Performance and Safety of COTS 18650 Li-ion Cells from Various Manufacturers

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Outline

• Cell Characteristics
• Performance of Panasonic Cells
• Safety of Panasonic Cells
• Performance of Moli STOBA cells
• Safety of Moli STOBA cells
• Performance of LG cells at Different Temperatures
18650 Lithium-ion cells

Panasonic 3.1 Ah

LG 2.8 Ah

Moli STOBA 2.0 Ah
Panasonic 3.1 Ah Li-ion 18650 Cell

Performance and Safety Test Data
Panasonic 3.1 Ah Li-ion 18650 Cell

- **Sample 1**
  - Charge: C/2
  - Discharge: 1C
  - Capacity Change: -10.3%
  - Reversal Change: +0.88%
  - Cycle 1: 2.93 Ah
  - Cycle 300: 2.54 Ah

- **Sample 2**
  - Charge: C/2
  - Discharge: C/5
  - Capacity Change: -12.7%
  - Reversal Change: -1.5%
  - Cycle 1: 3.0 Ah
  - Cycle 250: 2.62 Ah

- **Sample 3**
  - Charge: C/2
  - Discharge: C/10
  - Capacity Change: -9.2%
  - Reversal Change: -14.5%
  - Cycle 1: 3.04 Ah
  - Cycle 150: 2.76 Ah
Panasonic Li-ion 3.1 Ah 18650 Cell

**Sample 1**
- Ch: C/5
- Disch: 1C

- **Cycle 1:** 2.92 Ah
- **Cycle 300:** 2.64 Ah

- **Cap. Change:** -9.6%
- **Re Change:** +0.86%

**Sample 2**
- Ch: C/5
- Disch: C/2

- **Cycle 1:** 2.95 Ah
- **Cycle 250:** 2.63 Ah

- **Cap. Change:** -10.8%
- **Re Change:** -0.6%

**Sample 1**
- Ch: C/5
- Disch: C/3

- **Cycle 1:** 2.98 Ah
- **Cycle 200:** 2.66 Ah

- **Cap. Change:** -10.7%
- **Re Change:** -14.4%

**Sample 2**
- Ch: C/5
- Disch: C/10

- **Cycle 1:** 3.03 Ah
- **Cycle 125:** 2.85 Ah

- **Cap. Change:** -5.9%
- **Re Change:** -16.4%
Panasonic 3.1 Ah Li-ion 18650 Cell

- Cap. Change: -11.9%
- Re Change: +0.54%

- Cap. Change: -20.5%
- Re Change: -1.8%
Panasonic 3.1 Ah Li-ion 18650 Cell

Performance Capabilities at 0°C
- Cap Change: -5%
- -15% of RT

Performance Capabilities at -20°C
- Cap Change: -80%
- -53% of RT

Performance Capabilities at -10°C
- Cap Change: -54%
- -21% of RT

Performance Capabilities at 30°C
- Cap Change: -3.9%
- 3.5% of RT
Panasonic 3.1 Ah Li-ion 18650 Cell

Performance Capabilities at 40°C

Cap Change: -3.2%
4.5% of RT
Panasonic 3.1 Ah Li-ion 18650 Cell
Panasonic 3.1 Ah 18650 Li-ion Cell

**Over-Charge 8 Series at 1 C current**

- **Current (A)**: 0.00 to 3.50
- **Voltage (V)**: 3.00 to 70.00

Max Voltage = 41.13 V

Cell #1, #3, #5, #7 CID activated creating open circuit

**Test C1: Over-Charge Test Cell 5 of 8 Cells in Series**

- **Voltage (V)**: 3.50 to 5.50
- **Temperature (°C)**: 20 to 60

Max Temp = 57.26 °C

Max Voltage = 5.10 V

CID activated
Panasonic 3.1 Ah Li-ion 18650 Cell

Over-Discharge to 0 V

Peak Temperature = 58.22 °C

Normal Cycle Charge

Normal Cycle Charge Failed

Discharge to 1 V

Discharge to 0 V
Panasonic 3.1 Ah Li-ion 18650 Cell
Panasonic 3.1 Ah Li-ion 18650 Cell Series String External Short (10 mohms)

<table>
<thead>
<tr>
<th>Cell #</th>
<th>Final Voltage (V)</th>
<th>External Resistance (mOhm)</th>
<th>Maximum Current (A)</th>
<th>Maximum Temp (°C)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.95</td>
<td>9.7</td>
<td>-</td>
<td>31.60</td>
<td>No vent or fire</td>
</tr>
<tr>
<td>2</td>
<td>3.95</td>
<td>9.7</td>
<td>-</td>
<td>32.73</td>
<td>No vent or fire</td>
</tr>
<tr>
<td>3</td>
<td>3.95</td>
<td>9.7</td>
<td>-</td>
<td>30.96</td>
<td>No vent or fire</td>
</tr>
<tr>
<td>4</td>
<td>3.95</td>
<td>9.7</td>
<td>-</td>
<td>31.04</td>
<td>No vent or fire</td>
</tr>
<tr>
<td>5</td>
<td>3.95</td>
<td>9.7</td>
<td>-</td>
<td>35.15</td>
<td>No vent or fire</td>
</tr>
<tr>
<td>6</td>
<td>3.94</td>
<td>9.7</td>
<td>-</td>
<td>42.42</td>
<td>No vent or fire</td>
</tr>
<tr>
<td>7</td>
<td>0.00</td>
<td>9.7</td>
<td>-</td>
<td>45.43</td>
<td>Smoked, no fire, burn mark on cathode tab</td>
</tr>
<tr>
<td>8</td>
<td>3.94</td>
<td>9.7</td>
<td>-</td>
<td>38.63</td>
<td>Smoked, no fire, burn mark on cathode tab</td>
</tr>
<tr>
<td>9</td>
<td>3.95</td>
<td>9.7</td>
<td>-</td>
<td>31.12</td>
<td>No vent or fire</td>
</tr>
<tr>
<td>Overall</td>
<td>-</td>
<td>9.7</td>
<td>92.13</td>
<td>-</td>
<td>No vent or fire</td>
</tr>
</tbody>
</table>
Panasonic 3.1 Ah Li-ion 18650 Cell

Simulated Internal Short with .125" Rod

Max Temp Prior to Fire = 44.15 °C

Voltage (V)

Time (h:mm:ss)
Panasonic 3.1 Ah Li-ion 18650 Cell
Moli STOBA 2.0 Ah Li-ion 18650 Cell

Performance and Safety Test Data
Moli STOBA 2.0 Ah Li-ion Cell

Cap. Change: - 6.3 %
Re Change:+ 7.96%

Cap. Change: -11.6 %
Re Change: +26.7%

Cap. Change: -9.7 %
Re Change: +13.98%

Cap. Change: - 2.4 %
Re Change: 0%
Moli STOBA 2.0 Ah Li-ion Cell

- **C/5 Charge / 1C Discharge**
  - Cap. Change: -6.3%
  - Re Change: +11.2%

- **C/5 Charge / C/5 Discharge**
  - Cap. Change: -5.1%
  - Re Change: +1.5%

- **C/5 Charge / C/2 Discharge**
  - Cap. Change: -6.8%
  - Re Change: +10.5%

- **C/5 Charge / C/10 Discharge**
  - Cap. Change: -1.97%
  - Re Change: 0%
Moli STOBA 2.0 Ah Li-ion Cell

**C/1 Charge / C/1 Discharge**
- Cap. Change: -8.8%
- Re Change: 16.3%

**1C Charge / C/2 Discharge**
- Cap. Change: -9.8%
- Re Change: 11.23%
Moli STOBA 2.0 Ah Li-ion Cell

Performance Capabilities at 0°C

< 17.1% of RT

Performance Capabilities at -20°C

< 39.75% of RT

Performance Capabilities at -10°C

< 26.2% of RT

Performance Capabilities at 30°C

< 3.2% of RT
Moli STOBA 2.0 Ah Li-ion Cell

Performance Capabilities at 40°C

> 4.8% of RT

Internal Resistance

Depth of Discharge (%)
Moli STOBA 2.0 Ah Li-ion Cell

Fresh Cell

Cycled Cell
Moli STOBA 2.0 Ah Li-ion Cell
Moli STOBA 2.0 Ah Li-ion Cell
Moli STOBA 2.0 Ah Li-ion Cell

Temp Ramp Rate: 1.5 deg C/min.
Moli STOBA 2.0 Ah Li-ion Cell
Vent and Burst Pressure Test Data

Sample 14 vent opened at a pressure of 155 psi.
Sample 15 vent opened at a pressure of 145 psi.

Sample 10 burst at a pressure of 859 psi. Failure around crimp seal.
Sample 11 burst at a pressure of 645 psi. Failure around crimp seal.
LG 2.8 Ah Li-ion 18650 Cell

Performance at Various Temperatures
LG 2.8 Ah Li-ion 18650 Cell

Disch Capacity at 23 deg C: 1.53 Ah
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