



Static Capacity and Hybrid Pulse Power Characterization Test of Rechargeable Energy Storage Systems

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This standard specifies the test procedure for evaluating the performance for Hybrid Electric Vehicle (HEV), Plug-in Hybrid Electric Vehicle (PHEV), Extended Range Electric Vehicle (EREV) and Electric Vehicle (EV) batteries that are used in a vehicle environment.

1.1.1 Static Capacity. This test shall be used to evaluate the ability to meet vehicle Rechargeable Energy Storage Systems (RESS) performance metrics. The static capacity test measures device capacity in ampere-hours (Ah). Two types of discharge methods may be used in this test:

1. Constant Current (CC) discharge: Discharge at a specified constant current rate. The discharge is terminated on a specified discharge voltage limit. This type of discharge is also referred to as the extrinsic method.
2. Constant Current-Constant Voltage (CC-CV) discharge: Discharge at a specified constant current rate to a specified discharge voltage limit, followed by constant voltage float at the same voltage until a specified end of discharge termination condition is met. This type of discharge is also referred to as the intrinsic method.

1.1.2 Hybrid Pulse Power Characterization (HPPC). This test shall be used to evaluate the ability to meet vehicle RESS performance metrics. The HPPC test is intended to determine dynamic power capability in watts, over the device's useable charge and voltage range using a test profile that incorporates both discharge and regen pulses at various States of Charge (SOC).

1.2 Applicability. This standard applies to all RESS for passenger or commercial vehicles and trucks. General Motors shall approve all changes to the format and/or content of this test standard.

Hybrid controllers, Battery Disconnect Units (BDU), and other internal electrical/electronic components are required to meet GMW3172.

1.3 Remarks. This document provides the standard technical requirements for HEV, PHEV, EREV and EV batteries. A program-specific technical specification that is used in conjunction with this document may include additional program-specific requirements that are not referenced in this document and may supercede any requirements included in this document. In the case of any conflicts between this document and the program-specific technical specification, the program-specific technical specification takes precedence.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW3172

2.3 Additional References.

(ID) = This standard is limited to internal distribution within General Motors and shall not be distributed outside this company. Contact GM RESS Engineering for further instructions.

- CG2762 Default Test Parameters (ID)

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- United States Advanced Battery Consortium (USABC): FreedomCAR Battery Test Manual for Power-Assist Hybrid Electric Vehicles
- USABC: FreedomCAR Battery Test Manual for Plug-In Hybrid Electric Vehicles

3 Resources

3.1 Facilities. The test facilities and equipment shall be in good working order and shall have valid calibration. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment. Appropriate equipment is required to complete the test procedure defined in Section 4 to acquire and store all necessary data. Data must be recorded using appropriate software for the battery cycler in use. Data sources will include data measured by the battery cycler and any external process indicators, e.g., flow meters. There may be additional data sources.

3.2.1 Equipment Parameters. Unless stated otherwise, the information in Table 1 defines the minimum test equipment parameters and tolerances to be used for all testing.

Table 1: Equipment Parameters and Tolerances

Parameter	Range	Tolerance
Direct Current (DC) Voltage: Pack Level – Generate and Measure	0 V to 599 V	± 1 V
	600 V to 749 V	± 1.25 V
	750 V to 900 V	± 1.5 V
DC Voltage: Cell Level – Generate and Measure	0 V to 20 V	$\pm 0.1\%$ of Measured Value
DC Current: Pack Level – Generate and Measure	± 0 A to ± 19 A	± 0.5 A
	± 20 A to ± 99 A	± 1 A
	± 100 A to ± 199 A	± 1.25 A
	± 200 A to ± 500 A	± 2 A
DC Current: Cell Level – Generate and Measure	0 A to 4 A	± 0.050 A
	5 A to 19 A	$\pm 0.1\%$ of Measured Value
	20 A to 500 A	$\pm 1\%$ of Measured Value
Cell Balancing Criteria (if applicable)	Not applicable	$< 2\% \Delta$ SOC or as defined by the manufacturer or by GM battery system engineers

3.3 Test Vehicle/Test Piece. All cell, module and pack level RESS.

3.4 Test Time. See CG2762.

3.5 Test Required Information. All limits imposed by the battery manufacturer shall be observed over the course of testing. Power, current, voltage and temperature restrictions provided in written documentation by the manufacturer take precedence over any instructions given in this document.

3.6 Personnel/Skills. All personnel performing tests must have up-to-date training records in a high voltage training program.

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4 Procedure

4.1 Preparation.

4.1.1 Soft-packaged prismatic cells must be tested under a minimum external pressure of 28 kPa (4 psig) and metal can prismatic cells must be tested under a minimum external pressure of 69 kPa (10 psig).

4.1.2 Additional customer requests or requirements must be provided in writing prior to start of test.

4.1.3 All Devices Under Test (DUT) should be subjected to an initial inspection as defined by the requestor.

4.2 Conditions.

4.2.1 Environmental Conditions. Unless stated otherwise, the information in Table 2 defines the maximum test environment parameters and tolerances to be used for all testing. Testing performed at a given set point within the stated ranges may not require the equipment to utilize the full ranges shown in Table 2, however, the stated tolerances still apply.

Table 2: Environmental Parameters and Tolerances

Parameter	Range	Tolerance
Temperature Sensor: Measure	-40 °C to 85 °C	± 3 °C
Chamber Temperature: Generate and Measure	-40 °C to 85 °C	± 3 °C
Chamber Humidity: Generate and Measure	Not applicable	Not applicable
Lab Environment Temperature: Generate	25 °C	± 10 °C
Lab Environment Temperature: Measure	Not applicable	± 3 °C
Lab Environment Humidity: Measure	10% to 85% Relative Humidity (RH)	± 5% RH
Coolant Conditioner Temperature: Generate and Measure (if applicable)	-30 °C to 80 °C	± 3 °C

4.2.1.1 Unless otherwise specified by the test requestor, all testing should be conducted using environmental chambers and the humidity level should be set according to the requirements specified in Table 2. The ambient environment for the DUT should be maintained in accordance with manufacturer specifications.

4.2.1.2 Unless otherwise specified by the manufacturer, for cell level testing, if the change in temperature of the DUT reaches more than 20 °C with respect to the environment, the test must immediately enter a rest mode until the change in temperature of the DUT is less than 5 °C, with respect to the environment, and then continue. For rest mode > 1 h, halt test.

4.2.1.3 For cell level testing, a thermocouple must be placed in the center of the largest exposed area of the cell as shown in Figure 1. If the cell is constrained in a compression fixture, the thermocouple should not be compressed within the fixture. In this case, a thermocouple must be placed near the positive terminal and if the terminals are side by side, the thermocouple must be placed between the terminals. Another thermocouple must be placed nearby the cell to monitor environmental temperature.

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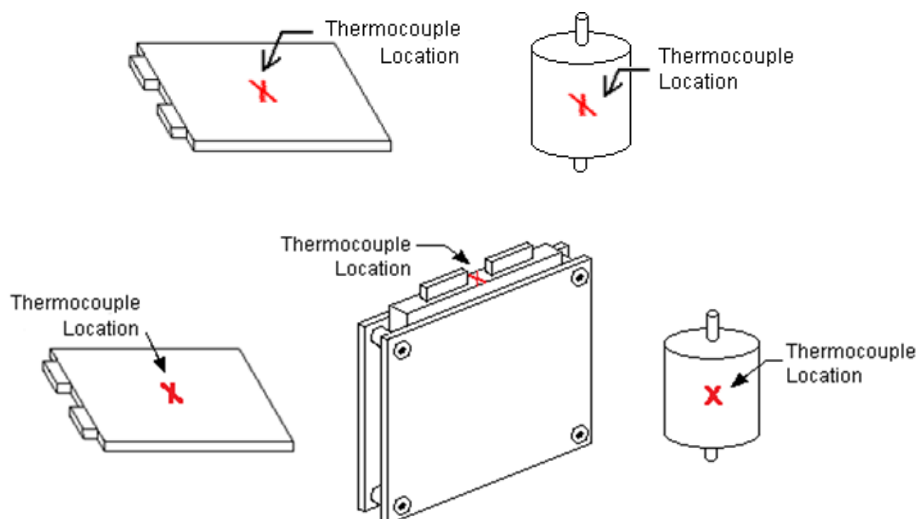


Figure 1: Examples of Thermocouple Locations on Various Cells

4.2.1.4 When tested in a new required temperature, i.e., a new test starts or a temperature change within the test, the DUT is required to have environmental conditioning according to 4.2.1.4.1 and 4.2.1.4.2, unless otherwise specified by the manufacturer or requestor.

4.2.1.4.1 Cell/Module Level DUTs.

- **Temperature:** If the previous test temperature is not equal to the desired test temperature, set the chamber temperature to the test temperature. When chamber temperature reaches the test temperature, soak ≥ 6 h. If the cell surface temperature and chamber are already at the test temperature, continue immediately.
- **Humidity:** Uncontrolled, monitored.

4.2.1.4.2 Pack Level DUTs.

- **Temperature:** Soak until average cell temperature equals the desired test temperature ($\pm$ temperature sensor tolerance as defined in Table 2), where delta cell temperature, i.e., cell temperature_{maximum} – cell temperature_{minimum}, is less than or equal to 5 °C **OR** If chamber and other temperature control device, e.g., chiller, set points do not align with desired test temperature, soak until average cell temperature remains constant, i.e., changes < 1 °C over 1 h, and delta cell temperature changes < 2 °C over the same hour.
- **Humidity:** Dew point should be kept lower than the chiller temperature for liquid cooled packs. Humidity should be uncontrolled and monitored for air cooled packs.
- **Cell Balancing:** Cell balancing may be required at certain specified times throughout testing. The cell balancing algorithm will be defined by the manufacturer or requestor.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

Note: Deviations from the requirements of this standard shall have been agreed upon by the laboratory and the test requestor.

4.2.2.1 Samples of components or material released to this standard shall be tested for conformity with the requirements of this standard and approved by the responsible GM department prior to the start of delivery of production level components or materials.

4.2.2.2 Any change to the component or material, i.e., design, function, properties, manufacturing process and/or location of manufacture requires a new release of the product. It is the sole responsibility of the supplier to provide the customer, unsolicited, with documentation of any change or modification to the product/process, and to apply for a new release.

4.2.2.3 If not otherwise agreed to, the entire verification test shall be repeated and documented by the supplier prior to start of delivery of the modified or changed product. In some cases, a deviation based on a limited subset of tests can be agreed to between the responsible GM department and the supplier.

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4.3 Instructions.

4.3.1 Static Capacity and HPPC. This test will be conducted with a cell, module or pack level RESS connected to equipment being used to perform the static capacity, HPPC and data acquisition. A detailed flowchart and profile of the instructions can be seen in Figure A1 in Appendix A. Default testing conditions and other information can be found in CG2762. Figure 2 shows examples of default static capacity and HPPC profiles.

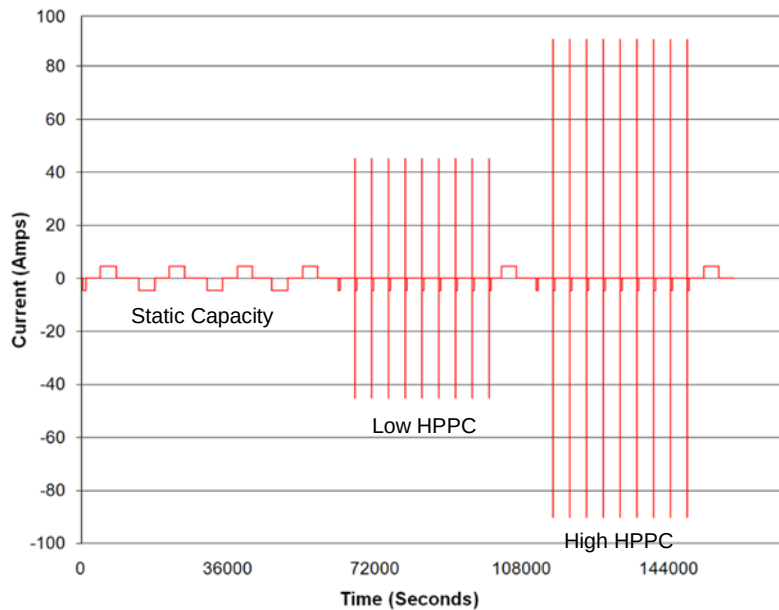


Figure 2: Example Static Capacity and HPPC Test Profile

Capacity tests are performed in one of two ways:

1. CC discharge (extrinsic): The DUT is discharged at constant current until a minimum voltage is reached.
2. CC-CV discharge (intrinsic): The DUT is discharged at constant current and then at a constant voltage upon reaching the minimum voltage.

Examples of CC and CC-CV discharge methods are shown in Figure 3.

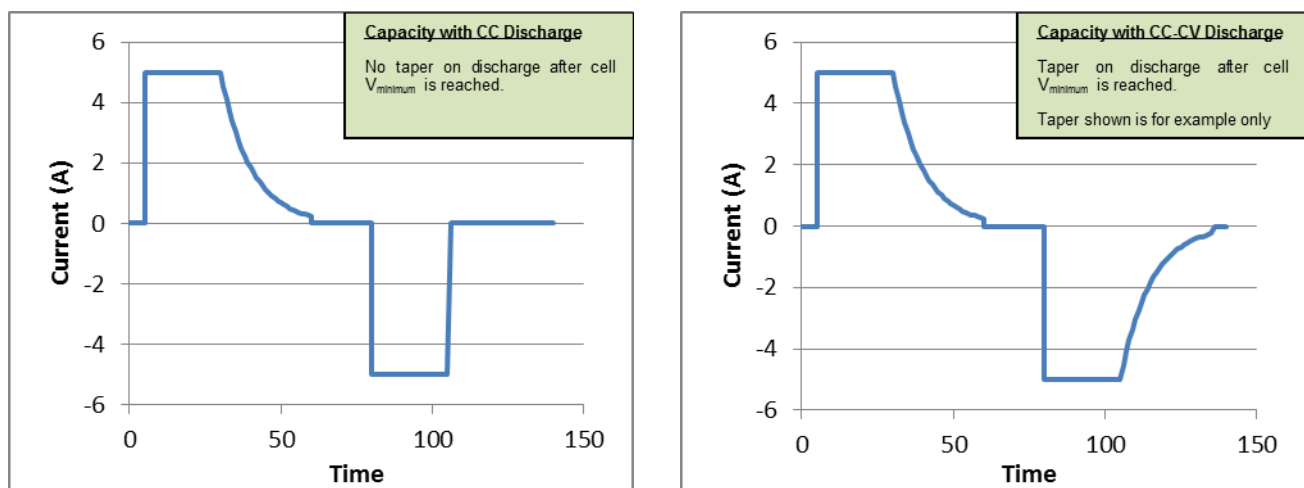


Figure 3: Examples of Capacity Test Profiles with CC or CC-CV Discharge

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