Solid Oxide Fuel Cell Power System Development DE-FE0001179

R. Kerr

Delphi

15th Annual Solid State Energy Conversion Alliance (SECA) Workshop

July 22-23, 2014

Sheraton Station Square Hotel

Pittsburgh, PA

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Outline

- Summary Highlights of Past Year
- Cell Testing
- Stack Testing
  - Thermal Cycling
  - Constant Current
- System Development and Testing

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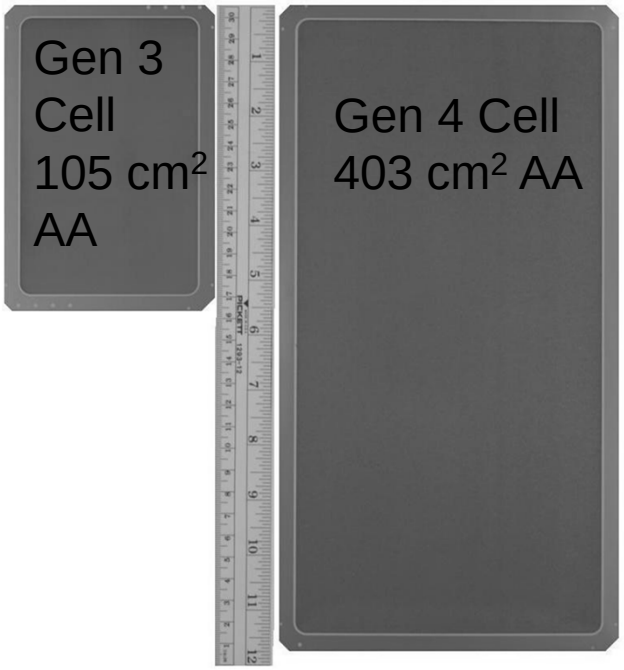
Gen 3 and Gen 4 Stacks

Gen3
9 Kg, 2.5 liters
for a 30-cell
stack, 1.5 kW



Gen4
57.5 Kg, 17.5 liters
for a 38-cell stack,
7 kW

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Performance Highlights Summary

- Fabricated 1,263 cells and 43 stacks of various Gen 3 and Gen 4 configurations in the past year
- Demonstrated over 5,000 hours continuous NOC durability on Gen 3 stacks and Gen 4 stack
  - Gen 3, 30-cell stack degradation rate demonstrated at 0.77%/1000 hrs
  - Gen 4, 40-cell stack degradation rate demonstrated at 1.1%/1000 hrs
- Completed 170 full thermal cycles on Gen 4 stack with less than 2% voltage degradation, and 110 full thermal cycles on a second Gen 4 stack with no measurable voltage degradation
- Completed investigations:
  - Redesigned Gen 4 stack loading mechanism for durability/cyclability
- System testing
  - Tested two multi-stack (3) power systems in test furnace
  - Progress on nine-stack power system test

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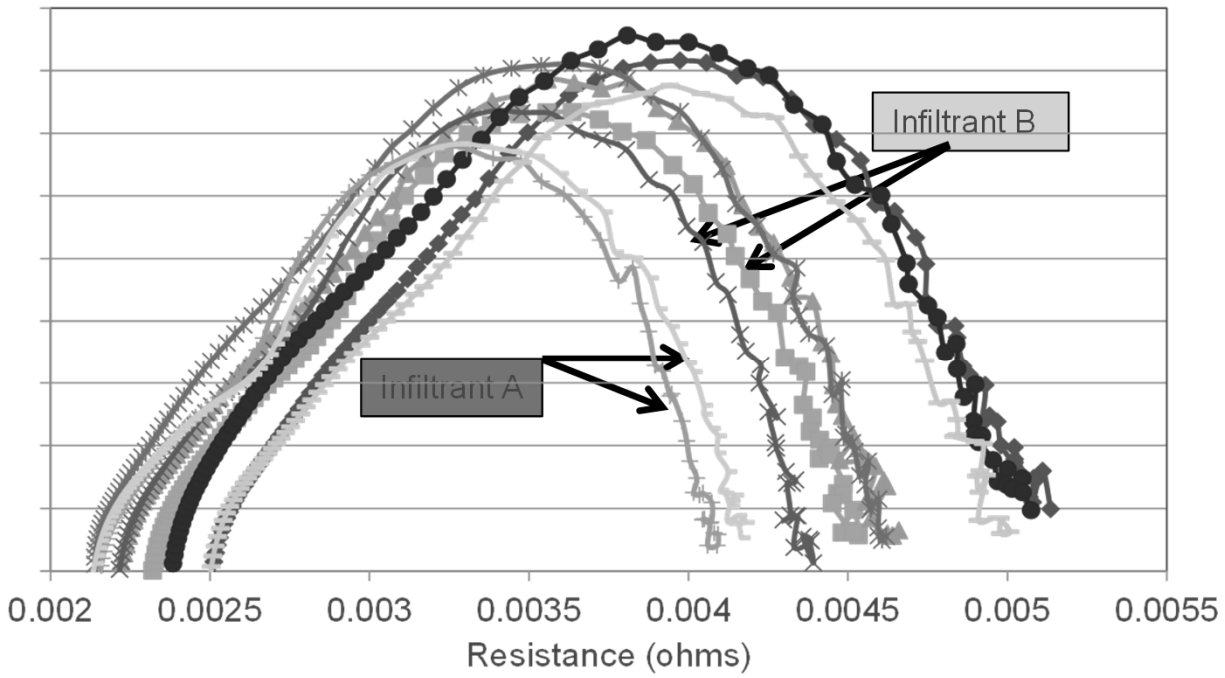
Nyquist Plots After 800 Hours

- NETL infiltrated four Delphi Gen 3 cells with either of two cathode infiltrants
- The four cells were built into a nine cell stack with five standard cells
- The stack has been operated with a variety of “constant current” conditions (approaching 3,000 hrs)



9 Cell Stack

5 Standard cells
2 Infiltrant A cells
2 Infiltrant B cells

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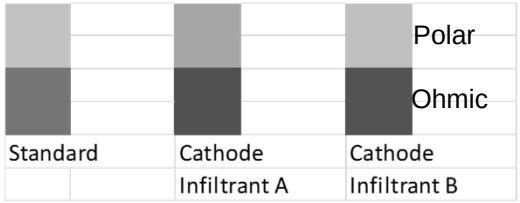
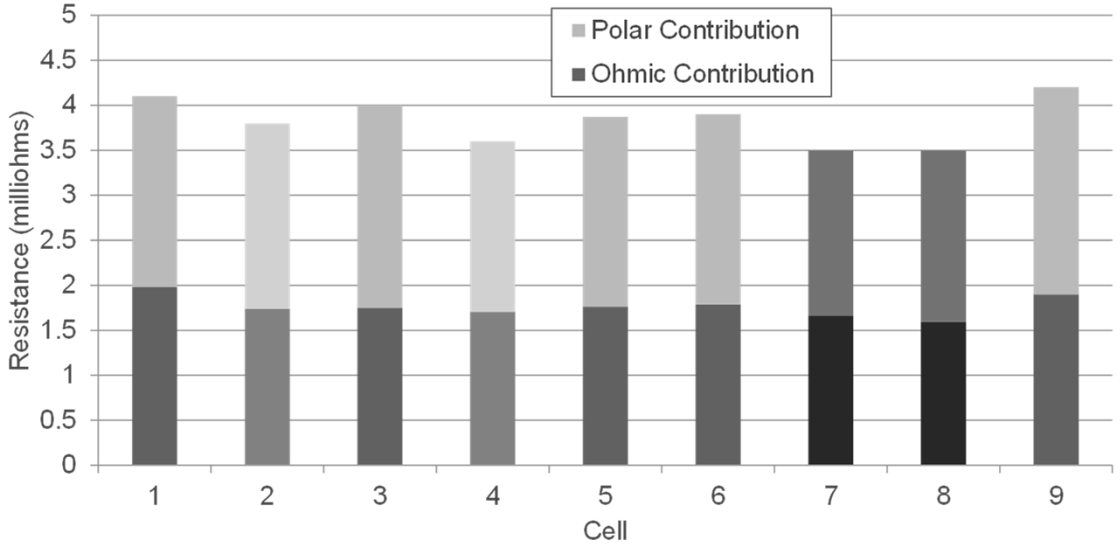
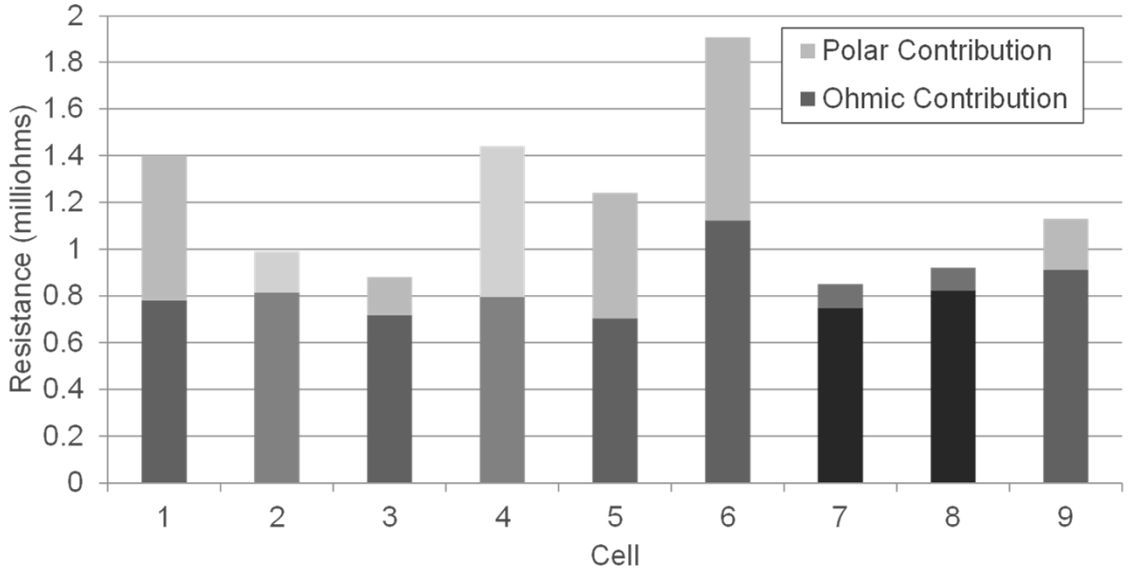
Cell Performance Changes at 1,500 Hrs

Initial Cell Resistances (at 120 hrs)





Increase in Cell Resistances at 1,500 hrs



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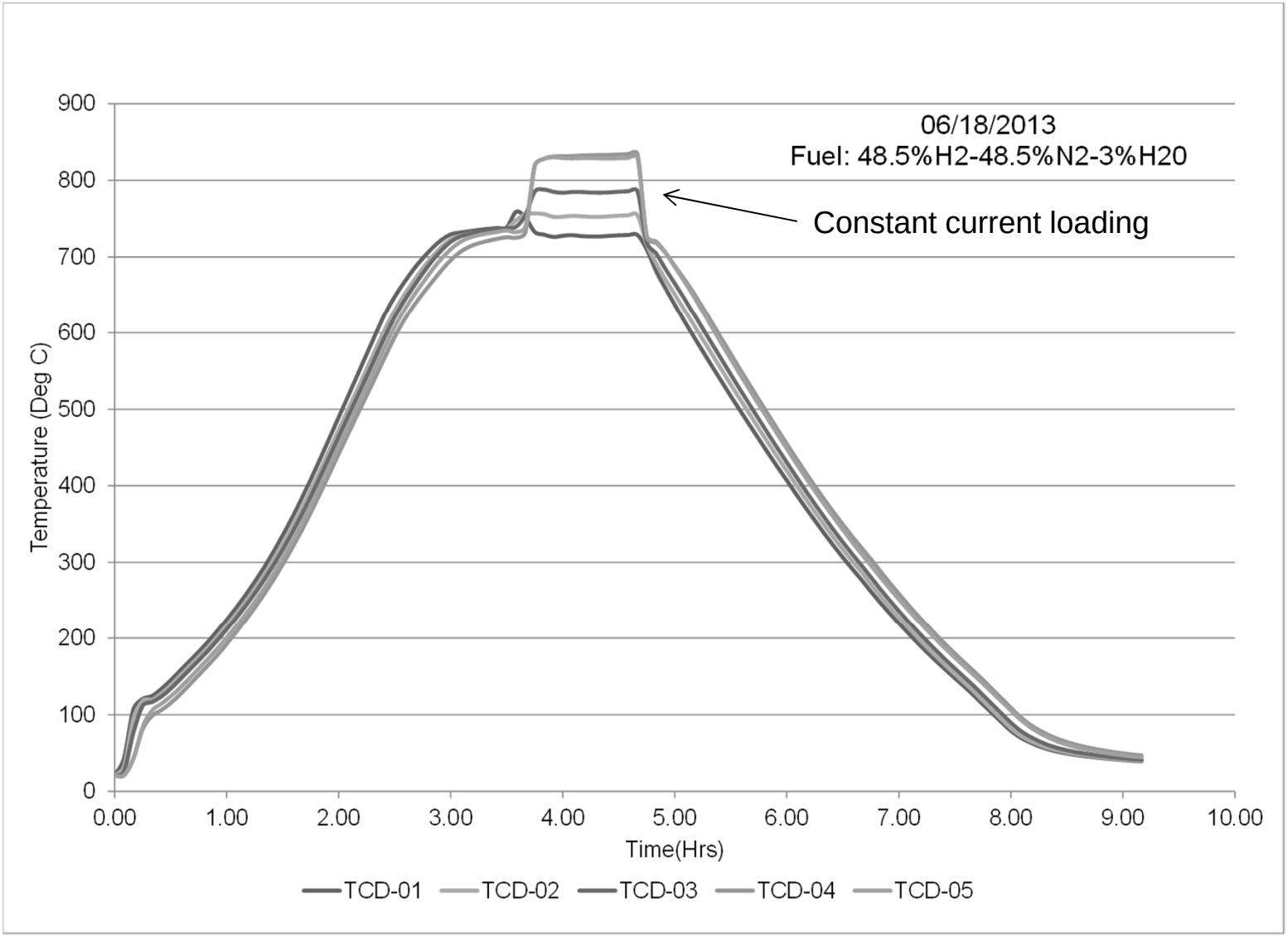
Development of Improved Loading Design for Gen 4 Stacks

- Accelerated testing provided through thermal cycling
  - From near RT to operating temp and back to near RT
  - Electrochemical performance monitored by one hour constant NOC current test at each thermal cycle
  - Thermal cycle duration about 10 hours
  - Off-stand stack leakage monitored at start of test, at varied intervals during the test, and at end of test
- Stack G080
  - Gen 4, 30-cell stack with standard loading mechanism
- Stack G040
  - Gen 4, 30-cell stack with loading provided through the test stand
- Stack G079
  - Gen 4, 40-cell stack with improved loading mechanism

Stack G080 Thermal Profile During Thermal Cycle 1



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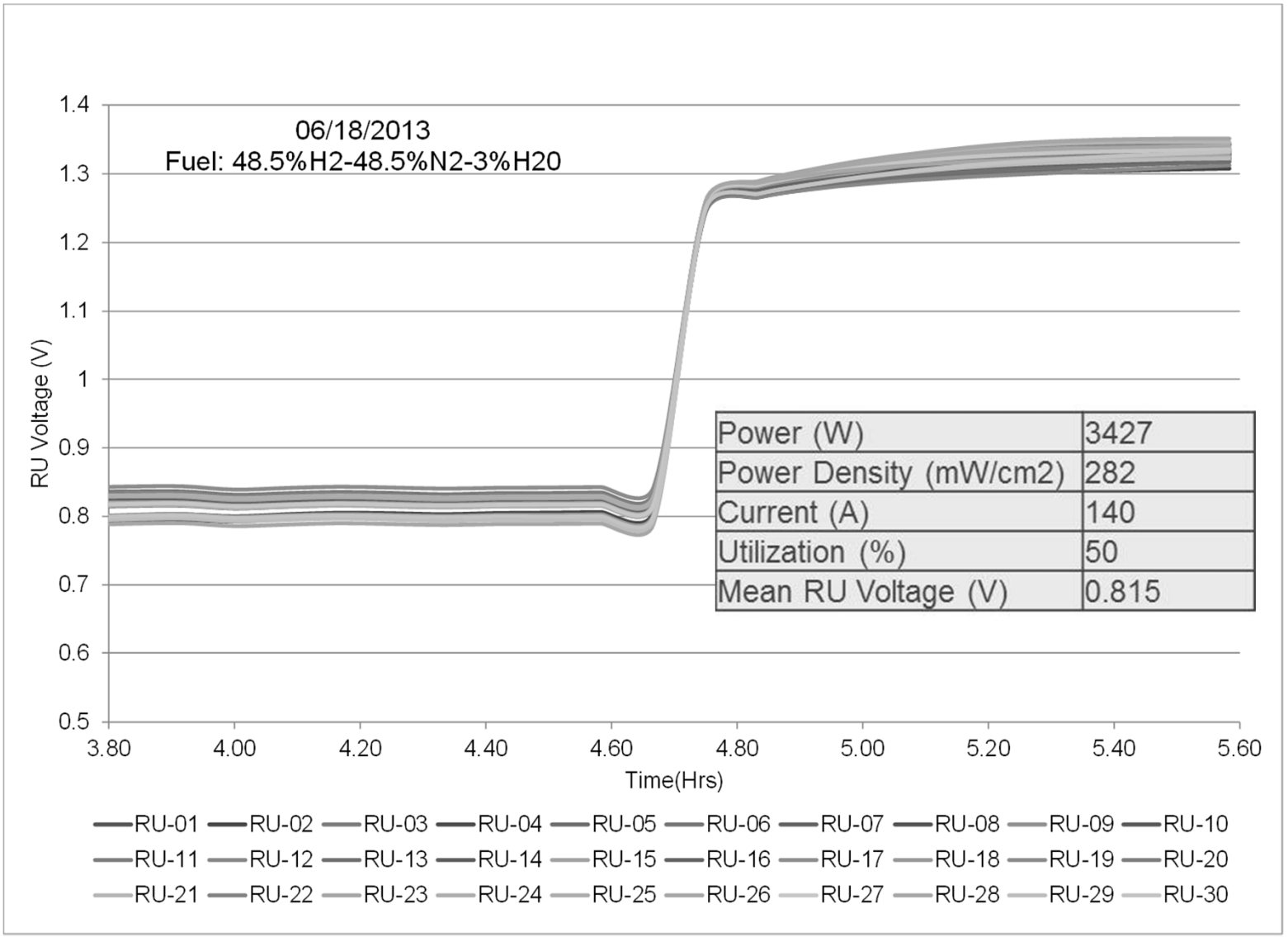
Stack G080, Thermal Cycle 1



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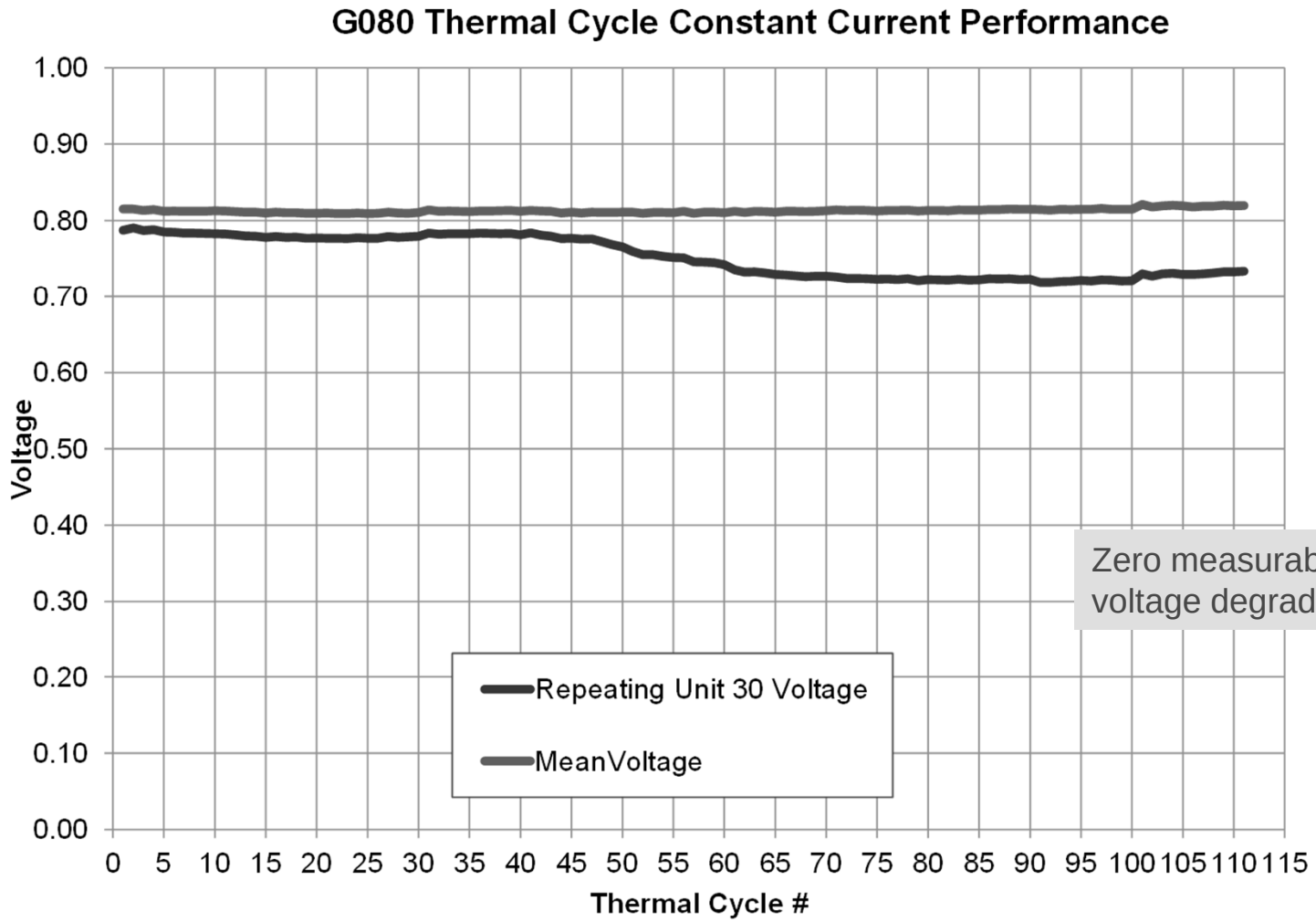
Thermal Cycle Performance of Gen 4, 30-Cell Stack G080



Zero measurable mean voltage degradation

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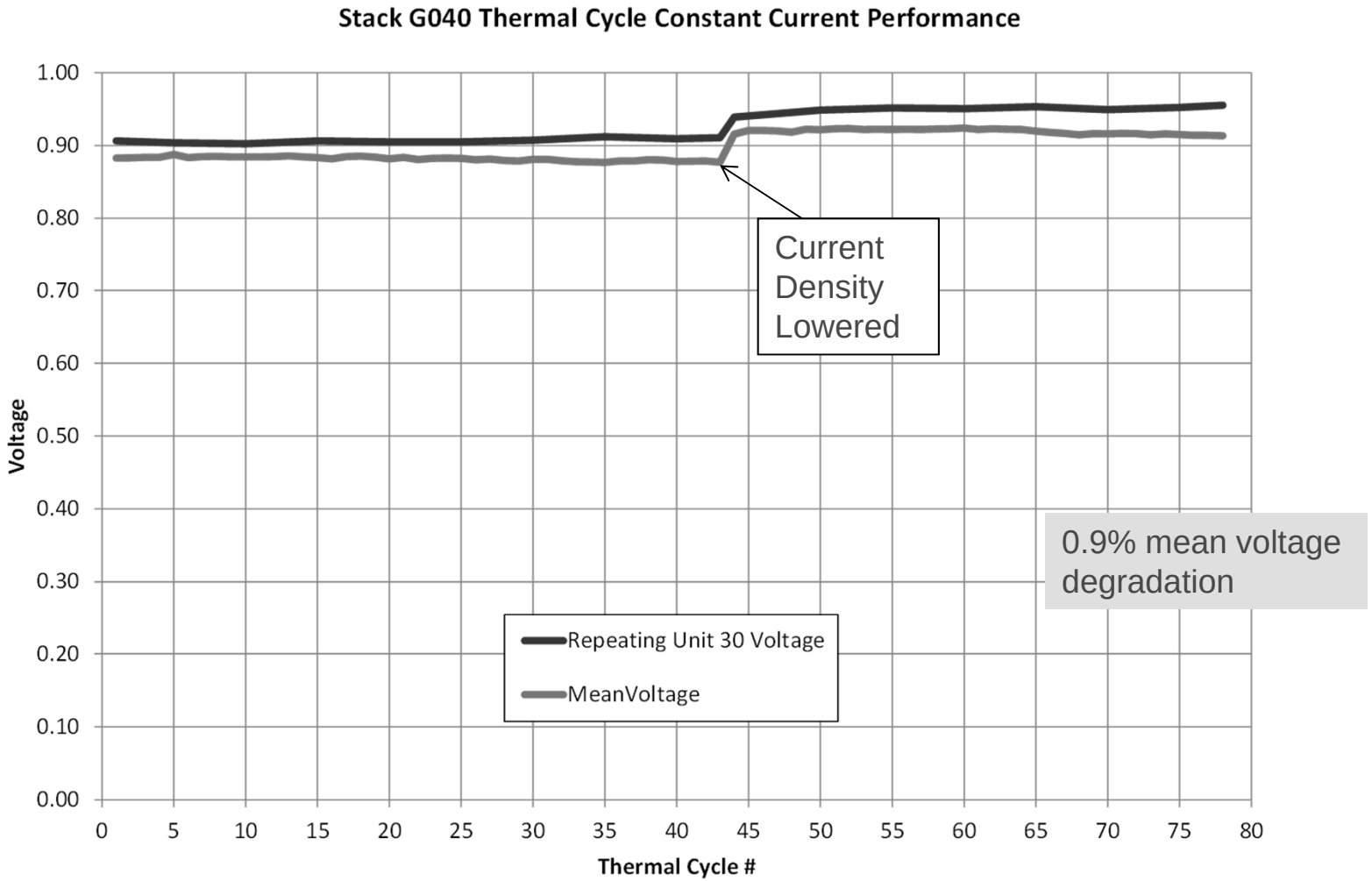
Thermal Cycle Performance of Gen 4, 30-Cell Stack G040



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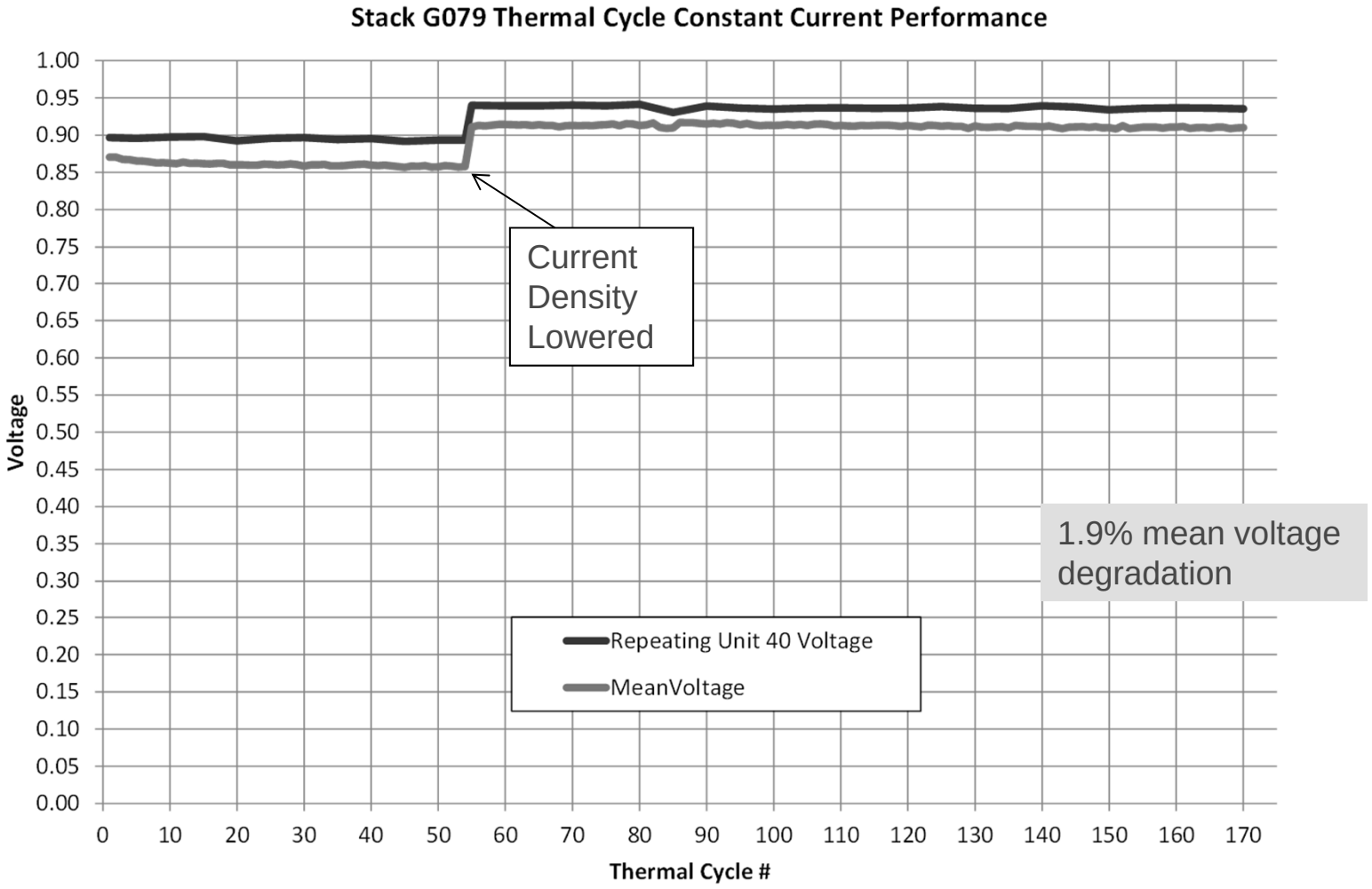
Thermal Cycle Performance of Gen 4, 40-Cell Stack G079



1.9% mean voltage degradation

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Stack Leakage Summary After Thermal Cycling

- Stack G079
  - 40-cell Gen 4 stack
  - Improved loading mechanism
  - Thermal cycled 170 cycles
  - No repeating unit to repeating unit seal leakage measured
  - Sheet metal component found to be cracked and exhibiting measurable leakage

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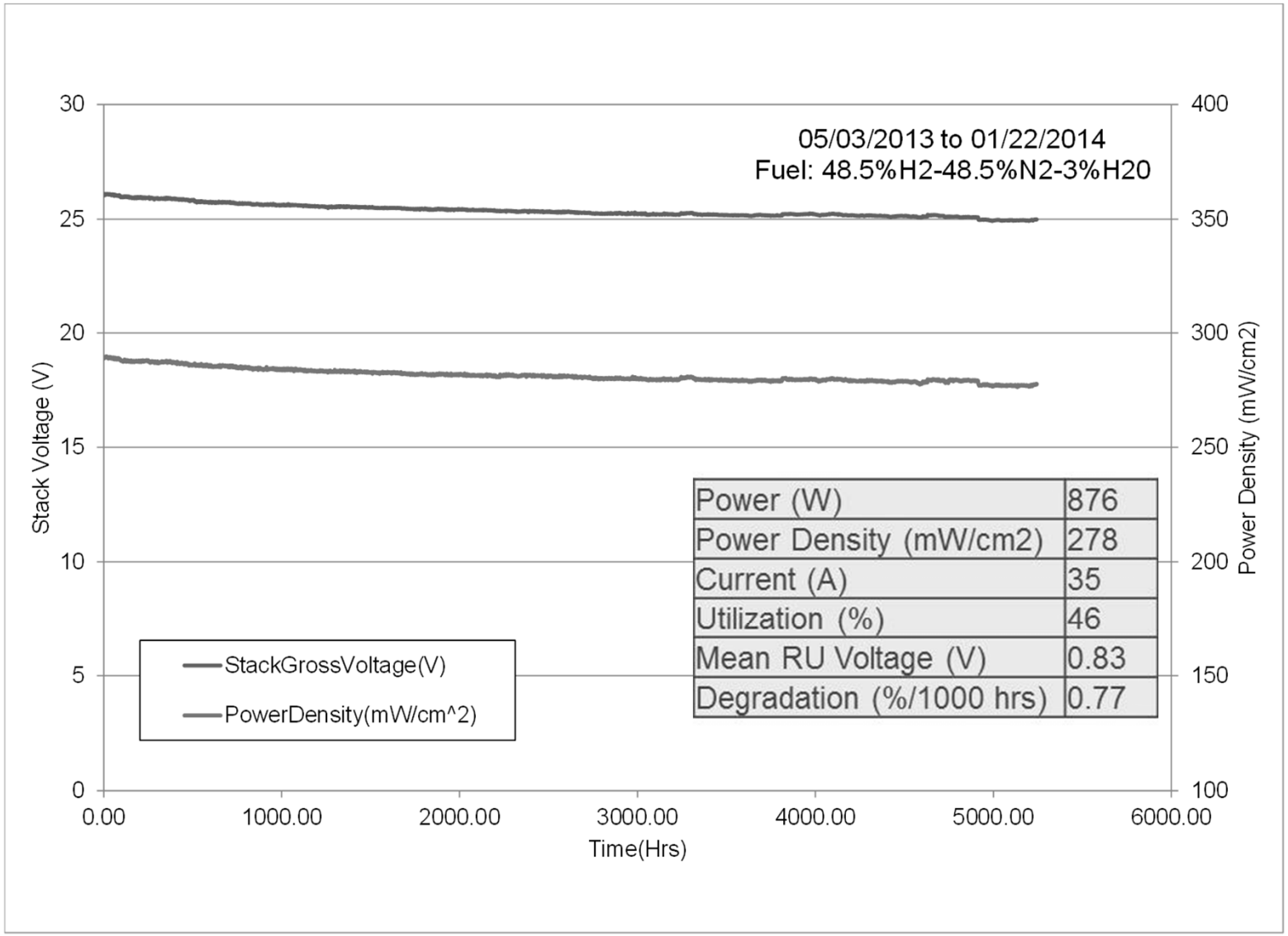
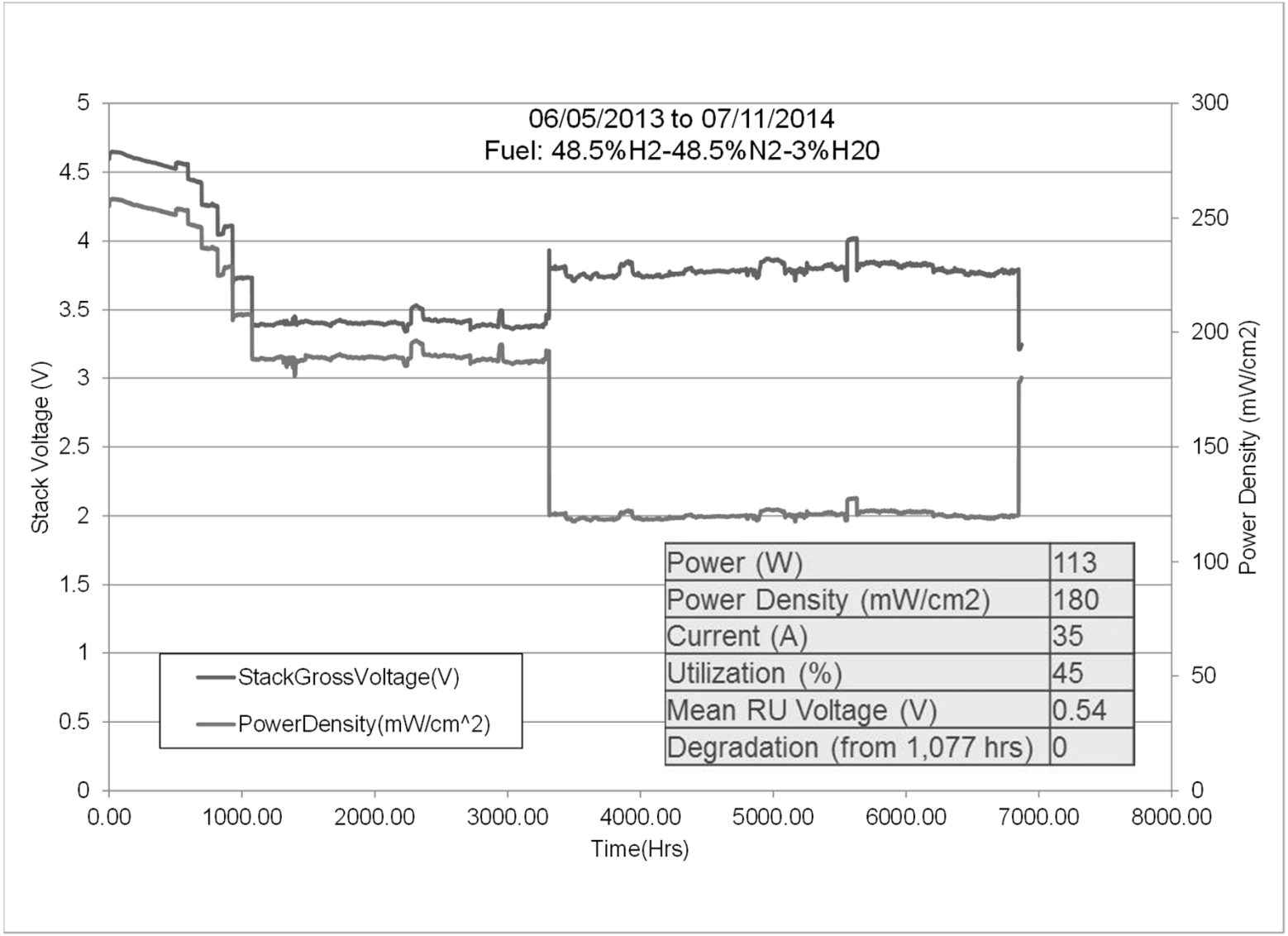
Gen 3, 30-Cell Stack Constant NOC Current (5,243 Hrs)



Gen 3, 6-Cell Stack Constant Current (6,870 Hrs)



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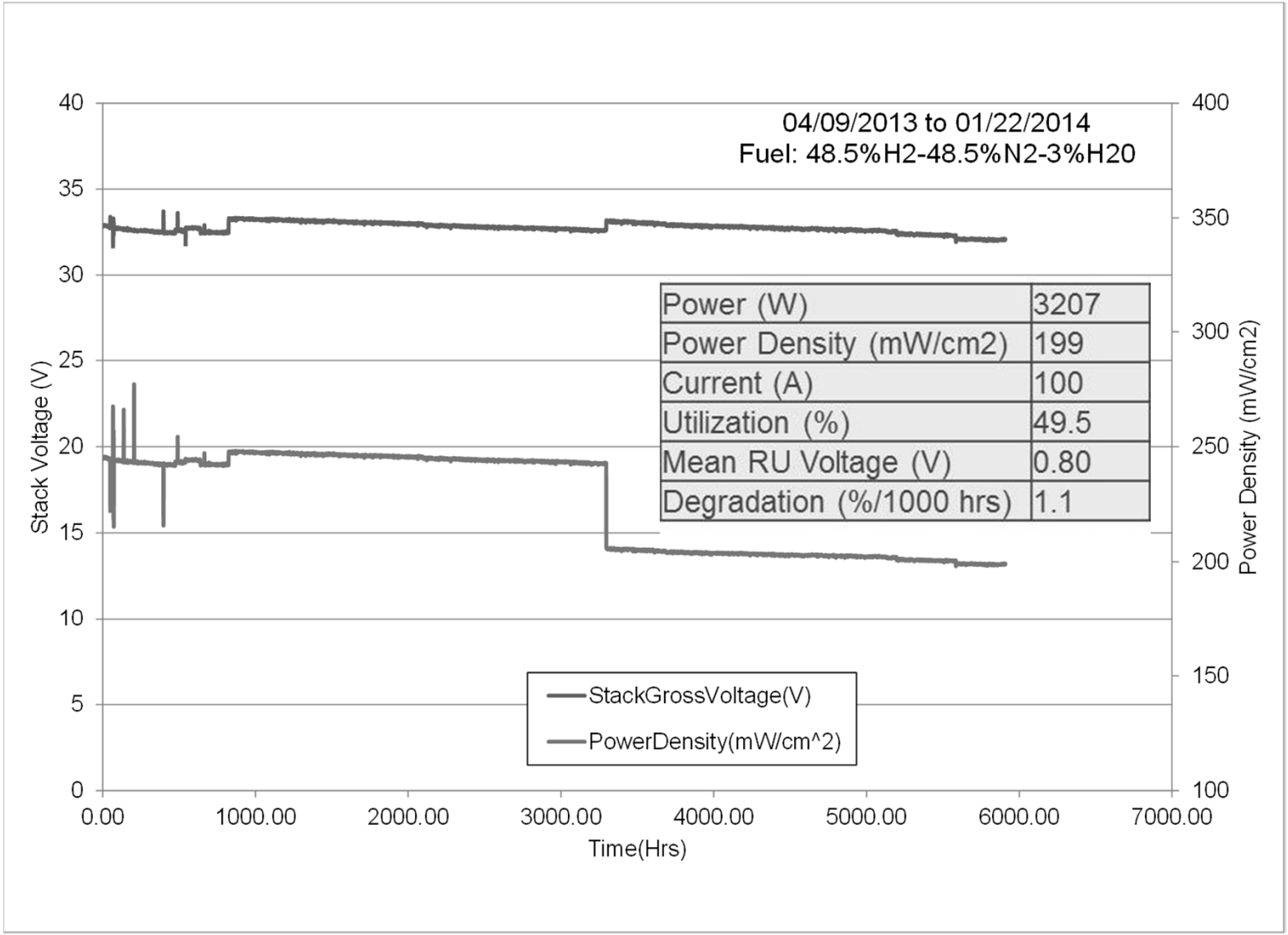
Gen 4, 40-Cell Stack Constant NOC Current (5,909 Hrs)



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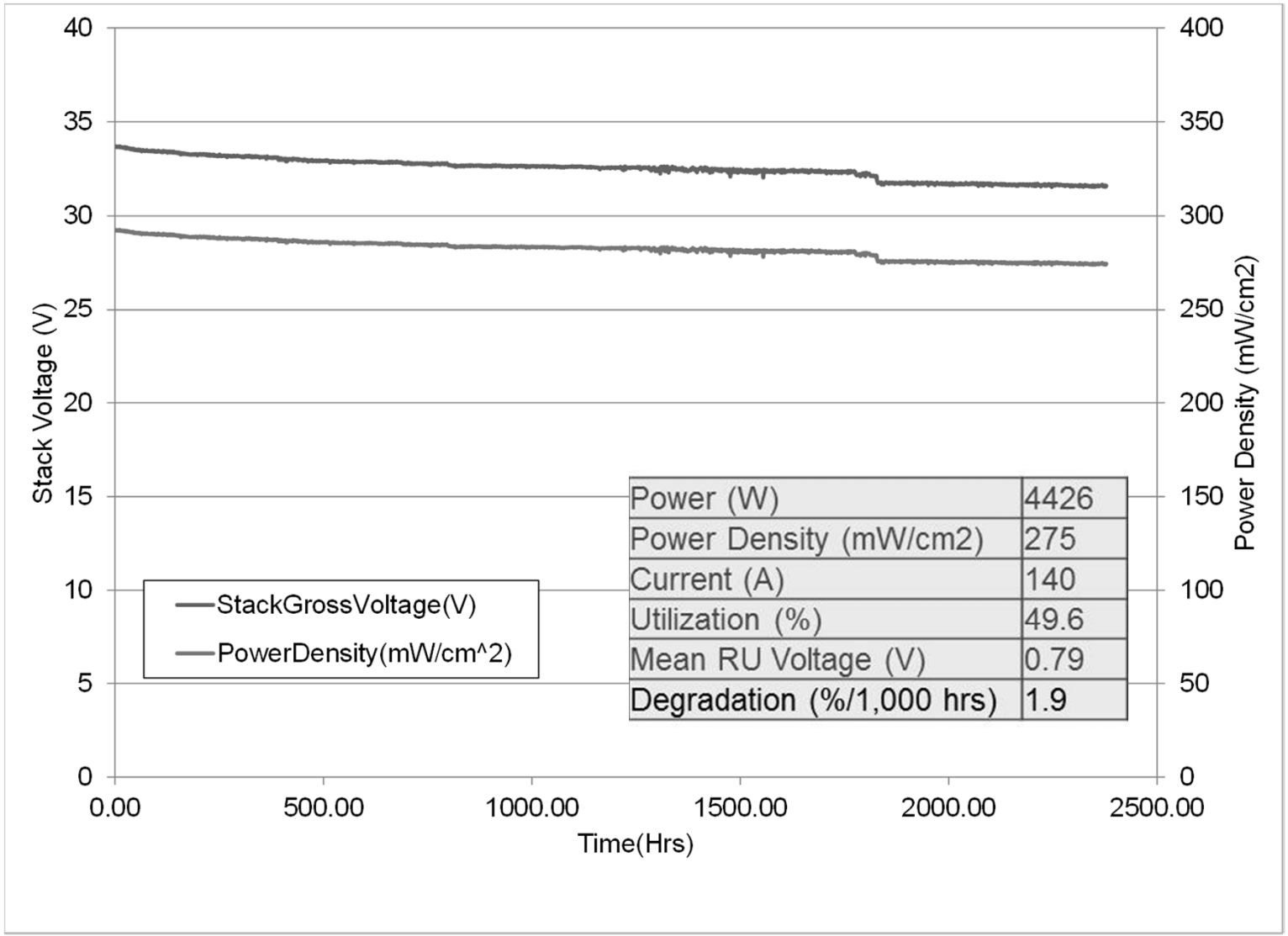
Gen 4, 40-Cell Stack Constant NOC Current (~2,400 Hrs)



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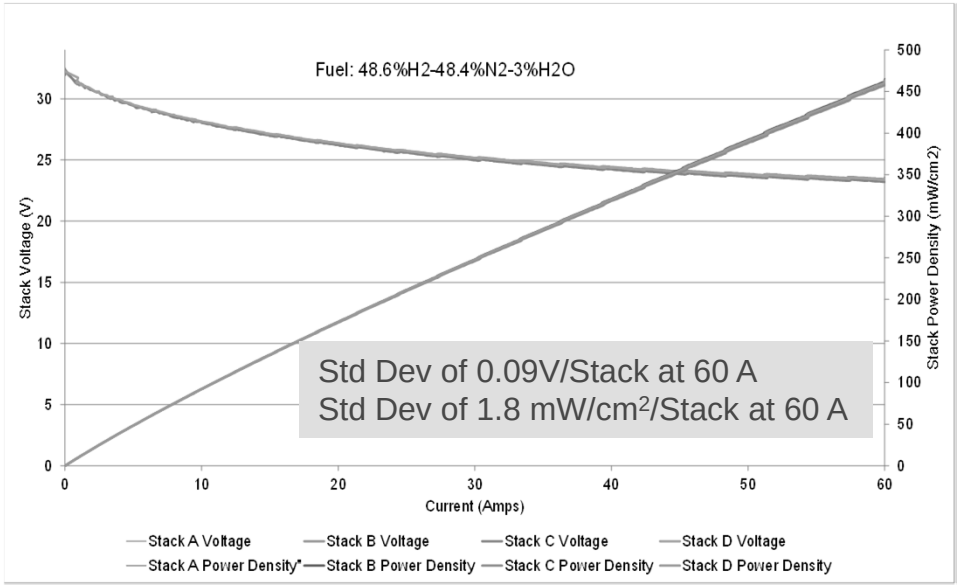
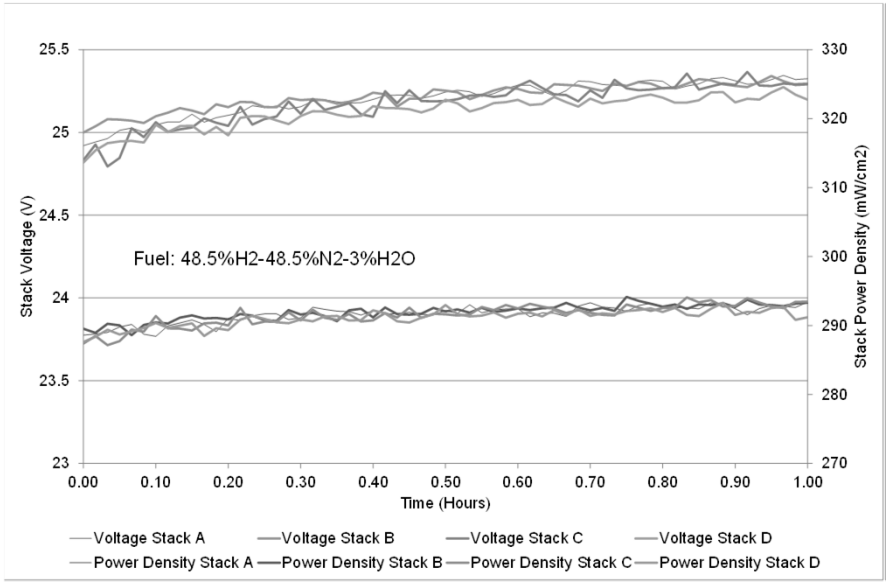
Thermally Self-Sustaining, Multiple Stack Systems

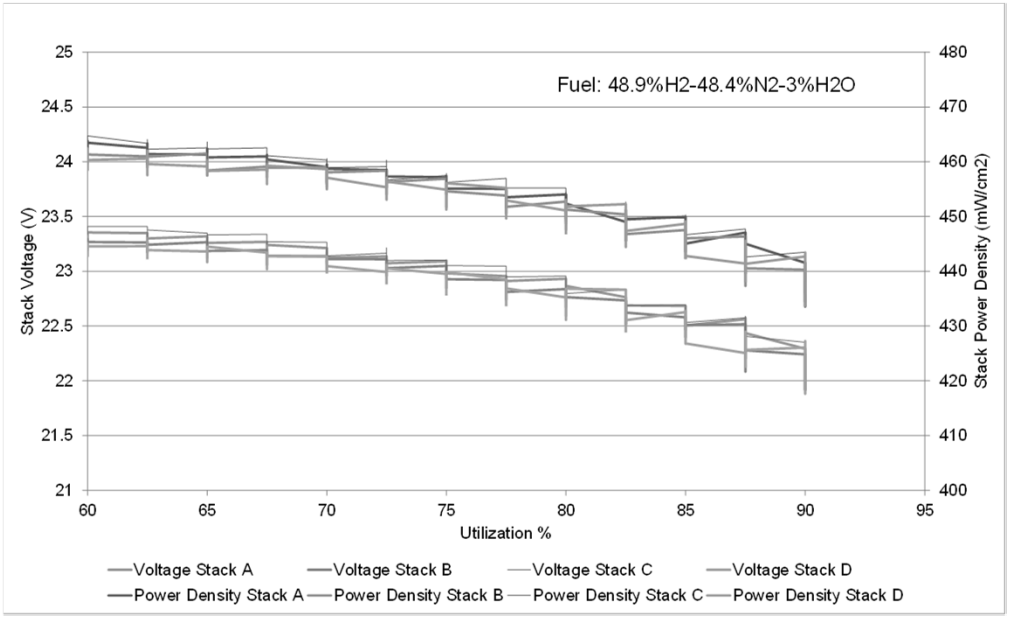
System	Timeframe	Stack Type	Number of Cells/Stack	Number of Stacks	Rated System Power	Electrical Configuration	Hot Zone Instrumentation
A	Q3 2013	Gen 3	29	3	4.5 kW	Two Stacks in Parallel, One Independent	Thermocouples - 51 Pressure Taps - 17 Voltage Leads 12
B	Q2 2014	Gen 3	29	3	4.5 kW	All Stacks in Series	Thermocouples - 32 Pressure Taps - 16 Voltage Leads 6
C	Q3-4 2014	Gen 3	29	9	13.5 kW	Stacks in Series-Parallel Architecture	Thermocouples - 23 Pressure Taps - 4 Voltage Leads 10

Stack Initial Performance Results, System A



Std Dev of 0.09V/Stack at 60 A
Std Dev of 1.8 mW/cm^2/Stack at 60 A





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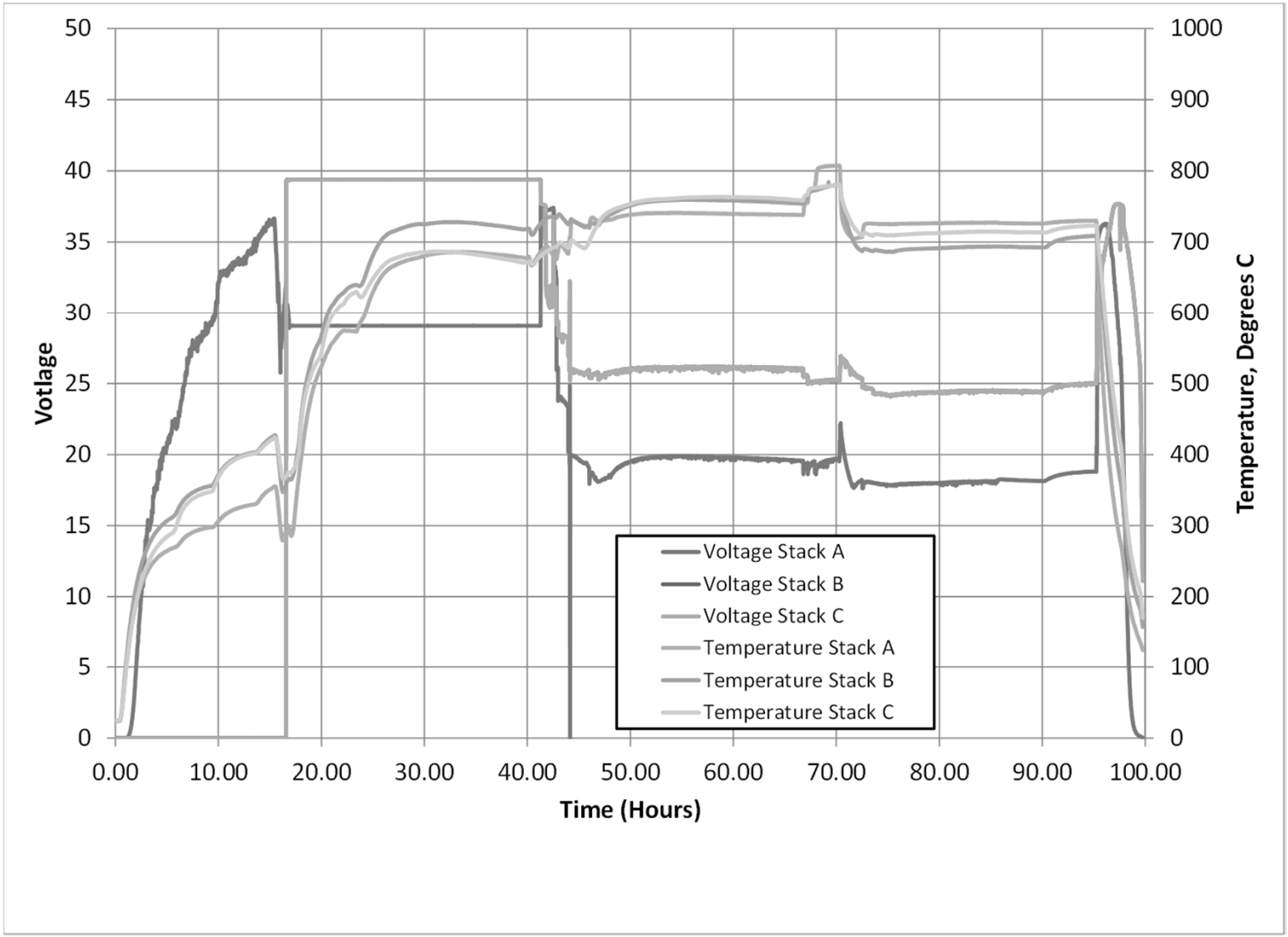
Stack Temperature & Power, System A



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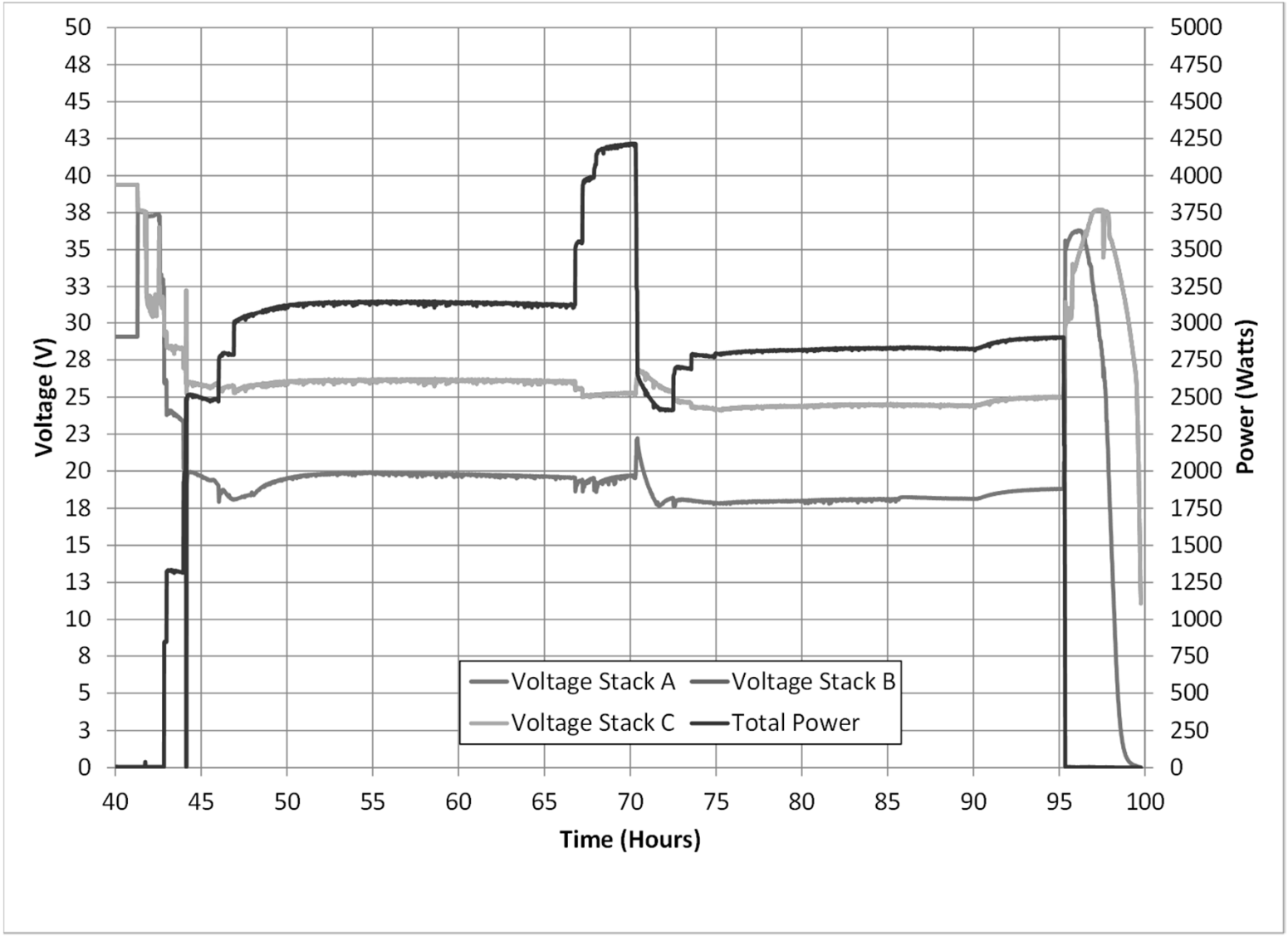
Stack Performance, System A



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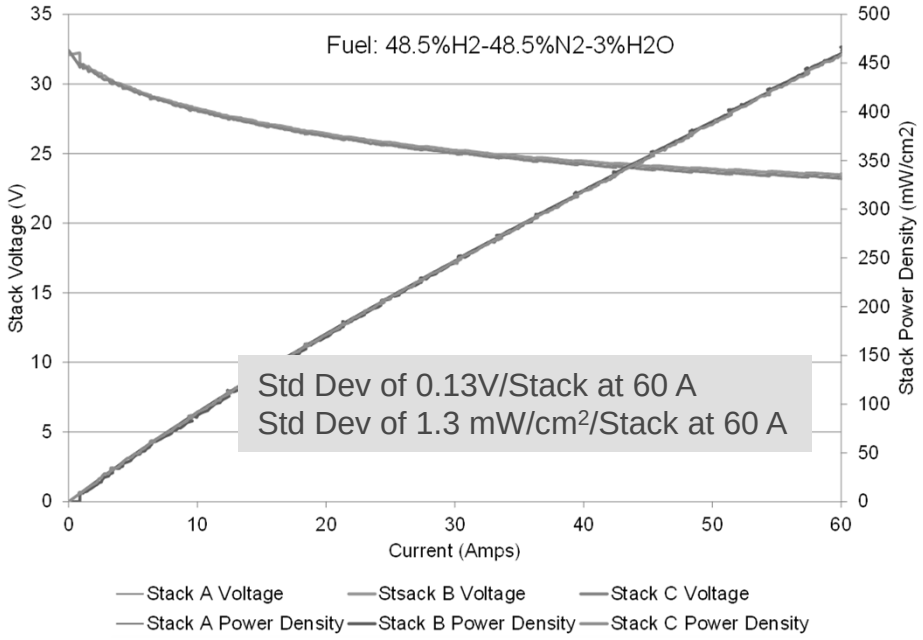
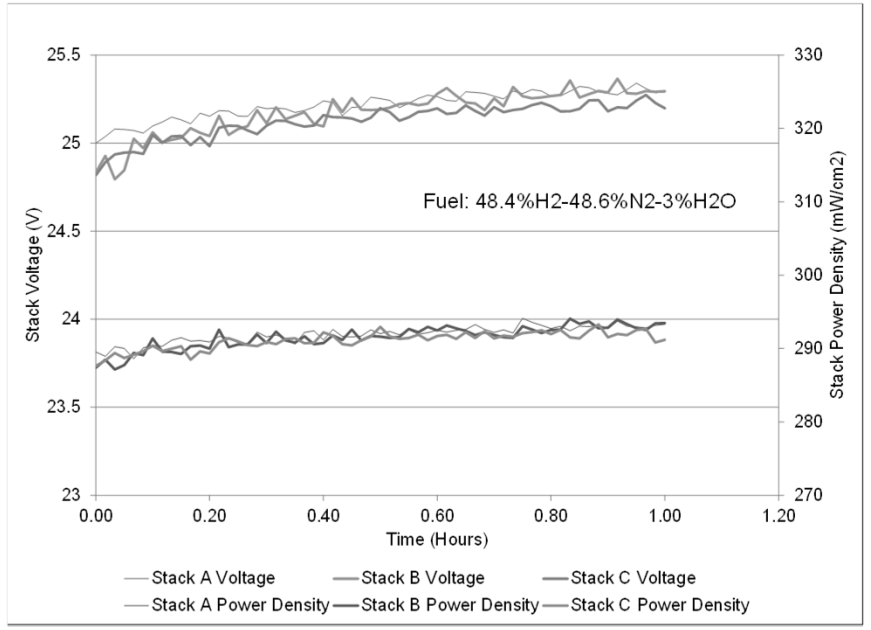
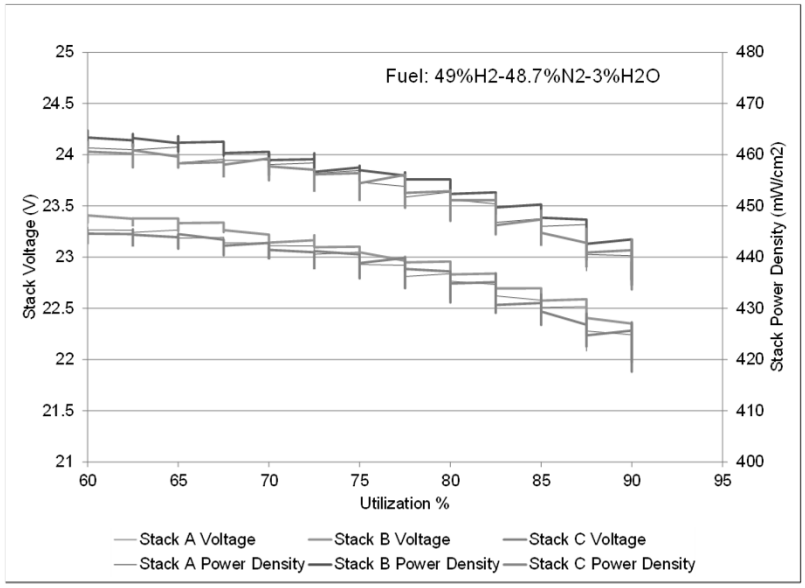
Stack Initial Performance Results, System B







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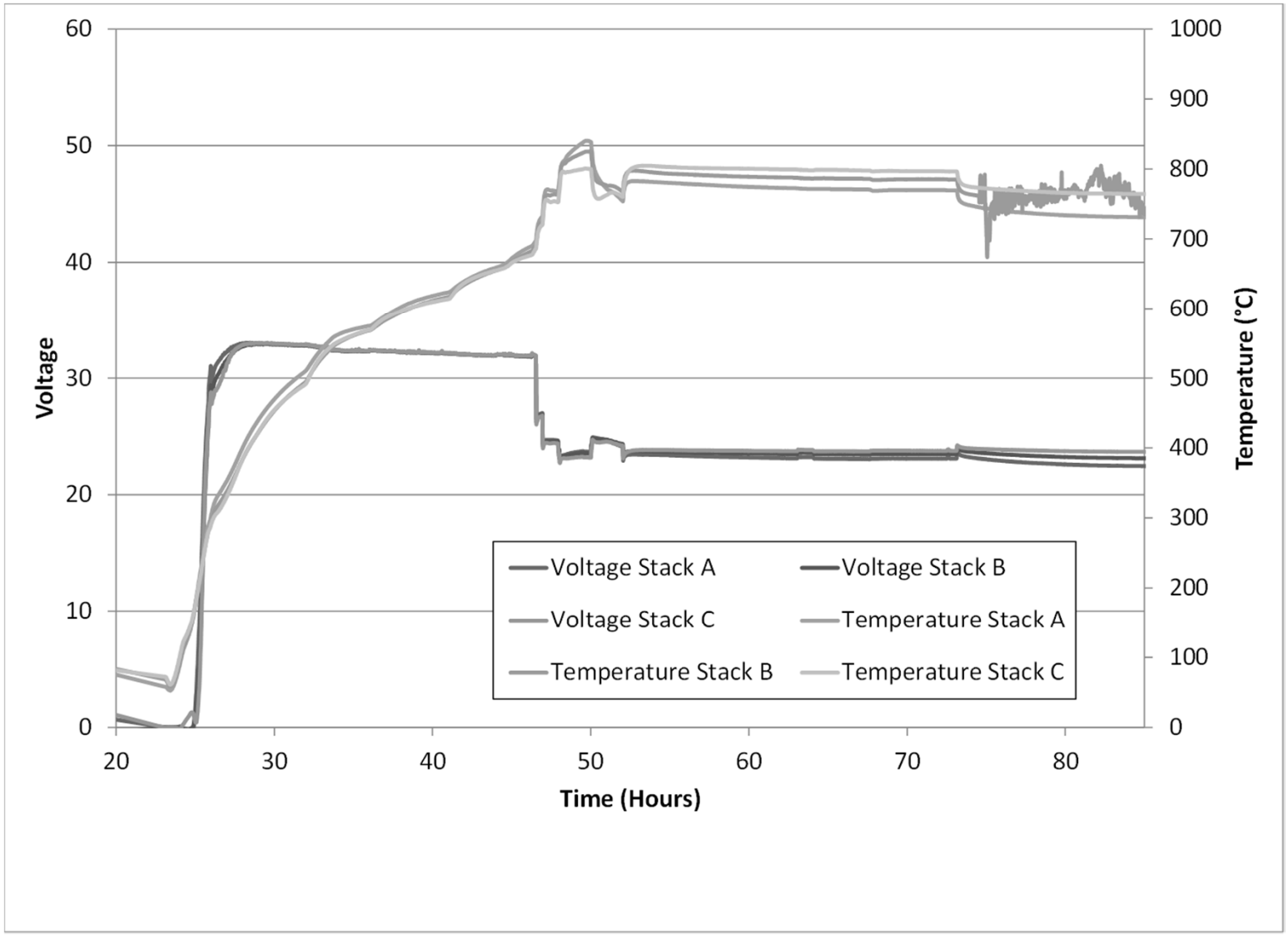
Stack Voltage and Temperature, System B



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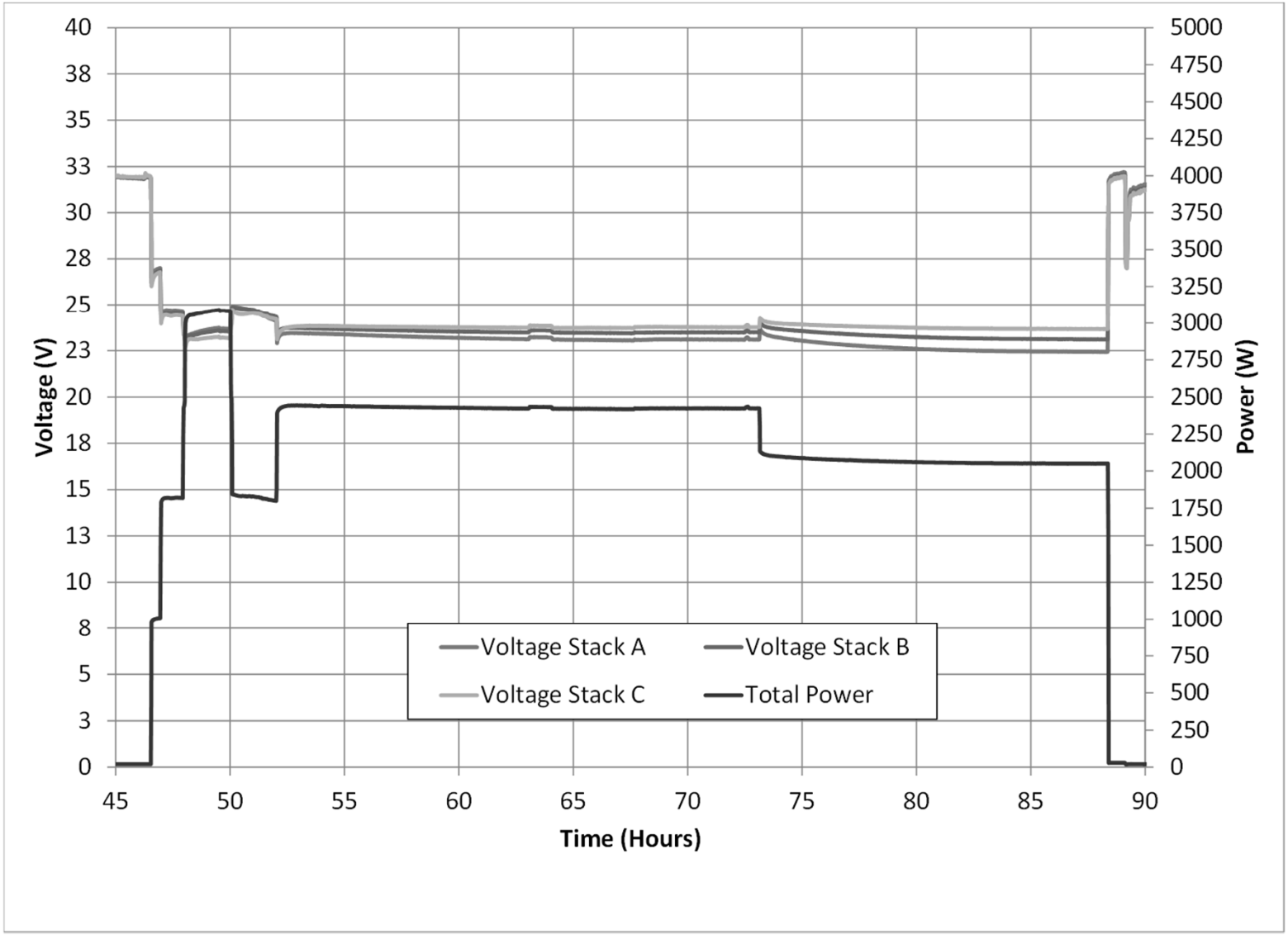
Stack Performance, System B



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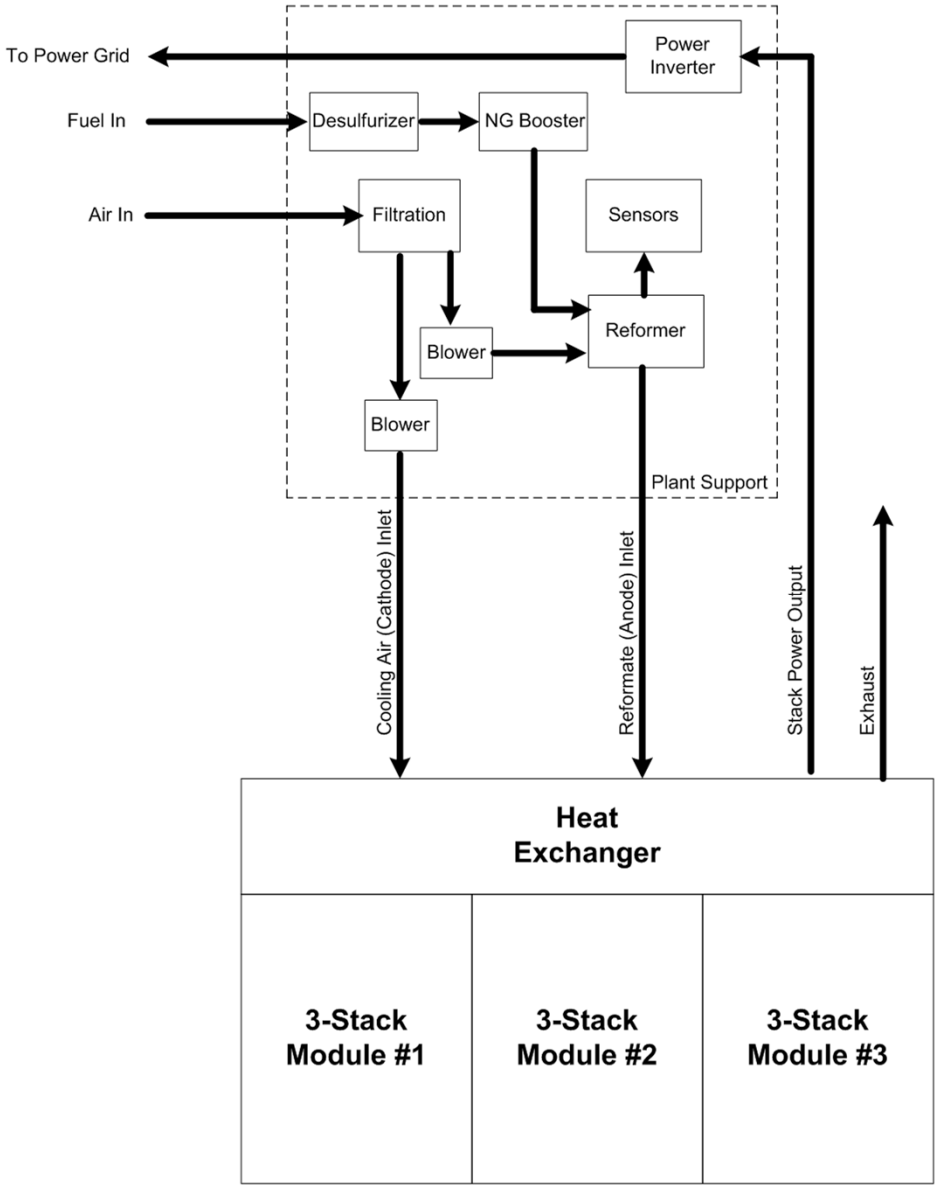
SECA System C Mechanical Schematic



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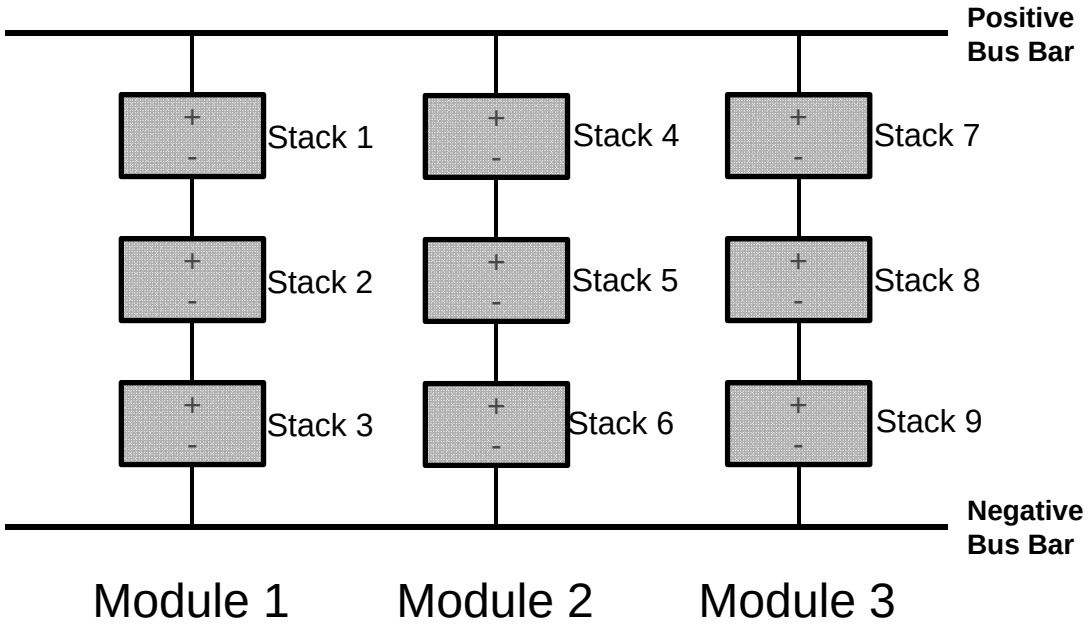
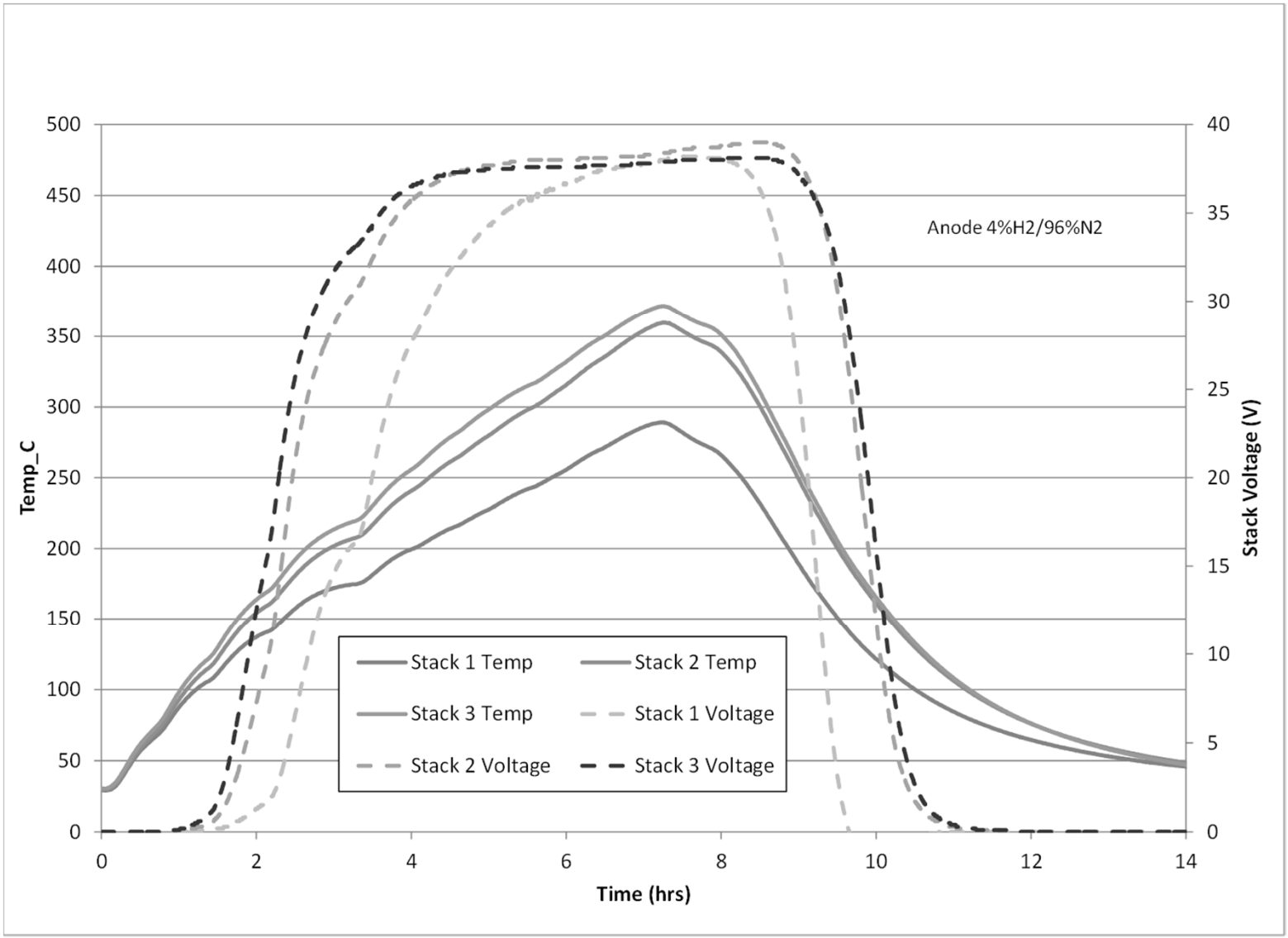
SECA System C Electrical Schematic

Three (3) stacks connected in series in each module and three (3) modules of three (3) stacks each connected in parallel

Stacks in series providing ~ 90 VDC and ~ 60 amps per module



System C Module End of Line Voltage and Temperature Test



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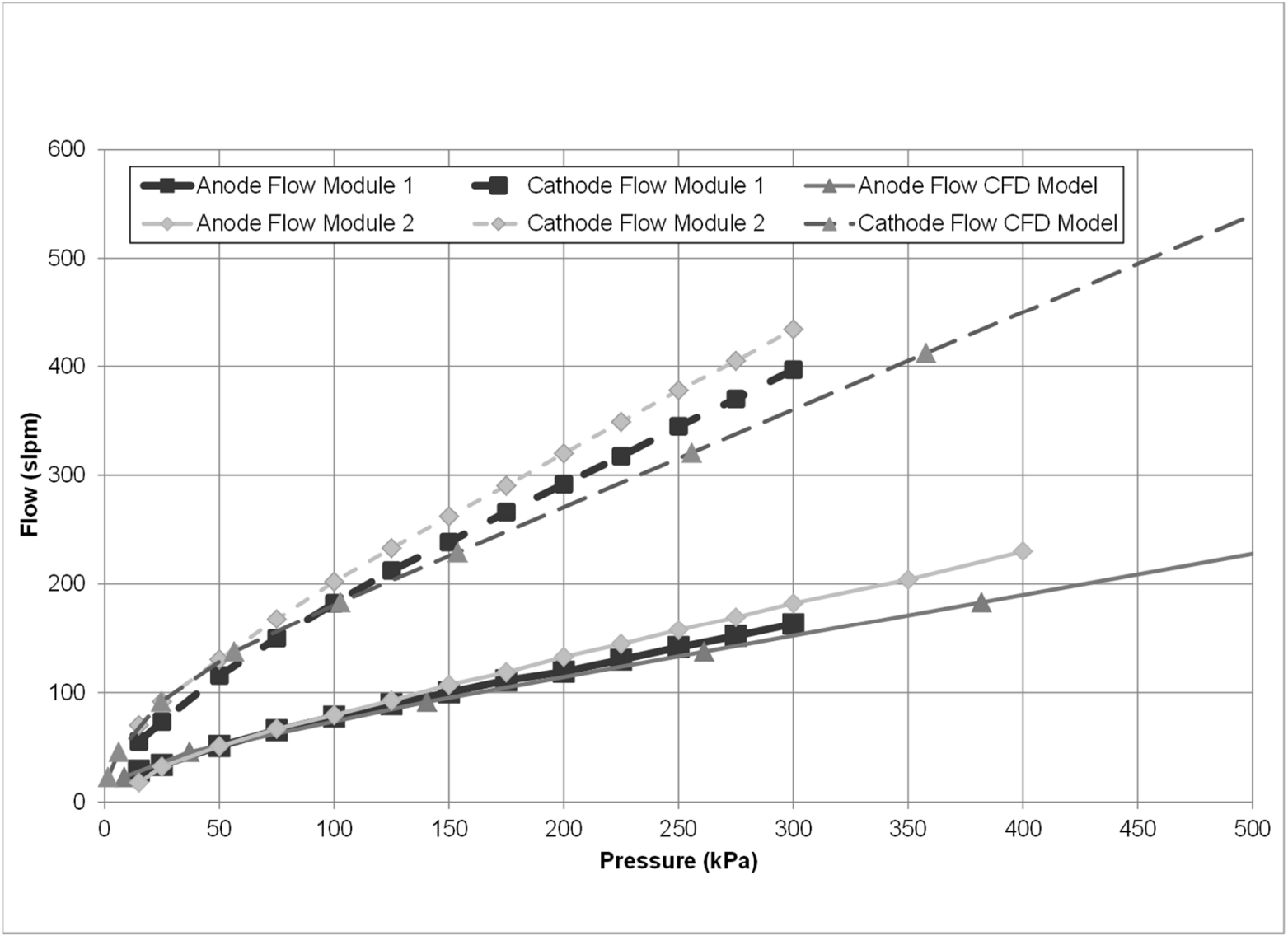
System C End of Line Module Flow Test



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Acknowledgements

Thanks to Joe Stoffa, Briggs White, and Shailesh Vora of the DOE for their support and technical guidance

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