

VIII.3 Component Standard Research and Development

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(G) **Insufficient Technical Data to Revise Standards**

The role of DOE/NREL is focused on the need to provide sound technical data in the form of test data and analysis for the purpose of revising relevant hydrogen codes and standards.

(H) **Insufficient Synchronization of National Codes and Standards**

Harmonization of national codes and standards is a top priority of the RCS efforts within the DOE Hydrogen and Fuel Cells Program.

(K) **No Consistent Codification Plan and Process for Synchronization of Research and Development (R&D) and Code Development**

Planning and prioritization is needed to guarantee that resources are well placed for the expeditious development of new and existing documents and to assure that codification activities are synchronized with the needs of the relevant technical committees.

Contribution to Achievement of DOE Safety, Codes & Standards Milestones

This project contributes to achievement of the following DOE milestones from the Hydrogen Codes and Standards section of the Fuel Cell Technologies Program's Multi-Year Research, Development and Demonstration Plan:

- Milestones: Completion of necessary codes and standards needed for the early commercialization and market entry of hydrogen energy technologies in support of the 2015 model year release planned for hydrogen fuel cell vehicles.

FY 2012 Accomplishments

- Completed oxygen dependence evaluation of multiple sensor platforms. This work was presented at the International Conference on Hydrogen Safety in San Francisco California and is being published in the International Journal of Hydrogen Energy. This work was identified as a need through multiple sensor users with needs for robust sensors capable of operation in reduced oxygen environments.
- Completed sensor test laboratory objective, for a fifth sensor platform as part of the NREL/Joint Research Centre (JRC) round robin inter-laboratory comparison, under a formal Memorandum of Understanding with the JRC laboratory (a European Commission funded laboratory). Round robin test result comparison provided validation of test methods.
- Collaboration with JRC's Cleaner Energy Unit and the Université du Québec at Trois-Rivières has led to an

Fiscal Year (FY) 2012 Objectives

- Support development of new codes and standards required for commercialization of hydrogen technologies.
- Create code language that is based on the latest scientific knowledge by providing analytical, technical and contractual support.
- Participate directly on codes and standards committees to identify technology gaps, then work to define research and development needs required to close those gaps.
- Conduct laboratory testing to provide a basis for improved code language.
- Collaborate with industry, university and government researchers to develop improved analytical and experimental capabilities.

Technical Barriers

This project addresses the following technical barriers identified in the Hydrogen Codes and Standards section of the 2012 Fuel Cell Technologies Program's Multi-Year Research, Development and Demonstration Plan:

(F) **Enabling National and International Markets Requires Consistent Regulations Codes and Standards (RCS)**

Standards being developed at the component level need to be harmonized across national and international jurisdictions, requiring technical expertise at the technical committee level to monitor and inform on issues of consistent requirements.

evaluation of numerous miniaturized hydrogen sensor platforms (e.g., micro-fabricated, micro-machined, thin-film) and an assessment of the resulting improvements in certain performance metrics as well as degradations in others. These results were presented at the World Hydrogen Energy Conference by our collaboration partners from the Université du Québec.

- Partnering with Lawrence Livermore and Los Alamos National Laboratory has led to results being presented at the 221st Electrochemical Society meeting on the subject "Humidity Tolerance of Electrochemical Hydrogen Safety Sensors Based on Yttria-Stabilized Zirconia (YSZ) and Tin-doped Indium Oxide (ITO)".
- Conducted Hydrogen Safety Sensor Workshop in Chicago Illinois leading to summary document with sensor application specific targets and recommendations. Follow up webinars are being held quarterly for continued communications with key stakeholders in the sensor industry.
- Support of hydrogen fuel cell electric vehicle crash test leakage measurements. Sensors were evaluated for crash test survivability, leading to a successful field deployment of a sensor platform at the Transportation Research Facility. The sensor is capable of measuring hydrogen or helium leakage during pre and post crash. Helium was selected as a surrogate test fluid during full vehicle crash testing.
- Designed and built multiple long-term exposure chambers with environmental controls for extended life testing of hydrogen safety sensors as part of the NREL/JRC Memorandum of Understanding. Accumulated data over a one year time period has been collected for 2% hydrogen exposures at two week intervals.
- NREL maintains a Memorandum of Understanding with Element One for the purposes of hydrogen safety sensor development. This work has led to Element One being awarded the Next Top Energy Innovator runner up award.
- NREL is working with the BAM laboratory in Germany (Federal Institute for Materials Research and Testing) to develop an outline for a hydrogen safety sensor textbook. A publisher has been contacted and work is moving forward to defining market needs.
- Component test validation work on Hydrogen Pressure Relief Device 1 (HPRD1) phase 1 has been completed. Results were utilized to modify test protocols in order to provide a more representative set of worst case conditions during cycle testing.
- Component validation testing needs are being identified through NREL subcontract efforts for the purpose of prioritizing for future resource allocation. In addition, NREL has organized a meeting, to be held at the end of the fourth quarter FY 2012 to bring together component

manufacturers for open discussion relative to component development needs.



Introduction

Development of codes and standards has been identified in the 2012 Fuel Cell Technologies Program's Multi-Year Research, Development and Demonstration Plan as a key area needing support for the commercialization and growth of hydrogen technologies. NREL is providing research and development support to these codes and standards organizations through validation testing, analytical modeling, and product commercialization efforts. NREL has been tasked with these responsibilities as defined in the 2012 Fuel Cell Technologies Program's Multi-Year Research, Development and Demonstration Plan.

Approach

NREL is participating on relevant codes and standards committees to help identify gaps and define research and development needs to close those gaps. Working at the committee level allows us to quickly identify areas that need R&D support and to work directly with the technical experts in planning a path forward. This process is instrumental in avoiding delays and setbacks in the development of new codes and standards and in the revision of existing codes and standards. By providing support from a national lab we are able to help establish codes and standards language with solid technical basis.

Hydrogen safety sensors are a key component for the safe commercialization of hydrogen technologies. NREL is tasked with being a national resource for testing sensors designed to meet the needs of this growing market. By developing standard test methods and measuring sensor performance of a wide range of sensors of different designs and from a many different manufacturers, NREL is characterizing sensor performance and identifying gaps relative to DOE performance targets. With this information we work closely with sensor manufacturers so that they can better understand the performance of their sensor relative to the needs of hydrogen stationary applications. This work is directed toward sensor R&D, such that sensor manufacturers, utilizing the resources of a national lab, can expedite their product development life cycle. In addition, the sensor market expertise gained by NREL will be used to support commercialization through development of representative codes and standards for safety sensor certification. Commercialization support includes collaboration with key stakeholders as well as direct participation on the relevant codes and standards committees.

Results

NREL has been working toward identifying gaps and supporting R&D efforts for developing new and improved hydrogen codes and standards. Results reported here are for efforts specifically directed at component level standards. Results are organized in the following three sections; Hydrogen Safety Sensors, Component R&D and Codes and Standards Support.

Hydrogen Safety Sensors

DOE published performance targets for hydrogen safety sensors in the multi-year RD&D plan. NREL's has identified more than 150 commercially available sensors and near-term developmental sensors from six sensor categories. Test data is being compiled in a generic format as a resource for end users. This format will allow for publishing a characterization study of the sensor market, while keeping individual results proprietary.

NREL completed validation testing of the sensor test apparatus that was built in FY 2010. Validation testing consisted of systems level testing to characterize the repeatability and reproducibility of the apparatus, showing capabilities surpassing requirements in certification standards. Capabilities were further validated through round robin testing completed with the JRC Institute for Energy laboratory in Petten Netherlands. NREL is now leveraging accomplishments in hydrogen safety sensor testing through our collaboration with the JRC laboratory.

NREL is currently working directly with more than 20 sensor developers to support commercialization as their products move from prototype designs to full-scale production. This effort is directed at providing independent evaluation and testing of sensor platforms. This work has been completed in conjunction with other DOE supported projects in developing new technologies that have shown promise in meeting the identified DOE sensor targets.

Component R&D

Compressing, storing and dispensing gaseous hydrogen at 70 MPa can be a challenging application for hardware that is available on the market today. As hydrogen fuel cell market penetration grows, component suppliers will be able to use increased sales volume to support development of product improvements. At the demonstration phase, the limited number of suppliers can benefit from National Laboratory research and development support. This is aimed at increasing the understanding of the fuel cell market needs then developing product that meet performance targets required by this new service. NREL is holding a meeting of component suppliers at the end of FY 2012 to discuss the merits of the Energy Systems and Integration facility and potential for product testing support. NREL also has a

subcontract in place to help identify and prioritize codes and standards validation test needs. These needs will be used for defining resources required for support of codes and standards development.

Codes and Standards Support

Through direct participation on the hydrogen components codes and standards committees, NREL has identified R&D gaps, including further HPRD testing, localized fire testing, tank level stress rupture testing and radio-frequency identification fill protocol validation. NREL has developed statements of work required to close these gaps and finalize these components requirements.

Conclusions and Future Direction

NREL made significant contributions in supporting commercialization of hydrogen sensor technologies. This includes collaborative work with domestic and international partners. NREL hosted a hydrogen sensor workshop in June 2011 and is following up with quarterly webinars to identify hydrogen sensor research and development gaps and to help define future sensor test laboratory direction. We continue to work closely with codes and standards development organizations to close gaps and promulgate codes and standards that are based on the latest technical knowledge. In addition to continuing to support component level codes and standards development, NREL will undertake a number of initiatives including:

- Identifying gaps to hydrogen technology commercialization.
- Providing national laboratory support needed to provide a sound basis for component level codes and standards content.
- Working directly with sensor manufacturers in order to reach performance targets defined in the 2012 Fuel Cell Technologies Program's Multi-Year Research, Development and Demonstration Plan.
- Executing sensor test laboratory testing over a wider range of environmental conditions and finalizing long-term exposure and response time testing methodologies.
- Leveraging our efforts with national and international collaborations to provide a path toward commercialization of hydrogen components that are designed to meet the latest safety standards.

FY 2012 Publications/Presentations

1. "Use of Hydrogen Safety Sensors Under Anaerobic Conditions – Impact of Oxygen Content on Sensor Performance", W.J. Buttner, R. Burgess, C. Rivkin, M.B. Post, L. Boon-Brett, G. Black, F. Harskamp, P. Moretto, International Conference on Hydrogen Safety (ICHS), Presented San Francisco, September, 2011 and submitted for publication in conference proceedings.

2. “Validation Testing in Support of Hydrogen Codes and Standards Development”, R.M. Burgess, M. McDougall, N.L. Newhouse, C. Rivkin, W.J. Buttner, M.B. Post, International Conference on Hydrogen Safety (ICHS), Presented San Francisco, September, 2011 and submitted for publication in conference proceedings.

3. “On-Board Storage (SAE J2579 rational for performance based criteria for on board hydrogen storage systems)” at the HySafe Hydrogen Safety Workshop, San Francisco CA, September 2011.

4. “FY2011 Year End Safety Sensor Testing Laboratory Accomplishments”, DOE Report, FY11 Annual Operating Plan, September 2011.

5. “NREL/DOE Hydrogen Safety Sensor Workshop Summary”, Document review completed December 2011, Submitted for publication as NREL technical report (Note: workshop held in Chicago, IL, June 2011).