CENTER FOR INFRASTRUCTURE ENGINEERING STUDIES

Transportation Fuel Research and Development: Statistically Validated Codes and Standards

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16. Abstract

The recent establishment of the National University Transportation Center at MST under the "Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users," expands the research and education activities to include alternative transportation fuels and other issues that are at the forefront of society and the national agenda. UMR in partnership with MTI will establish a rural hydrogen transportation test bed for developing, demonstrating, evaluating, and promoting hydrogen-based technologies in a real-world environment. The State of Missouri is ideally suited to develop and demonstrate the proper operation of hydrogen highways in a rural setting, which represents over 25 percent of the nation's transportation needs and which is not well-represented in the current major national projects. A holistic approach will be taken to address not just the technology but also public perception, permitting, safety standards, and education and training. A key partner already engaged is the NASFM, who regards this project as an "excellent candidate for the model approach to introducing hydrogen to communities." The tasks identified in five areas, viz., Infrastructure Development and Deployment, High-Pressure Composite Cylinders, Inspection and Monitoring, Statistically Validated Codes and Standards, and Safety, constitute a comprehensive research, development and demonstration program to address some of the challenges described in the U.S. Department of Transportation Hydrogen Roadmap 2005.

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Project Area 4: Statistically Validated Codes and Standards

As the prospect of a hydrogen economy becomes more and more plausible, it becomes increasingly important to establish reliable codes and standards for the safe handling of hydrogen as a fuel. While many organizations, both national and international, are working to produce guidelines for hydrogen, the standards that do exist are often inconsistent, and the sheer volume of material makes it difficult to quickly train professionals in the basics. Furthermore, harmony among the standards is essential for the commercialization of hydrogen, since investors and consumers alike must be assured that the technology is safe and reliable before they will invest their money in it. Unified standards are also necessary for emergency personnel, who must be able to respond appropriately to accidents and fires involving hydrogen.

While the terms "code" and "standard" are often used interchangeably, they are nonetheless defined differently. A code is a law or regulation that sets forth minimum requirements in the quality and performance criteria for the materials and methods related to the code's subject matter. A standard sets conditions or requirements that a material or method must meet, thereby providing an acceptable level of safety. A code becomes law when it is adopted by a jurisdiction, but a standard becomes law to the extent that it is referenced in an adopted code. Codes and standards are equally enforceable, but if they disagree, the code takes precedence. If a code is silent on an issue, then the appropriate standard is applicable to the extent of the reference to that standard [1].

To aid in the navigation of the available codes and standards, a short discussion of valuable introductory resources follows. A complete annotated listing of references, sorted by type, with multiple resources on introductory hydrogen safety, the properties of hydrogen, and the codes and standards relevant to its use as a fuel can be found in Appendix A. Additionally, all of the downloadable resources cited in the appendix can be found on the included CD.

The Hydrogen Safety Bibliographic Database, a searchable DOE database of reports, articles, books and other resources on the production, storage, distribution and use of hydrogen, can be accessed at <http://www.hydrogen.energy.gov/biblio_database.html>.

The New Jersey Hydrogen Learning Center, found at <http://www.policy.rutgers.edu/ceeep/newhome/njh2lc_policy4.html>, includes very helpful sections on hydrogen codes and standards (with a list of relevant standards), federal hydrogen policy, and hydrogen safety.

The Hydrogen Codes and Standards Portal, an extensive and searchable ANSI website that contains such resources as international hydrogen codes, standards for stationary and portable fuel cells, and the latest research developments in the field, can be found at <http://hcsp.ansi.org/default.asp>.

The Fuel Cell/Hydrogen Infrastructure Codes & Standards, a basic but very helpful NREL site that maintains, in real time, the status of all fuel cell code and standard activities, relevant links, and downloadable codes and standards for various regions and countries, may be accessed at <http://www.fuelcellstandards.com/10a-Main.htm>.

Finally, a Material Safety Data Sheet (MSDS) for hydrogen may be found at <http://www.praxair.com/praxair.nsf/d63afe71c771b0d785256519006c5ea1/f5322947a3ab1c8285256e5b0068ef96/$FILE/Hydrogen-Canada.pdf>. OSHA requires that an MSDS be available when workers handle a potentially hazardous material.

[1] NJ Hydrogen Learning Center website. http://www.policy.rutgers.edu/ceeep/newhome/njh2lc_policy4.html

Appendix A

Books

Handbook of Fuel Cells: Fundamentals Technology and Applications, Volume 3-Fuel Cell Technology and Applications, Part 1. 2003, John Wiley & Sons. Eds. Wolf Vielstich, Arnold Lamm, Hubert A. Gasteiger. ISBN 0-471-49926-9. Chapter 22, "Hydrogen safety, codes and standards for vehicles and stationary applications," is particularly useful. Found on pp. 257-267, it lists characteristics of hydrogen that make it a potential hazard and compares them to the safety parameters of other common fuels, such as gasoline. It also provides a walk-through of the design process for hydrogen fuel cell safety, and discusses domestic and international standards for fuel cell products. Finally, there is a section devoted to how to get a fuel cell vehicle approved by the proper authorities.

Articles

- **"Clean Air Program: Design Guidelines for Bus Transit Systems Using Hydrogen as an Alternative Fuel."** Office of Research, Demonstration, and Innovation, April 1999. A DOT guide to hydrogen bus systems, including a review of the properties of hydrogen, as well as its safety procedures and hazards. PDF available for download at http://transit-safety.volpe.dot.gov/Publications/CleanAir/BTS/BTSDesignGuidelines.pdf.
- **"Safety issues regarding fuel cell vehicles and hydrogen fueled vehicles."** The International Consortium for Fire Safety, Health & The Environment. An excellent introduction to the safety concerns surrounding the use of hydrogen fuel cells in

transportation. The PDF is available for download at http://www.dps.state.mn.us/fmarshal/Response/FuelCellHydrogenFuelVehicleSafety.pdf.

- **Hydrogen Codes and Standards Technical Report.** March 2003. The Partnership for Advancing the Transition to Hydrogen's report on the status of hydrogen standards in the United States, Canada, and Japan. The report itself isn't terribly useful, but it includes an extremely thorough listing and description of hydrogen codes and standards in the US, starting on page 36. The PDF can be downloaded at http://www.hpath.org/TechnicalReport.pdf.
- **Technical Plan--Codes and Standards.** April 2007. A report on the status and progress of hydrogen standard-making activities in the US. It includes a list of the organizations involved in making codes and standards, typical model codes, a description of private and public sector involvement, ongoing activities, and a breakdown of current standards by standard type (stationary fuel cell, fuel cell vehicles, etc). The PDF is available for download at http://www1.eere.energy.gov/hydrogenandfuelcells/mypp/pdfs/codes.pdf.

Websites

- **DOE/NREL "Workshop on Facilitating Permitting of Hydrogen Fueling Stations."** February 2007. Outline and downloadable Word document containing extensive information on developing, planning and obtaining permission to build hydrogen fueling stations, as well as the importance and methods of training local safety personnel in hydrogen handling. Very helpful in understanding the practical issues surrounding the construction of a hydrogen fuel station (HFS). http://www.hydrogenandfuelcellsafety.info/resources/workshops/07feb/index.asp
- **EERE Information Resources: Related Links for Associations.** April 2007. A DOE listing of the standard-making associations and organizations for hydrogen and fuel cell technologies. http://www1.eere.energy.gov/hydrogenandfuelcells/associations.html#assoc_standards
- **Hydrogen Safety Bibliographic Database.** A searchable DOE database of reports, articles, books and other resources on the production, storage, distribution and use of hydrogen. http://www.hydrogen.energy.gov/biblio_database.html
- **Hydrogen Analysis Resource Center.** March 2006. A searchable DOE site that provides well-documented data for hydrogen-related analytical activities. This includes the *Hydrogen Data Book*, a compendium of information on hydrogen and fuel cells, as well as calculation and analysis tools and guidelines for DOE hydrogen program analysis. http://hydrogen.pnl.gov/cocoon/morf/hydrogen
- **NJ Hydrogen Learning Center.** The State University of New Jersey-Rutgers' educational hydrogen site. It includes very helpful sections on hydrogen codes and standards (with a list of relevant standards), federal hydrogen policy, and hydrogen safety. http://www.policy.rutgers.edu/ceeep/newhome/njh2lc_policy4.html
- **"Developing Codes and Standards for a Hydrogen Energy Future."** January 2004. A very basic overview of the subject by Karen Hall. It includes the background and likely future of hydrogen fuel cell technology and the current efforts in industry and government to develop standards. http://www.astm.org/cgi-bin/SoftCart.exe/SNEWS/JANUARY_2004/hall_jan04.html?L+mystore+zefl7512

Presentations

- **Hydrogen Energy Technologies Workshop: Safety, Installations, and Permitting.** November 2006. Downloadable PDF presentations. By far the most useful was Jim Ohi's "Tools for Planning, Permitting and Siting Hydrogen Installations." It contains detailed organizational flowcharts showing which existing standards have jurisdiction in which circumstances, as well as an annotated listing of major resources on hydrogen safety. Also, Tom Elzey's "First-hand Experiences with Hydrogen Installations" provides advice about acquiring permits for hydrogen stations and indicates some of the code regulations currently in effect for them. http://www.hydrogenandfuelcellsafety.info/h2techWorkshop.asp

Data Sheets

- **Hydrogen Safety Fact Sheet** A brief, introductory overview of hydrogen safety. http://www.hydrogenassociation.org/safety/resources.asp
- **International Chemical Safety Cards: Hydrogen (H_2).** 1994. Peer-reviewed NIOSH safety sheet on the hazards of handling hydrogen and the prevention of hydrogen-related injuries. www.cdc.gov/niosh/ipcsneng/neng0001.html
- **Hydrogen Material Safety Data Sheet (MSDS).** October 2004. Downloadable PDF file from the company Praxair. OSHA requires that an MSDS be available when workers handle a potentially hazardous material. http://www.praxair.com/praxair.nsf/d63afe71c771b0d785256519006c5ea1/f5322947a3ab1c8285256e5b0068ef96/$FILE/Hydrogen-Canada.pdf

Codes and Standards

- **HFCIT Safety, Codes and Standards: Current Safe Operating Practices.** January 2007. A DOE overview of the above, including links to downloadable versions of NASA's *Safety Standard for Hydrogen and Hydrogen Systems* (cancelled in 2005); as well as the *Hydrogen Fuel Cell Engines and Related Technologies Course Manual*, mainly concerned with Type 3 and 4 Ballard fuel cell buses; and Air Products' Hydrogen Safety Information "Safetygrams." http://www1.eere.energy.gov/hydrogenandfuelcells/codes/safe_practices.html
- **Hydrogen Codes and Standards Portal.** An extensive and searchable ANSI website that contains such resources as international hydrogen codes, standards for stationary and portable fuel cells, and the latest research developments in the field. http://hcsp.ansi.org/default.asp
- **Fuel Cell/Hydrogen Infrastructure Codes & Standards.** A basic but very helpful NREL site that maintains, in real time, the status of all fuel cell code and standard activities, relevant links, and downloadable codes and standards for various regions and countries. http://www.fuelcellstandards.com/10a-Main.htm
- **NFPA 52: Vehicular Fuel Systems Code, 2006 Edition.** The National Fire Protection Agency's safety rules for hydrogen fuel systems, compressed natural gas systems, and liquefied natural gas systems on all vehicle types. Available for purchase at http://www.nfpa.org/catalog/product.asp?category%5Fname=&pid=5206&target%5Fpid=5206&src%5Fpid=&link%5Ftype=search.
- **NFPA 54: National Fuel Gas Code, 2006 Edition.** The National Fire Protection Agency's standards for fuel gas piping systems, fuel gas utilization equipment, and related accessories. This includes fuel gas systems that use hydrogen as a fuel. Available for purchase at http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=54.
- **NFPA 55: Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks, 2005 Edition.** The National Fire Protection Agency's standards for the storage, use, and handling of compressed gases. This includes chapters on gaseous and liquefied hydrogen systems at consumer sites. Available for purchase at http://www.nfpa.org/catalog/product.asp?category%5Fname=&pid=5505&target%5Fpid=5505&src%5Fpid=&link%5Ftype=search.
- **International Fire Code: Section 2209—Hydrogen Motor Fuel-Dispensing and Generation Facilities, 2003.** The International Code Council's code for hydrogen fueling stations. Available for download as a PDF at http://www2.rigov.org/pdf/inspections/2003InternationCodes/2003InternationalFireCode.pdf.
- **International Organization for Standardization: TC 197.** Purchaseable standards for, respectively, land vehicle fueling system interfaces and land vehicle fuel tanks for liquid hydrogen; product specifications for hydrogen fuel; hydrogen system safety; hydrogen generators using fuel processing technologies; transportable gas storage devices (hydrogen absorbed in reversible metal hydride); and compressed hydrogen surface vehicle refueling connection devices. http://www.iso.ch./iso/en/stdsdevelopment/tc/tclist/TechnicalCommitteeStandardsListPage.TechnicalCommitteeStandardsList?COMMID=4490&INCLUDESC=YES
- **ASME: PTC 50—Fuel Cell Power Systems Performance.** The American Society of Mechanical Engineers' code for test procedures and definitions for the performance characterization of fuel cell power systems. Available for purchase at http://catalog.asme.org/home.cfm?DESIGNATOR=PTC%2050&TAB=Designator.
- **ICC: International Fuel Gas Code, 2006.** The International Code Council's code addressing the design and installation of fuel gas systems. Available for purchase at http://www.techstreet.com/cgi-bin/detail?product_id=1253426.
- **ISO 13985—Liquid Hydrogen: Land Vehicle Fuel Tanks, 2006.** The International Organization for Standardization's standard for the construction requirements for refillable liquid hydrogen fuel tanks permanently attached to land vehicles, as well as the testing methods used to ensure that said tanks are safe. Available for purchase at http://www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=39892.
- **Hydrogen—1910.103.** A listing of the Occupational Health and Safety Administration's standards for handling hydrogen. http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9749
- **Hydrogen Codes and Standards.** The Partnership for Advancing the Transition to Hydrogen's listing of international hydrogen safety standards. http://www.hpath.org/codes-and-standards.asp.

Fire Models

- **"An Updated International Survey of Computer Models for Fire and Smoke."** Olenick, Stephen M. and Douglas J. Carpenter. *SFPE Journal of Fire Protection Engineering* 13 (2), 2003, pp.87-110. A comprehensive survey that identifies and categorizes 168 fire-modeling programs from multiple countries. The PDF is available for download at http://www.firemodelsurvey.com/pdf/Olenick_Carpenter_JFPE_87-110.pdf
- **"Progress Report on Fire Modeling and Validation."** W.W. Jones. NIST-IR 5835, February 1997. An overview of the status of the accuracy and practicality of computer-based fire models. http://www.fire.nist.gov/bfrlpubs/fire96/PDF/f96161.pdf
- **"A literature review of design fires for fire safety engineering."** Bwalya, A.; Sultan, M.; Bénichou, N. NRCC-38453. May 2004. The National Research Council Canada's overview of the concept of and principles behind design fires, along

with a list of relevant references. PDF available for download at http://irc.nrc-cnrc.gc.ca/pubs/fulltext/nrcc38453/nrcc38453.pdf.