This document includes updated Sections 2 and 7 of the draft proposed “California Certification and Installation Procedures for Medium- and Heavy-Duty Vehicle Hybrid Conversion Systems” (Handout #2) distributed at the July 13, 2016 Innovative Technology Regulation (ITR) public workshop. More information regarding the July 13, 2016 public workshop and development of the proposed ITR can be found at: http://www.arb.ca.gov/msprog/itr/itr.htm.

This document is provided to solicit stakeholder feedback at the July 26, 2016 Medium- and Heavy-Duty Vehicle Hybrid Technology Emission Test Procedures Public Work Group meeting. The draft language in this document is only intended to encourage stakeholder feedback and should not be construed as a formal regulatory proposal. Any stakeholder feedback submitted prior to the ‘45-day’ formal comment period will not be considered part of the official rulemaking record. If you would like any feedback submitted to be considered part of the record, you must re-submit it during the formal public comment period.

Draft Proposed California Certification and Installation Procedures for Medium- and Heavy-Duty Vehicle Hybrid Conversion Systems: Sections 2 and 7 (Hybrid Technology Emission Testing Element)

2. DEFINITIONS, ACRONYMS AND ABBREVIATIONS

These procedures incorporate by reference the definitions and abbreviations set forth in California Code of Regulations, title 13, section 2208 (Innovative Technology Regulation), and 40 Code of Federal Regulations, Part 1065, incorporated by reference herein, unless otherwise amended below.

(a) “55 Mile Per Hour (mph) Cruise Cycle” means the procedure described in 40 Code of Federal Regulations, Part 1037.510 (a), which is hereby incorporated by reference.

(b) “Average Driving Speed” means the distance traveled divided by the test cycle time, excluding any time during the test cycle at which the vehicle operates at zero miles per hour (i.e., idles or is otherwise at rest).

(c) “Base engine” means a California-certified configuration of a motor vehicle engine prior to any modifications necessary for the engine to operate as a hybrid.

(d) “Base vehicle” means a California-certified configuration of a motor vehicle prior to any modifications necessary for the vehicle to operate as a hybrid.

(e) “Coefficient of Variation” or “CV” for a data set is the normalized measure of the dispersion of a probability distribution, calculated as the ratio of the standard deviation to the mean.

DRAFT FOR JULY 26, 2016 PUBLIC WORK GROUP MEETING DISCUSSION
(f) “Engine automatic stop-start system” means a mechanism that automatically turns off the internal combustion engine when the vehicle is stopped, such as at a traffic light, and restarts when the vehicle operator pushes the accelerator.

(g) “Federal Test Procedure” or “FTP-75” means the test procedure as described in Code of Federal Regulations, Part 86.130-00 (a) through (d) and (f), which is hereby incorporated by reference.

(h) "Hybrid conversion system" or “conversion system” means a package of energy storage and delivery, ignition, emission control, on-board diagnostics (OBD), and engine components that are modified, removed, or added during the process of modifying a base engine or vehicle to operate as a hybrid.

(i) “Orange County Bus Cycle” means the procedure described in Appendix C of ARB’s Staff Report: Initial Statement of Reasons – Proposed Modifications to the Public Transit Fleet Rule and Interim Certification Procedures for Hybrid Electric Urban Transit Buses; September 6, 2002; which is hereby incorporated by reference.

(j) “Positive Kinetic Energy” or "PKE" means \(\frac{1}{\text{total distance}} \times \sum [(\text{velocity}(i)^2 - \text{velocity}^(i-1)^2)]\) summed over samples where velocity(i) > velocity(i-1), for velocity data collected on the interval of i = 1 to n number of time samples, evaluated on a one Hertz basis in feet/second\(^2\).

(k) “Transient Portion of the Heavy Heavy-Duty Truck 5 Mode Cycle” means the test cycle specified in 40 Code of Federal Regulations, Part 1037, Appendix I, which is hereby incorporated by reference.

(l) “US-06 Supplemental Federal Test Procedure” means the test cycle specified in 40 Code of Federal Regulations, Part 86.159-00, which is hereby incorporated by reference.

(m) “Useful life” for purposes of these procedures, means the duration, expressed in miles or operating hours, of the longest regulatory durability period for the new vehicle or engine emission standards to which the base vehicle or engine was certified.

(n) “Zero-emission power take-off” or “electric power take-off” (ePTO) means a method for taking power from an on-vehicle source (typically a battery) that produces no emissions of regulated pollutants and which can be used to power a non-vehicular device that is permanently connected to the vehicle and is not used to propel the vehicle.
7. HYBRID TECHNOLOGY EMISSION TEST PROCEDURES

(a) General Requirements

(1) A hybrid conversion of an ARB-certified vehicle between 6,001 and 14,000 pounds GVWR, or an ARB-certified engine installed in a vehicle between 6,001 and 14,000 pounds GVWR, must demonstrate compliance with these procedure’s exhaust emission requirements pursuant to Section 7(d).

(2) A hybrid conversion of an ARB-certified engine installed in a vehicle over 14,000 pounds GVWR must demonstrate compliance with these procedure’s exhaust emission requirements pursuant to either Section 7(c) or Section 7(d).

(3) In lieu of exhaust emission testing of PM pursuant to these procedures, a manufacturer may provide an engineering evaluation demonstrating that hybridization of the base engine or vehicle will not increase PM emissions. The Executive Officer shall evaluate said demonstration based upon data and other information provided by the manufacturer, including engine certification data, and his or her engineering evaluation of whether hybridization of the base engine or vehicle is likely to increase PM emissions.

(4) A compression-ignition engine must measure and report CO and HC emission results to the Executive Officer pursuant to these procedures, but shall be exempted from CO and/or HC exhaust emission test compliance evaluation pursuant to Section 7(c)(6) and Section 7(d)(5) of these procedures if the manufacturer provides an engineering evaluation demonstrating that hybridization of the base engine or vehicle will not increase CO and/or HC emissions. The Executive Officer shall approve such evaluation if he or she determines, based upon data and other information provided by the manufacturer, including engine certification data, and his or her engineering judgement, that the hybrid system’s operational characteristics are unlikely to increase emissions of these pollutants from the base engine or vehicle.

(b) Hybrid Technology Emission Test Plan

The manufacturer must submit a proposed Hybrid Technology Emission Test Plan as part of the application for Tier 2 or Tier 3 certification pursuant to Section 8. The proposed Hybrid Technology Emission Test Plan must be submitted at least sixty days prior to the proposed commencement of emission testing, and the manufacturer may not commence emission testing until the proposed plan has been approved in writing by the Executive Officer. The Hybrid Emission Test Plan and emission testing pursuant to this plan must comply with all applicable requirements of these procedures and represent a good faith effort by the applicant to utilize drive cycles that most accurately reflect how the hybrid vehicle will be operated in California. In addition, the plan must include
provisions for collecting data that can be used to accurately assess the actual in-use impact of converting applicable base engines or vehicles. The Executive Officer will evaluate the Hybrid Technology Emission Test Plan based upon his or her engineering judgement that it complies with requirements of these procedures and enables collection of accurate data that is likely to reflect the in-use emission impact of converting the applicable base engine or vehicle. An applicant must adhere to the Executive Officer-approved Hybrid Technology Emission Test Plan when conducting emission testing pursuant to these procedures.

The Hybrid Technology Emission Test Plan must be provided in a format approved by the Executive Officer. At a minimum, the Hybrid Technology Emission Test Plan must include the following elements:

(1) Contact Information: Identification of the contact person, phone number, physical address, and e-mail address of the responsible party submitting the application, and whether they are business or personal;

(2) Proposed Logistical Information: Proposed test date(s), location(s) or test facilities, and entity conducting the testing. Only emission testing conducted on approved dates and as otherwise described in this section will be considered valid for the purposes of these procedures. ARB reserves the right to have its employee(s) or representative(s) present during emission testing;

(3) Proposed Base and Hybrid Engine Information: Make(s), model(s) and model year(s); anticipated mileage at test start; fuel used; displacement (L); aspiration; maximum power (kW) and torque (Nm); emission aftertreatment technology; California NOx, HC, CO, and PM certification level; and family emission limit (FEL);

(4) Proposed Base and Hybrid Vehicle Information: Curb weight(s), gross vehicle weight rating(s) and test weight(s); anticipated mileage at test start; drive train description(s); and California NOx, HC, CO, and PM certification levels;

(5) Proposed Hybrid Energy Storage System Information: Battery description, including type of battery chemistry, usable energy capacity, battery pack voltage, number of battery modules, and an estimate of battery pack cycle life. The manufacturer must include descriptions of the battery management system and battery pack thermal management strategy (active or passive cooling), and provide the weight of each battery module, the weight of the battery pack (including removable pack structures), and any energy storage devices used in addition to, or in lieu of, batteries, such as ultra-capacitors, flywheels, hydraulic assist devices, or other energy storage technologies;
DRAFT PROPOSED INNOVATIVE TECHNOLOGY REGULATION –
HYBRID TECHNOLOGY EMISSION TESTING ELEMENT

(6) Conversion description: A description of the conversion system, including parts removed from the base vehicle, engine control system modifications, all major parts installed, calibration identification(s), and an electronic copy of calibration file(s);

(7) Proposed Operation of Mechanical and Electrical Accessories: Description of the base and hybrid vehicle’s mechanical and electrical accessories and their proposed usage during emission testing; and

(8) Additional Requirements: Applicants proposing to conduct emission testing pursuant to Section 7(c) of these procedures must also include the following in their proposed Hybrid Technology Emission Test Plan:

(A) Proposed Equipment: Description of the proposed emission test equipment and applicable equipment measurement techniques and calibrations to be used for measuring required engine and vehicle operating parameters; exhaust emissions; and location, elevation, and weather conditions;

(B) Proposed Test Route: Proposed test route descriptions, including route distances (miles) and times (seconds); average anticipated vehicle speeds (mph); percent at zero-speed (i.e., time during which the vehicle idles or is otherwise at rest); anticipated average PKE (feet per second squared); minimum elevation (feet above sea level); maximum elevation (feet above sea level); and aerial maps of proposed test routes;

(C) Cold-Start Strategy: Proposed strategy for evaluating cold-start emissions from the base and hybrid vehicle, pursuant to these procedures; and

(D) Defining a Valid Test Run: Proposed thresholds for the following parameters to ensure that all base and hybrid vehicles were driven over both of the required test routes as similarly as possible:

(i.) For the transient test route, the proposed coefficient of variation (CV) of average driving speed for each of the eight or more total base and hybrid vehicle test runs, and proposed CV for average PKE for the same base and hybrid vehicle test runs;

(ii.) For the high-speed route, proposed CV for average driving speed and proposed proximity to 55 mph at which the vehicle spends at least 80 percent of its time; and

(iii.) For both routes, proposed criteria for excluding a test run if idle time differs significantly from other vehicles tested over the same route. A vehicle with an engine automatic stop-start system must be emission tested with such system disabled.
(c) Portable Emission Measurement System (PEMS) Testing

Unless otherwise indicated in this section, emission test set-up and steps to execute the test process must be performed in accordance with the on-road testing element of *SAE International J1526: Fuel Consumption Test Procedure – Engineering Method* (SAE J1526), revised September 2015, and incorporated by reference herein. PEMS equipment specifications; measurement principles; verification requirements; and emission measurement, calibration, and verification methodologies are set forth in 40 Code of Federal Regulations, Part 1065, Subpart J.

(1) Vehicle Selection and Preparation.

The hybrid vehicle used for emission testing is to be the base engine or vehicle converted with the proposed hybrid system, as identified in the manufacturer’s conversion system application, while the vehicle with which it is compared must reflect the “pre-converted” base engine or vehicle configuration. For post-transmission hybrids, the manufacturer may propose, as part of its Hybrid Technology Emission Test Plan, to utilize the converted hybrid vehicle with the hybrid system disabled as the base vehicle if it can demonstrate that the engine and vehicle with the hybrid system disabled will operate with the same emission characteristics as the pre-converted vehicle.

(A) Mileage. Minimum mileage of baseline and hybrid vehicles for testing must be as follows at the time of emission testing:

(i.) To ensure emission stability, the baseline vehicle and the hybrid vehicle (after installation of the hybrid conversion system) must have accumulated a minimum of 4,000 miles. Vehicles with ePTO may alternately accumulate a minimum of 125 hours of operation prior to testing, if verified by a non-resettable, vehicle-integrated hour meter.

(ii.) If the odometer of one vehicle is less than or equal to 5,000 miles, the mileage on all baseline and hybrid vehicles must be within 1,000 miles of each other.

(iii.) If the odometer on all vehicles is greater than 5,000 miles but less than or equal to 10,000 miles on one vehicle, the mileage on all vehicles must be within 3,000 miles of each other.

(iv.) If the odometer on all vehicles is greater than 10,000 miles but less than or equal to 30,000 miles on one vehicle, the mileage on all vehicles must be within 10,000 miles of each other.
(v.) If the odometer is greater than 30,000 miles on all vehicles, the mileage on all vehicles must be within 50,000 miles of each other.

(vi.) Neither vehicle may have mileage that exceeds its regulatory useful life.

(B) Vehicle Test Weight. Heavy-duty vehicles are to be tested at the prescribed weight specified in Section D. 1.4.2. of the “California Interim Certification Procedures for 2004 and Subsequent Model Hybrid Electric and Other Hybrid Vehicles, in the Urban Bus and Heavy-Duty Vehicle Classes” (Amended December 12, 2013). Other vehicles’ test weights must follow 40 Code of Federal Regulations, Part 86.129-94’s specifications.

(C) Vehicle Pre-Conditioning. Vehicle pre-conditioning must be conducted to minimize the possibility of an infrequent diesel particulate filter (DPF) regeneration event during the emission test runs. The preconditioning may consist of an active forced DPF regeneration or a passive regeneration method consistent with the engine or aftertreatment manufacturer recommendations. If a DPF regeneration occurs during a test run, the run will be invalid and must be removed from the test data set. If the user lacks the capability to monitor appropriate regeneration messages over the controller area network (CAN) data bus, the exhaust temperature across the DPF should be measured to determine occurrence of an active DPF regeneration, as indicated by a sustained temperature increase across the DPF. Emission results are to be adjusted to account for regeneration events, pursuant to 40 Code of Federal Regulations, Part 86.004-28(i)(1).

(2) Test Route Selection.

(A) The hybrid and base vehicle must be emission tested over at least four valid test runs, as defined by the manufacturer and approved by the Executive Officer pursuant to these procedures, for each of the following two test routes:

(i) A transient route, with an average driving speed of between 15 and 30 mph and an average positive kinetic energy (PKE) of between 0.85 and 1.50 feet per second squared. This route must be representative of the transient, slower speed operation anticipated for the hybrid vehicle class and vocation, and should avoid freeway driving; and

(ii) A high-speed route, with the vehicle operating at least 80 percent of the time between 53 and 57 mph. If it is infeasible for the proposed hybrid or base vehicle to meet this criteria, the manufacturer may propose, as part of its Hybrid Technology Emission Test Plan, an alternate proximity around 55 mph that it commits to operate for at least 80 percent of the time. The Executive Officer will evaluate this alternate proposed proximity to 55 mph based upon his or her engineering evaluation of data or other information provided by the manufacturer regarding whether the hybrid or
base vehicle gearing or other attributes make it infeasible for the hybrid or base vehicle to consistently operate within 2 mph of 55 mph.

(B) For both routes, the manufacturer must also identify approximately what percent of time the vehicles are anticipated to operate at zero speed (i.e., the vehicle idles or is otherwise at rest).

(C) All test runs should be at least 20 minutes in duration, with an average grade of less than 5 percent. In identifying a proposed test route, a manufacturer should be cognizant that, everything else being equal, a longer test run is likely to provide reduced variance in average driving speed and PKE.

(D) The proposed high-speed test route and proposed transient test route must each begin and end at the same location (i.e., must be a closed circuit or loop), with the exception of cold-start tests, as described in Section 7(c)(3)(B). Multiple “laps” may represent a single test route. For example, a manufacturer may propose its 20 minute transient test route be represented by two ten minute laps over the same circuit. If the proposed test route includes multiple laps, each lap should have a length of at least 5 miles.

(E) A hybrid vehicle incapable of 55 mph operation due to a speed limiter may utilize the vehicle’s maximum operational speed instead of 55 mph for the high-speed route if the vehicle’s maximum operational speed is verified by the Executive Officer and approved as part of the proposed Hybrid Technology Emission Test Plan.

(F) The surface of all roads must be concrete or asphalt, and may not exceed 5,500 feet above sea level at any point. To maximize repeatability, the manufacturer should propose a test route with minimal anticipated traffic and, where possible, use of cloverleaves at turnaround points to allow for consistent operation of the base and hybrid vehicles during turns.

(G) The manufacturer must respect all local, State, and federal traffic- and safety-related requirements during vehicle testing.

(H) Nothing in these procedures is to be construed as prohibiting a manufacturer from conducting PEMS testing on a test track rather than on an over-the-road route. In lieu of the drive cycle selection criteria identified in Section 7(c)(2)(i) and (ii) of these procedures, above, PEMS testing conducted on a test track must utilize a speed trace to conform to the duty cycles identified in Section 7(d)(2) of these procedures.

(3) Emission Testing.

Unless otherwise indicated in this section, PEMS equipment specifications, measurement principles, verification requirements, and emissions measurement,
calibration, and verification methodologies are provided in 40 Code of Federal Regulations, Part 1065, Subpart J.

(A) Overview. For each test run over the high-speed test route and each test run over the transient test route, emissions must be recorded simultaneously on the hybrid and base vehicle, with one vehicle no more than one minute behind the other. For the high-speed route, the vehicles must be spaced at least 1,500 feet apart during freeway operation. The four test runs conducted over the high-speed route and the four test runs conducted over the transient test routes must each include at least one “cold-start” test. Manufacturers should dedicate at least two days to PEMS testing: one day to conduct at least four runs over the transient test route, with the first run of the day to be a cold-start test, and a second day to conduct at least four runs over the high-speed route, with the first run of the day to be a cold-start test.

(B) Charge-Depleting Hybrid-Electric Vehicles. A charge-depleting hybrid electric vehicle is to be emission tested in charge-sustaining mode, from the point at which the engine first turns on at the end of the vehicle’s AER. A charge-depleting hybrid-electric vehicle for which the ratio of the miles driven in charge-sustaining mode relative to the miles driven in charge-depleting mode is at least 0.98 must meet the emission test requirements of a charge-sustaining hybrid for the purposes of these procedures.

(C) Cold-Start Tests. Cold-start tests must include all emissions data from the moment the hybrid and base vehicles are started, including the actual start event. The hybrid and base vehicle must be cold soaked for a minimum of 12 hours at temperatures between 32 and 86 degrees Fahrenheit prior to each cold-start test. The vehicles must remain in the key off position for at least one minute, after which the test cycle begins. All test cycles must have a minimum of one minute of idling with continued emission sampling at the end of the cycle before the test cycle terminates, such that the analyzers are not missing emissions that are still in the sampling train. The test route used for each cold-start test run must be the same as that used for the hot-start test runs, with the exception that the cold-start test may begin at a different location on the test route, if it is infeasible to park the vehicle at the beginning of the test route for the required 12 hour cold soak period.

(i) Charge-Depleting Hybrids with AER: A cold-start test for a charge-depleting hybrid with AER is to be conducted after the vehicle has transitioned from charge-depleting and charge-sustaining mode, and then been cold soaked for the minimum 12 hour period (without charging the vehicle during the cold soak). Testing must measure and include emission data from the point at which the engine first turns on, including the actual engine start event.
(D) Hot-Start Tests: The hybrid and base vehicles must be warmed to operating temperature. Once the vehicles are at operating temperature, they must be turned off and remain in the "key off" position for approximately 20 to 30 minutes. The vehicles are to be restarted and idled for one minute, after which the test cycle is to begin and emission measurements are to be taken. At the end of the test cycle, the hybrid and base vehicles are to be returned to the "key off" condition.

(E) Net Energy Change. Net energy change calculations and variance determinations, and state-of-charge correction procedures must be performed in accordance with SAE International J2711: Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy-Duty Vehicles (SAE 2711), revised September 2002, and which is hereby incorporated by reference.

(F) Valid Test Run. All vehicles must be driven as similarly as possible over each of the at least four transient route runs, and over each of the at least four the high-speed route runs, respectively. The applicant should use the criteria identified in Section 7(c)(3)(F)(i) and (ii), below, for identifying valid test runs pursuant to these procedures.

(i) The CV of average driving speed and the CV of average PKE for all test transient route test runs should not exceed 10 percent; and

(ii) The CV of average driving speed for all high-speed test runs should not exceed 10 percent.

A manufacturer may propose alternate average driving speed or PKE variance thresholds as part of its Hybrid Technology Emission Test Plan. The Executive Officer will evaluate proposed alternate criteria based upon his or her engineering judgement and data provided by the manufacturer and from other sources, and make his or her determination as to whether the proposed alternate criteria provide an adequate basis for ensuring the proposed base and hybrid vehicles are being driven as similarly as possible over the proposed test routes, and whether proposed alternate criteria are likely to have an impact on validity of emission test results.

(G) An emissions runs and its data shall be deemed invalid and excluded as follows:

(i.) If the CV of average driving speed or CV of PKE do not meet the criteria identified in Section 7(c)(3)(F)(i) or (ii), above, or as otherwise defined in the Executive Officer-approved Hybrid Technology Emission Test Plan, the manufacturer must exclude the test run that is furthest from the mean for the noncompliant statistical set (average driving speed or PKE).
(ii.) A transient test run for any vehicle is to be excluded if its average driving speed or PKE is not within the range of 15 and 30 mph or 0.85 and 1.50 feet per second squared, respectively.

(iii.) Any test run that does not meet the criteria, as identified in the Executive Officer-approved Hybrid Technology Emission Test Plan, for consistency among runs in percent operation at zero-speed, or for proximity to 55 mph at which each vehicle spends at least 80 percent of its time (during the high-speed route), shall be excluded.

(H) For each excluded test run, the test run for the corresponding base or hybrid vehicle (i.e., the vehicle with which it was paired) must also be excluded, and the test run must be repeated by both vehicles. This process is to be repeated until the average driving speed and PKE meet the requirements of this section.

(I) The manufacturer may propose, as part of its Hybrid Technology Emission Test Plan, a statistical method for identifying and excluding measured emission data outliers. The Executive Officer will evaluate any proposed method for approval based upon the method’s adherence to established scientific and statistical principles for identifying outliers, his or her determination that the statistical method is to be consistently applied to both high and low emission results, and his or her engineering judgement regarding whether application of the proposed principle is likely to only exclude atypical emission results.

(J) While a test run deemed invalid pursuant to Sections 7(c)(3)(G) and (H) may not be used in the procedure’s emission calculations, the manufacturer must disclose, when reporting test results to the Executive Officer, all emissions and other data collected for all test runs (including those deemed invalid) conducted on days designated as an official emission test day in the applicant’s Hybrid Technology Emission Test Plan approved by the Executive Officer.

(4) Data Collection and Quality Control

The data identified in this section must be collected from SAE J1939 broadcast data, analog instrumentation, field records, or manufacturer information/specification sheets for all baseline and hybrid vehicles participating in PEMS testing. If proprietary equipment or information is needed to collect these signals, the applicant must make this equipment or information available to the Executive Officer within ten days upon request if needed for the purposes of confirmatory testing.

The actual signal value must always be used instead of a default or limp home value. For purposes of the calculated load, torque, fuel rate, and exhaust flow parameters, manufacturers must report the most accurate values that are calculated within the applicable electronic control unit (e.g., the engine control module). “Most accurate values,” in this context, must be values of sufficient accuracy, resolution, and filtering to be used for the purposes of in-use emission testing with the engine still in a vehicle (e.g., using PEMS). The following data must be collected for both the base and hybrid...
vehicle during each test run, and be reported to the Executive Officer on a second-by-
second interval in a format to be determined by the Executive Officer:

(A) The following data are to be collected from the engine control module (ECM):
   (i.) Real-Time Engine Power Output (i.e., engine actual torque, engine
   fractional torque and percent load);
   (ii.) Nominal Friction Percent Torque;
   (iii.) Actual Engine Torque;
   (iv.) Engine Speed;
   (v.) Rechargeable Energy Storage System Battery State-of-Charge (if
   applicable);
   (vi.) Rechargeable Energy Storage System Net Energy Change (if applicable);
   (vii.) Coolant Temperature;
   (viii.) Engine Fuel Rate;
   (ix.) Intake Air Flow Rate (may be measured by flow sensor);
   (x.) Fuel Temperature; and
   (xi.) Fault Status;

(B) The following data are to be collected by a global positioning system (GPS):
   (i.) Vehicle Position (Latitude, Longitude);
   (ii.) Elevation; and
   (iii.) Vehicle Speed (Latitude, Longitude, and Elevation as a function of time
   are to be measured by a GPS; a GPS may also be used to correct or
   calibrate ECM wheel-based speed);

(C) Additional required data and measurement techniques are identified below:
   (i.) Exhaust Mass Flow – Exhaust flow sensor (Pitot), other flow meter, or
   ECU broadcast data;
   (ii.) Exhaust Temperature at Aftertreatment System Inlet and Tailpipe –
   Temperature sensor;
   (iii.) Ambient Humidity – Humidity sensor;
   (iv.) Ambient Temperature – Temperature sensor; and
   (v.) Ambient Pressure – Pressure sensor;

(D) The following data and information are to be calculated and reported to ARB for
each test run:
   (i.) Cycle time (seconds);
   (ii.) Maximum vehicle speed (mph);
   (iii.) Average vehicle speed (mph);
   (iv.) Time (seconds) and percent of time at the following speeds (in mph): zero
   speed; 0+ to 5; 5+ to 10, 10+ to15; 15+ to 20; 20+ to 25; 25+ to 30; 30+ to
   35; 35+ to 40; 40+ to 45; 45+ to 50; 50+ to 55; 55+ to 60; 60+ to 65; 65+;
   (v.) Number of stops;
   (vi.) Average PKE (feet per second²);
(vii.) Fuel economy (miles per gallon);
(viii.) Plot of second-by-second speed versus time trace for both the hybrid and base vehicle; and
(ix.) Additional data collected pursuant to Section 7(c)(4)(A), (B), or (C), if so requested by the Executive Officer;

(E) Nitric oxide, nitrogen dioxide, total hydrocarbon, CO, and CO₂ emissions are to be measured by the PEMS unit. Fuel consumption of the hybrid and base vehicle are to be calculated based on mass balance of carbon-bearing emission gases, as described in 40 Code of Federal Regulations, Part 86 and SAE test method J1094a, both of which are hereby incorporated by reference; and

(F) The manufacturer must disclose to the Executive Officer data regarding all test runs conducted during the days of emission testing performed pursuant to Section 7(b)(1)(B) of these procedures, including test runs that are not included in emissions calculations and the reason(s) for their exclusion.

(5) Emission Calculations.

Average mass-based (grams per mile) emission values are first calculated, as adjusted for net energy change (calculated pursuant to Section 7(c)(3)(E)), for each of the following:

(A) Hybrid vehicle as driven over the high-speed route \( A_{\text{HybridHS}} \)
(B) Base vehicle as driven over the high-speed route \( A_{\text{BaseHS}} \)
(C) Hybrid vehicle as driven over the transient route \( A_{\text{HybridTransient}} \)
(D) Base vehicle as driven over the transient route \( A_{\text{BaseTransient}} \)

Emissions for each of the above ((A), (B), (C), and (D)) are to be calculated as:

\[
A = \left( \frac{1}{7} \left( \frac{M_{cs}}{D_{cs}} \right) + \frac{6}{7} \left( \frac{M_{hs}}{D_{hs}} \right) \right)
\]

Where:

\( A \) = grams per mile emissions
\( M_{cs} \) = mass (in grams) of cold-start test emissions for all valid cold-start tests
\( D_{cs} \) = distance (in miles) the vehicle drives during all valid cold-start tests
\( M_{hs} \) = mass (in grams) of hot-start test emissions for all valid hot-start tests
\( D_{hs} \) = distance (in miles) the vehicle drives during all valid hot-start tests

Average weighted emissions for each are then calculated as:

Average weighted hybrid emissions \( A_{\text{Hybrid}} \) =

\[
(A_{\text{HybridHS}} \times 0.18) + (A_{\text{HybridTransient}} \times 0.82)
\]
Average weighted base vehicle emissions ($A_{\text{Base}}$) = 

$\left( A_{\text{Base HS}} \times 0.18 \right) + \left( A_{\text{Base Transient}} \times 0.82 \right)$

Greenhouse gas exhaust emissions for the purposes of compliance are to be calculated based upon emissions directly measured by the PEMS unit.

(6) Criteria Pollutant Pass-Fail Determination. For each measured criteria pollutant, if $A_{\text{Hybrid}} \leq (A_{\text{Base}} \times 1.10)$, where 1.10 reflects a 10 percent test allowance, then the hybrid vehicle is found to not increase emissions of that pollutant. If $A_{\text{Hybrid}} \leq (A_{\text{Base}} \times 1.10)$ for NOx, CO, or HC, then the hybrid vehicle has passed these procedures’ emission criteria for the applicable pollutant. If $A_{\text{Hybrid}} > (A_{\text{Base}} \times 1.10)$ for NOx, CO, or HC, then the hybrid vehicle has failed these procedures’ emission criteria for the applicable pollutant.

(7) CO2 Emission Pass-Fail Determination. The hybrid vehicle CO2 emission reduction is calculated as $\left( (A_{\text{Base}} - A_{\text{Hybrid}})/A_{\text{Base}} \right)$. If the hybrid vehicle CO2 emission reduction $\geq 0.10$, then the vehicle has passed these procedures’ CO2 emission reduction criteria. If the hybrid vehicle CO2 emission reduction $< 0.10$, then the vehicle has failed these procedures’ CO2 emission reduction criteria.

(A) Vehicles with AER. For a hybrid vehicle between 6,001 and 8,500 pounds GVWR with AER, a utility factor (UF) shall be applied to average weighted hybrid CO2 emissions:

$$A_{\text{Hybrid}} = \left( A_{\text{Hybrid HS}} \times 0.18 \right) + \left( A_{\text{Hybrid Transient}} \times 0.82 \right)) \times (1 - UF(D))$$

where UF(D) is the utility factor for a vehicle that achieves at least D miles AER. For such a vehicle, UF(D) are to be determined according to SAE International J2841: Surface Vehicle Information Report (SAE J2841), revised in September 2010, which is hereby incorporated by reference, from the Fleet Utility Factors (FUF) Table in Appendix B, or using a polynomial curve fit with “FUF Fit” coefficients from Table 2: Utility Factor Equation Coefficients.

For vehicles above 8,500 pounds GVWR with AER, a manufacturer may propose a UF as part of its Hybrid Technology Emission Test Plan, to be calculated as the FUF for a medium- or heavy-duty hybrid vehicle with AER pursuant to SAE J2841 procedures and based upon electronic in-use daily mileage data for the proposed hybrid vehicle class and vocation. The Executive Officer may approve, deny, or adjust the proposed UF based upon his or her engineering judgement and evaluation of this and other available relevant data and information.

(8) A manufacturer wishing to repeat an emissions test as a result of failing a required emission criteria must first submit a new Hybrid Technology Emission Test Plan.
pursuant to these procedures for Executive Officer approval. Such a plan must provide for retesting of the all required pollutants, and must include a detailed description of what changes are proposed in subsequent emission testing to address the hybrid vehicle’s failure to meet these procedures’ emission criteria.

(d) Chassis-Dynamometer Emission Testing

Unless otherwise indicated in this section, hybrid and base vehicle emission testing are to conform to the requirements of Section D of the “California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric and Other Hybrid Vehicles, in the Urban Bus and Heavy-Duty Vehicle Classes” (Amended December 13, 2013), which is hereby incorporated by reference. All chassis-dynamometer equipment specifications, measurement principles, verification requirements, and emissions measurement, calibration, and verification methodologies are provided in 40 Code of Federal Regulations, Part 1065.

(1) Vehicle Selection and Preparation. Vehicle selection and preparation must be performed in accordance with the requirements set forth in Section 7(c)(1) of these procedures.

(2) Duty Cycle Selection. The hybrid and baseline vehicles are to each be tested over two test cycles, one representing transient-like operation and the other representing high-speed operation. A light- or medium-duty vehicle is to be tested over the Federal Test Procedure (FTP-75), to represent transient-like operation, and over the US-06 Supplemental Federal Test Procedure, to represent high-speed operation. A heavy-duty vehicle is to be tested over the Transient Portion of the Heavy Heavy-Duty Truck 5 Mode Cycle, to represent transient-like operation, with the exception of transit buses, which are to use the Orange County Bus Cycle. A heavy-duty vehicle is to be tested over the 55 mph Cruise Cycle, to represent high-speed operation. A manufacturer may propose, as part of its Hybrid Technology Emission Test Plan, an alternate test cycle in lieu of the transient-like test cycles identified in this section. For light-, medium-, or heavy-duty vehicles, the Executive Officer may approve this alternate test cycle to reflect transient-like operation if he or she determines, based upon his or her engineering judgement and data provided by the applicant, that the proposed alternate test cycle more accurately represents the hybrid vehicle’s anticipated in-use activity, as operated by California fleets.

A heavy-duty vehicle with ePTO may conduct chassis-dynamometer emission testing pursuant to the hybrid-PTO test procedures defined in 40 Code of Federal Regulations, Part 1037.525 in lieu of the specified transient-like duty cycle.
(3) Charge-Depleting Hybrid-Electric Vehicles. A charge-depleting hybrid electric vehicle shall conform to the requirements of Section 7(c)(3)(B) of these procedures.

(4) Emission Calculations. Average exhaust emissions calculations are conducted pursuant to Section 7(c)(5) of these procedures, with the exception that for a vehicle between 6,001 and 14,000 pounds GVWR, emission calculations for Section 7(c)(5)(A), (B), (C), and (D) shall be determined using the following equation:

\[ A = ((0.43)(M_{cs}/D_{cs}) + (0.57)(M_{hs}/D_{hs})) \]

(5) Emission Pass-Fail Determinations. NOx, HC, and CO emission pass-fail determinations are conducted pursuant to Section 7(c)(6) of these procedures, and CO2 emission pass-fail determinations are conducted pursuant to Section 7(c)(7) of these procedures.

(e.) All-Electric Range Determination. Determination of AER must be performed in accordance with the provisions of this section.

A hybrid vehicle's AER is defined as the distance, after the battery has been fully charged, that the vehicle is capable of traveling with the engine off before the engine turns on for the first time, and is determined in accordance with Section 7(e) of these procedures. The vehicle is to be tested for AER in default mode, or in normal mode if the vehicle does not have a default mode.

(1) PEMS Tested Vehicles. The AER of a vehicle that it tested with a PEMS pursuant to Section 7(c) of these procedures must be demonstrated over the transient test route on which the vehicle is PEMS tested. The location at which the engine first turns on must be captured by the GPS system and recorded, and the distance traveled must be identified by the vehicle odometer or other mechanism approved by the Executive Officer as part of the Hybrid Technology Emission Test Plan. The altitude at the start of the test and the point the engine first turns on must be recorded, and the altitude of the location at which the engine first turns on may not be more than 100 feet lower than the altitude of the starting location. The starting point of such a test route should be no more than 100 feet higher in elevation than the lowest point of the route, to avoid the possibility of invalid AER determinations.

(2) Other Vehicles. A vehicle that is demonstrated to meet the emissions criteria of these test procedures on a chassis dynamometer must have its AER demonstrated on the chassis dynamometer over the transient-like duty cycle utilized pursuant to Section 7(d) of these procedures.
(f) A heavy-duty hybrid engine being emission tested for the purposes of California Code of Regulations, title 13, section 2208.1, subdivision (c)(1)(C) shall also be governed by the following criteria:

(1) **Vehicle Selection and Preparation.** When selecting vehicles for testing pursuant to Section 7(c) or (d) of these procedures, the baseline and hybrid vehicle must be of the same vehicle class and intended vocation, and be identical or as closely matched as possible in MY, engine power and displacement, number of axles and real axle ratios, electrical and mechanical accessories (such as power steering and brakes), body style and external surface contours, aerodynamic configuration, wheel circumference, rear differential, transmission type (e.g., automatic, automated manual, etc.), and accessories. To be comparable, the baseline and hybrid vehicle must be able to accomplish the same function, with similar performance, utility, and durability attributes. Vehicles must be tested with all body equipment and appendages intact (e.g., mirrors, bumpers, etc.), and with the same mechanical and electrical accessories in operation, such that the power demand on the vehicles during testing is representative of the expected power demand on the vehicles while in use. The power and displacement of the engines used in the base and hybrid vehicles may differ if this difference is directly related to the more-efficient functioning of the hybrid system, such as use of a smaller engine in the hybrid configuration. A baseline engine or vehicle may be from a different MY relative to the hybrid vehicle if the engine, aftertreatment, and on-board diagnostics system is functionally unchanged between the two MYs and if all other vehicle characteristics are substantially similar, with the exception of the hybrid system.

(2) **Fuel Specifications.** When conducting emission testing pursuant to Section 7(c) or 7(d) of these procedures, both base and hybrid vehicles must use an identical gaseous or liquid fuel, unless a base vehicle using a different fuel is approved in advance by the Executive Officer. If an appropriate base vehicle that utilizes the same fuel type as the hybrid vehicle is unavailable, the Executive Officer may approve use of an alternate base vehicle fuel type that best represents the typical fuel used by a newly manufactured vehicle in the intended vehicle class and vocation. For example, a gasoline-fueled Class 6 hybrid truck may warrant use of a diesel-fueled Class 6 base truck for the purposes of emission testing, because Class 6 vehicles are typically diesel fueled.

(3) **Post-Transmission Powertrain Vehicle Simulation.** In lieu of conducting emission testing pursuant to Section 7(c) or (d) of these procedures, a hybrid engine certifying to meet “Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Vehicles – Phase 1” pursuant to 40 Code of Federal Regulations, Part 1037.555, which is hereby incorporated by reference, may use the post-transmission powertrain vehicle simulation
emissions data derived pursuant to said certification testing to demonstrate CO₂ emission compliance with the requirements of California Code of Regulations, title 13, section 2208.1, subdivision (c)(1)(a). Such a test that concurrently measures NOx, CO, and HC emissions in the identical fashion as done for CO₂ emissions pursuant to 40 Code of Federal Regulations, Part 1037.555 may use the NOx, CO, and HC emissions data derived pursuant to said certification testing to also demonstrate NOx, CO, and HC emission compliance for the purposes of California Code of Regulations, title 13, section 2208.1, subdivision (c)(1)(a). In such case, the percent CO₂ reduction is calculated as follows:

\[
\text{Percent CO}_2 \text{ reduction} = \text{IF} \times 100
\]

Where

\[\text{IF} = \text{the CO}_2 \text{ Improvement Factor calculated pursuant to 40 Code of Federal Regulations, Part 1037.615.}\]

For each required pollutant, if (Emission Rate A * 1.10) > Emission Rate B, where Emission Rates A and B have the meanings described in 40 Code of Federal Regulations, Part 1037.615(b)(2)(iii), then the hybrid vehicle is found to not increase emissions of that pollutant.