SAND2011-7984P

Life Cycle Testing and Evaluation of Energy Storage Devices

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Sandia National Laboratories

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SNL Energy Storage System Analysis Laboratory

Providing reliable, independent, third party testing and verification of advanced energy technologies for cell to MW systems

Testing Capabilities Include:

Cell Testing

- Temperature chambers for thermal control
- 100+ cell and battery testing channels:
  - 72 V 1000 A Bitrode (2 Channels)
  - 60 V 200 A Arbin (2 Channels)
  - 36 V 100 A Bitrode (3 Channels)
  - 36 V 25 A Bitrode (5 Channels)
  - 10 V 10 A Arbin (48 Channels)
  - 5 V 3 A Arbin (48 Channels)

72 V 1000 A Bitrode (2 Parallel Channels)

System Testing

- Temperature chambers for thermal control
- New Energy Storage Test Pad (ESTP) expands testing capabilities to include megawatt (MW) scale energy storage. This versatile facility is capable of testing in several configurations for many different applications.

Energy Storage Test Pad (ESTP) (April 2010)

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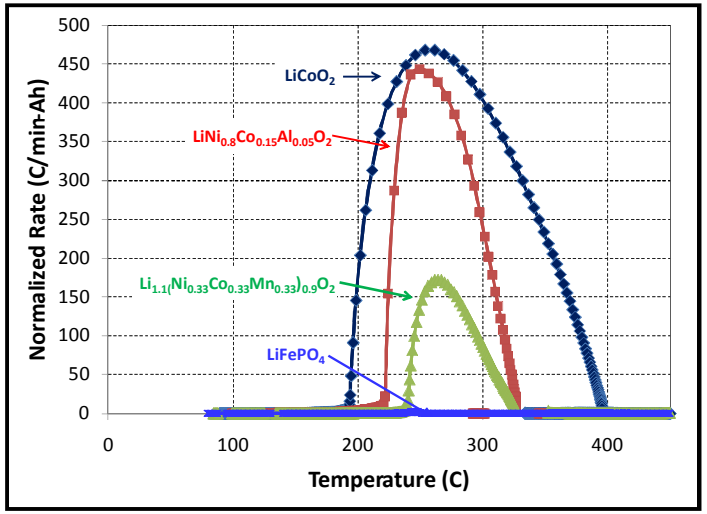
SNL Battery Abuse Testing Laboratory

Battery testing, cell measurements, and materials development to support the development of inherently safe lithium-ion chemistries

- **Safety and abuse tolerance evaluation of energy storage devices from cells to kWh batteries:**
  - **Mechanical abuse**
  - **Thermal abuse**
  - **Electrical abuse**
- **Understanding degradation mechanisms that lead to cell failure**
- **Provide experimental data to support abuse and thermal modeling**
- **Cell prototyping facility for materials development**

Understanding abuse tolerance



50 Wh failure event

5 Wh failure event

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FY 2011 testing activities

Cell Level Testing

East Penn Advanced Battery Cells
(D. Enos 4:00 pm Thur.)

Altairnano Lithium-titanate oxide cells 60 Ah and 11 Ah

International Battery Li-$FePO_4$ Cells

Module Level Testing

East Penn Ultrabattery® Modules

Furukawa Ultrabattery® Modules

RedFlow 10kWh Zn-Br flow battery module
(D. Rose 10:00 am Friday)

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FY11 Testing of Ultrabattery® modules

East Penn

- Both Ultrabattery® designs incorporate a supercapacitor in parallel with the negative electrode in a VRLA 12 cell, 1,000 Ah, 24V battery module.
- Tested with both a 'PV' and 'utility' cycle.

Furukawa

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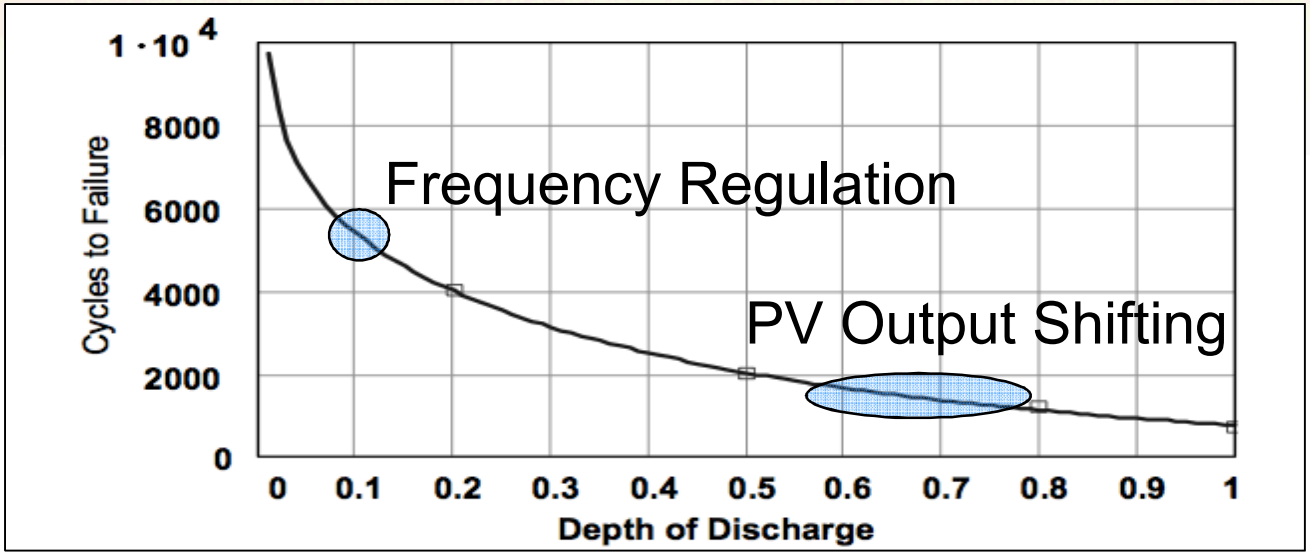
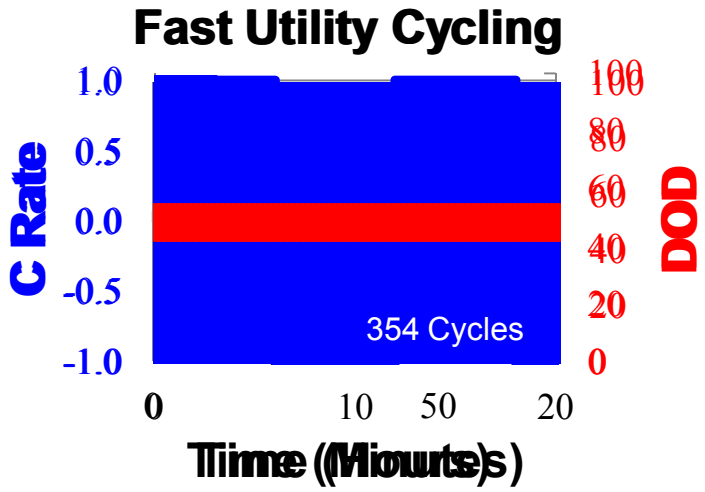
Cycling protocols employed in testing



VRLA Life cycle data *S. Drouilhet, B.L. Johnson, 1997 NREL*



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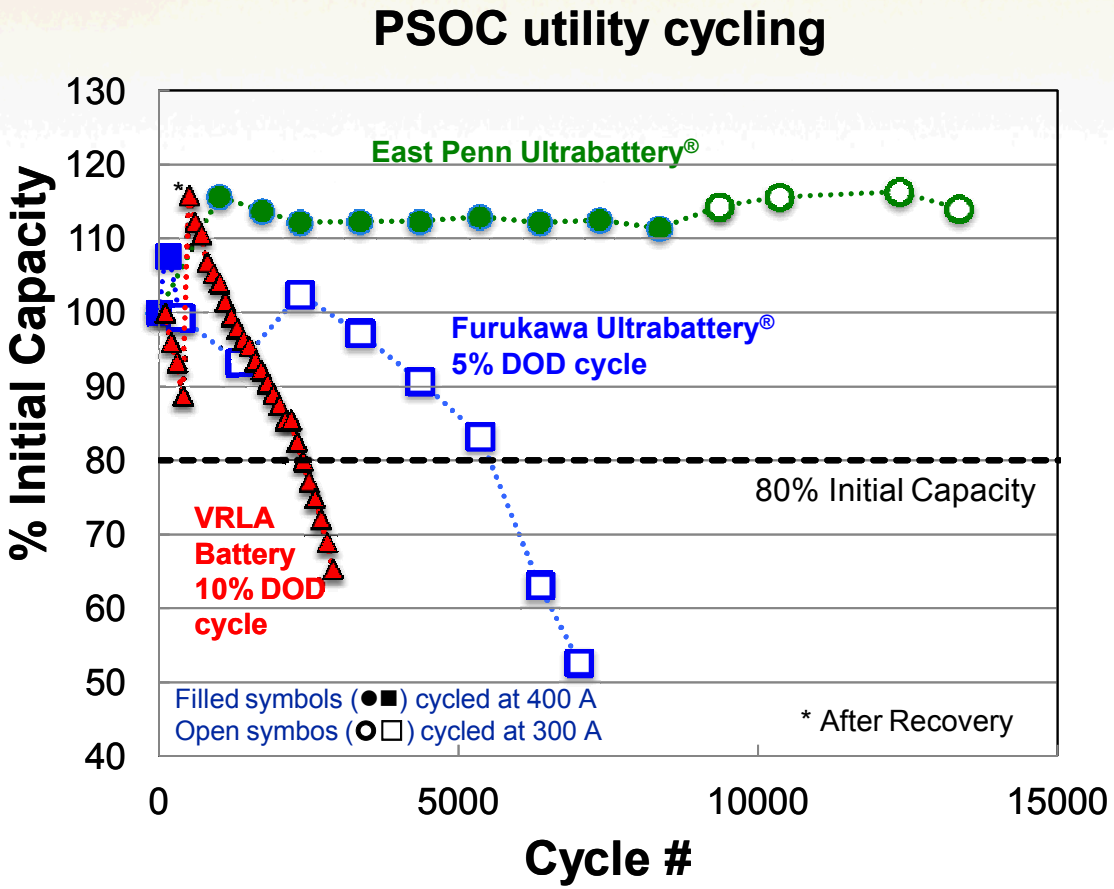
East Penn Ultrabattery® performs much longer than VRLA



Furukawa Ultrabattery® operated at elevated temperatures, leading to thermally activated degradation

East Penn Ultrabattery® shows no capacity loss after more than 13,000 cycles without recovering the battery

- Ultrabatteries® 1,000 AH, 0.4 C and 0.3 C 5% PSOC cycling
- VRLA 30 AH, 1C 10% PSOC cycling
- Temperature rise in Ultrabattery® modules required reducing current for further testing

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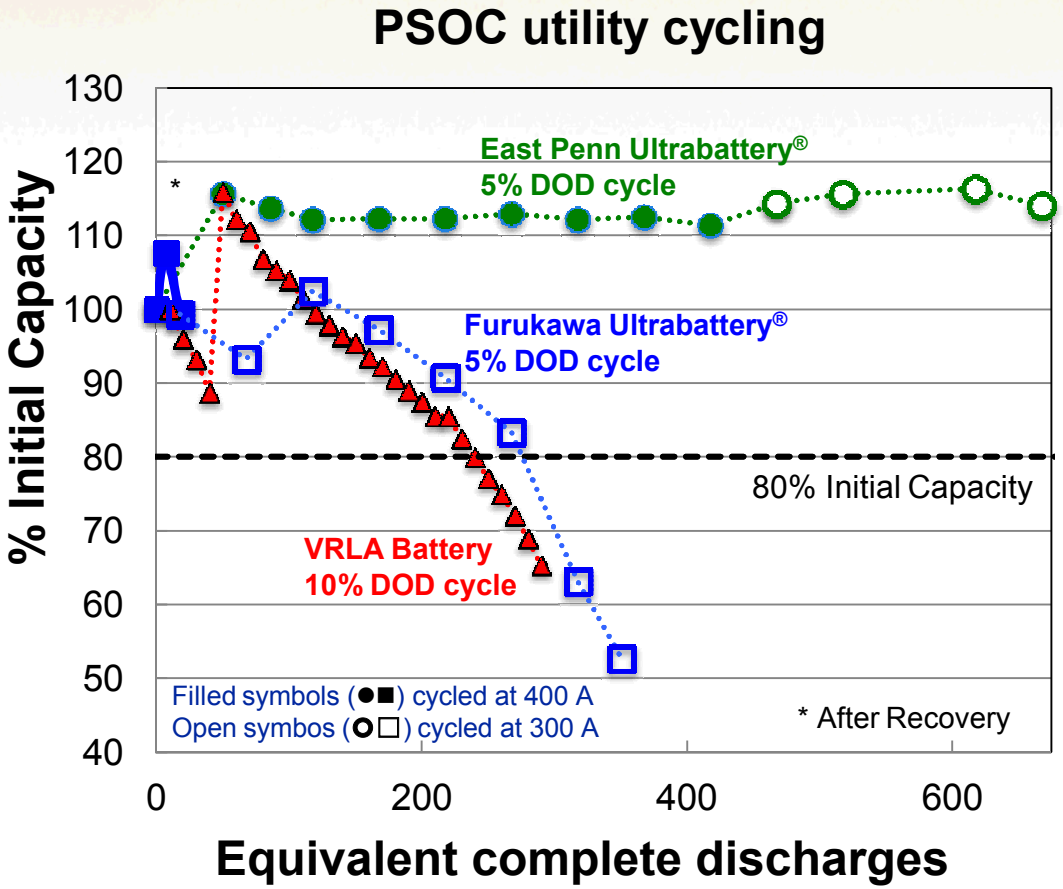
East Penn Ultrabattery® performs much longer than VRLA



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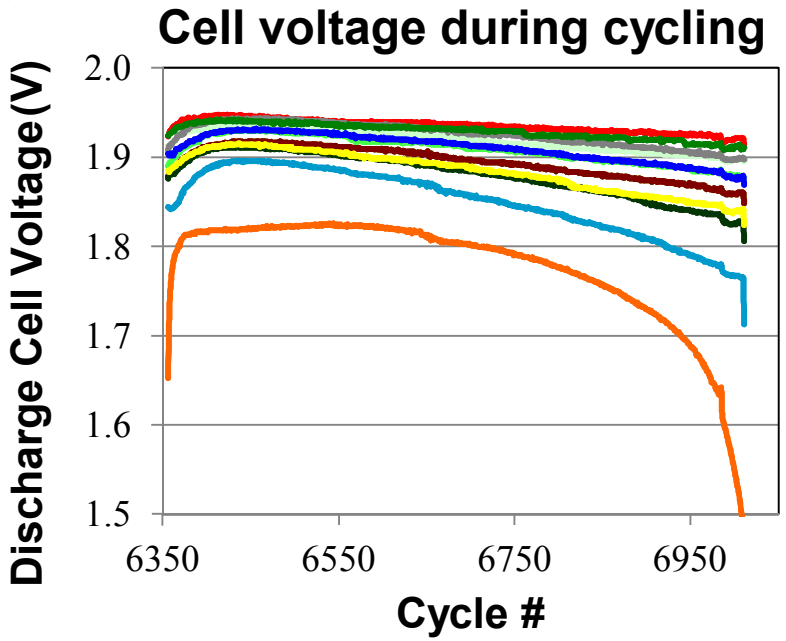
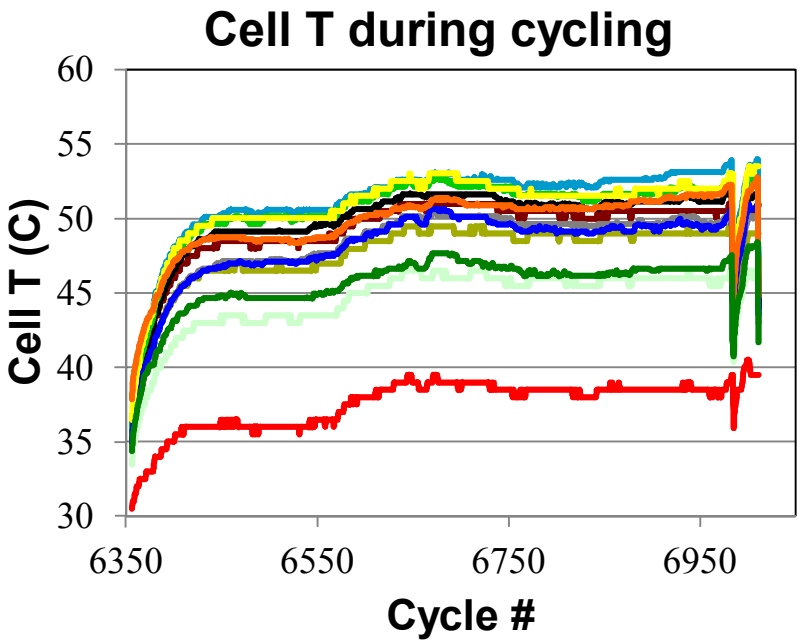
Elevated temperatures occurred in Furukawa Ultrabattery®





Furukawa Ultrabattery® operated at elevated temperatures, leading to thermally activated degradation

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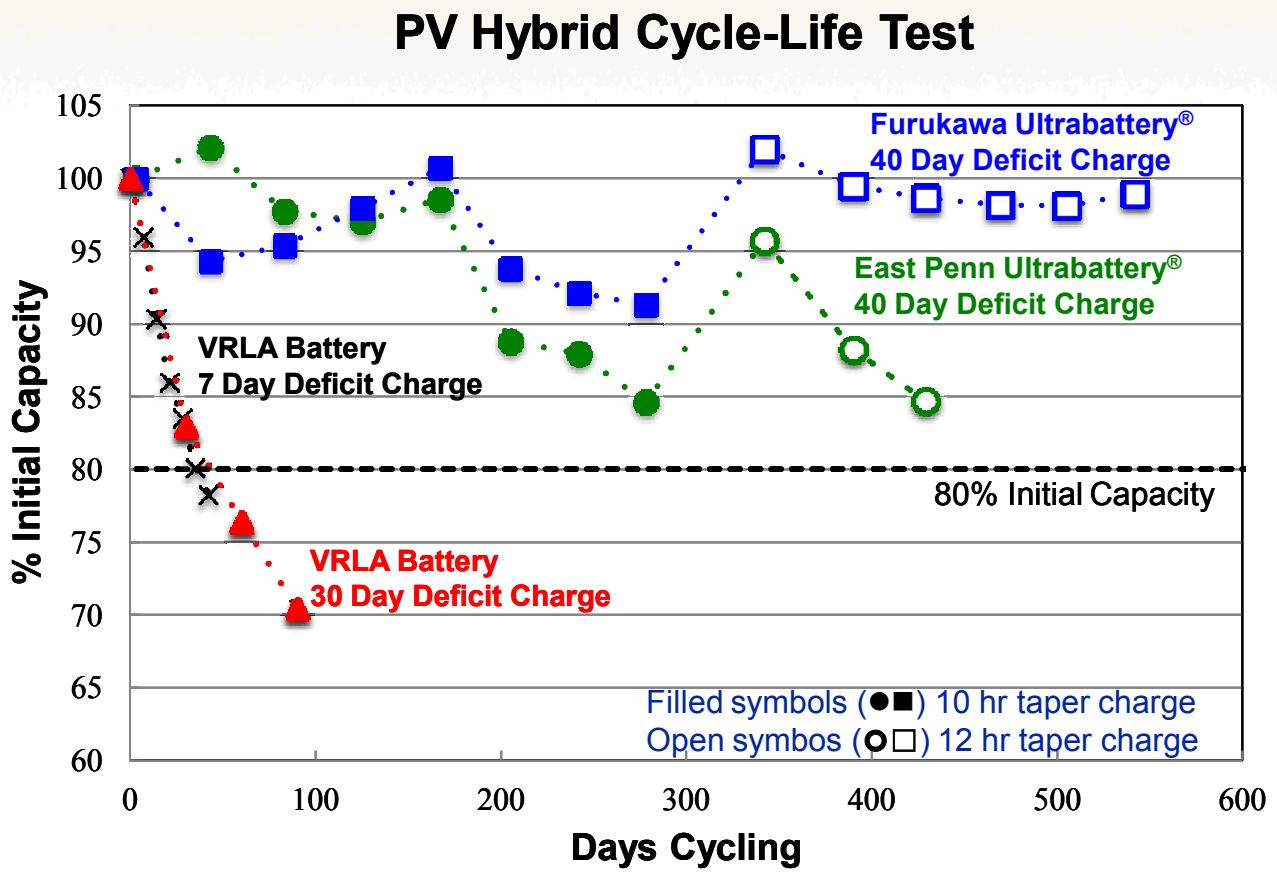
Ultrabatteries® also perform much longer in PV cycling than VRLA



Even at 40 day deficit charge, Ultrabatteries® have performance far surpassing traditional VRLA batteries even with as low as a 7 day deficit charge (without recovery by taper charge).

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Cell level testing underway

FY11 testing on battery cells

- International battery Li-ion $FePO_4$ large format prismatic cells (160 Ah, 3.2 V)

- Altairnano lithium-titanate oxide cells (60 Ah and 11 Ah, 2.3 V)

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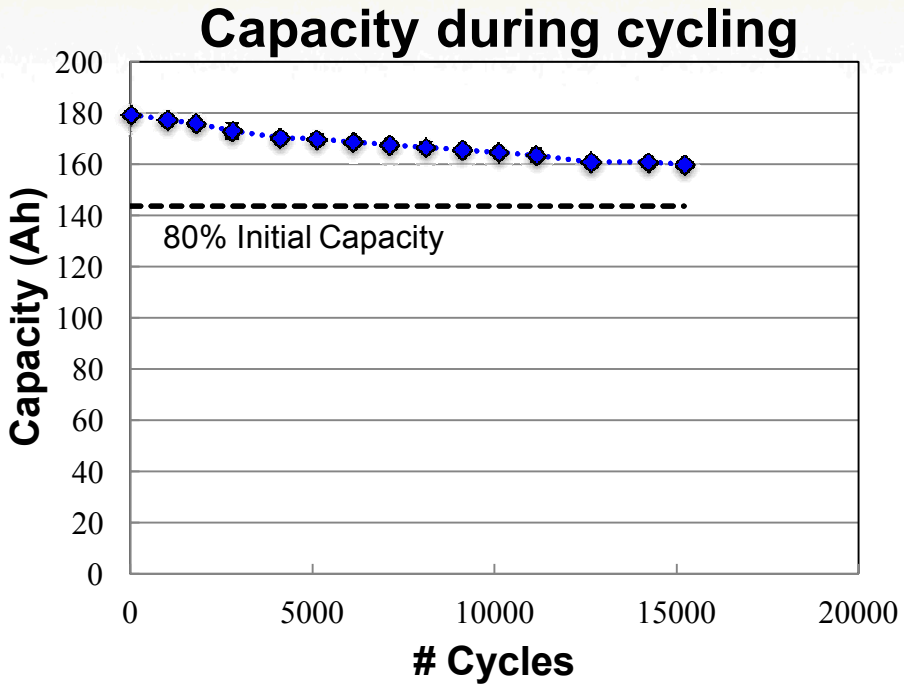
International battery cell capacity remains high after 15K+ cycles

International battery Li-ion $FePO_4$ large format prismatic 160 Ah cells



Two International Battery cells currently operating under utility cycle testing protocol: 10% SOC cycles at 100 A current

11% capacity loss after 15,000+ cycles

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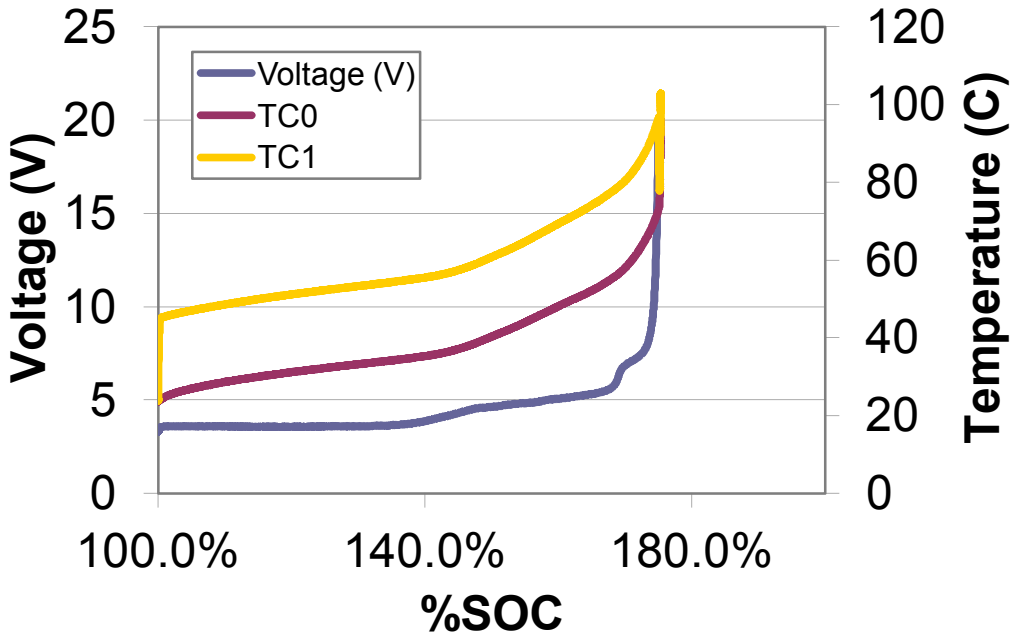
International battery cell performed well under aggressive abuse



Under overcharge abuse the cell vented and the case deformed but remained intact without catastrophic failure and thermal runaway did not occur.

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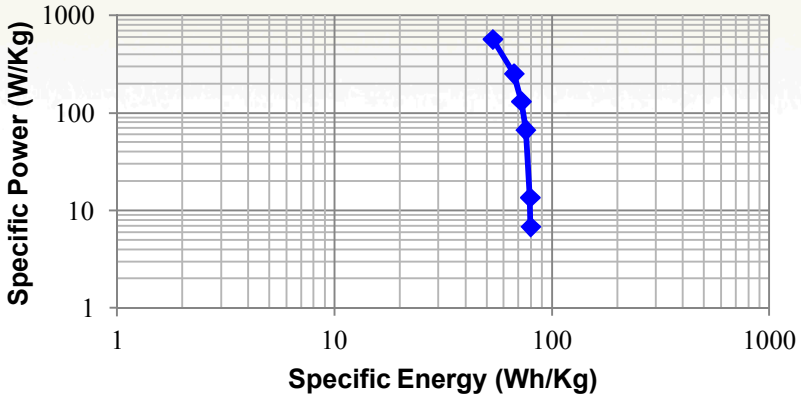
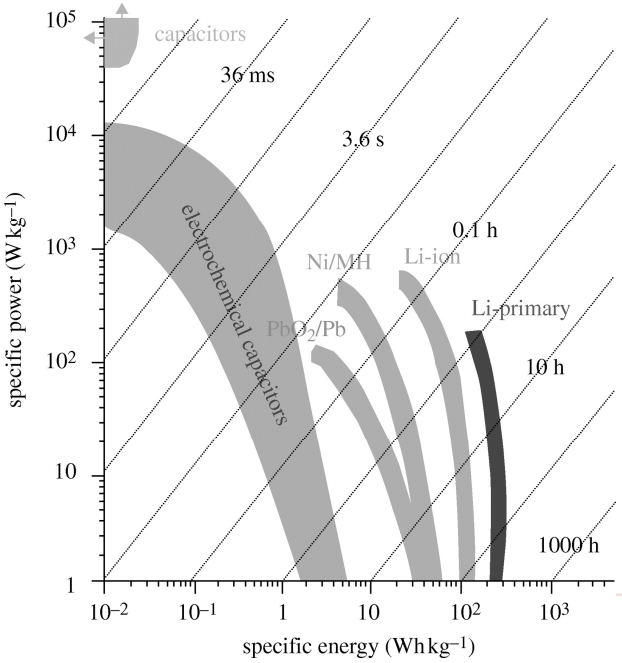
Characterization of Altairnano cells

Initial Capacity	12.58 ± 0.06 Ah
3 Month Self-Discharge	4.82 ± 0.03%

60 Ah cells pulse charge and discharged testing used to develop battery impedance models for power electronics
(D. Fregosi Poster Session)

FY12 Planned Evaluation
Hybrid Pulse Power Tests
Utility PSOC Pulse Cycling
Abuse Testing
Extend testing to 60Ah cells





Simon P , Gogotsi Y Phil. Trans. R. Soc. A 2010;368:3457-3467

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Summary/conclusions to date

- East Penn Ultrabattery® performs best in fast utility cycling, completing over 13,000 5% cycles with no loss in capacity.
- Furukawa Ultrabattery® performs best under deep DOD slow PV cycling, even at 40 day deficit charging.
- International Li-ion $FePO_4$ cells have lost 11% of the initial capacity after over 15,000 10% cycles.
- Altairnano Li-titanate oxide cells have had initial characterization and will be cycled in FY12.

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FY-12 testing activities

- Complete cycling of UltraBattery® modules and International Li-$FePO_4$ Cells
  - Continue Utility Cycle Test; end condition of 20% capacity loss or 365 days cycled
- Utility Cycle Altairnano Li-Titanate Oxide Cell
  - Utility Cycle Test end condition of 20% capacity loss or 1 yr is complete
- Bring flow battery testing online with:
  - Red Flow Zn-Br modules
  - CCNY Ni-Zn modules

A RedFlow 5 kW 10 kWh zinc-bromine flow battery module.

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Acknowledgments

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– *Thank you to collaborating battery manufacturers*

ALTAIR NANO

international battery

redflow advanced energy storage

Deka EAST PENN manufacturing co., inc.

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