GM WORLDWIDE ENGINEERING STANDARDS	Test Procedure	GMW17870

General Specification for Power Temperature Cycling (PTC) Testing

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 procedure to subject a Rechargeable Energy Storage System (RESS) to Power Temperature Cycling (PTC) testing to ensure its robustness to thermal fatigue and contact degradation that is caused by temperature changes and possible mismatching of the Coefficient of Thermal Expansion (CTE) of materials. At least 25% of the overall thermal damage must be done by PTC. The combination of PTC and Thermal Shock (TS), i.e., GMW17871, is used to demonstrate the required level of 97% reliability and 50% confidence.

1.2 Applicability. RESS pack, section, and/or module systems, components or materials. **Note:** Samples of systems, components or materials 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 systems, components or materials.

1.3 Remarks. This standard describes methods for evaluating RESS systems, components or materials, i.e., Device Under Test (DUT), in their intended subsystem assembly using temperature extremes specified in applicable Battery and/or Cell Manufacturer Specifications and/or DUT Subsystem Technical Specifications (SSTS) or Component Technical Specifications (CTS). The performance measure is determined by the Functional Status Classification (FSC), see Table A1 in Appendix A, PTC is Class A. A Program Specific Technical Specification may include additional program specific requirements that are not referenced in this standard and may supersede any requirements of this standard. In the case of any conflicts between this standard 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.

IEC 60068-2-14 ISO 16750-4

2.2 GM Standards/Specifications.

GMW16390 GMW17871

2.3 Additional References.

- Battery and/or Cell Manufacturer Specifications and/or DUT SSTS or CTS
- Customer Requests and/or Requirements, i.e., Test Request
- Program Specific Technical Specification

3 Resources

3.1 Facilities.

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

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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. Sized for the RESS to be tested.

3.2.1 Environment Chamber.

3.2.2 Voltage and Current Cycler.

3.2.3 Coolant Conditioner. Liquid cooled RESS only.

3.2.4 Fan. Air cooled RESS only.

3.2.5 Data Acquisition System (DAQ). Appropriate equipment is required to acquire and store all necessary data. Data must be recorded using appropriate software for the cycler in use. Data sources will include data measured by the cycler and any external process indicators, i.e., flow meters. There may be additional data sources.

3.3 Test Vehicle/Test Piece. Air or liquid cooled RESS pack, section, and/or module.

3.4 Test Time.

Calendar time:	10 days to 60 days
Test time:	4 h to 10 h/cycle
Coordination time:	16 h

3.5 Test Required Information. All limits imposed by the Battery and/or Cell Manufacturer Specifications and/or DUT SSTS or CTS shall be observed over the course of testing. In the case of any power, current, voltage and temperature conflicts between this standard and the Battery and/or Cell Manufacturer Specifications and/or DUT SSTS or CTS, the Battery and/or Cell Manufacturer Specifications and/or DUT SSTS or CTS take precedence.

3.6 Personnel/Skills. All personnel performing tests must have up to date training in a high voltage training program and be familiar with IEC 60068-2-14 and ISO 16750-4.

3.7 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 Review the Customer Requests and/or Requirements, i.e., Test Request. **Note:** This is to be provided in writing prior to the start of the test.

4.1.2 Review the applicable Battery and/or Cell Manufacturer Specifications and/or DUT SSTS or CTS conditions for test parameters. Optionally, test parameters can be documented by the test requestor using Table A2 in Appendix A.

4.1.3 Refer to GMW16390 for Test Leg information.

4.1.4 Perform DUT initial inspection as defined by the test requestor.

4.2 Conditions. Cell balancing is to be conducted continuously during the entire length of the test.

4.2.1 Environmental Conditions.

4.2.1.1 Unless specified otherwise by the test requestor, the ambient environment for the DUT should be maintained in accordance with the Battery and/or Cell Manufacturer Specifications and/or DUT SSTS or CTS using the tolerances of Table 1.

4.2.1.2 Unless specified otherwise by the test requestor or defined in the Battery and/or Cell Manufacturer Specifications and/or DUT SSTS or CTS, when changing temperature, i.e., a new test starts or a temperature change occurs within the test, the DUT is required to have environmental conditioning per 4.2.1.2.1 and 4.2.1.2.2.

4.2.1.2.1 Temperature. See 4.3.2 for control of temperature during the test.

4.2.1.2.2 Humidity. Minimize humidity throughout test, preferably ≤ 20% RH.

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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Table 1: Environmental Parameters and Tolerances (for this standard)

Parameter	Range	Tolerance
Chamber Temperature, Generate and Measure	-40 °C to 90 °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	-30 °C to 80 °C	± 1 °C

4.3 Instructions.

4.3.1 General Procedure Notes.

4.3.1.1 Operating Type. Varies: 1.25, 3.1, and 3.2. See Table A3 in Appendix A.

4.3.1.2 Monitoring. Continuous: Cell (thermistor) temperatures, cell voltages, Ambient Temperature, Chamber (T_{amb}), isolation (when maximum cell (thermistor) reaches 25 °C) and any additional data as specified in the Customer Requests and/or Requirements, i.e., Test Request.

4.3.1.3 Criteria. The FSC shall be Class A (Table A1 in Appendix A1), the RESS shall be fully functional before, during and after test. Isolation resistance as measured during the test, may degrade during the course of the test, but shall not exceed minimum isolation resistance values as specified in the Battery and/or Cell Manufacturer Specifications and/or DUT SSTS or CTS. The minimum isolation as measured during the test should be > 1 MΩ. Note any signs of electrolysis or electromigration within the RESS, if present. A cell level Design Review Based on Test Results (DRBTR) inspection and cell tear down (positive middle negative cell in a module) is required.

During the electrical cycling, the RESS shall cycle using durability current profiles based on the Battery and/or Cell Manufacturer Specifications and/or DUT SSTS or CTS operating temperatures and current limits. These limits shall be defined and agreed upon between the RESS Validation and RESS System Engineer (Table A2 in Appendix A).

The RESS shall not cycle during the cold transition to accelerate the cold transition time.

The State of Charge (SOC) at SOT should be the Initial State of Charge (SOC_0). During the test, the SOC should remain centered at SOC_0 ± 15%.

Cell balancing shall be conducted continuously during the entire length of the test based on the cell SOC.

The duration of the test will depend on the length of time needed by the RESS to reach the target limits.

The chamber limits are set in order to accelerate the temperature changes as much as possible without going over RESS ambient temperature limits. However, if these conditions are having too great an impact on cell temperature or other components, and complete dwell times are not reached before temperature limits are reached, it is at the discretion of the RESS Validation Engineer to set appropriate minimum and maximum chamber limits.

As long as the cell target temperatures are being reached, and the full dwell time at those temperatures is conducted, then the thermal cycling requirements are achieved.

4.3.2 Test Steps. Figure 1 is pictorial of the Test Steps.

Step 1. Precondition the RESS to SOC_0 and 25 °C (average cell temperature). When cell temperature delta is ≤ 5 °C conduct an isolation check (Operating Type 3.1). It is desired that the chamber humidity is reduced to < 20% RH before continuing. The RESS must be set to Operating Type 3.1 before proceeding. See Table A3 in Appendix A for a definition on Operating Types.

Step 2. Set the chamber to Maximum Ambient Temperature, Chamber ($T_{max\ amb}$), and start the RESS durability current profile (Operating Type 3.2) as specified by Requestor. See Table 2.

Step 3. When the first DUT reaches Maximum Cell Temperature, Excursion ($T_{max\ cell\ excursion}$), set the chamber to (Maximum Cell Temperature, Extreme ($T_{max\ cell\ extreme}$) + $T_{max\ cell\ excursion}$)/2 and start a 30 minute timer.

Note: The "first DUT" is the one where its maximum cell temperature reaches $T_{max\ cell\ excursion}$ first.

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Step 4. When the last DUT maximum cell temperature reaches $T_{max\ cell\ excursion}$ or the timer reaches 30 minutes, set the chamber temperature to $T_{max\ cell\ excursion}$. Begin the 15 minute dwell. Discontinue test if the delta Maximum Cell Temperature ($T_{max\ cell}$) between all the DUTs is > 3 °C at the 30 minute limit and inspect the test setup.

Note: The "last DUT" is the one where its maximum cell temperature reaches $T_{max\ cell\ excursion}$ last.

Step 5. When the dwell time is complete, set the chamber to Minimum Ambient Temperature, Chamber ($T_{min\ amb}$). Stop the RESS durability current profiles (Operating Type 1.25).

Step 6. When the first DUT reaches Minimum Cell Temperature, Excursion ($T_{min\ cell\ excursion}$), set the timer for 30 minutes. When the last DUT reaches $T_{min\ cell\ excursion}$, or the timer reaches 30 minutes, begin the 15 minute dwell (Operating Type 3.1). Discontinue the test if the delta Minimum Cell Temperature ($T_{min\ cell}$) between all the DUTs is greater than 5 °C at the 30 minute limit and inspect the test setup.

Step 7. When the dwell time is complete, set the chamber to $T_{max\ amb}$, and resume RESS durability current cycling (Operating Type 3.2).

Step 8. When $T_{min\ cell}$ = 25 °C, stop durability current cycling, conduct isolation and SOC checks (Operating Type 3.1). If RESS SOC is ≥ 15% of SOC_0, recondition RESS to SOC_0. Once complete, proceed with RESS durability current profile as specified by Requestor.

Note: One full PTC cycle is complete after RESS recharge and isolation check is complete.

Step 9. Repeat Step 3 (Operating Type 3.2) through Step 9 if the maximum cycle count has not been reached. If all cycles required are completed, return chamber to 25 °C and test is complete. See Table A4 and Table A5 in Appendix A for recommended sample size and cycles based on where the RESS is located in vehicle.

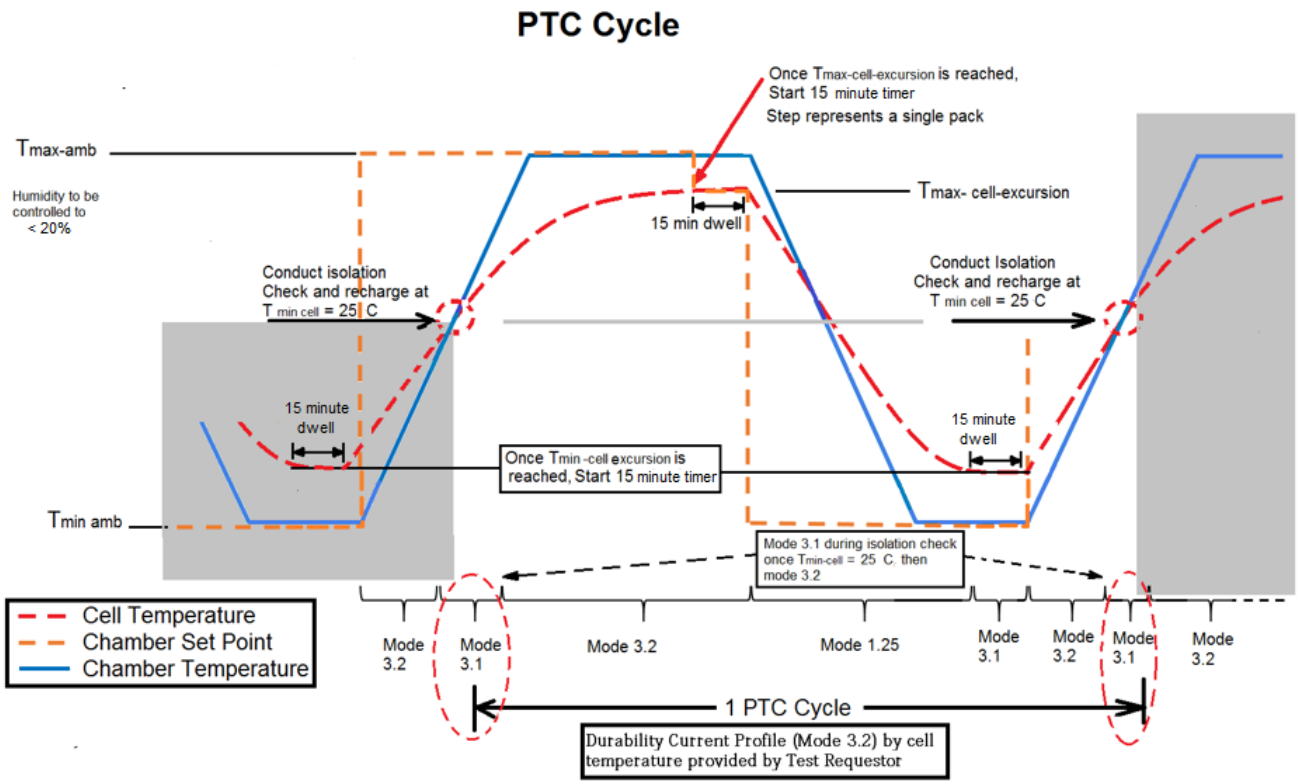

Figure 1: PTC Thermal Cycling and Operating Type Sample (Single DUT Profile)

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