SAND2015-7750C

Performance and Life Cycle Analysis of Energy Storage Devices

Summer Ferreira and Wes Baca

September 23, 2015

Sandia National Laboratories

Exceptional service in the national interest

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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SNL Energy Storage System Analysis Laboratory

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Mission:

Develop and implement analytics to assess the performance and life of energy storage technologies to advance the adoption of stationary storage solutions.

Problem:

- Current testing methods differ by lab, manufacturer and customer leading to excessive and “apples to oranges” results
- Life of storage technologies uncertain yet critical to validating economics
- Potential storage customers, i.e. utilities, without experience in storage, are reluctant consumers.

Approach:

Develop advances through:

- Test protocols, using direct research and standards activities
- high precision testing spun off as an ARPA-E grant recipient in 2013

Provide ongoing:

- expertise in testing programs to customers
- verification of specific technologies

Participation in Standards Activities

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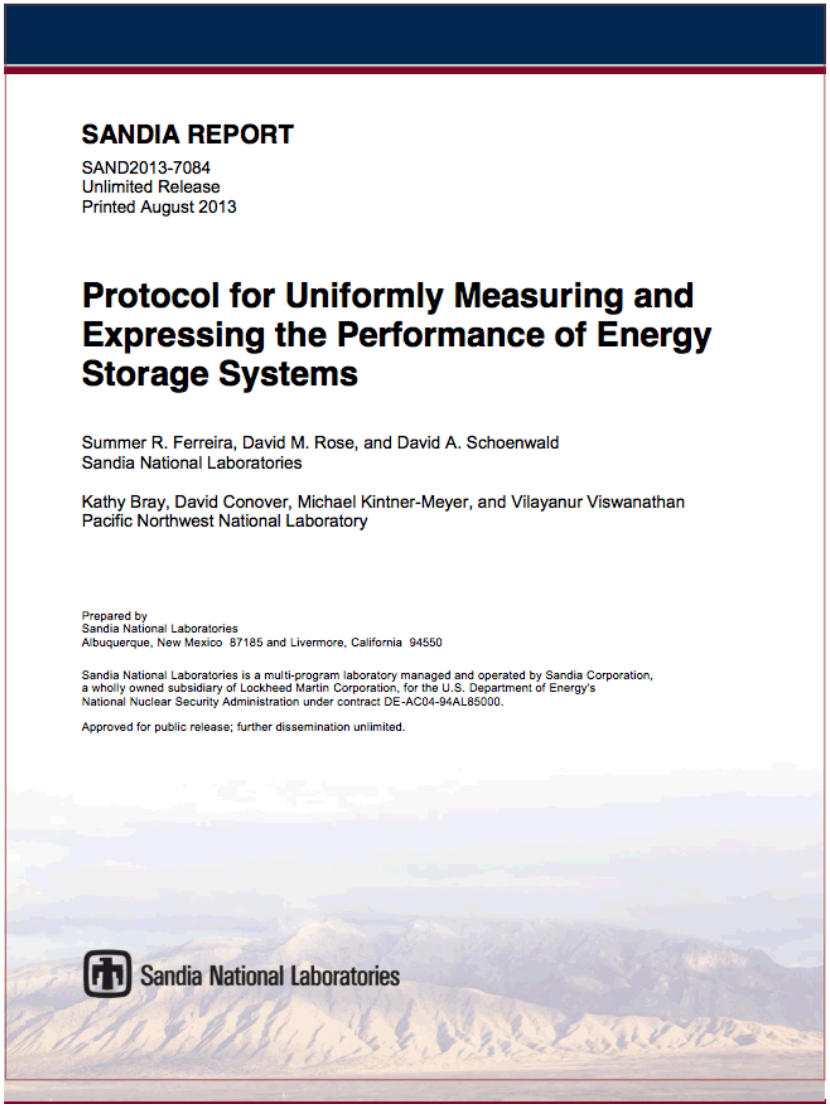
DOE Performance Protocol

- Included broad input from utility and manufacturing side.
- Initial testing and comments are welcome.

In the last two years there has been a call for standard language and testing, with definitions. In response standards development has been a large priority.



SANDIA REPORT

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Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems

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http://www.sandia.gov/ess/pubs_tech.html

SNL Energy Storage System Analysis Laboratory

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

Testing Capabilities Include:

- Expertise to design test plans to fit technologies and their potential applications
- OE supported testing
- CRADA opportunities
- WFO arrangements

Cell, Battery and Module Testing

- 14 channels from 36 V, 25 A to 72 V, 1000 A for battery to module-scale tests
- Over 125 channels; 0 V to 10 V, 3 A to 100+ A for cell tests

72 V 1000 A Bitrode (2 Channels)

Energy Storage Test Pad (ESTP)

System Testing

- Up to 1 MW, 480 VAC, 3 phase
- 1 MW/1 MVAR load bank

SNL **Energy Storage System Analysis Laboratory**

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Analysis Laboratory capabilities include:

- 125+ Cell test channels: 0 V to 10 V, 3 A to 100+ A
- 14 Battery test channels: 36 V, 25 A to 72 V, 1000 A

Expanded Capabilities in FY ’12:

- **34 test channels from 5 V – 60 V to 15 A – 500 A**
- **Potentiostat/galvanostats for spectral impedance**
- **Multimeters, shunts and power supply for high precision testing**
- **Temperature chambers**
- **IR camera**

Expanded number of test channels by 25% including other lab capabilities

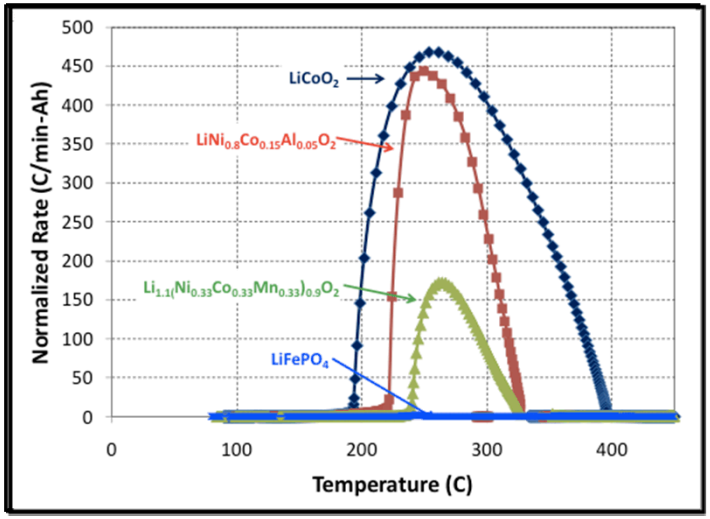
72 V 1000 A Bitrode (2 Parallel Channels)

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

FY 2015 testing activities

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Conventional Li-Ion

Altairnano Lithium-titanate
Gen I 11AH

Altairnano Lithium-titanate
Gen II 13 AH

A123 14 Ah pouch

Advanced Technologies

AQUION ENERGY

ery

Grid
Si anod

Gridtential™

FY 2016 Projects

Sandia National Laboratories

http://www.sandia.gov/batterytesting/

Apply for testing partnerships: Consulting, analysis and verification of power sources including: cells, batteries, systems, and fielded projects

Advanced Energy Storage Device Testing

- Overview
- Capabilities
- Technical Staff
- Safety
- Making a Request for Testing
- Testing Calendar
- Standard Testing Protocols
- FAQs

Life Cycle Testing and Evaluation of Energy Storage Devices Overview SAND2014-18823O [4mb pdf]

The 2015 fall application will open October 5th and close October 25th for energy storage analysis proposals.

The database is currently open for *FAST-Track* Proposals
These should be limited in scope and have strong justification for expedited processing.

REQUEST BATTERY TESTING

Request Testing

CALENDAR

View ESTP Calendar

Contact:
Project Lead
Dr. Summer Ferreira
505.844.4864

Publications

Sandia Reports EXIT

Related Links

Energy Storage Systems

FY 2015 testing activities

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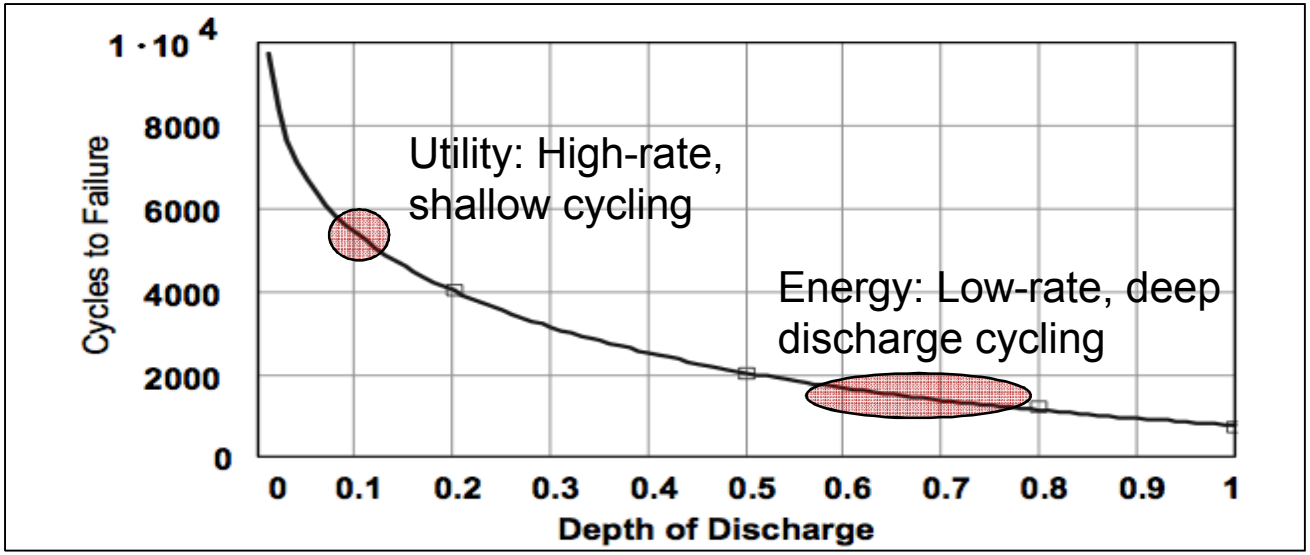
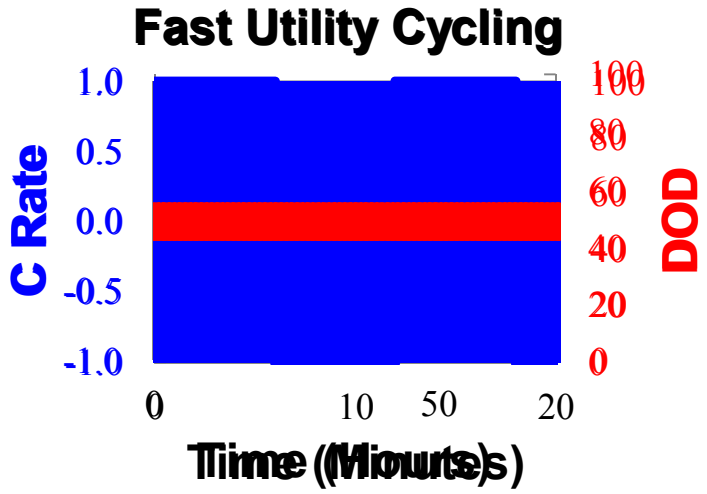
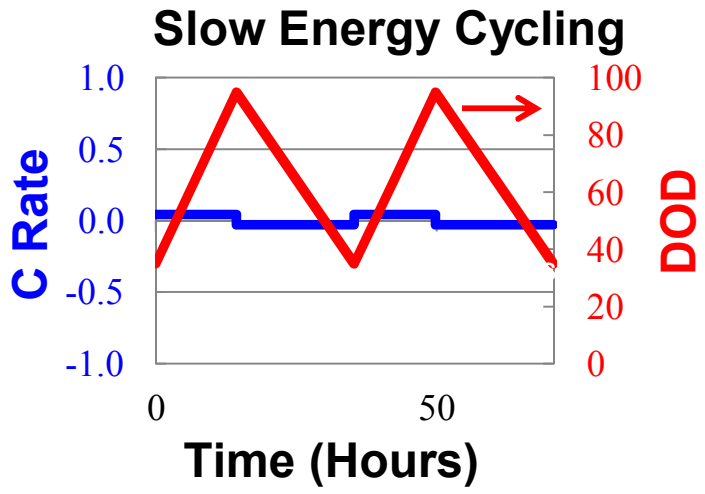
Li-Ion Technology	Specs and Chemistry		Advanced Technology	Specs and Chemistry
Lithium Titinate Oxide  ALTAIR NANO 	**Anode:** Nano-LTO spinel	**Cathode:** 11Ah $LiCoO_2$ and $LiCoNiAlO_2$ 13Ah $LiCoNiMnO_2$	Aquious Hybrid Ion  AQUION ENERGY	Activated carbon anode MnO spinel Cathode
Lithium Iron Phosphate  A123 SYSTEMS		Doped nano-LFP EESAT Tuesday	Bipolar Pb-Acid  Gridtential	Si wafers substrate Bipolar Configuration

Cycling protocols employed in testing



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





LTO Characterization

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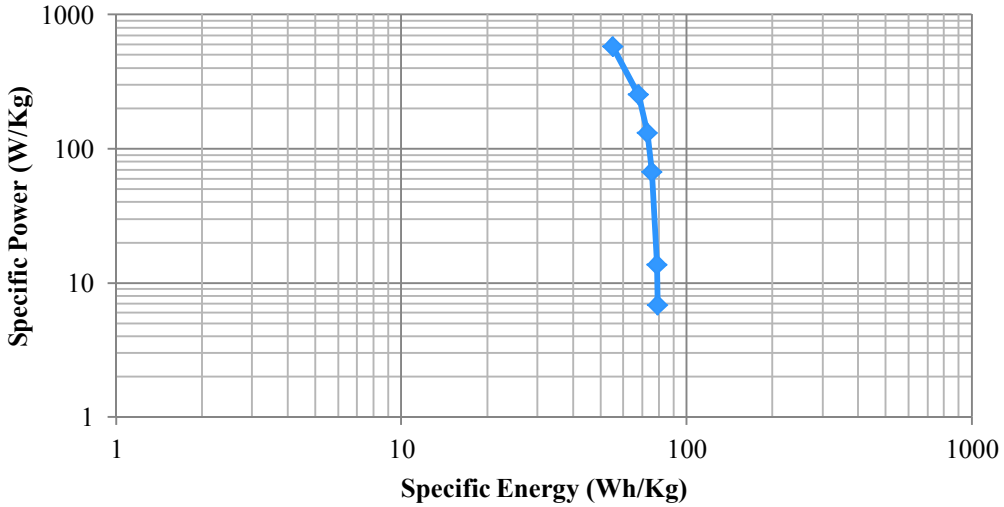
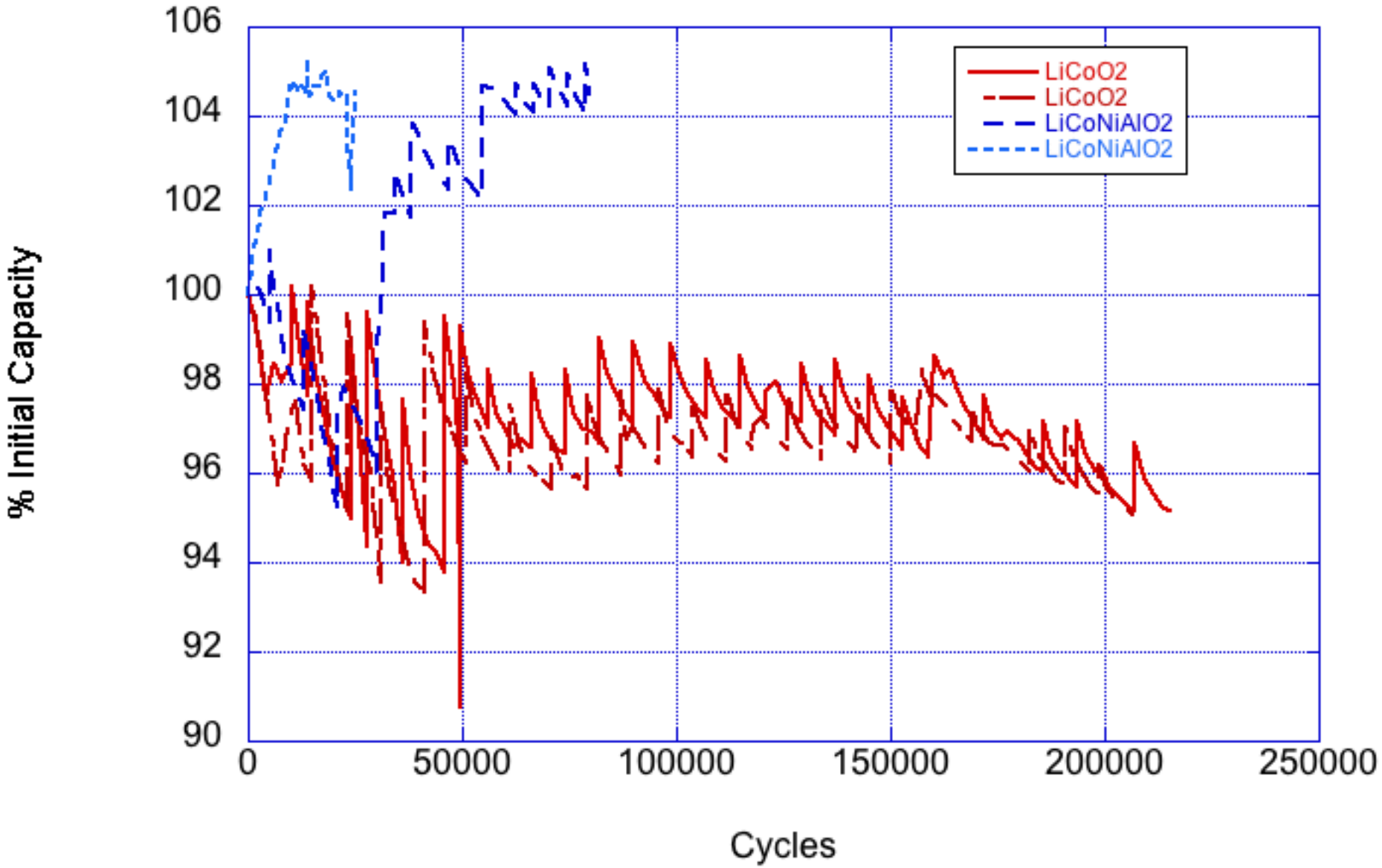
LTO/ $LiCoO_2$ and $LiCoNiAlO_2$

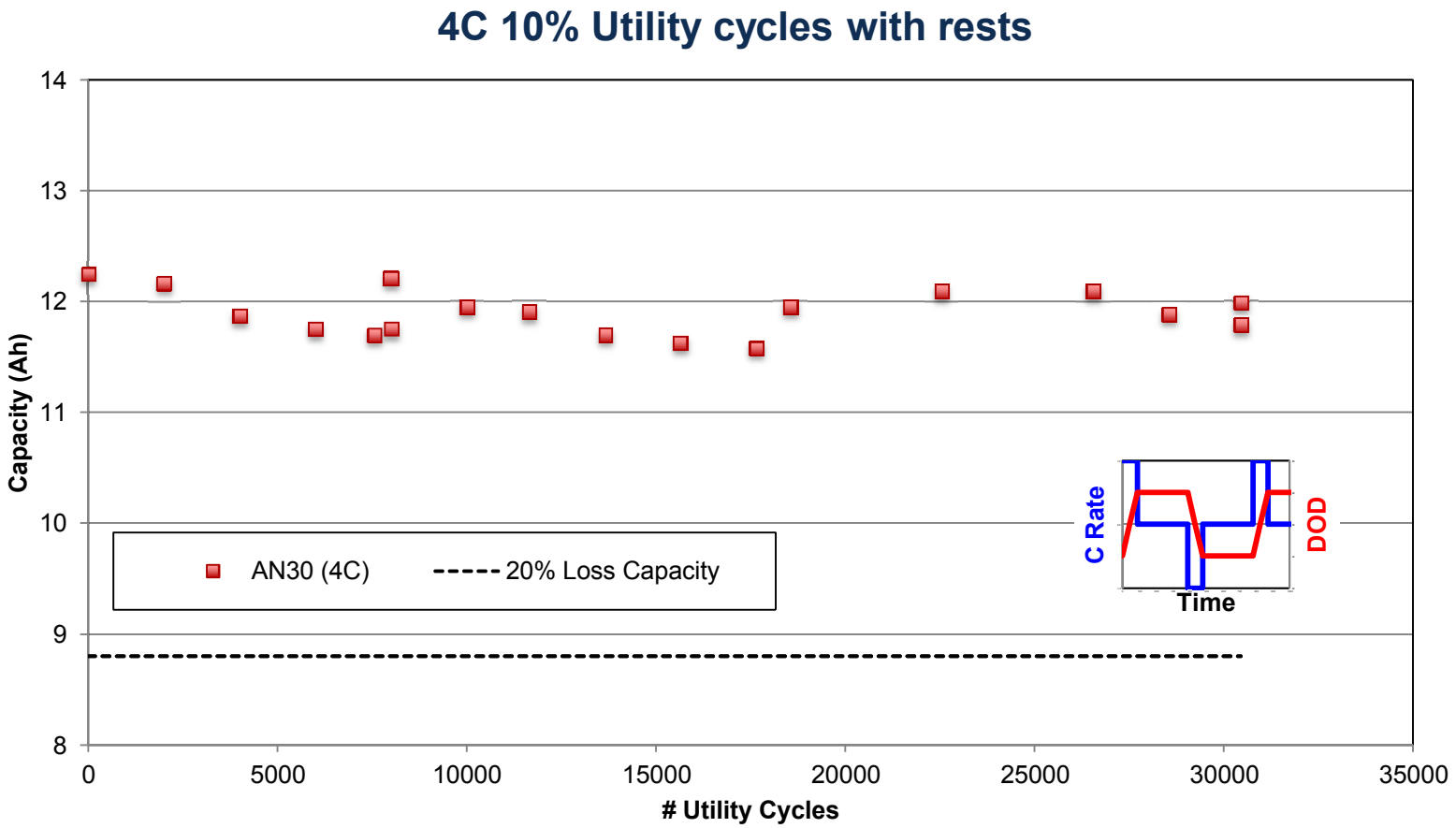
	Average	Standard Deviation
Capacity (Ah)	12.58	0.06
Voc (V)	2.531	0.006
R (μΩ)	2642	147
Mass (kg)	0.367	0.001
3 Month Self Discharge	4.825%	0.025%



LTO Lifecycle testing continuing



LTO Lifecycle testing continuing



Equivalent throughput energy of 3,000 full discharge cycles

~2% capacity loss after 30K+ cycles

LTO Lifecycle testing

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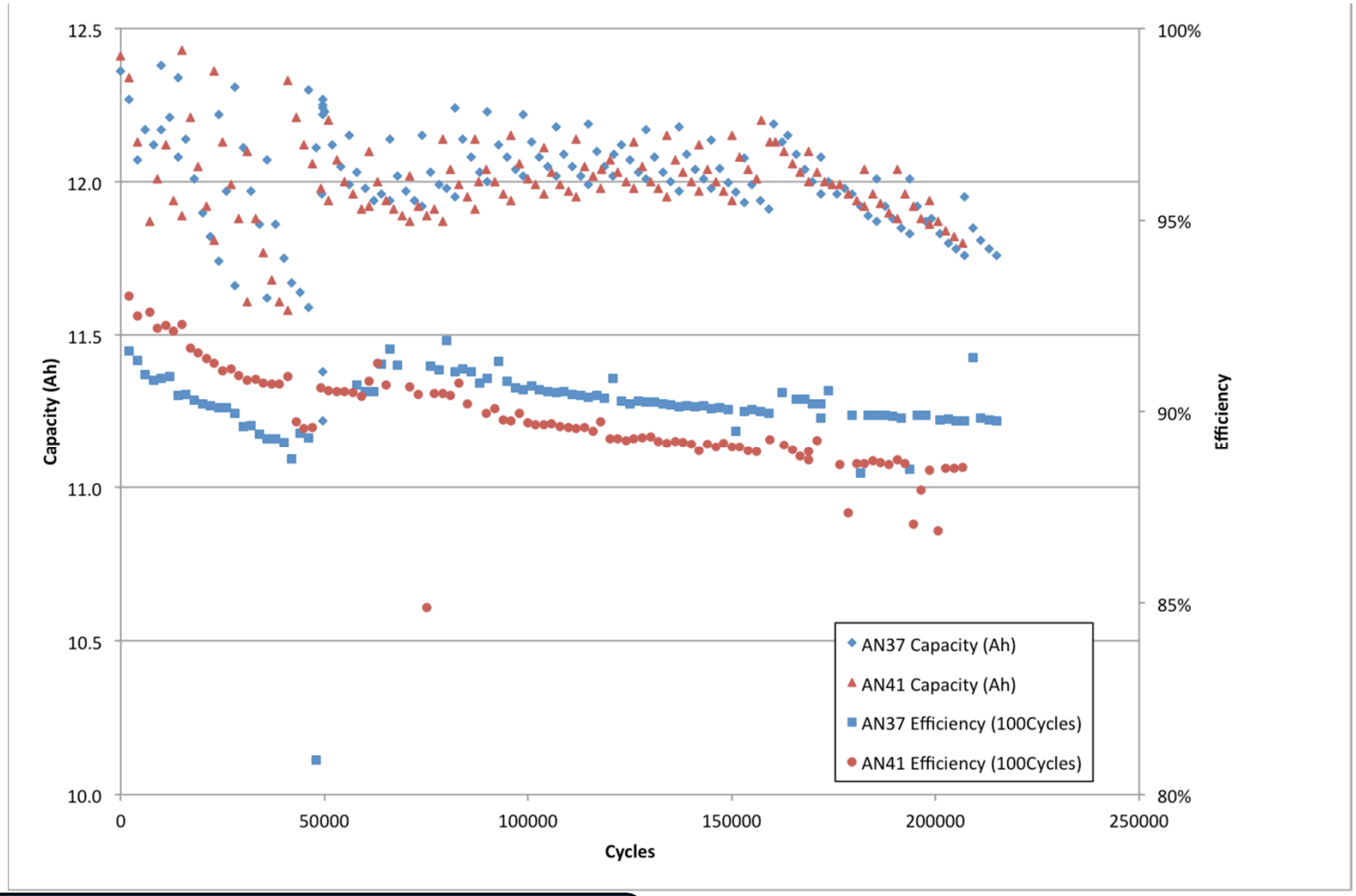
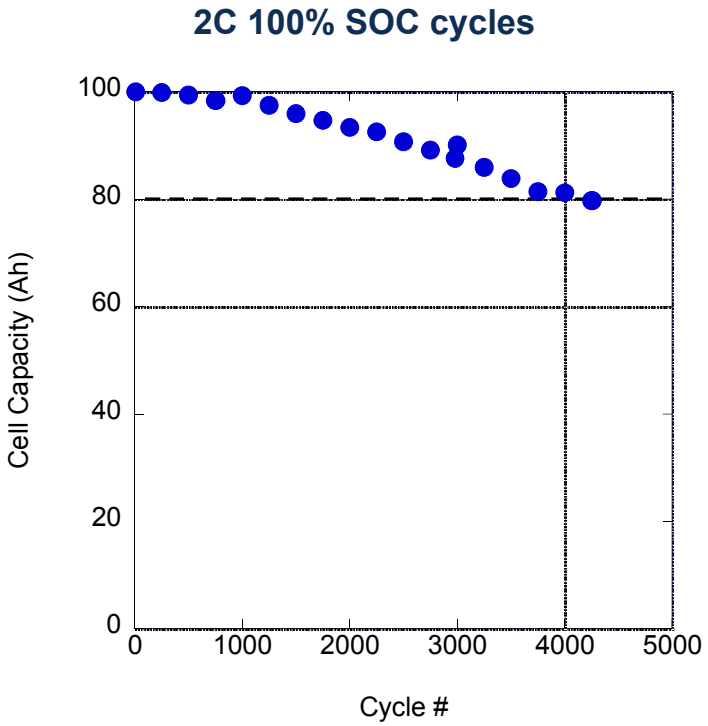
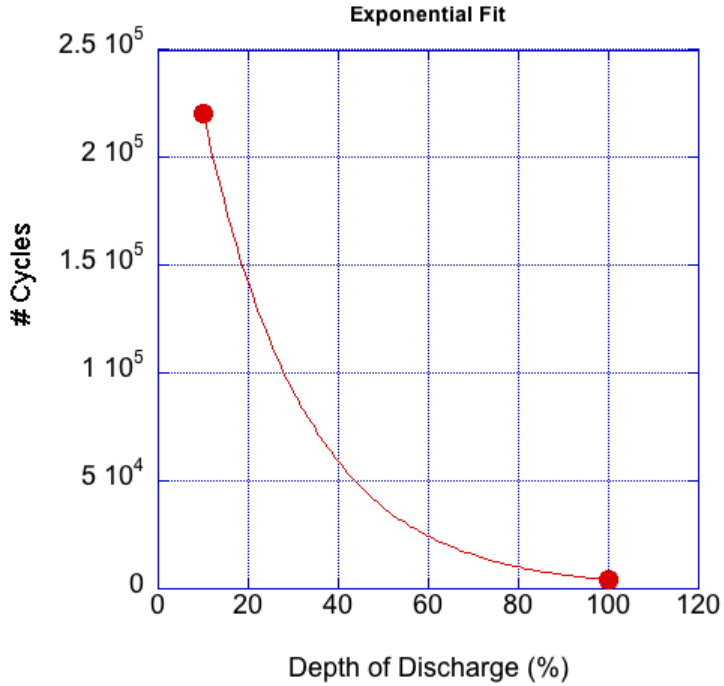


Equivalent throughput energy of 20,000 full discharge cycles

~3% capacity loss after 100K+ cycles

LTO Lifecycle testing





Depth of Discharge	# Cycles	% Throughput
10%	220,000+ (5% Cap loss)	2,200,000%
100%	4200	420,000%

AHI Battery PSOC tests

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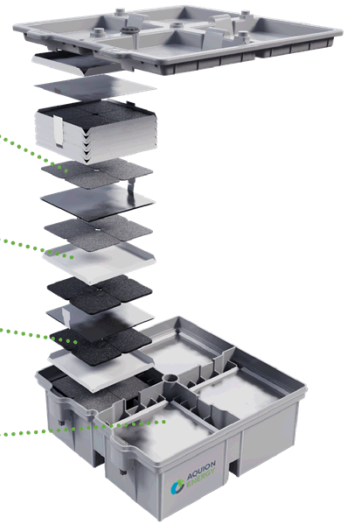
Design

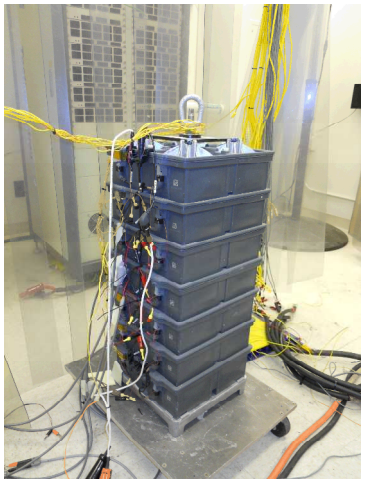
+ CATHODE
Manganese Oxide spinel structure hosts intercalation reaction

+ SEPARATOR
Non-woven cellulosic material

+ ANODE
Activated carbon composite with pseudocapacitive and intercalation reactions

+ ELECTROLYTE
Sodium sulfate in an aqueous solution





Performance metrics

PRODUCT INFORMATION

Time (h)	2	4	8	12	20
Current (A)	9.5	6.1	3.9	3.0	2.1
Capacity (Ah)	19	24.4	31.2	36	42
Energy (Wh)	680	991	1,300	1,480	1,700

Constant Current Discharge, 30°C

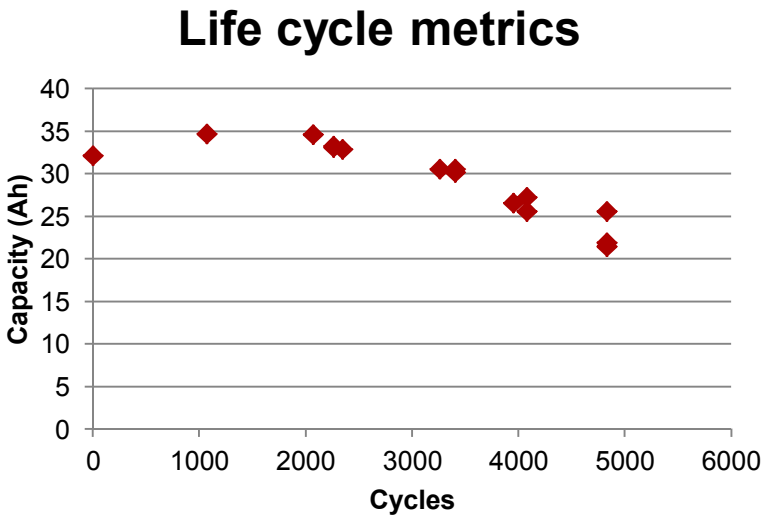
Voltage Range	35 to 52 Vdc
Nominal Capacity	42 Ah at C/20, 30°C
Nominal Energy	1,700 Wh at C/20, 30°C

OPERATION & PERFORMANCE

Cycle Life	>3,000 cycles
Operating Temperature Range	-5 to 40°C
Round Trip DC Efficiency	>85% at C/20 rate, 30°C
Charge / Discharge Modes	CC, CP, CV, AC ripple tolerant

Discharge rate (A)	Discharge capacity (Ah)
1	42.8
2	38.1
4	29.4
6	25.8
8	19.3
9.9	21.6
15	12

Life cycle:



Bipolar Pb-Acid Analysis

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Alpha

Battery Type: VRLA AGM

Nominal Voltage: 6V (3 cells)

Nominal Power (15 min): 20W/Cell

Rated Capacity:

20-hr (0.36A to 5.25V): 9.6 Ah
10-hr (0.65A to 5.25V): 8.1 Ah
5-hr (0.9A to 5.10V): 7.0 Ah
2-hr (2.7A to 4.80V): 5.4 Ah

Approximate Weight:
4.60 lbs (2.09 kg)

Internal Resistance (approx.):
45 milliohms

Max Discharge Current (5 sec): 30 A

Max Short-Duration Discharge Current (0.1 sec): 100 A

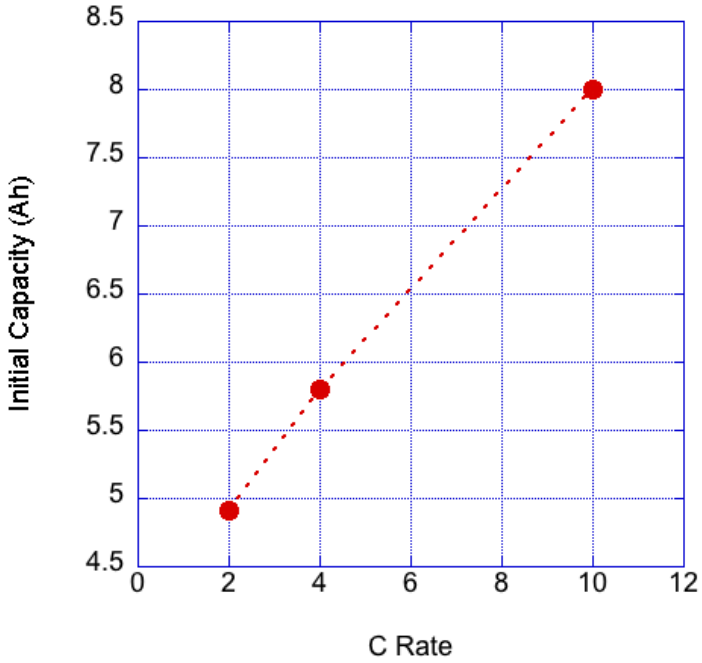
Charging Voltage @ 68°F (20°C)
Standby Use: 2.25V/Cell
Cycle Use: 2.45V/Cell

Maximum Charge Current: 1.8A

Case: ABS Plastic

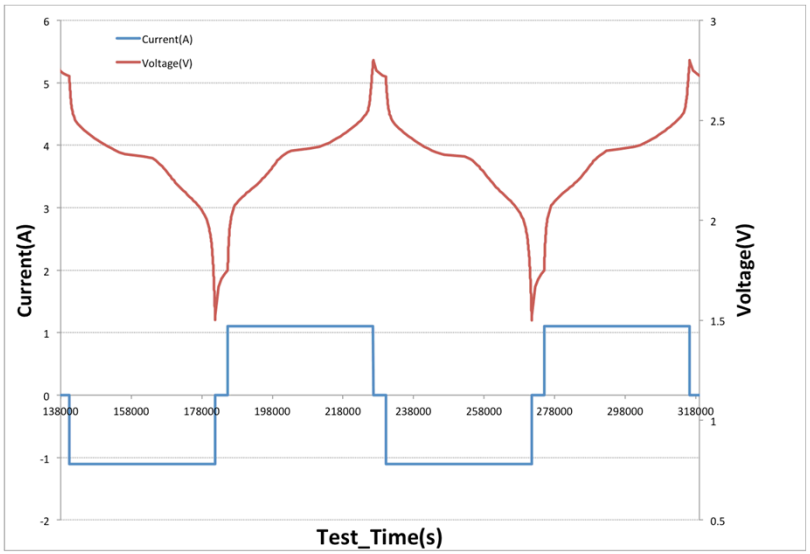
Dimensions (Tolerances are +/- 0.5mm):
L: 2.27 in (57.7 mm)
W: 5.20 in (132 mm)
H: 6.38 in (162 mm)

Specific Gravity at 100% SOC: 1.26



High Precision Commercial Tester Development

- With Arbin Instruments and Ford Motor company received an ARPA-E grant to develop and validate a **commercial high precision and high power battery tester**
- Two prototype testers in house
- Goal is fast prognostics of battery life from high precision measurements
- **Available for projects through collaboration**



Summary

- DOE pre-protocol report released. Activities in developing and using test regimes is central to our mission. More aggressive tests, and varied protocols including stacked testing under investigation with initial promising results for stacked waveform testing.
- Third party validation and long term cycling continues for a variety of chemistries considered for stationary applications on semiannual basis.
- Longer lifecycles demand efforts in prognostics. Expanded activities in high precision testing supported by outside funds and an objective for FY'16.

Contact Information:

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