

## V.L.5 Fuel Cell Balance of Plant Reliability Testbed\*

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Lockheed Martin-IDT, Akron, OH

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\*Congressionally directed project

## Technical Targets

Reliability of the fuel cell system BOP components is a critical factor that needs to be addressed prior to fuel cells becoming fully commercialized. Failure or performance degradation of BOP components has been identified as a life-limiting factor in fuel cell systems [1]. The goal of this project will be to develop a series of test beds that will test system components such as pumps, valves, sensors, fittings, etc., under operating conditions anticipated in real PEM fuel cell systems. Results will be made generally available to begin removing reliability as a roadblock to the growth of the PEM fuel cell industry.

Stark State College students participating in the project, in conjunction with their coursework, will gain technical knowledge and training in the handling and maintenance of hydrogen, fuel cells and system components as well as component failure modes and mechanisms. This fuel cell work force development program will result in students trained in PEM fuel cell system technology.

**TABLE 1.** Progress towards Meeting Technical Targets for BOP Components for Transportation Applications

Characteristic	Units	2010/2015 Stack Targets	2011 Project Status
Durability with cycling at operating $T \leq 80^{\circ}\text{C}$	Hours	5,000	To be determined

## Fiscal Year (FY) 2011 Objectives

There are two primary objectives of this project:

- To establish a testing project resulting in a reliability database for candidate proton exchange membrane (PEM) fuel cell balance-of-plant (BOP) components.
- To enhance the education of the technical workforce trained in PEM fuel cell system technology.

## Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

### (A) Durability

This project also addresses the following technical barrier from the Education section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

### (D) Lack of Educated Trainers and Training Opportunities

## FY 2011 Accomplishments

- Students are being trained on the construction, programming and operation of the life cycle test beds.
- Commercial off-the-shelf test components have been identified based on functionality, cost and size.
- Candidate sensors have been purchased, integrated and tested in the test beds.
- Testing protocols have been designed for each component.
- Students have:
  - Fabricated third testbed.
  - Fabricated and tested housing and electrical design for sensors.
  - Implemented  $I^2C$  protocol.
  - Incorporated Hydrogen Safety Plan protocol in testbed operation.



## Introduction

One of the major challenges that must be addressed by the fuel cell industry prior to commercialization is the reliability of the components of a system. To this end Stark State College of Technology and Lockheed Martin have teamed to address this critical factor.

## Approach

Stark State College of Technology and Lockheed Martin have developed a series of test beds that test fuel cell system components such as pumps, tubing types, sensors, valves etc., operating under conditions anticipated in real PEM fuel cell systems. The test beds operate under various conditions continuously. Parts that continue operating demonstrate lifetime for potential fuel cell systems. Parts that have failed are removed and examined to learn the cause of the failure. Feedback will allow manufacturers to improve the products for future use in PEM fuel cells. Results will allow for a path towards removing reliability as a roadblock to the growth of the PEM fuel cell industry. A total of three test beds have been developed for this project; two at Stark State College of Technology and one at Lock Martin. In each case students in the engineering technology will monitor the test beds as part of their education program.

## Results

A fuel cell system consists of a fuel cell and its supporting BOP – the pumps, valves, sensors, fittings, piping, etc. needed to turn a fuel cell into a useful power plant. Components in this complex system can have long-term exposure to hydrogen, air (oxygen), high purity water, heat and other chemicals. The BOP reliability test beds will be a simplified design, simulating the conditions of an operating fuel cell. The first two test beds are designed to replicate humidified hydrogen exposure in the PEM fuel cell at  $\leq 80^{\circ}\text{C}$ . These test beds are a hydraulic loop simulation of the fuel cell system to test the piping, connectors, sensors, valves, pumps, etc., without the fuel cell. Testing will be done to simulate the flow rates, temperature and pressure of operation, initially under a humidified nitrogen system with eventual operation under reactant conditions. This exposure would simulate the anode flow areas just before the fuel cell entrance and conditions in the hydrogen re-circulation loop. The humidified hydrogen would be circulated using a hydrogen blower such as the Parker Hannifin Model 55™ Univane rotary compressor [2].

Figure 1 shows the test bed process flow diagram. The test bed design can be viewed as two “separate” pieces. The upper flow diagram designated “Life Cycle Test” is the loop that will circulate humidified hydrogen. This loop will be

PEM BOP RELIABILITY TEST STAND: 27 MAY 09

### LIFE CYCLE TEST PARAMETERS:

Pressure.....50 psia target, 15 – 100 psi function by design  
 Temperature.....80°C target, 20 – 80°C max function by design  
 Relative Humidity.....95%RH target, 5 – 95%RH function by design

ALL DEVICES FM APPROVED,  
 OR EQUIVALENT FOR H2 SERVICE

### LIFE CYCLE TEST DEVICES:

Analog and digital output to NI Hardware,  
 4-20 mA, 0-5V, 0-10V, RS-232  
 Thermocouple, K-Type  
 %RH detectors, Vaisala,  
 5 – 95% RH, 95% - 100% RH  
 Heaters, Heat trace, 1000 W, 110 VAC  
 Stainless control valves, 316SS option to control  
 Stainless tubing, 1/2" OD, 316SS  
 High Purity Regulators  
 Sample Cylinders, Stainless  
 H2, N2, Air input streams  
 Silenced exhausts

### Equipment Legend

- Powered bellows valve
- Plug Valve
- Accelerometer (quantity)
- LVDT
- Regulator
- Needle Valve
- Pressure Relief Valve
- Trace Heater
- Analog Pressure Gauge
- Humidity indicator, analog out
- 1/2" 316L SS TUBE, 100 ft., est. Liquid Drain
- Thermocouple

Dynamic Response Test  
 Pre- and Post- Test  
 Assessment

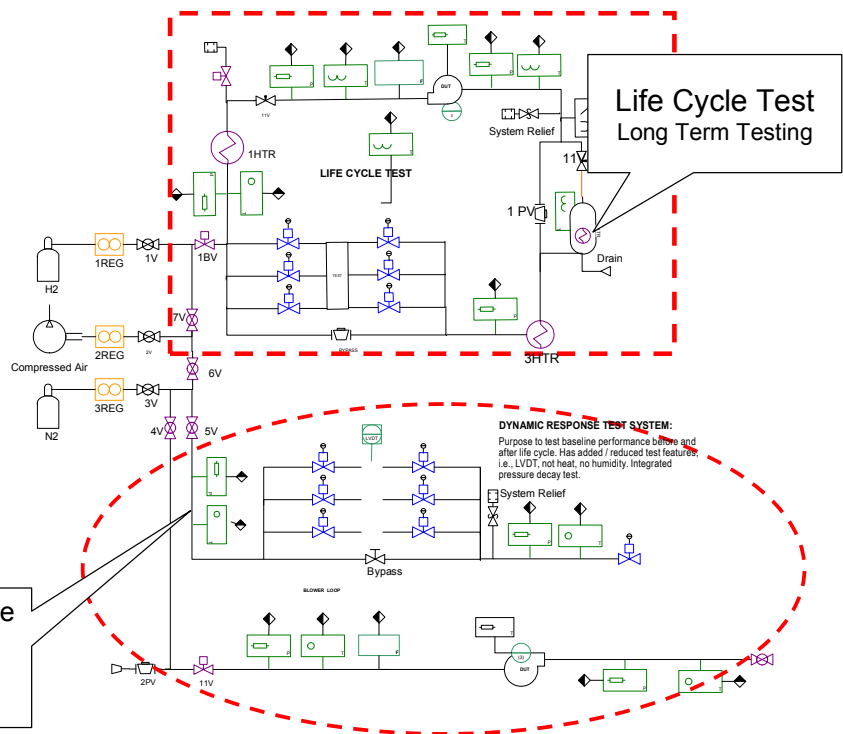


FIGURE 1. Fuel Cell BOP Reliability Test Bed Design

pre-tested with nitrogen for leaks before hydrogen usage. Operating conditions will be 50 psi static, 80°C, 70-95% relative humidity and 6-7 SCFM flow rate in the closed-loop system. The lower loop is designated for dry nitrogen or air only. The lower loop consists of the blower platform and the dynamic response test system. This section is for the pre- and post-test validations in our reliability testing, pump performance mapping, and pressure decay (leak) testing of the components.

A LabVIEW-based data acquisition program has been written for each test stand to log critical experimental parameters. Pressure, temperature and humidity sensors are currently under test. The testing protocol consisted of comparison of devices under test with traceable probes. The device then underwent testing to verify accuracy, measuring range and short term stability before longer term testing. Figures 2 and 3 show example evaluation testing for candidate pressure transducers. The system transducers

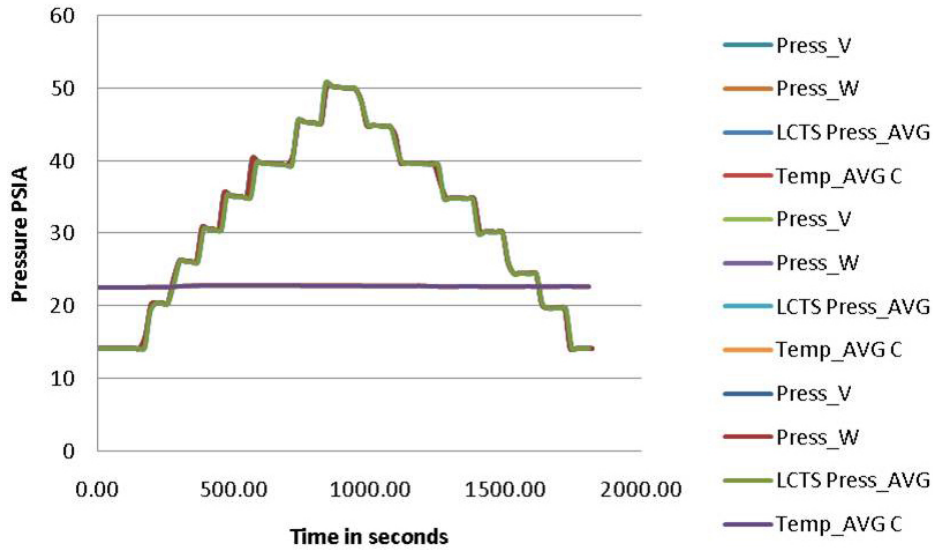


FIGURE 2. Testing Performance of Pressure Sensors

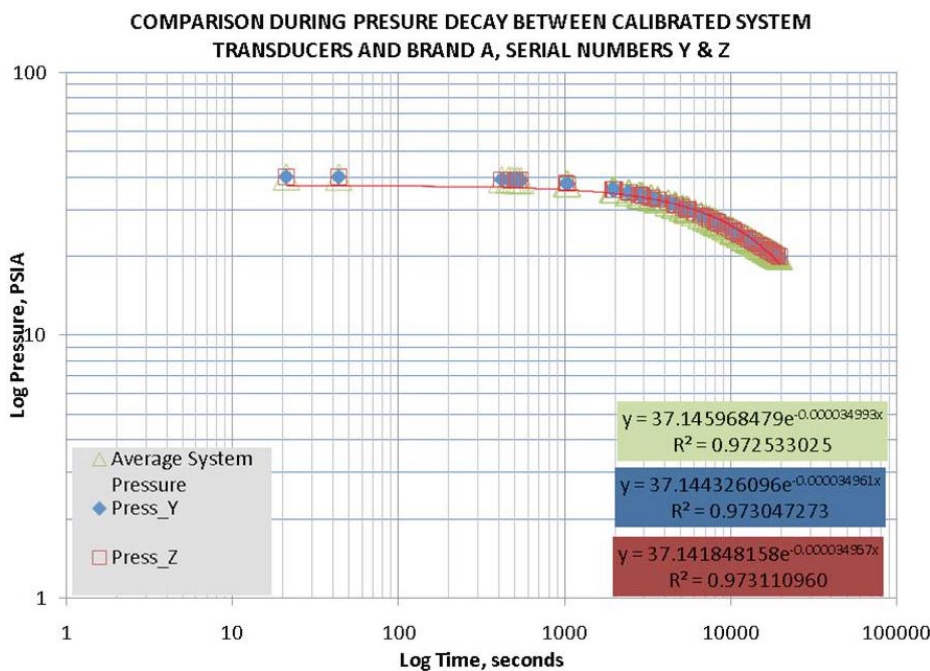


FIGURE 3. Pressure Decay Comparison

are traceable to the National Institute of Standards and Technology using a HEISE PTE-1 Calibrator with 0-200 psig pressure module to 0.02% accuracy.

A trade study of pressure sensing elements led to a product decision matrix of low-cost pressure transducers from large original equipment manufacturers. Of the transducers specified and evaluated thus far, two failures, one soft and one hard failure, have occurred under time conditions less than the PEM BOP and manufacturer's ratings. Sensors that have qualified continue to be tested on the Life Cycle testbed, exposed to high temperatures and humidity.

Low-cost, lightweight precision temperature sensors, typically procured in high quantities, required repackaging in a form that would impose negligible impedance on performance. These sensors were built-in with a high performance epoxy encapsulant of very high thermal conductivity and very low electrical conductivity. Evaluation of the temperature sensors and several encapsulation designs are continuing on the Life Cycle testbed. Integrated humidity and temperature sensors, in compact, lightweight form are also under test. These sensors utilize the I<sup>2</sup>C protocol for allowing upward of 100 sensors to be connected serially to a single data bus, eliminating the need for multiple controller cards. Special housings were also designed for these sensors and fabricated. Humidity/temperature sensors are currently being evaluated in the Life Cycle testbed.

Student training has been ongoing for the operation of the testbed. The training has continued for participating students to have a greater depth of understanding in LabVIEW programming and exposure to a broader range of software programming techniques to implementation of the I<sup>2</sup>C protocol. Training has included embedded controller information for LabVIEW programming and compiling to make a stand-alone program for data acquisition, control and analysis of the data, implementation of testing protocol, as well as compliance with the Hydrogen Safety Plan protocol.

## Conclusions and Future Directions

- Further characterization of lower cost sensors over a wider range of test conditions.
- Further refinement of sensor housing and electronics for lower price sensors.
- Investigation of electrical actuated valves including modifications for improving flow, lowering power consumed and decreasing size and weight [3].
- Permeation testing of different tubing materials.
- The future is being planned with students being trained on the construction, programming and operation of the life cycle test beds.
- A one year extension no cost extension has been requested.

## FY 2011 Publications/Presentations

1. *Fuel Cell Balance of Plant Reliability Testbed*, Vern Sproat and Rob Shutler, Poster session at DOE Hydrogen Program Annual Merit Review, Washington, D.C., May 2011.

## References

1. *Automotive Fuel Cell R&D Needs*, Craig Gittleman, David Masten, and Scott Jorgensen, DOE Fuel Cell Pre-Solicitation Workshop March 16, 2010.
2. *Cost Analyses of Fuel Cell Stack/Systems*, J. Sinha, S. Lasher, and Y. Yang, DOE Hydrogen Program Annual Report, V.A.3.
3. *Balance of Plant Needs and Integration of Stack Components for Stationary Power and CHP Applications*, Chris Ainscough, DOE Fuel Cell Pre-Solicitation Workshop - March 16, 2010.