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Li-ion EMU Battery Testing

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EMU BATTERY LIFE TESTING OBJECTIVES

- A 45Ah Li-ion battery comprised of five (5) Yardney prismatic cells is being evaluated to replace the silver-zinc cells in the Extra-vehicular Mobility Unit (EMU).
- The tests being conducted at Symmetry Resources are to determine if the 5 cell battery can meet the mission objective of 500 duty cycles and maintain a minimum voltage of 16.0 V without an individual cell voltage dropping below 3.0V.
- 40 Real Time cycles were conducted to develop BOL trend data (This accomplishment would exceed the current silver-zinc capability).
- Decision to switch to accelerated cycling for the remaining 460 cycles was made since “Real Time” cycling requires 1 day/cycle.

This presentation covers the initial test data

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WHY CHANGE THE EMU BATTERY?

Silver Zinc Design	Li-ion Design
11 Zn/AgO Cells in Series	5 $LiNi_{1-X}Co_xO_2$ Cells in Series
Cell Compliment Wt = 11.6 lbs	Cell Compliment Wt = 12.2 lbs
Cell Compliment Cost = $10K	Cell Compliment Cost = $20K
45Ah Capacity BOL (Full Cap)	45Ah Capacity BOL (Full Cap)
425 Day Wet Life, 32 Cycle Life	Goal of 5 yr Wet Life, 500+ Cycle Life
237.6 Wh/L BOL	262.8 Wh/L BOL
141.0 Wh/Kg BOL	148.8 Wh/Kg BOL

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EMU BATTERY LIFE TESTING

Characterization Testing at 50°C, 25°C, -10°C

40 Real Time Cycles at 25°C

460 Accelerated Cycles at 25°C

Characterization Testing at 50°C, 25°C, -10°C

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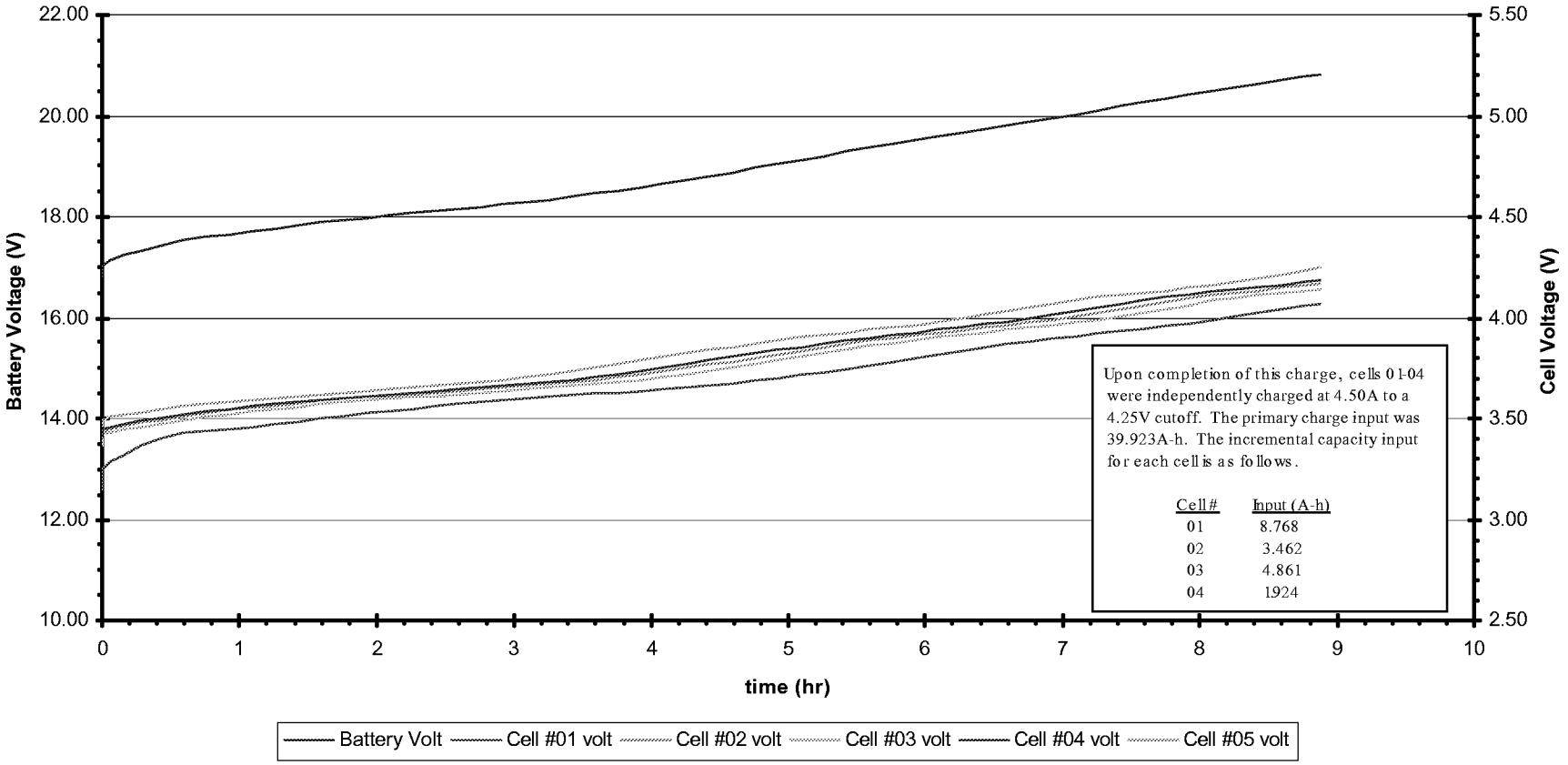
YTP 45A-h Li-Ion EMU Battery Cycling Tests

Initial Conditioning Cycle, 25 deg. C

Battery/Cell Charge Voltage Profiles

4.50A to 21.0V (4.25V) battery (cell) voltage



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CHARACTERIZATION TESTING

Stabilize at Temperature

Charge at 4.5 amps to Battery Voltage of 21.0V or Cell Voltage 4.2V

Discharge at 10.0 amps to Battery Voltage of 14.5V or Cell Voltage of 2.7V

50°C Capacity = 48.09Ah (107.0% of 25°C)

25°C Capacity = 44.96Ah

-10°C Capacity = 31.31Ah (69.6% of 25°C)

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REAL TIME CYCLING

Discharge at 3.8 amps for 7 hours or Battery Voltage of 16.0V, Cell Voltage of 3.0V

Charge at 1.55 amps for 20 hours or Battery Voltage of 20.5V, Cell Voltage of 4.1V

Every 20th Cycle, Continue Discharge to Battery Voltage of 16.0V, Cell Voltage of 3.0V

40 CYCLES COMPLETED

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ACCELERATED CYCLING

Discharge at 11.0 amps for 2 hours 25 minutes or Battery Voltage of 16.0V, Cell Voltage of 3.0V

Charge at 11.0 amps to a Battery Voltage of 20.5V, Cell Voltage of 4.1V.

Then charge at 5.0 amps to a Battery Voltage of 20.5V, Cell Voltage of 4.1V.

Then charge at 2.0 amps to a Battery Voltage of 20.5V, Cell Voltage of 4.1V.

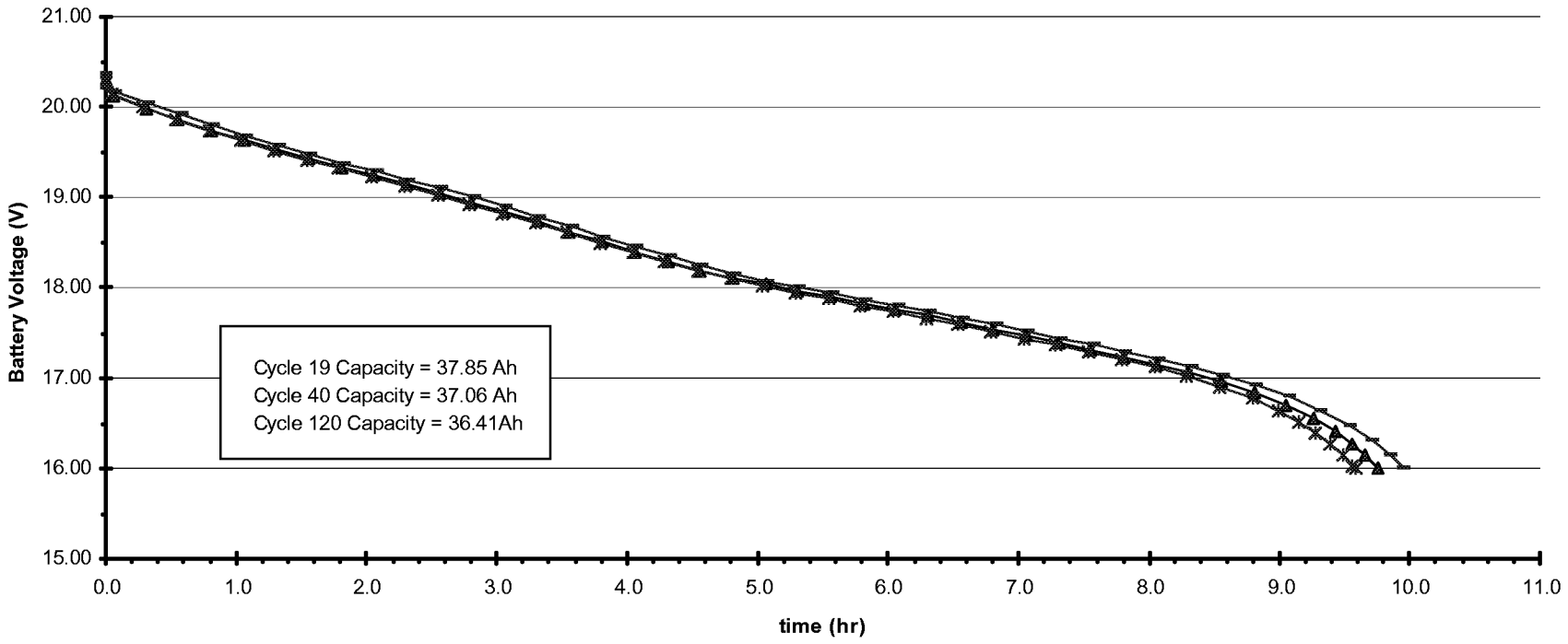
Then charge at 1.0 amp to a Battery Voltage of 20.5V, Cell Voltage of 4.1V.

Every 20 Cycles Discharge Battery at 3.8 amps to 16.0V (Cell Voltage of 3.0V)

CYCLING IN PROGRESS

CYCLE 19, 40 AND 120 BATTERY DISCHARGE VOLTAGE COMPARISONS

(Discharged at 3.8amps to 16.0V)



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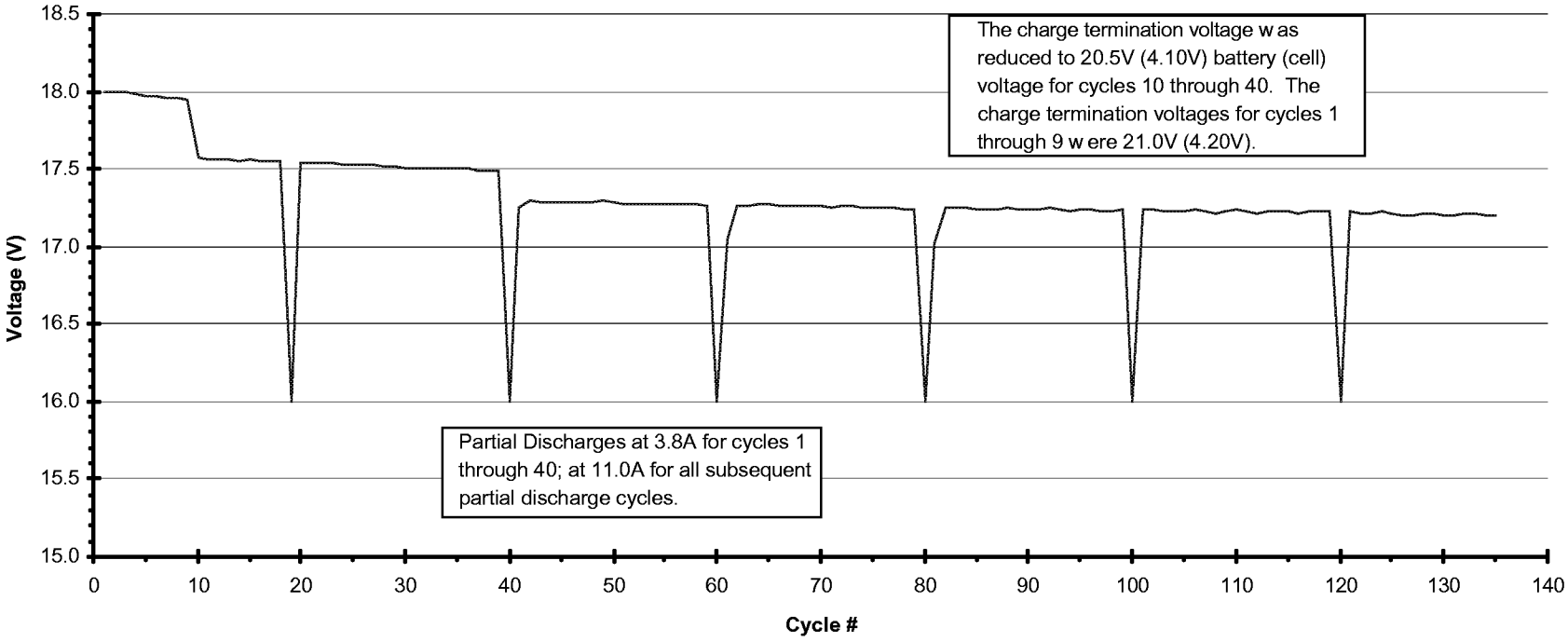
YTP 45A-h, 5-cell Li-Ion EMU Battery Cycling Tests

Real Time and Accelerated Cycling at Room Temp.

End-of-Discharge Battery Voltage versus Cycle Trend

3.8A to 16V (3.0V) battery (cell) voltage on 20 cycle interval; All other cycles to 26.6A-h



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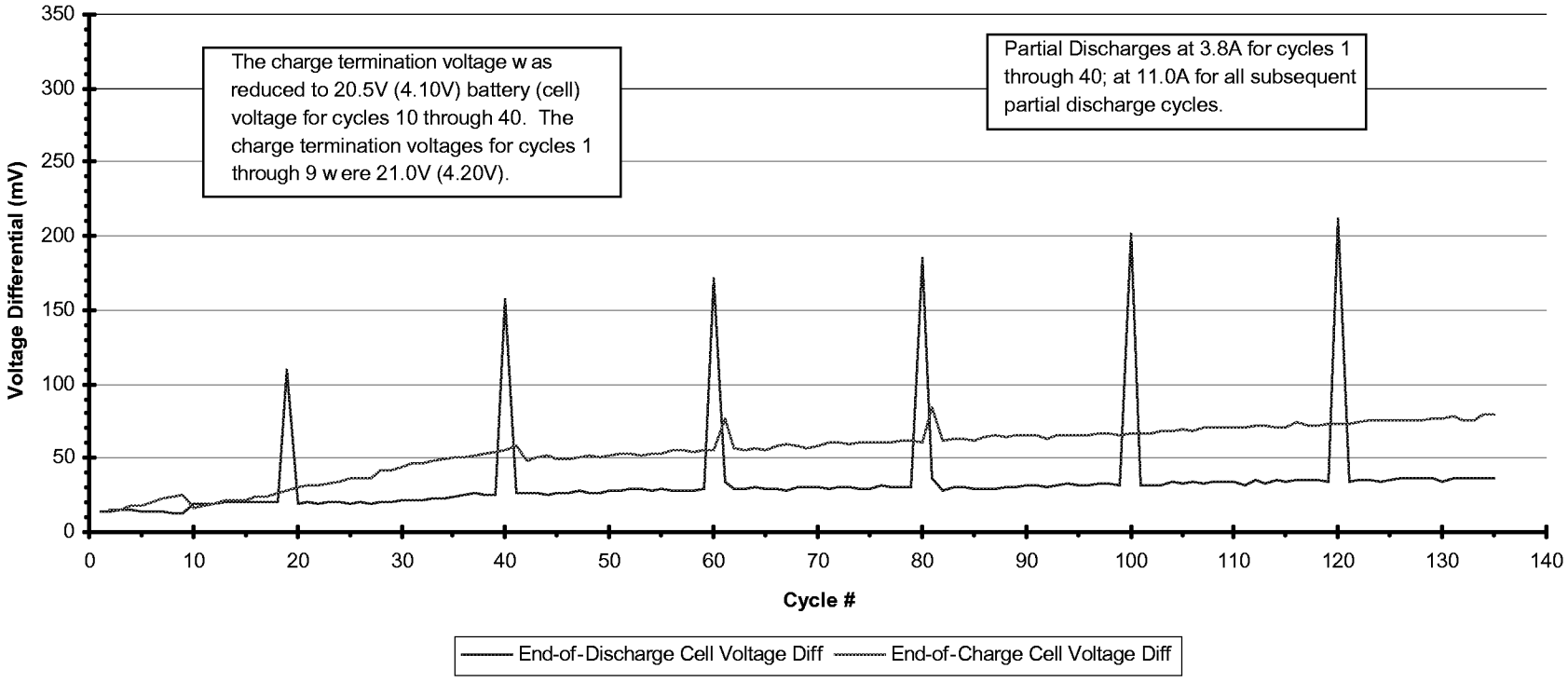
YTP 45A-h, 5-cell Li-Ion EMU Battery Cycling Tests

Real Time and Accelerated Cycling at Room Temp.

End-of-Discharge and End-of-Charge Cell Voltage Differentials

3.8A to 16V (3.0V) battery (cell) voltage on 20 cycle interval; All other cycles to 26.6A-h



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SUMMARY

- The Data Indicates the Potential to Meet the 500 Cycle Objective Within the EMU Mission Requirements.
- Capacity to 16.0 Volts at 120 Cycles (36.41Ah) Exceeds Requirement by 36.9 %.
- Battery Charge Method and Cell Protective Circuitry Need to be Addressed.
- 40 Additional Cells Have Been Ordered for Additional Performance and Safety/Abuse Testing for This Cell Design.