State of California
AIR RESOURCES BOARD

PRELIMINARY DRAFT STAFF REPORT

PROPOSED AMENDMENTS TO THE LOW-EMISSION VEHICLE REGULATIONS TO ADD AN EQUIVALENT ZERO-EMISSION VEHICLE (EZEV) STANDARD AND ALLOW ZERO-EMISSION VEHICLE CREDIT FOR HYBRID-ELECTRIC VEHICLES

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EXECUTIVE SUMMARY

Advanced hybrid-electric vehicles (HEVs) and other advanced technology vehicles have the potential to play a long-term role in alleviating the environmental, energy, and other concerns associated with conventional vehicles. As a result of the research and development of these technologies, manufacturers and entrepreneurs have approached the Air Resources Board (ARB) and asked for an opportunity to demonstrate equivalent emission benefits to the ARB's zero-emission vehicle requirement through the use of new transportation technologies.

In response to these requests, the ARB directed the staff to evaluate the potential role of HEVs within the framework of the zero-emission vehicle requirement. In response to the Board's direction, the staff has met with a number of parties interested in HEVs and conducted a public forum to discuss the policy and air quality implications of allowing extremely low-emitting HEVs to receive at least partial credit toward the zero-emission vehicle requirement. Based on the information provided to date, the ARB staff is proposing amendments to the regulations that would establish performance-based standards and thus provide greater flexibility for industry to meet California's emissions requirements. The amendments would have no effect on the current zero-emission vehicle definition or the unique benefits that battery-electric technology offers --- namely no refueling emissions and no deterioration in emission control equipment.

The ARB staff is proposing amendments to add a new "equivalent zero-emission vehicle" (EZEV) emission standard, which is equal to the minor level of in-basin power plant emissions of oxides of nitrogen (NOx) and reactive organic gases (ROG) associated with charging battery-powered electric vehicles. The new standard is intended to provide an additional mechanism for technologies that can achieve extremely low tailpipe emissions to receive credit towards the zero-emission vehicle requirement. Since these technologies will likely have some tailpipe emissions, it is necessary to provide an additional standard in the regulations. Evaporative and refueling emissions would be counted along with exhaust emissions. Vehicles certified to the EZEV standard would be credited toward a manufacturer's zero-emission vehicle requirement on a one-to-one basis. The proposed certification standards for NOx and non-methane organic gas (NMOG) are:

Proposed Equivalent Zero-Emission Vehicle Certification Standards

Pollutant	Emissions Level
NOx	0.02 grams per mile
NMOG	0.004 grams per mile

Staff also proposes to amend the regulations to provide partial zero-emission vehicle credit for HEVs capable of providing a significant all-electric range. The proposed amendments acknowledge the fact that such HEVs could perform as electric vehicles for much of their operation. Under this proposal, the vehicle would have to be capable of at least a 30-mile all-electric range and have an auxiliary power unit certified to the ultra-low emission vehicle standards. The amount of zero-emission vehicle credit would be based on transportation survey data used in combination with the vehicle's all-electric range.

I. INTRODUCTION

In September 1990, the Air Resources Board (ARB or "Board") adopted the Low-Emission Vehicle and Clean Fuels (LEV) regulations. These regulations took effect in 1994 and require automakers to meet increasingly strict "fleet average" emission requirements each year through 2003. These regulations also require large-volume auto manufacturers to begin introducing zero-emission vehicles in model-year 1998. The only technology expected to meet the zero-emission vehicle (ZEV) standard by 1998 is the electric vehicle (EV) powered by electrochemical batteries.

At the time the LEV regulations were adopted, the Board directed the staff to update the Board at least biennially on the status of the implementation of the regulations and to propose any appropriate modifications. Since 1990, the Board has held two public meetings (June 1992 and May 1994) to discuss the status of technology development of low- and zero-emission vehicles, and two regulatory hearings (November 1991 and January 1993) to update the regulations.

The Board first acknowledged the unique capability of hybrid-electric vehicles (HEVs) to reduce vehicular emissions when the LEV regulations were adopted in 1990. At that time, the Board was aware of several prototype HEVs that featured a conventional internal combustion engine auxiliary power unit, which in series with the electric motor, served to extend vehicle range. However, because these engines were typically fueled with volatile liquids such as gasoline, they still produced significant evaporative emissions. In addition, as conventional engines, they were subject to in-use deterioration of emission control equipment with age or lack of maintenance. In the view of the Board, these HEVs, while capable of battery-only operation, were clearly not capable of providing the equivalent emissions benefits of pure EVs.

To provide an appropriate incentive to manufacturers who chose to produce hybrids, the LEV regulations established special non-methane organic gas (NMOG) emission levels based on the range the vehicle could operate on batteries alone. As an example, for a HEV with an auxiliary power unit certified to the ultra-low emission vehicle (ULEV) emissions standard, and capable of an all-electric range of 60 miles, the vehicle would be credited with emissions half way between the ULEV and ZEV standards.

The role of HEVs was again addressed by the Board at the second review of the regulations in May 1994. At this review, the Board directed the staff to evaluate the potential role of hybrid-electric vehicles within the framework of the ZEV requirement, and to report back to the Board on the staff's findings. In response, the ARB staff has gathered information from industry and other interested parties regarding HEVs and the potential for advanced HEVs to reduce mobile source emissions. On May 9, 1995, the ARB staff held a public forum to discuss both the policy and technical issues associated with HEVs. The staff also presented initial concepts for allowing ZEV credit for HEVs. Effort was made to gather information from all impacted parties during and after the forum. The information obtained was used to help refine the initial concepts into the proposal contained within this package.

The ARB staff is proposing amendments to add a new "equivalent zero-emission vehicle" (EZEV) emission standard, equal to the emissions associated with battery-powered electric vehicles. The amendments would have no effect on the current zero-emission vehicle definition or the unique benefits that battery-electric technology offers. The standard is based on the power plant emissions of oxides of nitrogen (NOx) and reactive organic gases (ROG) that are associated with the use of pure electric vehicles, and is about 10 times more stringent than the ULEV standard. The new standard is intended to provide an additional mechanism for technologies that can achieve extremely low tailpipe emissions to receive credit towards the ZEV requirement. Since these technologies will likely have some tailpipe emissions, it is necessary to provide an additional standard to the regulations. Vehicles certified to the EZEV standard, would be credited toward a manufacturer's ZEV requirement on a one-to-one basis.

The ARB staff also proposes that a HEV receive partial ZEV credit if it is capable of significant all-electric range (at least 30 miles) and has an auxiliary power unit certified to the ultra-low emission vehicle standards. This concept acknowledges the fact that such HEVs perform as electric vehicles for much of their operation. The amount of partial ZEV credit would be based on transportation survey data used in combination with the vehicle's all-electric range.

The ARB staff is not aware of any large-volume manufacturer that plans to develop and market such a vehicle in the near term. However, the staff believes it is important to provide the flexibility needed to allow manufacturers an opportunity to certify vehicles that can provide emission reductions equivalent to an electric vehicle, and therefore count toward the ZEV requirement.

II. DESCRIPTION OF THE LOW-EMISSION VEHICLE PROGRAM

The LEV program is a critical component of California's long-term plan for reducing air pollution from light- and medium-duty mobile sources. The program requires implementation of advanced mobile source control strategies to substantially improve California's air quality problem. The following is a summary of the LEV program.

A. LEV Emission Standards

The LEV program establishes emission standards for four categories of vehicles, each with increasingly stringent emission requirements: transitional low-emission vehicles (TLEV), low-emission vehicles (LEV), ultra-low emission vehicles (ULEV), and zero-emission vehicles (ZEV). The largest class of vehicles to which the LEV regulations apply is comprised of passenger cars and light-duty trucks (weighing less than 3,750 pounds). The 50,000-mile emission standards applicable to this class are shown in Table II-1.

TABLE II-1
Light-Duty Low-Emission Vehicle 50,000-Mile Exhaust Emission Standards

Vehicle Class[1]	NMOG (grams/mile)	CO (grams/mile)	NOx (grams/mile)
TLEV	0.125	3.4	0.4
LEV	0.075	3.4	0.2
ULEV	0.040	1.7	0.2
ZEV	zero	zero	zero

1 "NMOG" (non-methane organic gas) is comprised of non-methane hydrocarbons and all oxygenated hydrocarbons.

A unique feature of the LEV program is its market-based approach to implementation which affords considerable flexibility to manufacturers. Manufacturers are not required to phase-in specific percentages of light-duty vehicles (with the exception of ZEVs, which will be discussed in the following section). Instead, a fleet average emission level for NMOG is set for each year. Manufacturers can certify any combination of vehicles as long as the overall fleet average emission level is met. Compliance is determined by calculating the sales weighted average NMOG emissions of a manufacturer's fleet. Additional flexibility is provided through the use of a marketable credit trading system. Manufacturers that exceed the fleet average requirement accumulate credits that can be banked, traded or sold to other manufacturers. The fleet average requirement for passenger cars and light-duty trucks weighing less than 3,750 pounds is shown in Table II-2.

TABLE II-2
Passenger Cars and Light-Duty Trucks (0-3750 pounds)

Model Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Fleet Avg NMOG (g/mi)	0.250	0.231	0.225	0.202	0.157	0.113	0.073	0.070	0.068	0.062

The requirements for medium-duty vehicles are approached differently. Because of the diversity of vehicle classes in this category, it was not practical to create a fleet average requirement. Instead, manufacturers of medium-duty vehicles are required to meet certain percentage phase-in requirements, but they can accumulate marketable emission credits by exceeding these phase-in percentages. This credit system also affords medium-duty vehicle manufacturers considerable compliance flexibility.

B. The Requirement for Zero-Emission Vehicles

The only instance in which the LEV regulations require the introduction of a vehicle with a specific emission level is the ZEV. The LEV regulations define a ZEV as "any vehicle which is certified by the Executive Officer to produce zero emissions of any criteria pollutant under any and all possible operational modes and conditions." Beginning in 1998, all large-volume manufacturers (those with sales in California exceeding 35,000 vehicles per year) are required to introduce certain percentages of ZEVs, as shown in Table II-3. In 2003, the ZEV requirement will also apply to intermediate-volume manufacturers, i.e. those manufacturers that sell between 3,001 and 35,000 vehicles in California each year.

TABLE II-3
ZEV Requirement

Model Year	1998	1999	2000	2001	2002	2003+
% Requirement	2	2	2	5	5	10

Generating ZEV Credits

Each ZEV that a manufacturer produces and delivers for sale in California is credited toward its ZEV requirement. If a manufacturer produces more ZEVs than are required in a given year, it earns ZEV credits. The amount of credits generated by an "excess" ZEV is based on the allowable emissions of the average new vehicle it will be replacing. The credit is expressed in units of grams of NMOG per mile. For each model year, a manufacturer would determine the "excess" number of ZEVs it produced and delivered for sale in California, and multiply that number by the passenger car and light truck grams per mile NMOG fleet average emission level required for that model year. For example, 10 excess ZEVs produced in the 1998 model year would generate ZEV credits of 1.57 grams per mile (10 x 0.157 grams per mile), while 10 ZEVs produced in the 1994 model year would generate ZEV credits of 2.50 grams per mile (10 x 0.25 grams per mile).

The existing ZEV credit framework provides a significant amount of flexibility, since manufacturers may forego producing ZEVs in a given year by using credits from early production of ZEVs or by obtaining credits from other manufacturers. Manufacturers are also allowed to make up any deficits by the end of the following year without penalty. If a manufacturer does not make up its deficit, they are required to pay a penalty, which is designed to help equalize the competitive effects of those manufacturers who make the investment to meet the ZEV requirements with those who do not.

C. Hybrid-Electric Vehicle NMOG Credits

At the time the LEV regulations were adopted in 1990, the ARB was aware of several prototype HEVs. These vehicles typically featured a conventional internal combustion engine auxiliary power unit (APU) which served to extend vehicle range. To encourage the development of HEVs that are designed to operate for long distances in the all-electric mode, and thereby promote driving in the "zero-emissions" mode, the regulations provide credit to HEVs based on the vehicle's all-electric range. The vehicle's APU must be certified to one of the LEV standards. This credit is only provided for the purpose of calculating a manufacturer's NMOG fleet average and does not count towards the ZEV requirement.

To illustrate how the LEV regulations currently provide additional NMOG credits for HEVs, consider a HEV with an APU certified to the ULEV standards. If this vehicle has an all-electric range of 60 miles or greater, it is granted additional NMOG credit equal to one-half of the difference between the NMOG certification standard of the APU (in this case, ULEV) and the next most stringent certification standard (in this case, ZEV). The same HEV with a 40 to 59 mile all-electric range would be granted additional credit equal to 25 percent of the difference between the ULEV and ZEV NMOG certification standards. No additional NMOG credit is provided for a HEV with an all-electric range of less than 40 miles. Table II-4 illustrates the possible NMOG emission levels of an HEV certified as an ULEV, based on all-electric range. This NMOG level is used in calculating a manufacturer's fleet average emission level for determining compliance with the LEV regulations. In contrast, a conventional (i.e., non-hybrid electric) vehicle certified to the ULEV standards receives an NMOG level of 0.040 grams per mile. The Type A, B, and C designation refers to the vehicle's all-electric range.

TABLE II-4
Current HEV Certification Categories[1]

HEV Type	All-Electric Range (miles)	NMOG Level (grams/mile)
A	$\geq$ 60	0.02
B	40 to 59	0.03
C	0 to 39	0.04

1 For HEVs with APUs certified to ULEV emission levels.

III. PROPOSED AMENDMENTS TO ADD AN EQUIVALENT ZERO-EMISSION VEHICLE CERTIFICATION STANDARD

The ARB staff proposes that several amendments be made to the LEV regulations to allow ZEV credit for vehicles that have emissions comparable to the power plant emissions associated with pure electric vehicles. In reviewing HEV technology, the staff had originally proposed that ZEV credit be allowed for two distinct types of HEVs, dubbed Class I and Class II HEVs. However, in recognizing that other technologies, such as extremely clean fuel cell vehicles or hydrogen-powered combustion vehicles, may also be able to certify to the Class I concept, the staff has renamed this category as equivalent zero-emission vehicle or "EZEV."

The staff proposes that this new certification standard, "equivalent zero-emission vehicle" correspond to the power plant emission levels associated with EVs. Vehicles that certify to the EZEV standard would be counted toward a manufacturer's ZEV requirement. These vehicles would be required to maintain their emissions at or below the EZEV certification standards for the entire life of the vehicle. However, for certification purposes, a manufacturer would be required to demonstrate that the vehicle's total emissions, including exhaust, evaporative and refueling emissions, do not exceed the EZEV certification standards over a 100,000-mile life.

Evaporative emissions include hot soak emissions, diurnal emissions, resting losses and running losses. In-use vehicle testing would be used to determine compliance with the certification standards throughout the life of the vehicle. EZEVs that exceed the certification standards would be subject to recall. The vehicle would also be required to employ an on-board diagnostic system, and would be subject to inspection and maintenance requirements.

A. Background

Under the LEV regulations, a ZEV is defined as "any vehicle which is certified by the Executive Officer to produce zero emissions of any criteria pollutant under any and all possible operational modes and conditions." Battery-powered electric vehicles are currently the only vehicles that fulfill this definition. Although EVs emit no exhaust or evaporative emissions, there are power plant emissions associated with generating the energy needed to charge the EV batteries. In the "Staff Report: 1994 Low-Emission Vehicle and Zero-Emission Vehicle Program Review" dated April 1994, the ARB staff presented an estimate of EV emissions in the South Coast Air Basin (SCAB) based on average power plant emissions. The results of this analysis are summarized in Table III-1.

TABLE III-1
Average SCAB Power Plant Emissions Associated with EVs[1]

NOx (g/mi)	ROG (g/mi)
0.01	0.001

1 Based on 33 percent in-basin power generation. Vehicle efficiency is assumed to be 0.35 kilowatt-hours per mile (kWhr/mile). Power plant emissions are assumed to be 0.15 lbs/MWhr NOx and 0.02 lbs/MWhr ROG.

The staff's analysis of average power plant emissions represented a fairly simplified approach to the evaluation of EV emissions. A more thorough approach would examine the emissions from the individual power plants in the SCAB that would generate the electricity needed for EVs. However, the approach used in the April 1994 report enabled the staff to estimate the magnitude of EV-related power plant emissions in a timely manner.

B. Current ARB Analysis of EV Emissions

To conduct a more thorough assessment of the power plant emissions associated with EVs and improve upon the analysis conducted for the April 1994 staff report, the staff requested the assistance of the California Energy Commission (CEC) staff to analyze the emissions associated with the additional, or marginal, power that will be generated to satisfy EV demand in the SCAB. The ARB and CEC staffs decided on a number of different assumptions (e.g., number of EVs, vehicle efficiency, miles travelled per year) that would characterize the additional demand for electricity due to EVs. The CEC staff then used the Elfin model (Electric Utility Financial and Production Cost Model, owned and maintained by the Environmental Defense Fund) to estimate the amount of additional electricity that would need to be generated under several scenarios, and to predict which power plants would produce this marginal electricity. The NOx and ROG emission factors associated with those plants were used to arrive at the total emissions expected to occur in the SCAB due to the use of EVs. A vehicle emission rate (in grams per mile) was calculated by applying an EV efficiency value. A draft report describing this work has been prepared by the CEC staff, and is attached as Appendix C.

The CEC staff ran the Elfin model using several different combinations of assumptions regarding the number of EVs that will be distributed to the SCAB, the times of day that EVs will be charged and the efficiency of EVs. The ARB staff has summarized these different combinations of assumptions into six scenarios, which are described in detail in Appendix B. The ARB staff selected one of these scenarios as the "primary scenario," because the staff believes it represents the most appropriate characterization of EV implementation in the SCAB. The primary scenario is described in Table III-2. The results of the CEC staff's analysis for the primary scenario are presented in Table III-3. Results for the other scenarios are presented in Appendix B.

TABLE III-2
Summary of Assumptions: ARB Staff Primary Scenario

Years Analyzed	Number of EVs in SCAB	Charging Profile	Efficiency (kWhr/mi)	Miles Driven per Year
2000 & 2010	775,000 in 2010 (55% of state-wide EVs)	84% Off-Peak 16% On-Peak	0.24 to 0.35	10,000

TABLE III-3
Marginal Electric Vehicle In-Basin Emission Rates[1]

Primary Scenario: 84% Off-Peak/16% On-Peak, 55% SCAB Distribution

Efficiency (kWhr/mi)	2000		2010	
	NOx (g/mi)	ROG (g/mi)	NOx (g/mi)	ROG (g/mi)
0.24	0.017	0.001	0.012	0.002
0.35	0.020	0.001	0.020	0.003

1 Emission rates represent a weighted average of emissions for Southern California Edison and Los Angeles Department of Water and Power.

The in-basin EV emission rates in Table III-3 are extremely low. However, the overall emissions impact due to EVs in the SCAB may in fact be even lower. Power plants located in the SCAB are subject to increasingly stringent emission requirements through 2010 under the South Coast Air Quality Management's (SCAQMD's) RECLAIM program. Under this program, power plants are required to reduce emissions of NOx from their facilities or purchase RECLAIM Trading Credits (RTCs) from other sources. However, in their analysis the CEC staff determined the emissions from power plants without adjusting these emissions for scenarios in which utility NOx emissions were projected to exceed RECLAIM allotments. In such situations, the utility would be required to offset these exceedances by either applying control equipment or by purchasing RTCs from other sources. Using either approach, overall emissions in the SCAB due to EVs would be reduced.

C. Proposed Equivalent Zero-Emission Vehicle (EZEV) Certification Standards

The ARB staff proposes to include a new classification of vehicle to the LEV regulations to be defined as:

> "Equivalent Zero-Emission Vehicle" or "EZEV" means any vehicle which is certified to the EZEV exhaust emission standards.

The EZEV category is intended to reflect the minor level of emissions associated with battery-powered electric vehicles and would have no effect on the current zero-emission vehicle definition. The new standard merely provides an additional mechanism for technologies that can achieve extremely low tailpipe emissions to receive credit towards the zero-emission vehicle requirement. Since these technologies will likely have some tailpipe emissions, it is necessary to provide an emissions standard within the regulations. The staff's proposed certification standards for EZEVs are presented in Table III-4. The proposed NOx standard of 0.02 grams per mile corresponds to the emission rate estimated for the primary scenario, and also lies at the top of the range of NOx emissions for all six of the scenarios that the ARB staff considered. The proposed NMOG standard of 0.004 grams per mile is slightly higher than the ROG emission rate predicted for the primary scenario, but represents the upper bound of ROG emission rates for all of the scenarios considered. The proposed carbon monoxide (CO) and particulate matter (PM) emission standards correspond to one-tenth of the existing CO and PM standards for ULEVs. These values are not based on power plant emission levels, but are the same percentage of the ULEV standards as the NOx and NMOG EZEV standards. The staff believes that future advanced technology vehicles would be able to achieve the proposed CO and PM emission levels. It is not the staff's intention to have the proposed CO or PM emission standards limit the ability of technology to certify to the EZEV standard. The staff does not propose a separate formaldehyde emission standard as formaldehyde will be counted in the NMOG emissions of the vehicle.

TABLE III-4
Proposed EZEV Certification Standards

Vehicle Type	Loaded Vehicle Weight (LVW) (pounds)	APU Durability Basis	NOx (g/mi)	NMOG (g/mi)	CO (g/mi)	PM (g/mi)
PC[1]	all	vehicle life	0.02	0.004	0.17	0.004
LDT[2]	0-3750					

1 Passenger car
2 Light-duty truck

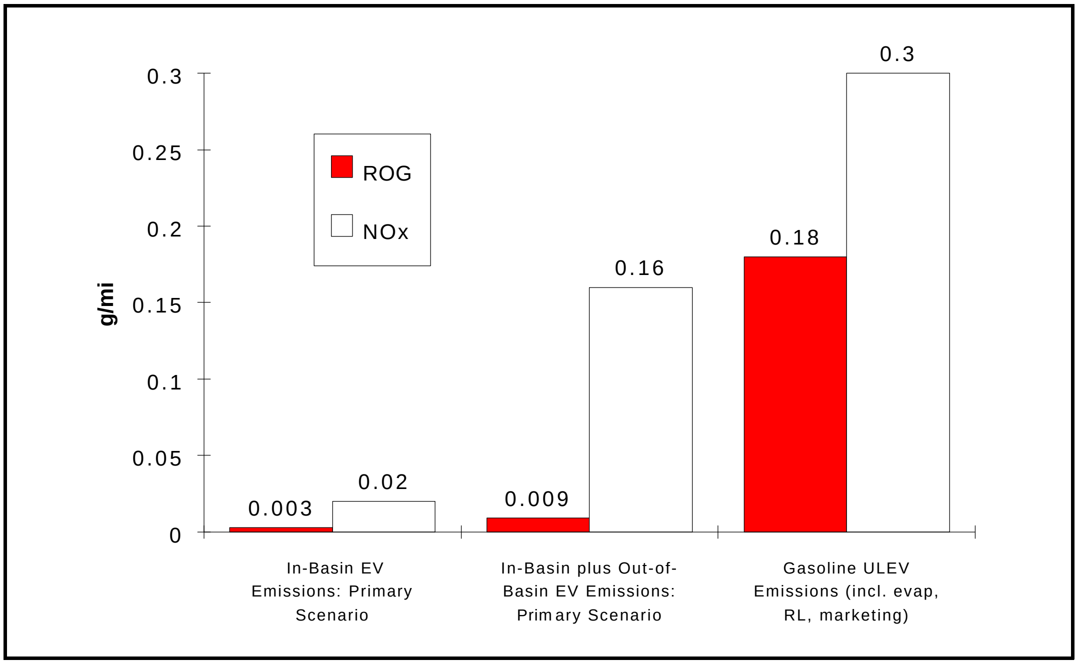
The staff proposes that, in order to certify to the EZEV standards, a vehicle would need to have exhaust, evaporative, and refueling emissions that do not exceed the emission rates in Table III-4 for the entire life of the vehicle. By including refueling emissions in the determination of compliance with the EZEV standards, the staff is attempting to account for a majority of the fuel-cycle emissions associated with the EZEV. The staff recognizes that there are other fuel-cycle emissions that occur prior to vehicle refueling (e.g. fuel production and transportation emissions). This is addressed in more detail in the following section. For certification purposes, manufacturers would be required to demonstrate compliance with the EZEV standards up to 100,000 miles on the vehicle engine or auxiliary power unit. In-use testing would be used to verify compliance throughout the vehicle life. Vehicles failing to maintain emissions at the level of the EZEV certification standards would be subject to recall. EZEVs would also be required to employ an on-board diagnostic system, and would be subject to inspection and maintenance requirements. EZEVs would also be required to meet the general requirements for cold temperature exhaust CO and the 50° F emission test requirements for NMOG, NOx, and CO.

D. Discussion of Issues

o Out-of-basin emissions

The proposed EZEV certification standards are based on power plant emissions within the SCAB. The CEC staff also evaluated emissions from power plants located outside of the SCAB that will generate electricity for use by EVs that operate in the SCAB. Figure III-1 compares the in-basin EV emissions associated with the primary scenario to the in-basin plus out-of-basin emissions for the same scenario.

FIGURE III-1
A Comparison of In-Basin EV Emissions to Total EV and ULEV Emissions



The in-basin plus out-of-basin power plant emissions include emissions from relatively dirty coal-fired power plants located outside of California. Emissions, including exhaust, evaporative, and fuel marketing emissions, for a gasoline-powered ULEV are also displayed. Figure III-1 shows EVs are still much cleaner than a ULEV, even when the out-of-basin power plant emissions are included.

The Los Angeles area has the most severe air quality problem in the United States. Although power plants outside the SCAB, and in particular out-of-state power plants, are allowed to emit at higher levels than those within the SCAB, in-basin power plants have been subject to stringent emissions requirements in order to improve air quality. Because of this, in-basin power plant emissions due to the use of EVs are extremely low. While it is important to recognize the total air quality impact of EVs both within and outside of the SCAB, it would be inappropriate to allow an EZEV to count toward a manufacturer's ZEV

requirement if it emits at the higher out-of-basin emission levels while operating in the SCAB, as this would seriously reduce the effectiveness of the LEV regulations.

o Applicability to other air basins within California

The proposed EZEV certification standards are based on the power plant emissions associated with EVs operated in the SCAB. These emissions may be either higher or lower than the power plant emissions associated with EVs operated in other areas of California. For example, the Sacramento region obtains most of its electricity from sources outside the area. Therefore, the power plant emissions associated with EVs within the Sacramento area are very low. For areas such as Sacramento, the substitution of a EZEV for a ZEV could result in a small increase in emissions. While it is important to recognize this fact, it is essential that the EZEV emission standards be consistent statewide. It would not be practical to establish separate certification standards for each air basin within California. For this reason, it is logical to base the certification standards on power plant emissions in the SCAB, the area with the worst air quality problem.

o Accounting for the full fuel-cycle emissions of an EZEV

The proposed EZEV certification standards are based on the power plant emissions associated with the use of an EV. These emissions comprise nearly all of the fuel-cycle emissions associated with an EV. In order to make an appropriate comparison, therefore, the emissions associated with an EZEV should also account for the full fuel-cycle, including fuel production and marketing emissions. The staff has attempted to account for a majority of the fuel-cycle emissions of an EZEV by including refueling emissions along with exhaust and evaporative emissions in determining compliance with the EZEV certification standards. However, the staff recognizes that there are additional fuel-cycle emissions that occur prior to vehicle fueling, such as emissions associated with fuel production and transportation. These emissions are very difficult to quantify. The ARB staff has a contract with Acurex Environmental Corporation to evaluate the full fuel-cycle emissions for several different fuels. A final report is expected in Fall 1995. Once the results of this report are available, the staff may modify the current proposal to require that EZEVs account for fuel-cycle emissions that occur prior to vehicle fueling. Power plant fuel production and transportation emissions would also need to be added to the EZEV certification standards.

o EZEV durability requirement

One of the significant benefits of electric vehicles is that they do not experience deterioration of an emissions control system--they are zero-emission vehicles throughout

the vehicle life. Because manufacturers would be allowed to use EZEVs to satisfy their ZEV requirement, the EZEV must provide an equivalent air quality benefit. If the emissions from an EZEV were to increase beyond the original certification standards over time, the vehicle would no longer provide the same air quality benefits as a ZEV. In order to ensure that the EZEV emissions remain comparable to the emissions associated with an EV throughout the vehicle's life, the staff proposes that the emissions remain at or below the EZEV certification standard for the entire life of the vehicle. Vehicles certifying to the EZEV standard would be required to demonstrate compliance up to 100,000 miles on the vehicle engine or APU. In-use vehicle testing would be used to determine compliance with this requirement throughout the vehicle life. EZEVs that exceed the certification standards at any point in the life of the vehicle would be subject to recall. If a HEV that is eligible to certify to the EZEV standard is designed to operate on stored battery power for a significant portion of the total vehicle miles, the manufacturer may petition the Executive Officer to reduce the certification demonstration requirement to a level below 100,000 miles. However, in no case shall the certification demonstration requirement be less than 50,000 miles.

o RECLAIM

The SCAQMD's RECLAIM program requires that power plants in the SCAB significantly reduce emissions of NOx through 2010. In order to achieve these reductions, utilities may apply emission control equipment to their facilities or purchase RECLAIM Trading Credits (RTCs) from other companies that reduce emissions beyond what is required. In their analysis, the CEC staff used emission factors that were provided by utilities for the Electricity Report 94 (ER94). This information indicated that Southern California Edison (SCE) and Los Angeles Department of Water and Power (LADWP) plan to apply emission control equipment to some of their facilities to meet their RECLAIM requirements. However, in many of the EV scenarios that were evaluated by the CEC staff, the results indicate that RECLAIM allotments would be exceeded. In practice, once utilities reach their RECLAIM allotments, they will need to either apply additional emission controls or purchase RTCs in order to expand production. The CEC staff did not attempt to predict the manner in which a utility will choose to comply with RECLAIM. As a result, the EV emission rates may overestimate the overall emissions impact associated with EVs in the SCAB.

IV. PROPOSED AMENDMENTS TO PROVIDE PARTIAL ZEV CREDIT FOR HYBRID-ELECTRIC VEHICLES

The staff also proposes to allow partial ZEV credit for HEVs that have a significant all-electric range. The proposed amendments acknowledge the fact that such HEVs perform as electric vehicles for much of their operation. To ensure the greatest use of all-electric operation possible, and to limit the amount of emissions during APU operation, the proposal requires that:

- **the vehicle's APU must be certified to the ULEV emission standards**
- **the vehicle's total emissions, including exhaust, evaporative and refueling emissions, do not exceed the certification standards**
- **the vehicle must have a minimum 30 mile all-electric range**

A HEV that is designed to operate on battery power for a significant number of miles can be viewed as operating as an ZEV during those all-electric miles. However, the staff is concerned that significant uncertainty exists regarding the operator's actual use of the vehicle. Ideally, the operator would charge the vehicle overnight. In actuality, however, the vehicle operator may neglect to recharge the batteries overnight, thereby relying on APU power the following day. As the vehicle ages, the operator could decide to forego the expense of replacing the battery pack when it is no longer capable of carrying a full charge. The vehicle would then provide a significantly reduced all-electric range and in some cases may operate on APU power alone. The staff has incorporated a safety factor in the proposed ZEV credit amounts to account for these uncertainties. Alternatively, a manufacturer could apply technological safeguards to reduce the level of uncertainty in actual vehicle operation. Under this proposal, such an alternative approach would have to be submitted to the Executive Officer for approval.

A. Vehicle Requirements

The following describes the staff's proposed requirements that must be met in order for a HEV to be eligible to receive partial ZEV credit.

Auxiliary Power Unit Emission Standards

The staff proposes that in order to qualify for partial ZEV credit, a HEV must employ an APU that is certified to the ULEV emission standards. The regulations currently allow a HEV to receive additional NMOG credit as long as the vehicle's APU is certified to either the TLEV, LEV, or ULEV standard. However, the staff does not believe

it is appropriate to grant partial ZEV credit for a HEV unless it meets the most stringent emissions standard when operating on the APU.

As with the requirements for EZEV certification, HEVs earning partial ZEV credit would be required to demonstrate that the vehicle's total emissions, including exhaust, evaporative and refueling emissions, do not exceed the certification standards over a 100,000-mile life. This requires that the APU meet standards that are more stringent than the ULEV emissions requirements. However, in-use vehicle testing would be used to determine compliance with the certification standards throughout the life of the vehicle. Vehicles that exceed the certification standards would be subject to recall. The vehicle would also be required to employ an on-board diagnostic system, and would be subject to inspection and maintenance requirements. A manufacturer may petition the Executive Officer to reduce the certification demonstration requirement to a level below 100,000 miles if the manufacturer can demonstrate that the APU will accumulate significantly less than 100,000 miles over the vehicle life. However, in no case shall the requirement be below 50,000 miles. The APU must also meet the general requirements for cold temperature exhaust carbon monoxide and the 50º F emission test requirements for NMOG, NOx and CO.

Minimum Range Requirement

The staff proposes that to qualify for partial ZEV credit, a HEV must have a minimum all-electric range of 30 miles. The staff based this value on a study entitled "State of the Commute 1994"[1] by Commuter Transportation Services, Inc. in Los Angeles, which provides an estimate of the average round-trip commute distance in the Los Angeles area. The study found that the average daily round-trip commute was 33 miles in 1994. The staff believes that requiring a 30 mile all-electric range will provide ZEV credit to those HEVs capable of meeting the majority of the daily commute requirements of the average person while in battery-only operation. If the minimum range requirement were lower than 30 miles, the staff believes that a significant number of trips would be made on APU power alone. While it may be theoretically possible for a HEV with a very short all-electric range to complete many short trips in the all-electric mode, the staff believes that it is unlikely that a HEV would be recharged frequently throughout the day. As a result, the amount of mileage that a HEV with a very short all-electric range would be used as a pure electric vehicle would be significantly less than the actual mileage associated with all short trips.

B. Calculation of ZEV Credit

The following section describes the methodology the staff used to calculate the amount of ZEV credit a HEV would be eligible to receive under the proposal. The methodology would require that:

- **the amount of ZEV credit be determined based on the vehicle's all-electric range**
- **a safety factor be applied to account for uncertainties in actual use patterns**

Percent of Vehicle Miles Traveled Accommodated in the All-Electric Mode

The amount of ZEV credit that a HEV ULEV could receive is related to the percentage of vehicle miles traveled (VMT) that the vehicle is capable of accommodating in the all-electric mode. To estimate the percent of daily VMT that could be accommodated in the all-electric mode, survey data regarding the distribution of daily VMT must be compared to the all-electric range of the HEV. The staff proposes to use both the United States Department of Transportation's 1990 Nationwide Personal Transportation Survey[2] and the 1994 State of the Commute Survey to estimate daily travel patterns. Information from the two surveys was used to estimate the percentage of VMT that a HEV could accommodate using battery operation only. The estimates are presented in Table III-5. As shown in the Table, an estimated 68 percent of all travel could be met with a HEV capable of 30 miles of all-electric range under optimal conditions and use. A HEV capable of 90 miles all-electric range could be used for an estimated 88 percent of all travel.

TABLE III-5
Percent of VMT Potentially Accommodated in HEV All-Electric Mode

All-Electric Range (miles)	Percent of VMT
30	68
40	75
50	79
60	83
70	85
80	86
90	88

Application of the Safety Factor

Ideally, to confirm that HEV technologies will yield real and quantifiable emission benefits, the ARB would assess and demonstrate HEVs through real-world testing and develop information on how the vehicles would be used. However, due to a lack of vehicles, there is little real-world experience with the design and operation of HEVs that might qualify for ZEV credit. It has been suggested that the amount of ZEV credit be equal to the maximum theoretical mileage that could be operated on electric power (using average trip-length data from the Nationwide Personal Transportation Survey). Due to unquantified human behavior and vehicle technology elements, such as neglecting to plug in the vehicle or delaying replacement of deteriorating batteries, a safety factor must be included to account for non-optimum use of the APU. Moreover, until HEVs are available and in-use data is obtained, it is not possible to accurately predict driving patterns and charging patterns, and thus the associated emissions benefits from HEVs. Consequently, the staff believes that it is appropriate to include a 0.5 safety factor to account for these uncertainties.

To receive any ZEV credit, the vehicle design must include mechanisms to ensure that the battery would be recharged from the wall plug instead of the APU. This is necessary to ensure that the battery energy needed to provide the certified all-electric range of the vehicle can not simply be generated using APU power. If this battery energy were generated by the APU, the HEV would not be equivalent to a pure EV while operating in the all-electric mode.

The staff proposes a mechanism to allow manufacturers to reduce or eliminate the application of the safety factor through the use of technological safeguards. To qualify for an exemption, at a minimum, the ARB staff would expect that the vehicle design prevent the APU from being operated manually, used to meet high-load conditions, or used to operate accessories. Furthermore, the vehicle design should require the owner to replace the battery pack once it has reached its end of life. The manufacturer would be responsible for providing information and petitioning the ARB's Executive Officer to eliminate the safety factor on a case-by-case basis.

Proposed Credit Values

Table III-6 provides a summary of both the NMOG and ZEV credits that may be generated by HEVs meeting the above requirements. Given the uncertainty in actual HEV operation, the proposed credit ratios are based on the value at the low-end of each range. That is, for a HEV capable of an all-electric range between 40 and 49 miles, the proposed

amendments would provide the vehicle with 75 percent the ZEV credit of a pure electric vehicle. This value is the estimated percentage of VMT that a HEV with a 40 mile range could conceivably accommodate with battery-only operation.

The amount of credit is different for three types of vehicles: Type 1, Type 2, and Type 3. The Type 1 category refers to those hybrid ULEVs that are certified having technological safeguards (approved by the ARB's Executive Officer), to eliminate the safety factor. Type 2 hybrid ULEVs meet the same requirements as for Type 1. However, this class of vehicle does not include technological safeguards to ensure optimal zero-emission use. As a result, Type 2 hybrid ULEVs are subject to application of the 0.5 safety factor and therefore would receive half the ZEV credit provided the Type 1 hybrid ULEVs. Type 3 refers to HEVs employing an APU certified to either the TLEV or LEV standards. These vehicles do not meet the requirements for ZEV credit, but will continue to be eligible for extra NMOG credits. For ULEV HEVs having a range of less than 30 miles, no ZEV credit would be granted and the NMOG credit would remain at the level of the ULEV emission standards. The proposal also redefines the existing nomenclature for the various range categories. Category A now refers to a HEV capable of between 30 to 39 miles of all-electric range. Category B refers to a HEV capable of between 40 to 49 miles. A total of seven range categories would replace the three now included within the regulations.

TABLE III-6
Proposed Credit Ratios for HEVs with Significant All-Electric Range

HEV Category	All-Electric Range[1] (miles)	Type 1 ULEV		Type 2 ULEV	
		NMOG (g/mi)	ZEV (Credit Multiplier)	NMOG (g/mi)	ZEV (Credit Multiplier)
AA	0 - 29	0.04	0	0.04	0
A	30 - 39	0.04	0.68	0.04	0.34
B	40 - 49	0.03	0.75	0.03	0.37
C	50 - 59	0.03	0.79	0.03	0.39
D	60 - 69	0.02	0.83	0.02	0.41
E	70 - 79	0.02	0.85	0.02	0.42

F	80 - 89	0.01	0.86	0.01	0.43
G	≥ 90	0.01	0.88	0.01	0.44

It has been suggested that any amendments to provide ZEV credit do so for every additional mile of electric range. That is, a manufacturer would receive more ZEV credit for producing a vehicle with a 53 mile all-electric range than for producing a vehicle with a 52 mile all-electric range. There are several reasons for not providing a continuum of ZEV credit. First, the values for ZEV credit are based on the transportation survey information that summarizes the travel patterns and habits of people using conventional gasoline-powered vehicles. It is extremely uncertain exactly how hybrid-electric vehicles will be used. Until HEVs are available and in-use data is obtained, it is impossible to accurately predict the driving patterns of individuals using these vehicles.

Second, the vehicle's range will decrease as the vehicle's battery pack ages. As an example, a vehicle may be certified having an all-electric range of 50 miles. As the battery's ability to store energy deteriorates, this range will decrease. Since the end of battery life is expected to be at 80 percent of original capacity, this HEV could continue to be used until its range is only 40 miles.

Third, the incremental benefit for each mile of additional range over 40 miles is fairly small. As mentioned above, a vehicle with an all-electric range of 40 miles could, under ideal conditions, be used for 75 percent of all VMT in the battery-only mode. This percentage slowly increases to just over 85 percent at 90 miles of all-electric range. For these reasons, the staff proposes providing additional credit at every 10 mile increment between 30 and 90 miles of all-electric range.

C. The Relationship Between ZEV and NMOG Credits

The amendments proposed in this package are primarily for the purposes of determining the amount, if any, of ZEV credit that a HEV could receive. The proposed amendments do have some impact on the existing calculation of additional NMOG credits for HEVs not meeting the ZEV requirements. Because the staff proposes to establish categories in 10-mile all-electric range increments for HEV ULEVs, new classifications are also needed for HEVs with APUs meeting TLEV and LEV emission standards.

Table III-7 summarizes the proposed NMOG credits that would be granted to HEVs using APUs that have been certified to either the TLEV or LEV standard. As mentioned above, these vehicles are not eligible to receive ZEV credit. The staff proposes, however, to provide additional NMOG credit for HEVs capable of at least 80 miles of all-electric range

beyond what is currently provided in the regulations for TLEV and LEV hybrids. The staff proposes that the NMOG credit values in Table III-7 replace the existing NMOG credits.

TABLE III-7
Proposed Categories for TLEV, LEV, and ULEV Hybrids

HEV Category	All-Electric Range	Type 3		
		TLEV NMOG Credit (g/mi)	LEV NMOG Credit (g/mi)	ULEV NMOG Credit (g/mi)
AA	< 30	0.125	0.075	0.040
A	30 - 39	0.125	0.075	0.040
B	40 - 49	0.113	0.066	0.030
C	50 - 59	0.113	0.066	0.030
D	60 - 69	0.100	0.057	0.020
E	70 - 79	0.100	0.057	0.020
F	80 - 89	0.085	0.050	0.010
G	≥ 90	0.085	0.050	0.010

V. ISSUES RELATED TO TEST PROCEDURES

Test procedures to evaluate APU emissions and all-electric range are needed to determine compliance with the standards proposed by the staff. The current test procedures to determine APU emissions and all-electric range were intended to be representative of all emission profiles and to be as consistent as possible with the test procedures for conventional vehicles. However, the LEV regulations were adopted in 1990, when fewer HEV design options were being considered. Consequently, the current test procedures may not adequately address all testing issues that could arise.

In 1992, the Society of Automotive Engineers formed a HEV task force, comprised of representatives from the automotive industry, the United States Environmental Protection Agency, and other interested parties, to develop a HEV test procedure that best quantifies HEV emissions and fuel economy. The task force has recently produced a draft test procedure that classifies HEVs into four categories based on a combination of all-electric range capability and the hybrid-mode charging characteristic of the vehicle. The

task force is currently investigating modifications to this method that would shorten and simplify the procedure without comprimising accuracy. The ARB staff will draw on information from the task force when amending the current test methods.

The basic elements of the ARB's current HEV test procedure consists of an all-electric range test, an exhaust emissions test conducted during the auxiliary power unit mode, and an evaporative emissions test. After reviewing the existing HEV test procedures, the ARB staff has concluded that the test procedure is still relevant and adequate for testing virtually all types of hybrid designs with relatively minor modifications. Appendix D discusses in more detail the minor modifications being considered by the staff to improve upon the current procedures.

APPENDIX A

PROPOSED AMENDMENTS TO THE CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 1988 AND SUBSEQUENT MODEL PASSENGER CARS, LIGHT-DUTY TRUCKS, AND MEDIUM-DUTY VEHICLES

State of California
AIR RESOURCES BOARD

PROPOSED

CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 1988 AND SUBSEQUENT MODEL PASSENGER CARS, LIGHT-DUTY TRUCKS, AND MEDIUM-DUTY VEHICLES

Adopted: May 20, 1987
Amended: December 20, 1989
Amended: January 22, 1990
Amended: December 26, 1990
Amended: July 12, 1991
Amended: August 12, 1992
Amended: October 23, 1992
Amended: May 28, 1993
Amended: September 17, 1993
Amended: September 22, 1993
Amended: September 22, 1994
Amended: ___________________
Amended: ___________________

NOTE: The regulatory amendments proposed for this workshop are shown in underline to indicate additions and ~~strikeout~~ to indicate deletions from the version of the test procedures adopted on September 22, 1993. On September 28, 1995 the ARB will conduct a public hearing to consider proposed modifications to the test procedures as part of the medium-duty vehicle rulemaking. For that rulemaking, added text are identified herein by *italics*; deletions are shown in *~~italicized strikeout~~*.

The numbering convention employed in this document, in order of priority, is: 1.a.1.i.A. Any references within specific sections in the Code of Federal Regulations are denoted in order of priority as: (a)(1)(i)(A) - the same numbering system employed in the Code of Federal Regulations.

CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 1988 AND SUBSEQUENT MODEL PASSENGER CARS, LIGHT-DUTY TRUCKS AND MEDIUM-DUTY VEHICLES

The provisions of Subparts A, B, and C, Part 86, Title 40, Code of Federal Regulations as set forth in Appendix I, to the extent they pertain to Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles, are hereby adopted as the California Exhaust Emission Standards and Test Procedures for 1988 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles, with the following exceptions and additions.

1. Applicability

No Change

2. Definitions

~~*a*~~. "Administrator" means the Executive Officer of the Air Resources Board (ARB).

~~*Bd*~~. "Alcohol fuel" means either methanol or ethanol as those terms are defined in these test procedures.

~~*Aw*~~. "All-Electric Range Test" means a test sequence used to determine the range of an electric vehicle or of a hybrid electric vehicle without the use of its auxiliary power unit. The All-Electric Range Test cycle consists of alternating the Highway Fuel Economy Schedule and the Urban Dynamometer Driving Schedule (see 9.f. of these test procedures).

~~*Ai*~~. "Battery assisted combustion engine vehicle" means any vehicle which allows power to be delivered to the driven wheels solely by a combustion engine, but which uses a battery pack to store energy which may be derived through remote charging, regenerative braking, and/or a flywheel energy storage system or other means which will be used by an electric motor to assist in vehicle operation.

~~*As*~~. "Battery pack" means any electrical energy storage device consisting of any number of individual battery modules which is used to propel electric or hybrid electric vehicles.

"Category" means a hybrid-electric vehicle certified to the ULEV exhaust emissions standards with a range as determined by the All-Electric Range Test, while maintaining the specified speed and time requirements throughout the test and without use of the auxiliary power unit, as defined by the following table:

Category	All-Electric Range
AA	≤ 29
A	30-39
B	40-49
C	50-59
D	60-69
E	70-79
F	80-89
G	≥ 90

**~~b~~.	"Certificate of Conformity" means Executive Order certifying vehicles for sale in California.**

**~~c~~.	"Certification" means certification as defined in Section 39018 of the Health and Safety Code.**

**~~Ap~~.	"Certification level" means the official exhaust or evaporative emission result from an emission-data vehicle which has been adjusted by the applicable mass deterioration factor and is submitted to the Executive Officer for use in determining compliance with an emission standard for the purpose of certifying a particular engine family. For those engine families which are certified using reactivity adjustment factors developed by the manufacturer pursuant to Appendix VIII of these test procedures, the exhaust NMOG certification level shall include adjustment by the ozone deterioration factor.**

**~~m~~.	"Continually regenerating trap oxidizer system" means a trap oxidizer system that does not utilize an automated regeneration mode during normal driving conditions for cleaning the trap.**

**~~Am~~.	"Conventional gasoline" means any certification gasoline which meets the specifications of 40 CFR 86.113-90(a), including the specifications of (a)(1)(i) but excluding the specifications of (a)(1)(ii) as amended by Section 9.a.1. of these test procedures. For the purpose of determining the ozone-forming potential of conventional gasoline vehicle exhaust emissions, gasoline meeting the specifications of Appendix VIII, note (9) of these test procedures shall be used.**

**~~Bb~~.	"Dedicated Ethanol Vehicle" means any ethanol-fueled motor vehicle that is engineered and designed to be operated solely on ethanol.**

**~~u~~.	"Dedicated Methanol Vehicle" means any methanol-fueled motor vehicle that is engineered and designed to be operated solely on methanol.**

**~~Ax~~.	"Defeat Device" means an auxiliary emission control device (AECD) that reduces the effectiveness of the emission control system under conditions which may reasonably be expected to be encountered in normal vehicle operation and use, unless (1) such conditions are substantially included in the Federal emission test procedure, (2) the need for the AECD is justified in terms of protecting the vehicle against damage or accident, or (3) the AECD does not go beyond the requirements of engine starting.**

**~~v~~.	"Diesel-cycle" means powered by an engine where the primary means of controlling power output is by limiting of the amount of fuel that is injected into the combustion chambers of the engine.**

~~Ak~~. "Diesel Engine" means any engine powered with diesel fuel, gaseous fuel, ~~*ethanol, or methanol*~~ *or alcohol fuel* for which diesel engine speed/torque characteristics and vehicle applications are retained.

~~Aa~~. "Dual-fuel vehicle" means any motor vehicle that is engineered and designed to be capable of operating on gasoline or diesel and on compressed natural gas or liquefied petroleum gas, with separate fuel tanks for each fuel on-board the vehicle.

~~Af~~. "Electric vehicle" means any vehicle which operates solely by use of a battery or battery pack. This definition also includes vehicles which are powered mainly through the use of an electric battery or battery pack, but which use a flywheel that stores energy produced by the electric motor or through regenerative braking to assist in vehicle operation.

~~Ay~~. "Element of Design" means any control system (i.e., computer software, electronic control system, emission control system, computer logic), and/or control system calibrations and/or the results of systems interaction, and/or hardware items on a motor vehicle or motor vehicle engine.

~~Bc~~. "Ethanol" means any fuel for motor vehicles and motor vehicle engines that is composed of either commercially available or chemically pure ethanol (CH_3CH_2OH) and gasoline as specified in section 9.a. (Fuel Specifications) of these test procedures. The required fuel blend is based on the type of ethanol-fueled vehicle being certified and the particular aspect of the certification procedure being conducted.

~~Ba~~. "Ethanol vehicle" means any motor vehicle that is engineered and designed to be operated using ethanol as a fuel.

<u>"Equivalent Zero-Emission Vehicle" or "EZEV" means any vehicle which is certified to the EZEV exhaust emission standards.</u>

~~Al.~~ "Fuel fired heater" means a fuel burning device which creates heat for the purpose of warming the passenger compartment of a vehicle but does not contribute to the propulsion of the vehicle.

~~t~~. "Fuel-Flexible Vehicle" or "FFV" means any methanol-fueled or ethanol-fueled motor vehicle that is engineered and designed to be operated using any gasoline-methanol or gasoline-ethanol fuel mixture or blend.

~~i~~. "Gaseous fuels" means liquefied petroleum gas, compressed natural gas, or liquefied natural gas fuels for use in motor vehicles.

~~e~~. "Heavy-duty engine" means an engine which is used to propel a heavy-duty vehicle.

~~f~~. **"Heavy-duty vehicle" means any motor vehicle having a manufacturer's gross vehicle weight rating greater than 6000 pounds, except passenger cars.**

A~~j~~. **"Hybrid electric vehicle"** *or "HEV"* **means any vehicle which is included in the definition of a "series hybrid electric vehicle", a "parallel hybrid electric vehicle", or a "battery assisted combustion engine vehicle".**

~~y~~. **"Incomplete vehicle" means any vehicle which does not have the primary load carrying device or container attached. In situations where individual marketing relationships makes the status of the vehicle questionable, the Executive Officer shall determine whether a specific model complies with the definition of incomplete vehicle.**

A~~z~~. **"Intermediate Temperature Cold Testing" means testing done pursuant to the driving cycle and testing conditions contained in 40 CFR Part 86 Subpart C, at temperatures between 25º F (-4º C) and 68º F (20º C).**

A~~o~~. **"Intermediate volume manufacturer" is any vehicle manufacturer with California sales between 3,001 and 35,000 new light- and medium-duty vehicles per model year based on the average number of vehicles sold by the manufacturer each year from 1989 to 1993; however, for manufacturers certifying for the first time in California, model year sales shall be based on projected California sales.**

g. "Light-duty truck" *or "LDT"* **means any motor vehicle, rated at 6000 pounds gross vehicle weight or less, which is designed primarily for purposes of transportation of property or is a derivative of such a vehicle, or is available with special features enabling off-street or off-highway operation and use.**

"Loaded Vehicle Weight" or "LVW" means the vehicle curb weight plus 300 pounds.

A~~c~~. **"Low-emission vehicle" or "LEV" means any vehicle certified to low-emission standards.**

~~h~~. **"Medium-duty vehicle"** *or "MDV"* **means any pre-1995 model year heavy-duty vehicle having a manufacturer's gross vehicle weight rating of 8,500 pounds or less, any 1992 and subsequent model-year heavy-duty low-emission, ultra-low-emission, or zero-emission vehicle having a manufacturer's gross vehicle weight rating of 14,000 pounds or less, or any 1995 and subsequent model year heavy duty vehicle having a manufacturer's gross vehicle weight rating of 14,000 pounds or less.**

B~~e~~. **"Methane Reactivity Adjustment Factor" means a factor applied to the mass of methane emissions from natural gas fueled vehicles for the purpose of**

determining the gasoline equivalent ozone-forming potential of the methane emissions.

~~r~~. **"Methanol" means any fuel for motor vehicles and motor vehicle engines that is composed of either commercially available or chemically pure methanol (CH_3OH) and gasoline as specified in section 9.a. (Fuel Specifications) of these procedures. The required fuel blend is based on the type of methanol-fueled vehicle being certified and the particular aspect of the certification procedure being conducted.**

s. **"Methanol vehicle" means any motor vehicle that is engineered and designed to be operated using methanol as a fuel.**

***~~Bf~~*.** **"Natural gas" means either compressed natural gas or liquefied natural gas.**

***~~Bg~~*.** **"Natural gas vehicle" means any motor vehicle that is engineered and designed to be operated using either compressed natural gas or liquefied natural gas.**

~~z~~. **"Non-methane organic gas" (or "NMOG") means the sum of non-oxygenated and oxygenated hydrocarbons contained in a gas sample as measured in accordance with the "California Non-Methane Organic Gas Test Procedures" as adopted July 12, 1991 and last amended *~~September 22, 1993~~* ______________.**

~~n~~. **"Non-regeneration emission test" means a complete emission test which does not include a regeneration.**

~~x~~. **"Organic Material Hydrocarbon Equivalent" (or "OMHCE") means the sum of the carbon mass contributions of non-oxygenated hydrocarbons, methanol, and formaldehyde as contained in a gas sample, expressed as gasoline-fueled vehicle hydrocarbons. In the case of exhaust emissions, the hydrogen-to-carbon ratio of the equivalent hydrocarbon is 1.85:1. In the case of diurnal and hot-soak emissions, the hydrogen-to-carbon ratios of the equivalent hydrocarbons are 2.33:1 and 2.2:1, respectively.**

***~~Ar~~*.** **"Organic material non-methane hydrocarbon equivalent" (or "OMNMHCE") for methanol-fueled vehicles means the sum of the carbon mass contribution of non-oxygenated hydrocarbons (excluding methane), methanol, and formaldehyde as contained in a gas sample, expressed as gasoline-fueled hydrocarbons. For ethanol-fueled vehicles, "organic material non-methane hydrocarbon equivalent" (or "OMNMHCE") means the sum of carbon mass contribution of non-oxygenated hydrocarbons (excluding methane), methanol, ethanol, formaldehyde and acetaldehyde as contained in a gas sample, expressed as gasoline-fueled hydrocarbons.**

~~w~~. **"Otto-cycle" means powered by an engine where the primary means of controlling power output is by limiting the amount of air and fuel which can enter the combustion chambers of the engine. Gasoline-fueled engines are otto-cycle engines.**

***A~~q~~*.** **"Ozone deterioration factor" means a factor applied to the mass of NMOG emissions from TLEVs, LEVs, or ULEVs which accounts for changes in the ozone-forming potential of the NMOG emissions from a vehicle as it accumulates mileage.**

***A~~h~~*.** **"Parallel hybrid electric vehicle" means any vehicle which allows power to be delivered to the driven wheels by either a combustion engine and/or by a battery powered electric motor.**

~~d~~. **"Passenger car"** ***or "PC"*** **means any motor vehicle designed primarily for transportation of persons and having a design capacity of 12 persons or less.**

~~l~~. **"Periodically regenerating trap oxidizer system" means a trap oxidizer system that utilizes, during normal driving conditions for cleaning the trap, an automated regeneration mode which can be easily detected.**

A~~n~~*.** **"Reactivity adjustment factor"** ***or "RAF" **means a fraction applied to the mass of NMOG emissions from a vehicle powered by a fuel other than conventional gasoline for the purpose of determining a gasoline-equivalent NMOG emission value. The reactivity adjustment factor is defined as the ozone-forming potential of the exhaust from a vehicle powered by a fuel other than conventional gasoline divided by the ozone-forming potential of conventional gasoline vehicle exhaust.**

~~k~~. **"Regeneration" means the process of oxidizing accumulated particulate matter. It may occur continually or periodically.**

~~o~~. **"Regeneration emission test" means a complete emission test which includes a regeneration.**

~~p~~. **"Regeneration interval" means the interval from the start of a regeneration to the start of the next regeneration.**

***A~~g~~*.** **"Series hybrid electric vehicle" means any vehicle which allows power to be delivered to the driven wheels solely by a battery powered electric motor, but which also incorporates the use of a combustion engine to provide power to the battery and/or electric motor.**

"Super-Low-Emission Vehicle" or "SLEV" means any medium-duty vehicle certified to super low-emission standards.

A~~b~~. **"Transitional low-emission vehicle" or "TLEV" means any vehicle certified to transitional low-emission standards.**

~~j~~. **"Trap oxidizer system" means an emission control system which consists of a trap to collect particulate matter and a mechanism to oxidize the accumulated particulate.**

"Type 1 HEV" means a hybrid electric vehicle that is certified to the ULEV exhaust emission standards, including evaporative and fuel marketing emissions, has a all-electric range corresponding to Category A, B, C, D, E, F or G and has been determined by the Executive Officer to employ adequate technological safeguards to maximize all-electric operation.

"Type 2 HEV" means a hybrid electric vehicle that is certified to the ULEV exhaust emission standards, including evaporative and fuel marketing emissions, and has a range corresponding to Category A, B, C, D, E, F or G.

"Type 3 HEV" means a hybrid electric vehicle that is certified to the TLEV, LEV or ULEV exhaust emission standards and has a range corresponding to Category AA, A, B, C, D, E, F or G.

A~~v~~. **"Type ~~C~~3 Category AA hybrid electric vehicle" means a hybrid electric vehicle which achieves a range of 0 to ~~3~~29 miles in the All-Electric Range Test, while maintaining ~~minimal~~ the specified speed and time requirements throughout the test and without use of the auxiliary power unit, or which has been designated by the manufacturer as having a range of less than 4~~0~~30 miles without the use of the auxiliary power unit. This definition shall also apply to any hybrid electric vehicle which allows the operator to control the time or mode of operation of the auxiliary power unit either directly or indirectly (with the exception that a mechanism which allows the operator only to shut off the auxiliary power unit is permissible for Category A, B, C, and D HEVs), to any hybrid electric vehicle which can be operated solely through the use of the auxiliary power unit, to any hybrid electric vehicle which utilizes a climate control system that cannot be operated without using the auxiliary power unit, ~~and all other types of hybrid electric vehicles, excluding Type A and Type B hybrid electric vehicles.~~**

A~~t~~. **~~"Type B hybrid electric vehicle" means a hybrid electric vehicle which achieves a range of 59 miles in the All-Electric Range Test, while maintaining minimal speed and time requirements throughout the test and without use of the auxiliary power unit.~~**

A~~u~~. **~~"Type A hybrid electric vehicle" means a hybrid electric vehicle which achieves a minimum range of 60 miles in the All-Electric Range Test, while maintaining minimal speed and time requirements throughout the test and without use of the auxiliary power unit.~~**

~~A~~d. "Ultra-low-emission vehicle" or "ULEV" means any vehicle certified to ultra-low emission standards.

~~q~~. "Useful Life" means a period of use denoted by the emission standards to which a given vehicle is certifying. For those light-duty and medium-duty vehicles certified to optional 100,000 mile standards and those 1993 and subsequent vehicles certified to 100,000 mile emission standards, and those transitional low-emission, low-emission, and ultra-low-emission vehicles, including hybrid electric vehicles, certified to 100,000 mile emission standards, the useful life shall be 10 years or 100,000 miles, whichever first occurs. For 1995 and subsequent medium-duty vehicles and medium-duty low-emission and ultra-low emission vehicles certified to 120,000 mile emission standards, the useful life shall be 11 years or 120,000 miles, whichever first occurs. For light-duty and medium-duty vehicles, certified only to 50,000 miles, the useful life shall be 5 years or 50,000 miles, whichever first occurs.

~~A~~e. "Zero-emission vehicle" or "ZEV" means any vehicle which is certified by the Executive Officer to produce zero emissions of any criteria pollutants under any and all possible operational modes and conditions. Incorporation of a fuel fired heater shall not preclude a vehicle from being certified as a ZEV provided the fuel fired heater cannot be operated at ambient temperatures above 40º F and the heater is demonstrated to have zero evaporative emissions under any and all possible operational modes and conditions.

3. Standards

The following standards represent the maximum projected exhaust emissions for the useful life of the vehicle.

- **a. [No Change]**
- **b. [No Change]**
- **c. [No Change]**
- **d. [No Change]**
- **e. [No Change]**
- **f. [No Change]**

g. The exhaust emissions from new 1992 and subsequent model-year transitional low-emission vehicles, low-emission vehicles, ~~and~~ ultra-low-emission vehicles and equivalent zero-emission vehicles shall not exceed:

EXHAUST MASS EMISSION STANDARDS FOR TRANSITIONAL LOW-EMISSION VEHICLES, LOW-EMISSION VEHICLES, ~~AND~~ ULTRA-LOW-EMISSION VEHICLES, AND EQUIVALENT ZERO-EMISSION VEHICLES IN PASSENGER CAR AND LIGHT-DUTY TRUCK VEHICLE CLASSES[6,7,8,9,10]
["grams per mile" (or "g/mi")]

Vehicle Type[1]	Loaded Vehicle Weight (lbs)	Durability Vehicle Basis (mi)	Vehicle Emission Category	Non-Methane Organic Gases[3,4]	Carbon Monoxide	Oxides of Nitrogen[5]
PC and LDT	All 0-3750	50,000	TLEV	0.125 (0.188)	3.4 (3.4)	0.4(0.4)
			LEV	0.075 (0.100)	3.4 (3.4)	0.2 (0.3)
			ULEV	0.040 (0.058)	1.7 (2.6)	0.2 (0.3)
			EZEV	0.004	0.17	0.02
		100,000	TLEV	0.156	4.2	0.6
			LEV	0.090	4.2	0.3
			ULEV	0.055	2.1	0.3
			EZEV	0.004	0.17	0.02
LDT	3751-5750	50,000	TLEV	0.160 (0.238)	4.4 (4.4)	0.7 (0.7)
			LEV	0.100 (0.128)	4.4 (4.4)	0.4 (0.5)
			ULEV	0.050 (0.075)	2.2 (3.3)	0.4 (0.5)
			EZEV	0.004	0.17	0.02
		100,000	TLEV	0.200	5.5	0.9
			LEV	0.130	5.5	0.5
			ULEV	0.070	2.8	0.5
			EZEV	0.004	0.17	0.02

(1) "PC" means passenger cars.
"LDT" means light-duty trucks.
"LVW" means loaded vehicle weight.
"Non-Methane Organic Gases" or "NMOG" shall mean the total mass of oxygenated and non-oxygenated hydrocarbon emissions.

(2) "TLEV" means transitional low-emission vehicle.
"LEV" means low-emission vehicle.
"ULEV" means ultra-low-emission vehicle.
"EZEV" means equivalent zero-emission vehicle.

(3) ***Compliance with NMOG Standard.*** ~~*"Non-Methane Organic Gases" (or "NMOG") shall mean the total mass of oxygenated and non-oxygenated hydrocarbon emissions.*~~ **To demonstrate compliance with an NMOG standard, NMOG emissions shall be**

measured in accordance with the "California Non-Methane Organic Gas Test Procedures" ~~as~~ adopted July 12, 1991 *and as last amended* ____________.

a. *Reactivity Adjustment.* For TLEVs, LEVs, and ULEVs certified to operate on a fuel other than conventional gasoline, including fuel-flexible and dual-fuel vehicles when certifying on a fuel other than gasoline, manufacturers shall multiply the exhaust NMOG certification levels by the applicable reactivity adjustment factor set forth in Section 13 of these test procedures, or established by the Executive Officer pursuant to Appendix VIII of these test procedures. In addition, *natural gas* ~~*(NG)*~~ vehicles certifying to TLEV, LEV or ULEV standards shall calculate a reactivity-adjusted methane exhaust emission value by multiplying the methane exhaust certification level by the applicable methane reactivity adjustment factor set forth in section 13 of these test procedures. The product of the exhaust NMOG certification levels and the reactivity adjustment factor shall be compared with the exhaust NMOG mass emission standards established for the particular vehicle emission category and fuel to determine compliance. For ~~*NG*~~ *natural gas* vehicles, the reactivity-adjusted NMOG value shall be added to the reactivity-adjusted methane value and then compared to the exhaust NMOG mass emission standards established for the particular vehicle emission category to determine compliance. EZEVs and Type 1 and 2 HEVs are prohibited from adjusting exhaust NMOG certification levels by the application of a reactivity adjustment factor.

~~a~~b. *Fleet Average Requirement.* Each manufacturer shall certify PCs or LDTs to meet the exhaust mass emission standards for TLEVs, LEVs, ULEVs, or to the exhaust emission standards of Sections 3.b., 3.e., or 3.f. of these test procedures, or as Zero-Emission Vehicles such that the manufacturer's fleet average NMOG values for California-certified PCs and LDTs from 0-3750 lbs. LVW, and LDTs from 3751-5750 lbs. LVW produced and delivered for sale in California are less than or equal to the requirement for the corresponding Model Year, Vehicle Type, and LVW Class in Section 3.h. of these test procedures.

c. Requirements for EZEVs, Type 1 and 2 HEVs. For EZEVs, Type 1 and Type 2 HEVs certified to these standards, NMOG shall mean the sum of exhaust, evaporative (including hot soak emissions, diurnal emissions, resting losses and running losses) and fuel marketing emissions. For certification purposes, fuel marketing emissions shall be determined by the Executive Officer.

(4) *NMOG Standards for Fuel-Flexible and Dual-Fuel Vehicles.* Fuel-flexible and dual-fuel PCs and LDTs from 0-5750 lbs. LVW shall be certified to exhaust mass emission standards for NMOG established for the operation of the vehicle on an available fuel other than gasoline, and gasoline as specified in Section 9.a.1. of these test procedures.

a. *Reactivity Adjustment.* For TLEVs, LEVs, and ULEVs, when certifying for operation on a fuel other than gasoline, manufacturers shall multiply the exhaust NMOG certification levels by the applicable reactivity adjustment factor. In addition to multiplying the exhaust NMOG certification levels by the applicable reactivity adjustment factor, ~~*NG*~~ *natural gas* vehicles shall multiply the exhaust methane certification level by the applicable methane reactivity adjustment

factor and add that value to the reactivity-adjusted NMOG value. The certification levels for fuel-flexible or dual-fuel vehicles when certifying on gasoline shall not be multiplied by a reactivity adjustment factor.

b. *Standards for Operation on Gasoline.* For PCs and LDTs from 0- ~~*3750*~~ *5750* lbs. LVW, the applicable exhaust mass emission standard for NMOG when certifying the vehicle for operation on gasoline shall be:

<u>Standards of Fuel-Flexible and Dual-Fuel Vehicles Operating on Gasoline</u>

Vehicle Type	Weight (LVW)	Emission Category	Durability Vehicle Basis (g/mi)	
			50,000 Mile	100,000 Mile
PCs, LDT	All, 0-3750	TLEV	0.25	0.31
		LEV	0.125	0.156
		ULEV	0.075	0.090
LDT	3751-5750	TLEV	0.32	0.40
		LEV	0.160	0.200
		ULEV	0.100	0.130

~~*(i) For TLEVs, 0.25 g/mi and 0.31 g/mi for 50,000 and 100,000 miles, respectively.*~~

~~*(ii) For LEVs, 0.125 g/mi and 0.156 g/mi for 50,000 and 100,000 miles, respectively.*~~

~~*(iii) For ULEVs, 0.075 g/mi and 0.090 g/mi for 50,000 and 100,000 miles, respectively.*~~

~~*c. For LDTs from 3751-5750 lbs. LVW, the applicable exhaust mass emission standard for NMOG when certifying the vehicle for operation on gasoline shall be:*~~

~~*(i) For TLEVs, 0.32 g/mi and 0.40 g/mi for 50,000 and 100,000 miles, respectively.*~~

~~*(ii) For LEVs, 0.160 g/mi and 0.200 g/mi for 50,000 and 100,000 miles, respectively.*~~

~~*(iii) For ULEVs, 0.100 g/mi and 0.130 g/mi for 50,000 and 100,000 miles, respectively.*~~

(5) *Highway NOx Standard.* The maximum projected emissions of "Oxides of Nitrogen" (or "NOx") measured on the federal Highway Fuel Economy Test (HWFET; 40 CFR 600 Subpart B) shall not be greater than 1.33 times the applicable light-duty vehicle standards shown in the table. Both the projected emissions and the HWFET standard shall be rounded in accordance with ASTM E29-67 to the nearest 0.1 g/mi before being compared. <u>For EZEVs and all hybrid electric vehicles, the maximum</u>

projected emissions of NOx measured on the federal Highway Fuel Economy Test shall not exceed the applicable light-duty vehicle standards shown in the table.

(6) ***Intermediate In-Use Compliance Standards.*** **The standards in parentheses are intermediate in-use compliance standards for 50,000 miles. For PCs and LDTs from 0-5750 lbs. LVW, including fuel-flexible and dual-fuel vehicles when operating on an available fuel other than gasoline, intermediate in-use compliance standards shall apply to TLEVs through the 1995 model year, ~~*and*~~ to LEVs ~~*and ULEVs*~~ through the 1998 model year, *and to ULEVs through the 2000 model year.* In-use compliance with standards beyond 50,000 miles shall be waived through the 1995 model year for TLEVs, and through the 1998 model year for LEVs and *and the 2000 model year for* ULEVs.**

a. ***Reactivity Adjustment.*** **For TLEVs, LEVs, and ULEVs designed to operate on a fuel other than conventional gasoline, including fuel-flexible and dual-fuel vehicles when operating on a fuel other than conventional gasoline, exhaust NMOG emission results shall be multiplied by the reactivity adjustment factor to determine compliance with intermediate in-use compliance standards for NMOG. In addition to multiplying the exhaust NMOG emission results by the applicable reactivity adjustment factor, ~~*NG*~~ *natural gas* vehicles shall multiply the exhaust methane emission results by the applicable methane reactivity adjustment factor and add that value to the reactivity-adjusted NMOG value.**

b. ***Standards on Gasoline.*** **For fuel-flexible and dual-fuel PCs and LDTs from 0-~~*3750*~~ *5750* lbs. LVW, intermediate in-use compliance standards for NMOG emissions at 50,000 miles when the vehicle is operated on gasoline shall be:**

Intermediate Standards for Fuel-Flexible and Dual Fuel Vehicles Operating on Gasoline

Vehicle Type	Weight (LVW)	Emission Category	Durability Vehicle Basis (g/mi) 50,000 mi
PCs, LDT	All, 0-3750	TLEV	0.32
		LEV	0.188
		ULEV	0.100
LDT	3751-5750	TLEV	0.41
		LEV	0.238
		ULEV	0.128

~~***0.32 g/mi, 0.188 g/mi and 0.100 g/mi for TLEVs, LEVs and ULEVs, respectively.***~~

~~*c. For fuel-flexible and dual-fuel LDTs from 3751-5750 lbs. LVW, intermediate in-use compliance standards for NMOG emissions at 50,000 miles, when the vehicle is operated on gasoline, shall be 0.41 g/mi, 0.238 g/mi and 0.128 g/mi for TLEVs, LEVs and ULEVs, respectively.*~~

(7) *Particulate Standard*. Manufacturers of diesel vehicles shall also certify to particulate standards at 100,000 miles. For all PCs and LDTs from 0-5750 lbs, the particulate standard is 0.08 g/mi, 0.08 g/mi, and 0.04 g/mi for TLEVs, LEVs, and ULEVs, respectively. The particulate standard for EZEVs shall be 0.004 g/mi.

(8) *50ºF Requirement*. Manufacturers shall demonstrate compliance with the above standards for NMOG, carbon monoxide and NOx at 50º F, according to the procedure specified in Section 11k of these test procedures. ~~Hybrid electric vehicles n~~Natural gas and diesel-fueled vehicles shall be exempt from 50º F test requirements.

(9) *Limit of In-Use Testing*. In-use compliance testing shall be limited to vehicles with fewer than 75,000 miles. EZEVs and Type 1 and 2 HEVs shall be subject to in-use compliance testing for the full life of the vehicle.

(10) *HEV Requirements.*

(a) Deterioration factors for hybrid electric vehicles shall be based on the emissions and mileage accumulation of the auxiliary power unit. For certification purposes only, deterioration factors for EZEVs and Type 1 and 2 HEV ULEVs shall be calculated for 100,000 miles of auxiliary power unit operation.

(b) Compliance with Standards. For certification purposes only, Type ~~A~~ 3 Category D, E, F, and G hybrid electric vehicles shall demonstrate compliance with 50,000 mile emission standards (using ~~50,000 mile~~ deterioration factors derived from 50,000 mile durability testing), and demonstrating compliance with 100,000 mile emission standards shall not be required. For certification purposes only, Type ~~B~~3 Category B and C hybrid electric vehicles shall demonstrate compliance with 50,000 mile emission standards (using ~~50,000 mile~~ deterioration factors derived from 50,000 mile durability testing) and 100,000 mile emission standards (using ~~75,000 mile~~ deterioration factors derived from 75,000 mile durability testing). For certification purposes only, Type ~~C~~3 Category AA and A hybrid electric vehicles shall demonstrate compliance with 50,000 mile emission standards (using ~~50,000 mile~~ deterioration factors derived from 50,000 mile durability testing) and 100,000 mile emission standards (using ~~100,000 mile~~ deterioration factors derived from 100,000 mile durability testing). EZEVs and Type 1 and 2 HEVs shall demonstrate compliance with 50,000 mile emission standards (using deterioration factors derived from 50,000 mile durability testing) and 100,000 mile emission standards (using deterioration factors derived from 100,000 mile durability testing).

(c) Vehicles certifying as Type 1 HEVs must petition the Executive Officer and provide evidence to demonstrate that the vehicle design maximizes all-electric operation and employs technological safeguards to avoid full-time auxiliary power unit operation should the electric drive system become inoperative for any reason (e.g., failure to recharge, deterioration of the battery pack, electric motor failure, etc.).

h. The fleet average non-methane organic gas exhaust mass emission values from the passenger cars and light-duty trucks produced and delivered for sale in California by a manufacturer each model year shall not exceed:

FLEET AVERAGE NON-METHANE ORGANIC GAS EXHAUST MASS EMISSION REQUIREMENTS FOR LIGHT-DUTY VEHICLE WEIGHT CLASSES (7)(8)(9)
[grams per mile" (or "g/mi")]

Vehicle Type[1]	Loaded Vehicle Weight (lbs.)	Durability Vehicle Basis (mi)[7]	Model Year	Fleet Average Non-Methane Organic Gases[2,3,4,5,6]
PC and LDT	All 0-3750	50,000	1994	0.250
			1995	0.231
			1996	0.225
			1997	0.202
			1998	0.157
			1999	0.113
			2000	0.073
			2001	0.070
			2002	0.068
			2003 and subsequent	0.062
LDT	3751-5750	50,000	1994	0.320
			1995	0.295
			1996	0.287
			1997	0.260
			1998	0.205
			1999	0.150
			2000	0.099
			2001	0.098
			2002	0.095
			2003 and subsequent	0.093

(1) "PC" means passenger cars.
"LDT" means light-duty trucks.
"MDV" means medium-duty vehicles.
"LVW" means loaded vehicle weight.

(2) "Non-Methane Organic Gases" (or "NMOG") shall mean the total mass of oxygenated and non-oxygenated hydrocarbon emissions.

(3) For the purpose of calculating fleet average NMOG values, vehicles which have no tailpipe emissions but use fuel fired heaters and which are not certified as ZEVs shall be treated as Type 1 ~~A~~ Hybrid Electric Vehicles ~~(or "Type A HEV ULEVs")~~.

(4) *Calculation of Fleet Average NMOG Value (PCs and LDTs from 0-3750 lbs. LVW)*. Each manufacturer's fleet average NMOG value for the total number of PCs and

LDTs from 0-3750 lbs. ~~*"Loaded Vehicle Weight" (or* "~~LVW~~")~~ produced and delivered for sale in California shall be calculated in units of g/mi NMOG according to the following equation, where the term "Produced" means produced and delivered for sale in California:

{[(No. of Vehicles Certified to the Exhaust Emission Standards in Section 3.b. of these test procedures and Produced) x (0.39)] +
[(No. of Vehicles Certified to the *phase-in* Exhaust Emission Standards in Section 3.e. of these test procedures and Produced) x (0.25)] +
[(No. of Vehicles Certified to the Exhaust Emission Standards in Section 3.f. of these test procedures and Produced) x (0.25)] +
[(No. of TLEVs Produced excluding HEVs) x (0.125)] +
[(No. of LEVs Produced excluding HEVs) x (0.075)] +
[(No. of ULEVs Produced excluding HEVs) x (0.040)] +
(HEV contribution factor)} ÷
[Total No. of Vehicles Produced, Including ZEVs, EZEVs and HEVs].

a. "HEV contribution factor" shall mean the NMOG emission contribution of HEVs to a manufacturer's fleet average NMOG value. The HEV contribution factor is the sum of the individual HEV factors and shall be ~~calculated~~ in units of g/mi. The individual HEV factor is calculated by multiplying the number of HEVs in a given category that are ~~as follows, where the term "Produced" means~~ produced and delivered for sale in California by the appropriate HEV contribution factor:

HEV CONTRIBUTION FACTOR (g/mi)

HEV Category	All-Electric Range	Type 1 ULEV	Type 2 ULEV	Type 3 HEV		
				ULEV	LEV	TLEV
AA	≤ 29	0.04	0.04	0.04	0.075	0.125
A	30-39	0.04	0.04	0.04	0.075	0.125
B	40-49	0.03	0.03	0.03	0.066	0.113
C	50-59	0.03	0.03	0.03	0.066	0.113
D	60-69	0.02	0.02	0.02	0.057	0.100
E	70-79	0.02	0.02	0.02	0.057	0.100
F	80-89	0.01	0.01	0.01	0.050	0.085
G	≥ 90	0.01	0.01	0.01	0.050	0.085

~~**{[No. of "Type A HEV" TLEVs Produced] x (0.100) +**~~
~~**[No. of "Type B HEV" TLEVs Produced] x (0.113) +**~~
~~**[No. of "Type C HEV" TLEVs Produced] x (0.125) +**~~

~~**{[No. of "Type A HEV" LEVs Produced] x (0.057) +**~~
~~**[No. of "Type B HEV" LEVs Produced] x (0.066) +**~~
~~**[No. of "Type C HEV" LEVs Produced] x (0.075) +**~~

~~**{[No. of "Type A HEV" ULEVs Produced] x (0.020) +**~~
~~**[No. of "Type B HEV" ULEVs Produced] x (0.030) +**~~
~~**[No. of "Type C HEV" ULEVs Produced] x (0.040)]}**~~

b. ZEVs <u>and EZEVs</u> classified as LDTs 3751-5750 lbs. LVW which have been counted toward the ZEV requirement for PCs and LDTs 0-3750 lbs. LVW as specified in note (9) shall be included in the above equation of note (4).

c. Beginning with the 1996 model year, manufacturers that produce and deliver for sale in California *PCs and* LDTs 0-3750 lbs. LVW that are certified to the Tier I exhaust emission standards in 40 CFR 86.094-8 and 86.094-9 shall add the following term to the numerator of the fleet average NMOG equation in note (4) and calculate their fleet average values accordingly: [(No. of Vehicles Certified to federal Tier I exhaust emission standards and Produced) x (0.25)].

(5) *Calculation of Fleet Average NMOG Value (LDTs 3751-5750 lbs. LVW.*) Manufacturers that certify LDTs from 3751-5750 lbs. LVW, shall calculate a fleet average NMOG value in units of g/mi NMOG according to the following equation, where the term "Produced" means produced and delivered for sale in California:

{[(No. of Vehicles Certified to the Exhaust Emission Standards in Section 3.b. of these test procedures and Produced x (0.50)] +
[(No. of Vehicles Certified to the Phase-In Exhaust Emission Standards in Section 3.e. of these test procedures and Produced) x (0.32)] +
[(No. of Vehicles Certified to the Exhaust Emission Standards in Section 3.f. of these test procedures and Produced) x (0.32)] +
[(No. of TLEVs Produced excluding HEVs) x (0.160)] +
[(No. of LEVs Produced excluding HEVs) x (0.100)] +
[(No. of ULEVs Produced excluding HEVs) x (0.050)] +
(HEV contribution factor)} ÷
(Total No. of Vehicles Produced, Including ZEVs<u>, EZEVs</u> and HEVs).

a. "HEV contribution factor" shall mean the NMOG emission contribution of HEVs to a manufacturer's fleet average NMOG value. The HEV contribution factor <u>is the sum of the individual HEV factors and</u> shall be ~~calculated~~ in units of g/mi. <u>The individual HEV factor is calculated by multiplying the number of HEVs in a given category that are</u> ~~as follows, where the term "Produced" means~~ produced and delivered for sale in California <u>by the appropriate</u> HEV contribution factor:

HEV CONTRIBUTION FACTOR (g/mi)						
HEV Category	All-Electric Range	Type 1 ULEV	Type 2 ULEV	Type 3 HEV		
				ULEV	LEV	TLEV
AA	≤ 29	0.05	0.05	0.05	0.160	0.160
A	30-39	0.05	0.05	0.05	0.160	0.160
B	40-49	0.037	0.037	0.037	0.145	0.145
C	50-59	0.037	0.037	0.037	0.145	0.145
D	60-69	0.025	0.025	0.025	0.130	0.130
E	70-79	0.025	0.025	0.025	0.130	0.130
F	80-89	0.015	0.015	0.015	0.085	0.085
G	≥ 90	0.015	0.015	0.015	0.085	0.085

~~**a. "HEV contribution factor" shall mean the NMOG emission contribution of HEVs to a manufacturer's fleet average NMOG value. The HEV contribution factor shall be calculated in units of g/mi as follows, where the term "Produced" means produced and delivered for sale in California: HEV contribution factor =**~~

~~**{[No. of "Type A HEV" TLEVs Produced] x (0.130) +**~~
~~**[No. of "Type B HEV" TLEVs Produced] x (0.145) +**~~
~~**[No. of "Type C HEV" TLEVs Produced] x (0.160) +**~~
~~**{[No. of "Type A HEV" LEVs Produced] x (0.075) +**~~
~~**[No. of "Type B HEV" LEVs Produced] x (0.087) +**~~
~~**[No. of "Type C HEV" LEVs Produced] x (0.100) +**~~
~~**{[No. of "Type A HEV" ULEVs Produced] x (0.025) +**~~
~~**[No. of "Type B HEV" ULEVs Produced] x (0.037) +**~~
~~**[No. of "Type C HEV" ULEVs Produced] x (0.050) +**~~

b. Only ZEVs and EZEVs which have been certified as LDTs 3751-5750 lbs. LVW and which have not been counted toward the ZEV requirements for PCs and LDTs 0-3750 lbs. LVW as specified in note (9) shall be included in the equation of note (5).

c. Beginning with the 1996 model year, manufacturers that produce and deliver for sale in California LDTs 3751-5750 lbs. LVW that are certified to the Tier I exhaust emission standards in 40 CFR 86.094-9 shall add the following term to the numerator of the fleet average NMOG equation in note (5) and calculate their fleet average NMOG values accordingly: [(No. of Vehicles Certified to federal Tier I

exhaust emission standards and Produced and Delivered for Sale in California) x (0.32)]

(6) ***Requirements for Small Volume Manufacturers.*** **As used in this section 3.h. of these test procedures, the term "small volume manufacturer" shall mean any vehicle manufacturer with California sales less than or equal to 3000 new PCs, LDTs, and MDVs per model year based on the average number of vehicles sold by the manufacturer each model year from 1989 to 1991, except as otherwise noted below. For manufacturers certifying for the first time in California, model-year sales shall be based on projected California sales. In 2000 and subsequent model years, small volume manufacturers shall comply with the fleet average NMOG requirements set forth below.**

a. Prior to the model year 2000, compliance with the specified fleet average NMOG requirements shall be waived.

b. In 2000 and subsequent model years, small volume manufacturers shall not exceed a fleet average NMOG value of 0.075 g/mi for PCs and LDTs from 0-3750 lbs. LVW calculated in accordance with note (4).

c. In 2000 and subsequent model years, small volume manufacturers shall not exceed a fleet average NMOG value of 0.100 g/mi for LDTs from 3751-5750 lbs. LVW calculated in accordance with note (5).

d. If a manufacturer's average California sales exceeds 3000 units of new PCs, LDTs, and MDVs based on the average number of vehicles sold for any three consecutive model years, the manufacturer shall no longer be treated as a small volume manufacturer and shall comply with the fleet average requirements applicable for larger manufacturers as specified in Section 3.h. of these test procedures beginning with the fourth model year after the last of the three consecutive model years.

e. If a manufacturer's average California sales falls below 3000 units of new PCs, LDTs, and MDVs based on the average number of vehicles sold for any three consecutive model years, the manufacturer shall be treated as a small volume manufacturer and shall be subject to requirements for small volume manufacturers as specified in Section 3.h. of these test procedures beginning with the next model year.

(7) ***Calculation of NMOG Credits/Debits; Procedure for Offsetting Debits.*** **In 1992 and subsequent model years, manufacturers that achieve fleet average NMOG values lower than the fleet average NMOG requirement for the corresponding model year shall receive credits in units of g/mi NMOG determined as:**

[(Fleet Average NMOG Requirement) - (Manufacturer's Fleet Average NMOG Value)] x (Total No. of Vehicles Produced and Delivered for Sale in California, Including ZEVs, EZEVs and HEVs).

a. Manufacturers with fleet average NMOG values greater than the fleet average requirement for the corresponding model year shall receive debits in units of g/mi NMOG equal to the amount of negative credits determined by the aforementioned equation. For any given model year, the total g/mi NMOG credits

or debits earned for PCs and LDTs 0-3750 lbs. LVW and for LDTs 3751-5750 lbs. LVW shall be summed together. The resulting amount shall constitute the g/mi NMOG credits or debits accrued by the manufacturer for the model year.

b. For the 1994 through 1997 model years, manufacturers shall equalize emission debits within three model years and prior to the end of the 1998 model year by earning g/mi NMOG emission credits in an amount equal to their g/mi NMOG debits, or by submitting a commensurate amount of g/mi NMOG credits to the Executive Officer that were earned previously or acquired from another manufacturer. For 1998 and subsequent model years, manufacturers shall equalize emission debits by the end of the following model year. If emission debits are not equalized within the specified time period, the manufacturer shall be subject to the Health and Safety Code section 43211 civil penalty applicable to a manufacturer which sells a new motor vehicle that does not meet the applicable emission standards adopted by the state board. The cause of action shall be deemed to accrue when the emission debits are not equalized by the end of the specified time period. For the purposes of Health and Safety Code section 43211, the number of vehicles not meeting the state board's emission standards shall be determined by dividing the total amount of g/mi NMOG emission debits for the model year by the g/mi NMOG fleet average requirement for PCs and LDTs 0-3750 lbs. LVW applicable for the model year in which the debits were first incurred.

c. The g/mi NMOG emission credits earned in any given model year shall retain full value through the subsequent model year.

d. The g/mi NMOG value of any credits not used to equalize the previous model-year's debit, shall be discounted by 50% at the beginning of second model year after being earned, discounted to 25% of its original value if not used by the beginning of the third model year after being earned, and will have no value if not used by the beginning of the fourth model year after being earned.

e. In order to verify the status of a manufacturer's compliance with the fleet average requirements for a given model year, and in order to confirm the accrual of NMOG credits or debits, each manufacturer shall submit an annual report which sets forth the production data used to establish compliance by no later than March 1 of the calendar year following the close of the model year.

(8) ***Credits for Pre-1994 Model Year Vehicles.*** **Manufacturers that produce and deliver for sale in California vehicles certified to the phase-in exhaust emission standards in Section 3.e. of these test procedures or vehicles certified to the exhaust emission standards in Sections 3.f. or 3.g. of these test procedures and/or ZEVs in the 1992 and 1993 model years, shall receive emission credits as determined by the equations in notes (4), (5), and (7).**

a. For PCs and LDTs from 0-3750 lbs. LVW, the fleet average NMOG requirement for calculating a manufacturer's emission credits shall be 0.390 and 0.334 g/mi NMOG for vehicles certified in the 1992 and 1993 model years, respectively.

b. For LDTs from 3751-5750 lbs. LVW, the fleet average NMOG requirement for calculating a manufacturer's emission credits shall be 0.500 and

0.428 g/mi NMOG for vehicles certified in the 1992 and 1993 model years, respectively.

c. Emission credits earned prior to the 1994 model year shall be considered as earned in the 1994 model year and discounted in accordance with the schedule specified in note (7).

(9) *ZEV Requirements*. While meeting the fleet average requirements, each manufacturer shall certify, produce, and deliver for sale in California at least *the following percentages of ZEVs set forth in the table below.*

Model Year	Required Percentage per Model Year
1998	2
1999	2
2000	2
2001	5
2002	5
2003 and subsequent model years	10

~~2% ZEVs each model year from 1998 through 2000, 5% ZEVs in 2001 and 2002, and 10% ZEVs in 2003 and subsequent model years.~~ **These percentages shall be applied to the manufacturer's total production of PCs and LDTs 0-3750 lbs. LVW delivered for sale in California.**

a. *Calculation of ZEV Credits*. Manufacturers which produce for sale in California more ZEVs than required in a given model year shall earn ZEV credits, which shall have units of g/mi NMOG. The amount of ZEV credits earned shall be equal to : ~~the number of ZEVs required to be produced and delivered for sale in California for the model year subtracted from the number of ZEVs actually produced and delivered for sale in the model year~~

{[the number of ZEVs and EZEVs produced and delivered for sale in the model year] +

[the number of Type 1 Category G HEVs produced and delivered for sale in the model year x (0.88)] +

[the number of Type 1 Category F HEVs produced and delivered for sale in the model year x (0.86)] +

[the number of Type 1 Category E HEVs produced and delivered for sale in the model year x (0.85)] +

[the number of Type 1 Category D HEVs produced and delivered for sale in the model year x (0.83)] +
[the number of Type 1 Category C HEVs produced and delivered for sale in the model year x (0.79)] +
[the number of Type 1 Category B HEVs produced and delivered for sale in the model year x (0.75)]} +
[the number of Type 1 Category A HEVs produced and delivered for sale in the model year x (0.68)] +
[the number of Type 2 Category G HEVs produced and delivered for sale in the model year x (0.44)] +
[the number of Type 2 Category F HEVs produced and delivered for sale in the model year x (0.43)] +
[the number of Type 2 Category E HEVs produced and delivered for sale in the model year x (0.42)] +
[the number of Type 2 Category D HEVs produced and delivered for sale in the model year x (0.41)] +
[the number of Type 2 Category C HEVs produced and delivered for sale in the model year x (0.39)] +
[the number of Type 2 Category B HEVs produced and delivered for sale in the model year x (0.37)]} +
[the number of Type 2 Category A HEVs produced and delivered for sale in the model year x (0.34)] -
[the number of ZEVs required to be produced and delivered for sale in California for the model year] x ~~and then~~ multiplied by the fleet average requirement listed in section h. of these test procedures for PCs and LDTs 0-3750 lbs. LVW for that model year. All ZEV credits earned prior to the 1998 model year shall be treated as if earned in the 1998 model year and shall be discounted in accordance with notes (7)c and (7)d.

b. *Submittal of ZEV Credits*. A manufacturer may meet the ZEV requirements in any given model year by submitting to the Executive Officer a commensurate amount of ZEV credits. These credits may be earned previously by the manufacturer or acquired from another manufacturer. The amount of ZEV credits required to be submitted shall be calculated by subtracting the number of ZEVs produced and delivered for sale in California by the manufacturer for the model year from the number of ZEVs required to be produced by the manufacturer for the model year and then multiplying by the fleet average requirement for PCs and LDTs 0-3750 lbs. LVW for that model year.

c. *Requirement to Make Up a ZEV Deficit*. Manufacturers which certify, produce, and deliver for sale in California fewer ZEVs than required in a given model year shall make up the deficit by the end of the next model year by submitting to the Executive Officer a commensurate amount of ZEV credits. The amount of ZEV credits required to be submitted shall be calculated by subtracting the number of ZEVs actually produced and delivered for sale in California by the manufacturer for the model year from the number of ZEVs required to be produced by the manufacturer for the model year and then multiplying by the fleet average

requirements for PCs and LDTs 0-3750 lbs. LVW for the model year in which the deficit is incurred.

d. ***Penalty for Failure to Meet ZEV Requirements.*** **Any manufacturer which fails to produce and deliver for sale in California the required number of ZEVs or submit an appropriate amount of ZEV credits and does not make up ZEV deficits within the specified time period shall be subject to the Health and Safety Code section 43211 civil penalty applicable to a manufacturer which sells a new motor vehicle that does not meet the applicable emission standards adopted by the state board. The cause of action shall be deemed to accrue when the ZEV deficits are not balanced by the end of the specified time period. For the purposes of Health and Safety Code section 43211, the number of vehicles not meeting the state board's standards shall be calculated according to the following equation:**

(No. of ZEVs required to be produced and delivered for sale in California for the model year) - (No of ZEVs actually produced and delivered for sale in California for the model year) - [(Amount of ZEV credits submitted for the model year) / (the fleet average requirement for PCs and LDTs 0-3750 lbs. LVW for the model year)].

e. **ZEVs classified as MDVs or ZEVs and EZEVs classified as LDTs 3751-5750 lbs. LVW may be counted toward the ZEV requirement for PCs and LDTs 0-3750 lbs. LVW and included in the calculation of ZEV credits as specified in note (9)a., if the manufacturer so designates.**

f. **Small volume manufacturers shall not be required to meet the percentage ZEV requirements. However, small volume manufacturers may earn and market credits for ZEVs they produce and deliver for sale in California.**

g. **Intermediate volume manufacturers shall not be required to meet the percentage ZEV requirements before the 2003 model year.**

i. **[No Change]**

j. **[No Change]**

k. **The cold temperature exhaust carbon monoxide emission levels from new 1996 and subsequent model-year passenger cars, light-duty trucks and medium-duty vehicles shall not exceed:**

1996 AND SUBSEQUENT MODEL-YEAR COLD TEMPERATURE CARBON MONOXIDE EXHAUST EMISSIONS STANDARDS FOR PASSENGER CARS, LIGHT-DUTY TRUCKS, AND MEDIUM-DUTY VEHICLES[1,2]
(grams per mile)

Vehicle Type	Loaded Vehicle Weight (lbs.)	Durability Vehicle Basis (mi)	Carbon Monoxide
Passenger Car	All	50,000	10.0
Light-Duty Truck	0-3750	50,000	10.0
Light-Duty Truck	3751-5750	50,000	12.5
Medium-Duty Vehicle	0-3750	50,000	10.0
Medium-Duty Vehicle	3751-8500[3]	50,000	12.5

(1) **These standards are applicable to vehicles tested in accordance with 40 CFR Part 86 Subpart C, at a nominal temperature of 20º F (-7º C).**

(2) **Natural gas vehicles, diesel-fueled vehicles, ~~hybrid electric vehicles~~, and zero-emission vehicles are exempt from these standards. <u>EZEVs and hybrid electric vehicles must demonstrate compliance with these standards.</u>**

(3) **Medium-duty vehicles with a gross vehicle weight rating greater than 8,500 lbs. are exempt from this standard.**

4. Initial Requirements

[No Change]

5. Maintenance Requirements

[No Change]

6. Demonstrating Compliance

[No Change]

7. Small-Volume Manufacturer's Certification Procedures

[No Change]

8. Alternative Procedures for Notification of Additions and Changes

[No Change]

9. Test Requirements

[No Change]

10. Optional 100,000 Mile Certification Procedure

[No Change]

11. Additional Requirements

a. - j. [No Change]

k. 50ºF Emission Test Requirement. Following a 12 to 36 hour cold soak at a nominal temperature of 50º F, emissions of CO and NOx measured on the Federal Test Procedure (40 CFR Part 86), conducted at a nominal test temperature of 50º F, shall not exceed the standards for vehicles of the same emission category and vehicle type subject to a cold soak and emission test at 68 to 86º F. For all TLEVs, emissions of NMOG and formaldehyde at 50º F shall not exceed the 50,000 mile certification standard multiplied by a factor of 2.00. For all LEVs, emissions of NMOG and formaldehyde at 50º F shall not exceed the 50,000 mile certification standard multiplied by a factor of 1.75. For all ULEVs, emissions of NMOG and formaldehyde at 50º F shall not exceed the 50,000 mile certification standard multiplied by a factor of 2.0. <u>For all EZEVs, Type 1 and 2 HEVs, emissions of NMOG at 50ºF shall not exceed the NMOG certification standard.</u> Emissions of NMOG shall be multiplied by a reactivity adjustment factor, if any, prior to comparing with the 50,000 certification standard multiplied by the specified factor.

The test vehicles shall not be subject to a diurnal heat build prior to the cold start exhaust test or evaporative emission testing.

i. For the 50º F emission test, the nominal preconditioning, soak, and test temperatures shall be maintained within 3º F of the nominal temperature on an average basis and within 5º F of the nominal temperature on a continuous basis. The temperature shall be sampled at least once every 15 seconds during the preconditioning and test periods and at least once each 5 minutes during the soak period. A continuous strip chart recording of the temperature with these minimum time resolutions is an acceptable alternative to employing a data acquisition system.

ii. The test site temperature shall be measured at the inlet of the vehicle cooling fan used for testing.

iii. The test vehicle may be fueled before the preconditioning procedure in a fueling area maintained within a temperature range of 68 to 86º F. The preconditioning shall be conducted at a nominal temperature of 50º F. The requirement to saturate the evaporative control canister(s) shall not apply.

iv. If a soak area remote from the test site is used, the vehicle may pass through an area maintained within a temperature range of 68 to 86º F during a time interval not to exceed 10 minutes. In such cases, the vehicle shall be restabilized to 50º F by soaking the vehicle in the nominal 50^0 F test area for

six times as long as the exposure time to the higher temperature area, prior to starting the emission test.

v. The vehicle shall be approximately level during all phases of the test sequence to prevent abnormal fuel distribution.

Manufacturers shall demonstrate compliance with this requirement each year by testing at least three PC or LDT and three MDV emission data and/or engineering development vehicles (with at least 4000 miles) which are representative of the array of technologies available in that model year. Only TLEVs, LEVs, ~~and~~ ULEVs, and EZEVs, are to be considered for testing at 50º F. It is not necessary to apply deterioration factors (DFs) to the 50º F test results to comply with this requirement. Testing at 50º F shall not be required for fuel-flexible and dual-fuel vehicles when operating on gasoline. Natural gas, ~~hybrid electric~~ and diesel-fueled vehicles shall also be exempt from 50º F testing.

The following schedule outlines the parameters to be considered for vehicle selection:

1. Fuel control system (e.g., multiport fuel injection, throttle body electronic fuel injection, sequential multiport electronic fuel injection, etc.)
2. Catalyst system (e.g., electrically heated catalyst, close-coupled catalyst, underfloor catalyst, etc.)
3. Control system type (e.g., mass-air flow, speed density, etc.)
4. Vehicle category (e.g., TLEV, LEV, ULEV, EZEV)
5. Fuel type (e.g., gasoline, methanol, etc.)

The same engine family shall not be selected in the succeeding two years unless the manufacturer produces fewer than three engine families. If the manufacturer produces more than three TLEV, LEV, ~~or~~ ULEV, or EZEV engine families per model year, the Executive Officer may request 50º F testing of specific engine families. If the manufacturer provides a list of the TLEV, LEV, ~~and~~ ULEV, and EZEV engine families that it will certify for a model year and provides a description of the technologies used on each engine family (including the information in items 1 through 5 of the vehicle selection parameters listed above), the Executive Officer shall select the engine families subject to 50º F testing within a 30 day period after receiving such a list and description. The Executive Officer may revise the engine families selected after the 30 day period if the information provided by the manufacturer does not accurately reflect the engine families actually certified by the manufacturer.

l. Emission Control System Continuity at Low Temperature. For each engine family certified to TLEV, LEV, ~~*or*~~ ULEV, <u>or EZEV</u> standards, manufacturers shall submit with the certification application, an engineering evaluation demonstrating that a discontinuity in emissions of non-methane organic gases, carbon monoxide, oxides of nitrogen and formaldehyde measured on the Federal Test Procedure (40 CFR Part 86) does not occur in the temperature range of 20 to 86º F. For diesel vehicles, the engineering evaluation shall also include particulate emissions.

12. Identification of New Clean Fuels to be Used in Certification Testing

[No Change]

13. Reactivity Adjustment Factors

[No Change]

14. Cold Temperature Test Procedure

a. General Applicability

In paragraph 86.201-94:

1. Amend subparagraph (a) to read:

(a) This subpart describes procedures for determining the cold temperature carbon monoxide (CO) emissions from 1996 and later model year new passenger cars, light-duty trucks, and medium-duty vehicles (excluding natural gas vehicles, diesel-fueled vehicles, ~~hybrid electric vehicles~~, and zero-emission vehicles). Vehicles which certify to EZEV, Type 1, and Type 2 HEV standards must demonstrate compliance with these requirements.

b. Equipment Required; Overview

In paragraph 86.206.94:

1. Amend subparagraph (a) to read:

(a) This subpart contains procedures for exhaust emission tests on passenger cars, light-duty trucks, and medium-duty vehicles (excluding natural gas vehicles, diesel-fueled vehicles, ~~hybrid electric vehicles~~, and zero-emission vehicles.) Vehicles which certify to EZEV, Type 1, and Type 2 HEV standards must demonstrate compliance with these requirements. Equipment required and specifications are as follows:

2. Amend subparagraph (a)(1) to read:

(a)(1) Exhaust emission tests. Exhaust from vehicles (excluding natural gas vehicles, diesel-fueled vehicles, ~~hybrid electric vehicles,~~ and zero-emission vehicles) is tested for gaseous emissions using the Constant Volume Sampler (CVS) concept (Section 86.209). Vehicles which certify to EZEV, Type 1, and Type 2 HEV standards must demonstrate compliance with these requirements. Equipment necessary and specifications appear in 40 CFR Part 86, Section 86.208 through 86.214.

3. Amend subparagraph (a)(2) to read:

(a)(2) Fuel, analytical gas, and driving schedule specifications. Fuel specifications for exhaust emission testing for gasoline-fueled vehicles are specified in 40 CFR Part 86, Section 86.213. Fuel specifications for exhaust emission testing for alcohol-fueled vehicles and liquified petroleum gas vehicles are specified in Section 9.a. of these Test Procedures. Analytical gases are specified in 40 CFR Part 86, Section 86.214. The EPA Urban Dynamometer Driving Schedule (UDDS) for use in emission tests is specified in 40 CFR Part 86, Section 86.215 and Appendix I.

Appendices I through VIII

[No Change]

APPENDIX B

TECHNICAL BACKGROUND FOR PROPOSED EQUIVALENT ZERO-EMISSION VEHICLE CERTIFICATION STANDARDS

APPENDIX B

TECHNICAL BACKGROUND FOR PROPOSED EQUIVALENT ZERO-EMISSION VEHICLE CERTIFICATION STANDARDS

Introduction

This appendix presents the technical background for the ARB staff's proposed equivalent zero-emission vehicle (EZEV) certification standards for oxides of nitrogen (NOx) and non-methane organic gases (NMOG). The proposed certification standards are based on the marginal NOx and reactive organic gases (ROG) emissions that are projected to occur in the South Coast Air Basin (SCAB) due to the use of electric vehicles in the SCAB. A vehicle that certifies to the proposed EZEV emission standards would be credited toward a manufacturer's zero-emission vehicle (ZEV) requirement.

Background

A number of studies have been conducted that evaluate the emissions associated with the use of electric vehicles (EVs). In the "Staff Report 1994 Low-Emission Vehicle and Zero-Emission Vehicle Program Review" dated April 1994, the ARB staff presented EV emissions that were based on average power plant emissions in the South Coast Air Basin. This was a fairly simple and straightforward method of evaluating EV emissions. Other studies have evaluated the power plant emissions associated with the additional, or marginal, electricity that will need to be produced to satisfy the additional demand from EVs. Such studies use a production cost model such as the Elfin model to predict which power plants will produce the marginal electricity used by EVs. The California Energy Commission (CEC) staff has recently completed a draft study for the ARB staff that uses the Elfin model to predict the marginal power plant emissions associated with EV use in the SCAB. The ARB staff proposes to use the results of this latest CEC staff analysis to establish the EZEV certification standards.

The Los Angeles area has the worst air quality in the state, and for this reason the SCAB is the area where ZEVs are most urgently needed. Any EZEV technology that is substituted for a ZEV should exhibit emissions that are no higher than the incremental power plant emissions that are predicted to occur in the SCAB due to EVs. The ARB staff recognizes that some of the electricity used by EVs in the SCAB will be generated outside the SCAB. While these out-of-basin emissions are important and should be addressed, the staff believes it would not be appropriate to allow a EZEV to count toward a manufacturer's ZEV requirement if it emits at the higher out-of-basin emission level while operating in the SCAB.

A Summary and Comparison of Previous Work

Previous analyses of the marginal power plant emissions associated with the use of EVs in Southern California have been conducted over the past two years by the Southern California Gas Company[1], the Environmental Defense Fund and Natural Resources Defense Council[2], and the electric utilities[3]. The marginal in-basin power plant emissions results from these studies are presented in Table B1. The assumptions that were used to arrive at these results are summarized in Table B2.

Table B1
Results of Previous Marginal EV Emissions Analyses

Study	Electric Vehicle Emission Rate (based on in-basin power plant emissions)	
	NOx (grams per mile)	ROG (grams per mile)
EII/SCG[1]	0.046 (minivan)	0.019 (minivan)
EDF/NRDC[2]	0.005 (PC) 0.011 (LDT)	0.002 (PC) 0.005 (LDT)
EPRI[3] SCE Case LADWP Case	 0.012 (PC) 0.014 (PC)	 0.006 (PC) 0.002 (PC)

1 Energy International, Inc., for the Southern California Gas Company. May 1994. "Comparison of Fuel Cycle Emissions for Electric Vehicle and Ultralow Emissions Natural Gas Vehicle," Report No. 9452R446. Bellevue, WA.

2 Environmental Defense Fund and Natural Resources Defense Council. June 1994. "What's the Charge? Estimating the Emissions Benefits of Electric Vehicles in Southern California." Oakland, CA.

3 Electric Power Research Institute. May 1994. "EV Emissions Benefits in California," Technical Brief 104068. Palo Alto, CA.

As will be shown, the NOx emission rates reported for EVs in the EDF/NRDC and EPRI studies are lower than the results of the CEC's recent analysis. One reason is that the EDF/NRDC and EPRI analyses used power plant information from the CEC's Electricity Report 92 (ER92). In ER92, in-basin power plant emission rates for NOx were assumed to be controlled to 0.15 lbs/MWh in accordance with SCAQMD Rule 1135. The SCAQMD subsequently rescinded Rule 1135 and adopted the RECLAIM program, which requires that utilities cap NOx emissions at specified levels, either by reducing emissions from their own facilities or by purchasing RECLAIM Trading Credits (RTCs) from other facilities that reduce emissions beyond what is required. The CEC's recent analysis used power plant information provided by the utilities for ER94. This information reflects power plant emissions under RECLAIM. Because utilities can offset excess emissions by purchasing RTCs under RECLAIM, some power plant emission rates in ER94 may be higher than the power plant emissions that would have occurred under Rule 1135.

Table B2
Summary of Key Assumptions Used in Previous Marginal EV Emissions Analyses

Study	Year Analyzed	Number of EVs	Miles per Year	Energy Efficiency (kWhr/mi)	Charging Profile
EII/SCG	2000	15,500 PC 37,600 LDT	15,360 PC 17,900 LDT	0.38 MDV	most betwn 6pm & 3am, with am spike
EDF/NRDC[1]	2010	770,000 PC 374,000 LDT	14,300 PC 15,600 LDT	0.216 PC 0.473 LDT	semi-controlled (66% betwn 12am & 6am)
EPRI					most betwn 6pm & 3am, with am spike
SCE	2011[2]	597,000 PC	14,700 PC	0.26 PC	
LADWP	2011[2]	245,000 PC	15,300 PC	0.26 PC	

1 Summary of primary scenario. Other scenarios were analyzed.
2 Year 2000 was also analyzed.

Sierra Research, Inc. (Sierra) has also recently released a report addressing regional emissions, including the Pacific region (defined as California, Oregon and Washington)[4]. However, Sierra did not evaluate marginal power plant emissions and the report does not specifically address emissions in the South Coast Air Basin. Instead, Sierra evaluated average emissions from fossil fuel-powered plants located throughout the Pacific region, based on an assumption that these plants will provide all of the marginal power needed to fuel EVs. Because Sierra used a simplified approach, their results are not directly comparable to the results from studies that modeled marginal power plant emissions using Elfin. For this reason the ARB staff has not included their results in Table B1.

Current CEC Marginal EV Emissions Analysis

At the request of the ARB staff, the CEC's Electricity Resource Assessment Office has evaluated the marginal power plant emissions associated with the use of EVs in the SCAB. A draft report of the CEC staff's analysis is attached as Appendix C. The CEC used the Elfin model to predict which power plants will be used to meet the increased demand for electricity as EVs are incorporated into the vehicle fleet, and to estimate the amount of electricity each power plant will provide. The emission factors associated with these power plants were used to arrive at the total emissions expected to occur due to the use of EVs. A vehicle emission rate (in grams per mile) was calculated by applying an EV efficiency value.

The CEC staff evaluated a number of scenarios. Power plant emissions for the Southern California Edison (SCE) and Los Angeles Department of Water and Power (LADWP) service territories were predicted for two years, 2000 and 2010. For each of these years, two EV charging profiles were examined, using two vehicle efficiency values and assuming three different rates of EV distribution within the SCAB. Table B3 summarizes the key assumptions used in the CEC staff's marginal EV emissions analysis. The ARB staff has organized the various sets of assumptions used by the CEC staff into six scenarios. These scenarios are summarized in Table B4.

Table B3
Summary of Key Assumptions Used in CEC Marginal EV Emissions Analysis

Years Analyzed	Number of EVs Distributed to SCAB in 2010	Miles Driven Per Year	Energy Efficiency (kWh/mi)	Charging Profile
2000 2010	40%[1] = 564,000 55%[1] = 775,000 80%[1] = 1,128,000	10,000	0.24 to 0.35	84% off-peak/16% on-peak 95% off-peak/5% on-peak

1 **Represents projected percent distribution of statewide EVs to the SCAB. 70 percent of the SCAB EVs are projected to be charged in SCE territory and 27 percent are projected to be charged in LADWP territory (3 percent are projected to be charged in the municipal utility territories).**

Table B4
Definition of Scenarios

Percent of Statewide EVs Distributed to SCAB	Charging Profile	
	84% Off-Peak 16% On-Peak	95% Off-Peak 5% On-Peak
40%	Scenario A	Scenario D
55%	Scenario B	Scenario E
80%	Scenario C	Scenario F

Scenarios A and D assume that 40 percent (564,000) of the EVs operated statewide in 2010 will be distributed to the SCAB. This figure is based on the ARB's emission inventory data and represents the statewide distribution of all vehicles. Scenarios B and E assume that 55 percent (775,000) of the EVs operated statewide in 2010 will be distributed to the SCAB. This represents a scenario in which the ARB's emission inventory distribution is adjusted so that all EVs are distributed only to four areas of California: South Coast, San Diego, Bay Area and Sacramento. This type of distribution would result in approximately 55 percent of the EVs located in the SCAB. Scenarios C and F assume that 80 percent (1,128,000) of the EVs operated statewide in 2010 will be distributed to the SCAB. This scenario is based on a CEC staff projection that a significant majority of the EVs will be distributed to the SCAB because the SCAB will offer more infrastructure and other incentives to EV owners.

The ARB requested that the CEC evaluate two efficiency values, 0.24 kilowatt-hours per mile (kWh/mi) and 0.35 kWh/mi. These values were chosen based on data from General Motors Corporation and Ford Motor Company vehicles currently in use. Supporting data were taken from results of vehicle tests conducted by ARB staff and others. These efficiency values take into account accessory loads and charger efficiency. Transmission line and distribution losses are taken into account by the CEC staff in their calculation of the energy needed to meet EV demand.

The results of the CEC staff's analysis are summarized in Tables B5 through B10.

Table B5
Marginal Electric Vehicle In-Basin Emission Rates
Scenario A: 84% Off-Peak/16% On-Peak, 40% SCAB Distribution

Efficiency (kWhr/mi)	Utility	2000		2010	
		NOx (g/mi)	ROG (g/mi)	NOx (g/mi)	ROG (g/mi)
0.24	SCE	0.022	0.001	0.012	0.002
	LADWP	0.018	0.002	0.012	0.001
	Weighted[1] Avg.	0.021	0.001	0.012	0.002
0.35	SCE	0.026	0.001	0.019	0.004
	LADWP	0.022	0.003	0.018	0.002
	Weighted[1] Avg	0.025	0.002	0.019	0.003

1 **Weighted average calculated assuming 72 percent of the EVs used in the SCAB will be charged in SCE service territory, and 28 percent of the EVs used in the SCAB will be charged in the LADWP service territory.**

Table B6
Marginal Electric Vehicle In-Basin Emission Rates
Scenario B: 84% Off-Peak/16% On-Peak, 55% SCAB Distribution

Efficiency (kWhr/mi)	Utility	2000		2010	
		NOx (g/mi)	ROG (g/mi)	NOx (g/mi)	ROG (g/mi)
0.24	SCE	0.018	0.001	0.012	0.002
	LADWP	0.015	0.002	0.013	0.001
	Weighted Avg.	0.017	0.001	0.012	0.002
0.35	SCE	0.021	0.001	0.021	0.004
	LADWP	0.019	0.002	0.018	0.002
	Weighted Avg	0.020	0.001	0.020	0.003

Table B7
Marginal Electric Vehicle In-Basin Emission Rates
Scenario C: 84% Off-Peak/16% On-Peak, 80% SCAB Distribution

Efficiency (kWhr/mi)	Utility	2000		2010	
		NOx (g/mi)	ROG (g/mi)	NOx (g/mi)	ROG (g/mi)
0.24	SCE	0.014	0.001	0.014	0.002
	LADWP	0.013	0.002	0.013	0.001
	Weighted Avg.	0.014	0.001	0.014	0.002
0.35	SCE	0.018	0.001	0.021	0.004
	LADWP	0.018	0.002	0.023	0.003
	Weighted Avg	0.018	0.001	0.022	0.004

Table B8
Marginal Electric Vehicle In-Basin Emission Rates
Scenario D: 95% Off-Peak/5% On-Peak, 40% SCAB Distribution

Efficiency (kWhr/mi)	Utility	2000		2010	
		NOx (g/mi)	ROG (g/mi)	NOx (g/mi)	ROG (g/mi)
0.24	SCE	0.023	0.002	0.010	0.004
	LADWP	0.008	0.001	0.016	0.002
	Weighted Avg.	0.019	0.002	0.012	0.003
0.35	SCE	0.027	0.003	0.014	0.005
	LADWP	0.012	0.002	0.022	0.003
	Weighted Avg	0.023	0.003	0.016	0.004

Table B9
Marginal Electric Vehicle In-Basin Emission Rates
Scenario E: 95% Off-Peak/5% On-Peak, 55% SCAB Distribution

Efficiency (kWhr/mi)	Utility	2000		2010	
		NOx (g/mi)	ROG (g/mi)	NOx (g/mi)	ROG (g/mi)
0.24	SCE	0.019	0.002	0.010	0.004
	LADWP	0.008	0.001	0.015	0.002
	Weighted Avg.	0.016	0.002	0.011	0.003
0.35	SCE	0.024	0.003	0.013	0.005
	LADWP	0.012	0.002	0.024	0.003
	Weighted Avg	0.021	0.003	0.016	0.004

Table B10
Marginal Electric Vehicle In-Basin Emission Rates
Scenario F: 95% Off-Peak/5% On-Peak, 80% SCAB Distribution

Efficiency (kWhr/mi)	Utility	2000		2010	
		NOx (g/mi)	ROG (g/mi)	NOx (g/mi)	ROG (g/mi)
0.24	SCE	0.016	0.002	0.009	0.004
	LADWP	0.008	0.001	0.017	0.002
	Weighted Avg.	0.014	0.002	0.011	0.003
0.35	SCE	0.022	0.002	0.015	0.005
	LADWP	0.012	0.002	0.025	0.002
	Weighted Avg	0.019	0.002	0.018	0.004

<u>Selection of the Primary Scenario</u>

The ARB staff believes that the scenario which most closely predicts actual EV power plant emissions in the SCAB is Scenario B. This scenario assumes that the number of EVs in the SCAB will be higher than what would be predicted by the distribution of conventional vehicles (55 percent as opposed to 40 percent). It also predicts that 16 percent of vehicle charging will occur during on-peak hours, accounting for the likelihood that, despite efforts to encourage off-peak charging, some EV owners may need to charge their vehicle during the day. The staff believes that a 0.35 kWhr/mi vehicle efficiency in the year 2010 is a conservative prediction, and therefore the values associated with this vehicle efficiency represent a realistic upper bound.

<u>Discussion of Issues</u>

o Out-of-basin emissions

Some of the electricity used to recharge EVs in the SCAB will be generated out of the basin. For the SCE system, approximately 55 percent of the energy used for EVs will be generated out of the basin in 2010. For the LADWP system, approximately 40 percent of the energy used for EVs will be generated out of the basin in 2010. The CEC staff's draft

report, contained in Appendix C, discusses this out-of-basin power generation in more detail. It is important to recognize the environmental impacts of these out-of-basin emissions. Table B11 summarizes the in-basin plus out-of-basin emission rates for EVs operated in the SCAB for the primary scenario. These emission rates include emissions from relatively dirty coal-fired power plants operating outside of California.

Table B11
In-Basin Plus Out-of-Basin Marginal EV Emissions
Year 2010, Scenario B[1]

Efficiency (kWh/mi)	Utility	NOx (g/mi)	ROG (g/mi)
0.24	SCE	0.104	0.007
	LADWP	0.115	0.002
	Weighted[2] Average	0.107	0.006
0.35	SCE	0.157	0.011
	LADWP	0.169	0.003
	Weighted[2] Average	0.160	0.009
Gasoline ULEV emissions in the SCAB[3] (includes deterioration)		0.30	0.18[4]

1 **84% off-peak/16% on-peak, 55 percent of statewide EVs distributed to SCAB**
2 **Weighted average calculated assuming 72 percent of the EVs used in the SCAB will be charged in SCE service territory, and 28 percent of the EVs used in the SCAB will be charged in the LADWP service territory.**
3 **Emissions account for conditions unique to the SCAB, including ambient temperature, average speed and average trip length.**
4 **This value includes an estimated 0.13 g/mi ROG to account for the evaporative, running loss and gasoline marketing emissions associated with gasoline vehicles using Phase II gasoline. Emissions from oil refining are not included.**

Table B11 shows that the in-basin plus out-of-basin marginal NOx and ROG emission rates for an EV operating at the 0.35 kWh/mi efficiency level are still well below the emission rates for an ultra-low emission vehicle.

The Los Angeles area has the most severe air quality problem in the United States. Although power plants outside the SCAB, and in particular out-of-state power plants, are allowed to emit at higher levels than those within the SCAB, in-basin power plants have been subject to stringent emissions requirements in order to improve air quality. In-basin power plant emissions due to the use of EVs are therefore extremely low. While it is important to recognize the total air quality impact of EVs both within and outside of the SCAB, it would be inappropriate to allow a EZEV to count toward a manufacturer's ZEV requirement if it emits at the higher out-of-basin emission levels while operating in the SCAB, as this would seriously reduce the effectiveness of the LEV regulations.

o Efficiency values

The ARB staff chose to examine two EV efficiency values. EVs are assumed to have an average efficiency between 0.24 kWh/mi and 0.35 kWh/mi. Official literature from General Motors indicates that the efficiency of the Impact operating on a city driving schedule is 0.20 kWh/mi, and official literature from Ford indicates that the efficiency of the Ecostar is 0.30 kWh/mi. The following assumptions can be applied to these efficiency values to obtain a "plug-to-wheels" efficiency value: 1) a worst case 20 percent penalty when accessories are operating, 2) accessories are used during 50 percent of the vehicle operating hours, and 3) charger efficiency is 90 percent. Applying these assumptions, the efficiencies of the Impact and Ecostar correspond to the 0.24 kWh/mi to 0.35 kWh/mi efficiency range.

Test results for Solectria vehicles also indicate that this efficiency range is appropriate. In July 1994, the ARB staff reported test results for a Solectria Force equipped with an Ovonic Battery Company nickel-metal hydride (NiMH) battery. The efficiency of this vehicle was 0.15 kWh/mi on the urban driving schedule. 1994 EV America test results for a lead-acid battery powered Solectria Force indicated an efficiency of 0.17 kWh/mi. Vehicle efficiencies for many currently available EVs are within the 0.24 kWh/mi to 0.35 kWh/mi range, even accounting for accessory loads and charger efficiency. The ARB staff believes that this range is realistic, especially considering the technology advancements that are expected to provide significant efficiency improvements by 2000.

Proposed EZEV Certification Standard

Table B12 presents the ARB staff's proposed EZEV certification standards for NOx, NMOG, carbon monoxide (CO) and particulate matter (PM). The staff is not proposing a separate formaldehyde emission standard, as formaldehyde will be accounted for in the NMOG emission measurement. The proposed NOx certification standard of 0.02 grams per mile represents the upper level of the range of NOx emission rates for the various scenarios that were evaluated by the CEC staff for 2010, and corresponds to the NOx value projected for a 0.35 kWh/mi EV in 2010 under the ARB staff's primary scenario. The proposed NMOG certification standard of 0.004 grams per mile represents the upper bound of ROG emission levels from the various scenarios. The proposed CO certification standard of

0.17 grams per mile and the proposed PM certification standard of 0.004 grams per mile correspond to one-tenth the current ULEV certification standards for passenger cars and light-duty trucks. For the purposes of certifying as an EZEV, vehicle emissions would be calculated as the sum of exhaust emissions, evaporative emissions and refueling emissions. EZEVs would be required to demonstrate compliance with these standards to 100,000 miles on the engine or APU, and maintain their emisions at or below the certification standards for the entire vehicle life. Vehicles would also be required to employ an on-board diagnostic system and would be subject to inspection and maintenance requirements.

Table B12
Proposed EZEV Certification Standards

Vehicle Type	Loaded Vehicle Weight (LVW) (pounds)	APU Durability Basis	NOx (g/mi)	NMOG (g/mi)	CO (g/mi)	PM (g/mi)
PC[1]	all	vehicle life	0.02	0.004	0.17	0.004
LDT[2]	0-3750					

[1] **Passenger car**
[2] **Light-duty truck**

References

1. **Energy International, Inc. May 1994. "Comparison of Fuel Cycle Emissions for Electric Vehicle and Ultra-Low Emissions Natural Gas Vehicle," Report No. 9452R446, Bellevue, Washington. Sponsored by the Southern California Gas Company.**

2. **Chapman, Francis, C. Calwell, D. Fisher, and R. Finson. June 1994. "What's the Charge?: Estimating the Emission Benefits of Electric Vehicles in Southern California," Environmental Defense Fund, Oakland, California, and Natural Resources Defense Council, San Francisco, California.**

3. **EPRI Technical Brief, May 1994. "EV Emissions Benefits in California," Electric Power Research Institute, Palo Alto, California.**

4. **Austin, Thomas C. and Laurence Caretto. April 1995. "Power plant Emissions and Energy Consumption Associated With Electric Vehicle Recharging," Sierra Research, Inc., Sacramento, California. Presented at the 5th Coordinating Research Council On-Road Vehicle Emissions Workshop.**

APPENDIX C

CALIFORNIA ENERGY COMMISSION STAFF DRAFT "ELECTRIC VEHICLES AND POWER PLANT EMISSIONS" JUNE 20, 1995

NOT AVAILABLE
(Contact Tom Evashenk @ (916) 445-8811 to receive a hard copy)

APPENDIX D

DISCUSSION OF HYBRID-ELECTRIC VEHICLE TESTING ISSUES

A. Background

When the Low-Emission Vehicle regulations were adopted in 1990, no hybrid electric vehicles (HEVs) were available for testing to act as a guide in developing emission test procedures, and even today, this class of vehicle is still in the development stage. Therefore, since there are many possible vehicle configurations in terms of battery and auxiliary power unit (APU) operation that can affect HEV emissions, test procedures were drafted to address all possible emission profiles that could be expected from these vehicles. The procedures were also designed to encourage development efforts to minimize HEV emissions and to be consistent with those for conventional vehicles. Since then, however, industry and others have expressed concern with the regulatory requirements, and during the May 1994 Low-Emission Vehicle Technology Review, requested the ARB to re-examine them as to whether they properly account for the emission benefits these vehicles can offer. As a result, the Board directed staff to revisit all relevant HEV issues and report back at the earliest opportunity. After reviewing the existing HEV test procedures, the ARB staff has concluded that with some adjustments the procedures remain suitable for testing virtually all types of hybrid designs.

The basic elements of ARB's current HEV test procedure are an all electric range test (AERT), an exhaust emission test, and an evaporative emission test. Figure 1 shows the proposed test sequence for 1993 to 1995 model year hybrid electric vehicles and Figure 2 shows the proposed test sequence for 1996 and subsequent model year hybrid electric vehicles.

B. SAE HEV Test Procedures

Since 1992, the Society of Automotive Engineers (SAE) HEV task force, comprised of representatives from the automotive industry, United States Environmental Protection Agency (EPA), and other interested parties, has been in the process of developing an HEV test procedure which attempts to realistically quantify HEV emissions and fuel economy (Figure 3). As a result of these efforts, the task force recently produced a draft HEV test procedure titled SAE J1711. The procedure classifies HEVs into four categories based on a combination of all-electric range capability and the hybrid-mode charging characteristic of the vehicle and requires five days to complete. HEVs that have a "useful capability" for all-electric range are classified as having a "commuting electric range", and those that lack such a capability are classified as having a "reserve electric range." These two categories are further classified into those that are capable of continuous driving cycles in the APU mode without progressively depleting the battery (charge sustaining) and those that allow battery depletion (charge depleting). However, depending on the category of HEV being tested, one or more steps (days) may be eliminated. The task force is currently investigating methods to shorten and simplify the procedure without compromising accuracy and is soliciting comments and suggestions in this regard.

C. All-Electric Range Test

Current ARB requirements

In the current test procedure, the AERT is conducted over alternating Highway Fuel Economy Test (HWFET) cycles and Urban Dynamometer Driving Schedule (UDDS) cycles (Figure 3). The AERT may be performed either prior to vehicle preconditioning in the test sequence or can be performed separately outside the context of the emission test sequence. Before beginning the AERT, the battery pack is charged to a full state-of-charge (SOC). Regenerative braking is allowed during the test and set according to the manufacturer's specifications. The AERT is terminated when one of the following conditions occurs:

a) the vehicle is no longer able to maintain within 5 miles per hour of the speed requirements or within 2 seconds of the time requirements of the driving schedules without the use of the APU, or

b) the APU turns ON.

During the test, the battery voltage, battery current, vehicle speed, battery power, total energy used, time, and regenerative energy (if applicable) are recorded. After completion of the test, the vehicle is charged to a full state-of-charge and the A.C. KW-hr used during charging is recorded.

Proposed modifications:

1. All-electric range determination:

Currently, for conventional vehicles, manufacturers are required to report the city and highway performance specifications separately. Similarly, to more accurately determine the city and highway performance of HEVs, the staff proposes that HEVs be tested on two separate and independent electric range tests, one consisting only of repeated UDDS cycles and the other of repeated HWFET cycles (Figure 3). The proposed procedure would yield separate city and highway all-electric ranges and energy consumption rates which would enable the consumer to better understand the range of his/her vehicle under different operating conditions by providing more accurate city and highway electric energy consumption rates over the full operating range of the battery. The combined all-electric range would then be calculated from the measured city and highway all-electric ranges.

2. Electric-range test termination criteria:

The ARB staff proposes that the conditions for terminating the AERT be changed to be consistent with the requirement for conventional vehicles. This would allow the consumer to compare HEV all-electric performance with conventional vehicles on an equal basis. In addition, the test is to be terminated should conditions arise which would result in damage to the vehicle or battery pack. Therefore, the AERT is to be terminated if any one of the following conditions occurs:

a) the vehicle fails to maintain the tolerance specified for conventional vehicles (2 miles per hour of the speed requirements or within 1 second of the time requirements of the driving schedules) for more than 2 seconds, or

b) the APU turns ON, or

c) the battery pack parameters such as battery pack voltage and temperature fall outside the manufacturer's specified operating range.

<u>Comparison of ARB and SAE test procedures</u>

With the proposed changes to the current ARB regulations, the ARB's all-electric range test will be virtually identical to SAE's test method with minor differences. For those vehicles with reduced performance, the SAE proposes that a less stringent criterion for test termination be applied. According to SAE's proposal the test would be terminated when the vehicle fails to maintain within 4 miles per hour of the speed requirements or within 2 seconds of the time requirements. The resulting range test result is then recorded as a "full performance all-electric range" distinct from an all-electric range test designation. However, the ARB believes that this approach will be of little value in determining the vehicle's range under real-world conditions.

Another minor difference between the two methods is that, before the beginning of both the city and highway all-electric range tests, the SAE requires two driving cycles with the battery at a full SOC to determine the energy efficiency of the vehicle. The battery is then charged back to a full SOC before beginning the all-electric range test. On the other hand, the ARB determines energy efficiency from the data collected during the all-electric range test (Figure 3). The ARB believes that energy efficiency determination portion of SAE's test method is redundant since the energy efficiency can be determined directly from the range test. In addition, the ARB's method is likely to be more accurate since the energy efficiency is averaged over larger distances and over the entire operating range of the battery.

D. Exhaust Emission Test

<u>Current ARB requirements</u>

The exhaust test sequence begins with a fuel drain and fill followed either by the AERT or by a cold soak for a minimum of 6 hours to allow the vehicle to stabilize to ambient temperature prior to the vehicle pre-conditioning. Following the preconditioning drive, the fuel tank is again drained and filled and the vehicle is cold soaked for a period of 12 to 36 hours before conducting the exhaust emission test. During the cold soak period, the vehicle's canister is purged and loaded in preparation for the evaporative emission test which follows immediately after the exhaust emissions test (Figure 1&2). If the manufacturer chooses to conduct the AERT separately from the emission test, the battery must be discharged to the appropriate SOC during the cold soak prior to the beginning of the exhaust emission test. The exhaust emission test is conducted over one Federal Test Procedure-75 (FTP-75) cycle which includes a cold start test and a hot start test. At the beginning of the exhaust emission test, the battery pack SOC should satisfy one of the following conditions: (1) the SOC is at the lowest level allowed by the control unit of the

APU, or (2) the SOC is set such that the APU operation will be at its maximum power level at the beginning of and throughout the emission test (Figure 3). Such an approach serves to characterize the maximum possible emissions among all possible operating modes. In addition, HEVs are subject to the new, enhanced evaporative emission test and standards similar those that conventional vehicles must meet.

Proposed modifications:

1) Some HEVs' APU duty cycle may depend on the rate of discharge of the battery pack. In such cases, the level of APU operation at cold start will be determined by the driving cycle used to drain the battery to the point at which the APU turns ON, which in turn affects cold start emissions. Therefore, to ensure that test results from such vehicles reflect real-world emissions, the ARB proposes a standardized method for discharging the battery. One of the following methods must be used to discharge the battery pack:

a) driving the vehicle at a constant speed of 50 mph on the dynamometer.
b) driving the vehicle over continuous UDDS cycles on the dynamometer.

Alternatively, the vehicle manufacturer may specify a battery pack discharge procedure (such as discharging to a load bank) with a discharge rate equivalent to either of the above methods. Another situation in which the draining of the battery would be necessary is when the vehicle's battery exhibits an increase in SOC during cold soak without external charging.

Note: This is not a concern for the Highway NOx test, since the pre-conditioning cycle consists of driving on a highway cycle with the APU on immediately before conducting the emission test.

2) Since it would be difficult to determine the appropriate battery SOC level at which the APU operates at its maximum power level without extensive testing, the ARB proposes that manufacturers be required to supply the APU control algorithm and the procedure to accurately drain the battery to the intended SOC.

Comparison of ARB and SAE test procedures

1. Start-of-test criteria

The SAE method proposes that the vehicle be operated in the HEV mode over repeated UDDS cycles to determine the "maximum" and "minimum" SOC levels achievable in the HEV mode of operation. Then it requires that the vehicle be emission tested once with the battery SOC at the beginning of the test at the "maximum" level and a second time, with battery SOC at the "minimum" level (Figure 3). During each of these tests, the net change in battery SOC is recorded. The emissions from the vehicle in the APU mode are then calculated by assuming a linear correlation between change in battery SOC and emissions. The ARB does not concur with SAE's proposed method for the following reasons:
a) Since HEVs certified to an emission standard should meet the standard under all operating modes, the ARB believes it is appropriate to test the vehicle in the mode most likely to have the highest emissions. Therefore, the ARB requires the SOC at the

beginning of the test be at the lowest level allowed by the control unit of the APU which is equivalent to the "minimum" SOC level as defined by the SAE method.

b) Determination of the "maximum" and "minimum" SOC levels would require significant additional testing time and resources. Instead, the ARB would require the manufacturer to provide such information based on an engineering analysis of the APU control algorithm and the procedure to drain the battery to the appropriate SOC. The ARB reserves the right to conduct its own testing to determine the appropriate SOC for emission testing.

c) The ARB is not aware of any data to support the assumption that change in battery SOC is linearly correlated with emissions.

2. Emission test cycle

Consistent with the requirements for conventional vehicles, the ARB method requires that the emission test be conducted over the FTP cycle. Such an approach will allow comparison of the test results from HEVs with conventional vehicles on an equal basis. On the other hand, the SAE method requires two consecutive UDDS cycles.

E. HEV Evaporative Emissions Test

Immediately following the exhaust emission test, HEVs operating on gasoline, liquified petroleum gas, and alcohols are subject to evaporative emission testing. HEVs with sealed fuel systems which can be demonstrated to have no evaporative emissions are exempt from evaporative emission testing. 1993 to 1995 model-year HEVs must undergo the three-day diurnal test sequence (Figure 1) while 1996 and subsequent model-year HEVs must undergo the supplemental two-day diurnal test sequence in addition to the three-day diurnal test sequence (Figure 2).

F. Other requirements

HEVs will be required to meet the appropriate Highway NOx standards and those HEVs certified as low-emission vehicles will, in addition, be required to meet the 50 degree test requirements as specified in the Exhaust Emission Standards and Test Procedures - 1988 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles and incorporated by reference in Title 13, California Code of Regulations, Section 1960.1.

G. Regenerative Braking

Although current regulations allow the use of regenerative braking systems during testing, it does not address the issue of how to accurately simulate on-road regenerative braking characteristics on the dynamometer in that only the vehicle's two drive wheels operate during testing. Currently, the ARB is investigating changes to the test procedures to address the use of regenerative braking. The ARB is working with the SAE Light Duty Vehicle Performance and Measurement Standards Committee to identify an appropriate test methodology. One method being considered is the application of a constant retarding force by the dynamometer controller whenever the conventional vehicle brakes are engaged. The constant retarding force is determined by estimating the percentage of the

total on-road braking force from the non-drive axle. At least one major manufacturer has indicated that an Electronic Control Unit (ECU) program change would be necessary to simulate regenerative braking on the dynamometer. This is because their regenerative braking system is linked to the anti-lock brake system (ABS) and would disable regenerative braking, judging the non-drive wheels as locked (ABS failure).

In addition, the ARB will soon initiate a test program with Southern California Edison to evaluate regenerative braking performance of various EVs on the road as well as under dynamometer driving conditions. These programs will ensure that the ARB gains better understanding of the regenerative braking issues and that improved test methods are identified.

H. Air-conditioning

For HEVs equipped with air-conditioning systems which derive power from the vehicle battery, current regulations require that the road load be increased by the incremental horsepower required to operate the air-conditioning unit. The incremental horsepower is determined by recording the difference in energy required to operate in the all-electric mode to complete the running loss test fuel tank temperature profile test sequence (as defined in the "California Evaporative Emission Standards and Test Procedures for 1978 and Subsequent Model Motor Vehicles") without air conditioning and the same vehicle tested over the running loss fuel tank temperature profile test sequence with air-conditioning. In response to industry's complaint that such a test would require significant resources and time, the staff proposes that manufacturers may be allowed to employ alternative methods of accounting for air-conditioning loads with Executive Officer approval based on a determination of correlation with actual air-conditioning loads.

For conventional vehicles, a 10 percent increase in road load power has traditionally been used to estimate real-world air-conditioning loads. Based on the realization that this 10 percent increase underestimates actual air-conditioning load, the Federal EPA, along with the ARB, is currently evaluating more realistic methods to simulate real-world air conditioning loads on the dynamometer. The methods being considered range from environmental chamber testing to increasing the road load power adjustment. Once EPA approves a method for conventional vehicles, then the ARB would evaluate the appropriateness of applying that same method for HEVs.

1. State of the Commute, 1994, Federal Highway Administration, December 1994.

2. 1990 Nationwide Personal Transportation Survey, U.S. Department of Transportation, December 1991.