



SURFACE VEHICLE RECOMMENDED PRACTICE

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Performance Rating of Lithium-Ion Battery Module

RATIONALE

The document is a companion document to SAE J1798/1 and is intended to fulfill the electrical performance testing procedures and evaluation methods needed for utilizing Lithium-Ion Battery Module (LIBM) requiring individual cell monitoring. An LIBM requires a “system” approach, which includes circuitry and/or software for purposes of measurement and control.

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1. SCOPE

This document provides a recommended electrical performance testing guideline for LIBM, which makes up an xEV (Battery Electric Vehicles and Hybrid Electric Vehicles) battery pack system. This testing guideline may also be used for other applications, such as stationary, vessel, and aircraft. However, using the guideline for other applications should be determined by the users of this document.

Users of this document may also be interested in conducting tests on battery cells and/or battery packs. To avoid conducting potentially redundant tests between cells, modules, and packs, this document does not specify which tests need to be conducted. Determination of which tests need to be conducted is at the user's discretion and should be based on individual module applications. Rather than specifying which tests need to be conducted, this document describes how each test is to be conducted.

This document provides a matrix of tests that can be selectively picked for the application requirements in order to standardize testing procedures for their specific application needs. Performance values from the tests in this document can be for comparative purposes, confirmation, and other reasons. However, pass/fail criteria are not part of this document. It is up to the customer and supplier to determine what the pass/fail criteria are. If the measured value is to be used to determine battery module ratings, the tested modules should be representative of those to be manufactured.

LIBM consists of multiple cells grouped and electrically interconnected in various series and parallel configurations - typically noted as "XXP XXS." Fully functional LIBM shall have a battery monitoring system to allow for the proper control and operation of individual cell voltage and module temperature monitoring. The LIBM configuration shall accommodate for cell compression, retention, thermal heat transferal, electrical isolation, and a hold-down method.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1715 Hybrid Electric Vehicle (HEV) and Electric Vehicle (EV) Terminology

2.1.2 ISO Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

ISO 17025:2017 General Requirements for the Competence of Testing and Calibration Laboratories

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1715/2 Battery Terminology

SAE J2288 Life Cycle Testing of Electric Vehicle Battery Modules

SAE J3220 Lithium-Ion Cell Performance Testing

2.2.2 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 62660-1:2018 Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 1: Performance testing

2.2.3 ISO Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

ISO/TR 8713:2019 Electrically Propelled Road Vehicles - Vocabulary

3. DEFINITIONS

3.1 BATTERY CELL

An electrochemical device that is capable of producing electrical energy from chemical reactions or storing electrical energy through chemical reactions.

3.2 BATTERY ELECTRIC VEHICLE (BEV)

A vehicle that receives its onboard propulsion power solely from batteries, unlike a hybrid vehicle that may receive a portion of its power from a separately fueled power source, such as an internal combustion engine.

NOTE: This definition is taken from SAE J1715.

3.3 BATTERY MODULE

Refers to the multiple connections of electrochemical or electrostatic cells. Battery modules may or may not include sensors (such as voltage and temperature sensors), safety components, and a cooling structure so that each module can be controlled and managed independently.

3.4 BATTERY PACK

A battery assembly that consists of one or more modules.

NOTE: A pack may include sensors, interlocks, contactors, battery management controller, safety devices, thermal management, and structural components.

3.5 C_n

The capacity (C) obtained from a battery discharged at a constant current to an end-of-discharge condition (discharge cutoff voltage) in n hours at 25 °C.

NOTE: C_n is established once and is not adjusted through the battery's life.

3.6 C_n/n RATE

The constant current rate at which a fully charged battery can be discharged to its discharge cutoff voltage in n hours at 25 °C. For example:

- a. C₁/1 - The constant current required to discharge modules in 1 hour at 25 °C
- b. C₂/2 - The constant current required to discharge modules in 2 hours at 25 °C
- c. C₃/3 - The constant current required to discharge modules in 3 hours at 25 °C

NOTE 1: If the rating is not supplied by the manufacturer, then the constant current rate may be calculated based on a fraction of the rated capacity. For example, if a module is rated at 100 Ah, then the C₁/1 discharge rate is 100 A, the C₂/2 is 50 A, and C₃/3 is 33 A. It is expected that using the method will result in discharge times less than 1, 2, and 3 hours for C₁/1, C₂/2, and C₃/3, respectively.

NOTE 2: C_n/n is also commonly written with or without subscript notation (for example: C/n, C/2; C_n, C₂).

3.7 CUTOFF VOLTAGE

Specified voltage of a battery at which the battery discharge or charge is terminated.

NOTE: In practical usage, the cutoff voltage most often refers to discharge cutoff voltage.

3.8 ENERGY DENSITY (VOLUMETRIC ENERGY DENSITY)

The rated energy of a battery divided by its volume.

3.9 HYBRID ELECTRIC VEHICLE (HEV)

A vehicle that can draw propulsion energy from both of the following sources of stored energy: (1) a consumable fuel and (2) a rechargeable energy storage system (RESS) that is recharged by an electric motor-generator system, an external electric energy source, or both.

NOTE: This definition is taken from SAE J1715.

3.10 INITIAL CAPACITY

The first value reference point of battery rated capacity right after testing is initiated.

3.11 MEASUREMENT UNCERTAINTY

The range over which a measured value is expected to lie in within a given probability.

NOTE: Measurement uncertainty includes all random and systematic uncertainties of calibration, operation, and environmental conditions and is calculated/estimated per ISO 17025 requirements. Range is typically defined as percent of full scale (FS), which is the range of a given measurement instrument used or per reading for each measurement value independent of the range of the instrument used.

3.12 RATED CAPACITY

The manufacturer's specification of the total coulometric charge that can be withdrawn from a fully charged battery for a specified set of test conditions, such as discharge rate, temperature, discharge cutoff voltage, etc.

3.13 RATED ENERGY

The manufacturer's specification of the total energy that can be withdrawn from a fully charged battery for a specified set of test conditions, such as discharge rate, temperature, discharge cutoff voltage, etc.

3.14 SPECIFIC ENERGY

The discharge energy capacity of the battery divided by its mass under specified discharge conditions.

NOTE: The commonly used unit is Wh/kg.

3.15 STATE OF CHARGE

A commonly used working definition is:

$$SoC(t) = SoC(0) + \int_0^t \frac{i(t)}{C} dt \quad (\text{Eq. 1})$$

Here, the instantaneous current is $i(t)$ (if the system is negatively polarized, the current is negative) and the capacity of the cell is given as C , where C is a reference state defined under specific temperature and discharge rates. $SoC(t=0)$ is considered as fully charged.

NOTE: SOC is the representation of the level of charge of a battery relative to its referenced capacity through time. SOC is often expressed as a percentage based on a reference point as determined by the manufacturer (for example, 0% = empty charge; 100% = full charge).

4. ABBREVIATIONS

BEV	battery electric vehicle
DCR	direct current resistance
FS	full scale
HEV	hybrid electric vehicle
OCV	open circuit voltage
RESS	rechargeable energy storage system
RT	room temperature (25 °C ± 2 °C)
SOC	state of charge

5. BATTERY MODULE SELECTION

If the measured performance is to be used to establish or verify battery ratings, modules selected for testing should be representative of those to be manufactured and delivered to the market.

6. TEST CONDITIONS

6.1 SOC Adjustment

The SOC adjustment is the procedure to be followed for preparing LIBMs to the various SOC_s (x%) for the tests in this document.

Charge the LIBM with $C_3/3$ at RT until the upper voltage limit specified by the LIBM manufacturer is reached.

- Keep the LIBM stable for 6 hours at RT or as specified by the manufacturer.
- Discharge the LIBM at RT at a $C_3/3$ rate for $(100 - x)/100 \times 3$ hours for BEV applications and $C_1/1$ for $(100 - x)/100 \times 1$ hour for HEV applications, where the x is the SOC% adjustment for each test.