Navigating the Regulatory Maze for Lithium Batteries – Part II
UN/DOT Transportation Testing

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UN/DOT 38.3 Transportation Testing

US code of federal regulations, Title 49 (aka 49 CFR) addresses transportation safety. 49 CFR defines a hazardous material as “a substance or material that the Secretary of Transportation has determined is capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and has designated as hazardous under section 5103 of Federal hazardous materials transportation law (49 U.S.C. 5103)”. The Secretary of Transportation has determined that lithium cells and batteries are considered hazardous materials.

49 CFR part 171.7 references the “UN Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria”. Although the 4th edition is referenced, the 5th edition is now available. Lithium Battery Testing Requirements are detailed under section 38.3. Eight tests are defined, designated T.1 through T.8.

There are several common names given for this group of tests; all are referencing the same requirements:

- UN-DOT Tests
- UN “T” tests
- T1-T8 Testing
- Lithium Battery Transportation Tests
- UN ST/SG/AC.10/27/Rev.4

Note that these refer to the test requirements for the batteries themselves. The actual packaging tests and packaging requirements are covered separately within 49 CFR 178, Subparts L and M.
What Specifically is Covered Under 38.3?

- Lithium metal containing cells and battery packs
- Lithium ion (rechargeable) cells and battery packs

Does battery size matter?

Yes!

- UN/DOT defines “large” and “small” for both cells and batteries, based on either weight or Equivalent Lithium Content (ELC).
- Size plays a significant role in determining the number of cells/batteries required for testing.
- Test T.4 (Shock) contains a distinction for “large” and “small” (50G for large cells/batteries and 150G for small cells/batteries).
- Special provisions exist for “very large batteries”, detailed below.

For cells, size is based on lithium content in fully charged lithium metal cells or on Watt Hour Rating for lithium ion cells. (Watt Hour Rating = Amp Hour rating x Nominal Voltage)

- “Small” Cells:
  - up to 12 grams lithium content, or
  - up to 150 Wh for lithium ion cells

- “Large” Cells:
  - over 12 grams lithium content, or
  - over 150 Wh for lithium ion cells

For batteries, size is based on gross mass, no distinction between lithium metal or lithium ion battery chemistries:

- “Small” batteries are up to 12 kg.
- “Large” batteries are over 12 kg.
How many cells or batteries are required for the T Tests?

Primary Cells and Batteries:

- Primary Cylindrical Cells ➔ 40
- Primary Prismatic Cells ➔ 50
- Primary Batteries (both “large” and “small”) ➔ 8

Secondary Cells and Batteries:

- Secondary (Rechargeable) Cylindrical Cells ➔ 35
- Secondary (Rechargeable) Prismatic Cells ➔ 40
- “Small” Secondary (Rechargeable) Batteries ➔ 16*
- “Large” Secondary (Rechargeable) Batteries ➔ 8*

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* Sample quantity assumes batteries used in tests T.1 - T.5 are damaged and can not be used for test T.7

Special provisions for Battery Assemblies whose cells and modules have already passed all applicable tests:

- **Only 1** Battery needs to be tested for battery assemblies (up to 500 grams lithium metal or an ELC up to 6,200 Wh) whose cells and modules have already passed all applicable tests.
  - For Primary Battery Assemblies, tests T.3, T.4, and T.5 only, tested in the fully charged state.
  - For Secondary Battery Assemblies, tests T.3, T.4, T.5, and T.7 only, tested in the fully charged state, after 25 cycles

- **No testing is required** for very large battery assemblies (over 500 grams lithium metal or an ELC greater than 6,200 Wh) if they are equipped with a BMS (Battery Management System) capable of monitoring the battery assembly and preventing short circuits, over discharge between the batteries in the assembly, and any overheat or overcharge of the battery assembly.

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** Sample quantity assumes battery used in Tests T.3 - T.5 are NOT damaged and can be used for test T.7
T Test Descriptions:

Note:
Tests T.1 through T.5 shall be conducted in sequence on the same cell or battery. Tests T.6 and T.8 shall use new samples. Test T.7 may use samples from tests T.1 through T.5 if undamaged. Otherwise, new samples are required.

T.1:  Altitude Simulation

Low Pressure Testing
Simulates Unpressurized Aircraft (Cargo Area)
15,000 Meter Altitude (50,000 Feet)

TEST: Store Batteries at 11.6kPa for > 6 hours

CRITERIA:
- No Mass Loss, Leaking, Venting, Disassembly, Rupture, or Fire.
- Voltage within 10% of pre-test voltage

T.2:  Thermal Shock

Changes in Temperature Extremes: -40C, +75C

TEST: Store Batteries according to the following
   6 hours @ -40C (12 hours for large cells/batteries)
   <30minute transition
   6 hours @ +75C (12 hours for large cells/batteries)
   <30 minute transition
   Repeat for total of 10 cycles
May be performed in a single chamber or thermal shock chamber.

CRITERIA:
- No Mass Loss, Leaking, Venting, Disassembly, Rupture, or Fire.
- Voltage within 10% of pre-test voltage
T.3: **Vibration**

Simulates Vibration During Transportation

**TEST:** Secure samples to vibration table.
- **Sine Sweep:**
  - 7Hz – 200Hz – 7Hz in 15 Minutes
  - 12 Sweeps (3 hours)
  - 3 mutually perpendicular axes

**CRITERIA:**
- No Mass Loss, Leaking, Venting, Disassembly, Rupture, or Fire.
- Voltage within 10% of pre-test voltage

T.4 **Shock**

Simulates Impacts / Drops During Transportation

**TEST:** Secure samples to shock table
- **Half-Sine pulse**
  - 150G/6ms for small cells/batteries
  - 50G/11ms for large cells/batteries
  - 3 pulses per direction
  - 6 directions (+/-z, +/-x, +/-y)

**CRITERIA:**
- No Mass Loss, Leaking, Venting, Disassembly, Rupture, or Fire.
- Voltage within 10% of pre-test voltage

T.5: **External Short Circuit**

Simulates an external short to the terminals of the cell or battery.

**TEST:** Sample case monitored for temperature.
- Stabilize sample at temperature of +55°C
- Apply short circuit (<0.1ohm) across terminals.
- Maintain at least hour after sample temperature returns to +55 +/-2°C.
- Remove Short circuit and monitor sample for additional 6 hours.
T.6:  **Impact (Primary and Secondary Cells Only)**

Simulates an impact to the case of the cell.

**TEST:** Sample placed on flat surface, temperature monitored.
- 15.8mm diameter bar placed across the center of the sample.
- 9.1kg mass dropped onto bar above sample from 61cm height.
- One Impact per sample.
- Sample monitored for 6 hours after test.

**CRITERIA:**
- Case temperature does not exceed +170C
- No disassembly or fire within 6 hours of test.

**ALLOWED:**
- Venting mechanism activates

T.7:  **Overcharge (Rechargeable Batteries Only)**

Simulates an overcharge condition on a rechargeable Battery.

**TEST:** Sample connected electrically to a DC power Supply or Battery Charger/Cycler, with programmable voltage and current control.
- An overcharge current of 2x the manufacturers recommended charge current shall be applied for 24 hours.
- Charge Voltage applied:
  - If recommended Charge voltage is 18V or less: 2x charge voltage, up to 22V
  - If recommended Charge voltage is >18V: 1.2x maximum charge voltage
CRITERIA:
- No disassembly or fire within 7 days of test.

ALLOWED:
- Protection Device (fuse, current limiting circuit) activates.
- Venting mechanism activates

T8: Forced Discharge (Primary and Rechargeable Cells Only)

Simulates a forced discharge condition:
- Misconnected charger
- Series cell installed in reverse.

TEST: Sample connected in series with +12V DC Power Supply and load resistor.
Load resistor shall be sized to provide the maximum discharge current of the battery with 12V applied in series.
Duration is calculated from the rated Amp hours of the cell
Duration(h) = ratedAh / InitialCurrent(A)

CRITERIA:
- No disassembly or fire within 7 days of test.

ALLOWED:
- Protection Device (fuse, current limiting circuit) activates.
- Venting mechanism activates
Details on samples required for testing CELLS:

<table>
<thead>
<tr>
<th>CELLS:</th>
<th>Altitude</th>
<th>Thermal Shock</th>
<th>Vibration</th>
<th>Shock</th>
<th>External Short</th>
<th>Impact</th>
<th>Overcharge</th>
<th>Forced Discharge</th>
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<td>T.5</td>
<td>T.6</td>
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<td>T.8</td>
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<td>• Fully Discharged</td>
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<td>Primary Cells, Prismatic</td>
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<td>Rechargeable Cells, Cylindrical</td>
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<td>• 1st cycle, charged</td>
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<td>• 1st cycle 50% discharged</td>
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<td>Rechargeable Cells, Prismatic</td>
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<td>• 1st cycle, charged</td>
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<td>• 1st cycle fully discharged</td>
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<td>N/A</td>
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<td>• 1st cycle 50% discharged</td>
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<td>• 50 cycles, fully discharged</td>
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Details on samples required for testing BATTERIES:

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<tr>
<th>BATTERIES:</th>
<th>Altitude</th>
<th>Thermal Shock</th>
<th>Vibration</th>
<th>Shock</th>
<th>External Short</th>
<th>Impact</th>
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<td>Small Primary Batteries (up to 12kg)</td>
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<td>• Fully Discharged</td>
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<td>Large Primary Batteries (over 12kg)</td>
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<td>Small Rechargeable Batteries (up to 12kg)</td>
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<td>• 1st cycle, charged</td>
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<td>4*</td>
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<td>• 50 cycles, charged</td>
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<td>• 1st cycle, charged</td>
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<td>• 25 cycles, charged</td>
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<td>N/A</td>
<td>2*</td>
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</table>

* May use the same samples from tests T.1 - T.5 if undamaged. Otherwise, will require new samples.
Details on samples required for testing BATTERY ASSEMBLIES whose cells and battery modules that have passed all applicable tests:

BATTERY ASSEMBLIES whose cells and modules have passed UN/DOT 38.3 Testing:

<table>
<thead>
<tr>
<th></th>
<th>Altitude</th>
<th>Thermal Shock</th>
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</table>

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In the coming months, Intertek will provide a series of white papers on lithium battery safety standards, next up is IEC 62133 and the transition from UL 1642.

Intertek’s expertise in battery testing & energy storage services ensures products meet performance, reliability and safety criteria. Intertek has expanded global energy storage testing facilities and advisory services. Throughout design, manufacturing & system deployment cycles, Intertek provides evaluations for performance, electrical safety, interoperability, fit for use, component selection and more. Please visit our website at www.intertek.com/energy-storage, contact icenter@intertek.com or call your regional lab:

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