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Testing USABC Deliverables/Benchmarking

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DOE Vehicle Technologies Merit Review

February 25, 2008

This presentation does not contain any proprietary information

Office of Vehicle Technologies

FreedomCAR & Fuel Partnership

Testing USABC Deliverables/Benchmarking

- Purpose of Work
  - To provide DOE, USABC, and battery developers with reliable, independent, and unbiased performance evaluations of cells, modules, and battery packs
  - To benchmark battery technologies which were not developed with DOE funding to ascertain their level of maturity. This will help DOE use its limited resources to provide support to emerging technologies for the maximum benefit
  - To identify promising technologies
  - To perform battery performance and life evaluations on FreedomCAR contract deliverables

Barriers Addressed and Approach

- Barriers
  - Use repeatable, standardized measures to gauge battery performance and life
- Approach
  - Benchmarking
    - *Use the FreedomCAR test protocols to evaluate battery performance and life (calendar and cycle)*
    - *Use accelerated screening protocols to evaluate battery performance and cycle life*
  - USABC Contract Deliverables
    - *Use the FreedomCAR test protocols to evaluate battery performance and life (calendar and cycle)*
  - Analyze data for trends and model creation
    - *Project life without exhausting battery under test*
  - Participate in new manual creation and validation
    - *FY07, Technology Life Validation Manual and Plug-in Hybrid Battery Test Manual*

Approach (cont'd)

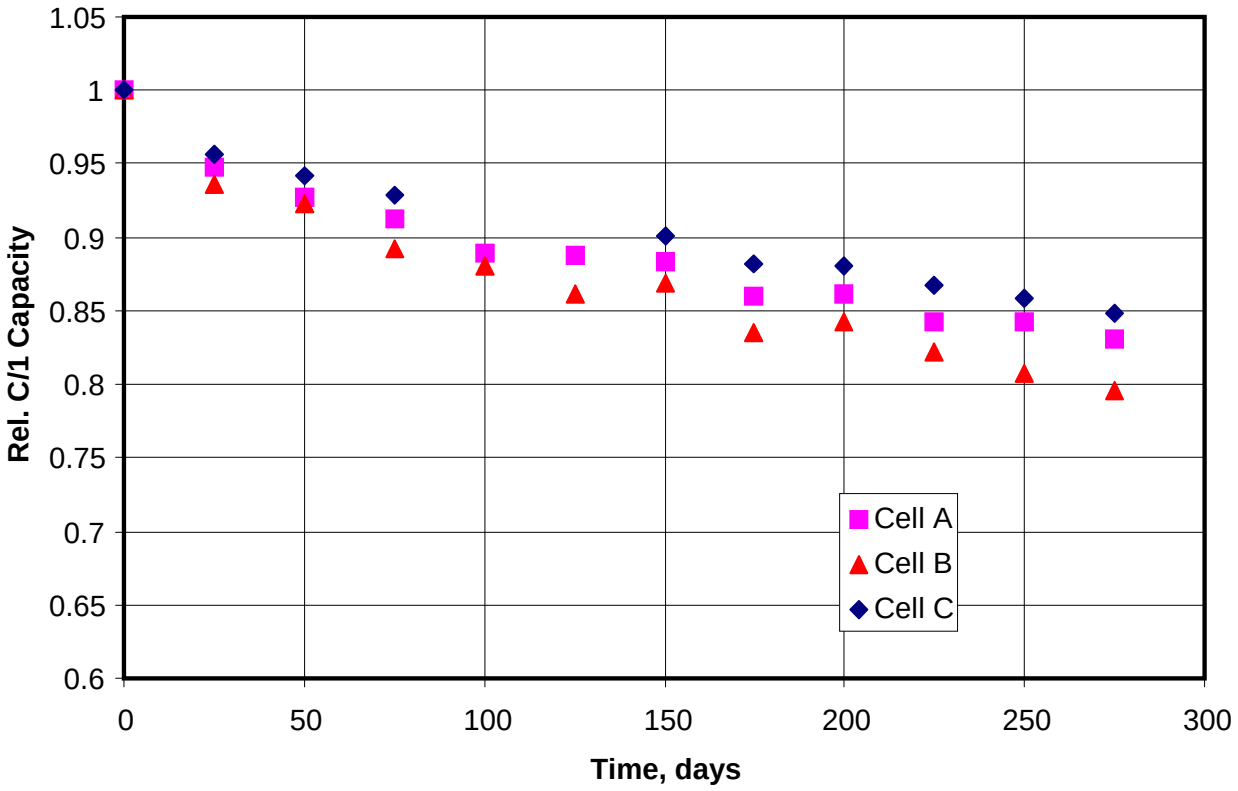
- Approach
  - The tests used are unbiased, allowing for a direct comparison of battery performance within a given technology and across technologies
  - The performance of small cells can be compared to that of large cells, modules and full-scale battery packs by using a battery-scaling factor (BSF)
    - *BSF: for a particular cell or module design, an integer which is the minimum number of cells or modules expected to be required to meet all the FreedomCAR performance and life goals, assuming a 30% power margin at the beginning of life*
    - *Usually, the BSF is calculated from the results of the HPPC-L test, using the plot of available energy vs. power*
  - Test manuals are available on the world-wide web: http://www.uscar.org/guest/article_view.php?articles_id=86

Performance Measures and Technical Results

- Testing of deliverables is an open-ended effort. Each year, milestones related to the expected deliverables are developed
- In FY07, the milestones were
  - HEV batteries: Benchmark battery technologies from GS-Yuasa, Hitachi, Lithium Technology/GAIA and A123Systems
    - *All benchmark testing was completed*
  - PHEV: Validate the new test manual using prototype cells. Provide comments to INL to refine the test manual
    - *Testing still in progress*
  - Benchmark battery technologies for vehicle applications
    - *Tested deliverables from ENAX, ThunderSky, Tianjin Lishen, SK Energy*

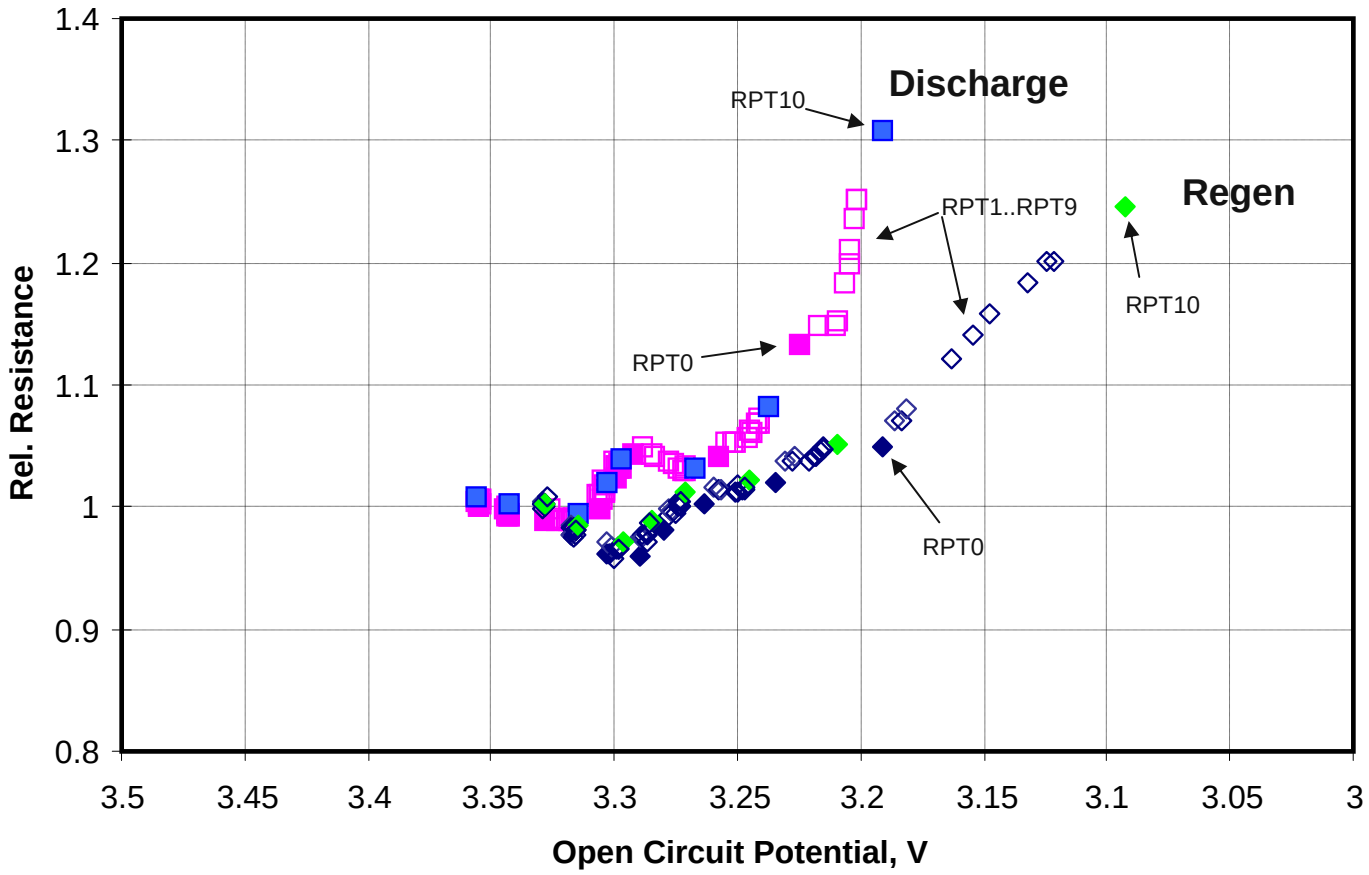
Example Results from a Benchmarking Test Using FreedomCAR Protocols

- 3 lithium-ion cells on calendar life test at 45°C and 60%SOC
- Capacity of the cells decreases with time



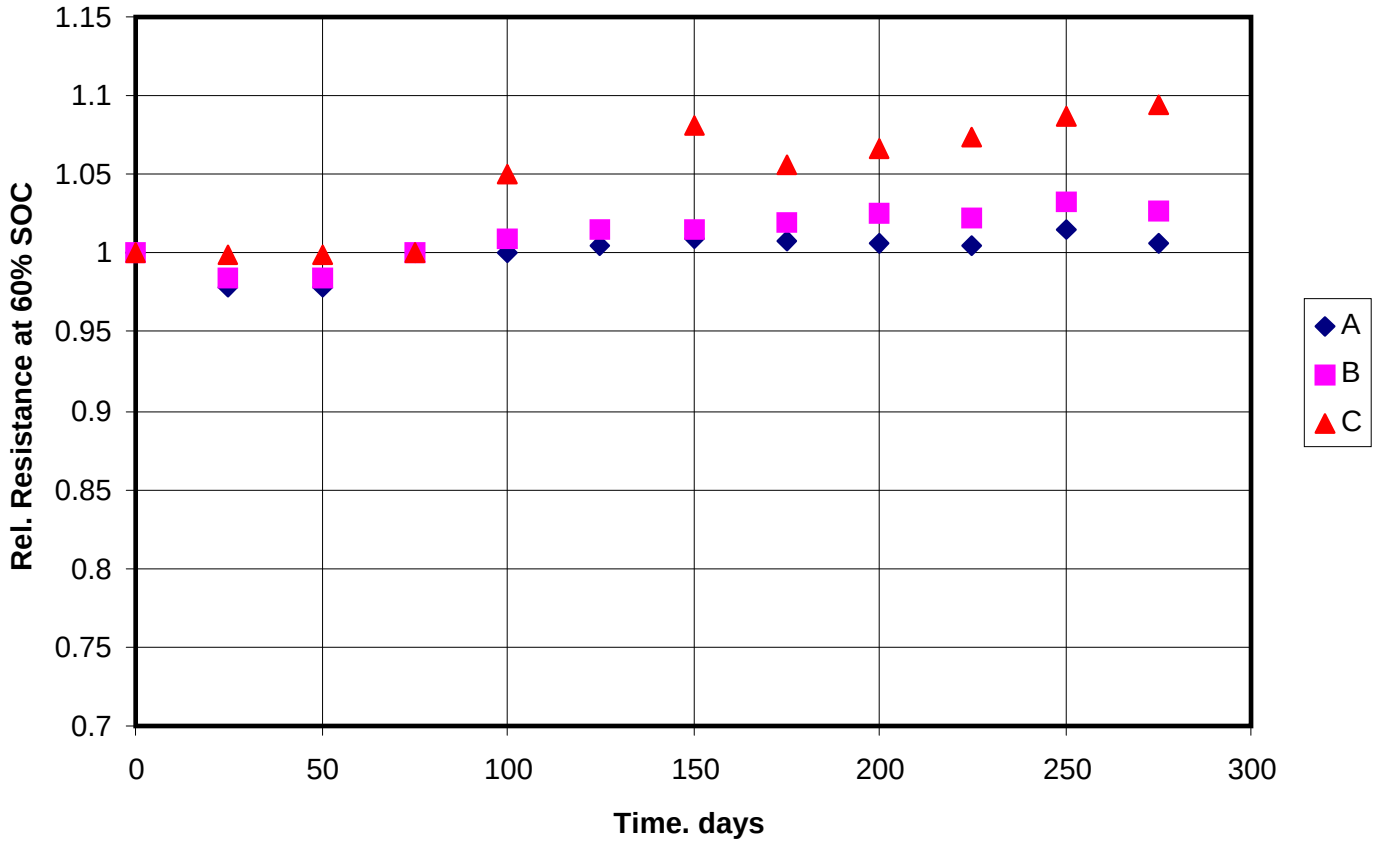
Results from Hybrid Pulse-Power Characterization Test

- See very little change in cell relative resistance in a typical cell

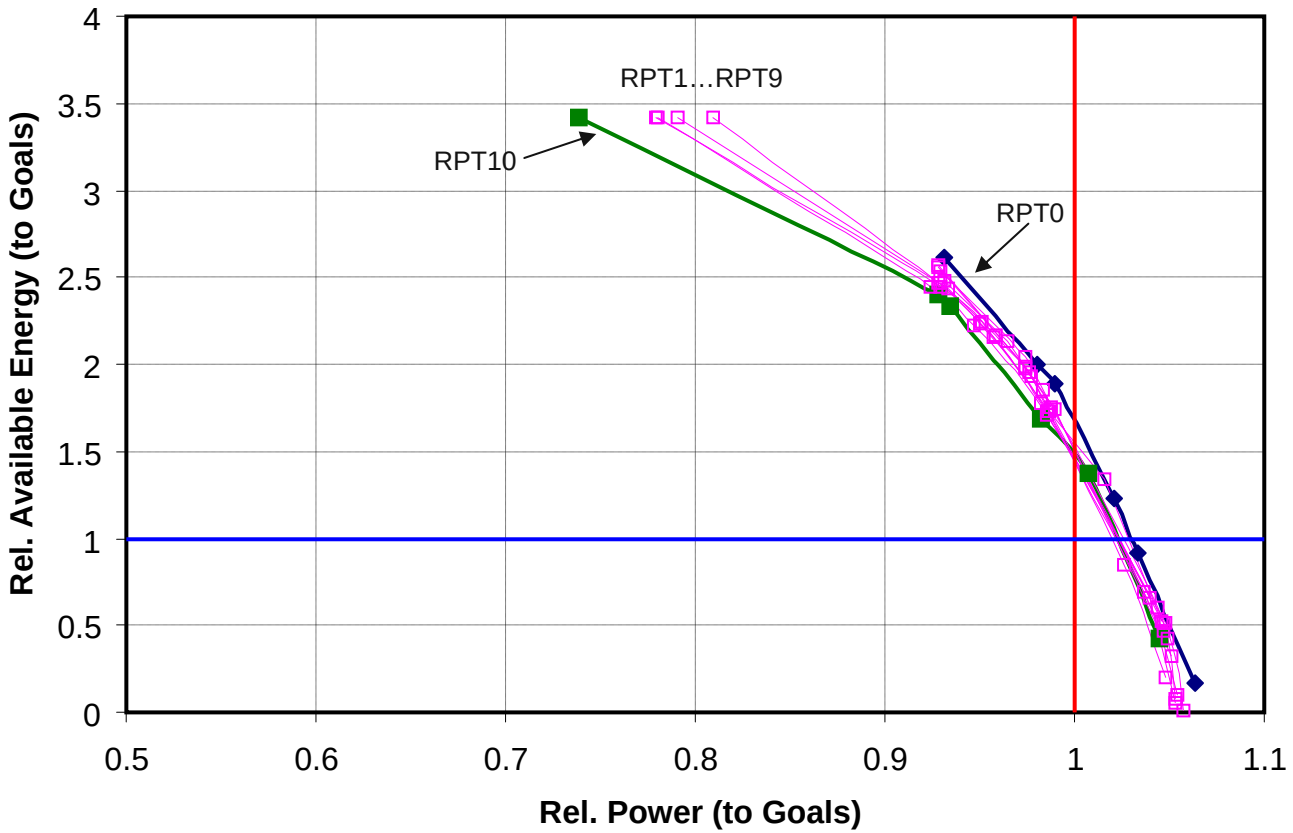


Observe Similar Behavior in Resistance versus Time for Other Cells in the Test

- Average increase: 4.2%
- Calendar life test at 45°C and 60% SOC
- Relative resistance values from HPPC test at 30°C



Available Energy v. Power Plot Shows Very Little Change With Time

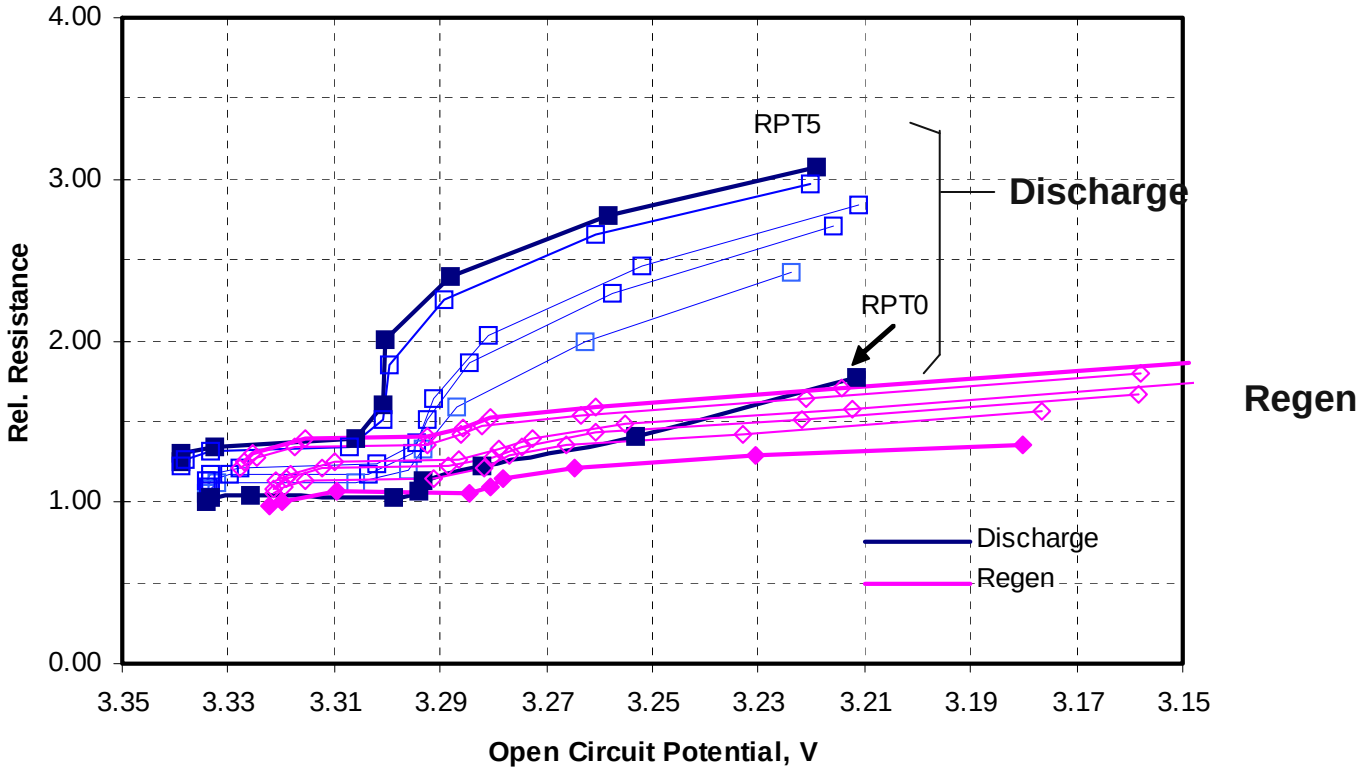


Accelerated Testing Protocols

- These protocols were designed to accrue many cycles on a battery quickly and to work on both high-energy and high-power cells
- These protocols are not PHEV tests
- High-energy protocol
  - Exact current levels depend on cell ratings
  - Characterization/Reference Performance Test (RPT) consists of constant-current capacity and HPPC at the low current level at 30°C
  - Constant-current cycle at 40°C
  - Every 50 cycles perform an RPT at 30°C
- High-power protocol
  - Characterization/RPT consists of C/1 constant-current capacity and HPPC at the low current level (5C) at 30°C
  - Constant-current cycle at 40°C at the 5C rate
  - Every 50 cycles perform an RPT at 30°C

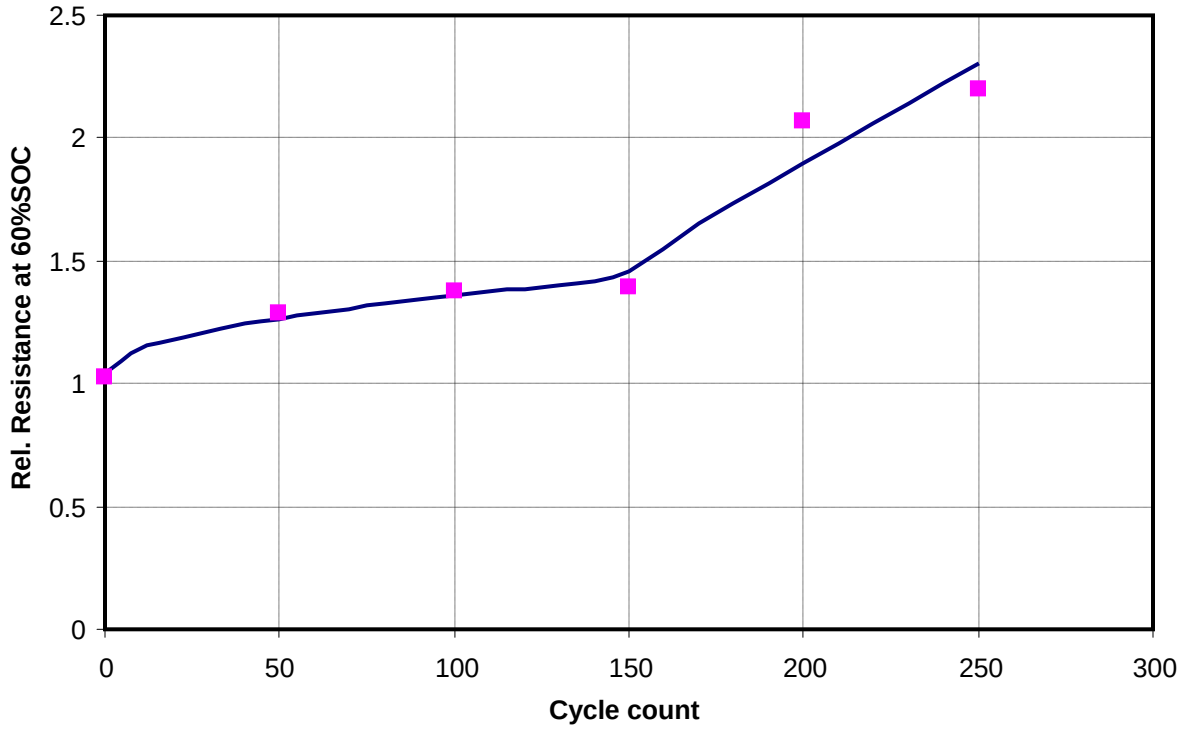
Example Test Results From High-Energy Battery Using the Accelerated Protocols

- Cycling at the C/2 rate
- HPPC-L at the 25% of I_{max} rates

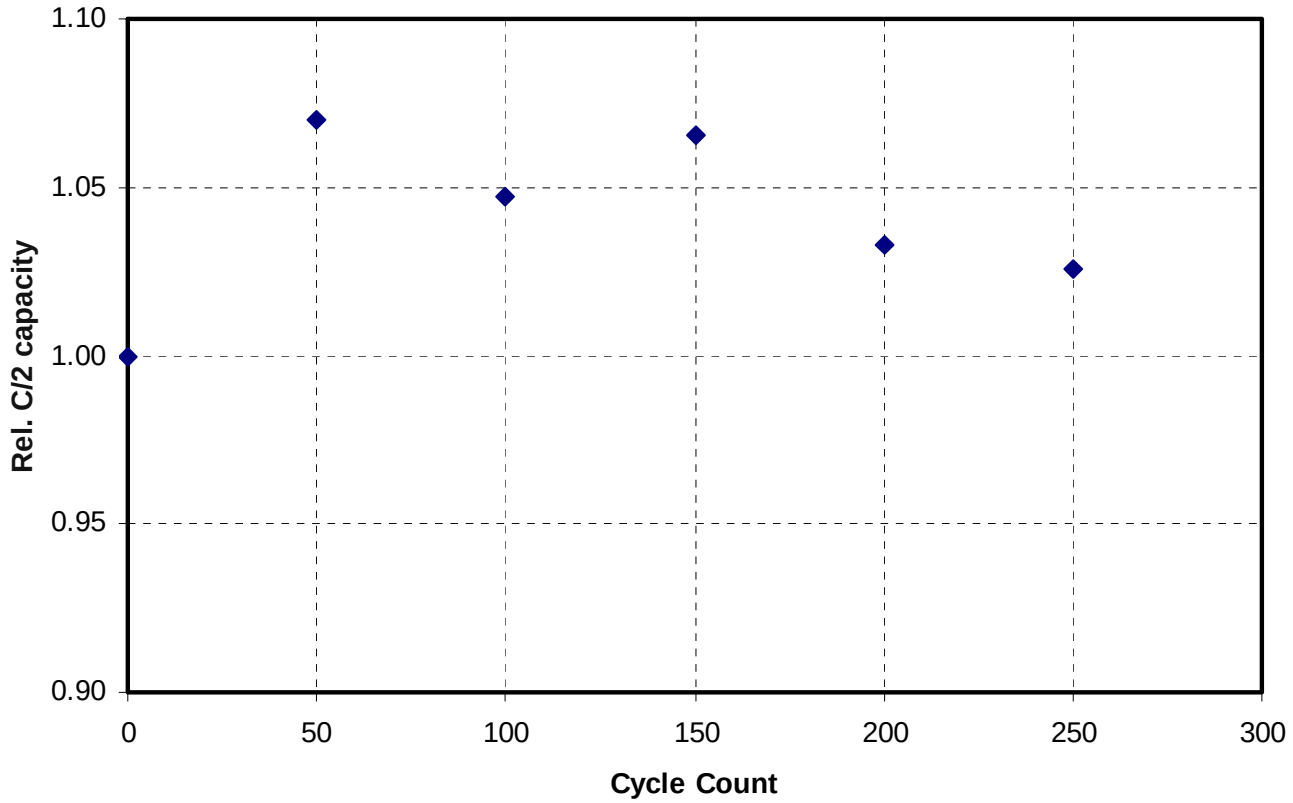


HPPC-L Discharge Resistance at 60%SOC Increases with Cycle Count

- Plot of discharge resistance shows possible evidence of a change in the mechanism of resistance increase
  - at $0 < t < 150$ cycles, $R = k\, t^{1/2}$
  - at $t > 150$ cycles, $R = k\, t$
- Cell reached EOL at 250 cycles

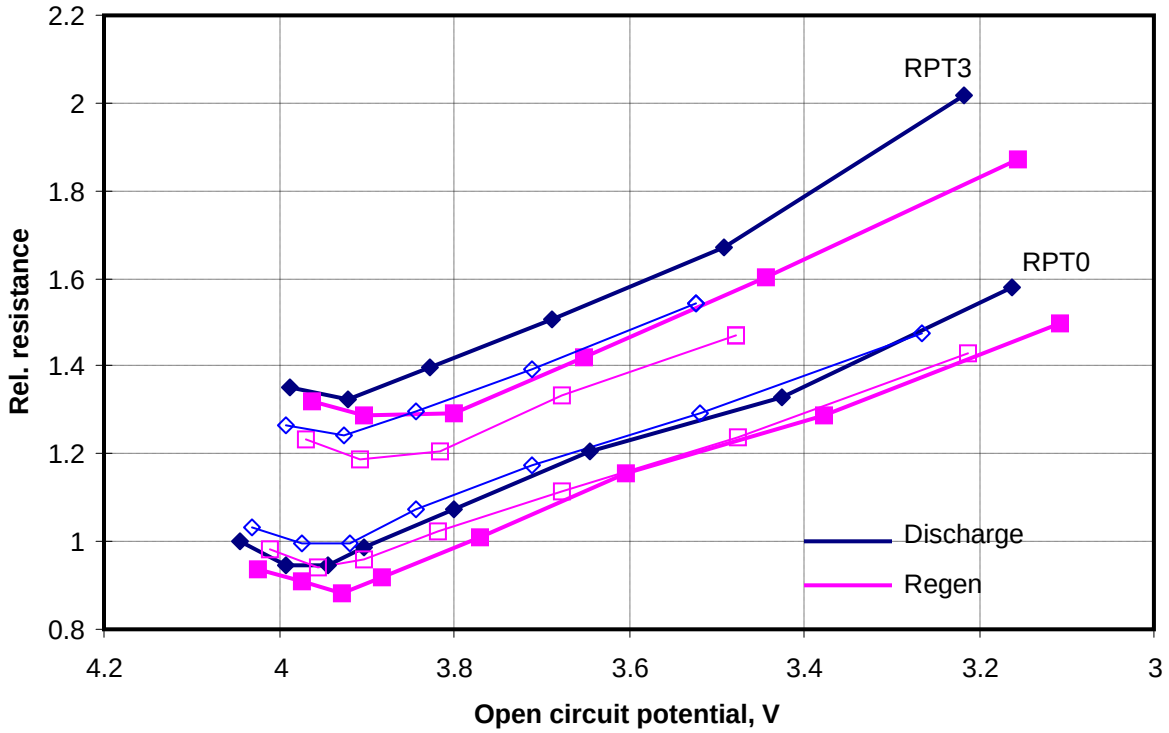


At the Same Time, C/2 Capacity is Fairly Constant

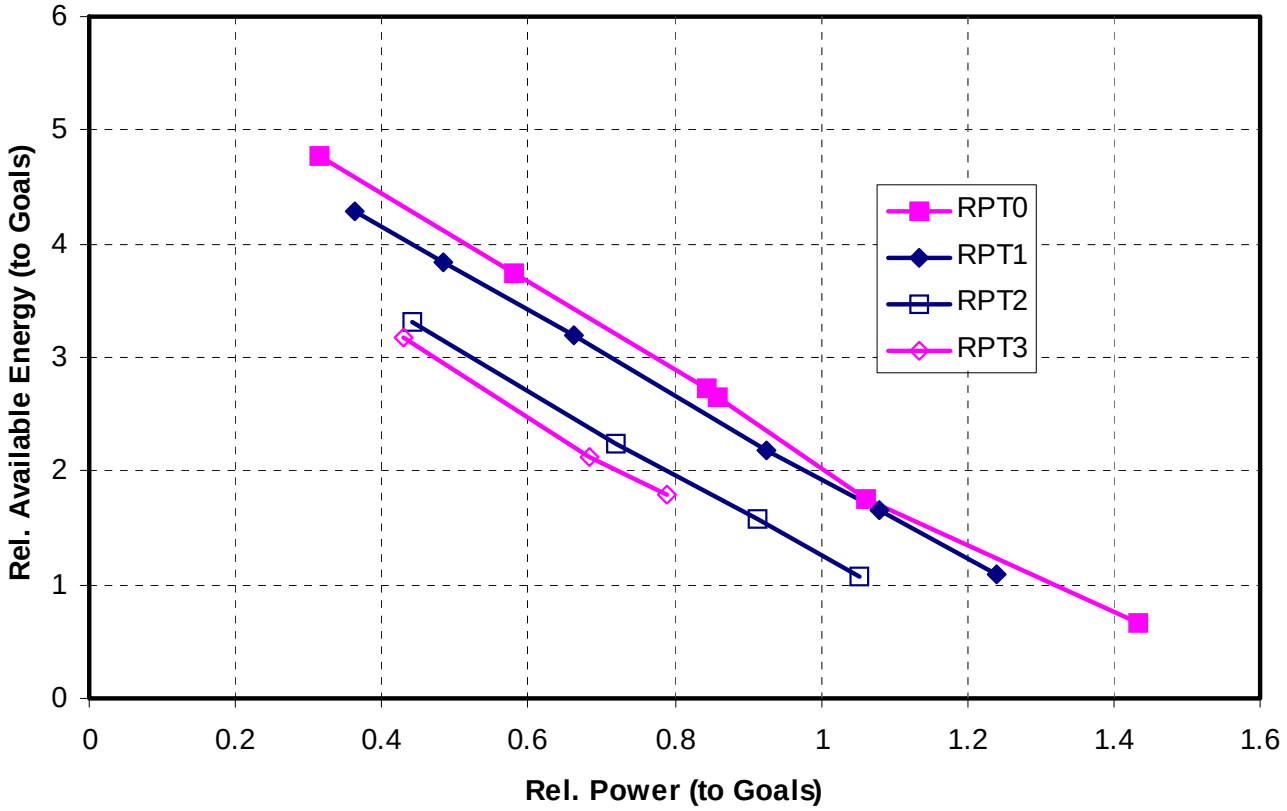


Example Test Results From High-Power Battery Using the Accelerated Protocols

- Cycle life test consisted of 0 to 100% charge/discharges at the 5C rate at 40°C
- Battery reached end of life after 203 cycles
- Rel. resistance values are from HPPC-L test using the 5C/3.75C rates



Power at the Goal Line Changes with Cycle Count



Activities for Next Fiscal Year

- Continue testing HEV contract deliverables
- Start testing PHEV contract deliverables
- Continue acquiring and benchmarking batteries from non-DOE sources
- Aid in refining standardized test protocols
- Upgrade and expand test capabilities to handle increase in deliverables (due to new PHEV program)

Summary

- Provide a valuable, independent capability to validate performance and life of advanced battery technologies
- Tested many different types of batteries using standard and accelerated protocols and provided fair comparisons between them (apples-to-apples)
- Some of the results indicated that unusual resistance increase/performance decrease mechanisms were present
- We continue to help DOE benchmark battery technology to learn its state of maturity
- Identified that aging mechanisms of different battery technologies are different
- Accelerated aging can be used to predict cell and battery life

Acknowledgment
This work was performed under the auspices of the US Department of Energy, Office of Vehicle Technologies, under Contract No. DE-AC02-06CH11357.