CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING FOR PLUG-IN HYBRID-ELECTRIC VEHICLES:

AMENDMENTS TO TEST PROCEDURES AND AFTERMARKET PARTS CERTIFICATION REQUIREMENTS

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2D+HS .... Supplemental Two-Day Diurnal plus Hot Soak
3D+HS .... Three-Day Diurnal plus High-Temperature Hot Soak and Running Loss
AER .... All-Electric Range
ARB .... California Air Resources Board
AT PZEV .... Advanced Technology Partial ZEV Allowance Vehicle
CCR .... California Code of Regulations
CO_2 .... Carbon Dioxide
CNG .... Compressed Natural Gas
EAER .... Equivalent All-Electric Range
EV .... Electric Vehicle
Evap .... Evaporative Emission
Exhaust .... Exhaust Emission
GVWR .... Gross Vehicle Weight Rating
HEV .... Hybrid-Electric Vehicle
HFEDS .... Highway Fuel Economy Driving Schedule
IC engine .... Internal Combustion Engine
ISOR .... Initial Statement of Reasons
LDT1 .... Light-Duty Truck with a loaded vehicle weight of 0-3750 pounds
LDT2 .... Light-Duty Truck with a loaded vehicle weight of 3751 pounds to a gross vehicle weight of 8500 pounds, or a “LEV I” light-duty truck with a loaded vehicle weight of 3751-5750 pounds
LEV I .... First generation Low-Emission Vehicle program, adopted in a 1990-1991 rulemaking, and generally applicable in the 1994-2003 model-years
LEV II .... Second generation Low-Emission Vehicle program, adopted in a 1998-1999 rulemaking, and generally applicable in the 2004 and subsequent model-years
LEV II Evap .... Evaporative emission standards adopted in LEV II Rulemaking
MIL .... Malfunction Indicator Light
MY .... Model-Year
OBD .... On Board Diagnostic
ORVR .... Onboard Refueling Vapor Recovery
OVCC HEV .... Off-Vehicle Charge Capable Hybrid-Electric Vehicle
PHEV .... Plug-in Hybrid-Electric Vehicle
PZEV .... Partial ZEV Allowance Vehicle
R_{cda} .... Actual charge depleting range
SAE .... Society of Automotive Engineers
SC03 .... SC03 Driving Schedule
SHED .... Sealed Housing for Evaporative Determination
SOC .... State of Charge
Type F .... Enhanced AT PZEV vehicle category within the ZEV Regulation

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Type G .... Enhanced AT PZEV vehicle category within the ZEV Regulation
UF .... Utility Factor
UDDS .... Urban Dynamometer Driving Schedule
US06 .... US06 Driving Schedule
U.S. EPA .... United States Environmental Protection Agency
VMT .... Vehicle Miles Traveled
ZEV .... Zero-Emission Vehicle

1. EXECUTIVE SUMMARY

In 1990, the California Air Resources Board (ARB or the Board) adopted an ambitious regulation to significantly reduce the environmental impact of light-duty vehicles through the commercial introduction of zero emission vehicles (ZEV) into the California fleet. Over the years, the ZEV program has evolved to include hybrid electric vehicle (HEV) technologies among compliance options. The regulation includes certification standards and test procedures for HEV and ZEV technologies. The most recent changes to the ZEV regulation, considered in March 2008 included provisions that strongly encourage commercialization of plug-in HEVs (PHEV) or off vehicle charge capable (OVCC) HEVs. OVCC HEVs may charge on or off the electric power grid. In the staff report, the term PHEV is used to refer to OVCC HEVs, that is, vehicles capable of charging on or off the grid.

This rulemaking focuses on adapting the current hybrid exhaust, evaporative emission and onboard refueling vapor recovery (ORVR) test procedures to address new configurations of PHEVs. The proposed changes to the exhaust test procedures more accurately determine the contribution of the electric drive and vehicle exhaust emissions for PHEVs, include a determination of an equivalent all-electric range, and provide test procedures for more advanced PHEVs. Staff is proposing amendments to the current evaporative and ORVR test procedures to ensure that the evaporative emissions of PHEVs are reasonably characterized for testing purposes when demonstrating compliance with the applicable evaporative-related emission standards.

Additional amendments in this rulemaking address PHEV conversions and ZEV range testing. Aftermarket PHEV conversion system manufacturers have developed products to convert existing HEVs to PHEVs. Staff proposes new certification requirements for PHEV conversion systems, which will include the proposed exhaust, ORVR and evaporative test procedures and will ensure that the converted vehicle continues to meet the original emission standards under the warranty provided to the consumers. Staff proposes to supplement the current all-electric range test with a procedure more appropriate for range determination of fuel cell electric vehicles, based on fuel consumption.

A more detailed description of the proposed amendments is in section four of the staff report.

The ARB staff recommends that the Board adopt the amendments as proposed in appendices A through G of this Initial Statement of Reasons (ISOR or staff report).

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2. INTRODUCTION

Plug-in hybrid-electric vehicles (PHEVs, also known as off-vehicle charge capable hybrid-electric vehicles or OVCC HEVs) utilize motive power supplied by an internal combustion engine (IC engine) and off-vehicle electricity stored in batteries or other energy storage systems. Electricity may be combined with motive power from the IC engine (conventional hybrid operation), provide exclusive vehicle propulsion until additional IC engine power is needed (all-electric range operation, or AER operation), or a combination of both of these operations (blended operation). Throughout this staff report we will refer to these vehicles by their more common name, PHEV. The use of this terminology should not imply that the charging sources are limited to the grid, as with the PHEV definition used in Pavely. Since the Pavely definition of PHEV cannot be changed in this rulemaking and for clarification on this point, the test procedures and regulation language will utilize the more inclusive terminology of OVCC HEVs. The OVCC terminology includes non-grid battery charging sources such as solar panels.

This staff report presents technical amendments to the Exhaust, Evap, and ORVR Test Procedures, and presents certification requirements for PHEV conversion kits. These amendments reflect the unique operating characteristics of PHEVs and are designed to more accurately measure exhaust and evaporative emissions. The proposed conversion kit certification requirements provide an opportunity for the aftermarket conversion of vehicles to PHEV operation, while ensuring that emissions post-conversion do not increase. An optional range test for fuel cell electric vehicles is also presented.

This report addresses the need for the proposed changes, presents a summary of the amendments or new requirements, discusses alternatives to the proposal, and presents the environmental and economic impacts of the proposal. Appendix A shows the proposed regulatory text. Appendices B through F contain the proposed amendments to the current exhaust, evaporative emission, and refueling test procedures. Appendix G contains the proposed new certification requirements for aftermarket PHEV conversion systems. Appendices H and I contain technical support documents for the proposed amendments to the exhaust and evaporative-related test procedures. Appendix J contains information about Onboard Diagnostics and the relation to aftermarket PHEV conversion systems. Appendix K contains additional information on the Economic Impact of the proposed exhaust and evaporative-related test procedure amendments.

3. BACKGROUND

3.1 Air Quality in California

Air quality in California has improved dramatically over the past 30 years, largely due to continued progress in controlling pollution from motor vehicles. Faced with ever more stringent regulations, vehicle manufacturers have made remarkable progress in advancing vehicle technology. Vehicles meeting the Air Resources Board's (ARB) most stringent emission certification standards achieve emission levels that seemed impossible when the ZEV program was adopted in 1990.

Despite this progress, air quality in many areas of the state still does not meet federal or state health-based ambient air quality standards. Mobile sources still are responsible for well over half of the ozone-forming emissions in California. The relative contribution of passenger cars and small trucks is expected to decline over time as new standards phase in, but in 2020 such vehicles will still be responsible for approximately 10 percent of total emissions based on the ARB emissions inventory.[1] State and federal law requires the implementation of control strategies to attain ambient air quality standards as quickly as practicable.

In 2004, the ARB adopted the first greenhouse gas (GHG) emission reduction measure in the nation, applicable to light-duty vehicles. The California Global Warming Solutions Act of 2006, Assembly Bill 32 (AB 32) gave ARB the responsibility for monitoring and reducing GHG emissions. AB 32 also established requirements for a comprehensive program of regulatory and market mechanisms to achieve real, quantifiable, and cost effective GHG emission reductions. It requires ARB and other state agencies to adopt regulations and other requirements that reduce GHG emissions to 1990 levels by 2020. In addition, Governor Schwarzenegger set a goal of an 80 percent reduction from 1990 GHG emission levels by 2050[2]. The transportation sector is the largest contributor of human caused GHG emissions in California: 38 percent of total carbon dioxide equivalent emissions in 2004. Seventy-four percent of the transportation emissions are contributed by passenger vehicles. Other programs and legislation, including Assembly Bill 1007 (State Alternative Fuels Plan), require the state to prepare new plans to increase the use of alternative fuels in California. These other programs indicate the need for significant use of the electric drive train as well as other actions to meet California's air quality, emission reduction, and climate change goals. Off-vehicle charge capable vehicles can help play an important role in reducing both GHG and criteria pollutant emissions.

3.2 PHEV Technology

In 2003, staff envisioned two types of hybrid vehicle operation: AER PHEVs (sometimes called series hybrids) and conventional hybrids. An AER PHEV utilizes an electric

[1] ARB 2007a.
[2] Executive Order S-03-05

motor exclusively for a period of time, thereby allowing the vehicle to have an all-electric range. These vehicles operate the electric motor utilizing the electricity in the battery until the charge is depleted and then switch to using the IC engine. The AER has been defined as the total miles driven electrically before the IC engine turns on for the first time. During AER operation the vehicle is operating in a charge depleting mode. When the battery state of charge (SOC) can no longer sustain the vehicle's requirements to solely operate on the electric motor, the vehicle will then transition to a combined IC engine and electric motor hybrid operation.

The Chevrolet Volt is one example of an AER PHEV. This vehicle relies exclusively on its battery to power an electric motor to drive the wheels in charge depleting operation. When the battery state-of-charge (SOC) drops to a charge-sustaining level, generally after about 40 miles of all-electric operation,[3] the IC engine starts in order to sustain the battery's SOC, like today's conventional HEVs. The Chevrolet Volt relies only on the electric motor to drive the wheels – the IC engine does not directly drive the wheels.

The conventional HEV utilizes an operating mode where both the electric motor and IC engine operate either simultaneously or independently to provide motive power. They do not plug in; their batteries are recharged by the IC engine and by recapturing energy while braking. In conventional hybrids the IC engine operates most of the time, thereby keeping the catalyst warm and operating more effectively. Examples of conventional HEVs include the Nissan Altima Hybrid, Toyota Prius, and Ford Escape Hybrid. The current Exhaust Test Procedures provide an accurate all-electric range determination from AER PHEVs such as the Chevrolet Volt and an accurate measurement of emissions from conventional HEVs.

Since 2003, the concept of a "blended PHEV" has emerged as an intermediate step between conventional HEVs and AER PHEVs. It is anticipated that conventional HEV models may evolve into blended PHEVs with the addition of extra battery capacity and the ability to charge from an external source. Blended PHEVs differ from an AER PHEVs in electric range because the IC engine may start anytime during operation, and usually before the off-vehicle charge energy has reached a charge-sustaining level. Blended PHEVs may operate the IC engine intermittently, either to provide more electrical power to the electric motor or to actually provide torque directly to the wheels. [4] Therefore, it is possible to have many IC engine starts within one trip. Proponents of blended PHEVs claim that these vehicles provide nearly the same reductions in green house gas (GHG) emissions and petroleum dependency as AER PHEVs with a less powerful, and less expensive electric drive system.

3.3 ZEV Program

In preparation for the recent ZEV program amendments, an independent panel of experts (Panel) reported on the status of ZEV technologies and their readiness for

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[3] General Motors 2008

[4] During the predominantly all-electric operating mode, engine operation should be infrequent and called for only under conditions of heavy load or acceleration requirements from the driver

commercialization prior to 2009 to the Board in May 2007. The Panel's report[5] identified the potential of PHEVs for commercialization. However, the Panel also concluded that amendments to current test procedures must be made to adequately address emissions and electric range from PHEVs.

The most recent amendments to the ZEV regulation classify PHEVs as enhanced advanced technology partial allowance zero-emission vehicles (enhanced AT PZEV). Manufacturers can produce enhanced AT PZEVs in combination with pure ZEVs to meet their ZEV requirement. To qualify as PZEVs, vehicles have additional requirements, including a warranty requirement of 15 years or 150,000 miles on all emission related components. To qualify for AT PZEVs, an additional warranty requirement on all zero-emission energy storage of 10 years or 150,000 miles devices must be met.

PHEVs may be certified at any number of emission categories. However only those PHEVs that meet super ultra low-emission vehicle (SULEV)[6] emission levels with zero evaporative emissions[7] can qualify for credit including specific advanced componentry allowances under the ZEV regulation. PHEVs may also qualify for a zero-emission vehicle miles traveled (VMT) allowance based on an AER or equivalent all-electric range (EAER) with specific driving schedules.

3.4 Emission Test Procedures

Exhaust Test Procedures

Exhaust emissions testing quantifies and evaluates criteria emissions under worst-case operating scenarios. Most emissions from vehicles occur at the start of IC engine operation, known as a "cold start." Emissions are controlled with catalysts which operate most efficiently when warm. The current "California Exhaust Emission Standards and Test Procedures for 2005 and Subsequent Model Zero-Emission Vehicles and 2001 and Subsequent Model Hybrid-Electric Vehicles, in the Passenger Car, Light-Duty Truck and Medium-Duty Vehicle Classes" (Exhaust Test Procedures) measure emissions produced from cold starts and "hot starts" (IC engine at optimal operating temperature) using driving schedules that simulate a range of low and high speed vehicle operation.

For both conventional HEVs and conventional vehicles, the engine operates most of the time and typically there is only one cold start. PHEVs can cycle the IC engine on and off several times throughout the operation. Depending on the operating conditions, these vehicles are capable of multiple cold starts throughout a test drive cycle. For these vehicles, the current test procedure does not evaluate the worst-case operating scenario. The proposal contains a series of tests to address the unique operating

[5] Kalhammer, et al. 2007
[6] ARB 2008c, Section E.1.1.2
[7] CCR title 13 Section 1978 E.1.(c)

characteristics of these vehicles to determine a procedure that evaluates the emissions under the worst-case operating scenarios.

The development of this test series is the result of a collaborative effort through the Society of Automotive Engineers (SAE) technical committee that is presently developing revisions to “Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles” (SAE J1711). SAE J1711 includes procedures for determining emissions and all-electric range of PHEVs. Whenever possible, ARB works closely with the SAE in the development of emissions-related test procedures. The technical committee included members from the automotive industry, environmental groups, ARB, and the U.S. EPA. ARB’s proposed Exhaust Test Procedures and the next revision of SAE J1711 are expected to be similar, and in some regards, identical. The SAE J1711 revisions will not be completed in time for ARB regulatory requirements. Consequently, this parallel SAE-ARB Exhaust Test Procedures development effort was required. Several auto manufacturers are urgently working towards near-term deployment of PHEVs, and therefore it was necessary for all parties to come to an agreement as to how to determine the emissions performance and EAER of these new vehicles. The SAE J1711 must also cover additional procedures that the current and proposed ARB Exhaust Test Procedures do not, for example, the development of fuel economy test procedures for hybrids. This challenging aspect of PHEV performance assessment may take substantial additional time in order for the SAE J1711 Technical Committee to reach agreement.

<u>All-Electric Range Determination Test Procedures for Fuel Cell EVs</u>

Testing requirements are relatively straightforward for ZEVs as they do not have IC engine- or fuel-associated emissions. These vehicles are tested to determine the range of the vehicle. Range testing is required for ZEVs intending to receive credit for ZEV program compliance. In the current AER Test Procedures, a ZEV is driven over the urban test cycle and the highway test cycle on a dynamometer until it is no longer able to meet the vehicle speed called for in the test. The distance driven up to that point is its AER. Fuel cell EVs and battery EVs can have significant ranges, which are proportional to dynamometer time. The test can be time and resource consuming for hydrogen fuel cell EVs that may attain ranges of 300 miles or greater. For example, a hydrogen fuel cell EV with a range of 300 miles would require performing forty 7.45 mile-long UDDS at an average speed of approximately 20 miles per hour with 10-minute cold soaks in between cycles, resulting in 21 hours of total dynamometer time.

As with the Exhaust Test Procedures, ARB staff worked with the SAE on the newly revised "Recommended Practice for Measuring Fuel Consumption and Range of Fuel Cell and Hybrid Fuel Cell Vehicles Fuelled by Compressed Gaseous Hydrogen," SAE J2572.[8] SAE J2572 addresses both the hydrogen measurement challenges and the duration of the current AER Test Procedures. The proposed procedures shorten the testing time for fuel cell EVs.

SAE may develop a similar abbreviated procedure for high range battery EVs. ARB will continue to follow the development of the potential Recommended Practice, and may consider inclusion of an abbreviated battery EV range test at a future date. In the meantime, the current AER test will be used.

Evaporative Emission and ORVR Test Procedures

Motor vehicle gasoline or other hydrocarbon evaporative emissions are classified into four types: running loss, hot soak, diurnal, and refueling. Running loss emissions occur when the vehicle is driven and originate from numerous sources within the fuel system. Hot soak emissions occur immediately after a vehicle is parked with its IC engine turned off and are due to the latent IC engine heat vaporizing residual fuel in the IC engine system. Diurnal emissions occur when a vehicle is parked and subjected to daily, summertime ambient temperature changes that cause an expansion of vapors in the fuel tank. Refueling emissions are fuel tank vapors that are volumetrically displaced from the tank as the tank is replenished with new fuel.

The evaporative emission control systems of modern gasoline vehicles limit emissions by using components made from advanced, non-permeable materials, and by capturing and holding vapors in an on-board carbon canister. This canister, which contains activated carbon material that collects hydrocarbon vapors, is the prime evaporative emissions control device. Vapors that form inside the fuel tank are routed to the canister for storage. These captured vapors are later routed or "purged" to the IC engine system to be combusted when the vehicle is driven. However, if a vehicle's evaporative emission control system is not properly designed, some vapors may escape to the atmosphere when the amount of tank vapors routed to the canister is greater than its storage capacity, or if the canister has not been purged adequately, "breakthrough" can occur.

There are two types of evaporative emission control systems. The first is an "integrated" system which uses a single canister to store the vapors produced by both the evaporative and refueling processes. The second is a "non-integrated" system which uses a separate canister to store vapors for each process. Until recently, the integrated evaporative emission control system was the only type used. Toyota Motors Corporation introduced a variation of the non-integrated system beginning with a 2005 model-year HEV. That system uses a single canister for storing only the refueling vapors while the other evaporative diurnal vapors remain stored inside the fuel tank

[8] SAE 2008a.

(i.e., “non-integrated refueling canister-only” system). As with an integrated system, all vapors are eventually routed to the IC engine for combustion once the vehicle is driven.

The current evaporative emission requirements were formally adopted by ARB in 1999 as part of the second generation of California’s LEV regulations (LEV II evap). Manufacturers demonstrate compliance with the LEV II evap standards for each of the four types of evaporative emissions using simulated “real-world” conditions. Determination of a vehicle’s evaporative emissions relies on two specific test sequences that are contained in the “California Evaporative Emission Standards and Test Procedures For 2001 and Subsequent Model Motor Vehicles” (hereinafter referred to as “Evap Test Procedures”). The first test sequence is the “Three-Day Diurnal plus High-Temperature Hot Soak and Running Loss” (3D+HS) procedure. The second test sequence is the “Supplemental Two-Day Diurnal plus Hot Soak” (2D+HS) procedure. Manufacturers are also required to demonstrate compliance with the applicable ORVR emission standards using another test sequence contained in the ORVR Test Procedures.
The current Evap and ORVR Test Procedures do not test PHEVs under the worst case scenario. As with the Exhaust Test Procedures, the Evap and ORVR Test Procedures need to be modified to account for the unique operating characteristics of PHEVs.

3.5 Aftermarket Parts

California Vehicle Code section 27156 prohibits sale, offer for sale, advertisement, or installation of any aftermarket parts that alter the design or performance of any required motor vehicle pollution control device or system. The same section authorizes ARB to exempt such parts from the prohibition if it finds that the parts do not reduce the effectiveness of any required pollution control device or do not cause vehicle emissions to exceed applicable standards. To allow evaluation and legal use of aftermarket parts, ARB adopted exemption procedures in 1977 with subsequent amendments in 1981 and 1990. Aftermarket parts exempted under these procedures are generally add-on parts or parts that modify the original parts they replace. The exemption procedures ensure that the aftermarket parts do not adversely affect vehicle emissions or On-Board Diagnostic (OBD) systems.[9] Aftermarket parts evaluated under these procedures typically do not require significant changes to the original vehicle. Examples of exempted aftermarket parts include air intake systems, superchargers, and controllers.

For parts that require more extensive changes to allow use of fuel other than gasoline and diesel, California Health and Safety Code section 43006 authorizes ARB to certify the fuel systems. To allow evaluation and legal use of fuel systems, ARB adopted certification procedures in 1975, 1983, and 1993. These procedures allow certification of alternative fuel conversion systems designed to convert gasoline or diesel vehicles to operate on liquefied petroleum gas, natural gas, or alcohol fuels. The certification procedures ensure that vehicles modified with alternative fuel conversion systems continue to meet emission standards throughout their useful life. This is accomplished through emission testing and demonstration of conversion system durability.

[9] Appendix J has more detailed information on the implications of OBD to aftermarket conversions.

Certification also requires demonstration of compliance with OBD requirements, conversion system and installation warranty, and in-use testing.

PHEVs are similar to fuel conversions, in that the addition of off-vehicle charge capability effectively converts the vehicle to allow another source of energy to provide motive power. As with OEM PHEVs these vehicles have unique operating characteristics, which need to be evaluated differently. The current certification procedures do not address these issues. As with other fuel conversions, additional test procedures and provisions are necessary to determine if the vehicle meets the applicable emission standards over the useful life of the vehicle.

4. Staff's Proposed Amendments

Staff's proposed amendments are designed to reflect the state of technology and provide appropriate emission test procedures for PHEV technologies. Other proposed changes are intended to clarify and simplify specific program requirements. The areas identified in this section represent the most significant changes being proposed.

4.1 Objectives

The following are the main objectives of this rulemaking and staff's proposed changes:

- Ensure test procedures adequately measure emissions from blended PHEVs, AER PHEVs, and conventional HEVs;
- Ensure Exhaust Test Procedures adequately determine an equivalent all-electric range for blended PHEVs to determine the zero-emission VMT allowance; [10]
- Determine the advanced componentry allowance[11] under both the Urban Dynamometer Driving Schedule (UDDS) and US06 driving schedules;
- Provide a mechanism for certifying conversions of HEVs, while ensuring emissions are not increased throughout the original equipment manufacturer warranty period; and
- Provide a condensed testing option for fuel cell EVs to determine the AER of the vehicle.

4.2 Hybrid Exhaust Test Procedures

The proposed Exhaust Test Procedures incorporate an accurate method for testing all types of PHEVs to determine the vehicle's electric range contribution, to accurately quantify exhaust emissions, and determine if vehicles qualify for the zero-emission VMT or advanced componentry allowances described in the ZEV regulation. ARB has worked closely with the SAE J1711 committee to develop Exhaust Test Procedures in order to provide a consistent approach for testing these vehicles. The proposed Exhaust Test Procedures will be required for the 2011 model-year. However, manufacturers may opt to use the proposed Exhaust Test Procedures for model-years prior to 2011.

In the current Exhaust Test Procedures, staff assumed that the electric motor would be used exclusively during the charge depletion mode, and thus the current Exhaust Test Procedures start collecting emissions after the battery's charge is depleted. The AER occurs during the charge depleting mode and is defined as operation that occurs prior to the start of the IC engine. Blended PHEVs operate differently. While blended PHEVs

[10] ARB 2008e, title 13 section 1962.1 (c) (3)
[11] ARB 2008e, title 13 section 1962.1 (c) (4) (B) 7 for UDDS and title section 1962.1 (c) (4) (B) 8 for US06.

can operate in an electric mode, the IC engine may start at any time to meet the driving condition demanded by the driver. For example, a blended PHEV may operate in an all-electric mode for 10 miles in a 25 mile trip. However, if the trip began with a hard acceleration, the IC engine would likely start to provide needed power. In this example, the AER as determined by the current procedure would be much less than 10 miles. Using the current AER definition, the electric contribution for the rest of the trip does not currently count toward the AER and is therefore not recognized for its benefit. The proposed Exhaust Test Procedures include an EAER determination, which is used to calculate the electric driving range during blended operation over an entire trip. This determination will allow blended PHEVs to qualify for a zero-emission VMT allowance in the ZEV regulation. Since electric range during blended operation cannot be directly measured, a method was developed to calculate EAER based on the amount of CO_2 emitted during vehicle testing.

Additionally, the current Exhaust Test Procedures do not accurately capture tailpipe emissions from blended and AER PHEVs. The current Exhaust Test Procedures are based on the premise that the IC engine does not operate in charge depleting mode, therefore emissions are not collected during this time. For instance, if the IC engine cycles on and off throughout charge depleting mode, the exhaust emissions could not be sampled under the current Exhaust Test Procedures. Likewise, for AER PHEVs the IC engine can start in the middle of a driving schedule, when the vehicle demands are different than at the start of a driving schedule. The current Exhaust Test Procedures will not capture the emissions from either of these situations. In the proposed Exhaust Test Procedures, emission sampling during charge depleting operation will now be required for all PHEVs. Emissions will continue to be captured until the battery SOC is depleted to the point where the IC engine operates more frequently to sustain a minimum battery SOC.

Staff proposes to split the Exhaust Test Procedures, including the AER determination, into two sections: 1) applicable for PHEVS,[12] and 2) applicable for conventional HEVs and ZEVs.[13] Appendix H contains a complete detailed explanation of all the proposed changes to the Exhaust Test Procedures.

The following amendments address changes for PHEVs.

Urban Charge Depleting Range Test

For a PHEV which has two distinct modes of operation, one using battery power alone and another in which motive power is derived from the engine only, the current procedure for the urban charge depleting range test to determine AER is accurate. For the urban charge depleting range test, continuous urban dynamometer driving schedule (UDDS) test cycles with a 10-minute soak period between each UDDS are conducted until charge-sustaining operation is achieved for two consecutive UDDS cycles (the second UDDS may be omitted if data is provided showing charge-sustaining operation

[12] Section F in the proposed Exhaust Test Procedures (Appendix D)
[13] Section E in the proposed Exhaust Test Procedures (Appendix D)

can be determined from one UDDS). For labs unable to perform this sequence, an alternative procedure is described in Appendix H. Appendix D contains the specific test procedure language relating to this alternative.

Highway Charge Depleting Range Test

Similarly, for the highway charge depleting range test, four continuous highway fuel economy driving schedule (HFEDS) test cycles are conducted. After every fourth HFEDS, an optional key-off soak period is provided to reset test cell equipment. The test sequence is continued until the vehicle achieves charge-sustaining operation for one highway cycle. As with the UDDS procedure, an alternative procedure is allowed for labs unable to perform this sequence. This procedure is in Appendix D and described in Appendix H.

Equivalent All-Electric Range (EAER)

Testing for equivalent all-electric range (EAER) is a new procedure designed to quantify the electric driving range provided by the battery-powered electric motor during blended operation mode of a PHEV. The procedure is based on comparing the propulsion energy contributed by the fuel-powered IC engine during charge-sustaining mode (when net energy is supplied by the engine only) to the proportion of propulsion energy contributed by the engine during charge depleting mode (when net energy is supplied by either the IC engine, the electric motor, or a combination of both.). EAER along with a utility factor (UF)[14] correction is used to determine the zero-emission VMT allowance. The UF is the estimation of the percentage of driving in the charge depleting mode.

Advanced Componentry Allowances

The proposed Exhaust Test Procedures also include two methods to determine if a PHEV qualifies for a Type F or Type G HEV advanced componentry allowances under the ZEV regulation. The proposed methods require that a vehicle be driven utilizing a specified drive cycle and ends when the IC engine first starts or when the vehicle fails to meet the speed tolerance of the drive schedule. Descriptions of the two proposed methods follows:

- the UDDS AER determination: the UDDS charge depleting range test consists of a repeated series of UDDS driving cycles. As discussed in the March 2008 ZEV program amendments, to qualify for a Type F advanced componentry allowance, the vehicle must be capable of achieving a 10-mile AER on this driving schedule.
- the US06 AER determination: the US06 charge depleting range test consists of a repeated series of US06 driving cycles. To qualify for a Type G advanced componentry allowance, the vehicle must be capable of achieving a 10-mile AER on the more aggressive US06 driving schedule.[15]

[14] SAE 2008b.
[15] Code of Federal Regulations title 40 volume 18 chapter 1 part 86 subpart B §86.164-08

Other Amendments to the Exhaust Test Procedures

Staff is also proposing amendments to the Exhaust Test Procedures for conventional HEVs and ZEVs. In general, these amendments align the procedures with those for PHEVs and provide clarification. Most of the changes occur in the charge-sustaining emission tests,[16] or relate to battery charging operations. A more comprehensive discussion is provided in Appendix H.

The proposed amendments to the "California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles"[17] amendments incorporate the proposed amendments to the hybrid Exhaust Test Procedures.[18]

4.3 All-Electric Range Determination Test Procedures for Fuel Cell EVs within the Hybrid Exhaust Test Procedures

There are three challenges with testing hydrogen fuel cell EVs in accordance with the current AER Test Procedures:

(1) The current AER Test Procedures were developed based on battery EVs and do not specifically address hydrogen fuel capacity or consumption measurements.

(2) The current AER Test Procedures require a complete range test of the fuel cell EV. The test can be time and resource consuming for hydrogen fuel cell EVs that may attain ranges of 300 miles or greater. For example, a hydrogen fuel cell EV with a range of 300 miles would require performing forty 7.45 mile-long UDDS at an average speed of approximately 20 miles per hour with 10-minute cold soaks in between cycles, resulting in 21 hours of total dynamometer time.

(3) A third challenge with the current AER Test Procedures for fuel cell EVs is related to the duration of the test. The extended duration of the current AER Test Procedure increases the possibility that the operator fails to meet the speed trace tolerance specifications of a single test cycle due to fatigue. If an error is made in a test cycle near the end of the vehicle range, a great deal of time is required to refill, stabilize, and retest the fuel cell EV.

ARB staff proposes to supplement the current AER Test Procedures for fuel cells by incorporating the newly revised SAE J2572 "Recommended Practice for Measuring Fuel Consumption and Range of Fuel Cell and Hybrid Fuel Cell Vehicles Fuelled by Compressed Gaseous Hydrogen". This SAE Recommended Practice addresses both the hydrogen measurement challenges and the impractical duration of the current AER Test for fuel cell EVs by reducing actual dynamometer testing to only two UDDS cycles (about 15 miles) with one 10-minute soak. Hydrogen consumption during this reduced

[16] The following four tests are all run in charge-sustaining mode: UDDS, HFEDS, SCO3, and US06.
[17] Appendix B
[18] Appendix C and Appendix D

duration test is measured to within one percent accuracy, and usable hydrogen storage capacity is also calculated. Instead of direct measurement of the vehicle's full range, these values are used to determine the range as follows:

Range (km) = Usable fuel amount (kg) / Fuel consumption (kg/km)

For a 300-mile hydrogen ZEV, this revised procedure would result in a reduction in dynamometer test time from 21 hours to 54 minutes. The proposed AER Test Procedures provide a method for calculating the AER of a fuel cell vehicle based on the fuel consumed over the UDDS and the highway driving schedule and the amount of usable hydrogen in the fuel tank.

Although the testing time challenge also exists for high range battery EVs, these abbreviated ZEV AER Test Procedures are not applicable to battery EVs because of additional challenges in consumption and capacity measurements for batteries. In addition, battery depletion may not be linear with mileage. SAE may develop a similar abbreviated procedure for high range battery EVs. ARB will continue to follow the development of the potential Recommended Practice, and may consider inclusion of an abbreviated battery EV range test at a future date. In the meantime, the current AER test will be used.

4.4 Evaporative Emissions Test Procedures

Some vehicles are exempted from the evaporative emission standards and test procedures, such as diesel- and compressed natural gas- (CNG) fueled vehicles, as well as HEVs with sealed fuel systems that have no evaporative emissions. However, the exemption for HEVs with sealed fuel systems has caused some confusion because the current evaporative regulations do not contain a definition of a "sealed fuel system." Staff's proposal addresses this issue.

For demonstrating compliance, a PHEV presents a challenge for accurately simulating real-world in-use testing conditions using the current Evap Test Procedures. This difficulty is due to the HEV's potential to be "always plugged-in" by an owner. In other words, the vehicle's battery could always be at a fully charged level, or at a high battery SOC, before any commute, which means that the vehicle could operate for a long time, perhaps for weeks, without ever operating its IC engine. This is a concern because without IC engine operation, the evaporative canister cannot purge its stored vapors, yet new evaporative emissions will be generated during each day's temperature diurnal. This will ultimately result in a release, or breakthrough, of vapors to the atmosphere.

Manufacturers are exploring various evaporative emission system designs for controlling evaporative diurnal and ORVR emissions in response to the evaporative control challenges presented by PHEVs. Staff believes that manufacturers will ultimately select designs that use a "non-integrated refueling canister-only" system because this design provides some technological advantages over conventional systems for effectively managing the real-world evaporative emission conditions created by the “always plugged-in” potential operation of these HEVs.

A brief description of the proposal follows. Refer to Appendix I for a complete detailed explanation of all the proposed changes to the Evap and ORVR Test Procedures.

Definition of a “Sealed Fuel System”

Staff proposes that the current Evap and ORVR Test Procedures be amended to include a definition of a “sealed fuel system.” The current Evap regulations and Evap Test Procedures apply to HEVs with “sealed fuel systems” which can demonstrate no emissions. However, the current Evap Test Procedures do not include a definition of a “sealed fuel system and this causes confusion of the applicability of the Evap standards and Test Procedures.[19] Specifically, staff recommends that a “sealed fuel system” be defined as a system that uses non-liquid fuels that are under very high pressures and has no evaporative emissions, by virtue of its design specifications. Accordingly, non-integrated refueling canister-only systems do not qualify as a sealed fuel system.

Preconditioning and Revisions to Test Procedures

The Evap and ORVR Test Procedures require a very detailed method for preparing or “preconditioning” a test vehicle and its evaporative control system before any emission testing is conducted. The current test procedures need to be modified to address the unique operating characteristics of PHEVs. Listed below are the major proposed revisions. Other relatively minor revisions (not listed below) are also proposed and are described in Appendix I.

- When conducting the sequences of the Evap and ORVR Test Procedures, staff proposes that the vehicle-preconditioning step be performed entirely with the vehicle’s IC engine operating in a “charge-sustaining mode”.[20] This will ensure that the test vehicle is properly conditioned with the certification test fuel.

- Staff proposes that the SOC of the test vehicle’s battery be set at appropriate levels in both of the sequences for the Evap and ORVR Test Procedures, so that the evaporative emissions are reasonably characterized with respect to the potential in-use “always plugged-in” condition for evaporative emissions testing.

- Staff proposes that a new “fuel-tank-refill” canister-loading preconditioning method for non-integrated refueling canister-only systems be added to the Evap and ORVR Test Procedures. This new method is necessary because the existing canister preconditioning methods do not apply to non-integrated systems that use a canister for controlling only refueling vapors. The new method is more appropriate because it represents “real-world” conditions.

[19] Appendix E, section 1.A.1
[20] “Charge-sustaining” mode means that the vehicle is propelled only by power from the engine.

- Because it is an additional technology to control evaporative emissions, staff proposes that a definition for a "non-integrated refueling canister-only system" be added to the Evap Test Procedures.

Revisions to the 2D+HS Test Sequence

In order to demonstrate that the evaporative emission control system of a PHEV has the capability for sufficiently purging a canister during a short driving event, staff proposes a revision to the 2D+HS test sequence. Specifically, the test would be performed with the vehicle's battery set at a low SOC level, thereby forcing the IC engine to operate, which in turn would force a demonstration of the IC engine's purge capability. To reduce the burden of actually performing this demonstration, manufacturers will have the option to conduct an alternative engineering evaluation demonstrating the evaporative emission control system's capability.

4.5 Aftermarket Parts Program

With increased numbers of HEVs on the road and growing interest in reducing gasoline consumption, maximizing electric-only drive, and concern about climate change, a number of Conversion System Manufacturers have developed PHEV conversion systems to provide extended electric driving range for HEV drivers. Many of the HEVs being targeted for PHEV conversion are some of the cleanest vehicles operating in California. With their California introduction in 2000, HEVs have become increasingly cleaner, with many HEVs now meeting the most stringent PZEV standards. PZEVs are warranted for emissions by the vehicle manufacturers for 15 years or 150,000 miles. The battery is considered an emission control part and is considered a zero-emission energy storage device used for traction power. As such, the battery is warranted for 10 years or 150,000 miles.[21] The battery on non-PZEV HEVs, which may also be converted, is warranted by the vehicle manufacturer for 7 years or 70,000 miles.

A typical PHEV conversion system adds a rechargeable battery to provide supplemental electrical energy and a controller to determine when to supply electrical energy from the add-on battery. Other PHEV conversion systems may involve more substantial changes like replacing the existing OEM battery with a larger capacity battery. These conversions impact the way the original vehicle was designed to operate. More electrical energy means less internal combustion engine operation with potential for higher cold start emissions, reduced emission canister purges causing higher evaporative emissions, and higher loading on existing electrical components, such as an electric motor, possibly leading to faster component wear and tear. Conversions also impact operation of the OBD system.[22]

There are current procedures for approving aftermarket parts and alternative fuel conversions systems, but neither procedure applies to PHEV conversions. Therefore, staff is proposing a new procedure to address PHEV conversions. The proposed

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[21] ARB 2008f. CCR title 13 section1962 (c) (2) (D) and ARB 2008e title 13 section 1962.1 (c) (2) (D).
[22] Additional information on OBD is in Appendix J.

procedures establish a certification process very similar to that already used by alternative fuel Conversion System Manufacturers. They would require Conversion System Manufacturers to submit an application package to initiate the certification process, perform emission, durability, and in-use testing, and provide documentation of consumer warranty. These new procedures also require that Conversion System Manufacturers meet OBD requirements. In the certification application, Conversion System Manufacturers must identify the vehicles to be converted, describe their PHEV conversion system and explain how it operates, describe their OBD system, and provide appropriate system labels and warranty. Conversion System Manufacturers must also provide a plan to demonstrate compliance with the emission and durability requirements in the application.

The PHEV conversion system must be tested and shown to be durable for the useful life of the vehicle. Durability testing can be carried out by installing the PHEV conversion system on a vehicle and accumulating mileage on the vehicle using an approved method for the vehicle's useful life. In lieu of whole vehicle aging, Conversion System Manufacturers have the option to age individual components or systems on a bench using an approved method. Once mileage accumulation or bench aging is complete, Conversion System Manufacturers must test the aged vehicle or vehicle with the aged components for emissions. Emission testing would be performed following the test procedures proposed in this rulemaking. To be eligible for certification, the vehicle must meet all the original certification standards. The procedures allow for Conversion System Manufacturers to propose alternative durability- and emission-testing methods that would effectively predict the deterioration of the PHEV converted vehicle as well as predict the useful life emissions of the converted vehicle.

The proposed procedures are written to provide flexibility depending on the extent of the amendments made. Staff envisions a typical PHEV conversion system to consist of a battery pack, sensors, and a controller. This would not alter the original engine or any of the original emission control parts. For such conversion, Conversion System Manufacturers may request use of OEM deterioration factors to estimate the useful life emissions of the converted vehicle. For PHEV conversion system durability, Conversion System Manufacturers may propose cycling of the battery for a period equivalent to the vehicle's useful life. It may entail charging and depleting of the battery under conditions that simulate in-use conditions. EAER or SOC data of the new system and the cycled system may be compared. Acceptance criteria may be proposed by Conversion System Manufacturers. Data or information on other electrical components may also be required to ensure durability.

For more extensive conversions, the use of OEM deterioration factors may not be appropriate. Such conversions would require more extensive testing, including emission-control-part aging and/or vehicle-mileage accumulation. Carry-over and carry-across of emission and durability data will be allowed upon demonstration that existing data adequately represent the emission and deterioration characteristics of the conversion system and vehicle to be certified. The proposed procedures would require

Conversion System Manufacturers to demonstrate that the converted vehicle has a fully compliant OBD system. Additional information on OBD is in Appendix J.
The proposed certification procedures would require Conversion System Manufacturers and installers of PHEV conversion systems to provide consumer warranties. The required warranty is similar to the warranty required for alternative fuel conversion systems and their installers, except for warranty periods for PZEVs. Conversion System Manufacturers would be required to warrant to the person having the vehicle converted and to each subsequent purchaser of the vehicle that the PHEV conversion system meets the following requirements:

- is designed and manufactured to conform with the applicable requirements of the certification procedures,
- is free from defects in materials and workmanship which cause the PHEV conversion system to fail to conform with the applicable requirements of the procedures or cause damage to any part on the converted vehicle.

For example, if the OEM designed an electrical part for regular hybrid operation, and the conversion required the part to be used more often, this could contribute to early failure. If the vehicle is still under the Conversion Warranty, the Conversion System Manufacturer would be responsible for replacement or repair of the part.

The warranty period begins from the date of installation and covers customer service and the full repair or replacement costs.[23] Table 4-1 shows the warranty requirements for conversions. The length of warranty is determined by the age of the vehicle, the emission category, and the cost to replace or repair the damaged parts.

[23] This includes the costs of diagnosis, labor, and parts, and any part on the converted vehicle that is damaged due to a defect in the conversion system.

Table 4-1: Conversion System Manufacturer Warranty Requirements

Type of vehicle	Time of conversion from vehicle's initial purchase	Type of Part	Length of Conversion Warranty
Non PZEV	Within 4 years[24]	Low cost parts	3 years or 50,000 miles
		High cost parts	7 years or 70,000 miles
	After 4 years[25]	Low cost parts	3 years or 25,000 miles
		High cost parts	3 years or 35,000 miles
PZEV	Within 6 years[26]	Zero emission energy storage devices used for traction power	10 years or 150,000 miles
		All other parts	15 years or 150,000 miles
	After 6 years[27]	All parts	5 years or 75,000 miles

Installers of PHEV conversion systems would be required to warrant to the vehicle owner and subsequent vehicle owners that conversion system will not fail to meet the certification procedure requirements due to incorrect installation, and that no part on the vehicle will be damaged due to incorrect installation. Installers of PHEV conversion systems shall install only those systems of a certified configuration and shall agree to cover the cost of repair of any vehicle upon which a noncertified configuration was installed. In addition, the installer shall agree to be responsible for any tampering fines that may be imposed as a result of improper installation of the PHEV conversion system. The warranties and agreements shall begin on the date of installation and be effective for 3 years or 50,000 miles, whichever occurs first. This warranty shall cover customer service and the full repair or replacement costs including the cost of diagnosis, labor, and parts, including any part on the converted vehicle that is damaged due to incorrect installation of the conversion system.

To ensure that the PHEV converted vehicles continue to operate as presented during certification, the proposed procedures contain in-use testing requirements for Conversion System Manufacturers. Upon request by ARB, a Conversion System

[24] This warranty period is the same as the warranty period specified for OEMs in section 2037(b), title 13, California Code of Regulations (CCR).
[25] The warranty period is three years or half the applicable warranty period mileage specified in section 2037(b), title 13, CCR, whichever occurs first from the date of installation.
[26] This warranty period is same as the warranty period specified for OEMs in section 1962(c), title 13, CCR.
[27] The warranty period is five years or half the applicable warranty period mileage specified in section 1962(c), title 13, CCR, whichever occurs first from the date of installation.

Manufacturer would be required to test a maximum of five PHEV conversion systems per year. Testing costs will be borne by ARB, except for those PHEV conversion systems that do not comply with the applicable emission standards. Conversion System Manufacturers would also be required to properly label the converted vehicle as a PHEV and maintain records of the conversions. Similar record keeping requirements would apply to installers of the PHEV conversion systems.

Table 4-2 summarizes the changes from what is currently required. The first column identifies the main requirements for conversions, while the second through fourth columns address the proposal and the current procedures available.

Table 4-2: Comparison of Staff's Proposal to Current PHEV Conversion Options

	Staff's Proposal	**Current Requirements**	
		Small Volume Manufacturer requirements	**Vehicle Code section 27156 exemption**
Vehicles that can be converted to PHEVs	HEVs	All vehicles	Only vehicles outside OEM warranty
Certification applicability	IC engine family/test group	IC engine family/test group	Similar model-years
Emission Standards	Must meet original certification standards	Treated as a new vehicle, therefore can choose certification standards	Must meet original certification standards
Durability	Demonstrate or if applicable apply OEM deterioration factor	Demonstrate full compliance	Apply OEM deterioration factor
OBD II	Demonstrate full compliance	Demonstrate full compliance	Demonstrate no degradation
Warranty requirements	Conversion system, unless system causes OEM part failure	Whole vehicle	N/A
Subject to in-use testing, warranty reporting, etc	In-use testing only, cost to ARB if compliant	Must meet all OEM requirements	N/A

Potential impacts to OBD

Today's vehicles are incredibly complex; therefore, it is difficult to accurately predict the full impact of aftermarket conversion systems to the OBD system until specifics are known about the base vehicle and about the hybrid modification itself. However, based on staff's experience, there are several areas where added hybrid functionality will likely require OBD revision or further development. These include extended idle-off which may disable other monitors that only function at idle. Monitors that fail to run because IC engine operation is too short or infrequent and development of monitoring strategies for newly added components such as switches and controllers.

Staff understands that most Conversion System Manufacturers will need some time to revise monitoring strategies and develop new solutions to bring a compliant product to the marketplace. Accordingly, staff is proposing to use the existing deficiency provisions in the OBD regulation that allow certification of systems that fall short of fully meeting all of the OBD system requirements. Deficiencies can be awarded in most cases where the manufacturer has made a good faith effort to comply and has a plan to come into full compliance as expeditiously as possible. Using this mechanism, staff could certify systems that fall short in one or more areas as long as the manufacturer had attempted to comply and had a valid plan to address the shortcomings in a reasonable timeframe.[28] Conversion System Manufacturers will still need to meet the vast majority of the OBD requirements and relief is expected to primarily be needed in the area of minimum monitoring frequency. Further, such relief could only be granted for short term relief and only in cases where the Conversion System Manufacturer has determined what is needed to come into full compliance and has a plan to do so in an expeditious manner. Staff's proposal should allow Conversion System Manufacturers to gain necessary in-use experience and to use that information to refine the system.

4.6 Additional Amendments

<u>Non-Substantive Changes</u>

Staff proposes minor non-substantive amendments to the Exhaust, Evap, and ORVR Test Procedures. In particular, staff proposes to add a Terminology section to the Exhaust Test Procedures. Staff also proposes to revise Figures 2, 3A, and 3B in the Evap Test Procedures to improve their clarity and to make the applicable terminology consistent with the language in the test procedures themselves, as well as with the federal versions of the test procedures. Also, the existing canister-loading-related definition of a "2-gram breakthrough," contained within the body of the Evap Test Procedures, is relocated to the "Definitions, Acronyms, Terminology" section of those same test procedures. Other proposed changes include revisions to the formats of some of the section indicators to make them consistent throughout the test procedures, corrections to current text, and other miscellaneous grammatical corrections.

[28] ARB will not approve systems with such reduced monitoring frequency that any monitors are effectively disabled or the vehicle is otherwise incompatible with the Smog Check inspection process.

5. REGULATORY ALTERNATIVES

Staff evaluated alternatives for each of the three main proposed amendments separately: Exhaust Test Procedures, Emission Test Procedures related to evaporative emissions, and Aftermarket Conversion System Certifications.

5.1 Exhaust Test Procedures

Do Not Amend

The alternative of keeping the current procedure is not reasonable because it does not adequately assess exhaust emissions, or the contribution of the electric motor to blended PHEVs. The current Exhaust Test Procedures underestimate the contribution of electric energy to vehicle operation for blended PHEVs during normal driving conditions. Only PHEVs with a significant all-electric range would qualify for ZEV advanced componentry and zero-emission VMT allowance credits using the current procedures. Additionally, the current Exhaust Test Procedures do not accurately assess emissions during charge depleting operation for blended and non-blended PHEVs. As a result, staff rejected this alternative.

Wait for SAE 1711 to be Adopted

New procedures are needed for expected introduction of PHEVs for ZEV regulation compliance before projected completion of the SAE process. ARB's proposed Exhaust Test Procedures closely follow the Draft SAE J1711 Procedure. Therefore, this is not a viable option.

5.2 Evaporative Test Procedures

Do Not Amend

The alternative of not amending the current California Evap Test Procedures is not reasonable because it would prevent specific technical revisions to these test procedures that are necessary in order to certify PHEVs. Thus, this alternative would impede the commercial introduction of these vehicles within the timeframes required under the ZEV regulations. Therefore, staff rejected this alternative.

Wait for the adoption of federal PHEV Evap and ORVR Test Procedures.

Current federal regulations do not provide any measures to certify PHEVs. Indeed, as the United States Environmental Protection Agency (U.S. EPA) indicated when the federal National Low-Emission Vehicle rulemaking was proposed in 1997, U.S. EPA planned to rely on California's lead in emission control rulemaking to address HEV technological advances. In addition, the National Highway Traffic Safety Administration's recent rulemaking discussion of plug-in hybrids in its proposed fuel economy standards for 2011 – 2015 model-year passenger cars and light-duty trucks involves exhaust emissions and not evaporative emissions. Accordingly, relying on the adoption of any federal regulations that address PHEV evaporative emission controls is not a viable alternative.

5.3 Aftermarket Conversion System Certification

ARB currently does not have certification procedures that are directly applicable to the sale of PHEV conversion systems. Given the absence of such procedures, staff considered two alternatives.

Require Certification as a New Vehicle

The first alternative would require a Conversion System Manufacturer to essentially recertify a vehicle with a PHEV conversion system installed as a new vehicle and be issued a new vehicle Executive Order for the combination of the vehicle and the PHEV conversion system. Under this alternative, a Conversion System Manufacturer would have to procure a vehicle then fully emission test that vehicle with the PHEV conversion system installed. This would subject Conversion System Manufacturers to all of ARB's current new vehicle certification provisions and require certification fee payment as new vehicle manufacturers. Conversion System Manufacturers would also be required to warrant the entire vehicle with the PHEV conversion system instead of only the PHEV conversion system. This would impose very significant costs to Conversion System Manufacturers that essentially would make it infeasible. It would also mean that owners of HEVs would not be able to get their cars converted because the kits would only be allowed on essentially new vehicles.

Use Existing Vehicle Code Section 27156 Exemption Requirements

Under the second alternative, ARB would evaluate PHEV conversion systems using the existing Vehicle Code section 27156 exemption procedures. The exemption procedures do not contain any warranty provisions. Because PHEV conversion systems impact emission control parts like the battery, ARB would only consider systems for vehicles no longer covered by their original warranty. This alternative was rejected because it would prevent Conversion System Manufacturers from legally selling PHEV conversion systems for vehicles less than 10 years old (the battery warranty period for many OEM HEVs).

6. ECONOMIC IMPACTS

There are three main sections to consider the proposed amendments: costs associated with the proposed conversion certification procedures, capital costs and testing costs associated with the proposed PHEV related test procedures, and costs associated with the fuel cell range test.

The proposed certification PHEV conversion system procedures open an opportunity for Conversion System Manufacturers to enter the in-use vehicle market. In addition, the proposed certification procedures prevent the illegal sale of converted vehicles. Conversion System Manufacturers will not incur any additional costs over what is expected for OEMs. Therefore, the economic impacts associated with aftermarket certification of PHEV conversion systems will be similar to those economic impacts discussed below relating to the Exhaust and Evap Test Procedures. In addition, the cost to test PHEV conversion systems will be on the lower end of the cost range, as these conversion systems are not eligible for zero-emission VMT or advanced componentry allowances and therefore do not need to conduct as many tests. Conversion System Manufacturers modifying vehicles outside of the OEM warranty will see a marginal increase in costs of about $200 for additional application costs. Conversion System Manufacturers modifying vehicles still under OEM warranty will be allowed to use the aftermarket certification process instead of recertifying the vehicle as a small volume manufacturer. The recertification costs for certifying as a small volume manufacturer are considerable and therefore the proposed certification process will provide these Conversion System Manufacturers a substantial cost savings.

The proposed test procedure amendments will be required for both OEMs and Conversion Systems Manufacturers producing PHEVs. As with Conversion System Manufacturers, OEMs are not required to produce PHEVs. PHEVs are an optional vehicle technology strategy that OEMs can use to meet their regulatory requirements in the ZEV regulation. For those manufacturers choosing to produce PHEVs and PHEV conversion systems, the proposed PHEV exhaust, evaporative-related, and aftermarket regulatory amendments are expected to result in a net cost increase above the current regulatory cost for certifying PHEVs. Staff anticipated that 150,000 enhanced AT PZEVs would be produced in the 2012 through 2017 model-years.[29] Assuming 10 OEMs produce enhanced AT PZEVs with each manufacturer producing two models, staff estimates that the incremental cost to be less $15 per vehicle. Staff does not expect any additional costs for certifying conventional HEVs. The incremental cost for OEMs producing an enhanced AT PZEV PHEV is $25,000 over the cost to produce a conventional HEV.[30] The incremental cost of this rulemaking is not noticeable compared to the incremental cost to produce these vehicles.

[29] ARB 2008a, This estimate is based on manufacturers complying with the ZEV regulation through the production of ZEVs and enhanced AT PZEVs. Enhanced AT PZEVs may be used to meet up to 70% of the requirement during Phase III (2012 - 2014) and up to 50% during Phase IV (2015 – 2017).
[30] ARB 2008d. Table 6.1

No cost will be incurred from the optional fuel cell range test. The proposed amendments reduce the number of test cycles required for range determination. The cost savings to manufacturers is proportional to the range of the fuel cell EV.

Therefore, the proposed amendments are expected to have minimal to no adverse impacts on business competitiveness, California employment, or on business creation, elimination, and expansion. The remaining sections focus on the minimal cost of the proposed test procedures related to PHEVs.

6.1 Legal Requirement

Sections 11346.3 and 11346.5 of the Government Code require State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination, or creation, and the ability of California business to compete. State agencies are required to estimate the cost or savings to any state or local agency, and school districts. The estimate is to include any nondiscretionary cost or savings to local agencies and the cost or savings in federal funding to the state.

6.2 Potential Impacts on Business

The proposed amendments are expected to benefit Conversion System Manufacturers. However, some businesses conducting Exhaust and Evap Test Procedures may be adversely affected by the proposed amendments to the regulation. As mentioned above, the amendments increase the cost of performing exhaust and evaporative emission tests of PHEVs.

<u>Potential Impacts for PHEV Conversion Systems</u>

Conversion System Manufacturers will not incur any additional costs beyond what the OEMs would see. Some cost savings may be seen by Conversion System Manufacturers modifying vehicles still under OEM warranty. Currently, these manufacturers must certify the entire converted vehicle as a small volume manufacturer. The cost of recertifying vehicles as a small volume manufacturer is considerable and therefore the proposed aftermarket certification process will provide these Conversion System Manufacturers a substantial cost savings.

<u>Estimated Costs to OEMs and Independent Laboratories</u>

Using independent laboratories able to conduct SULEV tests as a baseline, staff assessed the ability of these laboratories to conduct the proposed procedures. These costs are broken down into two main components and are discussed in separate subsections: capital costs and testing costs.

Capital Costs

Staff does not believe revisions to software or hardware are necessary to conduct the proposed Evap Test Procedures. However, testing facilities may need to make modifications to address the proposed amendments to the Exhaust Test Procedures. To accommodate the new test cycles in the proposed procedure, such as the continuous urban test, continuous highway test, and continuous US06, some test facilities may require hardware and software upgrades. These upgrades are estimated to cost from $20,000-$100,000 depending on what is necessary. This would be a one-time additional cost. Laboratories needing to upgrade their software will see costs on the lower end of the spectrum. Other laboratories may need to make both software and hardware amendments, which cost as much as $100,000. Staff anticipated that 150,000 enhanced AT PZEVs would be produced in the 2012 through 2017 model-years.[31] Assuming 10 OEMs produce enhanced AT PZEV PHEVs and that OEMs pass the capital costs on to the consumers of just these vehicles, staff estimates that the incremental cost to be less than $5 per vehicle. The increased testing costs will not impact manufacturers of conventional HEVs. It is important to note that some of these laboratories will be able to conduct the tests without any amendments. The proposed procedures are not expected to significantly change facility maintenance costs. Staff believes that all Conversion System Manufacturers will utilize independent laboratories to test their PHEV conversion systems. Although independent laboratories may need to make modifications, these costs will be passed on to the manufacturers as consumers of the laboratories.

Testing Costs

These amendments will increase the cost of testing a PHEV, because more test cycles and additional test procedures will be required. Most OEMs have testing facilities and will conduct their own testing. Costs to these OEMs will include test facility amendments and labor. For those OEMs that utilize independent labs to conduct tests, staff does not anticipate that the individual cost of each required test will increase. However, due to the additional tests and test cycles needed, additional testing time will increase dynamometer demand. Staff believes that the laboratories have adequate capacity to address the assessed increase in testing. However, if outside testing demand increases beyond the independent laboratories available capacity, market forces may temporarily increase the cost of individual tests. The increased testing costs will not impact manufacturers of conventional HEVs.

Costs to conduct the tests already include the additional labor costs and dynamometer time associated. While the incremental cost increase is difficult to calculate without knowing the number of tests needed to complete the Charge Depleting portion of tests, staff anticipates that the incremental cost increase to certify most HEVs will range between $6,050 and $7,450 per engine family for both the Evap and Exhaust Test

[31] ARB 2008a. This estimate is based on manufacturers complying with the ZEV regulation through the production of ZEVs and enhanced AT PZEVs. Enhanced AT PZEVs may be used to meet up to 70% of the requirement during Phase III (2012 - 2014) and up to 50% during Phase IV (2015 – 2017).

Procedures as currently proposed. The OEM may incur an additional testing cost of $2,000, if a Type G advanced componentry allowance is desired. Additional details on this analysis are in Appendix K. These costs will likely be passed on to consumers.

Costs Associated with the Proposed Exhaust Test Procedures

In comparing the current Exhaust Test Procedures with the proposed Exhaust Test Procedures, an analysis was made for a PHEV that has only AER during charge depleting operation since it can be fully tested by both procedures. A hypothetical PHEV with a 40-mile AER was chosen as the additional electric operation would increase total testing costs. The increased cost to test these vehicles would be around $4,800. OEMs choosing to certify their vehicles for Type G advanced componentry allowance would incur additional costs of approximately $2,000, bringing the total to around $6,800.

The typical overall costs of testing a blended PHEV are expected be less than that of testing a PHEV with significant all-electric range for the proposed procedure. The smaller battery size of anticipated blended PHEV will provide less electric range and require fewer test cycles to deplete the battery, resulting in reduced testing costs. In addition, blended PHEVs are unlikely to undergo additional testing for Type G credit, reducing testing costs. Therefore, the increased cost to test most PHEVs would be around $3,400. Staff anticipates that the majority of vehicles produced in the early years will be blended. As battery technology improves, staff anticipates more vehicles moving towards AER PHEV technology. Additional details on this analysis are in Appendix K.

Costs Associated with the Proposed Evaporative Test Procedures

An additional cost to a manufacturer would involve the possible increase in the amount of vehicle-preconditioning UDDS cycles performed in the Evap and ORVR Test Procedures. Since the proposal requires that the vehicle-preconditioning be conducted in a charge-sustaining mode of IC engine operation, some amount of vehicle driving in a charge-depleting mode may be necessary to decrease the battery energy level in order to reach the required charge-sustaining mode. However, this charge-depleting mode of driving can be done over an off-road test track course, thereby relieving a manufacturer of the additional expense of conducting actual UDDS cycles in a laboratory. Although the number of extra charge-depleting UDDS cycles that are necessary may vary depending on a particular HEV’s design, staff used two charge-depleting UDDS cycles for estimation purposes. Thus, staff estimates that the incremental cost associated with performing the vehicle-preconditioning step for PHEVs would be $1,250 per evaporative test.

In addition, a PHEV that is equipped with a non-integrated refueling canister-only system must load its refueling canister using the new method as specified in the proposal. Staff estimates that the incremental cost of using that new method is $1,400 per evaporative test. Accordingly, the total incremental cost is estimated to be $2,650 per evaporative test for a PHEV equipped with a non-integrated refueling canister-only system. The number of evaporative tests that would be conducted by a manufacturer in order to certify an evaporative family is unknown by staff because that information is proprietary to the manufacturer. However, these additional costs are expected to be passed on to the manufacturers as customers of the laboratories. Additional details on this analysis are in Appendix K.

6.3 Potential Impact on Business Competitiveness

The proposed amendments to the Exhaust and Evap Test Procedures are not expected to have a significant impact on the ability of California businesses to compete with businesses in other states. For any California-certified PHEV, a manufacturer must comply with the proposed Exhaust Test Procedures requirements. In addition, for any California-certified PHEV that is equipped with a non-integrated refueling canister-only system, the manufacturer must comply with the proposed requirements in the Evap Test Procedures. There are no manufacturers that currently certify light-duty vehicles that are headquartered in California.

6.4 Potential Impact on Employment

The proposed amendments to the Exhaust and Evap Test Procedures are not expected to cause a change in California employment. Additional exhaust and evaporative testing may result in creation of some additional jobs as demand for testing rises.

6.5 Potential Impact on Business Creation, Elimination, or Expansion

The proposed amendments to the Exhaust and Evap Test Procedures are not expected to have a noticeable impact on the status of California business creation, elimination, or expansion. Additional testing can be handled with the existing labs. However, if demand for testing rises above the capacity currently available, market forces will indicate the need for expansion or the creation of additional laboratories.

6.6 Potential Impact on Small Businesses

The proposed amendments to the Exhaust and Evap Test Procedures for PHEVs are not expected to have a noticeable impact on the status of California businesses including small businesses. The OEMs that would benefit most by this regulation are not small businesses. Most laboratories and Conversion System Manufacturers would qualify as small businesses. The proposed amendments provide additional business opportunities for these businesses. Therefore these companies will likely pass any increased costs on to the consumer, as staff expects these businesses to experience an increase in demand for their services and products.

6.7 Potential Costs to Local and State Agencies

Staff believes the proposed Exhaust and Evap Test Procedures are the most cost-effective means of achieving exhaust emissions control for PHEVs. The proposed amendments have no fiscal impacts on local agencies. The only costs to state government, as a result of the proposed amendments, would be to ARB for conducting Exhaust and Evap Test Procedures for compliance testing of PHEVs. This is estimated to be around $240,000 dollars in fiscal year 2009/2010. For clarification of these costs they are broken out individually in the Exhaust and Evap Test Procedures sections below.

Potential Costs Related to Exhaust Test Procedures

These additional costs would be associated with the increase in performing additional UDDS and HFEDS tests to comply with the proposed Exhaust Test Procedures. There is additional cost associated with creating new test cell software to run the newly created continuous highway and city test schedules resulting in a one-time cost of $40,000 in 2009/2010. Any certification confirmatory and in-use compliance testing of these HEVs will likely not be conducted by ARB until after the 2011 model-year introduction. Beyond the costs addressed above, the proposed amendments are not expected to result in any other increases in costs for local agencies.

Potential Costs Related to Evaporative Test Procedures

As with the Exhaust Test Procedures, additional costs would be associated with the possible increase in performing extra UDDS cycles when preconditioning test vehicles, as well as when using the new canister-loading method when testing PHEVs that are equipped with non-integrated refueling canister-only systems. Specifically, using this new canister-loading method would require the modification of one of ARB's current Haagen-Smit Laboratory evaporative emission testing chambers (Sealed Housing for Evaporative Determination, or SHED) to accommodate performing the ORVR Test Procedures. Furthermore, additional SHED staff would be required in order to perform the new canister-loading method. Any certification confirmatory and in-use compliance testing of these HEVs will likely not be conducted by ARB until after the 2011 model-year introduction. Thus, the proposed SHED modification, and additional staff, would not be necessary until that time. The one-time cost to modify one of the existing SHEDs is estimated at $200,000 in 2009/2010. The proposed amendments are not expected to result in an overall increase in costs for local agencies.

7. ENVIRONMENTAL IMPACTS

While these procedures do not specifically reduce or increase emissions, the amendments that staff is proposing in this rulemaking ensure that the emissions from PHEVS are characterized appropriately. This then allows staff to determine if OEM PHEVs qualify for ZEV credit, and ensure that PHEV conversion systems will not increase emissions.

7.1 Program Benefits

The amendments to the test procedures will ensure that the expected emission benefits from PHEVs identified in the Zero-Emission Vehicle Program are realized. The ZEV and Aftermarket Parts programs encourage manufacturers to design and build robust electric motors, IC engines and emission control systems to comply with the emission requirements during their useful life.

7.2 Energy Diversity and Energy Demand

The PHEV and fuel cell EV technologies expected to benefit from these amendments typically use fuel more efficiently, and thus when fully commercialized will reduce demand for petroleum fuels. These technologies also use non-petroleum fuels, such as electricity and hydrogen, which help diversify the transportation fuel market. The proposed amendments are consistent with recent reports that recommend increased vehicle efficiency and increased use of alternative fuels.

7.3 Environmental Justice

State law defines environmental justice as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. The Board has established a framework for incorporating environmental justice into ARB's programs consistent with the directives of State law. The proposed regulation would benefit all Californians by ensuring that PHEVs comply with certification emission standards throughout their useful life.

Staff's proposed changes provide a mechanism to determine compliance with all light-duty and medium-duty mobile source regulations. ARB's environmental justice policy calls for reduction in health risks from criteria pollutants in all communities, including low-income and minority communities. While staff's proposed changes do not directly affect low-income and minority communities, they do provide a mechanism to measure emissions from vehicles. This allows ARB staff to independently assess these vehicles, which in turn helps ensure ARB's environmental justice policy. Many low-income and minority communities are located near heavily traveled freeways. By measuring the emissions of air pollutants from light-duty and medium-duty vehicles, the proposed regulation will provide data for enforcement programs to assess compliance with the exhaust and evaporative emission standards. Several ARB programs set these standards and these standards provide air quality benefits by reducing exposure to, and associated health risk from, these pollutants.

8. CONCLUSION AND STAFF RECOMMENDATION

8.1 Summary of Staff Proposal

Staff's proposed amendments accommodate revisions needed to address PHEV technologies. These amendments provide greater flexibility in manufacturer compliance with the ZEV Program and assess emissions issues related to this PHEV technology. The staff proposal contains the following specific amendments:

Table 8-1: Summary of Proposed Amendments

Goal	Solution
Determine PHEV exhaust and evaporative emissions	Amend Exhaust, Evap, and ORVR Test Procedures to address IC engine cold start issues
Determine if vehicles qualify for Advanced Componentry allowance	Incorporate US06 and UDDS AER tests into Exhaust Test Procedures
Determine if vehicles qualify for zero-emission Vehicle Miles Travelled allowance	Define EAER and incorporate into calculations for zero-emission VMT allowance
Reduce testing burden for Fuel Cell EV Range Test	Utilize procedures to determine range based on fuel consumption
Evaluate aftermarket PHEV conversion systems	Design certification requirements to address issues associated with PHEVs

8.2 Staff Recommendation

ARB staff recommends that the Board approve this proposal.

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