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Performance Characteristics of Electrochemical Capacitors Including, Abuse Testing, for Use in Electric Utility Applications

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Why Electric Utility Work in an EV Meeting

- **DOE energy storage program mission is to develop advanced electricity storage and power electronics technologies, in partnership with industry, for modernizing and expanding the electric supply. This will improve the quality, reliability, flexibility and cost effectiveness of the existing system.**
- **Electric utilities need energy/electricity storage to mediate between variable sources and variable loads**

(Without storage, energy generation must equal energy consumption)

- **Requirements for storage in utilities are similar to PHEV and HEV needs both for performance and safety**

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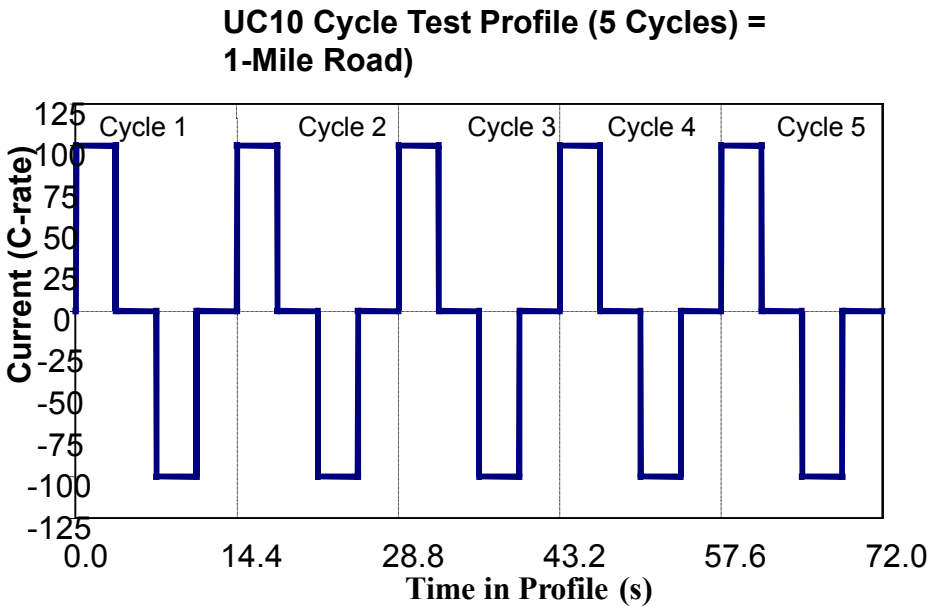
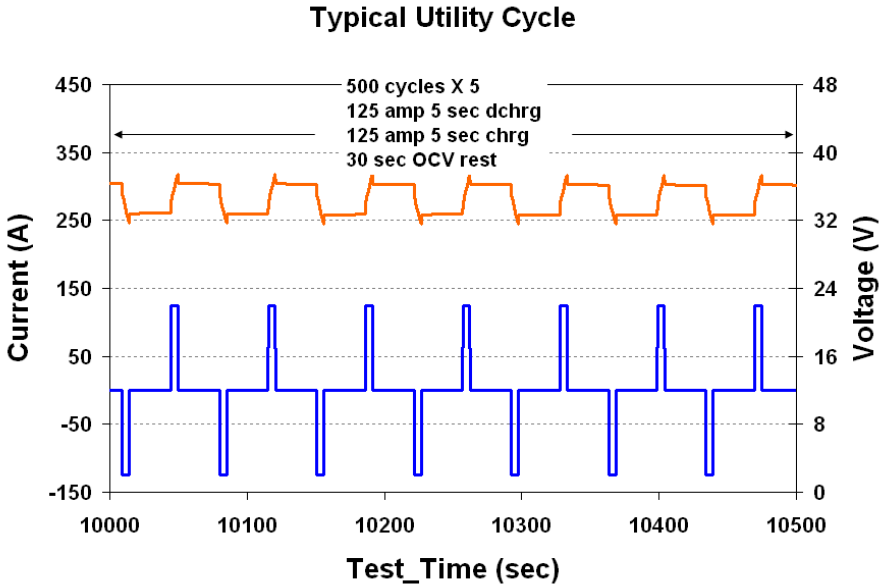
PSOC Capability is Required for both EV and Utility Applications





EV PSOC Cycle

Utility PSOC Cycle

PSOC = Partial State of Charge

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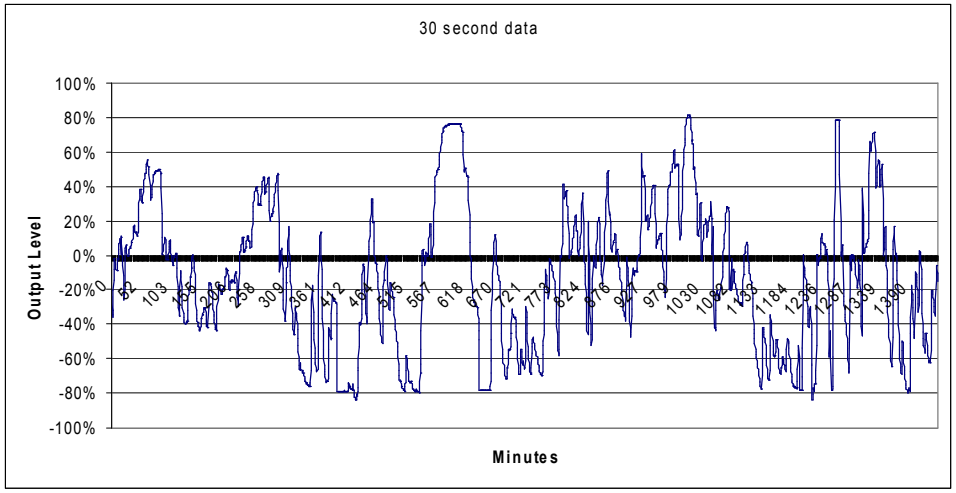
Some Utility Applications Requiring PSOC Operations

Ultra-Capacitors

can provide smoothing for Wind Turbine Sites



Ultra-Capacitors can provide smoothing for Frequency Regulation

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Super Capacitors Available Using Different Electrolytes

- Acetonitrile (ACN) is expected to
  - Provide lower resistance devices
  - With possible safety concerns
- Propylene Carbonate (PC) is expected to
  - Provide much higher resistance devices
  - With improved safety

Super Capacitors Using PC & ACN from Same Supplier Were Tested to See the Extent of Performance Differences

- Performance Testing
  - Resistance Measurements
  - Performance in Utility Cycle
- Safety Tests
  - Over Temperature
  - Over Voltage

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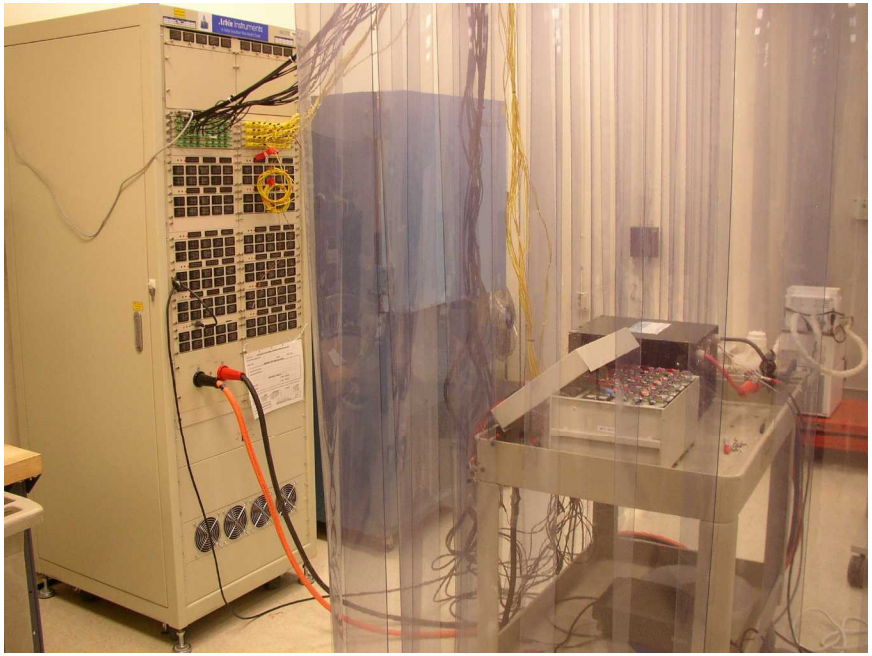
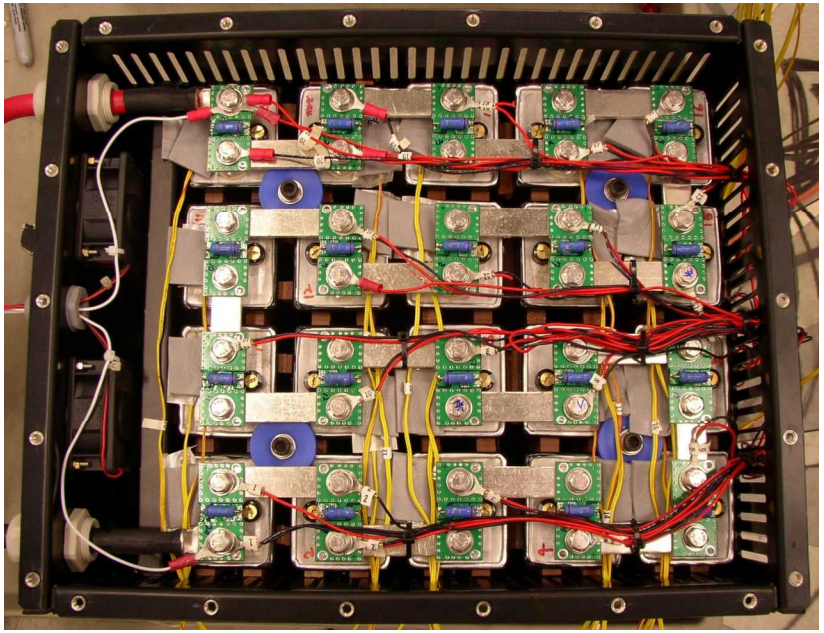
Performance Test Set Up





All Modules Were Wired so Voltage and Temperature Could be Recorded for Each Cell

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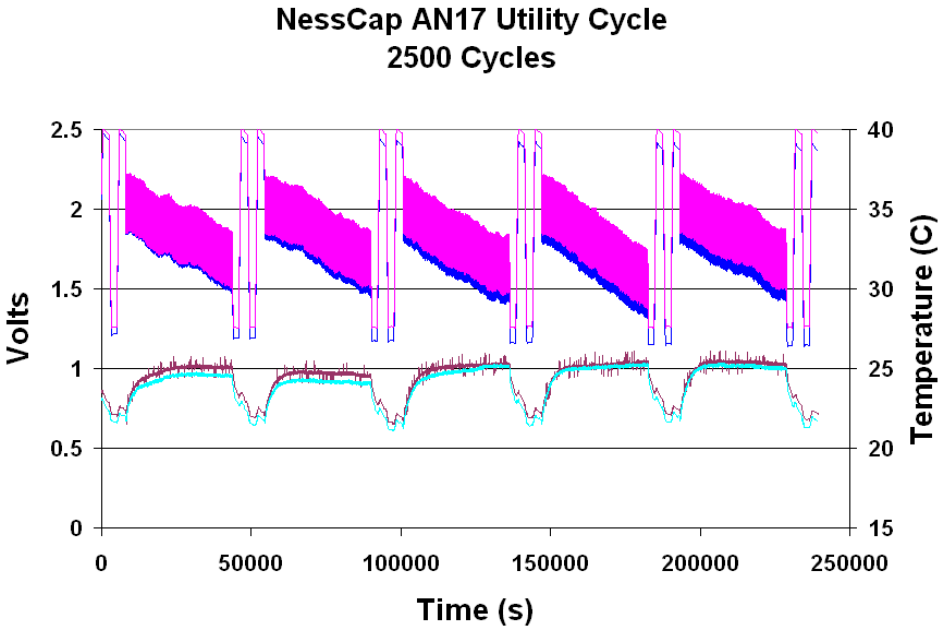
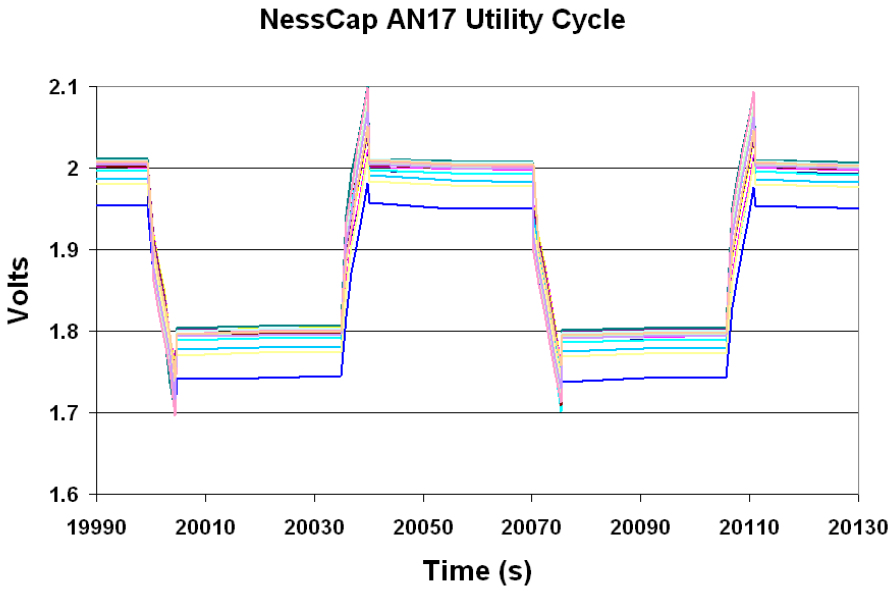
Testing of ACN Devices Using the Utility Cycle



Results from Individual Cell Tests from Modules with Results from Highest and Lowest Cells Shown for 2500 Cycles



Results from Individual Cell Tests from Modules with Results for all Cells Shown for 2 Cycles

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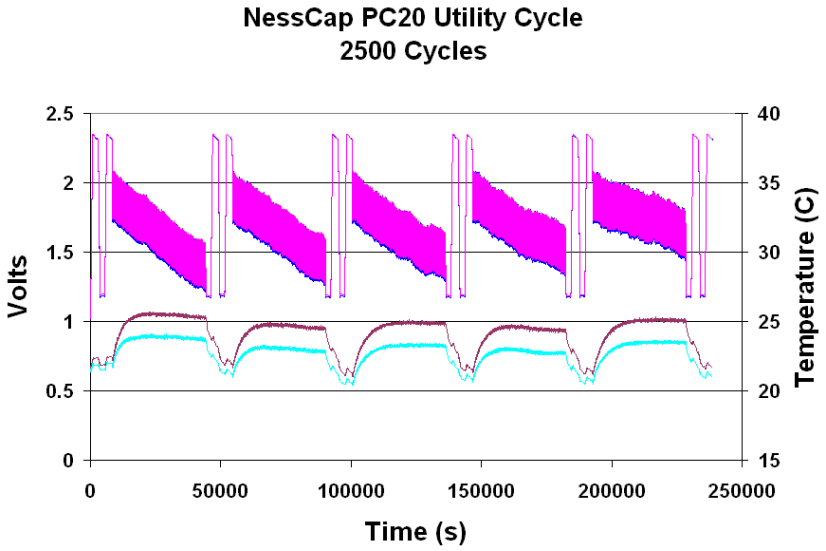
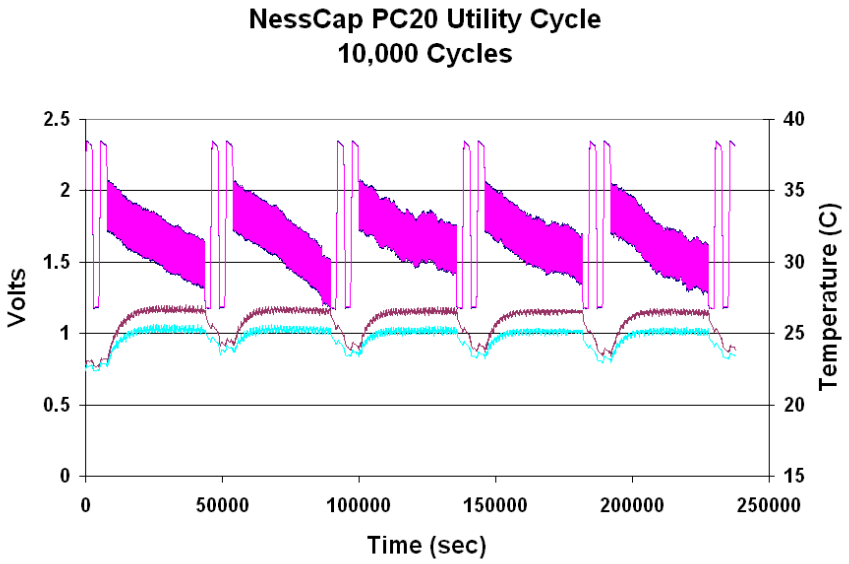
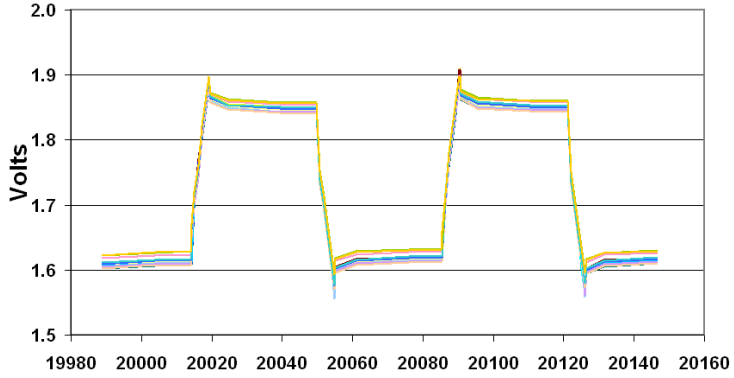
Testing of PC Device Using the Utility Cycle





Results from Individual Cell Tests from Modules with Results from Highest and Lowest Cells



Results from Individual Cell Tests from Modules with Results for all Cells Shown for 2 Cycles

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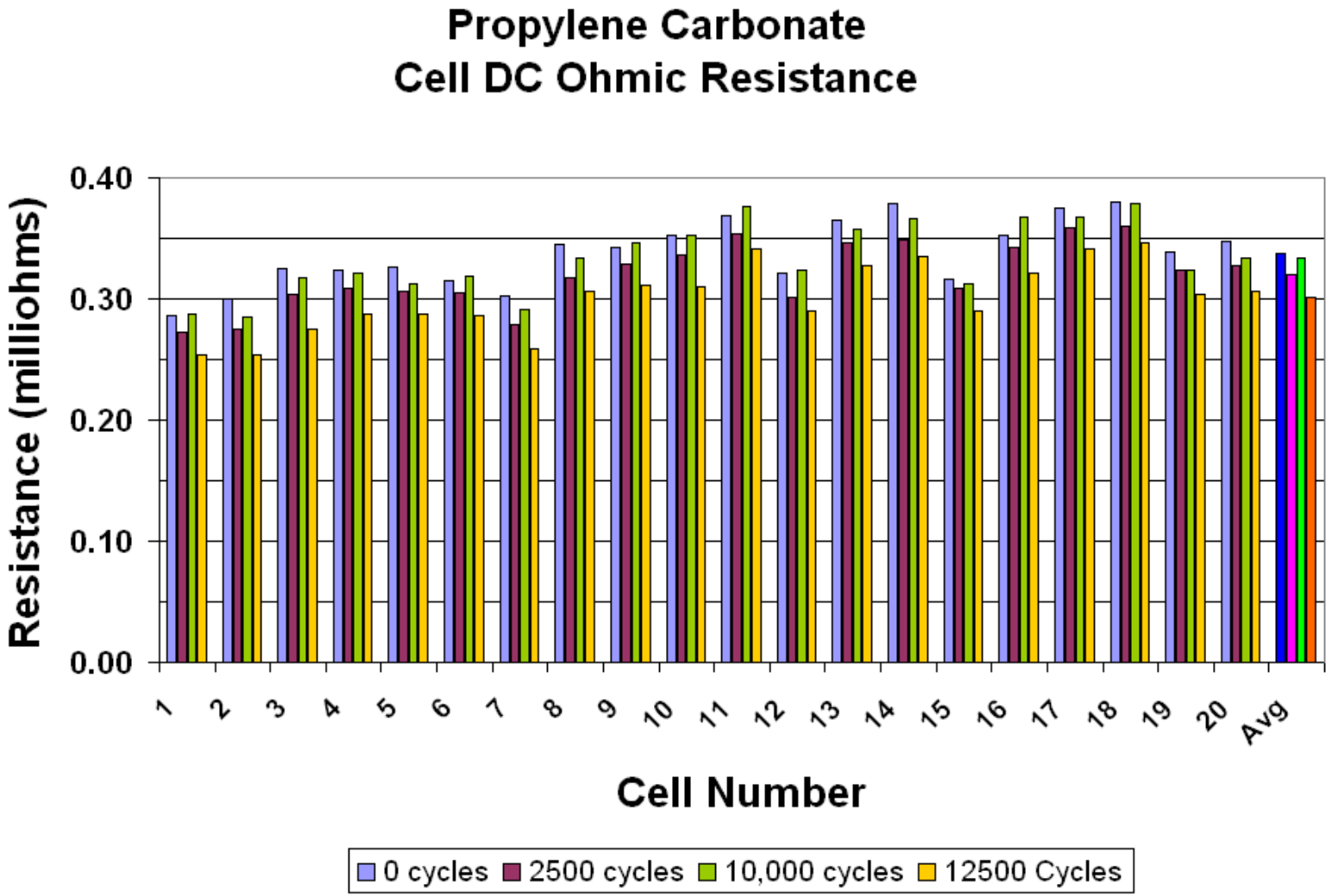
Change in Resistance as a Function of Test Cycle for PC



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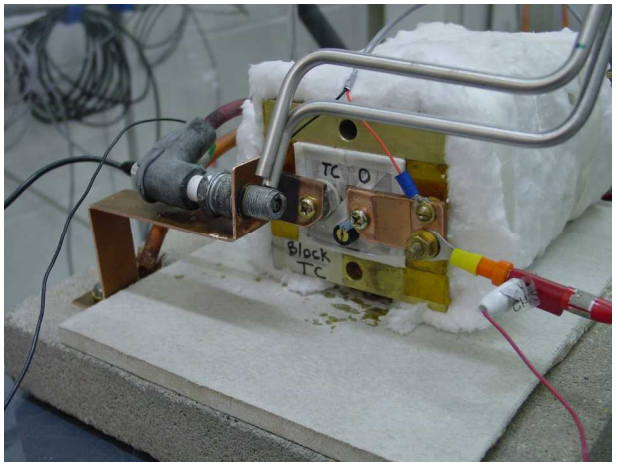
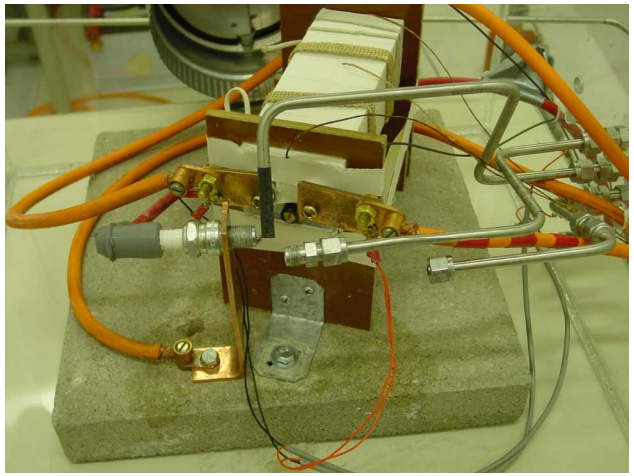
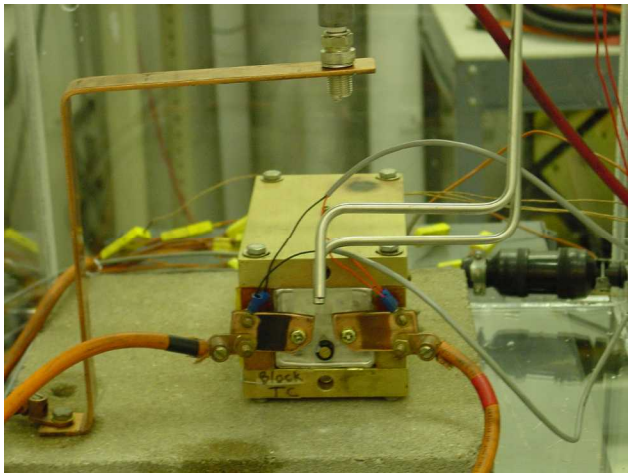
Abuse Test Setup for PC and ACN







ACN

PC

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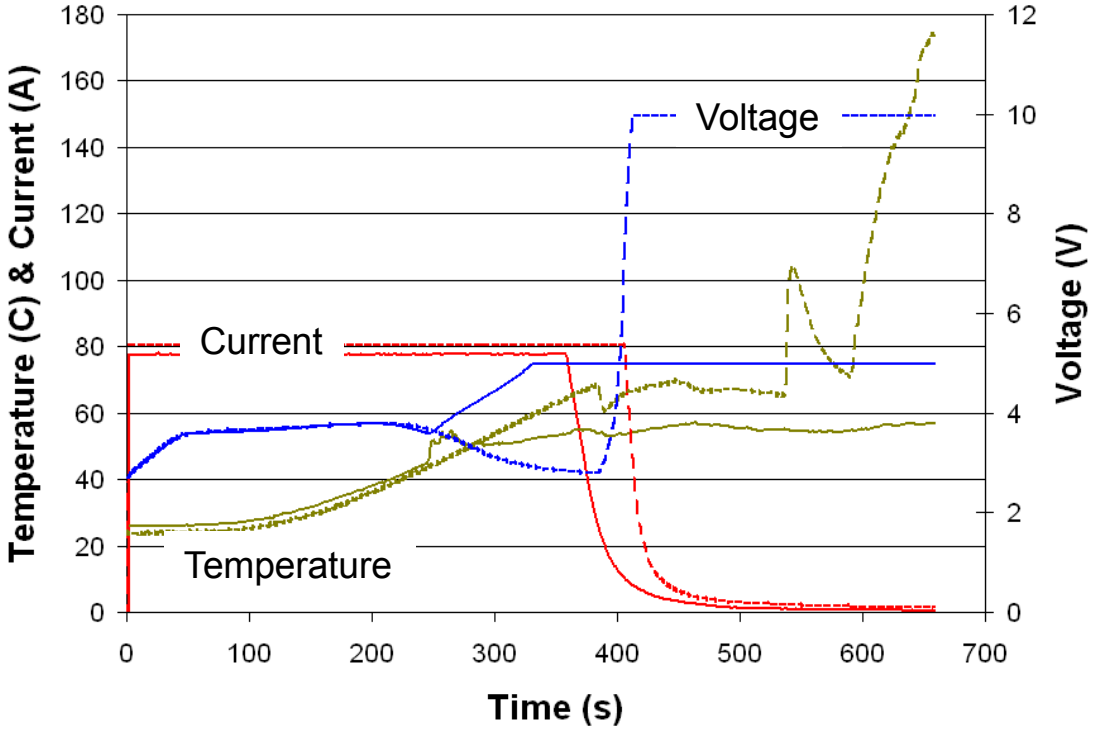
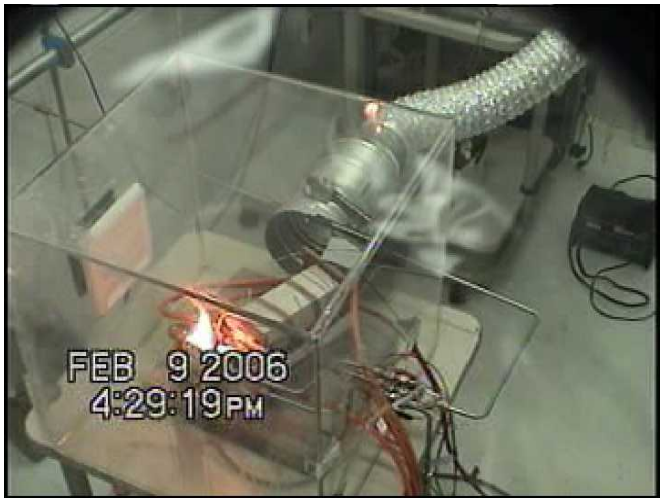
Test Procedure

- Over-voltage Test
  - Charge at ~60-80 Amps
  - Contain vented gases in 45.7 cm (18”) square clear plastic box
  - Measure gases with Residual Gas Analyzer (RGA-MS), Fourier Transform Infrared Spectrometer (FTIR), Drager indicator tubes and Soda-lime tube for HCN
  - Provide Spark in Test Box
- Over-temperature Test Heat at 5°C/min to venting
  - Contain vented gases in 45.7 cm (18”) square clear plastic box
  - Measure gases with Residual Gas Analyzer (RGA-MS), Fourier Transform Infrared Spectrometer (FTIR), Drager indicator tubes and Soda-lime tube for HCN
  - Provide Spark in Test Box

ACN Abuse Testing (Over Voltage)





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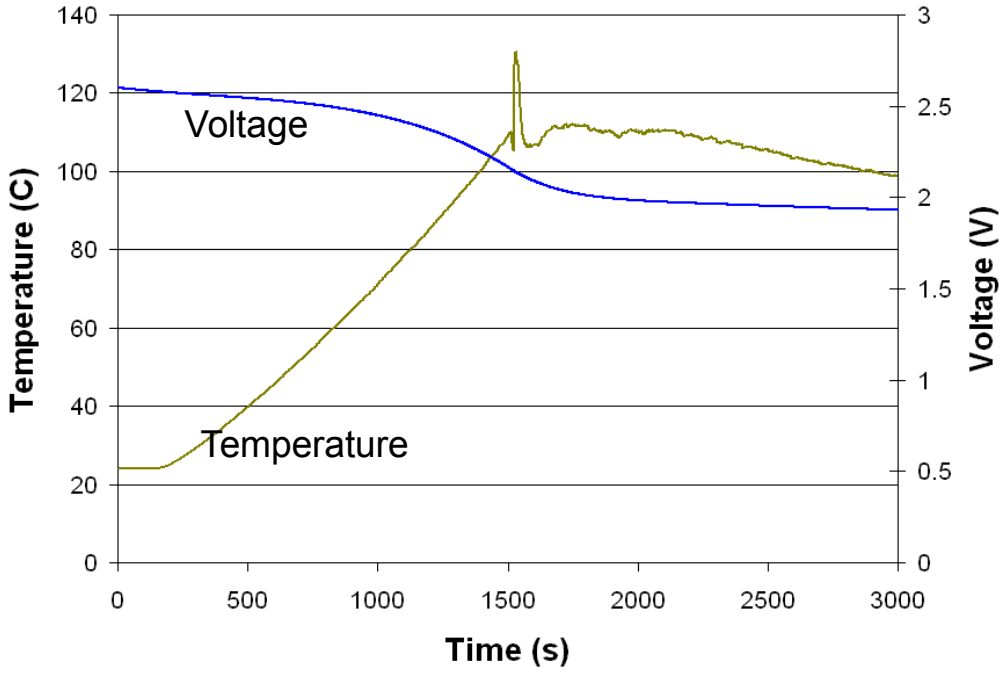
ACN Abuse Testing (Over Temperature)



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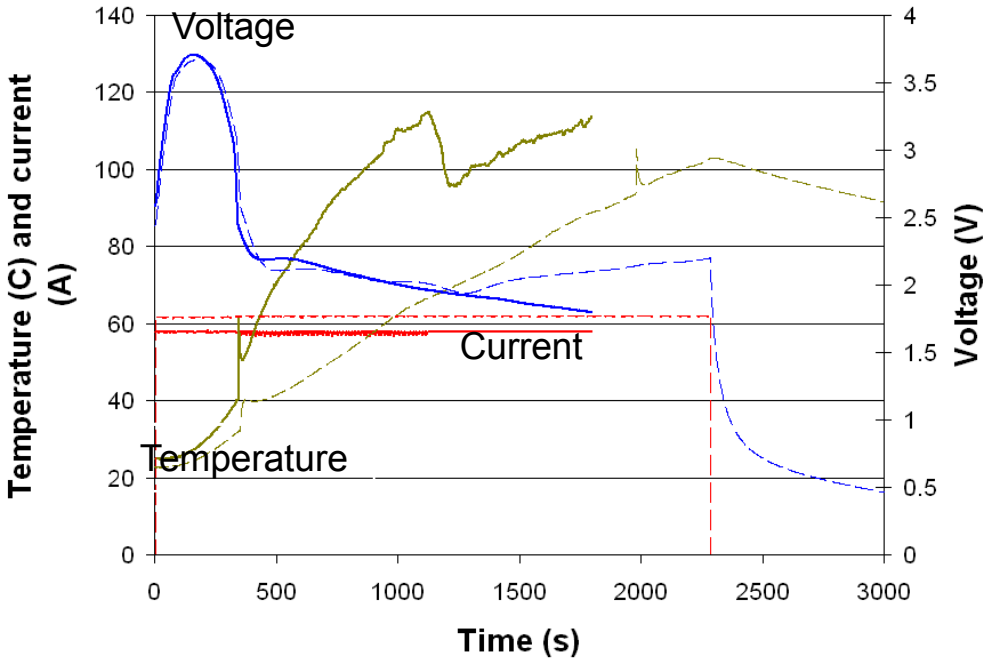
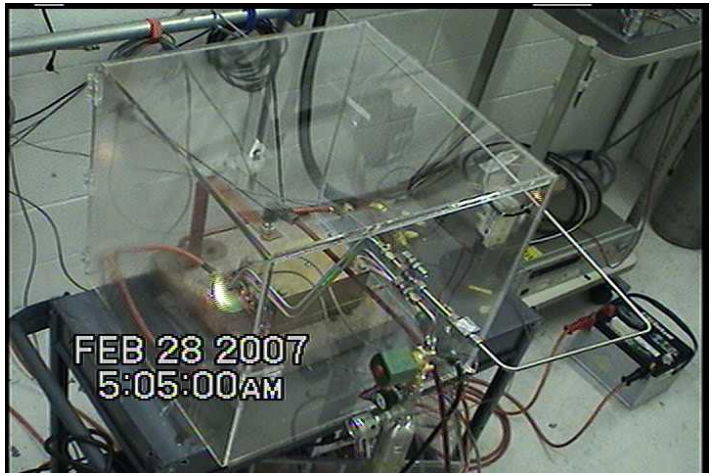
PC Abuse Testing (Over Voltage)





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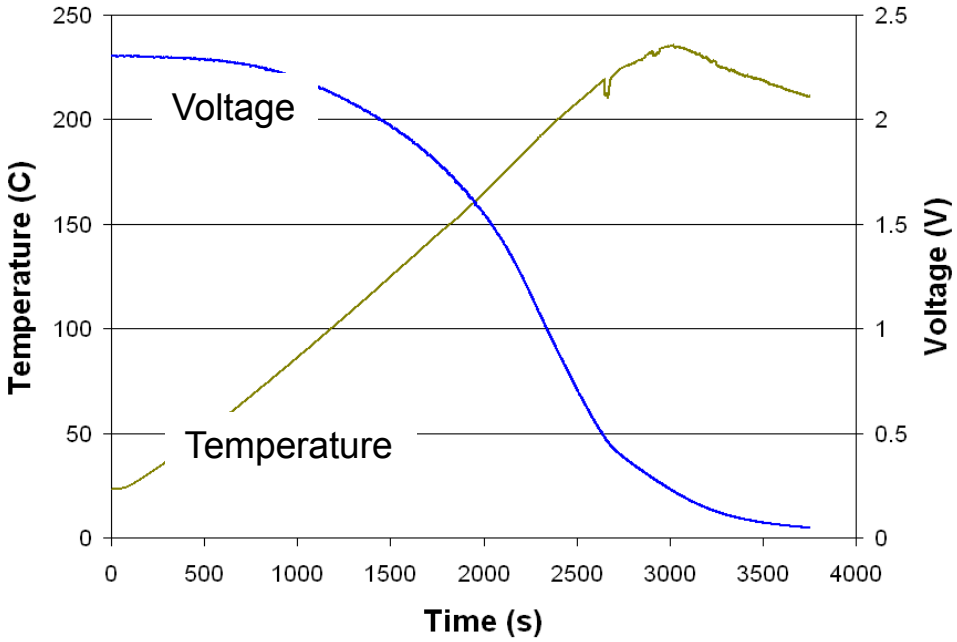
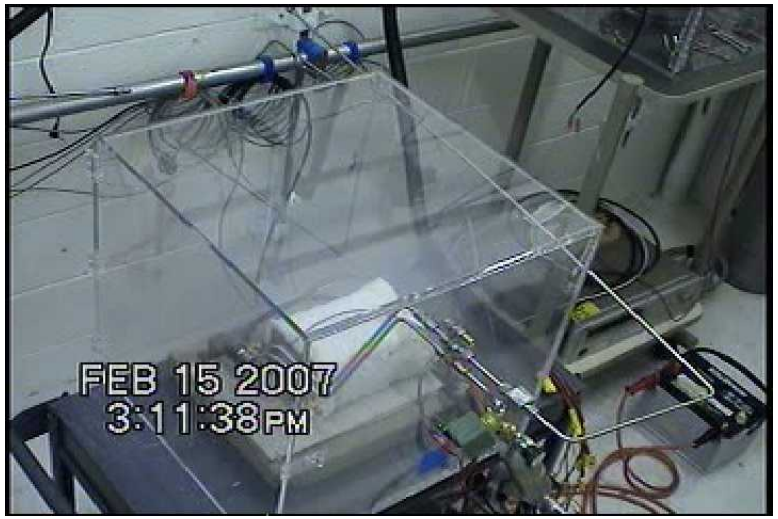
PC Abuse Testing
(Over Temperature)





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Summary

- Performance Testing
  - PC and ACN Super capacitors perform thousands of PSOC cycles
  - Resistance appears to stay constant within tester margin
  - Resistance of PC based super capacitors in same range as ACN based devices
- Abuse Testing
  - ACN with ignition source burns in both over voltage and over temperature tests
  - PC appears to have a much shorter burn in over voltage condition