



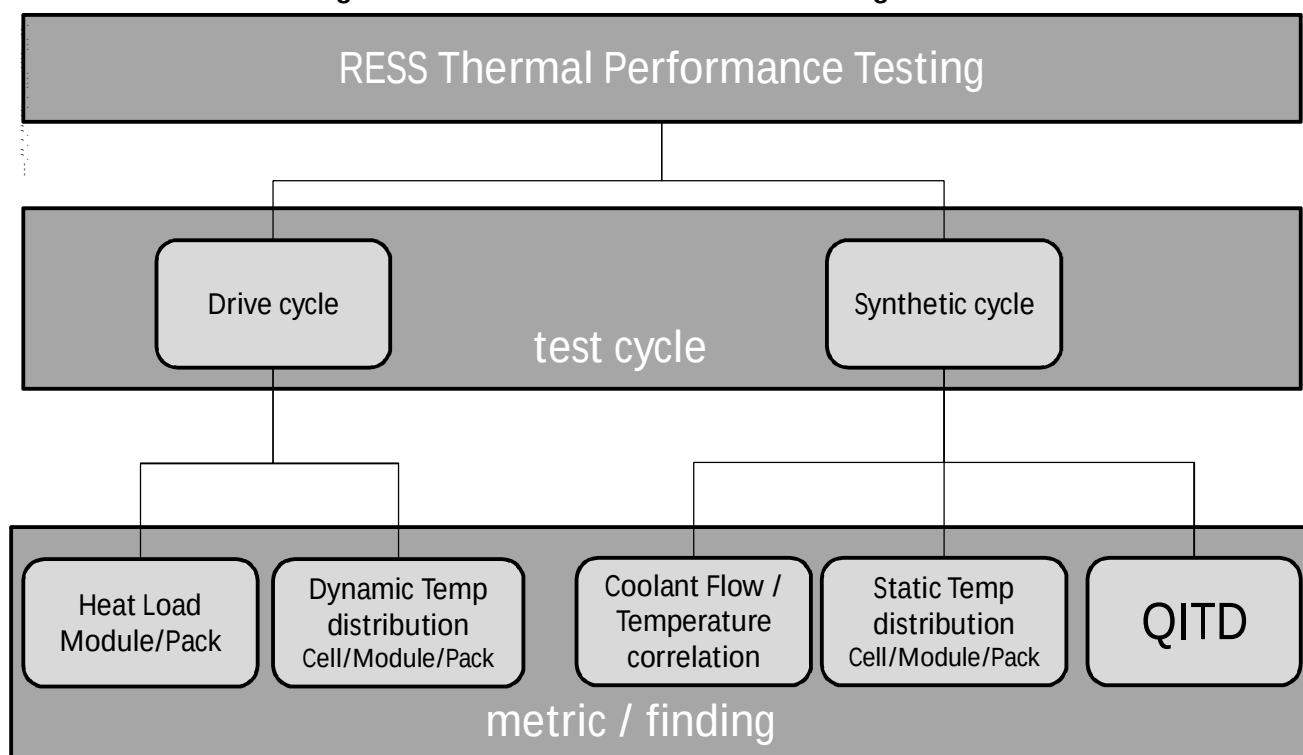
Thermal Characterization Test of Rechargeable Energy Storage Systems

1 Scope

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.

Figure 1: RESS Thermal Performance Testing Overview



1.1 Purpose. This standard specifies the test procedure to characterize the performance of the thermal management system for Hybrid Electric Vehicle (HEV), Plug-in Hybrid Electric Vehicle (PHEV), Extended Range Electric Vehicle (EREV) and Battery Electric Vehicle (BEV) batteries that are used in a vehicle environment (see Figure 1).

1.1.1 Heat Load. Average heat load that the RESS generates during performing different drive cycles and releases to the coolant medium.

1.1.2 Dynamic Temperature Distribution. This test shall be used to evaluate the temperature distribution in x, y and z-direction of a specific Module-design over the course of a driving cycle.

1.1.3 Coolant Flow/Temperature Correlation. This test shall be used for coolant (air or liquid) flow vs. heat load (released to the coolant) evaluation.

1.1.4 Static Temperature Distribution. This test shall be used to evaluate the temperature distribution in x, y and z-direction of a specific Module-design over the course of a steady state condition.

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Originating Department: GME Specification Center

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1.1.5 QITD. This test shall be used to evaluate the ability to meet vehicle rechargeable energy storage systems (RESS) thermal performance metrics. QITD defines the ability to reject heat at specific temperature level. QITD is derived/calculated from Coolant temperature Inlet and Outlet as well as volume flow and Cell temperature on the cell surface.

1.2 Foreword. This standard 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 supersede 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.

1.3 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.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW16460

2.3 Additional References.

Cell Manufacturer Specification

RESS Specification

3 Resources

3.1 Facilities. See paragraph 3.2.

3.2 Equipment.

- Appropriate equipment is required to complete the test procedure defined in paragraph 4 to acquire and store all necessary data.
- Data shall 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, i.e., 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.

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Table 1: Equipment Parameters and Tolerances

Parameter	Range	Tolerance
Temperature (Coolant) – Measure	(-40 to +85) °C	± 0.1 °C
Temperature (Surface) – Measure	(-40 to +85) °C	± 0.5 °C
Chamber Temperature – Generate and Measure	(-40 to +85) °C	± 3 °C
Chamber Humidity – Generate and Measure	(0 to 95) % Relative Humidity (RH)	± 5 % RH
Lab Environment Temperature – Measure	+25 °C	± 10 °C
Lab Environment Humidity – Measure	(10 to 85) % RH	± 5 % RH
Coolant Conditioner – Generate	(-30 to +90) °C	± 1 °C
Maximum Cell Temperature ^{Note 1}	+55 °C	Not applicable
Voltage Sensor – Measure ^{Note 1}	(0 to 450) V	± (0.1 % rdg + 0.1 V) ^{Note 2}
Current Sensor – Measure ^{Note 1}	(-300 to 300) A	± (0.1 % rdg + 0.02 A) ^{Note 2}

Note 1: Range will depend on: Cell chemistry / RESS Application.

Note 2: rdg = Reading

Note: High accuracy voltage and current sensor for pack-resistance calculation needed only.

All temperature sensors used within one test shall be equilibrated to achieve a higher relative accuracy. The Error shall be < 0.2 °C between sensor readings.

3.3 Test Vehicle/Test Piece.

3.3.1 Position and number of sensors shall be according DRE for all module and RESS. DRE should also consider of cell delta temperatures.

3.3.2 Insulation against environment shall reduce heat loss; gaps in insulation shall be reduced to a minimum.

3.4 Test Time. Not applicable.

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.

3.6.1 All personnel performing tests must have up-to-date training records in a high voltage training program.

3.6.2 Personal Protection Equipment (PPE). PPE, such as high voltage gloves, face shields, fire extinguishers, etc., shall be in good working order and available in the immediate area used in the execution of the testing.

4 Procedure

4.1 Preparation.

4.1.1 All Devices Under Test (DUT) shall be subjected to an initial inspection as defined by the requestor. Additional customer requests or requirements must be provided in writing prior to start of test.

4.1.2 Complete all necessary connections following manufacturer specified procedure (HV-connections by electrically trained personnel).

4.2 Conditions.

4.2.1 Environmental Conditions. Not applicable.

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.

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4.3 Instructions.

4.3.1 Drive Cycle.

4.3.1.1 Vehicle Drive Cycle.

Drive cycles depending on vehicle power request. (e.g. US06, HW, City, Top Speed 2 % Grade, etc.).

General approach: Simulate real life behavior (BOL).

Assumption: Vehicle and battery model is available to convert vehicle speed to battery power.

Figure 2: Vehicle Speed to Battery Current

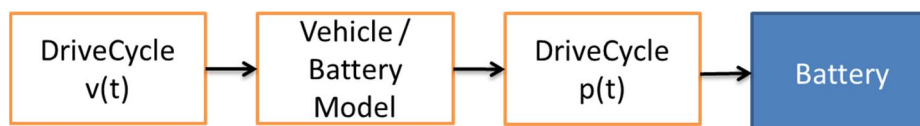
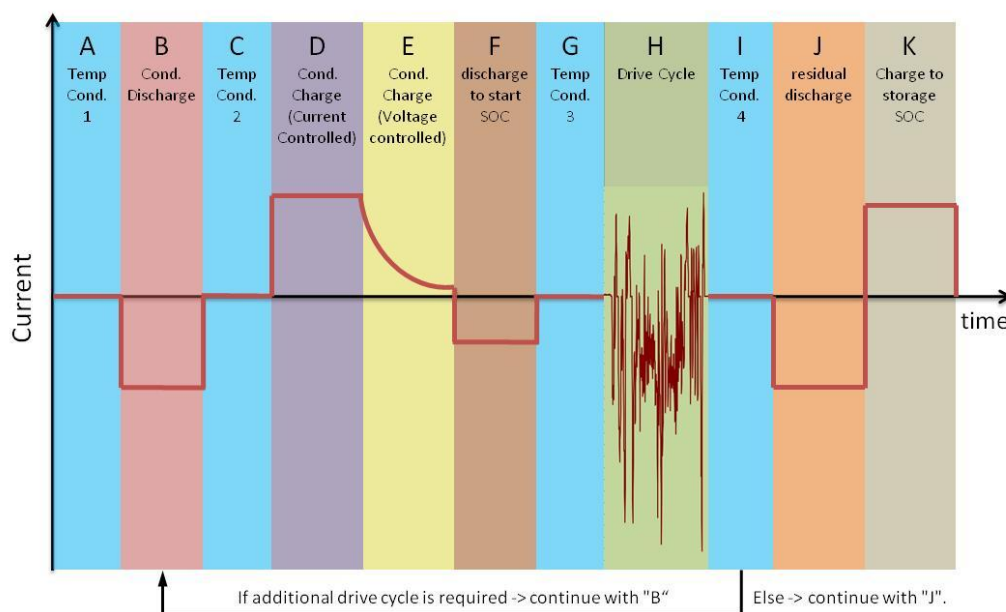


Figure 3: Test Procedure Drive Cycle



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Table 2: Test Procedure Description Drive Cycle

Test Section	step name	Task
	setup connections	complete all necessary connections following manufacturer specified procedure (HV-connections by electrically trained personnel)
	install MSD/DAQ	install MSD and Data Acquisition
	set teststand limits	set teststand-control-limits U_cell_max_lim_static and U_cell_min_lim_static, additional safety limits for tst-safety-shutdown will be set
	startup	initialize DUT to a running state per the manufacturer specified procedure
A	Temperature Conditioning 1	allow DUT temperature to stabilize at desired test temperature until avg_cell_temp-criterion is met
B	Conditioning Discharge	predischarge DUT at 1C/h (C = manufacturer specified Capacity)
B	End of Cond. Discharge	stop predischage when MinCellVolt <= U_cell_min_lim_static
C	Temperature Conditioning 2	allow DUT temperature to stabilize at desired test temperature until avg_cell_temp-criterion is met
D	Cond. Charge (Curr.Controlled)	charge DUT to 100% SOC at 1C/h
D	end of Cond. Charge	stop 1C/h-charge when MaxCellVoltage >= U_cell_max_lim_static
E	Trickle-charge (Voltage Contr)	trickle-charge / cell voltage clamp (voltage-controlled MaxCellVolt = U_cell_max_lim_static)
E	end of Trickle-charge	stop trickle-charge when I_charge <= tricklecharge_stop_current
F	discharge to start SOC	discharge battery to SOCact as defined in test request (lower discharge current = less time @ temp cond 2)
G	Temperature Conditioning 2	allow DUT temperature to stabilize at desired test temperature until avg_cell_temp-criterion is met
H	Drive Cycle	Apply repeating drive cycle RESS power traces according to "RESS in Vehicle Load Trace". (Definition of drive cycle has to be provided by test requester)
H		Stop Test at SOC as defined in test request
I	Temperature Conditioning 3	Cool Down System with DAQ active and cooling settings same as during drivecycle
		If add drivecycle required goto "B" else continue with "J" and "K"
J	residual discharge	Discharge DUT to to minCell Voltage with 1C/h-discharge rate
K	conditioning charge	charge DUT to storage_SOC to ensure storage compliance (this step may be skipped if other tests with same DUT follow consecutively)

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Figure 4: Overview Test Procedure Drive Cycle (Example EREV)

Vehicle Drive Cycle Test

1. RESS conditioning according to table
2. Apply repeating US06 RESS power traces according to "RESS in Vehicle Load Trace"
3. Stop test at 12% SOC
4. Recharge and condition RESS
5. Repeat test with LA92, Highway, City
6. Recharge and condition RESS
7. Adjust RESS power until RESS off heat of 3,1 kW is reached; wait, until all RESS temperatures stabilized for ~ 10 minutes

	Start of Test	End of Test
RESS / Cell	Mule; 2P96S, LG P2.6, 26,05 Ah	
SOC	78,7%	12%
RESS Temperature	20 °C	< 32°C
rest/soak time	5 h (?)	n.a.
cell balance	100 % (?)	n.a.
special sensors	high accurate vlt. and current sensors; coolant flow meter; coolant in & out temp. sensor	
special RESS set up	n.a.	
RESS operating hours	BOL	n.a.

4.3.2 Synthetic Cycle. The defined synthetic cycle (part H according to Figure 5) ensures constant start- and end-SOC (charge neutral). This allows to rerun the cycle for extended period of time and eliminates the SOC-dependant part of the internal resistance.

In general, a common profile shall be a pulse/rectangular or sin wave. Amplitude and frequency depend on cell specifications.

To achieve reproducible results a complete test sequence (Figure 5) is necessary. The pulse test (H) shall contain a minimum of one current range and one coolant flow rate. Depending on the test request, a test matrix of current range and coolant flow rate (Table 4) can be tested in section "H" – for steady state conditions.

If no State of Charge shift occurs the different flow and current amplitude can be driven at once. Please see Table 3 for detailed information.

4.3.2.1 QITD. QITD shall determine thermal performance for each Module, section or RESS. QITD generates a characteristic number to evaluate different designs independent from heat load.

Note: Cell properties and sensor placement influence results.

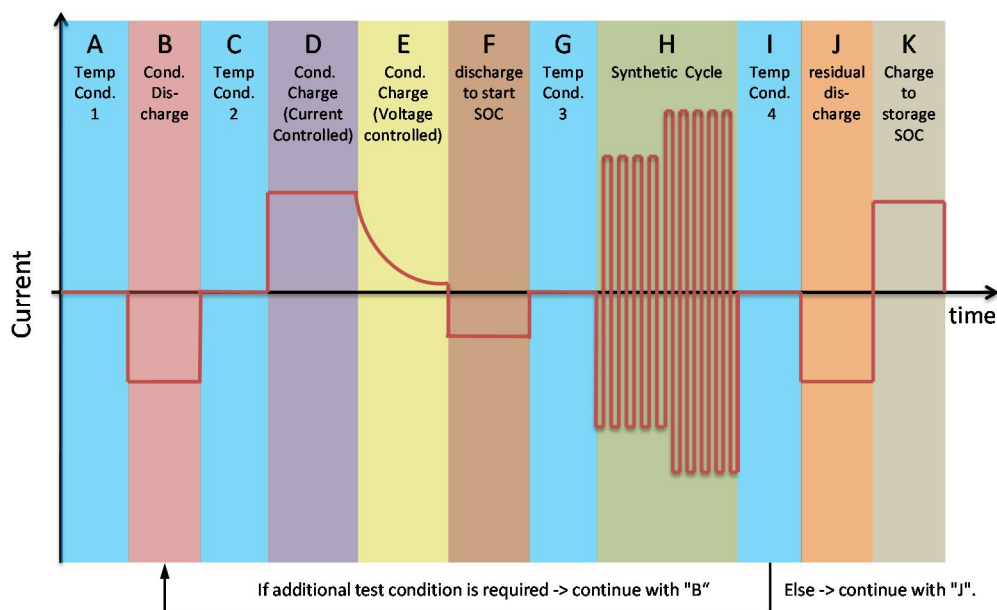
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Figure 5: Test Procedure Synthetic Cycle



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