Versa Power Systems Stack Testing Summary

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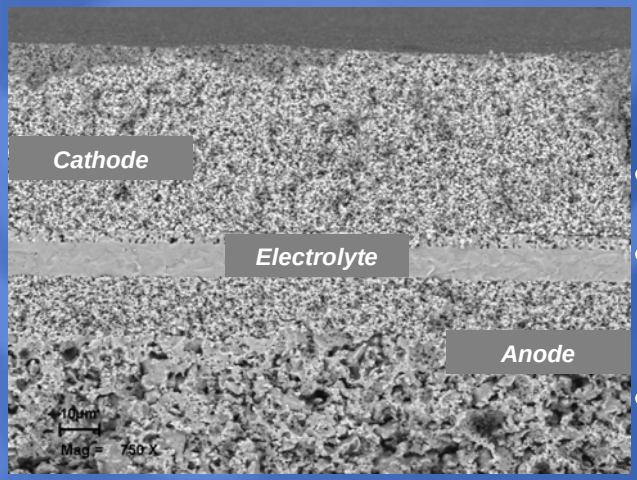
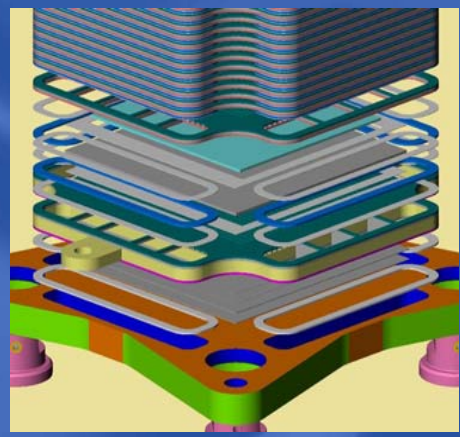
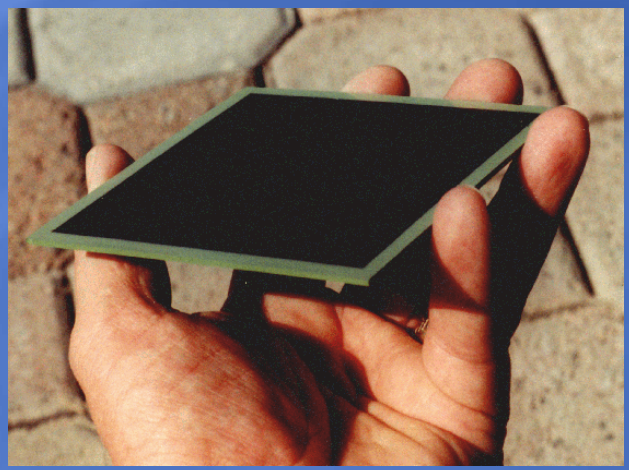
4 June 2007

VPS Stack



- Anode supported cells
- Uncoated ferritic stainless steel sheet metal interconnect
- Cross-flow fluid delivery with manifolds integrated into the interconnect but not through the cell
- Compressible ceramic gasket seals





Present Stack Module

Cell Active Area = 121 cm^2

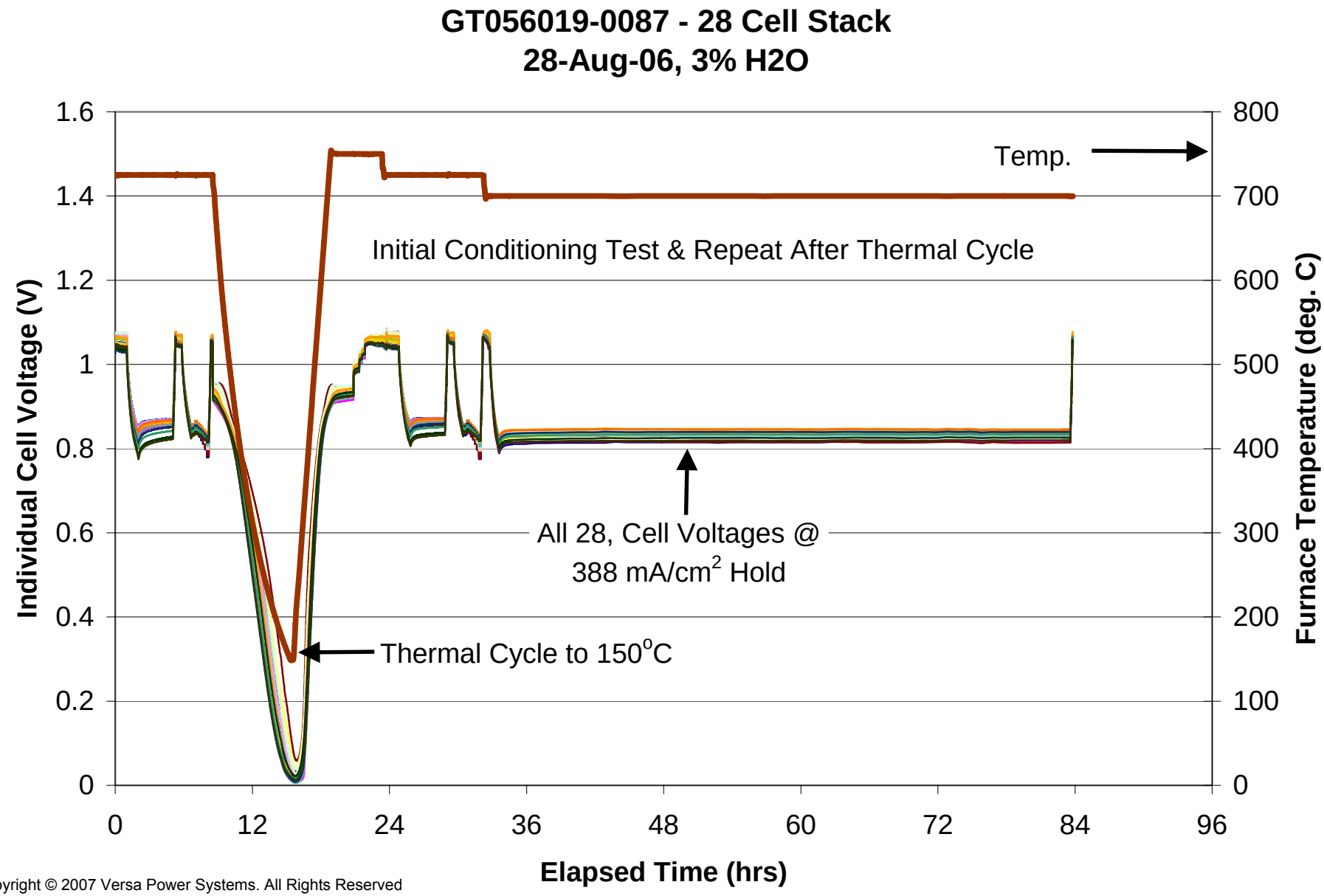
Number of Cells = 28

Power output = 1.0 kW

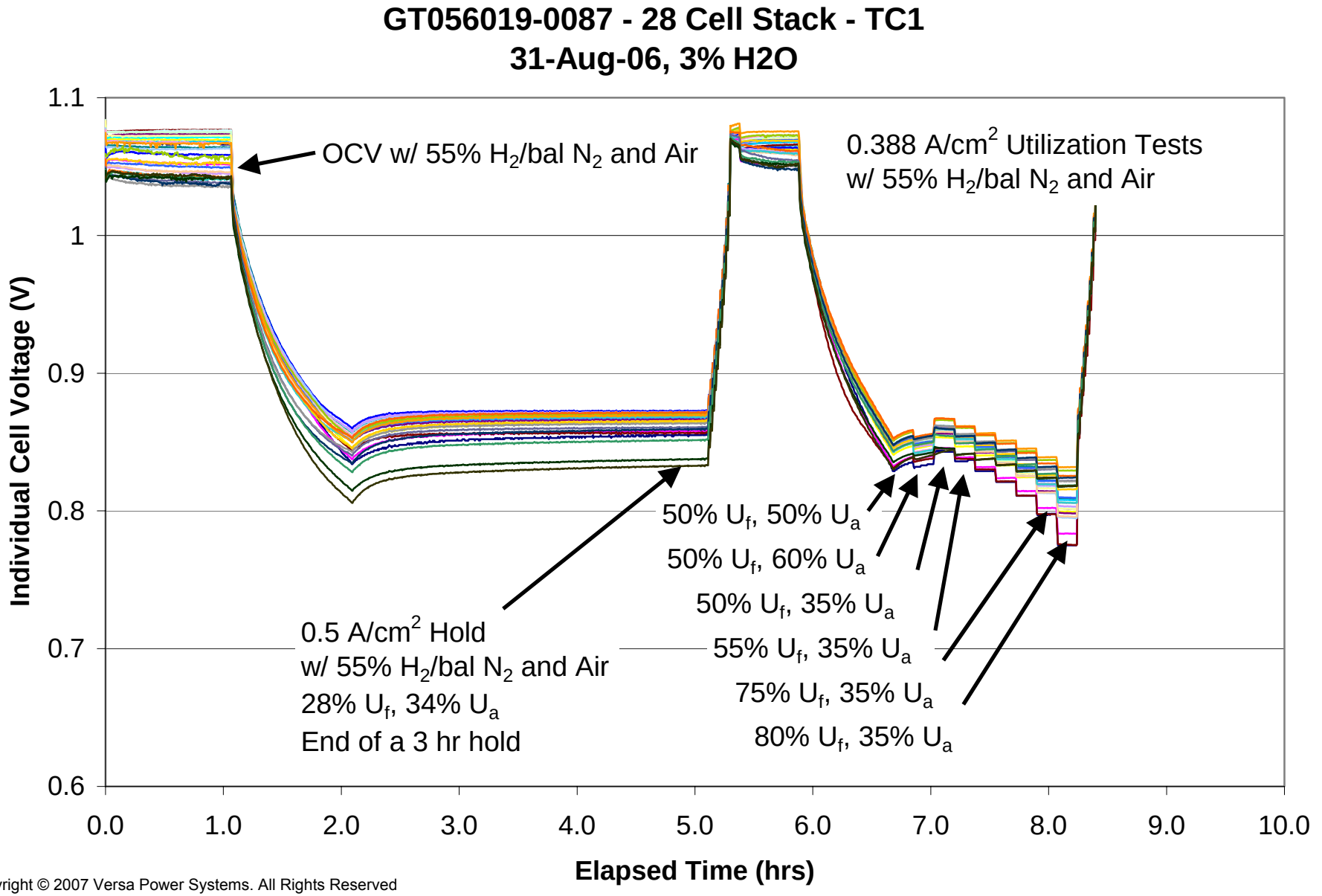
Stack Testing Methodology

- **Stack Testing at Versa falls into 3 categories**
  - **Standard testing that focuses on the initial qualification of a stack**
  - **Long-term degradation testing which studies voltage degradation over time**
  - **Thermal cycle testing that focuses on the voltage loss that occurs over multiple thermal cycles**

Standard Qualification Testing



Standard Qualification Testing – TC1



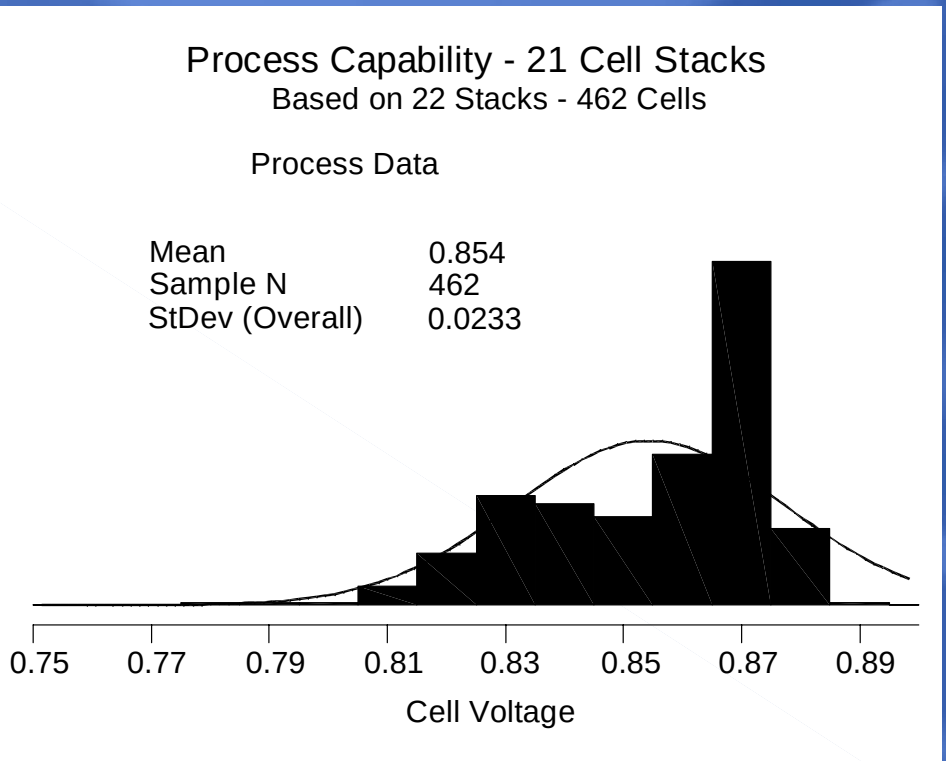
Stack Qualification Minimum Requirements

Condition Descripion	Conditions	Requirement
Open Circuit Voltage	1.65 slpm/cell H2, 1.35 slpm/cell N2	**All cells >1.01 V**
Full Flows, 0.5A/cm2	28% U_f, 34% U_a, 0.5 A/cm^2, 725°C	**All cells >0.8 V**
Air Utilization	50% U_f, 60% U_a, 0.388 A/cm^2, 725°C	**All cells >0.7 V**
Fuel Utilization	75% U_f, 50% U_a, 0.388 A/cm^2, 725°C	**All cells >0.7 V**
Thermal cycle Degradation	Each condition is compared before and after the thermal cycle at 0.5 A/cm^2 and 0.388 A/cm^2	**No cell degradation >0.006V**

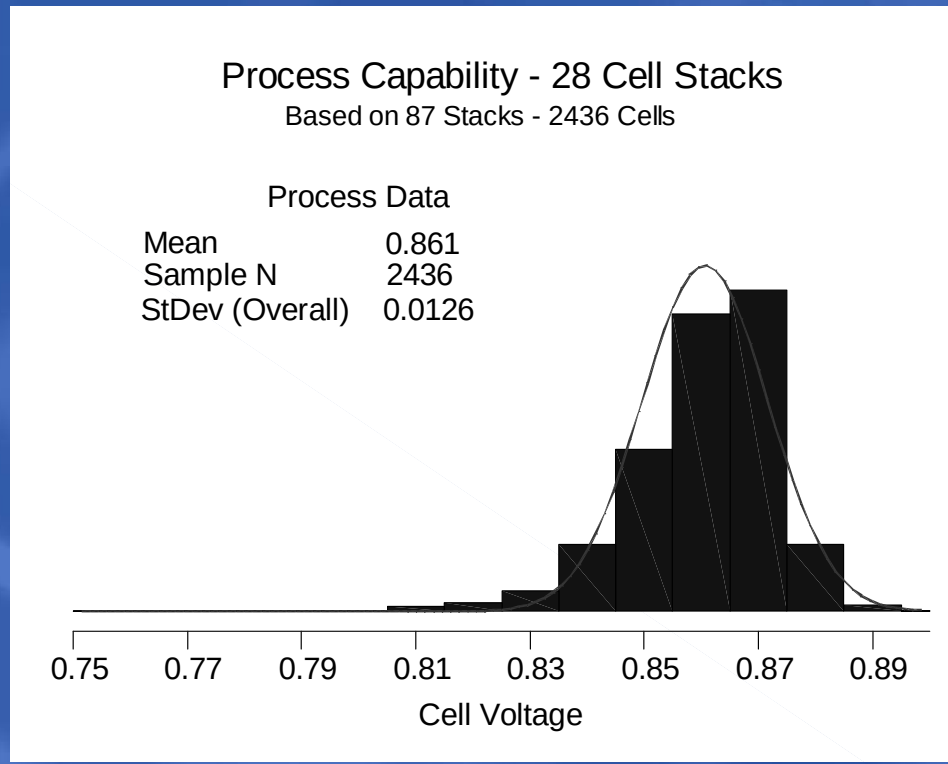
Stacks must meet these minimum requirements to proceed to other testing

Overview of Internal Testing Results
- Initial Performance Summary -

2004 - 2005



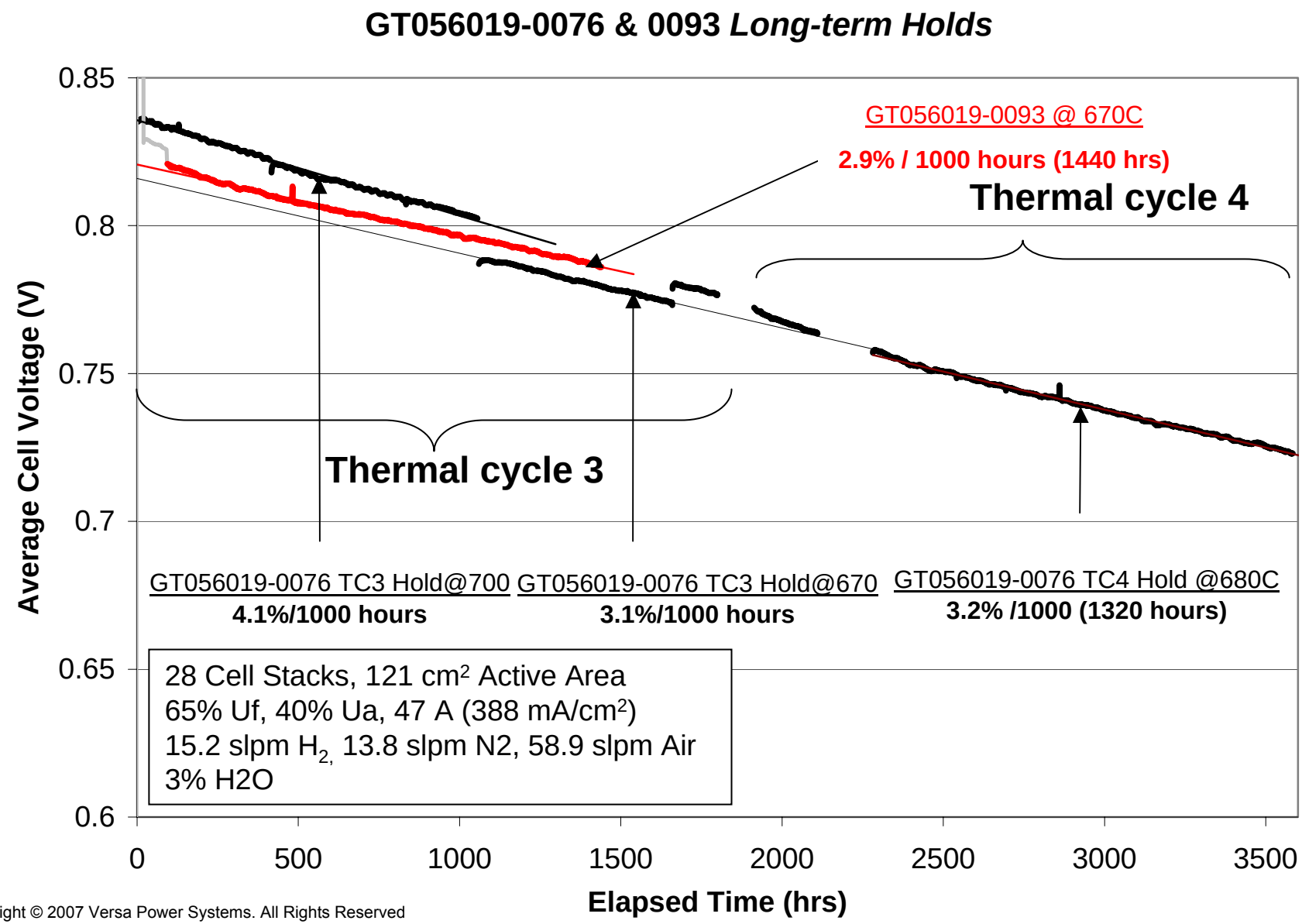
2005 - 2006



**The analysis shows an increase average cell voltage by a statistically significant 7 mV during the scale up from 21 to 28 cell stacks.*

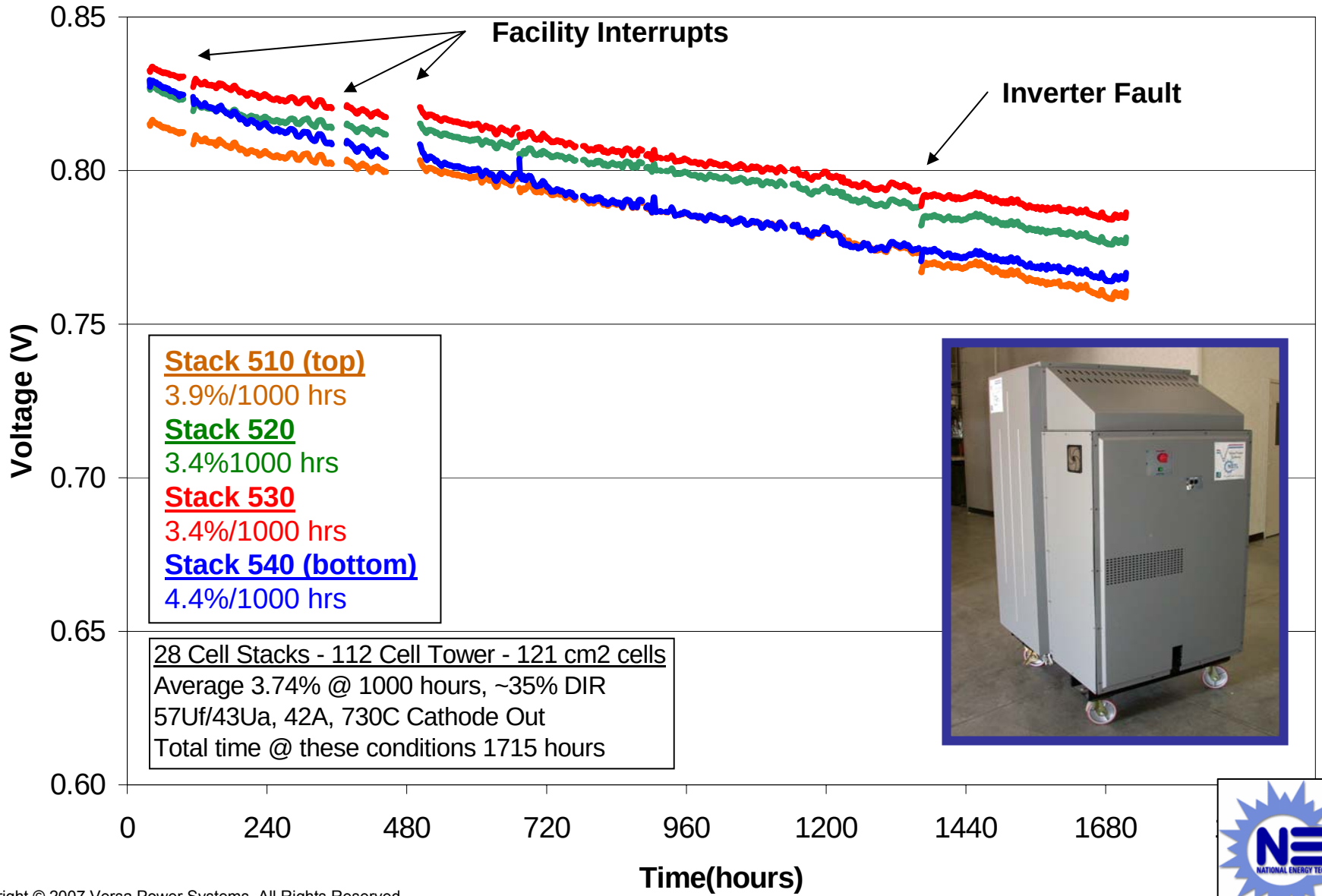
Long Term Degradation Testing

- VPS in Calgary, Alberta -



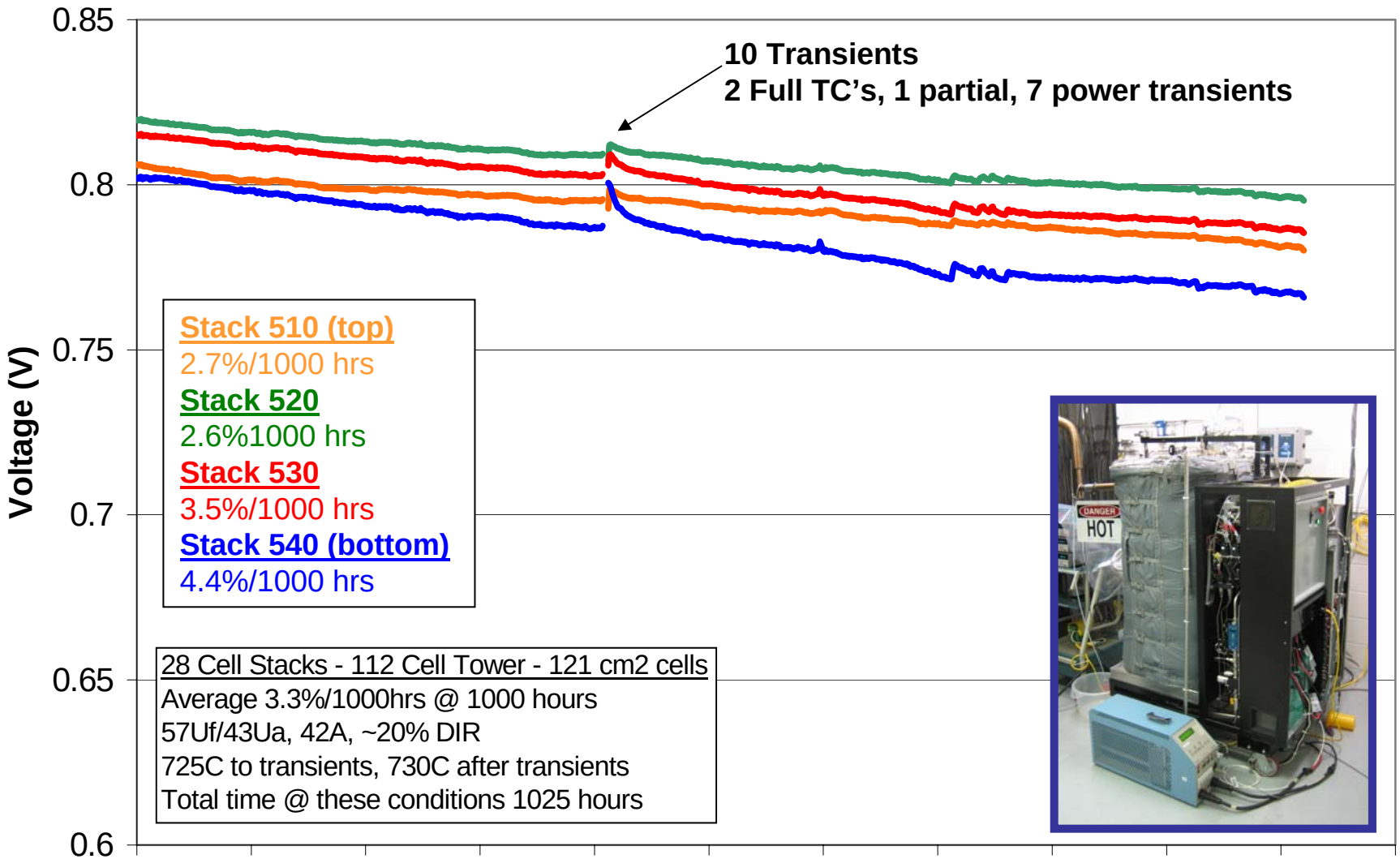
System Testing – Stack Degradation

- 5 kW SECA test at NETL in Morgantown, WV -



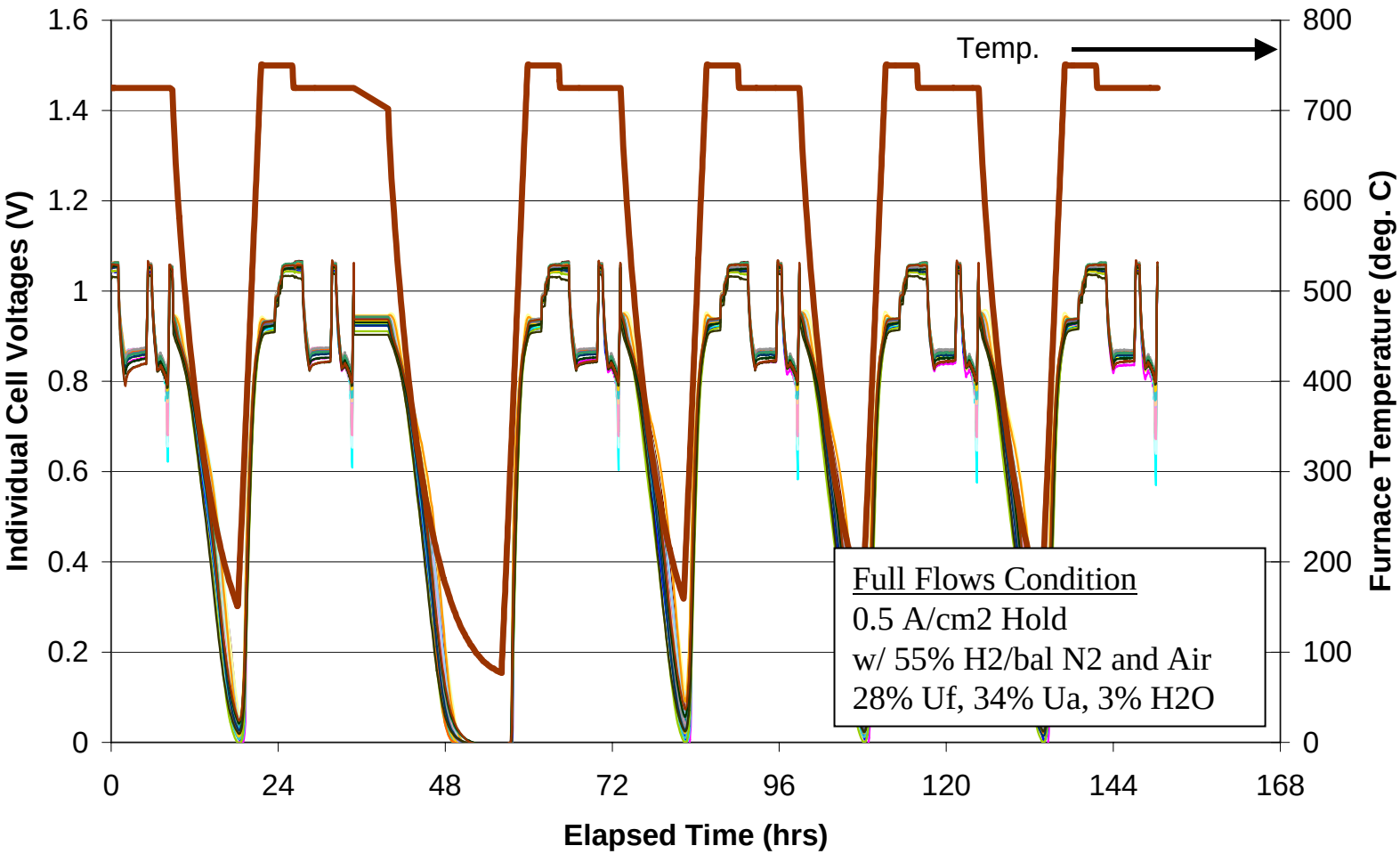
System Testing – Stack Degradation

- 5 kW SECA test at CPG, Minneapolis, MN -



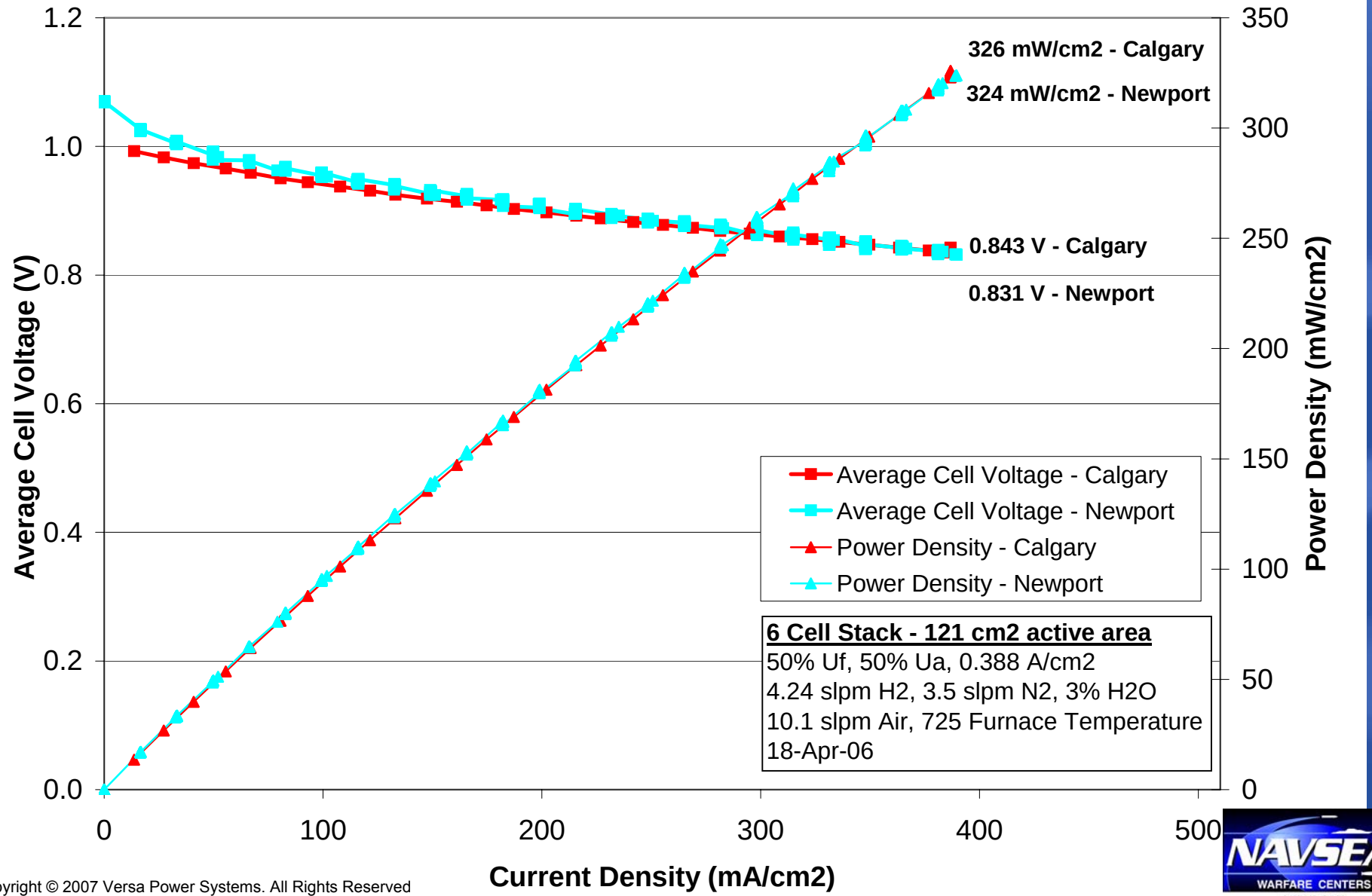
Thermal Cycle Testing

- VPS in Calgary, Alberta -

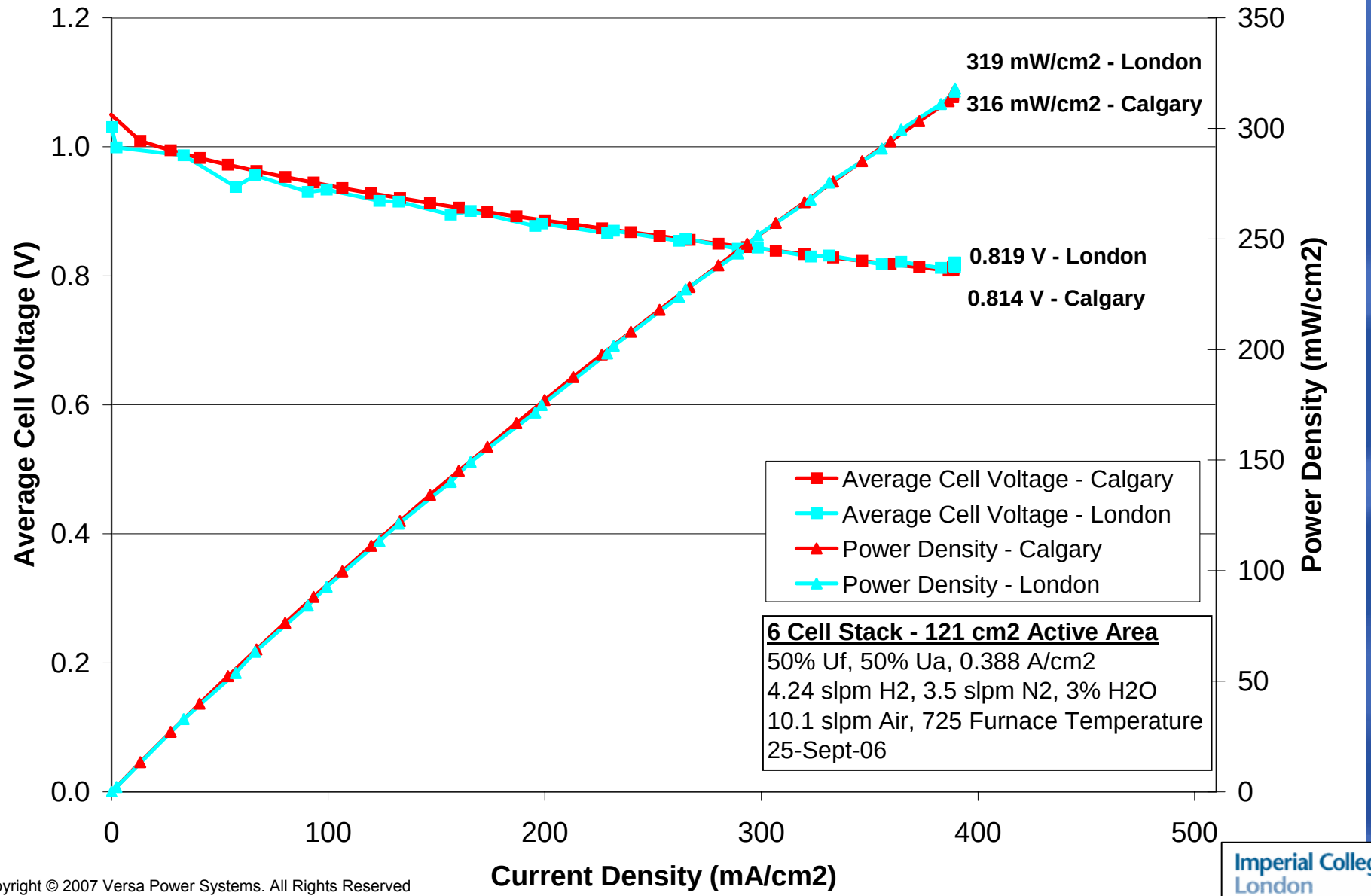


*The cell voltage degradation over 5 thermal cycles at 0.5 A/cm2 was 0.5%

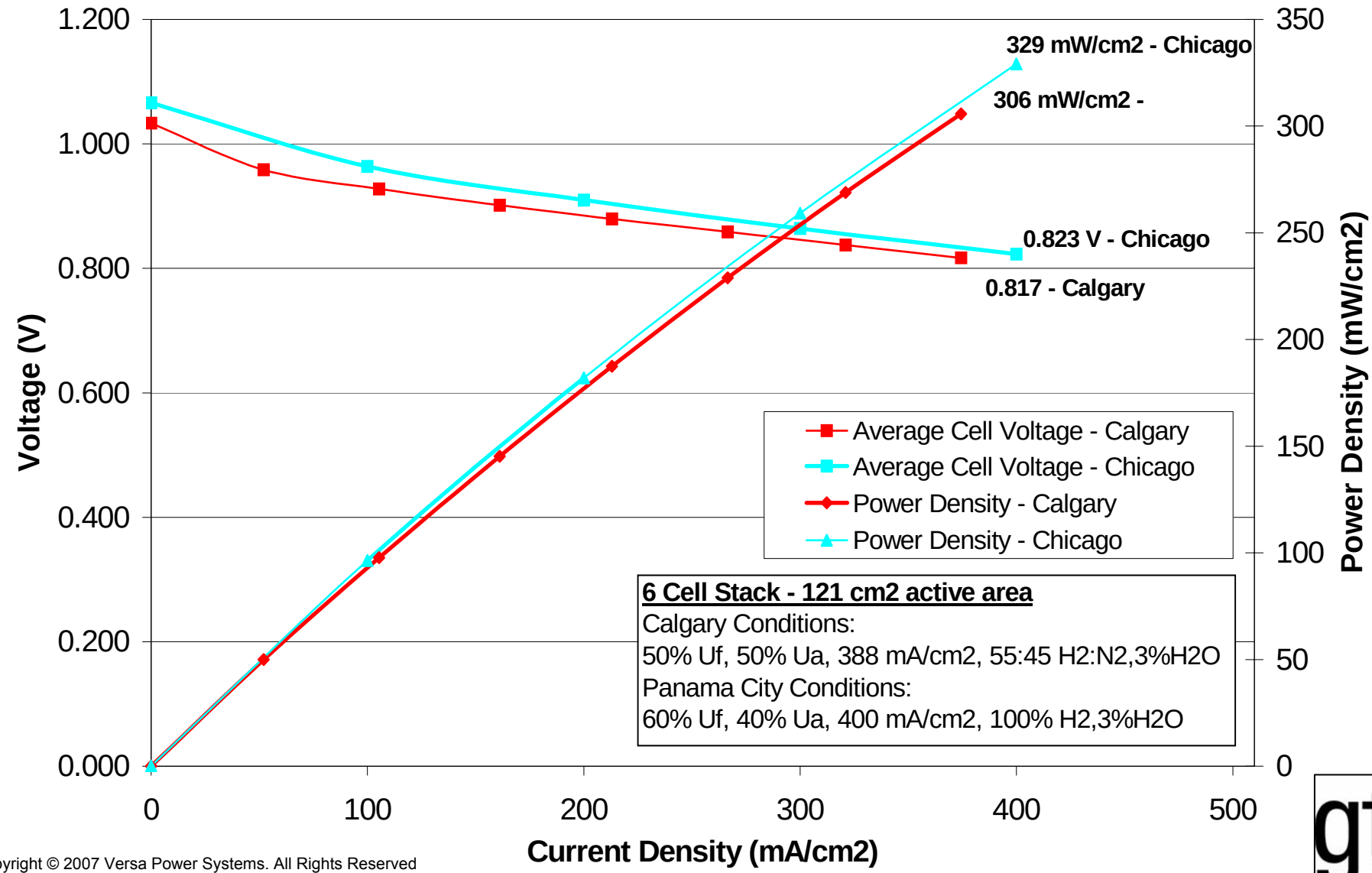
US Naval Underwater Warfare Center – Newport, RI
- Unmanned Underwater Vehicles -



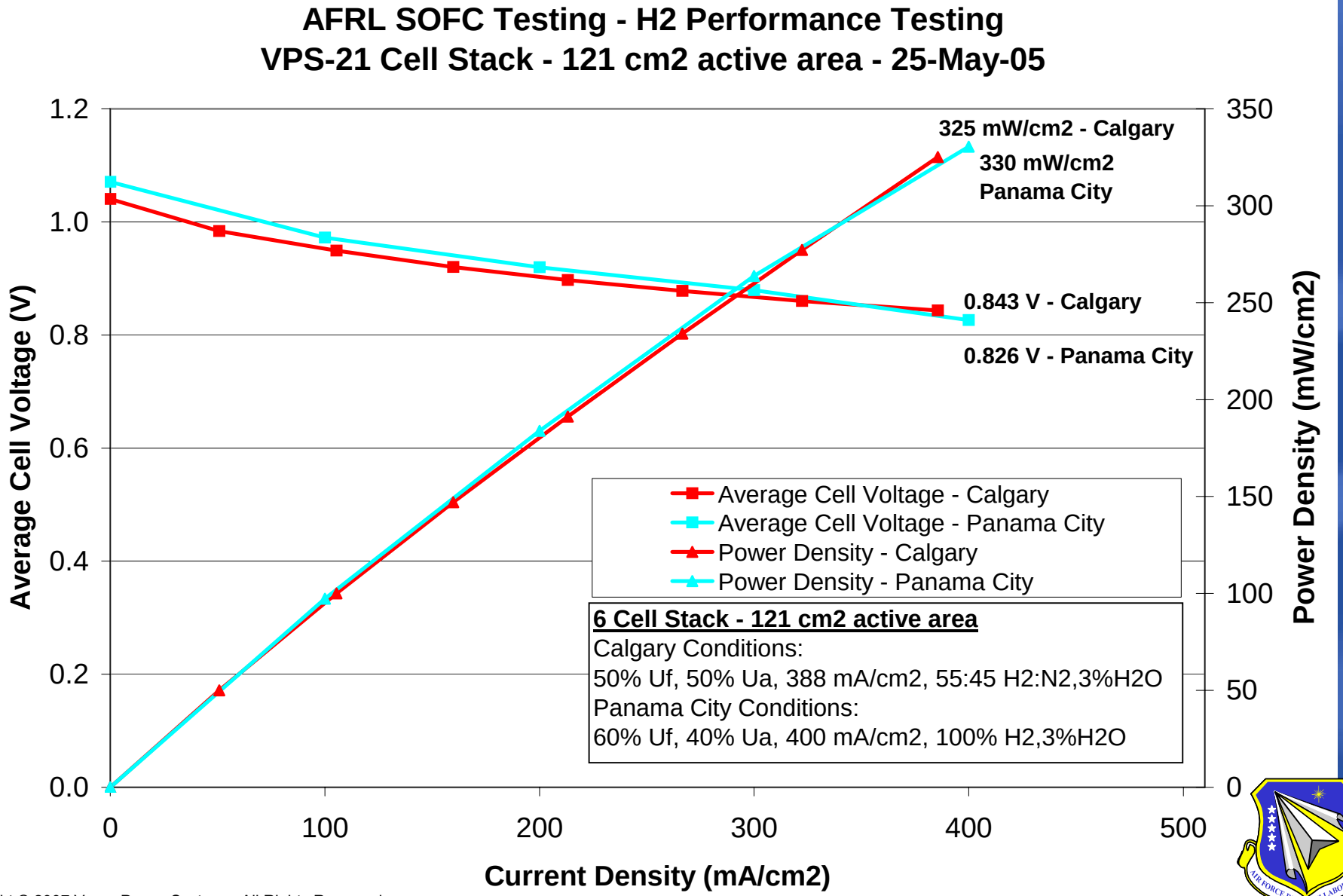
Imperial College – London, England
- Battery/Hybrid for Automotive -



Gas Technology Institute – Chicago, Illinois
- US Department of Defence Program – Logistical Fuels -



US Air Force Research Labs - Panama City, Florida
- JP-8 Logistical Fuels Research -



Summary

- VPS utilizes an internally manifolded, anode supported SOFC stack
- Stack Development is reliant on **standardized testing** that allows statistical analysis tools to be used to direct stack and stack component development
- **Repeatable testing results** have been demonstrated internally, in system and these results have been externally verified by the US Naval Underwater Warfare Centre, Imperial College, Gas Technology Institute and the US Air Force Research Lab
  - Internal stack degradation rates for the VPS production stack are **2.9 to 3.1%/1000 hrs**
  - System Testing results yield comparable stack degradation rates of **2.6% to 4.4%/1000 hrs**
  - Stack Performance has been demonstrated within **+/- 2%** by 4 independent organizations at external sites – after being shipped using standard shipping methods

Acknowledgements

Versa Power Systems Team
FuelCell Energy
Cummins Power Generation
U.S. Naval Underwater Warfare Center
Imperial College
Gas Technology Institute
U.S. Air Force Research Labs
U.S. Department of Energy
National Energy Technology Laboratory
(DOE / NETL) under Award Numbers
DE-FC26-04NT41837 (FCE)
DE-FC26-01NT41244 (CPG)