U.S. Department of Energy

Onboard Storage Tank Workshop

Workshop Notes

April 29, 2010

Sandia National Laboratories – Livermore, CA

Report from the Onboard Storage Tank Workshop

Livermore, CA
April 29th, 2010

The Onboard Storage Tank Workshop was held on April 29th, 2010, at Sandia National Laboratories (SNL) in Livermore, CA. The Workshop was co-hosted by SNL and the United States Department of Energy (DOE). The purpose of the Workshop was to identify key issues including research and development (R&D) needs, regulations, codes and standards (RCS), and a path forward to enable the deployment of hydrogen storage tanks in early market fuel cell applications.

Background

The objectives of the Workshop were to:

- Provide initial follow up to the DOE and Department of Transportation (DOT) compressed natural gas (CNG) and hydrogen fuels international workshop, and to help prepare for a second international workshop planned for September 2010;
- Address specific technical topics discussed at the international workshop including Type 4 tank, Pressure Relief Device (PRD) testing and tank service life and tracking;
- Review specific RCS for on-board hydrogen tanks including the Society of Automotive Engineers (SAE) J2579 and Global Technical Regulations (GTR);
- Identify and discuss any remaining key issues requiring additional R&D, testing and validation.

This report provides an overview of each of the panel discussion and outlines the specific gaps and action items identified by the Workshop attendees. A list of attendees is provided at the end of the report.

Presentations

CNG and Hydrogen Fuels: Lessons Learned for the Safe Deployment of Vehicles Workshop

Jim Ohi, Consultant for the DOE presenting on behalf of Antonio Ruiz, DOE

Jim Ohi presented a summary of the DOE-DOT CNG-Hydrogen Workshop. The international workshop was held in Washington, D.C., in December 2009 to exchange information among experts from China, India, Canada, Brazil, and the U.S. on CNG and hydrogen fuels for vehicles and to share lessons learned from deployment of these vehicles in public transit, fleets, and consumer transportation. The workshop resulted in a number of action items, including holding a follow up workshop to address key issues, and to explore collaborative opportunities in safety R&D and harmonization of regulations, codes and standards. This workshop was held in part to begin discussion and planning for an international workshop to follow up the one held in Washington, D.C. Some of the key issues identified in the first workshop were addressed in more detail and are summarized in the presentations below. Meeting notes, an agenda and a list of all presentations can be found at the DOE website link below:

www.hydrogenandfuelcells.energy.gov/wkshp_cng_and_h2.html

Tank Testing and R&D

Joe Wong, Powertech

Joe Wong reviewed data from Type 4 tank testing, which is more performance-based than testing for Type 1, 2, and 3 tanks. Unsatisfactory test results of Type 4 tanks were due primarily to leaks and were from tanks of one manufacturer that is no longer in business. The leaks were caused by problems with plastic liners and the long-term integrity of connection between the plastic liner and the tank boss. Many thousands of Type 4 tanks are in service in CNG vehicles throughout the world and have a good record for safety.

Gaps:

1. Data on long-term integrity of connection between plastic liner and boss of tank
2. Further testing to validate SAE J2579
3. Localized fire testing and mitigation of localized fires

Action Items:

1. Integrate tank safety and incident databases compiled by Powertech, Clean Vehicle Education Foundation (CVEF) and other sources
2. Analyze data on Type 4 tank failure modes

SAE J2579 Validation and Harmonization

Chris Sloane, Consultant for the DOE

Chris Sloane presented on the "Development of Safety Standards for Compressed Hydrogen Storage at SAE – International." The presentation focused on performance-based design qualification requirements for compressed hydrogen storage systems, including hydrogen embrittlement, fire and permeation.

Gaps:

1. Refine test procedures to determine whether there will be leak before burst
2. Refine fire test to start with localized heating and proceeding to a fully engulfing fire
3. Inspection protocol/process to allow reuse of tanks
4. More focus on addressing and reducing the frequency of failure modes vs. current emphasis on R&D and analysis of consequences and mitigation (reducing impacts of consequences) of failure modes

Action Items:

1. Revise SAE J2579 to address:
   - Determination of leak before burst
   - Fire testing to include localized heating progressing to fully engulfing fire
2. Recertification of tanks for reuse
3. Assess DOE risk assessment activities and explore more emphasis on reducing frequency of key failure modes

Type 4 Tank Testing: Status in China

J.P. Hsu, Smart Chemistry

J.P. Hsu presented, "Defect Analysis of Vehicle Compressed Natural Gas Composite Cylinders" which was based on a translation of a report on Type 4 tank certification testing in China. The report summarized test results that show a high failure rate of Type 4 tanks, which led to a prohibition of using such tanks in China. The paper traced the high rate of failure to manufacturing defects in the high-density polyethylene (HDPE) cylinder lining. The paper cited differences in linear expansion coefficients and slow cylinder pressure and temperature cycle during the gas compressing and releasing process as the direct causes for the tank defect.

Gaps:

1. Better understanding of Type 4 tank certification process in China
2. Comparison of testing processes in U.S. and China
3. Impacts of depressurization on deformation of liners in Type 4 tanks

Action Items:

1. Include comparison of Type 4 tank certification procedures in China and U.S. during next workshop
2. Develop test procedures to determine effects of depressurization on Type 4 tank liners

Tank Service Life, Tracking and Removal

Doug Horne, CVEF

Doug Horne presented on the importance of periodic inspection and end of life issues for high-pressure storage cylinders. Doug discussed how tank life may be shorter than vehicle life and that methods to track, inspect, and enforce tank service life in vehicles is needed. He proposed methods to inspect and, if necessary, remove tanks at the end of service life.

Gaps:

1. No credible enforcement of inspection requirements under Natural Gas Vehicle (NGV)2
2. Enforceable procedures to address potential discrepancy between tank life and vehicle life
3. Tank life could be regulated under federal law, e.g. Federal Motor Vehicle Safety Standards (FMVSS), but enforcement will be through vehicle inspection and registration enforced state by state

Action Items:

1. Explore annual vehicle registration process as a way to enforce inspection and end of life requirements for high-pressure vehicular storage tanks
2. Evaluate Type 4 tanks nearing end of service life for unexpected degradation of physical properties

Hydrogen Pressure Relief Device (HPRD-1) Status and Validation

Julie Cairns, CSA Standards

Julie Cairns presented on HPRD-1 for compressed hydrogen vehicle fuel containers. Testing is underway at Powertech to validate a proposed test method for determining hydrogen service suitability of PRD designs. Powertech identified 3 "good" PRD designs and identified 1 "bad" PRD design for testing, and initial results are expected later this summer. Future topics for R&D and testing identified include corrosion resistance design qualifications and ozone exposure. Julie also described needs for component and subsystem testing and certification for hydrogen fueling stations.

Gaps:

1. Validation testing of component standards other than HPRD-1
2. Completion of hydrogen gas vehicle fueling station compressor certification standard – Heavy Goods Vehicle (HGV) 4.8 – given frequency of leaks due to compressors in SNL Quantitative Risk Analysis (QRA) work

Action Items:

1. Identify key component standards for validation testing
2. Accelerate completion and validation of hydrogen gas vehicle fueling station compressor certification standard

Fuel Quality and Metering: Status and Needs

John Mough, California Department of Weights and Measures (DWM)

John Mough presented on the Department's responsibility to regulate hydrogen fuel quality specifications in California. The Department's jurisdiction over hydrogen fuel quality regulation stems from legislation in California Senate Bill (SB) 76. Currently, California does not regulate hydrogen fuel quality and is only beginning to find methods to regulate pump and metering requirements at fueling stations. John identified actions that need to be taken in order for fuel suppliers to sell fuel to the public at California's 21 hydrogen filling stations, including greater funding and continued work with SAE International and ASTM International. To date no manufacturer has submitted a dispenser to the DMW for certification required before such dispensers can be used to sell hydrogen fuel to the public. A link to California SB 76 can be found below:

http://www.hydrogenhighway.ca.gov/sb76/sb76.htm

Gaps:

1. None of the 21 hydrogen fueling stations in CA can sell to the public as no dispenser company has submitted a device for type approval by the DWM
2. Round-robin testing of ASTM International to sample and measure contaminants in hydrogen fuel

Action Items:

1. Continue collaboration among CA DWM, ASTM International and SAE on fuel quality requirements and analytical methods
2. Identify laboratories capable of validating ASTM International methods in round robin testing
3. Address funding requirements for round robin testing of analytic methods for critical hydrogen fuel contaminants

70 MPa Fast-Fill Model Validation

Bill Winters, SNL

Bill Winters presented on modeling work being done with transient temperature (T) and pressure (P) and other properties of a compressible gas during fueling and defueling in a rigid vessel. Although uniformity of the P field in the tank can be assumed, the spatial T field in the vessel can vary greatly during and for some time after filling or defiling. Under SAE 2601, the maximum allowable temperature of the gas during fill is 85°C to protect the integrity of the storage vessel. SNL has developed a model to assess 70MPa fast-fill protocols but needs data to validate the model. An earlier attempt to validate the model was inconclusive. Discussion at the workshop showed renewed interest by industry in validating the model and making it available to industry to benchmark proprietary models.

Gaps:

1. Validation data for fast-fill model developed by SNL

Action Items:

1. Work with industry (tank manufacturers and auto original equipment manufacturers (OEMs)) to obtain data needed for model validation
2. Convene initial follow up meeting with industry at the DOE Annual Merit Review if possible

Nondestructive Evaluation (NDE) Methods, Validation and Applications

Regor Saulsberry, NASA-White Sands Test Facility (WSTF)

Regor Saulsberry gave an overview of NDE tools and capabilities at NASA-WSTF that can be used to examine materials and components for structural integrity, discontinuities, and proper assembly. For example, NASA-WSTF can conduct stress rupture NDE inspection and monitoring of tanks at pressure. Other NDE tools and methods of interest include portable Raman spectrometry and acoustic emission (AE) analysis. Of particular interest is the potential of using AE analysis to track variability in manufacturing of Type 4 tanks.

Gaps:

1. Application and validation of NDE methods for tank certification, monitoring, and recertification
2. Application of NASA-WSTF expertise in NDE to vehicular tank issues

Action Items:

1. Evaluate technical methodology for stress rupture NDE and application to inspection and monitoring at pressure
2. Explore application of NDE methods to monitor key tank properties during service
3. Apply NDE methods to track variability in tank manufacturing

Attendees

(In-Person and Webinar)

Salvador Aceves: Lawrence Livermore National Laboratories (LLNL)
Nico Bouwkamp: California Fuel Cell Partnership (CaFCP)
Robert Burgess: National Renewable Energy Laboratory (NREL)
Jackie Button: CaFCP
Julie Cairns: CSA Standards
Greg Chirdon: CSA Standards
Ronald Czischke: Underwriters Laboratories (UL)
Daniel Dedrick: SNL
Chris Dicken: Plug Power
Sara Dillich: DOE
Isaac Ekoto: SNL
David Farese: Air Products
Tom Felter: SNL
Neal Fornaciari: SNL
Monterey Gardiner: DOE
Marty Gresho: FP2FIRE
Mark Groethe: SRI International
Aaron Harris: Nuvera Fuel Cells
Bill Houf: SNL
JP Hsu: Smart Chemistry Corporation
Craig Jensen: Hawaii Hydrogen Carriers, LLC (HHC)
Jay Keller: SNL
Jeff LaChance: SNL
Steve Medwin: Raymond
Chris Moen: SNL
John Moncrief: Norris Cylinder
Norm Newhouse: Lincoln Composites
Josip Novkovic: CSA Standards
Brian Nowicki: Nuvera Fuel Cells
Jim Ohi: Consultant for the DOE
Harold “Butch” Phillippi: Exxon Mobile

Carl Rivkin: NREL
Antonio Ruiz: DOE
Chris San Marchi: SNL
Dan Shumaker: SENTECH, Inc.
Chris Sloane: Consultant for the DOE
Brian Somderday: SNL
Scott Ullman: Plug Power
Steve Weiner: Pacific Northwest National Laboratory (PNNL)
Robert Wichert: United States Fuel Cell Council (USFCC)
Bill Winters: SNL
Joe Wong: PowerTech