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

Ch: C/2 Disch: 1C

Cap. Change: -10.3%
Re Change: +0.88%

Sample 3
Cycle: 2.93 Ah
Cycle 300: 2.64 Ah

Cap. Change: -12.7%
Re Change: -1.5%

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

Cycle: 3.0 Ah
Cycle 250: 2.62 Ah

Cap. Change: -13.3%
Re Change: -5.8%

Sample 1
Ch: C/2 Disch: C/2

Cycle: 2.93 Ah
Cycle 300: 2.54 Ah

Cap. Change: -9.2%
Re Change: -14.5%
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 1**
- Ch: C/5
- Disch: C/5
- Cycle 1: 2.98 Ah
- Cycle 200: 2.66 Ah

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

**Sample 1**
- 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 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

Charge and Disch: C/5

Performance Capabilities at -20°C

Cap Change: -80%
-53% of RT

Performance Capabilities at -10°C

Cap Change: -54%
-21% of RT

Charge and Disch: C/5

Performance Capabilities at 30°C

Cap Change: -3.9%
3.5% of RT

Charge and Disch: C/5
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

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

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

Current (A) / Voltage (V)

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

**External Short (10 mohms)**

- **2 hours**
  - Max Current = 76.48 A
  - Max Temperature = 62.02 °C

- **4 hours**
  - Max Current = 90.06 A
  - Max Temperature = 72.82 °C

**Voltage (V) / Current (A) / Temperature (°C)**

**Time (h:mm:ss)**

**Current (A)**

**Time (s.s.)**
Panasonic 3.1 Ah Li-ion 18650 Cell Series String External Short (10 mohms)
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

Heat-to-Vent

<table>
<thead>
<tr>
<th>Voltage (V)</th>
<th>Temperature (°C)</th>
</tr>
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<tbody>
<tr>
<td>5.0</td>
<td>600</td>
</tr>
<tr>
<td>4.5</td>
<td>550</td>
</tr>
<tr>
<td>4.0</td>
<td>500</td>
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<td>3.5</td>
<td>450</td>
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<td>3.0</td>
<td>400</td>
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<td>300</td>
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<td>250</td>
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<tr>
<td>0.5</td>
<td>150</td>
</tr>
<tr>
<td>0.0</td>
<td>100</td>
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</tbody>
</table>

Fire at 188.63°C

Time (h:mm:ss)

0:00:00 0:15:00 0:30:00 0:45:00 1:00:00 1:15:00
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**
  - Capacity: -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

$< 17.1\% \text{ of RT}$

Performance Capabilities at -20°C

$< 39.75\% \text{ of RT}$

Performance Capabilities at -10°C

$< 26.2\% \text{ of RT}$

Performance Capabilities at 30°C

$< 3.2\% \text{ of RT}$
Moli STOBA 2.0 Ah Li-ion Cell

Performance Capabilities at 40°C

> 4.8% of RT

Internal Resistance

Capacity (Ah)

Cycle Number

Internal Resistance (mΩ)

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

Overdischarge (Discharge to 1 VDC & Charge-Discharge Cycle) Sample 16

Overdischarge (Voltage Reversal) Sample 16
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

Discharge Capacity at 23 deg C: 1.53 Ah
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