U.S. Department of Energy Hydrogen Component and System Qualification Workshop

Sandia National Laboratory, Livermore, CA

November 4, 2010

Background

The Workshop was held at the Combustion Research Center, Sandia National Laboratories, Livermore, CA, on November 4, 2010. The goal of the Workshop was to identify key needs, barriers, and actions to facilitate the qualification and listing of hydrogen and fuel cell systems and components essential for widespread market deployment. To this end, representatives of fuel cell and hydrogen components and systems manufacturers, certification and listing organizations, automotive OEMs, and other interested parties were invited by the U.S. Department of Energy (DOE) to provide information and discuss issues, needs, and priorities in the certification and listing process and procedures.

To clarify terminology used in these notes, products undergo testing under a certification process described below. If a product can meet or exceed the requirements of the process, it is considered "qualified" or "certified" according to those requirements. Listing is the result of this process, whereby a product can carry a stamp or symbol from the certifying organization that it is suitable and safe to use for the intended purpose.[1]

Certification and listing are intended to establish confidence among consumers that a product is suitable and safe to use for a specified purpose. Similarly, for authorities having jurisdiction (AHJ), certification and listing of hydrogen and fuel cell components and systems facilitates approval to install and operate such components and systems within their jurisdictions. The process of certification and listing involves submitting a product to an independent third party for testing and evaluation according to requirements and procedures adopted by that party. In the U.S., the most prominent of such third party testers and evaluators include Underwriters Laboratories (UL) and CSA International/OnSpeX (CSA). In turn, UL and CSA are accredited by the American National Standards Institute (ANSI) in accordance with ISO/IEC Guide 65, which specifies general requirements for third-party operation of a product certification system. ANSI accreditation covers approval of key policy documents and review of the evaluation process, accreditation decisions, and monitoring/auditing programs. Other accrediting agencies include OSHA, NIST, and EPA.

The product certification process required by UL is described below (adapted from www.ul.com)

> To establish certification, samples of a product submitted by manufacturers for certification are tested and evaluated. If UL decides the product fulfills all applicable requirements it authorizes the manufacturer to apply a certification mark to production of the samples submitted, or issues a certificate or notification that the product is now certified by UL. Before the manufacturer releases products with a certification mark, UL must initiate Follow-up Service in which periodic audits of products at the factory are completed. For some products, factory samples are selected for retesting at UL. Certification continues until the manufacturer requests termination or fails to fulfill a requirement. UL must evaluate modifications to certify products before the modified product is authorized to bear the Mark or be considered certified.

Manufacturers pay for the cost of the initial evaluation process as well as ongoing maintenance fees for factory audits.

[1] The definitions of listing and labeled in the California Fire Code (Attachment A) should be referred to as well.

That lack of a product listing can impede market deployment of an alternative fuel is exemplified by the resistance of AHJs to allow dispensing of E15 ethanol and gasoline blends until UL determined and notified AHJs that existing fuel dispensers certified under UL 87 for intended use with ethanol blends up to E10 can be used with ethanol blends up to 15 percent. UL conducted tests to determine whether such dispensers were safe to use for E15 blends because of the increased potential for degradation of the metals and materials (e.g., plastics, elastomers, and composites) used in a dispensing system with an increased percentage of ethanol in the blend.

In Europe, there is a CE mark[2] that is a mandatory conformance mark on many products placed on the single market in the European Economic Area (EEA). The CE marking certifies that a product has met EU consumer safety, health, or environmental requirements. Originally "CE" stood for "Communauté Européenne" ("European Community"). According to the European Commission today, the CE logo has become a symbol for free marketability of industrial goods within the EEA without any literal meaning. By affixing the CE marking to a product, the manufacturer – **on his sole responsibility** – declares that it meets EU safety and health and environmental requirements.[3]

Key Findings and Issues

The presentations and discussion at the Workshop are summarized to help frame issues, needs, and priorities identified by participants representing the fuel cell and hydrogen industries and certification and listing organizations. Antonio Ruiz, DOE Technology Manager for the Safety, Codes and Standards subprogram (SCS), opened the workshop by highlighting its objectives and explaining how the information presented and discussed will help DOE align activities supported by the SCS with the certification needs and priorities of industry. The workshop could also identify R&D needs to facilitate the testing and certification process. Mr. Ruiz emphasized that DOE does not, nor does it intend to, engage directly in qualification or listing of components and systems. That said, test data and information as well as technical expertise are available from the DOE national laboratories to facilitate the process of qualification and listing whenever appropriate. Mr. Ruiz asked the workshop participants to help the SCS subprogram determine whether and how it can help facilitate the process of qualifying and listing key hydrogen and fuel cell components and systems to better enable their market deployment.

Experience and lessons learned by industry

Those presenting on behalf of hydrogen and fuel cell component and system manufacturers were:

Aaron Harris, Nuvera (by webinar)—PEMFC power pack for fork lifts
Chris Radley, Altergy (by webinar)—PEMFC for telecom backup power
Norm Newhouse, Lincoln Composites—Type 2, 3, 4 composite pressure vessels
Balsu Lakshmanan, GM/R&D—light-duty fuel cell vehicles

In addition to the presenters, Bryan Clever, of OPW-FC (www.opwglobal.com), a manufacturer of hydrogen fueling components, including nozzles, receptacles, and in-line breakaways, provided information through a phone conversation with Robert Wichert; David Frank of Hydrogenics, a major manufacturer of electrolyzers, provided input via an email to Jim Ohi; and Constantinos Minas of Plug Power participated in the discussion via the webinar.

[2] http://www.export.gov/cemark/index.asp
[3] It should be noted that the CE marked and certified nozzles and parts displayed at the workshop, courtesy of Robert Wichert, were not listed or labeled for use in the U.S. The nozzles and parts listed and labeled by CSA were likewise not CE certified but were listed and labeled by CSA for use.

Costs and Benefits of Product Certification and Listing

Because manufacturers must bear the cost of the product certification and listing process, which can be substantial, particularly for a small or start-up company, they must decide if and when to submit a product into this process. Aaron Harris characterized this decision as a classic "chicken and egg" problem: whether to determine the market potential of new product through demonstration and defer certification until there is customer demand for it ("egg"), or to make the investment and certify the product knowing that it will meet a customer need and avoid missed opportunities when the market expands ("chicken"). Mr. Harris acknowledged that it is difficult for customers to trust an uncertified product and that Nuvera's customer base is less diverse than for other hydrogen fuel cell products. Although Mr. Harris did not say so explicitly, it seems that Nuvera will come down on the side of the "chicken" and seek certification and listing of its product line.[4]

Chris Radley gave a strong endorsement for the need of certification and listing and stated that Altergy was able to sell more than MW quantities of its fuel cell systems only after the systems were listed. To date, twelve of its fuel cell systems are tested, certified, and listed by CSA, and the products meet or exceed the requirements of applicable codes and standards, including CSA FC-1 (stationary fuel cell power systems), NFPA 853 (installation of stationary fuel cell power systems), and NFPA 55 (storage, use, and handling of compressed gases and cryogenic fluids in portable and stationary containers, cylinders, and tanks).[5]

Altergy supports product listing because the fuel cell industry is newly emerging and has a low tolerance for incidents, given the public's perception of hydrogen (as a dangerous substance). Listing ensures that proper engineering has been performed and lowers risk to the manufacturer, buyer, industry, and community. Listing also facilitates AHJ review and obtaining permits for installation and operation. Mr. Radley also strongly urged working with standards organizations as early in the design process as possible.

Lessons Learned and Other Issues and Needs for Fuel Cell Component Certification

Robert Wichert reported on a conversation with Bryan Clever that summarized OPW-FC's lessons learned concerning certification and listing of fuel cell components. One problem was that the principal certification and listing organizations do not recognize and accept test and laboratory results from each other, even though all are qualified and accredited organizations.[6] Even when test procedures were just slightly different, testing had to be repeated if the testing was done by another certifying organization. Although proprietary testing methods and standards and a for-profit business situation described below make collaboration highly unlikely, perhaps there are "pre-competitive" testing needs that can be facilitated by DOE to mitigate this barrier to more rapid and less costly certification and listing of certain critical components and subsystems. Other issues noted by Mr. Clever included lack of consensus on a definition of a "worst case" failure scenario for a given component or system and widely varying requirements for dissipation of static electricity. Cycle testing is the time determining factor in the certification process, and more data on polymer degradation and lifetime are needed but difficult to obtain.

[4] Nuvera has not certified its existing demonstration units.
[5] Altergy units are also CE-certified.
[6] It should be noted that UL accepts test data from third-party laboratories that are certified as capable of conducting tests to UL requirements.

A key need is more data and guidance on materials compatibility, e.g., hydrogen embrittlement as well as degradation of non-metallic materials induced at low-temperature. Although hydrogen resistant materials were identified (e.g., special 316L stainless steel with high nickel content), all metals are known to be affected by hydrogen, and no clear specification on what constitutes a good material exists. It was also noted that 316L stainless steel has a range of nickel composition and only the upper range was described as being resistant to hydrogen. Furthermore, there are different standards for stainless steel in different countries, and current grades for stainless steel have variable compositions, resulting in a material of a specified grade that may or may not be hydrogen resistant. There is also a need to clarify "what defines a hydrogen resistant material" and assess and correlate (if needed) existing standard approaches (e.g., ASME KD-10, ASME B31.12) and test protocols to determine resistance to hydrogen embrittlement.

Product Certification Perspective and Needs of Automotive OEMs

Balsu Lakshmanan recommended that DOE focus its efforts on pre-competitive R&D needs of the auto industry rather than the product certification process. He noted that PEMFC systems contain a lot of plastic materials and components whose structural integrity are critical for the safe operation of these systems in a vehicle and recommended that DOE focus on material qualification testing of polymeric materials used in PEMFC and BOP systems in fuel cell vehicles. Durability testing to assess leaching and out-gassing of constituents in such materials under fuel cell operating conditions would be very useful for the fuel cell vehicle OEMs.[7] Mr. Lakshmanan noted that under GM's material qualification planning, quality requirements at the component levels are five and ten times more severe and rigorous than at the subsystem and vehicle levels, respectively. In other words, successful commercial deployment of fuel cell vehicles depends on rigorous quality assurance at the component level.

As for codes and standards needs and issues, Mr. Lakshmanan noted that GM has its own worldwide set of internal standards based on ISO, ASTM, and other recognized international standards, and components are certified internally. Test engineers must convince compliance engineers that components they are responsible for have met certification requirements. Likewise, component suppliers must have their manufacturing processes certified by GM. The internal certification of components is consistent with the self-certification of automobiles under DOT FMVSS requirements in the U.S.

Testing and Certification of Composite Pressure Vessels

Norm Newhouse pointed out that certification of composite pressure vessels for different applications (vehicular, stationary, and transportable) are based on several available standards for each of those applications and that requirements that pressure vessels be certified or listed varies widely among authorities having jurisdiction (AJHs) in the U.S. and abroad. While a number of standards and regulations against which to certify pressure vessels are available for stationary (e.g., ASME BPVC, CSA B51-Pt 3) and transportable (e.g., DOT/PHMSA 49 CFR, UN COE, EN 12245, ISO 1119-3) applications, requirements incorporated in these regulations, codes and standards should be harmonized as more AHJs begin to require certification and listing of pressure vessels in their jurisdictions. For example, California is likely to require an ASME listing for pressure vessels based on the July 2010 edition of the BPVC. There are also a number of standards and regulations applicable to vehicular applications (e.g., HGV2, SAE J2579, ISO 11439, ISO TS15869, CSA B51 Pt. 2, FMVSS 304 (CNG), ECE R110) that need to be harmonized as well.

[7] NREL is leading a team studying the effects of system and air contaminants on PEMFC performance and durability; see www.hydrogen.energy.gov/pdfs/review10/fc048_dinh_2010_o_web.pdf.

Lincoln Composites (LC) subjects its tanks to internal qualification testing based on CSA HGV-2 requirements. While LC tanks have a nominal service life of 15 years, tests of tanks that approached the end of service life showed no indications of excessive permeation or loss of strength. Visual inspection is working well to meet in-service requirements, and ASME is developing guidelines for applying non-destructive evaluation (NDE) techniques to facilitate enforcement of inspection requirements. Such inspections are mandatory for stationary and transportable applications, but voluntary for vehicular applications. Pressure vessels are highly regulated, and the certification process is complicated.

Should DOE require certification and listing as a condition of funding demonstration projects?

Robert Wichert stated that one way to accelerate deployment of hydrogen and fuel cell systems is for DOE to require certification and listing of components and systems as a condition of receiving funding for demonstrations involving such components and systems. There was not much discussion on this topic, but the participants at the workshop did not seem to support Mr. Wichert's suggestion.[8]

Perspective of Certification and Listing Organizations

Those presenting the perspective of certification and listing organizations were:

Glenn Mahnken, FM Global
Ron Czischke, UL (by webinar)
George Gruss, CSA

Glenn Mahnken noted that FM Global insures property based on assessments of field inspectors (not actuaries) who apply engineering standards to determine hazards for a given occupancy (use of property). The engineers prepare loss prevention data sheets upon which the risks of property loss and insurance premiums are based. FM Approvals is a separate certification and listing company within FM Global with a focus on loss prevention products, such as fire protection equipment, electrical equipment, hazardous location equipment, fire detection, signaling and other electrical equipment, roofing products, and smoke detection. FM Global conducts tests in its own laboratories and under agreements with other laboratories located throughout the world.

Approval standards upon which FM Approval bases its testing and certification process are available at www.fmglobal.com. Mr. Mahnken mentioned that FM Approvals is preparing an approval standard for combustible gas detectors[9] that may be relevant for the deployment of hydrogen and fuel cell technologies. FM Approvals is also preparing a feasibility study of warehouses that use hydrogen fuel cell lift trucks and indoor hydrogen fueling under its highly protected risk (HPR) business plan. The study will include preparation of an approval standard for indoor hydrogen fuel dispensers and a loss prevention data sheet that will cover hazards of and safeguards for use of such dispensers. The outline of the study that Mr. Mahnken described appears to be comprehensive and will include:

- hydrogen release potential and exposures to clients;

[8] In a previous discussion of this suggestion during a teleconference call of the National Hydrogen and Fuel Cell Codes and Standards Coordinating Committee, Aaron Harris disagreed, stating that certification and listing costs would dilute funds allocated for demonstrations and lessen their acceleration of early market deployments. There are examples, however, where certification of components may help prevent failures or problems in the field during large-scale demonstrations of new technologies. The transition from demonstration to deployment is not always clear-cut and should be considered in addressing this question.
[9] This standard is now available from FM Global.

- maximum allowable release rates and amounts defined by system failure scenarios; and
- certified emergency shutdown systems, including hydrogen detection systems and shut-off valves.

Mr. Mahnken stated that FM Approvals is aware of applicable CSA standards and will work with CSA so that it will not duplicate work already done. It is also evident that FM Approvals should use and adapt data available from DOE and Sandia. In a conversation with Jim Ohi, Mr. Mahnken agreed to work with DOE and other certification organizations in establishing a common pre-competitive basis for such work.

Ron Czischke noted that certification and listing should not be used interchangeably with "approval." Certification means that all foreseeable hazards have been assessed, while listing signifies that all requirements of certification have been met and the product can be installed under ANSI-approved codes. Mr. Czischke also clarified other common terms, such as "classification," where the scope of investigation is limited (for example, in lift trucks where only fire, shock, and tip-over are addressed as in the current version of UL 2267) and "recognition," which states conditions of acceptability for components.

Certification tests at UL are based on requirements in published standards or, in cases where applicable published standards are not available, UL prepares an outline of investigation that includes test methods and requirements. The client (manufacturer) pays for preparing and executing the outline of investigation. An outline of investigation is published for public review and can expedite the listing process to meet the requirements of an AHJ.

George Gruss described the three divisions of the CSA Group. CSA International is the testing and certification division that evaluates, tests, and certifies product designs to published, nationally recognized safety standards. When applicable standards are not yet available, as may be the case for new technologies, CSA International relies on internal and external experts to develop test methods and requirements and publishes interim requirements.[10] The certification process, using the applicable product standards, includes evaluation of product construction, product testing, an evaluation report, and an initial factory audit. Once a Certificate of Compliance is issued, CSA conducts quarterly factory inspections to verify that the manufacturer is adhering to production requirements of the approved product design. The manufacturer is required to conduct production line testing as well as some periodic audit tests to verify that the production is consistent with the certified design.

Large and complex products or systems, such as fuel cell systems, that cannot be easily moved to or accommodated within CSA facilities, can be certified under a "witness testing program" where the product is tested at the manufacturer's facility and witnessed by a CSA International specialist. In order to conduct witness testing, the test equipment and laboratory facility must be evaluated for compliance to ISO Guide 17025.

The OnSpeX division of the CSA Group conducts product performance and quality assurance evaluations of products as requested by retailers or product manufacturers. This is above and beyond the product certification testing done by CSA International. OnSpeX, an independent testing organization, is used to verify manufacturer's claims of product performance, quality, etc. OnSpeX can also provide technical assistance in product design.

[10] Note from Robert Wichert: where published standards are not available, CSA can prepare "desktop standards" analogous to UL outlines of investigation. Not having a published standard is not a barrier to listing but can result in increased costs to prepare the outline of investigation or the "desktop standard."

The CSA Group also includes CSA Standards, a standards development organization for North America. CSA Standards is actively involved in developing standards for hydrogen fueled vehicle components, fueling station components, as well as fueling stations. CSA Standards was very active in developing standards for natural gas vehicle components and fuel cells.

For hydrogen fueling, CSA International will launch a hydrogen component certification program in January 2011 and a station certification program in January 2012. As part of this program, CSA International will invest about $500K to design and build a Hydrogen Dispenser Test Apparatus (HDTA) that can qualify hydrogen dispensers and fueling stations under applicable CSA (HGV 4 series) and SAE standards (e.g., J2600, J2719). The HDTA will be tested and validated under a pilot during 2011. The design, construction, testing, and validation of the HDTA will be coordinated with relevant activities of the DOE SCS program.

Recommended Actions for DOE (underlined) on topic (italics) discussed at the workshop

Inform and Educate AJHs on Certification and Listing Process

Chris Radley recommended that DOE interact with AHJs to inform and educate them on the role, function, and process of product certification, approval, and listing, and Ron Czischke recommended that AJHs be educated on inspection and enforcement of service life requirements for components.

Information on the process and purposes of component and system certification and listing should be included in NREL's on-line training course and incorporated in NREL's workshops for code officials.

Identify and Facilitate Collaboration on Pre-competitive Testing and Certification Activities with FM Global, UL, OnSpex

Bryan Clever suggested that it may be possible to address "pre-competitive" testing issues that can lead to more rapid and less costly certification and listing of certain critical components and subsystems. These issues include lack of consensus on a definition of a "worst case" failure scenario for a given component or system, widely varying requirements for dissipation of static electricity, and time consuming and costly cycle testing requirements.

Meet with FM Global, UL, and OnSpex to identify and explore collaboration (with DOE facilitation) on pre-competitive aspects of certifying and listing critical hydrogen and fuel cell components and systems.

Encourage and enable FM Approvals to collaborate with Sandia National Laboratories as well as UL and CSA OnSpex in preparing a feasibility study of warehouses that use hydrogen fuel cell lift trucks and indoor hydrogen fueling.

Coordinate the design, construction, testing, and validation of the CSA International's Hydrogen Dispenser Test Apparatus with relevant activities of the DOE SCS program.

Harmonize requirements for certification and listing of composite pressure vessels based on existing standards for vehicular, stationary, and transportable applications.[11]

Address hydrogen material compatibility and stability of polymeric materials in PEMFC systems

There is a need to implement a new grade of stainless steel to assure stakeholders that it is compatible with hydrogen (e.g., 316L stainless steel but with minimum nickel content). There are different standards for stainless steel in different countries. Furthermore, the current grades for stainless steel have variable compositions, resulting in a material of a specified that may or may not be hydrogen resistant.

Clarify "what defines a hydrogen resistant material" and assess and correlate (if needed) existing standard approaches (e.g., ASME KD-10, ASME B31.12) and test protocols to determine resistance to hydrogen embrittlement

Develop a database of hydrogen resistant materials

Both GM and OPW identified polymer degradation and lifetime as a key R&D need--the concern here is degradation of polymers by hydrogen and out-gassing of contaminants that will affect the performance and durability of PEMFCs.

Develop non-metallic materials that are compatible with lower temperatures for use in seals

Assess the scope of the NREL-led project on PEMFC system contaminants (footnote 2 above) and, if needed, incorporate an R&D project in the SCS R&D Roadmap and MYPP to assess durability, degradation (including leaching and out-gassing of constituents), and lifetime of polymeric materials used in critical PEMFC components under fuel cell operating conditions. Inform the codes and standards community about the NREL-led project.

[11] For effective international harmonization, Robert Wichert recommends an effort analogous to the UN Working Party 29 (on Global Technical Regulations for hydrogen vehicles) under an international treaty to allow CE approval of hydrogen components and hydrogen equipment to be accepted by listing agencies as sufficient proof of certification for listing and labeling purposes. Continuing monitoring of manufacturing by the listing agency would still be required.

Attachment A

2010 California Fire Code

http://publicecodes.citation.com/st/ca/st/b300v10/st_ca_st_b300v10_2_sec002.htm?bu=CA-P-2010-000008

LISTED. Equipment, materials, products or services included in a list published by an organization acceptable to the fire code official and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, product or service meets identified standards or has been tested and found suitable for a specified purpose.

For applications listed in Section 1.11 regulated by the Office of the State Fire Marshal, "listed" shall also mean equipment or materials accepted by the state fire marshal as conforming to the provisions of the State Fire Marshal's regulations and which are included in a list published by the State Fire Marshal. LABELED. Equipment, materials or products to which have been affixed a label, seal, symbol or other identifying mark of a nationally recognized testing laboratory, inspection agency or other organization concerned with product evaluation that maintains periodic inspection of the production of the above-labeled items and whose labeling indicates either that the equipment, material or product meets identified standards or has been tested and found suitable for a specified purpose.

LISTING AGENCY [HCD 1 & 2] means an agency approved by the department that is in the business of listing and labeling products, materials, equipment and installations tested by an approved testing agency, and that maintains a periodic inspection program on current production of listed products, equipment and installations, and that, at least annually, makes available a published report of these listings. For additional information, see Health and Safety Code Section 17920(i).

LABELED. Equipment, materials or products to which have been affixed a label, seal, symbol or other identifying mark of a nationally recognized testing laboratory, inspection agency or other organization concerned with product evaluation that maintains periodic inspection of the production of the above-labeled items and whose labeling indicates either that the equipment, material or product meets identified standards or has been tested and found suitable for a specified purpose.

2209.2.1 Approved equipment.
Cylinders, containers and tanks; pressure relief devices, including pressure valves; hydrogen vaporizers; pressure regulators; and piping used for gaseous hydrogen systems shall be designed and constructed in accordance with Section 3003, 3203 or NFPA 55.

2209.2.2 Listed equipment.
Hoses, hose connections, compressors, hydrogen generators, dispensers, detection systems and electrical equipment used for hydrogen shall be listed for use with hydrogen. Hydrogen motor fueling connections shall be listed and labeled for use with hydrogen.

Attachment B

Presentation by Advanced Industrial Science and Technology (AIST)

Dr. Etsuo Akiba of the Research Institute for Ubiquitous Energy Devices (UBIQEN) at AIST gave a presentation on "Near Term Fuel Cell Applications in Japan" that focused on deployment of 1KW PEMFC systems for residential applications. Dr. Akiba also addressed what he called an urgent need to relax regulations governing hydrogen and fuel cell technologies in Japan by 2015 when up to 13 companies plan to build hydrogen fuel cell (HFC) systems. By 2020, assembly line production of HFC systems will begin, and by 2025, there will be 2 million fuel cell vehicles on the road and 1,000 hydrogen fueling stations (HFS) in place. To enable commercial deployment at such a scale, Dr. Akiba highlighted the following needs and issues:

- codes and standards for 70MPa HFS
- dispensing hydrogen at CNG stations
- simplifying safety inspections for hydrogen systems
- relaxing the $350m^3$ limit for hydrogen storage in residential areas
- relaxing design coefficients (safety factors?) to be more comparable to those in the US and the EC
- expand the types of steel useable for hydrogen storage and systems—only 316L can be used in Japan
- allow use of Type 3 and Type 4 tanks (now limited to vehicular use) for hydrogen delivery and storage

The issues brought up by Dr. Akiba offer concrete opportunities for technical collaboration between the U.S. and Japan and should be discussed and acted upon by the SCS team.