State of California
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS

PROPOSED AMENDMENTS TO
CALIFORNIA EXHAUST AND EVAPORATIVE
EMISSION STANDARDS AND TEST PROCEDURES FOR
PASSENGER CARS, LIGHT-DUTY TRUCKS AND MEDIUM-DUTY VEHICLES
"LEV II"

and

PROPOSED AMENDMENTS TO CALIFORNIA
MOTOR VEHICLE CERTIFICATION, ASSEMBLY-LINE
AND IN-USE TEST REQUIREMENTS
"CAP 2000"

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EXECUTIVE SUMMARY

In 1994, the Air Resources Board (ARB) approved a revision to the State Implementation Plan (SIP) that contains clean air strategies needed to meet the health-based 1-hour federal ozone air quality standard. The ozone SIP includes mobile source Measure M2 that calls for the adoption of technology-based emission control strategies for light-duty vehicles to be implemented beginning with the 2004 model year and a reduction of 25 tons per day (tpd) reactive organic gases plus oxides of nitrogen (ROG plus NOx). In addition to Measure M2, the SIP relies on the development of additional technology measures (the mobile source "Black Box") to provide another 75 tpd ROG plus NOx needed for attainment in the South Coast Air Basin. The staff's proposal achieves the M2 SIP commitment and will provide additional emission reductions to cover shortfalls in defined ARB measures and make progress on the Black Box. The reductions will also ensure continued progress toward meeting state and new federal air quality standards for ozone and particulate matter.

The proposal being presented in this rulemaking affects all passenger cars, light-duty trucks and medium-duty vehicles and includes new standards for both exhaust and evaporative emissions. The exhaust emission proposal includes a 0.05 gram/mile LEV and ULEV NOx standard, a new emission category -- Super-Ultra-Low-Emission Vehicle (SULEV), increased durability requirements, a declining manufacturer fleet average emission requirement, a restructuring of the light-duty truck category to reflect the increasing usage of trucks and sport utility vehicles for personal transportation and a requirement that these vehicles meet the same numerical emission standards as passenger cars, the allowance of partial zero-emission vehicle (ZEV) credit for exceptionally clean vehicles, lower emission standards for medium-duty vehicles, and numerous technical updates and revisions to the motor vehicle test procedures. This rulemaking also includes extensive revisions to streamline the certification process and increase in-use testing requirements, to reflect similar changes being proposed by the United States Environmental Protection Agency.

The exhaust standards proposed in this rulemaking present a significant challenge to automobile manufacturers over the next ten years. Staff has endeavored to provide compliance flexibility to manufacturers wherever possible in phasing-in the proposed LEV II standards. This proposal is structured to allow manufacturers to adapt their introduction of LEV II vehicles in accordance with their normal production schedules while still requiring a steady phase-in of LEV II vehicles.

Staff conducted a research and test program to determine the technological feasibility of the proposed "LEV II" standards. Some of the basic emission control approaches projected to be used for LEV II vehicles are currently being utilized on new vehicles; accordingly, staff expects that manufacturers will continue to improve current LEV I program technology to meet the LEV II standards. The results of staff's testing indicate that the LEV II standards are technologically feasible. Staff estimates that the cost to produce LEV II vehicles compared to LEV I vehicles will range from approximately $71 to $279 per vehicle, depending on the vehicle type.

The evaporative emission proposal consists of lower diurnal and hot soak evaporative emission standards of up to 80 percent from current standards; increased evaporative emission durability requirements from 10 years or 100,000 miles, whichever first occurs, to 15 years or 150,000 miles, whichever first occurs; and technical updates and modifications to the evaporative test procedures. The proposed implementation of the reduced standards would be 40 percent of applicable vehicles in the 2004 model year, 80 percent in the 2005 model year, and 100 percent in the 2006 and subsequent model years.

Staff conducted a test program to investigate the sources of evaporative emissions and potential emission control strategies, and held numerous meetings with automotive manufacturers to gather evaporative emission information. The projected technologies for compliance with the proposed evaporative standards would consist of improvements to vehicle fuel tanks and associated connections, revised fuel system lines and connections, updated vehicle carbon canisters, revised gas caps, and the use of intake manifold carbon filters. Some of these potential technologies are already being used on current vehicles. Staff estimates that the retail cost of compliance with the reduced evaporative standards is $25 per vehicle.

The estimated emission reduction benefits in the South Coast Air Basin for the proposed adoption of these standards are 51 tpd NOx and 6 tpd ROG in 2010 using the current inventory. The estimated cost-effectiveness of the staff's proposal averages approximately $1.00 per pound of ROG + NOx reduced. This cost-effectiveness is well within the range of other motor vehicle control measure costs. The staff recommends that the Board adopt the staff proposal.

I. INTRODUCTION

Although significant strides have been made toward improving California's air quality, health-based state and federal air quality standards continue to be exceeded in regions throughout California. Areas exceeding the federal 1-hour ozone standard include the South Coast Air Basin, San Diego County, the San Joaquin Valley, the Southeast Desert, the Broader Sacramento area and Ventura County. With promulgation of the new federal eight-hour ozone standard, more areas of the State are likely to be designated as nonattainment. Ozone (created by the photochemical reaction of reactive organic gases (ROG) and oxides of nitrogen (NOx)) leads to harmful respiratory effects including lung damage, chest pain, coughing, and shortness of breath, especially affecting children and persons with compromised respiratory systems. Other environmental effects from ozone include crop damage. In addition, because ozone precursors, such as NOx, also react in the atmosphere to form particulate matter (PM), reductions in NOx will be crucial to meet existing state and federal PM_{10} standards, as well as the new federal standards for fine particulate matter ($PM_{2.5}$).

California's plan for achieving the federal 1-hour ozone standard is contained in the California State Implementation Plan (SIP) that was approved by the Board in 1994. A significant part of the SIP pertains to the control of mobile sources, which are estimated to account for approximately 60 percent of ozone precursors statewide. The SIP calls for new measures to cut ozone precursor emissions from mobile sources to half of what the emissions would be under existing regulations. SIP mobile source measure M2 (Improved Control Technologies for Light-Duty Vehicles), which calls for the adoption of technology-based emission control strategies for light-duty vehicles to be implemented beginning with the 2004 model year, is expected to achieve emission reductions of 25 tons per day (tpd) of ROG plus NOx by 2010 from light-duty vehicles in the South Coast Air Basin. In addition to Measure M2, the SIP for the South Coast Air Basin (an extreme ozone nonattainment area) relies on the development of additional technology measures as allowed in Section 182(e)(5) of the Clean Air Act Amendments of 1990, in order to attain the ozone air quality standard by the required 2010 deadline. The SIP calls for additional motor vehicle emission reductions in the South Coast Air Basin of approximately 75 tpd ROG plus NOx (these emission reductions are referred to as the mobile source "Black Box").

One purpose of this rulemaking, therefore, is to address the requirements of California's SIP Measure M2 and to introduce advanced technology measures to achieve additional emission reductions needed for the South Coast Air Basin. The reductions will also ensure continued statewide progress toward meeting state and federal air quality standards for ozone and particulate matter. The emission reduction estimates contained in this report pertain to the South Coast Air Basin (SoCAB) because the benefits are currently credited only to the South Coast in the 1994 ozone SIP. However, the emission reductions are needed statewide. The LEV II regulations will help achieve and maintain the federal one-hour ozone standard in regions such as the San Joaquin Valley and the Sacramento area, the federal eight-hour ozone and particulate matter standards in a number of areas, and the State ozone and particulate matter standards throughout California.

Although the proposed amendments would affect passenger cars, light-duty trucks and medium-duty vehicles, the heart of the staff proposal is a requirement that sport utility vehicles and heavier trucks meet passenger car standards. The proposal would also lower tailpipe standards for all vehicles, lower manufacturer fleet average non-methane organic gas (NMOG) standards, lower evaporative emission standards, revise the criteria for determination of zero-emission vehicle (ZEV) credits, and include numerous technical modifications that would update the regulations and test procedures to account for developing technologies such as hybrid electric vehicles. While staff will be proposing additional flexibility in determining the eligibility of a vehicle for receiving a ZEV credit, revisions to the 2003 and subsequent model year 10% ZEV requirement will not be considered in this rulemaking. Finally, staff will be proposing modifications to the Smog Index Label specifications to include the proposed new emission standards, and modifications to the NMOG Test Procedures to reflect updates in laboratory procedures and instrumentation. Except for the evaporative amendments, these proposed amendments will be discussed in Part II of this Staff Report. The evaporative emission proposal will be discussed in Part III.

Another aspect of this rulemaking covers proposed amendments to the certification and in-use compliance requirements for motor vehicles. In 1995, the U.S. Environmental Protection Agency (U.S. EPA), ARB and the automobile manufacturers signed a Statement of Principles that states:

> "... the Signatories commit to working together to achieve regulatory streamlining of light-duty vehicle compliance programs, including reduction of process time and test complexity, with the goal of more optimal resources spent by both government and industry to better focus on in-use compliance with emission standards."

Since then, staff has been working with U.S. EPA and the automobile industry to develop a streamlined motor vehicle certification process coupled with an enhanced in-use compliance program (called "Compliance Assurance Program" or "CAP 2000"). As part of the effort, California agreed to harmonize to the greatest extent possible with the federal programs in order to further reduce the regulatory burden on automobile manufacturers, while at the same time ensuring that stringency of the California programs is not reduced in any way. The amendments being proposed in this rulemaking are a result of this process and will be discussed in Part V of this Staff Report.

Finally Part IV addresses some proposed modifications to the on-board diagnostic system phase-in requirements and Parts VI and VII present the economic and environmental impacts of the LEV II proposal.

II. PROPOSED AMENDMENTS TO CALIFORNIA'S LOW-EMISSION VEHICLE EXHAUST EMISSION STANDARDS (LEV II)

A. BACKGROUND

In 1990, California adopted the most stringent exhaust regulations ever for the control of emissions from light- and medium-duty vehicles with its Low-Emission Vehicle (LEV) Program. Today's passenger cars and light-duty trucks are over 90% cleaner than when they were first regulated in the 1960s. This section provides an overview of the original LEV Program. Because a major element of this rulemaking is a proposed change in the treatment of heavier vehicles, the overview focusses on the vehicle weight classifications in the current program.

1. Vehicle Classes and Exhaust Emission Standards. Under the LEV regulations, different tailpipe emission standards apply to vehicles in different weight classifications, with heavier light and medium trucks generally allowed to emit more pollutants. There are currently seven vehicle classifications that fall under the LEV program:

passenger cars (PCs) (all weights);
light-duty trucks
    0-3750 lbs. loaded vehicle weight (LVW)[1] ("LDT1") and
    3751-5750 lbs. LVW ("LDT2");
medium-duty vehicles
    3751- 5750 lbs. test weight (TW) ("MDV2"),
    5751-8500 lbs. TW ("MDV3"),
    8501-10,000 lbs. TW ("MDV4"), and
    10,001-14,000 lbs. TW ("MDV5").

The weight classifications for trucks were created in recognition of the larger load carrying capacity and more rigorous duty cycle of trucks that could lead to more severe emission deterioration. Testing of light-duty trucks and medium-duty vehicles also accounts for these differences in load carrying capacities. While LDTs are tested with an extra 300 pounds added to the weight of the vehicle, the weight at which a MDV is tested is higher because it is based on one-half of the payload of the vehicle (generally 1,000 lbs. or more) plus the curb weight. Because the payload of an MDV can vary even within the same model (e.g., a Ford F150 can have a payload ranging from 1390 to 2435 lbs.), the same vehicle platform can have vehicles in

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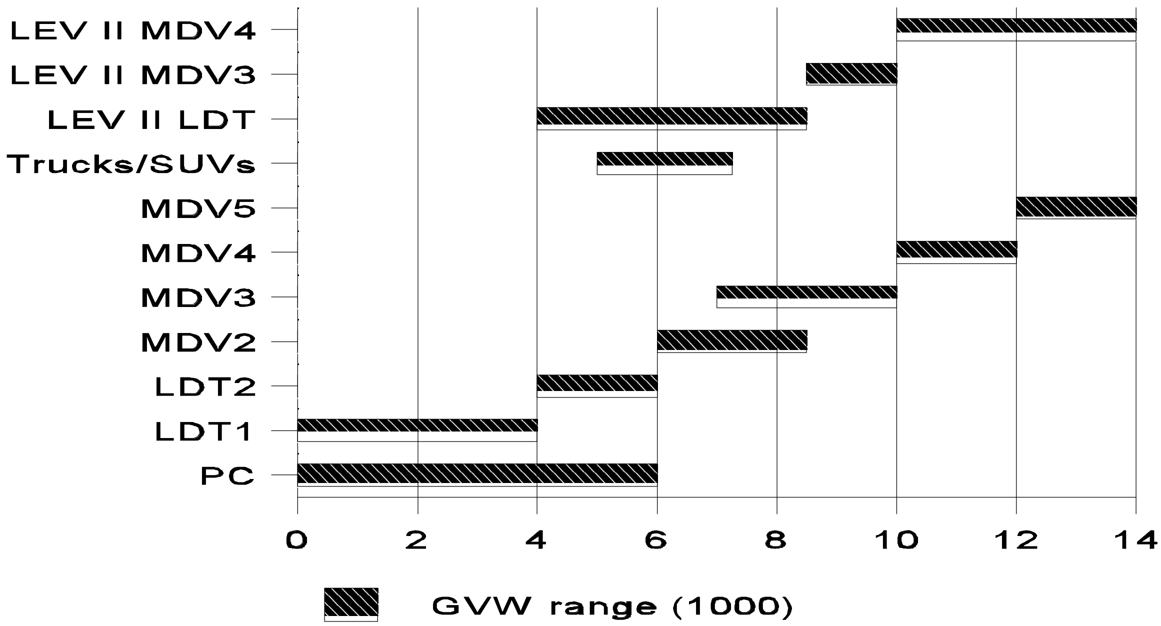
[1] There are several classifications for vehicles based on weight. Curb weight is defined as the actual weight of the vehicle. Loaded vehicle weight (LVW) is defined as the curb weight of the vehicle plus 300 pounds. Gross vehicle weight rating (GVW) is the curb weight of the vehicle including the full payload. Test weight (TW), also known as adjusted loaded vehicle weight (ALVW), is the weight at which a medium-duty vehicle is tested and is defined as the average of a vehicle's curb weight and gross vehicle weight.



both the LDT2 or MDV2 categories because the higher payload will cause some of the vehicles to be placed in the MDV2 category. Payloads can also vary between vehicles in the MDV2 and MDV3 categories causing the same model to be certified in both categories because of payload differences. This figure also includes the proposed LEV II vehicle classes that will be discussed later in this report.

Within each vehicle classification there are also several low-emission vehicle standards to which a vehicle may certify. In order of increasing stringency, these standards are: transitional low-emission vehicle (TLEV), low-emission vehicle (LEV), ultra-low-emission vehicle (ULEV) and super-ultra-low-emission vehicle (SULEV) and are set forth in Table II-1.

Table II-1

Current Exhaust Mass Emission Standards for TLEV, LEV, and ULEV Passenger Cars and Light-Duty Trucks and LEV, ULEV and SULEV Medium-Duty Vehicles

Vehicle Type	Mileage for Compliance	Vehicle Emission Category	NMOG (g/mi)	Carbon Monoxide (g/mi)	Oxides of Nitrogen (g/mi)	Formaldehyde (mg/mi)	Diesel Particulate (g/mi)
All PCs; LDT1s (0-3750 lbs. LVW)	50,000	Tier 1	0.25	3.4	0.4	n/a	0.08
		TLEV	0.125	3.4	0.4	15	n/a
		LEV	0.075	3.4	0.2	15	n/a
		ULEV	0.040	1.7	0.2	8	n/a
LDT2s 3751-5750 lbs. LVW	50,000	Tier 1	0.32	4.4	0.7	n/a	0.08
		TLEV	0.160	4.4	0.7	18	n/a
		LEV	0.100	4.4	0.4	18	n/a
		ULEV	0.050	2.2	0.4	9	n/a

Vehicle Type	Mileage for Compliance	Vehicle Emission Category	NMOG (g/mi)	Carbon Monoxide (g/mi)	Oxides of Nitrogen (g/mi)	Formaldehyde (mg/mi)	Diesel Particulate (g/mi)
MDV2s 3751-5750 lbs. TW	50,000	Tier 1	0.32	4.4	0.7	18	n/a
		LEV	0.160	4.4	0.4	18	n/a
		ULEV	0.100	4.4	0.4	9	n/a
		SULEV	0.050	2.2	0.2	9	n/a
MDV3s 5751-8500 lbs. TW	50,000	Tier 1	0.39	5.0	1.1	22	n/a
		LEV	0.195	5.0	0.6	22	n/a
		ULEV	0.117	5.0	0.6	11	n/a
		SULEV	0.059	2.5	0.3	6	n/a
MDV4s 8501 -10,000 lbs. TW	50,000	Tier 1	0.46	5.5	1.3	28	n/a
		LEV	0.230	5.5	0.7	28	n/a
		ULEV	0.138	5.5	0.7	14	n/a
		SULEV	0.069	2.8	0.35	7	n/a
MDV5s 10,001-14,000 lbs. TW	50,000	Tier 1	0.60	7.0	2.0	36	n/a
		LEV	0.300	7.0	1.0	36	n/a
		ULEV	0.180	7.0	1.0	18	n/a
		SULEV	0.09	3.5	0.5	9	n/a

There are additional emission standards at 100,000 miles for passenger cars and light-duty trucks and 120,000 miles for medium-duty vehicles.

2. Phase-In Requirements. One of the flexibilities of the LEV Program is that a manufacturer may chose the standards to which each vehicle is certified provided the overall fleet meets the specified phase-in requirements. For passenger cars and light-duty trucks, the NMOG exhaust emissions averaged over a manufacturer's entire light-duty product line must meet the following values based on the 50,000 mile NMOG standard to which each vehicle is certified.

Table II-2
Fleet Average NMOG Requirements

Vehicle Category	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
PCs; LDTs 0-3750	0.250	0.231	0.225	0.202	0.157	0.113	0.073	0.070	0.068	0.062
LDTs 3751-5750	0.320	0.295	0.287	0.260	0.205	0.150	0.099	0.098	0.095	0.093

The only instance where a specified percentage is required is for zero-emission vehicles, where each large and intermediate volume manufacturer must produce 10% of its PC and LDT1 production volume as zero-emission vehicles beginning in 2003. The separate fleet average values for the heavier category of light-duty trucks reflects the higher emission standards applicable to these trucks and the lack of a separate ZEV requirement pertaining to these vehicles.

There are two types of medium-duty vehicles - those that are certified using the chassis dynamometer (the left column of Table II-3) and those certified using an engine dynamometer (the right column of Table II-3). Medium-duty vehicles have separate low-emission vehicle phase-in requirements based on a percent phase-in schedule because the numerous vehicle weight classifications make a fleet average requirement difficult to implement.

Table II-3
Medium-Duty Vehicle Phase-In Requirements

Model Year	Chassis Certified Vehicles (% Sales)			Engine Certified Vehicles (% Sales)		
	Tier 1	LEV	ULEV	Tier 1	LEV	ULEV
1998	73	25	2	100	0	0
1999	48	50	2	100	0	0
2000	23	75	2	100	0	0
2001	0	80	20	100	0	0
2002	0	70	30	0	100	0
2003	0	60	40	0	100	0
2004 +	0	60	40	0	0	100

B. SUMMARY OF PROPOSED LEV II AMENDMENTS

In order to meet the SIP commitments, staff considered the following strategies: restructuring the light-duty truck category to include larger trucks and sport utility vehicles (SUVs) and requiring them to meet passenger car standards, lower tailpipe standards, lower fleet average requirements, increased durability requirements, lower evaporative emission standards (discussed in Part III), and partial zero-emission vehicle credits for exceptionally clean vehicles. In addition staff is proposing technical modifications to the hybrid electric vehicle test procedures to accommodate emerging hybrid technologies, modifications to the Smog Index label to incorporate the proposed lower exhaust and evaporative emission standards and updates to the NMOG Test Procedures to reflect updates in laboratory procedures and instrumentation. The following is a description of the staff proposal. A complete description of the regulatory amendments is contained in the appendices.

1. Proposal to Require SUVs and Heavier Trucks to Meet Passenger Car Standards. When the light-duty truck (LDT) and medium-duty vehicle (MDV) categories were first established, the majority of vehicles in the MDV category were primarily used for work purposes (e.g., a Ford F150 was used by electricians, plumbers, painters, etc.). Because these work vehicles have a larger load carrying capacity and a potentially more rigorous duty cycle, separate and numerically less stringent emission standards were developed that account for more severe emission deterioration. The high sales numbers of full size pick-up trucks, and the more recent introduction of extremely popular SUVs, however, has greatly altered the light- and medium-duty truck use patterns. Whereas these vehicles were traditionally used for work purposes, it is now very common for trucks and SUVs to be used primarily for personal transportation (i.e., as passenger cars). In addition, SUVs have been increasing in market share and now constitute almost 15% of the vehicle market. *Automotive News* (October 13, 1997) reports that the U.S. new vehicle market, "once dominated by cars, is approaching a car/light-duty truck split" with cars declining from 80% in 1980 to 54% in 1997. Light trucks (including SUVs) have increased from 20% in 1980 to almost 46% in 1997. This trend has a substantial impact on California's air quality because, although these vehicles are used as passenger cars, they are certified to the more lenient gram per mile (g/mi) emission standards designed for work trucks.

For this reason, staff is proposing a substantial restructuring of the light-duty truck category to include SUVs and heavier light trucks under 8500 lbs. GVW and to require them to meet the same standards as passenger cars. The trucks and SUVs that would be affected by this rulemaking include light trucks such as the Toyota RAV4 and Ford Ranger; medium-light trucks such as the Jeep Grand Cherokee, Chevy Blazer and Ford Explorer; all mini-vans; and the heavier light trucks such as the Ford F150, Ford Expedition, Chevrolet Suburban and Dodge Ram 1500 trucks. Vehicles that are likely to remain in the proposed medium-duty vehicle category include the yet to be introduced Ford Excursion, Ford F250 and F350 Super-Duty trucks, Dodge Ram 2500 and 3500 trucks, the largest version of the Chevrolet Suburban and many full size vans.

In establishing the standards that would apply to SUVs and the heavier light trucks, staff took into account that while the truck standards are currently differentiated into separate weight classes to account for their load carrying capacity, the same is not true for passenger car standards. Although passenger cars can be used for towing or carrying moderate loads as do pick-up trucks, SUVs and minivans, the heavier, larger PCs are required to meet the same emission standards as the smallest models because all vehicles are primarily used for personal transportation. With the substantial increase in the number of pick-up trucks, SUVs and minivans being primarily used as passenger cars, staff believes that they should also be required to meet passenger car standards. While automobile manufacturers seem to acknowledge that it is possible to achieve passenger car emission levels for trucks at low mileage, they contend that maintaining low levels for the useful life of the truck is doubtful. However, recent advancements in emission control technologies should enable the low emission levels to be maintained for the useful life of these vehicles. The use of advanced, high durability catalysts, in particular, would make the vehicles less susceptible to deterioration from load carrying or towing conditions.

In determining the criteria for the new truck category, staff considered several options. The biggest obstacle in selecting an appropriate vehicle weight criterion is how to distinguish work trucks from trucks used primarily for personal transportation. Another important consideration is how to ensure that trucks used primarily for personal transportation would not be certified to the higher weight categories just to avoid more stringent truck standards. One option involved differentiation based on type of axle (semi-floating vs. full floating axle) but this was not selected because almost all of the heavier personal-use SUVs are equipped with a full floating axle as standard equipment. Curb weight was also considered because it appeared to provide the least likely opportunity for manufacturers to slip vehicles into the higher weight categories that have more lenient standards. Consideration was also given to treating work trucks differently based on the number of wheels or trailer towing capacity.

After considerable discussion with manufacturers, staff is proposing that the cutpoint be based on GVW and selected 8,500 lbs. GVW as the dividing point. Since most pick-up trucks and SUVs have a curb weight less than 5,500 lbs. and a payload between 1,000-2000 lbs., it is anticipated that the majority of the heavier trucks will fall in the new LDT2 category below 8,500 lbs. GVW. It appears unlikely that manufacturers would unnecessarily add payload to trigger a numerically higher standard because of the negative impact on fuel economy, performance and cost. Therefore, staff is proposing that the light-duty truck category be restructured whereby trucks between 3751 lbs. LVW and 8,500 lbs. GVW would be combined in a new LDT2 truck category; the lightest weight category, 0-3750 lbs. LVW would remain the same because the ZEV requirement only affects this truck class; and trucks over 8,500 lbs. GVW would remain in the medium-duty vehicle category. The new LDT2 light-duty truck category would affect the current light-duty truck 3751-5750 lb. LVW classification and all trucks currently classified as medium-duty vehicles under 8,500 lbs. GVW.

In recognition that some of the heavier trucks in the new truck category will be engineered for more rigorous duty, however, staff is proposing that a small percentage (up to 4%) of a manufacturer’s truck sales in the new LDT2 category be allowed to certify to a marginally higher NOx emission standard than the other vehicles in this class. The only other stipulation for using this allowance would be that the vehicles must have a maximum base payload rating (GVW minus base curb weight) of 2500 lbs. or higher (this prevents manufacturers with limited sales of these types of vehicles from applying the allowance to the lighter vehicles that do not need the allowance). The trucks that will likely be considered for this category are ones that have counterparts in the over 8,500 lbs. GVW category such as the Ford F250, GM 2500 series and Chrysler 2500 series (the numbers of such vehicles currently being produced is the basis of the 4% determination). Based on a review of certification data, staff estimates that the number of vehicles that would potentially be considered is less than 25,000 trucks annually from all manufacturers. The emission impact is expected to be minimal because of the small number of vehicles affected and because the proposed standard of 0.07 g/mi NOx at 50,000 miles is only slightly higher than the 0.05 g/mi NOx LEV emission level for most of the vehicles in this class. The 120,000 mile standard would be 0.10 g/mi NOx. To determine the number of vehicles that would be eligible, a manufacturer would apply the 4% cap to the projected sales of its light-duty truck fleet from 3751 lbs. LVW to 8500 lbs. GVW. This approach removes the need to distinguish work trucks from those designed for light-duty service based on some set of arguable criteria.

2. Proposed Exhaust Emission Standards. In this rulemaking staff is proposing new "LEV II" standards for light- and medium-duty vehicles that represent a significant strengthening of the preexisting LEV standards. First, as mentioned above, staff is proposing that light-duty trucks that fall into the new LDT2 truck category meet the same standards applicable to passenger cars. Second, staff is proposing a 0.05 g/mi NOx standard for light-duty LEVs and ULEVs. Third, staff is proposing that the full useful life for both passenger cars and light-duty trucks be increased from 100,000 miles to 120,000 miles. Fourth, staff is proposing the introduction of a new emission standard -- Super-Ultra-Low-Emission Vehicle or "SULEV" -- for passenger cars and light-duty trucks. Fifth, staff is proposing a reduction in the light-duty diesel particulate matter standards to 0.04 g/mi for TLEVs and to 0.01 g/mi for LEVs, ULEVs and SULEVs. Finally, staff is proposing an optional extension of the full useful life to150,000 miles while still meeting the same numerical 120,000 mile standards for which commensurate additional fleet average NMOG credit would be provided. Table II-4 below sets forth the proposed LEV II standards, a discussion of each aspect of the proposal follows.

Table II-4

Exhaust Mass Emission Standards for New 2004 and Subsequent Model TLEVs, LEVs, ULEVs, and SULEVs in the Passenger Car, Light-Duty Truck and Medium-Duty Vehicle Classes

Vehicle Type	Mileage for Compliance	Vehicle Emission Category	NMOG (g/mi)	Carbon Monoxide (g/mi)	Oxides of Nitrogen (g/mi)	Formaldehyde (mg/mi)	Diesel Particulate (g/mi)
All PCs; LDTs <8,500 lbs. GVW Vehicles in this category are tested at their loaded vehicle weight (curb weight plus 300 pounds)	50,000	TLEV	0.125	3.4	0.4	15	n/a
		LEV	0.075	3.4	0.05	15	n/a
		LEV(1)	0.075	3.4	0.07	15	n/a
		ULEV	0.040	1.7	0.05	8	n/a
	120,000	TLEV	0.156	4.2	0.6	18	0.04
		LEV	0.090	4.2	0.07	18	0.01
		LEV(1)	0.090	4.2	0.10	18	0.01
		ULEV	0.055	2.1	0.07	11	0.01
		SULEV	0.010	1.0	0.02	4	0.01
	150,000 (Optional)	TLEV	0.156	4.2	0.6	18	0.04
		TLEV(2)	0.125	4.2	0.5	18	0.04
		LEV	0.090	4.2	0.07	18	0.01
		LEV(1)	0.090	4.2	0.10	18	0.01
		ULEV	0.055	2.1	0.07	11	0.01
		SULEV	0.010	1.0	0.02	4	0.01

Vehicle Type	Mileage for Compliance	Vehicle Emission Category	NMOG (g/mi)	Carbon Monoxide (g/mi)	Oxides of Nitrogen (g/mi)	Formaldehyde (mg/mi)	Diesel Particulate (g/mi)
MDVs 8500 - 10,000 lbs. GVWR Vehicles in this category are tested at their adjusted loaded vehicle weight (curb weight plus ½ payload)	120,000	LEV	0.195	6.4	0.2	32	0.12
		ULEV	0.143	6.4	0.2	16	0.06
		SULEV	0.100	3.2	0.1	8	0.06
MDVs 10,001-14,000 lbs. GVWR Vehicles in this category are tested at their adjusted loaded vehicle weight (curb weight plus ½ payload)	120,000	LEV	0.230	7.3	0.4	40	0.12
		ULEV	0.167	7.3	0.4	21	0.06
		SULEV	0.117	3.7	0.2	10	0.06

(1) This optional LEV standard applies to up to 4% of a manufacturer's LDT2 fleet with a maximum base payload in excess of 2500 lbs. See section II-1 above for a discussion of this standard.

(2) This optional TLEV standard is applicable for 150,000 miles only (e.g., no 50K or 120K standard) and is not eligible for supplemental fleet average NMOG credit.

(a) **Proposed passenger car and light-duty truck standards.** Staff based the proposed lower LEV and ULEV standards on recent certification data that suggest light-duty trucks would be able to meet passenger car standards and that both passenger cars and light-duty trucks would be able to meet a 0.05 g/mi NOx standard. To confirm the feasibility of a 0.05 g/mi NOx standard, staff tested several late model vehicles. A discussion of the test results to date and technological feasibility of this proposal is contained in Section C.

Staff is proposing that the TLEV standard be kept at current levels and is also proposing addition of an optional 150,000 mile standard for TLEVs only. This is to provide for the sale of limited numbers of high fuel economy engines that currently exhibit relatively high NOx emissions, but also show promise of lower NOx emissions with additional development. Direct injection gasoline and diesel engines would most likely utilize this option. The declining fleet average requirement, however, would generally allow fewer vehicles to utilize this option in successive years, thereby spurring rapid progress in lowering NOx emissions. These engines exhibit low CO_2 emissions that would help reduce global warming. With this optional 150,000 mile standard, the emission warranty requirements for high cost parts would be increased from 7 years/70,000 miles to 8 years/100,000 miles and in-use testing requirements would be extended from 75,000 miles to 105,000 miles.

Finally, staff is proposing intermediate in-use compliance standards for the first two years of a LEV II vehicle's introduction in order to provide manufacturers with an "in-use compliance margin." Without some experience in meeting a new emission standard, the manufacturer assumes a certain amount of risk for unanticipated problems encountered in the field. With additional compliance margin for two years, the manufacturer has the ability to make small adjustments as needed if in the first two years of production the vehicles are too close to the standard. This saves the manufacturer cost and engineering staff time, while ensuring good emission performance.

(b) **Proposed extension of useful life to 120,000 miles**. Current data on vehicle miles traveled indicate that, on average, passenger cars are driven 122,000 miles, light-duty trucks 110,000 miles, and medium-duty vehicles 118,000 miles during their first ten years of life. In addition, emission control systems have become more robust over the last several years as manufacturers strive to meet 100,000 mile low-emission standards and on-board diagnostic requirements. This trend coupled with the convergence of mileage accumulation among these groups suggests adoption of an updated, uniform useful life criterion. Accordingly, staff is proposing that, for passenger cars and light-duty trucks, the full useful life be defined as 10 years and 120,000 miles, whichever occurs first. The time constraint for medium-duty vehicles would be aligned with that for passenger cars and light-duty trucks at 10 years and the mileage would remain the same at 120,000 miles.

(c) **Proposed SULEV Standard**. Staff is proposing creation of a new light-duty SULEV standard because recent technology developments indicate that gasoline, alternative fuel and hybrid electric vehicles could potentially reach emission levels significantly lower than the ULEV standard. The proposed emission values represent staff's estimate of levels that can be achieved cost effectively using the best available control technology, though not necessarily the most exotic, and using a variety of fuels including Phase 2 gasoline. In October, 1997, Honda announced that an advanced prototype gasoline Accord could achieve exhaust emission levels near zero. Honda has also presented data for a compressed natural gas vehicle with emission levels at one tenth of current 50,000 mile ULEV requirements over its full useful life. This vehicle is currently available for sale in California. In addition, many automobile manufacturers have indicated they are seriously considering plans to mass-produce hybrid electric vehicles (HEVs) and some manufacturers have unveiled their close-to-production prototypes. Toyota is currently selling an HEV equipped with both an electric motor and a 1.5 liter gasoline engine in Japan. Given the potential for some hybrid designs to utilize constant speed auxiliary power unit operation and quick lightoff catalytic converters, achieving emissions at the proposed SULEV emission level is possible. Thus, staff is proposing the creation of a new emission category, SULEV, for these very clean vehicles to which manufacturers could choose to certify.

The new SULEV category would have two separate useful life mileages -- 120,000 miles and an optional 150,000 mile useful life. Sales of vehicles certified to either SULEV standard would help manufacturers reduce their fleet average NMOG values (see paragraph (e) for a discussion of the 150,000 mile provision). In addition, staff is proposing that SULEVs that meet additional criteria would be eligible to receive a partial ZEV allowance (see section 4).

(d) **Proposed particulate matter standards**. The effects of particulate matter (PM) on health and visibility are of increasing concern, especially PM emissions 2.5 microns or less in size ($PM_{2.5}$). In response to these concerns, the U.S. EPA has promulgated new ambient air quality standards for $PM_{2.5}$. Since mobile source emissions are a major contributor to $PM_{2.5}$, staff is proposing a full useful life LEV, ULEV and SULEV PM standard of 0.010 g/mi for light-duty diesel vehicles and trucks less than 8,500 lbs. GVW. Diesel vehicles certifying to TLEV standards would be required to meet a full useful life PM standard of 0.04 g/mi. These standards are intended to provide an upper limit on PM emissions from vehicles used in large measure for personal transportation.

The data for light-duty diesel vehicles suggest that significantly more development is needed for these vehicles to meet a 0.010 g/mi PM standard. Recent certification data from two light-duty diesel vehicles show PM emissions of 0.05 g/mi and NOx emissions of 0.7 g/mi. Given the low NOx standards being proposed for LEV II and the difficulty associated with simultaneously achieving both low NOx and PM emissions from diesel engines, it is unclear whether diesel vehicles will be able to achieve a 0.01 g/mi LEV or ULEV PM standard in the foreseeable future. However, with further improvements to engine controls and the development of lean-NOx catalyst technology, light-duty diesels may be able to meet the 0.04 g/mi TLEV PM standard. Use of particulate traps also remains an option. Also, the federal government and domestic automakers in the Partnership for a New Generation of Vehicles (PNGV), which is developing an 80 mile per gallon mid-size car for 2004 using diesel technology, has established an 0.01 gram per mile PM emission goal.

(e) **Optional 150,000 Mile Certification.** The ARB's inventory shows that approximately 20 percent of all vehicle miles traveled are from vehicles that have accumulated between 100,000 and 150,000 miles. Emissions from these vehicles represent a significant portion of the emission inventory. In order to promote vehicles that are durable even after their defined useful life (120,000 miles), staff is proposing an optional 150,000 mile certification standard equal to the applicable 120,000 mile standard (this specific option would not be available to TLEVs that certify to the special 150,000 mile option as covered in section (a)). Manufacturers that certify to this optional standard would need to meet the following enhanced requirements:

(i) The vehicle would be certified to the applicable 120,000 mile standard at 150,000 miles;

(ii) The emission warranty requirements for high cost warranty parts would be increased from 7-years/70,000 miles to 8-years/100,000 miles; and

(iii) High mileage in-use compliance testing requirements would be extended from 75,000 miles to 105,000 miles.

For certifying to this optional standard, manufacturers would receive additional NMOG credits towards compliance with the fleet average requirements. Specifically, under this proposal, the vehicles certifying to the optional 150,000 mile standard will use an NMOG value that is 85% of the 50,000 mile certification standard for the purpose of calculating the fleet average requirement.

Table II-5
150,000 Mile Fleet Average NMOG Values

Model Year	Emission Category	NMOG Emission Standard Value	
		All PCs; LDT1s	LDT2s
2000 and subsequent model year vehicles certified to the optional 150,000 mile "LEV II" standards for PCs and LDTs	TLEVs	0.11	0.11
	LEVs	0.06	0.06
	ULEVs	0.03	0.03
	SULEVs	0.0085	0.0085

This value was calculated based on the following assumptions. Staff estimated the benefit attributable to vehicles that are certified to the optional standard to be approximately the difference between the applicable 120,000 mile standard and the OBD II malfunction indicator light threshold. Staff assumed that after a vehicle exceeds its 120,000 mile useful life, the on-board diagnostic system would be the primary means of alerting the driver if emissions exceed 1.5 times the 120,000 mile-standard and that for vehicles certifying to the optional 150K standard, it is expected the vehicle would still be at or below the 120,000 mile-standard even after exceeding 120,000 miles of operation in order to comply with the standards. Mathematically, the benefit of a vehicle that is certified to the optional standard relative to a vehicle that is not, is as follows:

NMOG benefit (in grams) = (OBD II threshold - 120,000 mile standard) x (30,000 miles)
= [(1.5 x 120,000 mile std.) - (120,000 mile std.)] x 30,000
= 0.5 x (120,000 mile std.) x 30,000

The above NMOG benefit that is accrued from extending compliance from 120,000 miles to 150,000 miles is then spread over the full useful life to determine the amount by which the 50,000 mile standard should be lowered to characterize a vehicle certified to the optional 150,000 mile standard as follows:

Adjustment to the 50,000 mile standard = NMOG benefit (in grams) ÷ 120,000 miles
= [0.5 x 120,000 mile std. x 30,000] ÷ 120,000
= (120,000 mile std.) ÷ 8

Using this approach, staff estimated the adjustment to the 50,000 mile standard for light-duty TLEVs, LEVs and ULEVs. In each case, the adjustment was greater than or equal to 0.15 times the 50,000 mile standard. Therefore, staff is proposing that the adjustment for all vehicles certifying to this optional standard be set at 0.15 times the 50,000 mile standard.

Consequently, vehicles certifying to the optional 150K standard would be counted as being certified to (in grams/mile):

= 50,000 mile std. - (0.15 x 50,000 mile std.)

= 0.85 x 50,000 mile standard

for the purpose of calculating the fleet average requirement. Choosing this option would result in a manufacturer achieving a lower NMOG fleet average, and thus provide an incentive to increase the durability of the vehicle.

(f) **NMOG credit for vehicles certified to the proposed zero-fuel evaporative emission standard**. Vehicles certified to the proposed zero-fuel evaporative emission standard would qualify to receive an NMOG credit (in g/mile) that could be applied towards demonstrating compliance with the NMOG tailpipe emission standard. The NMOG credit was determined relative to a baseline vehicle meeting the proposed reduced evaporative emission standard. Using the EMFAC7G model, the relative grams per test of fuel evaporative emission benefit was converted into a g/mi value. The NMOG credit for a vehicle meeting the true zero-fuel evaporative standard would be 0.006 grams/mile.

(g) **Proposed medium-duty vehicle emission standards**. Although the new LDT2 truck category would include the vast majority of light-duty trucks, there are some SUVs and trucks that would fall into the new medium-duty category (e.g., Ford Excursion and some Chevrolet Suburbans). In order to ensure about the same degree of stringency that is applied to light-duty trucks under 8,500 lbs. GVW, while still taking into account the potentially more rigorous duty cycle of vehicles in the medium-duty category, staff is proposing new standards that will be substantially equivalent in stringency to the light-truck standards but numerically higher. (See Table II-4 for a list of the proposed standards.) One of the reasons for the numerically higher standards is that light-duty trucks are tested with 300 lbs. added to the vehicle curb weight while medium-duty vehicles are tested with half their payload (usually about 1,000 to 1,500 lbs.) added to the vehicle curb weight. This adds stringency to the standard because the heavier test weight makes it more difficult for the vehicle to comply. Another factor to consider is that there are relatively few vehicles in this category (although the number of vehicles is increasing rapidly this year) but there are a wide variety of configurations. This adds cost to the vehicles because of the numerous calibrations that manufacturers must adjust to reconfigure each test group. Therefore, staff is proposing numerically higher emission standards that are almost equal in stringency to the standards for light-duty trucks but remain cost-effective. The emission standards being proposed are only applicable at 120,000 miles to harmonize with the standards being proposed by U.S. EPA. See Section C. below for a discussion of the expected technologies that would be used to meet these new standards.

(h) **Updates to the NMOG Test Procedures**. The purpose of the modifications being proposed to the NMOG Test Procedures is to update laboratory test procedures and suggested operating parameters to provide more accurate and reliable data. A complete description of the amendments is contained in Appendix H of this Staff Report.

(i) In addition to the above, staff is proposing several detailed technical amendments to the standards. A complete description of these amendments is described in the appendices. Some of the more pertinent proposed modifications include the following: Tier 1 standards will no longer apply after the 2003 model year for LDVs and MDVs; the 50°F multiplier for SULEVs would be 2.0 (the same as for LEVs and ULEVs); the SFTP standard for SULEVs will be the same as for LEVs and ULEVs; and the cold temperature carbon monoxide standard for SULEVs would also be 10.0 g/mi.

3. Proposed Phase-In Requirements.

(a) Passenger Cars and Light-Duty Trucks. One of the most important features of the current LEV Program is the ability of manufacturers to chose the standards to which vehicles are certified as long as the emissions of their entire product line meet a fleet average requirement. This provides flexibility to manufacturers because they can adapt their phase-in to better fit their product development schedules, as long as the fleet average is at or below the required levels. The current LEV I fleet average requirements decline through the 2003 model year after which they remain constant. Under LEV II, the fleet average requirement would continue to decline from 2004 through the 2010 model year. Although the vehicle emission standards for LDT1s and LDT2s are identical, the two categories are not combined into one fleet average requirement because the percentage ZEV requirement is based on the production volume of PCs and LDT1s. Table II-6 sets forth the proposed fleet average requirements for passenger cars/light-duty trucks (LDT1) and light-duty trucks (LDT2).

Table II-6

FLEET AVERAGE NMOG
EXHAUST MASS EMISSION REQUIREMENTS FOR
LIGHT-DUTY VEHICLE WEIGHT CLASSES
(50,000 mile Durability Vehicle Basis)

Model Year	Fleet Average NMOG (grams per mile)	
	All PCs; LDT1s	LDT2s
2004	0.053	0.085
2005	0.049	0.076
2006	0.046	0.062
2007	0.043	0.055
2008	0.040	0.050
2009	0.038	0.047
2010+	0.035	0.043

The fleet average requirement for trucks in the new LDT2 truck category is slightly higher than those for passenger cars in order to provide a longer phase-in period for ULEVs and SULEVs. This would give manufacturers more time to adapt their most capable passenger car emission control technology to trucks in the new category that must achieve greater emission reductions because their emission levels are currently much higher than passenger cars. In addition, the truck fleet average is higher because it does not include a ZEV requirement (the passenger car fleet average requirement includes zero-emission vehicles, which automatically lowers a manufacturer's fleet average because they are counted as zero in the fleet average equation.)

Although manufacturers choose their own implementation schedule, the following is a possible phase-in scenario that staff judged to be feasible in the 2004-2010 time frame (and was used to develop the fleet average values).

Table II-7
One Possible Percentage Implementation Schedule for PCs and LDT1s

Model Year	TLEV	LEV	ULEV	SULEV	ZEV
2004	2	48	35	5	10
2005	2	40	38	10	10
2006	2	35	41	12	10
2007	1	30	44	15	10
2008	1	25	44	20	10
2009	1	20	49	20	10
2010	1	15	49	25	10

Table II-8
One Possible Percentage Implementation Schedule for LDT2s

Model Year	TLEV	LEV	ULEV	SULEV	ZEV
2004	19	81	0	0	0
2005	16	63	21	0	0
2006	8	48	38	6	0
2007	2	43	50	5	0
2008	1	35	54	10	0
2009	1	25	64	10	0
2010	1	20	64	15	0

In order to provide the greatest flexibility possible, manufacturers would have the option of certifying a portion of their fleet to the current LEV standards as well as to the LEV II standards prior to the 2007 model year as long as they meet or exceed a 25/50/75/100% phase in over four years of the LEV II standards. Manufacturers would also be allowed to accrue debits for these first three years to allow them more flexibility in developing their product plans. By 2007, however, the current LEV standards would no longer apply and all deficits would need to be made up by the end of each model year.

(b) Medium-Duty Vehicles. The current regulations require that manufacturers must produce 60% of their medium-duty fleet as LEVs and 40% as ULEVs by the 2004 model year. Staff is proposing that the percent requirements be amended to require 40% LEVs and 60% ULEVs beginning in the 2004 model year. These percentages would apply to medium-duty vehicles certified to either the LEV I standards or the LEV II standards depending on a manufacturer's production schedule; however, Tier 1 MDVs could no longer be certified after the 2003 model year and the LEV I medium-duty LEVs and ULEVs could no longer be certified after the 2006 model year. In addition, a manufacturer must certify at least a portion of its fleet each year to the LEV II standards.

4. Partial ZEV Allowance Proposal to provide the flexibility to use multiple qualifying technologies to meet ZEV requirements.

(a) Background. When ARB adopted the original LEV program in 1990, the ZEV requirements were written to be technology neutral, that is, any technology could be used as long as it had zero vehicle emissions. However, battery-powered electric vehicles were considered the only technology available to meet the ZEV requirements in the near-term. In the eight years since the original program was adopted, a plethora of new, advanced technologies have been developed. Many of these technologies are capable of achieving extremely low levels of emissions on the order of the power plant emissions that occur from charging battery-powered electric vehicles, and some demonstrate other ZEV-like characteristics such as inherent durability and partial zero-emission range.

As a result of these new vehicle technologies, ARB staff is proposing additional flexibility in the ZEV program to broaden the scope of vehicles that could qualify for meeting some portion of the ZEV requirement. Manufacturers would decide which mix of vehicles to use to meet the 10% ZEV requirement with the exception that large-volume manufacturers would have to meet at least 40% of the requirement using true ZEVs. The applicable ZEV allowance for each vehicle type would be determined based on a set of criteria designed to identify and reward ZEV-like characteristics in a variety of advanced-technology vehicles. Revisions to the 2003 and subsequent model year 10% ZEV requirement will not, however, be considered in this rulemaking.

ZEVs are the "Gold Standard." Battery-powered electric vehicles and other ZEVs such as hydrogen fuel cell vehicles hold distinct air quality advantages over technologies that utilize a conventional fuel such as gasoline in a combustion engine. These advantages include 1) extremely low fuel-cycle emissions in California and 2) inherent emission durability. High volatility liquid fuels such as gasoline are responsible for significant fuel cycle emissions, i.e., emissions that occur upstream from the vehicle due to production, transportation, and vehicle fueling. Vehicles with combustion engines inevitably will exhibit increased emission levels as the vehicle ages. They are also subject to becoming gross polluters if critical emission control systems fail in-use. Although new vehicles have more durable emission control systems and on-board diagnostics systems that are effective in alerting owners to emission-related problems, owners may not respond to failure signals promptly. California's inspection and maintenance program will not capture vehicles that are operated without being registered and repair cost limits may permit continued operation of some high-emitters. For these reasons, staff considers vehicles that have no components with the potential to produce emissions, i.e. true ZEVs, to be the "gold standard" of even the cleanest, most advanced new technologies.

California Needs ZEVs To Meet Long-Term Air Quality Goals. The commercialization of ZEVs is critical to the long-term success of California's clean air program. Even with the full implementation of the proposed LEV II program, emissions from light-duty vehicles would still represent a significant portion of total emissions in the South Coast Air Basin. Achieving the new air quality standards for particulate matter, not to mention the state ozone standard, will require further reductions. Taking into account the anticipated growth in the number of light-duty vehicles and the number of miles they travel each day, it is clear that in order to achieve these goals we need to essentially eliminate emissions related to vehicle deterioration and fuel use from a significant portion of the light-duty vehicle fleet. ZEVs can accomplish this goal.

The ZEV Program has Resulted in Many Success Stories. The ZEV requirements have been instrumental in promoting battery and vehicle research and development. As a result, a wide variety of battery-powered electric vehicles are now available to fleets and the general public. No less important, the program has also been successful in spawning a large variety of extremely low-emission vehicle technologies, many of which may not have gained significant attention without the ARB's ZEV requirements. Many of these technologies have at least some qualities inherent to ZEVs, such as extremely low emissions and extended durability, partial all-electric range or the use of an inherently durable non-combustion engine. The ARB staff believes it is good public policy to encourage these advanced technologies.

Table II-9
Comparison of ZEVs with Advanced Technology Vehicles

Advanced Technologies with Extremely Low-Emission or Zero-Emission Capability	Qualities in Common with ZEVs
Gasoline SULEV	Emissions comparable to EV-related power plant emissions and extended durability
Compressed Natural Gas SULEV	same as above plus very low fuel-cycle emissions
HEV with significant all-electric range	partial zero-emission range
Methanol reformer fuel-cell vehicle[1]	extremely low emissions

Advanced Technologies with Extremely Low-Emission or Zero-Emission Capability	Qualities in Common with ZEVs
Direct methanol fuel-cell vehicle[1]	extremely low emissions
Stored hydrogen fuel-cell vehicle[1]	ZEV
Battery-powered electric vehicle	ZEV

[1]Due to their inherent efficiency of operation, fuel cell vehicles can also result in reduced emissions of carbon dioxide, a greenhouse gas.

Benefits of the Proposal. Staff believes this modified approach to counting vehicles toward the ZEV requirements would promote the continued development and commercialization of high-performance battery-powered electric and zero-emitting fuel cell vehicles while encouraging advanced technology vehicles with the potential for extremely low-emission performance. Technologies that best accomplish ARB's goal of achieving inherent durability and essentially zero vehicle and fuel-related emissions would receive the highest ZEV allowance. A manufacturer would be able to decide which mix of vehicles makes the most technological and economic sense based on its own strengths in each area. Further, under this proposal true ZEVs with at least 100 miles driving range would receive multiple ZEV credits to ensure steady market introduction in the early years when battery costs will be high. Staff believes this flexible approach would result in the commercialization of a broad range of new, advanced technologies, all of which would be valuable in meeting California's air quality goals. However, in order to ensure the continued development of zero-emission technologies, staff is proposing that a large-volume manufacturer be required to meet at least 40 percent of the ZEV requirement with true ZEVs.

(b) The Proposal. The process of calculating ZEV allowances for candidate vehicles consists of assigning basic "allowances" consisting of a baseline allowance, a zero-emission VMT allowance, and a low fuel-cycle emission allowance.

(1) Baseline ZEV allowance requirements. In order for a vehicle to receive any ZEV allowance, a vehicle would need to satisfy the requirements for receiving the "baseline ZEV allowance." To receive this allowance, the first requirement would be for the vehicle to at least meet the SULEV standard (emissions from vehicles in this category are close to emissions from powerplants associated with recharging electric vehicles) at 150,000 miles and also satisfy applicable second generation on-board diagnostics requirements (OBD II) and the zero-fuel evaporative emission requirements proposed in this rulemaking (see part III of this staff report). It is important to note that while the SULEV standard is a 120,000 mile requirement, vehicles that qualify for ZEV credit would need to meet the SULEV standard for 150,000 miles. The vehicle manufacturer would also need to provide a 150,000 mile emission warranty such that all malfunctions identified by the vehicle's OBD II system would be repaired under warranty for a period of 15-years or 150,000 miles, whichever occurs first. The ARB staff believes that these conditions are necessary to ensure that vehicles receiving credit for near zero emissions are able to maintain them throughout the life of the vehicle. Vehicles meeting the above requirements would receive a 0.2 baseline ZEV allowance.

(2) Zero-emission VMT allowance. An additional allowance is provided based on the potential for realizing zero-emission vehicle miles traveled (VMT) (e.g. capable of some all-electric operation traceable to energy from off-vehicle charging), up to a maximum of 0.6. On the other hand if a vehicle does not have any zero-emission VMT potential but is equipped with advanced ZEV componentry, then the vehicle may qualify to earn an additional 0.1 ZEV allowance.

(i) Allowance for vehicles with significant zero-emission VMT potential. Many clean technologies, including some fuel-cell vehicles and hybrid electric vehicles, have the potential for zero emissions associated with some portion of the VMT. Under this proposal, such vehicles would receive a zero-emission VMT allowance, proportional to the estimated zero-emission VMT potential as a percent of total VMT which is the zero-emission VMT factor. To receive this credit, a manufacturer would need to provide an estimate of the likely zero-emission VMT potential of their particular vehicle design based on actual in-use data, an engineering evaluation of the vehicle's operational strategy and any other relevant information to validate the estimate. Upon review and approval of the manufacturer's estimate, this would be used by the Executive Officer to further calculate a zero-emission VMT allowance based on the following equation:

zero-emission VMT allowance = 0.6 x zero-emission VMT factor

The methodology to calculate the zero-emission VMT factor is described below.

Zero-emission VMT factor. For vehicles with significant city all-electric range (AER) capability such as some hybrid electric vehicle designs and others, the zero-emission VMT potential is estimated according to the following equation:

zero-emission VMT factor =	0.0	For city AER < 20 miles
	(30 + (0.5 x city AER))/80	For 20<=city AER <=100 miles
	1.0	For city AER > 100 miles

This equation is based on a 1990 Department of Transportation report showing cumulative VMT as a function of trip length for the Pacific northwest region, which includes California. For vehicles with AER less than 20 miles, staff believes that there is a high likelihood that consumers may not utilize the zero-emission VMT potential. For example, it may be too much trouble for some consumers to "plug in" for very little zero-emission range. Consequently, they would not be eligible to receive a zero-emission VMT allowance.

Some manufacturers are developing parallel hybrid electric vehicle designs that deliver improved fuel economy but do not have any significant all-electric range. Under this proposal, such vehicles would not qualify for a zero-emission VMT allowance because without wall re-charging capability that provides significant all-electric range, such vehicles would not exhibit the lowest emission characteristics. Consequently, such vehicles would not receive any zero-emission

VMT allowance under this category, although they could receive some allowance under a provision explained in the next section.

In addition, vehicles eligible to receive credit under this category that are equipped with software and/or other strategies allowing maximum realization of zero-emission VMT potential of the vehicle by promoting off-vehicle charging may qualify for an additional allowance of 0.1. The Executive Officer shall determine whether or not to approve the additional credit based on a number of factors including whether the strategy is tamper-proof, effective, or other similar factors.

Some vehicles have potential for zero-emissions for one regulated pollutant (e.g., NOx) while having low-levels of emissions of other regulated compounds (e.g., NMOG). One such vehicle could be an on-board methanol reformer fuel-cell vehicle. This vehicle has virtually no NOx emissions since the operational temperature of the reformer is typically lower than the temperature required for NOx formation. Consequently, in order to credit such vehicles for zero-emission capability of a specific pollutant, staff is proposing that this vehicle receive a zero-emission VMT factor of 0.5.

(ii) Allowance for vehicles that do not have any zero-emission VMT potential but are equipped with advanced ZEV componentry. Vehicles that do not have significant zero-emission VMT potential but are equipped with advanced batteries, an electric power-train, and other advanced ZEV technologies can qualify for a zero-emission VMT allowance of 0.1, subject to approval by the Executive Officer. This additional allowance is provided in recognition of the vehicle's contribution to helping develop advanced batteries and powertrains that assist in commercializing ZEV technologies. One such vehicle would be the Toyota Prius, assuming it is designed to meet the SULEV standard. The Prius is equipped with a limited number of advanced nickel metal hydride (NiMH) batteries and an advanced electric drive-train.

(3) Low fuel-cycle emission allowance. Another characteristic that qualifies a vehicle to receive an additional ZEV allowance is the use of fuels with very low full fuel-cycle emissions to propel the vehicle. Under this proposal, a vehicle that uses fuel(s) with very low fuel-cycle emissions can receive a ZEV allowance up to a maximum of 0.2. The fuel-cycle emissions associated with a particular fuel are the total emissions associated with the production, marketing and distribution estimated as grams per unit of fuel. These emissions are then converted into grams/mile by applying the fuel-economy estimate of the vehicle. In order to receive this allowance, a manufacturer must demonstrate, using peer-reviewed studies or other relevant information, and subject to approval by the Executive Officer, that marginal NMOG emissions associated with the fuel used by the vehicle are lower than or equal to 0.010 grams per mile. It should be noted that for the purpose of providing this allowance, fuel-cycle NOx emissions are not considered in the determination since marginal NOx emissions for virtually all fuels are uniformly very low. Fuel-cycle emissions must be calculated based on near-term production methods and infrastructure assumptions. At this time, it appears that only gaseous fuels could very likely qualify for this allowance. Some liquid fuels, for example methanol, may also qualify with vehicle efficiency improvements and with the use of improved refueling evaporative controls.

If more than one fuel is used to propel a vehicle, then this ZEV allowance is awarded based on the percent of total vehicle miles traveled using fuel(s) with low fuel-cycle emissions. To illustrate, assume a hybrid electric vehicle with significant all-electric range uses off-vehicle charging electrical energy to propel the vehicle for 70 percent of the total VMT and another fossil fuel (e.g. gasoline) for the remaining 30 percent of the total VMT. In this case, only the off-vehicle electrical energy use meets the low fuel-cycle emission requirement. Consequently, the ZEV allowance awarded to this vehicle would be 70 percent of 0.2, which is equal to 0.14.

(c) Summary of the partial ZEV allowance. The partial ZEV allowance awarded to a specific vehicle, then, is the sum of the allowances earned by the vehicle including the baseline, zero-emission VMT and low fuel-cycle emissions. The following summarizes the allowance proposal:

Table II-10
Partial ZEV Allowance Proposal

Characteristic	Pre-requisite or optional requirement?	ZEV allowance
Baseline allowance - Meets SULEV at 150K & 150K emission warranty	Pre-requisite for vehicles to receive any allowance	0.2
Zero-emission VMT allowance [(1)(2)]	Optional - qualifies vehicle for additional allowance	(0.6 x zero-emission VMT factor)
Low fuel-cycle emission allowance	Optional - qualifies vehicle for additional allowance	up to 0.2
Partial ZEV allowance		**Sum of the above**

[(1)] Additional allowance of 0.1 would be given to vehicles that employ strategies to maximize off-vehicle charging under the zero-emission VMT allowance category, subject to the condition that allowance in this category not exceed the maximum allowed value of 0.6.

[(2)] Vehicles that do not qualify for any zero-emission VMT factor can receive an additional ZEV allowance of 0.1 if those vehicles are equipped with advanced ZEV componentry such as advanced batteries, electric powertrain and other non-emission technologies.

(d) Limits on partial ZEVs towards meeting the ZEV requirements.

Applicable to large-volume manufacturers. Staff proposes to require that 40% of the ZEV requirement be met by true ZEVs and vehicles that receive a ZEV allowance of 1.0. This would serve to ensure sufficient production volumes of advanced battery electric vehicles, stored hydrogen fuel-cell vehicles or other non-emission vehicles that do not deteriorate. Maintaining this production requirement can help ensure continued technical development and pilot production process optimization and afford some economies of scale to help make these true zero-emitting vehicles affordable and more competitive in the 2005 to 2010 time frame.

Applicable to small and intermediate volume manufacturers. Small and intermediate volume manufacturers have indicated that it would be cost-prohibitive for them to individually produce very low volume advanced technology true ZEVs in the foreseeable future, given the relatively small number of vehicles that would be required to meet 40% of the ZEV requirement. Consequently, in order to address this concern, ARB proposes that intermediate volume manufacturers be allowed to satisfy the 10% ZEV requirement using only partial ZEV allowances, if they choose to do so.

(e) An additional incentive for ZEVs. In order to encourage manufacturers to introduce zero-emission vehicles early and with relatively long driving range, which is one of the most important characteristics to consumers, staff is proposing to provide an additional incentive in the form of a ZEV multiplier. Only true ZEVs or vehicles that receive a ZEV allowance of 1.0 would be eligible to use these multiple credits. The following table details the number of ZEV credits as a function of range and model-year.

Table II-11
Multiple ZEV Credits

All-electric range, miles	MY 1999-2000	MY 2001 -2002	MY 2003-2005	MY 2006-2007
100-175	6-10	4-6	2-4	1-2

Note: Values for ranges in between 100 and 175 would be determined by linear interpolation between the values shown in the above schedule.

ZEVs that have a refueling time of less than 10 minutes (e.g. a stored hydrogen fuel cell vehicle) and a minimum driving range of 100 miles per refueling would be counted as having unlimited all-electric range and, consequently, would qualify to receive the maximum allowable ZEV credit for that model-year.

(f) This proposal allows the flexibility to use more than one qualifying technology to meet the ZEV requirements. Under this proposal, qualifying technologies receive an allowance ranging from 0.2 ZEV credit to multiple ZEV credits depending on their emission characteristics, use of advanced technologies to make vehicles that are more acceptable to consumers and other factors. Staff believes this proposal would provide manufacturers the flexibility to produce vehicles qualifying for ZEV credit that they envision would be most successful in the market-place and would best meet consumer expectations.

Overall, this proposal should allow considerable flexibility to manufacturers, incentivize new near-term zero-emission technologies, and maintain the true ZEV development efforts -- eventually yielding more near zero emission reduction options than might otherwise be achieved.

(g) Examples of the application of the proposal

Table II-12
Examples of Partial ZEV Allowance Calculation

Technology/Manufacturer	Baseline allowance	Zero-emission VMT allowance	Low fuel-cycle allowance	**Partial ZEV allowance [3]**
Gasoline SULEV	0.2	0.0	0	**0.2**
Hybrid gasoline SULEV with no AER, equipped with adv. batteries, electric powertrain	0.2	0.1	0	**0.3**
CNG SULEV	0.2	0.0	0.2	**0.4**
Gasoline Hybrid SULEV w/ 20-mile AER, off-veh. recharging	0.2	0.3	0.1	**0.6**
On-board methanol reform. Fuel Cell (FC) vehicle	0.2	0.3[1]	0.2[2]	**0.7**
Hybrid SULEV with NIMH bat. (60 whr/kg) and 100-mile range.	0.2	0.6	0.2	**1.0**
On-board hydrogen FC vehicle w/ off-board partial oxidation reforming of hydrogen using fuel with low fuel-cycle emiss.	0.2	0.6	0.2	**1.0**

1) Assumes on-board methanol reformer produces virtually no NOx emissions
2) Assumes methanol has very low fuel-cycle emissions
3) Partial ZEV allowance= Baseline allowance + Zero-emission VMT allowance + Low fuel-cycle allowance

5. Proposed Amendments to Hybrid Electric Vehicle (HEV) Test Procedures.

(a) HEV technology has progressed rapidly in recent years. When ARB first adopted HEV test procedures in 1993, HEV technology was mostly in the concept stage of development. As such, the ARB procedures were limited in scope in terms of testing various HEV designs due to the lack of available information. Today, as some automobile manufacturers approach full scale HEV production, the current data available on HEV technology requires the ARB to update the HEV test procedures

HEV technology combines a wide variety of energy storage devices (e.g., batteries, ultracapacitors and flywheels) with an equally diverse array of auxiliary power units (e.g., internal combustion engine, fuel cells, gas turbines or sterling engine) so that the operating strategy for managing vehicle operation can be very complex. However, the result is a vehicle that is capable of very low emissions and higher fuel economy than its conventional gasoline or diesel counterparts. HEVs are one of the more promising technologies expected to meet the proposed SULEV emission standards.

A typical HEV combines a battery pack and an electric motor(s) with an auxiliary power unit (APU) that generates mechanical energy either to drive the wheels directly or to provide electricity for the battery pack and/or motor(s). There are basically two pathways for the energy to travel from the APU -- in series or parallel. With a series HEV, the APU supplies electricity to the battery pack and/or to the electric motor(s) that in turn drives the wheels. The parallel HEV has two independent propulsion systems where the wheels are either driven by the APU mechanically or by the motor(s) when electricity is supplied by the battery pack. Although the series and parallel classifications provide a general description of HEV operation, this simplified view is not adequate to describe the more sophisticated HEV designs that direct APU energy to the wheels, battery pack, and motor(s) in varying degrees.

Merging electric vehicle technology with conventional automobiles allows an HEV to operate as an electric vehicle at times while providing the driving range of a conventional vehicle. An HEV can shut off the APU during certain driving situations such as being stopped at a traffic signal in order to reduce emissions and conserve fuel. Further energy savings can be gained through regenerative braking that can recover energy while decelerating an HEV by using the electric motor(s) to convert the kinetic energy of vehicle motion into electric energy for battery storage. To maximize emission benefits, HEVs can be designed to allow battery charging from an off-vehicle source to provide all-electric operation. During all-electric operation, the battery pack, charged from an electric wall outlet, supplies all the energy to drive the HEV until the battery state-of-charge is reduced to a level that activates the APU. Most manufacturers, however, are not designing HEVs with significant all-electric range because of the added weight and cost of the battery pack. Indeed, a large battery pack is not necessary for HEVs and most tend to have smaller high power battery packs.

The task of evaluating and testing HEVs requires test procedures to be comprehensive and sufficiently flexible to address a wide variety of HEV technologies, yet specific enough to generate meaningful data. For the proposed HEV test procedures, staff focused on developing provisions to allow conventional driving cycles to be used for HEV testing, require normal hybrid operation during testing, and minimize testing without compromising data. By using standard driving cycles for HEV testing, conventional vehicle emission standards would be applied for HEV certification. Efforts were made to avoid artificial test conditions by operating the HEV within its design parameters. An example of an undesirable test condition would be to force the APU to operate during a driving situation when the APU would normally be shutoff. Finally, the amount of testing that may be done on an HEV to test all possible modes of operation could become excessive. Therefore, staff endeavored to measure emissions based on representative HEV operation over a given test cycle.

The staff proposal provides modifications to standard vehicle certification tests. Specifically, the Federal Test Procedure (FTP), the Highway Fuel Economy Test for measuring oxides of nitrogen emissions, and the Supplemental Federal Test Procedure (SFTP) are being modified to accommodate the diverse HEV operating strategies currently being developed by industry. Modifications to these certification tests involve establishing protocols for vehicle preconditioning and setting initial HEV battery state-of-charge for emission testing, and establishing criteria for determining valid emission tests.

While test procedures were being developed, three HEVs from Mitsubishi were available for evaluation. One of these HEVs was equipped with a gasoline fueled APU and lead-acid batteries while the other two were equipped with a compressed natural gas APU and lithium-ion batteries.

(b) Coordinating with the Society of Automotive Engineers (SAE) and U.S. EPA. Staff has been meeting regularly with the SAE for information sharing and technical input. The SAE committee developing hybrid test procedures consists of engineers from the automobile industry and an environmental vehicle specialty company. This committee was formed several years ago to establish a standard HEV protocol known as Recommended Practice J1711 that measures both emissions and fuel economy. Other participants in this regular meeting include staff from the National Renewable Energy Laboratory who lend their expertise in conducting emission and fuel economy test modeling to evaluate test procedures. More recently staff from the U.S. EPA have joined in the discussions providing a perspective from the federal level. SAE has nearly completed J1711 and plans to send out a draft version of their procedures for review in September, 1998.

The proposed ARB procedures share some of the requirements with J1711. For example, a type of HEV that is capable of operating without wall charging is classified as a charge sustaining HEV. As the classification implies, this HEV type sustains the battery pack charge indefinitely as long as the fuel supply for the APU is maintained. The J1711 and ARB common test protocol would require that the HEV battery pack end the emission test with as much energy content as when the emission test began in order to be an acceptable test. The objective is to neither charge nor deplete the battery by the end of the test. This is done to reflect the fact that in real world driving, the battery pack would be equally charged and discharged on average and result in no net change in battery pack energy level.

Some of the differences between J1711 and the ARB procedures are primarily driven by the issue of fuel economy measurement. The ARB does not require fuel economy measurement for certification so that the ARB procedures focus on measuring emissions produced by the APU's highest emitting normal operating mode. On the other hand, J1711 includes fuel economy measurement as well as emission testing. To this end, J1711 requires that all driving modes available to an HEV operator be tested and the results equally weighted.

The ARB procedures as well as J1711 rely on accurately measuring battery state-of-charge (SOC) to determine valid emission testing. SOC, expressed in percent, represents the amount of electrical energy available relative to the total energy capacity of the battery. To determine battery SOC, battery voltage and current flow into and out of the battery must be measured as a function of time. The accuracy of determining SOC may be difficult since transient vehicle operation presents challenges in measuring the required electrical parameters. Although the ARB procedures rely on setting the initial SOC accurately for an emission test, staff believes that in the controlled environment of a test facility, this requirement is not difficult to achieve. Furthermore, once the initial SOC is set, the procedures would require that the net energy flow experienced by the battery be determined and not the actual SOC. The test criterion for a valid charge-sustaining HEV test would require that the battery experience no net change in battery energy within a tolerance at the end of the test, as discussed previously.

The U.S. EPA has recently begun investigating methods to test HEVs. Preliminary discussions with EPA indicate that they are inclined to allow manufacturers to provide their own test procedures for EPA approval. Although ARB has a provision for manufacturers to request alternative HEV test procedures, ARB is proposing revisions to the current HEV procedures to better reflect current hybrid technology. Staff intends to continue updating the test procedures as new information has become available.

6. Proposed Amendments to Zero-Emission Vehicle Test Procedures. Staff is proposing some modifications to the certification and testing requirements for ZEVs primarily to incorporate suggestions to staff by industry regarding the test procedures. The proposed modifications include the adoption of a ULEV emission standard for the fuel fired heater when operating at ambient temperatures, the requirement to use a single roll electric dynamometer for more representative test results, specifications for a battery break-in period to ensure uniform testing and amendments to the driving schedules for the determination of all-electric range, and finally an ARB-generated requirement to submit battery DC energy data during charge and discharge events.

Amendments to the all-electric range test are aimed at facilitating electric vehicle (EV) testing. The changes being made would reduce test time while continuing to provide accurate results. Changes to the certification requirements for fuel-fired heaters would include a requirement that the heater meet ULEV emission levels at FTP test temperatures of 68°F to 86°F rather than meet SULEV emission levels tested at 40°F. Although the fuel-fired heater is not expected to operate above 40°F, manufacturers expressed concern that testing at this low temperature would be costly and time consuming. Since it is expected that the emission impact of the fuel fired heaters will be minimal due to operation limited to cold weather conditions when the potential for ozone formation is low, staff is proposing that the heater be tested at maximum output between 68°F and 86°F at a level not to exceed the ULEV standard, which should still be reasonably protective of air quality under heater operating conditions and would not require additional cold test facilities.

Manufacturers certifying EVs would be required to submit test data on vehicle performance and energy consumption that includes information on city and highway driving range, AC wallplug recharge energy use, and battery pack energy capacity measurements. Measurement of AC wallplug energy in AC kiloWatt-hours (AC kWhrs), combined with EV driving range test results, provides an AC energy-per-mile figure of AC Watthours per mile (AC Whr/mi). This information is important and is used by ARB to assess the air quality benefits of

EVs based on powerplant emissions, as well as monitor technical progress in EV and battery development, and promote the use of efficient EV technologies.

Although current certification of EVs only requires manufacturers to submit AC wallplug energy use data during overnight charging, manufacturers are currently encouraged, but not required, to also submit DC battery output energy data during battery discharge (city/highway driving) and DC input energy data during overnight battery recharging. The new proposed certification requirements would include submittal of DC energy input and output at the EV battery pack. While AC energy can be directly used to determine ZEV emission levels, DC energy data would allow ARB to better understand and evaluate ZEV component performance and battery deterioration characteristics and the excess energy consumption that would result. Excessive battery, drivetrain or charger deterioration could result in significant AC energy usage that could lead to higher power plant emissions. Including the DC energy data in the certification application would provide a reliable, complete database each year that could be accessed when studying deterioration characteristics of in-use EVs years later. Because manufacturers are already providing this information for HEVs, staff does not believe requiring similar information for EV certification results in a significant hardship. Given the benefits that DC energy data offer to evaluating EVs in-use, it is important that ARB receive this information consistently each year.

7. Proposed Amendments to California Smog Index Label. Smog indices were adopted for light-duty vehicles in 1995 to provide consumers with an indication of the relative contribution of new light-duty vehicles to smog formation based on exhaust NMOG, NOx and evaporative HC emissions from each vehicle. The smog index is calculated as follows:

$$\text{SMOG INDEX} = \frac{\underset{\text{(new vehicle)}}{\text{exhaust NMOG (g/mi) + exhaust NOx (g/mi) + evaporative HC (g/mi)}}}{\underset{\text{(baseline vehicle)}}{\text{exhaust NMOG (g/mi) + exhaust NOx (g/mi) + evaporative HC (g/mi)}}}$$

Beginning with the 1998 model-year, smog indices are displayed to the vehicle purchaser on a smog index label affixed to the window of new cars and light-duty trucks, allowing vehicle purchasers to more easily identify low-emitting passenger cars and light-duty trucks.

Staff is proposing to update the smog indices for 2000 and subsequent model-year vehicles, incorporating new information and the changes to the LEV regulations that are currently being proposed for 2004 and subsequent model-year vehicles. Staff is also proposing to update the graphics and content of the smog index label shown in the "California Motor Vehicle Emission Control and Smog Index Label Specifications" ("Label Specifications") to increase consumer awareness and understanding of the label, and to add language clarifying the requirements of the new label format. Finally, staff is proposing the addition of a "fleet average smog index" to the label to provide the consumer with a comparison of a particular vehicle/model to the entire vehicle fleet. A copy of the proposed Smog Index label is attached to this report. A detailed description of the proposed updates to the 2000 and subsequent model-year smog index calculations and smog index label are presented in Appendix G.

(a) Summary of the Proposed Smog Indices and Fleet Average Smog Indices.

(1) The following smog indices would apply to 2000 through 2003 model-year passenger cars and light-duty trucks 0- 5750 lbs. LVW:

Table II-13
2000 - 2003 Model-Year Smog Indices

	2.0g/ diurnal + hot soak test, 0.05 g/mi - running loss test, at 100,000 miles	**Evap. Exempt**	**Diesel Vehicle - Evap. Exempt**
LEV I			
Passenger Car/Light-Duty Truck 1 (0-3750 lbs. LVW)			
Tier 1	1.00	0.90	1.82
TLEV	0.83	0.73	0.73
LEV	0.48	0.38	0.38
ULEV	0.43	0.33	0.33
ZEV	n/a	0.00	n/a
Light-Duty Truck 2 (3751-5750 lbs. LVW)			
Tier 1	1.51	1.42	2.64
TLEV	1.29	1.19	1.19
LEV	0.79	0.69	0.69
ULEV	0.72	0.63	0.63
ZEV	n/a	n/a	n/a

(2) The following smog indices would apply to 2004 and subsequent model-year passenger cars and light-duty trucks 0-8500 lbs. GVW:

Table II-14
2004 and subsequent Model-Year Smog Indices

	Enhanced Evap. 2.0g/ diurnal + hot soak test, 0.05 g/mi - running loss test, at 100,000 miles	PCs and LDTs 0.5 g/ diurnal + hot soak test, 0.05 g/mi - running loss test, at 150,000 miles	LDTs < 6,000 lbs. GVW 0.65 g/ diurnal + hot soak test, 0.05 g/mi - running loss test, at 150,000 miles	LDTs 6,001-8,500 lbs. GVW 0.90 g/ diurnal + hot soak test, 0.05 g/mi - running loss test, at 150,000 miles	Evap. Exempt
LEV I					
Passenger Cars and Light-Duty Trucks (0-3750 lbs. LVW)					
TLEV	1.00	0.91	0.92	0.94	0.88
LEV	0.58	0.49	0.50	0.52	0.46
ULEV	0.52	0.43	0.44	0.46	0.40
ZEV	n/a	n/a	n/a	n/a	0.00
Light-Duty Truck s (3751-5750 lbs. LVW)					
TLEV	1.56	1.47	1.48	1.50	1.45
LEV	0.96	0.87	0.88	0.89	0.84
ULEV	0.87	0.79	0.79	0.81	0.76
ZEV	n/a	n/a	n/a	n/a	0.00
LEV II					
Passenger Cars; Light-Duty Trucks (0-3750 lbs. LVW); Light-Duty Trucks (3751 lbs. LVW - 8500 lbs. GVWR)					
TLEV	1.00	0.91	0.92	0.94	0.88
LEV	0.33	0.24	0.25	0.26	0.21
ULEV	0.27	0.18	0.19	0.20	0.15
SULEV	0.17	0.08	0.09	0.10	0.05
ZEV	n/a	n/a	n/a	n/a	0.00

(3) The following fleet average smog indices would apply to 2000 through 2003 model-year passenger cars and light-duty trucks 0-5750 lbs. LVW and 2004 and subsequent model-year passenger cars and light-duty trucks 0-8500 lbs. GVW:

Table II-15
2000 and subsequent Model-Year Fleet Average Smog Indices

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010 and subsequent
0.54	0.53	0.52	0.50	0.47	0.36	0.27	0.19	0.18	0.18	0.17

8. Non-Methane Organic Gas Credits for Vehicles Utilizing Ozone Reduction Technologies.

(a) Background. In March 1995, Engelhard Corporation, a major supplier of catalysts to the automobile manufacturers, announced the development of a catalytic coating (PremAir™) effective in reducing ambient ozone that could be applied to vehicle radiators. Subsequently, Engelhard approached the ARB and requested consideration of NMOG credits for vehicles using this technology. In addition, several vehicle manufacturers have expressed an interest in obtaining NMOG credits by equipping their vehicle radiators with this catalyst coating. Accordingly, staff has identified several issues relevant to the analysis of the air quality benefits of this technology. The relevant issues and a framework to provide the appropriate NMOG credits to this technology are outlined below. Other direct ozone reducing technologies may be developed in the future that may also qualify for NMOG credits. Staff proposes that NMOG credits allotted to this technology be applied to manufacturers' vehicle emissions when certifying to the applicable emission standards.

(b) Air Quality Benefits of Ozone Reducing Technologies. The unique nature of this technology presents a significant challenge to quantifying the air quality benefits attributable to its use on motor vehicles. Two analysis methods have been suggested. One method is use of an Airshed Model (AM), a three dimensional photochemical air quality grid model that predicts ozone concentrations using time and space varying emissions, meteorology, photochemistry and other parameters. Onroad emission data for input to the AM can be generated by models such as DTIM2, which utilizes vehicle activity estimates from regional transportation models and emission factors from either MOBILE5a or EMFAC7F. Inputs to DTIM2 include hourly estimates of vehicle speed, hourly ambient temperatures, and mix of vehicle types. The AM can then be modified to accept the volume of air swept by the vehicle fleet which, when combined with a negative source term incorporating an ozone scavenging efficiency factor and cell volume, calculates the hourly removal rate for ozone per cell. Air quality benefits for this technology calculated by the AM would be updated as improved versions of the AM and models used to generate input data are developed.

The second method, a federal test procedure (FTP) mass based approach, calculates the ozone reduction from a vehicle equipped with the radiator catalyst coating over the FTP (the FTP is the test procedure used to determine vehicle emission compliance with tailpipe standards). The g/mi ozone reduced by the catalyst can then be converted to tailpipe FTP NMOG g/mi using the specific reactivity of a low-emission vehicle for phase 2 gasoline. However, one vehicle manufacturer has noted that grams of ozone reduced per mile traveled by PremAir™ depends on the local concentration of ozone, a factor not addressed by this method. Accordingly, staff is proposing that the AM method be used to determine equivalent NMOG benefits for this technology.

Ozone Indicator Used to Calculate Ozone Reducing Technology Benefits. Using the Urban Airshed Model (UAM), Systems Applications International (SAI) has compared the ozone reductions from treated radiators for the South Coast Air Basin (SCAB) fleet against the ozone reductions achieved by removing a select portion of the inventory for volatile organic compounds. For calculation purposes, SAI assumed all vehicles in the SCAB were treated with this catalyst coating and used a single radiator size for the vehicle fleet. SAI then calculated the per vehicle benefits on a high ozone episode day for a variety of indicators including a reduction in the 1 hour peak ozone, a reduction in the SCAB 8 hour ozone peak, and the reduction in population exposure to ozone. The estimated benefits ranged from an equivalent tailpipe VOC reduction on the order of 0.01 g/mi for the change in the 1 hour peak ozone to a maximum on the order of 0.02 g/mi for reductions in population ozone exposure.

It has been suggested that NMOG credits be derived from the benefits calculated from the reductions in population exposure to ozone. As noted above, this would result in a maximum value for NMOG credits for this technology. However, California is required to meet a federal peak ozone standard. Therefore, it seems logical that the benefits for this technology be calculated for reductions in the 1 hour peak ozone. Furthermore, the AM model runs should include the 2010 inventory to assure that the ozone attainment plan would not be compromised.

Titration of Ozone by Vehicle Nitric Oxide (NO) Emissions. Vehicle emissions of NO are readily reactive with ozone thereby reducing the amount of ambient ozone available for treatment by coated radiators. A 1995 report outlining the results of a test program in the Cincinnati area confirms this scavenging effect, demonstrating on average a 40% reduction in roadway ozone concentrations compared to fixed site measurements. SAI has suggested that the scavenging effect of vehicle NO is limited by a number of factors and in all cases may be no higher than 30 ppb. The resolution of this issue is non trivial and may not be fully resolved without a lengthy test program. Therefore, until more definitive data are available, staff proposes that the more conservative estimate from the Cincinnati study (40% reduction of ambient ozone concentration) be used to adjust the ambient ozone concentrations used by the AM to calculate NMOG credits.

(c) Other Issues Affecting Allocation of Vehicle Ozone Benefits. While the AM is being proposed as an appropriate mechanism to determine the quantify the air quality benefits of this technology, several factors unique to each vehicle model influence the amount of ozone reduced per vehicle mile traveled. Therefore, manufacturers will need to submit data specific to each vehicle model for which it seeks NMOG credits.

Airflow. The volume of ambient air processed by the direct ozone reduction technology is another parameter critical to assessing the air quality benefits of this technology. Manufacturers are generally designing their vehicles to optimize vehicle aerodynamics in order to achieve fuel economy improvements. Consequently, on many vehicles, manufacturers are reducing the volume of air flowing through the radiator to a level sufficient for cooling purposes only. In addition, the volume of air impacted by the direct ozone reduction technology may be unique to each vehicle model depending on vehicle design. Accordingly, the airflow through the direct ozone reduction technology for each vehicle model must be quantified in order to adjust the benefit derived from the AM to determine the applicable NMOG credit.

Durability. The affects of time, road grime, and weather on the direct ozone reduction technology is unknown at this time. Although some durability tests have been conducted on the PremAirTM technology, more data are needed to quantify deterioration of the ozone reducing efficiency in-use. Therefore, when certifying vehicles equipped with direct ozone reduction technologies, the manufacturer should submit data quantifying deterioration of the ozone reducing efficiency over the full useful life of the vehicle. This deterioration factor would be used to adjust the benefit derived from the AM in determining the applicable NMOG credit.

OnBoard Diagnostics (OBD). Under this proposal direct ozone reducing technologies would receive NMOG credits to offset tailpipe emissions which are subject to OBD requirements. The OBD regulation requires monitoring of all emission control components to assure the effectiveness of the LEV program in-use. Furthermore, while under this proposal manufacturers would be required to replace the direct ozone reduction technology under warranty, absent OBD, for failures occurring beyond the warranty period there would be no assurance that the technology would be repaired. Accordingly, staff proposes that the performance of this technology be monitored.

Maintenance and Warranty. For vehicles receiving an NMOG emission credit for direct ozone reduction technologies, the manufacturer would be required to warrant replacement of the direct ozone reduction device as required for other high price emission control components, for 7 years or 70,000 miles, whichever first occurs. Direct ozone reduction technologies on vehicles certifying to the 150,000 mile option available in LEV II should be warranted for eight years or 100,000 miles, whichever first occurs.

(d) NMOG Credit Proposal. Staff is proposing that an NMOG credit be allotted to vehicles equipped with this technology that would be used to adjust vehicle tailpipe emissions when certifying to emission standards. Accordingly, for vehicles equipped with this technology, manufacturers would subtract the applicable NMOG credit from vehicle emissions when determining compliance to the applicable emission standard. Outlined below is the proposed method to determine NMOG credits for this technology.

NMOG Credits Calculated Using the AM. Using the AM to determine the air quality benefits for the direct ozone reduction technology, the manufacturer would submit the following data to receive NMOG credits for vehicles equipped with this technology.

1) A complete description of the parameters and assumptions used in the AM to calculate the air quality benefits. The description must include justifications for the parameter values and assumptions used in the AM. These parameters would include vehicle radiator size, ozone reducing efficiency of the device at speeds encountered in the model, percent ambient ozone suppression by vehicle NO emissions, airflow rate through the device at the speeds encountered in the AM, and any other parameters germane to the calculation of the air quality benefits.

2) The airflow through the direct ozone reduction technology at the speeds encountered in the AM for the vehicle model seeking NMOG credits.

3) Data demonstrating the average efficiency of the direct ozone reduction technology over the speeds encountered in the AM for the vehicle model seeking NMOG credits.

4) Data quantifying deterioration of the efficiency of the direct ozone reduction technology over the full useful life of the vehicle. The data must include the effects of time, mileage, and seasonal changes on the technology and simulate exposure of the technology to typical in-use conditions.

5) A description of the OBD system proposed for this technology. The description should include the methodology used to determine efficiency of the direct ozone reduction technology and the criteria used to illuminate the MIL.

For each vehicle model, the vehicle radiator size, the demonstrated efficiency of the direct ozone reduction technology, and the airflow rate through the device would be used to adjust the NMOG credit derived from the AM for each vehicle model.

C. TECHNOLOGICAL FEASIBILITY OF PROPOSED STANDARDS

Since adoption of the Low-Emission Vehicle regulations in 1990, emission control technologies have continued to evolve rapidly. In general, the emission control technologies on today’s low-emission vehicles are less complex and involve less new hardware than the staff’s initial projections in 1990. This is because both emission performance and durability of some familiar emission controls have significantly improved. In the early years of the LEV program implementation, virtually all low-emission vehicles were certified to the less stringent TLEV standard but as technologies improved and the fleet average decreased, the number of vehicles certified to the LEV and ULEV standards has increased accordingly.

In the 1998 model year, TLEVs comprise 43% of the new light-duty vehicles; LEVs make up 26% of new vehicles, and gasoline-powered ULEVs are now in the marketplace with the introduction of the ULEV Honda Accord. The number of LEVs and ULEVs will continue to increase in future model years as the fleet average decreases while TLEVs will commensurately decrease in numbers. In meeting the stringent LEV and ULEV standards, new vehicles have not generally required the use of new, sophisticated emission controls as some had predicted. Instead, refinements of Tier I technologies that have been utilized for years are being employed. For example, the ULEV Honda Accord utilizes more sophisticated fuel control so that it can reduce hardware and complexity in other areas (e.g., only one underfloor catalyst is used; no close-coupled catalyst is needed).

In December 1996, ARB staff provided its most recent update on the status of implementation of the LEV I program. At that public meeting, staff concluded that the technologies needed to comply with the current Low-Emission Vehicle program (with the most emphasis on meeting the more stringent ULEV emission category) were available and being utilized on many current vehicles. This conclusion was based on analyzing the emission controls on TLEVs and LEVs, and information available on ULEVs at that time. Since that last program update, staff's assessment has not changed significantly; in fact, the current technology projection for ULEVs is even simpler and less complex than the last update.

Many of the basic emission control approaches projected to be used on ULEVs have been utilized on new vehicles for several years to meet less stringent emission standards. The most significant improvements have been to traditional catalysts, which now warm up very rapidly and are substantially more durable than past technology, and to fuel control, which is much more precise and accurate than previous systems. In the following section, the technologies projected by ARB staff to be utilized on ULEV vehicles will be presented. This technology projection is based on the "matured" technology expected of 2003 model year ULEVs. Many of these technologies were described in the December 1996 status of implementation update and are presented here again for information purposes. A basic tenet of the original LEV program is that the vehicle technology and fuels must be linked to achieve the greatest emission reductions. This remains the case, as there is a growing body of evidence demonstrating that low sulfur content and other modifications to both gasoline and diesel, such as have been adopted in California significantly improve the emission performance of low-emission vehicles. Manufacturers believe that further reductions in fuel sulfur would assist in meeting the proposed LEV II emission standards. This is especially true for diesels, where it appears that sulfur, even at current levels, poisons the catalysts and deteriorates exhaust gas recirculation systems that are both needed to lower NOx emissions.

1. LEV I Emission Control Technology. While reducing emission levels of current vehicles is being achieved through various means, there are four basic aspects of current emission control systems that vehicle manufacturers have been improving to achieve low-emission levels. These are more precise fuel control, better fuel atomization and delivery, improved catalytic converter performance and reduced base engine-out emission levels. The emission control technologies being used for low-emission vehicles to comply with the LEV I program are listed in Table II-16. It is important to note that low-emission vehicles do not require the use of all of the technologies. The list just provides the range of current low-emission technologies. The choices and combinations of low-emission technologies ultimately utilized by vehicle manufacturers are dependent on the engine-out emission levels of the vehicle, the effectiveness of the prior emission control system, and individual manufacturer preferences.

Table II-16

Low-Emission Vehicle Technologies	
Dual Oxygen Sensors	Close-Coupled Catalysts
Universal Exhaust Gas Oxygen Sensors	Engine Calibration Techniques
Individual Cylinder Air-Fuel Control	Leak-Free Exhaust Systems
Adaptive Fuel Control Systems	Increased Catalyst Loading
Electronic Throttle Control Systems	Improved High-Temperature Washcoats
Abbreviated Engine Start Systems	Electrically-Heated Catalysts
Reduced Combustion Chamber Crevice Volumes	Electric Air Injection
Sequential Multi-Point Fuel Injection	Full Electronic Exhaust Gas Recirculation
Air-Assisted Fuel Injectors	Hydrocarbon Adsorber Systems
Heated Fuel Injectors	Engine Designs to Reduce Oil Consumption
Improved Induction Systems	Heat-Optimized Exhaust Pipes

(a) Technologies for Improving Fuel Control

Dual Oxygen Sensors. Maintaining the air-fuel ratio (A/F) at stoichiometric (where the amount of air is just sufficient to completely combust all of the fuel) is an important factor in achieving lowest engine emissions in three-way catalyst systems. In order for the emission control system to operate most efficiently, the A/F must remain within a very narrow range (less than 1% deviation) around stoichiometric. Modern vehicles have traditionally performed fuel control with a single oxygen sensor (O2S) feedback system. While this fuel control system is capable of maintaining the A/F with the required accuracy under steady-state operating conditions, the system accuracy is challenged under rapidly changing throttle conditions and is reduced as the sensor ages. Therefore, to improve fuel control and in-use emission performance at high mileage, most low-emission vehicles incorporate improved control algorithms combined with dual-oxygen sensors.

Since an O2S may not perform as accurately when it has aged, a second O2S placed downstream of one or more catalysts in the exhaust system can be used to monitor and adjust for deterioration of the front, primary sensor, thereby maintaining precise fuel control. Should the front O2S, which operates in a higher temperature environment, begin to exhibit slow response or drift in its calibration point, the secondary O2S is relied upon for modifying the fuel system controls to compensate for these aging effects. By placing the second sensor further downstream from the hot engine exhaust where it is also less susceptible to poisons, the rear sensor would not be likely to age significantly over the life of the vehicle. In this way, a dual O2S system maintains good fuel control -- and attendant low emissions -- as a vehicle ages. Because of their effectiveness, most light-duty vehicles now utilize dual oxygen sensors for fuel control.

Manufacturers have also elected to use dual oxygen sensors on all new vehicles to accomplish the catalyst monitoring requirement of California's On-Board Diagnostic II regulation.

Universal Exhaust Gas Oxygen Sensors (UEGOs). Vehicles that employ lean A/F control strategies (i.e., use less fuel than required to achieve a stoichiometric ratio) are utilizing one or more UEGOs for fuel control in lieu of conventional oxygen sensors. This is because conventional oxygen sensors cannot accurately measure A/Fs other than stoichiometric. Conventional oxygen sensors are "limit" switches in that they can only determine that the engine's A/F is higher or lower than stoichiometric; they do not have the capability of recognizing specific A/Fs. In contrast, UEGOs are capable of recognizing a wide-range of A/F since the voltage output of the UEGO is "linear" (i.e., each voltage value corresponds to a certain A/F). Therefore, maintaining a lean A/F is attainable with the use of UEGO sensors. Since operating lean of stoichiometric during cold-start situations can assist the heating of the catalysts, some low-emission vehicles incorporate these sensors. In addition to their capability of maintaining a tight lean A/F, some manufacturers claim UEGOs allow the fuel control system to maintain a tighter band around stoichiometric. In this way, UEGOs assist vehicles in achieving very precise control of the A/F. A small percentage of LEVs will rely on the use of UEGOs and it is projected that some ULEVs will as well.

Individual Cylinder A/F Control. In order to further improve fuel control, some ULEVs utilize software algorithms to perform individual cylinder fuel control. While dual O2S systems are capable of maintaining A/F ratios within a narrow range, some vehicle manufacturers believe that even more precise control is needed for ULEVs and a couple have already developed an individual cylinder control system. On most current vehicles, fuel control is modified whenever the O2S determines that the combined A/F of all cylinders in the engine or engine bank is "too far" from stoichiometric. The needed fuel modifications (i.e., inject more or less fuel) are then applied to all cylinders simultaneously. Although this fuel control method will maintain the "bulk" A/F for the entire engine or engine bank around stoichiometric, it would not be capable of correcting for individual cylinder A/F deviations that can result from differences in manufacturing tolerances, wear of injectors, or other factors. With individual cylinder fuel control, A/F variation among cylinders will be diminished, thereby further improving the effectiveness of the emission controls. By modeling the behavior of the exhaust gases in the exhaust manifold and using software algorithms to predict individual cylinder A/F, a feedback fuel control system for individual cylinders can be developed. Except for the replacement of the conventional front O2S with a UEGO sensor and a more powerful engine control computer, no additional hardware is needed in order to achieve individual cylinder fuel control. Software changes and the use of mathematical models of exhaust gas mixing behavior are required to perform this operation. UEGOs are currently being utilized by at least 2 vehicle manufacturers on 1998 model year vehicles.

Adaptive Fuel Control Systems. In order to maintain good driveability, responsive performance, and optimum emission control, fluctuations of the A/F must remain small under all driving conditions including transient operation. Virtually all current fuel systems incorporate an adaptive fuel control system that automatically adjusts the system for component wear, varying environmental conditions, varying fuel composition, etc., to more closely maintain proper fuel control under various operating conditions. For some fuel control systems today, this adaptation process affects only steady-state operating conditions (i.e., constant or slowly changing throttle conditions). However, most vehicles are now being introduced with adaptation during "transient" conditions (e.g., rapidly changing throttle, purging of the evaporative system).

Accurate fuel control during transient driving conditions has traditionally been difficult because of the inaccuracies in predicting the air and fuel flow under rapidly changing throttle conditions. Because of air and fuel dynamics (fuel evaporation in the intake manifold and air flow behavior) and the time delay between the air flow measurement and the injection of the calculated fuel mass, temporarily lean A/F ratios can occur during transient driving conditions that can cause engine hesitation, poor driveability and primarily an increase in NOx emissions. However, by utilizing fuel and air mass modeling, vehicles with adaptive transient fuel control are more capable of maintaining accurate, precise fuel control under all operating conditions. Virtually all LEVs and ULEVs will incorporate adaptive transient fuel control software.

Electronic Throttle Control ("Drive-By-Wire") Systems. As mentioned above, the time delay between the air mass measurement and the calculated fuel delivery presents one of the primary difficulties in maintaining accurate fuel control and good driveability during transient driving conditions. For vehicles that utilize a conventional mechanical throttle control, quick throttle openings can result in a lean A/F spike in the combustion chamber. Although air and fuel modeling algorithms can be developed to compensate for these time delay effects, some manufacturers are choosing to incorporate electronic throttle control to better synchronize the air and fuel flow to achieve proper fueling during transients (e.g., the driver moves the throttle, but the fuel delivery is momentarily delayed to match the inertial lag of the increased airflow). An increasing number of vehicles are expected to utilize this technology in the next few years.

(b) Technologies for Improving Fuel Atomization and Delivery

Sequential Multi-point Fuel Injection. Unlike conventional multi-point fuel injection systems that deliver fuel continuously or to paired injectors at the same time, sequential fuel injection can deliver fuel precisely when needed by each cylinder. With less than optimum fuel injection timing, fuel puddling and intake manifold wall wetting can occur, both of which hinder complete combustion. Use of sequential fuel injection systems help especially in reducing cold start emissions when fuel puddling and wall wetting are more likely to occur and emissions are highest. Because of the emission reductions and other performance benefits "timed" fuel injection offers, sequential fuel injection systems are now used on virtually all light-duty vehicles.

Air-Assisted Fuel Injectors. In addition to maintaining a stoichiometric A/F, it is important that a homogeneous air-fuel mixture is delivered at the proper time and that the mixture is finely atomized to provide the best combustion characteristics and lowest emissions. Poorly prepared air-fuel mixtures, especially after a cold-start and during the warm up phase of the engine, show significantly higher emissions of unburned hydrocarbons since combustion of the mixture is less complete. To further encourage a homogeneous mixture, air-assisted fuel injectors are being used. By providing better fuel atomization, more efficient combustion can be attained which should aid in improving fuel economy and reducing emissions. Since achieving good fuel atomization is difficult when the air flow into the engine is low, air-assisted fuel injection can be particularly beneficial in reducing emissions at low engine speeds. This technique improves idle smoothness, thereby permitting a lower engine idle speed and reduced fuel consumption. Further, industry studies have shown that the short burst of additional fuel needed for responsive, smooth transient maneuvers can be reduced significantly with air-assisted fuel injection due to a decrease in wall wetting in the intake manifold. Several manufacturers currently utilize these systems on some of their vehicles. ARB projects that about 50 percent of LEVs and ULEVs will eventually utilize air-assisted fuel injection.

Heated Fuel Injectors. As an alternative or complement to air-assisted injectors, some manufacturers may utilize heated fuel injectors to improve fuel vaporization/atomization. These injectors improve fuel atomization by providing heat to the fuel right before it is injected into the combustion chamber. This added heat combined with high pressure fuel injection atomizes the fuel mixture as it enters the combustion chamber, thereby yielding more complete combustion of the air-fuel mixture.

Improved Induction Systems. Vehicle manufacturers are also incorporating improvements to the air induction system to enhance air-fuel mixing. Through the use of technologies such as variable intake systems and variable valve timing, the amount of swirl, turbulence, and velocity of the intake charge can be increased, especially during cold-start and low load operating conditions where sufficient swirl and turbulence tend to be lacking. By providing a strong swirl formation in the combustion chamber, the air-fuel mixture can mix sufficiently; smooth, complete combustion can be achieved, thereby reducing emissions. All LEVS and ULEVs are projected to incorporate improved air induction systems.

(c) Technologies for Improving Catalyst Performance

Close-Coupled and Underfloor Catalysts. Three-way catalytic converters traditionally utilize rhodium and platinum as the catalytic material to control the emissions of all three major pollutants (hydrocarbons (HC), CO, NOx). Although this type of catalyst is very effective at converting exhaust pollutants, rhodium, which is primarily used to convert NOx, tends to thermally deteriorate at temperatures significantly lower than platinum. Recent advances in palladium and tri-metal (i.e., palladium-platinum-rhodium) catalyst technology, however, have improved both the light-off performance (light-off is defined as the catalyst bed temperature where pollutant conversion reaches 50% efficiency) and high temperature durability over previous catalysts. In addition, other refinements to catalyst technology such as higher cell density substrates and adding a second layer of catalyst washcoat to the substrate (dual-layered washcoats) have further improved catalyst performance from just a year ago.

Typical cell densities for conventional catalysts are 400 cells per square inch (cpsi). However, some vehicles available today use 600 cpsi catalyst substrates. If catalyst volume is maintained at the same level, using a 600 cpsi catalyst versus a 400 cpsi catalyst effectively increases the amount of surface area for reacting with pollutants. Catalyst manufacturers have been able to increase cell density without increasing thermal mass (and detrimentally affecting catalyst light-off) by utilizing thinner walls between each cell.

Double layer technologies allow optimization of each individual precious metal used in the washcoat. This technology can provide reduction of undesired metal-metal and/or metal-base oxide interactions while allowing desirable interactions. Industry studies have shown that durability and pollutant conversion efficiencies are enhanced with double layer washcoats. These recent improvements in catalysts are perhaps the most significant development that enable manufacturers to meet the LEV and ULEV standards at relatively low cost.

With the improvements in light-off capability, catalysts may not need to be placed as close to the engine as previously thought. However, if placement closer to the engine is still required for better emission performance, these improved catalysts would be more capable of surviving the higher temperature environment without deteriorating. Currently, many vehicles already utilize close-coupled catalysts. In the future, increasing numbers of vehicles are expected to utilize this technology as the emission standards become more stringent since close-coupling the catalysts to the engine can provide more heat, allowing them to become effective quickly.

Because of the improved performance of three-way catalysts, virtually all light-duty vehicles are expected to continue using this technology without the need for other aftertreatment devices such as electrically-heated catalysts (EHCs).

Heat-Optimized Exhaust Pipe. Improving insulation of the exhaust system is another method of furnishing heat to the catalyst. Similar to close-coupled catalysts, the principle behind insulating the exhaust system is to conserve the heat generated in the engine for aiding catalyst warm-up. Through the use of laminated thin-wall exhaust pipes, less heat will be lost in the exhaust system, enabling quicker catalyst light-off. As an added benefit, the use of insulated exhaust pipes will also reduce exhaust noise. Increasing numbers of manufacturers are expected to utilize air-gap exhaust manifolds (i.e., manifolds with metal inner and outer walls and an insulating layer of air sandwiched between them) for further heat conservation.

Engine Calibration Techniques. Besides the hardware modifications described above, low-emission vehicles also utilize engine calibration changes such as a brief period of substantial ignition retard, increased cold idling speed, and leaner air-fuel mixtures to quickly provide heat to a catalyst after cold-starts. Since only software modifications are required, engine calibration modifications provide manufacturers with an inexpensive method to quickly achieve light-off of catalytic converters. When combined with close-coupled catalysts and the other heat conservation techniques described above, engine calibration techniques can be quite effective at providing the required heat to the catalyst for achieving ULEV emission levels without auxiliary heating devices such as EHCs. Merely two years ago, the ARB projected that all ULEVs and some LEVs would require the use of EHCs to meet the requirements, but it now appears that nearly all vehicles will be able to achieve ULEV emission levels without requiring the assistance of an EHC. Heat producing engine calibrations such as described above are already in production and are projected to be incorporated on all low-emission vehicles.

Leak-Free Exhaust System. Improving exhaust systems to be leak-free also reduces emission levels. Air leaks in the exhaust system can cause an oxidation environment in the three-way catalyst at low speeds that would lead to an increase in NOx emissions. Also, should air leaks occur upstream or near the oxygen sensors, fuel control could be erratic and/or overly rich in response to the leaking unmetered air. This would not only affect driveability but also would increase emission levels. Because of their emission benefits, vehicle manufacturers will continue incorporating leak-free exhaust systems as the emission standards become more stringent.

The system typically consists of an improved exhaust manifold/exhaust pipe interface plus a corrosion-free flexible coupling inserted between the exhaust manifold flange and the catalyst to reduce stress and the tendency for leakage to occur at this joint. This system is already incorporated on many vehicles. Use of this type of system, assuming use of corrosion-free steel, can also reduce warranty costs due to customer complaints of noise from leaking joints. Further, improvement in the welding process for catalytic converter canning would assure less air leakage into the converter and provide reduced emissions. Virtually all low-emission vehicles will incorporate leak-free exhaust systems.

Electrically-Heated Catalysts. While the techniques described above will allow more heat to be provided quickly to the catalyst, some larger vehicles or those with tightly packaged engine compartments that require catalysts be placed underfloor may need additional help from auxiliary heating devices to achieve ULEV emission levels. Various strategies have been proposed to provide additional heat to the catalyst such as electrically-heated catalysts, exhaust gas burners, and energy storage devices. Of all these strategies, the electrically-heated catalyst has received the most attention since the technology has been shown to be feasible, cost-effective, and is ready to be introduced commercially.

In the early years of EHC development, there was concern that the electrical energy and power requirements needed to provide the heat energy necessary for ULEV emissions would require major upgrades to a vehicle's electrical system, including alternator upgrades, a separate dedicated battery to power the EHC and other electrical improvements. Recent advancements in EHC designs, however, have substantially reduced this concern. Most vehicles that utilize EHC systems will likely power the EHC directly from the alternator, or solely from the vehicle's battery, or from a combination of power from the vehicle battery and alternator.

Electric Air Injection. Although many ULEVs are expected to operate lean of stoichiometric or near stoichiometric after a cold-start, there will be some vehicle applications where this will not be possible because of driveability concerns. For these vehicles, a brief period of cold operation with a rich A/F mixture will be necessary. Although operating with a rich A/F mixture provides more stable combustion and better driveability when the engine is cold, it would also increase emissions of unburned HC and CO out of the engine. In order to control these emissions, vehicles that incorporate a rich cold-start fueling strategy are expected to include an electric air injection system to inject air upstream of the three-way catalyst so that a stoichiometric A/F ratio at the catalyst can be achieved for optimum emission performance. To further enhance quick catalyst light-off, ignition retard is being utilized with electric air injection to provide additional heat to the catalyst.

The use of air injection also appears likely on some EHC-equipped vehicles. With EHC systems, substantial reductions in HC and CO emissions can be achieved with air injection because the EHC can reach light-off temperature in about 3 seconds after starting the engine. Since NOx emissions are not a problem with a cold engine, the excess air that air injection provides should not significantly increase these emissions.

Unlike previous air injection systems that are powered by pumps driven by the engine, future air injection pumps will be electrically powered. Advantages of using electric air pumps include higher overall efficiencies, lower costs, increased reliability, and the ability to be turned off when not needed.

Hydrocarbon Adsorber Systems. If the limiting factor for a vehicle to comply with the low-emission vehicle requirements is the control of HC, one possible solution could be HC adsorber systems. There have been several different types of HC adsorber systems proposed for use in motor vehicles over the past several years. Some of these systems are very complex with multiple valves, pipes, and heat exchangers while some are simpler in design and do not utilize any valves or other moving parts. Nonetheless, these systems all operate on the same principle. They are designed to trap the HC while the catalyst is cold and unable to convert the HC by utilizing an adsorbing material that holds onto the hydrocarbons. Once the catalyst is warmed up, the trapped HC are released from the absorption material and directed to the fully functioning downstream three-way catalyst. While this principle sounds simple, the technical solution is not uncomplicated, because the adsorption and desorption of the HC need to be timed correctly to prevent premature release of the unburned HC (i.e., the HC must be released only after the catalyst has warmed-up). Staff has been informed by some manufacturers that HC adsorbers may be used on some LEVs and ULEVs that have severe underhood space constraints. One HC adsorber system has recently received tentative approval for incorporation of an adequate monitoring strategy for meeting On-Board Diagnostics II requirements.

(d) Technologies to Reduce Engine-out Emission Levels

Reduced Crevice Volumes. Emission performance is also being improved by reducing crevice volumes in the combustion chamber. Unburned fuel can be trapped momentarily in crevice volumes before being subsequently released. Since trapped and re-released fuel can increase engine-out emissions, the elimination of crevice volumes would be beneficial to emission performance. To reduce crevice volumes, vehicle manufacturers are designing engines to include pistons with reduced top "land heights” (the distance between the top of the piston and the first ring). Although reducing the top land height could reduce the durability of the piston, improved design and materials allow moving the ring higher on the piston.

Reduced Oil Consumption. Lubrication oil which leaks into the combustion chamber also has a detrimental effect on emission performance since the heavier hydrocarbons in oil do not oxidize as readily as those in gasoline and some components in lubricating oil may tend to poison the catalyst and reduce its effectiveness. Also, oil in the combustion chamber may trap HC and later release them unburned. To reduce oil consumption, vehicle manufacturers are tightening the tolerances and improving the surface finish on cylinders and pistons, improving piston ring design and materials, and improving exhaust valve stem seals to prevent excessive leakage of lubricating oil into the combustion chamber. Virtually all low-emission vehicles with newly redesigned engines also incorporate features to reduce oil consumption.

Electronic Exhaust Gas Recirculation (EGR). One of the most effective emission controls for reducing NOx emissions is exhaust gas recirculation. By recirculating spent exhaust gases into the intake manifold to reenter the engine, peak combustion temperatures are lowered and NOx emissions are thus reduced.

Many EGR systems in today’s vehicles utilize a control valve that requires vacuum from the intake manifold to regulate the EGR flow rate. Under part-throttle operation where EGR is needed, engine vacuum is sufficient to open the valve. However, during throttle applications near or at full-throttle, engine vacuum is too low to open the EGR valve. While EGR operation only during part-throttle driving conditions has been sufficient to control NOx emissions for most vehicles in the past, the more stringent NOx standards for LEVs and ULEVs and emphasis on controlling off-cycle emission levels may require more precise EGR control and additional EGR during heavy throttle operation to reduce NOx emissions. Vehicle manufacturers are increasingly using electronic EGR valve actuators in order to provide more precisely-controlled EGR rates for low emission levels. Therefore, use of these electronic systems allow engines to receive the optimal amount of EGR for all driving conditions.

Abbreviated Engine Start Systems. During the brief engine starting period, high amounts of HC are emitted due to incomplete combustion of the air/fuel mixture as the engine transitions from the low engine cranking speed to the running idle speed. To reduce this period of high HC emissions, some manufacturers are investigating high torque starter systems that can spin the engine at approximately 500 rpm for quicker starts. Manufacturers are investigating combining the alternator with the starter to achieve this high level of starting performance. The system is integrated with the engine flywheel/torque converter, and may require use of a separate 32 volt or higher battery. With the combined starter/alternator, the alternator pulley and brackets could be eliminated, thereby offsetting some of the increased cost of the system. In addition to reduced emissions, there are other benefits that can be gained from this system. Since electrically powered components are more efficient than those driven by pulleys or hydraulics, fuel economy should improve by converting to electric pumps, power steering and air conditioning compressors that could be operated by this high capacity system.

2. Projected LEV II Technologies (PCs and Trucks ≤ 8500 lbs.) As described earlier, the proposal for LEV II would require significant NOx reductions not only for vehicles in the current light-duty vehicle category but also would include trucks and SUVs up to 8500 lbs. GVW. In addition, although NMOG and CO emission standards would remain at the same LEV I levels for current light-duty vehicles, the under 8500 lbs. GVW trucks and SUVs would require more significant reductions of these emissions to comply with the proposed LEV II requirements. To meet these new requirements, staff believes that additional refinements to mature LEV I technology will allow the majority of cars and trucks to comply with LEV II standards. In the following section, LEV II technologies that would be incremental to the LEV I technologies described earlier will be discussed in more detail. Similar to the step needed to improve Tier I vehicles to LEV I levels, the primary means for additional reductions will rely on improvements to aftertreatment, fuel control and delivery, and engine-out emissions.

(a) Increased Catalyst Volume and Substrate Cell Density. As mentioned in the previous section, increasing catalyst volume and substrate cell density can significantly improve catalyst performance. Typical LEV I (LEV and ULEV) passenger cars currently have catalyst volume/engine displacement ratios of about 0.7 to over 1.0 while many trucks have ratios of 0.6 or less. In order to comply with the new combined LEV II standards, most vehicles will likely need catalyst volumes greater than the displacement of their engines. During the 2003-2004 timeframe it is projected that all cars and trucks subject to the LEV II requirements will typically utilize 600 cpsi catalyst substrates for good pollutant conversion efficiencies especially in close-coupled locations. Since these higher cell density substrates effectively provide more surface area for pollutant conversion, catalyst volumes may not need to be increased as much as with conventional substrates to achieve LEV II levels. Industry papers also indicate that work on substrates with cell densities as high as 900 cpsi is now being conducted with promising results. On vehicles with large underfloor catalysts, however, industry technical papers have indicated that the effectiveness of high cell density substrates are not as significant. This behavior may be due to the high pressure drop across the catalyst.

(b) Increased Catalyst Loading and Improved Washcoats. In addition to increasing catalyst volume and cell density, staff projects that increased catalyst loading and improved catalyst washcoats will also be needed to achieve LEV II emission levels. In general, increased noble metal loading (up to a certain point) will reduce exhaust emissions because it increases the opportunities for pollutants to be converted to harmless constituents. Typical catalyst loading on current LEVs and ULEVs range from less than 50 g/ft^3 to as high as 300 g/ft^3. To achieve LEV II levels, staff believes that catalysts will be loaded to the 100 - 300 g/ft^3 range. Precious metal loading will be dependent upon the precious metals used and other catalyst design parameters (e.g., warm-up catalysts tend to have higher loadings than underfloor catalysts in multi-catalyst systems). A recent development that staff believes is very promising are palladium/rhodium catalysts. Since rhodium is very efficient at converting NOx, catalyst suppliers have been investigating increasing the amount of rhodium in catalysts for improved NOx conversion.

Palladium/rhodium catalysts have been installed on some ARB test vehicles and are being evaluated now. Initial ARB 50,000 mile aging performance results on these vehicles have been promising. While at least one vehicle manufacturer has stated that palladium/rhodium catalysts are thermally more sensitive than other catalyst technologies (i.e., palladium-only) and would deteriorate more noticeably with mileage, staff believes that based on discussions with some suppliers and our own test results, improved washcoat designs (e.g., double-layer washcoats) will reduce thermal deterioration on these catalysts.

Thus, washcoat design will be very important for achieving and maintaining LEV II emission levels. New washcoat formulations are now thermally stable up to 1050 ^{o}C. This is a significant improvement from conventional washcoats, which are stable only up to about 900 ^{o}C. This improved resistance to high temperature degradation should allow close-coupled catalysts to maintain their emission performance even under severe driving conditions. Continued work on improving catalyst performance will likely result in even better thermal durability and emission performance in the near future.

(c) Improved Catalyst Light-off with Secondary Air Injection (SAI) and Retarded Spark Timing. It is well established that a warmed-up catalyst is very effective at converting exhaust pollutants. Recent tests on advanced catalyst systems have shown that over 90% of emissions during the Federal Test Procedure (FTP) are now emitted during the first two minutes of testing after engine start up. Although improvements in catalyst technology have helped reduce catalyst light-off times, additional help may be needed to achieve LEV II emission levels. There are several methods to provide additional heat to the catalyst many of which have already been described in the previous section such as EHCs, and ignition retard with or without electric air injection. It is projected that all LEV II vehicles will utilize ignition retard and that many also include electric air injection.

3. Medium-Duty Vehicles (8,500 - 14,000 lbs. GVW). Under the proposed LEV II exhaust emission standards, auto manufacturers are also required to substantially reduce emissions from medium-duty-vehicles (MDVs). Of the two categories remaining in this class of vehicles using the new classification, vehicles with 8,501 - 10,000 lbs. GVW are the focus in this technical assessment for MDVs. Currently there are no MDVs in the 10,001 - 14,000 lbs. GVW category that are chassis certified, and few are expected in the future. However, any such vehicles would likely employ much of the technology of the 8,5001 - 10,000 lbs. GVW category. Currently, to meet the existing emission standards for this category of vehicles, manufacturers are essentially using many of the same emission control technologies they are employing on their LDVs. These technologies include dual heated oxygen sensors, sequential multi-point fuel injection, exhaust gas recirculation, three way-catalysts, and in some cases secondary air injection as shown in the following table. However, a more extensive use of available technologies would likely be needed to comply with the proposed LEV II requirements. A brief description of the staff's projection of the technologies for MDVs is described below.

(a) Catalyst system changes. In order to achieve the emission reductions called for in LEV II, manufacturers would likely rely on improvements in existing emission control technologies and placement of the catalysts closer to the engine. Vehicles in this class utilize mostly V-8 engines with dual exhaust banks. In some vehicles, the two banks are joined with a "Y" pipe and only a single underfloor catalytic converter is used. On vehicles with dual exhaust systems, one underfloor catalytic converter is used for each bank. Furthermore, some vehicles also employ warm-up catalysts. To meet the LEV II requirements, manufacturers would likely still utilize underfloor catalytic converters, however, the location of the converter would likely be moved closer to the engine to reduce light-off time. In addition, dual palladium-only warm-up catalysts (also known as "pipe catalysts") using ceramic or metallic substrates may be added to further improve emission performance. Although, metallic substrates are usually more expensive than ceramic substrates, some believe they may require less precious metal loading than ceramic substrates due to the reduced light-off times they provide. In addition, manufacturers are expected to use advanced catalyst formulations with improved washcoat technologies and higher precious metal loadings. These advanced catalysts (though not necessarily the pipe catalyst, which would likely be palladium-only catalysts) would utilize washcoats in which separate layers are applied on the substrate for each precious metal. This type of layered design provides an opportunity to tailor the washcoats for optimum performance of each precious metal. This double layer technology also improves the aging stability of the converters, especially in the case of palladium-rhodium catalysts.

(b) Other emission control system improvements. Further reductions in exhaust emissions can be achieved by lowering engine out emissions and utilizing improved fuel preparation and delivery. Most EGR systems used in current MDVs are already electronically controlled. Since reduction of NOx emissions is the primary target under the LEV II requirements, further refinements of the EGR control algorithms may be needed. Staff anticipates that electronic EGR will be utilized on all vehicles in this category. Manufacturers may also adopt changes in engine calibrations that provide ignition timing retard and higher idle speeds during cold start in order to supply more heat to the catalyst for quicker light-off times to further reduce HC and NOx emissions.

4. LEV II Technical Feasibility Evaluation Program. ARB is conducting two test programs to evaluate the feasibility of lower NOx standards - one for trucks and the other for passenger cars. Both test programs rely primarily on installing advanced catalyst systems, many of which are bench aged to 50,000 miles, on test vehicles to achieve lower emission levels. However, alterations to calibrations of EGR, ignition timing, secondary air injection, or fuel control have been incorporated on some of the vehicles. Although staff is estimating the emission reduction capability and durability of advanced catalysts through this effort, our limited access to modifying fuel and spark timing strategies or to alter other engine systems restricts our ability to achieve what expert automotive engineers can achieve given their comparatively enormous resources and experience plus another 5 to 7 years of development time. Staff also expects catalysts to continue to improve beyond today's impressive performance. All of these factors, plus consideration of vehicle and emission measurement variability and other issues were considered in proposing these final emission standards. Each of the test programs is discussed in more detail below.

(a) Passenger Car Test Program. Five recent model-year gasoline vehicles are being evaluated for LEV II program emission capability. Each of the five test vehicles was tested for baseline emissions at approximately 4000 miles before any modifications to the vehicle's emission controls were made. The average emissions from these FTP tests are listed in Table II-17.

Table II-17
Average FTP emissions of OEM test vehicle at approximately 4000 miles.

Test Vehicle	NMHC (g/mi)	CO (g/mi)	NOx (g/mi)
1997 Mercury Sable	0.035	0.9	0.072
1998 Mercury Grand Marquis	0.048	0.6	0.014
1998 Nissan Altima	0.031	0.7	0.040
1998 Toyota Avalon	0.044	0.4	0.111
1998 Honda Accord EX	0.025	0.3	0.066

After these baseline FTP results were complete, new advanced catalysts were installed on each test vehicle. In general, the advanced catalysts were placed in the same position as the OEM catalysts. Two of the vehicles had small "pipe catalysts" added to the OEM configuration. FTP tests were then conducted. If the emission results were not below the proposed LEV II standards with a reasonable margin, engine calibration modifications such as ignition retard at engine start, O2 sensor biasing, or air injection modifications were applied to reduce tailpipe emission levels. In a couple instances, approximately 4000 miles were accumulated on the "green" catalysts before FTP tests were again conducted. The emission test results for the advanced catalyst vehicles are listed in Table II-18. It is interesting to note that the Mercury Grand Marquis was the best performer despite its large size and high weight, plus a large displacement V8 engine.

Table II-18
Average FTP emissions of test vehicle with modifications and advanced catalysts.

Test Vehicle	Approx. Mileage on Adv. Catalyst	NMHC (g/mi)	CO (g/mi)	NOx (g/mi)	Modifications
1997 Mercury Sable	0	0.029	1.0	0.036	Air Injection Time
1998 Mercury Grand Marquis	4000	0.033	0.5	0.004	None
1998 Nissan Altima	0	0.028	0.7	0.033	Fuel Biasing
1998 Toyota Avalon	N/A	N/A	N/A	N/A	N/A
1998 Honda Accord EX	0	0.026	0.4	0.035	Ignition Retard

On some cars, bench aging of the catalyst systems to 50,000 miles may be performed. This will depend on the availability of bench aging time and resources, but most of the aged advanced catalysts were not available in time to be included in this report.
The only available aged catalyst test result is shown in Table II-19. With a 50,000 mile bench aged catalyst and oxygen sensors, the emission performance of the Honda Accord is just below the proposed emission standards.

Table II-19
FTP Test Results
(Advanced Catalyst, A/F sensor, & O2 sensor bench-aged to 50,000 miles).

Test Vehicle	Approx. Mileage on Adv. Catalyst	NMHC (g/mi)	CO (g/mi)	NOx (g/mi)	Modifications
1998 Honda Accord EX	50,000	0.032	0.6	0.048	Ignition Retard

Staff will make available any other test data that are completed before the scheduled Board hearing. At this time, the automotive industry has generally acknowledged that the proposed emission standards for passenger cars can likely be met in the timeframe they would be required.

Staff did not attempt to evaluate achieving SULEV emission levels, but notes that Honda has indicated they will consider producing such a vehicle based on their ZLEV gasoline prototype. Also, hybrid electric vehicles such as the Prius are being planned for introduction in the U.S. meeting the SULEV standards.

(b) TRUCK/SUV Test Program. In order to evaluate the capability of achieving LEV II emission levels on trucks and SUVs below 8500 GVW, ARB procured two identically equipped 1998 Ford Expeditions as our primary test vehicles. The Expedition was chosen for this demonstration because it represents the upper tier of the LDT2 vehicle weight category and exhibits very capable emission performance relative to other vehicles in this class. The technical specifications of the two vehicles, identified hereafter as Vehicle #2 and Vehicle #3, are listed in Table II-20.

Table II-20
Technical Specifications for 1998 Ford Expedition (Vehicles #2, #3)

Class	MDV3
Engine	5.4 Liter V-8 Triton Engine
Transmission	4 speed automatic
Tires	P255/70R16
Body style	Sport Utility
Drive Type	RWD, 4 X 4
Engine Family	WFMXA05.4JGC
Test Weight	6000 lb. (official test weight would be 5500 lbs.)
Aftertreatment	Dual three-way catalysts X 2; Dual heated oxygen sensors X 2; Exhaust gas recirculation; Sequential multi-port fuel injection
Calibration	8-46U

Certification emission results for this vehicle both at 4000 miles and 50,000 miles are shown in Table II-21.

Table II-21
Certification Results of 1998 Ford Expedition

Miles	Test Weight	NMHC (g/mi)	CO (g/mi)	NOx (g/mi)
4000	6000	0.066	1.2	0.04
50,000	6000	0.080	1.5	0.14

Both ARB test vehicles were emission tested as received over the FTP cycle in the baseline OEM configuration at about 2000 miles. The average results of these tests are presented in Table II-22.

Table II-22 Expedition Testing
Baseline FTP Emissions-OEM Configuration (6000 lbs.)

Vehicle	No. of Tests	NMHC g/mi	CO g/mi	NOx g/mi	CO_2 g/mi	Fuel Economy mi/gal
Vehicle #2	8	0.090	1.69	.030	662	12.9
Vehicle #3	6	0.077	1.57	.031	661	13.0

ARB obtained two identical non-aged Pd/Rh advanced catalyst systems for each of these vehicles. The advanced catalyst systems and the oxygen sensors from these vehicles were bench-aged at Southwest Research Institute in San Antonio, Texas. Bench-aging was performed to simulate 50,000 in-use miles using a representative cycle specified by Ford Motor Company for this vehicle. After bench-aging, the catalyst systems and oxygen sensors were shipped back to ARB, installed on the test vehicles and tested for emissions. Results are shown in Table II-23.

Table II-23
Expedition FTP Emissions
With Advanced Catalyst & O_2 Sensors Bench-Aged to 50,000 miles (6000 lbs.)

Vehicle	No. of Tests	NMHC g/mi	CO g/mi	NOx g/mi	CO_2 g/mi	Fuel Econ mi/gal
# 2	4	0.111	3.32	0.048	663	12.9
# 3	7	0.112	2.91	0.052	650	13.1

After conducting the initial set of baseline tests with the aged catalyst and oxygen sensors, staff noted that both test vehicles exhibited gradually increasing emissions with normal FTP pre-conditioning. Considerable testing ensued in an attempt to regain the initial emission levels. At one point, staff removed both sets of aged advanced catalysts and sensors and placed them on two other rented Expeditions. Both of these added vehicles displayed identical as received OEM baseline emissions as the first two, but installation of both sets of aged advanced catalysts and sensors yielded high NOx emissions in the vicinity of 0.1 g/mi. After further repeat FTP testing, even the first two Expeditions with aged components yielded stabilized NOx emissions about 0.10 - 0.14 g/mi.

After investigation, it appears that the altered oxygen storage capacity of the aged catalysts has affected the ability of the stock fuel system calibration to maintain optimum emissions (as current advanced fuel systems cycle slightly rich and slightly lean of the target air/fuel ratio (stoichiometric) for optimum catalyst conversion efficiency, oxygen is stored in the catalyst during the lean excursion and is used to convert HC and CO during rich excursions. With aging, the ability of a catalyst to store oxygen declines, but with proper adjustment of the fuel control, catalyst efficiency can still be maintained very well with the newest advanced catalysts). Staff learned that some manufacturers (including Ford) typically bench age new catalyst technologies to 50,000 and 100,000 miles, and then tailor the fuel system to achieve optimum emission levels at each aging interval. Revised fuel look-up tables are incorporated into the computer software. By tracking catalyst oxygen storage, modified fueling can be implemented as the catalyst ages in order to maintain lowest emissions. Unfortunately, staff has no such capability for modifying software to achieve this fuel tailoring. That our first two test vehicles achieved NOx emissions of about 0.05 g/mi when the aged catalysts were first installed seems to have been fortuitous, and perhaps the long-term fuel trim required some time to begin a modified fueling strategy in response to detecting a decline in oxygen storage with the aged catalysts installed, eventually leading to higher emissions.

Despite these hurdles, staff was able to regain most of the initial good emission performance of the first two Expeditions by using a modified preconditioning procedure. It was noted that when using the FTP test cycle for preconditioning, emissions would remain high, but that by running several on-road test loops with a "key-off" between loops to potentially stabilize fuel adaptive "learning," NOx emissions could be brought back to a 0.04 - 0.06 g/mi level. It is believed that on-road operation yielded higher catalyst temperatures than FTP driving, and therefore improved oxygen storage. This approach seemed to provide a better match of fuel learning and aged catalyst performance for lower emissions than other efforts.

Discussions with catalyst suppliers indicate that with proper fuel tailoring adjustments, these latest technology palladium-rhodium designs lose virtually none of their emission conversion capability over more than 100,000 miles of aging. The small increases in emissions of our two Expeditions without the benefit of proper fuel tailoring tends to verify this claim.

Vehicle #3 seems to have the best match of fueling to the aged advanced catalyst, and was thus modified to include an electric air injection system to determine what level of NMOG and CO emission reductions might be obtained. Air was injected at the front of each exhaust manifold, though a more effective system would introduce the air at each exhaust port (which would be done by including air passages cast into the engine cylinder heads). Early results from this testing available at the time of release of this staff report are shown in Table II-24. These are our best results to date, and additional optimization and repeat testing will be done to explore this system's capability within our modification and testing constraints.

Table II-24

FTP Emission Tests - Vehicle #3
Air Injection Testing with Aged Advanced Catalyst System/O2 Sensors

Condition	No. of Tests	NMHC g/mi	CO g/mi	NOx g/mi	CO_2 g/mi	Fuel Economy (mi/gal)
Baseline Onroad Prep (w/o air injection)	3	0.144	2.54	0.047	660	12.9
With Air Injection	1	0.072	0.618	0.042	659	13.0

These results provide evidence that the proposed emission standards for the LDT2 category would be feasible. Despite the considerable limitations of the staff's test program, a NOx level near the expected target of 0.035 g/mi was achieved that vehicle manufacturers would need to allow for vehicle and testing variability and "headroom." NMHC emissions of our test vehicle are in the LEV category even though the fuel system was not tailored to the characteristics of the aged advanced catalysts, the air injection system may not yet be optimum, and a host of other methods to reduce NMOG emissions was not available to ARB staff. Numerous technologies described earlier might be applied to improve HC, CO and NOx emissions, including individual cylinder fuel control, (probably incorporating UEGO sensors), retarded spark timing, heated fuel injectors, greater mixture turbulence, higher cell density catalysts, abbreviated engine starting, and others.

Tests on the Ford Expeditions were conducted at a 6,000 lb. test weight, which is probably the highest test weight of any vehicle in the new LDT2 category (the appropriate test weight of the Expedition is 5500 lbs.). Most vehicles will have test weights well below this maximum and should, therefore, be capable of even lower emissions than we have seen in our testing (note that staff is also proposing that 4 percent of a manufacturer's LDT2 category be allowed to certify at a higher emission level, which would include their heavier vehicles tested at or below 6000 lbs., further easing their task). Even then, in the next five to six years before the most difficult vehicles would be required to meet the new LEV II program emission standards, catalyst technology will surely improve further (some of the catalyst vendors mentioned that in the next six months they will have significantly improved catalysts than the ones provided to ARB).

The 1999 5.4L Ford Expedition (Engine family: XFMXAO5.4JGC) is equipped with a catalyst system identical in catalyst volume, close coupled location, and configuration to ARB's advanced catalyst system, except that our advanced catalyst has significantly higher precious metal loading than the 1999 OEM system. In addition, Ford used the identical bench aging procedure for the certification OEM catalyst that was used by ARB to age our advanced catalyst. The following table provides a comparison of the emission results after aging our advanced catalyst and the certification emissions of the 1999 OEM system.

Table II-25
Ford Expedition Emission Comparison
ARB Advanced Catalyst and 1999 Expedition Certification Data

Catalyst	Test Weight (lbs.)	Description	Mileage	NMHC (g/mi)	CO (g/mi)	NOx (g/mi)
Advanced ARB Vehicle #3 (2 tests)*	6000	Virtually identical to 1999 OEM system, except increased precious metal loading	50,000	0.144	2.5	0.047
1999 OEM system*	6500		50,000	0.092	1.7	0.1
1999 OEM system*	6500		120,000	0.126	3.1	0.1

*Aged using Ford's thermal bench aging procedure.

The results from the OEM system indicate that the 1999 Expeditions are very close to meeting the proposed LEV II standards for NOx (numerous other technology measures are available to lower HC without increasing NOx), even though automobile manufacturers would have another 6 years to meet the proposed standards for their most difficult to control vehicles. Since our advanced catalysts have significantly higher precious metal loading than the OEM system, our lower NOx level was expected. Furthermore, since the OEM system is able to achieve lower hydrocarbon emissions with a lower precious metal loading than our advanced catalyst system, emission performance of our advanced catalyst should be further improved with proper tailoring of the fuel-control strategy to match the advanced catalyst requirements. Finally, the OEM certification emission levels were generated with the vehicle tested at 6,500 lbs, so that emission levels should be even lower when tested at the 6000 lb. weight of our test vehicles or at the actual Expedition loaded vehicle weight of 5500 lbs.

Also of interest are the two additional rental Ford Expeditions acquired for testing, as mentioned earlier. Despite these vehicles being rental vehicles that probably receive abusive treatment, their baseline emissions were virtually the same as our first two low mileage vehicles, after having accumulated 14,000 and 17,000 miles of service, as shown in Table II-26. The emission performance of all Expedition test vehicles was tightly grouped, demonstrating that these advanced catalysts and control systems markedly reduce variability and do not show an increase in emissions at least between 1500 and 17,000 miles.

Table II-26
FTP Test Results

Test Vehicle	Approx. Mileage on Vehicle	NMHC (g/mi)	CO (g/mi)	NOx (g/mi)	Notes
Vehicle #2	1500	0.090	1.69	0.030	Average of 8 tests
Vehicle #3	2500	0.077	1.57	0.031	Average 6 tests
Vehicle #6	14,000	0.074	1.13	0.030	
Vehicle #7	17,000	0.091	1.64	0.031	

In view of the above findings, staff concludes that the PC/LDT1 and new LDT2 emission standards as proposed would be feasible in the prescribed implementation timeframe. In making this conclusion, staff assumes that manufacturers will need to achieve 0.035 g/mi NOx emissions on their 50,000 mile test vehicles in order to have adequate headroom to ensure vehicles on average will pass emission requirements in-use. Staff is willing to conduct biennial technology reviews to track progress in meeting these requirements.

(c) Medium-Duty Vehicle Evaluation. Staff performed additional emission tests of the Ford Expedition with an aged advanced catalyst system (but with the fuel tailoring and other limitations described previously) at a test weight representative of vehicles in the medium-duty vehicle weight category in order to propose emission standards for the MDV class (these tests were conducted without air injection). Tests were conducted at 7500 lbs., which represents a typical vehicle's curb weight plus one-half the load carrying capacity in the 8500 - 10,000 lb. GVW class. Although the Expedition was not designed to be tested at this weight (and catalyst volume is probably undersized for optimum emission reduction), it still performed very well as shown in Table II-27.

Table II-27
FTP Test Results

Test Vehicle	Catalyst	NMHC (g/mi)	CO (g/mi)	NOx (g/mi)	Notes
Vehicle #2	OEM	0.152	2.76	0.118	2000 miles, 7500 lbs. test wt.
Vehicle #3	Aged Advanced w/o air injection	0.190	4.03	0.096	50,000 mile aged catalyst, 7500 lbs. test wt., (4 tests)

Due to the potentially more rigorous service medium-duty vehicles are expected to encounter compared to vehicles in the proposed LDT2 category, coupled with the larger engine and exhaust volumes that must be heated to achieve catalyst lightoff, higher HC, CO and NOx emissions would be expected compared to vehicles in the LDT2 class. Given these realities, staff considered the performance of the Expedition tested at 7500 lbs. and then added margin for slower lightoff of the catalyst system due to larger catalyst volumes commensurate with larger displacement engines in this category (but moderated somewhat by the potential use of very durable small pipe catalysts located close to the engine and other potential HC reduction strategies). Then headroom was added due to the more rigorous service life in generating the proposed standards shown in Table II-4.

Staff also examined certification data on a 1998 and a 1999 model-year Ford F250 Super Cab 4WD truck (which falls in the medium-duty vehicle 8500-10000 GVW category). The 50,000 and 120,000 mile certification values are shown in Table II-28.

Table II-28
Ford F-250 Certification Emission Levels

Catalyst	Test Weight (lbs.)	Description	Mileage*	NMHC (g/mi)	CO (g/mi)	NOx (g/mi)
LEV II-ULEV		Proposed standard	120,000	0.143	6.4	0.2
1998 OEM	6000 - 6500	Virtually identical to 1998 Expedition OEM configuration, but with decreased volume and precious metal loading	50,000	0.14	1.6	0.2
1998 OEM	6000-6500		120,000	0.17	2.1	0.31
1999 OEM	7000-8000	Single underfloor catalyst, w/ catalyst volume equiv. to the 1998 F-250 system	50,000	0.23	1.9	0.1
1999 OEM	7000-8000		120,000	0.31	2.4	0.21

* aged using modified AMA cycle (high-speed cycle)

The 1998 F250 was equipped with a catalyst identical in configuration but with lower catalyst volume and lighter precious metal loading than the 1998 Expedition and yet was able to achieve low NOx emission levels. Also, in the 1999 model-year, the F250 super-duty is equipped with a single underfloor catalyst with catalyst volume equivalent to the 1998 F250 super-duty system and was able to achieve NOx emission levels close to proposed LEV II-ULEV NOx standards for the MDV (8500-10,000 GVW) class. From this data, it appears that with increased catalyst loading to that of today's Expedition and a close-coupled configuration or use of air injection, the F250 vehicles in the 8500-10,000 GVW category should be able to meet the proposed LEV II standards for this class. As before, additional emission control measures are available to further reduce emissions.

5. Low-Emission Measurement. Accurate measurement of vehicle emissions is needed to provide manufacturers with the assurance that they have achieved the targeted emission levels for their vehicles. Furthermore, uncertainties in emission measurements could result in differences in vehicle emission measurements between the manufacturers' and regulatory agencies' test facilities. This could prove problematic in determining whether the manufacturers are in compliance with the standards.

In response to the low emission standards adopted by the ARB in 1990, the American Industry/Government Emissions Research Consortium (AIGER) was formed. The members of AIGER are; ARB, General Motors, Ford, Chrysler, and the U.S. EPA. The purpose of the AIGER consortium is to explore the development of new instrumentation and sampling techniques for low-emission vehicles. Several AIGER projects have shown promise in providing more accurate measurement at low levels and are expected to mature in the near future. Furthermore, the manufacturers of emission measurement instrumentation have been working to improve the measurement capability of their current equipment. These improved instruments have generally been incorporated into the manufacturers' and regulatory agencies' test facilities. ARB has made several incremental improvements to its test facility to enhance emission measurement at low levels. These improvements consist of: installation of a single roll electric dynamometer for more consistent vehicle loading from test to test, installation of a variable volume sampling system and a remote mixing tee with heated dilution air to reduce condensation of the exhaust sample, and lower instrument ranges. In the near future, ARB is planning to heat the dilute exhaust ducting to the bag sample orifice and replace all teflon tubing with stainless steel to reduce the occurrence of sample hang up interfering with instrument performance.

ARB has been testing vehicles emitting at ULEV emission levels since 1990, and has not encountered significant problems with measuring at these low levels or experienced unusual test-to-test variability. In 1994, ARB tested a ULEV prototype Honda Accord equipped with an advanced emission control system. The vehicle was also tested at Honda's facility in Los Angeles with very good agreement between the two facilities. Recently, ARB performed confirmatory emission testing of the Honda natural gas Civic with certification emission levels one tenth of the current ULEV standard and again achieved good agreement with Honda's test facility in Japan. Staff recognizes, however, that further improvements in emissions measurement capability are needed and will continue to work with industry and the U.S. EPA to improve emission test equipment and methods.

D. COST ANALYSIS

The ARB staff has performed a comprehensive cost analysis of the proposed LEV II exhaust emission requirements applicable to passenger car, light-duty trucks and medium-duty vehicles. Specifically, staff estimated the incremental cost of a ULEV II compared to a ULEV I vehicle for passenger car, light-truck (3751 lb. LVW- 8500 lb. GVW), and medium-duty (8500-10,000 lb. GVW) applications and the incremental cost of a SULEV vehicle for four and six-cylinder passenger car and light-truck applications.

In performing the cost analysis, the cost of parts was not particularly difficult to obtain, but internal corporate costs would have been more difficult since accounting procedures within each company vary, and such costs are not generally revealed. Nonetheless, most vehicle manufacturers now rely increasingly on suppliers of many emission-related parts (e.g. catalysts, air pumps, and many others) to assume more of the engineering development costs and involve them very early in the vehicle development process. Manufacturers rely on these suppliers to produce the final components, rather than source the parts through its own internal facilities. By obtaining parts prices from suppliers, much of the internal costs of automobile manufacturers do not need to be calculated separately, since they are already included in the final cost of parts produced completely by suppliers.

From the following analysis, the following conclusions were drawn:

- Incremental retail costs of ULEV II and SULEV vehicles compared to a ULEV I vehicle are:

Category	ULEV II (in $)	SULEV (in $)
PC	71	131
LDT 1	46	105
LDT 2	184	279
MDV 2	208	-
MDV 3	209	-
MDV 4	134	-

- The cost-effectiveness of vehicles meeting the LEV II program requirements relative to the LEV I program would be favorable, averaging approximately $1.00 per pound of pollutants reduced. Motor vehicle control measures typically range up to $5 per pound of emissions while stationary source controls range up to $10 per pound of emissions reduced. Further, the incremental cost-effectiveness of a SULEV light-truck compared to a ULEV II vehicle is reasonable, ranging from $2.19 per pound to $4.76 per pound, depending on the calculation method used.

1. Cost methodology. The ARB cost estimates reflect many of today's low cost producers that rely heavily on suppliers to assist in the development of vehicles from the initial concept stage through the final production process. The present supplier industry is highly competitive and usually incurs lower labor costs than the automobile manufacturers.

The first step taken by the staff in assessing costs was to define the systems and technologies that would likely be used by manufacturers to meet the required emission levels. The ARB continues to emission test the latest available hardware from component suppliers on numerous passenger-cars and light-trucks that have been assembled by ARB engineering staff. Based on ARB's testing, plus considerable discussion with industry engineers and component suppliers, consensus is forming on the most likely emission system configurations needed to meet the LEV II program requirements. From some of the discussions, and looking back at cost estimates provided for the LEV I program, it appears to ARB staff that manufacturers tend to overestimate the level of technology and amount of hardware needed to meet distant development goals.

For the most part, the cost to the manufacturers for the individual components in each of the systems currently under development are now fairly well established. Once emission systems have been defined and hardware costs determined, ARB's assessment of further costs to vehicle manufacturers becomes less clear since these costs are closely guarded by individual manufacturers and they may vary significantly within the industry, as noted above. Besides the cost of hardware, ARB considered additional variable costs including costs of assembly, shipping and warranty. Further, support costs (research, legal and administrative), investment recovery (machinery and equipment to manufacture the parts, assembly plant changes, vehicle development, and costs of capital recovery) and dealer costs (dealership operating costs and costs of capital recovery) are also included.

2. Cost Analysis. In performing this cost study, ARB departed from industry practice of assigning a fixed percentage of the manufacturer's variable cost to cover indirect costs (which include research, legal, and administrative costs), and instead, analyzed where such long term costs would actually occur. The reference vehicles for this cost study are 2003 model-year ULEV I vehicles for which ARB staff estimated the likely technology content based on early production current LEV I and ULEV I vehicles. For medium-duty vehicles, since currently there are very few engine families certified to ULEV I standards, the likely technology content on a 2003 ULEV I vehicle was estimated based on some confidential pre-production information supplied by automobile manufacturers. Also, staff assumed that engines are generally 4, 6, and 8 cylinder designs, although there are small volumes of 3, 5, 10 and 12 cylinder engines as well. Staff also focused on assessing the cost of ULEVs, and did not analyze LEVs, which would only be less costly than ULEVs. LEVs are really a transitional technology since by 2010, nearly all vehicles will be ULEV II calibrations with some portion of SULEVs and/or ZEVs in order to meet the fleet average requirements. Staff also expects that in order to meet the fleet average requirements, any SULEVs produced would likely be 4-cylinder designs, or maybe some 6-cylinder designs since smaller engines are easier and less costly control than larger ones.

Therefore, no SULEV estimate was made for 8-cylinder engines. For SULEVs, staff estimated that neither HC adsorbers or EHCs would be needed to meet a 0.01 g/mi NMOG standard (staff received some input from industry confirming this for at least the 4-cylinder engines).

Tables II-29 thru II-38 detail the cost analysis and since these tables are in Microsoft Excel format, they are attached to the end of the staff report instead of being interspersed in the text.

a) Variable Costs. In this section the cost of new parts added, additional assembly operations, any increases in the cost of shipping parts and any new warranty implications are addressed.

1) Cost of Part. In order to determine the increases in the cost of parts for meeting ULEV II and SULEV standards, an information gathering and analysis effort was conducted to determine the expected emission system configurations and technologies that would be utilized. Tables II-29-33 provide a detailed breakdown of component usage and costs for all of the emission control systems.

Universal Exhaust Gas Oxygen Sensors (UEGO). Discussions with manufacturers suggest that about half believe an UEGO sensor is important to helping achieve ULEV I or ULEV II emission levels (except for medium-duty vehicles greater than 8500 lb. GVW), while the remainder seem to believe they offer little additional benefit. In any event, the incremental cost of an UEGO continues to decrease, so that the latest estimate is a $10 incremental cost compared to a conventional oxygen sensor. For SULEVs, staff estimated that all manufacturers would use UEGOs for their incremental benefit. They would be used only for primary fuel control, with conventional sensors used downstream.

Air Assist Fuel Injection. For ULEV I or ULEV II vehicles, manufacturers also appear split on the use of air assist fuel injection as well, so that staff estimated manufacturers using them for ULEV I vehicles would continue to use them for ULEV II vehicles. Air assist fuel injection is primarily a technology used for improved HC control, and HC emission requirements are unchanged for the passenger cars. It is expected that light-duty trucks would utilize them in the same proportion as passenger cars for meeting ULEV II requirements. For SULEVs, all vehicles will likely need to utilize this technology in order to avoid more costly controls such as adsorbers or electrically heated catalysts. The cost of air assist fuel injection was estimated to be the same as in previous estimates, or about $2 additional per injector.

Heated Fuel Injectors. Improved HC control for larger displacement engines could result from improved vaporization of fuel from heated fuel injectors. Achieving ULEV II and SULEV HC levels when heating larger exhaust volumes and associated catalysts of the larger light-trucks will possibly lead to utilization of this approach on about half of these vehicles. The incremental cost is estimated to be $3 per injector.

Individual Cylinder Fuel Control. Perhaps one of the most important enablers for achieving ULEV II (including medium-duty vehicles in the 8500-10,000 lb. GVW category) or SULEV NOx emission levels will be the use of individual cylinder fuel control. Accordingly staff estimated all such future vehicles will use it. Although resources will be needed to develop this technology (research and development costs have been included under support costs), no additional hardware would be needed. Discussions with manufacturers indicated they would be utilizing computers with the processing capability needed to carry out this real time modeling for other purposes, so that additional computer costs were not included.

Retarded Spark Timing at Startup/ Electric Air Injection. Quick heating of the exhaust during the cold starting period will require use of retarded spark timing on all ULEV II and SULEV vehicles. In some cases it will be accompanied by modified fuel control and air injection. Modified timing and fuel control would not add hardware cost since these would require only calibration revisions. In those instances where electric air injection is used to further enhance this HC and NOx reduction strategy, staff assumed a cost of $50 for 4-cylinder vehicles and $65 for 6-cylinder and 8-cylinder vehicles for a complete system. The system cost was increased to $75 for medium-duty applications greater than 8500 GVW to account for the higher capacity electric air pump required on such applications. Manufacturers indicated that injecting air at the exhaust valve outlet assisted significantly in reducing HC emissions. Accordingly staff assumed that manufacturers would utilize engine heads with cast air injection passages, and that each head would require its own check valve.

Abbreviated Engine Start-up. Some manufacturers are exploring faster engine cranking speed to achieve near instant engine starting and reduced HC emissions. This could be achieved with an integral starter/alternator design. Staff allowed an additional $10 for this system relative to its emission benefits, although for the total system cost may be greater, especially in initial volumes (but there are cost savings from eliminating other mechanical/hydraulic systems that could all be electrically powered and, therefore, more efficient). This technology was estimated to be most important for SULEVs.

Low Thermal Capacity Exhaust Manifold. The lower thermal mass of these stainless steel manifolds aids retention of exhaust heat for quicker catalyst light-off, and was assumed to be used on about 75 percent of ULEV II vehicles (100 percent of 8 cylinder light-trucks) and all SULEVs.

Improved Catalyst Systems. For each vehicle category, staff considered whether any increases in catalyst volume, precious metal loading, and higher cell density were required in order to meet LEV II program standards and accordingly, estimated associated costs. Except for ULEV II passenger cars and 4-cylinder ULEV II trucks, catalyst volumes were increased for all other vehicles. All ULEV II and SULEV vehicles were assumed to use advanced thermally durable double-layer washcoats, increased precious metal loadings (including rhodium) and higher cell density substrates. ULEV II vehicles were assumed to use 600 cpi substrates while SULEV vehicles were assumed to use 900 cpi substrates. While passenger cars and LDT1 vehicles are estimated to achieve ULEV II standards without an increase in catalyst volume, six and eight cylinder light-trucks may require a significant increase in catalyst volume compared to that needed to meet ULEV I standards.

The specific increase in catalyst volume for various catalyst configurations was calculated by first estimating the sales-weighted catalyst volume of all 1998 models certified in a vehicle category and then applying to it an estimated percent increase applicable to that category. The estimated catalyst volume was then converted to a cost increase, by assuming that a typical catalyst would cost $50/liter. For example, SULEV vehicles are expected to incorporate additional close-coupled pipe catalysts, equivalent to a 20 percent increase in catalyst volume in order to provide additional compliance margin with the standards. It was also assumed that the rhodium loading of the catalyst systems would be increased in order to achieve and maintain very low NOx levels. ULEV II vehicles (including medium-duty vehicles 8500-10,000 lb. GVW) were assumed to use 12 gm/cu. ft. rhodium loading while SULEV vehicles were assumed to use 15 gm/cu. ft. loading. The additional rhodium costs were estimated using a price of $675/troy ounce. The additional catalyst volume, rhodium, and increased cell density costs for the various categories are detailed in Table II-34. Some manufacturers have expressed concern that LEV II requirements can potentially cause shortages of precious metals, thereby driving prices to unacceptable levels. However, industry experts in precious metals have indicated to staff that given adequate lead-time, mines typically increase production to meet market demand with very little temporary price increases, if any. Looking at the time-period from 1969 to 1989, although the demand for precious metals increased many fold, production has been able to keep pace and market forces have continued to keep prices competitive. Consequently, in taking a historical perspective, it appears that concerns regarding the availability of precious metals may be overstated by the automobile industry.

Engine Modifications. Additional cost for engine modifications to improve emissions was ascribed to 6 and 8 cylinder ULEV II vehicles and 4 and 6 cylinder SULEV vehicles. In some cases manufacturers could place an additional spark plug in the combustion chamber for improved combustion stability (and on a 4 valve per cylinder engine, it could delete an exhaust valve and related hardware to partially offset the cost), or they may add a swirl control valve, or make other changes to further improve engine-out emissions and/or increase cold start exhaust temperatures. Ten dollars was allowed for 4 and 6 cylinder engines, $15 for 8 cylinder engines and $20 for medium-duty applications greater than 8500 GVW that have typically lagged in sophistication relative to lighter-duty vehicles.

2) Cost of Assembly. As in the LEV I program, the LEV II program will rely on refinements to conventional technology. Judging from the detailed analysis in the LEV I program concerning increased assembly costs, which included a detailed evaluation of the likely array of catalyst designs and an associated estimate of increased catalyst welding costs, another detailed analysis for the LEV II program assembly costs would likely yield about the same small incremental assembly costs. Most of the assembly cost increase for LEV II program vehicles would be for the installation of greater numbers of electric air injection systems, where needed.

Electrically heated catalysts do not seem likely to be needed. In comparing ARB's previous cost study of the LEV I program (April, 1994), staff estimated an incremental cost per vehicle of $2 for assembling an air-injection system and $0.25 for assembly of an additional catalyst per vehicle.

3) Cost of Shipping. Additional shipping costs were allowed for the increased number of vehicles using electric air injection systems (an additional $0.25 per vehicle using an air pump system).

4) Cost of Warranty. Incremental warranty costs were added wherever air-injection systems were estimated to be utilized at the rate of $150 per system ($100 for parts and $50 for labor) and a failure rate of 0.1 percent was assumed.

Assembly, shipping and warranty costs are detailed in Tables II-39-40.

b) Support Costs. Support costs affecting the retail price of emission requirement changes include research costs, legal coverage for new issues, and administrative increases.

1) Research Costs. Manufacturers have until 2007 to fully phase-in vehicles meeting the LEV II standards. Providing a long lead-time permits large cost savings to the vehicle industry. Incorporation of the required changes can take place systematically within the existing new vehicle development process without incurring redesign to accommodate planned revisions due to frequently changing emission requirements.

Despite the cost savings permitted by long range standards setting, allocation of some additional cost to manufacturers for performing advance system development work is justified when engineering new types of technologies. Consequently, staff has added development cost that includes personnel, overhead and other miscellaneous costs for new technologies such as individual cylinder fuel control and advanced catalyst evaluations. Allowance also has been made for the cost of a fleet of advance development vehicles to carry out the activity. Each advance development vehicle was assumed to cost $100,000. Details of this assessment are shown in Table II-35. The costs incurred under this category have been distributed over 100,000 vehicles per year for a total of 8 years.

2) Legal and Administrative Costs. The ARB does not believe that the most likely hardware to be used will introduce liability issues or administrative increases, especially since manufacturers have had considerable experience for some years now with technologies likely to be used to meet LEV II standards. Consequently, no extra cost beyond what has been included under the LEV I program has been included.

c) Investment Recovery. This portion of the cost analysis includes accounting for machinery and equipment to manufacture parts, assembly plant changes (automation), vehicle development (engineering), and cost of capital recovery.

1) Machinery and Equipment to Manufacture Parts. Since all of the new components will be produced by suppliers, the costs of machinery and equipment to manufacture the part are already included in the piece costs.

2) Assembly Plant Changes (Automation). The primary changes from an assembly point of view are in the exhaust system configuration. Since exhaust systems are usually installed as an assembly, this should not affect the current assembly plant operation. Installation of an electric air pump system (i.e., the pump, power switch, shut-off valve, hoses, tubing and check valves) on those vehicles requiring one probably would not lend itself to automation. Therefore, no additional investment in automatic tooling is expected for air-injection systems (labor costs for installation of the pumps and associated parts was covered earlier).

3) Vehicle Development. Once the vehicle development program is handed off from advance engineering, calibration/certification engineers complete the emission control system design process. Since the new parts expected to be required on LEV II vehicles are not substantially different from current systems, no additional costs have been added beyond those already included under the LEV I program. Please note substantial costs were included in the LEV I program for investment costs for vehicle development such as additional dynamometers, low-emission measurement upgrades and others.

4) Cost of Capital Recovery. The cost of capital recovery (return on investment) was calculated at six percent of the total costs to the manufacturer. At least one large-volume manufacturer employs such an approach to calculate the cost of capital recovery. Table II-36 & II-37 show the calculations for the various vehicle applications.

d) Dealer Costs. Dealership costs include accounting for operating costs and the cost of capital recovery. Since the price of the vehicle would increase due to the LEV II program, it is appropriate to account for the additional interest that the dealer would pay for financing the cost of the vehicle and to cover the commission sales persons will receive as well. An interest rate of six percent was assumed on the incremental cost, and on average, vehicles were presumed to remain in the dealership inventory for one quarter. The increased commission paid to sales persons was calculated at three percent of the differential wholesale price. Dealer costs are shown in Tables II-39 & II-40.

3. Incremental Cost of the LEV II Standards. Tables II-39 & II-40 contain the incremental costs to the consumer of a ULEV II vehicle relative to a ULEV I vehicle for the various classes of vehicles and of a SULEV relative to a ULEV I vehicle.

E. OUTSTANDING ISSUES

1. Additional compliance flexibility. Some manufacturers have requested additional emission categories between TLEV/LEV and between ULEV/SULEV. Staff believes that there is already considerable compliance flexibility in the current proposal and that allowing two additional categories would need further justification. Staff will also further evaluate whether there would be a potential loss in emission benefits from additional categories. Under the proposal, manufacturers have five emission categories to which they can certify: TLEV, LEV, ULEV, SULEV and ZEV. They also have a fleet average requirement that allows them to implement the standards based on their normal changeover schedules and fleet mix. Adding additional categories could permit manufacturers to delay implementation of the cleaner technologies across more vehicle models. Nonetheless, staff has provided an allowance that 4 percent of a manufacturer's LDT2 sales of vehicles with a maximum base payload of 2500 lbs. can certify to a higher NOx standard than the remaining vehicles to allow for potentially higher emissions from vehicles that are designed for more rigorous duty than the "150" or "1500" series vehicles. The 4% allowance reflects the proportion of "250" or "2500" series work oriented trucks with a GVW less than 8500 lbs. that comprise the largest volume manufacturer's LDT2 vehicle fleet.

2. Eliminate Partial ZEV Allowance for Gasoline SULEVs. The environmental community has expressed strong doubts about the efficacy of allowing gasoline-powered SULEVs to receive a 0.2 partial ZEV allowance. However, staff believes that the proposed requirements (extended warranty, useful life and OBD requirements, etc.) would not only require extremely durable vehicles but would provide strong incentive for manufacturers to examine near zero technologies in conventional vehicles that will still comprise a significant portion of the fleet for many years to come. In addition, as mentioned earlier, the partial ZEV allowance proposal would allow manufacturers to successfully maintain true ZEV development efforts by providing this compliance flexibility for the near term.

3. Aftermarket Part Warranty Issues. Another issue that is of concern to independent vehicle repair facilities is the proposed 150,000 mile warranty requirement for vehicles eligible for a partial ZEV allowance and the 8 year/100,000 mile high cost parts warranty for vehicles certifying to the optional 150,000 mile standards.

Manufacturers electing to produce SULEVs that receive partial ZEV credit will need to provide 15 year/150,000 mile warranties on emission related components. Similarly, vehicles receiving additional fleet average NMOG credit would carry a slightly longer warranty on high cost emission-related parts. Staff expects that these vehicles will be designed to not require repairs during this extended interval because it is generally less expensive to improve the durability of a part rather than replace it under warranty. Consequently, there should be an overall reduction in emission-related repairs that would reduce revenue to the vehicle repair industry and aftermarket parts suppliers should manufacturers choose an extended warranty option. On the other hand, there would be a net cost savings to consumers since fewer emission-related repairs would be required throughout the vehicle lifetime. Improvements would also accrue in air quality from vehicles that would not operate for extended periods of time with emission-related malfunctions before owners either seek repairs, operate unrepaired vehicles because Smog Check cost limits for repair are exceeded, or operate unregistered vehicles to avoid repairs.

While on-board diagnostic systems lead to enhanced component durability (manufacturers are concerned that customers would be annoyed by illuminated malfunction lights) and in-use compliance programs ensure that vehicles remain durable for at least 75,000 - 105,000 mile intervals, an extended warranty is the most effective measure for ensuring a minimum of malfunctions throughout the full vehicle life. Because older, malfunctioning vehicles will continue to make healthful air quality unattainable, all reasonable measures are required to address this problem. Staff has concluded that an extended warranty would best ensure improved emission system durability for vehicles certified to optional standards with longer useful life periods.

Improved vehicle durability results in lower overall costs to society than continuing repairs of frequently malfunctioning vehicles. Perhaps helping to offset the effects on the repair industry of improved emission-related component durability from an extended emission warranty could be an increase in repairs due to proliferating comfort and convenience options on new vehicles. Some of these new options include electronic navigation systems; infrared night vision enhancement systems; sophisticated automatic temperature control systems; premium multi-speaker sound systems; collision avoidance systems; programmable electronic mirrors; electric seat adjusters, heaters and massagers; sophisticated dynamic stability control/anti-lock brake/traction control systems; and many more that should create new repair opportunities for this industry.

The independent vehicle repair industry also maintains that extended vehicle warranties lead to a shift in business to franchised dealers. With a loss of emission-related repairs to dealers, the independents maintain there is a further erosion in business because once an owner is in a dealership for warranty repairs, “upselling” of additional maintenance is also likely. They reason that consumers may accept the higher costs of dealership repairs to avoid the additional lost time and difficulties encountered in seeking other necessary maintenance at an independent repair facility.

Staff is not convinced, however, that there would be a net shift in business to dealerships due to an extended warranty. Extended warranties should result in emission-related components that are much less likely to fail in the earlier years of a vehicle’s life. Thus, fewer owners would seek dealer repairs in the earlier years compared with new vehicles owners today, potentially providing an increase in independent repair facility business for vehicle maintenance because of their perceived advantages over dealerships. Although warranty work would increase in later years by dealerships, it is not expected that there would be a net shift in business to dealerships; rather there is likely to be only a shift in timing of the maintenance and repair work during the life of the vehicle between independents and dealers. In addition, as a vehicle ages, customers generally become more cost conscious and are, therefore, even less likely to be influenced by upselling efforts of dealerships.

There is additional insight into this issue provided by the J.D. Power and Associates 1998 Service Usage and Retention Study as reported in *Automotive News* (June 1998). The study found that 46 percent of all customer-paid service work goes to independent service providers.

The reasons given for choosing the independent service providers is convenient location, price, and speed of service. While these are the reasons they choose the independents, the reason consumers leave the dealerships is quite different. The primary reason given for leaving the dealerships is dissatisfaction with service during the warranty period. Dealership customers said they had to take their vehicles back 70 percent of the time vs. 30 percent for independent providers. This may be due to the fact that warranty work is often more difficult to diagnose and involves more difficult repairs whereas independents more often perform maintenance work which is simpler and takes less time. *Automotive News* stated, "maintenance customers are easier to satisfy than repair customers. Dealerships get more of the repair work; aftermarket service providers get more maintenance work." This study then suggests that warranty work tends to actually steer consumers to the independents, rather than to the dealerships.

In view of these considerations, staff is not convinced that an extended warranty will create significant shifts in consumer provider choices and still remains the best solution to improve emission system durability.

Members of the independent vehicle repair industry also believe that the ARB lacks the authority to require warranties for longer periods than the periods specified in the state warranty statute, Health and Safety Code section 43205. It is the opinion of ARB legal counsel that state law does not preclude the ARB from including a longer warranty period as one of the elements of a more stringent *optional* standard where no manufacturer is required to certify any vehicles to the standard if the manufacturer does not choose to do so.

4. Does higher ozone on weekends in the South Coast Air Basin imply that NO_X control is unnecessary? Several studies in the past decade have documented that outdoor levels of ozone on the weekend are generally higher than on weekdays in the South Coast Air Basin (SoCAB), when emissions of ozone precursors — NOx and hydrocarbons — are presumably lower. The "weekend-weekday difference" has recently been analyzed by ENVIRON International Corporation in a study sponsored by the American Automobile Manufacturers Association (AAMA).[2] Consistent with previous studies, the ENVIRON investigators found that outdoor levels of NOx are lower (even more so than hydrocarbons) on weekend mornings than on weekday mornings. Based on what we believe to be an inconclusive analysis, they inferred that NOx control is counterproductive to reducing ozone levels. There are observations reported by ARB staff and others that lead to different conclusions on NOx control, as discussed below.

Many sites in the SoCAB show lower NOx levels from 6 to 10 a.m. on weekends than during weekdays. While ozone peaks are generally higher on Saturdays than during the week,

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[2] Stoeckenius, T. et al., Analysis of Weekend-Weekday Differences in Ozone and Ozone Precursors in the South Coast (Los Angeles) Air Basin, ENVIRON International Corporation report prepared for American Automobile Manufacturers Association, July 1998

this is not true at all monitoring sites. Furthermore, in a comparison of Saturdays to Sundays, lower morning NOx coincides with lower ozone at some sites. These findings contradict ENVIRON's conclusion that lower NOx invariably leads to higher ozone. Another observation that is inconsistent with ENVIRON's analysis is that ozone levels have declined in the SoCAB — more than anywhere else in the world — in response to California's program to control emissions of both NOx and hydrocarbons. Furthermore, over at least the past 15 years, ozone levels have declined on all days of the week.

The weekend-weekday effect is a complex, three-dimensional phenomenon that may be explained by differences in the amounts and timing of emissions during weekends as compared to weekdays. Anecdotally, traffic is higher on Friday night than during the rest of the week, and the resulting additional emissions may carryover to Saturday and create more ozone. Also, evidence is emerging that passenger cars are driven similar numbers of miles (within 80 to 90 percent) each day of the week, but that the weekend activity occurs later in the day when ozone formation from NOx is more chemically efficient. This observation would help explain why NOx levels are lower on weekend mornings and ozone is higher, although it is also likely that NOx emissions from diesel-fueled vehicles are reduced due to lower truck activity.

In the absence of tested emission inventories for each day of the week, our current understanding of the weekend-weekday difference is far from complete. Thus, to state any conclusions on control strategies with certainty is not appropriate at the present time. The ARB funded two studies with the University of California at Los Angeles on the weekend-weekday difference, and staff conducted several analyses, but again no definitive conclusions could be reached without day-of-week emission inventories. During the summer of 1997, the ARB funded a study with the University of California at Davis to collect vehicle activity data each hour of the week throughout southern California. This extensive database is currently being analyzed at Davis, and a more definitive understanding of day-of-week emissions will be achieved within a year.

F. REGULATORY ALTERNATIVES

Staff considered the following regulatory alternatives to the proposed LEV II exhaust amendments.

1. Do not amend current California LEV Program. Measure M2 of the California SIP calls for additional ROG plus NOx emission reductions from light-duty vehicles using advanced emission control technology. In order to accomplish these goals, the current LEV emission standards need to be amended to incorporate more stringent emission standards that could be achieved using advanced control technology. The targeted emission reductions in Measure M2 would not be achieved unless lower standards were proposed.

2. Adopt Federal Tier 2 Standards. The federal Clean Air Act requires U.S. EPA to adopt, under certain conditions, more stringent light-duty vehicle emission standards, known as

Tier 2 standards after the 2003 model year. These standards may be similar to the current California LEV standards, although U.S. EPA may choose to adopt more stringent standards if needed. The U.S. EPA is currently investigating the feasibility of adopting lower light-duty vehicle emission standards that could be commensurate with the proposed LEV II standards. These standards are anticipated to be promulgated some time in the next few years with an anticipated 2004, 2005 or 2006 model year implementation date. California plans to harmonize to the greatest extent possible with the phase-in of the federal Tier 2 standards once they are promulgated to allow manufacturers to more efficiently coordinate their California and federal implementation schedules. However, because California's air pollution problems are unique and more severe than in other parts of the country, staff determined that in order to achieve the emission reduction goals of SIP Measure M2, it would be necessary to implement standards that were specific to California and would achieve the necessary emission reductions beginning with the 2004 model year.

3. Adopt Less Stringent LEV II Standards. Staff believes that consideration of less stringent standards would put the state at the risk of not achieving the emission reduction goals of the SIP. Although AAMA presented a proposal that achieves the emission reduction goal of Mobile Source SIP Measure M2, it falls short of the emission reductions of the Black Box estimated for the staff's LEV II proposal by approximately 7 tpd. Given the large amount of emission reductions that are still needed from other areas of the SIP and to reduce ambient concentrations of fine particulates, staff believes that any relaxation of the LEV II proposal would seriously impact our ability to achieve the SIP goals.

The essence of AAMA's proposal is the removal of 6000 - 8500 lb. GVW trucks from the LDT2 category and placing them in a separate category with less stringent standards. The vehicles affected by this proposal include the highest selling vehicles in the nation, such as the Ford F-150, Dodge Ram and Chevrolet Silverado pick-up trucks, and many of the very popular sport utility vehicles -- Ford Expedition, Chevy Suburban and Yukon. The reason for the proposal is that AAMA does not believe that the LEV II proposal reflects "the physical reality that heavier vehicles with increased functionality have inherently higher emissions than the largest passenger cars." However, based on staff's technological feasibility demonstration in Section II.C of this staff report, the proposed LEV II standards can be met by these vehicles with sufficient headroom to ensure in-use compliance. In addition, even though AAMA characterizes its proposal as still affecting 85% of the fleet, this 15% that remains in the 6000 - 8500 lb. category comprises almost 33% of the NOx emission reductions that are anticipated in staff's proposal, or approximately 17 tpd.

AAMA's proposal for the above 6000 - 8500 lbs. trucks includes the following modifications:

- a separate, more lenient, percentage implementation schedule;
- testing at the more lenient loaded vehicle weight (curb weight plus 300 lbs.) rather than at the adjusted loaded vehicle weight (curb plus half payload);

- a SULEV NMOG standard that is twice that of staff's proposal;
- a LEV NOx level 6 times higher than the proposed LEV II standard; and
- a ULEV NOx level twice the staff proposal.

For passenger cars and light-duty trucks under 6,000 lbs. GVW, the AAMA proposal includes lowering the ULEV NOx standards for passenger cars and light-duty trucks under 6,000 lbs. GVW to offset the relaxation of the heavier light truck standards. However, AAMA is also proposing to double the LEV NOx standard, triple the SULEV NMOG standard and more than double the SULEV NOx standard for passenger cars.

Finally, AAMA/EMA requested that ARB adopt combined NMOG plus NOx emission standards rather than separate NMOG and NOx standards. While this proposal would provide additional flexibility to automobile manufacturers, it would also hamper ARB's efforts to achieve air-quality goals within the state. Specifically, different regions in California have varying needs in terms of NOx and hydrocarbon emission reductions in order to achieve attainment. Permitting a combined NMOG and NOx standard would result in greater uncertainty in predicting future air quality conditions in specific regions, and also would not permit targeting either more NMOG or NOx reductions in future motor vehicle emission standards rulemakings that would be needed to address the state's most troublesome air quality goals. In addition, as emission standards decrease in the ULEV to SULEV range, there remains little opportunity to take advantage of a combined standard.

Industry has countered that the Board has adopted a combined hydrocarbon plus NOx standard for other mobile source rulemakings such as utility engines and heavy-duty diesel vehicles. However, the Board has adopted a combined standard primarily in those cases where there is preponderance of one criteria pollutant (e.g. NOx) relative to the others such that emission inventory and modeling would not be compromised and targeting specific pollutants for reductions in future rulemakings would remain practical, and providing this additional flexibility would not diminish the emission reduction from "targeted" pollutant significantly.

Given staff's demonstration of technological feasibility and cost-effectiveness set forth in this report, our air quality goals would be compromised if relaxed standards were proposed.

III. SUMMARY OF EVAPORATIVE EMISSION PROPOSAL

A. BACKGROUND

Evaporative emissions from motor vehicles account for approximately half of the ROG motor vehicle emission inventory in the state. These emissions are due to gasoline vapors escaping from the vehicle into the atmosphere, and are highly dependent on ambient temperatures and the characteristics of the gasoline fuel. For example, high ambient temperatures and large changes in ambient temperatures throughout the day, such as those that occur in the summer months on many ozone-nonattainment days, exacerbate the potential for high evaporative emissions.

1. Evaporative Emissions. Evaporative emissions are classified into three types: running loss, hot soak, and diurnal emissions. Running loss emissions occur when the vehicle is driven and can originate from numerous sources within the fuel system and from fuel vapor overflow of the on-board carbon canister. Hot soak emissions occur immediately after a fully-warmed up vehicle is stationary with the engine turned off and are due to high underhood temperatures. Diurnal emissions occur when a vehicle is parked and are caused by daily ambient temperature changes. Most of these emissions result during increases in ambient temperatures which cause an expansion of the vapor in the fuel tank.

The main evaporative emission control device is the on-board carbon canister. Excess fuel vapors in the fuel tank are routed to the carbon canister for storage instead of being released into the atmosphere. The carbon canister is regenerated during vehicle operation when the fuel HC vapors stored in the canister are purged into the engine's intake system and subsequently burned in engine combustion. Evaporative emissions from the canister occur when the generated fuel vapors going to the canister are greater than its storage capacity, and thus, breakthrough of the canister occurs. Another main source of evaporative emissions is through permeation of hoses, joints, and plastic fuel tanks. Elastic hoses, made of rubber, plastic, and other materials, are used in areas of the fuel system where flexibility is needed. Other sources of evaporative emissions include engine breathing losses and fuel cap leakage.

2. Enhanced Evaporative Standards and Test Procedures. Beginning with the 1995 model year, the "enhanced" evaporative standards and test procedures were implemented, requiring effective control of the three types of evaporative emissions. Two test sequences are applicable for certification: (1) the 3-day diurnal-plus-hot-soak sequence ensures that running loss emissions, high-temperature hot soak emissions, and three days of diurnal emissions are controlled, and (2) the 2-day diurnal-plus-hot-soak sequence verifies that the canister is well purged during vehicle operation. During the evaporative tests, the vehicle is placed inside a sealed enclosure at elevated temperatures. The ambient concentration of hydrocarbon in the enclosure is measured to determine the amount of evaporative emissions released. Due to the nature of the testing, all vehicle evaporative emissions, including fuel and non-fuel, are measured. Non-fuel emission sources include interior trim, body paint, and tires. Compliance with three separate emission standards is required for the vehicle's useful life: a stand-alone running loss standard, a combined highest three-day diurnal plus high-temperature hot soak standard, and a combined highest two-day diurnal plus moderate-temperature hot soak standard. These standards are shown in Table III-1.

Table III-1
Current Enhanced Evaporative Standards

Class of Vehicle	**Three-Day Diurnal + Hot Soak (grams per test)**	**Two-Day Diurnal + Hot Soak (grams per test)**	**Running Loss (grams per mile)**
Passenger Cars, Light-Duty Trucks	2.0	2.5	0.05
Medium-Duty Vehicles (6,001 - 8,500 lbs. GVWR)			
with fuel tanks < 30 gallons	2.0	2.5	0.05
with fuel tanks ≥ 30 gallons	2.5	3.0	0.05
Medium-Duty Vehicles (8,501 - 14,000 lbs. GVWR)	3.0 [(1)]	3.5	0.05
	2.0 [(2)]	3.5	0.05
Heavy-Duty Vehicles (over 14,000 lbs. GVWR)	2.0	4.5	0.05
Hybrid Electric PCS, LDTs and MDVs	2.0	2.5	0.05

(1) The standards in this row apply to medium-duty vehicles certified according to the exhaust standards in Title 13, CCR, Section 1961.
(2) The standards in this row apply to incomplete medium-duty vehicles certifying to the exhaust standards in Title 13, CCR, Section 1956.8.

Despite notable evaporative emission reductions with the enhanced evaporative regulation, approximately half of the HC motor vehicle emission inventory projected for 2010 statewide continues to be evaporative emissions. Thus, due to its significant contribution to the HC emission inventory, a reduction in evaporative emissions beyond that achieved by the enhanced regulation would contribute to improved air quality in California.

3. Rulemaking Considerations. During the regulatory development of the evaporative proposal, staff considered possible reductions to the evaporative standards (diurnal-plus-hot-soak and running loss) and refueling standards (to control emissions that result from refueling of the vehicle fuel tank) based on the best available technology. Reductions in evaporative emissions from conventional systems as well as eliminating all fuel-related evaporative emissions were considered. Staff conducted numerous meetings with automotive manufacturers to gather information as well as performed evaporative emission testing on production vehicles.

After careful consideration, staff's analyses showed that significant reductions in the diurnal-plus-hot-soak standards are technologically feasible; this proposal is presented in section B. However, only limited information and data are currently available on reducing vehicle refueling emissions and running loss emissions using vehicle technology. In addition, the cost of an advanced fuel/evaporative system that is capable of completely eliminating fuel evaporative emissions is currently high. Therefore, only reductions in the diurnal-plus-hot-soak standards are proposed at this time. Staff plans to continue gathering vehicle refueling and running loss emission information and to consider modifications in a future rulemaking.

B. PROPOSED AMENDMENTS TO CALIFORNIA'S ENHANCED EVAPORATIVE EMISSION REGULATIONS

The staff recommends that the Board adopt reduced evaporative emission standards by amending section 1976, Title 13, California Code of Regulations, and incorporating the new document, "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles." The proposed regulatory language is contained in the appendices. Staff also proposes minor modifications to the evaporative test procedures in order to improve the calibration of equipment for low-level evaporative emission measurements and to clarify and update other test procedure requirements.

1. Proposed Reduced Evaporative Emission Standards. The staff proposes reduced evaporative emission standards, as shown in Table III-2, for the three-day diurnal-plus-hot-soak test and the two-day diurnal-plus-hot-soak test. The proposed standards are expressed in total vehicle HC evaporative emissions and include both fuel and non-fuel vehicle emissions. As in the case of the current standards, they would be applicable to gasoline-fueled, liquefied-petroleum-gas-fueled, and alcohol-fueled passenger cars, light-duty trucks, medium-duty vehicles, and heavy-duty vehicles, including flexible-fuel vehicles, dual-fuel vehicles, hybrid-electric vehicles, and zero-emission vehicles with fuel fired heaters. The running loss standards shown in Table III-2 are unchanged from the current requirements and are shown to illustrate the full set of evaporative standards for compliance purposes.

The proposed standards for passenger cars are significantly reduced from the current evaporative standards, almost an 80 percent reduction. The standards in the other vehicle categories are based on the proposed passenger car standards and are incrementally increased to account for higher non-fuel emissions of the larger vehicles. Data suggest that larger vehicles may have greater non-fuel evaporative emissions, likely due to an increased amount of interior trim, vehicle body surface area, and larger tires. Note that the proposed LEV II vehicle categories for light-duty trucks and medium-duty vehicles are reflected in the table. As discussed in Part II, the upper weight limit of the newly proposed light-duty truck category would be increased from 6,000 pounds GVW to 8,500 pounds GVW, consequently eliminating the previous medium-duty vehicle category in that range. Two sets of evaporative standards are proposed for the new light-duty truck category to account for the increased potential of higher non-fuel vehicle evaporative emissions for the larger vehicles in this category.

The proposed three-day diurnal-plus-hot-soak standards are numerically lower than the proposed two-day diurnal-plus-hot-soak standards to reflect that the three-day diurnal-plus-hot-soak standards are technology forcing. The main function of the two-day diurnal-plus-hot-soak standards is to ensure adequate purging of the carbon canister during vehicle operation. Compliance with the proposed evaporative standards would require improvements to conventional evaporative/fuel systems, as discussed in section C.3.

Table III-2
Proposed Evaporative Emission Standards

Class of Vehicle	**Hydrocarbon Standards**		
	Three-Day Diurnal + Hot Soak (grams per test)	**Two-Day Diurnal + Hot Soak (grams per test)**	**Running Loss* (grams per mile)**
Passenger Cars	0.50	0.65	0.05
Light-Duty Trucks (under 8,501 lbs. GVWR)			
under 6,000 lbs. GVWR	0.65	0.85	0.05
6,001 - 8,500 lb. GVWR	0.90	1.15	0.05
Medium-Duty Vehicles (8,501 - 14,000 lbs. GVWR)	1.00	1.25	0.05
Heavy-Duty Vehicles (over 14,000 lbs. GVWR)	1.00	1.25	0.05

* The running loss standards shown here are unchanged from the current requirements and are shown to illustrate the full set of evaporative standards for compliance purposes.

2. Proposed Useful-Life Requirement. The current useful-life requirements in which the vehicle must comply with the applicable evaporative emission standards are 10 years or 100,000 miles, whichever first occurs, for passenger cars and light-duty trucks; 11 years or 120,000 miles, whichever first occurs, for medium-duty vehicles; and 8 years or 110,000 miles, whichever first occurs, for heavy-duty vehicles. The proposed evaporative (running loss, diurnal, and hot soak) useful-life requirement is 15 years or 150,000 miles, whichever first occurs, for all applicable vehicles.

During the first 10 years of a vehicle's life, very little, if any, deterioration of evaporative emissions is expected, as suggested by vehicle certification data and available in-use industry data. However, there are concerns that significant evaporative emission deterioration may occur for vehicles more than 10 years old. These older vehicles are likely to experience fuel and evaporative component failures, resulting in evaporative emission increases many times that of a vehicle with a properly operating evaporative system. For example, elastomeric hoses used in the fuel and evaporative system, typically made of rubber or plastic, are prone to crack after years of usage, resulting in leaks.

Current data show that over 20 percent of the vehicle fleet in California are between 10 and 15 years old. Although these older vehicles are usually driven relatively less and have shorter trips than newer vehicles, diurnal and hot soak emissions continue to be emitted. In addition, the ARB's Emission Inventory Model shows that almost 20 percent of the total vehicle miles traveled in California are driven from vehicles that have accumulated between 100,000 and 150,000 miles, thus contributing to running loss emissions. Therefore, a significant portion of the vehicle fleet and of the vehicle miles traveled are from these older vehicles. The extended evaporative durability proposal would require manufacturers to demonstrate that the evaporative emission components are durable on older vehicles. The defects warranty requirements remain unchanged, as set by state regulations, at 3 years or 50,000 miles, whichever first occurs, for lower-cost emission related components and at 7 years or 70,000 miles, whichever first occurs, for high-cost emission related components.

3. Proposed Phase-in Schedule. The phase-in schedule for the implementation of the proposed evaporative standards is shown in Table III-3. As shown, the proposed implementation schedule is 40 percent in the 2004 model year, 80 percent in the 2005 model year, and 100 percent in the 2006 and subsequent model years. Compliance with the proposed phase-in schedule can be met with any mix of the applicable vehicles. In previous enhanced evaporative phase-in schedules, compliance was met based on two separate vehicle groups of (1) passenger cars and (2) the combined light-duty vehicles, medium-duty vehicles, and heavy-duty vehicles. In this proposal, allowing compliance based on the entire fleet would allow increased flexibility for a manufacturer. Additionally, in response to industry comments, optional alternative phase-in schedules are proposed to allow added compliance flexibility for manufacturers and to allow early implementation of the evaporative standards before the 2004 model year should a manufacturer choose to do so. The proposed methodology to calculate alternative phase-in schedules is the same as that provided for Supplemental Federal Test Procedure compliance and On-Board Diagnostic II compliance.

Table III-3
Proposed Phase-in Implementation Schedule for the Evaporative Standards

2004 MY	2005 MY	2006 and subsequent MY
40%	80%	100%

4. Test Procedure Modifications. Lowering the emission standards by the degree proposed will require some improvements to the current quality control procedures to ensure that the diurnal and hot-soak measurements are accurate at the proposed low levels. Currently calibration procedures are routinely performed and include the emission analyzer measurement of samples at known concentrations (recovery and retention checks). These checks ensure that the enclosures used for testing do not significantly leak or retain hydrocarbons. In current recovery and retention testing, between two and six grams of propane are injected into the enclosure, which is then sealed at a temperature of 105° F. The recovery measurement is performed after the propane is mixed and stabilized for up to 300 seconds. The propane is then measured and the amount compared with the amount injected. The difference must be less than 2 percent of the original injection amount for the enclosure to pass the test. If the recovery test is passed, then the test continues and the ambient temperature is cycled over the 24-hour diurnal temperature cycle. At the end of the cycle, the retention measurement is made. The propane is then measured and compared to the initial amount injected. If the difference is less than 3 percent of the original, then the test is valid.

During recent ARB test programs, the monthly recovery and retention checks were performed using one gram or less of propane, and both enclosures have regularly passed these tests. The proposal calls for the recovery and retention checks to be performed using the lower concentration of one gram of propane, with the same percent limits still applicable, to ensure measurement accuracy at emission levels near the proposed standards. In addition to the proposed regulatory change to the recovery and retention checks, non-substantive modifications were also made to clarify testing requirements.

5. Optional Zero-Fuel Evaporative Standards. Optional zero-fuel evaporative standards are also proposed that would allow a manufacturer to generate credits to meet the ZEV requirements and the NMOG fleet average requirements. The proposed zero-fuel evaporative standards would require the elimination of fuel evaporative emissions. The use of advanced fuel/evaporative systems that are capable of eliminating fuel evaporative emissions would be required for compliance with the proposed zero-fuel evaporative standards. These advanced systems include a sealed fuel system, a pressurized fuel system, and designs that would minimize evaporative emissions and fuel vapor generation, such as a bladder fuel tank and an improved insulated fuel tank. The proposed methodology to generate credits on a vehicle complying with the zero-fuel evaporative standard is discussed in Part II.

C. TECHNOLOGICAL FEASIBILITY OF PROPOSED STANDARDS

The following technological feasibility analysis has been performed for the proposed passenger car evaporative emission standard of 0.50 grams per three-day diurnal-plus-hot-soak test. Higher standards are applicable to light-duty trucks, medium-duty vehicles, and heavy-duty vehicles. Staff believes these standards can be met with relatively simple improvements to current evaporative and fuel systems. Technological feasibility for the proposed evaporative standards has been studied in two phases: modifying and testing of vehicles meeting the proposed emission standard levels, and an assessment of the hardware changes manufacturers will likely make on vehicles to comply with proposed emission standards.

In addition to the assessment of vehicle modifications, staff has also conducted analyses of the contribution of non-fuel vehicle background emissions and of testing variability. Staff conducted a series of meetings with automotive manufacturers to gather information on non-fuel vehicle background emissions and other issues, and tested two vehicles at the Haagen-Smit Laboratory to study non-fuel emissions. To investigate the variability of evaporative emission testing and to determine the compliance margin (headroom) needed as a result, staff analyzed in-use Industry data. Finally, staff assessed the feasibility of the proposed extended useful life requirement.

1. ARB Test Program. In the test program, staff tested five 1998 model-year vehicles. These vehicles were selected based on low certification evaporative emission values. Vehicle descriptions are given in Table III-4 below. To ensure that the vehicle did not have artificially high non-fuel evaporative emissions, the test vehicle was at least six months from the production date and had a minimum odometer reading of 2,500 miles. These vehicles were tested initially in the as-received condition and were tested thereafter in a modified configuration until the lowest evaporative emission levels were reached.

Testing was conducted using Phase II certification fuel with the three-day diurnal-plus-hot-soak evaporative procedure and a shortened version of this procedure (consisting of an abbreviated vehicle preconditioning, a high-temperature hot soak test, and a one-day diurnal test.) The shortened diurnal-plus-hot-soak test was designed for research purposes to give similar emission results as certain portions of the full test procedure and to minimize testing time. The shortened test procedure was used to initially evaluate the emission benefits of the vehicle modifications. The full three-day diurnal-plus-hot-soak procedure was used to fully assess the final evaporative test results of the modified vehicle. For both tests, the diurnal temperature cycle from 65° F to 105° F was used, with hot soak testing performed at 105° F.

Table III-4
Test Program Vehicles

Vehicle	Engine Displacement
Honda Civic	1.6 L
Hyundai Accent	1.5 L
Toyota Corolla	1.8 L
Toyota Camry	2.2 L
Toyota Avalon	3.0 L

Vehicle modifications were performed on each vehicle to reduce fuel evaporative emissions. Most of these modifications are not intended for production purposes and are considered analogous methods to reduce emissions. For example, using Tedlar and shrink tape around the fuel line connections are representative of improved, well-sealed connectors. The description of actual vehicle modifications that can be performed on production vehicles is provided in section C.3., “Potential Technology for Compliance with Proposed Standards.”

In general, the same modification procedure was applied to each vehicle although not every modification was performed on every vehicle. The first modification was the use of an additional canister to trap any vapors that would ordinarily be emitted from the vehicle canister.

The use of an additional canister was not envisioned as an actual design scenario for manufacturers to use. Rather, it was intended to represent the use of a slightly larger or additionally chambered canister which staff believes would yield nearly zero (< 0.04 g) daily emissions when tested under these conditions. The next modification made was the addition of a carbon intake air filter adjacent to the clean side of the normal air filter. This additional filter served to greatly reduce the hydrocarbon vapors that are gradually emitted to the environment from the engine during diurnal episodes and hot soaks.

Following these modifications, fuel line connections were sealed, using a combination of Tedlar (a non-permeable plastic) and shrink tape. In this case, the shrink tape served to hold the sealing material in place tightly against the fuel system connection. Rubber, nylon and plastic fuel lines were also wrapped with a combination of two different plastic films. Both films are believed to be generally impermeable to fuel hydrocarbons which would normally permeate through these fuel lines.

The last series of modifications that staff performed were the sealing of the fuel pump assembly exterior and the sealing of the fuel fill-pipe hose (an elastic, flexible tube connecting the vehicle fill-pipe to the fuel tank where gasoline is introduced during a refueling event). The fuel pump is mounted inside the fuel tank and sends gasoline to the engine. Although the assembly is sealed, significant vapor leaks still occur in current vehicles. In order to seal the fuel pump assembly, Tedlar and an automotive gasket sealant were used to re-seal the original seal. The fuel fill-pipe neck connections were sealed using the same Tedlar-shrink tape method as previously described for the fuel system connections. In addition, the fuel fill-pipe hose surface was wrapped using the same type of plastic films utilized for the fuel system hoses. Finally, a stiffer fuel cap without a pressure relief valve was used. This fuel cap generally showed lower evaporative emissions than the standard OEM fuel cap.

The vehicles in the test program were modified and evaporative emission tested. The previous series of modifications yielded significant emission reductions, as shown in Table III-5 below. Testing on the Honda Civic was not completed due to vehicle malperformance (as determined by Honda representatives.) The vehicle was thus removed from the test program and is not included in the table.

Table III-5
Test Data from the Evaporative Test Program

Vehicle	Baseline Diurnal + Hot Soak Results (g/test)	Final Diurnal + Hot Soak Results (g/test)	Reduction (g/test)
Hyundai Accent	0.497	0.261	0.236 (47%)
Toyota Corolla	0.278	0.220	0.058 (21%)
Toyota Camry	0.525	0.407	0.118 (22%)
Toyota Avalon	0.544	0.307	0.237 (44%)
Average	0.461	0.299	0.162 (35%)

The final diurnal-plus-hot-soak average result of 0.30 grams per test is well below the proposed passenger car standard of 0.50 grams per test, and allows for compliance margin for issues such as production tolerances and test cell-to-test cell variability. No two-day diurnal-plus-hot-soak tests were performed during the test program. However, it appears likely that the two-day diurnal-plus-hot-soak standards can be reduced proportionately to the three-day diurnal-plus-hot soak standards since they have similar emission sources. Although the two-day diurnal-plus-hot-soak test is primarily designed to ensure adequate canister purge during vehicle driving, the primary emission sources other than the canister are the same as in the three-day diurnal-plus-hot-soak test. Canister emissions may be similar in the two tests and are highly dependent upon the purge strategy used, and canister size and design. Therefore, the potential technologies described in section 3 would not only reduce three-day diurnal-plus-hot-soak emissions but also those from the two-day diurnal-plus-hot-soak test. By applying the proposed 75 percent reduction in the three-day diurnal-plus-hot-soak emission passenger car standard, the proposed two-day diurnal-plus-hot-soak standard then would be 0.65 grams per test.

In addition to the vehicles listed in Table III-5, staff also tested a Chevrolet Malibu, a vehicle with higher than average certification evaporative emissions. The baseline emission result of the Malibu was 1.1 grams per test on the shortened diurnal-plus-hot-soak test sequence. All the modifications performed on the four test vehicles were also made to the Malibu except that the production fuel cap was modified by adding another seal to the sealing surface instead of using the replacement fuel cap without a relief valve. The design of the Malibu fuel and evaporative system resulted in difficulty in effectively performing the analogous modifications. For example, the components attached to the fuel tank are spread out over such a wide surface area that the Tedlar/gasket sealant combination could not effectively cover all the components to reduce connection permeation. Thus on the Malibu, it is likely that the production modifications to fuel tank connections would result in greater emission reductions than found with the analogous modifications. The modified emission result was 0.59 grams per test on the three-day diurnal-plus-hot-soak test, a reduction of 0.51 grams per test or 46 percent (as compared to the baseline result conducted on the shortened test procedure). As noted above, production modifications would likely result in further reductions in fuel evaporative emissions. In addition, design modifications to minimize the number of fuel line connections, the amount of permeable materials, and the number of fuel tank connections would also likely reduce fuel evaporative emissions.

In order to better understand evaporative emissions from medium-duty vehicles, staff also performed testing on a 1999 model-year Chevrolet Suburban. This vehicle was manufactured in April 1998 and had accumulated over 15,000 miles. The three-day diurnal-plus-hot-soak test procedure was used to evaluate vehicle evaporative emissions. The modifications made to this vehicle consisted of replacing the fuel cap and adding a carbon filter to the vehicle's air intake system. The baseline emission result for the Suburban was 0.60 grams per test. The emission result for the vehicle in the modified condition was 0.53 grams per diurnal-plus-hot-soak test, a reduction of 0.07 grams or 12 percent with only minor modifications. Other modifications, such as those previously mentioned in this section, could result in further reductions of fuel-related emissions.

2. Current Evaporative Emission Technology. The ARB staff has studied current technology in its assessment of future technology needs for compliance with the proposed standards. Figure III-1, attached at the end of the Staff Report, shows a schematic of a vehicle fuel and evaporative system. On an ORVR-equipped vehicle, the location of the carbon canister will likely be in the rear of the vehicle instead of in the engine compartment as shown in the Figure. The future compliance technology, as described in section 3, "Potential Technology for Compliance with Proposed Standards," consists of upgrades to current emission technology, with few new or additional parts necessary for compliance. Today's evaporative systems are composed of the following technologies.

(a) Fuel Tanks and Associated Connections. Currently, fuel tanks are made of either carbon steel or plastic. Today's plastic tanks are significantly improved from those used in the past; the improved tanks consist of coextruded, multilayer construction with a barrier layer of ethylene vinyl alcohol (EVOH) to reduce permeation losses. Fuel tanks also contain several connections to other components including the fuel line to the engine, the return fuel line from the engine (if used), a vapor line(s) to the canister, the float device for measuring fuel tank level, and the fuel fill-pipe. The fuel tank also contains the fuel pump assembly which delivers fuel to the fuel line; a seal around the assembly is required inside the tank to minimize tank vapor losses. Figure III-2 shows a schematic of the fuel tank and its associated connections. Detailed descriptions of these connections are given below.

-Fuel line connections: (1) Plastic o-ring " quick connector" where two plastic pieces snap together creating a seal due to pressure on the o-ring. (2) A metal-to-metal threaded fitting where the seal is achieved through the torque placed on the metal or o-ring (if used); the return fuel line is typically similarly connected to the tank.

-Vapor line connections: The vapor lines are generally secured to the fuel tank vapor vent by means of a simple hose clamp, with the use of barbs on the sealing surface to ensure a tighter fitting.

-Fuel sending unit connection: The fuel sending unit, or fuel pump is mounted to the interior of the fuel tank. The unit contains an internal gasket, generally made of nitrile rubber (a relatively high-permeating material) and may be untreated for permeation or treated to reduce permeation.

-Fuel fill-pipe connection: The fuel tank connects with the fuel cap area through means of a metal fill-pipe, which generally contains two separate metal pieces. One piece is part of the fuel tank, while the other is connected to the vehicle body. To allow flexibility and relative motion of the metal pieces since they are secured to two different areas, the metal pieces are connected via a flexible hose. The connection of this hose with the fuel tank and the other metal piece is generally a simple hose clamp, as with the vapor line connections.

(b) Fuel System Lines and Associated Connections. Fuel vapor lines, whose primary purpose is evaporative emission control of fuel tank vapors, are generally constructed of nylon or rubber material. These lines may not be considered significant sources of hydrocarbon emissions. Fuel lines, designed to transfer fuel from the tank to the engine and back again (if applicable), do emit significant amounts of vapor through permeation, primarily through the elastic hoses where the fuel permeates through the hose wall and escapes into the environment. These hoses are presently constructed using a barrier layer of nylon-12, fluoroelastomer, and other low-permeation materials. Connections between fuel lines are generally either “quick-connectors,” metal-to-metal fittings, or hose clamps.

(c) Current Canisters. Vehicles use activated carbon canisters to adsorb hydrocarbon vapors generated in the fuel tank during vehicle operation or while the vehicle is parked between engine operation. These events are known as hot-soak events and diurnal events, with diurnal events constituting longer duration episodes. The canisters contain activated carbon and have ports to allow purging of the collected vapors to the engine. This purging occurs when the vehicle is driven. Air is drawn into the canister, “flushing” the carbon bed of fuel vapors; the air/fuel mixture is then sent to the engine for combustion. Most canisters today are divided into two carbon compartments separated by an air gap or filler material. This minimizes in-canister vapor migration toward the exit vent and thus reduces vapor emissions to the environment. Vehicles today emit approximately 0.12 grams of fuel vapor from the canister during one day of a standard certification test (AAMA/AIAM presentation given at a December 1997 LEVII Public Workshop.) This number would likely be significantly higher if no carbon compartmentalization was employed.

(d) Current Fuel Caps. Fuel caps are used to seal the fuel tank and to prevent release of vapor emissions from the fuel tank. These familiar caps twist in to a point at which the fuel cap is securely mounted to the body of the vehicle. The seal is created by an o-ring which makes contact between the cap and the interior mating surface of the fuel pipe; the torque, or twisting force, exerted upon the cap by the consumer causes compression of the o-ring and thus a seal. These fuel caps also include special pressure and/or vacuum relief mechanisms which are automatically engaged when tank pressure/vacuum exceeds a specified limit.

3. Potential Technology for Compliance with Proposed Standards. The potential technologies for compliance with the proposed evaporative standards are relatively simple improvements, generally requiring either a materials or design change. In fact, some of the potential technologies are already being used on some vehicles today. However, they are not currently used together to achieve the lowest possible evaporative emissions. The technologies are broken down into five main categories: improvements to the fuel tanks and associated connections; revised fuel system lines and connections; updated canisters; revised fuel caps; and the use of intake manifold carbon filters.

(a) Fuel Tanks and Associated Connections. Currently, both plastic and carbon steel fuel tanks are in use in vehicles. Steel fuel tanks are generally superior from an emissions perspective, as the fuel permeation rate through the steel tank shell is virtually zero. The December 1997 AAMA/AIAM presentation showed that current plastic tanks, by contrast, have emissions of 0.1 grams per day even when the EVOH barrier layer technology is used. This emission level would likely require improvement in order to meet the proposed standards. A current method under investigation to reduce permeation emissions through the plastic fuel tank shell is the use of a lower-permeating barrier layer, such as fluoropolymers. In addition, thicker EVOH layers may also improve emissions. The use of these technologies is expected to reduce emissions significantly from the current EVOH-attained levels.

Another source of emissions is through the components attached to the fuel tank, such as roll-over valves, fuel and vapor lines, the fuel fill-pipe, and the fuel sending unit. Use of a new technology for plastic fuel tanks--an injection molding process rather than the current blow-molding process--would allow more tank components to be introduced during the molding process which would then be completely sealed with a barrier layer.[3] In addition, for plastic tanks the polyethylene (highly permeable to hydrocarbons) used for welding pieces onto the fuel tank shell is currently untreated.[4] To lower permeation, the polyethylene can be treated by sulfonation or fluorination (processes used previously to treat plastic fuel tanks) or coated with a low permeation material to greatly reduce permeation.

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[3] R.H. Beck, Jr. Presentation on “Plastic Automotive Fuel Tanks.” New Polymer Technologies Innovations and Applications Conference. Philadelphia, PA. June 8-9, 1998.

[4] Ibid.

The fuel line tank connections could be significantly updated to reduce emission losses at these connections. Fuel line tank connections would likely become metal-to-metal fittings in order to eliminate losses at these sources. See Figure III-3 for a diagram of one type of these connections, which incorporate dual ferrules to enable no-loss fittings. (This type of fitting is so “tight” that it is used to contain deadly phosgene gas by the computer industry in places where workers are present. It is also used in laboratory settings worldwide for similar containment purposes.) With regard to vapor line connections, they are expected to remain unchanged due to the extremely small losses expected at these connections.

The main gasket presently used for the fuel sending unit is expected to undergo changes. This seal is generally constructed of nitrile rubber (an extremely-high permeation material) and may be coated with a low permeation material such as Teflon to lower these emissions. To further reduce emissions on the gasket, a material change form the extremely-high permeation nitrile rubber to a lower-permeation material such as fluoroelastomer would substantially reduce these emissions. Refer to Table III-6 for permeation rates of nitrile and fluoroelastomer.

Manufacturers have expressed concerns that fluoroelastomers cannot maintain their elastic properties at extremely low-temperatures (-20° to -40° C) and thus may result in the leakage of fuel and vapor through the gasket. Although many grades of fluoroelastomers will lose their elastic properties at these low temperatures, two specialty grades of Viton (a commercial brand name of fluoroelastomer)--GLT and GFLT-- are appropriate for low-temperature usage, with Viton GLT able to maintain its elasticity to temperatures as low as -30°C. In addition, for fluoroelastomers, the process is reversible so that when the ambient temperature rises above the material’s temperature threshold, the fluoroelastomer will regain its elastic properties. The availability of these materials would allow a lower-permeation gasket seal without losing effectiveness at low temperatures. Other seals used in the fuel tank component application also made of nitrile rubber can be upgraded to appropriate fluoroelastomers or other low permeation materials to reduce permeation emissions. These material changes should largely eliminate these sources of evaporative emissions.

The fuel fill-pipe and fill-pipe hose connections are also expected to undergo significant changes. One option for emission reduction is to employ metal ridges on the metal-to-rubber connection surface of the fuel fill pipe or other such mechanisms to ensure a tighter seal. Another option to reduce the connection emissions is to heat-mold the rubber directly onto the metal, ensuring a complete seal.

The rubber fill-pipe hose is typically constructed of nitrile rubber on the outer cover and includes an additional barrier layer such as fluoroelastomers and nylon-12 to reduce permeation. Significantly lower permeation constructions (for example, using fluoropolymers as the barrier layer) can likely be created for fuel fill-pipe hoses. Table III-6 shows the permeation rates of various materials used in the construction of hoses. The fluoropolymer, ethylene tetrafluoroethylene copolymer (ETFE), has a permeation rate lower than both fluoroelastomer and nylon-12, over 20 times and 180 times less, respectively. Other fluoropolymers, such as polytetrafluoroethylene (PTFE) and copolymer of tetrafluoroethylene and a perfluoroalkoxy monomer (PFA), also have low permeation rates similar to that of ETFE.[5] It should be noted that there are different grades of each material, dependent on the production process, the level of fluorination, and other factors. Although different permeation rates would be expected from the various grades, fluoropolymers--especially the superior grade--appear to outperform other materials in permeation control. In addition, it is expected that by increasing the thickness of the fluoropolymer barrier layer, the permeation rate would decrease proportionally.[6] Improved fuel-pipe hose and connections should largely reduce emissions from this area.

Table III-6
Permeation Rates for Various Materials[7]

Material	**Permeation Rate (g x mm)/(m^2 x day)**
Nitrile Rubber (33% ACN)	669
Fluorosilicone	455
Hydrogenated Nitrile Rubber (44% ACN)	230
Nylon-12	5.5
Fluoroelastomer (FKM A200 66% F)	0.8
Fluoropolymer -- ETFE	0.03

(b) Fuel System Lines and Associated Connections. In general, fuel system lines are used to connect the engine and the fuel tank. The rigid fuel lines are presently made of either carbon steel or nylon-12 with the use of elastic hoses at points requiring flexibility. Carbon-steel is an essentially zero-permeation material and would not be upgraded for emission purposes. However, nylon-12 lines have moderately high permeation rates when compared to carbon steel. Both nylon and elastic hose fuel line permeation and connection losses can be further reduced by more frequent use of low-permeable materials (such as ETFE or other fluoropolymers) and tighter fitting connections, respectively. As noted earlier with the fuel fill-pipe hose, the use of fluoropolymers, such as ETFE and PTFE, would decrease permeation emissions substantially, potentially an order of magnitude lower than nylon, and by increasing the thickness of the fluoropolymer layer, additional emission reductions would likely occur. Connections between

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[5] D. R. Goldsberry. "Fuel Hose Permeation of Fluoropolymers." SAE 930992. 1993.

[6] D. R. Goldsberry, S. E. Chillous, and R. R. Will. "Fluoropolymer Resins: Permeation of Automotive Fuels." SAE 910104. 1991.

[7] W. M. Stahl and R. D. Stevens. "Fuel-Alcohol Permeation Rates of Fluoroelastomers, Fluoroplastics, and Other Fuel Resistant Materials." SAE 920163. 1992.

segments of these lines are generally either "quick-connectors" or metal-to-metal fittings. (In most cases, however, these are not the pressure-tight fittings described previously.) The connections, as described earlier, could be replaced with metal-to-metal pressure-tight fittings to prevent any loss of vapor. Additionally, design modifications, such as maximizing the use of non-permeable lines, reducing the surface area of permeable hoses, and minimizing the number of connections, would also decrease the permeation losses through fuel lines and associated connections.

(c) Canister Improvements. Currently, most canisters employ a U-shaped vapor path to reduce vapor emissions, with some manufacturers also using one air compartment to separate the carbon beds in the canister. Typical canister losses are roughly 0.1 grams per diurnal. These canisters can be upgraded to provide even lower emissions; one manufacturer has stated that levels of 0.04 grams per day could be achieved using a slightly larger canister and slightly increased purge rates. Canister losses at or below this level are likely feasible on future vehicles. It is also possible that increased compartmentalization of the canister could reduce these levels further.

(d) Fuel Cap Improvements. Current fuel caps contain a nitrile rubber seal, which is effective when the fuel cap is twisted to the proper torque. Nitrile rubber is extremely flexible, but is also very permeable. Other suitable lower-permeation materials, such as fluoroelastomers, could be used to reduce emissions considerably at this part of the system (refer to Table III-6 for a comparison of the permeation rates). In addition, current fuel caps contain a pressure and/or vacuum relief mechanism which may allow small but significant leaks of vapor. Future fuel caps may require a re-design of this pressure and/or vacuum relief mechanism so that vapors do not escape until the pressure/vacuum limit is reached.

(e) Air Intake Carbon Filters. Engine breathing losses occur during parked episodes as a result of vapor leakage through engine seals, and also via direct emissions from the engine through the intake manifold and air induction system. These vapor emissions are under 0.1 grams per diurnal, with additional losses occurring during hot-soak events. These emissions can be captured by the use of an activated carbon filter, such as an activated-carbon-treated honeycomb monolith, incorporated in the intake manifold. Use of this technology is a relatively simple way to essentially eliminate engine breathing losses. General Motors has already used the monolith technology on a limited number of production 1995 2.2 liter Chevrolet Cavalier and Pontiac Sunfire vehicles. In addition, currently on the Chevrolet Malibu and some other vehicles, an untreated honeycomb monolith is used in the air intake area to ensure laminar air flow past the mass air flow sensor. Modifying this monolith with activated carbon would allow it to serve a dual purpose to control engine breathing loss emissions and to ensure laminar air flow.

4. Non-Fuel Vehicle Background Test Data. To investigate non-fuel vehicle background emissions, staff collected information from automotive manufacturers and from ARB testing. Table III-7 at the end of this section summarizes these non-fuel emission data. It should be noted that a standardized test procedure to evaluate non-fuel emissions was not used by each manufacturer since the testing was conducted independently. In general, the non-fuel emission testing on gasoline vehicles was performed by removing the fuel system and plugging any apertures to the engine to eliminate fuel sources. Many of the vehicles tested by industry were between three and nine months old (note that non-fuel emissions are expected to continue to decrease significantly for at least the first year.) Thus, stabilized non-fuel emission levels for these vehicles may actually be somewhat lower. Using the gathered test data as a conservative estimate of stabilized non-fuel emission levels, staff assessed the level of non-fuel emissions that may be expected from the different vehicle categories and adjusted the non-fuel emission allocations in the proposed emission standards accordingly.

The staff performed non-fuel background testing on electric vehicles. The two electric vehicles tested by the ARB, a Honda EV Plus and a Chevrolet S-10 pick-up, showed average diurnal results of 0.094 grams and 0.316 grams, respectively. In particular, the S-10 pick-up was tested at just 100 miles in February and still had a "new car" smell. More recent July testing of this vehicle at 1,270 miles yielded results of 0.25 grams per test, a decrease of 0.06 grams or almost a 20 percent reduction. This trend of non-fuel vehicle emissions decreasing during the first year following production is consistent with the expectation of considerable off-gassing of plasticizers and other hydrocarbons. According to vehicle manufacturers, vehicle non-fuel emissions generally decrease significantly during the first six months of vehicle operation and parking, where ambient temperatures can greatly affect the degree of aging encountered. Staff will continue testing the S-10 truck to further investigate this non-fuel emission decrease with time.

In addition, a prototype Mitsubishi hybrid electric vehicle designed to have extremely low evaporative emissions showed a total vehicle diurnal-plus-hot-soak result of 0.13 grams per test during testing at the ARB's laboratory, and 0.14 grams per test result during testing at Mitsubishi facilities. The non-fuel emissions on the Mitsubishi hybrid electric vehicle are expected to be considerably less than 0.14 grams per test due to the contribution of fuel evaporative emissions, likely under 0.10 grams per test.

In private meetings with staff, several manufacturers shared non-fuel vehicle background data from passenger cars and light-duty trucks. In addition, published information[8] on an Oldsmobile Regency, Chevrolet Lumina APV, and prototype Saturn Sedan showed background data ranging from 0.15 to 0.25 grams per day on the first day of the diurnal test.

Chrysler also submitted non-fuel background data from four passenger cars, averaging 0.38 grams per 24 hours. However, the data were considered unrepresentative of stabilized non-fuel emissions, as discussed below. Two of the vehicles were tested at zero mileage and at approximately four months after production. In the ARB test program, staff found that new vehicles only several months after production with essentially zero-mileage had very high non-fuel

[8] H. M. Haskew, W. R. Cadman, and T. F. Liberty. "Real-Time Non-Fuel Background Emission." SAE 912373. 1991.

background emissions. Consequently, before ARB staff tested vehicles, mileage accumulations to at least 2,500 miles were performed. Thus, given the zero-mileage accumulation and the insufficient vehicle aging, the data from these two vehicles are inappropriate for the purpose of evaluating actual non-fuel levels for standards setting. The other two vehicle data points were rejected because the fuel and vent-lines were merely "blown-out" (purged with an inert gas) and capped. In an SAE publication[9], it is demonstrated that this practice is not sufficient to negate the effects of fuel permeation through hoses, which are considered fuel emissions rather than vehicle non-fuel emissions. The hoses must be physically removed from the vehicle.

Non-fuel background data on 11 light-duty trucks and medium-duty vehicles were provided by Ford for staff's evaluation. The vehicles range from the 1984 to 1995 model years and were tested with the fuel and evaporative systems removed. Although a robust data set, the data from three of the vehicles (a 1984 E150, a 1984 F150, and a 1987 Chevy Pickup) were rejected by staff in its analysis because of the earlier vintage of the vehicles. These vehicles were not considered representative with regard to currently available non-fuel related materials and evaporative emission control components. The remaining eight vehicles, ranging from model years 1992 to 1995, included three light-duty trucks (a Ranger pick-up truck and two Explorers) and five medium-duty vehicles (two F-150 pick-up trucks and three E-150 vans). It should be noted that six of the eight vehicles were tested at or under 2,000 miles. This suggests that actual stabilized non-fuel levels for these vehicles are likely to be somewhat less than indicated here, although this amount is difficult to quantify.

Table III-7 shows the compilation of passenger car, light-duty truck, and medium-duty vehicle non-fuel emission data received from various manufacturers and generated by ARB testing. The vehicles tested by the ARB are indicated in the chart. The data suggest that passenger cars, averaging 0.17 grams per diurnal, would generally be expected to show lower non-fuel emissions than the larger vehicles. Non-fuel emissions on light-duty trucks and medium-duty vehicles were on average 0.05 and 0.21 grams per diurnal, respectively, higher than the average passenger car emissions. Staff used these data to adjust the proposed standards for light-duty trucks and medium-duty vehicles to account for this higher potential of non-fuel emissions, as described in more detail in section C.5.

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9 Ibid.

Table III-7
Non-Fuel Vehicle Emission Data from Manufacturers and ARB Testing

Passenger Cars		**Light-duty Trucks (under 6,001 lbs. GVWR)**		**Medium-duty Vehicles (6,001 - 8,500 lbs. GVWR)**	
Vehicle Model	**Diurnal (g/24-hr)**	**Vehicle Model**	**Diurnal (g/24-hr)**	**Vehicle Model**	**Diurnal (g/24-hr)**
EV Plus (ARB)	0.09	Eurovan	0.10	E150 Chateau	0.182
Mitsubishi HEV (ARB)	0.14 [1]	Nissan Truck	0.19	F150	0.316 [2]
Maxima	0.16 [2]	Lumina APV	0.20	E150 XLT	0.649 [2]
Regency	0.17	Explorer	0.248 [2]	-	-
1995 Camry	0.19 [3]	S-10 EV (ARB)	0.25	-	-
1998 Camry	0.22 [3]	Ranger	0.328	-	-
Saturn Sedan	0.23	-	-	-	-
AVERAGE	0.17	AVERAGE	0.22	AVERAGE	0.382

[1] The test result includes both fuel and non-fuel diurnal plus hot soak emissions.
[2] Two vehicles of the same model were tested, and the emission results were averaged.
[3] The test result includes diurnal and hot soak non-fuel emissions.

Most of the test data presented by industry consisted of only diurnal non-fuel emission levels, because the hot soak test could not be performed with the fuel system removed. Toyota Motor Corporation, however, was able to provide hot soak non-fuel emission levels by using an alternative method. For the 1998 Camry, the hot soak non-fuel emission contribution of the total emission level shown in Table III-7 was approximately 0.03 grams per test. In addition, another manufacturer provided data that showed hot soak non-fuel emissions are 0.05 grams per test. Using the average value, 0.04 grams per hot soak test, to adjust only the diurnal non-fuel passenger car data in Table III-7, the average non-fuel diurnal-plus-hot-soak emissions are 0.19 grams per test. For light-duty trucks and medium-duty vehicles, hot-soak non-fuel emissions were assumed to be 0.05 grams per test, yielding average non-fuel emissions for these classes of 0.27 grams and 0.43 grams, respectively.

5. Headroom and Variability of Test Vehicle Data. Concerns have been voiced by representatives from the automotive industry regarding the repeatability of test data in comparisons between vehicles of the same design. These issues are of significance due to their impact on "headroom," or the amount of compliance margin between the vehicle's certification emissions and the emission standard with which in-use vehicle compliance must be demonstrated.

Manufacturers generally design their vehicles to perform significantly below an emission standard, in order to minimize the risk of an in-use recall.

The staff has performed a study of these variability issues, using data submitted by Ford Motor Company. Ford tested nine Crown Victoria vehicles at nominal mileage points of 4,000, 8,000, 44,000, 74,000, and 104,000 miles. Actual mileage points ranged from 4,000 to 129,000 miles. The attached Figure III-4 shows the average emission results and standard deviations by mileage. The data suggest a gradual decrease in emissions with mileage, corresponding with a decrease in variability with mileage. These decreases may be attributable to "settling" of components, and to a decrease in background emissions with vehicle age. In order to determine an appropriate headroom factor for standards change, the staff has analyzed the variability from the entire data set. The main factors known to contribute to emission variability include test-to-test, testing-staff to testing-staff, SHED-to-SHED, and vehicle-to-vehicle. The total standard deviation for the data set, taken as an aggregate, is 0.27 grams, versus a mean of 0.80 grams. The coefficient of variation (percentage of the standard deviation to the mean) is then 34 percent. This coefficient is assumed to remain constant as emission levels are lowered to reach compliance with the proposed standards.

In order to determine an appropriate compliance margin based upon this variability, it is assumed that manufacturers would design vehicles such that 90 to 95 percent of the vehicles would comply with the emission standard. Using a standard statistical table[10], 90 and 95 percent of a normally-distributed population fall below the population mean plus 1.29 and 1.65 standard deviations, respectively. As the standard deviation is 34 percent of the mean for this case, the 90 percent compliance figure would be achieved at the mean plus 0.34x1.29 the mean, which equals 1.44 times the mean. A similar calculation for the 95 percent compliance figure yields 1.56 times the mean. The average of these two figures is 1.5 times the mean and suggests that a multiplicative headroom factor of 1.5 is necessary to comply with a given evaporative emission standard. [11]

Staff used three sources of information to determine appropriate emission standard levels: vehicle non-fuel emission data, data from the ARB test program, and the 1.5 compliance margin. The methodology is slightly more complex than would ordinarily be used due to the intent not to specifically require control of vehicle non-fuel emissions as part of this regulatory proposal. To assure that most vehicles (a minimum of roughly 80 percent) do not require the use of specific measures to reduce non-fuel emissions, the average vehicle non-fuel emissions from Table III-7

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[10] "Areas and Ordinates of the Normal Curve in Terms of X/σ," Basic Statistical Methods. Downie, N.M. and Heath, R.W. 1965. pp. 290-297.

[11] It is worth noting that for ARB's in-use compliance determination purposes, an average of at least 10 vehicles' emission results is used to determine compliance with an emission standard. On a statistical basis, this greatly lowers the risk of an in-use recall relative to the risk of a single vehicle failure.

have not been used to determine standards. Instead, the average value plus one standard deviation, per vehicle class, has been used. Using this higher value amounts to using a vehicle from the upper end of the non-fuel range for standards-setting, which in turn ensures that most vehicles would not require non-fuel control. Employing this method, the non-fuel emission values used for the passenger car and light-duty truck categories are 0.24 and 0.345 grams per diurnal-plus-hot-soak test, respectively. An estimate of fuel evaporative emissions for these vehicle categories was then added. From the ARB's emission testing, fuel emissions averaged roughly 0.11 grams per diurnal-plus-hot-soak test. Manufacturers are expected to be capable of further reducing fuel emissions below this level, especially given the leadtime before the proposed standards' implementation in the 2004 model year. Assuming a fuel emission value of 0.1 grams, and applying the 1.5 compliance margin yields the proposed standards of 0.50 grams for passenger cars and 0.65 grams for light-duty trucks.

For medium-duty vehicles 6501-8500 pounds GVWR, the proposed standard would be approximately 1.0 grams per test utilizing the same methodology used above for passenger cars and light-duty trucks. However, because of the limited non-fuel emission data (only three vehicle models in this category as shown in Table III-7), the appropriateness of a 1.0 gram standard was further investigated. The 1999 model-year Suburban tested by ARB staff showed emission results of 0.53 grams for the diurnal-plus-hot-soak test. This vehicle is currently one of the largest medium-duty vehicles sold, and would be expected to have relatively high non-fuel emissions. However, when the 1.5 compliance margin is applied to the 0.53 emission result, a standard of 0.8 grams is suggested.

The final piece of evidence staff considered for this medium-duty vehicle standard was the relative surface areas of light-duty trucks and medium-duty vehicles. The vehicle body is considered to be a primary contributor to non-fuel evaporative emissions. Based on the length and width (height was unavailable) of the ten highest sales-volume vehicles in each category, medium-duty vehicles have, on average, approximately 30 percent more surface area than do light-duty trucks. Multiplying the light-duty truck standard by 1.3 indicates a medium-duty standard of 0.85 grams. When the standards estimated in these three separate ways are averaged, the result is the proposed standard of 0.90 grams. Medium-duty vehicles of even higher weight (8501-14000 lbs. GVWR) are assumed to be slightly larger, and a standard of 1.0 grams is proposed, as with the heavy-duty vehicle class.

6. 150,000 Mile/15-Year Emission Durability Basis. The evaporative emission proposal includes extended durability requirements. Under the current regulation, vehicles are subject to in-use compliance standards for either 10 years or 100,000 miles, whichever first occurs. The proposed increased durability would lengthen these requirements to 15 years or 150,000 miles. In-use industry data and certification data suggest that compliance with the proposed evaporative standards at the extended durability test mileage is feasible.

As mentioned earlier, the in-use Ford Crown Victoria data show a decrease in vehicle emissions from 4,000 to 100,000 miles of 0.25 grams (compared to a 4,000-mile level of 0.88

grams). This is the most thorough in-use data available on enhanced evaporative vehicles. Although the data contain high levels of variability, the decrease may be attributable to "settling" of components as the vehicle ages, and to a decrease in non-fuel emissions with vehicle age. These data suggest that vehicle emission deterioration from low-mileage levels is unlikely to be a significant concern for vehicles certified to the proposed standards.

In addition, current deterioration factors (DFs) derived from certification durability testing indicate an average emission increase of 0.14 grams per 100,000 miles. The average DF would in actuality be far closer to zero if this average DF was calculated using the actual DFs generated in the certification programs. A significant fraction of the DFs is actually negative (vehicles exhibited evaporative emission decreases with mileage) and, by convention, are simply assigned a zero DF rather than a negative number. It may be that the initial 4,000 mileage point used for the DF generation was conducted on a vehicle with high non-fuel emissions due to limited vehicle age. Finally, the average DF increase is for vehicles certified to the current 2-gram diurnal-plus-hot-soak standard. Manufacturers are expected to design vehicles with far less deterioration in order to meet the proposed 0.5 gram standard. Using the ratio of the current to the proposed standards suggests that deterioration would be limited to no more than 0.035 grams per 100,000 miles, or 0.052 grams for 150,000 miles. These proportionate decreases in deterioration have been observed in the lowering of exhaust standards occasioned by the California LEV program.

D. COST-ANALYSIS

The retail cost of compliance for the evaporative proposal is the summation of the manufacturer and dealership costs. Staff estimates that the total incremental retail cost increase per vehicle of this proposal is approximately $25 per vehicle. The detailed cost analysis is outlined in this section.

1. Manufacturer Costs. Manufacturer costs can be divided into two parts: the variable cost, which includes a specific cost incurred by each vehicle produced for sale; and the fixed cost, which is independent of the number of vehicles produced. Variable costs are expressed as the sum of the additional hardware, assembly, warranty, and shipping costs per vehicle. Fixed costs are generally related to up-front expenditures such as tooling, investment in new facilities, and any increases in testing needs occasioned by the proposed evaporative regulations. The projected total manufacturer costs are $24.01 per vehicle, as shown in Table III-8.

(a) Variable Costs. The incremental hardware costs of this regulation have been estimated at $21.27 per vehicle. While the entire cost would not likely be required on every vehicle since some of the potential technologies are already being used in late model vehicles, it is provided as a conservative estimate of the variable cost per vehicle.

There would not likely be incremental assembly and shipping costs from the installation of the upgraded parts since the assembly labor requirements and shipping of the parts are comparable to that of current requirements. However, if the activated-carbon air intake filter was used, additional assembly and shipping costs would be required. The assembly and shipping costs of this component are approximately $0.25 and $0.10, respectively. In addition, there will not likely be an additional warranty cost as a result of the proposed evaporative regulation.

Table III-8
Incremental Costs Per Vehicle for the Evaporative Proposal

Category	**Cost**
Variable Costs	
Hardware	$20.92
Assembly	$0.25
Warranty	$0
Shipping	$.10
Fixed Costs	
Facility Upgrades	$0
Basic Research	$0
Advanced Engineering Research	$1.38
Legal	$0
Administration	$0
Investment Recovery	$1.36
Total Manufacturer Cost	$24.01
Dealership Cost	$1.08
Total Retail Cost	$25.09

Fuel Tanks and Associated Connections. Costs for improvements in this category include upgrading plastic fuel tanks; improved liquid fuel line tank connections; use of a lower permeation fuel sending unit seal and fuel fill-pipe hose; and improved fuel fill-pipe hose connections. Staff expects manufacturers would have a choice of using either metal tanks or plastic tanks, depending on the fuel tank configuration and fuel system packaging requirements. The cost estimate associated with making the required improvements is estimated at $5.00 per vehicle. This is based on the current percentage of vehicles using plastic tanks at approximately 25 percent and the assumed cost of $20.00 for upgrading the plastic tank.

The additional cost of the improved liquid fuel line tank connections (assumed as carbon-steel, purchased in bulk) is estimated at $4.00 per vehicle. This assumes the incremental cost of upgrading four fuel line connections from the fuel tank to the underbody fuel line. The number of connections is based on a fuel-return fuel system design. The additional cost of the upgraded fuel sending unit seal is estimated at $0.42 per vehicle. This is based on an assumed cost of nitrile rubber at $1 per pound and of Viton at $8 per pound, and a gasket weight of 1 ounce (0.06 pounds). For the fuel fill-pipe hose connections, the cost of the metal barbs (ridges) on the metal fuel fill-pipes is estimated at $1.00 per vehicle, while the cost of the upgrading the fuel fill-pipe hose is estimated at $2.00 per vehicle. The total incremental cost estimate for the improved fuel tank and associated connections is $12.42 per vehicle.

Fuel System Lines and Associated Connections. The incremental cost of the connection upgrades is estimated at $2.00 per vehicle, assuming two connection upgrades per vehicle. Currently, most manufacturers are using improved fuel-rail connections that would not need to be upgraded. However, the connections of the fuel-rail hose to the underbody fuel line may require upgraded connections. Again, the two connection upgrades are based on a fuel-return fuel system design. The cost estimate for the liquid and vapor fuel hose upgrades is $3.00 per vehicle. This assumes 10 feet of upgradable fuel hose per vehicle, with the original hose being nylon 12 (at $0.15 per foot), and the upgraded hose being a multilayer one with a barrier layer of Teflon (at $0.45 per foot.) This cost estimate does not include the upgrade made to the fuel fill-pipe hose which has already been estimated as described above. Total cost estimate for improvements to fuel lines and associated connections is $5 per vehicle.

Canister Improvements. The additional cost of the upgraded canister is estimated at $1.00 per vehicle for improvements to the canister including using additional compartments, a slightly large canister, and slightly increased purge rates.

Fuel Cap Improvements. Total cost of improvements is estimated at $0.50 per vehicle. These improvements include using a low-permeation material for the fuel cap seal and improvements to the pressure/vacuum relief mechanism to reduce leakage.

Air Intake Carbon Filter. The cost of including an activated carbon filter in the intake air compartment to capture engine breathing losses is estimated at $2.00 per vehicle.

(b) Fixed Costs. The fixed costs for this regulation have been subdivided into several categories: facility costs, basic research costs, advanced engineering research costs, legal costs, and administrative costs. The total fixed costs are estimated at $1.38 per vehicle.

Facility Costs. No increased test facility costs are expected to result from this regulation as no additional tests are specified by the proposed regulations.

Basic Research Costs. Manufacturers are not expected to incur additional basic research costs from this regulation as the large majority of the evaporative system components are expected to be purchased from suppliers. Basic research costs are therefore included in the component prices given in the variable cost section.

Advanced Engineering Research Costs. Manufacturers are expected to incur some additional costs in order to design and prove-out the new evaporative systems, although suppliers may in fact perform the actual system design work. A fleet of development vehicles to test out the new systems would be required, as well as personnel, over-head and other costs to allow proper assessment of the new systems. Staff is assuming that, per evaporative family, approximately 10 person-years of engineering staff would be required, along with a fleet of 10 development vehicles. At costs of $120,000 per person-year and $100,000 per development vehicle, the cost per evaporative family is $2.2 million. Each evaporative family is assumed to last 8 years before major redesign, and, on average, to sell 200,000 units per year. This figure differs from that for the exhaust emission calculations as there are considerably more exhaust families than evaporative emission families. The final cost of advanced engineering research is calculated as $1.38 per vehicle.

Legal Costs. The upgraded components that manufacturers are expected to use are not expected to incur additional vehicle liability risks. Most improvements involve tighter sealing of areas where fuel vapors could escape, so that overall liability would actually be expected to decrease. As manufacturers are not expected to design a significant number of the upgraded components to be used on future vehicles, it is unlikely that legal costs (such as would result from patent infringement issues) would occur in this area as well.

Administrative Costs. No additional administrative costs have been assumed as the evaporative system would not require additional parts relative to current vehicles. Therefore, the processes of component procurement, supply to manufacturing facilities, and overall scheduling are not expected to change significantly.

(c) Investment Recovery Costs. These costs generally include that of new machinery for production of an upgraded part, for changes to the assembly plants to install the new part, for vehicle development (advanced engineering), and for capital recovery. As parts are expected to be produced by suppliers, and assembly processes such as automation are unlikely to be affected by the proposed evaporative regulations, staff has ascribed no additional cost for the first two categories. Nor are facility additions expected to be required for development work, so that no investment recovery would occur here. For capital recovery, staff has calculated this as 6 percent of the total costs to the manufacturer, or $22.65 x 0.06 = $1.36 per vehicle.

2. Dealership Costs. These costs generally include the recovery of operating costs and of capital recovery. The increase in vehicle cost would create increased cost to the dealer of financing the vehicle (while it is on the dealership lot), and an increase in commission to the salesperson who sells the vehicle. The dealership is assumed to pay interest on the vehicle at a 6 percent annual rate and to retain the vehicle for three months. The increased finance cost is therefore 1.5 percent of the incremental retail cost of the vehicle, or $0.36 per vehicle. Similarly, the increased commission cost is assumed at 3 percent of the incremental cost of the vehicle and calculated as $0.72 per vehicle. Total costs for the dealership, as shown in Table III-8, are $1.08 per vehicle.

E. OUTSTANDING ISSUES

During the regulatory development, staff conducted two public workshops and numerous meetings with automotive manufacturers. Staff has incorporated comments and resolved concerns by the manufacturers to the extent possible without compromising the intent of the proposal. Some outstanding issues remain and are described below.

1. Stringency of the Standards. Industry has commented that the proposed evaporative standards are too stringent and would require significantly greater modifications than anticipated by staff. While staff agrees that the proposed standards are stringent and would require the elimination of the majority of fuel evaporative emissions, the potential vehicle modifications described herein are the best materials currently available and would reduce fuel evaporative emissions substantially. In addition, manufacturers have sufficient lead time to investigate additional potential modifications to comply with the proposed standard since the proposed implementation would not begin until the 2004 model year. Staff has determined that the proposed standards are technologically feasible, as discussed earlier in section C.3.

2. Non-Fuel Vehicle Evaporative Emissions. Manufacturers have commented that certain vehicle models may have substantially more non-fuel vehicle evaporative emissions than that allocated in the initially proposed emission standards. They have indicated that non-fuel emissions from some vehicles may even exceed the proposed standards. In evaluating non-fuel emissions, staff collected extensive test data from automotive manufacturers and conducted testing. Using the combined manufacturer and ARB data, adjustments to the proposed emission standards were made to account for the contribution of non-fuel emissions. Note that the data on non-fuel emission levels may actually overestimate the emission levels expected from stabilized vehicles since many of the test vehicles were not considered adequately aged and conditioned. The discussion of the non-fuel emissions is contained in section C.4.

In addition, high non-fuel vehicle emissions during the certification process may be a concern since the test vehicle is typically relatively new. (In the ARB test program, staff found high evaporative emissions on new vehicles but that these emission levels decreased significantly over time, such as on the S-10 EV truck.) Although a new test vehicle can be aged and conditioned to stabilize its non-fuel evaporative emissions, the manufacturer may not have the required time or facility resources to perform the aging process. Thus, the evaporative proposal includes a provision that allows the manufacturer to determine the expected stabilized non-fuel evaporative emission level of the certification test vehicle using non-fuel emission test data generated on a similar vehicle. For certification purposes, the stabilized non-fuel emissions plus the fuel evaporative emissions of the vehicle would be used to demonstrate compliance with the applicable evaporative emission standard. By allowing either sufficient aging of the test vehicle or the use of stabilized non-fuel emission levels, the concern of high non-fuel emissions during certification should be alleviated. In addition, to ensure that vehicles tested for in-use compliance testing do not have artificially high non-fuel emissions, in-use compliance evaporative testing will be conducted on vehicles that are at least one year after the production date and have a minimum odometer reading of 10,000 miles.

3. Testing Variability and Required Headroom. Manufacturers have contended that the variability of evaporative testing due to vehicle, facility, and other factors is very high and that a two-times headroom (compliance margin) is needed. However, staff has not received information and data in support of a two-times headroom. Therefore, staff did not use the manufacturers' proposed headroom factor in considering the proposed standards. Using in-use data submitted by Ford Motor Company on nine Crown Victoria vehicles, staff conducted an analysis to determine the appropriate factor. This data set consists of evaporative testing of the vehicles from 4,000 to 129,000 miles and is considered one of the most comprehensive enhanced evaporative emission data sets available. From these data, staff determined that a 1.5 headroom factor is appropriate (see section C.5.)

F. REGULATORY ALTERNATIVES TO EVAPORATIVE EMISSION PROPOSAL

During the rulemaking process, staff considered the following regulatory alternatives to the currently proposed evaporative amendments. Staff found that no other alternative considered would be more effective in carrying out the purpose for which the regulations were proposed or would be as effective or less burdensome to affected private persons than the proposed regulation.

1. Do not amend the evaporative standards. The current standards are similar in stringency to the federal evaporative standards. Staff has determined that evaporative emission reductions can be achieved through currently available advanced emission control technology. In order to accomplish part of the Measure M2 California SIP goal for additional ROG emission reductions, more stringent emission standards are required. The emission reductions achieved by reducing the evaporative standards would contribute toward the realization of this goal.

2. Adopt zero-fuel evaporative emission standards. Staff considered requiring all vehicles to meet a zero evaporative standard that effectively requires that all fuel evaporative emissions be eliminated. Although the technological concept is feasible and significant emission reductions can be achieved with this proposal, currently the cost for such systems would be relatively high. Until further development is made in this area, staff believes that it would be too costly to require all vehicles to meet the zero-fuel evaporative standard.

3. Adopt two-tier evaporative standards: "zero" and "near-zero." During the rulemaking process, staff considered the possibility of proposing the adoption of two-tiered standards in which 20 percent of a manufacturer's fleet would be required to certify to zero-fuel evaporative standards (eliminating essentially all fuel emissions) and 80 percent would be certified to near-zero standards (allowing nominal fuel evaporative emissions.) The 20 percent zero-fuel evaporative requirement would promote the development of and introduce substantially improved evaporative/fuel systems. After further analysis, the current incremental cost-effectiveness of the zero and near-zero standards could exceed typical measures of cost-effectiveness. Further development of zero evaporative/fuel systems would be required.

4. Adopt fuel-based evaporative standards. Since the evaporative test is conducted in an enclosure, the HC emission measurements would encompass evaporative emissions from the whole vehicle, including those from fuel and non-fuel sources. A fuel-based only evaporative standard was considered. However, the testing burden would be significantly greater by requiring twice the amount of testing than the current procedures. First, the vehicle (with the evaporative/fuel system intact) would be tested over the evaporative procedures in order to establish the whole vehicle emissions. Then the fuel and evaporative components would need to be removed and the vehicle without the evaporative/fuel system would be retested to determine its non-fuel emissions. Note that since the vehicle does not contain a fuel system, the engine cannot be operated and thus, only the diurnal portion of the test would be conducted. An engineering evaluation would be required to determine the non-fuel emission levels during the hot soak and running loss tests. This regulatory alternative poses a higher burden on manufacturers for certification testing and ARB for in-use compliance testing, as well as introducing theoretical elements of engineering evaluation for vehicle compliance rather than actual testing. Thus, the proposed evaporative standards that combine fuel and non-fuel emissions alleviate this burden and allow for more accurate quantification of evaporative emissions.

IV. PROPOSED AMENDMENTS TO THE MALFUNCTION AND DIAGNOSTIC SYSTEM REQUIREMENTS - 1994 AND SUBSEQUENT MODEL-YEAR PASSENGER CARS, LIGHT-DUTY TRUCKS AND MEDIUM-DUTY VEHICLES AND ENGINES.

OBD II Evaporative System Leak Detection.

The On-Board Diagnostic II (OBD II) regulation requires manufacturers to implement monitoring strategies to detect emission-related malfunctions on vehicles during in-use vehicle operation. For evaporative systems, the regulation currently requires detection of system leaks equal or greater in magnitude than a 0.040 inch orifice. However, in light of data suggesting that even smaller leaks occur in-use and that such leaks can cause evaporative emissions to exceed the applicable standards by as much as 15 times, the regulation requires a manufacturer, beginning with the 2000 model year, to implement diagnostic strategies capable of detecting leaks equal or greater in magnitude to a 0.020 inch orifice. The regulation requires a manufacturer to implement a 0.020 inch leak detection strategy on 50 percent of its 2000 model year vehicles, 75 percent of its 2001 model year vehicles, and on all vehicles subject to the requirement by the 2002 model year.

Some vehicle manufacturers have expressed concern that the phase-in requirements for 0.020 leak detection may be too aggressive and could result in the implementation of monitoring strategies that do not perform as frequently or accurately in-use as might be possible with some additional leadtime. ARB staff has regularly reported back to the Board on OBD II implementation issues based on manufacturers' progress towards meeting the requirements of the regulation. At these updates, such concerns are discussed and, if necessary, amendments to the regulation are proposed for the Board's consideration. The staff intends to bring its next report before the Board in mid-1999; however, a mid-1999 hearing would be on the eve of 2000 model year production and thus too late for manufacturers to take advantage of any amendments made with respect to 2000 model year requirements. Therefore, the staff is including this particular OBD II issue as part of the rulemaking under consideration.

The comments received by staff are most specifically directed to the relatively large 2000 model year phase-in level of 50 percent. Manufacturers have stated that 0.020 inch leak detection strategies have to be carefully designed to protect against false malfunction detections while ensuring reasonably frequent monitor operation in-use. Factors such as fuel volatility, ambient temperatures and consumer driving habits can affect the reliability of currently available monitoring technologies. Such factors must be properly taken into account by manufacturers to ensure that the monitoring strategy will work reliably in-use. Most manufacturers appear capable of implementing systems on 50 percent of their 2000 model year products; however, the manufacturers are concerned that unforeseen driving conditions not encountered during development testing could occur in-use and might affect the operation of the monitor. Therefore, manufacturers have requested a more gradual phase-in schedule for this requirement.

ARB staff agrees with the manufacturers that lower initial phase-in percentages could serve to maximize the performance of these systems in-use. A lower initial phase-in percentage would allow manufacturers to concentrate their resources to maximize the effectiveness of 0.020 inch leak detection strategies on a smaller percentage of their fleets first scheduled to meet the requirements. Further, should unexpected performance issues arise in-use, they would be confined to fewer vehicles, minimizing any negative impact on consumer and repair industry confidence in the OBD II system. The staff is proposing, therefore, to extend the phase-in period from 3 years to 4, spanning from the 2000 model year to the 2003 model year. The respective phase-in percentages for these years are proposed to be 20, 40, 70 and 100 percent.
Although the proposed amendment to the 0.020 inch evaporative leak detection phase-in provides some additional leadtime for manufacturers to meet the requirement, the staff does not believe that a significant adverse environmental impact would result. Maximized system reliability will help ensure that all malfunctions are detected while guarding against false malfunction indications. As mentioned previously, high confidence in the OBD II system is necessary to ensure that vehicle owners will seek prompt repair of detected malfunctions and will help the service industry to make accurate and complete repairs. Low confidence in OBD II systems could have negative emission impacts lasting beyond the one or two year implementation delays resulting from the revised phase-in.

V. PROPOSED AMENDMENTS TO CALIFORNIA'S MOTOR VEHICLE CERTIFICATION, ASSEMBLY-LINE AND IN-USE TEST REQUIREMENTS ("CAP 2000")

A. BACKGROUND

The California Health and Safety Code requires a manufacturer to demonstrate that its vehicles meet the applicable emission standards in three ways: at the time of certification, as the vehicles are produced on the assembly-line, and in actual customer use. These programs have been in place for many years. However, changing emission standards and advancements in automotive technology have reduced the effectiveness of the certification and assembly-line requirements. In 1995, the U.S. EPA, ARB and the automobile manufacturers signed a Statement of Principles that states:

> "... the Signatories commit to working together to achieve regulatory streamlining of light-duty vehicle compliance programs, including reduction of process time and test complexity, with the goal of more optimal resources spent by both government and industry to better focus on in-use compliance with emission standards."

Since then, staff has been working with U.S. EPA and the automobile industry to develop a streamlined motor vehicle certification process coupled with an enhanced in-use compliance program (called "Compliance Assurance Program" or "CAP 2000").

The goal of U.S EPA and ARB in CAP 2000 is to redirect manufacturer and government efforts toward in-use compliance, which would provide greater assurance that vehicles are actually complying with the standards in-use. The amendments being proposed in this rulemaking divert the significant resources presently devoted to motor vehicle certification and reallocate a portion of them towards in-use compliance. Reducing the regulatory burden during certification would provide manufacturers with more control over their production timing, which would provide significant savings, while the enhanced in-use test programs would provide more air quality protection. This proposal will be effective with the 2001 model year although manufacturers may certify their 2000 model year vehicles using the CAP 2000 framework as adopted by the Board. The following is a brief description of the current certification and in-use programs. Part B describes the amendments being proposed under CAP 2000.

Pre-Production Certification Procedure. In order to certify a vehicle for sale in California, a manufacturer must submit test data to the Executive Officer prior to the start of production that demonstrates the vehicle meets the applicable standards. This requires the use of procedures that enable the manufacturer to predict the anticipated emissions deterioration (called the "deterioration factor") of the vehicle in-use using pre-production, developmental vehicles. Once the deterioration factor is established, low mileage "emission-data" vehicles are tested and the emission results are adjusted using the deterioration factor to determine whether the vehicle meets the emission standards throughout its useful life. A manufacturer must provide this information for each "engine family," which is a group of vehicles having engines and emission control systems with similar operational and emission characteristics, in order to be granted an Executive Order (EO) approving vehicles in the engine family for sale in California.

Assembly-Line Production Procedure. Once an EO has been granted, section 2062, title 13, California Code of Regulations (CCR) requires the manufacturer to emission test a small portion of actual production vehicles in each engine family as they leave the assembly-line to ensure that the emissions of actual production vehicles also comply. This is called "quality-audit testing." Vehicles that do not comply with the standards are required to be repaired or the manufacturer could be subject to penalties.

Post-Production In-Use Compliance Procedure. The ARB procures late-model vehicles from their owners for emission testing to determine whether vehicles that have been properly maintained and used comply with the standards in actual use. If the ARB test data or emission control components are identified that demonstrate an engine family does not comply, the manufacturer must either submit a plan to remedy the non-conformity at the manufacturer's expense or be required to recall the vehicles. In either case, penalties could be assessed. The ARB in-use test program protects air quality because it not only forces the repair of non-complying vehicles but also acts as a substantial deterrent to manufacturers that wish to avoid the expense (both in cost and in lost customer satisfaction) associated with a recall.

The U.S. EPA administers essentially the same requirements under the Clean Air Act but because California is allowed to set its own emission control program, there are differences between the two programs. The next section describes the proposed "CAP 2000" program and how the proposed amendments affect California's certification and in-use programs.

B. SUMMARY OF PROPOSED MODIFICATIONS

In July, 1998, the U.S. EPA released its Notice of Proposed Rulemaking (NPRM) describing the proposed CAP 2000 program (63 FR 39654 (July 23, 1998)). Because U.S EPA and ARB have agreed to harmonize to the greatest extent possible, this section only will briefly summarize the key components of CAP 2000 with the focus directed at the impact of the proposed CAP 2000 amendments on California's programs. A complete description of the proposed federal amendments as well as the complete federal regulatory text is contained in the federal docket. A detailed description of the proposed regulatory amendments to the California programs is contained in Appendix B of this staff report.

1. Amendments to Pre-Production Certification Procedures. The proposed CAP 2000 program significantly reduces the emission testing and reporting requirements for certification and provides manufacturers with more control over roll out of their product lines. Currently manufacturers are required to establish emission deterioration data on every engine family using a low speed, high mileage test procedure (called the "AMA" cycle) or by approved bench aging the emission control components and then testing the vehicle with the fully aged components. Once the deterioration factor is determined the manufacturer must test two emission-data vehicles in every engine family. This is a costly and time-consuming process and may not provide a realistic appraisal of the ability of the vehicle to comply. Under CAP 2000, a manufacturer will be able to develop its own durability demonstration (with pre-approval by the Executive Officer) and apply it to several engine families that have been grouped into a broad category of vehicles called “durability groups” that exhibit similar deterioration characteristics. The durability demonstrations that manufacturers would be using are expected to provide a more realistic appraisal of the emission deterioration of the vehicles. Within each durability group, there are several “test groups” (similar to the current engine family designation) that are based on the emission standards to which a vehicle is certified. Manufacturers would then select one “worst case” vehicle from each test group to emission test rather than the two required under the current program. This reduction in testing would result in more than a 75% reduction in the number of durability demonstrations now required and a 50% reduction in the number of emission data vehicles tested.

In addition, CAP 2000 would provide more flexibility in the information required for certification. Under the current program, a manufacturer is required to submit all of the certification data prior to issuance of the EO. Under CAP 2000, only the most essential certification information (e.g., that the vehicle meets the standards) would be required before EO approval with the remainder (e.g., test parameters, or detailed maintenance instructions) being required prior to the end of the model year. Eliminating the requirement that all documentation must be submitted prior to EO approval means that production plans will not be held up for non-essential pieces of information.

2. Amendments to Assembly-Line Production Testing. Under the current California program, manufacturers are required to perform functional tests on every vehicle component during the assembly process and then conduct a full emission test for a portion of the vehicles (approximately 2%) at the end of the assembly-line. The proposed amendments to CAP 2000 would eliminate the 2% end-of-line emission tests because the proposed manufacturer-conducted in-use testing discussed in paragraph B.3 below is more likely to ensure that manufacturers utilize durable emission control systems to prevent a potential recall. Additionally, any misbuilds or any parts that are not operating within design parameters would continue to be detected by OBD II system checks conducted during the functional test on the assembly line.

When the quality audit testing was first instituted, vehicles utilized carbureted fuel systems and most emission control components were operated mechanically rather than electronically. The operating parameters varied much more than is found in today’s vehicles, where sophisticated electronic controls achieve very narrow operating regions. In the past, the much larger variability of components made it necessary to emission test a portion of the assembly-line vehicles to ensure that each vehicle was operating properly after assembly and could meet the applicable emission standards. In order to meet today’s low emission standards, however, vehicles utilize sophisticated electronic controls that exhibit little variability and are self tuning for optimum emission performance.

In addition, emission testing of a vehicle at zero miles is not a good indicator of the ability of a vehicle to meet today's low emission standards. The presence of manufacturing oils in the engine and other components will likely increase the emissions of a vehicle as they burn off when the engine is first started. There could also be increased positive crankcase ventilation valve emissions until the piston rings have had a chance to properly seat. With today's stringent standards, there is very little margin for error and these factors could affect the emission results while not being fully representative of the vehicle's ability to meet the standards over time.

Finally, because there have been very few failing engine families reported from assembly-line testing in recent years, and because the 100% functional test requirement is still in effect, staff believes that the quality audit test is no longer cost-effective and that the end-of-line testing resources would be better utilized on the in-use testing required by CAP 2000. Therefore staff is proposing that the 2% quality audit requirement be eliminated.

3. Implementation of Manufacturer-Conducted In-Use Testing Requirements. Under current California regulations, the ARB procures and tests customer vehicles that have been properly maintained and used. Based on a number of predictive tools (certification data that is too close to the standard at the time of certification, indications of failures from the on-board diagnostic systems, Smog Check results, warranty reports that indicate a problem, or a previously failing engine family), ARB staff targets engine families that may not pass the standards. The engine families identified for testing cover about 15% of the total annual vehicle production for California. The test program has been very successful and will continue to operate under CAP 2000.

The amendments being proposed in this rulemaking would additionally require manufacturers to procure and test customer vehicles both at 10,000 miles, at 50,000 miles and one vehicle from every test group at a minimum of 75,000, 90,000 or 105,000 miles depending on the useful life of the vehicle. Manufacturers are required to test vehicles "as received" (rather than screening to exclude vehicles that have not been properly maintained and used) from every test group. If the vehicles tested do not meet the applicable emission requirements, a manufacturer must then conduct a subsequent test program on properly maintained and used vehicles to determine whether remedial action is required. The information received from the manufacturer-conducted testing would verify the efficacy of the manufacturer's durability demonstration required during the certification process and would also be used by the ARB to target potential problem test groups for evaluation.

Aside from some requirements that are specific to California (e.g., evaporative emission requirements, and zero-emission and hybrid electric vehicle testing), the U.S. EPA and California in-use test program requirements are essentially the same.

C. COST ANALYSIS

In order to calculate the costs and potential savings due to CAP 2000, staff followed the U.S. EPA methodology and calculations used in its rulemaking. For the impact of CAP 2000 on California only, staff adjusted the U.S. EPA's numbers to reflect those vehicles and reporting requirements that are applicable to California only and that would be required above and beyond the federal requirements. For example, because manufacturers are required to submit certification applications to both U.S. EPA and ARB for every California vehicle, staff assumed that 10% of a manufacturer's information and reporting requirements would be applicable to California vehicles. Staff also assumed that the number of durability data and emission data vehicles would be lower to reflect California only vehicles (e.g., low-emission vehicles). The cost savings for elimination of the 2% quality audit testing applies only in California. The following is a summary of the costs and savings attributable to CAP 2000 for California:

	Minimum (millions)	Maximum (millions)
Net Information Savings	$ 2.0	$ 2.0
Net Durability Savings	8.9	14.7
Net Emission Vehicle Savings	0.8	1.3
Elimination of 2% Quality Audit Testing	26.6	47.5
	38.3	65.5
Cost of New In-Use Verification Program	$ 1.6	$ 7.8
Cost of In-Use Confirmatory Program	0	.3
	(1.6)	(8.1)
TOTAL ANNUAL CAP 2000 SAVINGS	$ 36.7	$ 57.4

With annual California sales in excess of 1.7 million vehicles, this amounts to an average reduction of approximately $28 per vehicle.

D. REGULATORY ALTERNATIVES

Because most of the certification streamlining effort was cooperatively developed in conjunction with U.S. EPA and industry, most of the proposed regulatory amendments are a result of examination of all the regulatory alternatives available to government and industry. Throughout the process, the goal of ARB staff was to eliminate requirements that are no longer cost-effective, reduce unnecessary testing, harmonize where possible with U.S. EPA while maintaining the stringency of the California programs. The following alternatives were considered by staff.

1. Do not amend current California regulations. Staff believes that keeping the current program would not provide the same level of protection that is anticipated under CAP 2000. For the reasons stated earlier in this staff report, staff believes that current certification and assembly-line test programs have become less effective and do not provide the degree of protection that would be afforded by a comprehensive in-use compliance program. Unnecessary certification testing and paperwork often delay and add significant cost to a manufacturer's production costs but do not likely provide the same degree of protection that would be provided by an in-use test program.

2. Adopt a California-only program. The ARB, EPA and automobile industry have been working together for over two years to develop a streamlined certification program coupled with an enhanced in-use test program that is harmonized to the greatest extent possible between California and EPA. During the process, the ARB worked diligently to protect the stringency of our own programs within the framework of the CAP 2000 proposal. The program being proposed in this rulemaking is the result of these extensive negotiations. The ARB staff believes that it would not be cost-effective or in the best interests of California to propose a separate program that would add undue regulatory burden on manufacturers with essentially little, if any, added benefit. The program being proposed in this rulemaking addresses California's concerns and essentially provides more protection than is present under the current programs.

3. Adopt the federal regulations. The proposal before the Board in this rulemaking is essentially equivalent to the federal program with minor exceptions for California-only programs (e.g., emission testing at 50ºF, zero-emission and hybrid-electric vehicle testing, evaporative test requirements). Staff believes that the proposed harmonization with the proposed federal amendments relieves manufacturers of unnecessary regulatory burden while the proposed manufacturer-conducted in-use test requirements would provide an even greater degree of protection than under the current in-use compliance program.

VI. ECONOMIC IMPACT ANALYSIS

Overall, the proposed exhaust and evaporative regulatory amendments are expected to have no noticeable impact on the profitability of automobile manufacturers. These manufacturers are large and are mostly located outside California although some have some operations in California. The proposed standards are expected to cost manufacturers about $285 million annually. Most manufacturers, however, are likely to pass on the bulk of the cost increase to their customers in the form of higher prices. The expected increase in the retail cost of a vehicle is estimated to range from $96 to $304 per vehicle with an average of about $215 per vehicle. However, the cost savings from the proposed CAP 2000 amendments would reduce the per vehicle cost by approximately $28. The net cost impact of the proposed amendments would, then be about $187 per vehicle, or an increase of less than one percent in the price of a vehicle. Staff believes, therefore, that the proposed amendments would cause no noticeable adverse impact in California employment, business status, and competitiveness.

A. Legal requirement. Section 11346.3 of the Government Code requires State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination, or creation, and the ability of California business to compete.

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

B. Affected businesses. Any business involved in manufacturing, purchasing or servicing passenger cars, light-duty trucks and medium-duty vehicles could be affected by the proposed amendments. Also affected are businesses that supply parts for these vehicles. California accounts for only a small share of total nationwide motor vehicle and parts manufacturing. There are 34 companies worldwide that manufacture California-certified light- and medium-duty vehicles and heavy-duty gasoline engines. Only one motor vehicle manufacturing plant is located in California, the NUMMI facility, which is a joint venture between GM and Toyota.

C. Potential impact on manufacturers. The proposed amendments are expected to impose additional costs on motor vehicle and parts manufacturers. An extensive cost analysis concerning each component of this rulemaking, including exhaust, evaporative and CAP 2000, is contained in each of the respective sections of this staff report. The analysis shows that the proposed amendments when fully phased in would cost motor vehicle manufacturers about $285 million annually. This cost increase is not expected to have a noticeable impact on the profitability of affected manufacturers. In 1997, the Big Three auto manufacturers alone reported approximately $16.5 billion in profit on sales of over $381 billion. Besides, most manufacturers are expected to pass on the bulk of the cost increase to auto purchasers in the form of higher prices.

D. Potential impact on repair facilities. Some independent repair facilities believe that a shift of their business to franchised dealerships will take place as a result of the proposed 150,000 mile warranty requirements for vehicles eligible to receive a partial ZEV allowance and the 8 year/100,000 mile high cost parts warranty for vehicles certifying to the optional 150,000 mile standards. However, staff believes that any shift from the independent repair facility to the franchised dealers should be slight. The staff acknowledges that there will be a decrease in repair business for both independent repair facilities and dealers, but that the overall costs to society are reduced when vehicles are more durable in the first place. Importantly, the number of older vehicles with malfunctions that go unrepaired must be substantially reduced in order to achieve healthful air quality.

As covered earlier, staff does not expect a significant loss of repair business from independents to dealerships because there is likely to be a shift in the timing of opportunities in a vehicle lifetime to increase repair work rather than a net reduction. Then again, it appears that the inability of the dealership to satisfy customers on warranty repairs seems to be the best source of customers for independent repair facilities.

E. Potential impact on vehicle operators. The potential impact of the proposed standards on the retail price of a new motor vehicle hinges on the ability of manufacturers to pass on the cost increase to vehicle purchasers. The manufacturer's per vehicle cost for the LEV II exhaust element will depend on the nature of the vehicle and the emission standard to which it is certified. Assuming that manufacturers are able to pass on the entire cost of compliance to vehicle purchasers, staff estimates the price increase would range from $96 to approximately $304 per vehicle, with an average of about $215 per vehicle. The LEVII tailpipe elements of this regulation account for $190 of the price increase per vehicle, while the remainder of $25 per vehicle is due to new evaporative emission standards. However, the proposed CAP 2000 is expected to result in cost savings of about $28 per vehicle to manufacturers, which would partially offset the expected price increase. Thus, the net increase in the retail price of a vehicle is estimated to be about $187 per vehicle. As the average retail price of a motor vehicle presently exceeds $19,000, the cost increase on average represents less than a one percent increase in the price of new motor vehicles. This is not expected to have a significant impact on California businesses and individuals purchasing motor vehicles. In addition, vehicle purchasers would actually benefit from the warranty provision of the proposed amendments which require an extension of vehicle warranty to 150,000 miles.

F. Potential impact on business competitiveness. The proposed amendments would have no adverse impact on the ability of California businesses to compete with businesses in other states as the proposed standards are anticipated to have only a minor impact on retail prices of new vehicles.

G. Potential impact on employment. The proposed amendments are not expected to cause a noticeable change in California employment because California accounts for only a small share of motor vehicle and parts manufacturing employment. There could be an increase in California employment, however due to the proposed CAP 2000 amendments. Because all but one automobile manufacturer is located outside of California, manufacturers would need to conduct their in-use testing using contract laboratories located in California. To the extent that manufacturers utilize contract laboratories, there could potentially be an increase in employment in California.

H. Potential impact on business creation, elimination or expansion. Other than the increase in the use of contract laboratories to conduct in-use testing, the proposed amendments are not expected to affect business creation, elimination or expansion.

I. Potential costs to local and state agencies. The proposed amendments are not expected to result in an increase in costs for state and local agencies especially since the increase in purchase cost of a new motor vehicle is insignificant compared to the price of a new vehicle.

VII. ENVIRONMENTAL IMPACT AND COST-EFFECTIVENESS ANALYSIS

A. AIR QUALITY BENEFIT

California's plan for achieving the one-hour federal ambient ozone standard is contained in the SIP that was approved by the Board in 1994. The SIP calls for emission reductions of 25 tpd of ROG plus NOx by 2010 from light-duty vehicles (Mobile Source Measure M2) in the South Coast Air Basin and additional emission reductions in the South Coast Air Basin of approximately 75 tpd ROG plus NOx (the inventory of these emissions is referred to as the "Black Box"). Although the emission reduction strategies identified in this report are designed to meet the ozone SIP commitment for the SoCAB, the remainder of the state would also achieve needed emission reductions in ozone and particulate matter precursor pollutants. The reductions will also ensure continued statewide progress toward meeting state and new federal air quality standards for ozone and particulate matter. The proposed emission standards will also provide additional reductions for CO.

Using EMFAC7G, the proposed LEV II amendments are estimated to provide approximately 57 tpd ROG plus NOx emission reductions for the SoCAB in 2010. This proposal would meet the M2 SIP commitment, provide additional emission reductions to cover shortfalls in defined measures, and make progress in reducing the Black Box.

The emission reductions anticipated from the proposed tailpipe standards are:

Table VII-1
PROJECTED IMPACT OF LEV II TAILPIPE PROPOSAL
(EMFAC7G; tpd SoCAB)

2010	PCs	LDT2s <6000 lbs. GVW	LDT2s 6000 - 8500 lbs. GVW	MDVs >8500 lbs. GVW	Total Reduction
ROG	1.17	0.93	1.19	0.01	3.30
CO	45.33	41.73	32.44	0.94	120.44
NOx	15.29	19.83	15.66	0.71	51.49

The emission reductions anticipated from the proposed evaporative standards are:

Table VII-2
PROJECTED IMPACT OF THE EVAPORATIVE PROPOSAL (tpd ROG)

	2010	2020
South Coast Air Basin	2.4	8.1
Statewide	6.4	24.4

1. Impact of Proposed LEV II Exhaust Emission Standards. In determining the anticipated emission reductions, staff relied on the current emission inventory model, EMFAC7G with minor adjustments.

In order to calculate the emission reductions, staff assumed a fleet average implementation rate for NMOG according to the Tables II-7 and II-8. For NOx emission reductions and implementation of the 120K standard, staff assumed a 25/50/75/100% implementation of the LEV II standards beginning in the 2004 model year. The emission rate for SULEVs was the same as that used for ULEVs times a ratio of the ULEV to SULEV standards. To account for the projected growth rates for trucks and SUVs the vehicle mix was adjusted to 51% for passenger cars, 33% for light-duty trucks, and 16% for medium-duty vehicles less than 8,500 lbs. GVW. The total population of these vehicles, the number of vehicle miles traveled per vehicle and the number of starts per vehicle were held constant. It should also be noted that the baseline includes the emissions attributable to the Supplemental Federal Test Procedure standards. The analysis for medium-duty vehicles over 8,500 lbs. GVW assumed a baseline emission standard of 0.230 g/mi NMOG, 5.5 g/mi CO and 0.7 g/mi NOx.

2. Impact of Proposed Evaporative Emission Standards. To estimate the emission benefits of the reduced diurnal-plus-hot-soak standards and proposed extended durability requirements, the emission inventory model EMFAC7G was used for the diurnal and hot soak analyses, and the model EMFACX (to be released in late 1998) was used for the running loss analysis (consisting only of the extended durability.) Adjustments to the model were made to account for the proposed phase-in schedule of 40 percent, 80 percent, and 100 percent beginning in the 2004 model year. Other adjustments include temperature and Reid vapor pressure correction factors to account for these conditions in the enhanced evaporative test procedure as compared to those in the model. The methodology was performed only for vehicles in SoCAB, and scaling factors were developed in order to project emissions for statewide purposes.

3. Impact of Proposed CAP2000 Amendments. The proposed CAP 2000 amendments would not be expected to result in any increase in emissions and thus would not be expected to adversely impact the environment. Rather, it is anticipated that the implementation of the manufacturer-conducted in-use test program would likely decrease emissions because vehicles would be more likely to comply with the standards in-use, which would provide greater protection of our air quality.

4. Net Impact. The total estimated reductions from the LEV II proposal for passenger cars, light-duty trucks and medium-duty vehicles less than 8,500 lbs. GVW for 2010 are 6 tpd ROG (exhaust and evaporative emissions) and 51 tpd NOx in the SoCAB in 2010.

B. ASSESSING THE SIP COMMITMENT

The M2 SIP commitment can be evaluated in many ways. Although M2 is a tonnage commitment -- meaning that the ARB is responsible for obtaining 25 tpd ROG plus NOx (10 tpd expected from ROG and 15 tpd expected from NOx) -- it is important to evaluate the emission benefits of the proposal using both the most current inventory and the assumptions in place when the SIP was adopted.

As seen in Table VII-3, using the most current inventory, this proposal meets the total tonnage requirement of SIP commitment M2. However, the proposal shifts some of the anticipated ROG reductions to NOx reductions, delivering 6 of the 10 tpd ROG expected in the SIP. Staff believes that the LEV II proposal is the most cost-effective approach to achieving our air quality goals. This proposal achieves significant emission reductions for NOx, which have the ancillary benefit of reduced secondary PM formation in the atmosphere. (One of the constituents of secondary PM_{10} is ammonium nitrate which is formed from NOx in the atmosphere.) The proposal will also provide significant CO emission reductions.

Table VII-3
2010 South Coast Air Basin Exhaust Emission Benefit from the LEV II Proposal
(Current Inventory in tpd)

Measure	Pollutant	Emissions Inventory		Proposed Regulation Reductions
		Baseline	With Staff Proposal	
Staff LEV II Proposal	HC	129	123	6
	NOx	238	187	51

Once the U.S. EPA approved the 1994 SIP, the emission inventories used in the SIP were frozen. Thus, to compare the benefits of the proposal with the M2 commitment and other SIP commitments, it is necessary to evaluate the LEV II proposal using “SIP currency.” The SIP analysis applies the staff’s proposal to the frozen inventory to obtain emission reductions in SIP currency. Although the calculated emission benefits provide an “apples to apples” comparison to the SIP commitment, it is important to note that the SIP analysis does not fully account for the benefits of the LEV II regulation. The staff’s proposal responds to inventory improvements, such as off-cycle emissions and a shift in the vehicle population to heavier trucks and SUVs, which were not reflected in the SIP inventory.

As shown in Table VII-4, the LEV II proposal meets the M2 SIP commitment and provides additional reductions. The additional reductions will be used to offset shortfalls in other defined ARB measures and make progress toward reducing the Black Box.

Table VII-4
2010 South Coast Air Basin Exhaust Emission Benefit of LEV II Proposal
(1994 SIP Currency, tpd)

Measure	Pollutant	Emissions Inventory		Proposed Regulation Reductions
		Baseline	With Staff Proposal	
Staff LEV II Proposal	HC	120	113	7
	NOx	231	188	44

C. COST-EFFECTIVENESS OF LEV II PROPOSAL

The estimated combined cost-effectiveness of the exhaust and evaporative emission proposal minus the CAP 2000 savings would range from approximately $0.50 to $1.39 per pound of ROG + NOx reduced, which is well under the range of other cost-effective air quality control measures.

1. Exhaust Emission Benefits. Staff calculated the exhaust emission benefits of the LEV II program standards compared to the corresponding LEV I program standards using the EMFAC7G emission model (Table II-38). In calculating the incremental cost-effectiveness, the staff used two approaches. The first method is referenced in the "California Clean Air Act: Cost-Effectiveness Guidance" published by ARB in 1990. This method divides the total incremental cost to the consumer by the total emission reductions. The emissions include total ROG, NOx and CO adjusted by a factor of seven to put it on a comparable basis. The second approach was to divide the total incremental cost by the total ROG and NOx emission reductions. The cost-effectiveness results are shown in Table II-38 at the end of this staff report. Assuming that ULEVs will require more control than LEVs, staff's analysis focused solely on ULEVs for all types of vehicles -- PCs, LDTs and MDVs. The cost-effectiveness of the various categories of the ULEV II vehicles relative to ULEV I vehicles ranges between approximately $0.67 and $1.53 per pound, which compares favorably with other emission control programs. Even the incremental cost-effectiveness of a SULEV compared to a ULEV II vehicle is reasonable, ranging from $2.19 per pound to $4.76 per pound, depending on the calculation method used. No benefit was assumed for reductions in toxic emissions even though such reductions will result from lower HC and NOx emissions.

2. Evaporative Emission Benefits. The vehicle lifetime evaporative emission benefits, also estimated using the EMFAC7G emission model, were conducted for each vehicle category. At an estimated cost of compliance per vehicle of $25, the cost-effectiveness of the evaporative proposal, shown in Table VII-5, is, on average, approximately $1.70 per pound of ROG reduced, which compares favorably with other emission control programs.

TABLE VII-5
Cost-Effectiveness of the Evaporative Proposal

Vehicle Category	Cost-effectiveness ($/lb. ROG)
PC	1.41
LDT	1.50
MDV (6,001-8,500 lbs. GVWR)	1.71
MDV (8,501-14,000 lbs. GVWR)	1.91
HDV	1.77

3. Combined Cost-Effectiveness. Table VII-6 shows the combined exhaust plus evaporative cost-effectiveness of the ULEV II and SULEV standards relative to corresponding ULEV I standards. It should be noted that these values do not include the significant cost savings attributable to the CAP 2000 proposal which would further reduce these values by approximately $0.20 per vehicle.

TABLE VII-6
Cost-Effectiveness of LEV II Tailpipe and Evaporative Emissions Proposal

Emission Category	LEV I Vehicle Classes	ROG + NOx ($/lb)	ROG+CO/7+NOx ($/lb)
ULEV II	PC	1.13	1.05
	LDT1	0.83	0.76
	LDT2	1.17	1.03
	MDV2	1.28	0.84
	MDV3 (<8500 lbs. GVW)	0.86	0.61
	MDV3 (>8500 lbs. GVW)	1.34	1.23
SULEV	PC	1.48	1.16
	LDT1	1.22	0.95
	LDT2	1.53	1.23