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forty years



EcoloCap Battery Test Summary

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Introduction

- Exponent was retained to characterize the charge and discharge performance of EcoloCap's 720 Ah battery
- Exponent performed a series of charge and discharge tests to determine the energy (Ah) of the 720 Ah battery at various charge/discharge currents at room temperature
- Exponent also characterized the temperature of the battery at selected locations on the battery enclosure during the charge/discharge tests



Introduction

- Exponent's testing was limited to charge/discharge currents up to 235 A (C/3.06)
- All tests were performed on a single battery received for testing
- The tested battery did not contain a battery management system for protection



Battery Information

- Nominal Capacity: 720 Ah
- Number of cells: 3
- Cell Configuration: 3S1P
(3 series 1 parallel)
- Nominal Voltage: 12.0 V





SUMMARY



Summary

- The measured battery energy (Ah) exceeded the battery's rating of 720 Ah under all test currents
 - The battery was tested for charge/discharge currents up to 235 A (C/3.06)
- The peak battery temperature was recorded on the top of the battery near the battery terminals
 - The peak temperature was recorded at 53°C at a current of 235 A
- The peak battery post temperature was recorded at 75°C



Summary

- The peak battery post temperatures were higher than the peak temperatures measured on the battery enclosure for all tests performed
 - The battery posts (positive and negative) were observed to have dislodged from their manufactured position during the 235 A charge test. This resulted in a lower overall efficiency of the battery at a current of 235 A likely due to heat related capacity losses
 - This may have also resulted in variations in the peak battery post temperatures measured during the tests



Summary

The evaluation conducted by Exponent is documented in this presentation. Should additional information become available or should additional testing or analysis provide further insight, Exponent reserves the right to amend these conclusions.



INSTRUMENTATION



Instrumentation

- Battery Voltage
- Battery Current
- Battery Positive Terminal Temperature (T Pos Term)
- Battery Negative Terminal Temperature (T Neg Term)
- Battery Top Left Temperature (T Top Left)
- Battery Top Right Temperature (T Top Right)
- Battery Top Center Temperature (T Top Ctr)
- Battery Front Top Temperature (T Front Side Top)
- Battery Front Center Temperature (T Front Side Ctr)
- Battery Left Side Center (T Left Side Ctr)
- Battery Rear Side Center (T Rear Side Ctr)
- Battery Back Side Top (T Back Side Top)
- Battery Back Side Center (T Back Side Ctr)

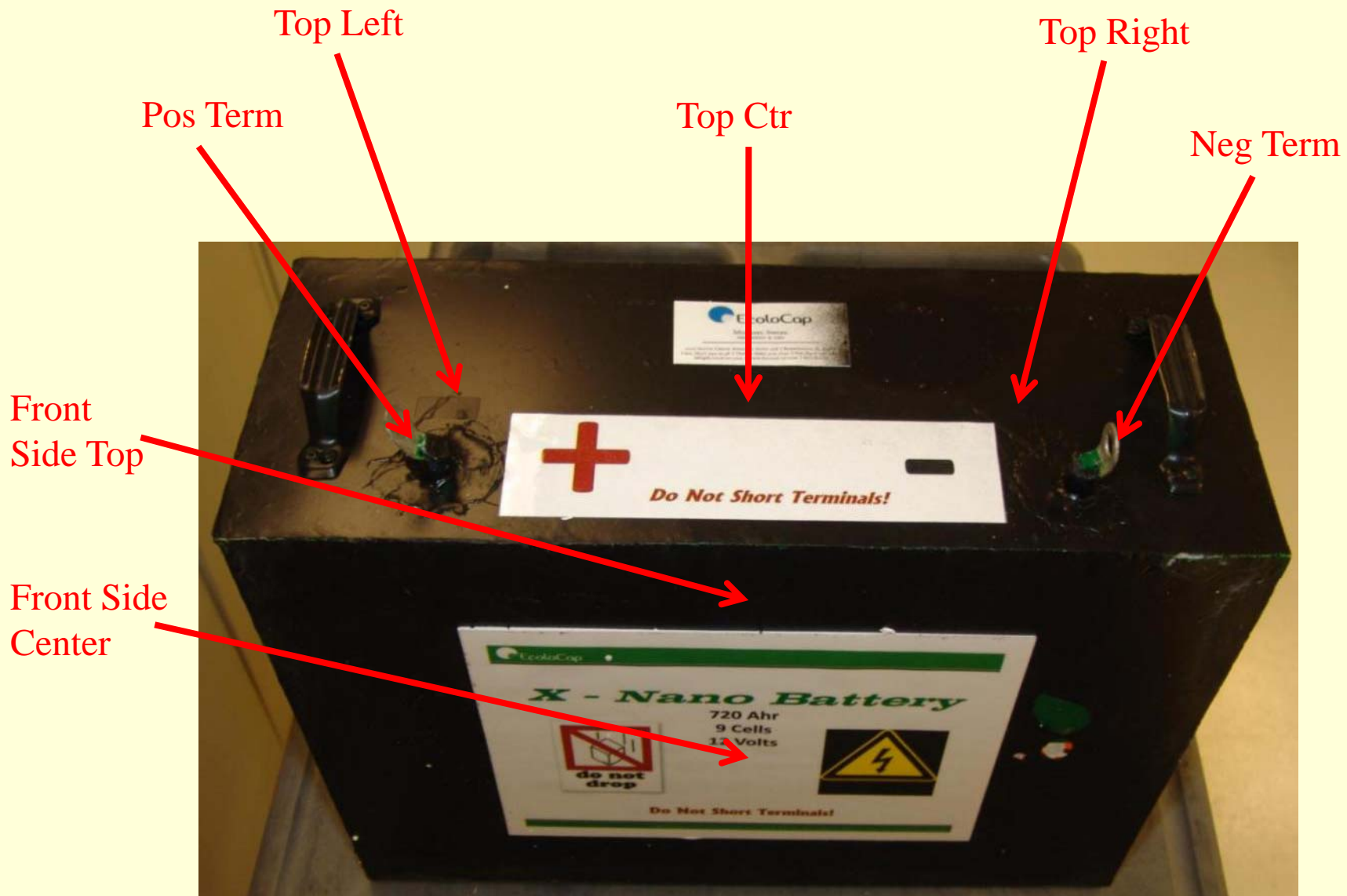


Instrumentation

- The temperature, voltage and current was recorded using a Fluke Hydra Logger (Model NO. 2045)
 - The data was recorded at a sampling frequency of 1 Hz
- The battery current was measured using a 2005-S LEM current transducer
 - Closed loop compensated current transducer based on the hall effect
 - 2000 A nominal, 3000 – A maximum, 100 kHz bandwidth
- A 0000 (4/0) AWG wire was used to connect the battery to the power supply/electronic load during the tests

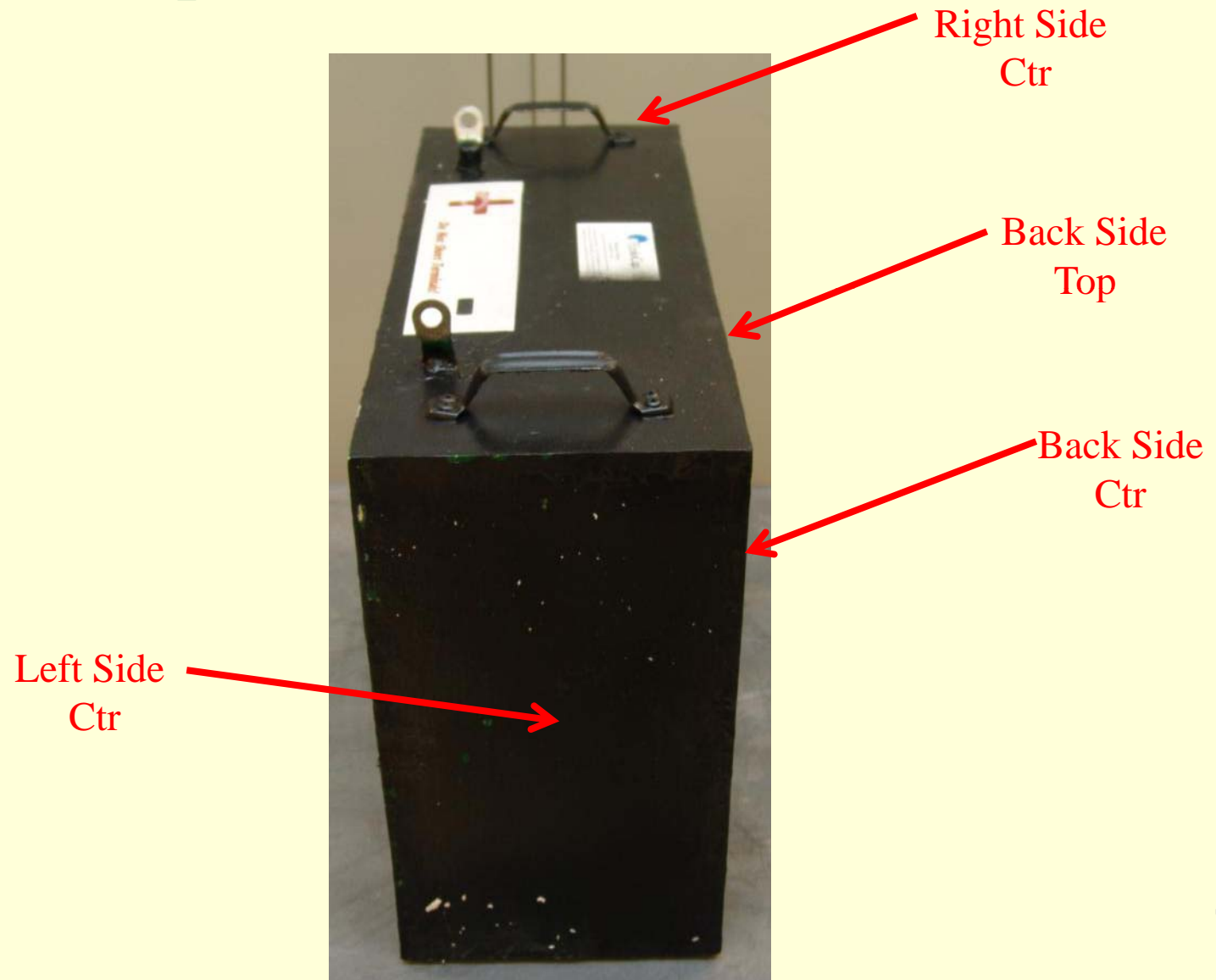


Thermocouple Locations



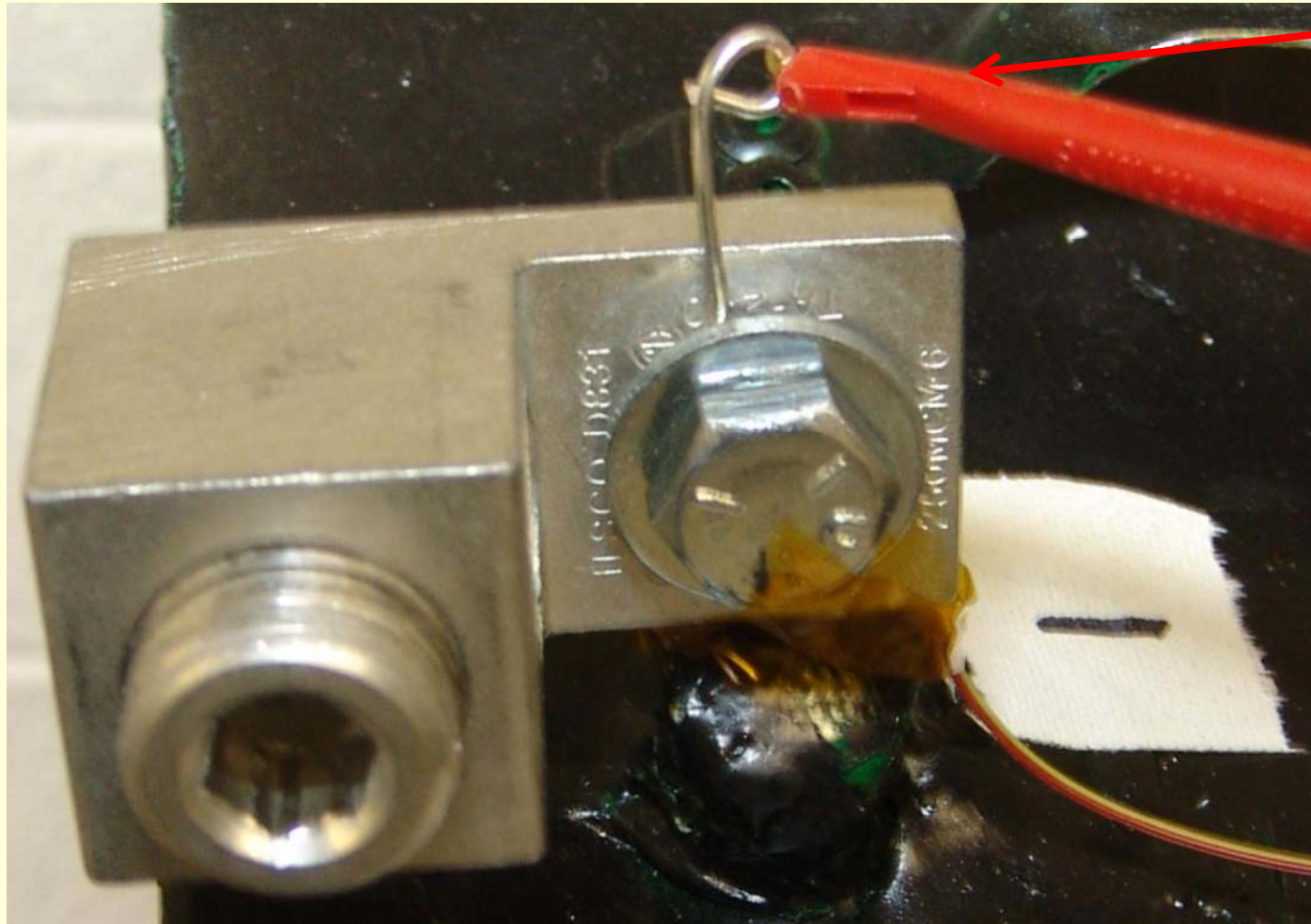


Thermocouple Locations





Terminal Connections



Voltage
Measurement
Terminal

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TEST PROTOCOL



Protocol

1. The battery was discharged at a constant current of 100 A until the battery voltage dropped to 9 V
2. The battery was then charged using a power supply set for an open circuit voltage of 12.6 V and the test charge current
 - Charging was terminated once the charge current dropped to 70 ± 5 A
3. The battery was then discharged using the test current until the battery voltage dropped to 9 V



Test Runs

- Steps 1-3 of the test protocol (Slide 17) were performed for the following currents:
 - 100 A
 - 150 A
 - 200 A
 - 235 A
- All tests were performed at an ambient temperature of $22 \pm 3^{\circ}\text{C}$.



TEST RESULTS

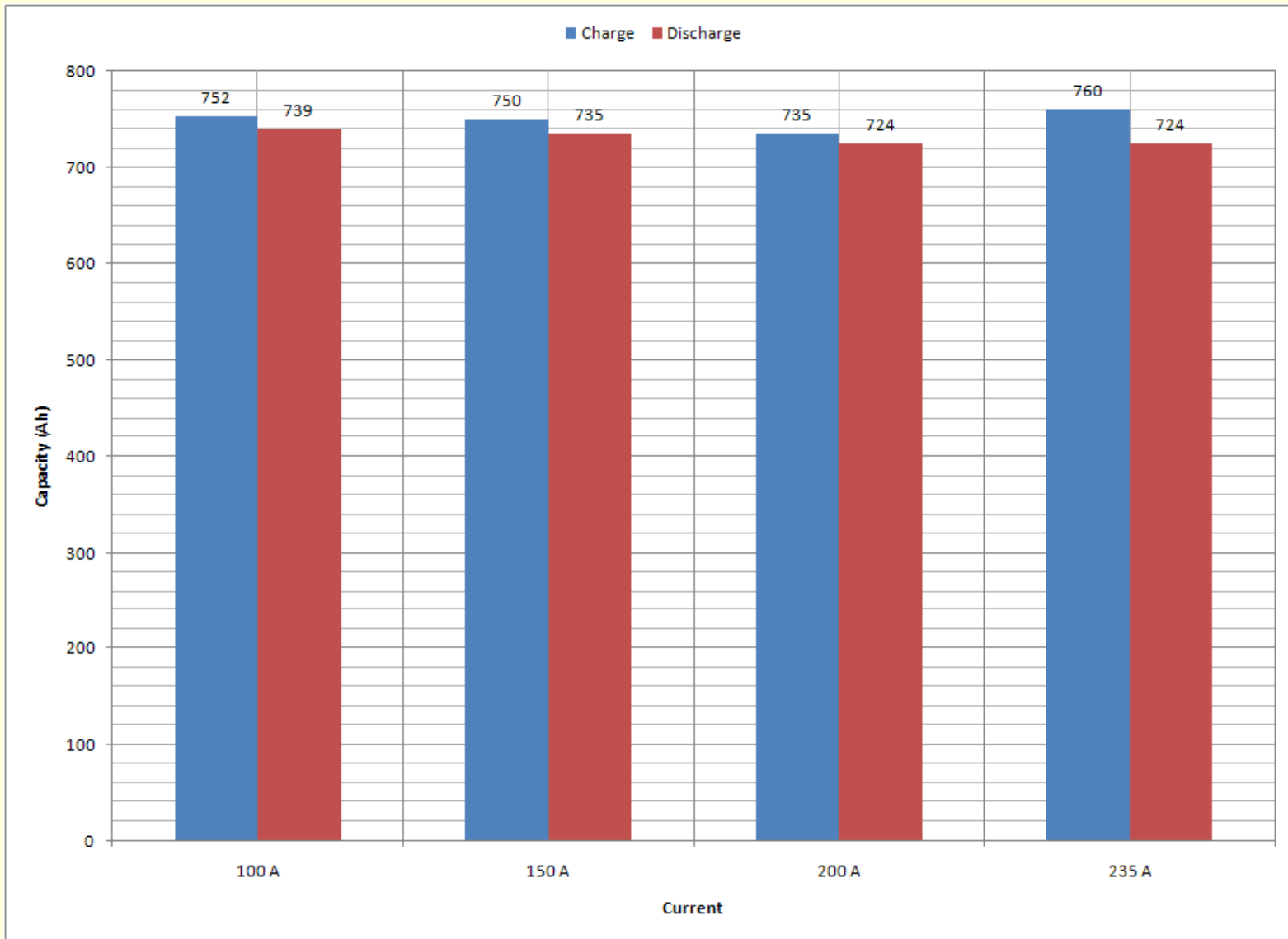


Test Results

Current (A)	Test	Measured Energy (Ah)	Efficiency (%)	Max/Min of Peak Measured Battery Surface Temperatures (°C)	Peak Positive Post Temperature (°C)	Peak Negative Post Temperature (°C)	Ambient Temperature (°C)
100	Charge	752	98	26/30	33	32	22
	Discharge	739		28/39	39	34	24
150	Charge	750	98	28/39	44	43	24
	Discharge	735		28/39	47	40	24
200	Charge	735	98.5	29/45	52	54	22
	Discharge	724		29/45	61	45*	23
235	Charge	760	95	31/53	66	66	22
	Discharge	724		29/59	75	60	24



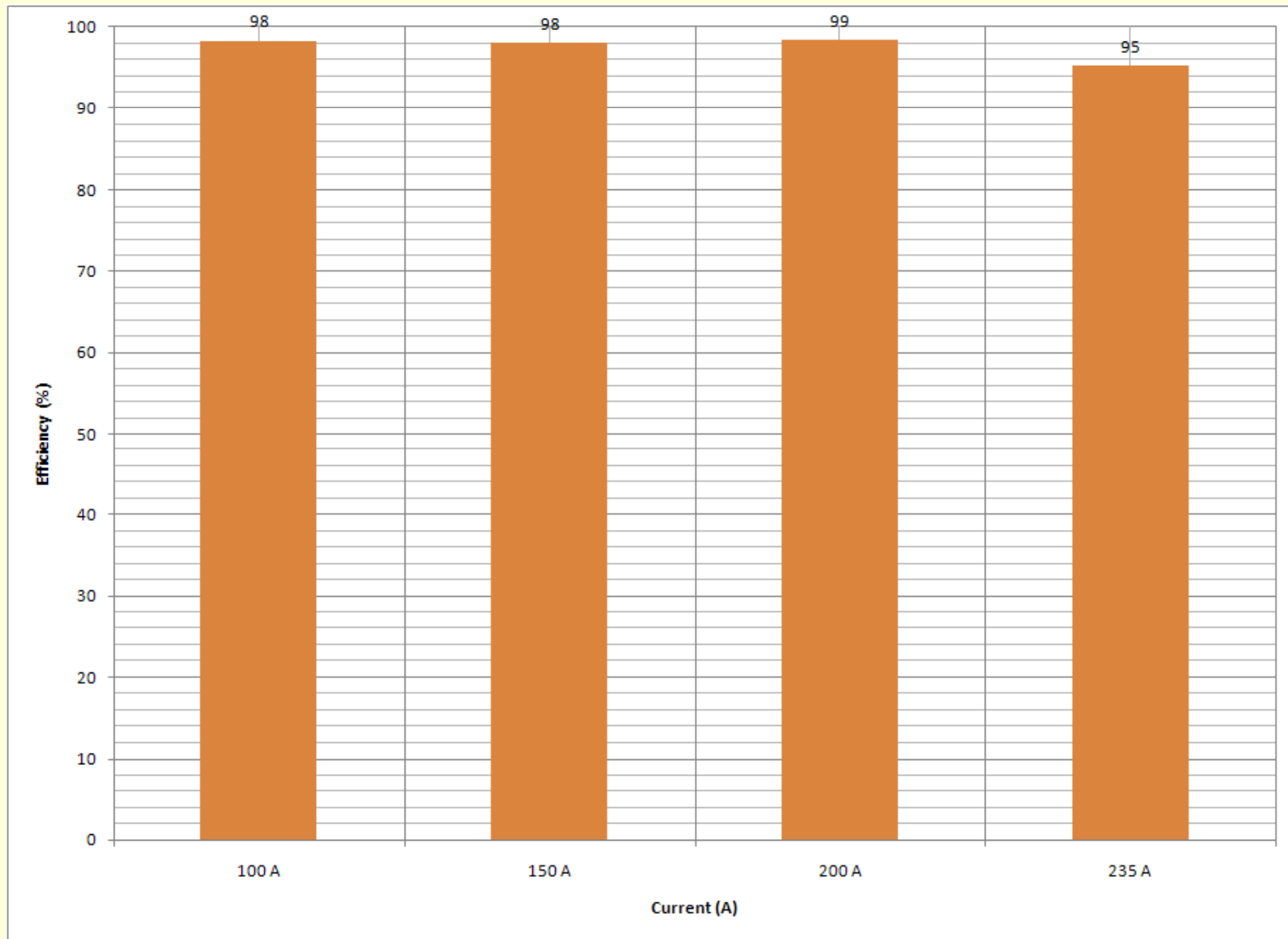
Charge/Discharge Energy (Ah)



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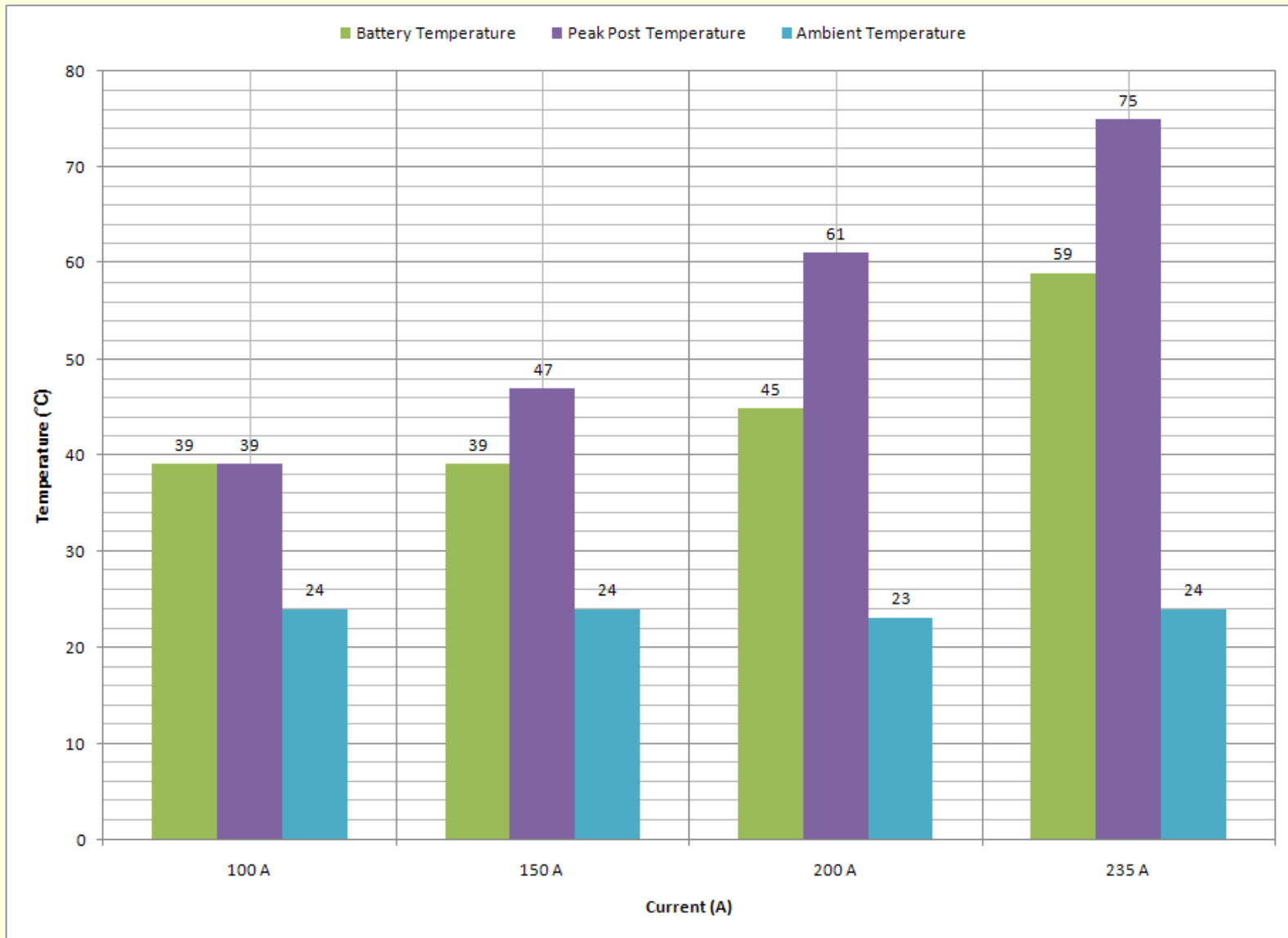
Efficiency (Discharge Capacity/Charge Capacity)



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Temperature Data Summary





BATTERY POST (POSITIVE TERMINAL) AFTER THE 235 A TEST



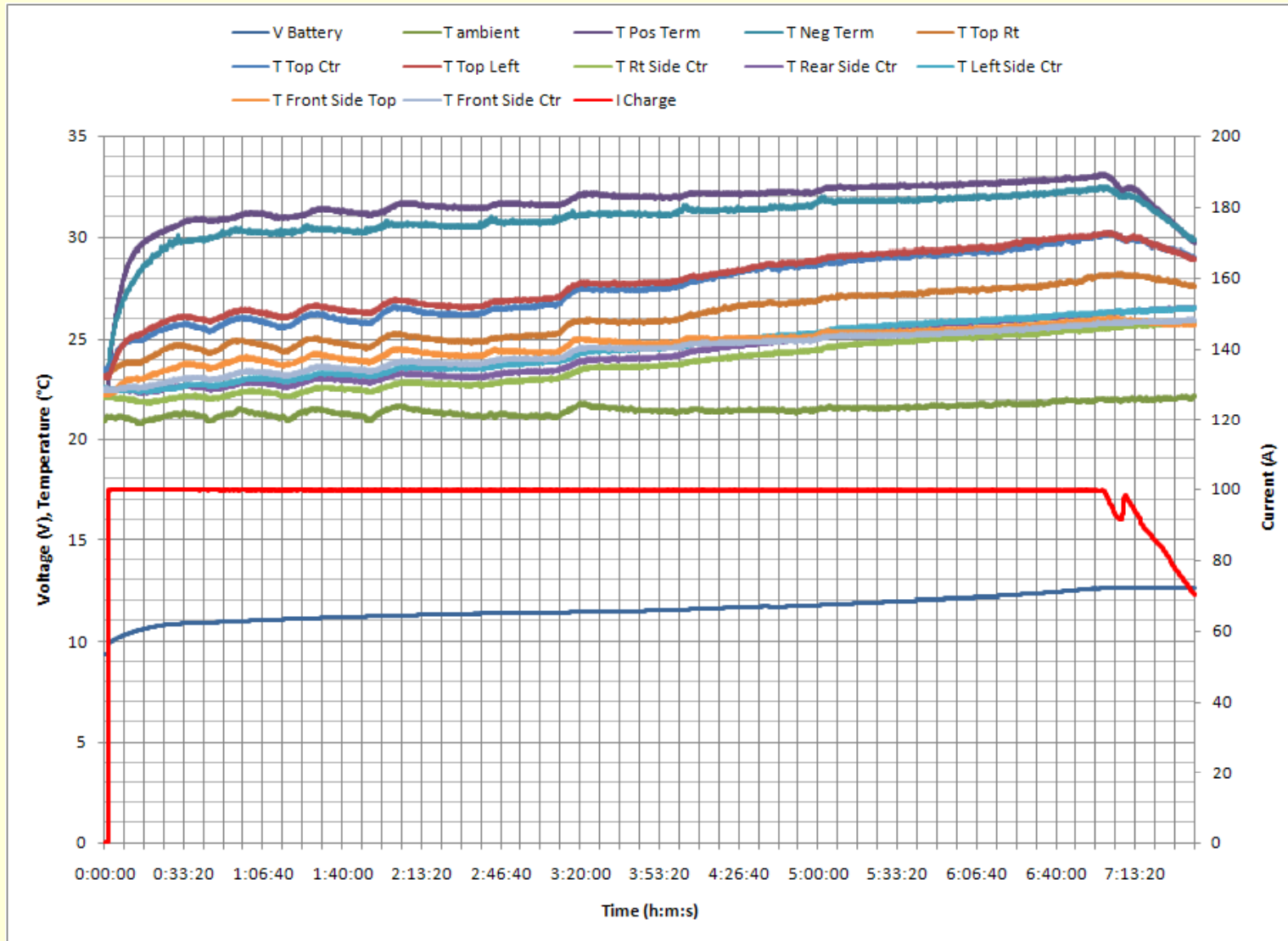
TEST DATA



100 A TEST DATA

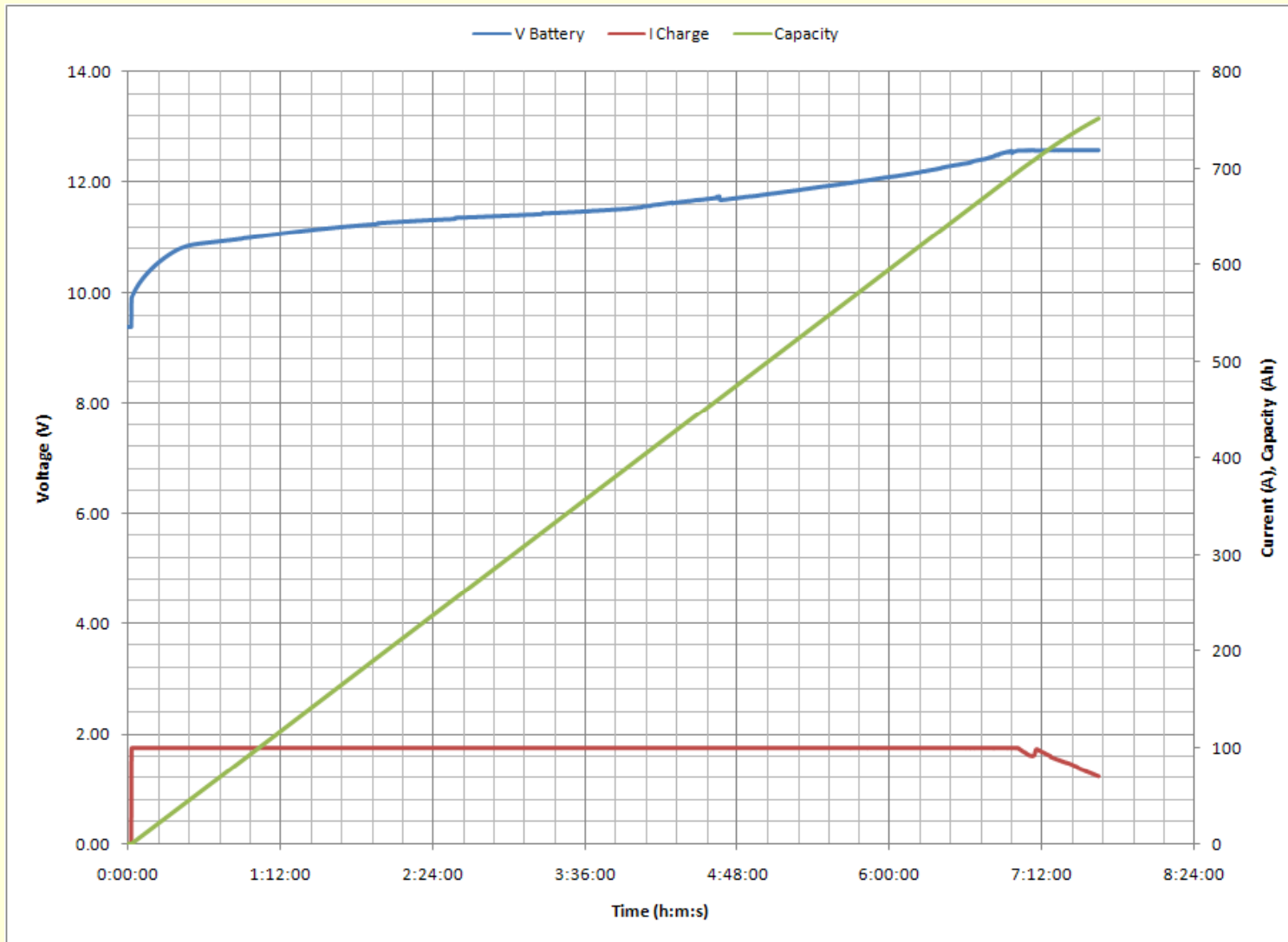


100 A Charge – Voltage, Current & Temperature



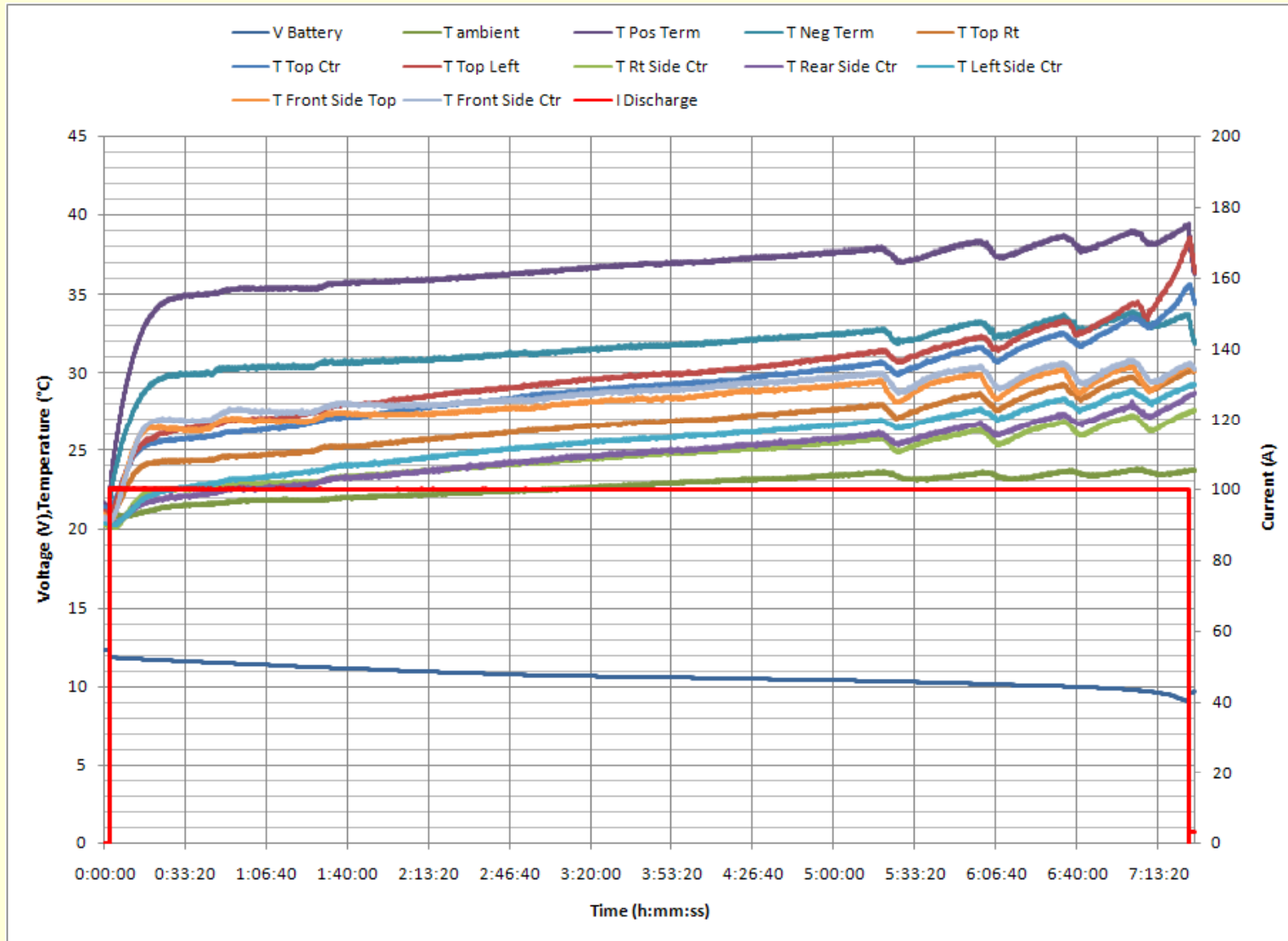


100 A Charge – Voltage, Current & Capacity



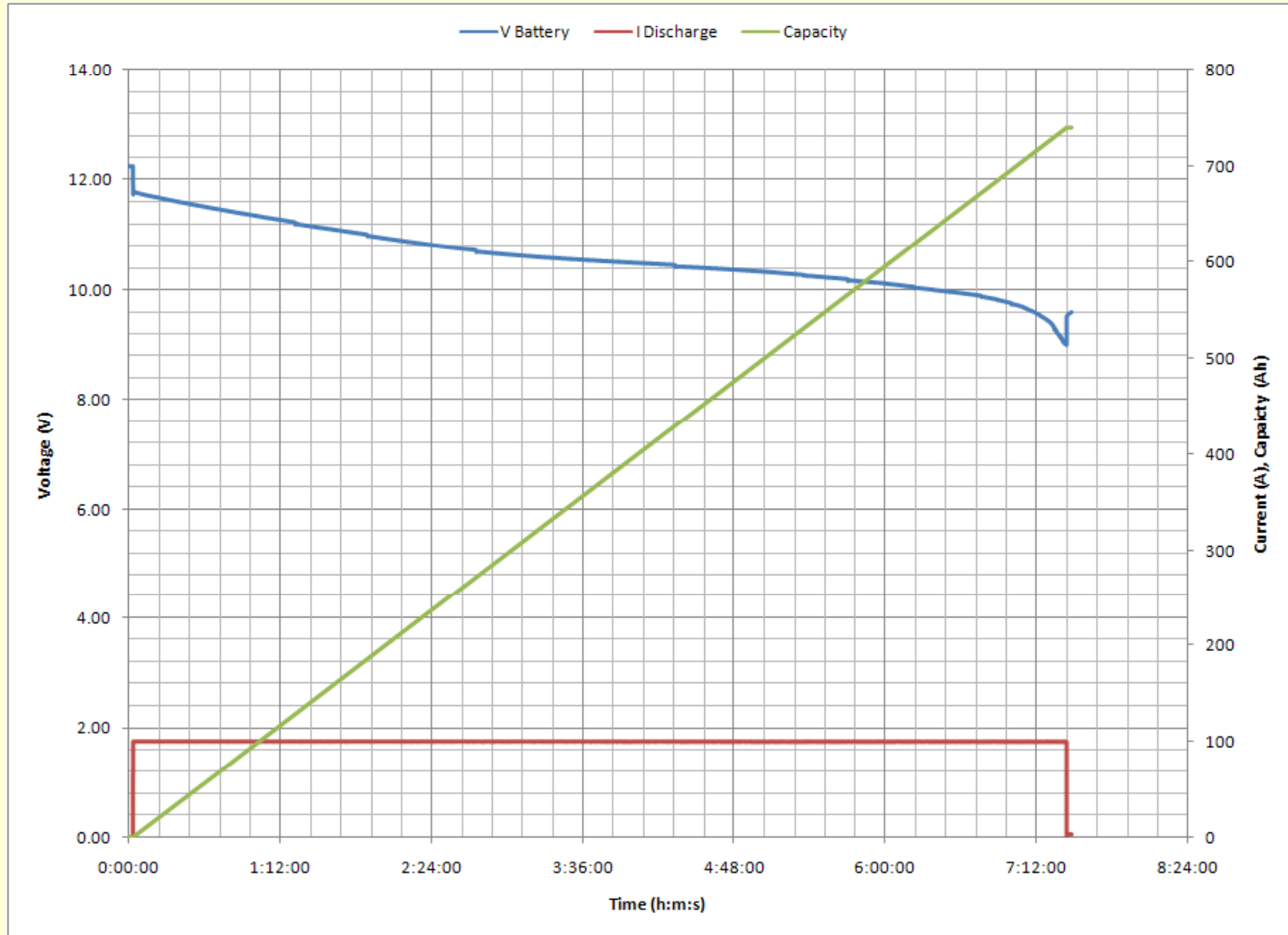


100 A Discharge – Voltage, Current & Temperature





100 A Discharge – Voltage, Current & Capacity



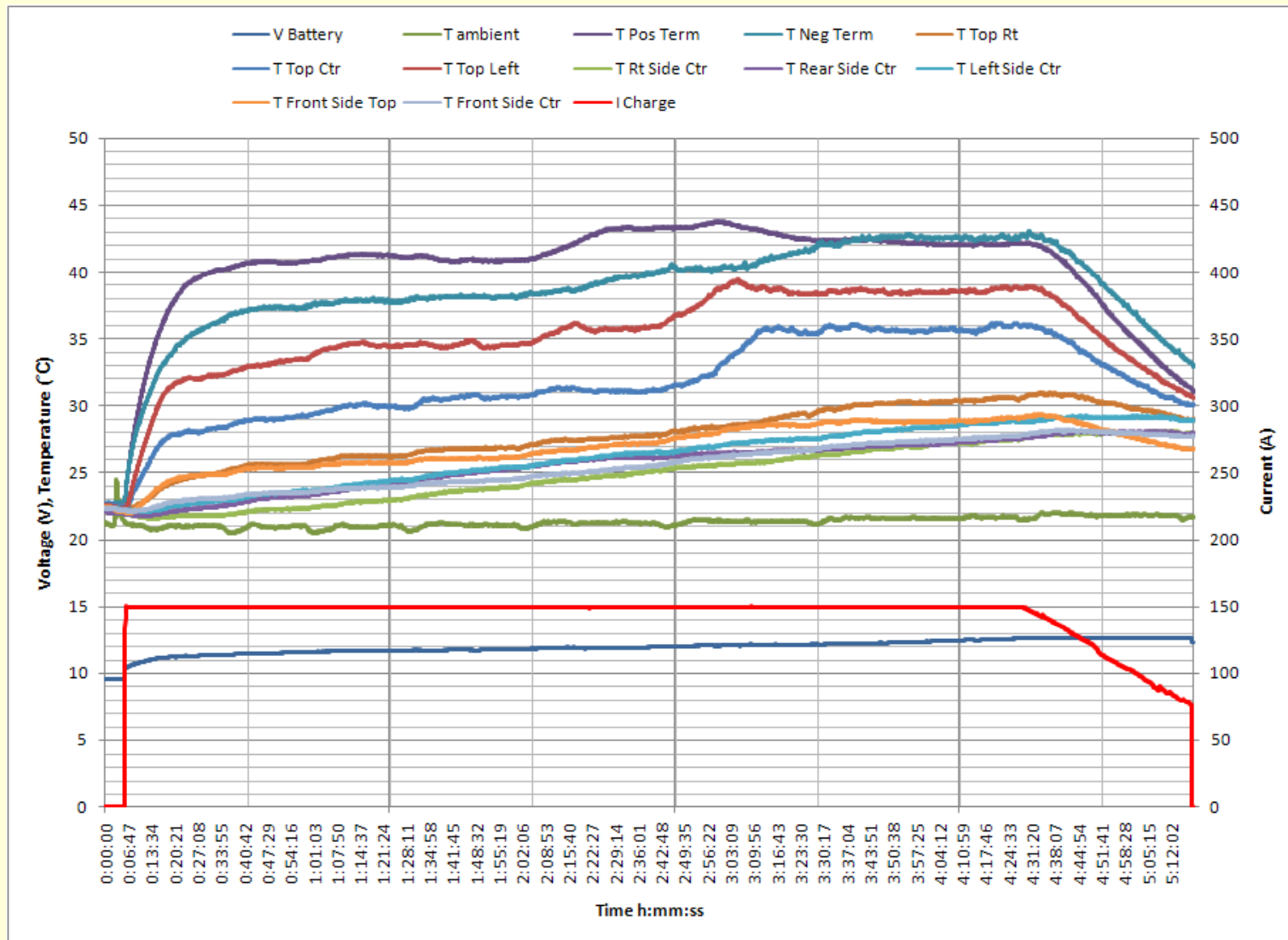
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150 A TEST DATA

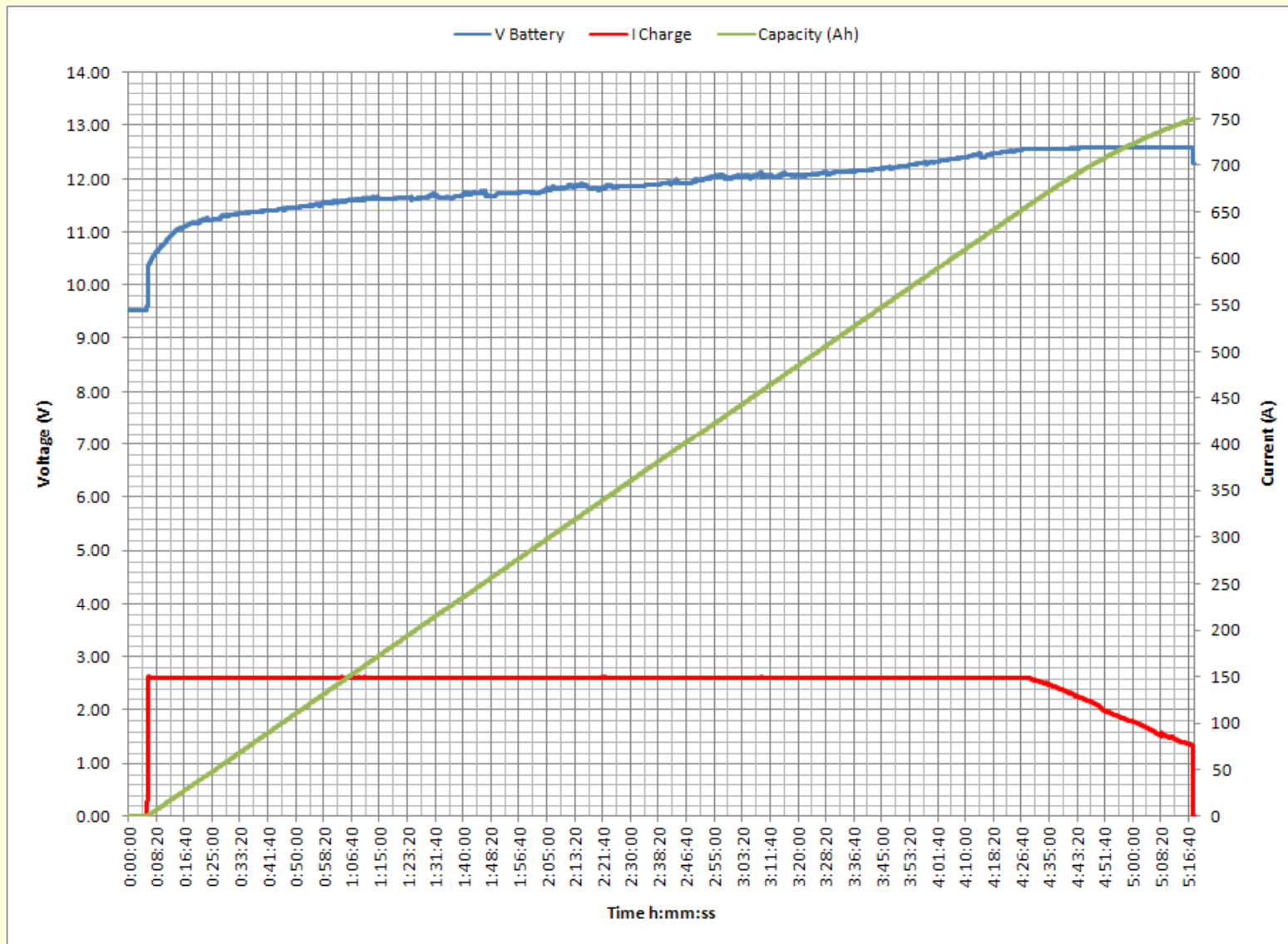


150 A Charge – Voltage, Current & Temperature



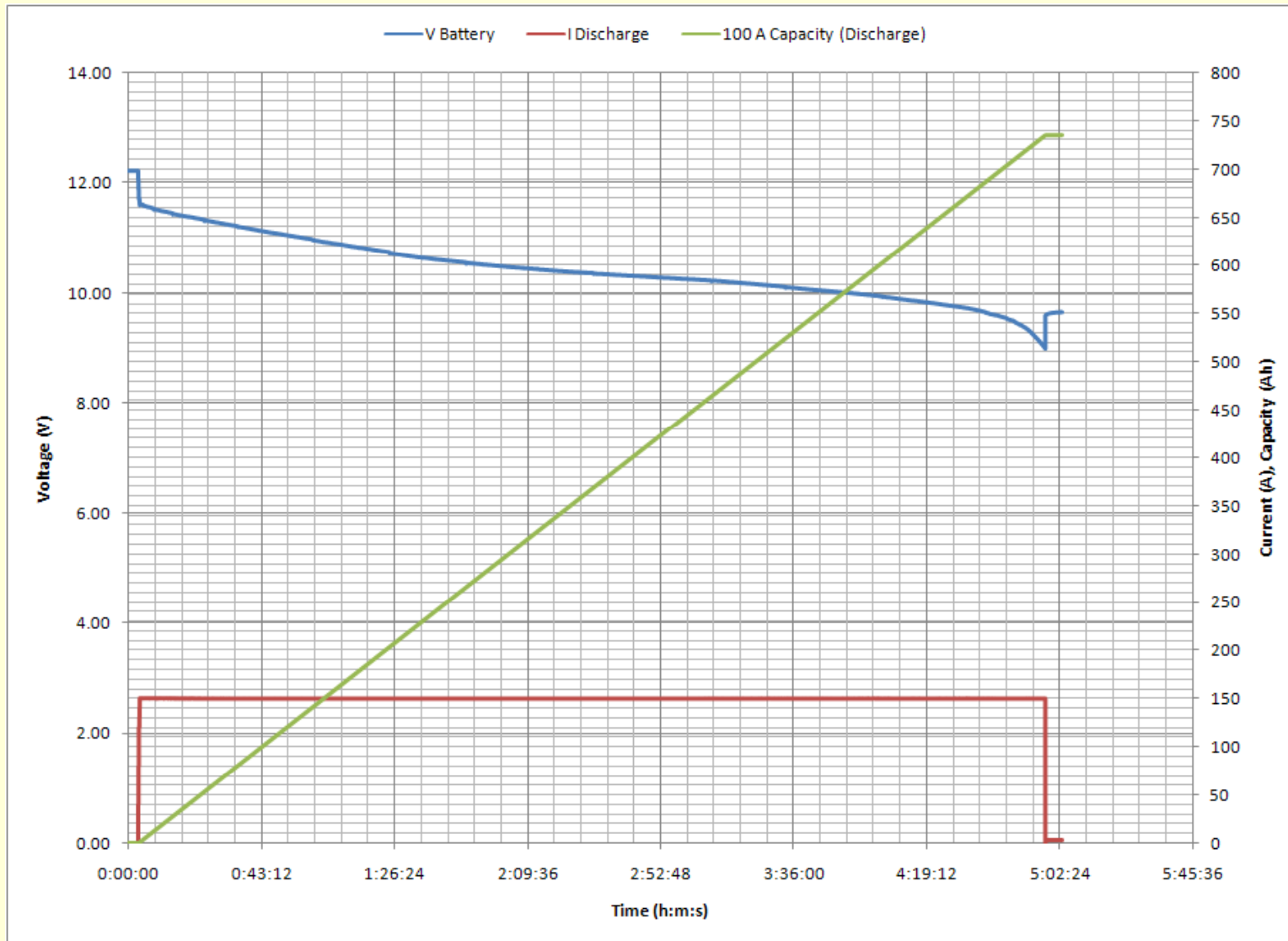


150 A Charge – Voltage, Current & Capacity





150 A Discharge – Voltage, Current & Capacity

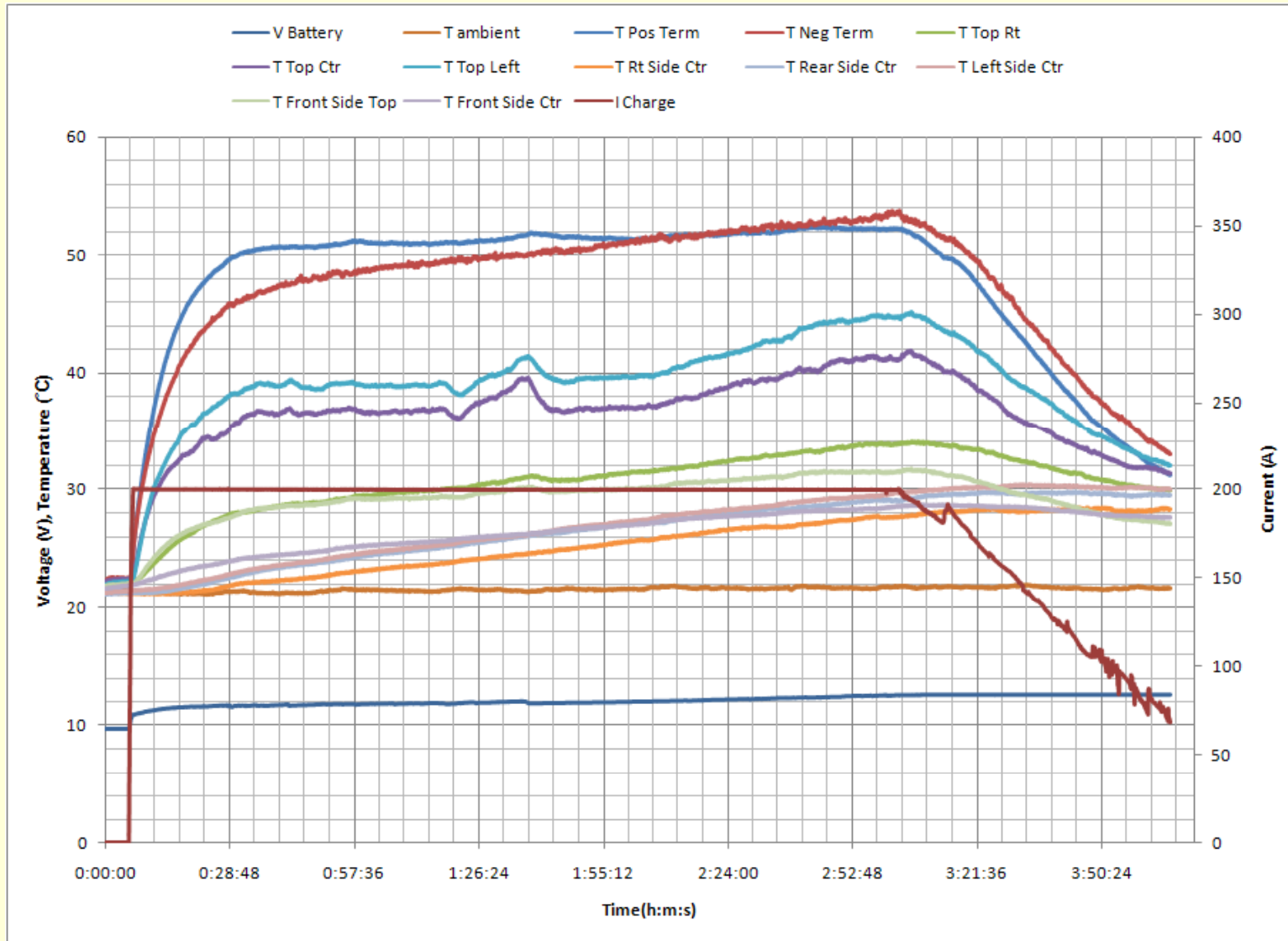




200 A TEST DATA

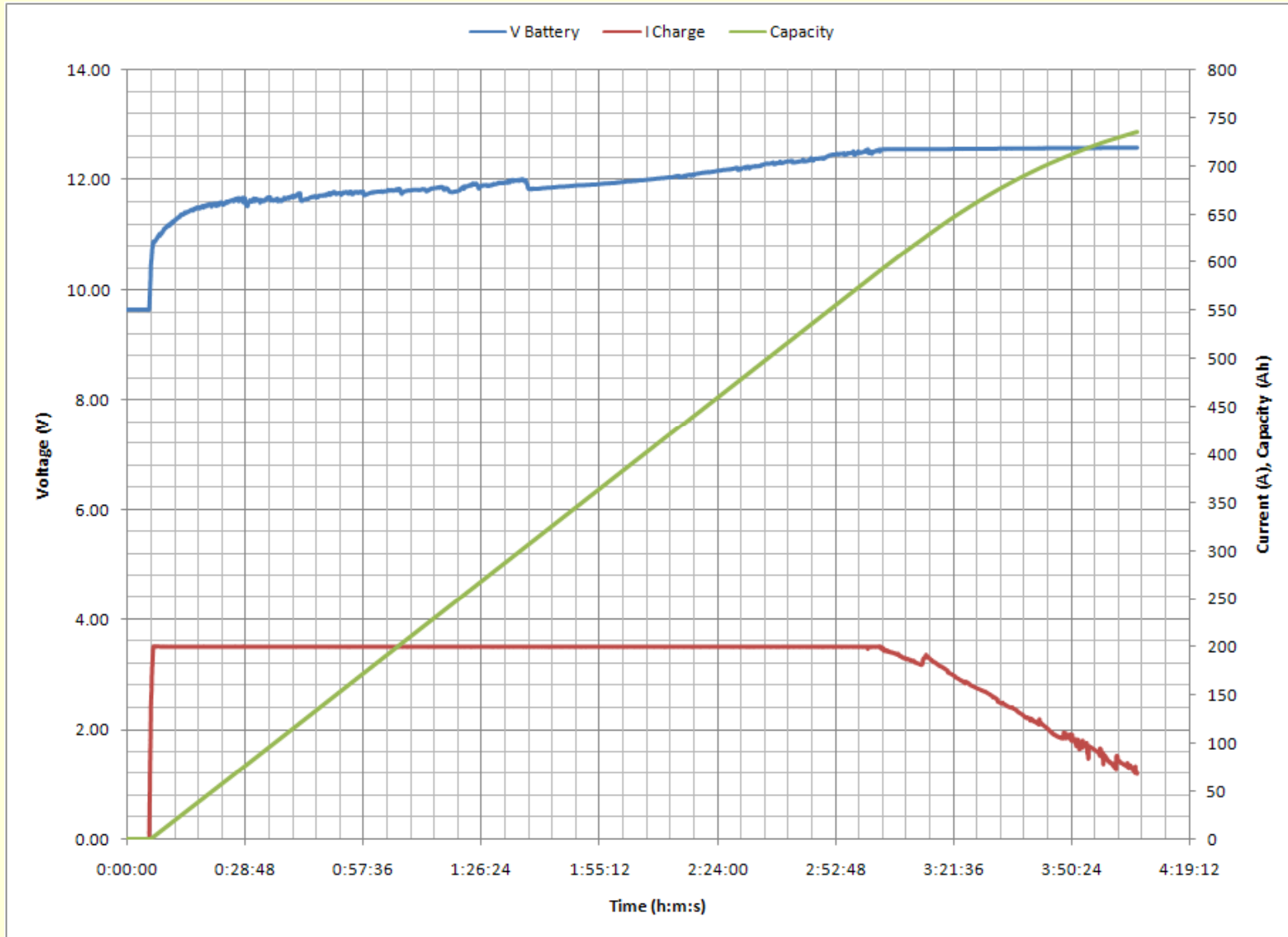


200 A Charge – Voltage, Current & Temperature



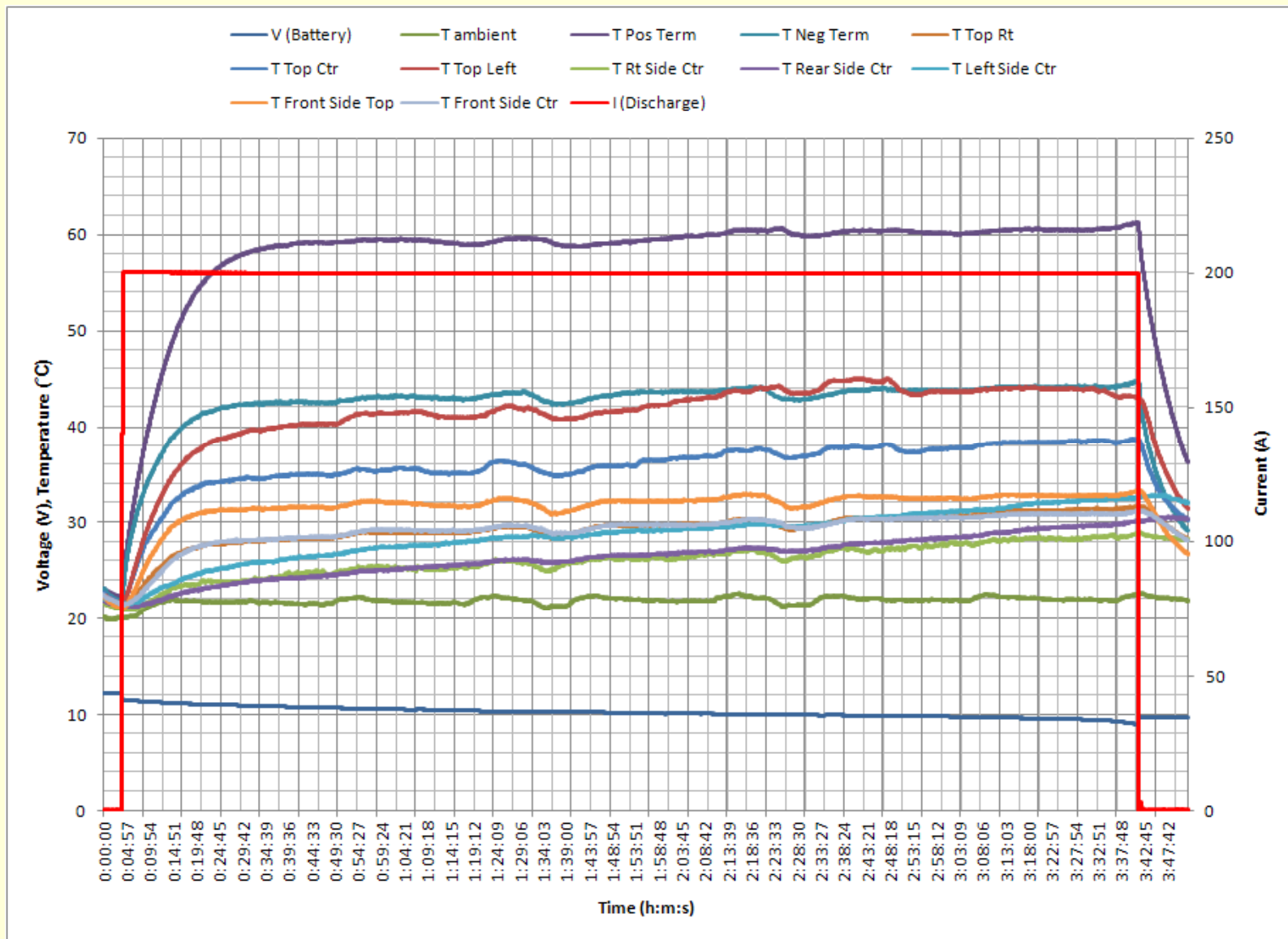


200 A Charge – Voltage, Current & Capacity



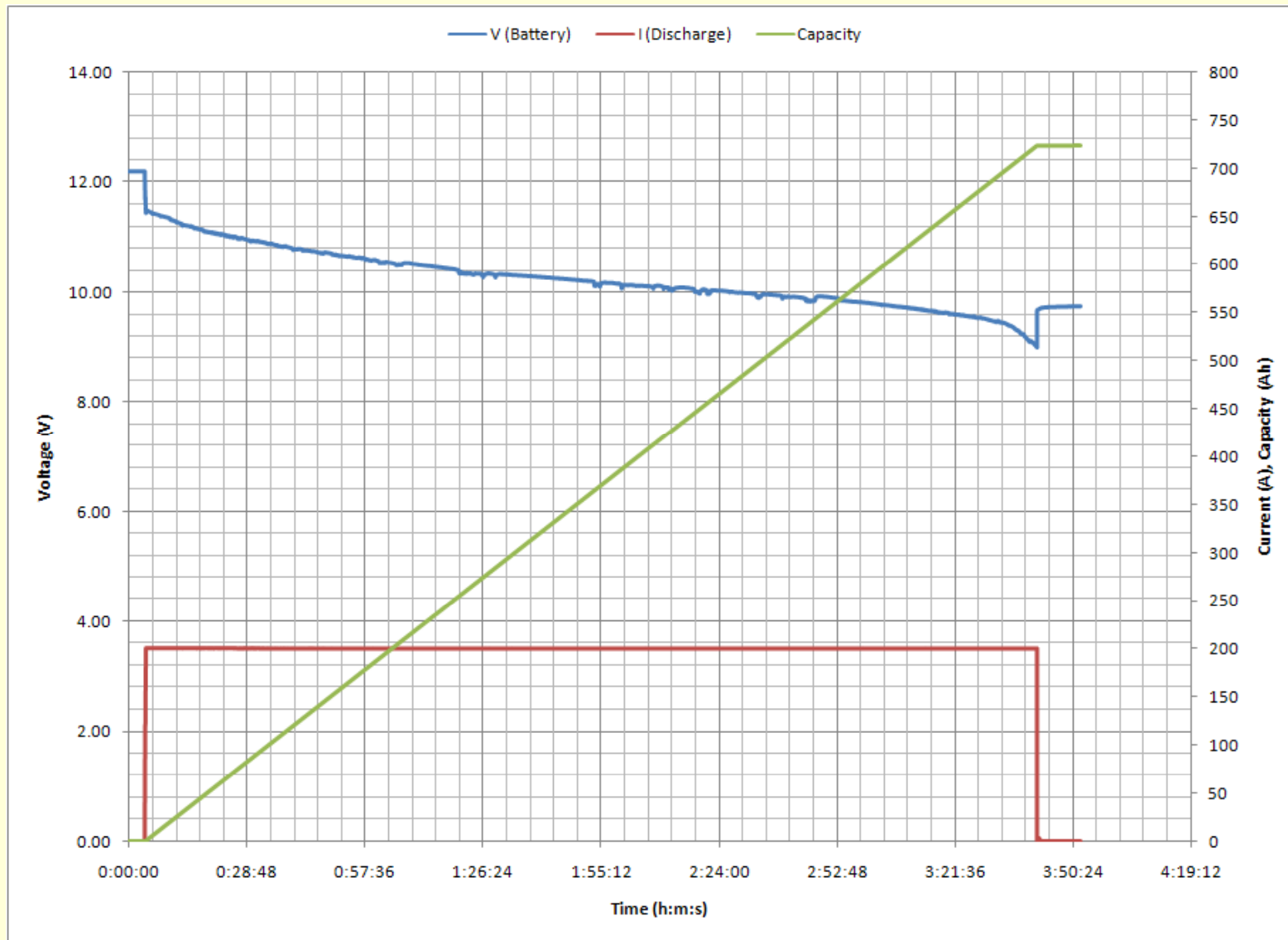


200 A Discharge – Voltage, Current & Temperature





200 A Discharge – Voltage, Current & Capacity



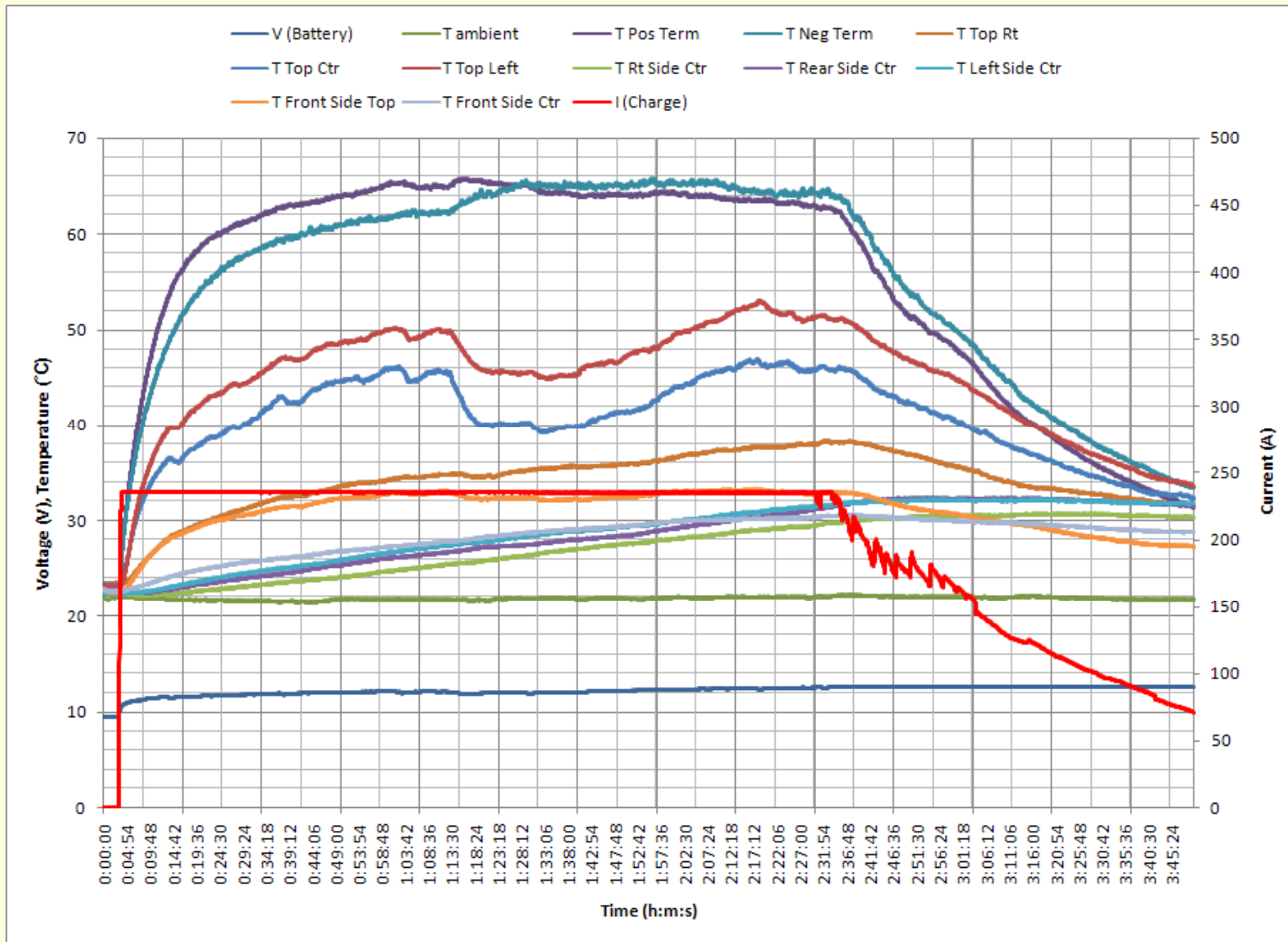
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235 A TEST DATA

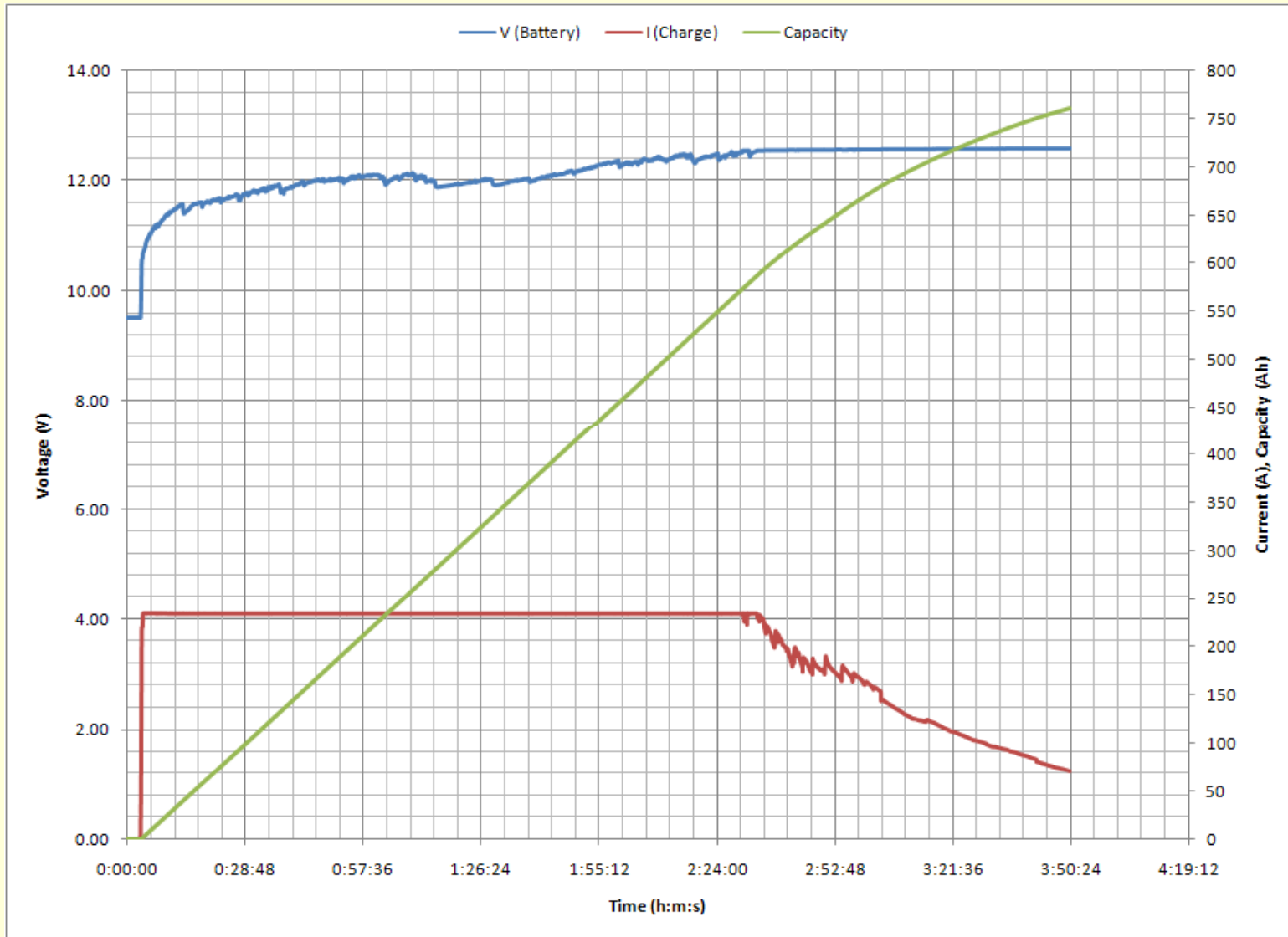


235 A Charge – Voltage, Current & Temperature



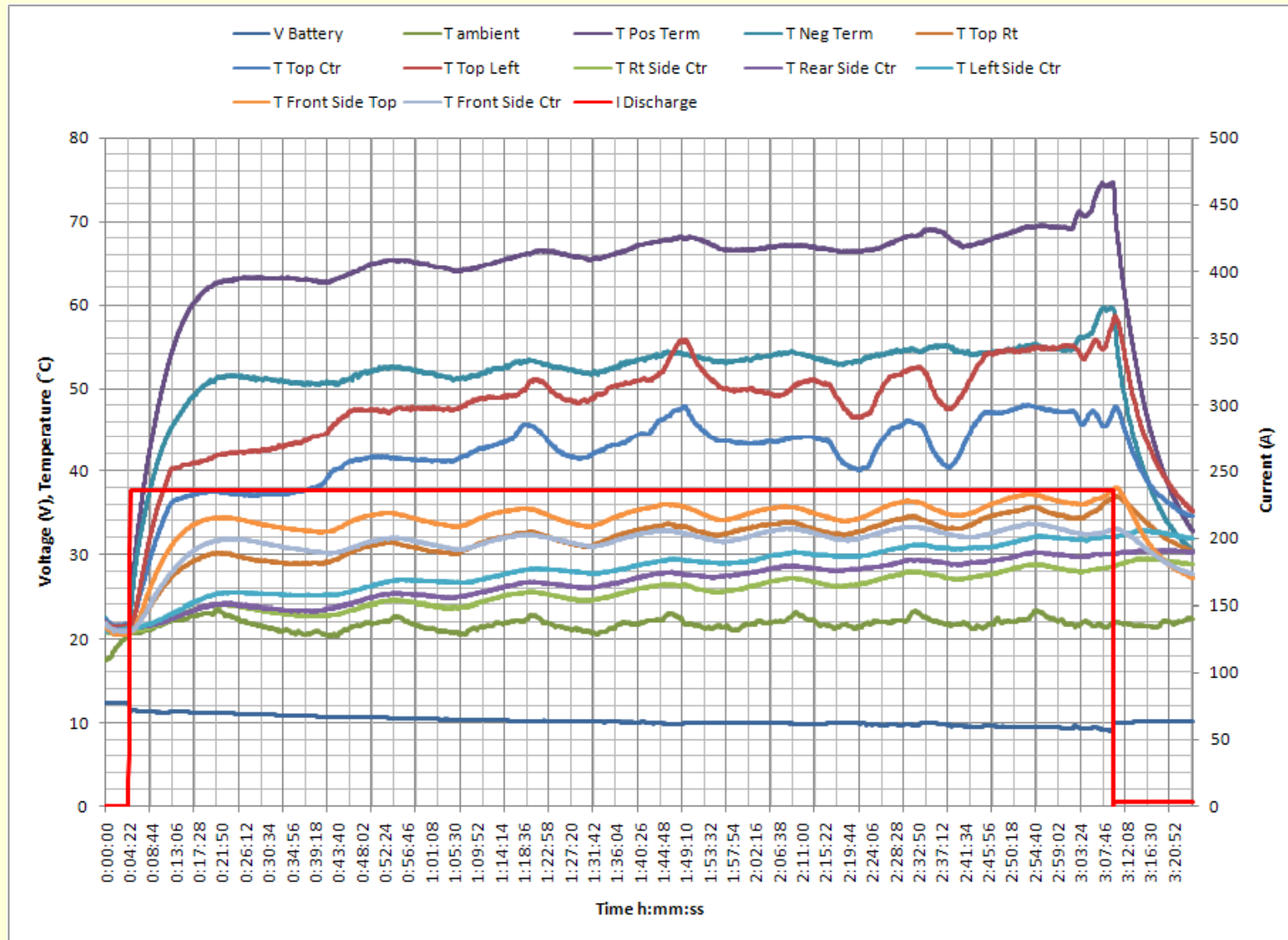


235 A Charge – Voltage, Current & Capacity





235 A Discharge – Voltage, Current & Temperature



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235 A Discharge – Voltage, Current & Capacity

