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01/05/82  
372363

# **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)
$39.660 \pm 0.079$	$64.91 \pm 0.18$	$18.12 \pm 0.03$

### Electrochemical Characteristics

- **Open Circuit Voltage**

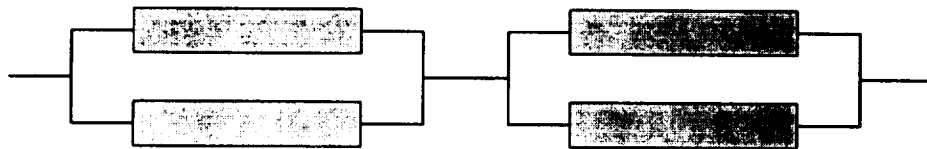
$3.858 \pm 0.015$  V

- **Closed Circuit Voltage**

$3.69 \pm 0.14$  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**

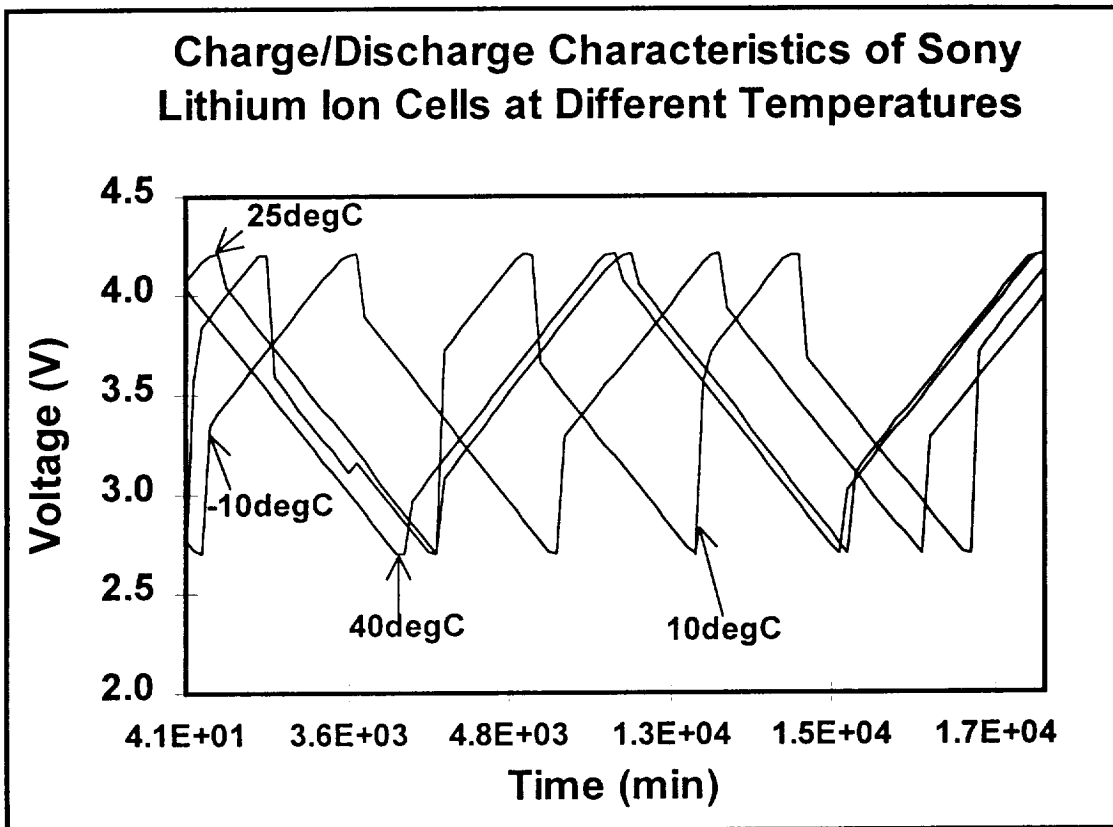


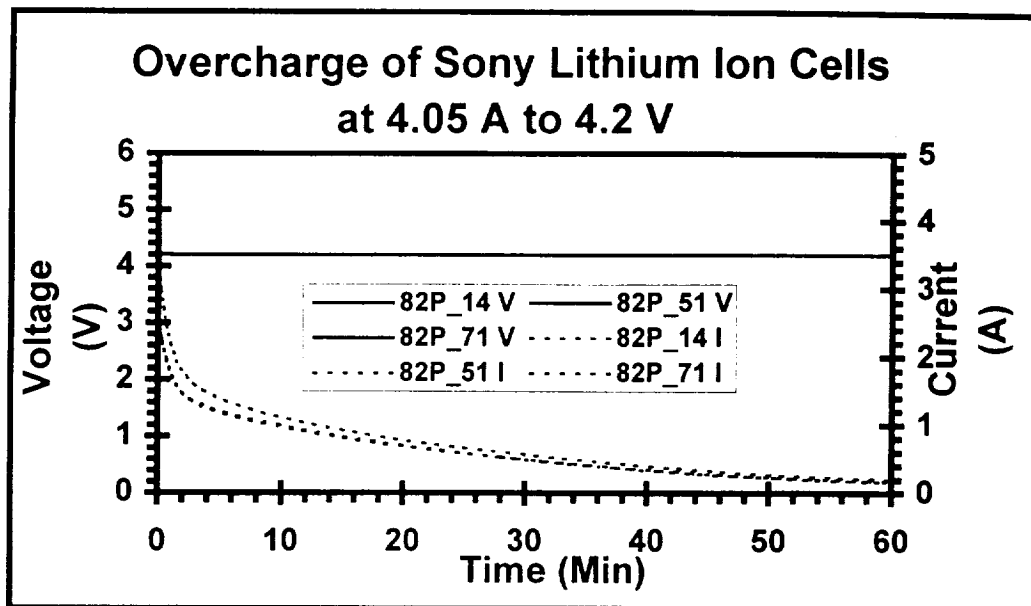
# Sony Lithium Ion Cells

## Electrochemical Characteristics

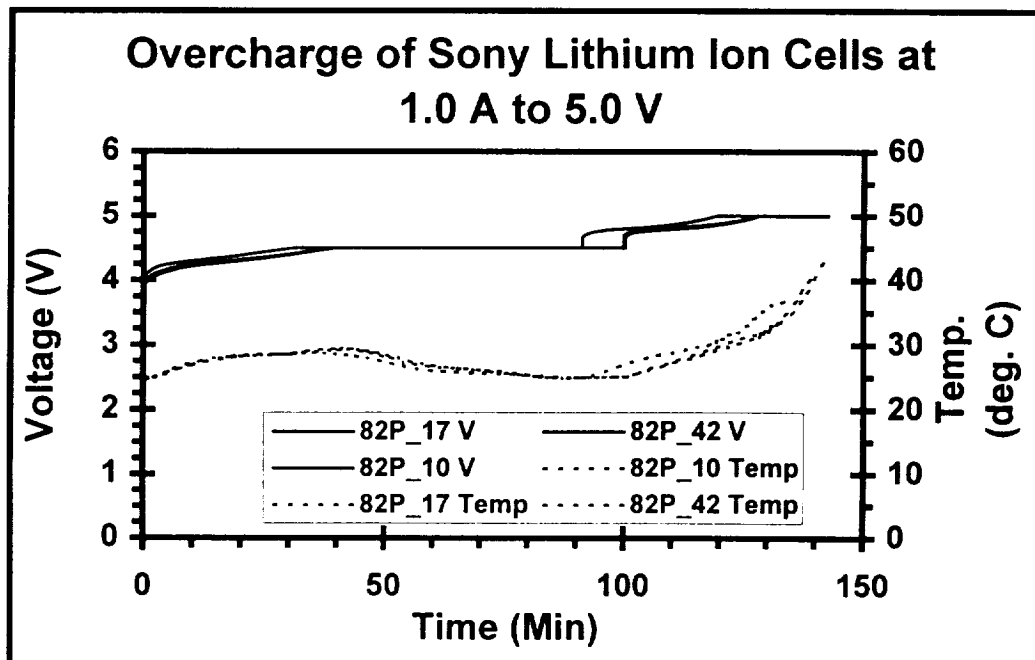
- Capacities at Different Temperatures

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

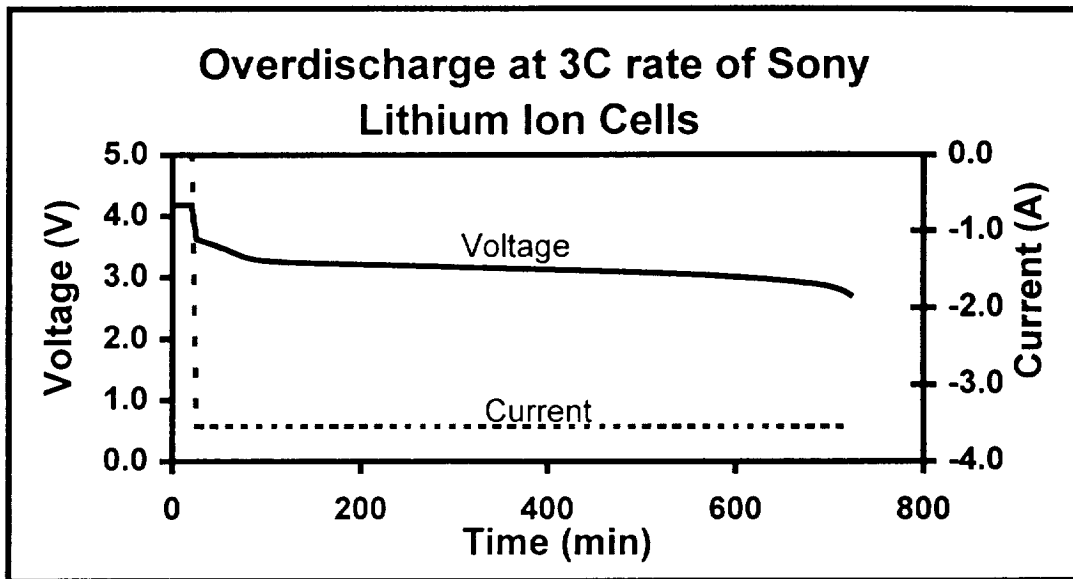




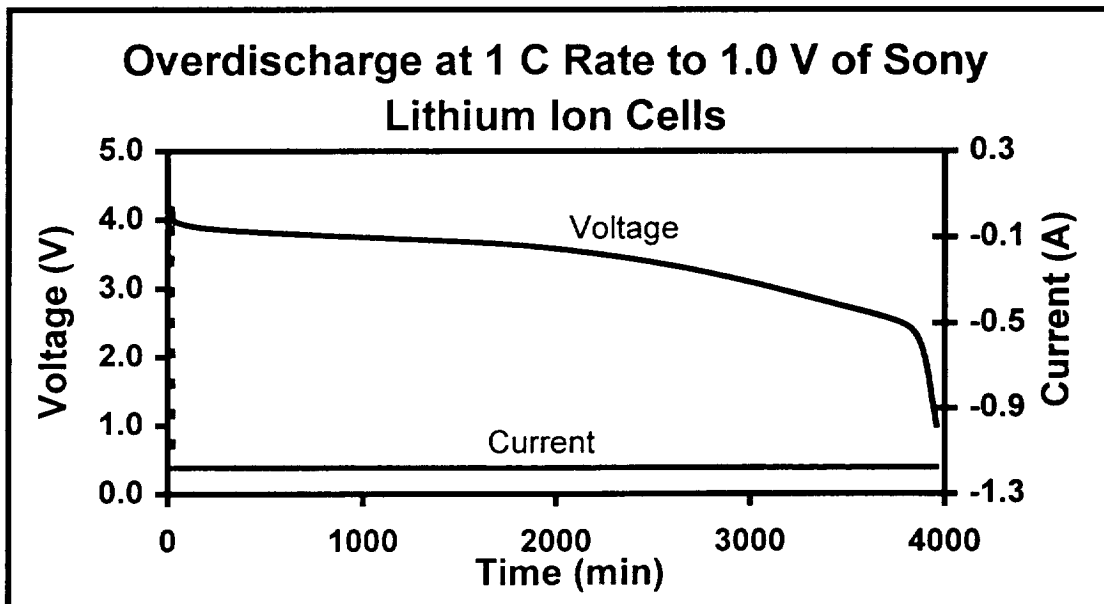
- Attains 4.2 V immediately.
- No venting, fire or explosions due to fast charge.



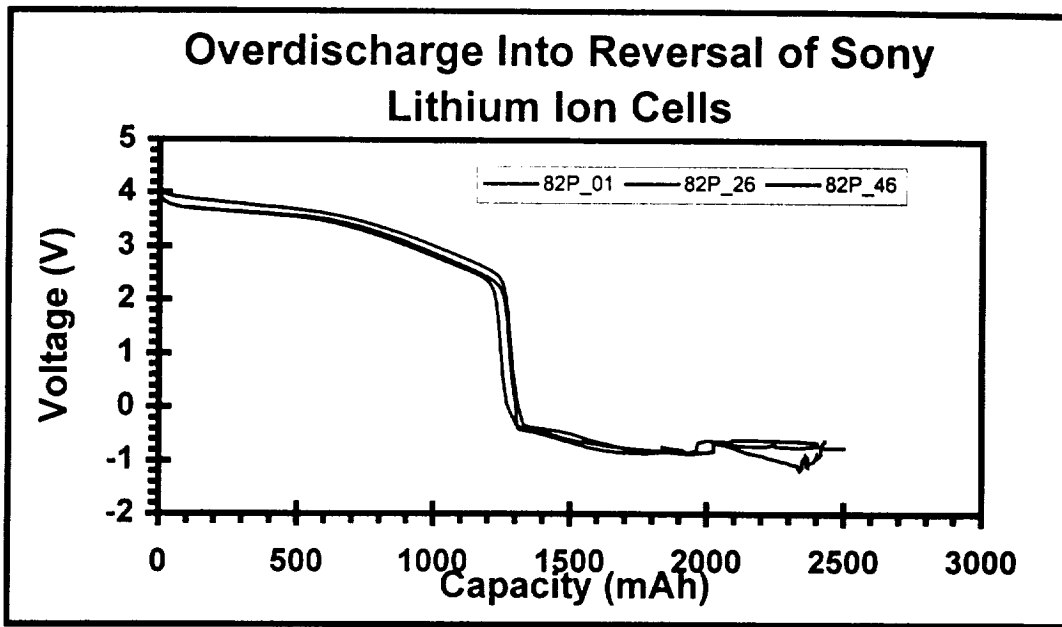
- Current Interrupt Device (CID) is activated when voltage reaches 5.0 V or when maintained at 5.0 V.



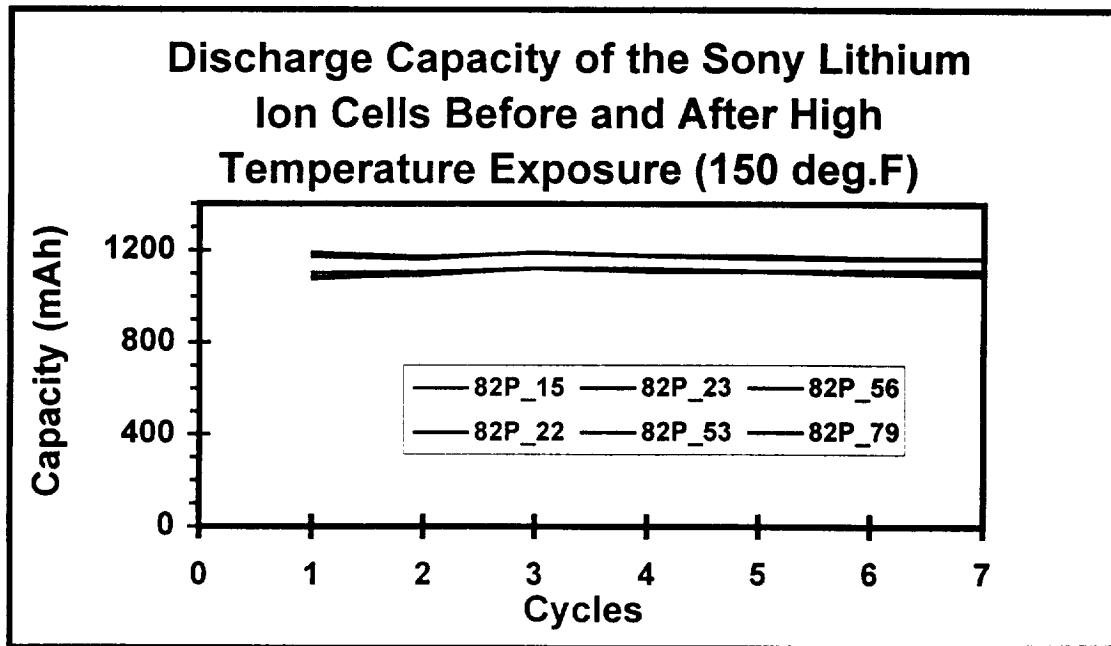
- Cells performed nominally on charge/discharge cycles.
- No venting, fire or explosions



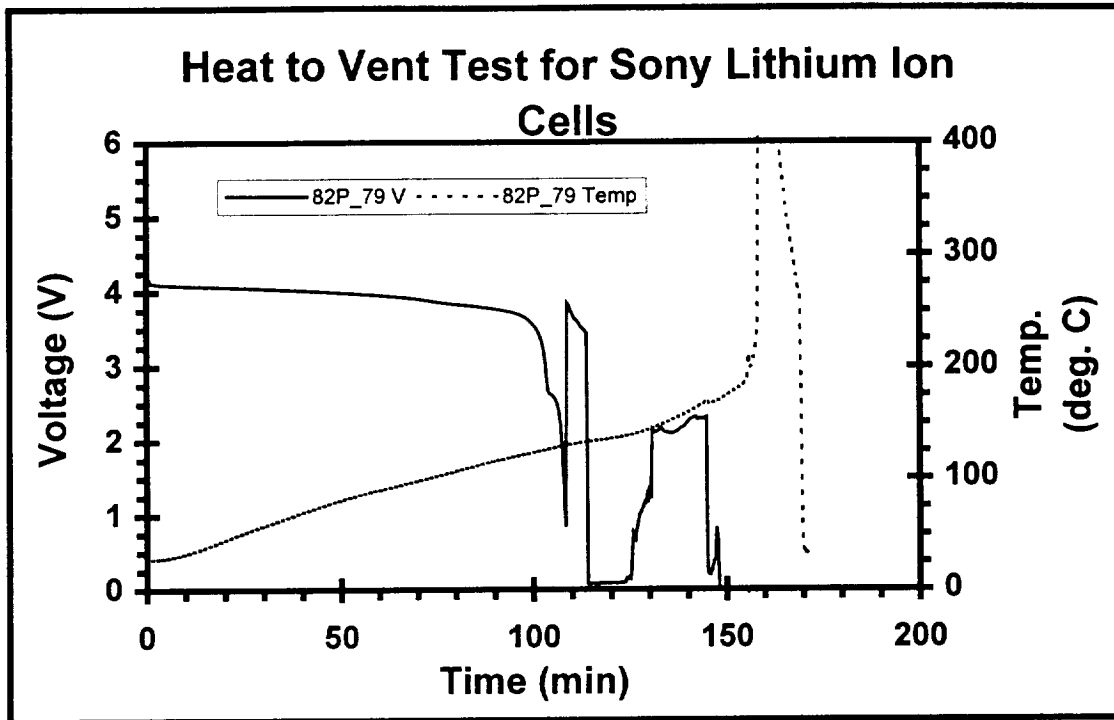
- Performed nominally on the few charge/discharge cycles carried out after test.
- No catastrophic events.



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



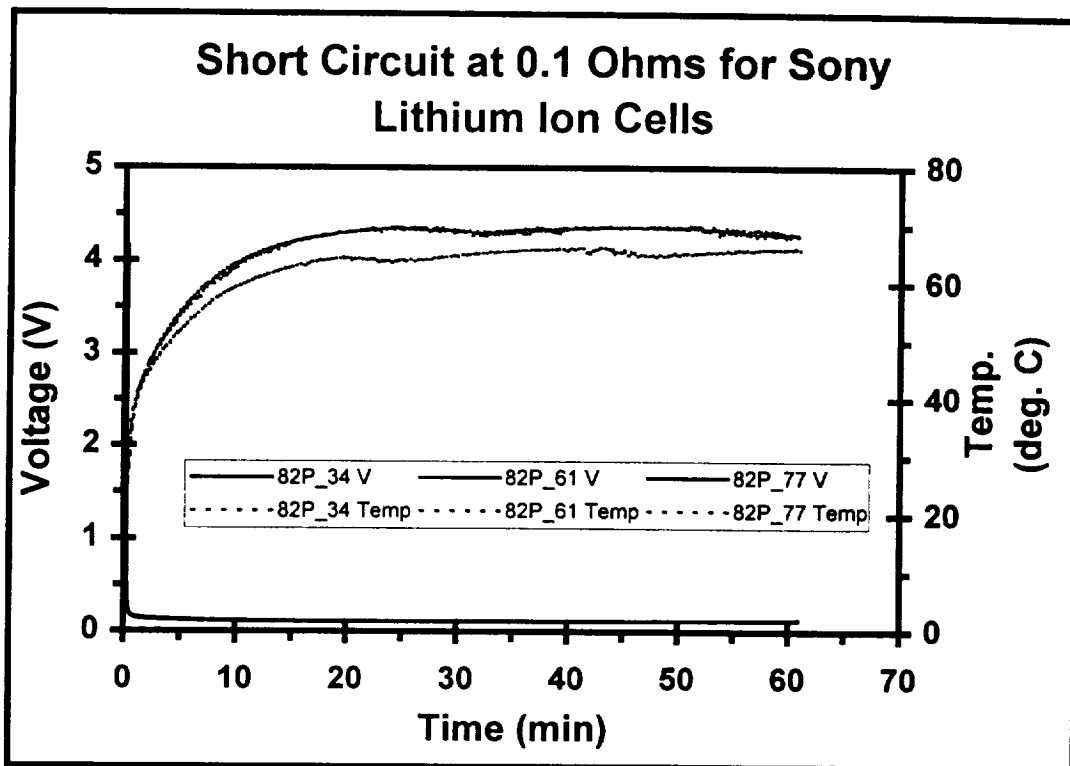
- No changes in functional performance of the cells after exposure to a temperature of 150 °F in an oven.
- No cell venting observed.



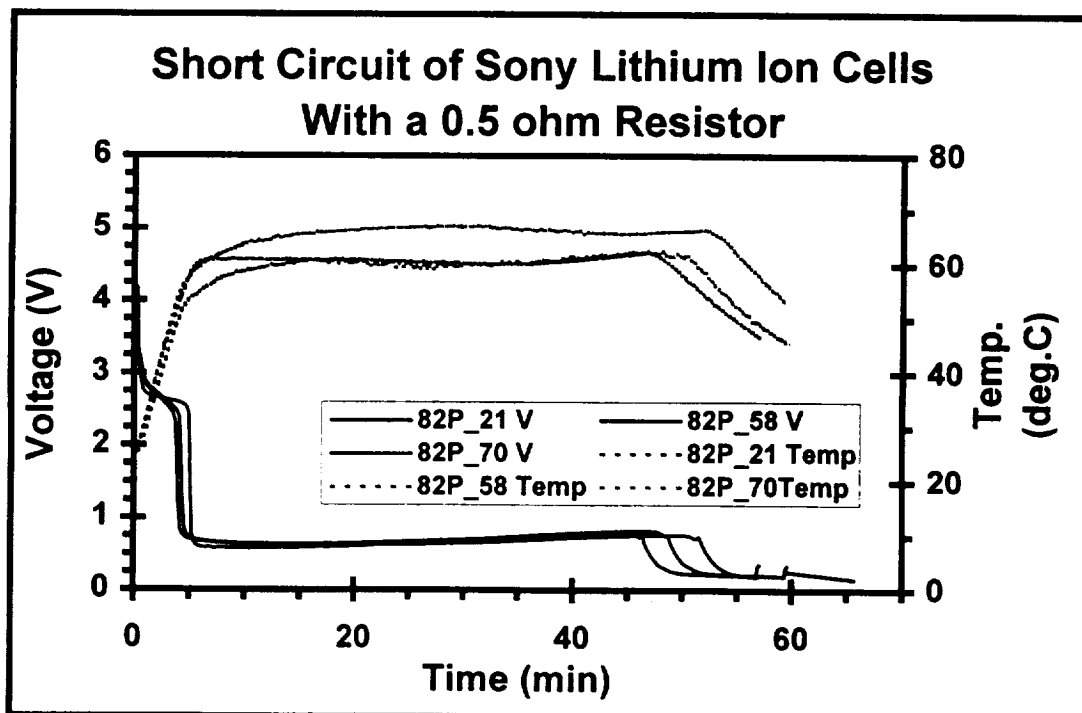
- Venting occurs above 150 °C.

### 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.

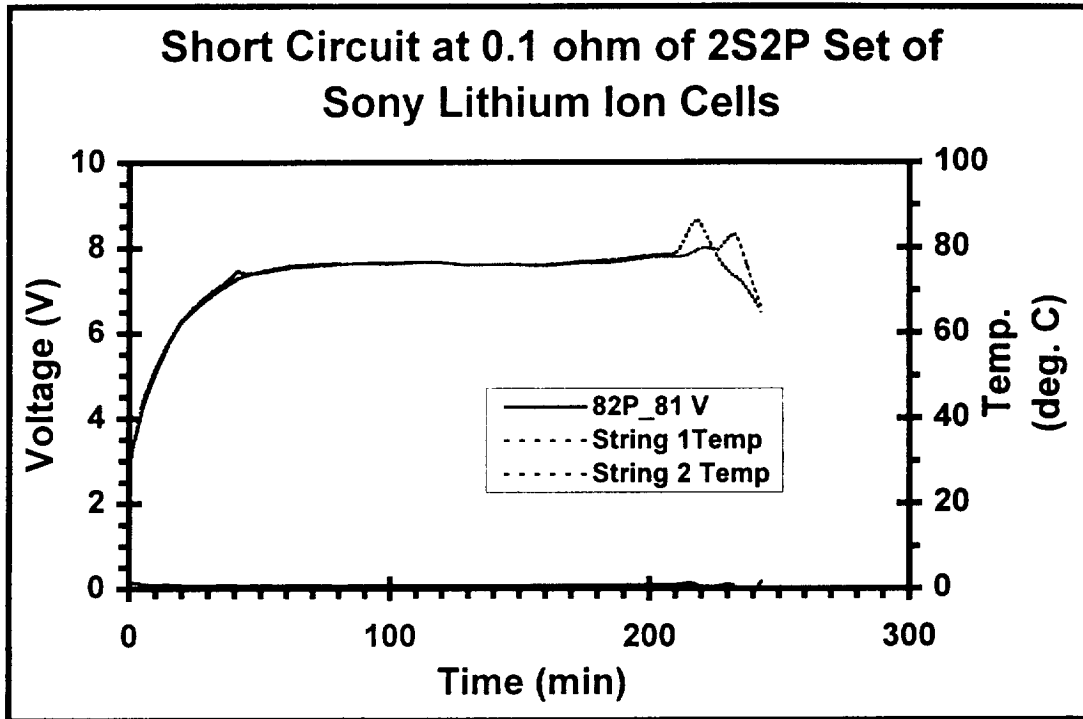


- PTC shuts off any electrical contact immediately.



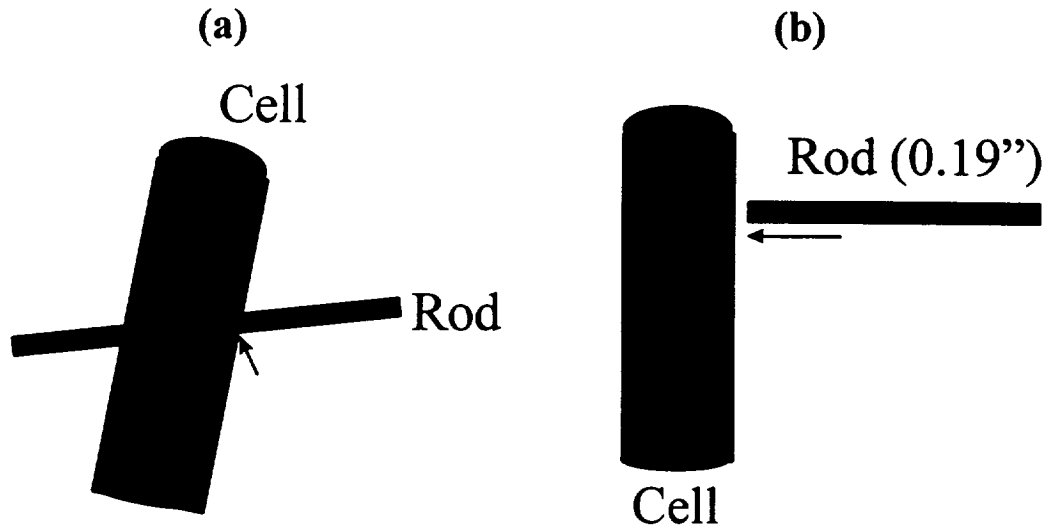
- PTC cuts off electrical contact.
- Electrical contact is reestablished when the PTC stabilizes.





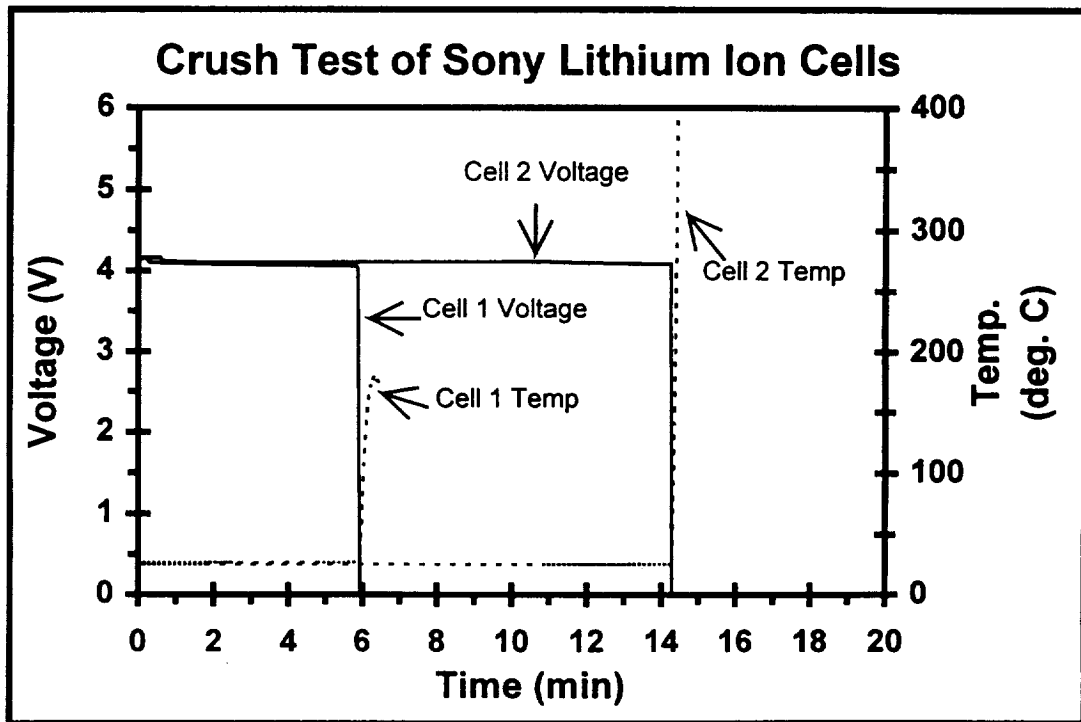
- PTC cuts off electrical contact by an increase in resistance.
- No weight changes in the short circuit tests indicating absence of venting.
- No catastrophic events in the short circuit tests carried out.

# Crush Test of Sony Lithium Ion Cells

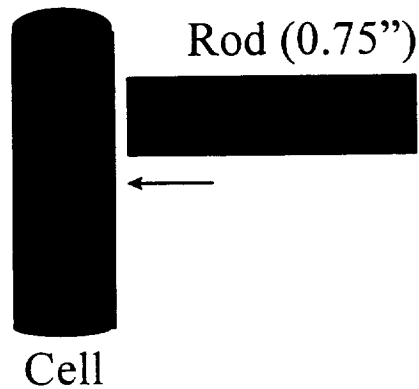


(a) No venting, fire or explosion

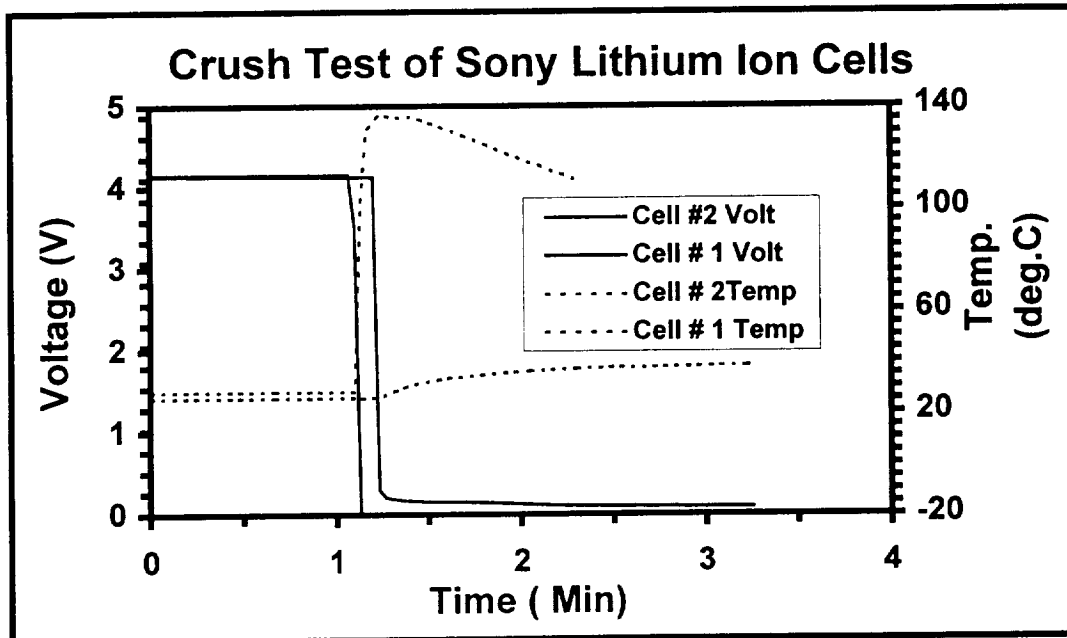
(b) Four cells out of six experienced violent venting with thermal runaway, the other two exploded.



(C)



**Steel Fixture**

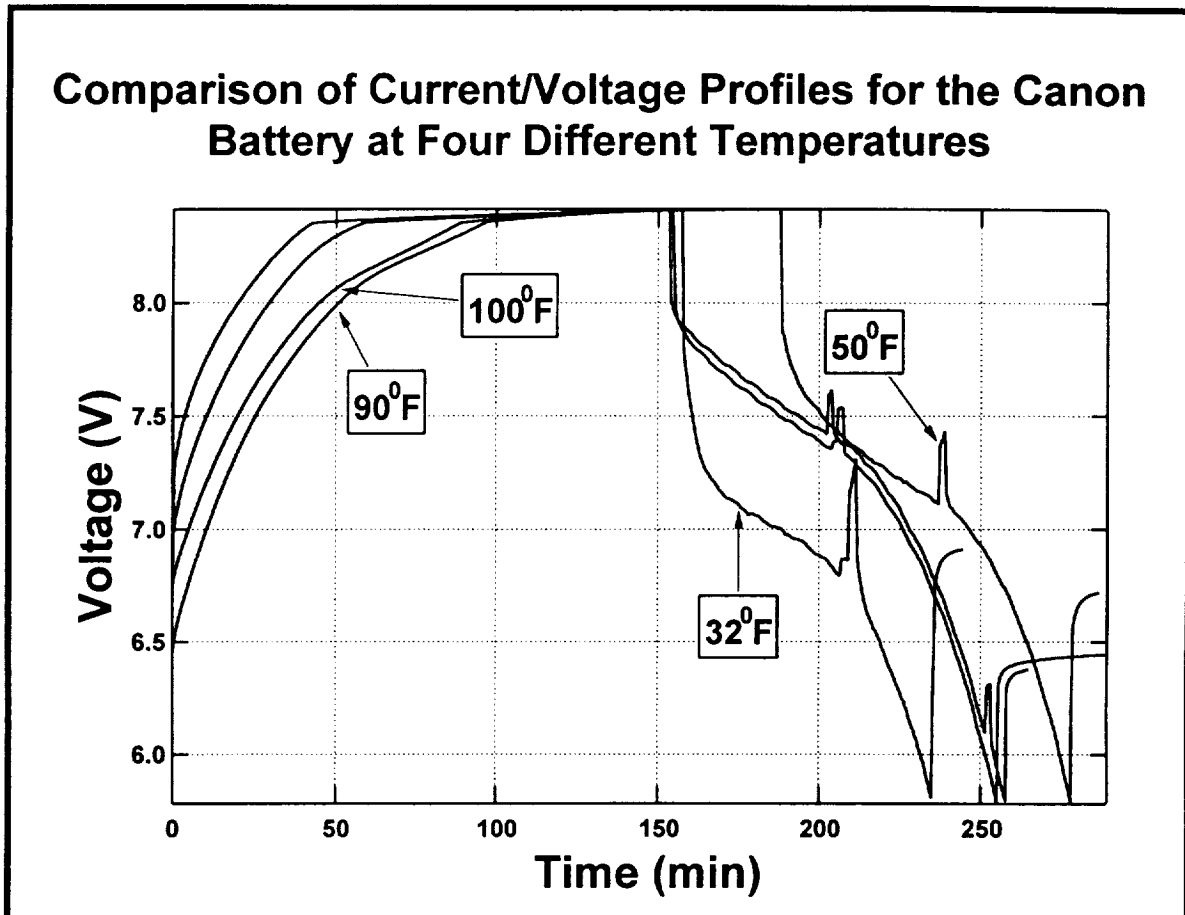


- No explosions. Three of four cells vented with temperatures between 80 °C to 100 °C. Fourth cell vented slowly with temperature around 40 °C.

**Teflon Fixture**

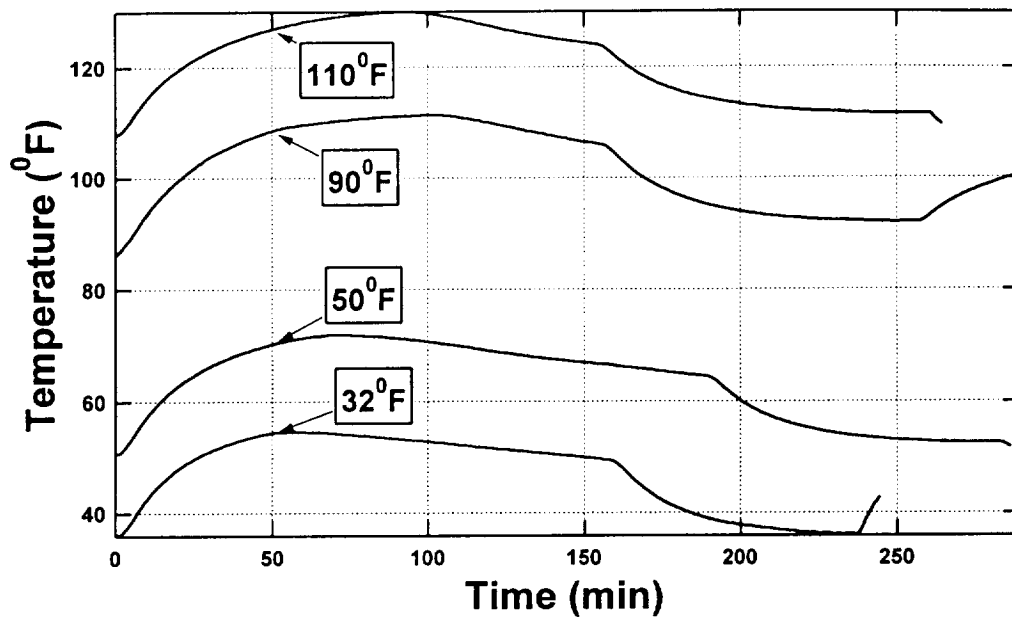
- No explosions.
- Three of four cells vented with temperatures reaching 400 °C. Split in can wall observed. One cell vented slowly with max. temperature of 100 °C.

## Battery Testing

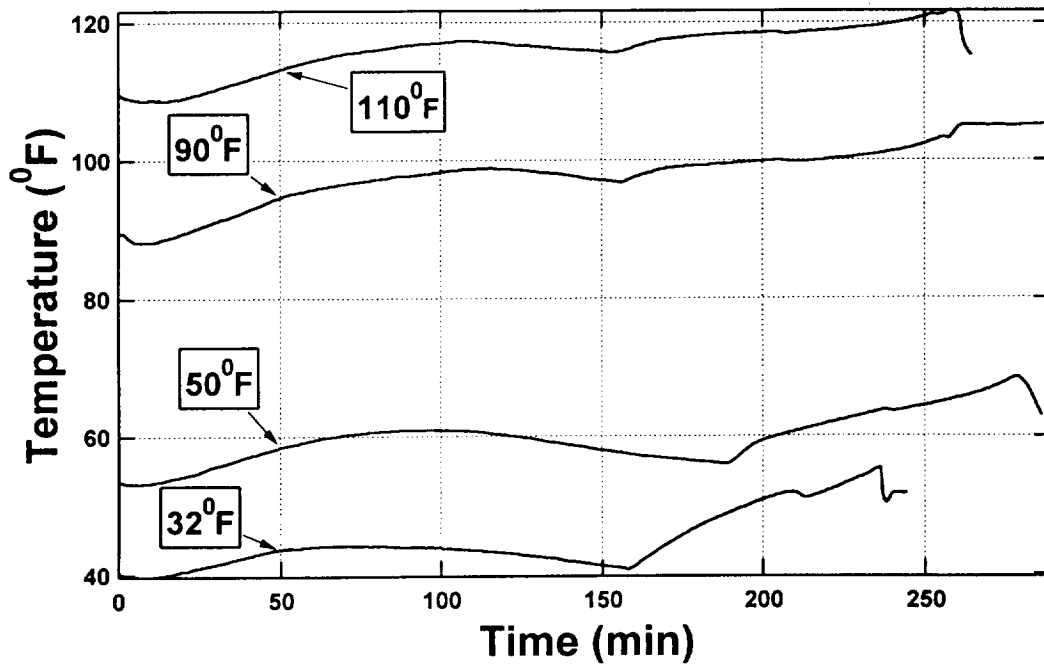


- Longer charging time is required at lower temperatures.
- At 50 °F, the battery required an additional 30 minutes to be fully charged.
- At 32 °F, during the 2½ hour period required for normal charging, only 75 % charging was obtained.
- Battery at room temperature can power the camcorder for 106 minutes. (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.

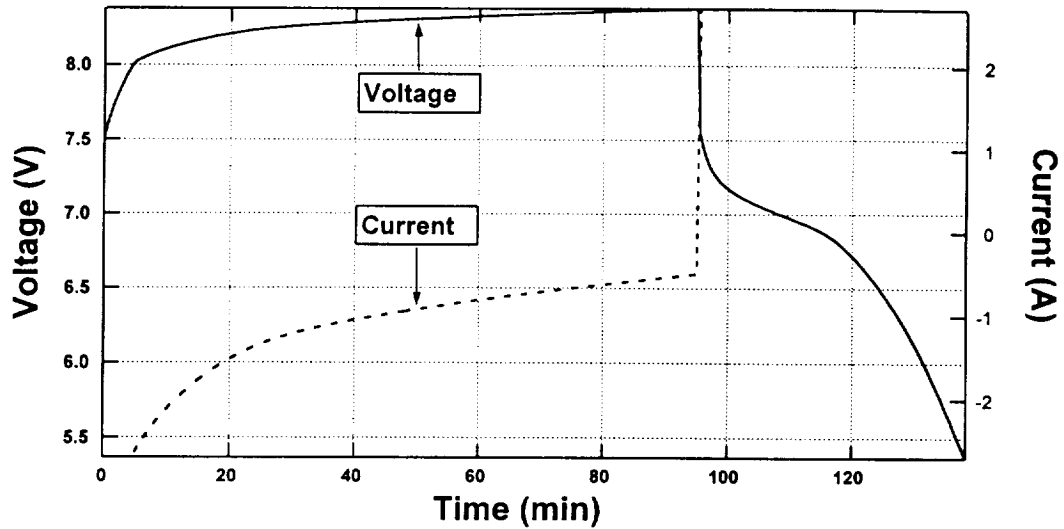
## Temperature Profile of Charger Under Different Thermal Conditions



## Temperature Profile of Battery Under Different Thermal Conditions

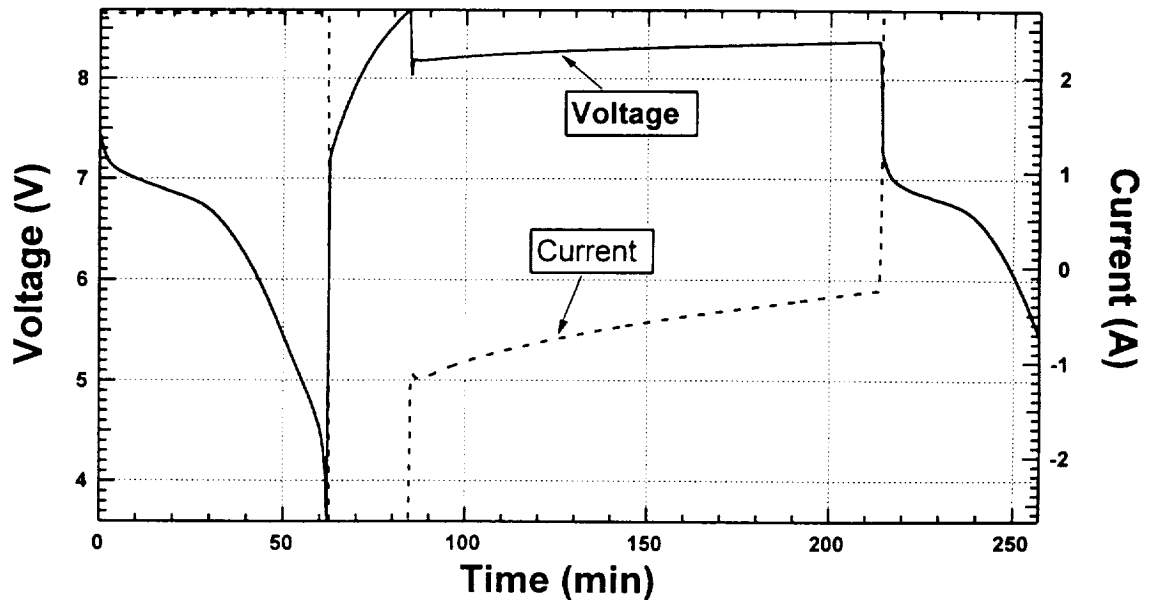


### Overcharge of Canon Battery with "Smart" Circuit Board to 10.0 V at 1C Rate



- Voltage does not go above 8.4 V

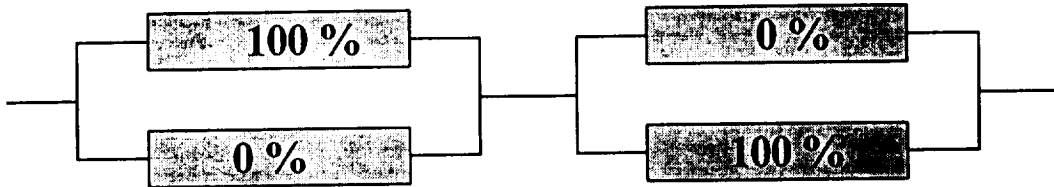
### Overdischarge of Canon Battery to 2.0 V followed by a Charge/Discharge at 1C Rate



- Voltage does not go below 3.8 V

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

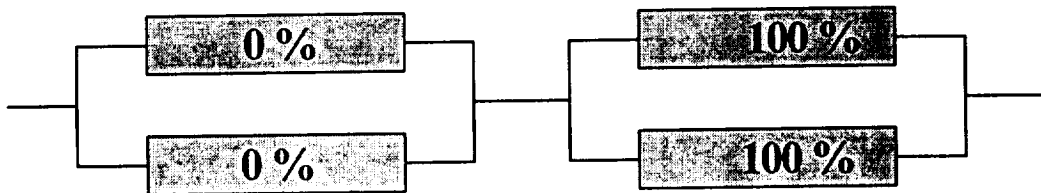
(a)



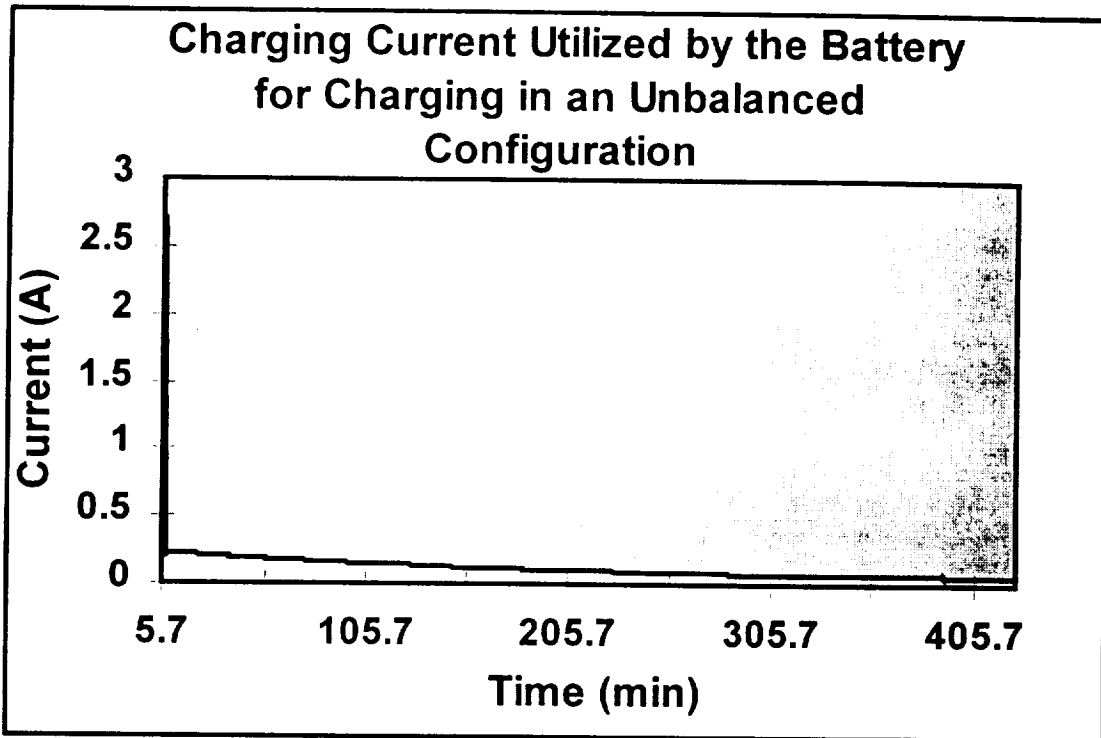
- Cells balance each other even in the absence of circuit board.
- A voltage of 3.8 V at the common nodes was obtained.

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

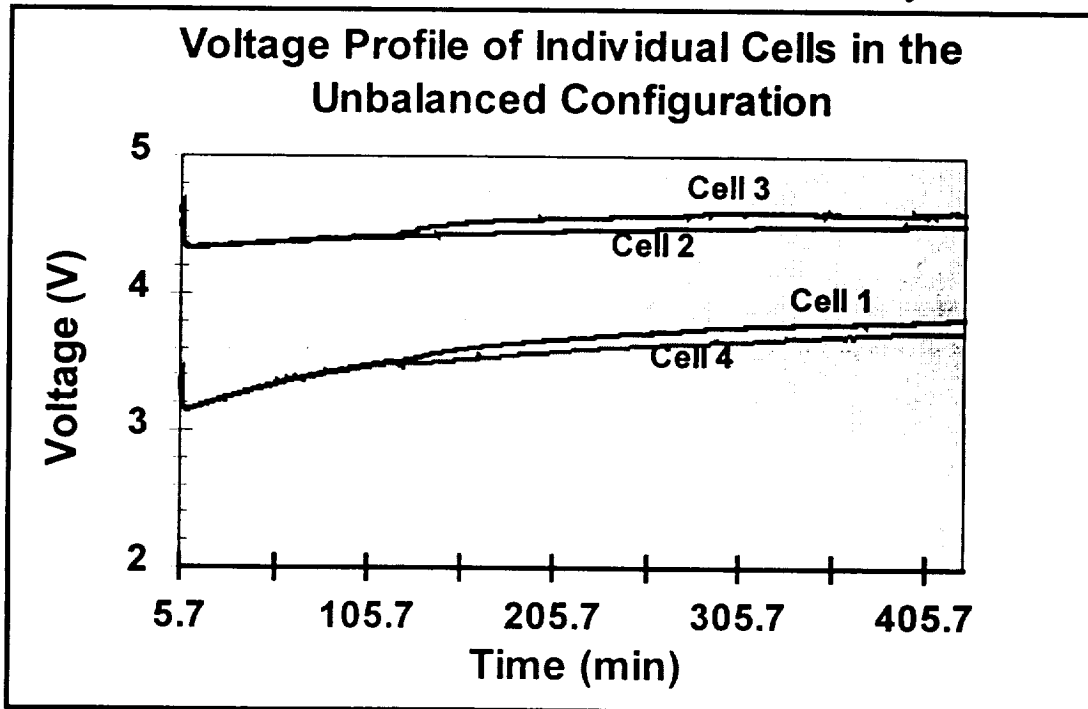
(b)



- 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.

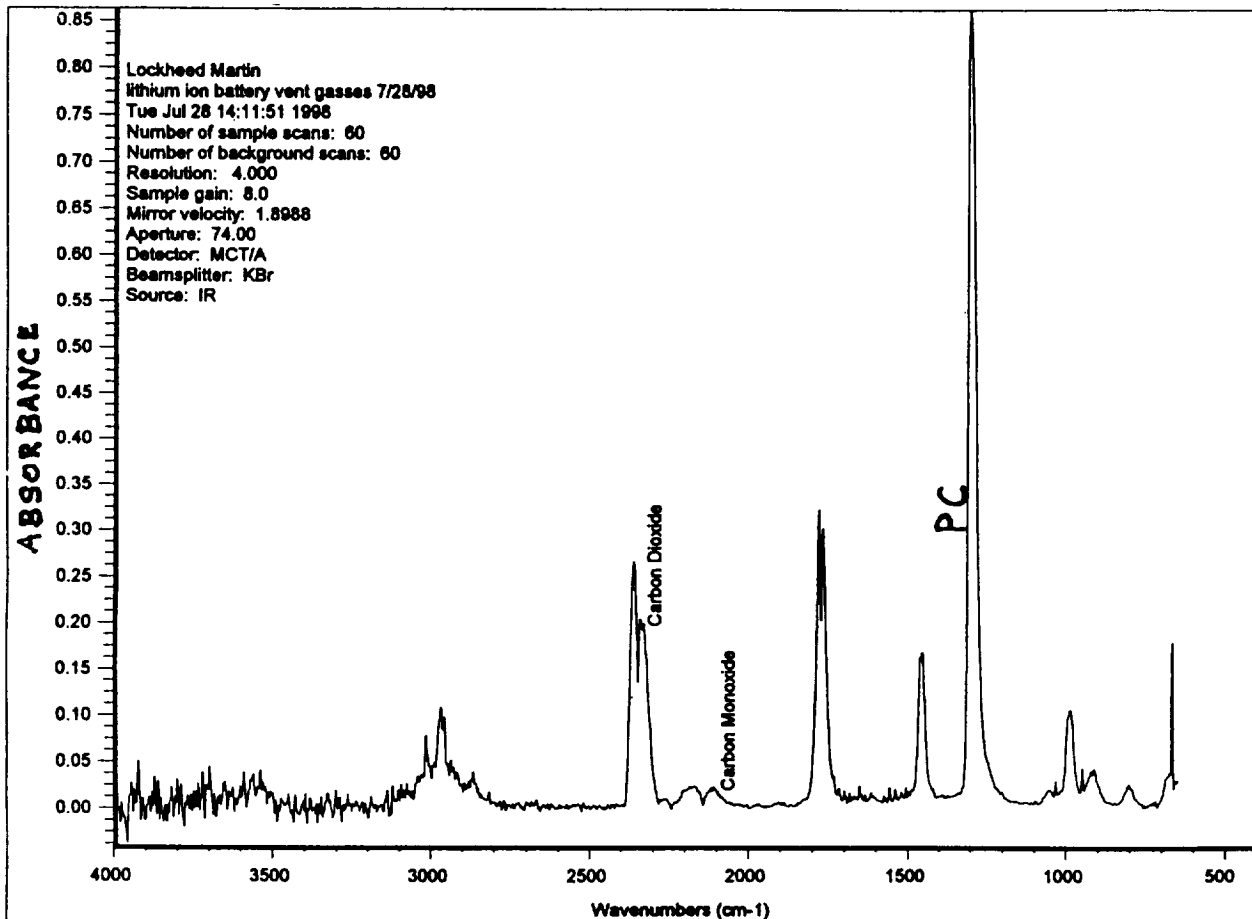


- Voltages rise slowly with the fully charged cells maintaining voltages around 4.5 to 4.6 V. The discharged cells take about 6 hours to reach 3.8 V.



# 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)

<u>Frequency</u>	<u>Level</u>
20-80 Hz	+3 dB/octave
80-350 Hz	0.040 g <sup>2</sup> /Hz
350-2000 Hz	-3 dB/octave

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

<u>Frequency</u>	<u>Level</u>
20-80 Hz	+3 dB/octave
80-350 Hz	0.1 g <sup>2</sup> /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).

<u>Frequency</u>	<u>Level</u>
20-80 Hz	+3 dB/octave
80-350 Hz	0.1 g <sup>2</sup> /Hz and 0.2 g <sup>2</sup> /Hz
350-2000 Hz	-3 dB/octave

- Finally the battery pack was also shocked 20 times with 11 ms, 20 g<sup>2</sup>/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<sub>2</sub> 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.**

## **ACKNOWLEDGEMENTS**

**Symmetry Resources, Inc. - Sammy Waldrop**

**Arbin Instruments - Dr. Tracy Piao**

**NASA-JSC:**

**ESTA - Jerry Steward**

**Shane Peck**

**Brent Hughes**

**Gwen Gilliam**

**Chem Lab - Bill Tipton**