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J2758

ISSUED APR2007

Issued 2007-04

Determination of the Maximum Available Power from a Rechargeable Energy Storage System on a Hybrid Electric Vehicle

RATIONALE

Not applicable.

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1. SCOPE

This document describes a test procedure for rating peak power of the Rechargeable Energy Storage System (RESS) used in a combustion engine Hybrid Electric Vehicle (HEV). Other types of vehicles with non fossil fuel primary engines, such as fuel cells, are not intended to use this test procedure.

1.1 Purpose

The purpose of this document is to provide a test procedure to determine RESS peak power so that a vehicle's ratio of RESS peak power rating to the sum of the Internal Combustion Engine power rating and the RESS peak power rating can be established. Because of the vehicle-specific nature of the RESS control and environment, this test is designed to calculate the RESS peak power for a specific vehicle. As a result, the same RESS used in a different vehicle must be retested to determine its peak power rating in the new HEV environment.

2. REFERENCES

2.1 Related Publications

The following publications are provided for information purposes and are not a required part of this document.

2.1.1 Other Publications

USABC (United States Advance Battery Consortium) Electric Vehicle Battery Test Procedures Manual, Rev 2, DOE/ID-10479, Jan. 1996

FreedomCAR Battery Test Manual for Power-Assist Hybrid Electric Vehicles, DOE/ID-11069, Oct. 2003

3. DEFINITIONS AND ACRONYMS

3.1 Rechargeable Energy Storage System (RESS)

A device that can be used to store, charge, or discharge electrical energy on board a vehicle, such as batteries and ultracapacitors.

3.2 Vmax

The smaller of the RESS steady-state maximum voltage and vehicle maximum allowable DC-link bus voltage that can be sustained indefinitely.

3.3 Vmin

The larger of the RESS steady-state minimum voltage and vehicle minimum allowable DC-Link bus voltage that can be sustained indefinitely.

3.4 Vmax-pulse

The smaller of the RESS maximum pulse voltage and vehicle maximum allowable DC-Link pulse voltage. The maximum pulse voltage is the voltage above Vmax that can be sustained for at least 10 seconds.

3.5 Vmin-pulse

The larger of the RESS minimum pulse voltage and vehicle minimum allowable DC-Link pulse voltage. The minimum pulse voltage is the voltage below Vmin that can be sustained for at least 10 seconds

3.6 Imax

The smaller of the RESS maximum current, as provided by the battery manufacturer, and the maximum allowable current on the vehicle DC-link.

3.7 Icc

The value of the current defined as the minimum of either the Imax or 20 times C_1/1 Rate.

3.8 Rated Capacity

Total Amp·hours (Ah) discharged at a Constant Current (CC) such that the RESS decreases from 100% to 0% state-of-charge (SOC) in one hour as provided by the battery manufacturer.

3.9 C_1/1 Rate

The CC at which the total RESS rated capacity is removed in 1 hour as provided by the battery manufacturer.

3.10 State of Charge (SOC)

Percentage of Amp·hours (Ah) remaining in RESS at C_1/1 rate relative to the static capacity as described in 4.2.2.1.

3.11 Constant Current (CC)

A value of electrical current held constant.

3.12 Constant Voltage (CV)

A value of electrical voltage held constant.

3.13 Constant Power (CP)

A value of electrical power held constant.

3.14 Test Temperature (TT)

A reasonably controlled temperature environment, also known as room temperature, defined as 26 °C±3 °C.

4. TEST DESCRIPTION

4.1 Test Conditions

4.1.1 Test Article

The test shall be performed at the pack level. To allow complete control of the SOC, the RESS Controller may be disabled for the duration of the test by the least intrusive means possible.

4.1.2 Environmental Temperature

The test shall be performed at Test Temperature (TT) as defined in 3.14.

4.2 Test Preparation

Unless otherwise noted, with the exception of temperature, all measurements and calculations should be to two significant digits (to the right of decimal point) at the indicated units. For temperature, an integer value will suffice.

4.2.1 Pertinent Information Required

Before beginning the test, the following vehicle specific information shall be gathered, which will be used to either configure the test or for calculation of the results.

4.2.1.1 Vehicle-Specific Target SOC

The Vehicle-Specific Target SOC is the SOC at which the battery spends most of its time during vehicle operation as determined by the HEV OEM. The vehicle master controller aims at keeping the battery at this SOC to accommodate multiple objectives of the vehicle design, including but not limited to:

- Availability of required discharge and charge pulse power at all times
- Life of the battery
- Fuel economy
- Performance objectives

As a result, depending on vehicle design objectives, the same RESS could have a different target SOC in different vehicle makes and brands.

The Target SOC of the RESS for the specific vehicle will be used as the SOC at which the peak power capability of the RESS is measured

4.2.1.2 Vehicle Minimum and Maximum Steady-state and Pulse Operating Voltages

These voltages are vehicle specific and shall be provided by the vehicle manufacturer.

4.2.1.3 Peak Power Constant-Current (CC) Pulse Test

The peak power capability of the RESS will be calculated from a 10-second CC Pulse of magnitude Icc, as defined in 3.7.

4.2.2 Battery Preparation

A critical element of preparing the RESS for peak power testing is to make sure the RESS is at the proper SOC and at TT prior to starting the test. In order to get the RESS to the proper target SOC, the capacity of the RESS needs to be established.

4.2.2.1 RESS Static Capacity Test Procedure

The following test procedure is recommended to establish a reference capacity called RESS Static Capacity and designated as *RESS_STATIC_CAPACITY* in ampere-hours. Steps 1 through 5 involve the procedure for discharging and then fully charging the RESS to full capacity and allowing it to relax at that state for 1 hour. These steps should be replaced by manufacturer-specific procedures in cases where there is a potential risk to personnel, or damage to the RESS, or respective test equipments. Once the RESS attained the full SOC and relaxed at that state for at least 1 hour, the RESS Static Capacity shall then be determined as the ampere-hours discharged from the voltage Vmax as defined in 3.2 to Vmin as defined in 3.3 at C_1/1 rate (steps 7 through 9). The RESS shall be soaked at TT for at least 24 hours prior to the test.

1. Discharge CC at C_1/1 Rate until Vmin is reached.

2. Rest at open-circuit one hour.

3. Charge CC at C_1/1 Rate until Vmax is reached.

4. Charge Constant Voltage (CV) at Vmax until the current drops below 0.10 A.

5. Rest at open-circuit for 1 hour at TT prior to starting the test.

6. Discharge the RESS from this state at C_1/1 Rate until Vmin is reached.

7. Determine RESS Static Capacity as the constant discharge current in amps (i.e. C_1/1 rate) multiplied by the time in hours it took to reach Vmin. This quantity is the initial RESS Static Capacity.

8. Repeat steps 1 through 7 of the static capacity test 3 times and record the capacity for each trial.

9. The final RESS Static Capacity will be the average of the 3 measurements.

4.2.2.2 Bringing RESS to Target SOC

To prepare the RESS for testing, the SOC of the RESS must be set to the Vehicle-Specific Target State of Charge.

1. Repeat steps 1 through 5 in 4.2.2.1 to bring the RESS to the SOC at Vmax. Use manufacturer-specific procedures as outlined in 4.2.2.1 to bring the RESS to Vmax in case they are different.

2. Remove the number of ampere-hours (Ah) corresponding to the target SOC at C_1/1 Rate. The number of Ah or capacity to be removed is calculated as:

$$CAPACITY\_TO\_REMOVE = RESS\_STATIC\_CAPACITY \times \frac{(100 - SOC_{TARGET})}{100} \quad \text{(Eq. 1)}$$

While the time to discharge (in hours) this capacity is calculated as:

$$TIME\_TO\_DISCHARGE = \frac{CAPACITY\_TO\_REMOVE}{C1\_RATE} \quad \text{(Eq. 2)}$$

The procedure ends when the required capacity is removed.

4.2.3 Peak Power Test Procedure

1. Rest 1 hour minimum after bringing the RESS to target SOC.

2. Measure the Open Circuit Voltage of the RESS and record its value as V1.

3. Apply a 10-second discharge Constant-Current Pulse of the magnitude Icc and measure the voltage response of the RESS with a 0.10 second time resolution.

4. Record the voltage value as soon as the current reaches the maximum value (the current is fully ramped up) of the 10-second discharge pulse as V2, and at the conclusion (before the current ramps down) of the 10-second pulse as V3 (Refer to Figure 1).