IX.2 Component Standard Research and Development

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Subcontractors:
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- Society of Automotive Engineers (SAE), Troy, MI

Project Start Date: Fiscal Year (FY) 2008
Project End Date: Project continuation and direction determined annually by DOE

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 from the Hydrogen Codes and Standards section (3.7.4) of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration (RD&D) Plan:

(A) Limited Government Influence on Model Codes
The code development process is voluntary, so the government can affect its progression, but ultimately it is up to the code development organizations (CDOs).

(B) Competition among SDOs and CDOs
The competition between various organizations hinders the creation of consistent hydrogen codes and standards. (SDO = standards development organization)

(C) Limited State Funds for New Codes
Budget shortfalls in many states and local jurisdictions impact the adoption of codes and standards because they do not always have the funds for purchasing new codes or for training building and fire officials.

(F) Limited DOE Role in the Development of International Standards
Governments can participate and influence the development of codes and standards, but they cannot direct the development of international standards.

(G) Inadequate Representation at International Forums
Participation in international forums and meetings is voluntary and, to date, has been limited by budgetary constraints.

(H) International Competitiveness
Economic competition complicates the development of international standards.

(I) Conflicts between Domestic and International Standards
National positions can complicate the harmonization of domestic and international standards.

(J) Lack of National Consensus on Codes and Standards
Competitive issues hinder consensus.

(K) Lack of Sustained Domestic Industry Support at International Technical Committees
Cost, time and availability of domestic hydrogen experts have limited consistent support of the activities conducted within the international technical committees.

(N) Insufficient Technical Data to Revise Standards
Research activities are underway to develop and verify the technical data needed to support codes and standards development, retrofitting existing infrastructure and universal parking certification, but are not yet completed.

Contribution to Achievement of DOE Codes & Standards Milestones

This project will contribute to achievement of the following DOE milestones from the Hydrogen Codes and Standards section of the Fuel Cell Technologies

Program Multi-Year Research, Development and Demonstration Plan:

- Milestone 18: Implement research program to support new technical committees for the key standards including fueling interface and fuel storage. (4Q 2007)
- Milestone 20: Draft standards for hydrogen detectors in stationary applications. (4Q, 2008)
- Milestone 21: Completion of necessary codes and standards needed for the early commercialization and market entry of hydrogen energy technologies. (4Q, 2012)

Accomplishments

- Completed validation testing of high-pressure composite overwrapped pressure vessel with induced flaws in support of ASME Boiler and Pressure Vessel code development.
- Completed validation testing of thermodynamic modeling used to generate SAE J2601 fill tables for hydrogen vehicle dispensing.
- Defined component level hydrogen compatibility testing being used to validate Canadian Standards Organization (CSA) hydrogen pressure relief device (HPRD) draft standard and initiated test program.
- Completed design/build/operations activities for NREL's Sensor Testing Laboratory and initiated testing program responsible for supporting sensor development and commercialization.
- Established sensor test laboratory collaboration partners both domestically and internationally, entering into a long term agreement to develop sensor test protocol, conduct round robin test method validation and provide sensor commercialization support with European Joint Research Centre laboratory.

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Introduction

Development of codes and standards has been identified 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 DOE multi-year RD&D plan.

Approach

NREL is participating on relevant codes and standards committees to help identify gaps and define research and development (R&D) 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 to commercialization of hydrogen technologies. NREL is tasked with building capability to test sensors for 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 will characterize the sensor market and identify gaps relative to the DOE targets. With this information we will be able to 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 will be 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 will be used to support commercialization through development of representative codes and standards for safety sensor certification. Commercialization support will include collaboration with key stakeholders as well as direct participation on the relevant codes and standards committees.

Results

NREL has been working on 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. There are four subject areas addressed in this report where significant achievements have been made during FY 2010. A summary of the four subject areas and corresponding gaps identified are presented in Table 1.

Tanks: ASME Boiler and Pressure Vessel Code – ASME has developed new requirements that address the certification of tanks designed for stationary hydrogen storage applications. In developing these standards, new language has been developed for composite overwrapped pressure vessel (COPV) designs defining required testing to insure survivability in the event of material flaws. Flaw testing is based on best engineering

TABLE 1. Hydrogen Component Standard Summary

Hydrogen Component Requirements	Technology Gap
Tanks *ASME Boiler and Pressure Vessel Code* New addition to test standard for composite overwrapped pressure vessels	High pressure performance testing being developed to insure survivability with flaw added to exterior surface requires testing to be used as basis for code language
Interface *SAE J2601 Fueling Protocol* New non-communication fill tables for hydrogen vehicle fueling are designed to insure temperature limits are not exceeded	Tables developed by thermodynamic modeling need to be validated with actual performance test data
PRD *CSA HPRD1 Pressure Relief Device* New performance based standard for temperature activated pressure relief device	Hydrogen service suitability test, designed to insure PRD operation is not compromised by hydrogen effect on materials, requires validation testing
Safety Sensors *Hydrogen leak detection NFPA 52 section 9.4.7.4* requires use of hydrogen leak detection for safe alarm and shutdown	DOE 2007 sensor workshop identified hydrogen safety sensor performance gaps relative to end user needs

knowledge, however there was a need for validating these test methods. NREL worked with ASME in identifying the need and defining a series of validation tests. This work was subsequently conducted at Lincoln Composites. Testing included subjecting tanks to pressure cycling followed by a burst test to determine residual strength. Flaws were cut at depths up to 40% of the wall thickness in both longitudinal and transverse directions. Results of the testing are shown in Figure 1. Post test burst data show that current design COPV tanks are able to maintain better than a two times safety factor with a worst case flaw.

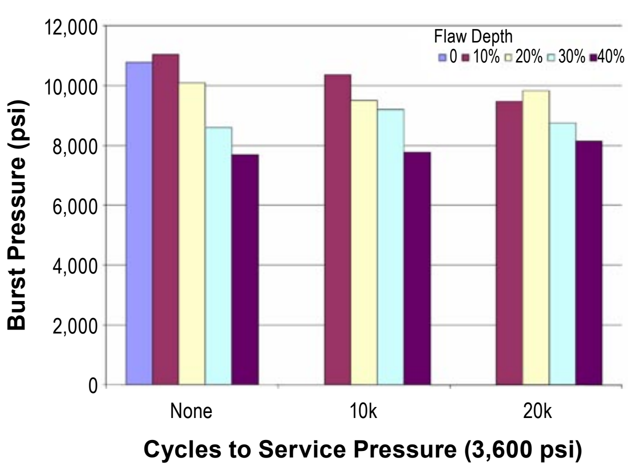

FIGURE 1. ASME Flawed Cylinder Testing, Burst Pressure vs. Cycling and Depth of Flaw

Interface: SAE J2601 Fueling Protocol – SAE standards for fueling rates in non-communication fill scenarios have been developed and are incorporated into the SAE J2601 standard, recently released as a technical information report. These fill rates are needed to insure against overfilling or exceeding temperature limits in the COPV tank. Fill tables have been developed based on thermodynamic modeling provided by a team of automotive manufacturers. The thermodynamic models take into account effects of Joule-Thomson heating, friction heating, thermal mass, pre-cooling and initial thermodynamic state. Validation testing was required to provide a sound basis for the data provided in the tables. NREL and SAE worked on defining a series of tests that include 35 and 70 MPa tanks, -20°C and -40°C pre-cooling and tank sizes ranging from 1.4 liter up to 9.8 liter internal volume. Fill cycle testing was conducted at Powertech labs. Results were shared with the SAE interface committee and it was determined that results showed good correlation and that there was no further modification to the tables required.

PRD: CSA HPRD1 Pressure Relief Device – Pressure relief devices have been identified as a key safety component on hydrogen storage systems. Inadvertent opening can result in a failure mode where there is a release of the entire contents of the storage vessel. Component standards for HPRD certification testing are being put in place to insure that these components have end of life reliability. NREL and CSA have worked toward defining scope of supply required to validate hydrogen service suitability testing as part of the CSA HPRD1 draft standard. Testing includes pneumatic cycle testing in hydrogen on three valves of three different designs. Also included in the test program are three surrogate designs made from materials that are known to show poor performance in hydrogen service. Post test metallurgical examination will be conducted to determine the extent of hydrogen related material degradation. Test components have been procured and testing has started. Completion of the contracted test program is scheduled for the end of FY 2010.

Hydrogen Safety Sensors – DOE has published performance targets for hydrogen safety sensors in the multi-year RD&D plan. NREL is working toward characterization of sensor performance relative to the DOE targets by testing commercially available sensors and near-term developmental sensors. Through research on the sensor market, over 140 different sensor technologies have been identified. Information on each of these designs is being compiled in spreadsheet format. This data resource includes manufacturer information, product specifications, contact lists and links to communication logs and test data. NREL has completed the design and build of a new custom test apparatus with capability for an expanded range of environmental test conditions and capacity to test multiple sensors concurrently. Figure 2 shows the new test apparatus.

NREL is currently working directly with sensor manufacturers, testing both commercially available product and near term prototype designs. In order to validate our test methods we have started a round robin test program with our sensor lab collaboration partner, the Joint Research Centre lab in the Netherlands. Selected sensors are being tested in both labs in order to show sensor performance is independent of any facility to facility differences. NREL is also collaborating with other national and international partners, including national laboratories, universities and codes and standards development organizations.

Conclusions and Future Directions

NREL has completed (or is near completion of) validation testing in support of ASME, SAE and CSA standards and will 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.

FIGURE 2. NREL Sensor Test Laboratory Apparatus

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.
- Developing national laboratory capabilities needed to provide a sound basis for component level codes and standards content.
- Focusing efforts toward working directly with sensor manufacturers in order to reach performance targets defined in the DOE multi-year RD&D plan.
- Expanding sensor laboratory capabilities to test over a wider range of environmental conditions and to add long-term exposure and response time test apparatus.
- Further our efforts on national and international collaboration in order to provide a path toward commercialization of hydrogen components.

FY 2010 Publications/Presentations

1. "ASME Flawed Cylinder Testing, Final Report", Lincoln Composites, J. Makinson, N. Newhouse, report # 09019, October 2009.

2. "ASME Flawed Cylinder Testing", N. Newhouse, ASME Pressure Vessel and Piping conference, July 2010.

3. "SAE J2601 Confirmation Testing Final Report", Powertech Labs Inc., M. McDougall, project # 19161-34, March 2010.

4. "Round robin testing of commercial hydrogen sensor performance – Observations and results", M. Post, NHA Conference and Expo, May 2010.

5. *Test protocol document, hydrogen safety sensor testing. Phase I, Non-flammable mixtures"*, R. Burgess, C. Blake, and C. Tracy, NREL/TP-560-42666, NREL Peer reviewed paper.

6. *"An Overview of Hydrogen Safety Sensors and Requirements"*, Buttner et al., 3rd International Conference on Hydrogen Safety (ICHS), September 2009.