

APPENDIX D

**PROPOSED AMENDMENTS TO THE HYBRID
EXHAUST EMISSION TEST PROCEDURES,
MODEL YEAR 2009 AND SUBSEQUENT**

California Environmental Protection Agency
AIR RESOURCES BOARD

**CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR
2009 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**

Adopted: [Insert date of adoption]
Amended: [Insert date of amendment]

Note: The proposed amendments to this document are shown in underline to indicate additions and ~~strikeout~~ to indicate deletions proposed by staff in the Notice of Public Hearing released December 5, 2008. The document in which the amendments are being shown is a version that was initially approved by the Board on March 27, 2008 for adoption as part of the “Rulemaking to Consider Adoption of the 2008 Amendments to the California Zero-Emission Vehicle Regulation.” That rulemaking is not yet final. For that reason, the document text also includes two sets of proposed changes that the Board authorized staff to offer for public comment as part of the March 27, 2008 rulemaking. The first set of changes noticed as 15-day changes to the March 27, 2008 rulemaking version are indicated by double underline to indicate additions and ~~double strikeout~~ to indicate deletions compared to the test procedures issued with the 45-day notice for the Board hearing. The second set of 15-day changes to the March 27, 2008 rulemaking version are indicated by dotted underline to indicate additions and ~~italics double strikeout~~ to indicate deletions. Existing intervening text that is not amended is indicated by “* *”. Page numbers in the table of contents will be amended in the final rulemaking if the proposal is approved by the Board.

NOTE: This document is incorporated by reference in section 1962.1, title 13, California Code of Regulations (CCR). Additional requirements necessary to complete an application for certification of zero-emission vehicles and hybrid electric vehicles are contained in other documents that are designed to be used in conjunction with this document. These other documents include:

1. “California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles” (incorporated by reference in section 1961(d), title 13, CCR);
2. “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles” (incorporated by reference in section 1976(c), title 13, CCR);
3. “California Refueling Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles” (incorporated by reference in section 1978(b), title 13, CCR);
4. OBD II (section 1968, et seq. title 13, CCR, as applicable);
5. “California Environmental Performance Label Specifications for 2009 and Subsequent Model Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Passenger Vehicles” (incorporated by reference in 1965, title 13, CCR);
6. Warranty Requirements (sections 2037 and 2038, title 13, CCR);
7. “Specifications for Fill Pipes and Openings of Motor Vehicle Fuel Tanks” (incorporated by reference in section 2235, title 13, CCR);
8. Guidelines for Certification of Federally Certified Light-Duty Motor Vehicles for Sale in California (incorporated by section 1960.5, title 13, CCR); and
9. “California Non-Methane Organic Gas Test Procedures,” (incorporated by reference in section 1961(d), title 13, CCR).

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**CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR
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A. Applicability

The emission standards and test procedures in this document are applicable to 2009 and subsequent model-year zero-emission passenger cars, light-duty trucks and medium-duty vehicles, and ~~2001~~ 2009 and subsequent model-year hybrid electric passenger cars, light-duty trucks and medium-duty vehicles. The general procedures and requirements necessary to certify a vehicle for sale in California are contained in the “California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles” (hereinafter “LDV/MDV TPs”), and apply except as amended herein. ~~A manufacturer may elect to certify a 2000 model year hybrid electric vehicle under these standards and test procedures and the LDV/MDV TPs.~~

B. Definitions and Terminology.

1. Definitions.

In addition to the following, these test procedures incorporate by reference the definitions and abbreviations set forth in the Title 40 Code of Federal Regulations (CFR) §86.1803-01, the definitions and abbreviations set forth in the LDV/MDV TPs, and the definitions set forth in section 1900, title 13, CCR.

“Advanced technology PZEV” or “AT PZEV” means any PZEV with an allowance greater than 0.2 before application of the PZEV early introduction phase-in multiplier.

“All-Electric Range” means the total miles driven electrically (with the engine off) before the engine turns on for the first time, after the battery has been fully charged. For a blended off-vehicle charge capable hybrid electric vehicle, the equivalent all-electric range shall be considered the “all-electric range” of the vehicle.

“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 the Highway Fuel Economy Schedule and the Urban Dynamometer Driving Schedule (see section E of these test procedures).

“Alternate Continuous Urban Test Schedule” means a repeated series of the following sequence: UDDS, 10 minute key-off hot soak, UDDS, and 10-20 minute key-off hot soak. This alternate procedure may be substituted for the Continuous Urban Test Schedule when the Continuous Urban Test Schedule cannot be performed.

“Alternate Continuous Highway Test Schedule” means a repeated series of the following sequence: HFEDS, 15 second key-on pause, HFEDS, and 10-20 minute key-off hot soak. This alternate procedure may be substituted for the Continuous Highway Test Schedule when the Continuous Highway Test Schedule cannot be performed.

“Auxiliary power unit” means a device that converts consumable fuel energy into mechanical or electrical energy. Some examples of auxiliary power units are internal combustion engines, gas turbines, or fuel cells.

“Battery electric vehicle” or “BEV” means any vehicle that operates solely by use of a battery or battery pack, or that is powered primarily through the use of an electric battery or battery pack but uses a flywheel or capacitor that stores energy produced by the electric motor or through regenerative braking to assist in vehicle operation.

“Battery or Battery pack” means any electrical energy storage device consisting of any number of individual battery modules or cells that is used to propel a battery electric or hybrid electric vehicle. These terms may also generically refer to capacitor and flywheel energy storage devices in the context of hybrid electric vehicles.

“Battery state-of-charge” means the quantity of electrical energy remaining in the battery relative to the maximum rated capacity of the battery expressed in percent.

“Blended off-vehicle charge capable hybrid electric vehicle” means an off-vehicle charge capable hybrid electric vehicle that uses the engine to supplement battery/electric motor power during charge depleting operation.

“Blended operation mode” means an operating mode in which the energy storage state-of-charge decreases, on average, while the vehicle is driven and the engine is used occasionally to support power requests.

“Charge-depleting” means that the battery of a hybrid electric vehicle ultimately fully discharges and impairs vehicle operation as the vehicle continuously operates over a given driving cycle when no off-vehicle charging is performed and the consumable fuel is regularly replenished. Hybrid electric vehicles are required to be classified as either charge sustaining or charge depleting over each driving cycle (i.e. UDDS, HFEDS, US06, or SC03).

“Charge-depleting net energy consumption” means the net electrical energy, E_{cd} , measured in watt-hours consumed by vehicle over the charge depleting cycle range, R_{cdc} . E_{cd} can be expressed as AC or DC watt hours, where appropriate.

“Charge-depleting (CD) mode” means an operating mode in which the energy storage state-of-charge (SOC) may fluctuate but, on average, decreases while the vehicle is driven. Hybrid electric vehicles are required to be classified as either charge-sustaining or charge-depleting over each driving cycle (i.e. UDDS, HFEDS, US06, or SC03).

“Charge depleting actual range or R_{cda} ” means the distance traveled on the Urban Charge Depleting Test Procedure at which the state-of-charge is first equal to the average state-of-charge of the two consecutive UDDS used to end the Urban Charge Depleting Test Procedure. This range must be accurate to the nearest 0.1 miles. (See section F.11.9.)

“Charge depleting actual range, highway or R_{cdah} ” means the distance traveled on the Highway Charge Depleting Test Procedure at which the state-of-charge is first equal to the average state-of-charge of the HFEDS used to end the Highway Charge Depleting Test Procedure. This range must be accurate to the nearest 0.1 miles.

“Charge depleting cycle range or R_{cdc} ” means the distance traveled on the Urban or Highway Charge Depleting Procedure up to the test cycle prior to where the state-of-charge is above the lower bound state-of-charge tolerance for one test cycle. This range will appear as the sum of a discrete number of test cycle distances. This range shall be accurate to the nearest 0.1 miles. (See section F.11.8.)

~~“Charge depletion range actual or R_{cdq} ”~~ means the distance achieved by a hybrid electric vehicle on a specified driving cycle at the point when the zero emission energy storage device is depleted of off vehicle charge and regenerative braking derived energy.

~~“Charge sustaining”~~ means that the battery of a hybrid electric vehicle ultimately does not fully discharge and impair vehicle operation as the vehicle continuously operates over a given driving cycle when no off vehicle charging is performed and the consumable fuel is regularly replenished. Hybrid electric vehicles are required to be classified as either charge sustaining or charge depleting over each driving cycle (i.e. UDDS, HFEDS, US06, or SC03).

“Charge-sustaining net energy consumption” means the net electrical energy, Ecs, measured in watt-hours consumed by vehicle during charge sustaining operation. For charge sustaining operation, this number should be ~ 0 .

“Charge-sustaining (CS) mode” means an operating mode in which the energy storage SOC may fluctuate but, on average, is maintained at a certain level while the vehicle is driven. Hybrid electric vehicles are required to be classified as either charge-sustaining or charge-depleting over each driving cycle (i.e. UDDS, HFEDS, US06, or SC03).

“Consumable fuel” means any solid, liquid, or gaseous matter that releases energy when consumed by an auxiliary power unit.

“Continuous Urban Test Schedule” means a repeated series comprised of an Urban Dynamometer Driving Schedules (UDDS), 40 CFR, Part 86, Appendix I, which is incorporated herein by reference; each test is followed by a 10 minute key-off soak period.

“Continuous Highway Test Schedule” means a repeated series comprised of four consecutive key-on Highway Fuel Economy Driving Schedules (HFEDS) with a 15 second key-on pause in-between each HFEDS. If this schedule cannot be performed continuously, a key-off soak up to 30 minutes is permitted after every fourth HFEDS.

“Continuous US06 Test Schedule” means a repeated series of US06 driving schedules (US06) with a key-on idle period of not less than one minute and not greater than two minutes between each US06.

“Electric drive system” means an electric motor and associated power electronics, which provide acceleration torque to the drive wheels sometime during normal vehicle operation. This does not include components that could act as a motor, but are configured to act only as a generator or engine starter in a particular vehicle application.

“Electric range fraction” means the fraction of electrical energy derived from off-vehicle charging and regenerative braking energy relative to total traction energy used over the charge depletion range on a specified drive cycle.

“Enhanced AT PZEV” means any PZEV that has an allowance of 1.0 or greater per vehicle without multipliers and makes use of a ZEV fuel.

“Equivalent all-electric range” means ~~the charge depletion range multiplied by the electric range fraction~~ ($EAER = R_{cd} \times ERF$) the portion of the total charge depleting range attributable to the use of electricity from the battery over the charge depleting range test.

“Fuel cell vehicle” or “FCV” means any vehicle that receives propulsion solely from an onboard fuel cell power system.

“Fuel-fired heater” means a fuel burning device that creates heat for the purpose of warming the passenger compartment of a vehicle but does not contribute to the propulsion of the vehicle.

“Grid-connected hybrid electric vehicle” means a hybrid electric vehicle that has the capacity for the battery to be recharged from an off-board source of electricity and has some all-electric range.

“Highway Fuel Economy Driving Schedule” or “HFEDS” means highway fuel economy driving schedule. See 40 CFR Part 600 §600.109(b).

“Hybrid electric vehicle” or “HEV” means any vehicle that can draw propulsion energy from both of the following on-vehicle sources of stored energy: 1) a consumable fuel and 2) an energy storage device such as a battery, capacitor, or flywheel.

“Hybrid fuel cell vehicle” or “HFCV” means any vehicle that receives propulsion energy from both an onboard fuel cell power system and either a battery or a capacitor.

“Neighborhood Electric Vehicle” or “NEV” means a motor vehicle that meets the definition of “low-speed vehicle” either in section 385.5 of the Vehicle Code or in 49 CFR §571.500 (as it existed on July 1, 2000), and is certified to zero-emission vehicle standards.

“NIST” means the National Institute of Standards and Technology.

“Off-vehicle charge capable” means having the capability to charge a battery from an off-vehicle electric energy source that cannot be connected or coupled to the vehicle in any manner while the vehicle is being driven. A grid-connected hybrid electric vehicle is one example of an off-vehicle charge capable hybrid electric vehicle.

“Placed in service” means having been sold or leased to an end-user and not just to a dealer or other distribution chain entity, and having been individually registered for on-road use by the California Department of Motor Vehicles.

“PZEV” means any vehicle that is delivered for sale in California and that qualifies for a partial ZEV allowance of at least 0.2.

“Regenerative braking” means the partial recovery of the energy normally dissipated into friction braking that is returned as electrical current to an energy storage device.

“SAE J2572” means the “Recommended Practice for Measuring Fuel Consumption and Range of Fuel Cell and Hybrid Fuel Cell Vehicles Fuelled by Compressed Gaseous Hydrogen,” as published by the Society of Automotive Engineers in October, 2008.

“Section 177 State” means a state that is administering the California ZEV requirements pursuant to section 177 of the federal Clean Air Act (42 U.S.C. § 7507).

“SC03” means the U.S. EPA SC03 driving schedule representing vehicle operation with air conditioning, as set forth in Appendix I of 40 CFR Part 86.

“SOC Net Change Tolerance” means the state-of-charge net change tolerance that is applied to the SOC Criterion for charge-sustaining hybrid electric vehicles when validating an emission test. See section ~~D.8~~ E.9 and F.10 of these procedures for tolerance specifications.

“SOC Criterion” means the state-of-charge criterion that is applied to a charge-sustaining hybrid electric vehicle to validate an emission test. The SOC Criterion requires that no net change in battery energy occurs over a given test cycle, i.e. the final battery state-of-charge that is recorded at the end of the emission test must be equivalent to the initial battery state-of-charge that is set at the beginning of the emission test. The SOC Net Change Tolerance shall be applied to the SOC Criterion.

“Type 0, I, I.5, II, III, and IV, and V ZEV” all have the meanings set forth in section C.4.4(a).

“US06” means the US06 driving schedule for aggressive driving as set forth in Appendix I of 40 CFR Part 86.

“**UDDS**” means urban dynamometer driving schedule as set forth Appendix I of 40 CFR Part 86.

“**Zero-emission vehicle**” or “**ZEV**” means any vehicle certified to zero-emission standards.

“**Zero-emission VMT**” means the vehicle miles traveled with zero exhaust emissions of any criteria pollutant (or precursor pollutant).

“**ZEV fuel**” means a fuel that provides traction energy in on-road ZEVs. Examples of current technology ZEV fuels include electricity, hydrogen, and compressed air.

2. Terminology.

	<u>Abbreviation</u>	<u>Units</u>
<u>Charge Depleting Actual Range</u>	R_{cda}	<u>mi</u>
<u>Charge Depleting to Charge Sustaining Range</u>	R_{cdcs}	<u>mi</u>
<u>Charge Depleting Net Energy Consumption</u>	E_{cd}	<u>wh</u>
<u>Charge Depleting CO₂ Produced</u>	M_{cd}	<u>g/mi</u>
<u>Charge Sustaining CO₂ Produced</u>	M_{cs}	<u>g/mi</u>
<u>Highway Charge Depleting Cycle Range</u>	R_{cdch}	<u>mi</u>
<u>Highway Electric Range Fraction</u>	ERF_h	<u>%</u>
<u>Highway Equivalent All-Electric Range</u>	$EAER_h$	<u>mi</u>
<u>Highway Equivalent All-Electric Range Energy Consumption</u>	$EAEREC_h$	<u>wh/mi</u>
<u>Urban Charge Depleting Cycle Range</u>	R_{cdcu}	<u>mi</u>
<u>Urban Electric Range Fraction</u>	ERF_u	<u>%</u>
<u>Urban Equivalent All-Electric Range</u>	$EAER_u$	<u>mi</u>
<u>Urban Equivalent All-Electric Range Energy Consumption</u>	$EAEREC_u$	<u>wh/mi</u>

C. Zero-Emission Vehicle Standards.

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3. Partial ZEV Allowance Vehicles (PZEVs).

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3.3 Zero-Emission VMT PZEV Allowance.

(a) *Calculation of Zero Emission VMT Allowance.* A vehicle that meets the requirements of section C.3.2 and has zero-emission vehicle miles traveled (“VMT”) capability will generate an additional zero emission VMT PZEV allowance, calculated as follows:

Urban Equivalent All-Electric Range (EAER)	Zero-emission VMT Allowance
$EAER_u < 10$ miles	0.0
$EAER_u \geq 10$ miles and $R_{cda} = 10$ miles to 100 <u>40</u> miles	$EAER_u \times (1 - UF_{R_{cda}}) / 14.6$ 11.028
$R_{cda} > 100$ 40 miles	1.58 $EAER_u / 29.63$

The urban equivalent all-electric range ($EAER_u$) and ~~urban~~ charge depletion ~~depleting actual~~ range ~~actual~~ (R_{cda}) shall be determined in accordance with sections ~~F.11 and E.3.2.1(2)(a)~~ F.5.5, respectively, of these test procedures. ~~The Utility Factor (UF) based on the charge depletion depleting actual range actual (R_{cda}) shall be determined according to the 0-100 mile 4th order curve fit from SAE J1711 J2841 PropDft 2008, issued March 1999, p52.~~

* * * *

D. Certification Requirements.

1. Durability and Emission Testing Requirements. All ZEVs are exempt from all mileage and service accumulation, durability-data vehicle, and emission-data vehicle testing requirements.

2. Information Requirements: Application for Certification. Except as noted below, the Part I (40 CFR §86.1843-01(c)) certification application shall include the following:

- 2.1 Identification and description of the vehicle(s) covered by the application.
- 2.2 Identification of the vehicle weight category to which the vehicle is certifying: PC, LDT 0-3750 lbs. LVW, LDT 3751-5750 lbs. LVW, LDT 3751 lbs. LVW - 8500 lbs. GVW, or MDV (state test weight range), and the curb weight and gross vehicle weight rating of the vehicle.
- 2.3 Identification and description of the propulsion system for the vehicle.
- 2.4 Identification and description of the climate control system used on the vehicle.
- 2.5 Projected number of vehicles produced and delivered for sale in California, and projected California sales.
- 2.6 Identification of the energy usage in kilowatt-hours per mile from:
 - (a) the battery output (DC energy) (to be submitted with the Part II certification application (40 CFR §86.1843-01(d)));
 - (b) the point when electricity is introduced from the electrical outlet (AC energy); and
 - (c) the operating range in miles of the vehicle when tested in accordance with the All-Electric Range Test set forth in section E, below. For off-vehicle charge capable hybrid electric vehicles certifying to section F, the manufacturer shall provide the energy usage in kilowatt hours per mile from the Urban Equivalent All-Electric Range and the Highway Equivalent All-Electric Range.
- 2.7 For those ~~ZEVs and HEVs~~ vehicles that use fuel-fired heaters, the manufacturer shall provide:
 - (a) a description of the control system logic of the fuel-fired heater, including an evaluation of the conditions under which the fuel-fired heater can be operated and an evaluation of the possible operational modes and conditions under which evaporative emissions can exist;
 - (b) the exhaust emissions value per mile produced by the auxiliary fuel-fired heater operated between 68°F and 86°F; and

- (c) the test plan which describes the procedure used to determine the mass emissions of the fuel-fired heater.

2.8 All information necessary for proper and safe operation of the vehicle, including information on the safe handling of the battery system, emergency procedures to follow in the event of battery leakage or other malfunctions that may affect the safety of the vehicle operator or laboratory personnel.

2.9 Method for determining battery state-of-charge, battery charging capacity and recharging procedures, and any other relevant information as determined by the Executive Officer.

2.10 Battery specific energy data and calculations as specified in section E.4 of these procedures including the weight of the battery system and the three hour discharge rate (C/3) energy capacity.

2.11 Vehicle and battery break-in period as specified in section E.2 of these test procedures.

2.12 Labeling shall conform with the requirements specified in section 1965, title 13, CCR and the ~~California Motor Vehicle Emission Control and Smog Index Label Specifications~~ “California Environmental Performance Label Specifications for 2009 and Subsequent Model Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Passenger Vehicles” (incorporated by reference therein).

2.13 For a ZEV, extended range HEV or PZEV that qualifies to receive one or more multipliers under sections C.3 - C.7, the manufacturer shall provide all information relevant to the vehicle’s qualification for, and the estimated value of, the multiplier(s). The Executive Officer may request additional information needed to appropriately characterize the vehicle. Based on the submitted information and other relevant data, the Executive Officer shall assign to the vehicle the highest multiplier(s) for which the manufacturer has demonstrated the vehicle qualifies at that time.

2.14 ~~Where~~ When a manufacturer plans to require any scheduled maintenance for a PZEV before 150,000 miles, the manufacturer must submit information demonstrating the need for each scheduled maintenance item before 150,000 miles, including actual in-use data, engineering evaluation of the durability of the part, or other relevant information. The manufacturer may require such maintenance for a PZEV only upon the Executive Officer’s determination, prior to certification, the manufacturer has demonstrated the need for the scheduled maintenance; this determination may not unreasonably be denied.

2.15 For off-vehicle charge capable hybrid electric vehicles certifying to section F, the manufacturer shall provide the Urban Charge Depleting Cycle Range, the Urban Charge Depleting Actual Range, the Charge Depleting to Charge Sustaining Urban Range, the Highway Charge Depleting Cycle Range, the Highway Charge Depleting Actual Range, the Charge

Depleting to Charge Sustaining Highway Range, the Urban Equivalent All-Electric Range, the Highway Equivalent All-Electric Range, the Urban Electric Range Fraction, and the Highway Electric Range Fraction.

3. ZEV Reporting Requirements. In order to verify the status of each manufacturer's compliance with the ZEV requirements for a given calendar year, each manufacturer shall submit a report to the Executive Officer at least annually, by May 1 of the calendar year following the close of the model year, that identifies the necessary delivery and placement data of all vehicles generating ZEV credits or allowances, and all transfers and acquisitions of ZEV credits. The manufacturer may update the report by September 1 to cover activities occurring between April 1 and June 30.

E. Test Procedures for 2011 and Subsequent Model Zero-Emission Vehicles (including Fuel Cell Vehicles and Hybrid Fuel Cell Vehicles) and All 2011 and Subsequent Model Hybrid-Electric Vehicles, Except Off-Vehicle Charge Capable Hybrid Electric Vehicles.

The “as adopted or amended dates” of the 40 CFR Part 86 regulations referenced by this document are the dates identified in the “California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles.” Unless otherwise noted, these requirements shall apply to all ZEVs (including fuel cell vehicles and hybrid fuel cell vehicles) and all HEVs, except off-vehicle charge capable HEVs. A manufacturer may elect to certify a 2009 or a 2010 model-year zero-emission vehicle or hybrid electric vehicle, except an off-vehicle charge capable hybrid electric vehicle, using this section E.

1. Electric Dynamometer. All ZEVs and HEVs must be tested using a 48-inch single roll electric dynamometer meeting the requirements of 40 CFR Subpart B, §86.108-00(b)(2) [October 22, 1996].

2. Vehicle and Battery Break-In Period. A manufacturer shall use good engineering judgment in determining the proper stabilized emissions mileage test point and report same according to the requirements of section D.2.11 above.

3. All-Electric Range Test for Zero-Emission Vehicles (including Fuel Cell Vehicles and Hybrid Fuel Cell Vehicles). All 2011 and subsequent ZEVs shall be subject to the All-Electric Range Test specified below for the purpose of determining the energy efficiency and operating range of the ZEV.

3.1 Determination of Urban All-Electric Range for Zero-Emission Vehicles.

3.1.1 Determination of Urban All-Electric Range for Battery Electric Vehicles.

(a) **Cold soak.** The vehicle shall be stored at an ambient temperature not less than 68°F (20°C) and not more than 86°F (30°C) for 12 to 36 hours. During this time, the vehicle’s battery shall be charged to a full state-of-charge. Charge time shall not exceed soak time.

(b) At the end of the cold soak period, the vehicle shall be placed or pushed, onto a dynamometer and operated through successive Urban Dynamometer Driving Schedules (UDDS), 40 CFR, Part 86, Appendix I [July 13, 2005], which is incorporated herein by reference. A 10-minute soak shall follow each UDDS.

(c) For vehicles with a maximum speed greater than or equal to the maximum speed on the UDDS, this test sequence shall be repeated until the vehicle is no longer able to maintain either the speed or time tolerances in 40 CFR §86.115-00 (b)(1) and (2) [October 22, 1996], or the manufacturer determines that the test should be terminated for safety reasons, e.g. excessively high battery temperature, abnormally low battery voltage, etc.

(d) For vehicles with a maximum speed less than the maximum speed on the UDDS, the vehicle shall be operated at maximum available power (or full throttle) when the vehicle cannot achieve the speed trace within the speed and time tolerances specified in 40 CFR §86.115-00(b)(1) and (2) [October 22, 1996]. The test shall be terminated when the vehicle speed when operated at maximum available power (or full throttle) falls below 95 percent of the maximum speed initially achieved on the UDDS or when the battery state-of-charge is depleted to the lowest level allowed by the manufacturer, or the manufacturer determines that the test should be terminated for safety reasons, e.g. excessively high battery temperature, abnormally low battery voltage, etc., whichever occurs first. For off-vehicle charge capable hybrid electric vehicles, this determination shall be performed without the use of the auxiliary power unit.

3.1.2 Determination of Urban All-Electric Range for Fuel Cell Vehicles and Hybrid Fuel Cell Vehicles.

(a) The urban all-electric range for a fuel cell vehicle and a hybrid fuel cell vehicle shall be determined in accordance with SAE J2572.

3.2 Determination of Highway All-Electric Range for Zero-Emission Vehicles and Range for Fuel Cell Vehicles and Hybrid Fuel Cell Vehicles.

3.2.1 Determination of Highway All-Electric Range for Battery Electric Vehicles.

(a) Cold soak. The vehicle shall be stored at an ambient temperature not less than 68°F (20°C) and not more than 86°F (30°C) for 12 to 36 hours. During this time, the vehicle's battery shall be charged to a full state-of-charge. Charge time shall not exceed soak time.

(b) At the end of the cold soak period, the vehicle shall be placed, either driven or pushed, onto a dynamometer and operated through two Continuous Highway Test Schedules of the Highway Fuel Economy Driving Schedule (HFEDS).

(c) For vehicles with a maximum speed greater than or equal to the maximum speed on the HFEDS, this test sequence shall be repeated until the vehicle is no longer able to maintain either the speed or time tolerances in 40 CFR §86.115-00 (b)(1) and (2) [October 22, 1996], or the manufacturer determines that the test should be terminated for safety reasons, e.g. excessively high battery temperature, abnormally low battery voltage, etc.

(d) For vehicles with a maximum speed less than the maximum speed on the HFEDS, the vehicle shall be operated at maximum available power (or full throttle) when the vehicle cannot achieve the speed trace within the speed and time tolerances specified in 40 CFR §86.115-00(b)(1) and (2) [October 22, 1996]. The test shall be terminated when the vehicle speed when operated at maximum available power (or full throttle) falls below 95 percent of the maximum speed initially achieved on the HFEDS or when the battery state-of-charge is depleted to the lowest level allowed by the manufacturer, or the manufacturer determines that the test

should be terminated for safety reasons, e.g. excessively high battery temperature, abnormally low battery voltage, etc., whichever occurs first.

(e) NEVs are exempt from the all-electric range highway test.

3.2.2 Determination of Highway All-Electric Range for Fuel Cell Vehicles and Hybrid Fuel Cell Vehicles.

(a) The highway all-electric range for a fuel cell vehicle and a hybrid fuel cell vehicle shall be determined in accordance with SAE J2572.

3.3 Recording requirements.

For all battery electric vehicles and hybrid electric vehicles, except off-vehicle charge capable hybrid electric vehicles: Once the vehicle is no longer able to maintain the speed and time requirements specified in E.3.1 or E.3.2 above, the vehicle shall be brought to an immediate stop and the following data shall be recorded:

(a) mileage accumulated during the All-Electric Range Test;

(b) Net DC energy from the battery that was expended during the All-Electric Range Test (may be reported as the total DC battery energy output and the total DC battery energy input during the All-Electric Range Test);

(c) AC energy required to fully charge the battery after the All-Electric Range Test from the point where electricity is introduced from the electric outlet to the battery charger; and

(d) DC energy required to fully charge the battery after the All-Electric Range Test from the point where electricity is introduced from the battery charger to the battery.

Battery charging shall begin within 1 hour after terminating the All-Electric Range Test.

3.4 **Regenerative braking.** Regenerative braking systems may be utilized during the range test. The braking level, if adjustable, shall be set according to the manufacturer's specifications for normal driving conditions prior to the commencement of the test. The driving schedule speed and time tolerances specified in E.3.1 or E.3.2 shall not be exceeded due to the operation of the regenerative braking system.

3.5 **Measurement Accuracy.** For battery electric vehicles, the overall error in voltage and current recording instruments shall be NIST traceable and accurate to $\pm 1\%$ of the maximum value of the variable being measured. Suggested equipment: amp meter/power meter capable of sampling voltage and current. Voltage and current shall be sampled at a minimum rate of 20 hz.

3.6 Watt Hour Calculation for Battery Electric Vehicles.

DC energy (watt hours) shall be calculated as follows

$$\text{DC energy} = \int v(t) * i(t) dt$$

Where v = vehicle DC main battery pack voltage

i = vehicle DC main battery pack current

3.7 Charger Requirements for Battery Electric Vehicles.

The standard charging apparatus (or equivalent) normally furnished with or specified for the vehicle shall be used for charging during vehicle testing.

4. Determination of Battery Specific Energy for ZEVs.

Determine the specific energy of batteries used to power a ZEV in accordance with the U.S. Advanced Battery Consortium's Electric Vehicle Battery Procedure Manual (January 1996), Procedure No. 2, "Constant Current Discharge Test Series," using the C/3 rate. The weight calculation must reflect a completely functional battery system as defined in the Appendix of the Manual, including pack(s), required support ancillaries (e.g., thermal management), and electronic controller.

5. Determination of the Emissions of the Fuel-fired Heater for Vehicles Other Than ZEVs.

The exhaust emissions result of the fuel-fired heater shall be determined by operating at a maximum heating capacity with a cold start between 68°F and 86°F for a period of 20 minutes and dividing the grams of emissions by 20. The resulting grams per minute shall be multiplied by 3.0 minutes per mile to obtain a grams per mile value.

6. Urban Emission Test Provisions for All Hybrid Electric Vehicles, Except Hybrid Fuel Cell Vehicles and Off-Vehicle Charge Capable Hybrid Electric Vehicles.

Alternative procedures may be used if shown to yield equivalent results and if approved in advance by the Executive Officer of the Air Resources Board.

6.1 Vehicle Preconditioning.

To be conducted pursuant to the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles" with the following supplemental requirements:

6.1.1 For hybrid electric vehicles that do not allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that causes the hybrid electric vehicle to operate the auxiliary power unit for the maximum possible cumulative amount of time during the preconditioning drive.

6.1.2 For hybrid electric vehicles that allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that satisfies one of the following conditions:

(i) If the hybrid electric vehicle is charge-sustaining over the UDDS, battery state-of-charge shall be set at the lowest level allowed by the manufacturer.

(ii) If the hybrid electric vehicle is charge-depleting over the UDDS, battery state-of-charge shall be set at the level recommended by the manufacturer for activating the auxiliary power unit when operating in urban driving conditions.

6.1.3 After setting battery state-of-charge, the hybrid electric vehicle shall be pushed or towed to a work area for the initial fuel drain and fill according to section III.D.1.4. of the “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles.”

6.1.4 Following the initial fuel drain and fill, the vehicle shall complete an initial soak period of a minimum of 6 hours. After completing the soak period, the vehicle shall be pushed or towed into position on a dynamometer and preconditioned. If the auxiliary power unit is capable of being manually activated, the auxiliary power unit shall be manually activated at the beginning of and operated throughout the preconditioning drive.

6.1.5 Within five minutes of completing preconditioning drive, battery state-of-charge shall be set at a level that satisfies one of the following conditions:

(i) If the hybrid electric vehicle does not allow manual activation of the auxiliary power unit and is charge-sustaining over the UDDS, then set battery state-of-charge to a level such that the SOC criterion in section F.10 would be satisfied for the dynamometer procedure (section E.6.2 of these procedures). If off-vehicle charging is required to increase battery state-of-charge for proper setting, off-vehicle charging shall occur during the second soak period of 12 to 36 hours.

(ii) If the hybrid electric vehicle does not allow manual activation of the auxiliary power unit and is charge-depleting over the UDDS, then no battery state-of-charge adjustment is permissible.

(iii) If the hybrid electric vehicle does allow manual activation of the auxiliary power unit, then set battery state-of-charge to manufacturer recommended level for activating the auxiliary power unit when the hybrid electric vehicle is operating in urban driving conditions.

6.2 Urban Dynamometer Procedure for All Hybrid Electric Vehicles, Except Hybrid Fuel Cell Vehicles and Off-Vehicle Charge Capable Hybrid Electric Vehicles.

To be conducted pursuant to 40 CFR §86.135-00 [October 22, 1996] with the following revisions. References to §86.110-94 shall mean §86.110-94 as last amended June 30, 1995.

6.2.1 Amend subparagraph (a).

Overview. The dynamometer run shall consist of two tests, a “cold” start test, after a second fuel drain and fill and a 12 to 36 hour soak period performed pursuant to the provisions of the “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles” and a “hot” start test following the “cold” start test by 10 minutes. Vehicle startup (with all accessories turned off), operation over the UDDS and vehicle shutdown make a complete cold start test. Vehicle startup and operation over the UDDS and vehicle shutdown make a complete hot start test.

For all UDDS tests, the exhaust emissions are diluted with ambient air in the dilution tunnel as shown in Figure B94-5 and Figure B94-6 (§86.110-94). A dilution tunnel is not required for testing vehicles waived from the requirement to measure particulates. Four particulate samples are collected on filters for weighing; the first sample plus backup is collected during the cold start test (including shutdown); the second sample plus backup is collected during the hot start test (including shutdown). Continuous proportional samples of gaseous emissions are collected for analysis during each test. For hybrid electric vehicles with Otto-cycle auxiliary power units, the composite samples collected in bags are analyzed for THC, CO, CO₂, CH₄ and NO_x. For hybrid electric vehicles that are not “off-vehicle charge capable,” and are equipped with petroleum-fueled diesel-cycle auxiliary power units (optional for natural gas-fueled, liquefied petroleum gas-fueled, and alcohol-fueled diesel-cycle vehicles), THC is sampled and analyzed continuously pursuant to the provisions of §86.110-94. Parallel samples of the dilution air are similarly analyzed for THC, CO, CO₂, CH₄ and NO_x. For hybrid electric vehicles with natural gas-fueled, liquefied petroleum gas-fueled, and alcohol-fueled auxiliary power units, bag samples are collected and analyzed for THC (if not sampled continuously), CO, CO₂, CH₄ and NO_x. For hybrid electric vehicles with alcohol-fueled auxiliary power units, alcohol and formaldehyde samples are taken for both exhaust emissions and dilution air (a single dilution air formaldehyde sample, covering the total test period may be collected). Parallel bag samples of dilution air are analyzed for THC, CO, CO₂, CH₄ and NO_x.

6.2.2 Subparagraphs (b) through (c). [No change.]

6.2.3 Delete subparagraph (d).

6.2.4 Subparagraphs (e) through (g). [No change.]

6.2.5 Amend subparagraph (h): The driving distance, as measured by counting the number of dynamometer roll or shaft revolutions, shall be determined for the cold start test and hot start test. The revolutions shall be measured on the same roll or shaft used for measuring the vehicle's speed.

6.2.6 Subparagraph (i). [No change.]

6.3 Urban Dynamometer Test Run, Gaseous and Particulate Emissions for All Hybrid Electric Vehicles, Except Hybrid Fuel Cell Vehicles and Off-Vehicle Charge Capable Hybrid Electric Vehicles.

To be conducted pursuant to 40 CFR §86.137-96 [March 24, 1993] with the following revisions:

6.3.1 Amend subparagraph (a): *General*. The dynamometer run shall consist of two tests, a "cold" start test, after a second fuel drain and fill and a 12 to 36 hour soak period performed pursuant to the provisions of the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles" and a "hot" start test following the cold start test by 10 minutes. The complete dynamometer test consists of a cold start drive of 7.5 miles (12.1 km) and a hot start drive of 7.5 miles (12.1 km). The vehicle shall be stored prior to the emission test in such a manner that precipitation (e.g., rain or dew) does not occur on the vehicle. The vehicle is allowed to stand on the dynamometer during the 10 minute time period between each test.

6.3.2 Amend subparagraph (b) as follows.

6.3.2.1 Amend subparagraph (b)(9): Start the gas flow measuring device, position the sample selector valves to direct the sample flow into the exhaust sample bag, the alcohol exhaust sample, the formaldehyde exhaust sample, the dilution air sample bag, the alcohol dilution air sample and the formaldehyde dilution air sample (turn on the petroleum-fueled diesel-cycle THC analyzer system integrator, mark the recorder chart, start particulate sample pump No. 1, and record both gas meter or flow measurement instrument readings, if applicable), and turn the key on. If the auxiliary power unit is capable of being manually activated, the auxiliary power unit shall be activated at the beginning of and operated throughout the UDDS.

6.3.2.2 Delete subparagraph (b)(13).

6.3.2.3 Amend subparagraph (b)(14): Turn the vehicle off 2 seconds after the end of the last deceleration (at 1,369 seconds).

6.3.2.4 Amend subparagraph (b)(15): Five seconds after the vehicle is shutdown, simultaneously turn off gas flow measuring device No. 1 and if

applicable, turn off the hydrocarbon integrator No. 1, mark the hydrocarbon recorder chart, turn off the No. 1 particulate sample pump and close the valves isolating particulate filter No. 1, and position the sample selector valves to the “standby” position. Record the measured roll or shaft revolutions (both gas meter or flow measurement instrumentation readings), and reset the counter. As soon as possible, transfer the exhaust and dilution air samples to the analytical system and process the samples pursuant to §86.140, obtaining a stabilized reading of the exhaust bag sample on all analyzers within 20 minutes of the end of the sample collection phase of the test. Obtain alcohol and formaldehyde sample analyses, if applicable, within 24 hours of the end of the sample period. (If it is not possible to perform analysis on the alcohol and formaldehyde samples within 24 hours, the samples should be stored in a dark cold (4°C to 10°C) environment until analysis. The samples should be analyzed within fourteen days.) If applicable, carefully remove both pairs of particulate sample filters from their respective holders, and place each in a separate petri dish, and cover.

6.3.2.5 Amend subparagraph (b)(18): Repeat the steps in paragraphs (b)(2) through (b)(17) of this section for the hot start test. The step in paragraph (b)(9) of this section shall begin between 9 and 11 minutes after the end of the sample period for the cold start test.

6.3.2.6 Delete subparagraph (b)(19).

6.3.2.7 Delete subparagraph (b)(20).

6.3.2.8 Amend subparagraph (b)(21): As soon as possible, and in no case longer than one hour after the end of the hot start phase of the test, transfer the four particulate filters to the weighing chamber for post-test conditioning, if applicable. For hybrid electric vehicles that do not allow manual activation of the auxiliary power unit and are charge-sustaining over the UDDS, a valid test shall satisfy the SOC criterion in section F.10.

6.3.2.9 Amend subparagraph (b)(24): Vehicles to be tested for evaporative emissions will proceed pursuant to the “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles.”

6.4 Calculations - Exhaust Emissions for All Hybrid Electric Vehicles, Except Hybrid Fuel Cell Vehicles and Off-Vehicle Charge Capable Hybrid Electric Vehicles.

To be conducted pursuant to 40 CFR §86.144-94 [July 13, 2005] with the following revisions:

6.4.1 Amend subparagraph (a): For light-duty vehicles and light duty trucks:

$$\underline{Y_{wm}} = 0.43 * \left(\frac{Y_c}{D_c} \right) + 0.57 * \left(\frac{Y_h}{D_h} \right)$$

Where:

(1) Y_{wm} = Weighted mass emissions of each pollutant, i.e., THC, CO, THCE, NMOG, NMHCE, CH₄, NO_x, or CO₂, in grams per vehicle mile.

(2) Y_c = Mass emissions as calculated from the cold start test, in grams per test.

(3) Y_h = Mass emissions as calculated from the hot start test, in grams per test.

(4) D_c = The measured driving distance from the cold start test, in miles.

(5) D_h = The measured driving distance from the hot start test, in miles.

6.4.2 Subparagraphs (b) through (e). [No change.]

6.5 Calculations - Particulate Emissions for All Hybrid Electric Vehicles, Except Hybrid Fuel Cell Vehicles and Off-Vehicle Charge Capable Hybrid Electric Vehicles.

To be conducted pursuant to 40 CFR §86.145-82 [November 2, 1982] with the following revisions. References to §86.110-94 shall mean §86.110-94 as last amended June 30, 1995.

6.5.1 Amend subparagraph (a): The final reported test results for the mass particulate (M_p) in grams/mile shall be computed as follows:

$$\underline{M_p} = 0.43 * \left(\frac{M_{pc}}{D_c} \right) + 0.57 * \left(\frac{M_{ph}}{D_h} \right)$$

Where:

(1) M_{pc} = Mass of particulate determined from the cold start test, in grams per vehicle mile. (See §86.110-94 for determination.)

(2) M_{ph} = Mass of particulate determined from the hot start test, in grams per vehicle mile. (See §86.110-94 for determination.)

(3) D_c = The measured driving distance from the cold start test, in miles.

(4) D_h = The measured driving distance from the hot start test, in miles.

6.5.2 Subparagraph (b). [No change.]

7. Highway Emission Test Provisions for All Hybrid Electric Vehicles, Except Hybrid Fuel Cell Vehicles and Off-Vehicle Charge Capable Hybrid Electric Vehicles.

To be conducted pursuant to 40 CFR §600.111-08 [December 27, 2006] with the following revisions.

7.1 Subparagraph (a). [not applicable - delete]

7.2 Amend subparagraph (b) as follows:

7.2.1 Amend subparagraph (b)(2): The highway fuel economy test is designated to simulate non-metropolitan driving with an average speed of 48.6 mph and a maximum speed of 60 mph. The cycle is 10.2 miles long with 0.2 stop per mile and consists of warmed-up vehicle operation on a chassis dynamometer through a specified driving cycle. A proportional part of the diluted exhaust emission is collected continuously for subsequent analysis of THC, CO, CO₂, and NO_x using a constant volume (variable dilution) sampler. Diesel dilute exhaust is continuously analyzed for hydrocarbons using a heated sample line and analyzer. Alcohol and formaldehyde samples are collected and individually analyzed for alcohol-fueled vehicles.

7.2.2 Amend subparagraph (b)(7)(i): The dynamometer procedure shall consist of two cycles of the Highway Fuel Economy Driving Schedule (§600.109(b)) separated by 15 seconds of idle. The first cycle of the Highway Fuel Economy Driving Schedule is driven to precondition the test vehicle and the second is driven for the fuel economy measurement.

7.2.3 Amend subparagraph (b)(7)(iii): Only one exhaust sample and one background sample shall be collected and analyzed for THC (except diesel hydrocarbons which are analyzed continuously), CO, CO₂, and NO_x. Alcohol and formaldehyde samples (exhaust and dilution air) are collected and analyzed for alcohol-fueled vehicles.

7.2.4 Add subparagraph(b)(7)(v): For hybrid electric vehicles that do not allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that causes the hybrid electric vehicle to operate the auxiliary power unit for the maximum possible cumulative amount of time during the HFEDS preconditioning cycle. For hybrid electric vehicles that allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that satisfies one of the following conditions:

(i) If the hybrid electric vehicle is charge-sustaining over the HFEDS, battery state-of-charge shall be set at the lowest level allowed by the manufacturer.

(ii) If the hybrid electric vehicle is charge-depleting over the HFEDS, battery state-of-charge shall be set at the level recommended by the manufacturer for activating the auxiliary power unit when operating in highway driving conditions.

7.2.5 Amend subparagraph (b)(9)(v): Operate the vehicle over one HFEDS preconditioning cycle according to the dynamometer driving schedule specified in §600.109-08(b) [December 27, 2006]. If the auxiliary power unit is capable of being

manually activated, the auxiliary power unit shall be manually activated at the beginning of and operated throughout the HFEDS preconditioning cycle.

7.2.6 Amend subparagraph (b)(9)(vi): When the vehicle reaches zero speed at the end of the HFEDS preconditioning cycle, the driver has 17 seconds to prepare for the HFEDS emission measurement cycle of the test. Reset and enable the roll revolution counter. During the idle period, one of the following conditions shall apply:

(i) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-sustaining over the HFEDS, the vehicle shall be momentarily turned off for 5 seconds and turned back on during the idle period. The battery state-of-charge shall be recorded after the hybrid electric vehicle has fully turned on.

(ii) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-depleting over the HFEDS, the vehicle shall remain turned on during the idle period.

(iii) For hybrid electric vehicles that allow the auxiliary power unit to be manually activated, the vehicle shall remain turned on with the auxiliary power unit operating during the idle period.

7.2.7 Add subparagraph (b)(9)(viii): At the conclusion of the HFEDS emission test, one of the following conditions shall apply:

(i) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-sustaining over the HFEDS, record the battery state-of-charge to determine if the SOC criterion in section F.10 is satisfied. If the SOC criterion is not satisfied, then repeat dynamometer test run from subparagraph (h)(6). A total of three highway emission tests shall be allowed to satisfy the SOC criterion.

(ii) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-depleting over the HFEDS, the emission test is completed.

(iii) For hybrid electric vehicles that allow the auxiliary power unit to be manually activated, the emission test is completed.

7.2.8 Delete subparagraph (b)(10).

7.3 Delete subparagraphs (c) through (e).

8. SFTP Emission Test Provisions for All Hybrid Electric Vehicles, Except Hybrid Fuel Cell Vehicles and Off-Vehicle Charge Capable Hybrid Electric Vehicles.

8.1 US06 Vehicle Preconditioning

To be conducted pursuant to 40 CFR §86.132-00 [October 22, 1996] with the following revisions.

8.1.1 Subparagraphs (a) through (m). [No change.]

8.1.2 Amend subparagraph (n): Aggressive Driving Test (US06) Preconditioning.

8.1.2.1 Amend subparagraph (1) as follows: If the US06 test follows the exhaust emission FTP or evaporative testing, the refueling step may be deleted and the vehicle may be preconditioned using the fuel remaining in the tank (see paragraph (c)(2)(ii) of this section). The test vehicle may be pushed or driven onto the test dynamometer. For hybrid electric vehicles that allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that satisfies one of the following conditions:

8.1.2.1.1 Delete subparagraph (i), and replace with: If the hybrid electric vehicle is charge-sustaining over the US06, battery state-of-charge shall be set at the lowest level allowed by the manufacturer. The auxiliary power unit shall be manually activated at the beginning of and operated throughout the US06 preconditioning cycle.

8.1.2.1.2 Delete subparagraph (ii), and replace with: If the hybrid electric vehicle is charge-depleting over the US06, battery state-of-charge shall be set at the level recommended by the manufacturer for activating the auxiliary power unit when operating in highway driving conditions. The auxiliary power unit shall be manually activated at the beginning of and operated throughout the US06 preconditioning cycle.

8.1.2.1.3 Subparagraphs (iii) through (iv). [No change.]

8.1.2.2 Subparagraph (2). [No change.]

8.1.3 Subparagraph (o). [No change.]

8.2 US06 Emission Test.

To be conducted pursuant to 40 CFR §86.159-08 [December 27, 2006] with the following revisions.

8.2.1 Amend subparagraph (a): Overview. The dynamometer operation consists of a single, 600 second test on the US06 driving schedule, as described in appendix I, paragraph (g), of this part. The hybrid electric vehicle is preconditioned in accordance with §86.132-00, to bring it to a warmed-up stabilized condition. This preconditioning is followed by a 1 to 2 minute idle period that proceeds directly into the US06 driving schedule during which continuous proportional samples of gaseous emissions are collected for analysis. If engine stalling should occur during testing, follow the provisions of §86.136-90 (engine starting and restarting). For hybrid electric vehicles with Otto-cycle auxiliary power units, the composite samples collected in bags are analyzed for THC, CO, CO₂, CH₄ and NO_x. For hybrid electric vehicles with diesel-cycle auxiliary power units, THC is sampled and analyzed continuously according to the provisions of §86.110. Parallel bag samples of dilution air are analyzed for THC, CO, CO₂, CH₄ and NO_x.

8.2.2 Amend subparagraph (b) as follows.

8.2.2.1 Amend subparagraph (b)(2): Position the test vehicle on the dynamometer and restrain.

8.2.3 Subparagraph (c). [No change.]

8.2.4 Amend subparagraph (d): Practice runs over the prescribed driving schedule may be performed at test point to permit sampling system adjustment.

8.2.5 Subparagraph (e). [No change.]

8.2.6 Amend subparagraph (f) as follows.

8.2.6.1 Amend subparagraph (f)(2)(i): Immediately after completion of the US06 preconditioning cycle, idle the vehicle. The idle period is not to be less than one minute or not greater than two minutes. During the idle period, one of the following conditions shall apply:

(i) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-sustaining over the US06, the vehicle shall be momentarily turned off for 5 seconds and turned back on during the idle period. The battery state-of-charge shall be recorded after the hybrid electric vehicle has fully turned on.

(ii) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-depleting over the US06, the vehicle shall remain turned on during the idle period.

(iii) For hybrid electric vehicles that allow the auxiliary power unit to be manually activated, the vehicle shall remain turned on with the auxiliary power unit operating during the idle period.

8.2.6.2 Amend subparagraph (f)(2)(ix): At the conclusion of the US06 emission test, one of the following conditions shall apply:

(i) For hybrid electric vehicles that do not allow manual activation of the auxiliary power unit and are charge-sustaining over the US06, record the battery state-of-charge to determine if the SOC criterion in section F.10 is satisfied. If the SOC criterion is not satisfied, then repeat dynamometer test run from subparagraph (f)(2)(i). A total of three US06 emission tests shall be allowed to satisfy the SOC criterion.

(ii) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-depleting over the US06, turn off vehicle 2 seconds after the end of the last deceleration.

(iii) For hybrid electric vehicles that allow the auxiliary power unit to be manually activated, turn off vehicle 2 seconds after the end of the last deceleration.

8.3 SC03 Vehicle Preconditioning.

To be conducted pursuant to 40 CFR §86.132-00 [October 22, 1996] with the following revisions.

8.3.1 Subparagraphs (a) through (n). [No change.]

8.3.2 Amend subparagraph (o): *Air Conditioning Test (SC03) Preconditioning.*

8.3.2.1 Amend subparagraph (1) as follows: If the SC03 test follows the exhaust emission FTP or evaporative testing, the refueling step may be deleted and the vehicle may be preconditioned using the fuel remaining in the tank (see paragraph (c)(2)(ii) of this section). The test vehicle may be pushed or driven onto the test dynamometer. For hybrid electric vehicles that allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that satisfies one of the following conditions:

8.3.2.1.1 Delete subparagraph (i), and replace with: If the hybrid electric vehicle is charge-sustaining over the SC03, battery state-of-charge shall be set at the lowest level allowed by the manufacturer. The auxiliary power unit shall be manually activated at the beginning of and operated throughout the SC03 preconditioning cycle.

8.3.2.1.2 Delete subparagraph (ii), and replace with: If the hybrid electric vehicle is charge-depleting over the SC03, battery state-of-charge shall be set at the level recommended by the manufacturer for activating the auxiliary power unit when operating in highway driving conditions. The auxiliary power unit shall be manually activated at the beginning of and operated throughout the SC03 preconditioning cycle.

8.3.2.2 Subparagraphs (2) through (3). [No change.]

8.4 SC03 Emission Test.

To be conducted pursuant to 40 CFR §86.160-00 [December 8, 2005] with the following revisions.

8.4.1 Amend subparagraph (a): *Overview.* The dynamometer operation consists of a single, 594 second test on the SC03 driving schedule, as described in appendix I, paragraph (h), of this part. The hybrid electric vehicle is preconditioned in accordance with §86.132-00 of this subpart, to bring the vehicle to a warmed-up stabilized condition. This preconditioning is followed by a 10 minute vehicle soak (vehicle turned off) that proceeds directly into the SC03 driving schedule, during which continuous proportional samples of gaseous emissions are collected for analysis. The entire test, including the SC03 preconditioning cycle, vehicle soak, and SC03 emission test, is either conducted in an environmental test facility or under test conditions that simulate testing in an environmental test cell (see §86.162-00 (a) for a discussion of simulation procedure approvals). The environmental test facility must be capable of providing the following nominal ambient test conditions of: 95°F air temperature, 100 grains of water/pound of dry air (approximately 40 percent relative humidity), a solar heat load intensity of 850 W/m², and vehicle cooling air flow proportional to vehicle speed. Section 86.161-00 discusses the minimum facility requirements and corresponding control tolerances for air conditioning ambient test conditions. The vehicle's air conditioner is operated or appropriately simulated for the duration of the test procedure (except for the 10 minute vehicle soak), including the preconditioning. If engine stalling should occur during testing, follow the provisions of §86.136-90 (engine starting and restarting). For hybrid electric vehicles with Otto-cycle auxiliary power units, the composite samples collected in bags are analyzed for THC, CO, CO₂, CH₄ and NO_x. For hybrid electric vehicles with diesel-cycle auxiliary power units, THC is sampled and analyzed continuously according to the provisions of §86.110. Parallel bag samples of dilution air are analyzed for THC, CO, CO₂, CH₄ and NO_x.

8.4.2 Amend subparagraph (b) as follows.

8.4.2.1 Amend subparagraph (b)(2): Position the test vehicle on the dynamometer and restrain.

8.4.3 Amend subparagraph (c) as follows.

8.4.3.1 Amend subparagraph (c)(9): Start vehicle (with air conditioning system also running). If the auxiliary power unit of the hybrid electric vehicle is capable of being manually activated, the auxiliary power unit shall be manually activated at the beginning of and operated throughout the SC03 emission test. Fifteen seconds after the vehicle starts, begin the initial vehicle acceleration of the driving schedule.

8.4.4 Amend subparagraph (d) as follows.

8.4.4.1 Amend subparagraph (d)(10): At the conclusion of the SC03 emission test, one of the following conditions shall apply:

(i) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-sustaining over the SC03, record the battery state-of-charge to determine if the SOC criterion in section F.10 is satisfied. If the SOC criterion is not satisfied, then turn off cooling fan(s), allow vehicle to soak in the ambient conditions of paragraph (c)(5) of this section for 10 minutes, and repeat dynamometer test run from subparagraph (d). A total of three SC03 emission tests shall be attempted to satisfy the SOC criterion.

(ii) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-depleting over the SC03, turn off vehicle 2 seconds after the end of the last deceleration.

(iii) For hybrid electric vehicles that allow the auxiliary power unit to be manually activated, turn off vehicle 2 seconds after the end of the last deceleration.

8.4.5 Subparagraph (e). [No change.]

9. State-of-Charge Net Change Tolerances for All Hybrid Electric Vehicles, Except Hybrid Fuel Cell Vehicles and Off-Vehicle Capable Hybrid Electric Vehicles.

9.1 For hybrid electric vehicles that use a battery as an energy storage device, the following state-of-charge net change tolerance shall apply:

$$\underline{(\text{Amp-hr}_{\text{final}})_{\text{max}} = (\text{Amp-hr}_{\text{initial}}) + 0.01 * \left(\frac{NHV_{\text{fuel}} * m_{\text{fuel}}}{V_{\text{system}} * K_1} \right)}$$

$$\underline{(\text{Amp-hr}_{\text{final}})_{\text{min}} = (\text{Amp-hr}_{\text{initial}}) - 0.01 * \left(\frac{NHV_{\text{fuel}} * m_{\text{fuel}}}{V_{\text{system}} * K_1} \right)}$$

Where:

- (Amp-hr_{final})_{max} = Maximum allowed Amp-hr stored in battery at the end of the test
(Amp-hr_{final})_{min} = Minimum allowed Amp-hr stored in battery at the end of the test
(Amp-hr_{initial}) = Battery Amp-hr stored at the beginning of the test
NHV_{fuel} = Net heating value of consumable fuel, in Joules/kg
m_{fuel} = Total mass of fuel consumed during test, in kg
K₁ = Conversion factor, 3600 seconds/hour
V_{system} = Average charge sustaining battery DC bus voltage (open circuit) during charge sustaining operation. This value shall be submitted for testing purposes, and it shall be subject to confirmation by the Air Resources Board.

9.2 For hybrid electric vehicles that use a capacitor as an energy storage device, the following state-of-charge net change tolerance shall apply:

$$\underline{(V_{final})_{max}} = \sqrt{V_{initial}^2 + 0.01 * \frac{(2 * NHV_{fuel} * m_{fuel})}{C}}$$

$$\underline{(V_{final})_{min}} = \sqrt{V_{initial}^2 - 0.01 * \frac{(2 * NHV_{fuel} * m_{fuel})}{C}}$$

Where:

- (V_{final})_{max} = The stored capacitor voltage allowed at the end of the test
(V_{final})_{min} = The stored capacitor voltage allowed at the end of the test
V_{initial}² = The square of the capacitor voltage stored at the beginning of the test
NHV_{fuel} = Net heating value of consumable fuel, in Joules/kg
m_{fuel} = Total mass of fuel consumed during test, in kg
C = Rated capacitance of the capacitor, in Farads

9.3 For hybrid electric vehicles that use an electro-mechanical flywheel as an energy storage device, the following state-of-charge net change tolerance shall apply:

$$\underline{(rpm_{final})_{max}} = \sqrt{rpm_{initial}^2 + 0.01 * \frac{(2 * NHV_{fuel} * m_{fuel})}{I * K_3}}$$

$$\underline{(rpm_{final})_{min}} = \sqrt{rpm_{initial}^2 - 0.01 * \frac{(2 * NHV_{fuel} * m_{fuel})}{I * K_3}}$$

Where:

- (rpm_{final})_{max} = The maximum flywheel rotational speed allowed at the end of the test

$(rpm_{final})_{min}$ = The minimum flywheel rotational speed allowed at the end of the test

$rpm_{initial}^2$ = The squared flywheel rotational speed at the beginning of the test

NHV_{fuel} = Net heating value of consumable fuel, in Joules/kg

m_{fuel} = Total mass of fuel consumed during test, in kg

K_3 = Conversion factor, $\frac{4\pi^2}{3600 \text{ sec}^2 - rpm^2}$

I = Rated moment of inertia of the flywheel, in $kg \cdot m^2$

F. Test Procedures for 2011 and Subsequent Model Off-Vehicle Charge Capable Hybrid Electric Vehicles.

The “as adopted or amended dates” of the 40 CFR Part 86 regulations referenced by this document are the dates identified in the “California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles,” unless otherwise noted. A manufacturer may elect to certify a 2009 or a 2010 model-year off-vehicle charge capable hybrid electric vehicle using this section F.

1. Electric Dynamometer.

All off-vehicle charge capable HEVs must be tested using a 48-inch single roll electric dynamometer meeting the requirements of 40 CFR Subpart B, §86.108-00(b)(2) [October 22, 1996].

2. Vehicle and Battery Break-In Period.

A manufacturer shall use good engineering judgment in determining the proper stabilized emissions mileage test point and report same according to the requirements of section D.2.11 above.

3. General Testing Requirements.

3.1 Recording requirements.

For off-vehicle charge capable hybrid electric vehicles: The following data shall be recorded for all charge depleting range and exhaust tests and for each individual test cycle therein:

(a) mileage accumulated during the All-Electric Range portion of the test, where applicable;

(b) Net DC energy from the battery that was expended during the test (may be reported as the total DC battery energy output and the total DC battery energy input);

(c) AC energy required to fully charge the battery after a charge depleting or charge sustaining test from the point where electricity is introduced from the electric outlet to the battery charger;

(d) DC energy required to fully charge the battery after a charge depleting or charge sustaining test from the point where electricity is introduced from the battery charger to the battery; and

(e) Net DC amp-hrs from the battery that was expended during the test (may be reported as the total DC amp-hrs output and the total DC amp-hrs input)

3.2 **Regenerative braking.** Regenerative braking systems may be utilized during the range test. The braking level, if adjustable, shall be set according to the manufacturer’s specifications for normal driving conditions prior to the commencement of the test. The driving

schedule speed and time tolerances specified in F.3.1 or F.3.2 shall not be exceeded due to the operation of the regenerative braking system.

3.3 Measurement Accuracy. The overall error in voltage and current recording instruments shall be NIST traceable and accurate to ±1% of the maximum value of the variable being measured. Suggested equipment: amp meter/power meter capable of sampling voltage and current. Voltage and current shall be sampled at a minimum rate of 20 hz.

3.4 Watt Hour Calculation.

DC energy (watt hours) shall be calculated as follows

$$\text{DC energy} = \int v(t) * i(t) dt$$

Where v = vehicle DC main battery pack voltage

i = vehicle DC main battery pack current

3.5 Charger Requirements

The standard charging apparatus (or equivalent) normally furnished with or specified for the vehicle shall be used for charging during vehicle testing.

4. Determination of the Emissions of the Fuel-fired Heater.

The exhaust emissions result of the fuel-fired heater shall be determined by operating at a maximum heating capacity with a cold start between 68°F and 86°F for a period of 20 minutes and dividing the grams of emissions by 20. The resulting grams per minute shall be multiplied by 3.0 minutes per mile to obtain a grams per mile value.

5. Urban Test Provisions for Off-Vehicle Charge Capable Hybrid Electric Vehicles.

Alternative procedures may be used if shown to yield equivalent results and if approved in advance by the Executive Officer of the Air Resources Board.

The criteria certification emissions for the Urban test shall be the worst case emissions of NMOG, CO, NOx, and PM from either the charge depleting or charge sustaining tests. The sum of NMOG + NOx emissions shall constitute the worst case for the charge sustaining or charge depleting modes of operation and determine the operation mode for US06 and SC03 emission tests.

Vehicles with more than one mode of operation for a given charge depleting or charge sustaining test cycle must be tested in the mode(s) which represents maximum operation of the auxiliary power unit. Confirmatory testing may also be performed in any mode of operation to ensure compliance with emission standards.

5.1 Vehicle Preconditioning.

To be conducted pursuant to the “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles” with the following supplemental requirements:

5.1.1 For vehicles that do not allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that causes the vehicle to operate the auxiliary power unit for the maximum possible cumulative amount of time during the preconditioning drive.

5.1.2 For vehicles that allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at the lowest level allowed by the manufacturer.

5.1.3 After setting battery state-of-charge, the vehicle shall be pushed or towed to a work area for the initial fuel drain and fill according to section III.D.1.4 of the “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles.”

5.1.4 Following the initial fuel drain and fill, the vehicle shall complete an initial soak period of a minimum of 6 hours. After completing the soak period, the vehicle shall be pushed or towed into position on a dynamometer and preconditioned. If the auxiliary power unit is capable of being manually activated, the auxiliary power unit shall be manually activated at the beginning of and operated throughout the preconditioning drive.

5.2 Urban Dynamometer Procedure for Off-Vehicle Charge Capable Hybrid Electric Vehicles.

To be conducted pursuant to 40 CFR §86.135-00 [October 22, 1996] with the following revisions. References to §86.110-94 shall mean §86.110-94 as last amended June 30, 1995.

5.2.1 Amend subparagraph (a).

Overview. The dynamometer run shall consist of a series of charge depleting tests, after a second fuel drain and fill and a 12 to 36 hour soak period performed pursuant to the provisions of the “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles.” Each charge depleting test shall consist of one UDDS followed by a 10 minute hot soak period until charge sustaining operation is achieved for two consecutive UDDSs. Once charge sustaining operation is achieved over two consecutive UDDSs, or a single UDDS if data is provided showing that charge sustaining operation can consistently be maintained over one UDDS, the vehicle shall be turned off and stored at an ambient temperature not less than 68°F (20°C) and not more than 86°F (30°C) for 12 to 36 hours. If the energy required to charge the vehicle from urban charge sustaining operation to full charge is not equivalent (within ± 1% of the AC energy) to the energy required to charge the vehicle

from highway charge sustaining operation to full charge, the vehicle must be recharged. If the energy required to charge the vehicle from urban charge sustaining operation to full charge is equivalent (within $\pm 1\%$ of the AC energy) to the energy required to charge the vehicle from highway charge sustaining operation to full charge, the vehicle may be recharged. The vehicle must be turned off during recharging. At the end of this cold soak period, the vehicle shall be placed or pushed onto a dynamometer. Vehicle emissions shall be measured over two UDDSs during charge sustaining operation, each separated by a 10 minute key-off hot soak period. The vehicle must meet SOC criterion in section F.10 from the start of the first UDDS until the end of the second UDDS.

For all exhaust emission tests, the exhaust emissions are diluted with ambient air in the dilution tunnel as shown in Figure B94-5 and Figure B94-6 (§86.110-94). A dilution tunnel is not required for testing vehicles waived from the requirement to measure particulates. For UDDSs, particulate samples are collected on filters for weighing during each UDDS. Each sample plus backup is collected during each UDDS (including shutdown). Continuous proportional samples of gaseous emissions are collected for analysis during each UDDS. For vehicles with Otto-cycle auxiliary power units, the composite samples collected in bags are analyzed for THC, CO, CO₂, CH₄ and NO_x. For vehicles with petroleum-fueled diesel-cycle auxiliary power units (optional for natural gas-fueled, liquefied petroleum gas-fueled, and alcohol-fueled diesel-cycle vehicles), THC is sampled and analyzed continuously pursuant to the provisions of §86.110-94. Parallel samples of the dilution air are similarly analyzed for THC, CO, CO₂, CH₄ and NO_x. For vehicles with natural gas-fueled, liquefied petroleum gas-fueled, and alcohol-fueled auxiliary power units, bag samples are collected and analyzed for THC (if not sampled continuously), CO, CO₂, CH₄ and NO_x. For vehicles with alcohol-fueled auxiliary power units, alcohol and formaldehyde samples are taken for both exhaust emissions and dilution air (a single dilution air formaldehyde sample, covering the total test period may be collected). Parallel bag samples of dilution air are analyzed for THC, CO, CO₂, CH₄ and NO_x.

5.2.2 Subparagraphs (b) through (c). [No change.]

5.2.3 Delete subparagraph (d).

5.2.4 Subparagraphs (e) through (g). [No change.]

5.2.5 Amend subparagraph (h): The driving distance, as measured by counting the number of dynamometer roll or shaft revolutions, shall be determined for all charge depleting and exhaust emission tests. The revolutions shall be measured on the same roll or shaft used for measuring the vehicle's speed.

5.2.6 Subparagraph (i). [No change.]

5.3 Urban Dynamometer Test Run, Gaseous and Particulate Emissions for Off-Vehicle Charge Capable Hybrid Electric Vehicles.

To be conducted pursuant to 40 CFR §86.137-96 [March 24, 1993] with the following revisions:

5.3.1 Amend subparagraph (a): *General.* The dynamometer run shall consist of a series of UDDSs, after a second fuel drain and fill and a 12 to 36 hour soak period performed pursuant to the provisions of the “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles.” The vehicle shall be stored prior to the emission test in such a manner that precipitation (e.g., rain or dew) does not occur on the vehicle. The vehicle is allowed to stand on the dynamometer during the 10 minute time period between each UDDS.

5.3.2 Amend subparagraph (b) as follows.

5.3.2.1 Amend subparagraph (b)(9): Start the gas flow measuring device, direct the sample flow into the exhaust sample bag, the alcohol exhaust sample, the formaldehyde exhaust sample, the dilution air sample bag, the alcohol dilution air sample and the formaldehyde dilution air sample, and turn the key on. If the auxiliary power unit is capable of being manually activated, the auxiliary power unit shall be activated at the beginning of and operated throughout the UDDS.

5.3.2.2 Delete subparagraph (b)(13).

5.3.2.3 Subparagraph (b)(14). [No change.]

5.3.2.4 Amend subparagraph (b)(15): Five seconds after the vehicle is shutdown, simultaneously turn off the gas flow measuring device and particulate sample pump. Record the measured roll or shaft revolutions (both gas meter or flow measurement instrumentation readings), and reset the counter. As soon as possible, transfer the exhaust and dilution air samples to the analytical system and process the samples pursuant to §86.140, obtaining a stabilized reading of the exhaust bag sample on all analyzers within 20 minutes of the end of the sample collection phase of the UDDS. Obtain alcohol and formaldehyde sample analyses, if applicable, within 24 hours of the end of the sample period. (If it is not possible to perform analysis on the alcohol and formaldehyde samples within 24 hours, the samples should be stored in a dark cold (4°C to 10°C) environment until analysis. The samples should be analyzed within fourteen days.) If applicable, carefully remove both pairs of particulate sample filters from their respective holders, and place each in a separate petri dish, and cover.

5.3.2.5 Amend subparagraph (b)(18): Repeat the steps in paragraphs (b)(2) through (b)(17) of this section for the hot start UDDS. The

steps in paragraph (b)(9) of this section shall begin between 9 and 11 minutes after the end of the sample period for the cold start UDDS.

5.3.2.6 Delete subparagraph (b)(19).

5.3.2.7 Delete subparagraph (b)(20).

5.3.2.8 Amend subparagraph (b)(21): As soon as possible, transfer the particulate filters to the weighing chamber for post-test conditioning, if applicable. For vehicles undergoing a cold start charge sustaining test, a valid test shall satisfy the SOC criterion in section F.10.

5.3.2.9 Amend subparagraph (b)(24): Vehicles to be tested for evaporative emissions will proceed pursuant to the “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles.”

5.4 Determination of Urban All-Electric Range and Urban Equivalent All-Electric Range for Off-Vehicle Charge Capable Hybrid Electric Vehicles.

5.4.1 The Urban All-Electric Range shall be defined as the distance that the vehicle is driven from the start of Urban Charge Depleting Range Test until the internal combustion engine first starts.

5.4.2 Cold soak and vehicle charging. The vehicle shall be stored at an ambient temperature not less than 68°F (20°C) and not more than 86°F (30°C) for 12 to 36 hours. During this time, the vehicle’s battery shall be charged to a full state-of-charge. The vehicle must be turned off during charging. Charge time shall not exceed soak time.

5.4.3 Urban Charge Depleting Range Test. At the end of the cold soak period, the vehicle shall be placed or pushed, onto a dynamometer and operated through the Continuous Urban Test Schedule until the SOC Net Change Tolerances (specified in section F.10 of these test procedures) that indicate charge sustaining operation are met for two consecutive UDDSs, or a single UDDS if data is provided showing that charge sustaining operation can consistently be maintained in one UDDS. The Alternative Continuous Urban Test Schedule may be substituted for the Continuous Urban Test Schedule if the test facility is unable to perform the Continuous Urban Test Schedule. Refer to sections F.5.5, F.5.6, and F.11, for calculations of urban exhaust emissions, urban particulate emissions, and equivalent all-electric range, respectively.

5.4.4 Urban Charge Sustaining Emission Test. The Urban Charge Sustaining Emission Test is conducted cold, and after charge sustaining operation has been reached, or an optional charge sustaining test mode has been activated, and no subsequent charge has been performed.

(i) Cold soak: The vehicle shall be stored at an ambient temperature not less than 68°F (20°C) and not more than 86°F (30°C) for 12 to 36 hours.

(ii) At the end of the cold soak period, the vehicle shall be placed or pushed onto a dynamometer, and two UDDSs shall be performed during charge sustaining operation, each separated by a 10 minute key-off hot soak period. The vehicle must meet the SOC criterion in section F.10 from the start of the first UDDS until the end of the second UDDS. If the SOC criterion is not satisfied, the test shall be stopped, the vehicle cold soak shall be conducted again, and the dynamometer test run shall be conducted again.

5.5 Calculations - Urban Exhaust Emissions for Off-Vehicle Charge Capable Hybrid Electric Vehicles.

To be conducted pursuant to 40 CFR §86.144-94 [July 13, 2005] with the following revisions:

5.5.1 Amend subparagraph (a):

Gaseous Emissions – Urban Charge Depleting Range Test.

For light-duty vehicles and light duty trucks:

$$\underline{Y_{wm}} = \underline{0.43 * \left(\frac{Y_c}{D_c} \right) + 0.57 * \left(\frac{\sum Y_n}{\sum D_n} \right)}$$

Where:

Y_{wm} = Weighted mass emissions of each pollutant, i.e., THC, CO, THCE, NMOG, NMHCE, CH₄, NO_x, or CO₂, in grams per vehicle mile.

Y_c = Mass emissions as calculated from the cold start UDDS, in grams per test.

D_c = The measured driving distance from the cold start UDDS, in miles.

n = number of hot start UDDSs in Charge Depleting operation

Gaseous Emissions – Urban Charge Sustaining Emission Test.

For light-duty vehicles and light-duty trucks:

$$\underline{Y_{wm}} = \underline{0.43 * \left(\frac{Y_c}{D_c} \right) + 0.57 * \left(\frac{Y_h}{D_h} \right)}$$

Where:

Y_{wm} = Weighted mass emissions of each pollutant, i.e., THC, CO, THCE, NMOG, NMHCE, CH₄, NO_x, or CO₂, in grams per vehicle mile.

Y_c = Mass emissions as calculated from the cold start UDDS, in grams per test.

Y_h = Mass emissions as calculated from the hot start UDDS, in grams per test.
 D_c = The measured driving distance from the cold start UDDS, in miles.
 D_h = The measured driving distance from the hot start UDDS, in miles.

5.5.2 Subparagraphs (b) through (e). [No change.]

5.6 Calculations - Urban Particulate Emissions for Off-Vehicle Charge Capable Hybrid Electric Vehicles.

To be conducted pursuant to 40 CFR §86.145-82 [November 2, 1982] with the following revisions. References to §86.110-94 shall mean §86.110-94 as last amended June 30, 1995.

5.6.1 Amend subparagraph (a):

Particulate Emissions – Urban Charge Depleting Range Test.

The final reported test results for the mass particulate (M_p) in grams/mile shall be computed as follows:

$$M_p = 0.43 * \left(\frac{M_{pc}}{D_c} \right) + 0.57 * \left(\frac{\Sigma M_{pn}}{\Sigma D_n} \right)$$

Where:

M_{pc} = Mass of particulate determined from the cold start UDDS, in grams per vehicle mile. (See §86.110-94 for determination.)

D_c = The measured driving distance from the cold start UDDS, in miles.

n = number of hot start UDDSs in Charge Depleting operation

Particulate Emissions – Urban Charge Sustaining Emission Test.

The final reported test results for the mass particulate (M_p) in grams/mile shall be computed as follows:

$$M_p = 0.43 * \left(\frac{M_{pc}}{D_c} \right) + 0.57 * \left(\frac{M_{ph}}{D_h} \right)$$

Where:

M_{pc} = Mass of particulate determined from the cold start UDDS, in grams per vehicle mile. (See §86.110-94 for determination.)

M_{ph} = Mass of particulate determined from the hot start UDDS, in grams per vehicle mile. (See §86.110-94 for determination.)

D_c = The measured driving distance from the cold start UDDS, in miles.

D_h = The measured driving distance from the hot start UDDS, in miles.

5.6.2 Subparagraph (b). [No change.]

5.6.3 **Equivalent All-Electric Range** shall be calculated in accordance with section F.11 of these test procedures.

6. Highway Test Provisions for Off-Vehicle Charge Capable Hybrid Electric Vehicles.

The third HFEDS of the Highway Charge Sustaining Test shall be used to calculate highway NOx emissions and must be within the SOC criterion in section F.10. As an option, the Highway Charge Sustaining Test may be performed with two HFEDS provided that the second HFEDS meets the SOC criterion in section F.10. In this case, the second HFEDS shall be used to calculate emissions.

Vehicles with more than one mode of operation for a given charge depleting or charge sustaining test cycle must be tested in the mode(s) which represents maximum operation of the auxiliary power unit. Confirmatory testing may also be performed in any mode of operation to ensure compliance with emission standards.

6.1 Vehicle Preconditioning.

If the Highway Charge Depleting Range Test is performed within 36 hours after completion of either the Urban Charge Depleting Range Test or the Urban Charge Sustaining Range Test, no preconditioning is necessary. If the Highway Charge Depleting Range Test is performed more than 36 hours after completion of either the Urban Charge Depleting Range Test or the Urban Charge Sustaining Range Test, the manufacturer shall precondition the vehicle pursuant to section F.5.1 of these test procedures, without loading the evaporative canister.

6.2 Highway Dynamometer Procedure for Off-Vehicle Charge Capable Hybrid Electric Vehicles.

To be conducted pursuant to 40 CFR §600.111-08 [December 27, 2006] with the following revisions. This section F.6.2 shall apply during both charge sustaining and charge depleting operation.

6.2.1 Subparagraph (a). [n/a]

6.2.2 Amend subparagraph (b) as follows:

6.2.2.1 Amend subparagraph (b)(2): The highway fuel economy test is designated to simulate non-metropolitan driving with an average speed of 48.6 mph and a maximum speed of 60 mph. The cycle is 10.2 miles long with 0.2 stop per mile and consists of warmed-up vehicle operation on a chassis dynamometer through a specified driving

cycle. A proportional part of the diluted exhaust emission is collected continuously for subsequent analysis of THC, CO, CO₂, and NO_x using a constant volume (variable dilution) sampler. Diesel dilute exhaust is continuously analyzed for hydrocarbons using a heated sample line and analyzer. Alcohol and formaldehyde samples are collected and individually analyzed for alcohol-fueled vehicles.

6.2.2.2 Replace subparagraph (b)(6) with: Cold soak: The vehicle shall be stored at an ambient temperature not less than 68°F (20°C) and not more than 86°F (30°C) for 12 to 36 hours. At the end of the cold soak period, the vehicle shall be placed, either driven or pushed onto a dynamometer.

6.2.2.3 Amend subparagraph (b)(7)(i): The Highway Charge Sustaining Emission Test is conducted cold, and after charge sustaining operation has been reached, or an optional charge sustaining test mode has been activated, and no subsequent charge has been performed.

Three HFEDSs, separated by a 15 second key-on hot soak period, shall be performed. The vehicle must meet the SOC criterion in section F.10 for the third HFEDS. If the SOC criterion is not satisfied, the test shall be stopped, and sections F.6.2.2.2 and this section F.6.2.2.3 shall be repeated. As an option, two HFEDSs may be performed in lieu of three HFEDSs if the SOC criterion is satisfied for the second HFEDS. Emissions shall be measured for all HFEDSs.

6.2.2.4 Amend subparagraph (b)(7)(iii): One exhaust sample and one background sample per each HFEDS shall be collected and analyzed for THC (except diesel hydrocarbons which are analyzed continuously), CO, CO₂, and NO_x. Alcohol and formaldehyde samples (exhaust and dilution air) are collected and analyzed for alcohol-fueled vehicles.

6.2.2.5 Add subparagraph (b)(7)(v): For vehicles that do not allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that causes the vehicle to operate the auxiliary power unit for the maximum possible cumulative amount of time during the HFEDS preconditioning cycle. For vehicles that allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at the lowest level allowed by the manufacturer.

6.2.2.6 Amend subparagraph (b)(9)(v): Operate the vehicle over the continuous highway test schedule, consisting of repeated HFEDSs according to the dynamometer driving schedule specified in §600.109-08(b) [December 27, 2006]. If the auxiliary power unit is capable of being manually activated, the auxiliary power unit shall be manually activated at the beginning of and operated throughout the HFEDS preconditioning cycle.

6.2.2.7 Amend subparagraph (b)(9)(vi): When the vehicle reaches zero speed between each HFEDS, the driver has 17 seconds to prepare for the HFEDS emission

measurement cycle of the test. During the idle period, one of the following conditions shall apply:

(a) For vehicles that do not allow the auxiliary power unit to be manually activated, the vehicle shall remain turned on during the idle period.

(b) For vehicles that allow the auxiliary power unit to be manually activated, the vehicle shall remain turned on with the auxiliary power unit operating during the idle period.

6.2.2.8 Add subparagraph (b)(9)(viii): At the conclusion of the HFEDS emission test, the following conditions shall apply: For vehicles that do not allow the auxiliary power unit to be manually activated and are charge-sustaining over the HFEDS, record the battery state-of-charge to determine if the SOC criterion in section F.10 is satisfied. If the SOC criterion is not satisfied, then repeat dynamometer test run from subparagraph (h)(6). Up to two highway emission tests shall be allowed to satisfy the SOC criterion.

6.2.2.9 Delete subparagraph (b)(10).

6.2.3 Delete subparagraphs (c) through (e).

6.3 Determination of Highway All-Electric Range and Highway Equivalent All-Electric Range for Off-Vehicle Charge Capable Hybrid Electric Vehicles.

6.3.1 The **Highway All-Electric Range** shall be defined as the distance that the vehicle is driven from the start of test until the internal combustion engine starts.

6.3.2 **Cold soak and vehicle charging.** The vehicle shall be stored at an ambient temperature not less than 68°F (20°C) and not more than 86°F (30°C) for 12 to 36 hours. During this time, the vehicle's battery shall be charged to a full state-of-charge. Charge time shall not exceed soak time.

6.3.3 **Highway Charge Depleting Range Test.** At the end of the cold soak period, the vehicle shall be placed or pushed, onto a dynamometer and operated through the Continuous Highway Test Schedule until the State-of-Charge Net Change Tolerances (specified in section F.10 of these test procedures) that indicate charge sustaining operation is met for one HFEDS. The Alternative Continuous Highway Test Schedule may be substituted for the Continuous Highway Test Schedule if the test facility is unable to perform the Continuous Highway Test Schedule. Refer to sections F.6.3.4, and F.11, for calculations of highway exhaust emissions and equivalent all-electric range, respectively.

If the energy required to charge the vehicle from highway charge sustaining operation to full charge is not equivalent (within $\pm 1\%$ of the AC energy) to the energy required to charge the vehicle from urban charge sustaining operation to full charge, repeat subparagraphs F.6.2.2 and

F.6.2.3. Battery charging in F.6.3.2 shall begin within one hour of the end of the Highway Charge Depleting Range Test.

6.3.4 Highway Charge Sustaining Emission Test. The Highway Charge Sustaining Emission Test is conducted cold, and after charge sustaining operation has been reached, or an optional charge sustaining test mode has been activated, and no subsequent charge has been performed:

(i) Cold soak: The vehicle shall be stored at an ambient temperature not less than 68°F (20°C) and not more than 86°F (30°C) for 12 to 36 hours.

(ii) At the end of the cold soak period, the vehicle shall be placed or pushed onto a dynamometer. Three HFEDSs, separated by a 15 second key-on hot soak period, shall be performed. The vehicle must meet the SOC criterion in section F.10 for the third HFEDS. If the SOC criterion is not satisfied, the test shall be stopped, and sections F.6.3.2, F.6.3.3, and this section F.6.3.4 shall be repeated. As an option, two HFEDSs may be performed in lieu of three HFEDSs if the SOC criterion is satisfied for the second HFEDS. Emissions shall be measured for all HFEDSs.

6.3.5 Equivalent All-Electric Range shall be calculated in accordance with section F.11 of these test procedures.

7. SFTP Emission Test Provisions for Off-Vehicle Charge Capable Hybrid Electric Vehicles.

Hybrid electric vehicles with more than one mode of operation for a given charge depleting or charge sustaining test cycle must be tested in the mode(s) which represents maximum operation of the auxiliary power unit. Confirmatory testing may also be performed in any mode of operation to ensure compliance with emission standards.

7.1 US06 Vehicle Preconditioning.

To be conducted pursuant to 40 CFR §86.132-00 [October 22, 1996] with the following revisions. This section 7.1 shall apply during charge sustaining operation or at an optional charge sustaining test mode that has been activated, if no subsequent charge has been performed.

7.1.1 Subparagraphs (a) through (m). [No change.]

7.1.2 Amend subparagraph (n) Aggressive Driving Test (US06) Preconditioning. as follows:

7.1.2.1 Amend subparagraph (1) as follows: If the US06 test follows the exhaust emission urban, highway, or evaporative testing, the refueling step may be deleted and the vehicle may be preconditioned using the fuel remaining in the tank

(see paragraph (c)(2)(ii) of this section). The test vehicle may be pushed or driven onto the test dynamometer. For vehicles that allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at the lowest level allowed by the manufacturer. The auxiliary power unit shall be manually activated at the beginning of and operated throughout the US06 preconditioning cycle.

7.1.2.1.1 Delete subparagraphs (i) and (ii).

7.1.2.1.2 Subparagraphs (iii) through (iv). [No change.]

7.1.2.2 Subparagraph (2). [No change.]

7.1.3 Subparagraph (o). [No change.]

7.2 US06 Emission Test.

To be conducted pursuant to 40 CFR §86.159-08 [December 27, 2006] with the following revisions. This section 7.2 shall apply during charge sustaining operation or at an optional charge sustaining test mode that has been activated, if no subsequent charge has been performed.

7.2.1 Amend subparagraph (a): *Overview*. The dynamometer operation consists of a single, 600 second test on the US06 driving schedule, as described in appendix I, paragraph (g), of this part. The vehicle is preconditioned in accordance with §86.132-00, to bring it to a warmed-up stabilized condition. This preconditioning is followed by a 1 to 2 minute idle period that proceeds directly into the US06 driving schedule during which continuous proportional samples of gaseous emissions are collected for analysis. If engine stalling should occur during testing, follow the provisions of §86.136-90 (engine starting and restarting). For vehicles with Otto-cycle auxiliary power units, the composite samples collected in bags are analyzed for THC, CO, CO₂, CH₄ and NO_x. For vehicles with diesel-cycle auxiliary power units, THC is sampled and analyzed continuously according to the provisions of §86.110. Parallel bag samples of dilution air are analyzed for THC, CO, CO₂, CH₄ and NO_x. The second US06 (the cycle after preconditioning) shall be used to calculate emissions and shall be within the state-of-charge net tolerances as calculated in section F.10.

7.2.2 Amend subparagraph (b) as follows.

7.2.2.1 Amend subparagraph (b)(2): Position the test vehicle on the dynamometer and restrain.

7.2.3 Subparagraph (c). [No change.]

7.2.4 Amend subparagraph (d): Practice runs over the prescribed driving schedule may be performed at test point to permit sampling system adjustment.

7.2.5 Subparagraph (e). [No change.]

7.2.6 Amend subparagraph (f) as follows.

7.2.6.1 Amend subparagraph (f)(2)(i): Immediately after completion of the US06 preconditioning cycle, idle the vehicle. The idle period is not to be less than one minute or not greater than two minutes. During the idle period, one of the following conditions shall apply:

(i) For vehicles that do not allow the auxiliary power unit to be manually activated and are charge-sustaining over the US06, the vehicle shall remain on during the idle period. The battery state-of-charge shall be recorded after the vehicle has started idle.

(ii) For vehicles that allow the auxiliary power unit to be manually activated, the vehicle shall remain turned on with the auxiliary power unit operating during the idle period.

7.2.6.2 Amend subparagraph (f)(2)(ix): For vehicles that do not allow manual activation of the auxiliary power unit and are charge-sustaining over the US06, determine if the SOC criterion in section F.10 is satisfied at the end of the US06 emission test. If the SOC criterion is not satisfied, then repeat dynamometer test run from subparagraph (f)(2)(i). Up to two US06 emission tests shall be allowed to satisfy the SOC criterion.

7.3 SC03 Vehicle Preconditioning.

To be conducted pursuant to 40 CFR §86.132-00 [October 22, 1996] with the following revisions. This section 7.3 shall apply during charge sustaining operation or at an optional charge sustaining test mode that has been activated, if no subsequent charge has been performed.

7.3.1 Subparagraphs (a) through (n). [No change.]

7.3.2 Amend subparagraph (o): *Air Conditioning Test (SC03) Preconditioning.*

7.3.2.1 Amend subparagraph (1) as follows: If the SC03 test follows the exhaust emission urban, highway, or evaporative testing, the refueling step may be deleted and the vehicle may be preconditioned using the fuel remaining in the tank (see paragraph (c)(2)(ii) of this section). The test vehicle may be pushed or driven onto the test dynamometer. For vehicles that allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at the lowest level

allowed by the manufacturer. The auxiliary power unit shall be manually activated at the beginning of and operated throughout the SC03 preconditioning cycle.

7.3.2.1.1 Delete subparagraphs (i) and (ii).

7.3.2.2 Subparagraphs (2) through (3). [No change.]

7.4 SC03 Emission Test.

To be conducted pursuant to 40 CFR §86.160-00 [December 8, 2005] with the following revisions. This section 7.4 shall apply during charge sustaining operation or at an optional charge sustaining test mode that has been activated, if no subsequent charge has been performed. References to §86.162-03 shall mean §86.162-03 as adopted October 22, 1996.

7.4.1 Amend subparagraph (a): *Overview.* The dynamometer operation consists of a single, 594 second test on the SC03 driving schedule, as described in appendix I, paragraph (h), of this part. The vehicle is preconditioned in accordance with §86.132-00 of this subpart, to bring the vehicle to a warmed-up stabilized condition. This preconditioning is followed by a 10 minute vehicle soak (vehicle turned off) that proceeds directly into the SC03 driving schedule, during which continuous proportional samples of gaseous emissions are collected for analysis. The entire test, including the SC03 preconditioning cycle, vehicle soak, and SC03 emission test, is either conducted in an environmental test facility or under test conditions that simulate testing in an environmental test cell (see §86.162-03 (a) for a discussion of simulation procedure approvals). The environmental test facility must be capable of providing the following nominal ambient test conditions of: 95°F air temperature, 100 grains of water/pound of dry air (approximately 40 percent relative humidity), a solar heat load intensity of 850 W/m², and vehicle cooling air flow proportional to vehicle speed. Section 86.161-00 discusses the minimum facility requirements and corresponding control tolerances for air conditioning ambient test conditions. The vehicle's air conditioner is operated or appropriately simulated for the duration of the test procedure (except for the 10 minute vehicle soak), including the preconditioning. If engine stalling should occur during testing, follow the provisions of §86.136-90 (engine starting and restarting). For vehicles with Otto-cycle auxiliary power units, the composite samples collected in bags are analyzed for THC, CO, CO₂, CH₄ and NO_x. For vehicles with diesel-cycle auxiliary power units, THC is sampled and analyzed continuously according to the provisions of §86.110. Parallel bag samples of dilution air are analyzed for THC, CO, CO₂, CH₄ and NO_x. The second SC03 (the cycle after preconditioning) shall be used to calculate emissions and shall be within the state-of-charge net tolerances as calculated in section F.10.

7.4.2 Amend subparagraph (b) as follows.

7.4.2.1 Amend subparagraph (b)(2): Position the test vehicle on the dynamometer and restrain.

7.4.3 Amend subparagraph (c) as follows.

7.4.3.1 Amend subparagraph (c)(8): Add the following: Immediately after completion of the SC03 preconditioning cycle, idle the vehicle. The idle period shall not be less than one minute and not greater than two minutes. During the idle period, one of the following conditions shall apply:

(i) For vehicles that do not allow the auxiliary power unit to be manually activated and are charge-sustaining over the SC03, the vehicle shall remain on during the idle period. The battery state-of-charge shall be recorded after the vehicle has started idle.

(ii) For vehicles that allow the auxiliary power unit to be manually activated, the vehicle shall remain turned on with the auxiliary power unit operating during the idle period.

7.4.3.2 Amend subparagraph (c)(9): Start vehicle (with air conditioning system also running). If the auxiliary power unit of the vehicle is capable of being manually activated, the auxiliary power unit shall be manually activated at the beginning of and operated throughout the SC03 emission test. Fifteen seconds after the vehicle starts, begin the initial vehicle acceleration of the driving schedule.

7.4.4 Amend subparagraph (d) as follows.

7.4.4.1 Amend subparagraph (d)(10): For vehicles that do not allow the auxiliary power unit to be manually activated and are charge-sustaining over the SC03, determine if the SOC criterion in section F.10 is satisfied at the end of the SC03 emission test. If the SOC criterion is not satisfied, then turn off cooling fan(s), allow vehicle to soak in the ambient conditions of paragraph (c)(5) of this section for 10 minutes, and repeat dynamometer test run from subparagraph (d). A total of two SC03 emission tests shall be attempted to satisfy the SOC criterion.

7.4.5 Subparagraph (e). [No change.]

7.5 Optional Cold Start US06 Range Test.

7.5.1 Cold soak and vehicle charging. The vehicle shall be stored at an ambient temperature not less than 68°F (20°C) and not more than 86°F (30°C) for 12 to 36 hours. During this time, the vehicle battery shall be charged to a full state-of-charge. The vehicle must be turned off during charging. Charge time shall not exceed soak time.

7.5.2 At the end of the cold soak period, the vehicle shall be placed or pushed onto a dynamometer, and shall be driven on a continuous US06 test cycle until either:

- (a) the auxiliary power unit starts, or
- (b) the vehicle can no longer meet the speed trace limits of the US06 driving schedule as specified in CFR 86 Appendix I to within 2 mph higher than the highest point on the trace within 1 second for the upper limit or within 2 mph higher than the lowest point on the trace within 1 second for the lower limit.

The instant either of these conditions are met the test shall be ended. The range for this test, in miles, shall be the distant driven from the start of the test to when condition (a) or (b) is met. Emission sampling is not required for this test.

8. 50°F and 20°F Test Provision for Off-Vehicle Charge Capable Hybrid Electric Vehicles.

8.1 To satisfy test requirements for the 50°F emission test, the vehicle shall be tested in the worst case (NMHC + NOx) of the urban charge sustaining range test or urban charge sustaining test as defined in section F.5. To satisfy test requirements for the 20°F emission test, the vehicle shall be tested in the worst case (CO) of the urban charge sustaining range test or urban charge sustaining test as defined in section F.5. For the 20°F and 50°F emission tests, the vehicle is not required to meet SOC net tolerances.

8.2 If the worst case for emissions is charge sustaining operation, the vehicle shall be preconditioned according to section F.5.1. There are two emission test options.

(i) A three phase test that includes phase one as the first 505 seconds of the UDDS, phase two as 506 seconds to the end of the UDDS, a 10 minute key-off soak period, and phase three the first 505 seconds of the UDDS. The first two phases test shall be counted as the first UDDS and the second and third phases will constitute the second UDDS. Emission weighting is as follows:

$$\underline{Y_{wm}} = \underline{0.43 * \left(\frac{Y_1 + Y_2}{D_1 + D_2} \right) + 0.57 * \left(\frac{Y_2 + Y_3}{D_2 + D_3} \right)}$$

Where:

Y_{wm} = Weighted mass emissions of each pollutant, i.e., THC, CO, THCE, NMOG, NMHCE, CH₄, NO_x, or CO₂, in grams per vehicle mile.

Y_1 = Mass emissions as calculated from phase one of the three phase test.

Y_2 = Mass emissions as calculated from phase two of the three phase test.

Y_3 = Mass emissions as calculated from phase three of the three phase test.

D₁ = The measured driving distance from phase one of the three phase tests, in miles.

D₂ = The measured driving distance from phase two of the three phase tests, in miles.

D₃ = The measured driving distance from phase three of the three phase tests, in miles.

(ii) A two phase test that includes phase one as a UDDS, a 10 minute key-off soak period, and phase two as a UDDS. Emission weighting for the four phase test will follow the procedure outlined in section F.5.5.1.

8.3 If measurement of worst case emissions requires the urban charge depleting range test to be performed, the vehicle shall be preconditioned according to section F.5.1 and fully charged. The continuous urban test schedule shall then be performed. The UDDS, in which the auxiliary power unit first starts, shall be the cold UDDS. Emissions shall be sampled according to one of the options in section F.8.2. For the three phase test option, if the auxiliary power unit starts in phase two of the UDDS, phase one emissions are considered zero for emission calculation purposes. Emissions are weighted according to section F.8.2.

9. Additional Provisions.

9.1 Confirmatory testing may be performed on all tests to establish if higher emissions occur at different states-of-charge in charge depleting mode. This is to ensure that cold start and other emissions standards are not exceeded at other operating SOCs.

9.2 Confirmatory testing may be performed on the US06 test or the manufacturer may provide data to show that potential cold start off-cycle emissions are controlled to the extent that they are controlled for the UDDS.

9.3 Confirmatory testing may be performed on vehicles equipped with an optional charge sustaining operation mode selector with selector set to simulate charge sustaining operation or in actual charge sustaining operation in accordance with section F of these test procedures.

9.4 A period of up to three hours may be used to initiate charge on the vehicle after either the urban or highway charge depleting range tests are completed.

9.5 Highway NO_x emissions may be determined from the HFEDS in the Highway Charge Depleting Range Test that demonstrates charge sustaining operation.

9.6 If data can be provided to show that the AC energy required to fully charge the vehicle following the urban charge depleting range test is greater than the AC energy required to recharge the vehicle after the highway charge depleting range test, then the measured AC energy required to recharge the vehicle following the urban charge depleting range test may be used to calculate the Highway Equivalent All-Electric Range Energy Consumption, in section F.11.7.

9.7 For an example of an off-vehicle charge capable hybrid electric vehicle with all-electric range and blended operation that has charge depleting actual range and charge depleting cycle range, please see section H, Figure 1.

9.8 For an example of charge depleting to charge sustaining range with and without transitional range and end of test conditions, please see section H, Figure 2.

10. State-of-Charge Net Change Tolerances.

10.1 For vehicles that use a battery as an energy storage device, the following state-of-charge net change tolerance shall apply:

$$\underline{(Amp-hr_{final})_{max} = (Amp-hr_{initial}) + 0.01 * \left(\frac{NHV_{fuel} * m_{fuel}}{V_{system} * K_1} \right)}$$

$$\underline{(Amp-hr_{final})_{min} = (Amp-hr_{initial}) - 0.01 * \left(\frac{NHV_{fuel} * m_{fuel}}{V_{system} * K_1} \right)}$$

Where:

(Amp-hr_{final})_{max} = Maximum allowed Amp-hr stored in battery at the end of the test

(Amp-hr_{final})_{min} = Minimum allowed Amp-hr stored in battery at the end of the test

(Amp-hr_{initial}) = Battery Amp-hr stored at the beginning of the test

NHV_{fuel} = Net heating value of consumable fuel, in Joules/kg

m_{fuel} = Total mass of fuel consumed during test, in kg

K₁ = Conversion factor, 3600 seconds/hour

V_{system} = Average charge sustaining battery DC bus voltage (open circuit) during charge sustaining operation. This value shall be submitted for testing purposes, and it shall be subject to confirmation by the Air Resources Board.

An alternate state-of-charge net tolerance may be used if shown to be technically necessary and if approved in advance by the Executive Officer of the Air Resources Board.

10.2 For vehicles that use a capacitor as an energy storage device, the following state-of-charge net change tolerance shall apply:

$$\underline{(V_{final})_{max} = \sqrt{V_{initial}^2 + 0.01 * \frac{(2 * NHV_{fuel} * m_{fuel})}{C}}}$$

$$\underline{(V_{\text{final}})_{\text{min}}} = \sqrt{V_{\text{initial}}^2 - 0.01 * \frac{(2 * NHV_{\text{fuel}} * m_{\text{fuel}})}{C}}$$

Where:

$\underline{(V_{\text{final}})_{\text{max}}}$ = The stored capacitor voltage allowed at the end of the test

$\underline{(V_{\text{final}})_{\text{min}}}$ = The stored capacitor voltage allowed at the end of the test

$\underline{V_{\text{initial}}^2}$ = The square of the capacitor voltage stored at the beginning of the test

$\underline{NHV_{\text{fuel}}}$ = Net heating value of consumable fuel, in Joules/kg

$\underline{m_{\text{fuel}}}$ = Total mass of fuel consumed during test, in kg

\underline{C} = Rated capacitance of the capacitor, in Farads

10.3 For vehicles that use an electro-mechanical flywheel as an energy storage device, the following state-of-charge net change tolerance shall apply:

$$\underline{(rpm_{\text{final}})_{\text{max}}} = \sqrt{rpm_{\text{initial}}^2 + 0.01 * \frac{(2 * NHV_{\text{fuel}} * m_{\text{fuel}})}{I * K_3}}$$

$$\underline{(rpm_{\text{final}})_{\text{min}}} = \sqrt{rpm_{\text{initial}}^2 - 0.01 * \frac{(2 * NHV_{\text{fuel}} * m_{\text{fuel}})}{I * K_3}}$$

Where:

$\underline{(rpm_{\text{final}})_{\text{max}}}$ = The maximum flywheel rotational speed allowed at the end of the test

$\underline{(rpm_{\text{final}})_{\text{min}}}$ = The minimum flywheel rotational speed allowed at the end of the test

$\underline{rpm_{\text{initial}}^2}$ = The squared flywheel rotational speed at the beginning of the test

$\underline{NHV_{\text{fuel}}}$ = Net heating value of consumable fuel, in Joules/kg

$\underline{m_{\text{fuel}}}$ = Total mass of fuel consumed during test, in kg

$\underline{K_3}$ = Conversion factor, $\frac{4\pi^2}{3600 \text{ sec}^2 - rpm^2}$

\underline{I} = Rated moment of inertia of the flywheel, in kg-m²

11. Calculations – Equivalent All-Electric Range for Off-Vehicle Charge Capable Hybrid Electric Vehicles.

11.1 Charge Depleting CO₂ Produced means the cumulative tailpipe CO₂ emissions produced, M_{cd}, in grams per mile during the charge depleting cycle range.

$$M_{cd} = \sum Y_i$$

where:

Y_i = The sum of the CO₂ grams per mile in the charge depleting mode from each test cycle (UDDS or HFEDS)

i = Number (UDDS or HFEDS) of the test over the charge depleting cycle range, R_{cdc}

11.2 Charge Sustaining CO₂ Produced - urban means the cumulative tailpipe CO₂ emissions produced, M_{cs}, in grams per mile, during the cold start charge sustaining urban test.

$$M_{cs} = Y_c + Y_h * \left[\frac{(R_{cdcu} - D_c)}{D_c} \right]$$

where:

R_{cdcu} = Urban Charge Depleting Cycle Range, in miles

D_c = The measured driving distance from the cold start UDDS, in miles

Y_c = Grams per mile CO₂ emissions as calculated from the cold start UDDS

Y_h = Grams per mile CO₂ emissions as calculated from the hot start UDDS

11.3 Charge Sustaining CO₂ Produced - highway means the grams per mile tailpipe CO₂ emissions produced, M_{cs}, during the cold start charge sustaining highway test.

$$M_{cs} = \left(\frac{R_{cdch}}{D_h} \right) * Y_h$$

where:

R_{cdch} = Highway Charge Depleting Cycle Range, in miles

D_h = The measured driving distance from the hot start HFEDS, in miles

Y_h = Grams per mile emissions as calculated from the hot start HFEDS

11.4 Urban Equivalent All-Electric Range (EAER_u) shall be calculated as follows:

$$EAER_u = \left(\frac{M_{cs} - M_{cd}}{M_{cs}} \right) * R_{cdcu}$$

where:

M_{cs} and M_{cd} are the sum of the grams per mile of tailpipe CO₂ emissions accumulated over the urban charge depleting cycle range, R_{cdcu} (mi).

11.5 Highway Equivalent All-Electric Range ($EAER_h$) shall be calculated as follows:

$$\underline{EAER_h} = \left[\frac{M_{cs} - M_{cd}}{M_{cs}} \right] * R_{cdch}$$

where:

M_{cs} and M_{cd} are the grams per mile of CO₂ emissions accumulated over the highway charge depleting cycle range, R_{cdch} (mi).

$$\underline{M_{cd}} = \sum Y_i$$

Y_i = The sum of the CO₂ grams per mile in the charge depleting mode from each test cycle (UDDS or HFEDS)

i = Number HFEDS tests in charge depleting operation

$$\underline{M_{cs}} = \left(\frac{R_{cdc}}{D_h} \right) * Y_h$$

Y_h and D_h are the CO₂ grams per mile and distance traveled, respectively, from the final charge sustaining (hot) test HFEDS (either the third or the second HFEDS, per section F.6.2.2.3).

11.6 Electric Range Fraction (%).

The Electric Range Fraction means fraction of the total miles driven electrically (with the engine off) for blended operation hybrid electric vehicles.

The Urban Electric Range Fraction (ERF_u) is calculated as follows:

$$\underline{ERF_u} (\%) = \left(\frac{EAER_u}{R_{cda}} \right) * 100$$

The Highway Electric Range Fraction (ERF_h) is calculated as follows:

$$\underline{ERF_h} (\%) = \left(\frac{EAER_h}{R_{cdah}} \right) * 100$$

11.7 Equivalent All-Electric Range Energy Consumption.

The Urban Equivalent All-Electric Range Energy Consumption (EAEREC_u) shall be calculated as follows:

$$\text{EAEREC}_u \text{ (wh/mi)} = \frac{E_{cd}}{\text{EAER}_u}$$

where:

E_{cd} = Total DC or AC electrical energy used to fully charge the vehicle battery from an external power source after the charge depleting test has been completed

The Highway Equivalent All-Electric Range Energy Consumption (EAEREC_h) shall be calculated as follows:

$$\text{EAEREC}_h \text{ (wh/mi)} = \frac{E_{cd}}{\text{EAER}_h}$$

where:

E_{cd} = Total DC or AC electrical energy used to fully charge the vehicle battery from an external power source after the charge depleting test has been completed

11.8 The Urban Charge Depleting Cycle Range, R_{cdcu}, (see section H for an illustration of R_{cdcu}) shall be defined as the distance traveled on the Urban Charge Depleting Procedure up to the UDDS prior to where the state-of-charge is above the lower bound state-of-charge tolerance for one test cycle given by:

$$\text{(Amp-hr}_{\text{final}}\text{)}_{\text{min}} = \text{(Amp-hr}_{\text{initial}}\text{)} - 0.01 * \left(\frac{NHV_{\text{fuel}} * m_{\text{fuel}}}{V_{\text{system}} * K_1} \right)$$

Where:

(Amp-hr_{final})_{min} = Minimum allowed Amp-hr stored in battery at the end of the test

(Amp-hr_{initial}) = Battery Amp-hr stored at the beginning of the test

NHV_{fuel} = Net heating value of consumable fuel, in Joules/kg

m_{fuel} = Total mass of fuel consumed during test, in kg

K₁ = Conversion factor, 3600 seconds/hour

V_{system} = Average charge sustaining battery DC bus voltage (open circuit) during charge sustaining operation. This value shall be submitted for testing purposes, and it shall be subject to confirmation by the Air Resources Board.

11.9 The Charge Depleting Actual Range, R_{cda} , shall be defined as the range at which the state-of-charge is first equal to the average state-of-charge of the one or two UDDSs used to end the Urban Charge Depleting Test. This range must be accurate to the nearest 0.1 miles. For an illustration of R_{cda} , see section H.

11.10 The Charge Depleting to Charge Sustaining Urban Range shall be defined as the distance driven in miles from the start of the Urban Charge Depleting Test through the UDDS preceding the one or two UDDSs used to end the Urban Charge Depleting Test.

11.11 The Highway Charge Depleting Cycle Range, R_{cdch} , shall be defined as the sum of the distance traveled on the Highway Charge Depleting Test up to the HFEDS prior to where the state-of-charge is above the lower bound state-of-charge tolerance for one test cycle given by:

$$\underline{(\text{Amp-hr}_{\text{final}})_{\text{min}} = (\text{Amp-hr}_{\text{initial}}) - 0.01 * \left(\frac{NHV_{\text{fuel}} * m_{\text{fuel}}}{V_{\text{system}} * K_1} \right)}$$

Where:

$(\text{Amp-hr}_{\text{final}})_{\text{min}}$ = Minimum allowed Amp-hr stored in battery at the end of the test
 $(\text{Amp-hr}_{\text{initial}})$ = Battery Amp-hr stored at the beginning of the test
 NHV_{fuel} = Net heating value of consumable fuel, in Joules/kg
 m_{fuel} = Total mass of fuel consumed during test, in kg
 K_1 = Conversion factor, 3600 seconds/hour
 V_{system} = Average charge sustaining battery DC bus voltage (open circuit) during charge sustaining operation. This value shall be submitted for testing purposes, and it shall be subject to confirmation by the Air Resources Board.

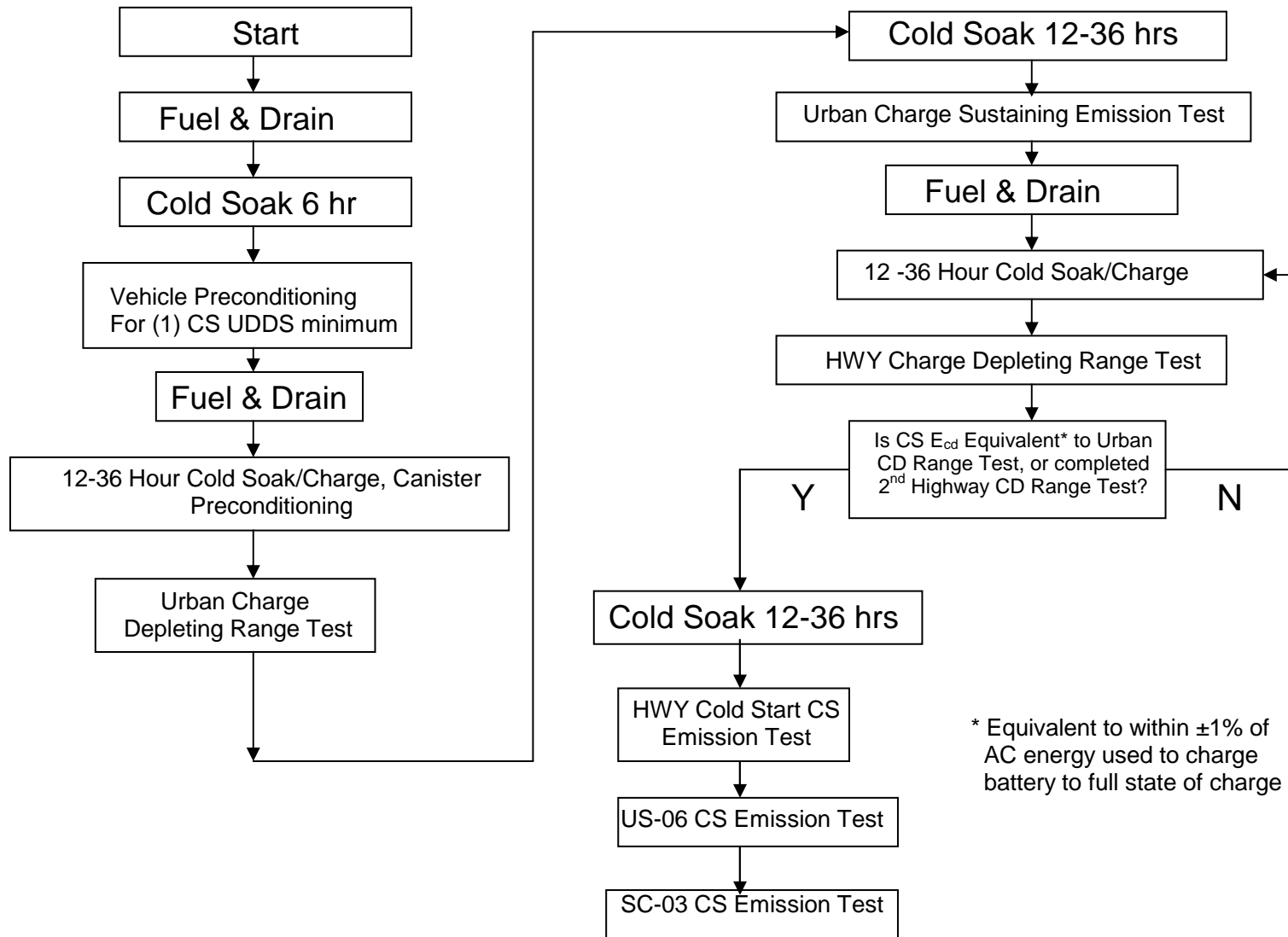
11.12 The Charge Depleting to Charge Sustaining Highway Range shall be defined as the distance driven in miles from the start of the Highway Charge Depleting Test through the HFEDS preceding the final HFEDS.

G. Off-Vehicle Charge Capable Hybrid Electric Vehicle Emission Test Sequence.

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[The diagram on the next page is proposed for addition.]

Proposed Off-Vehicle Charge Capable HEV Exhaust Emissions Test Sequence



* Equivalent to within $\pm 1\%$ of AC energy used to charge battery to full state of charge

H. Examples of Off-Vehicle Charge Capable Hybrid Electric Vehicle Terminology.

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[Figures 1 and 2 below are proposed for addition.]

Example of an Off-Vehicle Charge Capable HEV with AER and Blended Operation Undergoing the Urban Charge Depleting Range Test

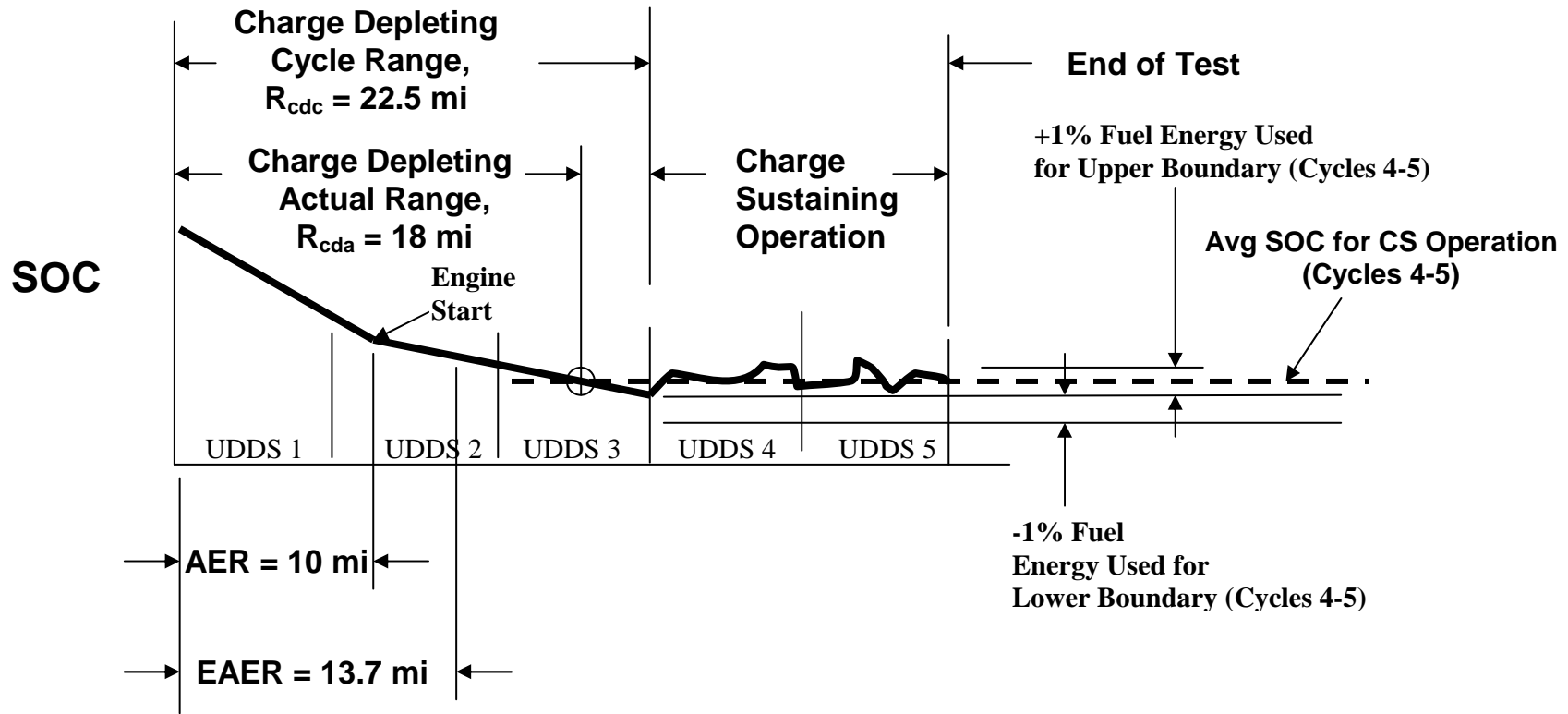
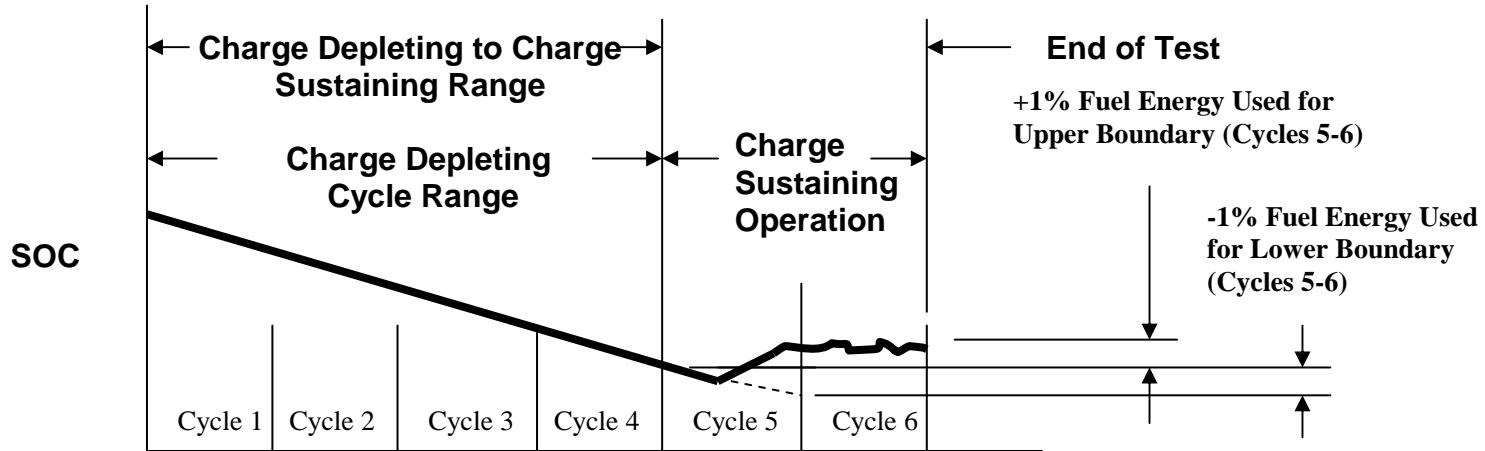


Figure 1

Example of Urban End of Test Conditions for Off-Vehicle Charge Capable HEV



Example of Urban End of Test Conditions for Off-Vehicle Charge Capable HEV with Transitional Range

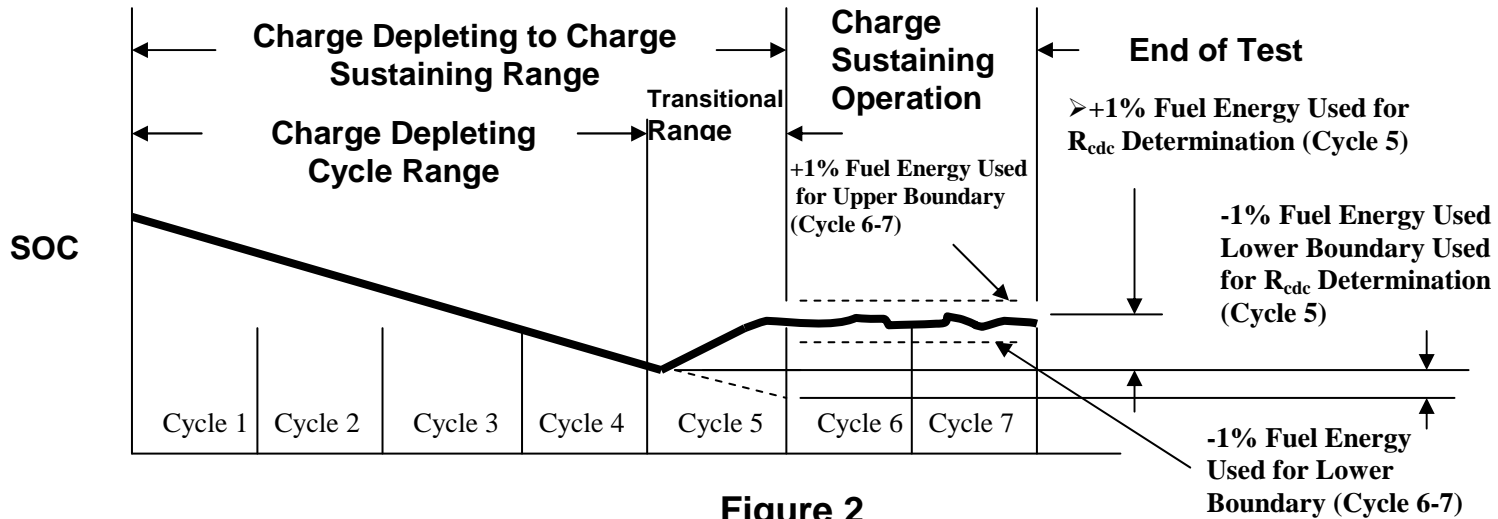


Figure 2

EI. Test Procedures for 2009 and 2010 Model Zero-Emission Vehicles and Hybrid-Electric Vehicles.

The “as adopted or amended dates” of the 40 CFR Part 86 regulations referenced by this document are the dates identified in the “California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles,” ~~incorporated by reference in section 1961(d), title 13, CCR.~~

1. Electric Dynamometer. All ZEVs must be tested using a 48-inch single roll electric dynamometer meeting the requirements of 40 CFR Subpart B, §86.108-00(b)(2).

2. Vehicle and Battery Break-In Period. A manufacturer shall use good engineering judgment in determining the proper stabilized emissions mileage test point and report same according to the requirements of section D.2.11 above.

3. All-Electric Range Test. All ~~2004~~ 2009 and subsequent ZEVs and only off-vehicle charge capable hybrid electric vehicles shall be subject to the All-Electric Range Test specified below for the purpose of determining the energy efficiency and operating range of a ZEV or of an off-vehicle charge capable hybrid electric vehicle operating without the use of its auxiliary power unit. For hybrid electric vehicles, the manufacturer may elect to conduct the All-Electric Range Test prior to vehicle preconditioning in the exhaust and evaporative emission test sequence specified in the “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles” ~~as incorporated by reference in section 1976, Title 13, CCR.~~

3.1 Cold soak. The vehicle shall be stored at an ambient temperature not less than 68°F (20°C) and not more than 86°F (30°C) for 12 to 36 hours. During this time, the vehicle’s battery shall be charged to a full state-of-charge.

3.2 Driving schedule.

3.2.1 Determination of Urban All-Electric Range-~~Urban~~.

(a) At the end of the cold soak period, the vehicle shall be placed, either driven or pushed, onto a dynamometer and operated through successive Urban Dynamometer Driving Schedules (UDDS), 40 CFR, Part 86, Appendix I, which is incorporated herein by reference. A 10-minute soak shall follow each UDDS cycle.

(b) For vehicles with a maximum speed greater than or equal to the maximum speed on the UDDS cycle, this test sequence shall be repeated until the vehicle is no longer able to maintain either the speed or time tolerances in 40 CFR §86.115-00 (b)(1) and (2), or the manufacturer determines that the test should be terminated for safety reasons, e.g. excessively high battery temperature, abnormally low battery voltage, etc. For off-vehicle charge capable hybrid electric vehicles, this determination shall be performed without the use of the auxiliary power unit.

(c) For vehicles with a maximum speed less than the maximum speed on the UDDS cycle, the vehicle shall be operated at maximum available power (or full throttle) when the vehicle cannot achieve the speed trace within the speed and time tolerances specified in 40 CFR § 86.115-00(b)(1) and (2). The test shall be terminated when the vehicle speed when operated at maximum available power (or full throttle) falls below 95 percent of the maximum speed initially achieved on the UDDS cycle or when the battery state-of-charge is depleted to the lowest level allowed by the manufacturer, or the manufacturer determines that the test should be terminated for safety reasons, e.g. excessively high battery temperature, abnormally low battery voltage, etc., whichever occurs first. For off-vehicle charge capable hybrid electric vehicles, this determination shall be performed without the use of the auxiliary power unit.

3.2.2 Determination of Highway All-Electric Range-~~Highway~~.

(a) At the end of the cold soak period, the vehicle shall be placed, either driven or pushed, onto a dynamometer and operated through two successive Highway Fuel Economy Driving Schedules (HFEDS), 40 CFR, Part 600, Appendix I, which is incorporated herein by reference. There shall be a 15 second zero speed with key on and brake depressed between two cycles and a 10-minute soak following the two HFEDS cycles.

(b) For vehicles with a maximum speed greater than or equal to the maximum speed on the HFEDS cycle, this test sequence shall be repeated until the vehicle is no longer able to maintain either the speed or time tolerances in 40 CFR § 86.115-00 (b)(1) and (2), or the manufacturer determines that the test should be terminated for safety reasons, e.g. excessively high battery temperature, abnormally low battery voltage, etc. For off-vehicle charge capable hybrid electric vehicles, this determination is optional and shall be performed without the use of the auxiliary power unit.

(c) For vehicles with a maximum speed less than the maximum speed on the HFEDS cycle, the vehicle shall be operated at maximum available power (or full throttle) when the vehicle cannot achieve the speed trace within the speed and time tolerances specified in 40 CFR § 86.115-00(b)(1) and (2). The test shall be terminated when the vehicle speed when operated at maximum available power (or full throttle) falls below 95 percent of the maximum speed initially achieved on the HFEDS cycle or when the battery state-of-charge is depleted to the lowest level allowed by the manufacturer, or the manufacturer determines that the test should be terminated for safety reasons, e.g. excessively high battery temperature, abnormally low battery voltage, etc., whichever occurs first. For off-vehicle charge capable hybrid electric vehicles, this determination shall be performed without the use of the auxiliary power unit.

(d) NEVs are exempt from the highway all-electric range ~~highway~~ test.

3.2.3 Recording requirements. Once the vehicle is no longer able to maintain the speed and time requirements specified in (2) above, or once the auxiliary power unit turns on, in the case of an off-vehicle charge capable hybrid electric vehicle, the vehicle shall be brought to an immediate stop and the following data recorded:

- (a) mileage accumulated during the All-Electric Range Test;
- (b) Net DC energy from the battery that was expended during the All-Electric Range Test (may be reported as the total DC battery energy output and the total DC battery energy input during the All-Electric Range Test);
- (c) AC energy required to fully charge the battery after the All-Electric Range Test from the point where electricity is introduced from the electric outlet to the battery charger; and
- (d) DC energy required to fully charge the battery after the All-Electric Range Test from the point where electricity is introduced from the battery charger to the battery.

Battery charging shall begin within 1 hour after terminating the All-Electric Range Test.

3.2.4 Regenerative braking. Regenerative braking systems may be utilized during the range test. The braking level, if adjustable, shall be set according to the manufacturer's specifications prior to the commencement of the test. The driving schedule speed and time tolerances specified in (2) shall not be exceeded due to the operation of the regenerative braking system.

4. Determination of Battery Specific Energy for ZEVs.

Determine the specific energy of batteries used to power a ZEV in accordance with the U.S. Advanced Battery Consortium's Electric Vehicle Battery Procedure Manual (January 1996), Procedure No. 2, "Constant Current Discharge Test Series," using the C/3 rate. The weight calculation must reflect a completely functional battery system as defined in the Appendix of the Manual, including pack(s), required support ancillaries (e.g., thermal management), and electronic controller.

5. Determination of the Emissions of the Fuel-fired Heater for Vehicles Other Than ZEVs.

The exhaust emissions result of the fuel-fired heater shall be determined by operating at a maximum heating capacity with a cold start between 68°F and 86°F for a period of 20 minutes and dividing the grams of emissions by 20. The resulting grams per minute shall be multiplied by 3.0 minutes per mile for a grams per mile value.

6. Hybrid Electric Vehicle FTP Emission Test Provisions.

Alternative procedures may be used if shown to yield equivalent results and if approved in advance by the Executive Officer of the Air Resources Board.

6.1 Vehicle Preconditioning.

To be conducted pursuant to the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles" ~~as incorporated by reference herein~~ with the following supplemental requirements:

6.1.1 Battery state-of-charge shall be set prior to initial fuel drain and fill before vehicle preconditioning.

6.1.2 For hybrid electric vehicles that do not allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that causes the hybrid electric vehicle to operate the auxiliary power unit for the maximum possible cumulative amount of time during the preconditioning drive.

6.1.3 For hybrid electric vehicles that allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that satisfies one of the following conditions:

- (i) If the hybrid electric vehicle is charge-sustaining over the UDDS, battery state-of-charge shall be set at the lowest level allowed by the manufacturer.
- (ii) If the hybrid electric vehicle is charge-depleting over the UDDS, battery state-of-charge shall be set at the level recommended by the manufacturer for activating the auxiliary power unit when operating in urban driving conditions.

6.1.4 After setting battery state-of-charge, the hybrid electric vehicle shall be pushed or towed to a work area for fuel drain and fill according to sections D.1.1. and D.1.2. of the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles" ~~as incorporated by reference herein.~~

6.1.5 Following fuel drain and fill, the vehicle shall be pushed or towed into position on a dynamometer and preconditioned. If the auxiliary power unit is capable of being manually activated, the auxiliary power unit shall be manually activated at the beginning of and operated throughout the preconditioning drive.

6.1.6 Within five minutes of completing preconditioning drive, battery state-of-charge shall be set at a level that satisfies one of the following conditions:

- (i) If the hybrid electric vehicle does not allow manual activation of the auxiliary power unit and is charge-sustaining over the UDDS, then set battery state-of-charge to a level such that the SOC Criterion (see section B., Definitions, of these procedures) would be satisfied for the dynamometer procedure (section 6.2 of these procedures). If off-vehicle charging is required to increase battery state-of-charge for proper setting, off-vehicle charging shall occur during 12 to 36 hour soak period.
- (ii) If the hybrid electric vehicle does not allow manual activation of the auxiliary power unit and is charge-depleting over the UDDS, then no battery state-of-charge adjustment is permissible.

(iii) If the hybrid electric vehicle does allow manual activation of the auxiliary power unit, then set battery state-of-charge to manufacturer recommended level for activating the auxiliary power unit when the hybrid electric vehicle is operating in urban driving conditions.

6.2 Dynamometer Procedure

To be conducted pursuant to 40 CFR § 86.135-00 with the following revisions:

6.2.1 Amend subparagraph (a): Overview. The dynamometer run consists of two tests, a “cold” start test, after a minimum 12-hour and a maximum 36-hour soak pursuant to the provisions of the “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles” ~~as incorporated by reference herein,~~ and a “hot” start test following the “cold” start test by 10 minutes. Vehicle startup (with all accessories turned off), operation over the UDDS and vehicle shutdown make a complete cold start test. Vehicle startup and operation over the UDDS and vehicle shutdown make a complete hot start test. The exhaust emissions are diluted with ambient air in the dilution tunnel as shown in Figure B94-5 and Figure B94-6. A dilution tunnel is not required for testing vehicles waived from the requirement to measure particulates. Four particulate samples are collected on filters for weighing; the first sample plus backup is collected during the cold start test (including shutdown); the second sample plus backup is collected during the hot start test (including shutdown). Continuous proportional samples of gaseous emissions are collected for analysis during each test. For hybrid electric vehicles with gasoline-fueled, natural gas-fueled and liquefied petroleum gas-fueled Otto-cycle auxiliary power units, the composite samples collected in bags are analyzed for THC, CO, CO₂, CH₄ and NO_x. For hybrid electric vehicles with petroleum-fueled diesel-cycle auxiliary power units (optional for natural gas-fueled, liquefied petroleum gas-fueled and methanol-fueled diesel-cycle vehicles), THC is sampled and analyzed continuously pursuant to the provisions of § 86.110. Parallel samples of the dilution air are similarly analyzed for THC, CO, CO₂, CH₄ and NO_x. For hybrid electric vehicles with natural gas-fueled, liquefied petroleum gas-fueled and methanol-fueled auxiliary power units, bag samples are collected and analyzed for THC (if not sampled continuously), CO, CO₂, CH₄ and NO_x. For hybrid electric vehicles with methanol-fueled auxiliary power units, methanol and formaldehyde samples are taken for both exhaust emissions and dilution air (a single dilution air formaldehyde sample, covering the total test period may be collected). Parallel bag samples of dilution air are analyzed for THC, CO, CO₂, CH₄ and NO_x.

6.2.2 Delete subparagraph (d).

6.2.3 Amend subparagraph (h): The driving distance, as measured by counting the number of dynamometer roll or shaft revolutions, shall be determined for the cold start test and hot start test. The revolutions shall be measured on the same roll or shaft used for measuring the vehicle’s speed.

6.3 Dynamometer Test Run, Gaseous and Particulate Emissions

To be conducted pursuant to 40 CFR § 86.137-96 with the following revisions:

6.3.1 Amend subparagraph (a): General. The dynamometer run consists of two tests, a cold start test, after a minimum 12-hour and a maximum 36-hour soak pursuant to the provisions of the “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles” ~~as incorporated by reference herein~~, and a hot start test following the cold start test by 10 minutes. The vehicle shall be stored prior to the emission test in such a manner that precipitation (e.g., rain or dew) does not occur on the vehicle. The complete dynamometer test consists of a cold start drive of 7.5 miles (12.1 km) and a hot start drive of 7.5 miles (12.1 km). The vehicle is allowed to stand on the dynamometer during the 10 minute time period between the cold and hot start tests.

6.3.2 Amend subparagraph (b)(9): Start the gas flow measuring device, position the sample selector valves to direct the sample flow into the exhaust sample bag, the methanol exhaust sample, the formaldehyde exhaust sample, the dilution air sample bag, the methanol dilution air sample and the formaldehyde dilution air sample (turn on the petroleum-fueled diesel-cycle THC analyzer system integrator, mark the recorder chart, start particulate sample pump No. 1, and record both gas meter or flow measurement instrument readings, if applicable), and turn the key on. If the auxiliary power unit is capable of being manually activated, the auxiliary power unit shall be activated at the beginning of and operated throughout the UDDS.

6.3.2 Delete subparagraph (13).

6.3.3 Amend subparagraph (14): Turn the vehicle off 2 seconds after the end of the last deceleration (at 1,369 seconds).

6.3.4 Amend subparagraph (15): Five seconds after the vehicle is shutdown, simultaneously turn off gas flow measuring device No. 1 and if applicable, turn off the hydrocarbon integrator No. 1, mark the hydrocarbon recorder chart, turn off the No. 1 particulate sample pump and close the valves isolating particulate filter No. 1, and position the sample selector valves to the “standby” position. Record the measured roll or shaft revolutions (both gas meter or flow measurement instrumentation readings), and reset the counter. As soon as possible, transfer the exhaust and dilution air samples to the analytical system and process the samples pursuant to § 86.140, obtaining a stabilized reading of the exhaust bag sample on all analyzers within 20 minutes of the end of the sample collection phase of the test. Obtain methanol and formaldehyde sample analyses, if applicable, within 24 hours of the end of the sample period. (If it is not possible to perform analysis on the methanol and formaldehyde samples within 24 hours, the samples should be stored in a dark cold (4°C to 10°C) environment until analysis. The samples should be analyzed within fourteen days.) If applicable, carefully remove both pairs of particulate sample filters from their respective holders, and place each in a separate petri dish, and cover.

6.3.3 Amend subparagraph (18): Repeat the steps in paragraphs (b)(2) through (b)(17) of this section for the hot start test. The step in paragraph (b)(9) of this section shall begin between 9 and 11 minutes after the end of the sample period for the cold start test.

6.3.4 Delete subparagraph (19).

6.3.5 Delete subparagraph (20).

6.3.6 Amend subparagraph (21): As soon as possible, and in no case longer than one hour after the end of the hot start phase of the test, transfer the four particulate filters to the weighing chamber for post-test conditioning, if applicable. For hybrid electric vehicles that do not allow manual activation of the auxiliary power unit and are charge-sustaining over the UDDS, a valid test shall satisfy the SOC Criterion (see Definitions, section B of these procedures).

6.3.7 Amend subparagraph (24): Vehicles to be tested for evaporative emissions will proceed pursuant to the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles" ~~as incorporated by reference herein.~~

6.4 Calculations - Exhaust Emissions

To be conducted pursuant to 40 CFR §86.144-94 with the following revisions:

6.4.1 Amend subparagraph (a): For light-duty vehicles and light duty trucks:

$$Y_{wm} = 0.43 * \frac{Y_c}{D_c} + 0.57 * \frac{Y_h}{D_h}$$

Where:

(1) Y_{wm} = Weighted mass emissions of each pollutant, i.e., THC, CO, THCE, NMHC, NMHCE, CH₄, NO_x, or CO₂, in grams per vehicle mile.

(2) Y_c = Mass emissions as calculated from the cold start test, in grams per test.

(3) Y_h = Mass emissions as calculated from the hot start test, in grams per test.

(4) D_c = The measured driving distance from the cold start test, in miles.

(5) D_h = The measured driving distance from the hot start test, in miles.

6.5 Calculations - Particulate Emissions

To be conducted pursuant to 40 CFR §86.145-82 with the following revisions:

6.5.1 Amend subparagraph (a): The final reported test results for the mass particulate (M_p) in grams/mile shall be computed as follows:

$$M_p = 0.43 * \frac{M_{pc}}{D_c} + 0.57 * \frac{M_{ph}}{D_h}$$

Where:

(1) M_{pc} = Mass of particulate determined from the cold start test, in grams per vehicle mile. (See § 86.110-94 for determination.)

(2) M_{ph} = Mass of particulate determined from the hot start test, in grams per vehicle mile. (See § 86.110-94 for determination.)

(3) D_c = The measured driving distance from the cold start test, in miles.

(4) D_h = The measured driving distance from the hot start test, in miles.

7. Hybrid Electric Vehicle Highway Emission Test Provisions

To be conducted pursuant to 40 CFR § 600.111-93 with the following revisions:

7.1 Amend subparagraph (b)(2): The highway fuel economy test is designated to simulate non-metropolitan driving with an average speed of 48.6 mph and a maximum speed of 60 mph. The cycle is 10.2 miles long with 0.2 stop per mile and consists of warmed-up vehicle operation on a chassis dynamometer through a specified driving cycle. A proportional part of the diluted exhaust emission is collected continuously for subsequent analysis of THC, CO, CO₂, and NO_x using a constant volume (variable dilution) sampler. Diesel dilute exhaust is continuously analyzed for hydrocarbons using a heated sample line and analyzer. Methanol and formaldehyde samples are collected and individually analyzed for methanol-fueled vehicles.

7.2 Amend subparagraph (f)(3): Only one exhaust sample and one background sample are collected and analyzed for THC (except diesel hydrocarbons which are analyzed continuously), CO, CO₂, and NO_x. Methanol and formaldehyde samples (exhaust and dilution air) are collected and analyzed for methanol-fueled vehicles.

7.3 Add subparagraph (f)(5): Battery state-of-charge shall be set prior to performing the HFEDS preconditioning cycle. For hybrid electric vehicles that do not allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that causes the hybrid electric vehicle to operate the auxiliary power unit for the maximum possible cumulative amount of time during the HFEDS preconditioning cycle. For hybrid electric vehicles that allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that satisfies one of the following conditions:

(i) If the hybrid electric vehicle is charge-sustaining over the HFEDS, battery state-of-charge shall be set at the lowest level allowed by the manufacturer.

(ii) If the hybrid electric vehicle is charge-depleting over the HFEDs, battery state-of-charge shall be set at the level recommended by the manufacturer for activating the auxiliary power unit when operating in highway driving conditions.

7.4 Amend subparagraph (h)(5): Operate the vehicle over one HFEDS preconditioning cycle according to the dynamometer driving schedule specified in § 600.109(b). If the auxiliary power unit is capable of being manually activated, the auxiliary power unit shall be manually activated at the beginning of and operated throughout the HFEDS preconditioning cycle.

7.5 Amend subparagraph (h)(6): When the vehicle reaches zero speed at the end of the HFEDS preconditioning cycle, the driver has 17 seconds to prepare for the HFEDS emission measurement cycle of the test. Reset and enable the roll revolution counter. During the idle period, one of the following conditions shall apply:

(i) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-sustaining over the HFEDS, the vehicle shall be momentarily turned off for 5 seconds and turned back on during the idle period. The battery state-of-charge shall be recorded after the hybrid electric vehicle has fully turned on.

(ii) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-depleting over the HFEDS, the vehicle shall remain turned on during the idle period.

(iii) For hybrid electric vehicles that allow the auxiliary power unit to be manually activated, the vehicle shall remain turned on with the auxiliary power unit operating during the idle period.

7.6 Add subparagraph (h)(9): At the conclusion of the HFEDS emission test, one of the following conditions shall apply:

(i) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-sustaining over the HFEDS, record the battery state-of-charge to determine if the SOC Criterion (see Definitions, section B of these procedures) is satisfied. If the SOC Criterion is not satisfied, then repeat dynamometer test run from subparagraph (h)(6). A total of three highway emission tests shall be allowed to satisfy the SOC Criterion. Manufacturers may elect to repeat dynamometer test run from subparagraph (h)(6) if battery energy level increased significantly relative to the initial battery state-of-charge set at the beginning of the HFEDS emission test.

(ii) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-depleting over the HFEDS, the emission test is completed.

(iii) For hybrid electric vehicles that allow the auxiliary power unit to be manually activated, the emission test is completed.

8. Hybrid Electric Vehicle SFTP Emission Test Provisions

8.1 US06 Vehicle Preconditioning

To be conducted pursuant to 40 CFR § 86.132-00 with the following revisions:

8.1.1 Amend subparagraph (n): Aggressive Driving Test (US06) Preconditioning. (1) If the US06 test follows the exhaust emission FTP or evaporative testing, the refueling step may be deleted and the vehicle may be preconditioned using the fuel remaining in the tank (see paragraph (c)(2)(ii) of this section). The test vehicle may be pushed or driven onto the test dynamometer provided that battery state-of-charge has not been set; otherwise, if battery state-of-charge is set prior to securing vehicle on dynamometer, vehicle shall be pushed or towed into position on dynamometer. Battery state-of-charge shall be set prior to performing the US06 preconditioning cycle. For hybrid electric vehicles that do not allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that causes the hybrid electric vehicle to operate the auxiliary power unit for the maximum possible cumulative amount of time during the US06 preconditioning drive. For hybrid electric vehicles that allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that satisfies one of the following conditions:

(i) If the hybrid electric vehicle is charge-sustaining over the US06, battery state-of-charge shall be set at the lowest level allowed by the manufacturer. The auxiliary power unit shall be manually activated at the beginning of and operated throughout the US06 preconditioning cycle.

(ii) If the hybrid electric vehicle is charge-depleting over the US06, battery state-of-charge shall be set at the level recommended by the manufacturer for activating the auxiliary power unit when operating in highway driving conditions. The auxiliary power unit shall be manually activated at the beginning of and operated throughout the US06 preconditioning cycle.

8.1.2 Delete subparagraphs (n)(1)(i) and (n)(1)(ii).

8.2 US06 Emission Test

To be conducted pursuant to 40 CFR §86.159-00 with the following revisions:

8.2.1 Amend subparagraph (a): Overview. The dynamometer operation consists of a single, 600 second test on the US06 driving schedule, as described in appendix I, paragraph (g), of this part. The hybrid electric vehicle is preconditioned in accordance with § 86.132-00, to bring it to a warmed-up stabilized condition. This preconditioning is followed by a 1 to 2 minute idle period that proceeds directly into the US06 driving schedule during which continuous proportional samples of gaseous emissions are collected for analysis. If engine stalling should occur during testing, follow the provisions of § 86.136-90 (engine starting and restarting). For hybrid electric vehicles with gasoline-fueled Otto-cycle auxiliary power units, the composite samples collected in bags are analyzed for THC, CO, CO₂, CH₄ and NO_x. For hybrid electric vehicles with petroleum-fueled diesel-cycle auxiliary power units, THC is sampled and analyzed continuously according to the provisions of § 86.110. Parallel bag samples of dilution air are analyzed for THC, CO, CO₂, CH₄ and NO_x.

8.2.2 Amend subparagraph (b)(2): Position (vehicle shall be pushed or towed if battery state-of-charge is set prior to securing to dynamometer otherwise vehicle may be driven as well) the test vehicle on the dynamometer and restrain.

8.2.3 Amend subparagraph (d): Practice runs over the prescribed driving schedule may be performed at test point, provided that battery state-of-charge setting is conducted after practice and an emission sample is not taken, for the purpose of finding the appropriate throttle action to maintain the proper speed-time relationship, or to permit sampling system adjustment.

8.2.4 Amend subparagraph (f)(2)(i): Immediately after completion of the US06 preconditioning cycle, idle the vehicle. The idle period is not to be less than one minute or not greater than two minutes. During the idle period, one of the following conditions shall apply:

(i) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-sustaining over the US06, the vehicle shall be momentarily turned off for 5 seconds and turned back on during the idle period. The battery state-of-charge shall be recorded after the hybrid electric vehicle has fully turned on.

(ii) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-depleting over the US06, the vehicle shall remain turned on during the idle period.

(iii) For hybrid electric vehicles that allow the auxiliary power unit to be manually activated, the vehicle shall remain turned on with the auxiliary power unit operating during the idle period.

8.2.5 Amend subparagraph (f)(2)(ix): At the conclusion of the US06 emission test, one of the following conditions shall apply:

(i) For hybrid electric vehicles that do not allow manual activation of the auxiliary power unit and are charge-sustaining over the US06, record the battery state-of-charge to determine if the SOC Criterion (see Definitions, section B of these procedures) is satisfied. If the SOC Criterion is not satisfied, then repeat dynamometer test run from subparagraph (f)(2)(i). A total of three US06 emission tests shall be allowed to satisfy the SOC Criterion. Manufacturers may elect to repeat dynamometer test run from subparagraph (f)(2)(i) if battery energy level increased significantly relative to the initial battery state-of-charge set at the beginning of US06 emission test.

(ii) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-depleting over the US06, turn off vehicle 2 seconds after the end of the last deceleration.

(iii) For hybrid electric vehicles that allow the auxiliary power unit to be manually activated, turn off vehicle 2 seconds after the end of the last deceleration.

8.3 SC03 Vehicle Preconditioning

To be conducted pursuant to 40 CFR §86.132-00 with the following revisions:

8.3.1 Amend subparagraph (o): Air Conditioning Test (SC03) Preconditioning.

(1) If the SC03 test follows the exhaust emission FTP or evaporative testing, the refueling step may be deleted and the vehicle may be preconditioned using the fuel remaining in the tank (see paragraph (c)(2)(ii) of this section). The test vehicle may be pushed or driven onto the test dynamometer provided that battery state-of-charge has not been set; otherwise, if battery state-of-charge is set prior to securing vehicle on dynamometer, vehicle shall be pushed or towed into position on dynamometer. Battery state-of-charge shall be set prior to performing the SC03 preconditioning cycle. For hybrid electric vehicles that do not allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that causes the hybrid electric vehicle to operate the auxiliary power unit for the maximum possible cumulative amount of time during the SC03 preconditioning drive. For hybrid electric vehicles that allow manual activation of the auxiliary power unit, battery state-of-charge shall be set at a level that satisfies one of the following conditions:

(i) If the hybrid electric vehicle is charge-sustaining over the SC03, battery state-of-charge shall be set at the lowest level allowed by the manufacturer. The auxiliary power unit shall be manually activated at the beginning of and operated throughout the SC03 preconditioning cycle.

(ii) If the hybrid electric vehicle is charge-depleting over the SC03, battery state-of-charge shall be set at the level recommended by the manufacturer for activating the auxiliary power unit when operating in highway driving conditions. The auxiliary power unit shall be manually activated at the beginning of and operated throughout the SC03 preconditioning cycle.

8.3.2 Delete subparagraphs (o)(1)(i) and (o)(1)(ii).

8.4 SC03 Emission Test

To be conducted pursuant to 40 CFR § 86.160-00 with the following revisions:

8.4.1 Amend subparagraph (a): Overview. The dynamometer operation consists of a single, 594 second test on the SC03 driving schedule, as described in appendix I, paragraph (h), of this part. The hybrid electric vehicle is preconditioned in accordance with §86.132-00 of this subpart, to bring the vehicle to a warmed-up stabilized condition. This preconditioning is followed by a 10 minute vehicle soak (vehicle turned off) that proceeds directly into the SC03 driving schedule, during which continuous proportional samples of gaseous emissions are collected for analysis. The entire test, including the SC03 preconditioning cycle, vehicle soak, and SC03 emission test, is either conducted in an environmental test facility or under test conditions that simulates testing in an environmental test cell (see Sec. 86.162-00 (a) for a discussion of simulation procedure approvals). The environmental test facility must be capable of providing the following nominal ambient test conditions of: 95°F air temperature, 100 grains of water/pound of dry air (approximately 40 percent relative humidity), a solar heat load intensity of 850 W/m², and vehicle cooling air flow proportional to vehicle speed. Section 86.161-00 discusses the minimum facility requirements and corresponding control tolerances for air conditioning ambient test conditions. The vehicle's air conditioner is operated or appropriately simulated for the duration of the test procedure (except for the 10 minute vehicle soak), including the preconditioning. If engine stalling should occur during testing, follow the provisions of §86.136-90 (engine starting and restarting). For hybrid electric vehicles with gasoline-fueled Otto-cycle auxiliary power units, the composite samples collected in bags are analyzed for THC, CO, CO₂, CH₄ and NO_x. For hybrid electric vehicles with petroleum-fueled diesel-cycle auxiliary power units, THC is sampled and analyzed continuously according to the provisions of § 86.110. Parallel bag samples of dilution air are analyzed for THC, CO, CO₂, CH₄ and NO_x.

8.4.2 Amend subparagraph (b)(2): Position (vehicle shall be pushed or towed if battery state-of-charge is set prior to securing to dynamometer otherwise vehicle may be driven as well) the test vehicle on the dynamometer and restrain.

8.4.3 Amend subparagraph (c)(9): Start vehicle (with air conditioning system also running). If the auxiliary power unit of the hybrid electric vehicle is capable of being manually activated, the auxiliary power unit shall be manually activated at the beginning of and operated throughout the SC03 emission test. Fifteen seconds after the vehicle starts, begin the initial vehicle acceleration of the driving schedule.

8.4.4 Amend subparagraph (c)(12): Turn the vehicle off 2 seconds after the end of the last deceleration.

8.4.5 Amend subparagraph (d)(7): Start vehicle (with air conditioning system also running). If the auxiliary power unit of the hybrid electric vehicle is capable of being manually activated, the auxiliary power unit shall be manually activated at the beginning of and operated throughout the SC03 emission test. Fifteen seconds after the vehicle starts, begin the initial vehicle acceleration of the driving schedule.

8.4.6 Amend subparagraph (d)(10): At the conclusion of the US06 emission test, one of the following conditions shall apply:

(i) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-sustaining over the SC03, record the battery state-of-charge to determine if the SOC Criterion (see Definitions, section B of these procedures) is satisfied. If the SOC Criterion is not satisfied, then turn off cooling fan(s), allow vehicle to soak in the ambient conditions of paragraph (c)(5) of this section for 10 minutes, and repeat dynamometer test run from subparagraph (d). A total of three SC03 emission tests shall be attempted to satisfy the SOC Criterion. Manufacturers may elect to repeat dynamometer test run from subparagraph (d) following a 10 minute soak in the ambient conditions of paragraph (c)(5) of this section if battery energy level increased significantly relative to the initial battery state-of-charge set at the beginning of SC03 emission test.

(ii) For hybrid electric vehicles that do not allow the auxiliary power unit to be manually activated and are charge-depleting over the SC03, turn off vehicle 2 seconds after the end of the last deceleration.

(iii) For hybrid electric vehicles that allow the auxiliary power unit to be manually activated, turn off vehicle 2 seconds after the end of the last deceleration.

9. State-of-Charge Net Change Tolerances

9.1 For hybrid electric vehicles that use a battery as an energy storage device, the following state-of-charge net change tolerance shall apply:

$$(\text{Amp-hr}_{\text{final}})_{\text{max}} = (\text{Amp-hr}_{\text{initial}}) + 0.01 * \frac{(\text{NHV}_{\text{fuel}} * m_{\text{fuel}})}{(\text{V}_{\text{system}} * K_1)}$$

$$(\text{Amp-hr}_{\text{final}})_{\text{min}} = (\text{Amp-hr}_{\text{initial}}) - 0.01 * \frac{(\text{NHV}_{\text{fuel}} * m_{\text{fuel}})}{(\text{V}_{\text{system}} * K_1)}$$

Where:

$(\text{Amp-hr}_{\text{final}})_{\text{max}}$	=	Maximum allowed Amp-hr stored in battery at the end of the test
$(\text{Amp-hr}_{\text{final}})_{\text{min}}$	=	Minimum allowed Amp-hr stored in battery at the end of the test
$(\text{Amp-hr}_{\text{initial}})$	=	Battery Amp-hr stored at the beginning of the test
NHV_{fuel}	=	Net heating value of consumable fuel, in Joules/kg
m_{fuel}	=	Total mass of fuel consumed during test, in kg
K_1	=	Conversion factor, 3600 seconds/hour
V_{system}	=	Battery DC bus voltage (open circuit)

9.2 For hybrid electric vehicles that use a capacitor as an energy storage device, the following state-of-charge net change tolerance shall apply:

$$(\text{V}_{\text{final}})_{\text{max}} = \sqrt{(\text{V}_{\text{initial}})^2 + 0.01 * \frac{(2 * \text{NHV}_{\text{fuel}} * m_{\text{fuel}})}{C}}$$

$$(\text{V}_{\text{final}})_{\text{min}} = \sqrt{(\text{V}_{\text{initial}})^2 - 0.01 * \frac{(2 * \text{NHV}_{\text{fuel}} * m_{\text{fuel}})}{C}}$$

Where:

$(\text{V}_{\text{final}})_{\text{max}}$	=	The stored capacitor voltage allowed at the end of the test
$(\text{V}_{\text{final}})_{\text{min}}$	=	The stored capacitor voltage allowed at the end of the test
$(\text{V}_{\text{initial}})^2$	=	The square of the capacitor voltage stored at the beginning of the test
NHV_{fuel}	=	Net heating value of consumable fuel, in Joules/kg
m_{fuel}	=	Total mass of fuel consumed during test, in kg
C	=	Rated capacitance of the capacitor, in Farads

9.3 For hybrid electric vehicles that use an electro-mechanical flywheel as an energy storage device, the following state-of-charge net change tolerance shall apply:

$$(\text{rpm}_{\text{final}})_{\text{max}} = \sqrt{(\text{rpm}_{\text{initial}})^2 + 0.01 * \frac{(2 * \text{NHV}_{\text{fuel}} * m_{\text{fuel}})}{(1 * K_3)}}$$

$$(\text{rpm}_{\text{final}})_{\text{min}} = \sqrt{(\text{rpm}_{\text{initial}})^2 - 0.01 * \frac{(2 * \text{NHV}_{\text{fuel}} * m_{\text{fuel}})}{(1 * K_3)}}$$

Where:

- $(\text{rpm}_{\text{final}})_{\text{max}}$ = The maximum flywheel rotational speed allowed at the end of the test
- $(\text{rpm}_{\text{final}})_{\text{min}}$ = The minimum flywheel rotational speed allowed at the end of the test
- $(\text{rpm}_{\text{initial}})^2$ = The squared flywheel rotational speed at the beginning of the test
- NHV_{fuel} = Net heating value of consumable fuel, in Joules/kg
- m_{fuel} = Total mass of fuel consumed during test, in kg
- K_3 = Conversion factor, $4\pi^2/(3600 \text{ sec}^2\text{-rpm}^2)$
- I = Rated moment of inertia of the flywheel, in kg-m^2