Test Specification – Brake Testing

Center for Evaluation of Clean Energy Technology (CECET)

An Intertek Company

430 S. 2nd Avenue

Phoenix, Arizona 85003-2418

Phone: (480) 525-5885

http://www.intertek.com/automotive
http://www.intertek.com/automotive/field-performance
http://www.cecet.com

Revision History Log

Revision No.	Revisions Description	Effective Date	Revised By	Approved By
0	Initial release	11/23/2015	Jeffrey Wishart	Jeremy Diez
1.0	Brake pedal force requirements added	4/8/2016	Tyler DeWitt	Jeffrey Wishart

Table of Contents

1 Objective

The objective of this Test Specification is to provide methods for testing and evaluating the braking performance for vehicles participating in the Advanced Vehicle Testing and Evaluation (AVTE) program or in other advanced vehicle testing. This Test Specification evaluates the braking capability of a vehicle while monitoring the regenerative braking characteristics. Both the stopping distance and the ability to maintain control of the vehicle (defined as staying in the course lane) are tested. This Test Specification outlines the requirements for experimental conduct. The actual specific steps for the test conduct are listed and described in the associated Center for Evaluation of Clean Energy Technology (CECET) internal Work Instruction document. This test is not intended to satisfy the requirements of Section 105 of 49 Code of Federal Regulations (CFR) 571.

2 Test Conduct

Documentation resulting from usage of this Test Specification shall be consistent, easy to understand, easy to read, and readily reproducible. All documentation required to complete testing shall be completed, approved, and ready for issue prior to commencing the testing it addresses. The following will abide by company policy:

- Review and approval of test results
- Storage and retention of records during and following testing activities
- Recording of any deviation from the outlined procedures and the reason for the deviation

3 Initial Conditions & Prerequisites

Prior to conduct of any portion of the testing, the following initial conditions and prerequisites shall be met. Satisfactory completion of these items should be verified.

Personnel

3.1 Personnel conducting testing under this Test Specification, i.e., the Test or Project Engineer(s), shall be familiar with the requirements of this Test Specification, shall be trained in accordance with company policy, and shall be certified by a Mandated Reviewer prior to commencing any testing activities. This requirement includes training in all aspects of the Test Specification, including its automatic shutdowns and safety procedures.

Vehicle Modes

3.2 Depending on the vehicle type, the vehicle to be tested may be capable of operating in more than one mode. The specific modes shall be determined by the Test Manager prior to testing; however, the default modes to be tested for each vehicle type are listed in Table A-1 of Appendix A. Vehicles shall be tested in the available modes, as applicable to vehicle function and capability. It should be noted that while a mode may apply to a type of vehicle, not all vehicles in the type will have the required functionality. It should be further noted that a vehicle is assumed to only have a mode applicable if the vehicle has full functionality within this mode. For example, some hybrid electric vehicles (HEVs) have an energy storage system (ESS)-Only Mode that can be used for low-acceleration and low-speed driving; since full functionality is not possible, the vehicles would not be tested in this mode. It is assumed that vehicles will have the same acceleration and deceleration when operating in sub-modes such as “ECO” and ‘SPORT” within the operating modes listed below unless otherwise specified. If this assumption is not applicable to a given test vehicle, all tests must be applied to each distinct sub-mode. The current modes and applicable vehicles are:

3.2.1 ESS-Only charge-depleting (CD) Mode is applicable to electric vehicles (EVs), some plug-in hybrid electric vehicles (PHEVs), and neighborhood electric vehicles (NEVs).

3.2.2 Blended CD Mode is applicable to some PHEVs.

3.2.3 Charge-sustaining (CS) Mode is applicable to HEVs and PHEVs.

3.3 3.2.4 Consumable Fuel Energy Converter (CFEC)-Only Mode is applicable to conventional spark ignition (SI) and compression ignition (CI) internal combustion engine vehicles (ICEVs), natural gas vehicles (NGVs), and hydrogen ICEVs (HICEVs).

Environmental Conditions

3.3.1 Road tests shall be performed on a road or test track, which is level to within 1%, and the roads shall be dry, clean, and smooth.

3.3.2 Ambient temperature during road testing shall be within the range of 41 °F (5 °C) to 100 °F (38 °C).

3.3.3 Tests shall not be conducted when wind speeds average more than 10 mph (16 km/h) or when peak wind speeds ate more than 12.3 mph (20km/h). Test should always be conducted during periods of minimum wind velocity.

3.3.4 Tests shall not be run during foggy conditions.

Vehicle Conditions

3.4.1 Vehicles should have accumulated a minimum of 4,000 miles (6,450 km) prior to this testing. Actual mileage shall be recorded prior to starting testing.

3.4 3.4.2 Vehicles shall be tested in its normal configuration with normal appendages (mirrors, bumpers, hubcaps, etc.)

3.4.2.1 The testing instrumentation shall be installed so it does not hinder vehicle operation or alter the operating characteristics of the vehicle. Mounting shall be accomplished so as to not interfere with a tow vehicle if required (nominally at the rear of the vehicle).

3.4.3 Vehicles shall be tested at delivered curb weight plus 332 ± 10 lb (including driver and test equipment), distributed in a manner similar to the original curb loading of the vehicle.

3.4.4 Vehicle Manufacturer's recommended tires and lubricants shall be used. Tires should have accumulated a minimum of 100 miles (160 km) and shall have at least 75% of the original tread depth remaining. All tire break-ins shall be performed on the test vehicle. Tread depth will be recorded in 1/32 inch increments prior to start of test.

3.4.5 Vehicle tires shall be inflated to the Vehicle Manufacturer's recommended cold inflation pressure as specified on the tire placard, corrected for the difference between ambient temperature and tire temperature. [Tire pressures will be increased 1 psi for each 13 °F; the preparation area is higher than the test area (or 1 kPa for each 1 °C)].

NOTE: Tire sizes and inflation pressures shall be in accordance with the requirements of the placard. At no time shall the tire's cold inflation pressure exceed the maximum pressure imprinted upon the tire's sidewall.

3.4.6 ESS temperatures throughout the testing shall be within supplier specifications.

3.5 3.4.7 Accessories shall not be used during testing.

Vehicle Charging

The following instructions apply to charging activities for all PHEVs and EVs. They shall not replace or supersede the requirements of any specific Vehicle Manufacturer. Should a conflict arise, the requirements of the Vehicle Manufacturer shall take precedence.

3.5.1 ESSs capable of receiving off-board electrical power shall always be charged and, if applicable, a specific state of charge (SOC) established, by using electric vehicle supply equipment (EVSE) recommended by the Vehicle Manufacturer.

3.5.2 Completion of charge by automatic termination of the vehicle, without an indicated fault on either the vehicle or the EVSE (if applicable), shall be considered 100% SOC for the ESS.

3.5.3 If while charging a fault occurs on either the vehicle or EVSE, testing shall be stopped until the cause of the fault can be determined. Once the fault cause is found, testing can only resume if no ESS power was used and if the fault does not indicate a possibility of introducing invalid test data. If the effect on testing is not definitive testing shall be restarted.

3.5.3.1 Every attempt shall be made to ensure an initial ESS SOC of 100% is obtained. The test shall be initiated with the ESS at greater than 90% SOC.

Instrumentation

3.6.1 All instrumentation used during testing shall be calibrated. The calibration shall be performed and documented in accordance with company policy.

3.6

3.6.2 All instrumentation shall have the accuracies and resolutions noted. Unless specific exceptions have been made by a Mandated Reviewer, the following identifies the minimum instrumentation specification that shall be installed and employed during the testing.

3.6.2.1 Time

a) Accuracy ± 0.1%
b) Resolution of 0.1s

3.6.2.2 Speed

a) Accuracy of ± 0.25 mph (0.4 km/h)
b) Resolution of 0.1 mph (0.2 km/h)

3.6.2.3 Temperature

The temperature indicating devices must have a resolution of 2 °F (1 °C) and an accuracy of ± 2 °F (± 1 °C). The sensing element shall be shielded from radiant heat sources.

3.6.2.4 Atmospheric Pressure

A barometer with an accuracy of ± 0.2 inches Hg (± 0.7 kPa) is necessary.

3.6.2.5 Tire Pressure

Accuracy requirement is ± 0.5 psi (± 4 kPa).

3.6.2.6 Brake Force

A force gauge that can measure up to 300 lbf (1334 N) with an accuracy requirement ± 3 lbf (13.3 N) is required.

3.6.2.7 Engine RPM (if applicable)

Accuracy requirement is ± 50 RPM

3.6.2.8 Battery Current (if applicable)

Accuracy requirement is ± 1 A

3.6.2.9 Battery Voltage (if applicable)

Accuracy requirement is ± 1 V

3.6.2.10 Motor Current (if applicable)

Accuracy requirement is ± 1 A

3.6.3 The minimum instrumentation required is a speed sensor. The ESS current and voltage may be obtained through digital vehicle signals if the accuracy has been validated. Wherever possible, analog signals should be included. The Test Manager shall determine what level of instrumentation and data acquisition rates are

deemed acceptable. The default acquisition rates for Intertek Testing Services, North America are 100 Hz for non-temperature-based data and 1 Hz for temperature-based data.

3.6.4 Where applicable, the data logger used for fleet testing purposes shall remain in the vehicle as a backup for track test data logging. Additionally, every attempt shall be made to record the track data on the datalogger used during fleet testing.

4 Test Activity Requirements

This section addresses the activities required to meet the stated purpose and objectives of this Test Specification.

This test qualitatively evaluates the controllability of a vehicle when attempting to stop from a specified speed on a dry asphalt surface and measures the distance required to bring the vehicle to a complete stop.

Testing shall be performed on a straight path with a minimum length of 400 feet. The width of the lane should be 12 feet.

Collected Test Data

4.1 The following data shall be collected during conduct of the various tests specified by this procedure.

4.1.1 Time

4.1.2 Vehicle speed

4.1.3 Vehicle distance traveled

4.1.4 Brake application force

Where possible and applicable, the following data should be collected in addition to the previous data.

4.1.5 ESS temperature

4.1.6 Max/Min cell temperature, where available

4.1.7 DC voltage (output from ESS during testing)

4.1.8 DC current (output from ESS during testing)

4.2

Collected Environmental Conditions Data

The following environmental conditions data shall be collected during conduct of the various tests specified by this procedure.

4.2.1 Ambient temperature at the beginning and end of test

4.3 4.2.2 Wind velocity at beginning and end of test

4.2.3 Wind direction at beginning and end of test

Braking Test

The purpose of the braking test is to measure the vehicle braking from 60-0 mph (20-0 mph for NEVs). This testing is to be completed subject to the initial conditions and prerequisites stated in Section 4 of this procedure.

4.3.1 Vehicles with a regenerative braking system shall have the system engaged during testing.

4.3.2 Vehicles with a driver-selectable regenerative braking power shall have the setting designated for the highest and the lowest regenerative power selected for testing.

4.3.3 The braking test must be conducted for each of the modes from Section 4.3 in which the vehicle is capable of operating. The applicable modes by vehicle type are included in Table A-1 in Appendix A.

4.3.4 If applicable, at a minimum, two braking tests in CD (both blended and ESS-only) mode should be conducted, starting with an SOC of 100% SOC. The vehicle should then be driven until the ESS SOC is at 50%, at which point two more braking tests (at minimum) shall be conducted, unless 50% is below the point at which CD mode is exited. In the latter case, only the 100% SOC results shall be reported.

4.3.5 If applicable, at a minimum, two braking tests in CS mode should be conducted.

4.3.6 If applicable, at a minimum, two braking tests in CFEC-only mode should be conducted.

Pass-Fail conditions

4.4

4.4.1 Any braking event in which a vehicle cannot be controlled within the confines of the testing lane shall be considered as having failed. The driver shall note all braking events in the testing documentation regardless of pass or fail condition.

4.4.2 Any vehicle failing to pass the braking test shall be removed from testing and inspected by the Vehicle Supplier. If no malfunctions are found by the Vehicle Supplier within a reasonable time, the test vehicle will be considered to have failed brake performance testing.

5 Glossary

APU: Auxiliary power unit. This is an engine coupled to a generator for the purpose of producing electricity. The electricity is normally used for propulsion purposes; however, in certain vehicles, the electricity can be used by off-board devices. If the latter capability exists, the testing described in this document is conducted

AVTE: Advanced Vehicle Testing and Evaluation

CECET: Center for Evaluation of Clean Energy Technology (CECET)

Charge-Depleting (CD) Mode: An operating mode in which the energy storage system (ESS) state of charge (SOC) is depleted (not continuously, but the trend is depletion) while the vehicle is driven. May be ESS-Only (i.e., the vehicle operates solely on energy from the ESS) or Blended CD (i.e., the vehicle operates on energy from both the ESS and the consumable fuel energy converter (CFEC)).

Charge-Sustaining (CS) Mode: An operating mode in which the energy storage system (ESS) state of charge (SOC) is maintained within a prescribed range by operation of a consumable fuel energy converter (CFEC).

Consumable Fuel Energy Converter (CFEC): An engine which consumes fuel to produce work (either electrical or mechanical).

Curb Weight: The total weight of the vehicle including batteries, lubricants, and other expendable supplies but excluding the driver, passengers, and other payloads.

Effective Date: After a document has been reviewed and approved, the first date the procedure can be utilized in an official capacity.

Energy Storage System (ESS): A component or system of components that stores energy and for which its supply of energy is rechargeable by an electric motor-generator system, an off-vehicle energy source, or both. Examples of ESSs include batteries, capacitors, and electromechanical flywheels.

ESS-Only Mode: An operator selectable vehicle operating mode in which the CEFC is disabled and the vehicle operates solely on energy from the ESS.

Gradeability: The maximum percent grade which the vehicle can traverse for a specified time at a specified speed. The gradeability limit is the grade upon which the vehicle can just move forward.

Initial Conditions: Conditions that must exist prior to an event occurring.

Initial State of Charge (SOC): ESS SOC at the beginning of a test.

Mandated Reviewer: The individual(s) responsible for the implementation of the AVTE program and of other advanced vehicle testing activities.

Prerequisites: Requirements that shall be met or resolved prior to an event occurring.

SAE: Society of Automotive Engineers

Shall: This word is used to indicate an item which requires adherence without deviation. ‘Shall’ is used to identify the binding requirements in a statement. A go or no-go criterion.

Should: This word is used to identify an item, which requires adherence if at all possible. ‘Should’ statements identify preferred conditions.

State of Charge (SOC): The ESS SOC is defined as the present capacity, (ampere-hours or watt-hours or miles), expressed as a percentage of the total available.

Test or Project Engineer: The individual(s) assigned responsibility for the conduct of any given test.

Test Mass (Weight): The mass [weight] of the vehicle as tested, including driver and all instrumentation

Tractive Force: The force available from the driving wheels at the driving wheel/ground interface.

Vehicle Manufacturer: Entity that manufactured the test vehicle.

6 References

None