Evaluation of Lead-Carbon Devices for Utility Applications

DOE Energy Storage Program
Sandia Contract 659172

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DOE Peer Review

September 29, 2008

Washington D.C.

Funding: Congressional ear-mark.

How brands take shape™

Program Overview

Phase One: *Explore possible advantages to carbon in energy storage*

- Evaluate lead based energy storage technologies
- Develop carbon for lead based technologies
  - Increase cycle life for some applications
  - Improve charging characteristics

Phase Two: *Investigate performance benefit and refine understanding*

- Verify performance
- Focus on material properties/mechanisms that result in performance benefit

Phase Three: *Determine best technology for application needs*

- Select best technology for 1 MW, 1 MWh utility demonstration

Program Participants

MeadWestvaco
Charleston, SC
Carbon Development
Lab and Battery Testing

Sandia National Laboratories
Albuquerque, NM
Nancy Clark
Tom Hund
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Battery Testing and Verification
Analytical Support

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Springfield, MO
Frank Fleming
Bob Shirk
Michelle Cantrell
Manufacturing and Battery Testing
Battery Expertise

Washington, DC
Imre Gyuk
Program Sponsor

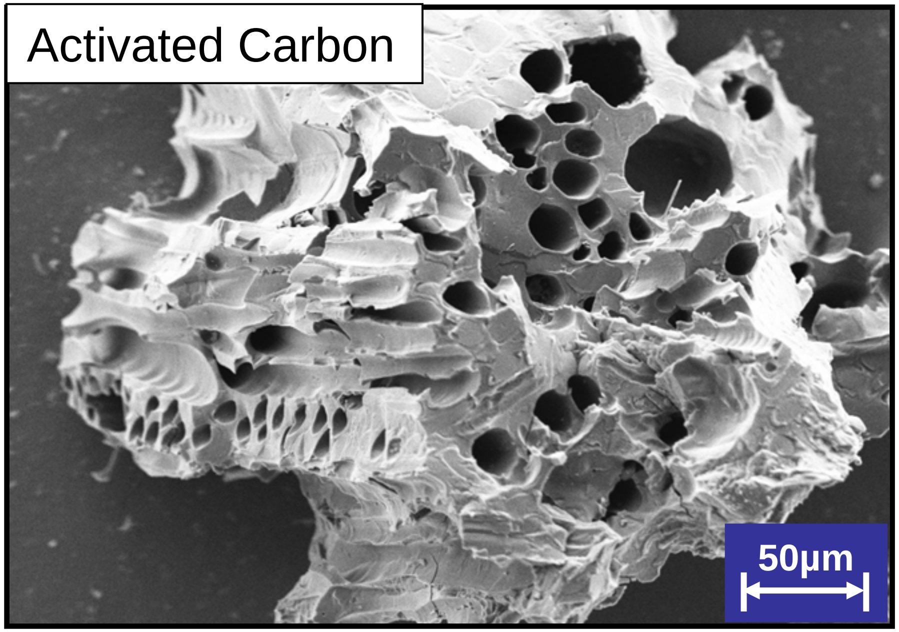
battery energy
power solutions for tomorrow's world
Fairfield, Australia
Dave Brown
Gel Battery Manufacturing

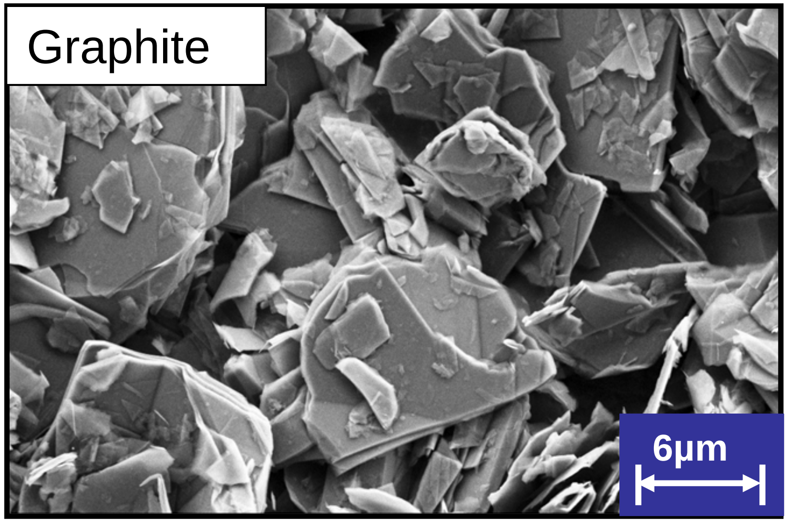
JBI Corporation
Genoa, OH
Joe Badger
Battery Testing (Std. Apps.)

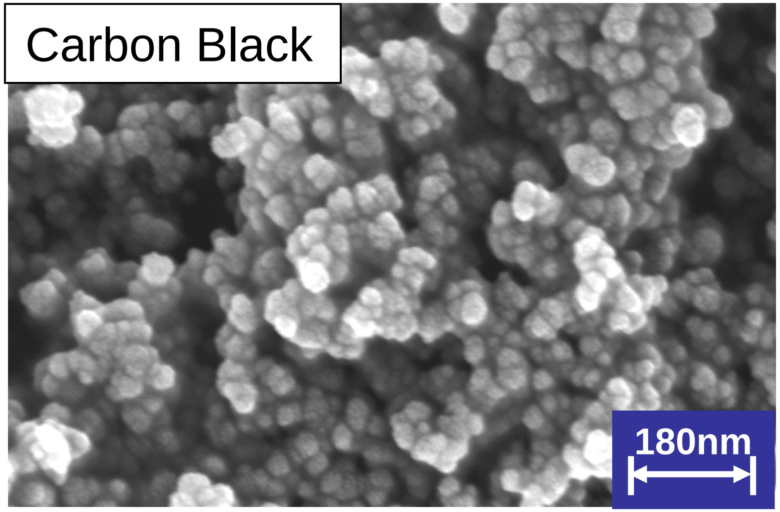
Hammond Expanders
A Division of HAMMOND GROUP, INC.
Hammond, IN
Matthew Spence
David Boden
Expander Development

Electric Transportation Applications
Phoenix, AZ
Don Karner
Russell Newnham
Battery Testing (Utility/Cycling)

Carbon Types







Phase 2 Previous Findings

NorthStar AGM Batteries

- No clear performance improvements from the carbon modifications tested or carbon purification

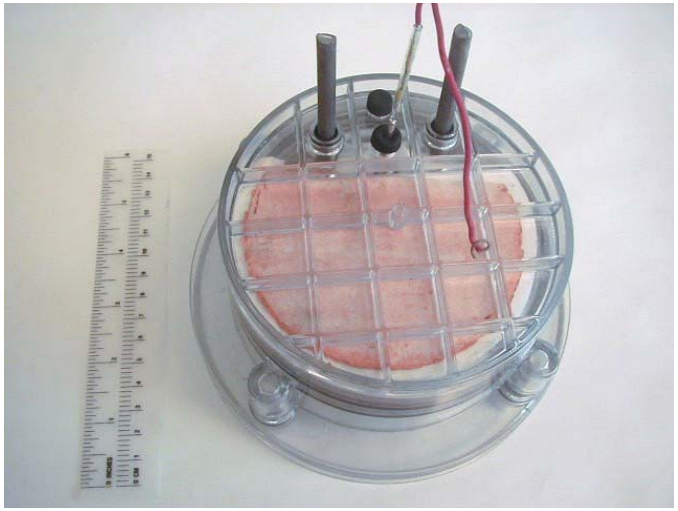
- The graphite/carbon black mix had the best cycling performance under the Advanced PSoC conditions.

Phase 2: Hammond Research Cells

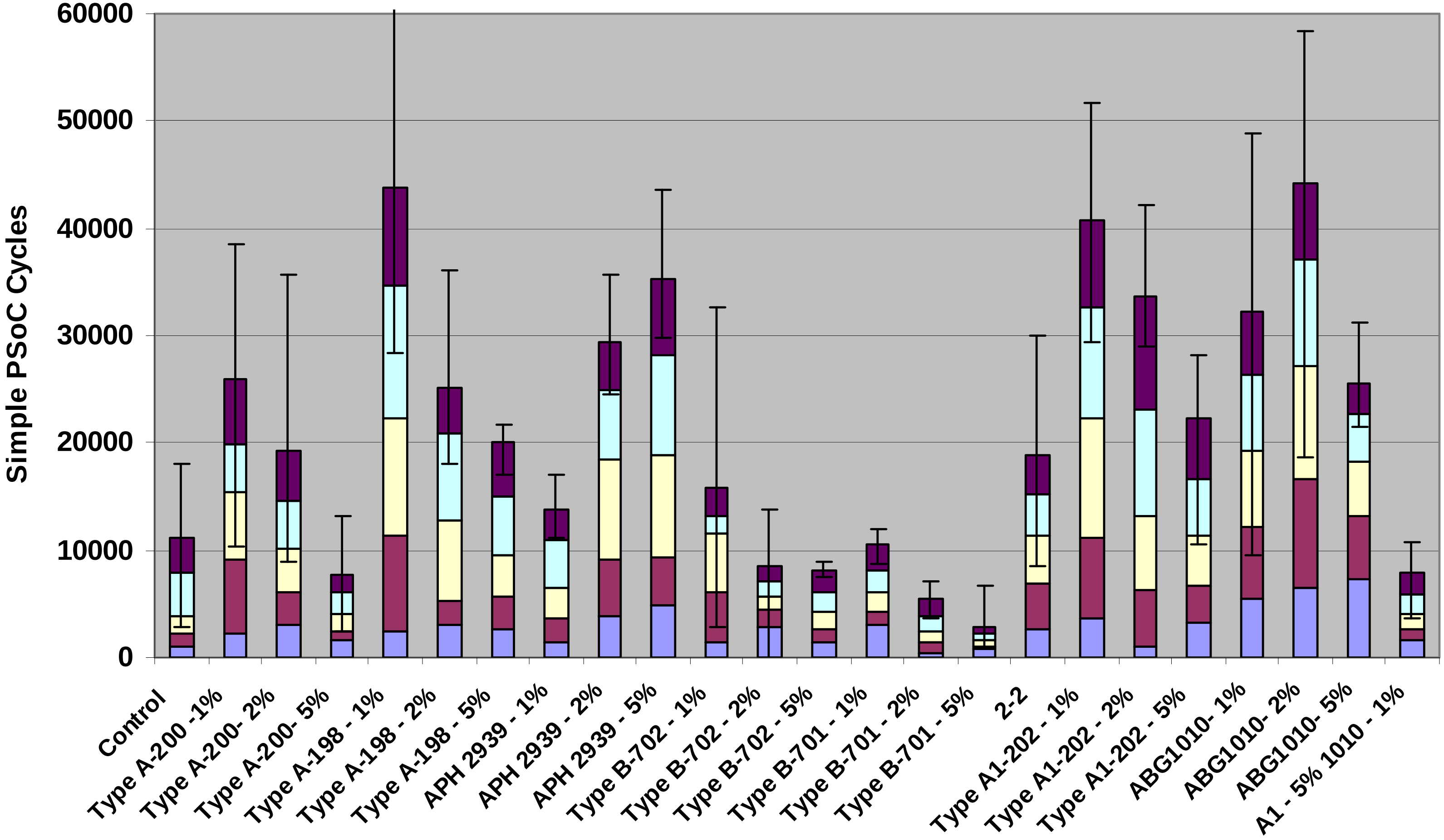
Group #	Loading	Carbon Type
21	0%	STD
1	1%	
2	2%	Type A X070200
3	5%	
5	1%	
6	2%	Type A X070198
7	5%	
8	1%	
9	2%	APH 2939
10	5%	
11	1%	
12	2%	Type B X070702
13	5%	
14	1%	
15	2%	Type B X070701
16	5%	
17	2%	2-2
18	1%	
19	2%	Type A1 X070202
20	5%	
22	1%	
23	2%	ABG1010
24	5%	
25	6%	Type A1 X070202 - 5% ABG1010 - 1%

Research Cells

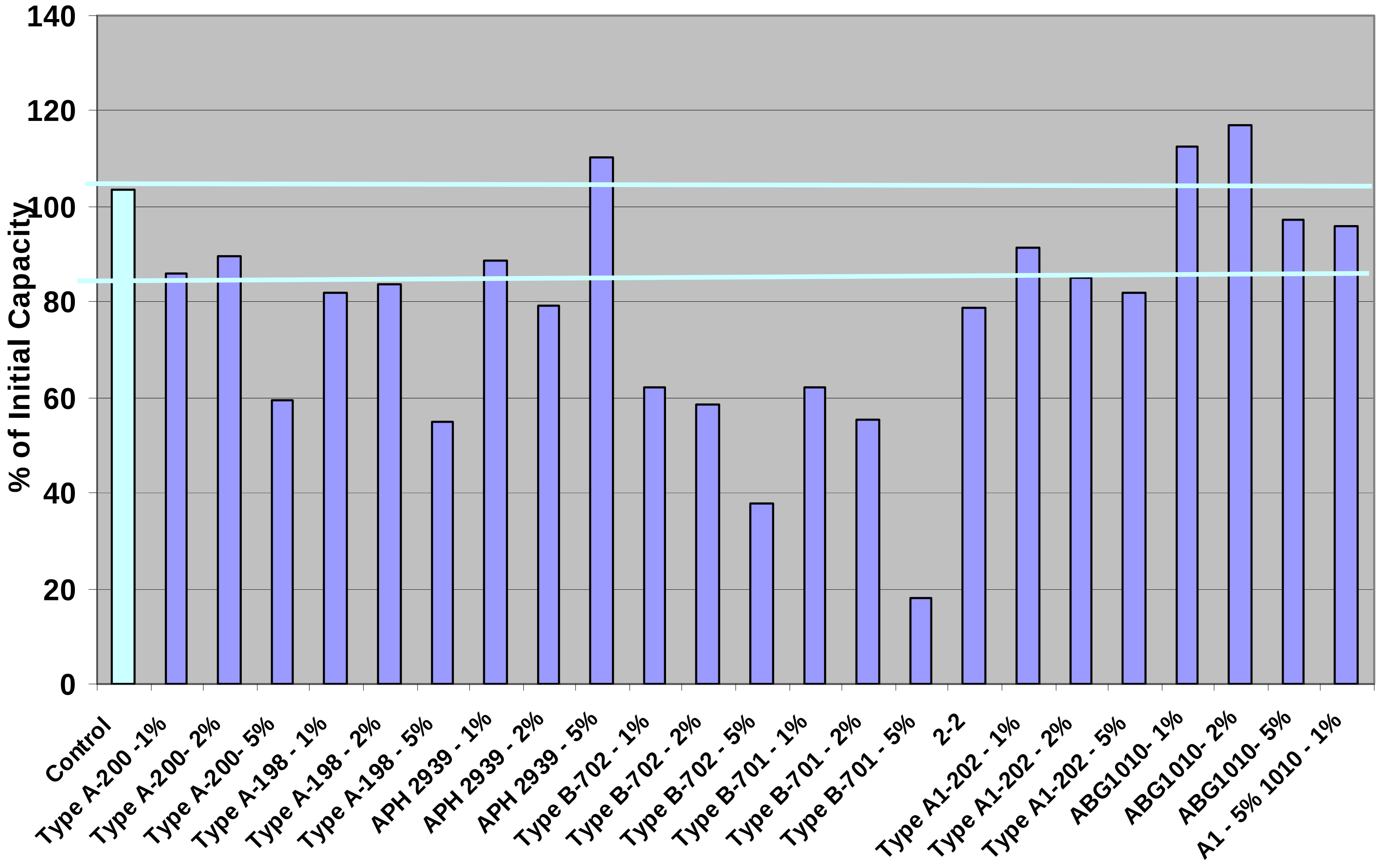
- 3-Plate (2P:1N)
- Type/Loading
- Simple PSoC cycling



Phase 2: Hammond Research Cells



Phase 2: Hammond Research Cells



Phase 2: Hammond Research Cells

- Activated carbons perform better at low loading (1%)
- Graphitic carbons perform better at mid to high levels (2%, 5%)
- Larger particle size activated carbons perform better
- Unwashed activated carbon shows good performance
- Mesoporous activated carbon performs better than microporous
- Synthetic expanded graphite performs better than natural flake at mid-loading (2%)
- Natural flake graphite performs better than synthetic expanded at high loading (5%)
- Mesoporous activated carbon (low loading) and graphite (high loading) are ideal

Phase 2: Battery Energy Gel Batteries

Battery Description	Carbon	Type
STD 1	0.16%	CB
STD 2	1%	CB
MWV-A	1%	MWV AC
MWV-B	2%	MWV AC
MWV-C	3%	MWV AC
MWV-D	1%	Graphite

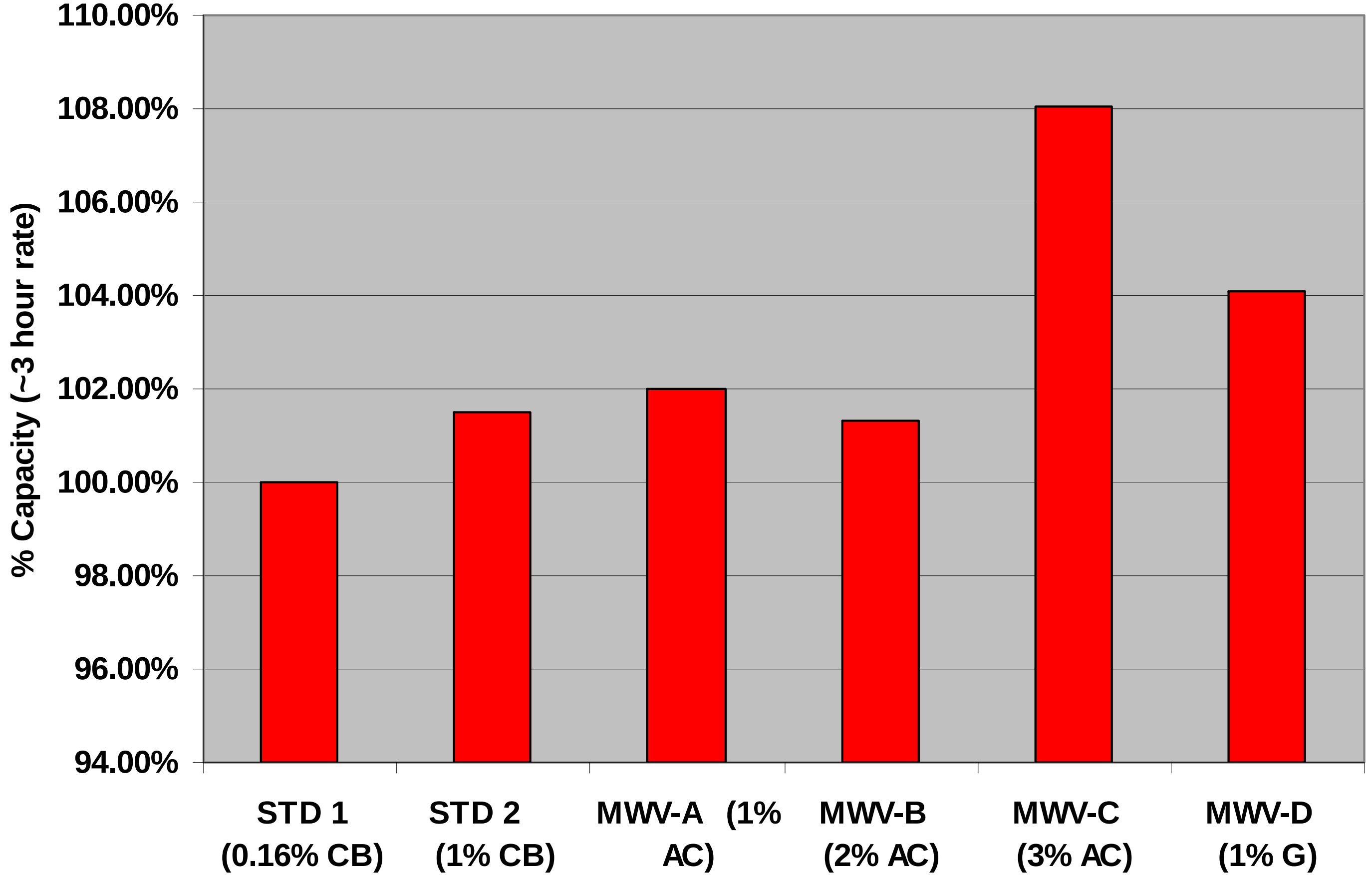
Gel VRLA Batteries
(Silica/Acid Electrolyte)
✓ Increased Cycle Life
✓ Improved Charge Efficiency
✓ Improved Heat Dissipation
✓ No Acid Stratification
Ideal for Wide PSoC Cycling

Cycle Testing

- Advanced PSoC: 50% - 53% SoC
- Aker Wade: 35% - 65% SoC
- Utility: 30% - 80% SoC

MWV

Phase 2: Battery Energy Gel Batteries



Phase 2: Battery Energy Gel Batteries Advanced PSoC Cycling Results

Battery	Initial Capacity	End Capacity	Post-EQ Capacity	% Retained Post-EQ
STD 1 0.16% CB	62.0	43.5	52.8	85.2
STD 2 1% CB	58.8	41.5	46.7	79.0
MWV A 1% AC	64.7	36.4	50.9	78.7
MWV B 2% AC	65.7	42.2	54.0	82.2
MWV C 3% AC	66.0	42.0	54.4	82.4
MWV D 1% G	60.6	40.3	46.7	79.0

Cycling performance: MWV C > MWVB > MWVA > STD 1, 2 > MWV D

MWV

Phase 2: Battery Energy Gel Batteries Aker Wade Cycling Results

Battery	Initial Capacity (Ah)	End Capacity (Ah) (after 13 weeks of cycling)	% Retained
STD 1 0.16% CB	99.7 100.2 101.0	103.5 104.0 104.7	104% 104% 104%
STD 2 1% CB	104.1 102.8 102.9	100.1 101.8 102.7	96% 99% 100%
MWV A 1% AC	92.4 94.9	91.8 92.9	99% 98%
MWV B 2% AC	105.4 103.9	97.6 98.3	93% 95%
MWV C 3% AC	109.3 106.9 106.8	102.3 101.8 101.7	94% 95% 95%
MWV D 1% G	109.5 108.3 108.3	105.3 106.5 107.1	96% 98% 99%

Cycling results: All batteries did well, STD 1 was the best

Phase 2: Battery Energy Gel Batteries Utility Cycling Results

Battery	Initial Capacity (Ah)	Capacity (Ah) after 13 weeks AW cycling	Capacity (Ah) after 3 months utility cycling	% Retained after utility cycling
STD 1	99.7	103.5	101.0	101%
0.16% CB	100.2	104.0	103.0	103%
MWV C	109.3	102.3	94.8	87%
3% AC	106.9	101.8	93.9	88%

- Previous work showed that a standard AGM battery did not perform well under a utility cycle (<40% of initial capacity after 10 weeks)
- Gel batteries are more suited for this type of utility cycling
- The carbon tested above did not provide cycle life performance benefit compared with STD 1

MWV

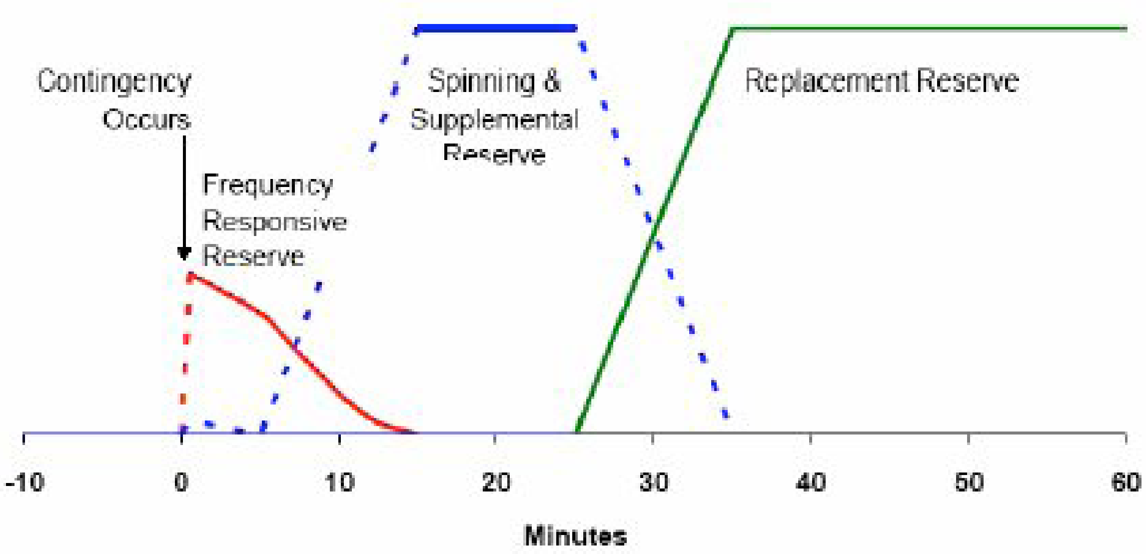
Phase 3: Utility Frequency Regulator

- Don Karner (ETA) prepared a conceptual design and cost forecast for a 1 MW, 1MWh utility frequency regulator (UFR) utilizing battery energy storage

- UFR designed to support equalization of power supply/demand on a utility electric grid

- UFR will be dispatched to minimize Area Control Error and operate as Frequency Responsive Reserve to provide short-term electric system frequency regulation

Electric System Area Control Error Regulation Components



Phase 3: Utility Frequency Regulator

- Based on the utility cycling results, the Battery Energy STD1 gel battery should provide a minimum of 2 to 3 years of continuous service at the assumed regulator power to energy ratio

- Gel batteries are the preferred battery product for the UFR

Phase 3: Utility Frequency Regulator Capital Cost Estimates

Recurring Cost	
Power Inverter	**$172,000**
Battery & Management System	**$1,759,000**
System Integration	**$1,797,000**
Total Recurring Cost	**$3,728,000**
Non-Recurring Cost	**$439,200**

MWV

Phase 3: Utility Frequency Regulator Suggested Next Steps

- To determine if the UFR is cost effective, an estimate of the revenue should be made
- Based on this estimate, the power/energy ratio should be optimized and the design adjusted accordingly
- Further gel battery testing should be completed to better define the optimum battery design/size and estimate operating costs

THANK YOU