APPENDIX B

CALIFORNIA INTERIM CERTIFICATION PROCEDURES FOR 2004 AND SUBSEQUENT MODEL HYBRID-ELECTRIC VEHICLES, IN THE URBAN BUS AND HEAVY-DUTY VEHICLE CLASSES

Adopted: [insert date of adoption]

A. Applicability

The certification procedures in this document are applicable to 2004 and subsequent model year heavy-duty hybrid-electric vehicles and urban transit buses (HEBs).

General procedures and requirements necessary to certify a heavy-duty engine for sale in California are set forth in "California Exhaust Emission Standards and Test Procedures for 1985 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles" (hereinafter "HDD TPs"), as incorporated in title 13, CCR, section 1956.8(b), and "California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Otto-Cycle Engines," (hereinafter "HDO TPs"), as incorporated in title 13, CCR, section 1956.8(d), for testing and compliance of heavy-duty diesel and Otto-cycle engines with exhaust emission standards.

The interim certification procedures are optional for the 2004 through 2006 model years. The Executive Officer shall review test results and in-use data gathered from the 2004 through 2006 model years and make recommendations to the Board in 2006 for modifying certification procedures for 2007 and subsequent model year HEBs and heavy-duty hybrid-electric vehicles.

B. Definitions

These certification procedures incorporate by reference the definitions and abbreviations set forth in 40 CFR §86.001-2 (October 22, 1996) and §86.004-2 (January 18, 2001), the definitions and abbreviations set forth in the HDD TPs, the definitions set forth in the HDO TPs, and the definitions set forth in title 13, CCR sections 1956.1 through 1956.8, unless otherwise amended below.

1. "Auxiliary power unit (APU)" means a device that converts consumable fuel energy into mechanical or electrical energy. Examples of auxiliary power units are internal combustion engines, turbines, and fuel cells.

2. "Baseline HEB engine" means the most representative heavy-duty engine in a specific heavy-duty engine family certified by the Executive Officer that will be used in a hybrid-electric drive system for a specific HEB family. Certified emissions from the selected engine will be used in calculating an emission factor to determine the appropriate emission reduction for a particular hybrid-electric drive system.

3. "Baseline urban transit bus" means a representative, non-hybrid-electric urban transit bus selected by the Executive Officer for chassis dynamometer testing. Exhaust emissions from the selected urban transit bus, as determined by the chassis dynamometer test procedure, will be used in conjunction with the certified emissions from the engine incorporated into the baseline urban transit bus to calculate a baseline emission factor.

4. “Battery” means a device that stores chemical energy and releases electrical energy.

5. “Battery rated Ampere-hour capacity” means the manufacturer-rated capacity of a battery in Ampere-hours obtained from a battery discharged at the manufacturer’s recommended discharge rate (C/1 – C/6) such that a specified minimum cut-off terminal voltage is reached.

6. “Battery State of Charge (SOC)” means the quantity of electric energy remaining in the battery relative to the maximum rated Ampere hour (Ah) capacity of the battery expressed in percent.

7. “Capacitor” means a device that stores energy electrostatically and releases electrical energy.

8. “Capacitor SOC” means the actual measured energy content of a capacitor and expressed as a percentage of the capacitor’s maximum rated voltage squared (V^2).

9. “CCR” means California Code of Regulations.

10. “CFR” means Code of Federal Regulations.

11. “Charge-depleting HEB” means an HEB that is designed to be recharged off-board under normal conditions. Under conditions of continuous operation, the RESS of a charge-depleting HEB ultimately fully discharges and impairs vehicle operation when no off-board charging is performed and the consumable fuel is regularly replenished.

12. “Charge-sustaining HEB” means an HEB that derives all of its energy from on-board fuel under normal usage. Under conditions of continuous operation, the RESS of a charge-sustaining HEB does not fully discharge and impair vehicle operation when no off-board charging is performed and the consumable fuel is regularly replenished.

13. “Electric drive components” means the electric motor, system controller, generator, and energy storage system (batteries, capacitors, and flywheels).

14. “Electromechanical flywheel” means a device that stores rotational kinetic energy and releases that kinetic energy to an electric motor-generator system, thereby producing electrical energy.

15. “Electromechanical flywheel SOC” means a percentage of the flywheel’s maximum-rated revolutions per minute squared (rpm^2), which is based on the actual measured energy content of an electromechanical flywheel.

16. “Emission factor” means the number calculated from exhaust emissions chassis dynamometer test results and engine dynamometer test results for a HEB or conventional urban transit bus. The number, expressed in units of bhp-hr/mi, is used to calculate an emission factor ratio.

17. “Emission Factor Ratio” means the number resulting from dividing the emission factor for a HEB by the emission factor for a baseline urban transit bus, and reflects the emission reduction capability of a hybrid-electric drive system.

18. “Hybrid-electric drive system” means the propulsion system comprised of the APU and the corresponding electric drive components connected with that APU.

19. “Hybrid-electric urban transit bus (HEB)” means an urban bus equipped with at least two sources of energy stored on board; this energy is converted to motive power using an electric drive motor and an APU. The electric drive motor must be used partially or fully to drive the vehicle’s wheels.

20. “HEB Family” means the basic classification unit of a manufacturer’s product line used for the purpose of test fleet selection, based on gross vehicle weight (either 24,000 lbs to 44,000 lbs, or greater than 44,000 lbs). A family may include any engine that certifies to the same standard as the HEB test vehicle.

21. “Net Energy Change (NEC)” means the net change in energy level of a RESS expressed in Joules (watt-seconds).

22. “Propulsion energy” means energy that is derived from the vehicle’s consumable fuel and/or RESS to drive the wheels. If an energy source is supplying energy only to vehicle accessories (e.g., a 12-volt battery on a conventional vehicle), it is not acting as a source of propulsion energy.

23. “Propulsion system” means a system that, when started, provides propulsion for the vehicle in an amount proportional to what the driver commands.

24. “Regenerative braking” means deceleration of the bus caused by operating an electric motor-generator system. This act returns energy to the vehicle propulsion system and provides charge to the RESS or to operate on-board accessories.

25. “Rechargeable Energy Storage System (RESS)” means a component, or system of components, that stores energy and for which the supply of energy is rechargeable by an electric motor-generator system, an off-vehicle electric energy source, or both. Examples of RESS for HEBs include batteries, capacitors, and electromechanical flywheels.

26. **"SOC"** See "Battery SOC".

27. **"SOC_{delta}"** means delta ampere-hours measured during a test.

28. **"SOC_{final}"** means SOC at the end of a test run (Ah, V^2, or rpm^2).

29. **"$SOC_{initial}$"** means SOC at the beginning of a test run (Ah, V^2, or rpm^2).

30. **"Total Fuel Energy"** means the total energy content of the fuel, in British Thermal Units (Btu) or kWh, consumed during a test as determined by carbon balance or other standard method and calculated based on the lower heating value of the fuel.

C. Heavy-duty Hybrid-Electric Drive System Certification Requirements

Compliance with the heavy-duty hybrid-electric vehicle standards requires the development of an emission factor ratio for a heavy-duty hybrid-electric drive system with a certified baseline engine and comparison of the corresponding emissions with the applicable (e.g., urban bus or heavy-duty diesel or Otto-cycle engine) exhaust emission standards for a given engine by model year.

For model years 2004 through 2006, no more than two parties (i.e. the engine/turbine/fuel cell manufacturer and the hybrid-electric drive manufacturer) shall be granted an individual Executive Order identifying the emission standard achieved by the engine/turbine/fuel cell and the hybrid-electric drive system. For 2007 and subsequent model years, only one Executive Order shall be granted identifying the emission standard achieved by the hybrid-electric drive system.

1. One Party Responsibility. Where one party is responsible for emissions, an Executive Order shall be granted identifying the emission standard achieved by the HEB.

1.1 Certification Standards. All 2004 and subsequent model year HEBs shall, by model year, meet the exhaust emission standards or optional emission standards set forth in title 13, CCR, section 1956.1. The exhaust emissions for the hybrid-electric drive system of the HEB shall be determined in accordance with section D of this document. The certification standard for the hybrid-electric drive system shall be determined in accordance with section E of this document.

2. Two Party Responsibility. Where two parties are responsible for emissions, two Executive Orders shall be granted. One Executive Order shall be granted to the engine/turbine/fuel cell manufacturer identifying the emission standard achieved and one Executive Order shall be granted to a second party identifying the emission standard of the hybrid-electric drive system.

2.1 Certification Standards. For model years 2004 through 2006, the heavy-duty engine, turbine, or fuel cell used as a motive source in a HEB shall, by model year and size, meet the exhaust emission standards or optional emission standards set forth in title 13, CCR, section 1956, 1956.1, 1956.7, or 1956.8. All 2004 and subsequent model year hybrid-electric drive systems shall, by model year, meet the exhaust emission standards or optional emission standards set forth in title 13, CCR, section 1956.1. The exhaust emissions for a hybrid-electric drive system shall be determined in accordance with section D of this document. The certification standard for the hybrid-electric drive system shall be determined in accordance with section E of this document.

3. 25 Percent Reduction Claim. For the 2004 through 2006 model years, hybrid-electric drive system manufacturers may claim a 25 percent reduction from the NOx certification standard of the engine or turbine incorporated as part of the hybrid-electric drive system in lieu of following the test procedures set forth in sections E and F. During that period, the Executive Officer may request the manufacturer to perform chassis testing of a HEB selecting this option in accordance with the test procedures in sections D and E. If testing data indicate a reduction of exhaust emissions of less than 25 percent, the HEB family shall receive that smaller reduction.

4. Useful Life. For the 2004 through 2006 model years, the useful life of the hybrid-electric drive system shall be 5 years or 150,000 miles, whichever comes first. After that time, the useful life of the hybrid-electric drive system shall meet the useful life requirements for urban transit buses as set forth in title 13, CCR, section 2112(20), as last amended October 24, 2002.

5. Emissions Warranty. For the 2004 and subsequent model years, the hybrid-electric drive system shall, by model year, meet the warranty requirements listed in title 13, CCR, sections 2035 and 2036, as last amended December 26, 1990 and May 15, 1999, respectively.

6. Durability and Emission Testing. An HEB family with less than 50 HEBs sold for the 2004 through 2006 model years shall be exempt from durability-data vehicle and emission-data vehicle testing. An HEB family in California with 50 or more HEBs sold, and any 2007 and subsequent model year HEB families shall meet the durability-data vehicle and emission-data vehicle testing as required in title 13, CCR, section 2111 et seq, as last amended December 28, 2000.

7. Labeling Requirements. The hybrid-electric drive system shall meet labeling requirements as set forth in title 13, CCR, section 1965, as amended by the HDD TPs and the HDO TPs. In addition to the information required by those labeling requirements, the hybrid-electric drive system manufacturer shall also include the following information on the hybrid-electric drive system label:

7.1 An unconditional statement of compliance with the appropriate model year California regulations; for example:

> "This vehicle (engine or hybrid-electric drive system, as applicable) conforms to California regulations applicable to [insert MY date] model year new, ___ (for 2004 and subsequent model years, specify heavy-duty Otto-cycle engines, heavy-duty diesel engines, or urban transit bus engine, as applicable)."

For federally certified vehicles certified for sale in California, the statement must include the phrase "conforms to U.S. EPA regulations and is certified for sale in California."

For 2004 and later model year hybrid-electric drive systems to be used in urban buses that incorporate an on-road heavy-duty diesel engine and are certified to the optional reduced-emission standards, the label shall contain the following statement in lieu of the above:

> "This hybrid-electric drive system conforms to California regulations applicable to [insert MY date] model year new urban bus engines and is certified to a NOx plus NMHC optional reduced-emission standard of [insert appropriate number] g/bhp-hr (for optional reduced-emission standards specify between 0.3 and 1.8, inclusive, at 0.3 g/bhp-hr increments), and a particulate matter standard of [insert appropriate number] g/bhp-hr (specify 0.03 g/bhp-hr, 0.02 g/bhp-hr, or 0.01 g/bhp-hr)."

7.2 For 2004 and subsequent model year hybrid-electric drive systems used in urban transit buses, if the manufacturer is assigned an alternative useful life period by the Executive Officer, the label shall contain the statement:

> "This engine has been certified to meet California standards for a useful life period of [specify] years or [specify] miles of operation, whichever occurs first. This hybrid-electric drive system's actual life may vary depending on its service application."

The manufacturer may alter this statement only to express the assigned alternate useful life in terms other than years or miles (e.g., hours or miles only).

7.3 For 2004 and subsequent model year hybrid-electric drive systems used in urban transit buses, the label shall contain the statement:

> "This hybrid-electric drive system has a primary intended service application as an urban transit bus engine. It is certified to the emission standards applicable to an urban transit bus."

8. Engine Service Manuals and Equipment Maintenance Signals. The hybrid-electric drive system manufacturer shall meet service manual and maintenance signal requirements as set forth in 40 CFR §86.004-38 (October 21, 1997) and §86.007-38 (January 18, 2001) as amended by the HDD TPs and the HDO TPs.

9. Rebuild Provisions and Recordkeeping Requirement. The heavy-duty engine rebuilding practices set forth in 40 CFR §86.004-40 (October 21, 1997) as amended in the HDD TPs and HDO TPs shall also apply to the hybrid-electric drive system.

10. Information Requirements. In addition to the requirements set forth in the HDD TPs and the HDO TPs, the certification application shall include the following:

10.1 Identification and description of the hybrid-electric drive system covered by the application.

10.2 Identification of the heavy-duty vehicle weight category to which the vehicle is certifying: light heavy-duty, medium heavy-duty, heavy-heavy duty, or urban transit bus; and the curb weight and gross vehicle weight rating of the vehicle.

10.3 Identification and description of the propulsion system for the vehicle.

10.4 Identification and description of the climate control system used on the vehicle.

10.5 Projected number of heavy-duty hybrid-electric vehicles produced and delivered for sale in California.

10.6 All information necessary for the 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.

10.7 Method for determining battery state-of-charge and any other relevant information as determined by the Executive Officer.

11. Safety Procedures. For 2004 and subsequent model years, a manufacturer shall conform to the requirements specified in title 13, CCR, division 2, chapter 6.5, articles 1, 3, and 8, inclusive.

D. Hybrid-Electric Drive System Test Procedures

These test procedures incorporate by reference SAE J2711, "Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy-Duty Vehicles" (April 2002), as modified in these test procedures to apply to HEBs sold in California. For the 2004 through 2006 model years, heavy-duty hybrid-electric vehicles may follow these or equivalent procedures provided the manufacturer obtains prior written approval from the Executive Officer (EO).

The test procedure for determining compliance with standards applicable to the turbine or fuel cell used as the motive power in a hybrid-electric bus shall be determined by the Executive Officer on a case-by-case basis.

1. Chassis Dynamometer Test Preparations

1.1 Test Site. The ambient temperature levels encountered by the test vehicle shall be no less than 20 °C (68 °F) and no greater than 30 °C (86 °F). Ambient temperatures shall be recorded at the beginning and end of the test period. Adequate test site capabilities for safe venting and cooling of batteries, protection from exposure to high voltage, and any other necessary precaution shall be provided during testing. A fixed-speed fan shall direct cooling air to the vehicle to maintain the engine operating temperature as specified by the manufacturer during testing, and shall be operated only when the vehicle is in operation. Fans for brake cooling may be utilized during testing.

1.2 Pre-Test Data Collection. Vehicle demographics shall be recorded prior to testing including the vehicle identification number, gross vehicle weight (from vehicle data plate), curb weight (from vehicle data plate or by weighing), engine manufacturer, model year and type, engine serial number, engine displacement and number of cylinders, engine rated power and speed, tire size, transmission type, number of speeds, presence or absence of retarder, exhaust gas aftertreatment type, and rear axle ratio. Pre-test data shall also include details of the type, power, and speed of the electric motor(s); and type and capacity of the RESS.

1.3 Fuel Specifications. The test fuel shall meet the certification specifications set forth in the HDD TPs and HDO TPs.

1.4 Vehicle Preparation. Vehicle preparation and preconditioning shall be conducted in accordance with 40 CFR §86.1231-90 (April 11, 1989) and 40 CFR §86.1232-90 (April 11, 1989).

1.4.1 Prior to testing, the vehicle shall be stabilized to a manufacturer-determined distance or to 4,000 miles.

1.4.2 Vehicles shall be tested at curb weight plus driver weight and one half seated passenger load using a weight of 150 lbs per passenger.

1.4.3 Manufacturer's recommended tires shall be used. Tire pressures shall be set at the beginning of the test at the pressure used to establish the dynamometer road-load coefficients and shall not exceed levels necessary for safe operation. Tires shall be conditioned as recommended by the vehicle manufacturer and shall be the same size as would be used in service.

1.4.4 The vehicle lubricants normally specified by the manufacturer shall be used.

1.4.5 The vehicle shall be driven with appropriate accelerator pedal movement to achieve the time-versus-speed relationship prescribed by the driving cycle. If test vehicles are equipped with manual transmission, the transmission shall be shifted in accordance with procedures that are representative of shift patterns that may reasonably be expected to be followed by vehicles in use.

1.4.6 If the vehicle has a regenerative braking system, the vehicle shall be tested on the dynamometer with the identical control strategy as used in service. Vehicles equipped with an antilock braking system or traction control system may require modifications (i.e. defeat) to those systems during dynamometer testing to achieve normal operation of the regenerative braking system.

1.4.7 If necessary, vehicles with air suspension may be aired up from an external source prior to testing. After the vehicle has reached sufficient air pressure to achieve proper suspension leveling and service brake operation, external air shall be disconnected from the vehicle and shall not be reconnected during emissions testing or between testing events during the key-off period.

1.4.8 Off-vehicle charging shall be allowed only for the battery conditioning of charge-sustaining HEVs.

1.5 Chassis Dynamometer Specifications. The chassis dynamometer shall be capable of mimicking the transient inertial load, aerodynamic drag and rolling resistance associated with normal operations of heavy-duty vehicles. The transient inertial load shall be simulated using appropriately sized flywheels or electronically controlled power absorbers. The driver shall be provided a visual display of the desired and actual vehicle speed to allow the driver to operate the vehicle on the prescribed cycle.

1.5.1. Coastdown analysis. The drag and rolling resistance shall be established as a function of vehicle speed as referenced in 40 CFR §1229-85 (October 6, 2000) or another appropriate method approved by the Executive Officer. The vehicle weight for the on-road coastdown shall be the same as the anticipated vehicle testing weight as simulated on the dynamometer. Vehicles equipped with regenerative braking systems that are activated at least in part when the brake pedal is not depressed shall have their regenerative braking systems disabled during the deceleration portion of coastdown testing, preferably through temporary software changes in the vehicle's control system

1.6 Test Instrumentation. Equipment referenced in 40 CFR §86.1301-90 (April 11, 1989) to 40 CFR §86.1326-90 (April 11, 1989) (including exhaust emissions sampling and analytical systems) shall be required for emissions measurements. All instrumentation shall be NIST-traceable (National Institute of Standards and Technology). The following instruments shall be required for as-needed usage: a DC wideband Ampere-hour meter with an integration period of less than 0.05 seconds if an integration technique is used; an instrument to measure a capacitor's voltage; an instrument to measure an electromechanical flywheel's rotational speed; an AC Watt-hour meter to measure AC Recharge Energy; and a voltmeter and ammeter. Tunnel flow volume shall be set at the minimum level possible for vehicles such that a carbon balance for fuel efficiency and a hydrocarbon balance for tunnel integrity can be performed accurately and the lowest possible detection limits can be determined. Emission levels that are determined to be below detection limit shall be cited as less than the detection limit value.

2. Chassis Dynamometer Test Procedure

2.1 Vehicle Propulsion System Starting and Restarting. The vehicle's propulsion system shall be started according to the manufacturer's recommended starting procedures in the owner's manual. Only equipment necessary to the primary propulsion of the vehicle during normal service shall be operated.

2.2 Driving cycles. Chassis testing shall include two separate test cycles as follows: one cold start and three hot start tests using the Orange County bus cycle (Appendix C); and one cold start and three hot start tests using the Urban Dynamometer Driving Schedule (UDDS) (40 CFR §86 Appendix I(d)) (April 29, 1998).

2.2.1 During the interim certification period, the Executive Officer may request data from one cold start and three hot starts using the Central Business District (CBD) cycle which will not be used for certification.

2.2.2 The applicant may request a substitution of one test cycle with one representative of specific transit fleet operation for approval of the Executive Officer.

2.2.3 The test vehicle shall be operated through at least one preliminary run of the desired test cycles to familiarize the driver with vehicle operation and verify function of laboratory instrumentation.

2.2.4 A cycle length of approximately 30 minutes shall be used for all chassis tests. For driving cycles less than 30 minutes in duration, repetitions of the cycle shall be run back-to-back for a total cycle length of approximately 30 minutes. Chassis tests shall also consist of a normalized condition prior to the test, including either a 12-hour cold soak or a warm-up followed by a 20- to 30-minute key-off period.

2.2.5 If at any point during the test vehicle propulsion is not possible or the driver is warned by the vehicle to discontinue driving because the RESS energy supply is too low, the test shall be considered invalid.

2.3 Cold and Hot Emission Tests

2.3.1 Cold start test cycles shall include all emission data from the moment the vehicle is started, including the actual start event. The vehicle shall be cold soaked for a minimum of 12 hours to ensure that all components are at ambient temperature. The vehicle shall remain in the key-off position for 30 minutes until testing begins. A separate vehicle or other equipment (e.g. electric heaters) as necessary shall be utilized to bring the dynamometer to operating temperature. The vehicle shall be started and idled for one minute, after which time the 30-minute test cycle shall commence. Emission measurements shall be taken from one minute before the vehicle is started through test cycle completion. At the end of the test cycle the vehicle shall be returned to the key-off condition.

2.3.2 Hot test cycles shall include all emission data from the moment the vehicle is started, excluding the actual start event. The vehicle shall be started and warmed to operating temperature utilizing the same test cycle that will be used for emission characterization. Multiple back-to-back hot test events must include a 20- to 30- minute key-off condition in between each test event. Once the vehicle is at operating temperature the vehicle shall be turned off and will remain in the key-off position for approximately 20 to 30 minutes. The vehicle shall be restarted and idled for one minute, at which time the 30-minute test cycle shall begin and emission measurements will be taken. At the end of the test cycle the vehicle shall be returned to the key-off condition.

2.4 Intra-test Pauses. Between two test events, the vehicle shall remain with the key switch in the key-off position for 20 to 30 minutes, with the engine enclosure closed and the brake pedal not depressed.

2.5 Test Termination. The test shall be terminated at the conclusion of the test run. If necessary, a one-minute idle may be added at the end of the test cycle before termination for collection of emissions remaining in the sampling train.

2.6 Data Recording.

2.6.1 The emissions from the vehicle exhaust shall be ducted to a full-scale dilution tunnel where the gaseous emissions of hydrocarbons, carbon monoxide, oxides of nitrogen (both nitric oxide and nitrogen dioxide) and carbon dioxide shall be measured on a continual basis at a frequency of 5 Hz or greater. An integrated bag sample of the dilution tunnel may be collected and analyzed for carbon monoxide and carbon dioxide levels, and these may be compared to the continuous measurements for carbon monoxide and carbon dioxide as a quality assurance check. Modal results must be within five percent of bag sample results for modal results to be used. Alternatively, the measured values for carbon monoxide and carbon dioxide may be obtained from the integrated bag sample. Particulate matter shall be measured gravimetrically using fluorocarbon-coated glass fiber filters by weighing the filters before and after testing. Filters shall be conditioned to temperature and humidity conditions as specified in 40 CFR §86.1312-88 (September 5, 1997).

2.6.2 For each constituent, a background sample using the same sampling train as used during the emission testing shall be measured before and after the emission test, and the background correction shall be performed as specified by 40 CFR §86.1343-88 (September 5, 1997). For a compressed natural gas-fueled vehicle, and in cases where non-methane hydrocarbons are a species of interest, the integrated methane and non-methane content of hydrocarbons shall be measured, using gas chromatography analysis of integrated bag samples for each run. If necessary, the tunnel inlet may be filtered for PM with a HEPA filter to aid in lowering the detection limits.

2.6.3 Fuel consumed shall be determined by carbon balance from the analytical instruments, and the number of dynamometer roll revolutions shall be used to determine the distance traveled during the driving cycles.

2.6.4 SOC of the vehicle shall be measured continuously (at a rate of 1Hz or greater) and recorded throughout the entire test. Recorded data shall then be time integrated against the emission measurement data at the beginning and end of the test to coincide with the emission measurement portion of the chassis test. Provided the SOC is measured, time sequenced and integrated in accordance with the procedures in this document, only the beginning and ending SOC values are necessary in the final test report. Both Ah and system voltage shall be recorded during the test, as outlined in the method for determining NEC.

3. Final Report.

3.1 Exhaust Emissions and FE. The exhaust emissions and fuel economy of the vehicle shall be reported in grams per mile and miles per diesel equivalent gallon, respectively. Total fuel energy shall be reported in British Thermal Units (Btu).

3.1.1 Calculations for exhaust emissions are referenced in 40 CFR §86.1342-90 (September 5, 1997) with the following revision to paragraph (a):

$$A_{WM} = (1/7)(Y_C/D_C) + (6/7)(Y_H/D_H)$$

Where:

A_{WM} = Weighted mass emission level in grams per vehicle mile

Y_C = Mass emissions from the cold start test in grams

Y_H = Averaged mass emissions from the hot start tests in grams

D_C = Measured driving distance from the cold start test in miles

D_H = Averaged measured driving distance from the hot start tests in miles

3.2 SOC Difference. The state of charge difference of the RESS shall be measured during the test and reported along with the RESS NEC.

3.3 Net Energy Change (NEC). NEC calculations for batteries, capacitors, and electromechanical flywheels are listed below.

3.3.1 Batteries. Either of two equations may be used to calculate the NEC for batteries:

(1) $$\mathbf{NEC = [SOC_{final} - SOC_{initial}] * V_{system} * K_1}$$

where

SOC = Battery SOC at the beginning and end of the test run, in Ampere-hours (Ah). If the SOC_{final} and $SOC_{initial}$ values are in amp-seconds, the conversion factor is not used.

V_{system} = Battery's DC nominal system voltage as specified by the manufacturer, in volts (V)

K1 = Conversion factor = 3600 (seconds/hour; not used if SOC_{final} and $SOC_{initial}$ values are in seconds)

or,

(2) $$\mathbf{NEC = SOC_{delta} * V_{system} * K_1}$$

where

SOC_{delta} = Delta Ampere-hours during a test

V_{system} = Battery's DC nominal system voltage as specified by the manufacturer, in volts (V)

K_1 = Conversion factor = 3600 (seconds/hour; not used if SOC_{final} and $SOC_{initial}$ values are in seconds)

3.3.2 Capacitors. The following equation calculates NEC for capacitors:

$$\mathbf{NEC = (C/2) * [SOC_{final} - SOC_{initial}]}$$

where

SOC = The capacitor SOC at the beginning and end of the test run, in $(V)^2$

C = Rated capacitance of the capacitor as specified by the manufacturer, in Farads (F)

3.3.3 Electromechanical Flywheels. The following equation shall be used to calculate NEC for electromechanical flywheels:

$$\mathbf{NEC = (1/2) * I * [SOC_{final} - SOC_{initial}] * K_2}$$

where

SOC = Flywheel state-of-charge at the beginning and end of the test run, in $(rpm)^2$

I =	Rated moment of inertia of the flywheel system, in kilogram-meter^2 (kg-m^2)
K_2=	Conversion factor = $4\pi^2/3600$ (rad^2/sec^2/rpm^2)

3.4 NEC Variance Determination.

3.4.1 Total Fuel Energy. Total fuel energy is the energy value of the fuel consumed by the internal combustion engine, turbine, or fuel cell during the test and shall be calculated using the following equation:

$$\textbf{Total Fuel Energy} = NHV_{fuel} * m_{fuel}$$

where

NHV_{fuel} =	Net heating value (per consumable fuel analysis as specified by ASTM) in Joules per kilogram (J/kg)
M_{fuel} =	Total mass of fuel consumed over test, in kilograms (kg)

3.4.2 Total Cycle Energy. The total cycle energy shall be reported in watt-seconds or converted to kWh.

Total Cycle Energy = Total Fuel Energy – NEC

3.4.3 Determination Procedure. To determine if a test run has an acceptable NEC, divide NEC by total cycle energy. If the absolute value of the calculation yields a number less than or equal to 2%, as shown in the equation below, the NEC variance is within tolerance levels.

$$\textbf{(NEC/total cycle energy) * 100\%} \le \textbf{2\%}$$

Test runs with NEC variance greater than +/- 2% shall be considered invalid.

3.5 Final Test Report. The final test report shall include all measured parameters, including vehicle configuration, vehicle statistics, test cycles, measured parameters and calculated test results.

4. Charge-Depleting Hybrid-Electric Vehicles.
Modifications to this procedure for measuring fuel economy and emissions of charge-depleting heavy-duty hybrid-electric vehicles may be made upon approval of the Executive Officer.

5. Conventional Drivetrain Urban Transit Buses. Modifications to this hybrid-electric drive system procedure for measuring fuel economy and emissions of conventional drivetrain urban transit buses may be made upon approval of the Executive Officer.

E. Certification by Emission Factor Ratio Application

The applicant shall provide both engine and vehicle test results when using the following procedure. Engine test results shall be obtained from an engine manufacturer who has complied with the HDD TPs, HDO TPs, or alternative procedures approved by the Executive Officer. Vehicle test results shall be obtained from the party certifying the hybrid-electric drive system in accordance with the procedures set forth in Section D of this document. An emission factor shall be calculated from the two results to determine the emissions reduction achieved by the hybrid-electric drive system.

1. Emission Factor. An emissions factor shall be calculated by following equation:

$$\mathbf{EF} = \frac{\textbf{Vehicle NOx (g/mi)}}{\textbf{Engine NOx (g/bhp-hr)}}$$

where

EF = emission factor of the vehicle in bhp-hr/mi

Vehicle NOx = weighted mass emissions level of NOx determined from chassis dynamometer testing in g/mi

Engine NOx = weighted mass emissions level of NOx determined from engine dynamometer testing in g/bhp-hr

Emission factors shall be calculated for HEBs and for baseline urban transit buses. The baseline urban transit bus shall be selected by the Executive Officer and tested by the Air Resources Board. The resulting data will be available for use by manufacturers applying for certification.

2. Emission Factor Ratio. An emission factor ratio shall be calculated by the following equation:

$$\mathbf{EFR} = \frac{\mathbf{EF}_{\mathbf{hybrid}}}{\mathbf{EF}_{\mathbf{baseline}}}$$

where

EFR = emission factor ratio

EF_{hybrid} = emission factor calculated for a hybrid-electric urban transit bus

$EF_{baseline}$ = emission factor calculated for a baseline urban transit bus

3. Application of Emission Factor Ratio for Hybrid-Electric Bus Certification. The NOx certification value for a hybrid-electric bus shall be calculated by applying the following equation:

$$\mathbf{HEB_{cert} = EFR * Engine\ NOx}$$

where

HEB_{cert} = hybrid-electric bus NOx certification value in g/bhp-hr

EFR = emission factor ratio

Engine NOx = weighted mass emissions level of NOx determined from engine dynamometer testing in g/bhp-hr