LOCKHEED MARTIN

ENGINEERING AND ABUSE TESTING OF PANASONIC LITHIUM-ION BATTERY AND CELLS

1999 NASA AEROSPACE BATTERY WORKSHOP

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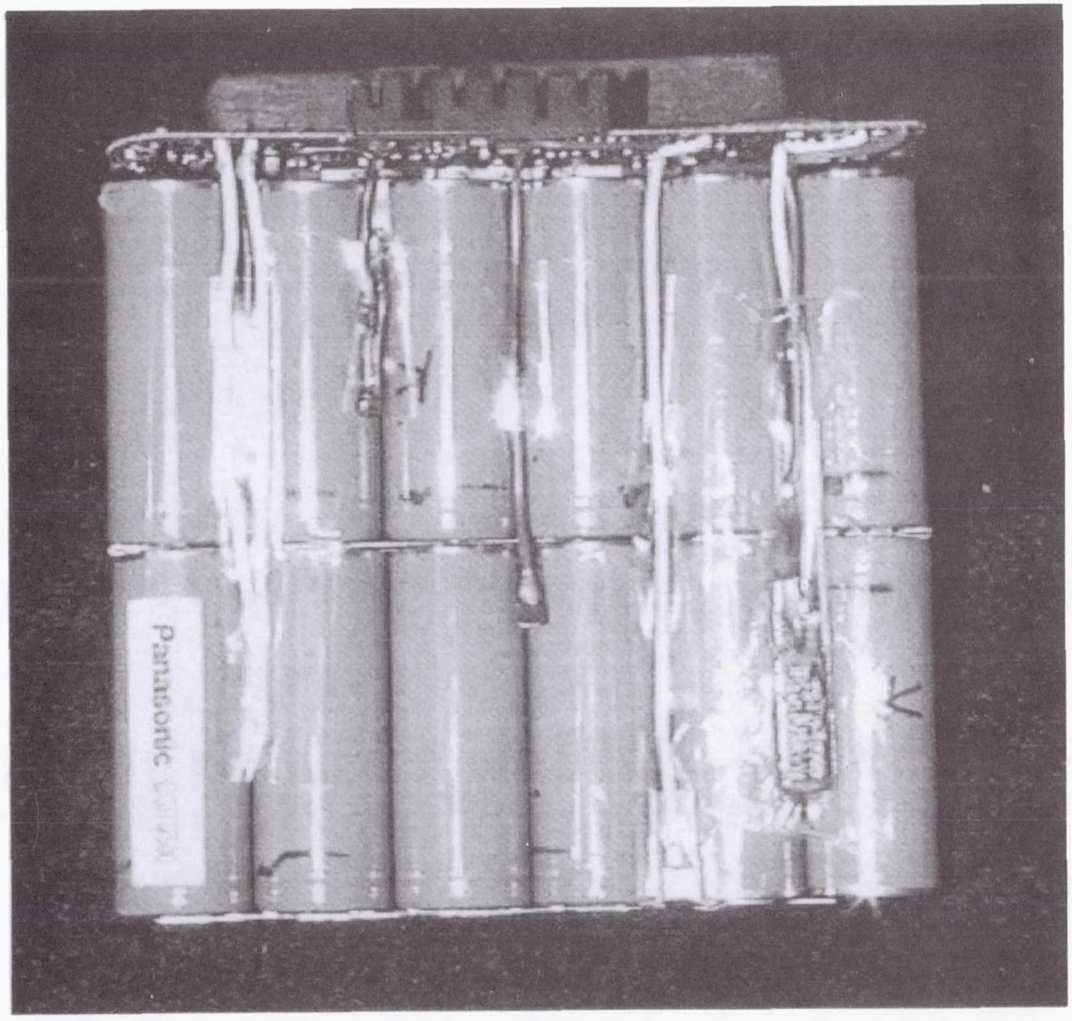
Panasonic Lithium-ion Battery in the IBM Thinkpad



Panasonic 17500 Lithium-ion Cells

Physical Characteristics

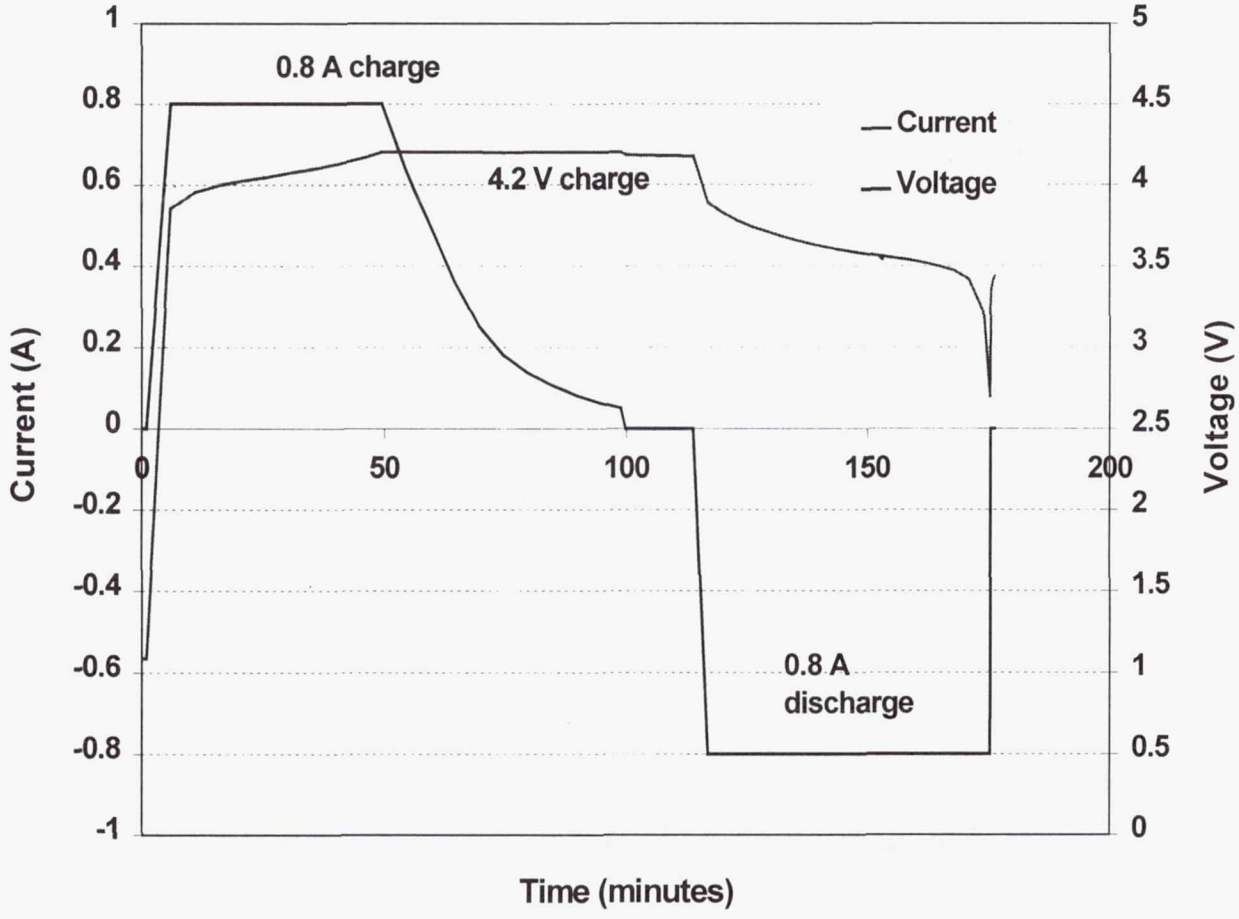
Weight: 24.43 ± 0.6 g
Diameter: 16.399 ± 0.4 mm
Length: 49.648 ± 1.2 mm

Electrochemical Characteristics

Open Circuit Voltage: 3.9 V

Capacity (room temperature): 0.81 Ah

Charge/Discharge Curves for Panasonic 17500 Li-ion Cell



Rate Capability of Panasonic 17500 Lithium-ion Cells Under Different Conditions of Charge and Discharge

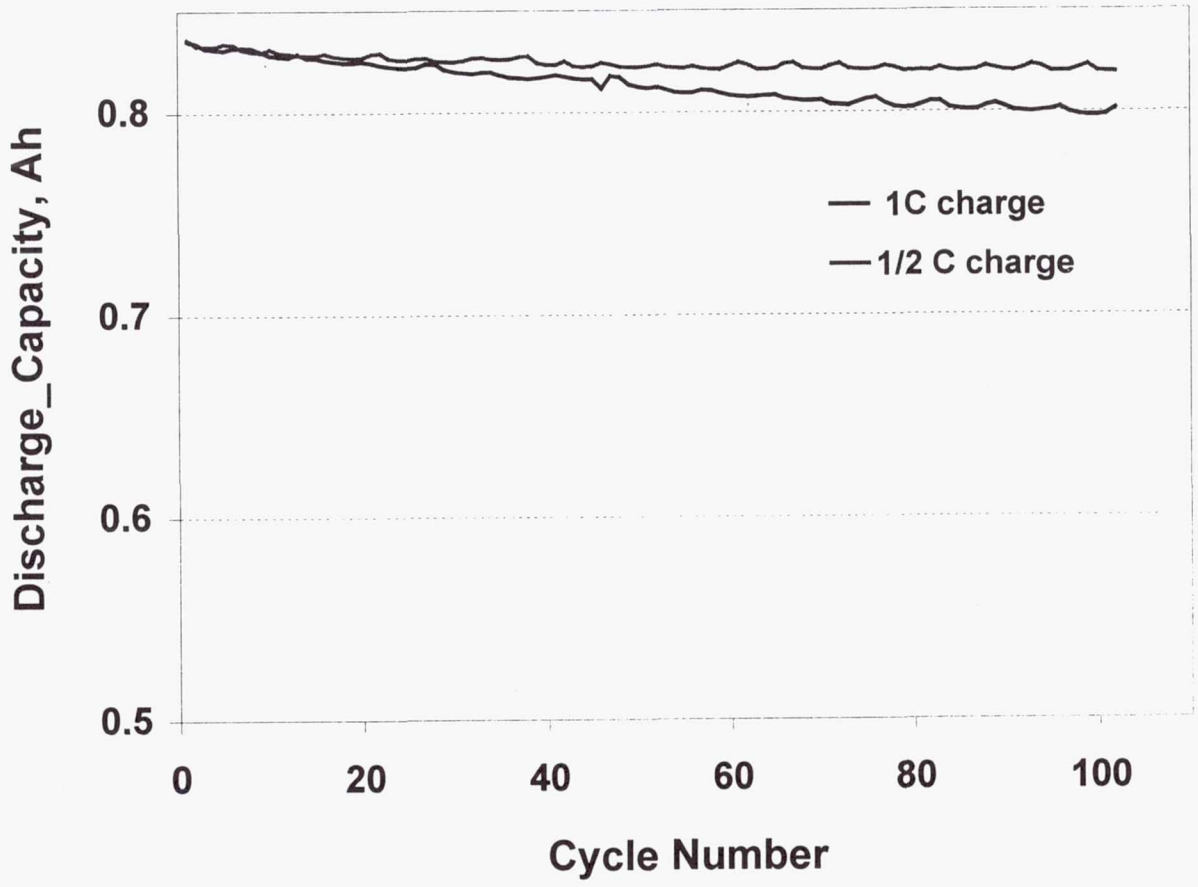
Cycle Number	1.0 C Charge			0.5 C Charge		
	1 C Discharge	0.5 C Discharge	0.25 C Discharge	1 C Discharge	0.5 C Discharge	0.25 C Discharge
1	0.816	0.837	0.828	0.824	0.837	0.840
5	0.810	0.832	0.827	0.817	0.835	0.838
25	0.801	0.820	0.816	0.802	0.826	0.832
50	0.788	0.809	0.804	0.799	0.822	0.826
100	0.774	0.794	0.792	0.792	0.819	0.822
CDR* Ah/Cycle	0.00038	0.00039	0.00037	0.00027	0.00017	0.00018

* CDR stands for Capacity Decay Rate. The shaded cell values were used to calculate the CDR. CDR=$(C_5-C_{100})/95$, C_5 and C_{100} are the capacities at cycle # 5 and 100, respectively.

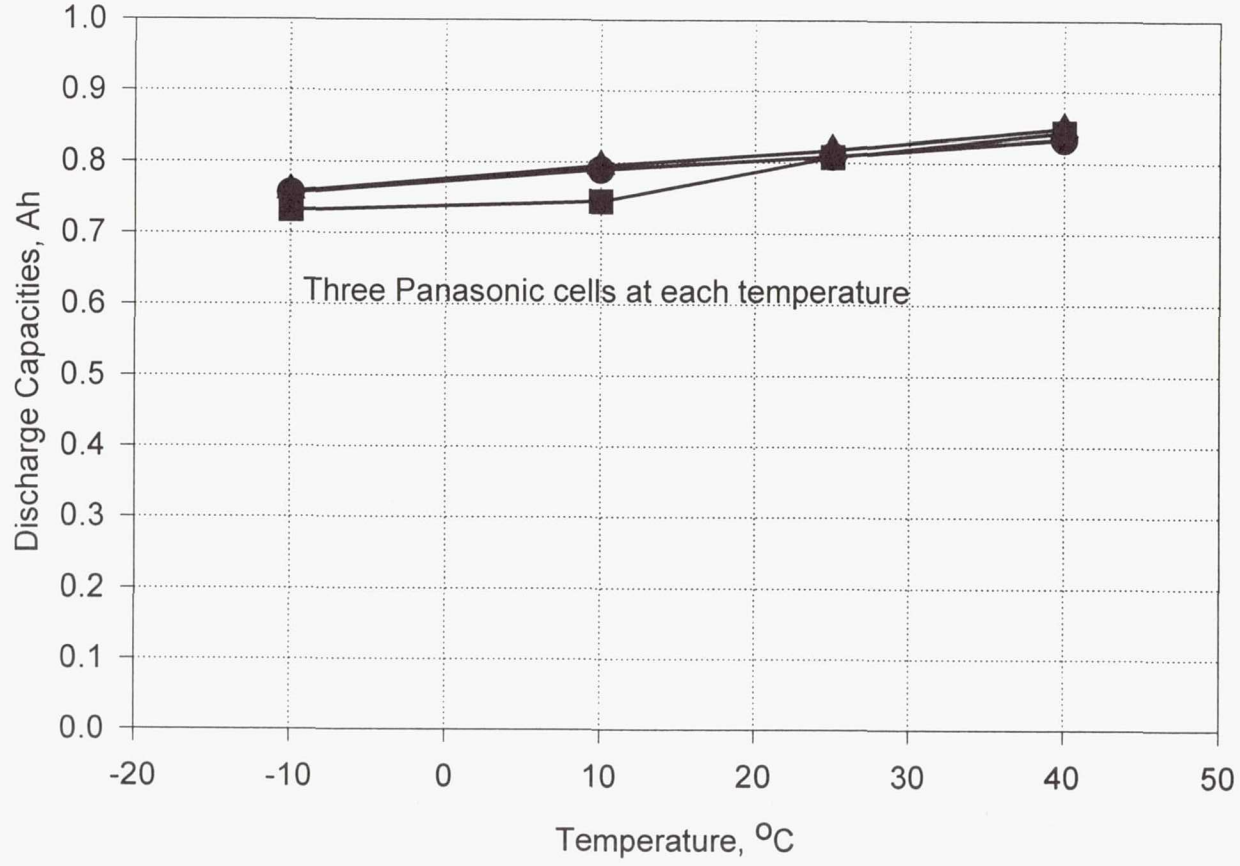
At 1 C Charge/ Discharge, Capacity Decay is 4%

At 0.5 C Charge/Discharge, Cacpacity Decay is 1.9 %

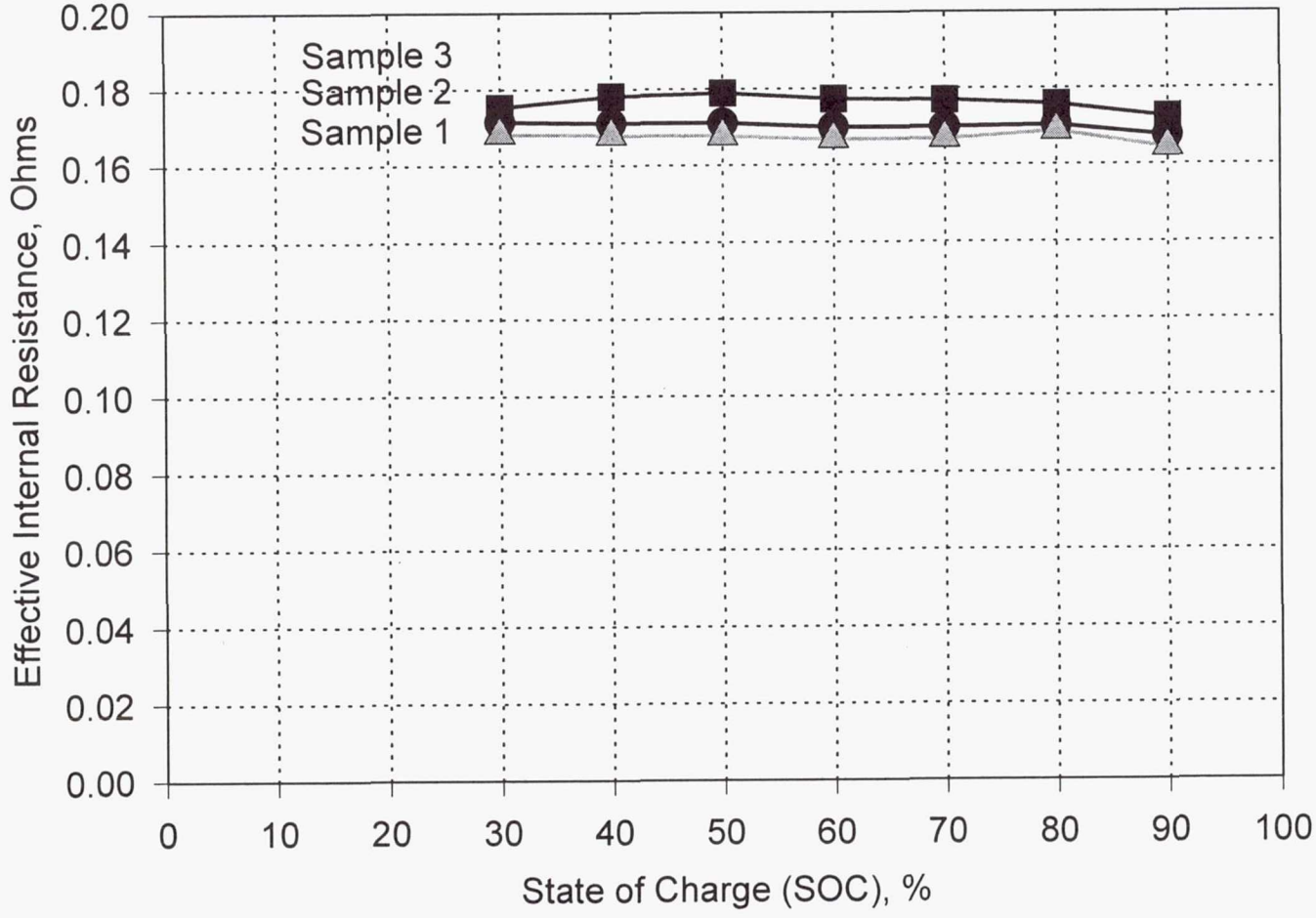
Discharge Capacity for the Panasonic cells at 0.5C Rate of Discharge and Different Rates of Charge



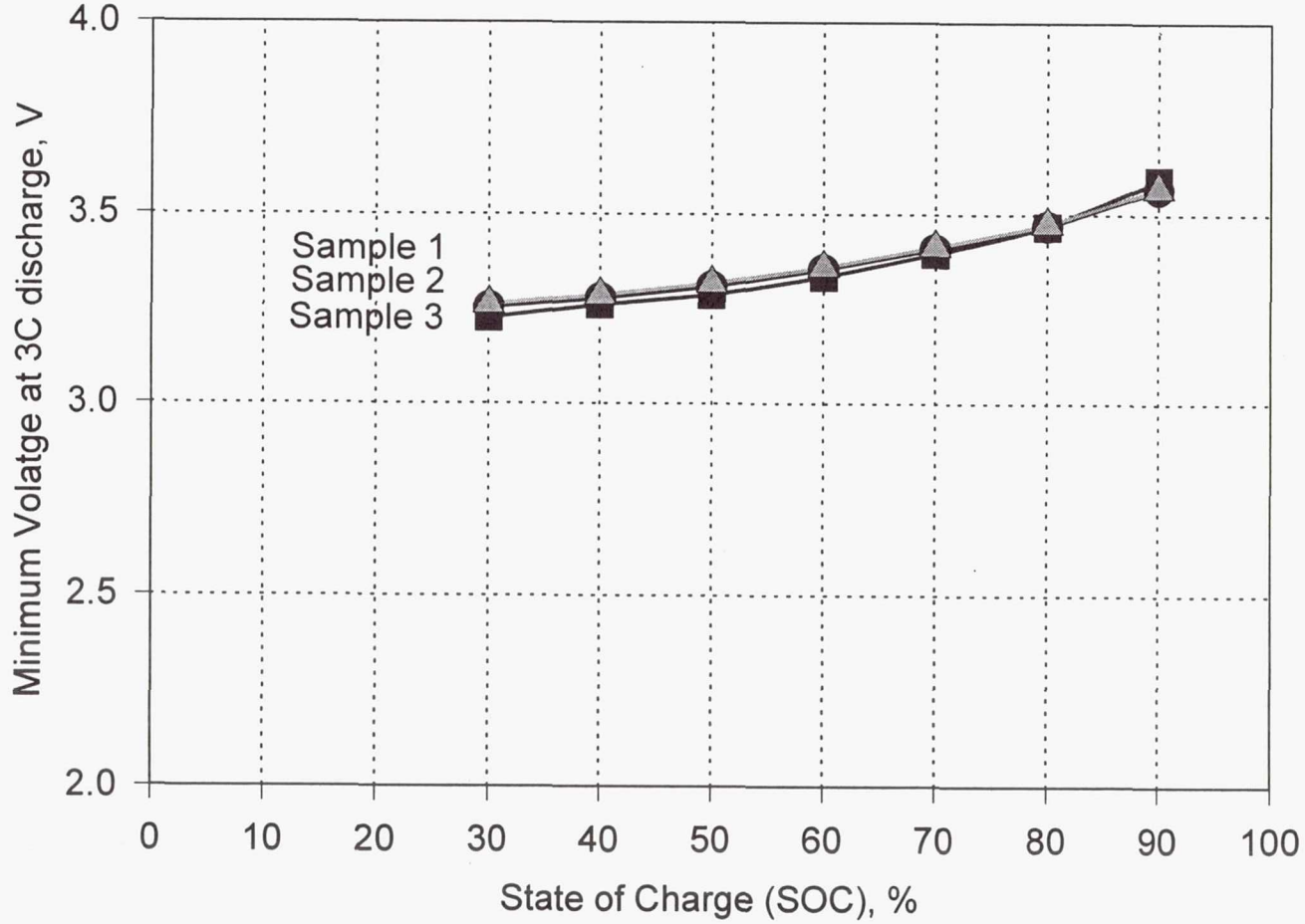
Discharge Capacities versus Temperature for the Panasonic 17500 Lithium-ion Cells



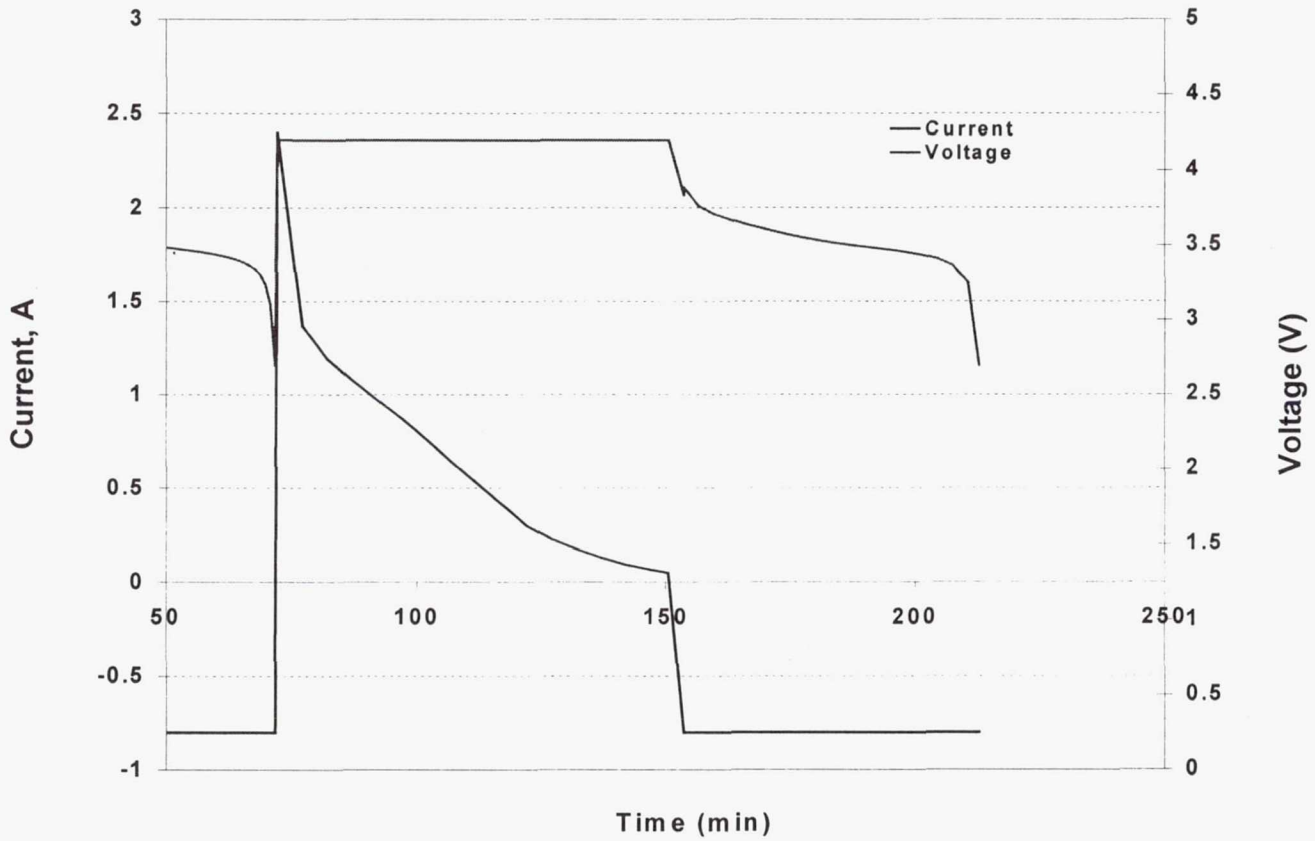
Effective Internal Resistance for the Panasonic Lithium-ion cells



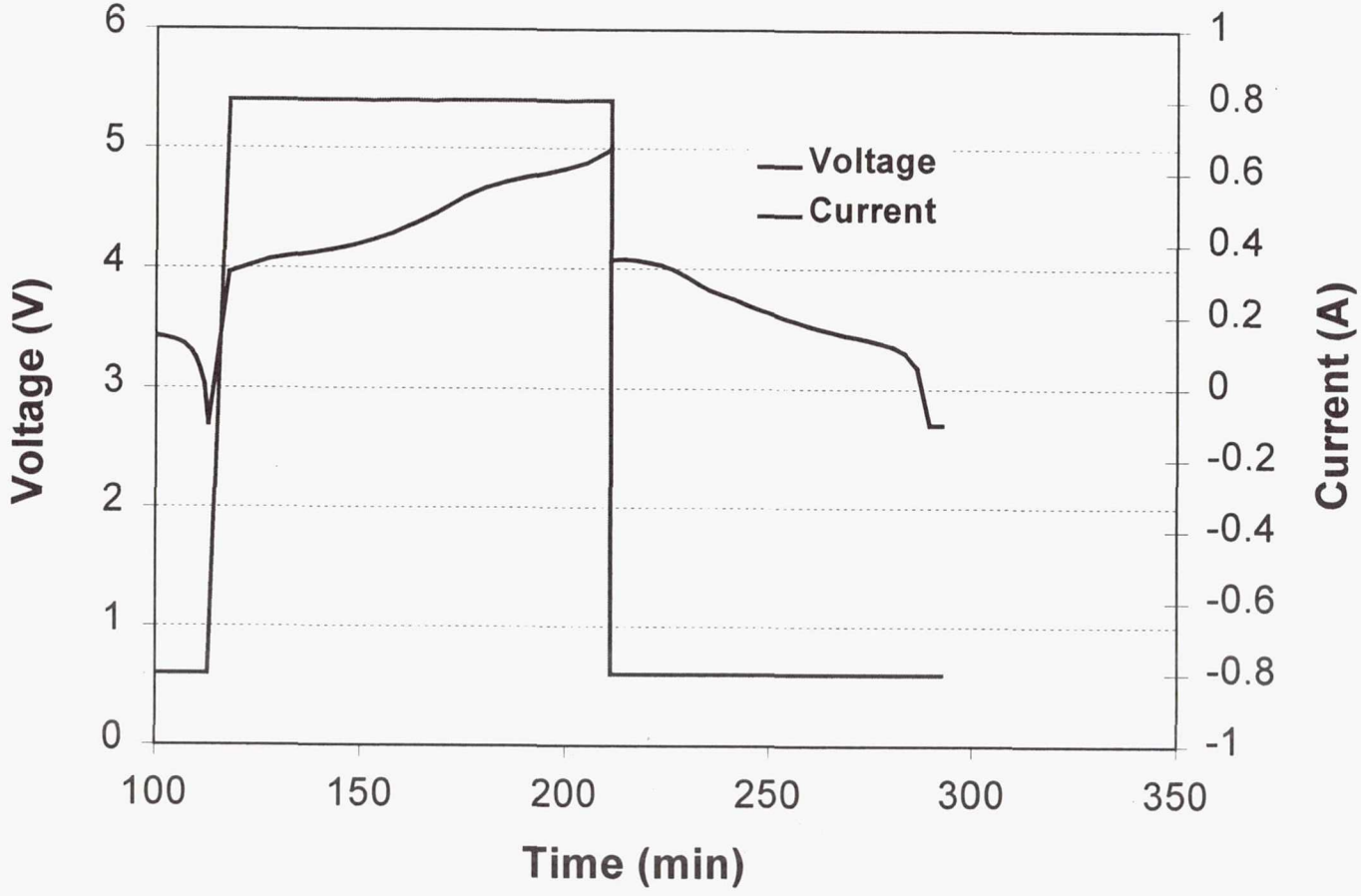
Minimum Voltages Obtained During the Discharge Pulse of the Internal Resistance Test



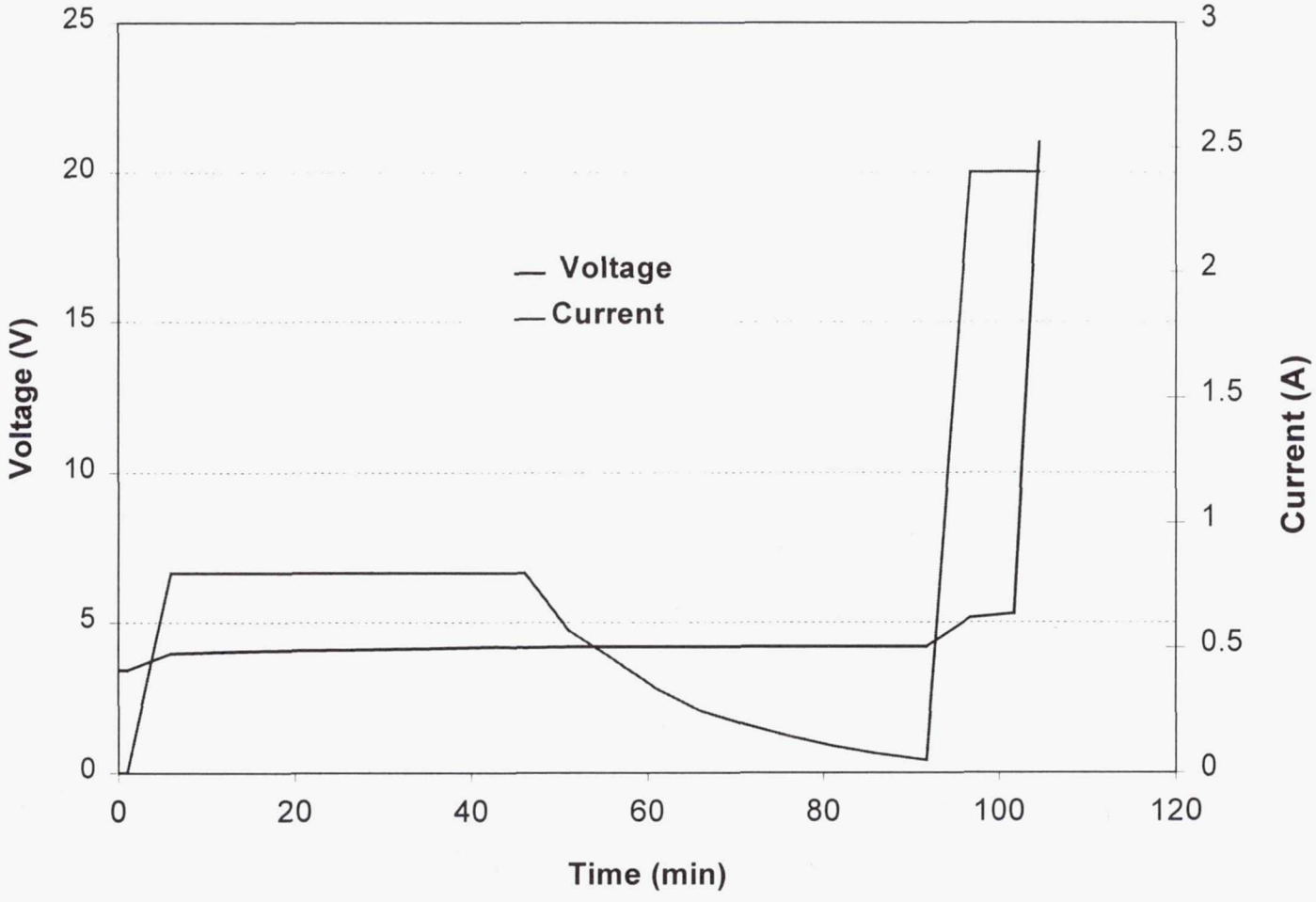
Charge Discharge Curve for Charge at 3C Rate to 4.2 V and Discharge with 1C Current to 2.7 V



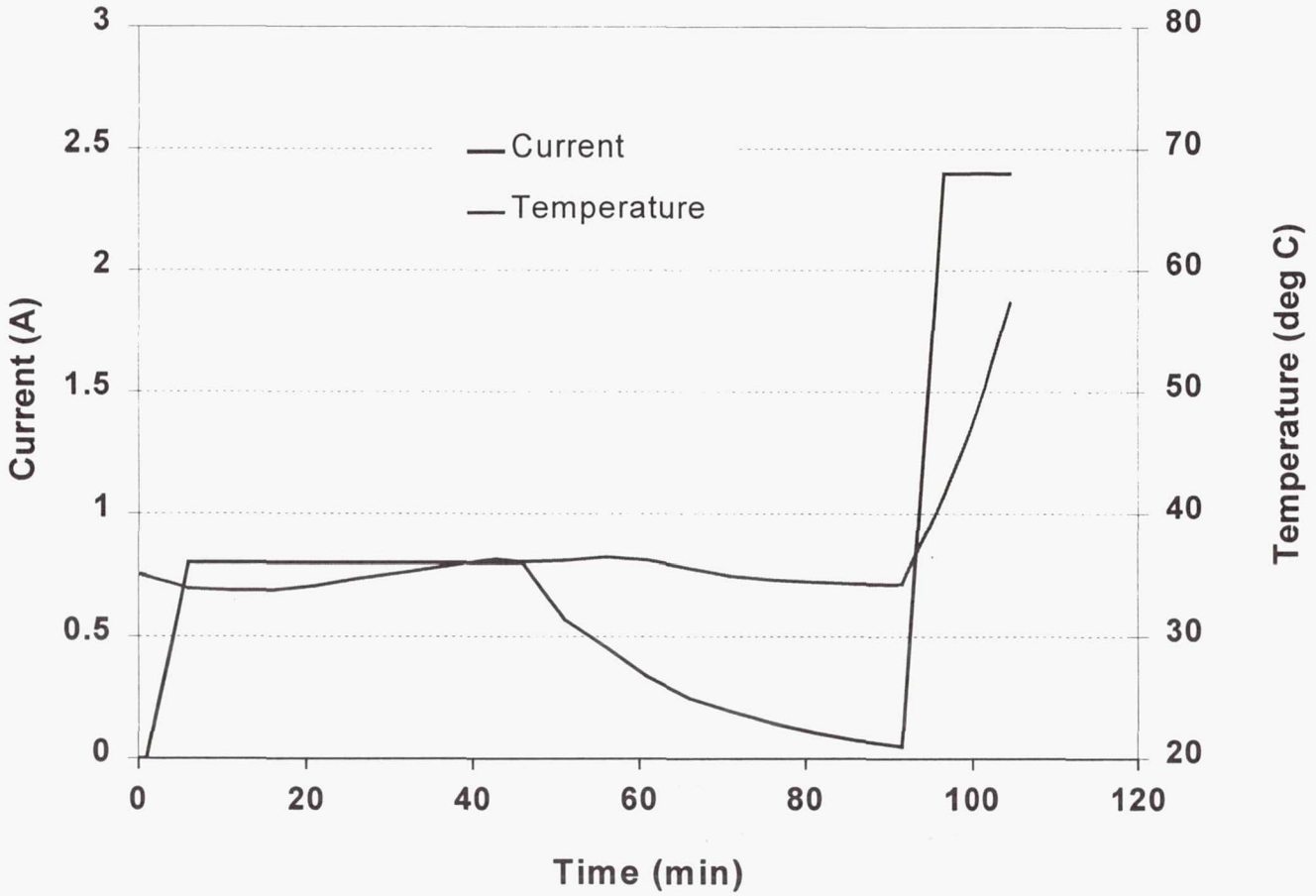
Charge-Discharge Curve for Charge to 5.0 V with a 1 C Current and Discharge to 2.7 V with 1C Current



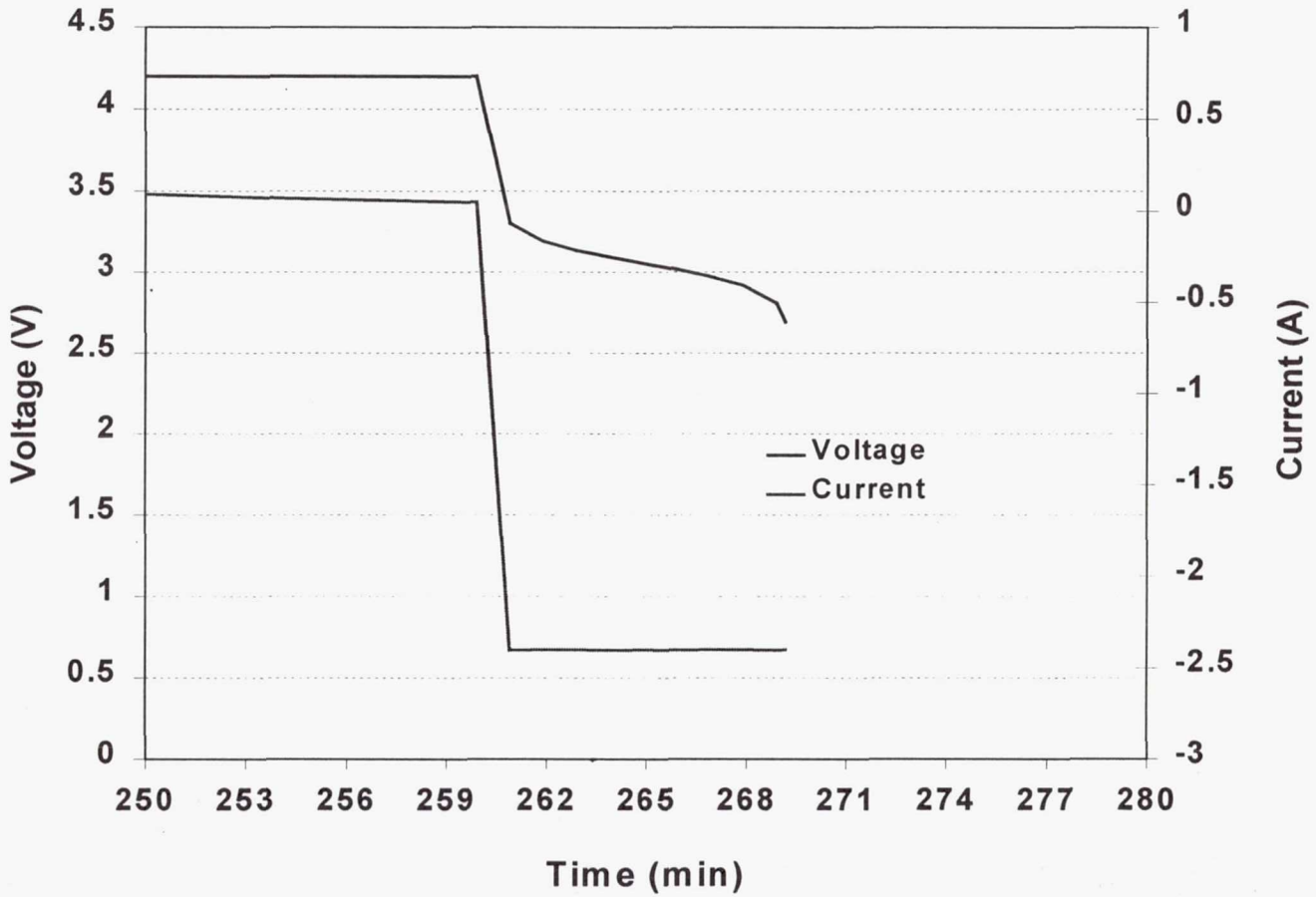
Overcharge Test Using a 3C Current to 12 V



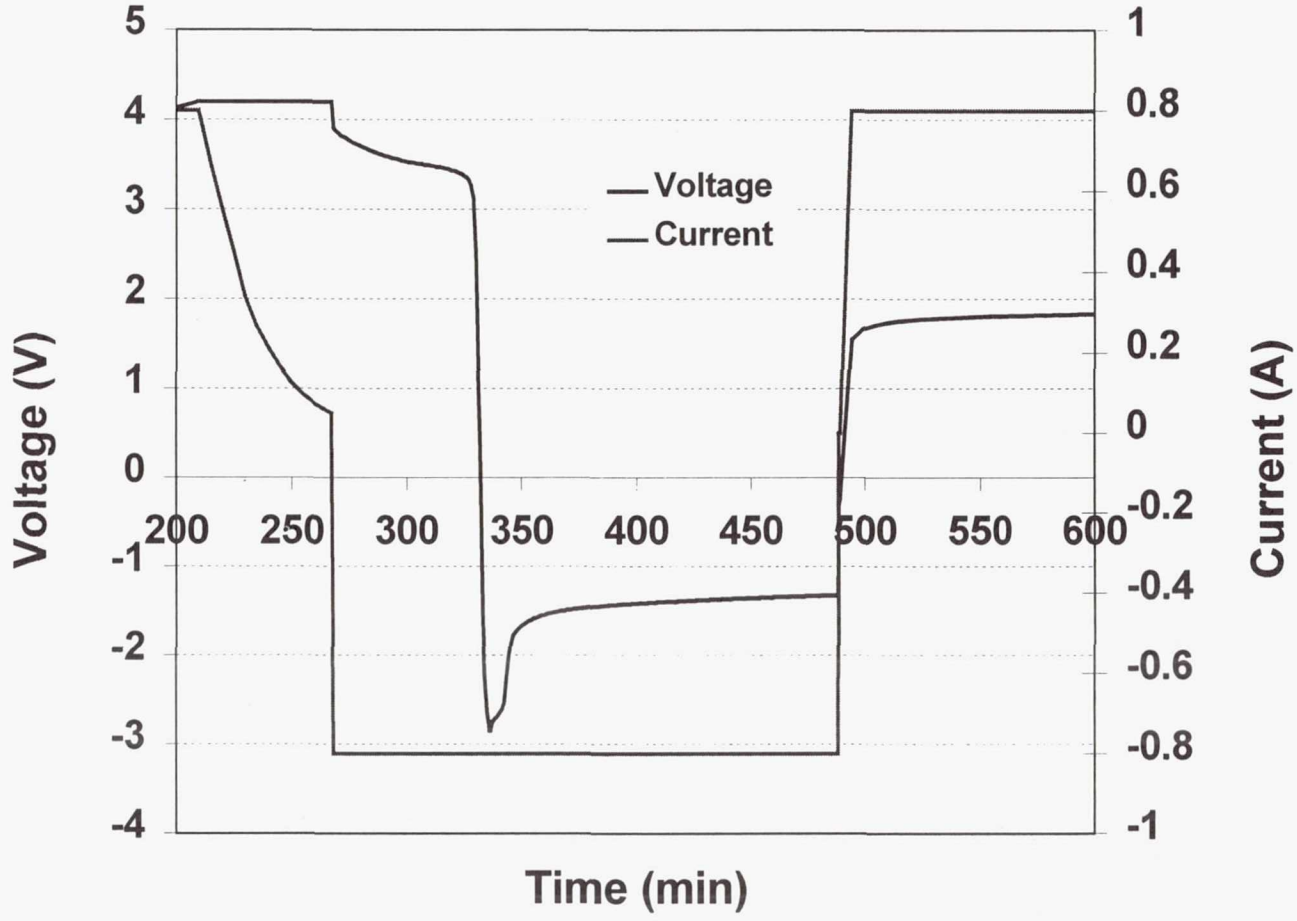
Current and Temperature Changes During a High Rate Overcharge (3C current) to 12 V



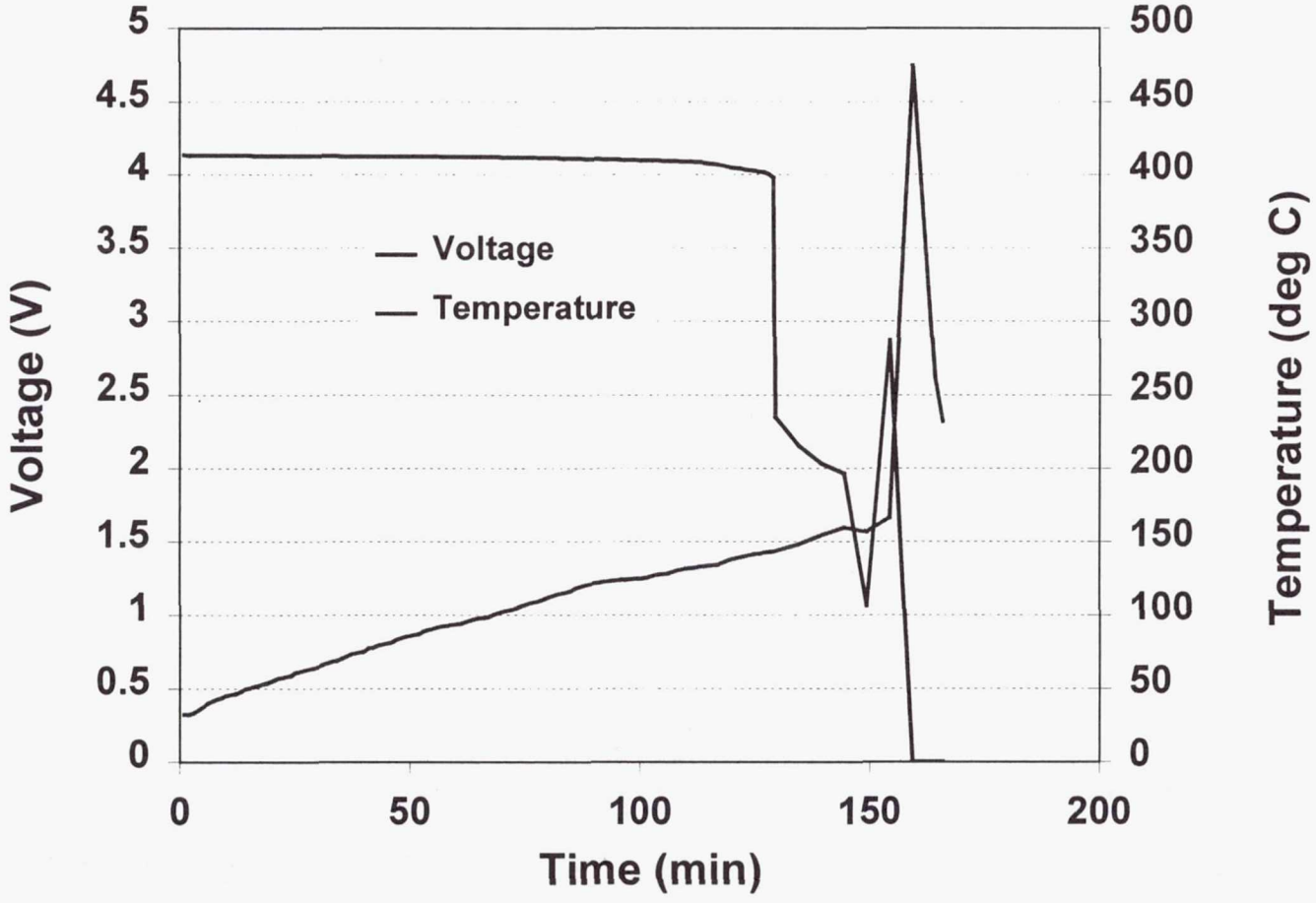
Discharge of Panasonic 17500 Lithium-ion Cells Using 3C Current



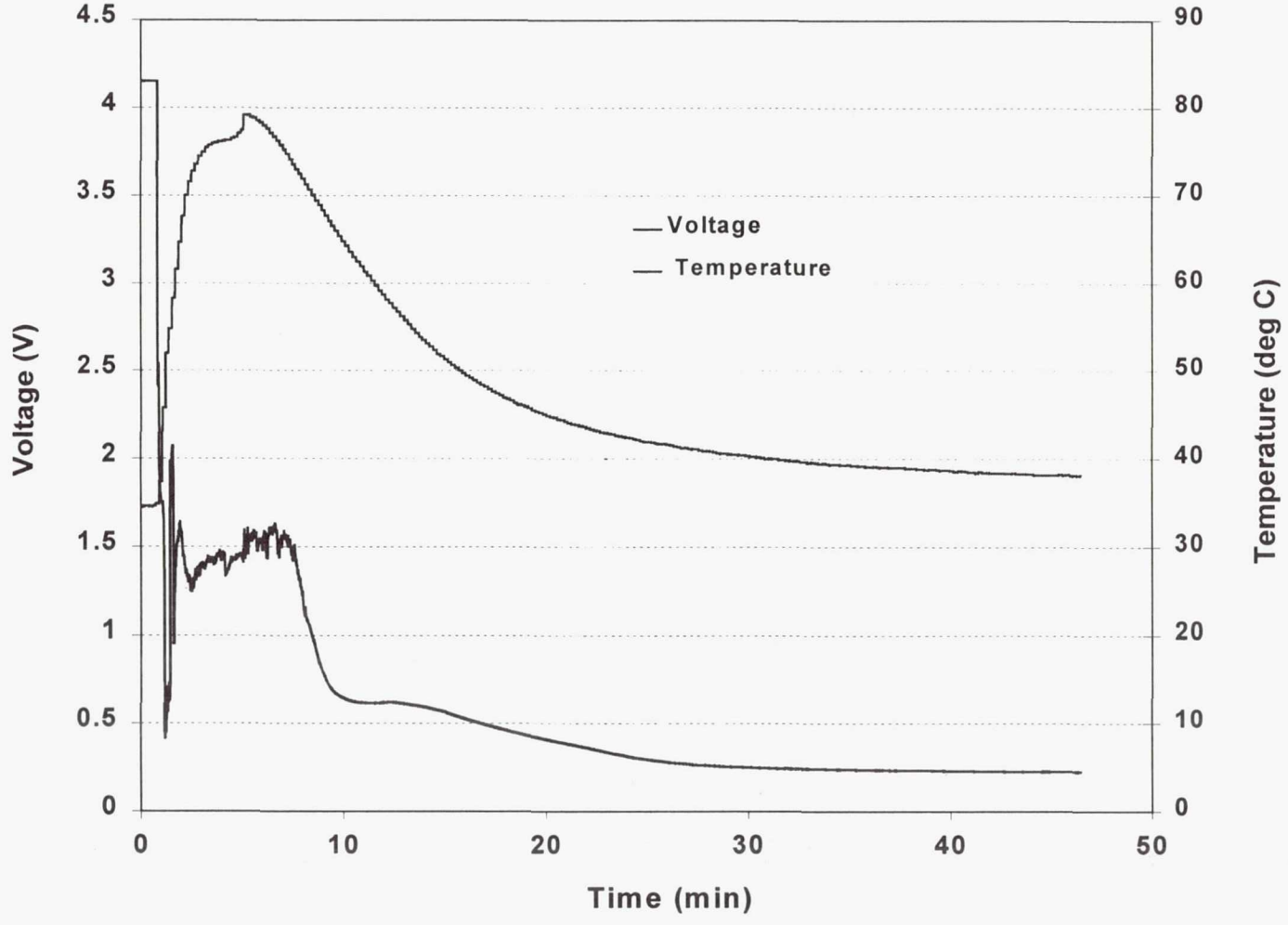
Current and Voltage Characteristics During Discharge into Reversal of Panasonic 17500 Lithium-ion Cells with 1C Current



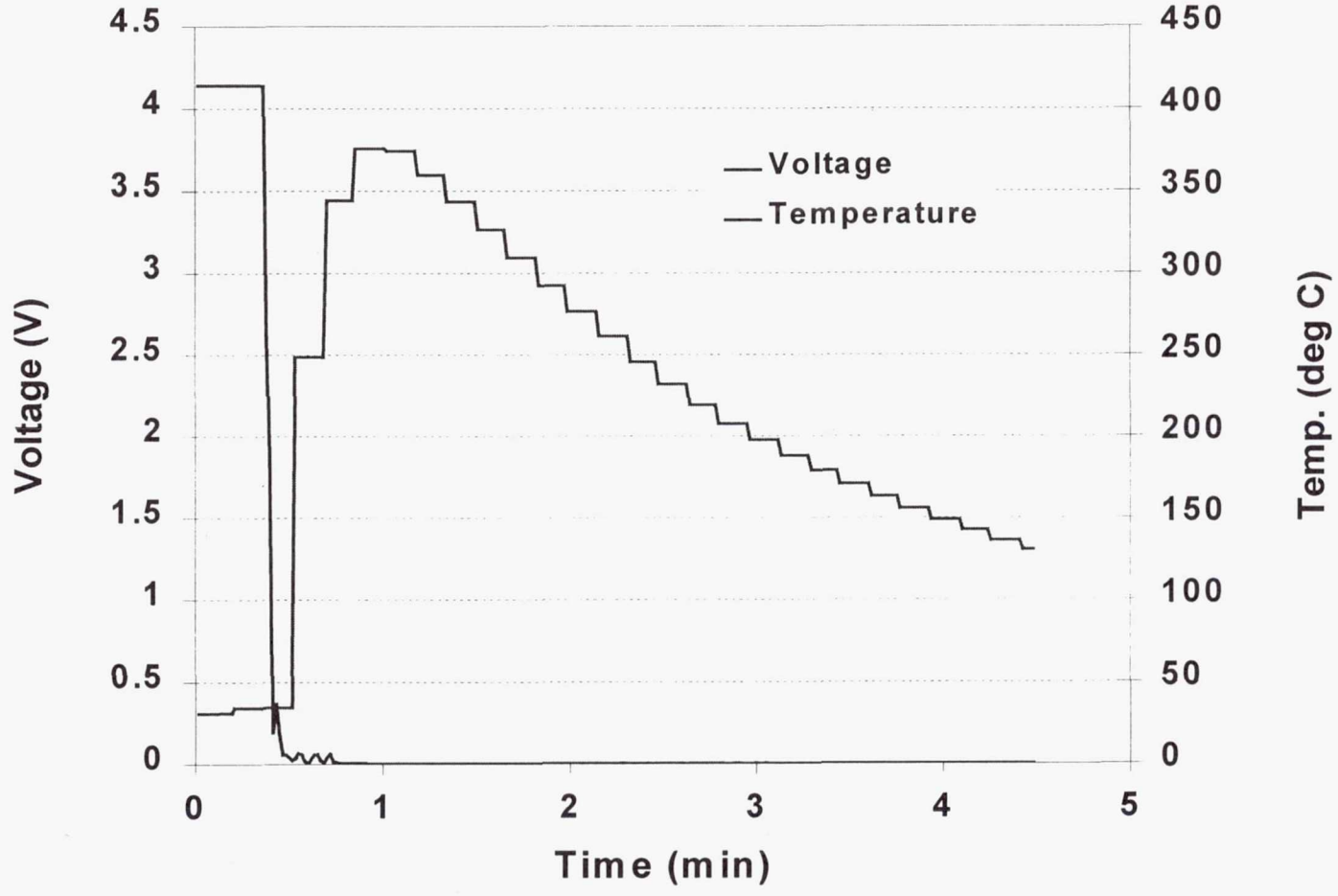
Heat-to-Vent of Panasonic 17500 Lithium-ion Cells



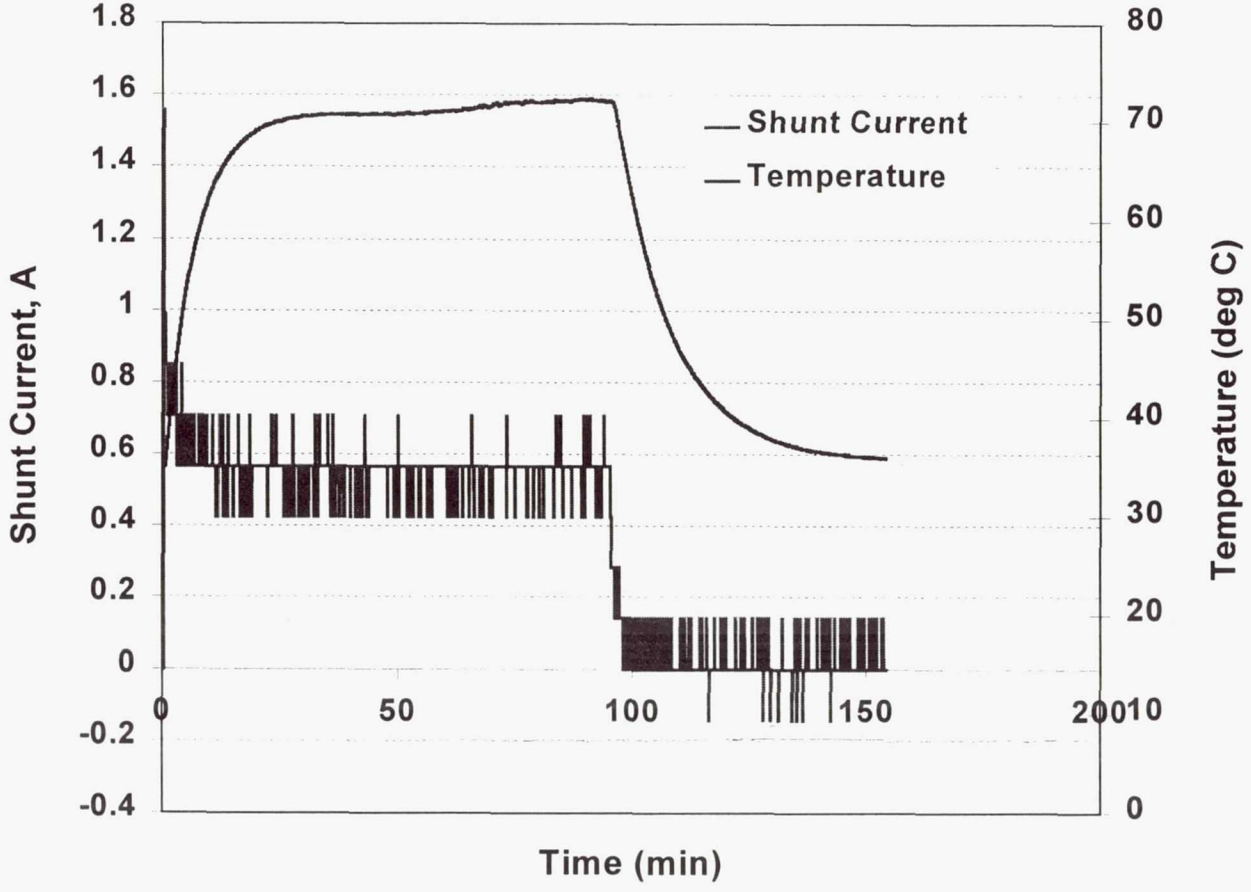
Voltage and Temperature Profile During a Soft Internal Short



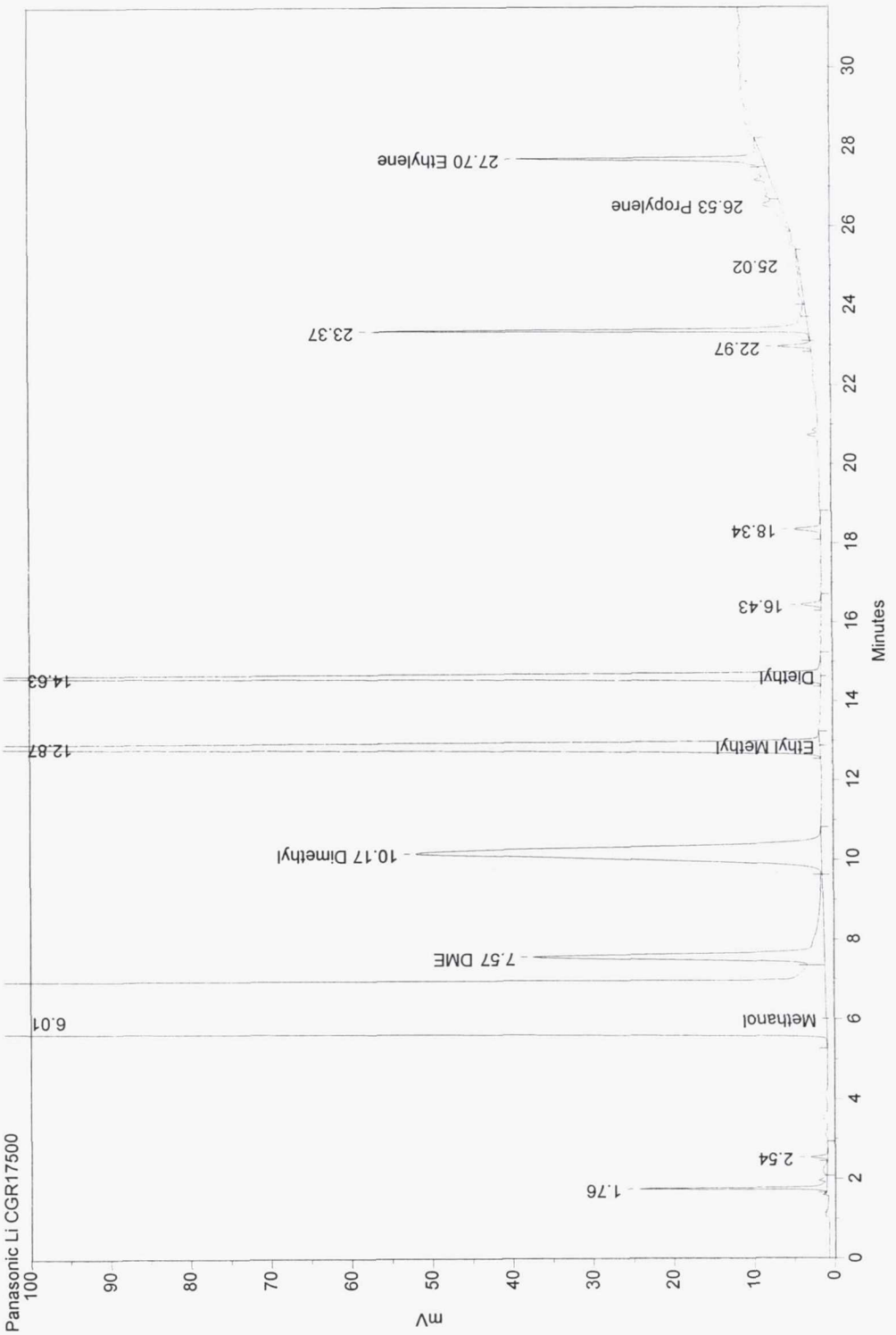
Voltage and Temperature Characteristics During a Hard Internal Short



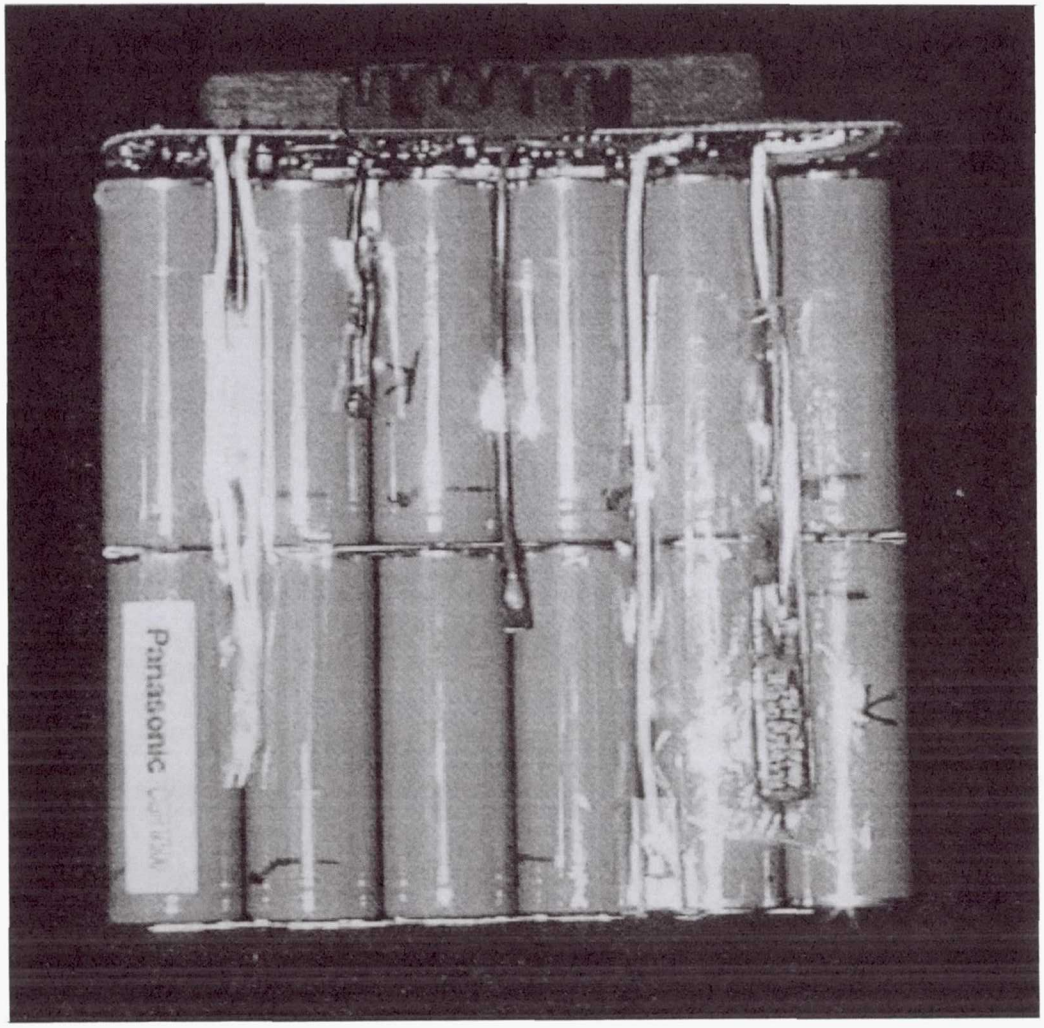
Current and Temperature Characteristics During An External Short Test Using 40 mohm Load



Electrolyte Analysis of Panasonic 17500 lithium-ion cell

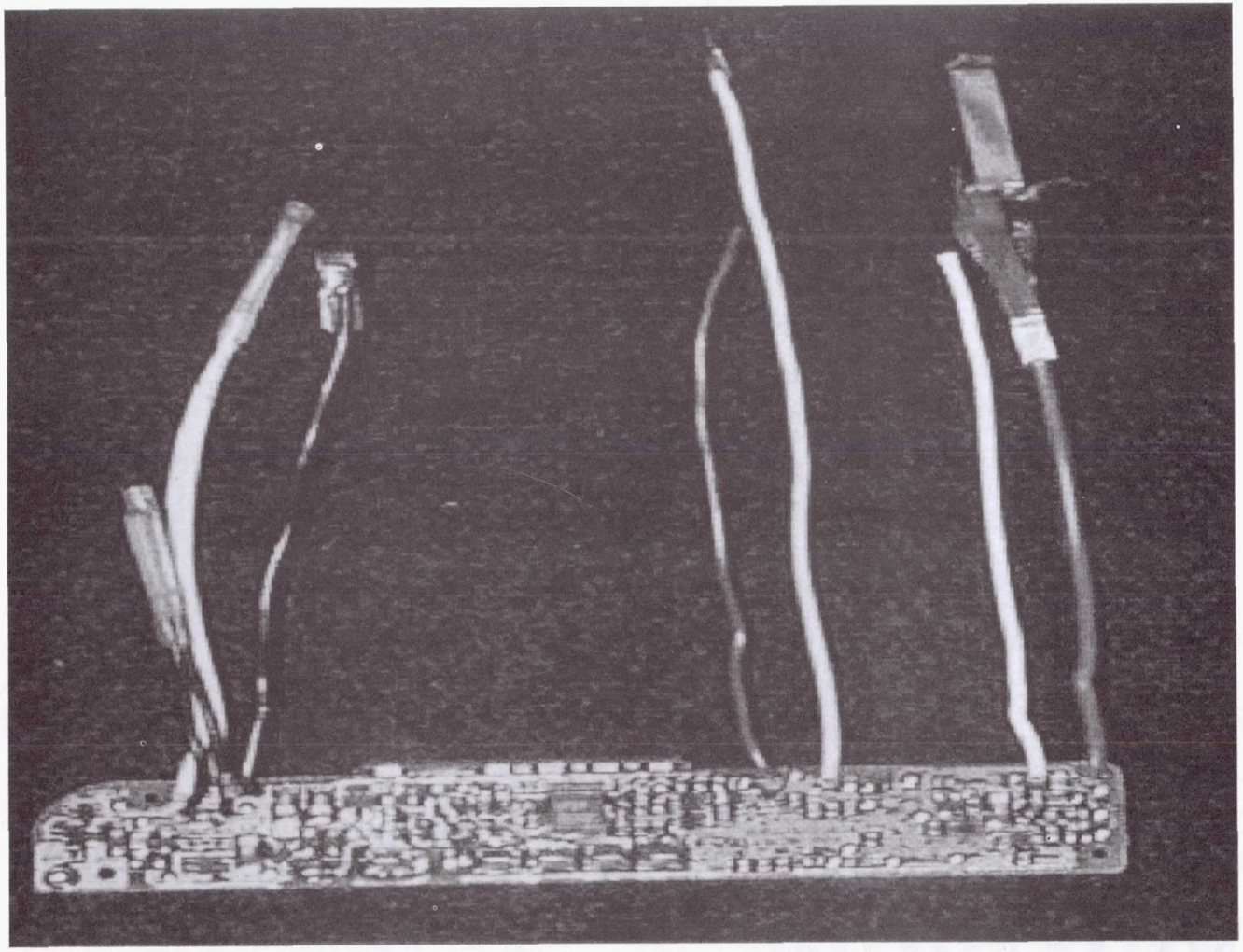


Panasonic Lithium-ion IBM Thinkpad Battery



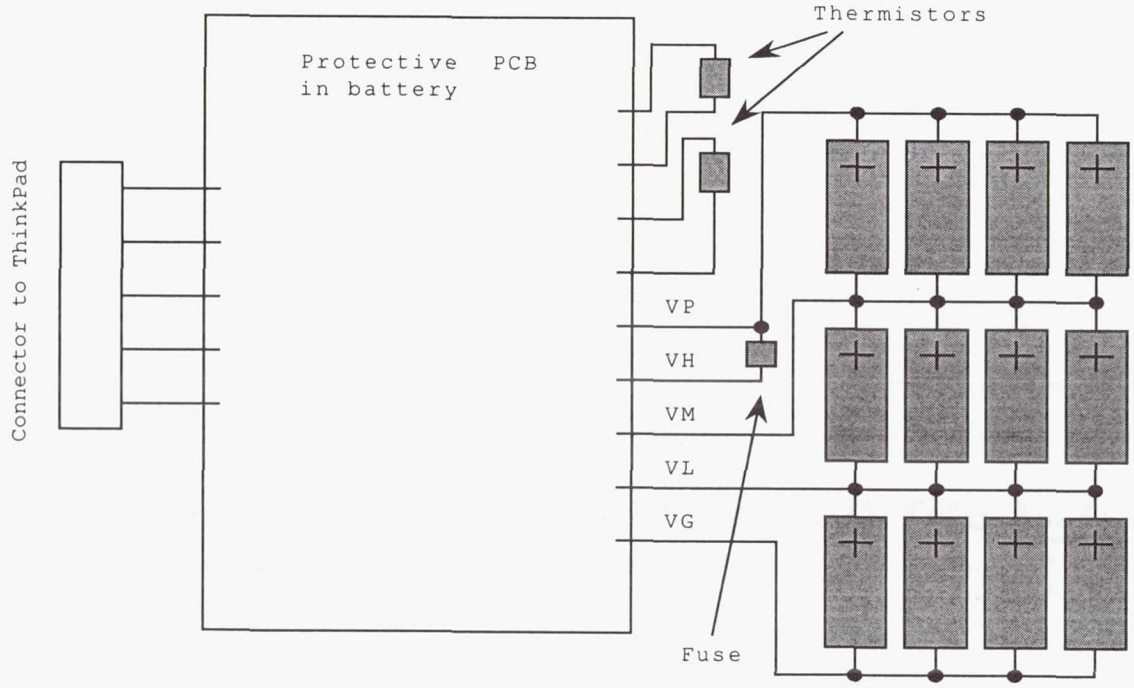
Weight: 366 g
Dimensions: 4'X 4.5'
Voltage: 10.8 V
Capacity: 3.0 Ah
Configuration: 4P3S (12 cells)

Circuit Board in the Panasonic Thinkpad Lithium-ion Battery

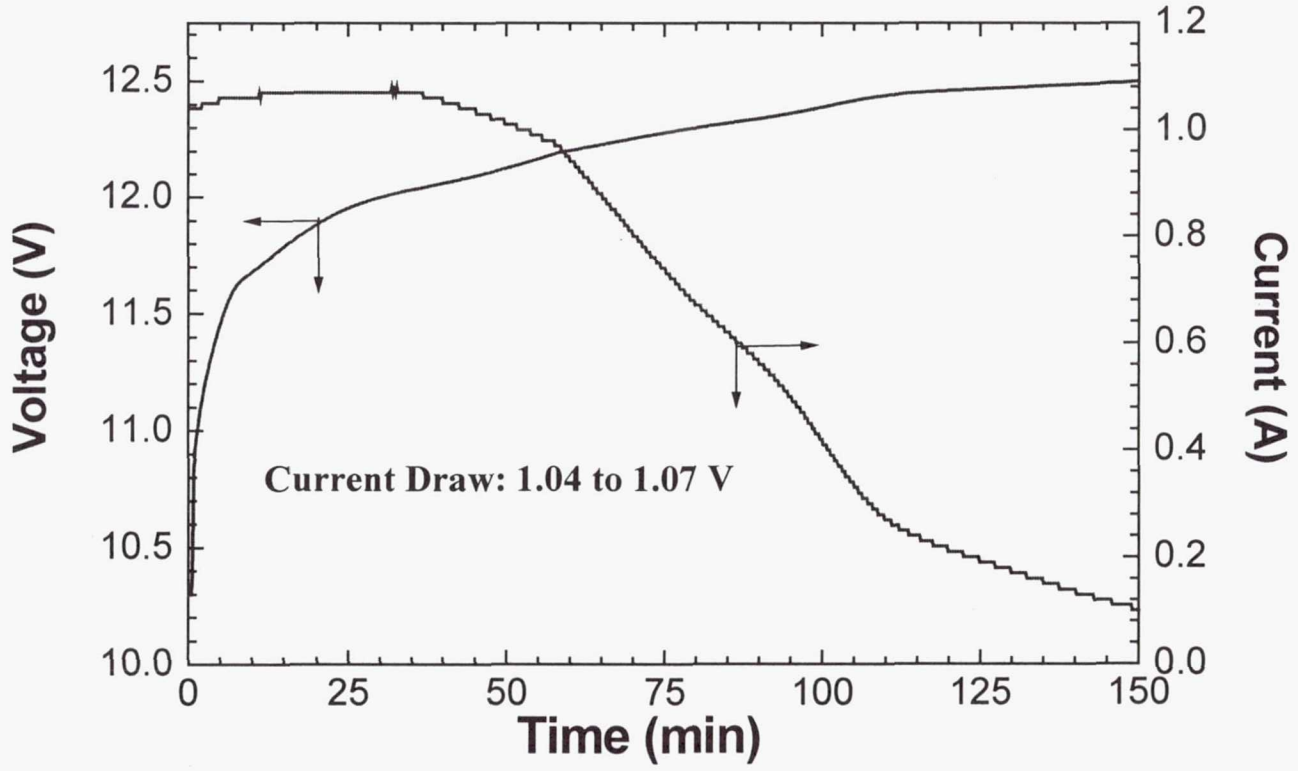


Circuit Board in the Panasonic Lithium-ion Battery

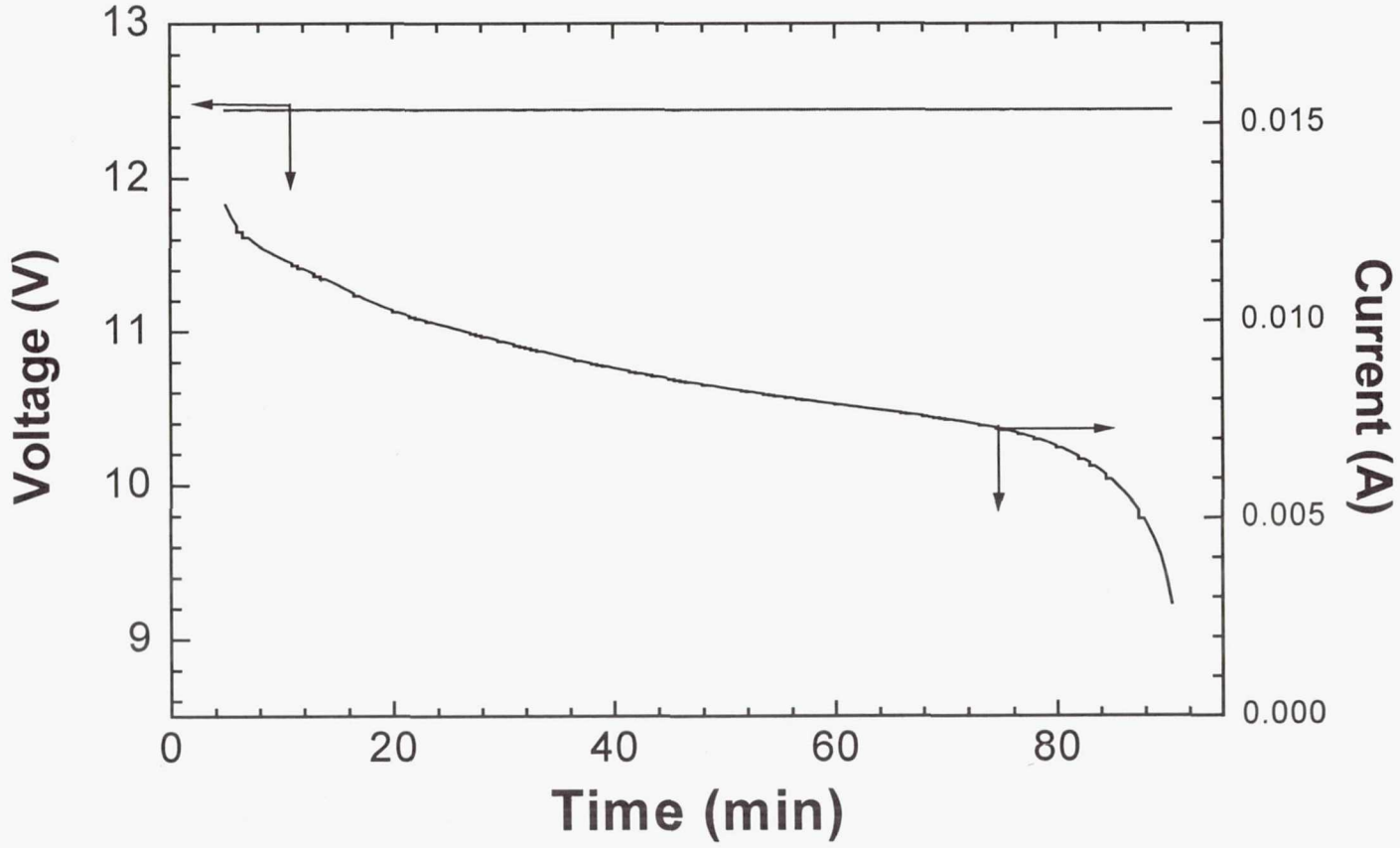
- Decisions about turning off charge and discharge switches based on cell bank voltages and current are made by firmware in microcontroller.
- Protective circuit performs capacity gauge function.
- Protective circuit can balance cell bank states-of-charge by putting small (15 mA) discharge currents on individual cell banks.



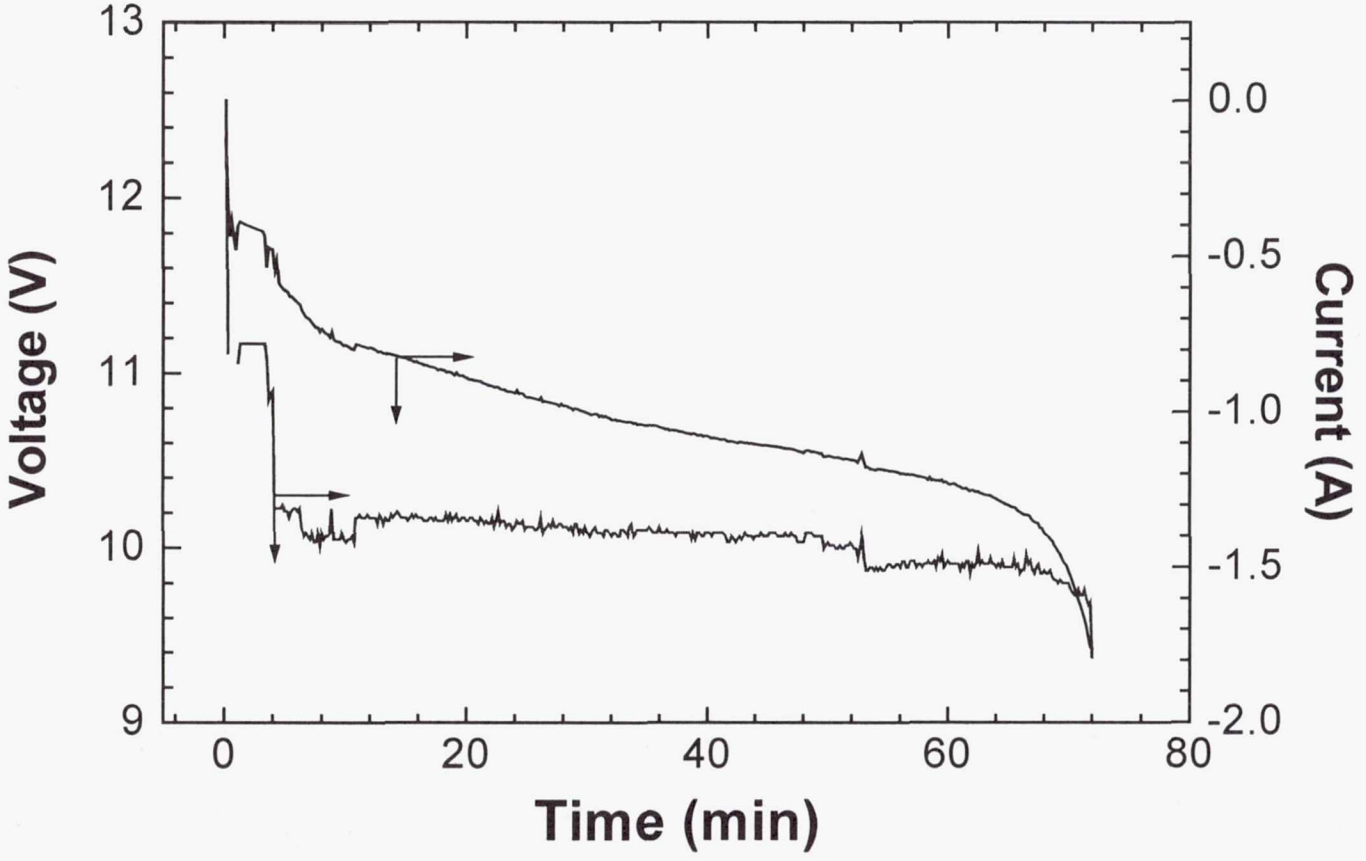
Current and Voltage During the Charging of a Panasonic Lithium-ion Battery Using the IBM Thinkpad Charger



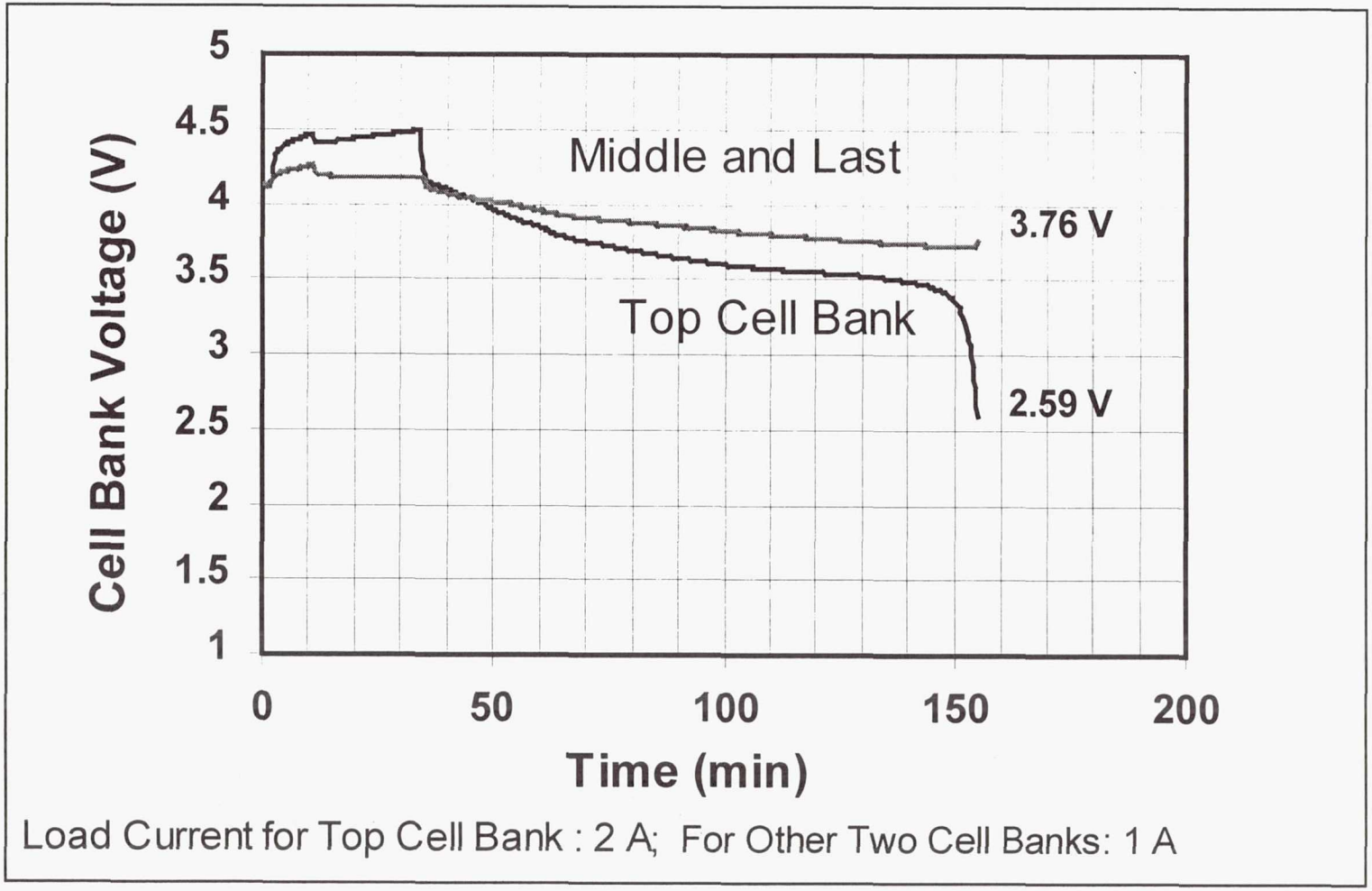
Discharge Characteristics of the Panasonic Lithium-ion Battery with No Programs Running



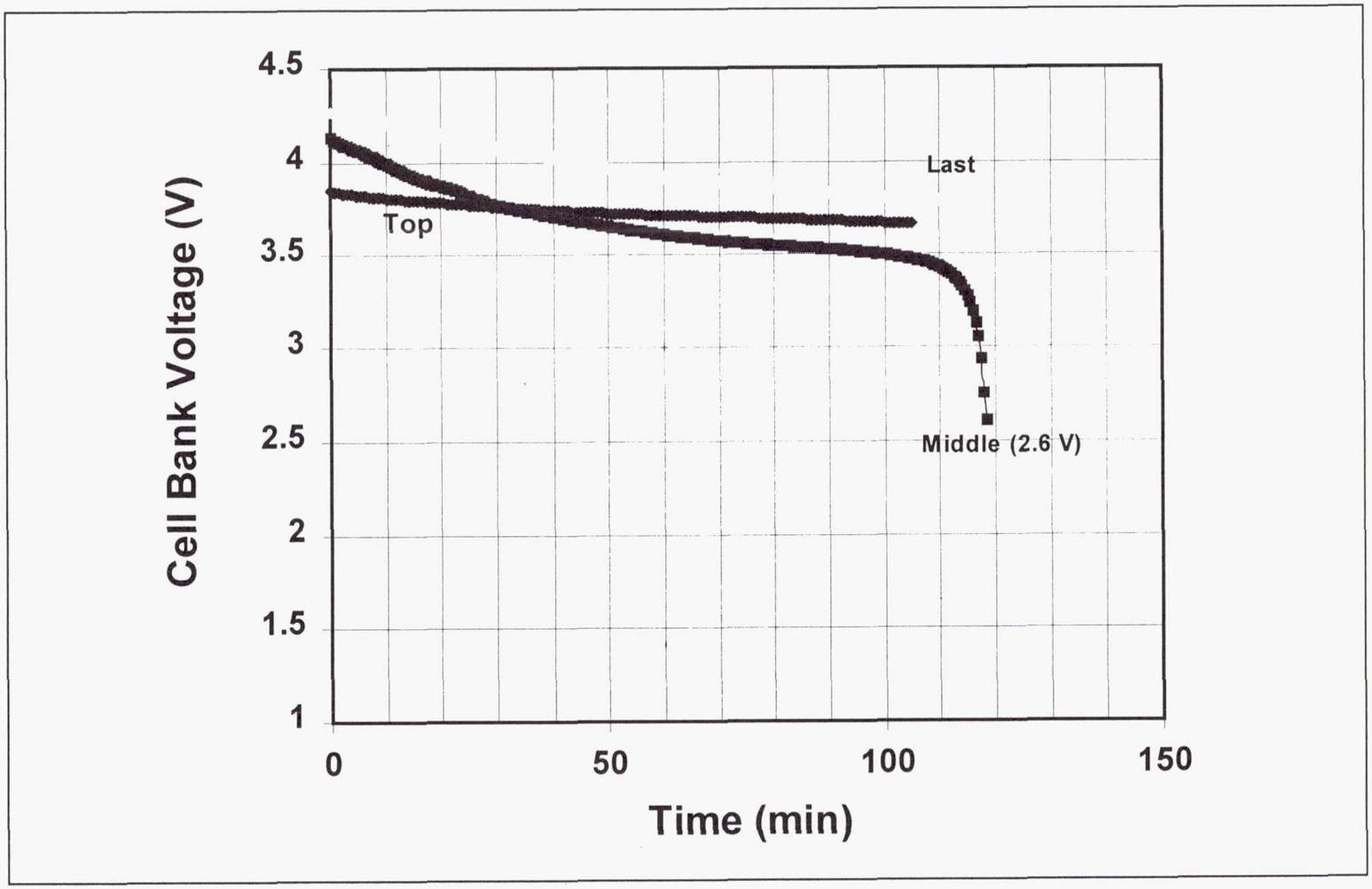
Discharge Characteristics of the Panasonic Lithium-ion Battery with the Program Running



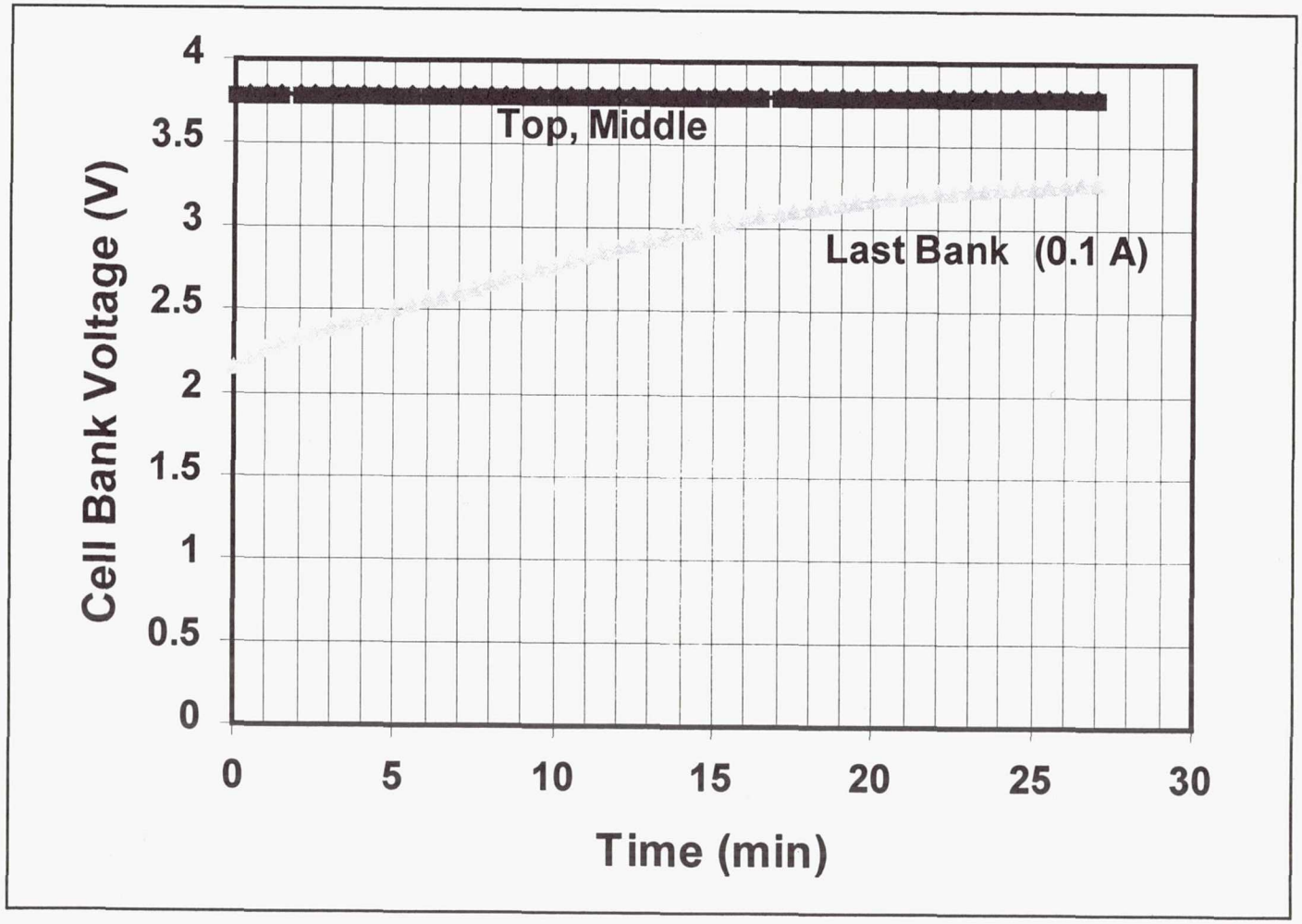
Voltage Profile of Individual Cell Banks During Overdischarge of Top Cell Bank



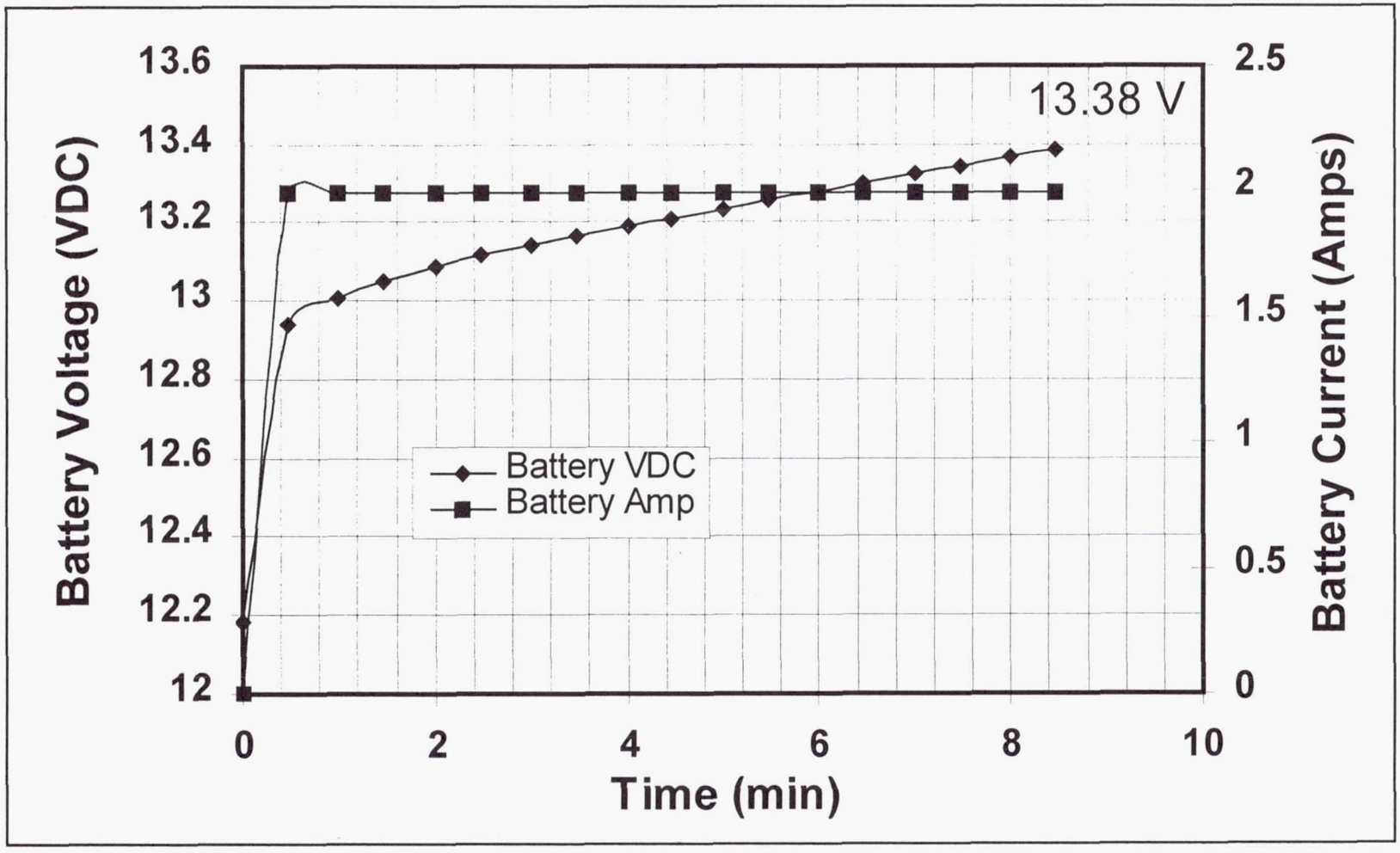
Voltage Profile of Individual Cell Banks During Overdischarge of Middle Cell Bank



Voltage Profile During Reset of Last Cell Bank after an Overdischarge



Current and Voltage Profile During An Overcharge of the Whole Battery using a 2 A Current



CONCLUSIONS

- Performance of the cells under different conditions of charge and discharge shows that the 0.5 C rate of charge and discharge might be the ideal condition for long term cycling.
- Overcharge and Overdischarge: The cells and the battery have adequate protection under both conditions to prevent any catastrophic occurrences.
- Temperatures above 150 °C are required to vent the cells or cause a thermal runaway. This situation is non-credible in the cabin of the Space Shuttle or ISS.
- Internal crushes can give different results depending on the nature of the crush. Soft shorts do not exhibit high temperatures or thermal runaway whereas hard internal shorts can exhibit temperatures above 400 °C and expel can contents.
- All batteries will be screened using a vibration test (0.067 g^2/Hz for one minute) for internal short before flight.

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