Test Specification – Range and Efficiency Testing

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Revision History Log

Revision No.	Revisions Description	Effective Date	Revised By	Approved By
0	Initial release	11/23/2015	Jeffrey Wishart	Jeremy Diez

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1 Objective

The objective of this Test Specification is to outline the method for testing the range, roundtrip efficiency of the energy storage system (ESS), and on-board charger performance of vehicles participating in Advanced Vehicle Testing and Evaluation (AVTE) program or in other advanced vehicle testing activities. This Test Specification outlines the methods for experimental conduct and data analysis. Testing is conducted in partial accordance with Society of Automotive Engineers (SAE) J227a, "Electric Vehicle Test Procedure". The actual specific steps for the test conduct are listed and described in the associated Intertek Center for Evaluation of Clean Energy Technology (CECET) internal Work Instruction document.

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.

3.1 Personnel

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 Range and Efficiency Test, including its automatic shutdowns and safety procedures.

3.2 Vehicle Conditions

3.2.1 Vehicles participating in advanced vehicle testing that do not have a charge-depleting (CD) mode will not undergo range testing.

3.2.2 Vehicles shall have accumulated a minimum of 4,000 miles (6,450 km) prior to this testing as part of the vehicle “break in”. Actual mileage shall be recorded prior to starting testing.

3.2.3 Vehicles shall be tested in its normal configuration with standard accessories (mirrors, bumpers, hubcaps, etc.)

3.2.3.1 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).

3.2.4 Vehicles shall be tested at delivered curb weight plus 332 ± 10 lb (151 ± 4.5 kg, including driver and test equipment), distributed in a manner similar to the original curb loading of the vehicle.

3.2.5 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 should be recorded (in mm) prior to start of test.

3.2.6 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 soak temperature. Tire pressures will be increased 1 psi for every 13 °F difference between the two temperatures.

3.2.7 ESS temperatures throughout the testing shall be within Vehicle Manufacturer specifications, where available.

3.2.8 Accessories shall not be used during testing.

3.3 Vehicle Modes

Only test vehicles that are capable of being driven in charge-depleting (CD) mode shall be range tested using this procedure. Vehicles incapable of being tested in CD mode will not be tested in this procedure.

3.3.1 PHEVs can have either blended OR ESS-only CD modes. Constant-speed range tests shall only be conducted for ESS-only CD modes. If a blended PHEV cannot achieve a required test speed without the ICE being operational, the test at this speed shall not be conducted.

3.3.2 EVs and NEVs operate solely in ESS-only CD mode (and cannot exhibit a blended CD mode).

3.4 Environmental Conditions

3.4.1 Road tests shall be performed on a road or test track and the roads shall be dry, clean, and smooth.

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

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

3.4.4 Tests shall not be run during foggy conditions for safety reasons.

3.5 Instrumentation

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

3.5.2 All instrumentation shall have the accuracies and resolutions noted. Unless specific exceptions have been made by the Test Manager, the following identifies the minimum instrumentation specification that shall be installed and employed during the testing. Note that not all of the instrumentation applies to the testing conducted for this Test Specification.

3.5.2.1 Time

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

3.5.2.2 Speed

a) Accuracy of ± 0.35 mph
b) Resolution of 0.1 mph

3.5.2.3 Temperature

a) Accuracy of ± 1 °C
b) Resolution of 1 °C

3.5.2.4 Atmospheric Pressure

a) Accuracy of ± 1.0 mm Hg
b) Resolution of 1.0 mm Hg

3.5.2.5 Wind Speed

a) Accuracy: ± 3% at 10 m/s
b) Resolution: 1 mph (1 m/s)

3.5.2.6 Wind Direction

a) Accuracy: ± 2°
b) Resolution: 1°

3.5.2.7 Relative Humidity

a) Accuracy: ± 2%
b) Resolution: 1%

3.5.2.8 Tire Pressure

a) Accuracy of ± 0.5 psi
b) Resolution of 0.5 psi

3.5.2.9 Current

a) Accuracy of ± 1 A
b) Resolution of 0.1 A

3.5.2.10 Voltage

a) Accuracy of ± 1 V
b) Resolution of 0.1 V

3.5.3 The minimum instrumentation required for this Test Specification 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.

3.5.4 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.

3.6 Vehicle Charging

The following instructions apply to charging activities for all PHEVs, EVs and NEVs. 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.

3.6.1 ESSs shall always be charged by using electric vehicle supply equipment (EVSE) that allows for charging at level(s) that are recommended by the Vehicle Manufacturer.

3.6.2 When a charge event is terminated by the vehicle, without an indicated fault on either the vehicle or the EVSE, the ESS SOC shall be considered to be 100%. For both the pre- and post-test charge events, every attempt shall be made to ensure that the SOC at the charge event termination is 100%.

3.6.3 If a fault is indicated on either the vehicle or EVSE during the post-test charge event, testing shall be stopped until the cause of the fault can be determined and corrected. 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.

3.6.4 After the range test has been completed, the charging of the vehicle will be accomplished with the energy input measured in order to determine ESS roundtrip

and charger efficiencies and energy consumption. In order to conduct the vehicle charging under similar environmental conditions as well as minimize vehicle power draw and self-discharge losses from the ESS when the vehicle is idle, the charging should occur as soon as possible after the range test has been completed.

4 Test Activity Requirements

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

4.1 Collected Test Data

4.1.1 Time

4.1.2 EVSE AC energy

4.1.3 Vehicle speed

4.1.4 ESS SOC

4.1.5 Vehicle ESS energy metric (i.e., energy 'bars')

4.1.6 Vehicle distance traveled

4.1.7 AC voltage (input from EVSE to vehicle during the post-charge charge event)

4.1.8 AC current (input from EVSE to vehicle during the post-charge charge event)

4.1.9 DC voltage of the ESS during charge events and range tests

4.1.10 DC current to/from the ESS during charge events and range tests

4.1.11 ESS temperature

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

4.2.2 Track temperature at the beginning and end of test

4.2.3 Wind velocity at beginning and end of test

4.2.4 Wind direction at beginning and end of test

4.2.5 Barometric pressure at beginning and end of test

4.3 Parameters to be calculated:

Using the collected samples, the required parameters shall be calculated and stored in a data file. The following parameters shall be calculated:

4.3.1 Average DC power out of the ESS

4.3.2 DC energy out of the ESS

4.3.3 Battery capacity discharge

4.3.4 Range at the set speed

4.3.5 Post-test charge AC energy from EVSE

4.3.6 Post-test charge DC energy into ESS from on-board charger

4.3.7 Post-test charge duration

4.3.8 AC electricity consumption rate, in Wh/mi

4.3.9 DC electricity consumption rate, in Wh/mi

4.3.10 ESS roundtrip efficiency

4.3.11 On-board charger efficiency

4.3.12 Overall trip efficiency

5 Reported Test Results

5.1 Test Data Analysis

5.1.1 The actual distance traveled is determined by including the drive from the staging area to the point at which the desired speed is achieved, plus the drive from the point at which the test has been completed back to the staging area.

5.1.2 The actual energy discharged from the ESS is determined by including during the drive from the staging area to the point at which the desired speed is achieved, plus during the drive from the point at which the test has been completed back to the staging area.

5.2 Efficiency Calculations

5.2.1 The ESS round-trip efficiency shall be calculated, and it is defined as:

$$\eta_{ESS\ Round-trip} = \frac{DC\ kWh\ out}{DC\ kWh\ in} \times 100$$

This metric is calculated by dividing the DC energy out of the ESS by the DC energy from the on-board charger into the battery.

5.2.2 The efficiency of the on-board charger shall be calculated, and it is defined as:

$$\eta_{On-Board\ Charger} = \frac{DC\ kWh\ in}{AC\ kWh\ in} \times 100$$

This metric is calculated by dividing the DC energy from the on-board charger into the ESS by the AC energy from the EVSE.

5.2.3 The overall trip efficiency shall be calculated, and it is defined as:

$$\eta_{Overall\ Trip} = \frac{DC\ kWh\ out}{AC\ kWh\ in} \times 100$$

This metric is calculated by dividing the DC energy out of the ESS by the AC energy from the EVSE.

6 Glossary

AVTE: Advanced Vehicle Testing and Evaluation

CECET: Center for Evaluation of Clean Energy Technology

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.

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

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

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. This is 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.

Blended Mode: A vehicle operating mode within CD mode in which propulsion power is drawn from the ESS and also supplemented by either continuous or intermittent use of the CEFC.

Charge-Depleting (CD) Mode: An operating mode in which the ESS SOC is depleted (not continuously, but the trend is depletion) while the vehicle is driven. May be ESS-Only or Blended.

Charge-Sustaining (CS) Mode: An operating mode in which the ESS SOC is maintained within a prescribed range by operation of a CFEC.

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 Checklist, Test Specification, or Work Instruction has been reviewed and approved, the first date the procedure can be utilized official data collection and testing.

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: A vehicle operating mode within CD mode in which the CEFC is disabled and the vehicle operates solely on energy from the ESS.

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

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

Vehicle Manufacturer: Entity that manufactured the test vehicle.

7 References

SAE J227A "Electric Vehicle Test Procedure" (cancelled in 1993)