QUALLION




Quallion Matrix Battery Technology for Lithium-ion Lead Acid Replacement & Wide Operating Temperature Range Cells

May 2011

Powering Life.

Introduction

- Employing a core strategy of leveraging R&D, niche focus, complementary and synergistic market entries
- Largest manufacturer of Lithium cells in the U.S.
- Best-of-breed system level approach for advanced battery technologies involving a core expertise from material selection to cell design and final battery pack configuration
- Products:
  - Materials
  - Cells
    - Primary
    - Secondary
    - Polymer
  - Batteries
    - Matrix Battery (MBD)
  - Intellectual Property Portfolio
    - Zero-Volt
    - SaFE-LYTE
- End Markets
  - Aerospace
  - Defense
  - Medical
  - Utility
  - Vehicle

Headquarters:
Sylmar, CA

Founded
1998

Employees
161

Sites
Sylmar, California
Detroit, Michigan
New York, New York

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Targeting and Dominating Key Niche Markets

Quallion focuses on organic growth within niche markets rather than highly commoditized markets

Medical

Defense

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Aerospace

Green Technology

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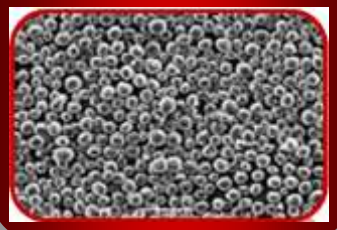
Overview of Battery Industry
Battery Market Stratification

Battery Market Stratification

Materials

Chemistries can be varied for high-energy, power, rate and capacity, safety.



Cell Design

Cell configurations include prismatic, cylindrical, flat stack, wound, large, small, polymer (pouch), hard case.

Electronics

Cell and battery management, power, safety, interface, communication (e.g., SM/CAN), balancing, state of health monitoring, modeling, grade of board parts.

Battery Pack

Pack design: safety, interconnects, spacing of cells, thermal gradients, heat ejection, environmental requirements, interface to application.

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Lithium-ion Challenges for Lead Acid Replacement

- Cost
  - Mitigated lifetime use, as long as lead acid is utilized for deep discharges
- Electronics
  - Battery must contain power electronics capable of high discharges while managing for external shorts
  - Safety for overcharge, overdischarge and over/under voltage
  - Charge management/regulation to ensure proper system function

Quallion Matrix™ Technology

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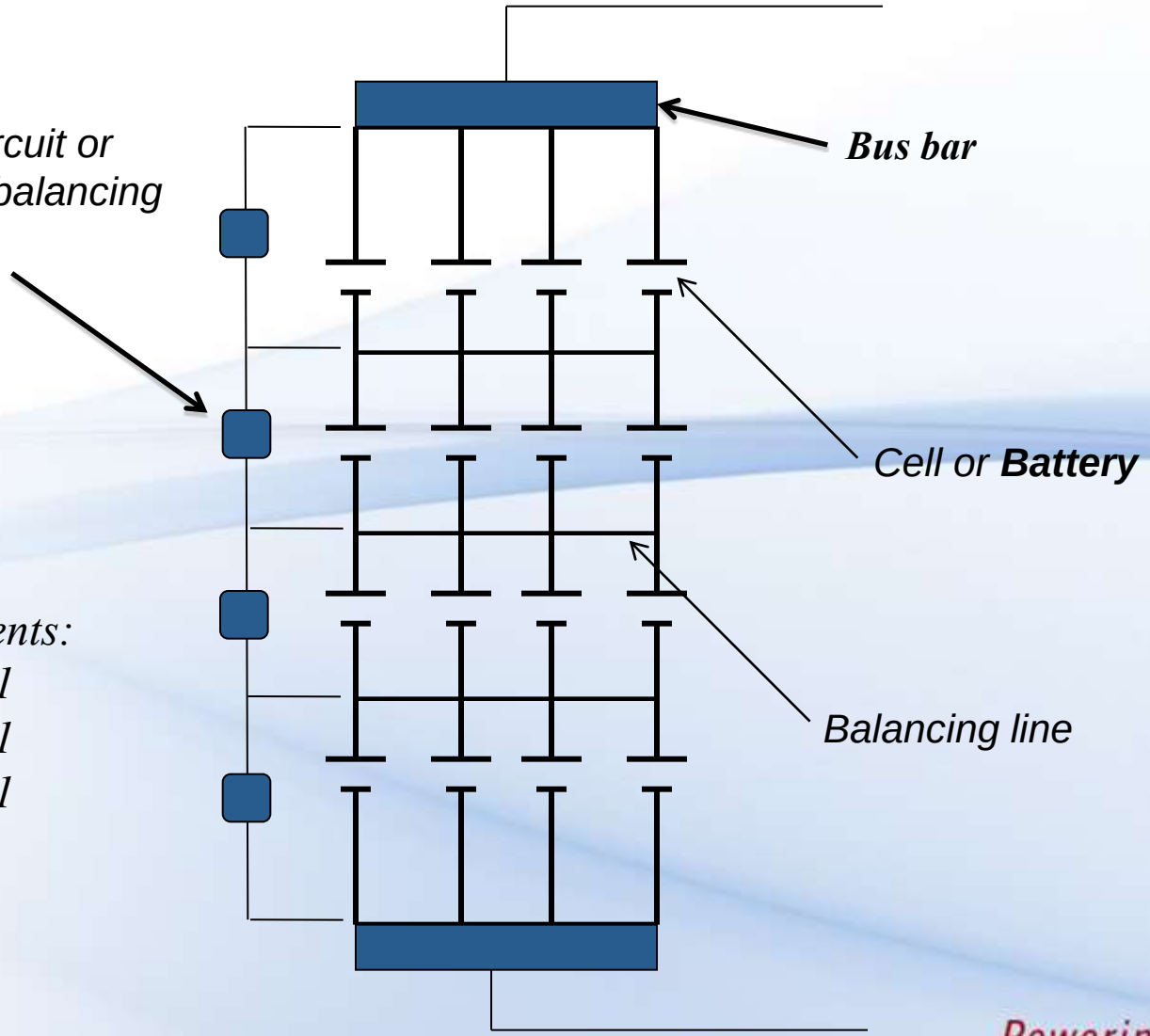
Patented Quallion Matrix™ Battery Structure



Quallion Patents:
US7479346B1
US7573233B1
US7573234B1

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Quallion Matrix™ Technology
Safety Aspects

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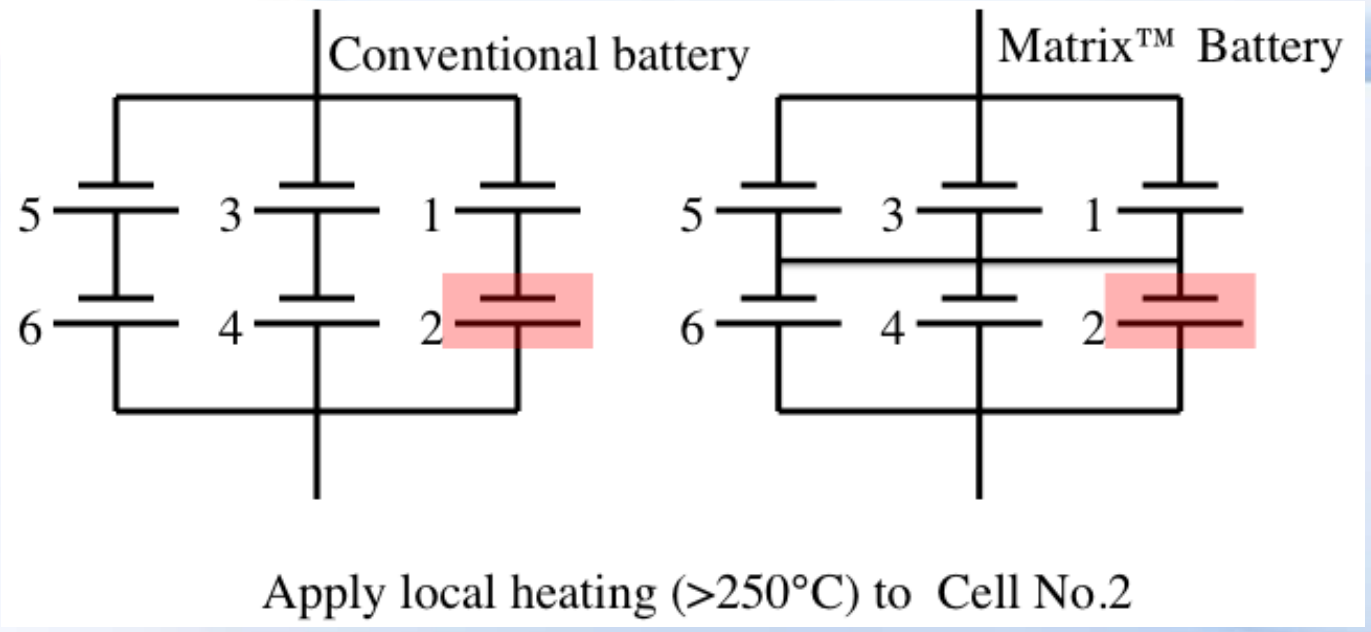
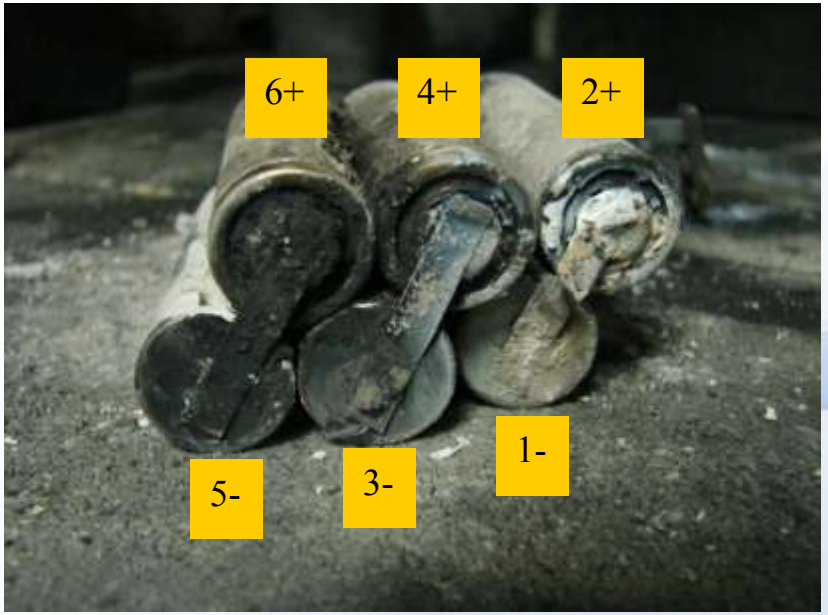
Matrix™ Battery: Advanced Safety Feature

Cell : 18650



Apply local heating (>250°C) to Cell No.2

Conventional Battery: Thermal Run-away Propagated to Entire Battery



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Matrix™ Battery: Thermal Run-away Localized to Only Cell #2

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Matrix™ Battery: Cell #3-6 Remain Functional

Cell number	Resistance (Ohm)	Voltage (V)
1	5600	-
2	-	-
3	0.04	4.14
4	0.026	4.107
5	0.03	4.14
6	0.03	4.08

Partial Penetration Test Conditions

- The module was charged with 53.3V, 3.5A (CCCV method) at room temperature (approximately 25 Deg C).
- The module was charged to 100% RSOC (reported by SMBUS communication).
- The module was penetrated with a 10 mm mild steel (conductive) pointed rod.
- The rate of penetration was approximately 8 cm/sec.
- The module was penetrated twice, once at the center of the outer cell and a second penetration between two outer cells.
- After penetrating the battery module, the test was monitored for one hour.

Partial Penetration Test Results

Penetration at the center of the cell.

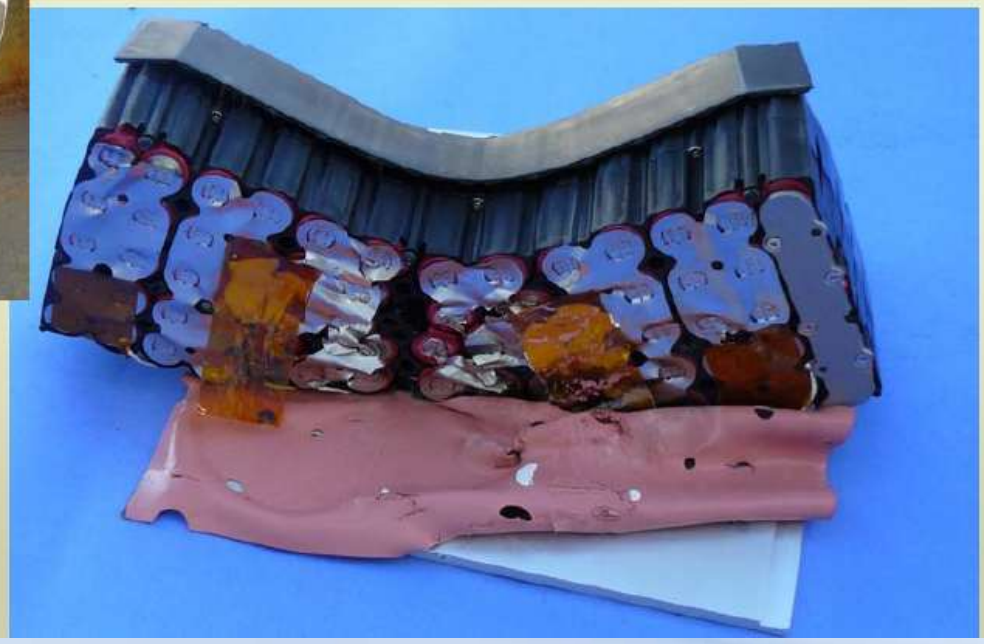
Penetration was between two adjacent cells.

0905865.000 A0T0 0110 R010

Crush Test Conditions

- The module was charged with 53.3V, 3.5A (CCCV method) at room temperature (approximately 25 Deg C).
- The module was charged to 100% RSOC (reported by SMBUS communication).
- The module was crushed between a flat plate and a textured plate as shown.
- Bottom flat plate was electrically isolated from the crush fixture.
- The crush occurred in two stages. In the first stage, crush is applied for 15% of the module's height, which is held for five minutes.
- In the second stage, crush was limited by a 47% displacement of the module's height and is held for five minutes.
- The module was observed for one hour after the test.

Crush Test Results



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Quallion Matrix™ Technology Survivability

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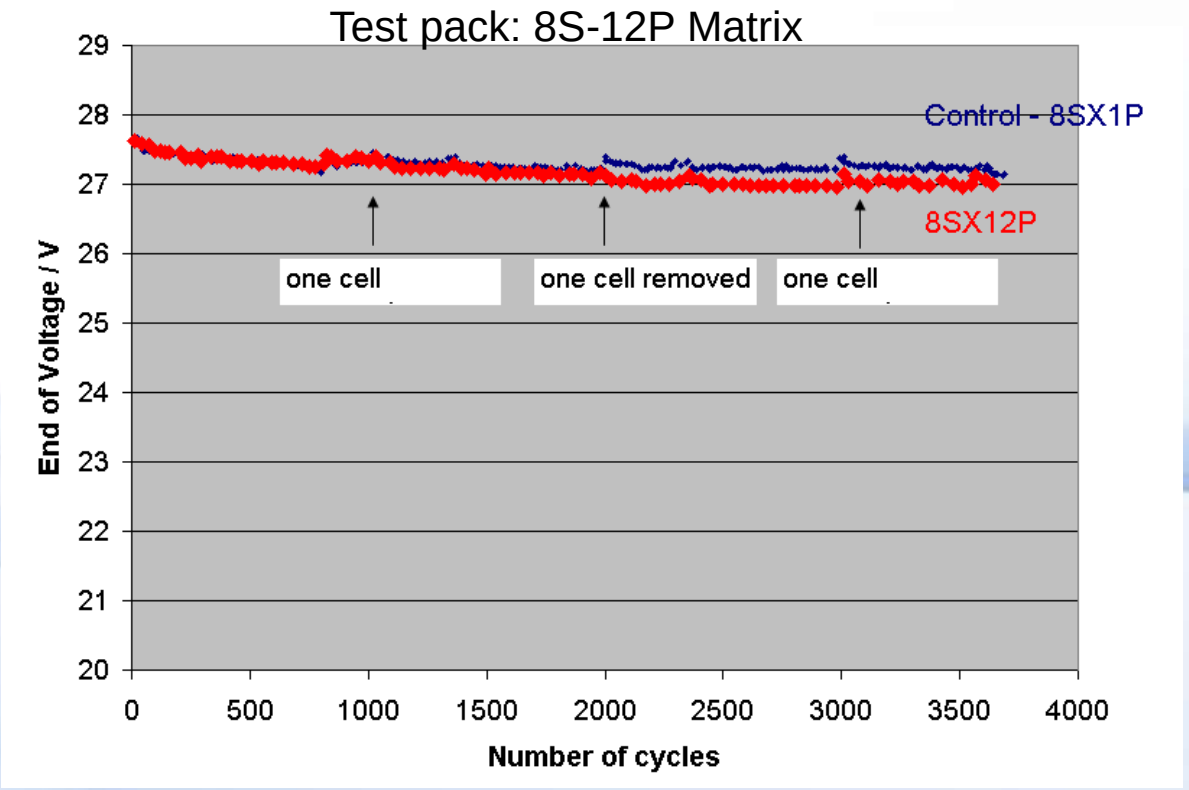
Increased Load Test on Matrix™ Battery

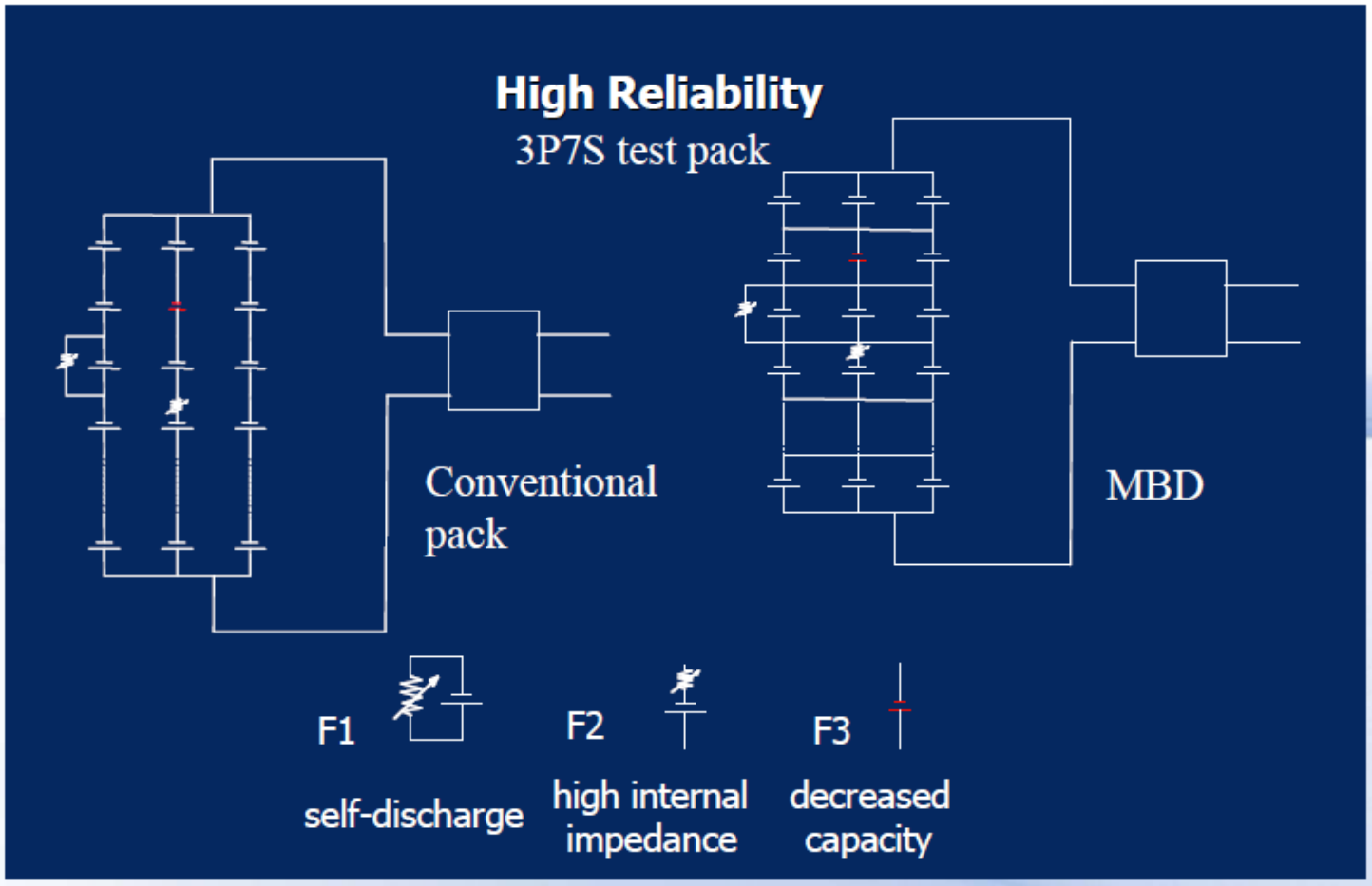
…A cell was removed at every 1000 cycles from pack

LEO cycle continued with no impact on battery voltage after 3750 Cycles with Three Failed Cells



Test Parameters
- 90-minute orbit
- Charge at 6 A to 32 V clamp with a taper to end of the charge period of 60 minutes
- Discharge current 9.6 A for 30 minutes
- DOD: 40%
- Removed one cell at 1000th cycle, second at 2000th cycle and the third at 3000th cycle; to understand the performance of the battery with three failed cells

Survivability Comparison: Matrix™ vs. Conventional



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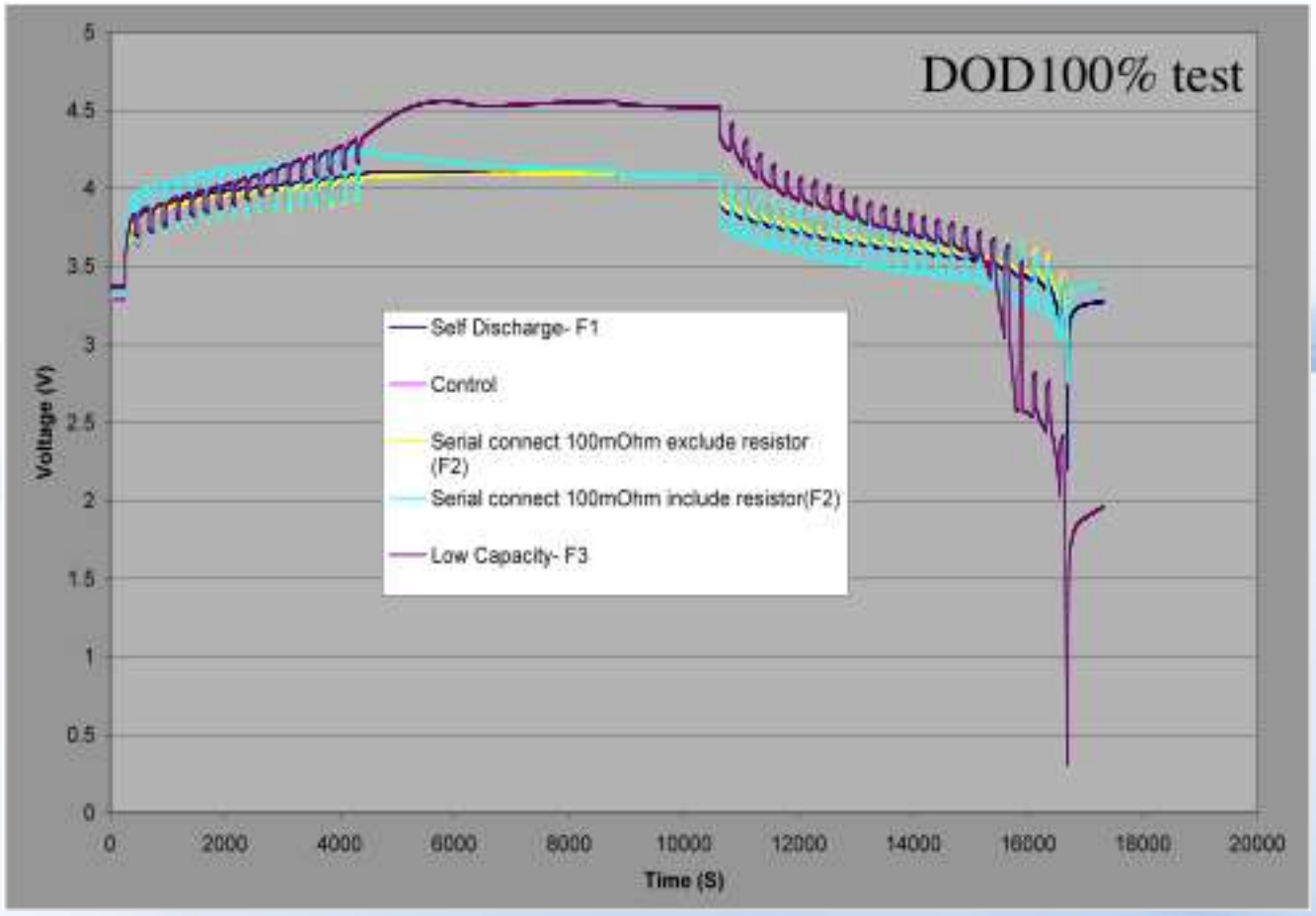
Conventional Pack: Failed in Overcharge at First Cycle



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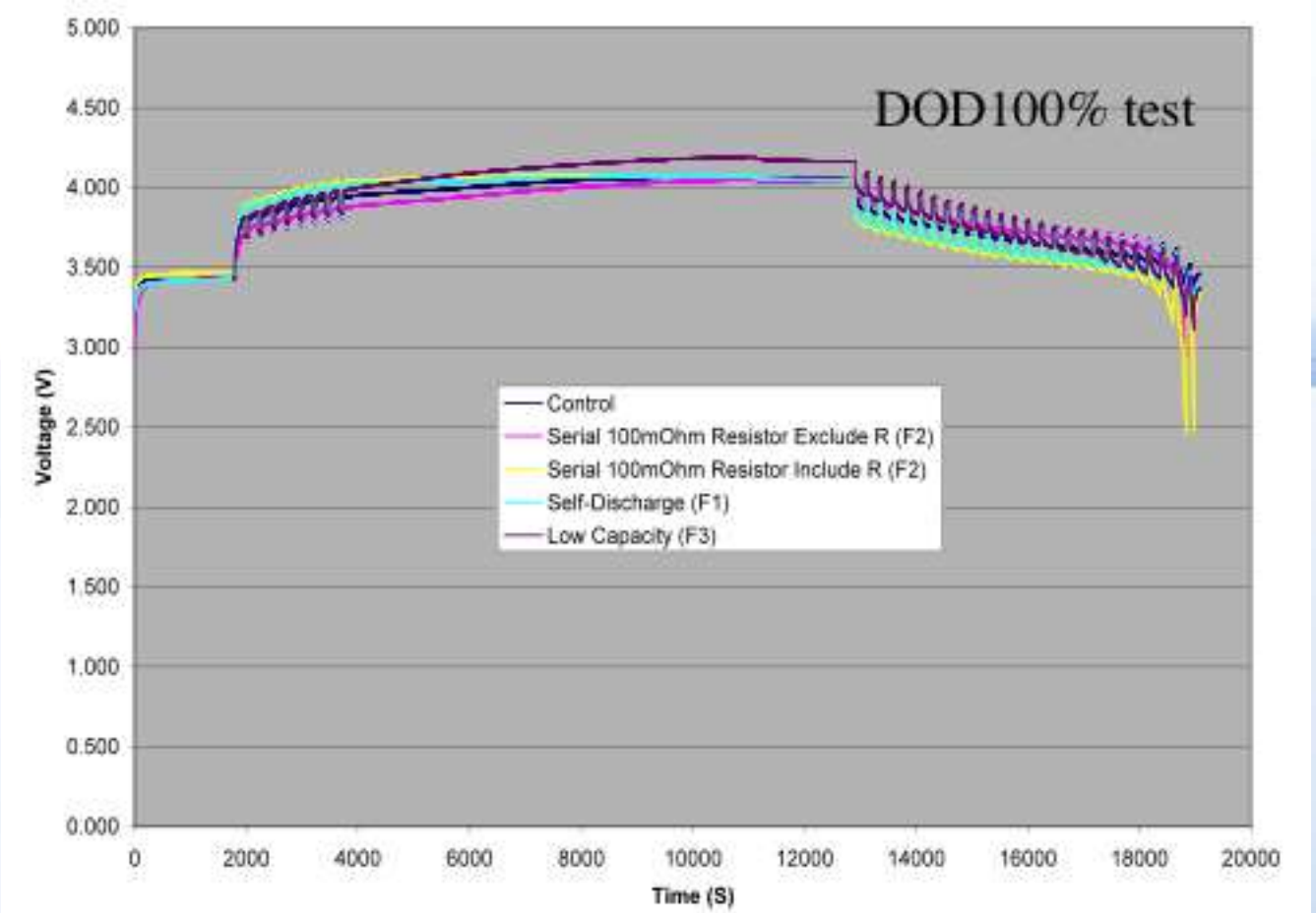
Matrix™ Battery:
No Overcharge & Survived an Additional 19 Cycles



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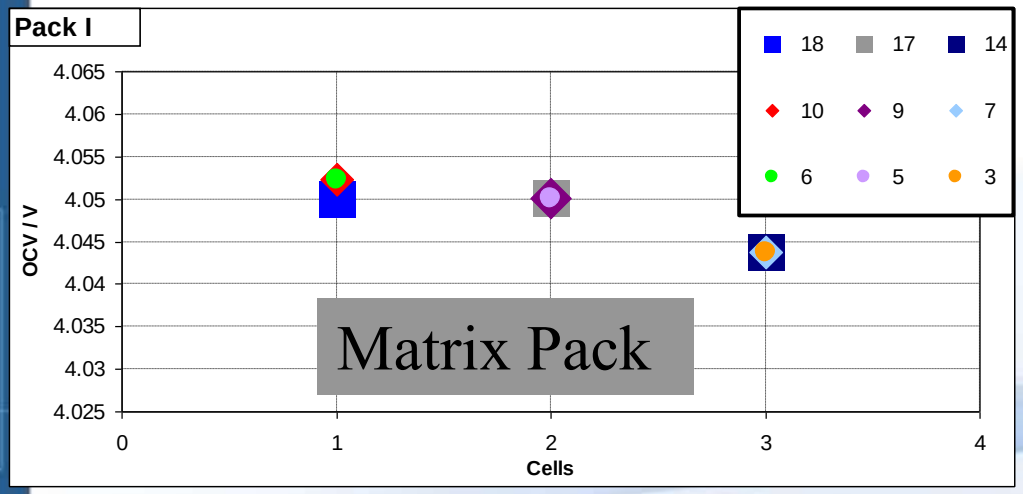
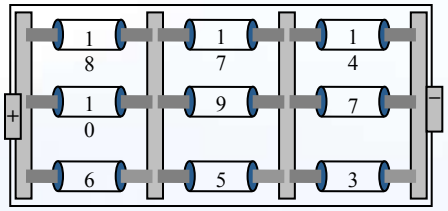
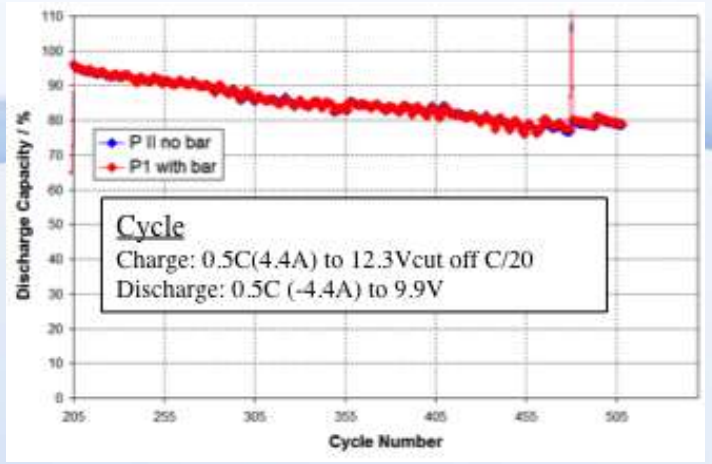
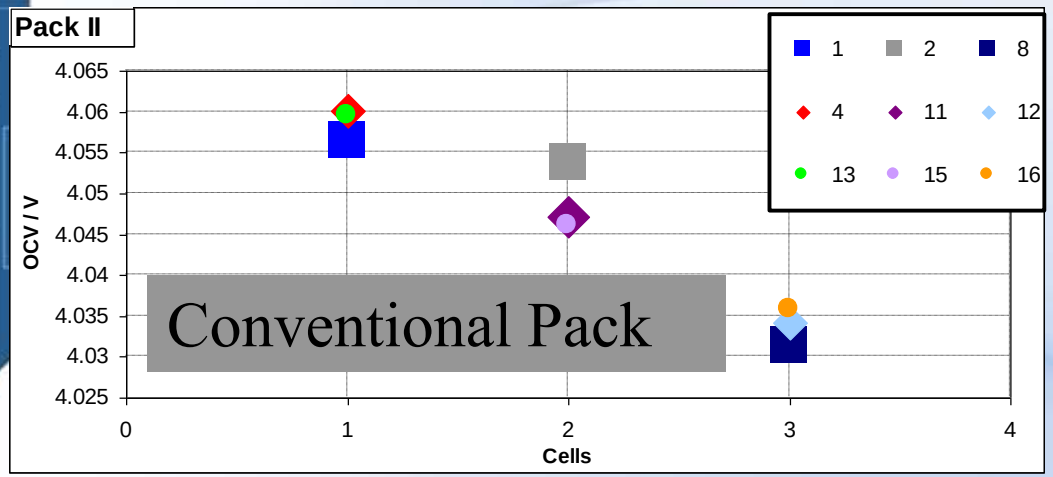
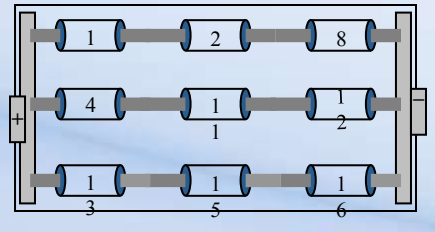
Matrix™ Battery:
Less Balancing Need for Pack after 300 Cycles











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Matrix™ Battery: Flexible Power/Energy Ratio

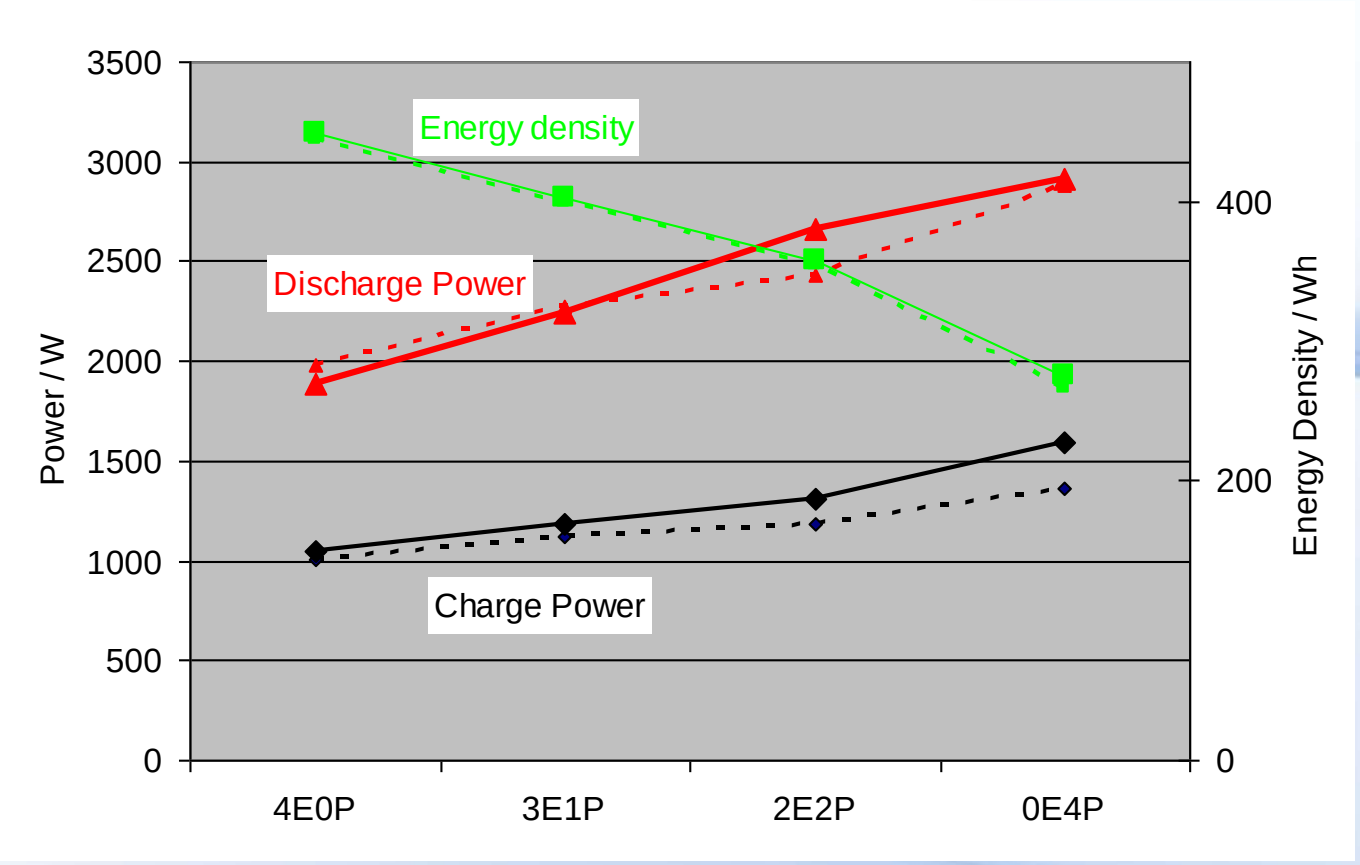
12S-4P with various HE/HP cell Mix

	HP Cells	HE Cells
Energy density	120Wh/kg	200Wh/kg
Power density	1000W/kg	200W/kg

Battery pack	Total number of cells	High power cells (18650 - 1.5 Ah)	High energy cells (18650 - 2.5Ah)	Weight (g) (including heat shrink tube, excluding tab)
4E0P	48	0	48	2208
3E1P	48	16	32	2176
2E2P	48	24	24	2160
0E4P	48	48	0	2112

12S-4P Hybrid Quallion Matrix™ Battery

… A matching correlation between design and performance



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Quallion HAM™ Technology

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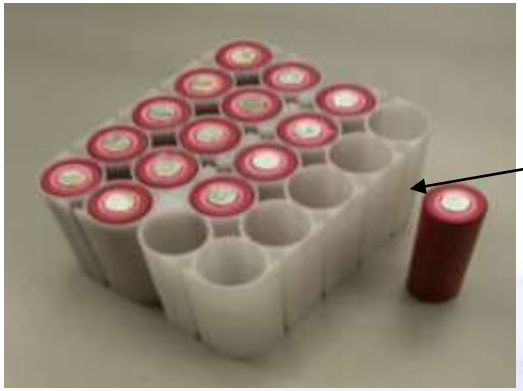
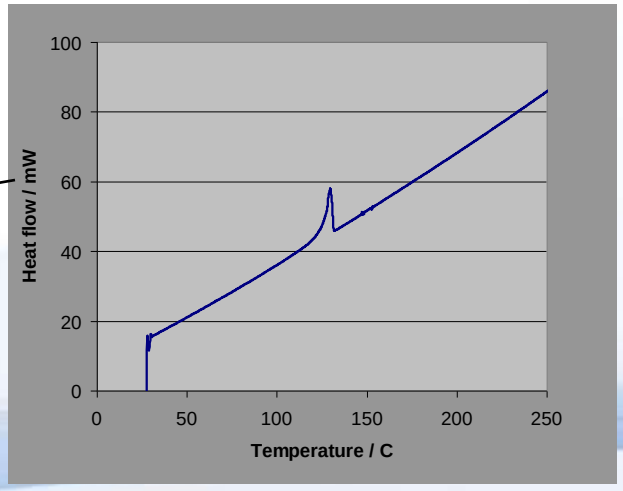
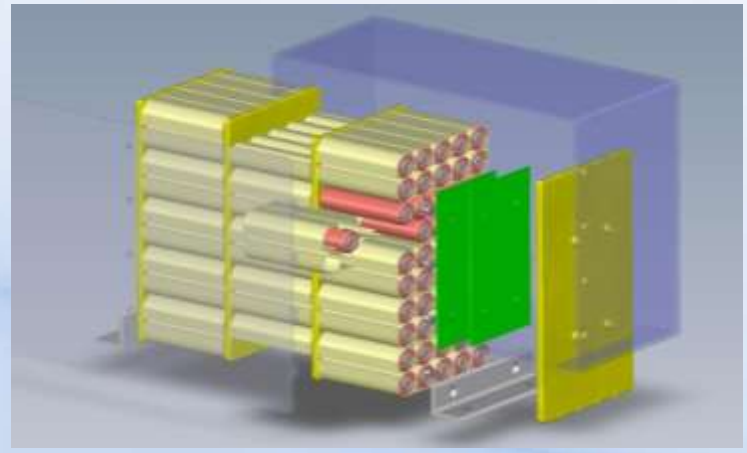
Quallion Heat Absorption Material (HAM™)Technology







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Overcharge Test with and without HAM™

Test Battery

18650 (1.5Ah high power) - 10 cells in Parallel connection.

Capacity- 15.0 Ah

with HAM sleeve

Overcharge Test Condition

Charge battery pack @6A to 12V, hold voltage @12V till temperature dropping

without HAM sleeve

Thermal Run-away Propagation without HAM™

Connection

After Test

Insulation

After Test

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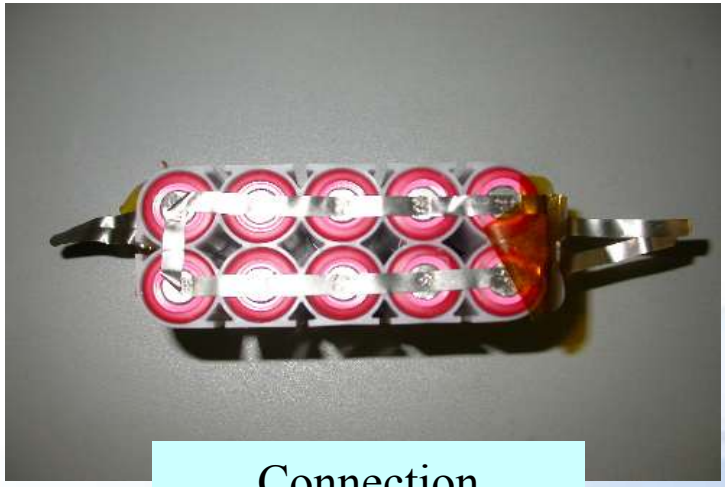
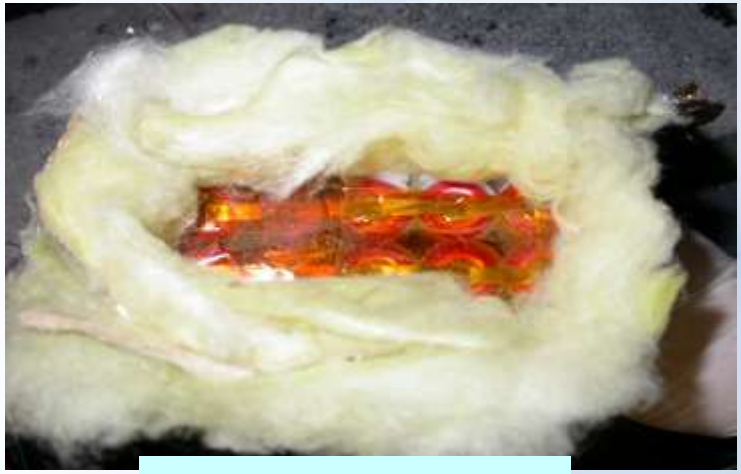
Thermal Dissipation with HAM™

HAM™ melted and latent heat stopped thermal run-away



Connection

After Test



Insulation

After Test

Quallion Matrix™ Technology In Large Lithium-ion Lead Acid Replacements

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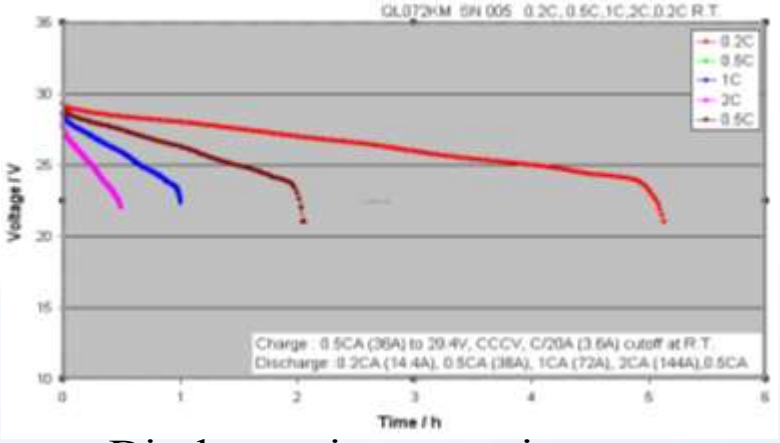
Quallion 24V, QL072KM 1250A Capable Battery System for HMMWV



Discharge time at various rates

Current Lead-Acid Battery
12V x2Series, 65Ah, 59lb x2

Quallion Drop-in Li-ion APU with Safety Circuit and Fuel Gauge
24V, 72Ah, 42lb

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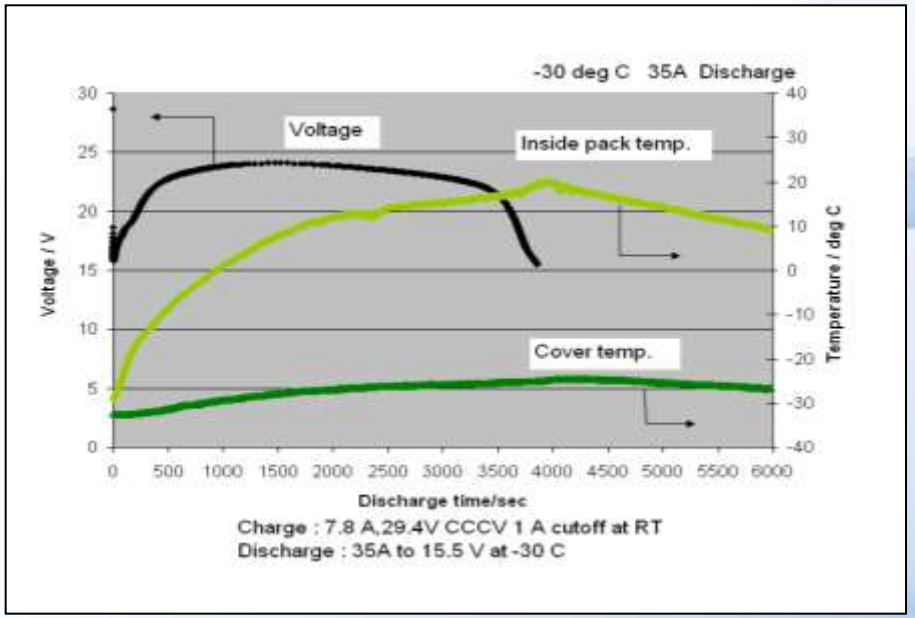
24V, 50Ah Lithium-ion Battery for U2 Vehicle

Li-ion Tech Demonstration Unit using QL038KM unit

- 38 Ah capacity
- Flight Demonstration Fall 2008 with future scale up to 50Ah



QL038KM -30°C, 30A discharge
(discharged 98% of nameplate capacity)

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24V, 8.25Ah Lithium-ion EBPS for C-17 Aircraft

Qualification Program to Replace Current Ni-Cd System

- Low maintenance & long life
- Fully integrated charge control electronics, battery management electronics & BIT/SOC capability
- -65ºF to 160ºF (with heaters)
- 8.5lbs
- Full charge in 75 minutes over 21V to 32V input range
- Plug-N-Play

24V, 38Ah Lithium-ion Battery for Little Bird, MH-47 & MH-60 Vehicles

- 24V Lithium-ion/Lead Acid Replacement
- 1100 amp pulse capability
- 38 Ah capacity
- 24 lbs

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Wide Operating Temperature Cell Designs

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Quallion Q18650-HP

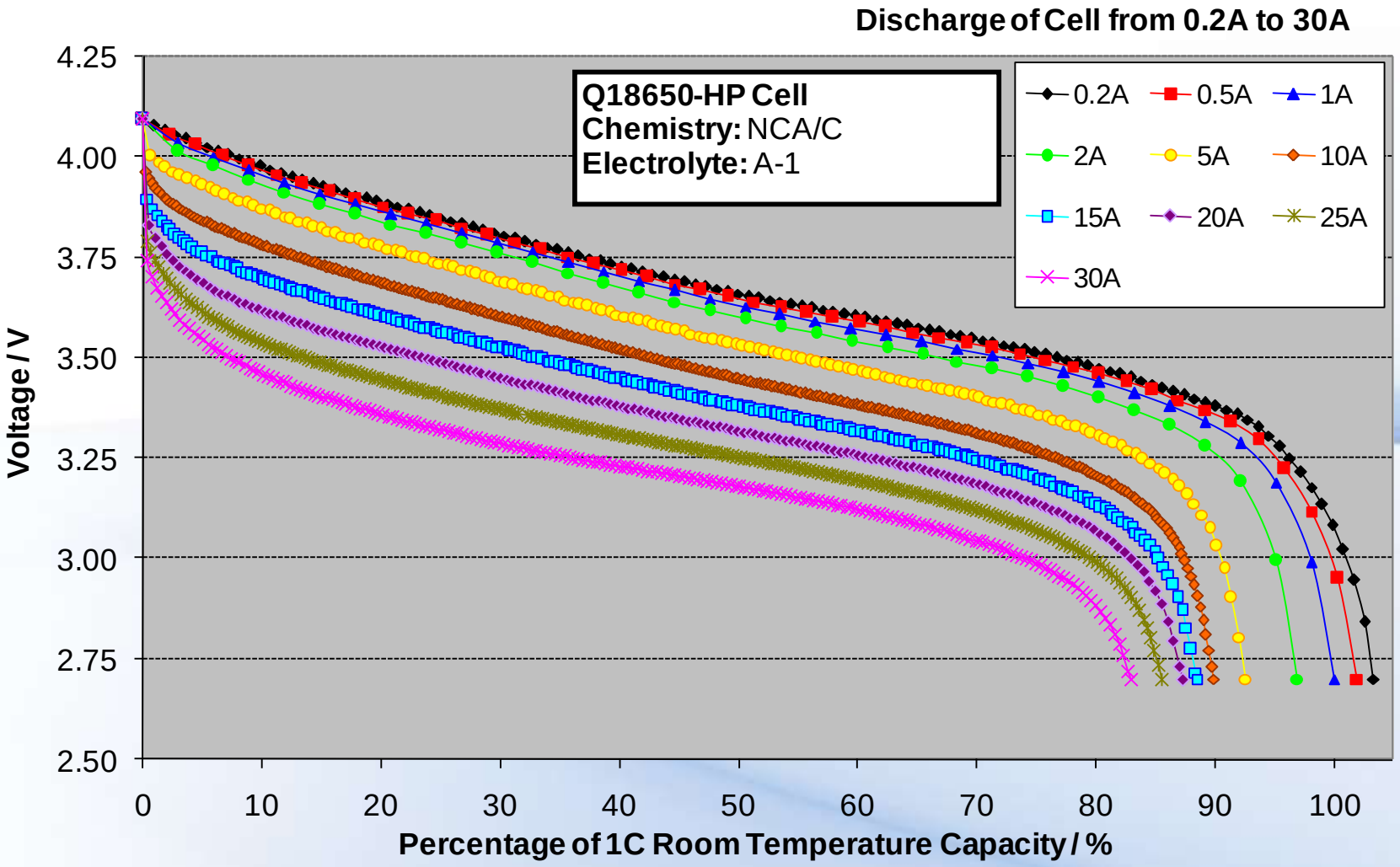
At -40°C, 30C rate discharge capable

Cell Specifications	
True Capacity / mAh*	1000
Energy Density / Wh/kg*	92
Energy Density / Wh/l*	217
Dimensions / mm	65 x 18 (H x d)
Weight / g*	39 ± 0.75

* Calculated values based on design

- **Operating Range** = -40°C to +71°C
- **Heritage Materials**
  - Active materials are the same as Quallion SATELLITE cells

Discharge Rate Data of Quallion HP Cell



Charge : 1.0A, 4.1V CCCV C/20 mA cutoff at RT
Discharge : 0.2, 0.5, 1, 2, 5, 10, 15, 20, 25, 30A to 2.7 V at RT

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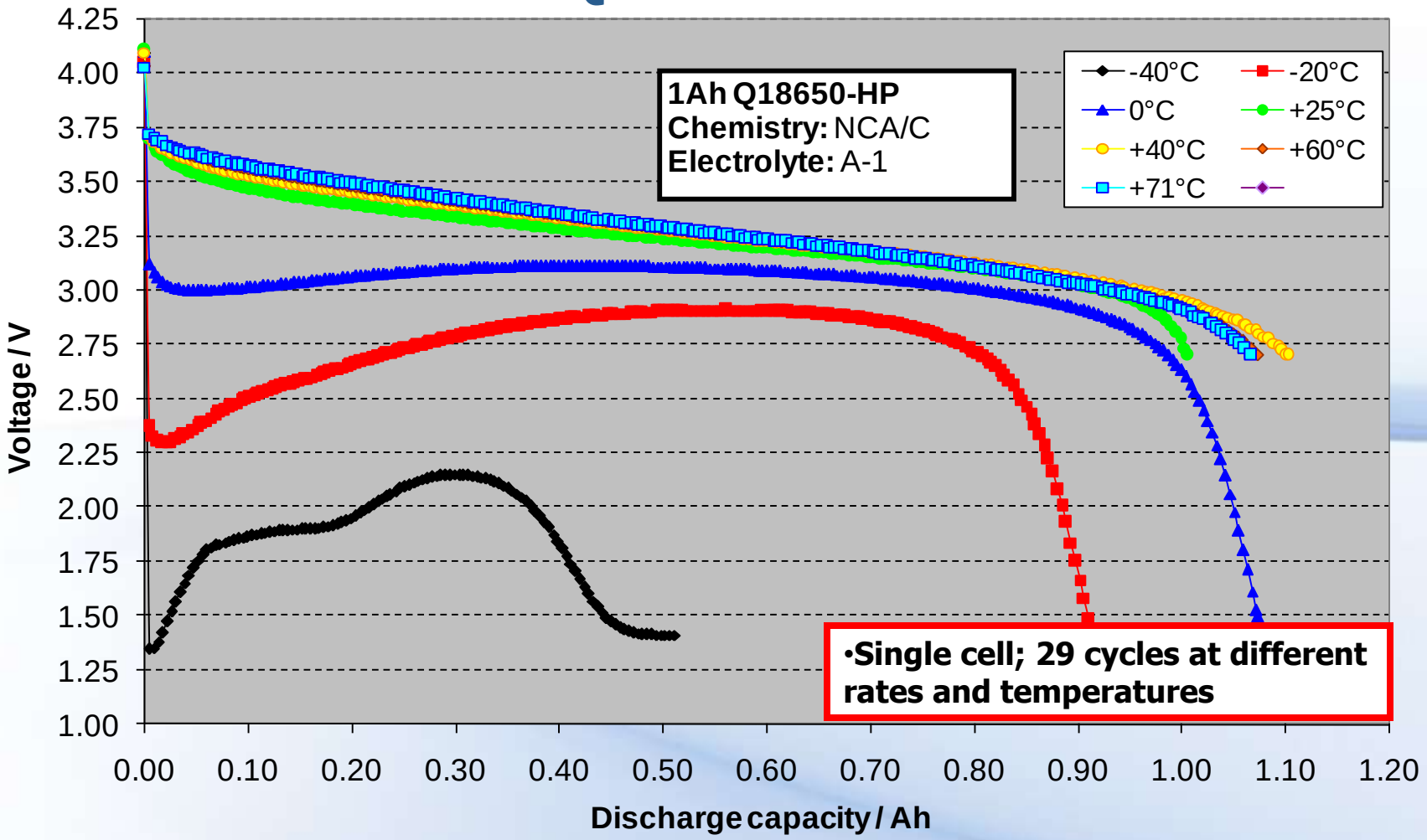
Discharge Temperature Data of Quallion HP Cell at 30C Rate



Charge : 1.0A, 4.1V CCCV C/20 mA cutoff at RT
Discharge : 30CA to 1.5V at -40 , -20 , 0 C or 2.7V at RT, +40 , +60 , and +71 C

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Quallion High Power 2.3Ah Cell

- Dimensions (without tabs) – 5.5” x 2.25” x .25”
- Weight – 75g

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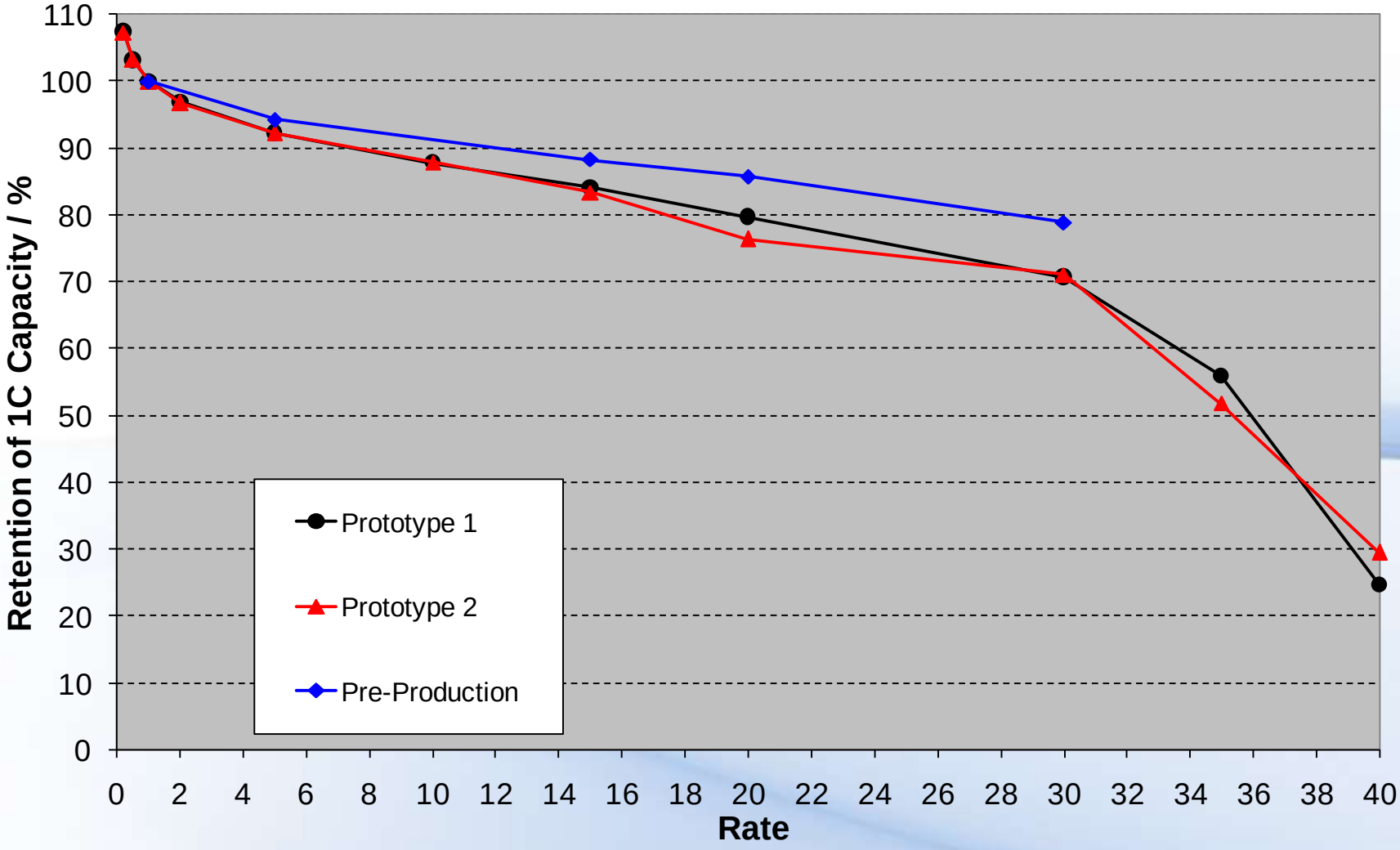
Pouch Cell

Cell Specifications	
Rated Capacity / mAh*	2300
Energy Density / Wh/kg*	110
Energy Density / Wh/l*	205
Dimensions	5.3 x 2.1 x 0.25 (H x W x T)
Weight / g	75 ± 0.75

- **Operating Range** = -40°C to +70°C
- **Heritage Materials**
  - Active materials are the same as Quallion SATELLITE cells
  - USG T3 program enables Quallion to produce Cathode and Anode material in-house by 2012

Rate Test Summary at RT



Charge : 1.0C A, 4.1V CCCV C/20 mA cutoff at RT
Discharge : 0.2, 0.5, 1, 2, 5, 10, 15, 20, 25, 30C A to 2.7 V at RT

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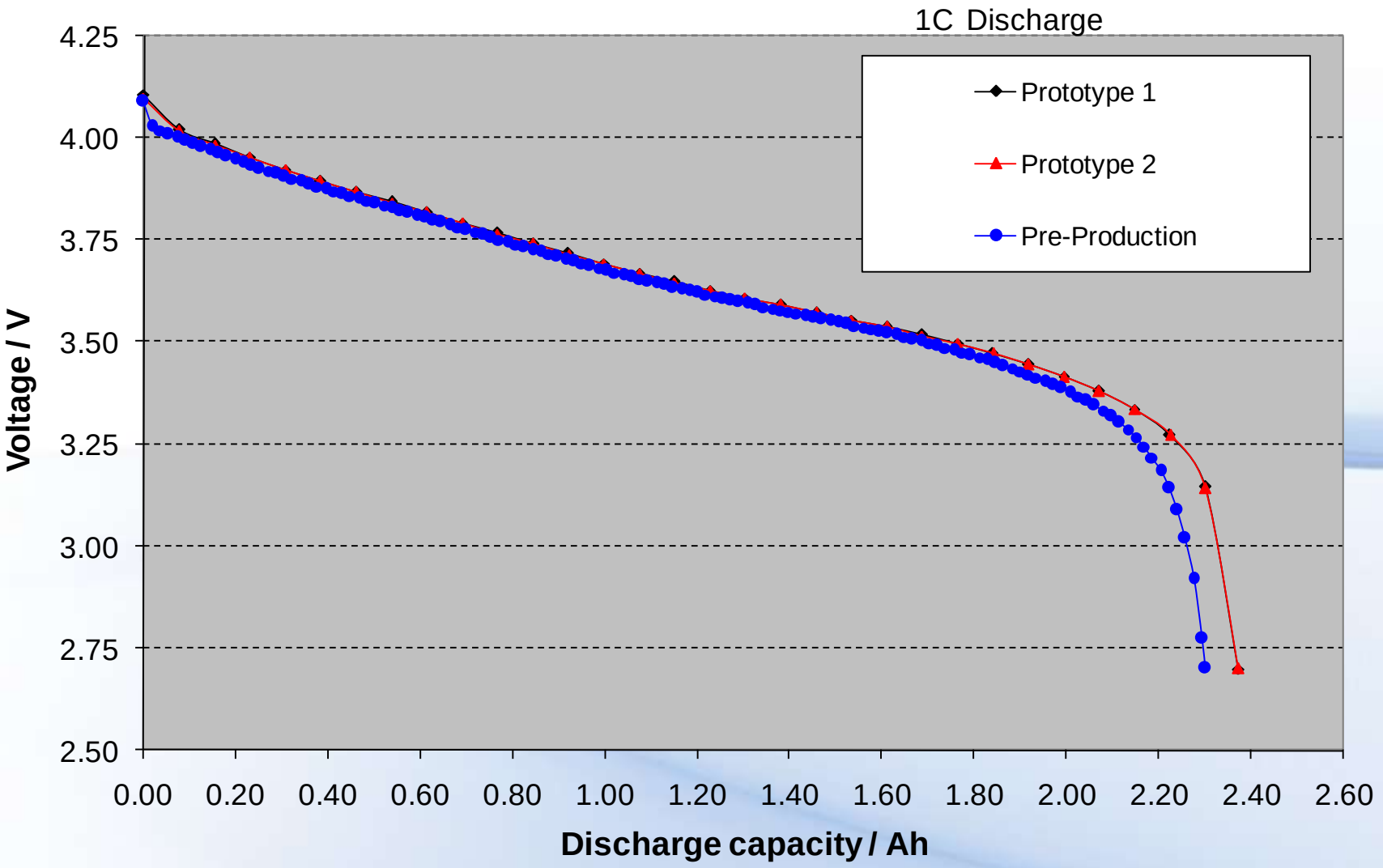
1C Discharge Rate Curve at RT



Charge : 1.0 CmA, 4.1V CCCV C/20 mA cutoff at RT
Discharge : 1 CmA to 2.7V at RT

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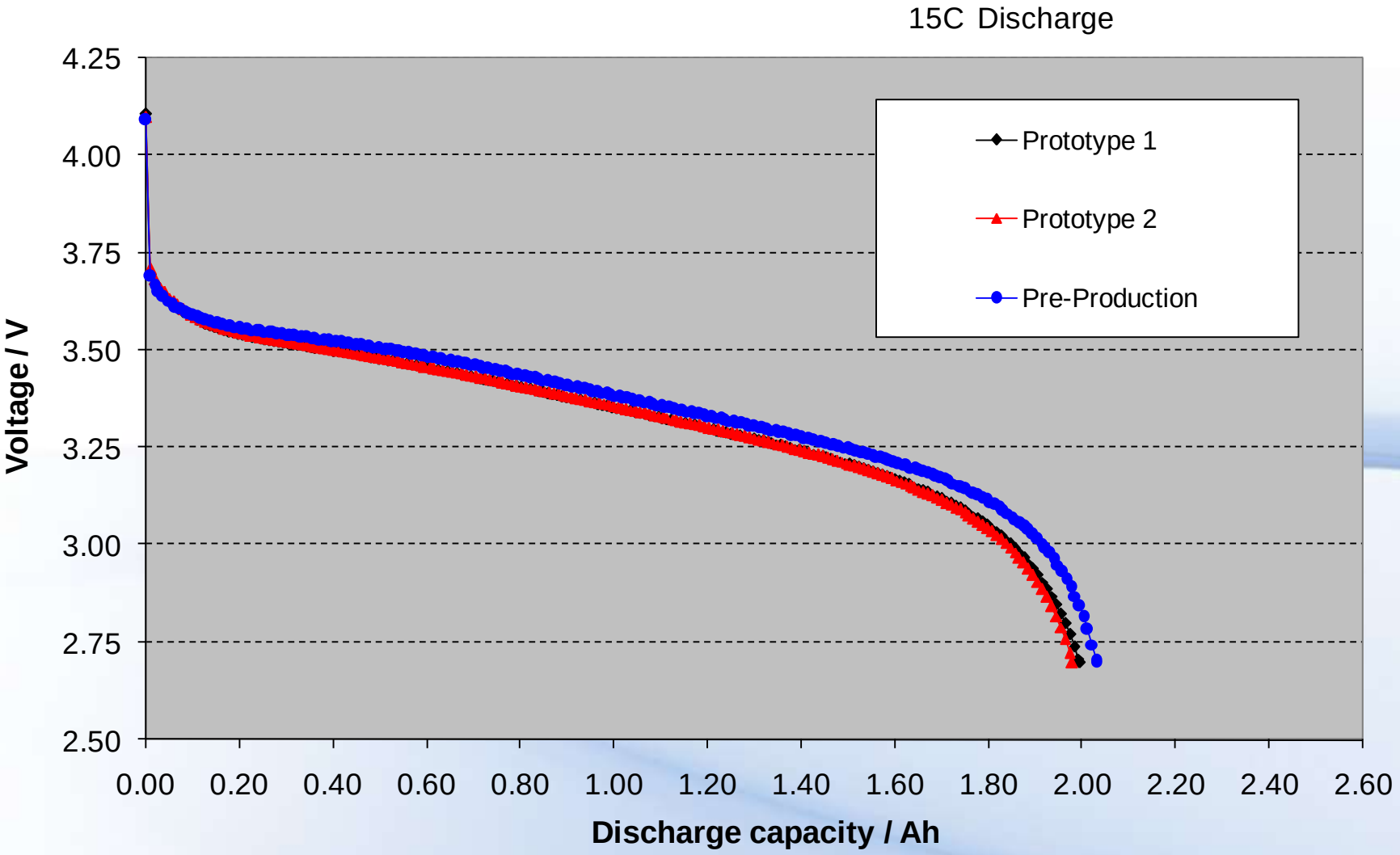
15C Discharge Rate Curve at RT



Charge : 1.0 CmA, 4.1V CCCV C/20 mA cutoff at RT
Discharge : 15 CmA to 2.7 V at RT

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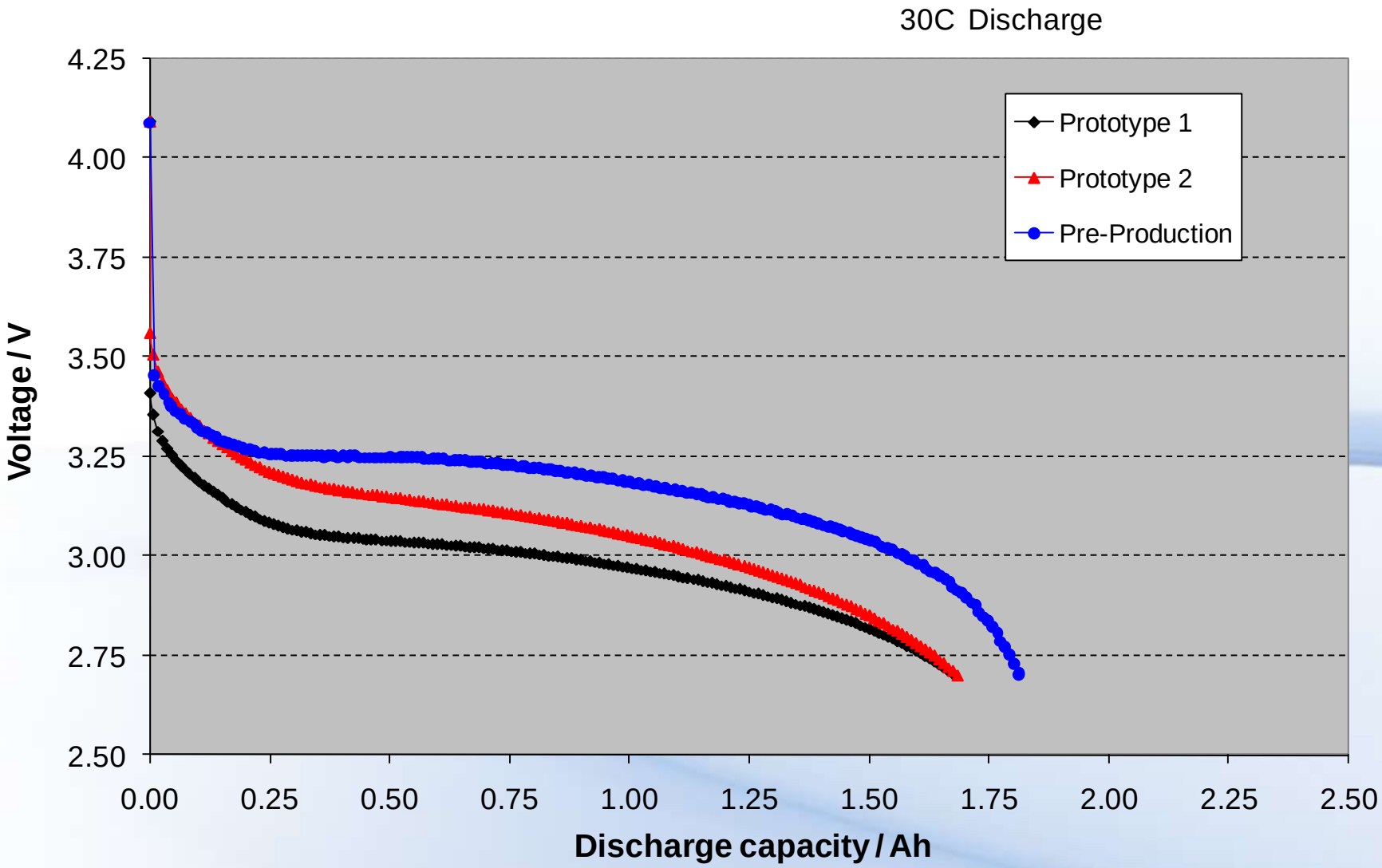
30C Discharge Rate Curve at RT



Charge : 1 CmA, 4.1V CCCV C/20 mA cutoff at RT
Discharge : 30 CmA to 2.7 V at RT

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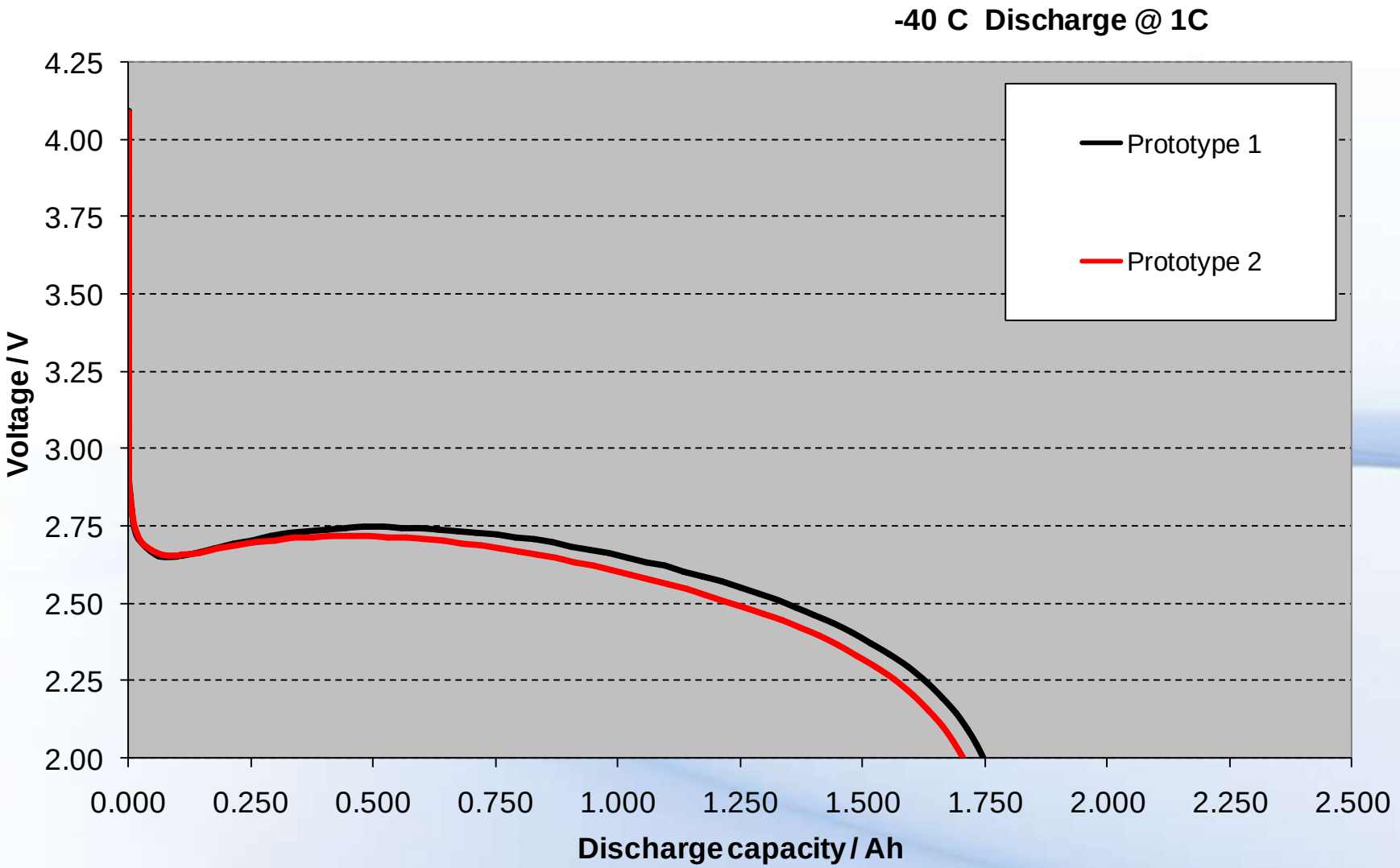
1C Discharge at -40°C



Charge : 1 CmA, 4.1V CCCV C/20 mA cutoff at RT
Discharge : 1 CmA to 1.5 V at -40 C

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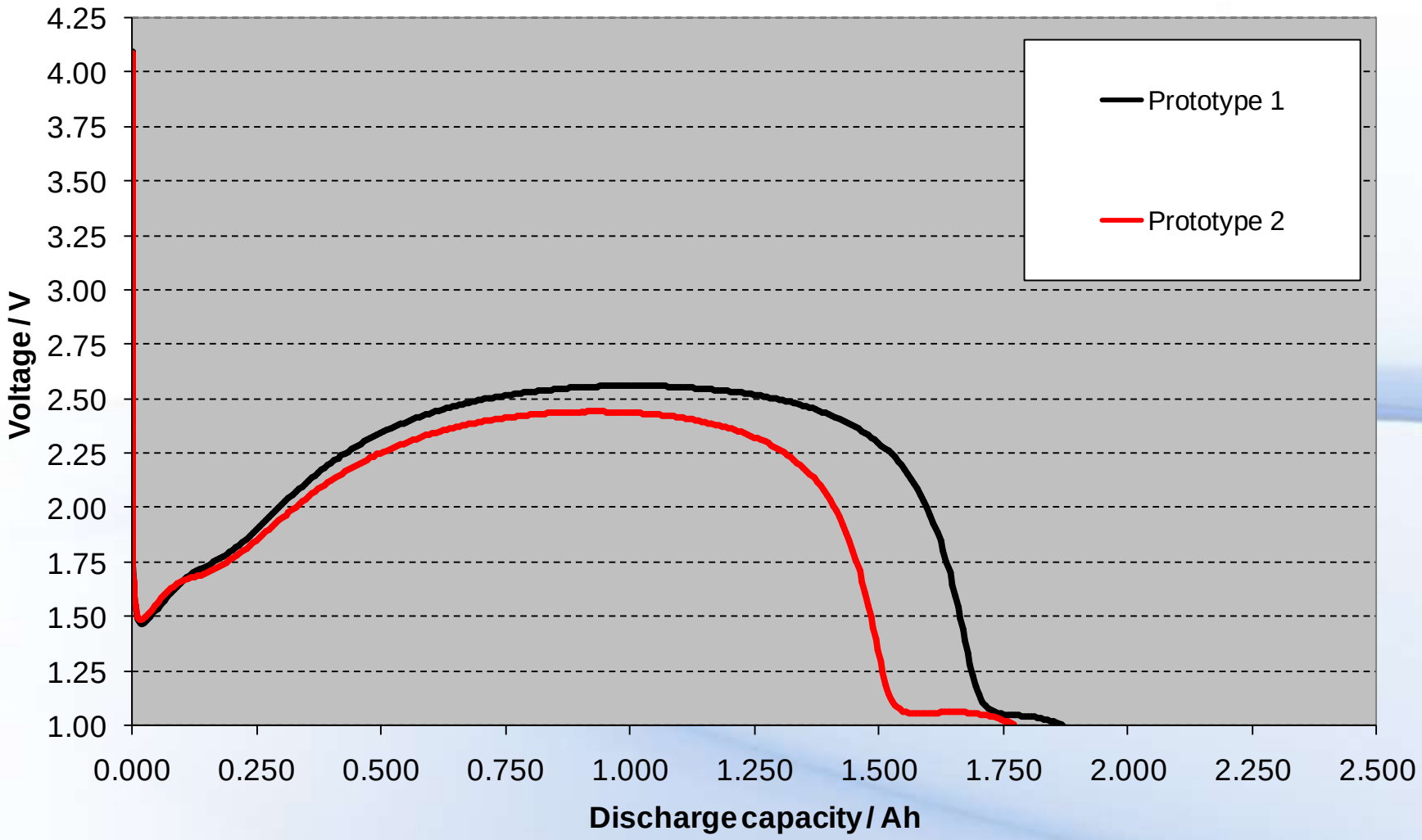
15C Discharge at -40°C



Charge : 1 CmA, 4.1V CCCV C/20 mA cutoff at RT
Discharge : 15 CmA to 1.0 V at -40 C

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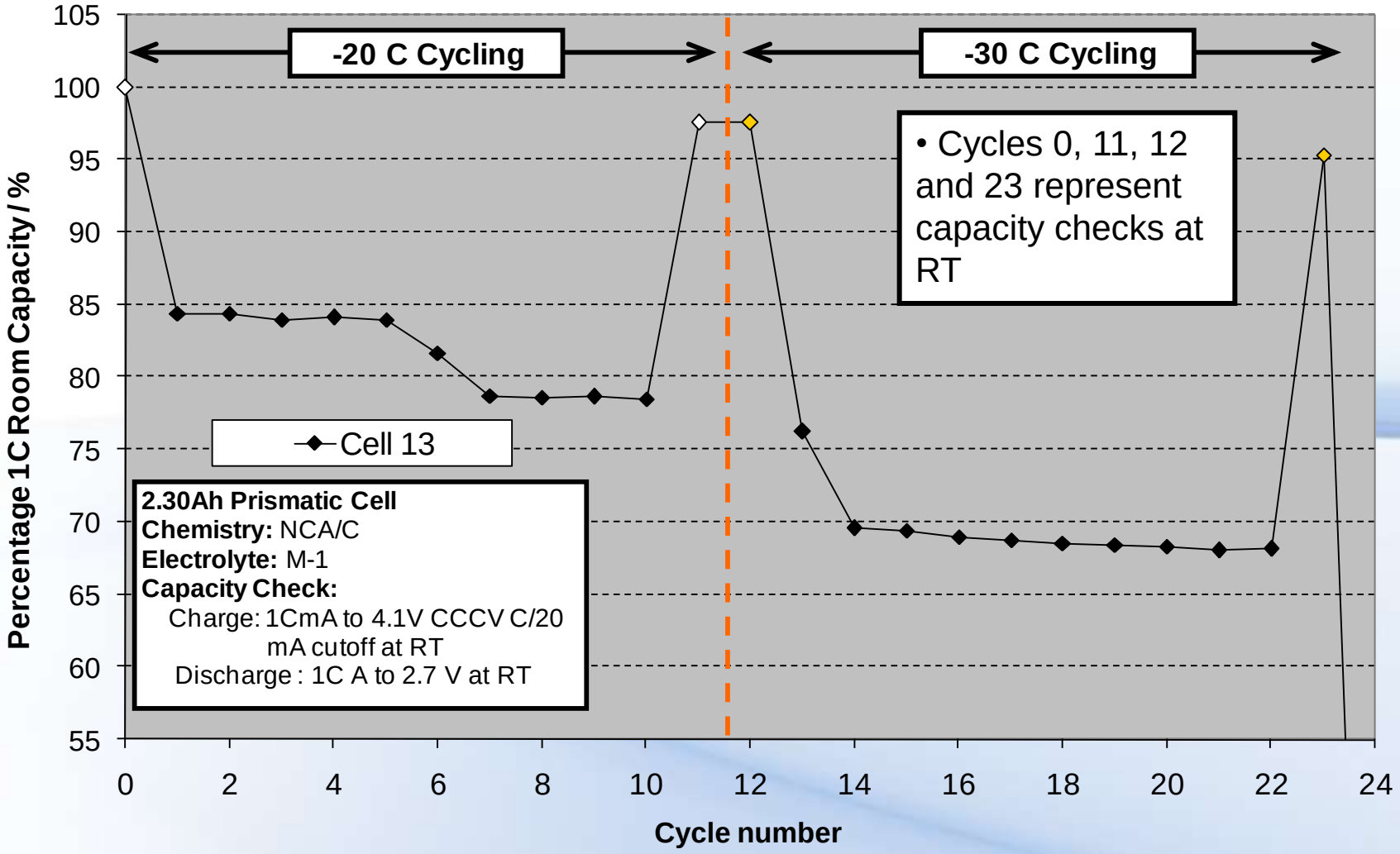
C/2 Charge/Discharge Cycling of Prismatic Cell at -20° & -30°C



Charge : C/2 A, 4.1V CCCV C/50 mA cutoff at -20 & -30 C
Discharge : C/2 A to 2.5 V at -20 & -30 C

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Quallion 10Ah Cell with Wide Operating Temperature

Cell Specifications	
Theoretical Capacity / mAh*	10000
Energy Density / Wh/kg*	82
Weight / g*	450

* Calculated values based on design

- **Operating Range** = -40°C to +71°C
- **Heritage Materials**
  - Active materials are the same as Quallion SATELLITE cells
  - Wide temperature electrolyte
- **5000 DOD 60% to 80% Cycling over Wide Temp Temperature Spectrum**
- **Cell to undergo life testing February 2011**

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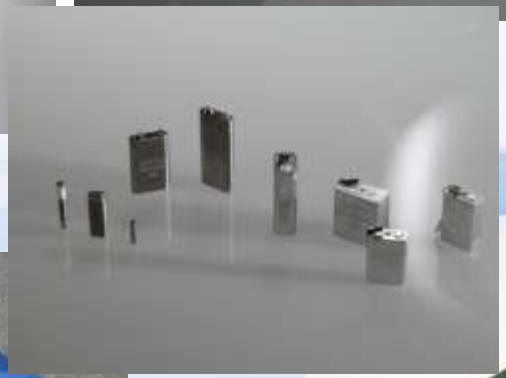

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