided in the Section IV, Discussion of Proposed Requirements.

[7] The regulations and related documents are accessible at http//www.epa.gov/OMSWWW/lev-nlev.htm.

Also proposed as part of the SFTP regulations are requirements specifying the use of a 48-inch single-roll dynamometer with electronic control of power absorption. Dynamometer improvements are needed due to the higher power absorption requirements of the US06 cycle. The larger rolls and electronic inertia simulation proposed for the new dynamometers provide a more realistic representation of actual road load forces compared to current dynamometer systems which use two smaller 8-inch rolls, mechanical inertia simulation, and hydrokinetic power absorption. Staff proposes that, as is the case in the Federal program, vehicles subjected to the SFTP be required to use the single-roll electric dynamometer or other dynamometer configurations demonstrated to yield equivalent or superior test results. For these vehicles, both FTP and SFTP testing would be conducted with the improved dynamometer system.

B. US06 and SC03 Emission Standards

For each of the affected vehicle weight categories, staff proposes a single set of standards that will apply to vehicles certified to the LEV, ULEV, and SULEV FTP exhaust emission standards. These standards are shown in Table 3. Although the proposed tests and emission standards can be appropriately applied to all affected vehicles regardless of fuel type, staff proposes to exempt alternative fuel vehicles from these SFTP requirements because of limited SFTP data available on these vehicles. In addition, reactivity adjustment factors similar to those in the LEV FTP program have not been developed for the SFTP tests. The reactivity adjustment factors are based on the reactivity of the components in the exhaust emissions. Because of the relatively low reactivity of the alternative fuel exhaust emissions, a lack of reactivity adjustment

Table 3. Proposed US06 and SC03 4,000 Mile Certification Standards for LEVs, ULEVs, and SULEVs

Vehicle Type	Loaded Vehicle Weight[A] (lbs.)	US06 (g/mi)		SC03 (g/mi)	
		NMHC+NOx	CO	NMHC+NOx	CO
PC	All	0.14	8.0	0.20	2.7
LDT	0-3,750	0.14	8.0	0.20	2.7
	3,751-5,750	0.25	10.5	0.27	3.5
MDV[B]	3,751-5,750	0.40	10.5	0.31	3.5
	5,751-8,500[C]	0.60	11.8	0.44	4.0

[A] "Loaded Vehicle Weight" is the vehicle's curb weight plus 300 pounds.
[B] For medium-duty vehicles, "Loaded Vehicle Weight" in this case means "Test Weight," which is the average of the vehicle's curb weight and gross vehicle weight.
[C] Applicable only to medium-duty vehicles under 8,501 pounds gross vehicle weight rating.

factors would be disadvantageous for these vehicles. Thus, staff proposes that the standards shown in Table 3 apply only to the gasoline, diesel, and hybrid (gasoline and diesel) electric vehicles.

All of the proposed SFTP standards for LEVs, ULEVs, and SULEVs will be applicable at 4,000 miles. Assurance of SFTP emission durability beyond 4,000 miles will be indirectly provided by the existence of useful-life FTP emission standards. In addition, use of On-Board Diagnostics II to monitor in-use emissions and to ensure proper operation of emission control components will provide added certainty of appropriate SFTP emission durability.

The proposed numerical standards were developed based on the results of the ARB and industry test programs. Staff evaluated the test data in the context of whether the vehicle was LEV-representative and made appropriate adjustments to the compliance margin factor. The compliance margin factor allows for headroom between the vehicle emission levels during certification testing and the emission standards to account for sources of emission variability. See Section VI, Issues Addressed During Regulatory Development, for further discussion of the development of these standards and the durability basis.

For vehicles certified to the Tier 1 and TLEV exhaust emission standards, staff proposes identical SFTP useful-life standards to those adopted by the U.S. EPA, as shown previously in Table 2. These useful-life standards will be applicable to passenger cars, light-duty trucks, and medium-duty vehicles under 8501 pounds gross vehicle weight rating (the last vehicle category is identical to the Federal heavy light-duty truck class.) As is the case in the Federal program, staff proposes higher SFTP emission standards for diesel passenger cars and light-duty trucks, and proposes to exempt heavier diesel trucks and all alternative fuel Tier 1 and TLEVs. Compliance with the Tier 1 and TLEV NMHC plus NOx standards would be based on a composite of the FTP, SC03, and US06 emissions at a weighting of 35 percent, 37 percent, and 28 percent, respectively. The optional composite CO standard would be computed on the same basis.

C. Implementation Schedule

Table 4 is the proposed implementation schedule applicable to vehicle classes certified to the proposed regulation. Although Tier 1 and TLEVs are certified to standards of different stringency than LEVs and ULEVs, the number of vehicles from both groups may be combined for the purposes of determining compliance with the phase-in schedule. Adequate time is therefore allowed for the phase-out of Tier 1 and TLEV engine families (as a result of the decreasing NMOG fleet average requirements) without being subjected to this regulation. To ensure an adequate phase-in of LEVs and ULEVs, the combined percentage of LEVs and ULEVs must also meet the required phase-in schedule. For added flexibility, staff is also proposing the same concept of equivalent phase-in schedules as that recently adopted by the Board for On-Board Diagnostics II requirements, with the exception that 100 percent of the affected vehicles must meet the proposed regulation in the final year of the phase-in schedule. In the equivalent phase-in methodology, credits are calculated by weighting the required percentages in each model year of the phase-in schedule, and the summation of these model-year credits is the total number of credits that are needed to comply with the regulations. Alternative phase-in schedules which are equal to or are greater than the required number of credits would be acceptable.

Table 4. Proposed SFTP Phase-In Percentages

Model Year	PC, LDT	MDV (under 8501 lbs. gross vehicle weight rating)
2001	25	-
2002	50	-
2003	85	25
2004	100	50
2005 and subsequent	100	100

IV. DISCUSSION OF PROPOSED REQUIREMENTS

A. US06 Test Procedure

The proposed US06 test requirements are identical to the requirements adopted by the U.S. EPA. The US06 exhaust test, using the driving schedule shown in Appendix 1, Figure C, is conducted as a *hot-stabilized* test, such that the vehicle is operated in a warmed-up condition with the critical emission control components (e.g., the catalytic converter and the oxygen sensor(s)) at typical operating temperatures. Since the test does not include start-up emissions, the vehicle engine is not turned off between the preconditioning drive and the exhaust test. Several vehicle preconditioning options are allowed for the vehicle to reach the hot-stabilized condition. If the vehicle has been soaked for two hours or less, the preconditioning drive may be either the first 505 seconds of the Urban Dynamometer Driving Schedule for passenger cars and light-duty trucks (hereinafter referred to as the "505" cycle), the last 866 seconds of the Urban Dynamometer Driving Schedule for passenger cars and light-duty trucks (hereinafter referred to as the "866" cycle), the highway cycle, the US06 cycle, or the SC03 cycle.[8] If the vehicle experiences soaks longer than two hours, the complete Urban Dynamometer Driving Schedule would be used as the preconditioning drive. Immediately following the preconditioning drive and without turning off the engine, the official US06 exhaust test is conducted.

Adjustments to the US06 test cycle are allowed for those vehicles in which some of the severe US06 accelerations are not representative in-use. One such adjustment is for low-powered vehicles. Five test cycle windows, varying from 14 to 30 seconds, have been identified

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[8] The referenced cycles, except for the highway cycle, are available in Appendix I of 40 CFR Part 86. The highway cycle is available in Appendix I of 40 CFR Part 600.

where adjustments are allowed. If a vehicle is at wide-open throttle for at least eight seconds within a particular window, a dynamic load adjustment to the dynamometer can then be applied to decrease the dynamometer load such that the vehicle then operates at less than wide-open throttle. Once the window ends, the dynamic load adjustment is removed. A second adjustment is for medium-duty vehicles. From the driving surveys, it was determined that, on average, these vehicles tend to be driven at lower speeds and less aggressively at higher speeds than passenger cars.[9] Thus, a lower US06 dynamometer inertia test weight than used during the FTP is allowed. The US06 inertia weight for medium-duty vehicles will be the curb weight plus 300 pounds. For FTP testing, the dynamometer inertia weight is determined by the test weight, which is the average of the curb weight and the gross vehicle weight.[10] (The use of the test weight to determine the dynamometer inertia weight for FTP testing is unchanged.)

Consistent with the Federal SFTP requirement, a minimum air-fuel ratio calibration is specified during commanded fuel enrichment to prevent excessive CO emissions. This requirement specifies that the air-fuel ratio may not, at any time, be richer than the leanest air-fuel mixture required to obtain maximum engine torque (termed “lean best torque”), with a tolerance of six percent of the lean best torque fuel consumption. If additional enrichment beyond lean best torque is required for engine or emission control hardware protection, the manufacturer may submit a request for ARB approval.

B. Air-Conditioner Test Procedure

The proposed SC03 air-conditioner test requirements are also identical to those adopted by the U.S. EPA. The air-conditioner exhaust test is conducted as a *hot-start* test using the new SC03 cycle (shown in Appendix 1, Figure D), such that the vehicle is started warmed-up with the critical emission control components (e.g., the catalytic converter and the oxygen sensor(s)) at typical operating temperatures. The standard preconditioning drive consists of the Urban Dynamometer Driving Schedule. However, if the vehicle engine was shut off less than two hours prior to the preconditioning, the following shorter cycles may be used instead: “505,” “866,” or SC03. Immediately following the preconditioning drive, the vehicle engine is turned off, and the vehicle is soaked for 10 minutes. Following the soak period, the SC03 exhaust test begins. The exhaust test is conducted in an environmental chamber with the air-conditioner turned on. The environmental chamber simulates the ambient conditions of a hot summer day.

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[9] U.S. EPA. Final Technical Report on Aggressive Driving Behavior for the Revised Federal Test Procedure Notice of Proposed Rulemaking. January 31, 1995.

[10] The amendments also include a correction of the mass formula to calculate the organic material non-methane hydrocarbon equivalent for ethanol vehicles.

The ambient testing specifications of the facility include a high ambient temperature (95°F), solar heat load (850 watts per square meter), humidity (100 grains of water per pound of dry air), and wind effects (proportional-speed cooling fan requirements.)

As an alternative, an air-conditioner simulation in the standard test cell can be used if it is demonstrated to correlate with environmental chamber testing. To account for variability, the minimum criteria are that the vehicle emissions with the air-conditioner on using the simulation must be at least 85 percent of the NOx emissions and 95 percent of the fuel consumption associated with environmental chamber testing. To obtain approval to use an alternative procedure, the manufacturer must submit a description of the simulation; additional required instrumentation, if any; data demonstrating the correlation between the simulation and the environmental chamber; and any vehicle-specific parameters.

The Executive Officer would have the authority to conduct testing either before or after certification to confirm that the simulation correlates with environmental chamber testing. During testing, if the selected vehicles fail the correlation criteria, the manufacturer can provide additional data to demonstrate that the simulation correlates with environmental chamber testing. If this cannot be demonstrated, the manufacturer must submit an engineering evaluation indicating the cause of the improper simulation and the extent of vehicles affected. The manufacturer will be given an opportunity to correct the failed simulation; otherwise, no further air-conditioner testing using the simulation will be accepted. While there is no penalty for failing the correlation demonstration, enforcement testing may be conducted with either the environmental chamber or the corrected simulation.

In the first three years of the SFTP phase-in (2001 to 2003 model years), manufacturers may use either of two air-conditioner simulations in a standard test cell without environmental chamber correlation approval. Although these simulations have been shown to correlate with the environmental chamber on some vehicles, the simulations have not consistently met the correlation criteria specified above. By allowing the use of these simulations on an interim basis, additional time is provided for manufacturers to develop an adequate simulation which correlates with environmental chamber testing. During the 2001 to 2003 model years, the simulation used for certification will also be used for enforcement testing. Beginning in the 2004 model year, only simulations which have been proven to adequately correlate with the environmental chamber will be allowed.

C. New Vehicle Audit Requirements

Staff proposes that the new vehicle audit requirements be applied to confirm compliance with the US06 and the SC03 emission standards beginning in the 2002 model year, which is the second year of the SFTP phase-in for passenger cars and light-duty trucks. Under section 2101, Title 13, California Code of Regulations, the Executive Officer has the authority to randomly select a reasonable number of vehicles representing any California vehicle engine family to inspect and test for compliance with the applicable emission standards. These vehicles are to be made available from the manufacturer and delivered to the ARB's Haagen-Smit Laboratory located in El Monte, California.

During the first six months of the first-year implementation of the proposed standards and test procedures, manufacturers can supply US06 and SC03 test data generated from new 2001 model year production vehicles certified to the proposed standards and test procedures. The location of the test facility and the quantity of test data are determined by the manufacturer. These data would be used to determine the accuracy of testing new vehicles at essentially zero mileage to determine compliance with the proposed 4,000 mile standards. The data would be reviewed by both manufacturers and ARB staff. Systemic problems associated with the testing would be identified and resolved jointly, whereas problems specific to a manufacturer would be addressed individually. If significant concerns are raised with the testing that cannot be resolved by ARB staff within the regulatory context, staff may reevaluate the new vehicle compliance requirements for SFTP testing.

Staff is not proposing an assembly-line testing component to the compliance requirements of the proposed regulations. In addition, a useful life requirement is not proposed. However, if indications of unexpected deterioration of US06 or air-conditioner emissions are found, staff anticipates revisiting the useful life standards and in-use compliance liability.

V. TECHNOLOGICAL FEASIBILITY

Reducing SFTP emission levels for compliance with the proposed SFTP emission standards can be achieved in a variety of ways. The primary means of achieving compliance will be described in this section. These methods include engine calibration techniques, optimizing exhaust gas recirculation (EGR) calibrations, and catalytic converter modifications. Before discussing technologies to reduce SFTP emissions, a brief description of improvements to current emission control components due to the LEV regulations is provided. Although production vehicles whose emission characteristics most resemble those of LEVs were chosen for the ARB test programs, some additional emission control improvements would be needed for the majority of the test vehicles to comply with the LEV FTP emission standards, which could subsequently affect SFTP emissions.

A. Emission Control Improvements Due to LEV Regulations

As part of the Low-Emission Vehicle and Clean Fuels Program, manufacturers are required to meet an annual NMOG fleet average requirement for passenger cars and light-duty trucks produced and delivered for sale in California. For passenger cars and light-duty trucks under 3751 pounds loaded vehicle weight, the fleet average requirement began in 1994 and declines each year through 2003. By the 2001 model year when the SFTP requirements are phased-in, the NMOG fleet average will be 0.070 g/mi, requiring that almost all vehicles be certified to the LEV (or lower) exhaust emission standards.

The Staff Report for the November 1996 biennial review of the Low-Emission Vehicle and Zero-Emission Vehicle Program identifies various technologies that may be utilized by vehicle manufacturers to reduce vehicle emissions in achieving LEV emission standards.[11] A combination of these technologies can be used depending on the vehicle and the emission reductions needed to comply with the LEV and ULEV standards. These technologies are divided into four general categories of improvements: fuel control, fuel atomization and delivery, exhaust gas aftertreatment, and the reduction of engine-out emissions. Certain technologies are expected to be utilized in all LEV and ULEV applications. Such technologies include sequential multiport fuel injection, adaptive fuel control systems, heat-optimized exhaust pipes, improvements to the catalytic converter system, engine calibration techniques, leak-free exhaust systems, and electronic EGR systems.

Staff expects that recent improvements in catalytic technology will perhaps be the most significant development that will enable manufacturers to produce LEVs and ULEVs at a relatively low cost. Recent advances include improvements to the substrate and precious metal processing techniques. The use of palladium-only and tri-metal three-way catalyst technology has improved the stoichiometric conversion efficiency, light-off performance, and high temperature durability compared to traditional (platinum and rhodium) three-way catalysts. These improved catalytic systems are currently being used in some production vehicles by several vehicle manufacturers.

Reducing a vehicle's FTP emissions to meet the more stringent LEV and ULEV exhaust emission standards will likely reduce SFTP emissions. Although it is difficult to quantify the decrease in SFTP emissions as a vehicle's FTP emissions are reduced to LEV and ULEV levels, emission control strategies that will reduce warmed-up FTP emissions will also generally reduce US06 and air-conditioner emissions.

B. US06 Emission Control Technologies

The test data from the low-mileage ARB US06 passenger car test program were used to determine the extent of control technologies needed to comply with the proposed US06 emission standards. Using a compliance margin factor of 1.5, passenger cars are expected to emit approximately 0.093 g/mi NMHC plus NOx emissions on the US06 test to comply with the proposed 0.14 g/mi US06 emission standard. According to a January 30, 1995 letter from the automotive manufacturers to the U.S. EPA, a compliance margin factor is needed to account for vehicle to vehicle emission variation due to the assembly process, vehicle configuration, testing process, and usage patterns. Manufacturers typically certify vehicles significantly below a

[11] California Air Resources Board. Mail-out #96-28: Staff Report for the Low-Emission Vehicle and Zero-Emission Vehicle Program Review. El Monte, California. November 1996.

given emission standard to account for these variabilities. The variation due to usage patterns was not considered in the determination of the appropriate headroom factor for these 4,000-mile standards because of the lack of noticeable different usage patterns at low-mileage.

As summarized in Appendix 2, Table C, the average optimized US06 emissions of twelve passenger cars tested by ARB were 0.092 g/mi NMHC plus NOx. The control strategies used to obtain these optimized emissions are the stoichiometric calibration and the "rich-bias" calibration. An average reduction of 68 percent in US06 NMHC plus NOx emissions on passenger cars was observed using the "rich-bias" calibration (the baseline emissions were 0.289 g/mi NMHC plus NOx). Only four out of the twelve vehicles tested, or 33 percent, exceeded the 0.093 g/mi NMHC plus NOx emission threshold noted above that would be required to comply with the proposed 0.14 g/mi NMHC plus NOx standard. Approximately half of the twelve vehicles tested were not LEV-representative vehicles, including the four vehicles that exceeded the NMHC plus NOx threshold. As noted previously, reduced NMHC plus NOx emissions on the US06 test are expected when the vehicle is redesigned with improved emission control technologies to meet the LEV emission standards.

Thus, based on the test program data, a conservative estimate is that at least 70 percent of LEVs will comply with the proposed US06 standards with only software modifications. The remaining 30 percent would require catalyst hardware modifications. Following are discussions of the software and hardware modifications that would be used in future LEVs and ULEVs to comply with the proposed US06 emission standards.

1. Stoichiometric Engine Calibration

As noted earlier, the U.S. EPA determined that in-use emissions increased by 0.014 g/mi of HC emissions and 1.6 g/mi of CO emissions due to high-speed and high-load driving relative to the FTP. The HC and CO emission increases during high-speed and high-load conditions are primarily associated with fuel enrichment which provides increased power output and reduces engine and catalyst temperatures (known as commanded enrichment). Commanded enrichment is more commonly used in low- to moderate-powered vehicles during these higher speed and load events. During these enrichment events, increased engine-out HC and CO emissions result from incomplete combustion. More significantly, fuel enrichment causes a decrease in catalyst HC and CO conversion efficiency.

On several passenger cars in the US06 test program, stoichiometric calibration computer chips (PROMs) were obtained from the respective manufacturers. These PROMs modify the vehicle engine calibration to maintain stoichiometric combustion and consequently, eliminate commanded enrichment. In Table 5, the HC and CO emissions with the use of stoichiometric calibration PROMs (no commanded enrichment) and production calibration PROMs (includes commanded enrichment) are shown. The average CO emissions of vehicles with the stoichiometric calibration were significantly lower compared to the average CO emissions of vehicles using production calibrations.

Manufacturers asserted that a full stoichiometric calibration is not feasible since stoichiometric combustion results in higher exhaust temperatures, possibly increasing catalyst deterioration and affecting engine durability. ARB staff acknowledges that fuel enrichment may be necessary under certain circumstances for protection of the catalysts and engine. Thus, to ensure minimal deterioration of the catalyst and effects on engine durability, the proposed US06 CO standards allow for limited commanded enrichment during the US06 test.

Table 5. ARB US06 Test Program: NMHC and CO Emissions of Passenger Cars with Production and Stoichiometric Calibrations

	# of Vehicles	Average NMHC (g/mi)	Average CO (g/mi)
Production Calibration	9	0.031	4.650
Stoichiometric Calibration	3	0.031	0.948
Percent Difference		0 %	80 %

2. <u>"Rich-Bias" Engine Calibration</u>

(a) <u>ARB Test Program</u>

Since the NOx component of the US06 NMHC plus NOx emissions is typically far greater than the NMHC contribution, reductions of NOx emissions are of primary importance to meet the US06 NMHC plus NOx emission standard. Staff used a calibration strategy known as "rich-bias" to reduce the US06 NOx emissions in the ARB test program.[12] "Rich-bias" calibration refers to modifying the engine calibration such that it is operating with slightly more fuel (an increase of approximately one percent or less) than is needed for stoichiometric combustion. Various "rich-bias" settings were tested until an optimal setting exhibiting the lowest US06 NMHC plus NOx emissions was found. Combined NMHC plus NOx emissions were used to determine emission optimization since the proposed emission standards are combined standards. The ARB tested twelve passenger cars, a light-duty truck, and six medium-duty vehicles using this emission control strategy.

Table 6 compares the average baseline NMHC plus NOx emissions and the "rich-bias" optimized emissions on the ARB test vehicles. The percent NMHC plus NOx reduction on passenger cars averaged 68 percent. Similar emission reductions were observed on light-duty

[12] Kwan, Parker, and Nolan. "Effectiveness of Engine Calibration Techniques to Reduce Off-Cycle Emissions." SAE Paper 971602.

trucks and medium-duty vehicles. ARB staff noted that on vehicles with inherently low baseline NMHC plus NOx emission performance on the US06 cycle, reductions in US06 NMHC plus NOx emissions were not observed using the "rich-bias" technique. The original calibration on these vehicles may have already included a slightly fuel-rich calibration for high-speed and high-load driving conditions or a generally richer calibration overall.

Table 6. ARB US06 Test Program: Average NMHC Plus NOx Reductions Using the "Rich-Bias" Calibration Technique

		Average NMHC plus NOx (g/mi)			
Test Vehicle	**# of Vehicles**	**Baseline**	**"Rich-Biased"**	**Difference**	**Percent Reduction**
PC	12	0.289	0.092	0.197	68
LDT (3751-5750 lbs. loaded vehicle weight)	1	0.418	0.156	0.262	63
MDV (3751-5750 lbs. loaded vehicle weight)	2	0.326	0.155	0.171	52
MDV (5751-8500 lbs. test weight)	4	0.558	0.267	0.291	52

(b) <u>"Rich-Bias" Overlap</u>

Due to similar low to moderate speed and load points on both the US06 and the FTP cycle, the "rich-bias" calibration method used by the ARB to reduce US06 NMHC plus NOx emissions could also affect FTP emissions. NMHC and CO emissions typically increase with the "rich-bias" calibration. Since the proposed US06 NMHC plus NOx standard is a combined standard, the NMHC emission increase can be offset by the relatively greater NOx decrease. However, in the FTP where separate NMOG (hydrocarbon) and NOx emission standards are applicable, the NMHC emission increase would be problematic. Thus, the potential of overstating the "rich-bias" emission benefits exists if the FTP emissions are adversely affected.

To address this potential effect on FTP emissions, only specific portions of the US06 calibration that fall outside the FTP speed and load points, i.e., high-speed and high-load points, can be selectively "rich-biased" to achieve US06 NOx reductions. Due to the complexity of modifying specific speed and load points in a calibration, partial "rich-bias" calibration testing was not conducted by ARB staff. However, staff employed a computer model using modal (second by second) emission data to estimate the actual US06 emission reductions without adversely affecting FTP emissions.[13] Modal data from a Pontiac Bonneville tested at 50,000-equivalent miles were available for this analysis. Because modal FTP emission data were limited, warmed-up Urban Dynamometer Driving Schedule modal emission data were used as a surrogate. By selectively "biasing" only the US06 regimes that fall outside the FTP, the computer model showed that over 90 percent of the full "bias" NMHC plus NOx emission reduction was maintained. At this partial "rich-bias" set point, the warmed-up Urban Dynamometer Driving Schedule NMHC and CO emissions were essentially unaffected, with NOx emission decreases of 0.076 g/mi.

(c) Manufacturer Test Program

Manufacturer US06 test data showed trends similar to those in the ARB test program using the "rich-bias" calibration. Manufacturers provided complete information on five prototype LEVs that were tested using the "rich-bias" calibration. Manufacturers made the "rich-bias" changes by modifying the software calibration such that only speed and load points outside the FTP were "rich-biased" and FTP emissions were minimally affected.

Table 7 shows the manufacturers' US06 average emission data on passenger cars and a light-duty truck at 50,000-equivalent miles (mileage obtained by aging the oxygen sensor(s) and catalytic system to 50,000 miles and placing them on a stabilized vehicle with approximately 4,000 miles odometer reading), and a medium-duty vehicle at 100,000-equivalent mile. The average passenger car NMHC plus NOx emission reduction using the "rich-bias" calibration was 45 percent.

Table 7. Manufacturer Prototype LEVs: Average US06 NMHC Plus NOx Reductions Using "Rich-Bias" Testing

		Average NMHC+NOx (g/mi)			
Test Vehicle	**# of Vehicles**	**Baseline**	**"Rich-Bias"**	**Difference**	**Percent Reduction**
PC	3	0.23	0.13	0.11	45
LDT (3751-5750 lbs. loaded vehicle weight)	1	0.124	0.124	0	0
MDV (3751-5750 lbs. test weight)	1	1.630	0.88	0.75	46

13 Kwan, Parker, and Nolan. "Effectiveness of Engine Calibration Techniques to Reduce Off-Cycle Emissions." SAE Paper 971602.

3. EGR Calibration

EGR is an emission control strategy to reduce NOx emissions. By recirculating exhaust gases into the intake manifold for use in the combustion process, the peak combustion temperatures are lowered. NOx formation, which is temperature-dependent, is consequently reduced. EGR flow rates are typically 15 percent of the intake volume for a typical engine and 20 to 25 percent for modern engines with high turbulence combustion chambers.[14]

Currently, EGR flow is controlled by several different methods in current motor vehicles. One type of EGR system regulates EGR flow by vacuum from the intake manifold. While engine vacuum is sufficient to open the EGR valve during part-throttle operations, the vacuum is too low to operate EGR near or at full-throttle applications during high speed and load operation on the US06 test. Another type of system used today is the electronically-actuated EGR system where the EGR flow can be electronically-regulated to provide more precise control of EGR rates. In this application, EGR valve operation is independent of intake manifold vacuum pressure. Thus, optimal EGR flow can be used during essentially all driving conditions. Finally, closed-loop electronic EGR systems, which allow for even better EGR flow control through feedback monitoring, are currently being used on many Ford production vehicles.

Based upon the 1996 Low-Emission Vehicle and Zero-Emission Vehicle Program review, all LEVs and ULEVs are projected to incorporate electronically-actuated EGR systems. This would provide EGR flow during heavy throttle operation of the US06 test. Manufacturers would have to determine the amount of flow required during these conditions without compromising combustion stability and driveability. While the use of EGR during wide-open throttle operation will be limited, staff expects that modest EGR flow rates during high-speed, high-load operation at less than wide-open throttle would reduce engine-out NOx emissions. For compliance with the proposed SFTP emission standards, optimized EGR flow rates during US06-type driving conditions are expected to be used on all vehicles that do not already include optimization at high-speed and high-load conditions.

4. Catalyst Modifications

Using the calibration modifications discussed above, staff expects that 70 percent of future vehicles can comply with the proposed US06 emission standards without hardware changes. The remaining 30 percent may require catalyst modifications, either by increasing precious metal loading or catalyst volume.

Exhaust gas aftertreatment systems have significantly improved as a result of the stringent LEV and ULEV emission standard requirements. Advanced catalyst formulations are currently available which allow for improved catalyst efficiency and increased durability. These advanced palladium-only and tri-metal catalytic converters are currently used on some production vehicles.

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[14] U.S. EPA. "Assessment of Technology Costs to Comply with Proposed FTP Revisions." Prepared by Energy and Environmental Analysis, Inc. Contract No. 68-C4-0056, WA4. September 1995.

Staff does not anticipate the US06 requirements will require further developments in catalyst formulation. Instead, for US06 emission standard compliance, staff expects relatively straightforward modifications to the currently available advanced catalyst systems. One such catalyst modification is increasing the precious metal loading to raise catalyst conversion efficiency. In particular, improving NOx conversion efficiency can be achieved by adding rhodium to palladium-only catalysts or increasing the rhodium loading in tri-metal and palladium-rhodium catalysts. Staff anticipates that approximately 15 percent of the future vehicle fleet would require increased catalyst loading to comply with the proposed US06 emission standards.

For the remaining 15 percent of the future vehicle fleet requiring catalyst modifications, staff expects that the catalyst volume will need to be increased. A conservative estimate of the average catalyst volume compared to engine displacement for LEVs is approximately 1 liter of catalyst per 1 liter of engine displacement. This catalyst volume to engine displacement ratio of 1 is greater than the ratio observed on the majority of vehicles tested in the ARB test program. As these test vehicles are modified with increased catalyst volume and more advanced formulations for LEV FTP emission standard compliance, US06 emission levels below those generated in the ARB test program are likely. As a conservative estimate, staff anticipates that a 20 percent increase in catalyst volume would be needed to comply with the proposed US06 standards. Therefore, the average catalyst volume to engine displacement on these vehicles (15 percent of future vehicle fleet) would be 1.20.

C. Air-Conditioner Emission Control Technologies

Similar to the US06 technology assessment, the test data from the ARB air-conditioner test program were used to determine the additional software and hardware modifications needed on vehicles to comply with the proposed SC03 emission standards. As described earlier in Section B, a headroom factor of 1.5 is used to account for emission variability. Using this headroom factor, manufacturers would certify passenger cars at approximately 0.13 g/mi NMHC plus NOx to comply with the proposed 0.20 g/mi NMHC plus NOx SC03 emission standard.

The NMHC plus NOx emissions of the eight passenger cars in the ARB test program averaged 0.36 g/mi during the SC03 cycle with the air-conditioner operating and without emission optimization. Using the “rich-bias” emission control strategy, the average NMHC plus NOx emissions were reduced to 0.13 g/mi. Four of the eight passenger cars exceeded the 0.13 g/mi NMHC plus NOx threshold noted in the preceding paragraph. These four vehicles do not have emission characteristics representative of LEVs. Thus, lower air-conditioner emissions are expected on these vehicles once they are redesigned to comply with the LEV FTP emission standards. The degree of SFTP emission decreases are dependent on the specific technologies employed to achieve FTP emission reductions.

As a conservative estimate, at least 70 percent of future LEVs will likely comply with the proposed SC03 emission standards with only software modifications. Hardware modifications would likely be required on the remaining 30 percent.

1. “Rich-Bias” Engine Calibration

As with the US06 test program, the ARB used the “rich-bias” engine calibration strategy to reduce air-conditioner NOx emissions on test vehicles. As discussed earlier, the “AC2” simulation was used over the SC03 cycle to simulate the air-conditioner emissions on a hot summer day. The AC2, conducted in a standard test cell, simulates the environmental chamber conditions by adding a heat load to the passenger compartment.

As shown in Table 8, substantial SC03 NMHC plus NOx emission reductions were obtained with the “rich-bias” calibration. The average SC03 NMHC plus NOx reduction for passenger cars was 64 percent, similar to those achieved in the ARB US06 test program. Relatively smaller reductions were observed in light-duty trucks and medium-duty vehicles. This is most likely because production calibrations for these vehicles already include a “rich-bias” at the higher speed and load points. As with the US06 test program, vehicles with low baseline SC03 emissions did not show an emission reduction with the “rich-bias” calibration technique. Again, this is likely a result of incorporating a slight “rich-bias” strategy at high speed and load points in the production calibration.

Because of similar speed and load points between the SC03 and FTP test cycles, the “rich-bias” of the SC03 engine calibration can potentially affect FTP emissions. To mitigate this effect, staff proposes to allow the use of air-conditioner-on specific calibrations which differ from air-conditioner-off calibrations, except for commanded enrichment and lean-on-cruise air-fuel calibration strategies. (Commanded enrichment and lean-on-cruise can be used if the same air-fuel calibration strategies are used regardless of whether the air-conditioner is in operation.) This provision allows added flexibility for the manufacturers to use the “rich-bias” to calibrate air-conditioner-on speed and load points specifically for air-conditioner emission control without affecting air-conditioner-off FTP emissions.

2. EGR Calibration

EGR systems can be optimized to control NOx emissions during the air-conditioner test. Based on a paper study, U.S. EPA concluded that an EGR flow rate increase of 5 percent could reduce engine-out NOx by approximately 10 percent with a corresponding increase of 7 percent engine-out HC. The exact NOx emission reduction is dependent on the original EGR flow rates and the impact on driveability. Although manufacturers have stated that optimized EGR calibrations are currently being used, it is unlikely that the EGR flow rates are optimized for all speed and load points during air-conditioner operation since existing regulatory requirements do not limit emissions for all driving conditions. As with the "rich-bias" calibration, staff also proposes to allow the use of an air-conditioner-on specific EGR calibration so that the air-conditioner-on emissions can be optimized without affecting air-conditioner-off FTP emissions. This provision allows added flexibility for the manufacturers to calibrate their EGR systems specifically for air-conditioner-on emission control.

Table 8. ARB Air-Conditioner Test Program: Average SC03 NMHC plus NOx Reductions Using the "Rich-Bias" Calibration Technique

		Average NMHC plus NOx (g/mi)			
Test Vehicle	**# of Vehicles**	**Baseline**	**"Rich-Biased"**	**Difference**	**Percent Reduction**
PC	8	0.360	0.131	0.229	64
LDT (3751-5750 lbs. loaded vehicle weight)*	4	0.277	0.166	0.111	40
MDV (3751-5750 lbs. loaded vehicle weight)*	1	0.091	0.091	0.000	0
MDV (5751-8500 lbs. test weight)*	3	0.420	0.313	0.107	25

* The light-duty truck and medium-duty vehicle portion of the test program was conducted under time constraints; consequently, duplicate tests at the optimal setting were not performed.

3. Catalyst Modifications

As noted earlier, software calibration modifications will likely allow 70 percent of future vehicles to comply with the proposed SC03 standards. Of the remaining 30 percent, staff expects that approximately 15 percent can comply with increased precious metal loading of rhodium, while the other 15 percent of the fleet will require an increase in catalyst volume. A more detailed explanation of the catalyst improvements was provided in Section V.B.4., Catalyst Modifications.

VI. ISSUES ADDRESSED DURING REGULATORY DEVELOPMENT

During the SFTP rule-development process, staff worked cooperatively with the U.S. EPA to develop one set of tests to control non-FTP emissions from motor vehicles. Staff is proposing US06 and SC03 test procedure requirements that are identical to those adopted by the U.S. EPA. The establishment of identical test procedures will permit manufacturers to limit testing costs by allowing one set of tests to demonstrate compliance with both the California and

Federal standards. Staff anticipates continuing this cooperative effort with the U.S. EPA in any future modifications to the SFTP test procedure requirements.

Automotive manufacturers contributed substantially to the rulemaking effort by providing test data and technical insight. Manufacturers conducted several test programs using environmental cells to determine real-world air-conditioner effects on emissions. Possessing the only environmental cells with emission testing capability, manufacturers provided air-conditioner data that would otherwise be unavailable to the U.S. EPA and the ARB. Manufacturers also agreed to test LEV prototype vehicles on the US06 and SC03 test cycle, thereby providing LEV data which would normally be inaccessible to staff. This level of manufacturer support is unprecedented and led to more comprehensive analyses in the development of the rulemaking. Discussed below are issues that arose during development of the test cycles and the proposed US06 and SC03 emission standards.

A. Test Cycle for Control of High-Speed, High-Load Emissions

As described earlier, the US06 test cycle was agreed upon by the U.S. EPA, the ARB and the motor vehicle industry in June 1994, following several months of discussions. It was developed by splicing together portions of the ARB01B and REPO5 test cycles that the ARB and U.S. EPA staff, respectively, developed to represent and control high-speed, high-load emissions. The US06 test cycle, at 10 minutes in length, is a relatively short test cycle. Both the ARB01B and REPO5 test cycles are over 20 minutes in length. In general, longer test cycles allow for a more representative and complete coverage of driving conditions for regulatory control, but also result in higher testing costs due to the additional testing time such longer cycles require.

In response to manufacturers' concerns, the U.S. EPA and ARB staff agreed to pursue a relatively short test cycle, but chose to over-represent the frequency of severe driving events (wherein the largest emission increases are observed) on this driving cycle. The result was the US06 driving cycle, wherein severe driving events (high accelerations and high speeds) are represented at two to three times the actual, in-use frequency of such events. One of the most severe events from the ARB01B cycle (an extended high-speed passing maneuver) was excluded because of manufacturer concerns that stoichiometric control over this regime could result in in-use catalyst deterioration. ARB staff did not agree with this concern but nevertheless chose to exclude the event due to its relatively minor impact. Since the frequency of this event is comparatively low, little, if any, loss of emission control is expected to result from its exclusion from the US06 test cycle.

Subsequent to the agreement on the US06 test cycle for control of high-speed, high-load emissions, a concern manifested over the control of emissions during extended high-speed cruise driving conditions. New test data indicated that manufacturers may use an enleanment strategy known as "lean-on-cruise" during extended high-speed cruises to improve fuel economy or for other purposes. Test data on two vehicles showed that, during steady-state, high-speed cruising conditions, the NOx tailpipe emission increase associated with lean-on-cruise was as high as *six* g/mi. The proposed stringent SFTP NMHC plus NOx standards would limit the use of lean-on-cruise air-fuel calibration strategies during the SFTP. Staff is proposing specific regulatory language that lean-on-cruise air-fuel calibration strategies cannot be used in normal driving conditions unless these strategies are also substantially utilized in the SFTP.

B. US06 Test: Selection of Emission Standards and Durability Basis

1. Level of Proposed Emission Standards

ARB staff is proposing US06 emission standards that have already received support from the motor vehicle industry. These standards are 0.14 g/mi NMHC plus NOx and 8.0 g/mi CO for passenger cars at 4,000 miles, with higher standards for heavier trucks and medium-duty vehicles up to 8,501 pounds gross vehicle weight rating. These 4,000-mile standards are expected to reduce actual, in-use high-speed, high-load emissions to the levels experienced in the more moderate FTP operation, so that little or no emission increases due to high-speed, high-load driving are expected to remain for LEVs.

During the ARB low-mileage US06 test program, staff and automotive manufacturers jointly analyzed the test data to determine appropriate levels for the US06 emission standards. Manufacturers opposed the establishment of US06 emission standards at a level of stringency that would drive the development of new emission control technologies and require hardware modifications on the majority of LEVs. Staff agreed that requiring significant hardware modifications on the majority of LEVs was not the objective of this rulemaking, and proposed standards that would not have such an effect. The technological feasibility of this proposed NMHC plus NOx emission standard was discussed earlier in Section V.B., US06 Emission Control Technologies.

2. Durability Basis for Proposed US06 Standards

With regard to the durability basis for the proposed standards, there are no in-use vehicle compliance requirements, as they are 4,000-mile standards without an in-use compliance element. This raises the issue of the adequacy of controls on in-use emissions, as high-speed, high-load emissions could potentially deteriorate during the life of the vehicle.

ARB staff believes that, while such an in-use emission risk potentially exists, it is likely to be minimized by the requirements of preexisting in-use FTP emission standards. In addition, On-Board Diagnostics II will closely monitor in-use emissions and will trigger the repair of any individual vehicle with emissions significantly above applicable limits. Should in-use high-speed, high-load emissions increase significantly during in-use operation, ARB staff believes that emission increases would also appear over the FTP cycle and be captured by either the ARB's in-use compliance testing of FTP emission standards or by On-Board Diagnostics II systems.

The possibility does remain that in-use vehicles may show high-speed, high-load emission deterioration not paralleled by deterioration over the FTP. For example, the deterioration of the underfloor catalyst is expected to be most prominent over the high-load modes which comprise the bulk of US06 emission control but are virtually absent from the FTP driving cycle. For this reason, in the future, ARB staff intends to conduct an assessment of in-use US06 emission deterioration. Should excess deterioration unique to high-speed, high-load conditions be found, ARB staff would then propose 50,000-mile and 100,000-mile standards for US06 emission control. However, as discussed between ARB staff and automotive manufacturers during the standard-setting process, the proposed standards should be stable at least through the proposed phase-in schedule to ensure that data are available on an adequate mix of vehicles certified to the SFTP requirements. Thus, proposing new SFTP emission standards can be done, at the earliest, subsequent to the last year of the proposed phase-in schedule.

C. Air-Conditioner Emission Control: Selection of Test Cycle and Test Conditions

1. Test Cycle

The SC03 test cycle was largely developed by the U.S. EPA; ARB staff did not participate significantly in its development. The U.S. EPA developed this cycle in an effort to more accurately represent driving behavior during the initial three minutes following the start of a trip (the current FTP is somewhat unrepresentative in this area), as well as to properly represent typical current urban driving. This cycle specifically excludes high-speed, high-load operation, since air-conditioner operation during these conditions appears to have a smaller emission impact than over typical urban driving. Some amount of emission control is necessarily lost by this exclusion. However, ARB staff is proposing regulatory language that specifically prohibits the use of air-conditioner-on control strategies that decrease emission control effectiveness, so that the exclusion of high-speed high-load driving on the air-conditioner test is expected to have a minimal emission effect.

2. Test Conditions

The proposed SC03 test is a hot-start test conducted in an environmental cell. The cell simulates the environmental conditions of a hot, sunny, comparatively humid day and thus provides a relatively “worst-case” situation for air-conditioner emissions. The temperature for testing would be 95°F, with 40 percent relative humidity, 850 Watts per square meter solar load, and road-speed airflow across the vehicle front. Other procedures are allowed if the manufacturer can demonstrate equivalency to environmental chamber testing. In addition, two additional procedures, known as AC1 and AC2, are allowed for certification during the first three years of the phase-in. Although ambient temperatures above 95°F do occur during summertime conditions, average ambient temperatures on days in which the air-conditioner is used are below 95°F. Thus, the test (analogously to the US06 test) will tend to overstate average in-use air-conditioner emission increases, providing additional assurance of air-conditioner emission control. Cold-start emissions are not covered by this test, but are not believed to be a significant contributor to the air-conditioner emission increase.

The automotive industry had strongly disagreed with the use of an environmental chamber, since these facilities are considerably more expensive than standard dynamometer test cells. However, no alternative could be found to adequately replicate emissions from this procedure. ARB staff believes that the environmental chamber test is currently the only test method that accurately simulates air-conditioner emission increases during ozone-season conditions, and therefore is proposing the same environmental chamber requirements as adopted by the U.S. EPA for future vehicle certification. As described previously, alternative air-conditioner simulations that correlate with this procedure would also be acceptable.

D. Air-Conditioner Test: Selection of Emission Standards

Emission standards for the air-conditioner test have been proposed to be roughly equivalent in stringency to the US06 standards, and to apply over the same durability basis for consistency. Table 9 compares US06 and SC03 NMHC plus NOx emission standards by vehicle class. For reference, "PC" refers to passenger cars; "LDT1" and "LDT2" refer to light-duty trucks from 0-3750 and 3751-5750 pounds test weight, respectively; and "MDV2" and "MDV3" refer to medium-duty vehicles from 3751-5750 and 5751-8500 pounds test weight, respectively.

Table 9. Proposed US06 and SC03 Emission Standard Comparison

Vehicle Class	US06 Standard (g/mi)	SC03 Standard (g/mi)
PC/LDT1	0.14	0.20
LDT2	0.25	0.27
MDV2	0.40	0.31
MDV3	0.60	0.44

The above proposed SC03 standards were discussed with the automobile industry during late 1996 and early 1997. Although staff believes that the passenger car and light-duty truck SC03 standard is somewhat less stringent than the US06 standard, the SC03 standards for the LDT2, MDV2 and MDV3 categories are believed to be at the same approximate stringency (requiring the same hardware for compliance) as the corresponding US06 standards. This is partly due to an observed phenomenon in which the air-conditioner systems in larger vehicles generally exert less load (relative to the engine size) than in passenger cars. For this reason the SC03 standards do not incrementally increase at the same rate (from PC to MDV3) as do the US06 standards. As with the US06 emission standards, the proposed SC03 standards will essentially require that air-conditioner-on emissions be controlled to the level of air-conditioner-off emissions, so that little or no air-conditioner-related emission increase will remain with the implementation of the proposed standards.

The lack of in-use compliance requirements for the air-conditioner test is not expected to pose a significant risk, since the air-conditioner test does not include the extremely-high load events where the effects of catalyst deterioration are expected to be most significant. In addition, because there is an overlap between the SC03 and FTP on the majority of the speed and load points, SC03 emission durability may also be similar to FTP durability. As stated previously, manufacturers are responsible for assuring that their vehicles comply with the in-use FTP emission standards. Thus, staff expects that the air-conditioner emission durability will also be indirectly controlled.

VII. ISSUES OF CONTROVERSY

During the past several years of cooperative effort with the U.S. EPA and the automotive industry, staff has worked with both parties to resolve many issues of controversy. In an April 1997 public mailout, the proposed regulation was sent to interested parties. Staff's current proposal includes modifications which reflect some of the written comments received. However, two significant issues remain, in which staff's position differs from the comments received. Both issues were brought forth by automotive manufacturers and relate to the proposed SFTP emission standards.

ISSUE #1: In staff's proposal, Tier 1 and TLEVs are subject to the same SFTP emission standards as those recently adopted by the U.S. EPA, while LEVs, ULEVs, and SULEVs have 4,000 mile emission standards. Industry requests that staff consider 4,000 mile emission standards for Tier 1 and TLEVs. The basis for this recommendation is to align the SFTP certification requirements of Tier 1 and TLEVs with those of LEVs, ULEVs, and SULEVs. The suggested methodology to establish 4,000 mile standards for Tier 1 and TLEVs is to increase the proposed LEV SFTP emission standards by the ratio of Tier 1 FTP to LEV FTP emission standards.

RESPONSE: Due to the small number of Tier 1 and TLEVs certified to the SFTP emission standards by the 2001 model year (when the proposed regulation would be phased-in), significant efforts were not undertaken by staff to develop emission standards for Tier 1 and TLEVs. However, the U.S. EPA in conjunction with automotive manufacturers conducted several test programs to quantify off-cycle emissions from Tier 1 vehicles. To simulate 50,000 miles of use, the test vehicles were equipped with aged exhaust emission components. Data from the test programs were subsequently used by the U.S. EPA to determine appropriate useful-life SFTP emission standards for Tier 1 vehicles. In addition, the Tier 1 SFTP emission standards developed by the U.S. EPA have been carefully scrutinized through the public process during the Federal rulemaking and determined to be appropriate for this vehicle class. Therefore, staff recommends that the emission standards adopted by the U.S. EPA also be applied to California Tier 1 and TLEVs.

ISSUE #2: Staff is currently proposing stand-alone SFTP emission standards in which the US06 and SC03 standards would need to be met separately. As discussed previously in Section

VI, the development of the proposed SFTP emission standards has been a joint effort between ARB and Industry staff. Through a series of lengthy and thorough discussions with Industry, the automotive industry has already shown support for these stand-alone standards. Industry now requests that ARB composite NMHC plus NOx standards for the US06 and SC03 tests for all vehicle classes. This request is consistent with industry's position that staff "leave the door open" to consider such an option. The suggested methodology is to weight US06 and SC03 emissions by 31.8 percent and 68.2 percent, respectively. Industry contends that the composite approach would provide added flexibility without losing air quality benefits.

RESPONSE: While composite standards provide added flexibility when compared to stand-alone standards, there would likely be an air quality disbenefit. Whereas manufacturers typically use an appropriate compliance margin on each test with stand-alone standards, the composite approach would likely reduce the compliance margin needed when the tests are weighted together. Thus, emission levels higher than those expected to comply with stand-alone standards would likely result under composite standards. A composite approach would then result in an inappropriate loss in the air quality benefits. After careful consideration, staff proposes to maintain the more environmentally-protective stand-alone SFTP standards.

VIII. ENVIRONMENTAL AND ECONOMIC IMPACTS

A. Environmental Impacts

The statewide and South Coast Air Basin air quality impacts of the proposed regulations are shown in Tables 10 and 11, respectively. These impacts include the effects of SFTP emission controls on passenger cars, light-duty trucks, and medium-duty vehicles up to 8501 pounds gross vehicle weight rating. Air quality benefits are shown as positive numbers, while dis-benefits are shown as negative numbers. Note that little CO emission benefits are expected and therefore are not shown in the tables. (A more detailed description of the environmental impact analysis is included in the staff's Technical Support Document.)

The proposed regulations for passenger cars and light-duty trucks would take effect on a 25-50-85-100 percent phase-in basis from the 2001 through 2004 model-years, so that full fleet-turnover will not take place until well after 2010, when the Board has committed to attaining the current Federal ozone standard in the 1994 State Implementation Plan. The air quality impacts of US06 and air-conditioner operation were not included in this State Implementation Plan, so that the above statewide emission reductions should not be considered a State Implementation Plan emission measure towards attainment of the Federal ozone standard. The most recent South Coast Air Basin Air Quality Management Plan for 2010 ozone attainment does employ the newly revised ARB motor vehicle emission model, EMFAC-7G, which includes most of the effects of the high-speed, high-load US06-type vehicle operation, although a different cycle is used for modeling purposes. Therefore, some of the above increases and reductions would be included in the baseline and attainment scenario, respectively, for the South Coast Basin ozone attainment plan. However, the EMFAC-7G model has not yet been updated to include the effects of real-world air-conditioner emissions, so that the baseline South Coast Air Basin inventory assumed in the 1997 Air Quality Management Plan is presently understating overall motor vehicle emissions.

Table 10. Statewide Inventory Air Quality Impacts of Proposed Regulation (Tons per Day)

Calendar Year	NMHC	CO	NOx
2010	-5.3	-	91.8
2015	-7.8	-	123.0
2020	-9.5	-	142.8

Table 11. South Coast Air Basin Inventory Air Quality Impacts of Proposed Regulation (Tons per Day)

Calendar Year	NMHC	CO	NOx
2010	-2.1	-	36.7
2015	-3.1	-	49.2
2020	-3.8	-	57.1

B. Economic Impacts

1. Costs to Motor Vehicle Manufacturers

(a) Assumptions Used and U.S. EPA's Cost Analysis

Motor vehicle manufacturers will incur additional costs to comply with the proposed regulations. These costs can be divided into fixed and variable costs. Fixed costs occur independent of production volumes and are usually equal to vehicle development, certification, and related costs. Variable costs are directly proportional to production volume and are usually equal to the cost of the increased vehicle hardware necessary to comply with a proposed regulation.

An unusually large proportion of the potential total costs for this rulemaking is fixed costs because of the expenditures associated with conducting the new certification tests, and the fact that most vehicles will not need any changes in hardware. The assignment of fixed costs to the California regulations depends in large part on the proportion of engine families for which separate certification tests will be conducted on "California-only" and on "49-state" vehicles, compared to "50-state" engine families undergoing just one set of tests for California and Federal certification. For a California-only engine family, all of the fixed costs are attributable to the California regulations. For a 50-state engine family, the fixed costs attributable to the proposed California regulations are appropriately calculated as 10 percent of the total fixed cost, since on average about 10 percent of the nation's new vehicles are sold in California. The remaining costs are attributable to the Federal SFTP requirements.

The staff has estimated costs under two alternative certification scenarios, Scenarios "A" and "B." There were 227 engine families certified in California for the 1996 model year, and in both scenarios staff assumes that approximately 230 engine families will be California-certified in subsequent model years through the next decade. At the present time, about one-half of the California engine families are certified as 50-state and therefore do not undergo separate State and Federal certification tests.

Under staff's Scenario A, Federal vehicles become subject to standards at the LEV level of stringency at some point between the 2001 and 2004 model years, as a result of implementation of either (a) the major vehicle manufacturers' ZEV Memoranda of Agreement commitments, (b) a National LEV program that is agreed-to by the OTC states and the automakers, or (c) Federal "Tier 2" standards that are overall equivalent to the LEV level. Under staff's Scenario B, the current Federal Tier 1 standards for light-duty vehicles remain in effect outside California indefinitely beyond the 2001 model year. Given the likelihood that at least one of the programs for LEV stringency nationally will be implemented, Scenario A is more likely to occur than Scenario B.

In Scenario A, staff assumes conservatively that approximately 65 percent of new passenger cars and light-duty trucks will be in 50-state engine families certified to the LEV emission standards by the 2003 model year (most if not all of the remaining California-only vehicles would be certified to the ULEV or ZEV standards). Assuming that passenger cars and light-duty trucks comprise 90 percent of the new vehicle fleet to which the proposed SFTP regulation is applicable, 58 percent of the total affected California new vehicle fleet would be in 50-state engine families, and 42 percent would be California-only.

In Scenario B, staff estimates that the greater stringency of the California LEV Program would mean that only about 10 percent of the 230 California engine families would be 50-state in the 2001 and subsequent model years. The remaining 90 percent would be California-only engine families.

Under both scenarios, staff assumes that the entire California new motor vehicle fleet by the 2001 model year will be LEVs, ULEVs, SULEVs or ZEVs. In actuality, staff estimates that something less than five percent of new motor vehicles will be certified to the Tier 1 and TLEV emission standards by the 2001 model year, since by that time the required fleet average non-methane hydrocarbon value will be below the LEV emission standard. The California costs associated with Tier 1 and TLEV compliance with the proposed regulations are identical to those calculated by the U.S. EPA for the Federal program. Since the LEV cost per vehicle for compliance with the staff proposal is significantly higher than the cost per vehicle estimated by the U.S. EPA for Tier 1 compliance with the Federal SFTP requirements, omitting Tier 1 and TLEV vehicles from the cost estimates represents a worst-case assumption.

The U.S. EPA conducted a detailed analysis of the costs associated with its SFTP program. The preliminary regulatory impact analysis was described in a Notice of Public Rulemaking (60 F.R. 7409) and presented at an April 19-20, 1995 public workshop. U.S. EPA's final Regulatory Impact Analysis contains two scenarios to calculate test facility costs, depending on the air-conditioner simulation used to conduct the SC03 test. As discussed in Section IV.B. of this report, the SC03 air-conditioner test is to be conducted in an environmental chamber with the air-conditioner turned on. However, manufacturers are allowed to use a less costly air-conditioner simulation in the standard test cell if a correlation is established with the environmental chamber. U.S. EPA developed one cost analysis based on the air-conditioner simulation, and the second based on use of an environmental cell.

Table 12 shows the annual Federal costs for the two air-conditioner scenarios, derived from U.S. EPA’s final Regulatory Impact Analysis (these costs do not include California-only vehicles, but do include the full cost of 50-state vehicles). The total Federal annual cost of compliance with the air-conditioner simulation option and the environmental cell testing was identified as $198.9 million and $244.5 million, respectively. U.S. EPA identified annual hardware costs of $92.7 million under both air-conditioner test options. Thus, the annual fixed

Table 12. U.S. EPA’s Projected Cost of Compliance with Federal SFTP Requirements

	Air-Conditioner Simulation	Environmental Cell
Total Annual Fixed Costs	$106,200,000	$151,800,000
Total Annual Variable Costs	$92,700,000	$92,700,000
Total Annual Costs	$198,900,000	$244,500,000
No. of Engine Families	340	340
Fixed Costs per Engine family	$312,000	$446,000

costs are the remaining $106.2 million and $151.8 million for the simulation scenario and the environmental cell scenario, respectively. By dividing the total annual fixed costs by the number of engines families (340) currently certified to the Federal standards, one can identify fixed costs per engine family for the Federal SFTP program of $312,000 and $446,000 for the air-conditioner simulation and the environmental cell testing, respectively.

For each engine family, the fixed costs include engine control recalibration, vehicle redesign, testing on redesigned engine families, certification durability demonstration, emission test facility modification, and certification costs. These costs per engine family also generally characterize the fixed costs of a California engine family to comply with the proposed regulations. Accordingly, staff made its cost estimates for the California program based on fixed costs of $312,000 and $446,000 for a California-only engine family under the two air-conditioner testing options.

(b) Vehicle Manufacturers' Costs for the California SFTP Program

The staff's cost estimates for the proposed California SFTP requirements are shown in Table 13. Based on the analysis described above, and assuming that 1.5 million vehicles certified under the proposed regulations will be sold annually in California, the annual fixed costs per vehicle are $22.80 - $32.60 under Scenario A, and $43.60 - $62.20 under the worst-case Scenario B.

Staff estimates the manufacturers' variable costs at $6.00 under both scenarios. As discussed in Section V, Technological Feasibility of the SFTP Emission Standards, staff believes that the majority of LEVs will require no hardware modifications to comply with the proposed standards. As noted earlier, of the 12 passenger cars tested at low-mileage by ARB staff, eight complied with the proposed US06 standard with a significant compliance margin through the use of the rich-bias strategy. Of the other four vehicles, three did not perform in an LEV-representative manner and would be expected to show lower US06 emissions when modified for LEV FTP compliance. The fourth vehicle is a Honda Civic TLEV, and an LEV version of this vehicle easily complied with the proposed requirements. For this reason, staff is assuming as a relatively conservative estimate that no more than 30 percent of the LEV fleet will require any hardware changes to comply with the US06 and SC03 requirements. Half of these modifications, or 15 percent of the vehicle fleet, are assumed to be increases in catalyst loading, while the other 15 percent are assumed to be increases in catalyst volume.

The catalyst loading increases will be primarily in rhodium, which is generally used for its NOx conversion capabilities. Staff is assuming a 0.5 gram per vehicle increase in rhodium; most vehicles that use rhodium presently use less than this amount. The current price of rhodium is approximately $6.60 per gram. However, this is at a historic low and is in part because of recent manufacturers' trend towards palladium-only catalysts and away from the previous platinum-rhodium catalysts. Staff is assuming that future rhodium costs will increase due to the increased rhodium demand occasioned by this regulation. In the U.S. EPA rule, an average future cost of rhodium is assumed to be equivalent to $22 per gram, so that the

Table 13. Cost of Compliance with California SFTP Requirements

	Scenario A (42% CA-Only Engine Families)		Scenario B (90% CA-Only Engine Families)	
	Air-conditioner Simulation	**Environmental Cell**	**Air-conditioner Simulation**	**Environmental Cell**
Total Annual Fixed Costs	$34,200,000	$48,900,000	$65,400,000	$93,300,000
Total Annual Variable Costs	$9,000,000	$9,000,000	$9,000,000	$9,000,000
Total Annual Costs	$43,200,000	$57,900,000	$74,400,000	$102,300,000
No. of Vehicles	1.5 million	1.5 million	1.5 million	1.5 million
Annual Fixed Costs per Vehicle	$22.80	$32.60	$43.60	$62.20
Annual Variable Costs per Vehicle	$6.00	$6.00	$6.00	$6.00
Total Annual Costs per Vehicle	$28.80	$38.60	$49.60	$68.20

additional cost of the increased rhodium is approximately $11 per vehicle. When multiplied by the 15 percent vehicle usage factor, this yields an additional fleet-wide cost of $1.65 per vehicle.

For the catalyst volume increases, staff has assumed that a 20 percent increase in catalyst volume will be sufficient for US06 and SC03 emission standard compliance. Again, it is unlikely that large catalyst volume changes would be required for compliance, since many vehicles presently contain sufficient catalyst volume to meet the proposed requirements. Assuming a current wholesale catalyst cost of $100, the cost per vehicle requiring this catalyst change is $20, and fleet-average cost equals 15 percent of $20, or $3 per vehicle. When combined with the catalyst loading cost calculated above, the total wholesale hardware cost of the proposed regulation is $4.65 per vehicle. Using the U.S. EPA assumption that the retail cost averages 29 percent higher than the wholesale cost, the total retail cost is calculated as $6.00 per vehicle. Using the annual 1.5 million vehicles figure, the variable costs yield a total annual cost of the proposed regulations of $9.0 million.

Table 13 shows that the estimated annual total cost of the proposed regulation under Scenario A is $43.2 million or $28.80 per vehicle with air-conditioning simulation testing, and $57.9 million or $38.60 per vehicle with air-conditioning environmental cell testing. Staff believes that Scenario A, with 42 percent California-only engine families, is the most likely outcome. Moreover, as long as air-conditioning simulation testing can be used successfully, the lower costs associated with that option would be expected. Under the worst-case Scenario B, with 90 percent California-only engine families, the annual total cost would be expected to be $74.4 million or $49.60 per vehicle with air conditioning simulation, and $102.3 million or $68.20 for environmental cell testing.

(c) <u>Impact on the Profitability of Domestic Automobile Manufacturers</u>

Using the most likely Scenario A, the combined cost to Ford, Chrysler and General Motors is estimated to be about $25.9 - 34.7 million annually. This cost is not expected to noticeably impact the profitability of these U.S. automobile manufacturers because in 1996, these manufacturers collectively reported approximately $13 billion in net profit. The estimated costs amount to a minor reduction in the profitability of the auto manufacturers — approximately 0.2 percent.

2. <u>Impact on Consumers</u>

No additional in-use vehicle maintenance costs or warranty repairs are expected from the proposed regulations, which will not likely require any additional components to be added to motor vehicles. Similar to other motor vehicle regulation costs, the additional costs to manufacturers will most likely be passed on to the California consumer. In such a case, staff expects that the proposed regulation will cause a maximum increase of about $30 - $40 in the price of a vehicle in California. However, consumers would likely experience a fuel economy benefit from the general removal of commanded enrichment air-fuel strategies. This fuel economy benefit is estimated to be approximately $16.56 per vehicle according to the U.S. EPA Regulatory Impact Analysis.

3. <u>Economic Impacts on California Business Enterprises</u>

The staff has considered the potential impacts of the proposed regulations on California business enterprises. Virtually none of the motor vehicle manufacturers producing California motor vehicles that will be subject to the California SFTP requirements are California businesses, and thus California businesses will experience no significant direct impacts.

California businesses purchasing motor vehicles will experience the small price increases estimated above, to the extent they are passed on by the manufacturer. Because these small vehicle price increases would not have a noticeable cost impact on California businesses, the proposed regulations are not expected to affect the creation or elimination of jobs within California, the creation of new businesses and the elimination of existing businesses within California, or the expansion of businesses currently doing business within the State of California.

Given the existence of the Federal SFTP requirements applicable nationwide, the proposed regulations will not have a significant adverse economic impact on the ability of California businesses to compete with businesses in other states.

C. Cost-Effectiveness

Table 14 shows the staff's cost-effectiveness estimates. The cost-effectiveness of the proposed regulations is calculated as follows, based on the analysis above. The NMHC plus NOx benefits reflect the emission reductions in 2020, when fleet turnover will be largely complete. Under the more likely Scenario A, the cost-effectiveness of the regulation is calculated at $887 per ton or $0.44 per pound with the air-conditioning simulation and $1,200 per ton or $0.60 per pound with the environmental cell test. This compares favorably to $5 per pound, which is a typical cost-effectiveness value for an air pollution control measure. The worst-case Scenario B yields a cost-effectiveness of $1,530 per ton or $0.77 per pound with the air-conditioning simulation and $2,110 per ton or $1.05 per pound with the environmental cell test.

There are several factors which could potentially impact these cost-effectiveness estimates. Considerations which could result in a higher cost per pound of emissions reduced include: the comparatively low usage of vehicle air-conditioners during the winter months in California (lowering the annual NMHC plus NOx emission reductions); and possible increases in vehicle hardware costs over what staff has estimated. With regards to air-conditioner usage, the cost-effectiveness of regulations is typically calculated for ozone non-attainment conditions (summertime), when the use of air-conditioners is at its maximum, so that, given current cost-benefit calculation methodology, lower-than-predicted emission benefits are not expected from this concern.

Considerations which could result in a lower cost per pound of emissions reduced include the fuel economy benefit to the consumer due to the removal of commanded enrichment air-fuel strategies. As previously indicated, the U.S. EPA estimates this benefit to be approximately $16.56 per vehicle. This is approximately half of the total cost staff has calculated above for the National LEV scenario, so that the proposed regulations may result in half the cost impact. In addition, the proposed regulations may result in emission benefits over the current FTP, so that total emission benefits may be larger than calculated above. Finally, it is possible that fewer hardware changes than staff has estimated may ultimately be required, lowering the cost of the proposed regulations. Staff believes that no reasonable cost-effectiveness scenario incorporating the above considerations is likely to result in a cost per pound of emissions reduced that is significantly different from the range of $0.44 to $1.05 per pound calculated above.

Table 14. Cost-Effectiveness

	Scenario A (42% California-Only Engine Families)		Scenario B (90% California-Only Engine Families)	
	Air-conditioner Simulation	**Environmental Cell**	**Air-conditioner Simulation**	**Environmental Cell**
Total Annual Costs	$43,200,000	$57,900,000	$74,700,000	$102,300,000
Average Daily Costs	$118,000	$159,000	$204,000	$280,000
NMHC plus NOx (tons/day)	133	133	133	133
CO (tons/day)	0	0	0	0
Total Emission Reduction (tons/day)	133	133	133	133
Cost-effectiveness ($/ton)	$887	$1200	$1,530	$2,110
Cost-effectiveness ($/pound)	$.44	$.60	$.77	$1.05

Appendix 1

Graphs of Various Driving Schedules

REPO5
ARB01B
US06
SC03

Appendix 2

ARB/Industry US06 Test Program

Table A. ARB/Industry US06 Test Program: Summary of 50,000-Mile Emissions (g/mi)

Passenger Cars and Light-Duty Trucks up to 3750 Pounds Test Weight

Control Strategies: Stoichiometric Calibration, Bias Optimization

Test Vehicle	NMHC	CO	NOx	NMHC+NOx
Honda ULEV[A]	0.004	0.378	0.021	0.025
ARB-Mazda 626[B]	0.023	1.802	0.042	0.066
GM-1	0.016	1.004	0.050	0.066
ARB-Accord	0.010	0.675	0.065	0.075
ARB-Grand AM[B]	0.037	4.905	0.049	0.086
Ford-1	0.013	0.6	0.101	0.114
Ford-2	0.004	2.1	0.12	0.124
GM-3[C]	0.014	1.210	0.117	0.131
ARB-Neon	0.014	2.059	0.172	0.186
Honda-1[C]	0.035	3.082	0.154	0.189
Nissan-1	0.06	0.83	0.140	0.20
ARB-Bonneville	0.019	1.539	0.182	0.201
ARB-Civic	0.087	2.204	0.134	0.222
ARB-Lexus SC300	0.074	1.446	0.164	0.238
ARB-Grand Marquis	0.011	2.750	0.245	0.256
Chrysler-1[C]	0.02	2.6	0.43	0.45
Toyota-1[C]	0.006	0.68	0.48	0.49
Average[D]	**0.029**	**1.899**	**0.117**	**0.146**

[A] "ULEV" means ultra-low-emission vehicle. This vehicle is not officially part of test program but is included to indicate emissions representing an ULEV.
[B] Tested under production calibration only.
[C] Tested with stoichiometric calibration but without bias optimization.
[D] Average excludes vehicles without bias optimization (footnote D), due to the effect of this optimization on reducing vehicle NMHC+NOx emissions.

Table B. ARB Industry US06 Test Program: Summary of 50,000-Mile Emissions (g/mi)

Light-Duty Trucks Over 3750 Pounds Test Weight and Medium-Duty Vehicles

Control Strategies: Stoichiometric Calibration, Bias Optimization

Test Vehicle	NMHC	CO	NOx	NMHC+NOx
Light-Duty Truck over 3750 Pounds Test Weight				
ARB-Ranger	0.040	1.677	0.290	0.330
Medium-Duty Vehicles[A] up to 8501 Pounds Test Weight				
GM-2 (MDV2, 90,000 miles)	0.028	3.7	0.583	0.611
Chrysler (MDV2, 100,000 miles)	0.06	5.56	0.82	0.88

[A] Both medium-duty vehicles were inadvertently tested at weights higher than those specified by the U.S. EPA regulations for the US06 test. In addition, these vehicles would be expected to show somewhat lower results when tested with 50,000-mile aged components.

Table C. ARB US06 Test Program: Summary of Low-Mileage Emissions (g/mi)

Control Strategies: Stoichiometric Calibration, Bias Optimization

Test Vehicle	NMHC	CO	NOx	NMHC+NOx
Passenger Car				
Dodge Intrepid	0.008	0.044	0.050	0.058
Honda Civic (LEV)	0.042	14.778	0.022	0.064
Honda Civic (TLEV)*	0.083	1.964	0.065	0.148
Honda Accord	0.009	1.018	0.033	0.042
Mazda 626	0.022	3.251	0.036	0.058
Mazda 929	0.033	3.126	0.118	0.151
Mercury Grand Marquis*	0.015	1.467	0.039	0.054
Nissan Maxima	0.053	1.995	0.090	0.143
Nissan Sentra	0.024	5.065	0.163	0.187
Plymouth Neon*	0.007	1.167	0.070	0.077
Pontiac Grand Am	0.042	4.650	0.025	0.067
Pontiac Bonneville**	0.017	0.754	0.035	0.052
Average	**0.030**	**3.273**	**0.062**	**0.092**
LDT (3751-5750 pounds loaded vehicle weight)				
Chevrolet Astrovan	0.091	3.72	0.065	0.156
MDV (3571-5750 pounds test weight)				
Chevrolet 1500 P/U	0.014	0.387	0.208	0.222
Ford F150 P/U	0.04	12.54	0.048	0.088
Average	**0.027**	**6.464**	**0.128**	**0.155**
MDV (5751-8500 pounds test weight)				
Chevrolet Suburban	0.105	7.23	0.200	0.305
Dodge Ram Van	0.058	7.66	0.349	0.407
Ford E-250 Van	0.009	2.73	0.201	0.21
Ford E-350 Van	0.081	13.63	0.064	0.145
Average	**0.063**	**7.813**	**0.204**	**0.267**

* Tested with stoichiometric calibration
** Tested on a twin-roll dynamometer

Appendix 3

ARB Air-Conditioner Test Program

ARB Air-Conditioner Test Program: Summary of Low-Mileage Emissions (g/mi)

Control Strategies: Stoichiometric Calibration, Bias Optimization

Test Vehicle	**NMHC**	**CO**	**NOx**	**NMHC+NOx**
Passenger Car				
Dodge Intrepid	0.063	1.600	0.096	0.159
Ford Taurus FFV	0.015	1.380	0.066	0.081
Honda Accord	0.007	0.290	0.117	0.124
Honda Civic (LEV)	0.021	1.440	0.082	0.103
Mazda (Prototype)	0.002	0.095	0.061	0.063
Plymouth Neon	0.010	2.390	0.183	0.193
Pontiac Bonneville	0.032	1.540	0.137	0.169
Pontiac Grand AM	0.040	1.760	0.116	0.156
Average	**0.024**	**1.312**	**0.107**	**0.131**
LDT (3751-5750 pounds loaded vehicle weight)*				
Chevrolet Astrovan	0.170	3.710	0.050	0.220
Chevrolet Blazer	0.045	0.491	0.106	0.151
Ford Aerostar**	0.013	0.271	0.133	0.146
Ford Explorer	0.030	1.510	0.117	0.147
Average	**0.065**	**1.496**	**0.10**	**0.166**
MDV (3571-5750 pounds test weight)*				
Ford F-150 P/U	0.024	0.460	0.067	0.091
MDV (5751-8500 pounds test weight)*				
Chevrolet Suburban	0.087	1.500	0.460	0.547
Ford E-250 Van	0.016	0.650	0.329	0.345
Ford E-350 Van	0.039	3.040	0.008	0.047
Average	**0.047**	**1.730**	**0.27**	**0.313**

* The LDT and MDV portion of the test program was conducted under time constraints; consequently, duplicate tests at the optimal setting were not performed.

** The air-conditioner system was somewhat underloaded using the AC2 simulation method, as the "Defrost" setting was necessary to return hot air to the air-conditioning system.

Appendix 4

Proposed Regulation Order

Proposed Amendments to Title 13, California Code of Regulations, Sections 1960.1 and 2101