



Testing and Evaluation of Energy Storage Devices

DOE Energy Storage Systems Research Program Annual Peer Review

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Objective (FY-08 Work)

- ◆ **Identify and test advanced battery technology including Valve Regulated Lead-Acid, (VRLA) and Li-ion (Li-FePO₄) for utility partial state of charge (PSOC) cycling applications. These applications may include:**
 - ❖ **Wind farm energy smoothing**
 - ❖ **Frequency regulation**
 - ❖ **Spinning reserve**



Energy Storage Technologies/Partners (FY-08 Work)

- ◆ **Sandia/MeadWestvaco (MWV)/NorthStar Supercap and Carbon Enhanced Lead-Acid VRLA Battery Work**
 - ❖ Test second generation of MWV carbon in NorthStar and Battery Energy batteries
- ◆ **Sandia/East Penn**
 - ❖ Test large format East Penn AGM VRLA for wind farm energy smoothing battery
- ◆ **Sandia/C&D**
 - ❖ Test large format solar C&D CPV vented (Sb/Se grid) battery for wind farm energy smoothing
- ◆ **Sandia/ILZRO**
 - ❖ Test CSIRO/Furukawa UltraBattery VRLA/supercap for PSOC utility applications
- ◆ **Sandia/LiFeBatt**
 - ❖ Test LiFeBatt (Li-FePO₄) Li-ion battery for PSOC utility applications

Energy Storage Devices Under Test (FY-08)

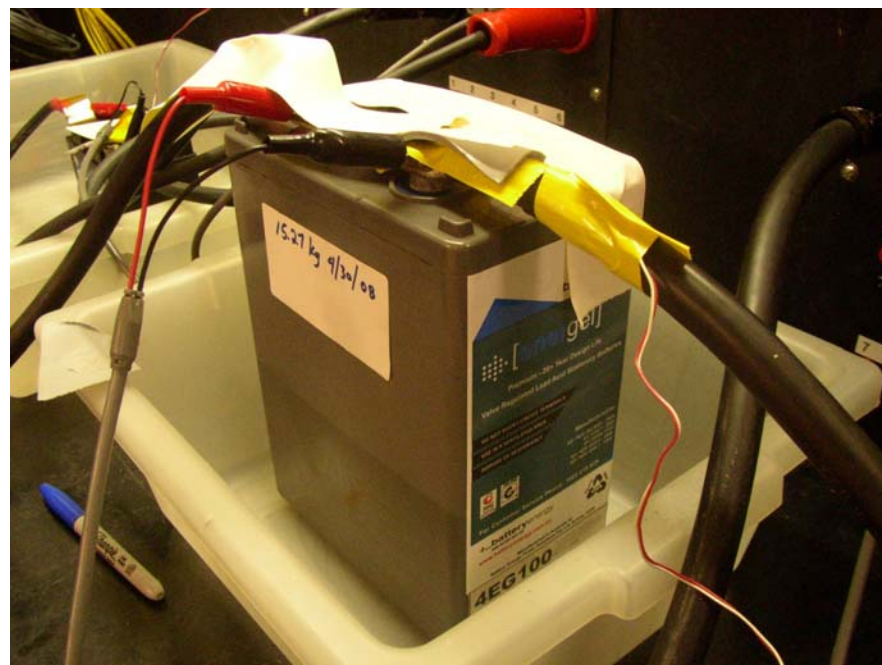
NorthStar/MWV

(Carbon Enhanced AGM VRLA Battery)



Battery Energy/MWV

(Carbon Enhanced VRLA Gel Battery)



Energy Storage Devices Under Test (FY-08)

C&D CPV550 Battery
(Deep-Cycle Vented Wind Farm
Battery)



East Penn AGM VRLA
(PSOC Cycling Wind Farm Battery)

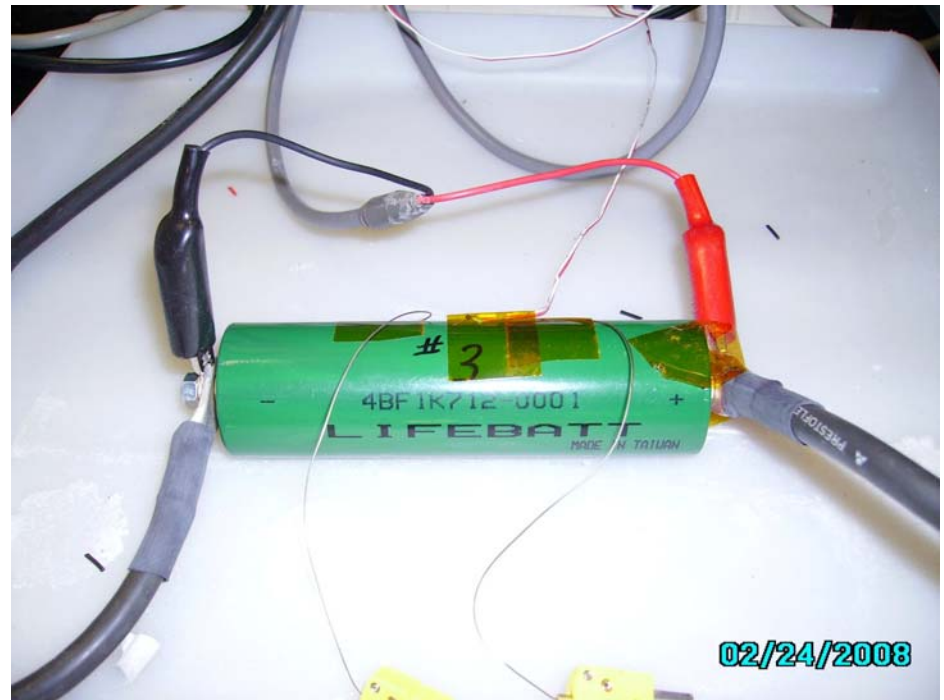


Energy Storage Devices Under Test (FY-08)

CSIRO/Furukawa UltraBattery
(VRLA/Supercap Carbon Enhanced
Battery)



LiFeBatt Li-ion (Li-FePO₄)
(Li-ion Battery)





Basic Test Plan For All Devices

- ◆ **Capacity.**
- ◆ **DC Ohmic resistance**
- ◆ **Power and energy density**
- ◆ **Float current**
- ◆ **Utility PSOC cycle test (10% DOD @ 50% SOC)**
- ◆ **Final DC Ohmic resistance**
- ◆ **Final capacity**



Additional Testing For The Li-ion (Li-FePO₄) Battery

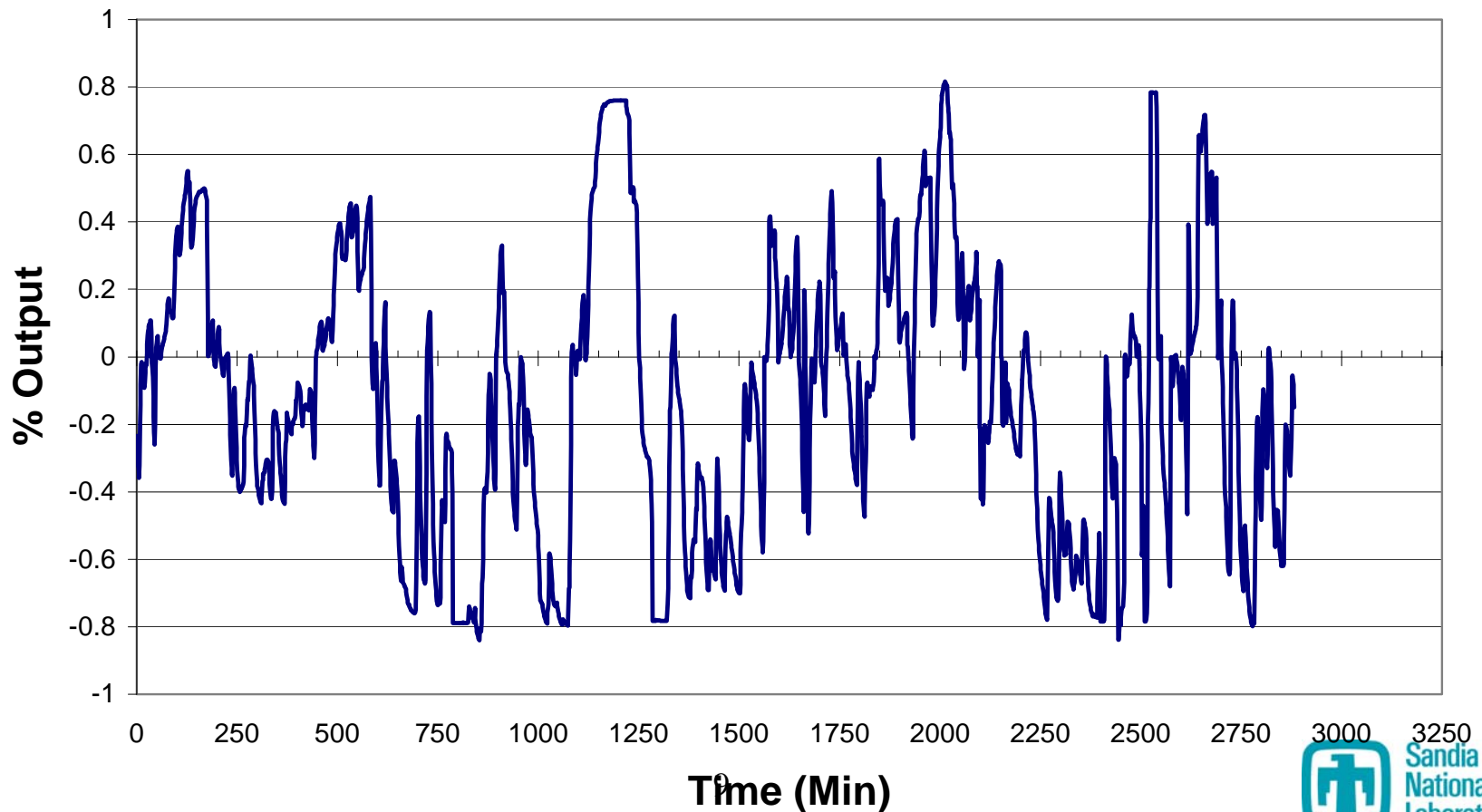
- ◆ AC spectral impedance
- ◆ Capacity as a function of temperature
- ◆ Hybrid pulse power test
- ◆ Over voltage/Charge abuse test



PSOC Utility Cycling (Actual Profile From PJM Ancillary Services)

Utility Profile

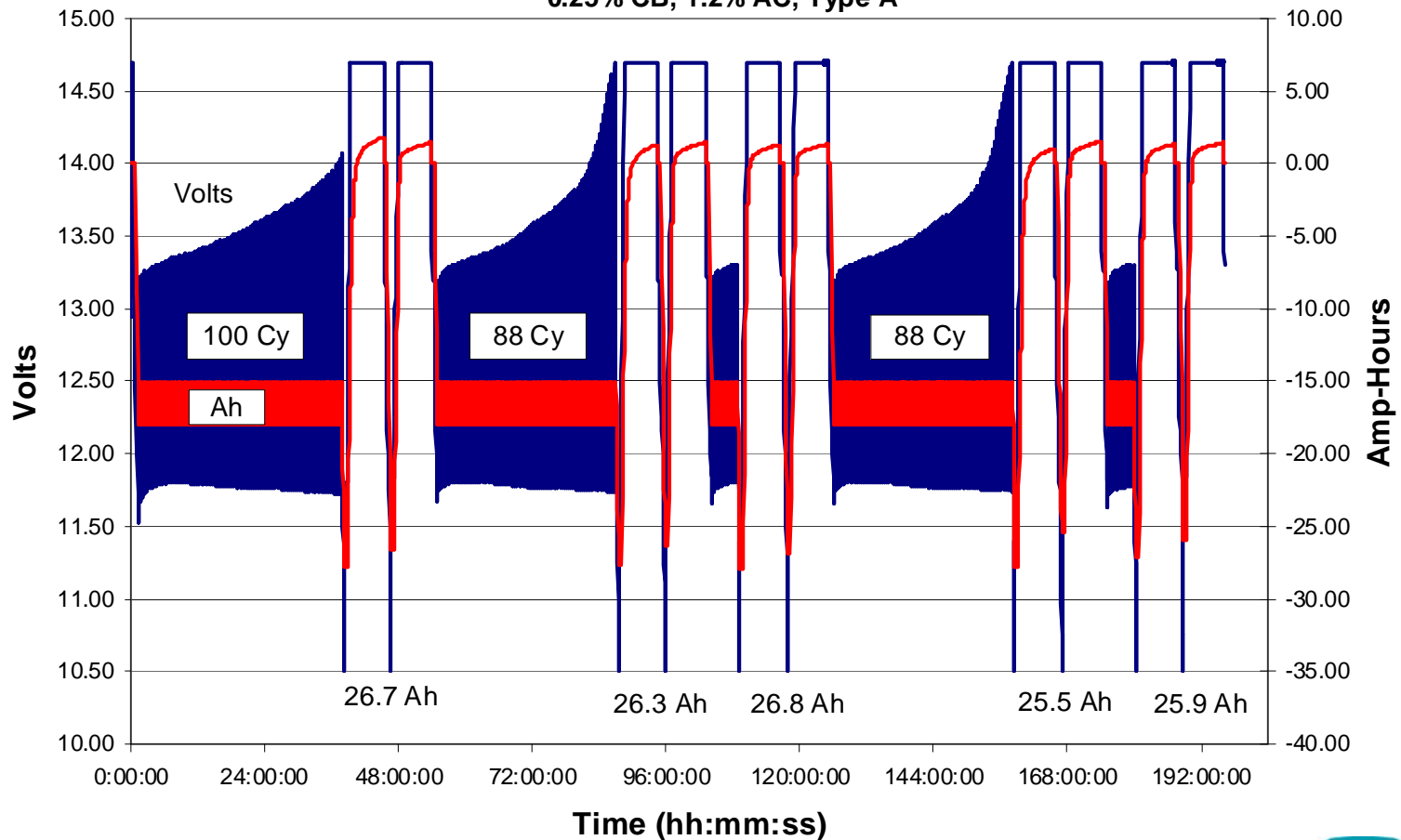
(Charles Koontz, WPS)



NorthStar/MWV Utility PSOC Cycling

MWV/NorthStar #242 (Run #7) Utility PSOC Cycle

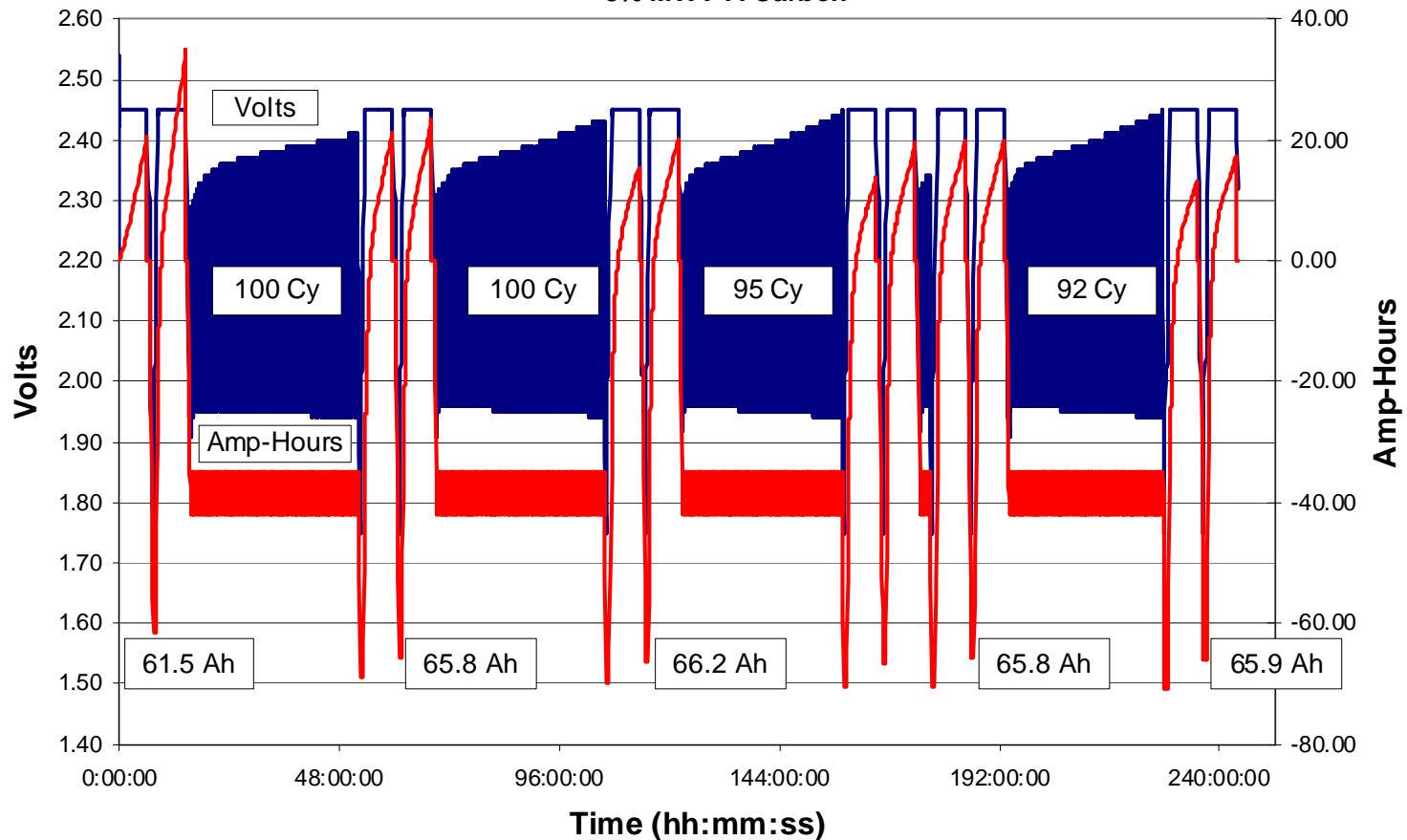
0 to 300 Cycles, 1C 6M, 30A Chr/Dch
0.25% CB, 1.2% AC, Type A



Battery Energy/MWV Utility PSOC Cycling

Battery Energy #221 (Blue) Utility PSOC Cycle

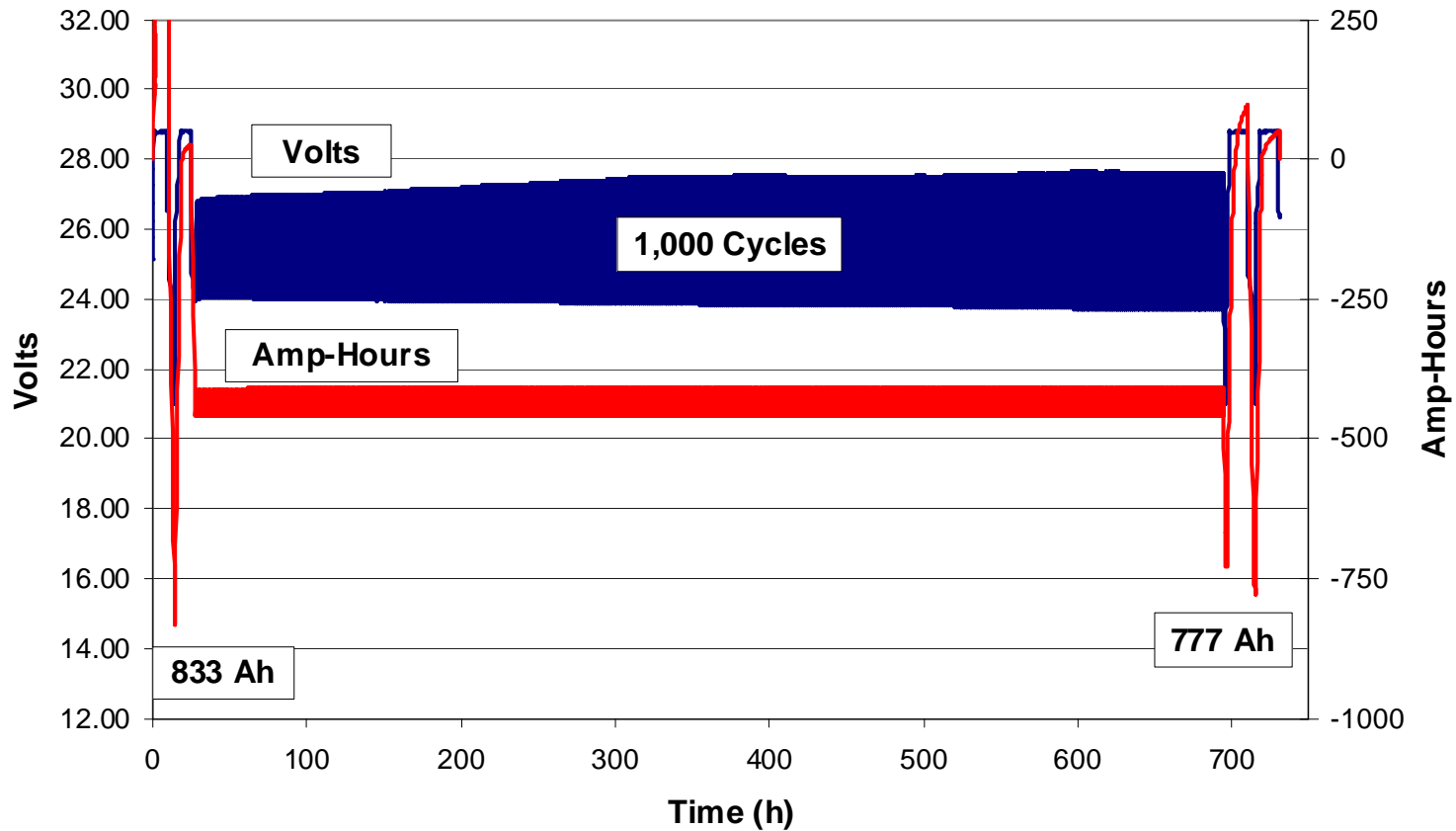
1C 6M, 70A Chr/Dch
3% MWV-A Carbon



East Penn Large Format Wind Farm Energy Smoothing Battery (Utility PSOC Cycling)

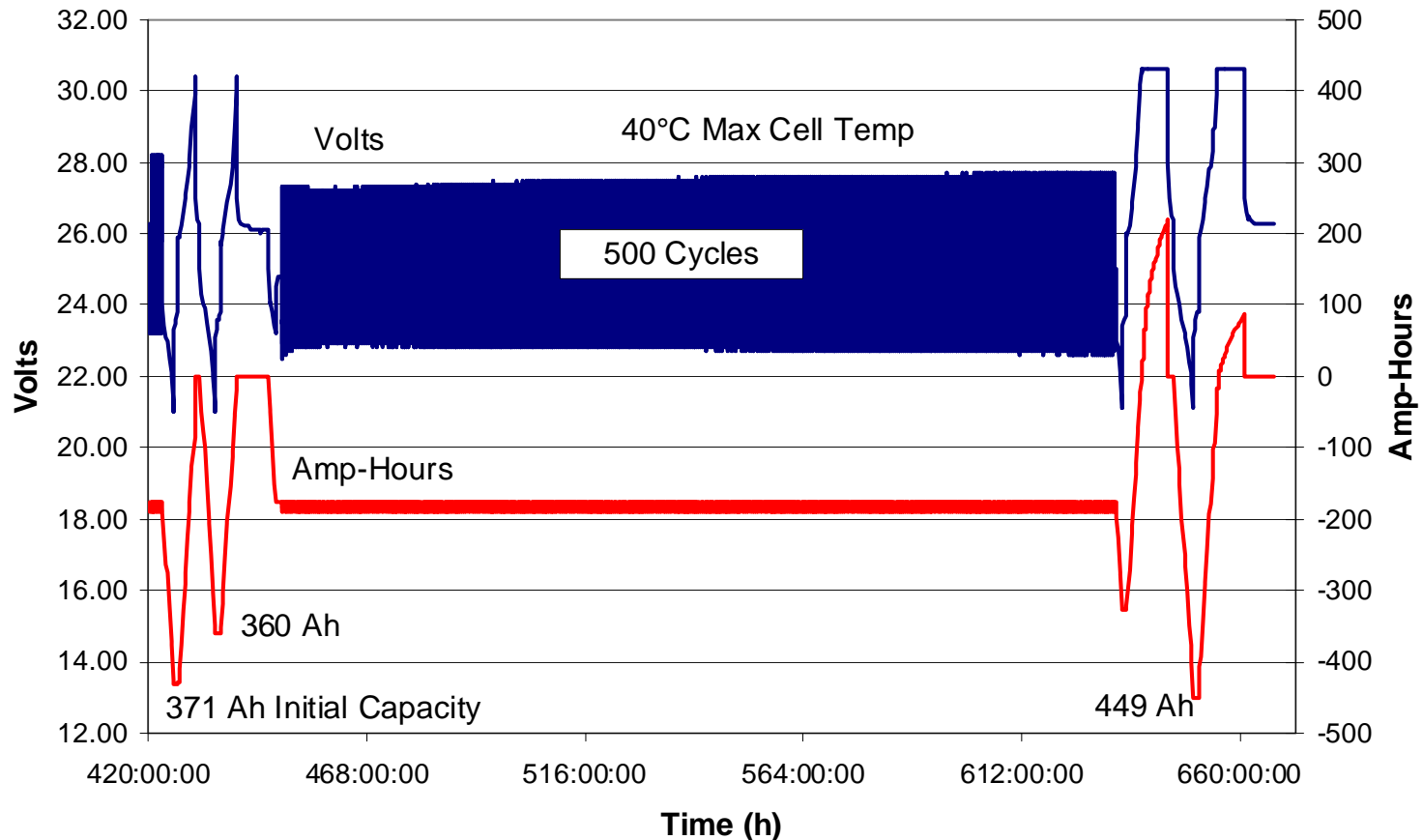
East Penn VRLA Wind Energy Smoothing Battery

371 to 1,371 Cycles, 200A (0.4C) Chr/Dch
AC Carbon With Optimized Grid and Separator



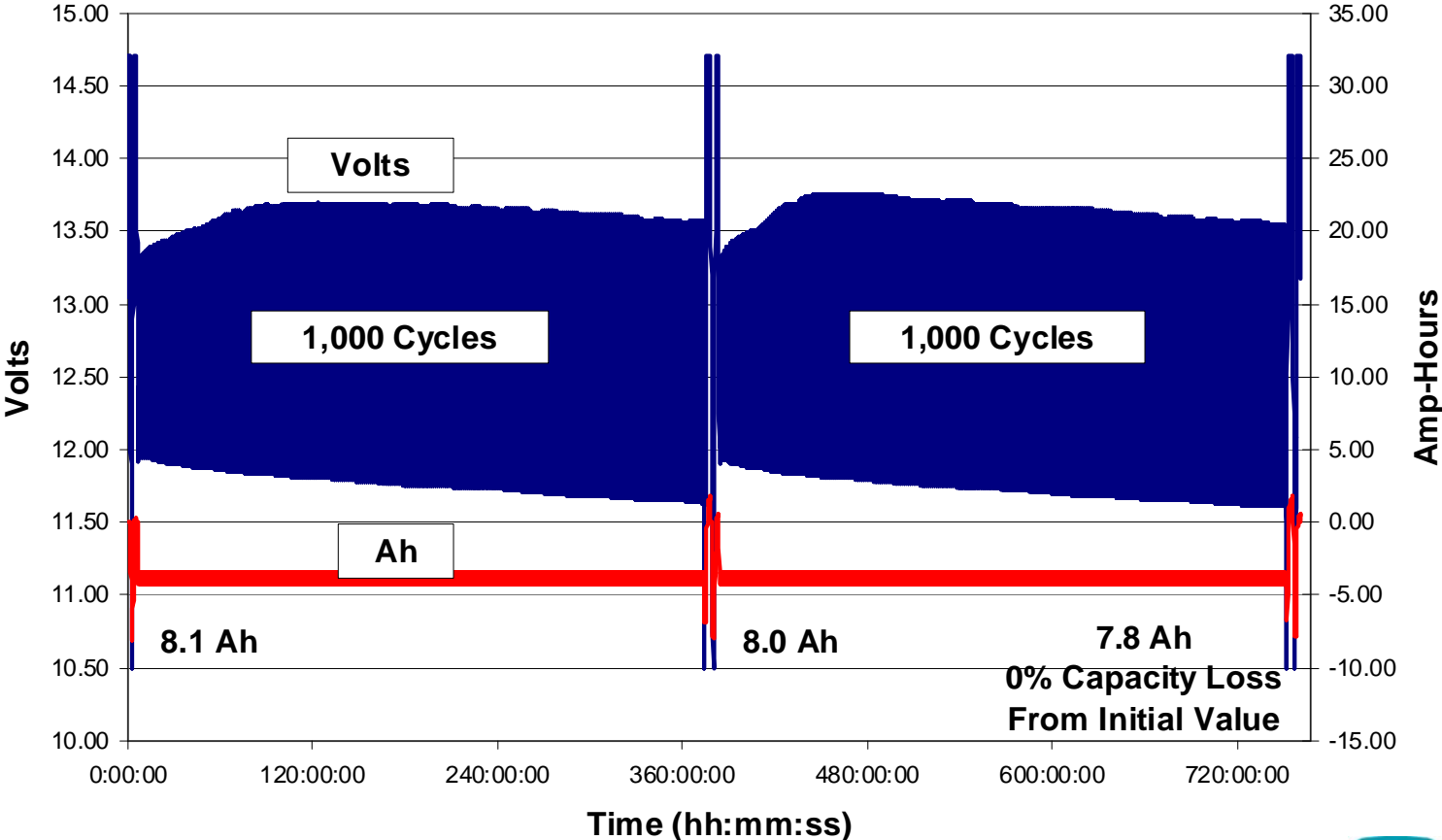
C&D CPV Large Format Wind Farm Energy Smoothing Battery (Utility PSOC Cycling)

C&D CPV550 Utility PSOC Cycle
150A Chr/Dch, 100A Capacity
Cycle 1,000 to 1,500



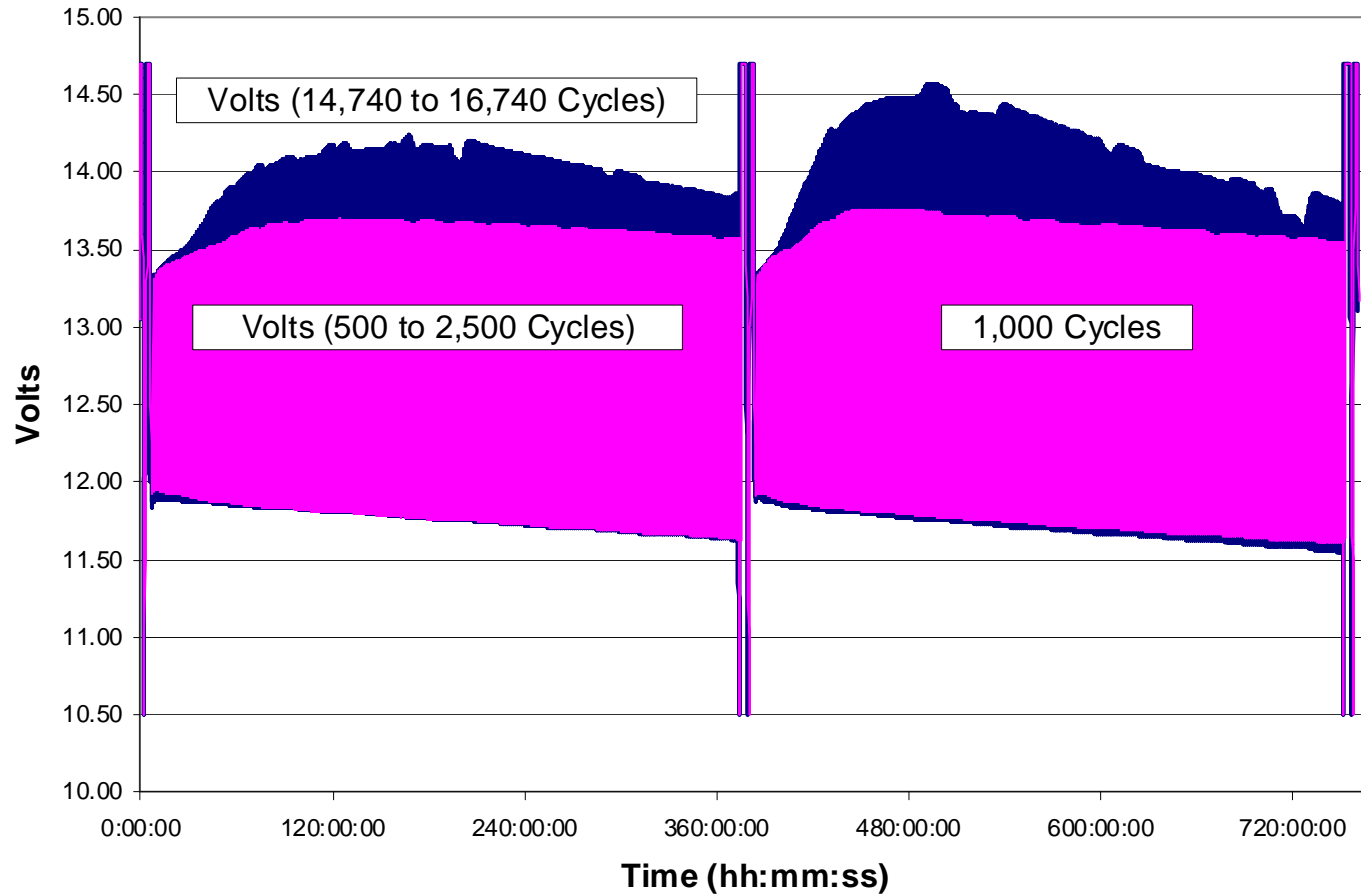
CSIRO/Furukawa UltraBattery (Utility PSOC Cycling)

UltraBattery Utility PSOC Cycling
500 to 2,500 cycles, 1C 6M, 7A Chr/Dch, 25C
Carbon Enhanced VRLA/Supercap



CSIRO/Furukawa UltraBattery (Utility PSOC Cycling)

UltraBattery Utility PSOC Cycling 1,000 Cycles 1C 6M, 7A Chr/Dch

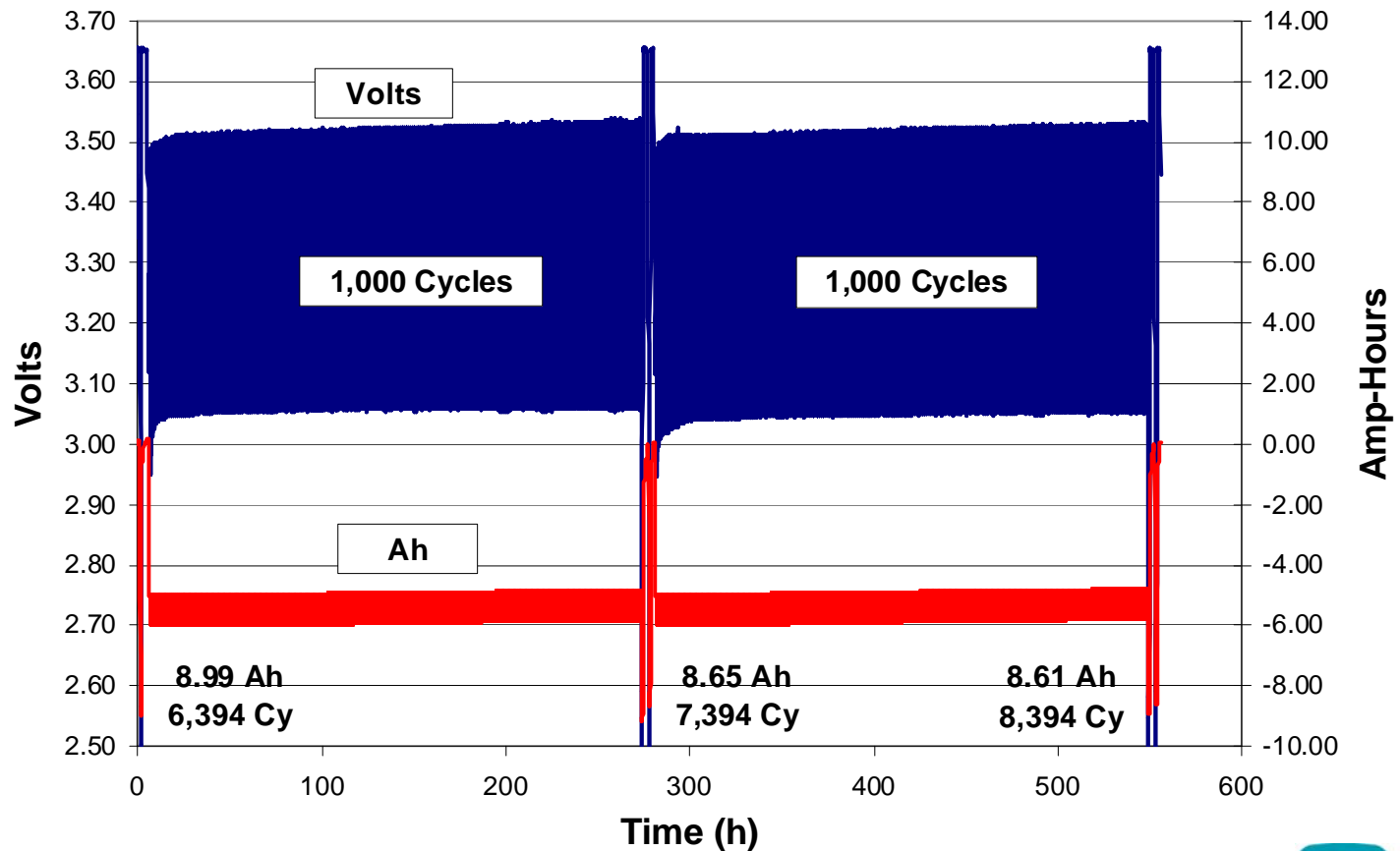


LiFeBatt Li-ion (Li-FePO₄) (Utility PSOC Cycling)

LiFeBatt Utility PSOC Cycle Test

2C 3M (20A) Chr/Dch

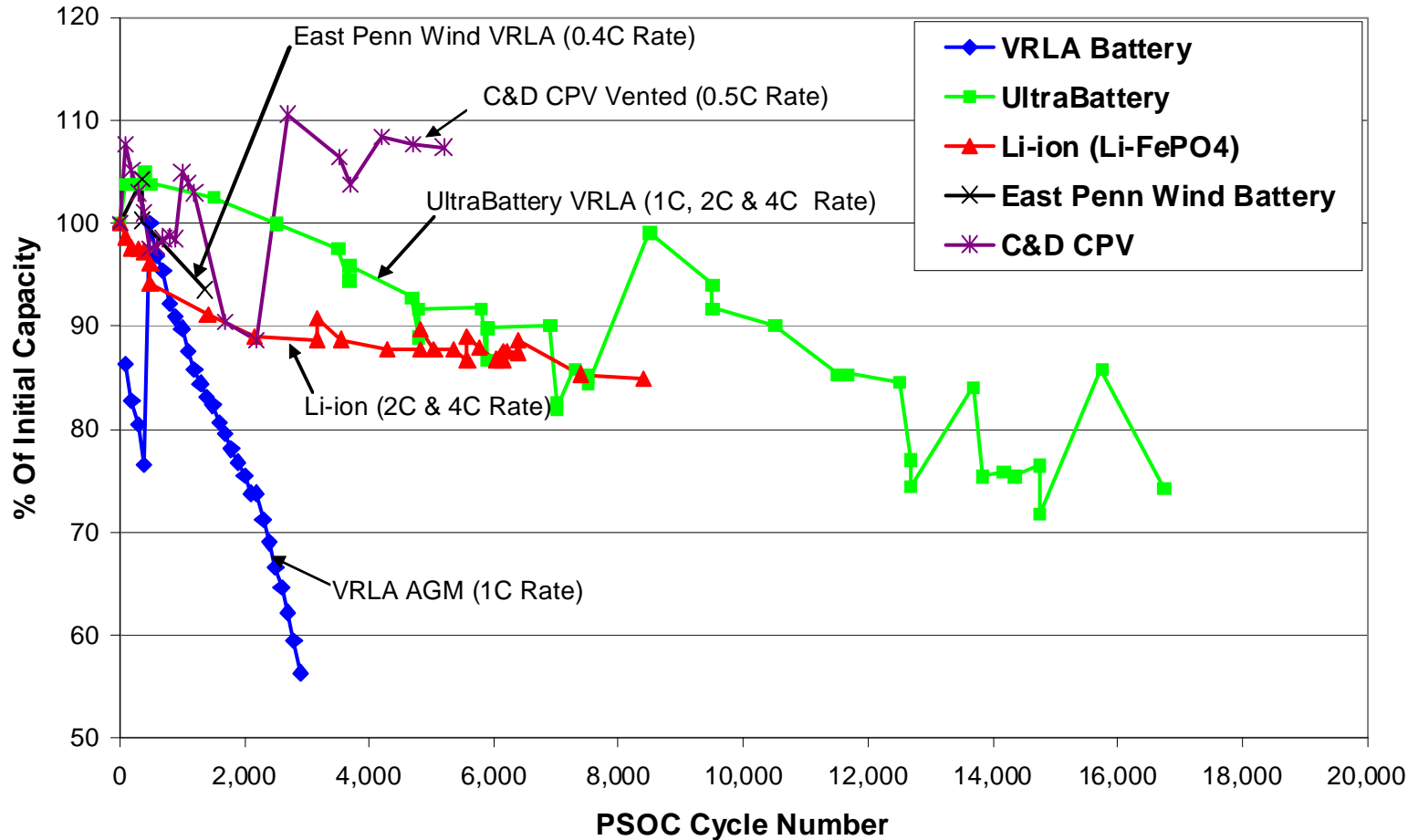
6,394 to 8,394 Utility PSOC Cycles



Summary

Utility PSOC Cycle-Life

Utility PSOC Cycle-Life 10% DOD





Summary

Utility PSOC Cycle-Life

- ◆ **The Sandia utility PSOC cycle-life testing has identified a number of battery technologies with good Utility PSOC cycle-life, such as:**
 - ❖ **UltraBattery (carbon enhanced VRLA with supercap) - up to 4C? rate**
 - ❖ **East Penn (carbon enhanced large format VRLA) – up to 1C rate**
 - ❖ **Li-ion (Li-FePO₄) – up to 4C? rate**
 - ❖ **C&D CPV (Sb+Selenium large format vented) – up to 0.5C rate**
- ◆ **The new carbon enhanced negative electrodes in VRLA batteries have dramatically improved utility PSOC cycle-life up to a factor of 10.**
- ◆ **The new Li-ion (Li-FePO₄) battery technology proposed for hybrid electric vehicles is comparable in utility PSOC cycle-life to the new carbon enhanced VRLA batteries.**
- ◆ **Future work will include completion of testing and may include an energy storage system implementation - such as the wind system at Condon BPA wind farm and/or other demonstrations.**