## 2011 DOE Vehicle Technologies

## U.S. Department of Energy Merit Review

# JCS PHEV System Development-USABC

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Johnson Controls – Saft

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Project ID #: ES005

This presentation does not contain any proprietary, confidential or otherwise restricted information.

## Overview

### Timeline

Project Start – June, 2008

Scope Change – July, 2009

Project Finish – April, 2011

Percent Complete – 95%

### Budget

Total Project Funding: $10,510K
JCS Share - $5,255K

CY10 Funding Received: $1,860K

Funding for CY10: $1,886K

### Barriers

System energy density of present systems is too low

Cycle-life vs. useable energy in PHEV mode

Cost tradeoffs to meet performance targets

### Partners

Johnson Controls and Saft

USABC Program Lead:
Renata Arsenault

DOE Contract Manager:
David Howell


Johnson Controls
saft


Battery Electric Vehicle
Johnson Controls
AZT
Zero Emissions


Battery Electric Vehicle
Johnson Controls
Zero Emissions

## Objectives

- Develop, build and test a prismatic cell for use in PHEV system design
- Develop Lithium-Ion PHEV Systems for 20 and 40 mile all-electric range applications.
- Optimize cell and system designs and hardware to meet program USABC goals and deliverables.

## Collaborations

- Saft - NMC Evaluations
- Entek - Advanced Separator Development

## Milestones

- Program scope change to prismatic cells and system (July, 2009) – *Approved*
- Deliver baseline energy NMC cylindrical cells for testing validation (November, 2010) – *Completed*
- Deliver baseline prismatic cells for National Lab testing (November, 2010) – *Completed*
- Deliver 20 and 40-mile thermal management design review summary (April, 2010) - *In Progress*
- Deliver improved prismatic cells for National Lab testing (April, 2011) – *In Progress*
- Deliver 20-mile capable PHEV hardware system (April, 2011) - *In Progress*
- Deliver 40-mile capable PHEV system design study (April, 2011) - *In Progress*

## Approach

- The initial development leveraged existing Saft prismatic cell manufacturing equipment and technology. Saft manufacturing equipment is capable for winding and stacking electrode options.
- Initial capacity target and system BSF calculated to use 30 Ah cells.
- JCS used an existing electrode size and configuration to begin evaluation of the NMC cathode.
- JCS redesigned cell mechanics for the target prismatic cell.
- Advance materials suppliers were researched and appropriate materials were evaluated to meet performance expectations.
- System hardware was developed for a 20-mile capable bench-test product, which will be evaluated by the National Labs.
- The system development approach for the 40-mile design will utilize this same prismatic cell, connected in parallel/series and improved for volumetric efficiency and cost.

## Technical Accomplishments and Progress

- Developed cell mechanics through several iterations to increase robustness and improve manufacturability.
- Developed applicable NMC chemistry through several generations to improve cell performance.
- Developed prismatic cell building capability in Milwaukee for both wound and stacked prismatic electrode configurations.
- Built, tested and delivered baseline NMC prismatic and cylindrical energy cells (November, 2010).
- Developed system design to build and test prototype multi-cell modules (September, 2010) and a prototype system (December, 2010).
- Using the cost model, demonstrated improved system cost and volume projections over the program duration.
- Delivered various summaries throughout the program.
- Developed and refined a Thermal simulation model for which projections were made. These simulations were later compared to actual results.
- Conducted and reported on cell abuse tolerance testing for overcharge nail penetration and propagation testing, all with successful results.

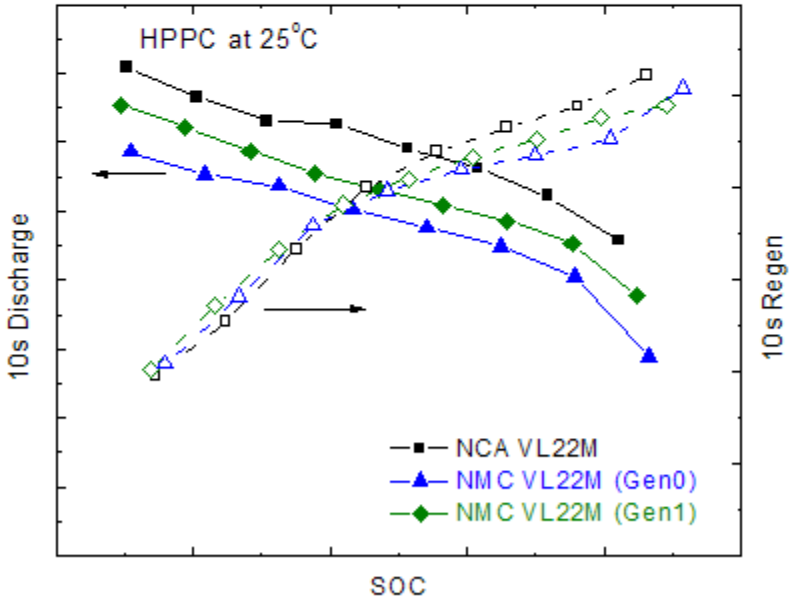
# Hardware Deliverables

Prismatic Cell

20-mile PHEV System

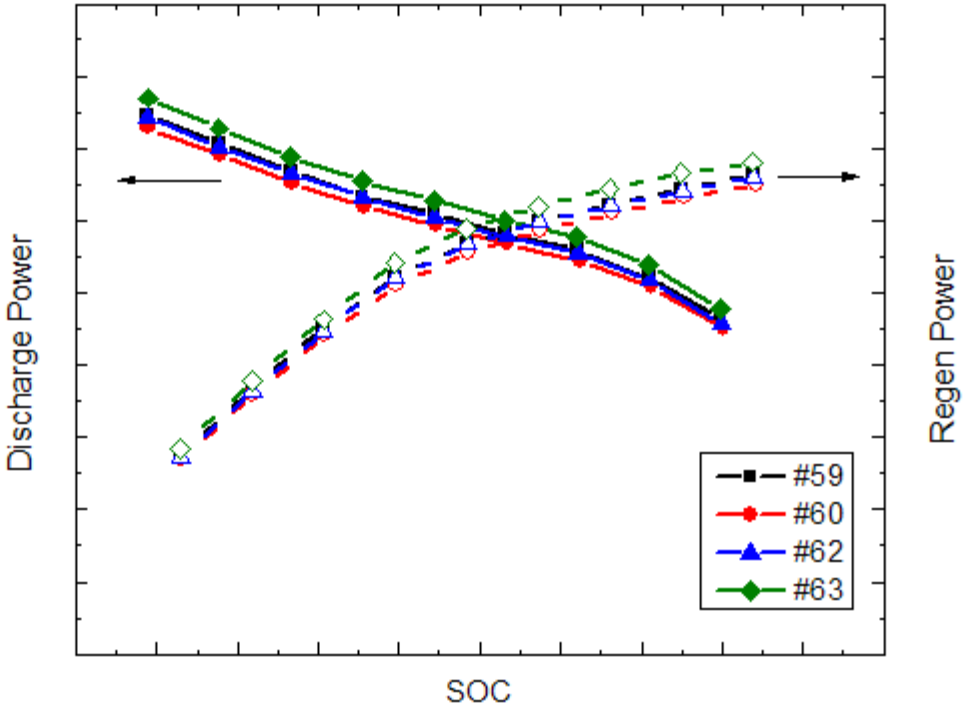

# Cylindrical NMC Cell - Initial HPPC

| Cell ID | Capacity (Ah) | | Discharge Power (10s, 60%SOC) (W) | Cell Resistance (10s, 60%SOC) (mOhm) |
|---|---|---|---|---|
| | 1C_Rate | 4C_Rate | | |
| **NMC Gen1** | **20.9** | **21.0** | **1092** | **2.79** |
| NMC Gen0 | 20.4 | 20.3 | 1030 | 2.90 |
| NCA | 21.4 | 19.3 | 1200 | 2.36 |

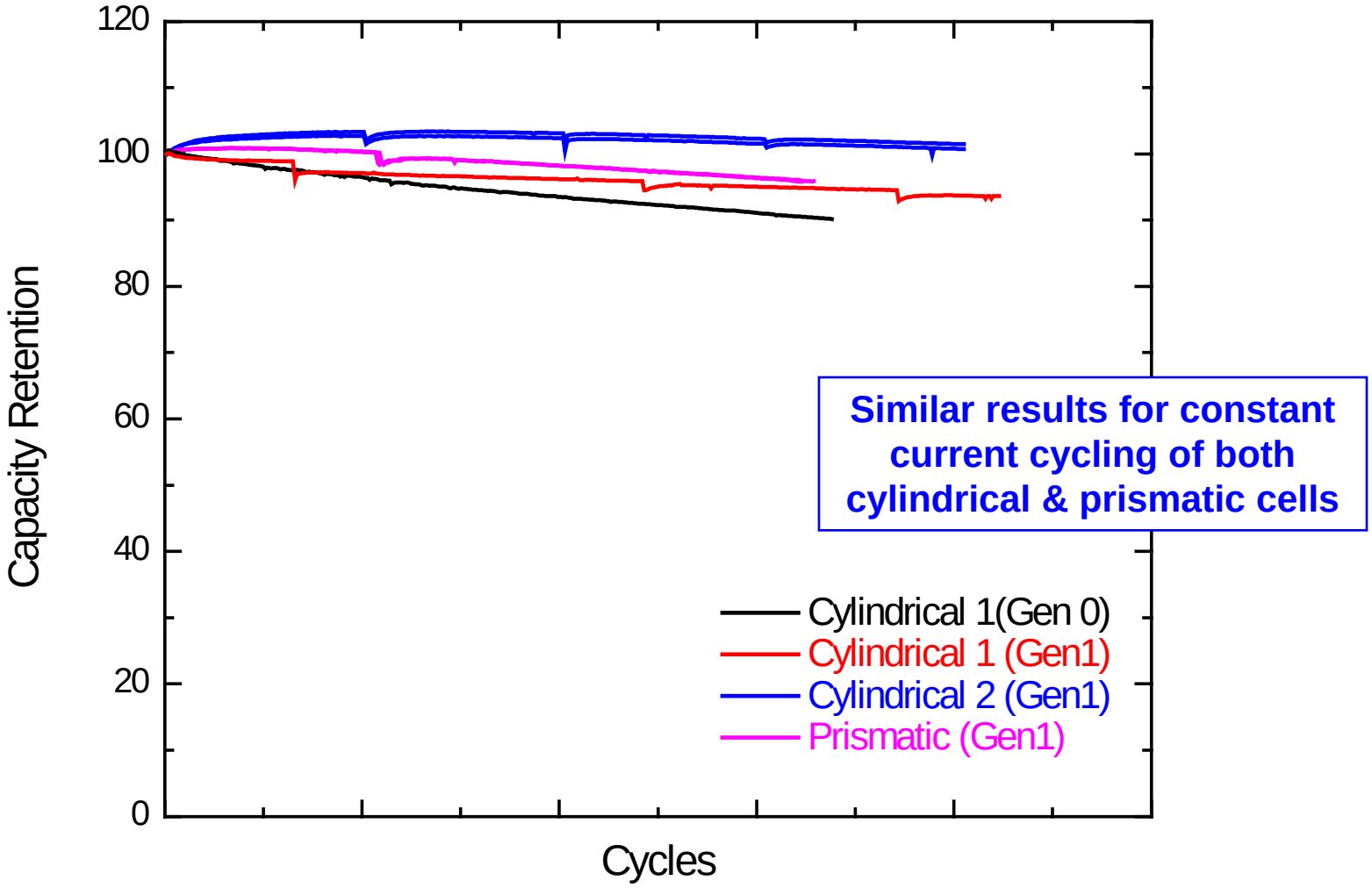


# Prismatic NMC – Initial HPPC at 25ºC

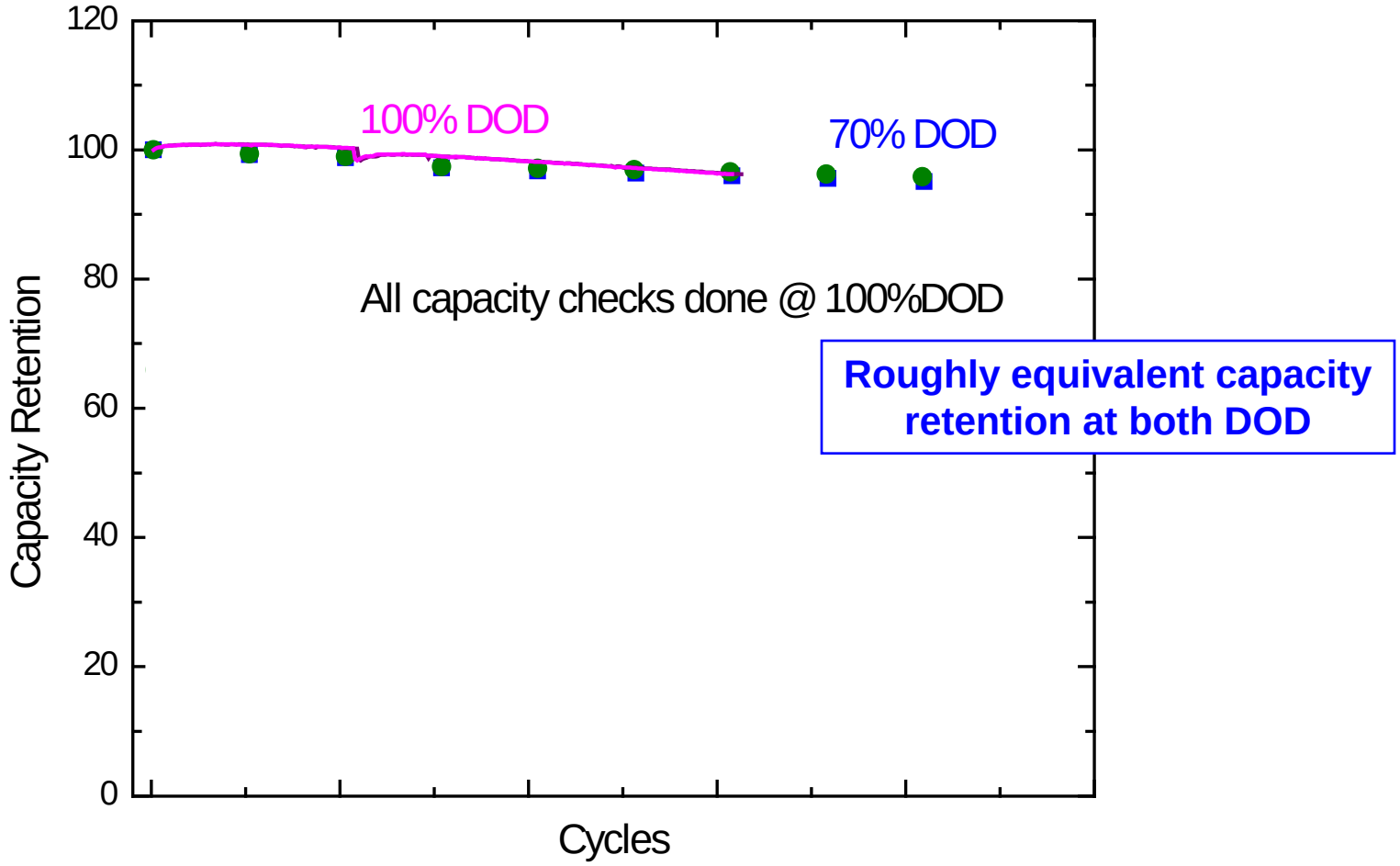
| Cell ID | Capacity (Ah) | | Discharge Power (10s, 50%SOC) (W) | Cell Resistance (10s, 50%SOC) (mOhm) |
|---|---|---|---|---|
| | 1C_Rate | 4C_Rate | | |
| M0229059 | 22.6 | 21.9 | 1183 | 2.49 |
| M0229060 | 22.5 | 21.8 | 1155 | 2.55 |
| M0229062 | 22.5 | 21.9 | 1175 | 2.51 |
| M0229063 | 22.6 | 21.9 | 1220 | 2.42 |



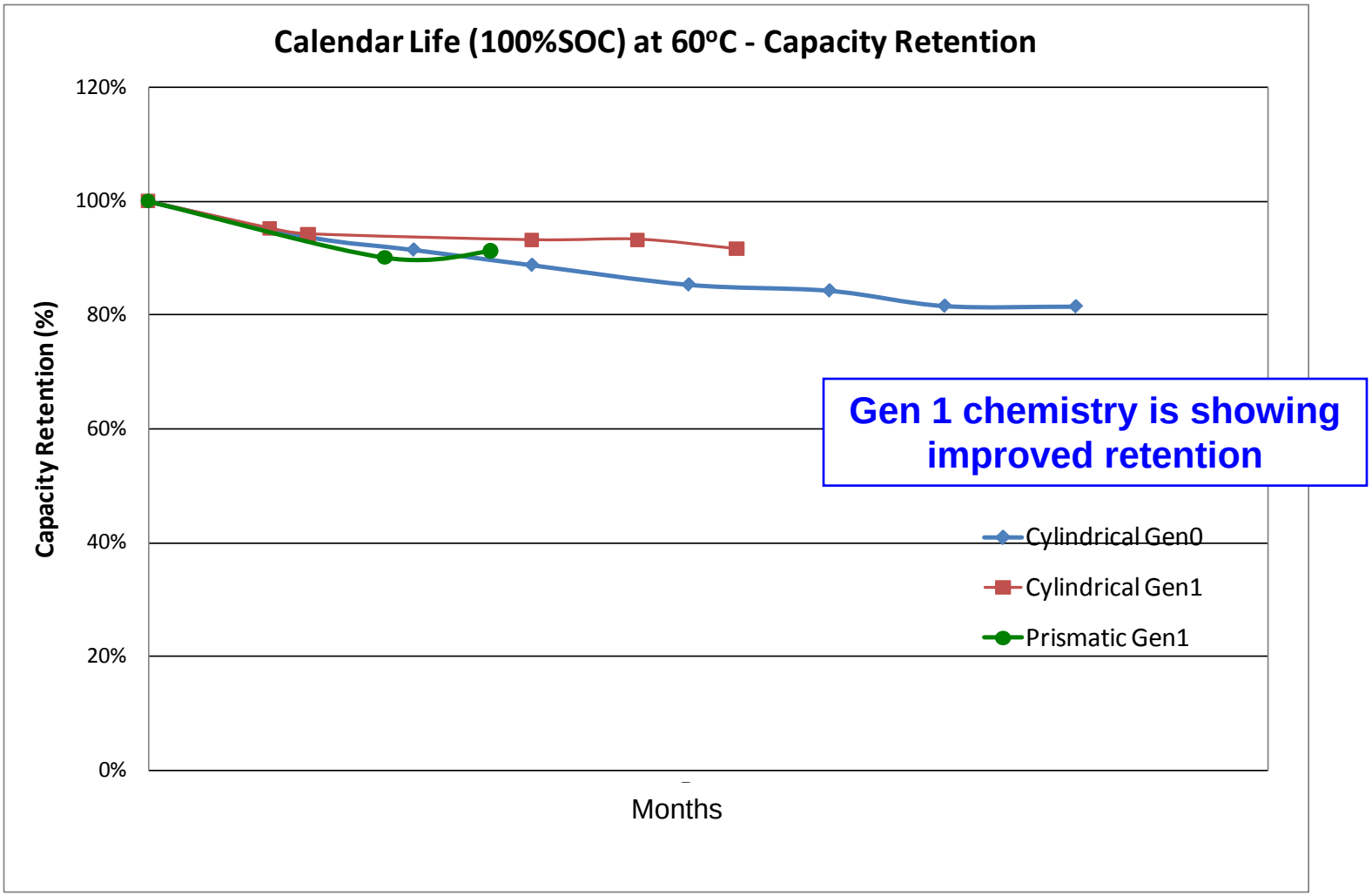
# Prismatic Cell C/2 Cycling at 45ºC (100%DOD) for Capacity Retention



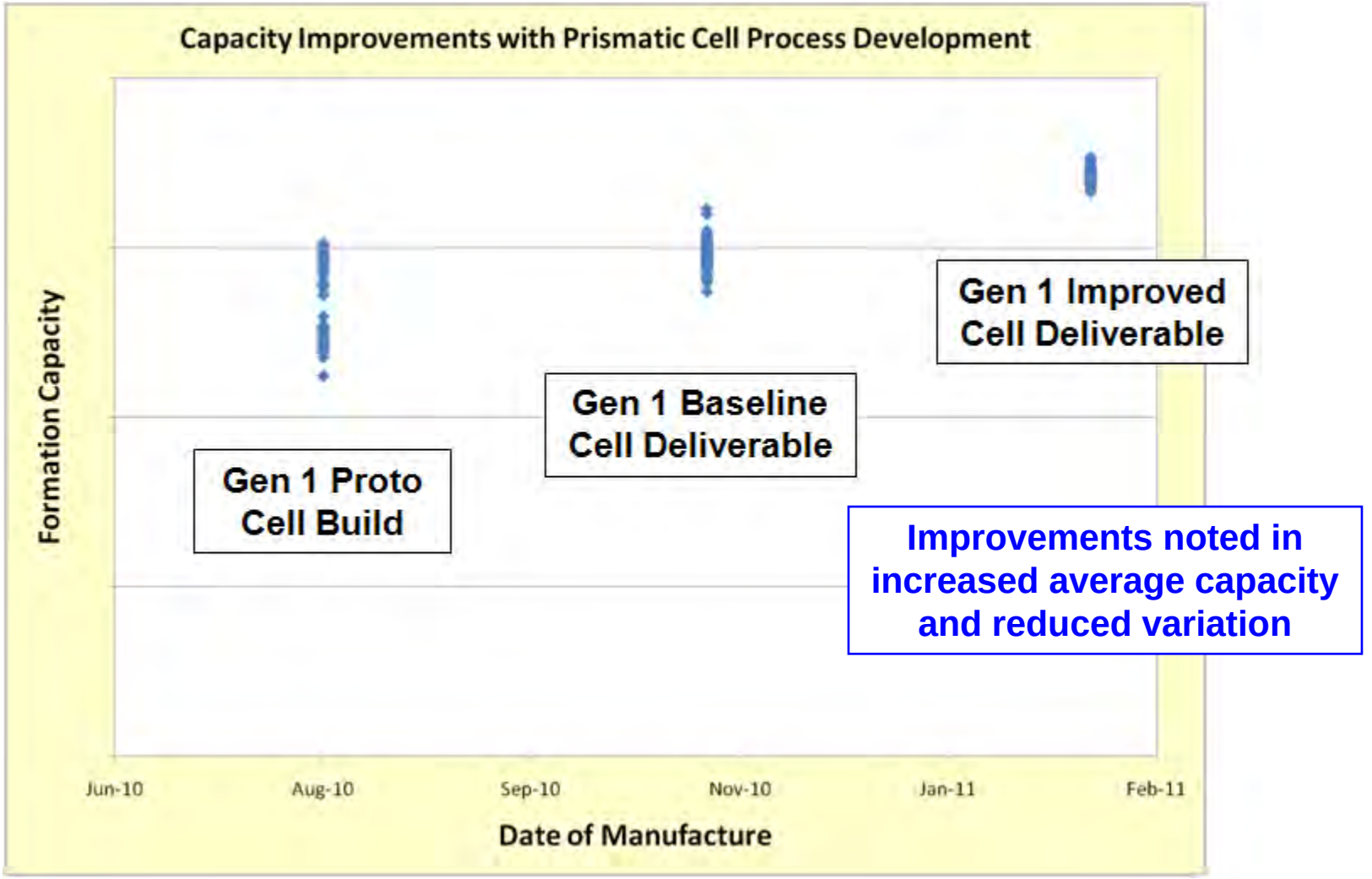
# Prismatic Cell C/2 Cycling at 45ºC for 100%DOD vs 70%DOD



# Prismatic NMC Calendar Life at 60ºC – Capacity Retention



# Capacity Improvement by Build

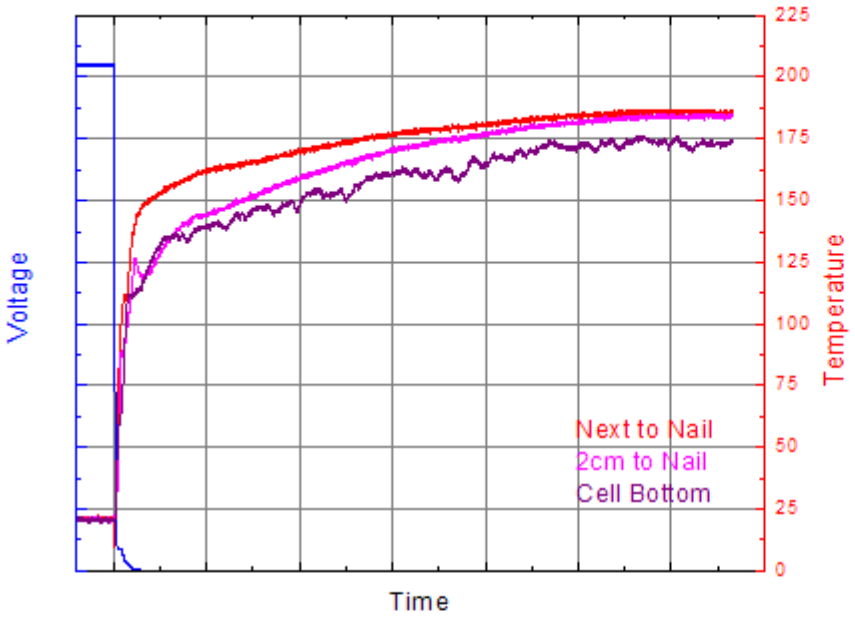


# Abuse Test Summary

| | | Nail | 32A Overcharge |
|---|---|---|---|
| Wound | Improved Design | EUCAR 4 | EUCAR 2 |
| | Improved Design/HMT-Sep. | EUCAR 4 | |
| Stack | Standard | EUCAR 4 | |
| | Improved Design | EUCAR 4 | |

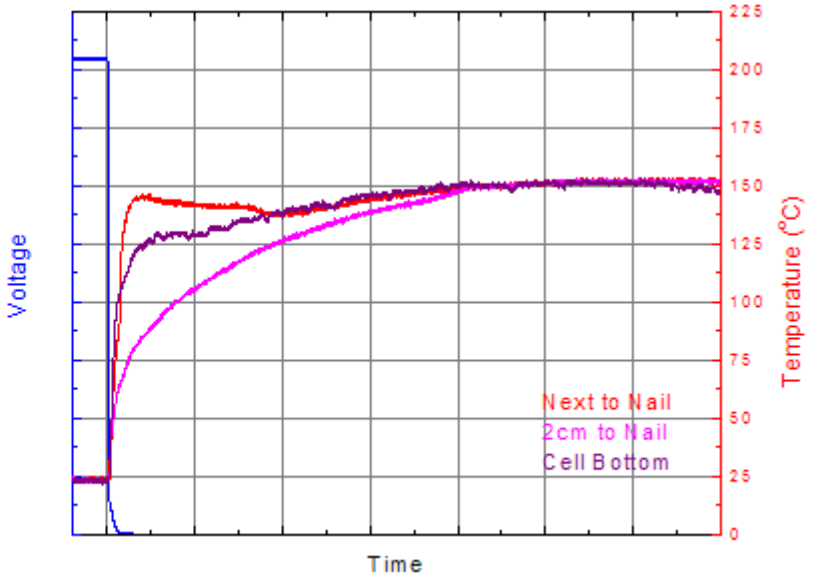
**All testing performed per FreedomCAR Procedure**
**Note: High Melting Temperature Separator (HMT)**

# Nail Penetration: Wound PL25M




HMT-Sep.

**Both designs produced EUCAR 4 results**



## Future Work

April, 2011

- Build, test and deliver improved prismatic cells for multiple lab evaluations
- Build, test and deliver 20-mile capable systems for lab evaluations
- Develop and present a 40-mile design study for best cost and size
- Present performance summaries at final Quarterly Review

## Summary

- Progress made for prismatic cell design and manufacturing to deliver NMC baseline cells with improved life and abuse tolerance from earlier proof-of-concept cells.
- Cell mechanics development for robust and low cost manufacturing
- As the system design has progressed, improvements have been presented and reported quarterly toward final delivery of the design study.
- Prismatic cell and system designs are meeting market demands and have attracted customers for JCS product development.
- Building product portfolio and manufacturing capability for prismatic energy and power cells