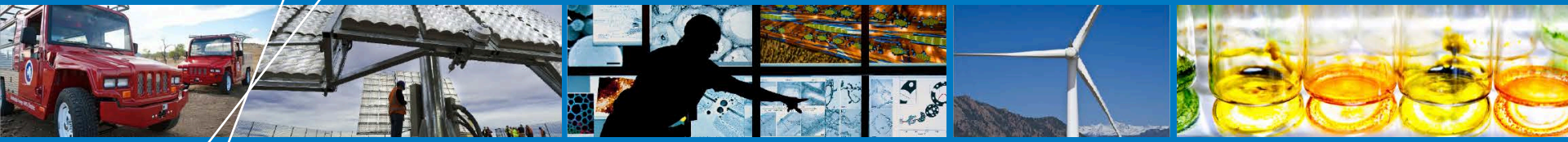
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

2013 DOE Hydrogen and Fuel Cells Program Review



Hydrogen Component Validation

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Project ID: TV019

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Overview

Timeline

Project start date: Sep. 2011
Project end date: Oct. 2013*

Barriers (2011 MYRDD)

D. Lack of Performance Data
G. Hydrogen from Renewable Sources

Budget

- Planned Funding for FY13: $265k

Partners

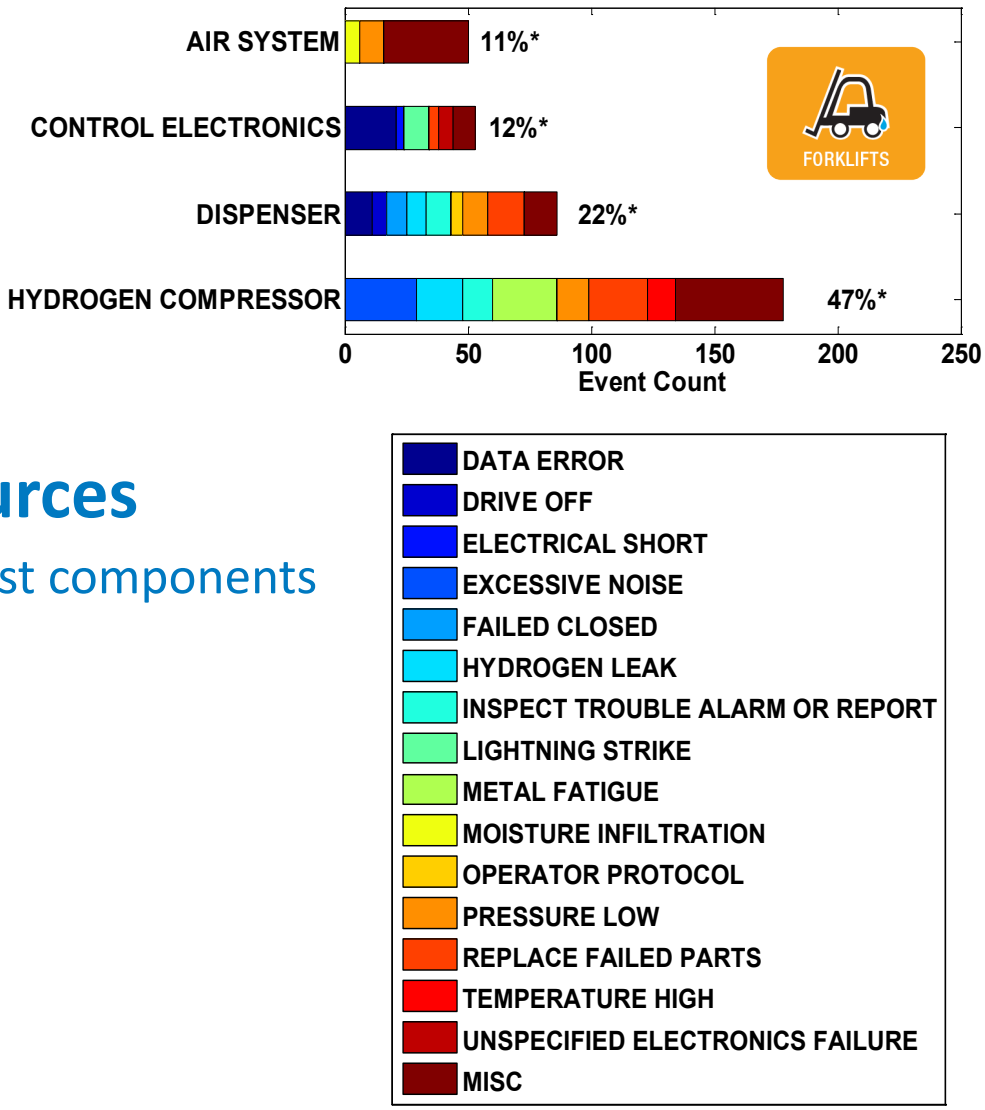
- PDC Machines (CRADA)
- Xcel Energy (CRADA)
- Proton OnSite (CRADA)
- Giner Electrochemical Systems

* Project continuation and direction determined annually by DOE

Relevance to Addressing Barriers

D. Lack of Current Performance Data

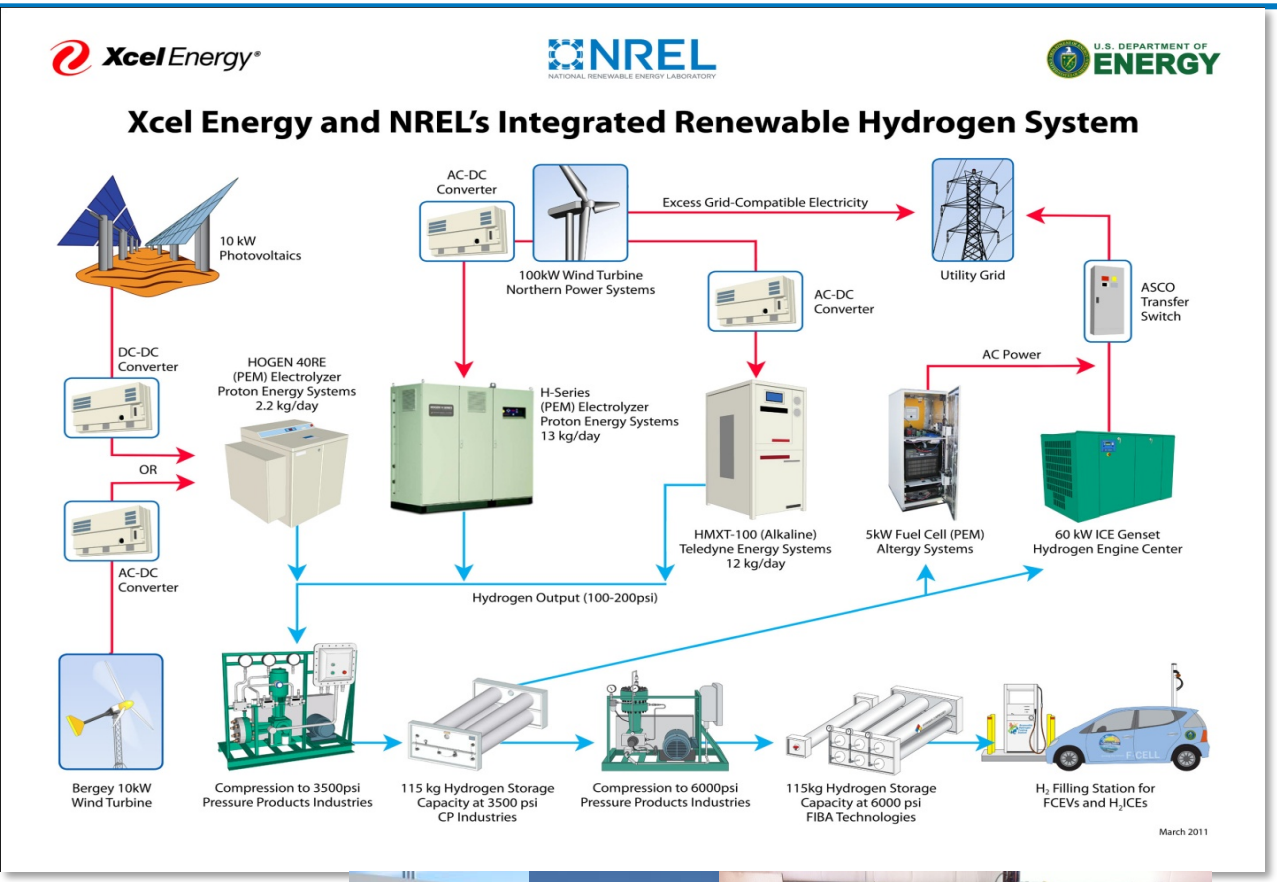
- Operational reliability & performance testing
- Compressors are #1 in downtime and maintenance event count
- Operation of compressors
  - Diaphragm and piston type



G. Hydrogen - Renewable Sources

- Focus on system integration, not just components
- Advanced grid integration

Approach: Fully Integrated System-Level Testing



Equipment Involved

Electrolyzers (Quantity: 5)
- 4 PEM, 1 Alkaline
- U.S. Army – Loan

Compressors (5)
- 3 diaphragm, 2 piston

Compressor (1)
- PDC Machines – CRADA

Hydrogen Storage (5)
- 350 kg, 3500 to 10k psig

Fuel cells (5, PEM)

Dispenser (350 bar)

Dispenser (In progress)

1 MW AC/DC Buss Network

100 kW Wind Turbine

Configurable PV array

Approach to Addressing Barriers

Operational Reliability & Performance Testing

- Partnered with compressor manufacturers (CRADA) to instrument, monitor and analyze performance in a relevant accelerated-testing environment (actual fueling station serving vehicles)

Advancing Instrumentation & Technology Transfer

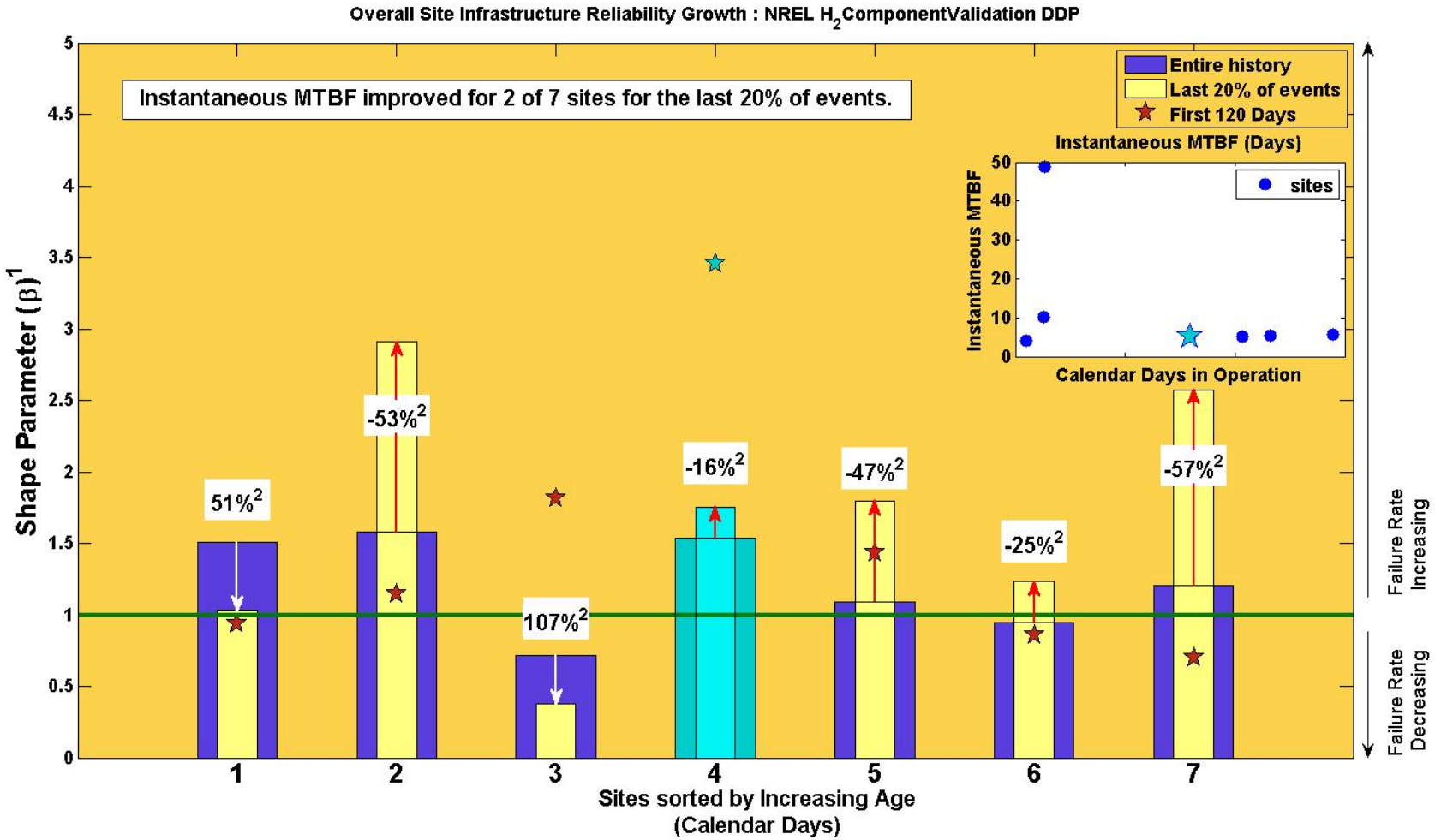
- NREL mass flow device for validating electrolyzer flow rate (PD031)
- Leveraging project with California (Work-for-Others)

Focusing on Systems-Level Integrated Testing (ESIF)

- Electrolyzer - Grid ancillary support (Technology Demonstration)
  - FY12 – Frequency disturbance mitigation, AC micro-grid
- Monitoring downtime and repairs of Xcel Energy/NREL Wind-to-Hydrogen demonstration facility (Utility CRADA)
- DOE-awarded system installed at ESIF to provide facility hydrogen

Accomplishment: Infrastructure Reliability

Detailed Data Product – Xcel Energy/NREL Wind-to-Hydrogen



1. IEC 61164:2004(E)., Reliability Growth - Statistical Test and Evaluation Methods, IEC. 2004.

2.% change in instantaneous MTBF

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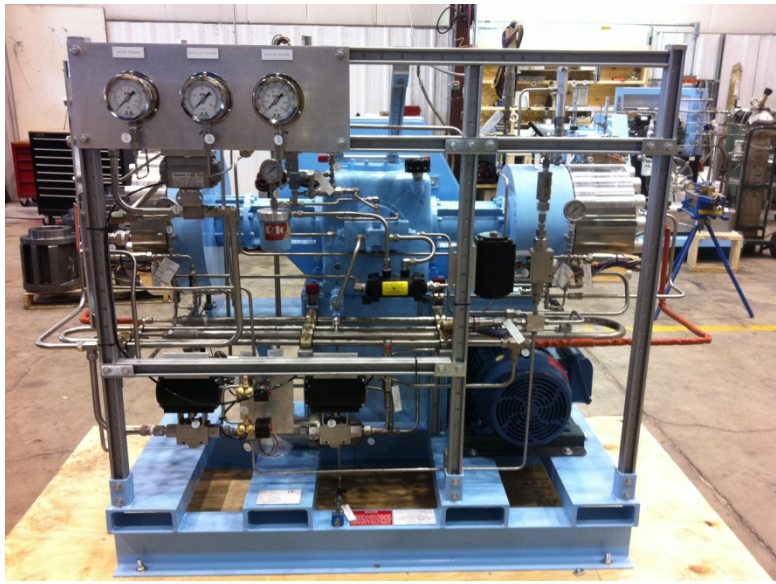
Accomplishment: Compressor Reliability & Performance

Industry Collaboration

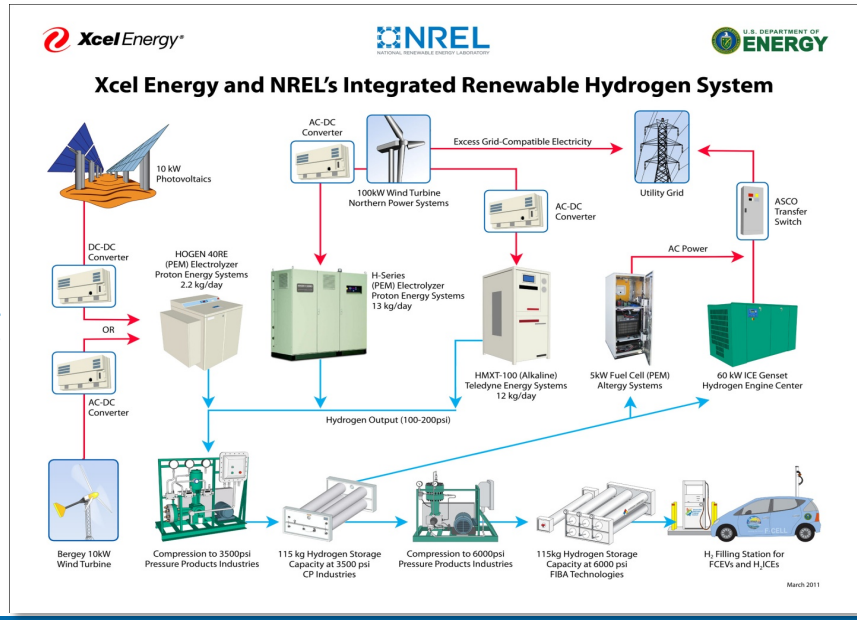
PDC Machines (CRADA)

- Fully instrumented diaphragm compressor
- Highly Accelerated Testing to begin FY13 Q4
- Test plan includes rebuilds and failure root cause analysis



Exercise Existing Test Platform

- Unattended operation
- Existing electrical and gas instrumentation
- Hydrogen used to fuel vehicles, support facility hydrogen needs and fuel cell testing
- New and rebuilt systems

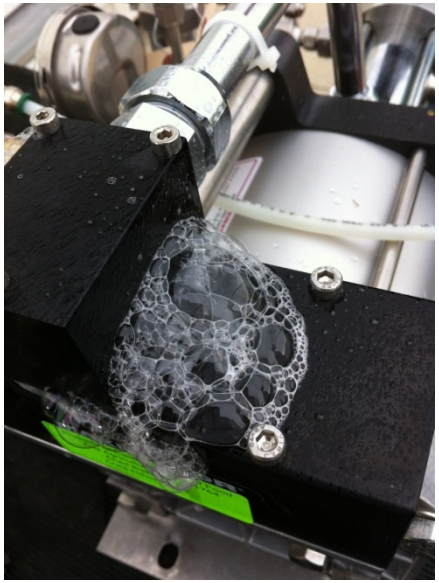


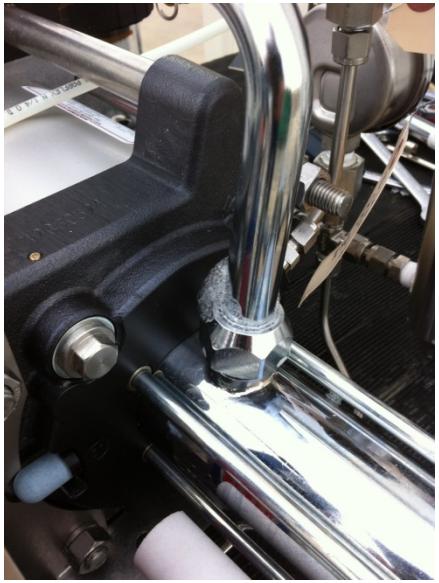
Accomplishment: Compressor Reliability & Performance

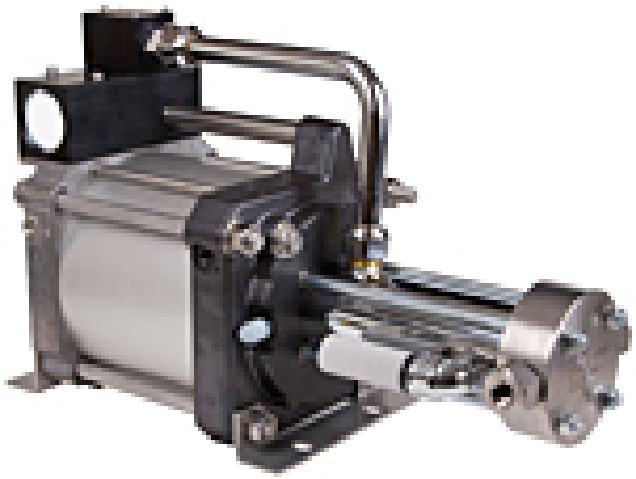
Flexible Installation at Wind-to-Hydrogen Test Facility

Gas Booster Installation and Operation

- Pneumatically-driven piston type system
- Accelerated life testing
- Issues surrounding air leaks
- 150 hours of operation as of April 1st
- Working towards 1000 hour milestone goal (August 2013)



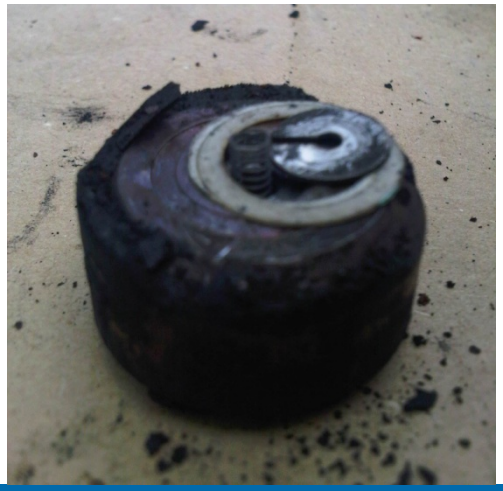




Compressor Performance – Analysis of Material

Working with diaphragm compressor manufacturer

- Working to understand failure
- Single-stage to 400 bar supporting vehicle refueling
- Compressor rebuild
  - Check valves
  - Diaphragms
- Additional cooling system (planned)



Accomplishment: Advancing Instrumentation

Technical Accomplishment – Error analysis of NREL's mass flow device.

Technical Details of Analysis;

- Compounding error of 1.04% dominated by volume assumption
- Z is compressibility factor
- Indicated on tank 5,370 in^3
- Tank data sheet 5,508 in^3

Measurement	Pressure Transducer	Temperature Probe (RTD)	Volume	Compressibility Factor
General Error	0.25% F.S.	± 0.15 °C	1%	0.01%
Actual Error	0.75 psi	0.15 °C	55.1 in^3	Varies with z

Accomplishment: Advancing Instrumentation

Technical Accomplishment – Repeatability testing of NREL's mass flow device (0.3% standard deviation)

Technical Details of Analysis;

- Three trials at different stack current
- Average stack current, temperature and flow rate with 95% confidence intervals
- NIST Handbook 44, Section 7.3 suggest multiple tests should not exceed 40% of the maintenance tolerance
  - Table T.2 provides a maintenance tolerance of 2%, resulting in 0.8%
- Standard deviation of 0.3%

	Trial 1 (n = 75)	Trial 2 (n = 24)	Trial 3 (n = 61)
Stack Current (A)	148.4 ± 0.1	119.8 ± 0.1	110.0 ± 0.04
Stack Temperature (°F)	98.8 ± 0.2	95.6 ± 0.2	94.7 ± 0.2
Measured Flow Rate (kg/hr)	**0.520 ± 0.0003**	**0.410 ± 0.0005**	**0.373 ± 0.0003**

Accomplishment: Integration with Renewable Sources

Accomplishment – Relocated and installed DOE-awarded (PD030) electrolyzer and NREL storage tank at ESIF

System installed at Energy Systems Integration Facility

- Electrolyzer will be modified to enable long-duration testing
- Air-driven gas booster and NREL storage tank to provide facility hydrogen gas to fuel cell labs
- System performance and reliability will be monitored and compared with relevant external sites

Collaborations

Formal

- PDC Machines (CRADA) – Compressor reliability testing
- MAETEC (NCAP) – Preparing to test electrolyzer
- Proton Onsite (CRADA) – Electrolyzer stack durability testing
- Xcel Energy (CRADA) – Wind-to-Hydrogen demonstration project since 2005

Information Sharing

- University of North Dakota/Energy & Environmental Research Center
- Worldwide electrolyzer and hydrogen component manufacturers

International

- ADvanced ELectrolyzer (ADEL) Workshop – (Foreign Payment)
- Risø-DTU (Denmark) – Modeling and experimental verification of enhanced energy storage systems

Future Work – RD&D Challenges

Operational Reliability & Performance Testing

- PDC Machines Compressor CRADA
  - Test plan includes long-duration compressor operation, periodic rebuild and maintenance
- Reach out to different compressor technology manufacturers

Systems-Level Integrated Testing with Renewable Sources

- Long-duration wind-profile power cycling of PEM stacks
- DOE-awarded electrolyzer modifications and long-duration testing

Summary

Relevance: Address barriers that include; lack of performance data, instrumentation, sensor accuracy, technology transfer and integration with renewable sources like wind and solar.

Approach: Work closely with industry to understand and improve compressor reliability, hydrogen mass flow limitations and exercise NREL's existing test platform.

Technical Accomplishments:

- Infrastructure Reliability: NREL tracking downtime and equipment faults at the Xcel Energy/NREL Wind-to-Hydrogen test facility.
  - NREL's reliability and MTBF in-line with other 350 bar refueling stations
- Installed gas booster system (piston type) at Wind-to-Hydrogen test facility
  - 120 hours operating towards 1000 hour milestone goal by August 2013
- Working with PDC Machines and other OEMs to understand and improve compressor reliability
- Analyzed error and repeatability of NREL designed and tested mass flow device

Technology Transfer & Collaborations: Two new CRADA's in 2013. Validate system performance and disseminate results to industry. Formal and informal partnerships with industry, academia and domestic/international researchers.

Proposed Future Research:

- Long-duration testing of piston and diaphragm compressors
- Reach out to different compressor technology manufacturers
- Make improvements to and operate DOE-awarded electrolyzer at ESIF
- Long-duration wind-profile power cycling of PEM stacks