V.O.8 Fuel Cell Balance-of-Plant Reliability Testbed*

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*Congressionally directed project

Objectives

There are two primary objectives of this project:

- To establish a testing program resulting in a reliability database for candidate proton exchange membrane (PEM) fuel cell balance-of-plant (BOP) components; and
- 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 (3.4) of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Durability

This project also addresses the following technical barriers from the Education section (3.9) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(D) Lack of Educated Trainers and Training Opportunities

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 Balance-of-Plant Components for Transportation Applications

Characteristic	Units	2010/2015 Stack Targets	2009 Project Status
Durability with cycling At operating T ≤80°C	Hours	5,000	To be determined

Accomplishments

- Two testbeds have been assembled.
- The third testbed is under development.
- Students are being trained to the Hydrogen Safety Plan.
- Students are being trained on the construction, programming and operation of the testbeds.
- Several test components have been identified.

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Introduction

One of the major challenges that needs to be addressed by the fuel cell industry prior to full commercialization is the reliability of the components that comprise the complete system, particularly the BOP. As a potential developer and integrator of fuel cell systems, the Stark State College of Technology's team member, Lockheed Martin, has identified BOP component reliability as a critical factor that needs to be addressed before fuel cell systems will be incorporated into aerospace platforms.

Approach

Stark State College of Technology and Lockheed Martin will develop a series of test beds that will test fuel cell system components such as pumps, valves, sensors, fittings, etc., operating under conditions anticipated in real PEM fuel cell systems. The test beds will operate continuously for months, or years, until a component fails. Parts that continue operating will have demonstrated lifetime for potential fuel cell systems. Parts that fail will be removed (the rest of the test bed restarted) and examined to learn why they failed. Feedback will be provided to manufacturers for product improvement. Results will be made generally available to begin removing reliability as a roadblock to the growth of the PEM fuel cell industry. A total of three test beds will be developed in this project – two at the Stark State College of Technology and one at Lockheed Martin. Those at the Stark State College of Technology will be built and monitored by engineering technology students as part of their education program. A database of parts, operating conditions and lifetime data will be generated and updated regularly.

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 ≤80°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 recirculation loop. The humidified hydrogen would be circulated using a hydrogen blower such as the Parker Hannifin Model 55™ Univane rotary compressor [2].

As required by the DOE, a Hydrogen Safety Plan was prepared to address the issues of working with hydrogen. The greatest hazard is combustion from leaking hydrogen. A failure modes and effects analysis of possible hazards leading to the accumulation of hydrogen and subsequent combustion was assessed for the test bed with the associated risk mitigation to limit or eliminate the components necessary to support a fire. All participants in the Fuel Cell Balance of Plant Reliability Testbed project are required to be trained in the safe use of hydrogen and compliance with the Hydrogen Safety Plan.

Renovation of the project laboratory space at Stark State College has been completed and complies with the safety standards.

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 recirculate the humidified hydrogen. This loop will be 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. This 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.

Test bed component selection is also critical to safe operation with hydrogen. Electronic devices required one or more of the following: Factory Mutual compliance, intrinsically safe designation, compliance with Class I, Division 1, Group B operation or designated for hydrogen use. Stark State Students have been selecting components and monitoring sensors for the operation of the test bed. All test bed equipment is commercial off-the-shelf, as components requiring non-recurring engineering costs or modification for fuel cell use were outside the scope of this project. Instruments were chosen for their compliance with materials and flow specifications. Students have been exposed to the various sensor instrumentation associated with fuel cells as well as the instrumentation and operation of fuel cells in the classroom.

Several issues with PEM fuel cell commercial off-the-shelf components have been documented as components for testing have been identified. Reliability data is incomplete for limited production components. Many components with design capabilities within the PEM fuel cell specifications have never been tested for any length of time under those conditions. Other components do not have the correct material compatibility to operate within PEM environment, especially with respect to exposure to hazardous gases and deionized water. Additionally, high development costs were necessary to modify some existing off-the-shelf components to become compatible with the PEM environment.

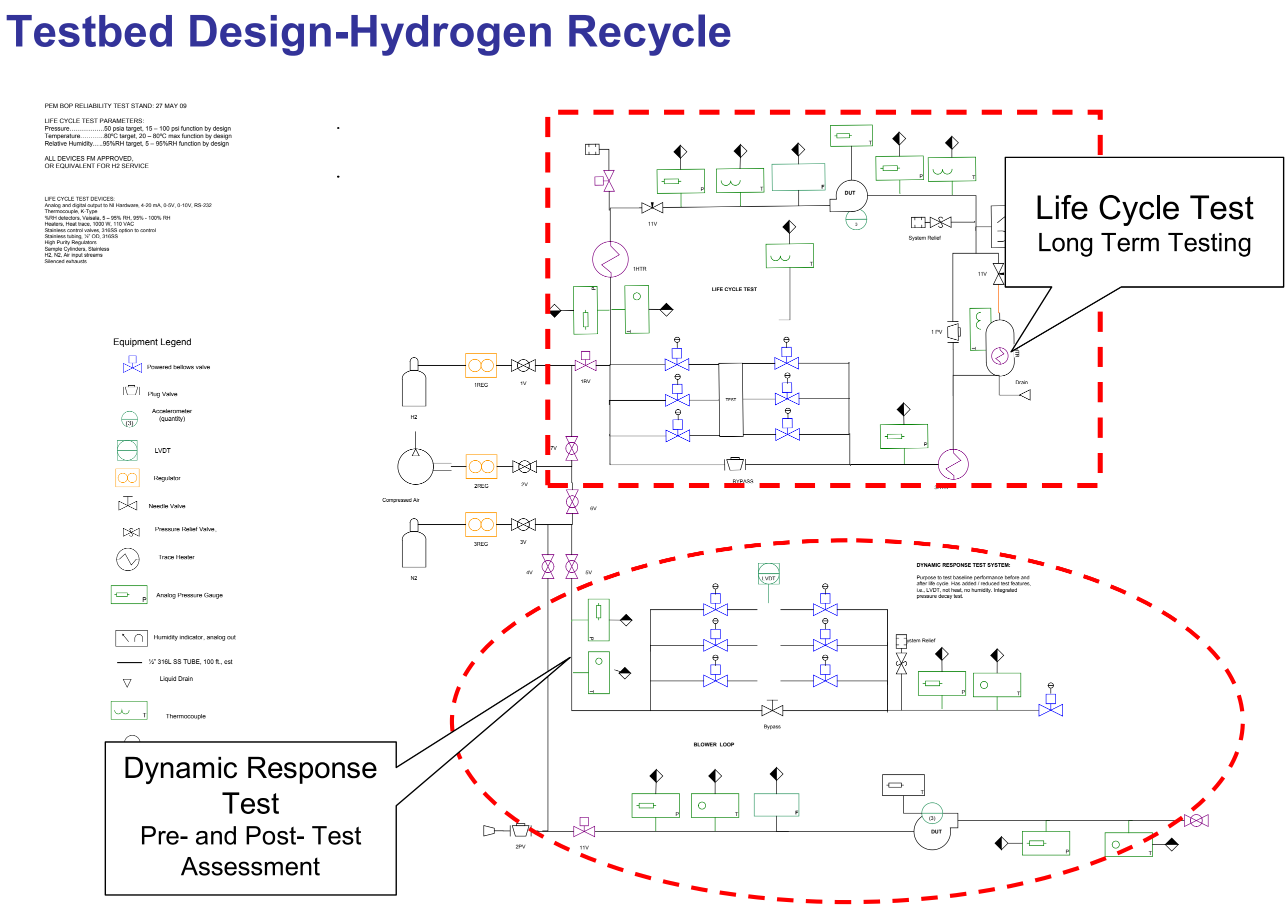

FIGURE 1. Fuel Cell BOP Reliability Test Bed Design

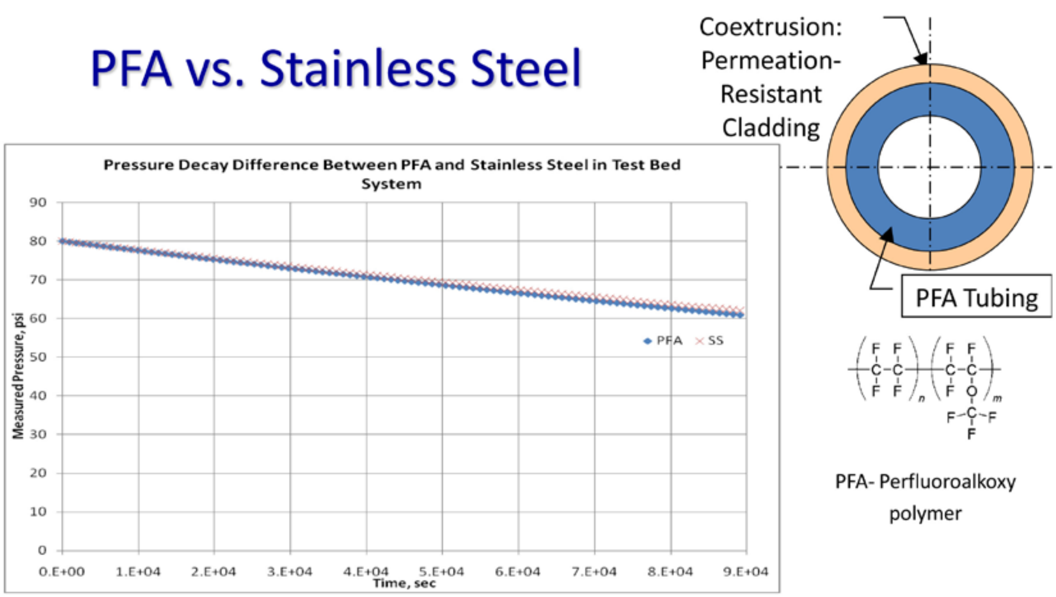

FIGURE 2. Pressure Decay Data for PFA Polymer Tubing

One component that has completed qualification testing is a limited run perfluoroalkoxy (PFA) polymer tubing with a permeation resistant cladding. This tubing is lighter weight than stainless steel and is resistant to deionized water, corrosion and chemicals. Initial pressure decay testing of the PFA tubing, shown in Figure 2, exhibits behavior similar in magnitude to stainless steel. The tubing must still be evaluated with respect to long-term exposure to the temperature, pressure and humidity of the PEM fuel cell environment. Other components designated for test include sensors and, potentially, valves which are known sources of reliability issues [3].

Student training has been ongoing for the operation of the test bed. 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. The 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. The MET231 Fuel Cell System class visited Lockheed Martin and thoroughly reviewed the test stand setup, the hardware instrumentation devices, and software of the Lockheed Martin's test stand. This opportunity greatly assisted the building process of the student's first test stand.

Conclusions and Future Directions

Safety protocols are in place at both Stark State College of Technology and subcontractor, Lockheed Martin, locations to ensure the safety of individuals working with and around the reliability test beds being created through this project. The first two BOP reliability test beds are assembled and instrumented for reliability testing. Candidate components are being pre-tested in preparation for long term testing. This project continues as a cooperative program between industry and an educational institution for hands-on training of the PEM fuel cell workforce.

Future Work:

- Operation of the test beds to obtain reliability data.
- Failure analysis of failed components.
- Construction and instrumentation of the third BOP reliability testbed in the coming academic year.

FY 2010 Publications/Presentations

1. *Fuel Cell Balance of Plant Reliability Testbed*, Vern Sproat and Debbie LaHurd, Poster session at DOE Hydrogen Program Annual Merit Review, Washington, D.C., June 2010.

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.