Evaluation of Safety and Performance of Sony Lithium Ion Cells

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Sony Lithium Ion Cells

Physical Characteristics

- **Dimensions (18650)**

Average Weight (g)	Average Height (mm)	Average Diameter (mm)
39.660 ± 0.079	64.91± 0.18	18.12 ± 0.03

Electrochemical Characteristics

- **Open Circuit Voltage**

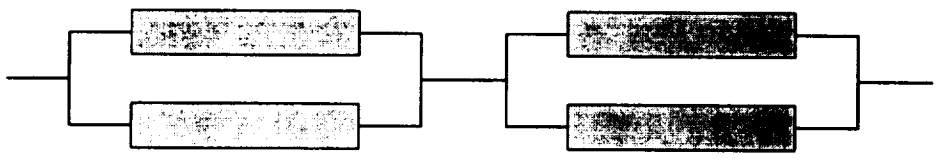
  3.858 ± 0.015 V

- **Closed Circuit Voltage**

  3.69 ± 0.14 V

Canon Battery (BP-927) Characteristics

- **Weight**: 185 g (approx.)
- **Dimensions**: 38.2 X 39 X 70.5 mm (approx.)
- **Voltage**: 7.2 V
- **Capacity**: 2700 mAh
- **Configuration**: 2P2S
- **Smart Circuit Board**

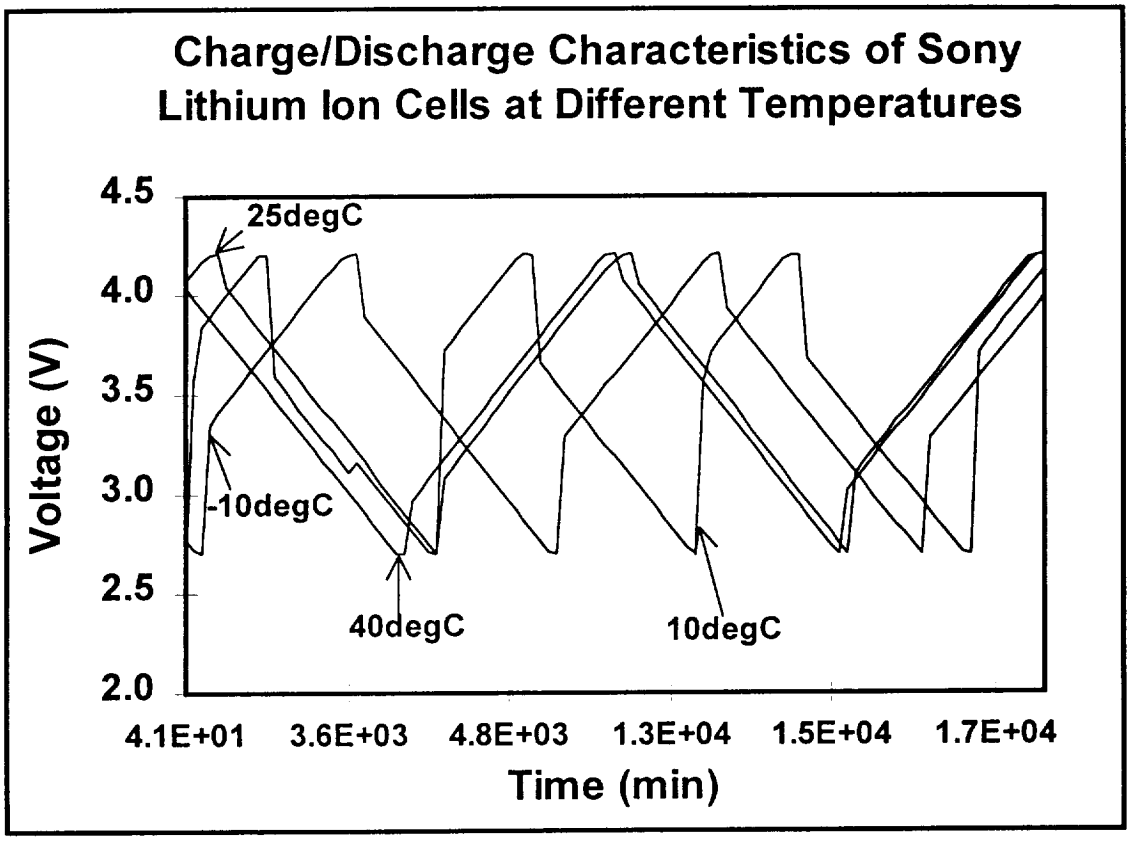


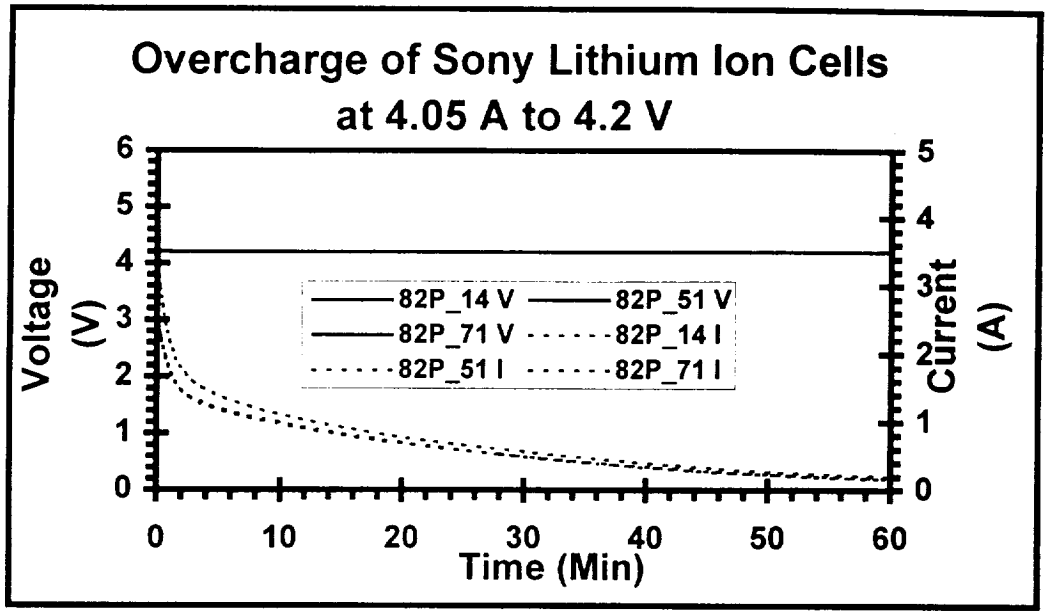
Sony Lithium Ion Cells

Electrochemical Characteristics

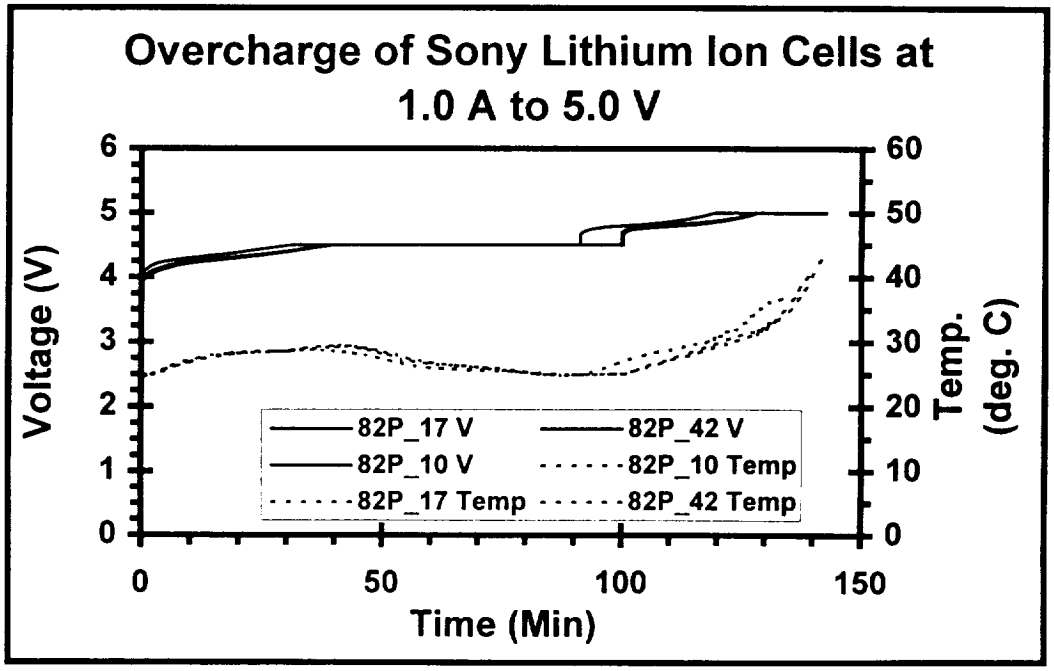
- **Capacities at Different Temperatures**

Temperature	Average Capacity (Ah)
40 °C	1.157
25 °C	1.18
10 °C	0.991
-10 °C	0.572

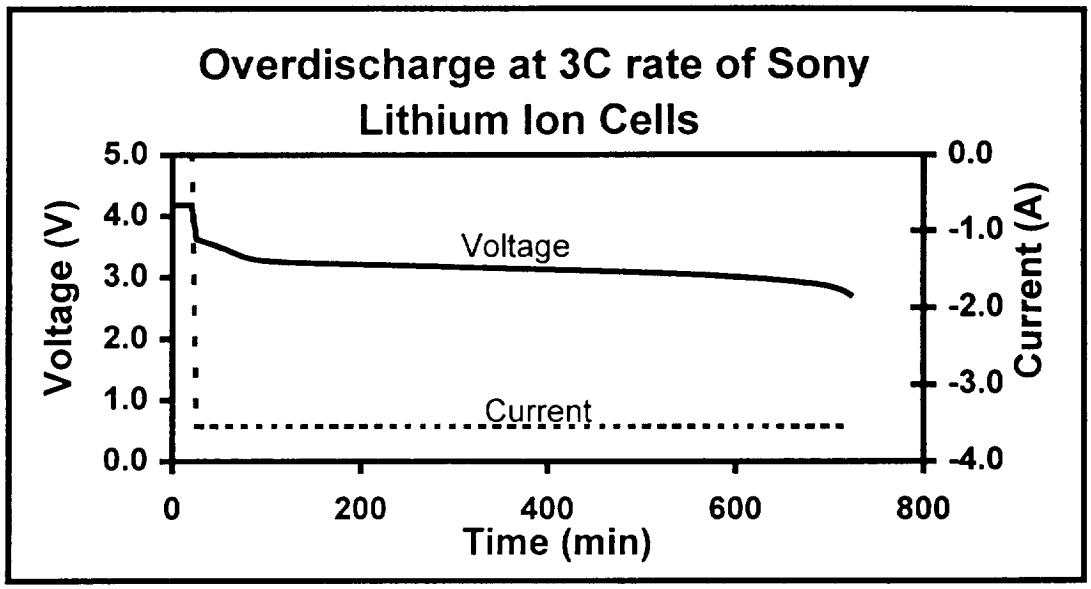




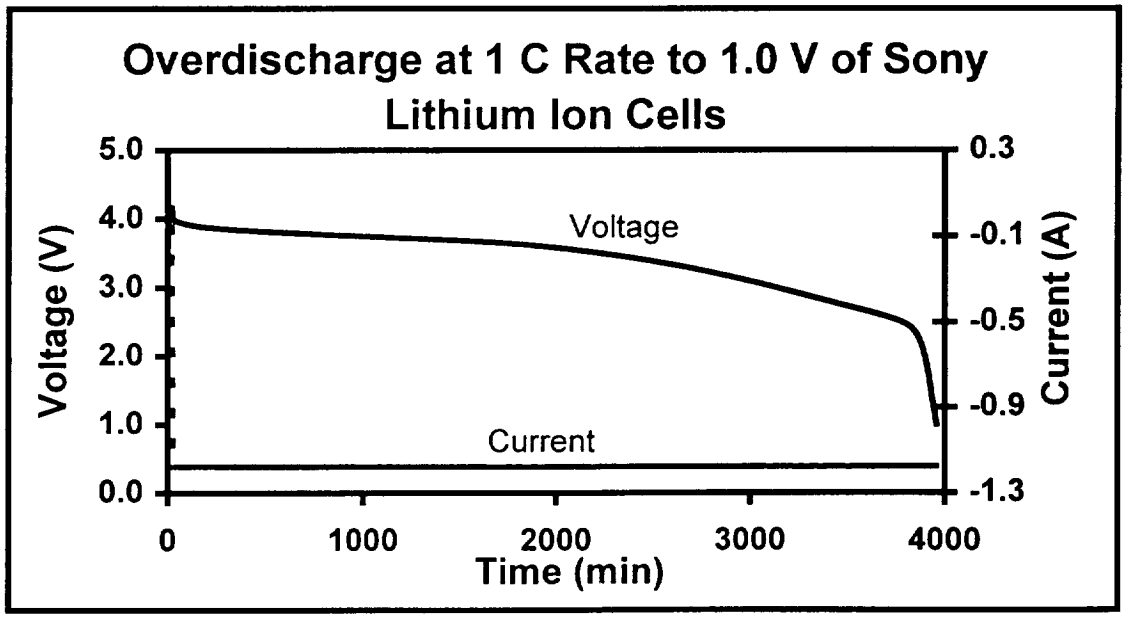
- Attains 4.2 V immediately.
- No venting, fire or explosions due to fast charge.



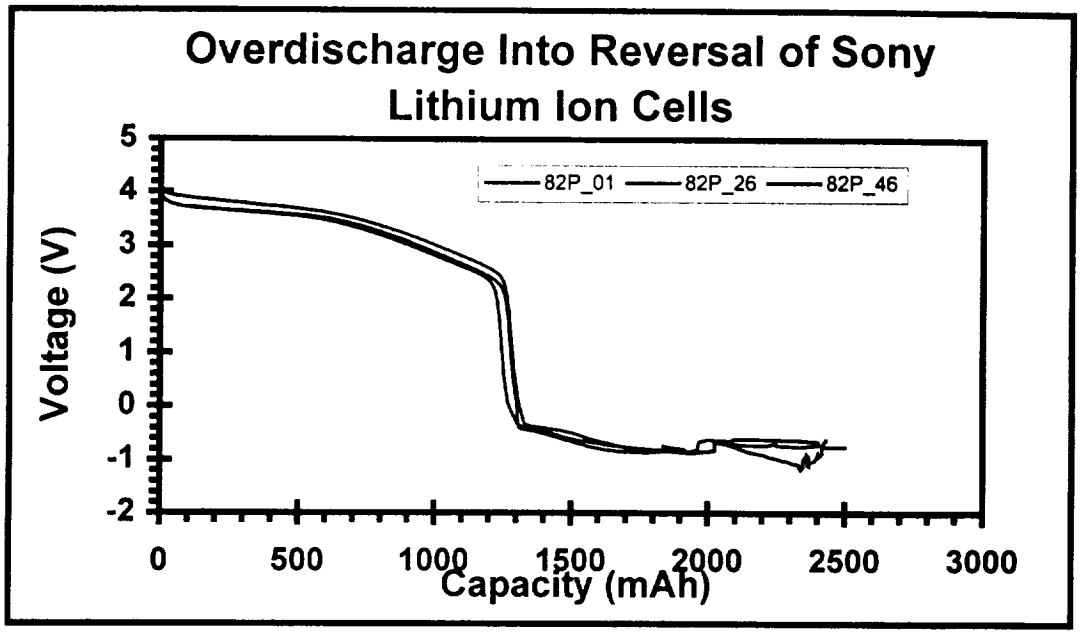
- Current Interrupt Device (CID) is activated when voltage reaches 5.0 V or when maintained at 5.0 V.



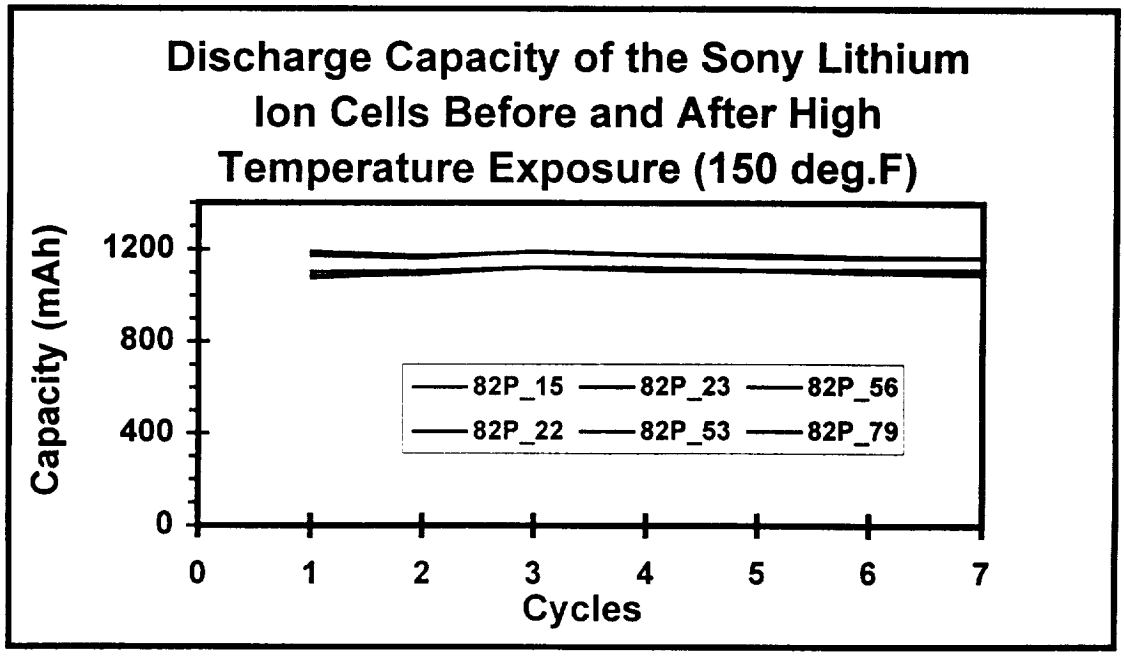
- **Cells performed nominally on charge/discharge cycles.**
- **No venting, fire or explosions**



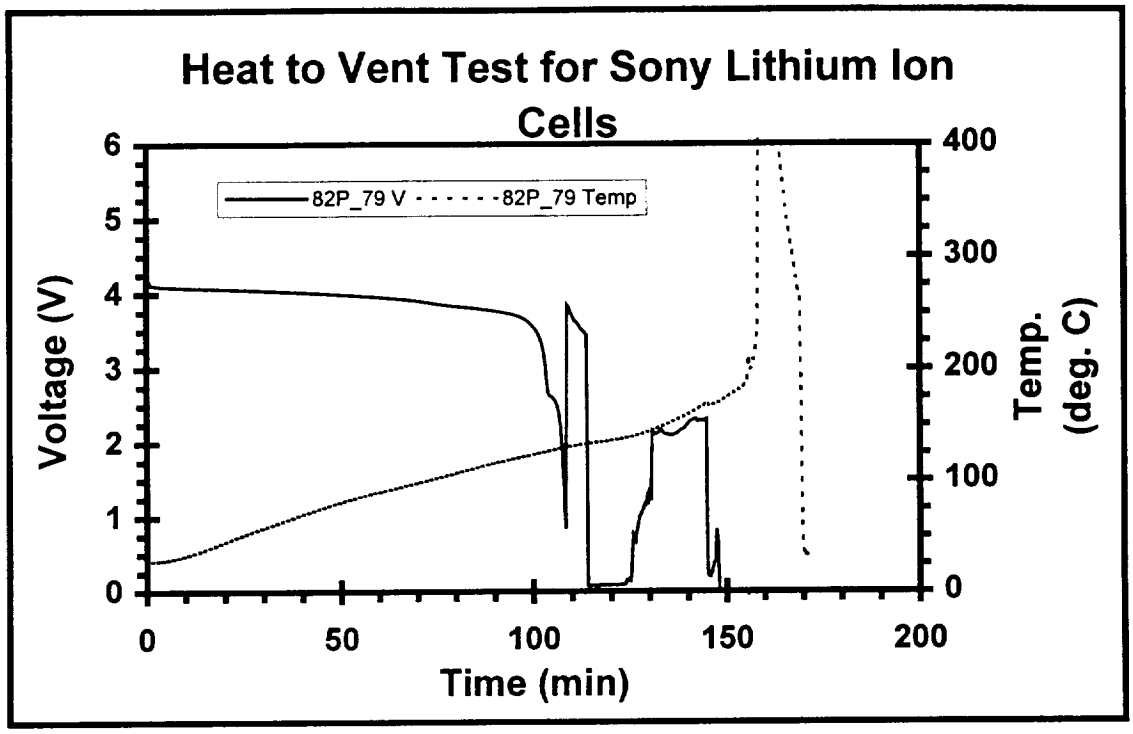
- **Performed nominally on the few charge/discharge cycles carried out after test.**
- **No catastrophic events.**



- Cells functional with no changes in capacity for the few cycles performed after test.
- No occurrence of cell venting.



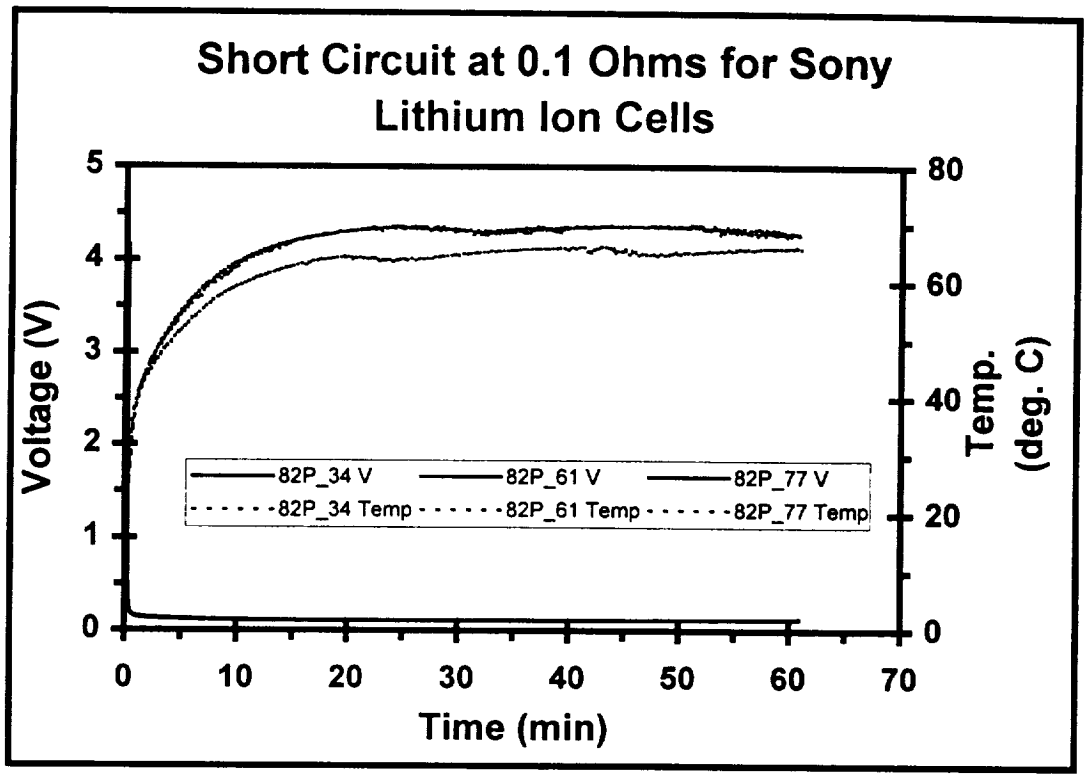
- No changes in functional performance of the cells after exposure to a temperature of 150 °F in an oven.
- No cell venting observed.



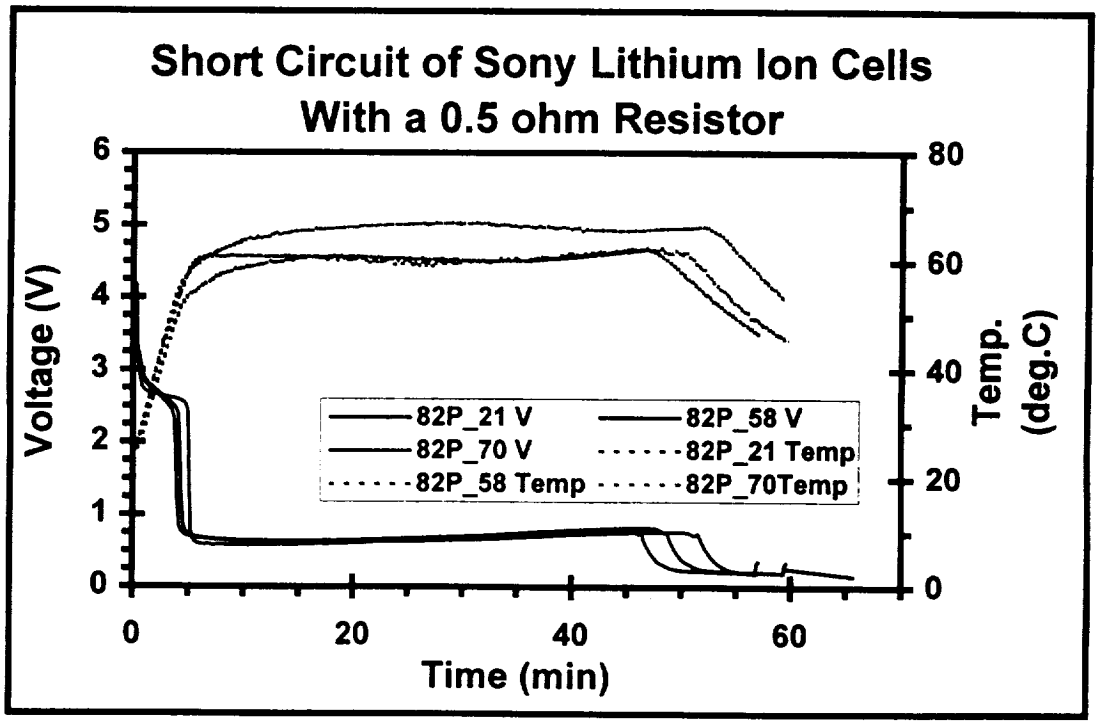
- Venting occurs above 150 °C.

Drop Test on Sony Lithium Ion Cells

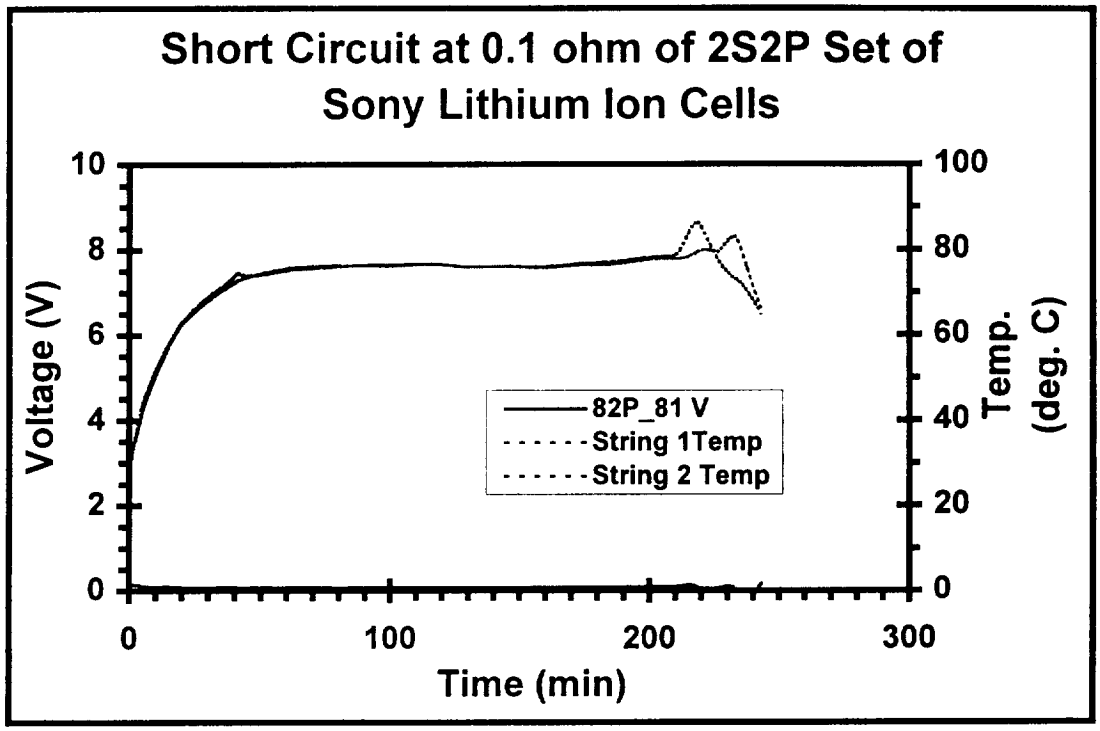
- Six cells dropped from a height of 6 ft. and 3 cells from a height of 3 ft.
- Physical damage such as dents around the circumference at the top and bottom.
- No events, no changes in capacity of cells
- No change in weight of cells to indicate occurrence of venting.



- PTC shuts off any electrical contact immediately.

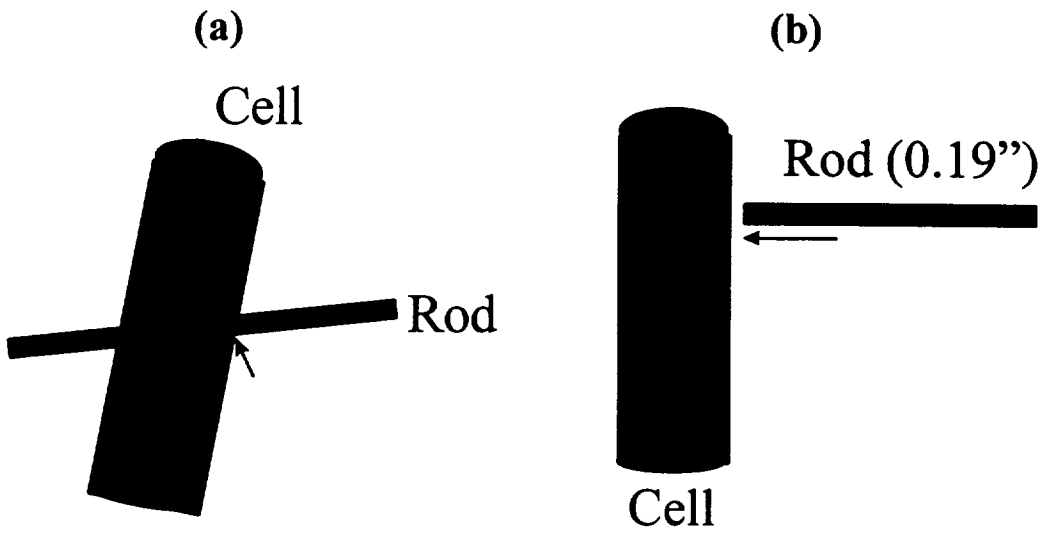


- PTC cuts off electrical contact.
- Electrical contact is reestablished when the PTC stabilizes.



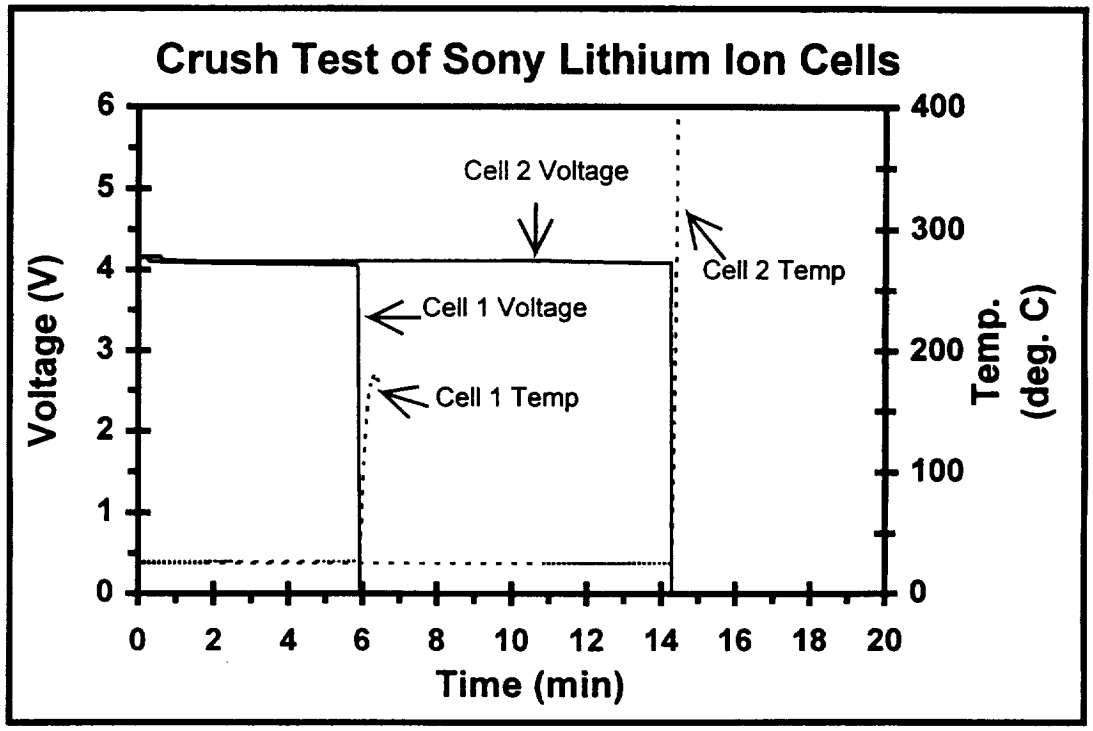
- **PTC cuts off electrical contact by an increase in resistance.**
- **No weight changes in the short circuit tests indicating absence of venting.**
- **No catastrophic events in the short circuit tests carried out.**

Crush Test of Sony Lithium Ion Cells

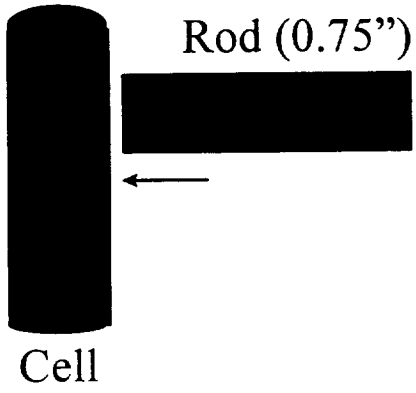


(a) No venting, fire or explosion

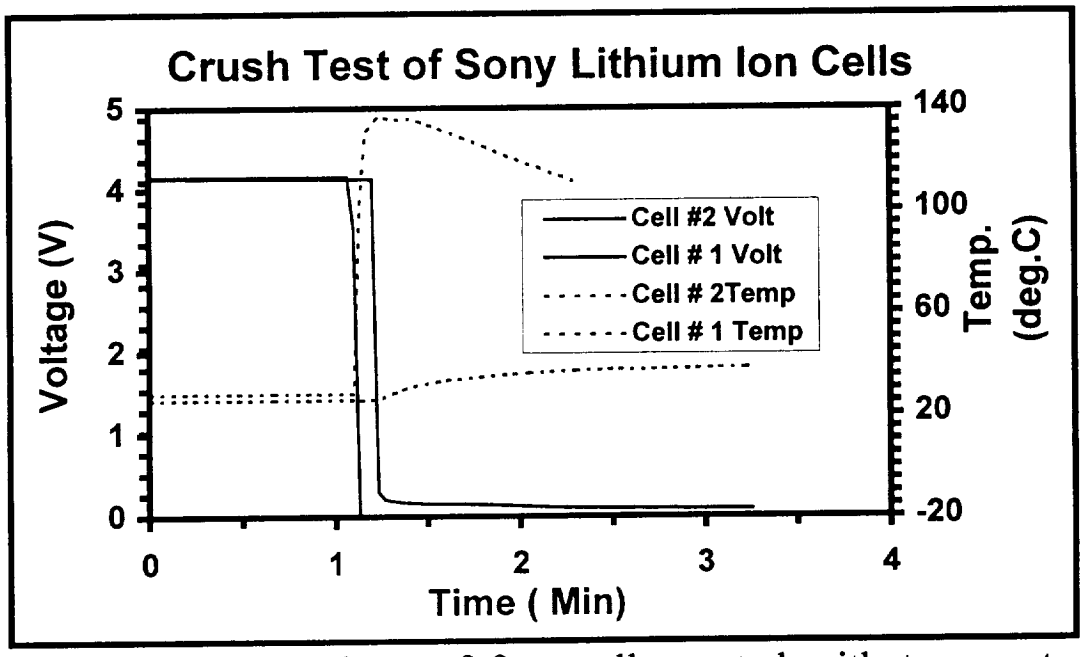
(b) Four cells out of six experienced violent venting with thermal runaway, the other two exploded.



(C)



Steel Fixture

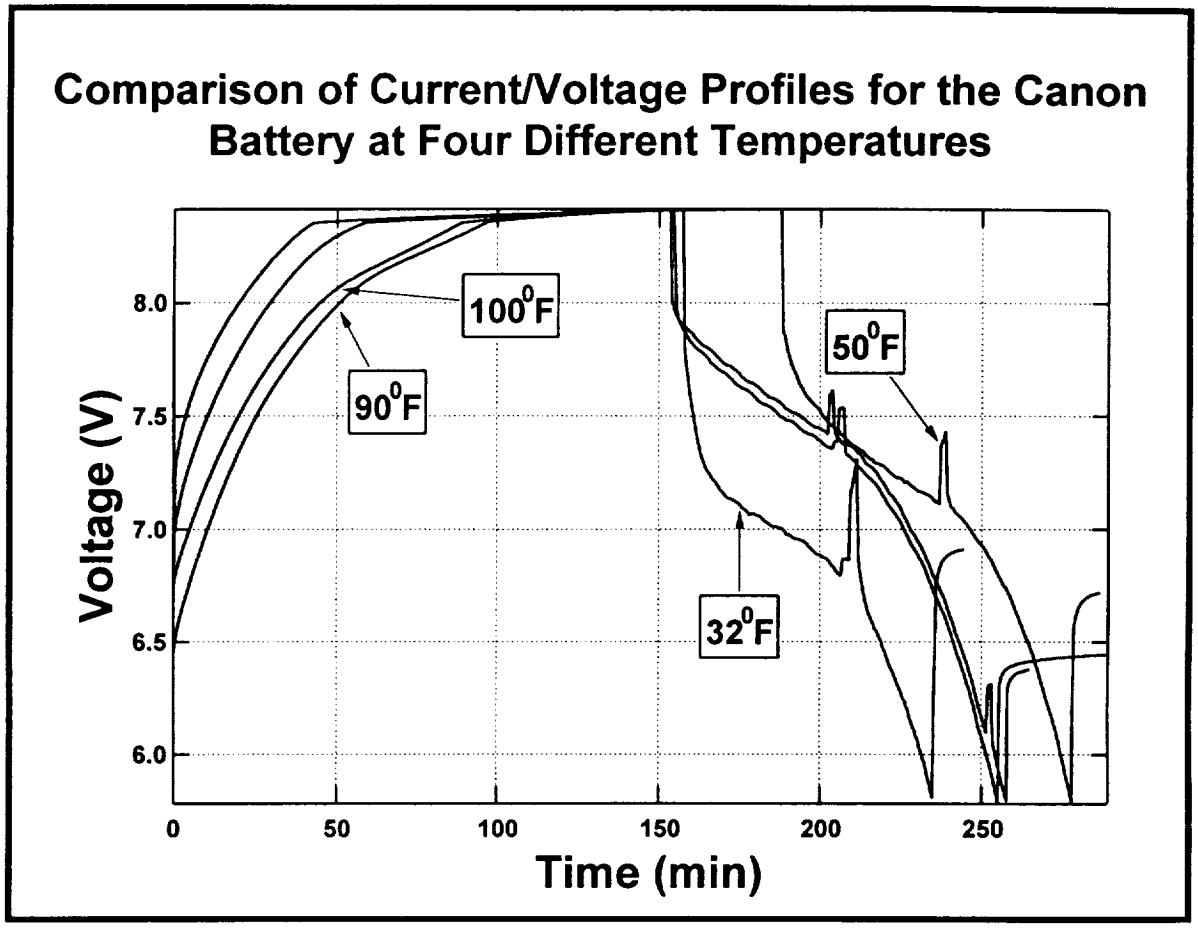


- No explosions. Three of four cells vented with temperatures between 80 °C to 100 °C. Fourth cell vented slowly with temperature around 40 °C.

Teflon Fixture

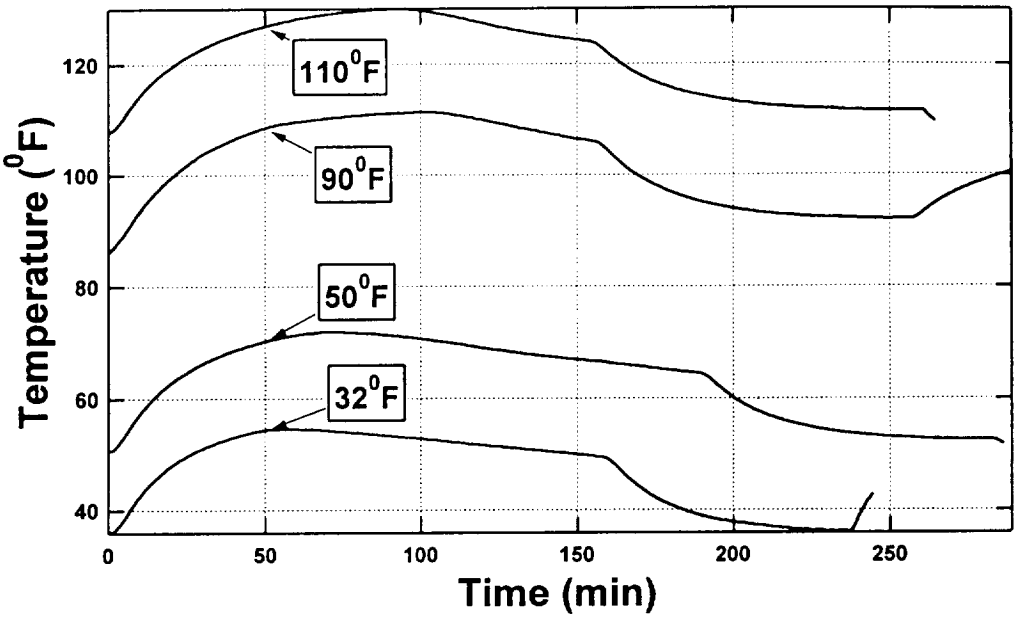
- No explosions.
- Three of four cells vented with temperatures reaching 400 °C. Split in can wall observed. One cell vented slowly with max. temperature of 100 °C.

Battery Testing

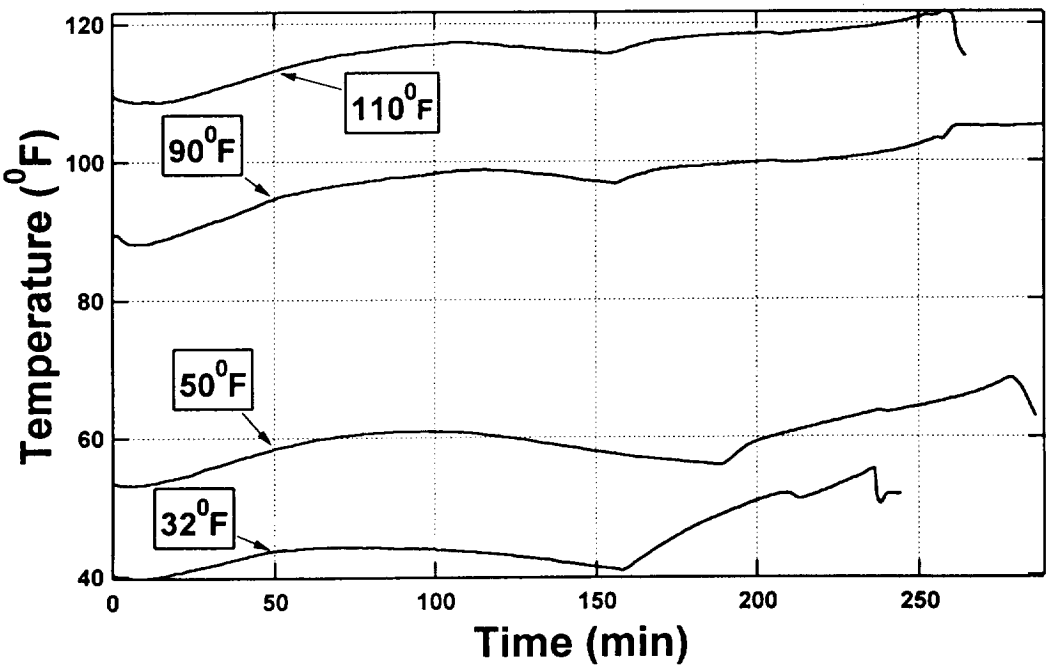


- **Longer charging time is required at lower temperatures.**
- **At 50 °F, the battery required an additional 30 minutes to be fully charged.**
- **At 32 °F, during the 2½ hour period required for normal charging, only 75 % charging was obtained.**
- **Battery at room temperature can power the camcorder for 106 minutes. (Manufacturer spec: 90 mins)**
- **At 90 °F and 110 °F, 100 minutes and 110 minutes respectively of camcorder run time was obtained.**
- **At 50 °F and 32 °F, 92 minutes and 78 minutes respectively of run time was obtained.**

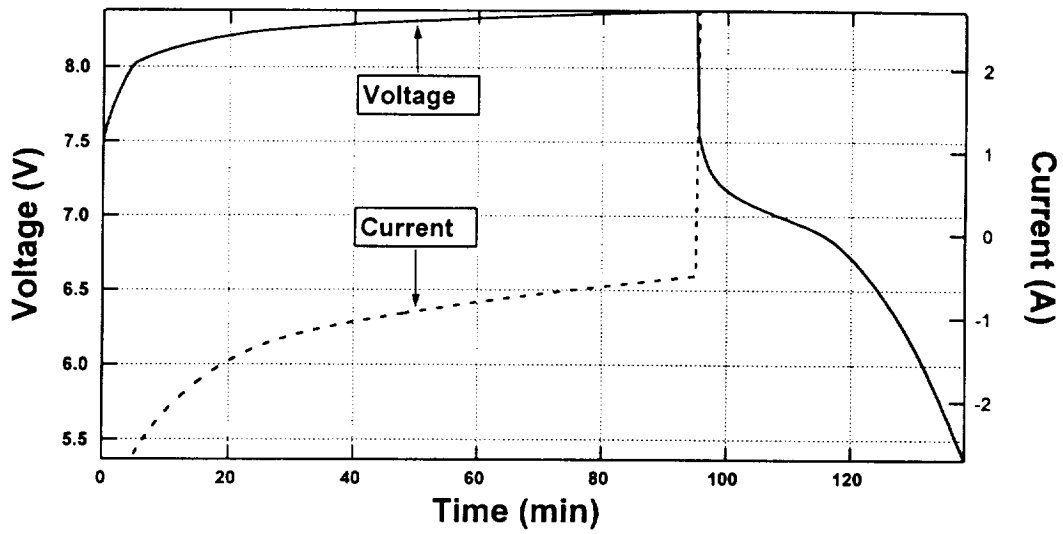
Temperature Profile of Charger Under Different Thermal Conditions



Temperature Profile of Battery Under Different Thermal Conditions

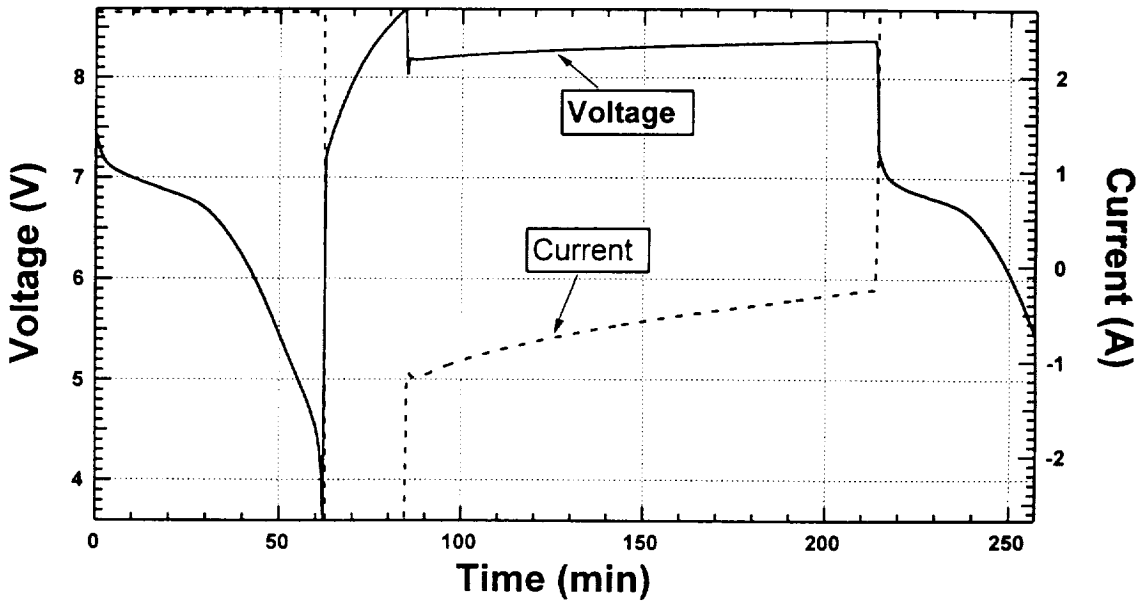


Overcharge of Canon Battery with "Smart" Circuit Board to 10.0 V at 1C Rate



- Voltage does not go above 8.4 V

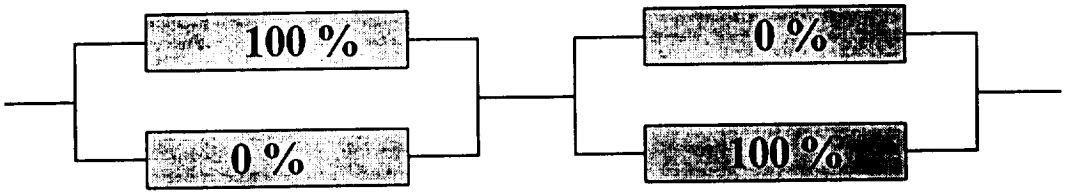
Overdischarge of Canon Battery to 2.0 V followed by a Charge/Discharge at 1C Rate



- Voltage does not go below 3.8 V

Charging of Lithium Ion Cells in an Unbalanced Configuration With and Without the Smart Circuit Board

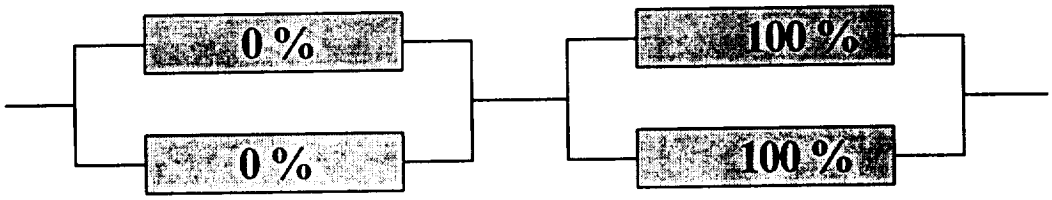
(a)



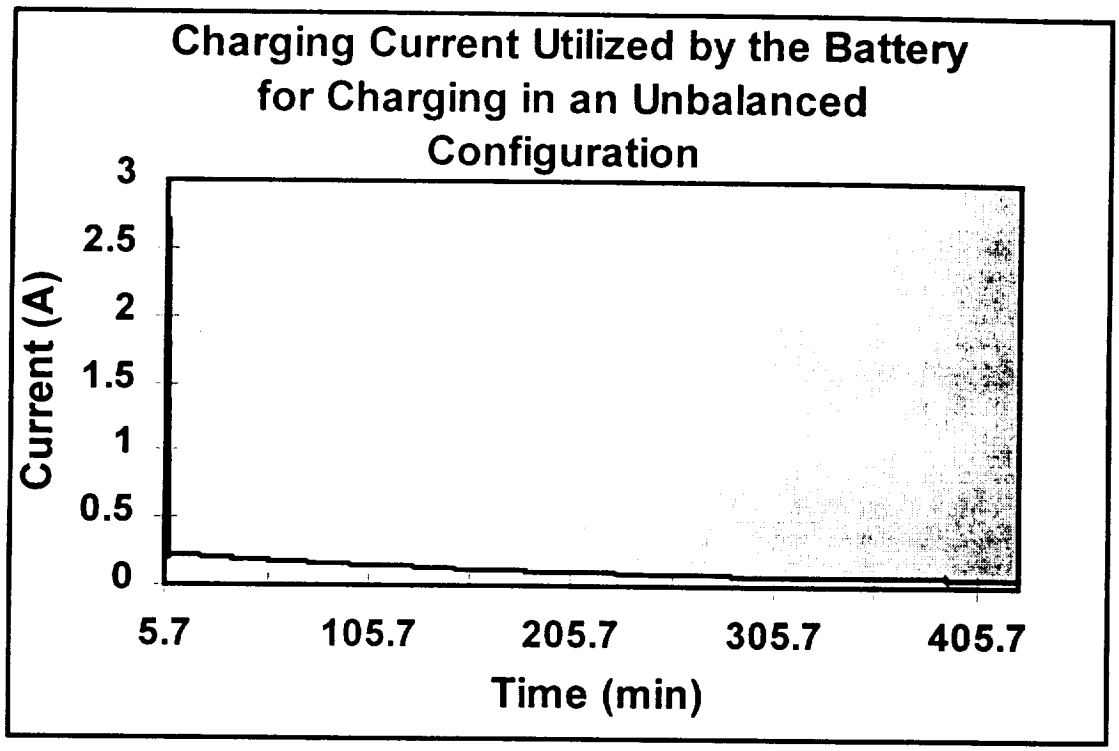
- Cells balance each other even in the absence of circuit board.
- A voltage of 3.8 V at the common nodes was obtained.

Charging of Lithium ion Cells in an Unbalanced Configuration with the Smart Circuit Board

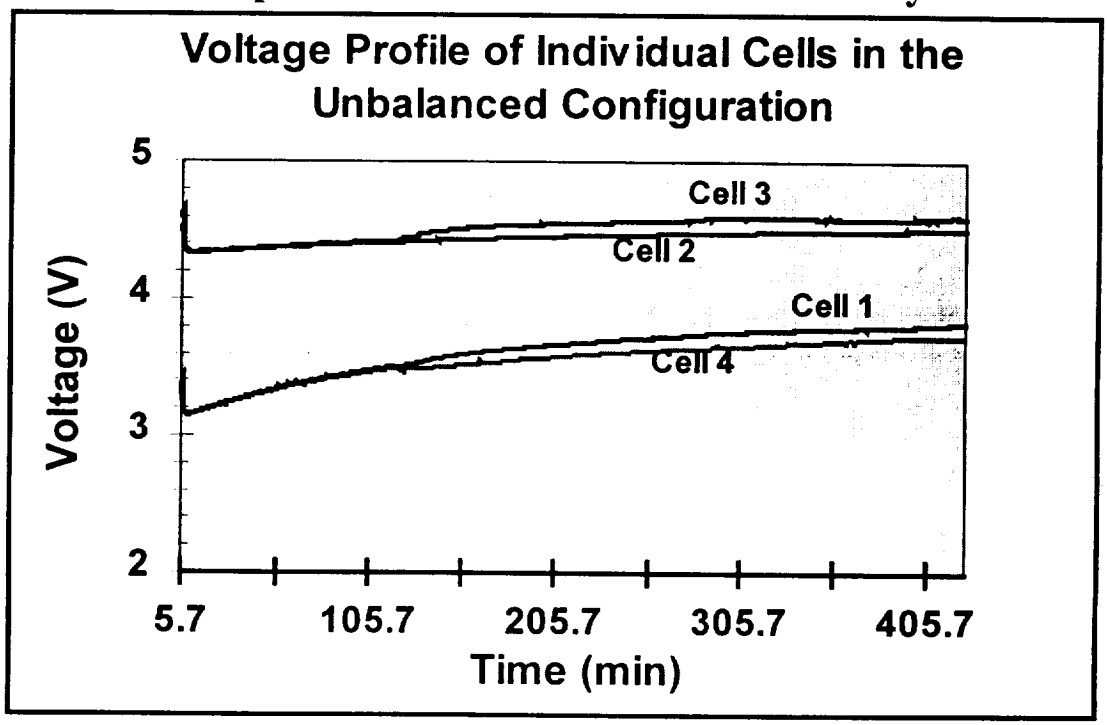
(b)



- Very slow charging of cells occurs.
- At the end of six hours the discharged cells (2.7 V) had reached only 3.8 V.
- The charged cells maintained voltage at about 4.4 to 4.5 V.



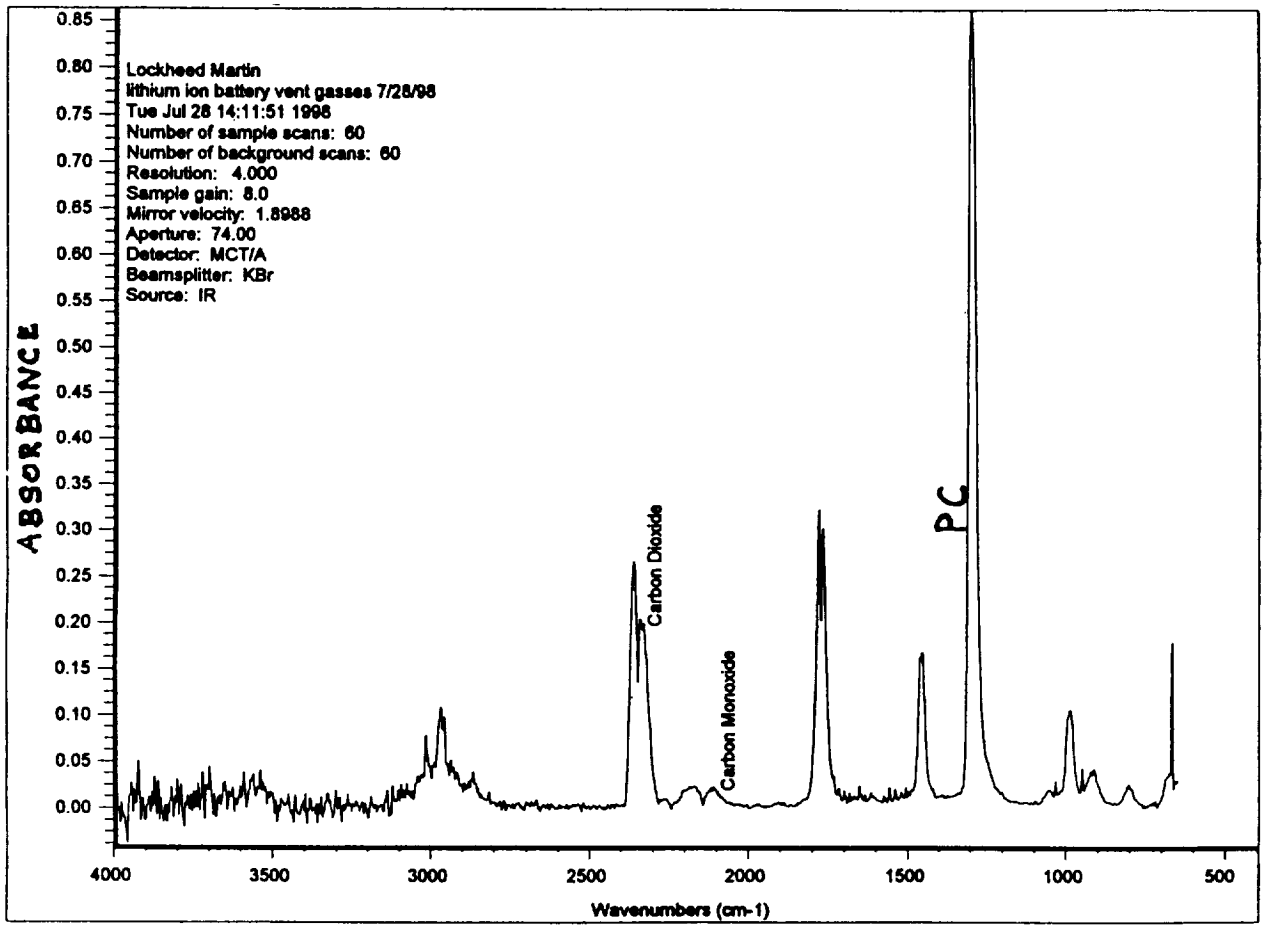
- Current drops to about 0.2 A almost immediately.



- Voltages rise slowly with the fully charged cells maintaining voltages around 4.5 to 4.6 V. The discharged cells take about 6 hours to reach 3.8 V.

Heat-to-Vent

- Cells thermally abused inside an abuse chamber to cause them to vent.
- Venting occurs above 350 °F, with thermal runaway.
- Vent gases were analyzed using FTIR, GC/MS and compared against standards.



Vibration Test

- **The charger, battery pack and cells were subjected to the following vibration spectrum for 15 mins (x, y, z axes)**

Frequency	Level
20-80 Hz	+3 dB/octave
80-350 Hz	0.040 g^2/Hz
350-2000 Hz	-3 dB/octave

- **Further subjected to the following spectrum for 5 mins (x, y, z axes)**

Frequency	Level
20-80 Hz	+3 dB/octave
80-350 Hz	0.1 g^2/Hz
350-2000 Hz	-3 dB/octave

- **The battery was subjected to the following spectrum and vibrated for 3 minutes in each of the three mutually perpendicular axes (x, y and z).**

Frequency	Level
20-80 Hz	+3 dB/octave
80-350 Hz	0.1 g^2/Hz and 0.2 g^2/Hz
350-2000 Hz	-3 dB/octave

- **Finally the battery pack was also shocked 20 times with 11 ms, 20 g^2/Hz sawtooth pulses.**

SUMMARY

- **Overcharge:** Tolerant
  CID activated at 5.0 V

- **Overdischarge:** Tolerant

- **High Temperatures:** Tolerant up to about 150 °F (66 °C) (temperature tested). Temperatures >150 °C are required to vent or explode cells. (PTC activated ~130 °C)

- **Drop Test:** Tolerant to drops from 3 ft and 6 ft.

- **External Short circuit:** PTC is activated immediately.

- **Crush Test:** Not consistent. Does not tolerate heavy crush without a heat sink.

- **Thermal tests on battery pack:** Tolerant at all temperatures tested.

- **Overcharging and Overdischarging:** In the battery pack, Smart Circuit board regulates current.

- **Unbalanced Configuration:** In the battery pack, Smart Circuit board regulates current and shunts it around.

- **Heat to vent:** CO, CO_2 gases present. Electrolyte contains DMC, EMC and PC.

- **Vibration test:** Tolerant to five times the level normally used for testing of in-cabin-stowed flight articles.

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