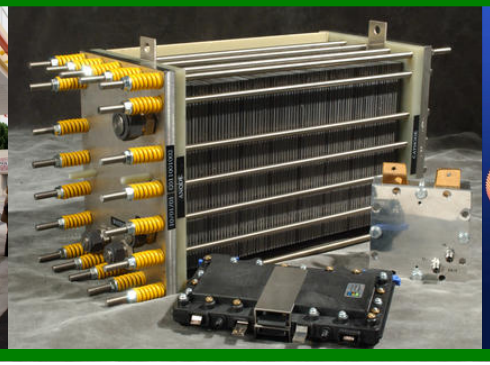
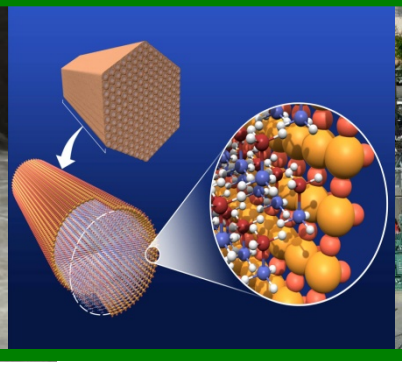
U.S. DEPARTMENT OF ENERGY

Safety, Codes and Standards
- Session Introduction -

Antonio Ruiz

2012 Annual Merit Review and Peer Evaluation Meeting
May 15, 2012

Goal & Objectives

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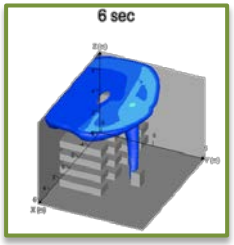
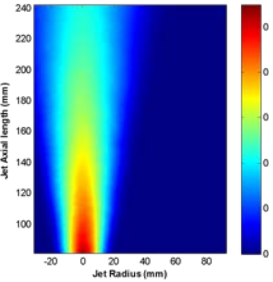
Enable the widespread commercialization of hydrogen and fuel cell technologies through the timely development of regulations, codes, and standards





Goals

- Develop and implement safety practices and procedures to ensure the safe operation, handling, and use of hydrogen and fuel cell technology
- Conduct critical R&D needed for the development of technically sound codes and standards and facilitate harmonization of domestic and international regulations, codes, and standards.

Objectives

- Ensure the safety of all projects funded by the DOE Fuel Cell Technologies Program
- Make available safety-related information resources and lessons learned with key stakeholders (first responders, regulators, and others)
- Identify and mitigate risk and understand insurability issues for widespread commercialization.
- Conduct R&D to provide critical data and information needed to define requirements in developing codes and standards.
- Develop and validate appropriate test methodologies for certifying hydrogen and fuel cell systems and components.

Challenges

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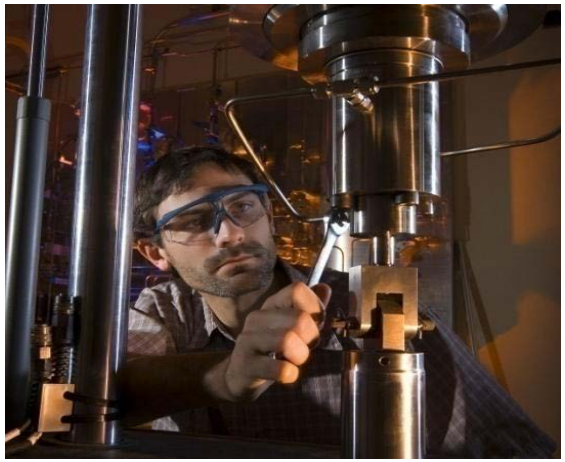
Lack of data needed for the development of critical codes and standards to enable the widespread commercialization of hydrogen and fuel cell technologies



Lack of…

- Synchronized codes and standards development and adoption with technology deployment and commercialization needs
- Coordination of R&D with codes and standards development cycle and revision schedule
- Domestic and international harmonization
- Adoption of the latest developed codes and standards
- Standardization of the permitting process for hydrogen infrastructure
- Data and hydrogen safety information (e.g., best practices and frequency data)
- Readily available training material for first responders and other key stakeholders

Overview

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Approach

Identify R&D needs

- Lead stakeholder workshops, develop R&D roadmaps
- Analyze existing codes and standards, safety knowledge
- Participate in technical working groups

Perform High-Priority R&D

- Understand foundational hydrogen behavior
- Quantitative Risk Assessments
- Compatible materials and components
- Develop and harmonize test protocols

Impact Codes and Standards

- Participate in and lead technical committees to develop requirements
- Publish R&D results

Harmonize Internationally

Global Technical Regulations (GTR Phase 1-SAE J2578, SAE J2579)
International Standards Development Organizations(e.g., ISO, IEC)
International Partnerships and Agreements (IPHE, IEA)

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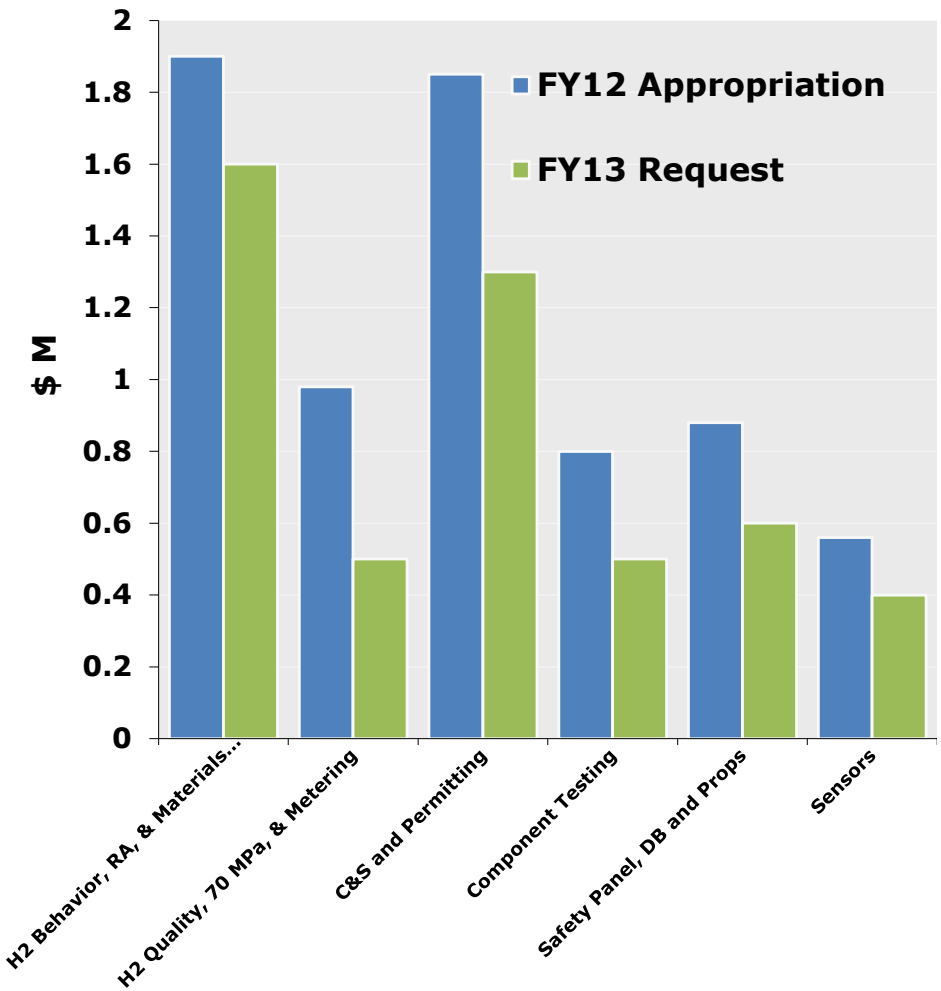
FY 2013 Request Allows for Continued Emphasis on Critical RCS

FY 2012 Appropriation = $7.0 M

FY 2013 Request = $5.0 M



Emphasis:

- Develop technical information and performance data to enhance codes and standards
- Facilitate the permitting of hydrogen fueling stations and early market applications
- Test, measure and verify hydrogen fuel specification
- Assess risks and establish protocols to identify and mitigate risk
- Harmonize test protocols for qualification and certification
- Harmonize hydrogen fuel quality and other key international standards
- Disseminate hydrogen “best practices” and safety information

Progress: National C&S Template

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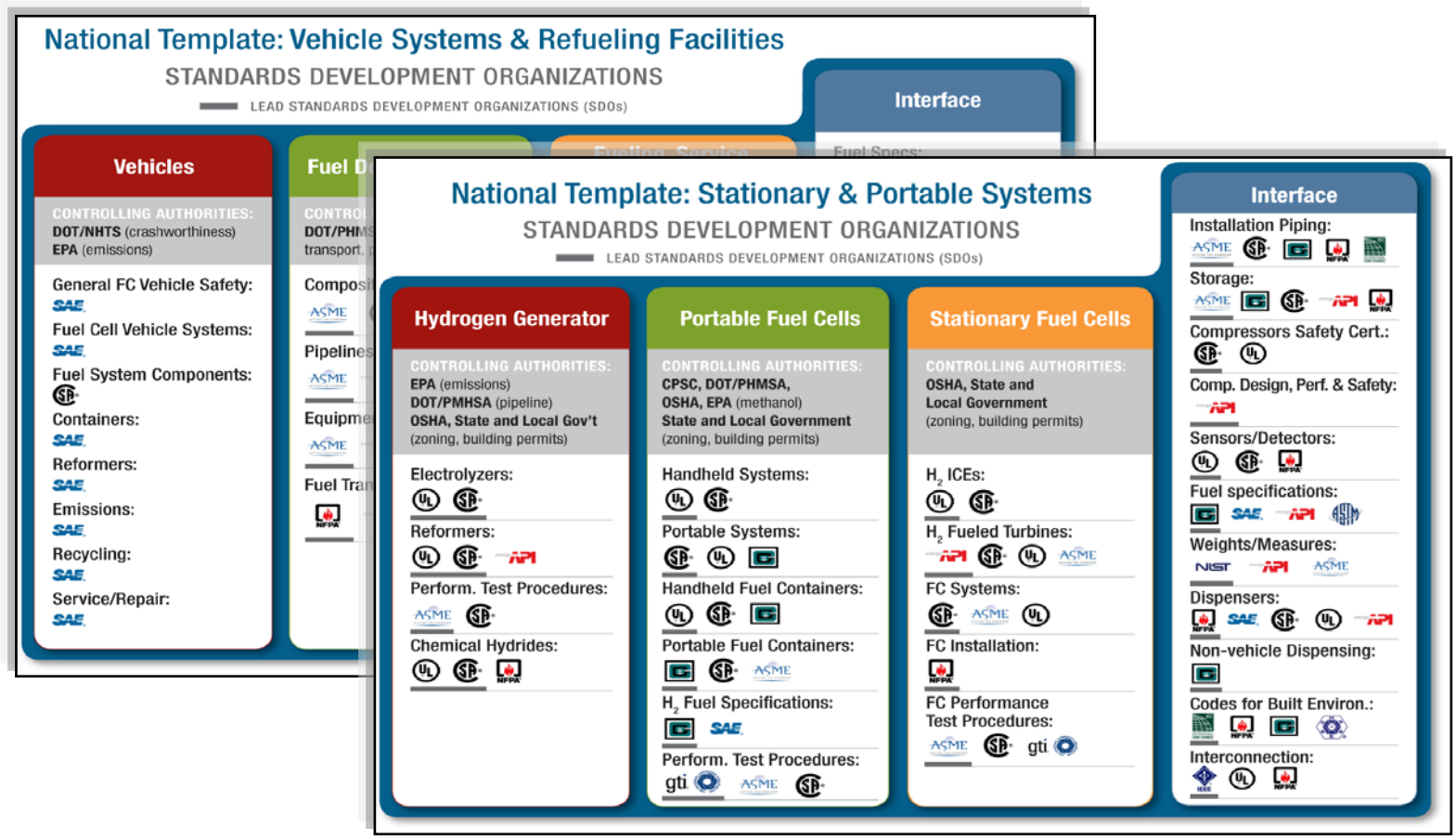
U.S. codes and standards development coordination



- *National template to delineate and coordinate critical roles of standards and model code development organizations*

www1.eere.energy.gov/hydrogenandfuelcells/codes/standards_organization.html

Progress: Safety, Codes & Standards

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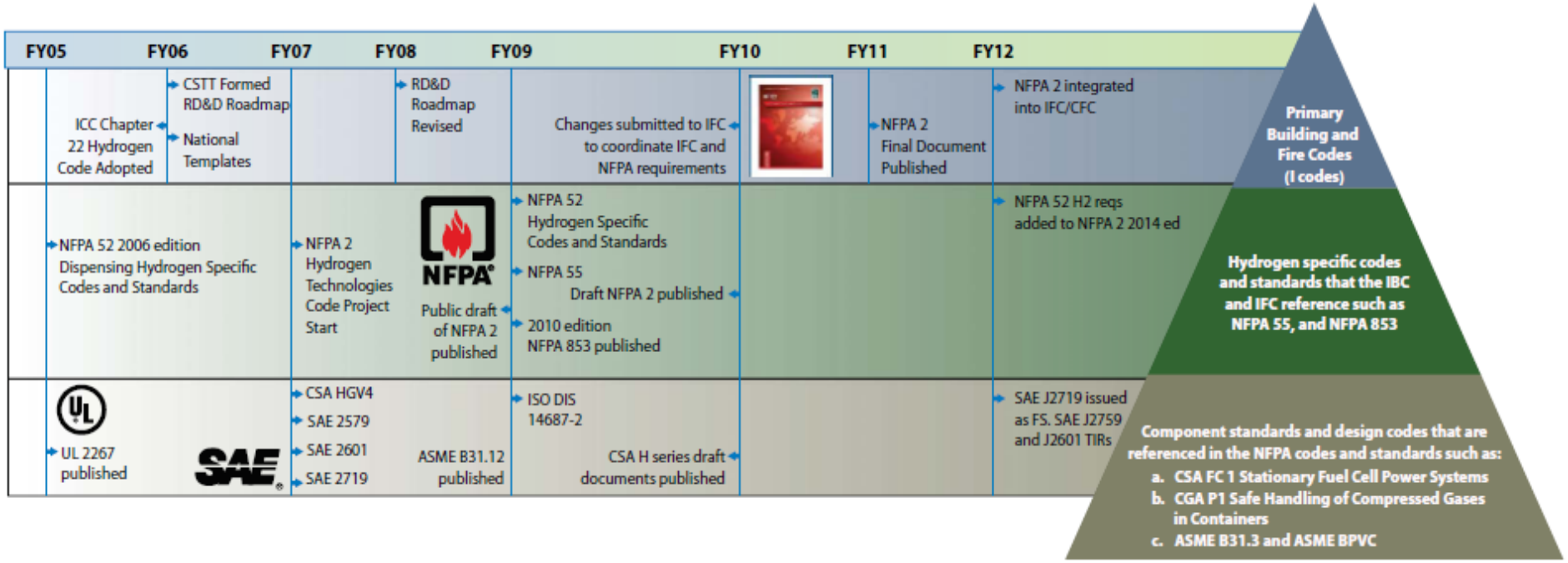
Timeline of Hydrogen Codes and Standards



Examples of Accomplishments:

- Demonstrated up to 50,000 refuelings of metals tanks for forklift applications
- Provided technical data and incorporated a risk-informed approach that enabled NFPA2 to update bulk gas storage separation distances
- Launched international round robin testing of Type IV tanks
- Implemented a science-based approach to develop an ISO standard for hydrogen fuel quality (standard approved).
- Completed R&D to enable Test Method for Evaluating Materials Compatibility standard.

Developed training material for first responders, code officials.
> 23,000 to-date (online & in-person)

The United States will use the GTR as the technical underpinning for the development of the U.S. Federal Motor Vehicle Safety Standard (FMVSS). Submitted to the U.N. ECE WP29 Dec. 2011, Target Acceptance Dec. 2012

Accomplishment

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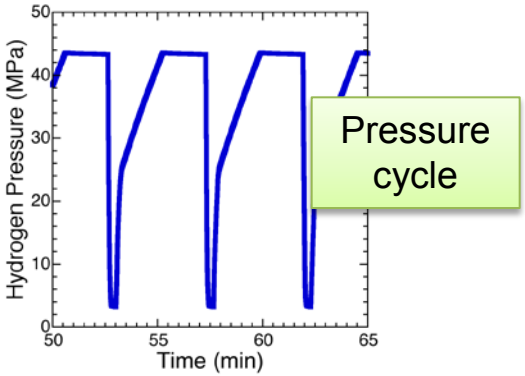
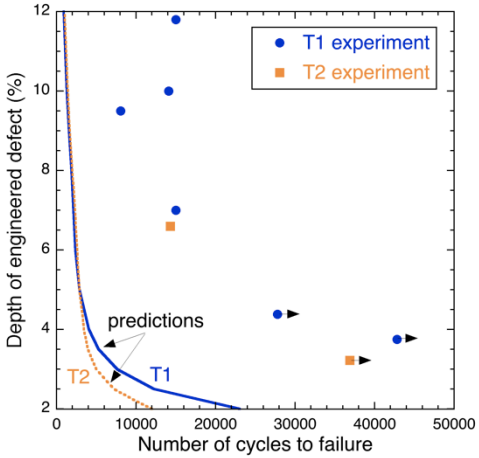
Full-scale pressure vessel testing supports CSA HPIT1 standard development.

- Engineered defects used to evaluate defect tolerance
- Vessels cycled to failure or up to 50,000 cycles
- Cycle-life compared to ASME design calculations for hydrogen pressure vessels
- Materials testing in gaseous hydrogen also performed
- All observed failures were leak-before-break
- Cycle-life calculations (with engineered defects) are conservative by factor of 4 or more
- Results used to justify design requirements in CSA HPIT1 standard





Proposed design requirements

- Quench and tempered Cr-Mo steels
- S_u (ultimate strength) ≤ 890 MPa
- hoop stress ≤ 0.4 S_u

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Approach

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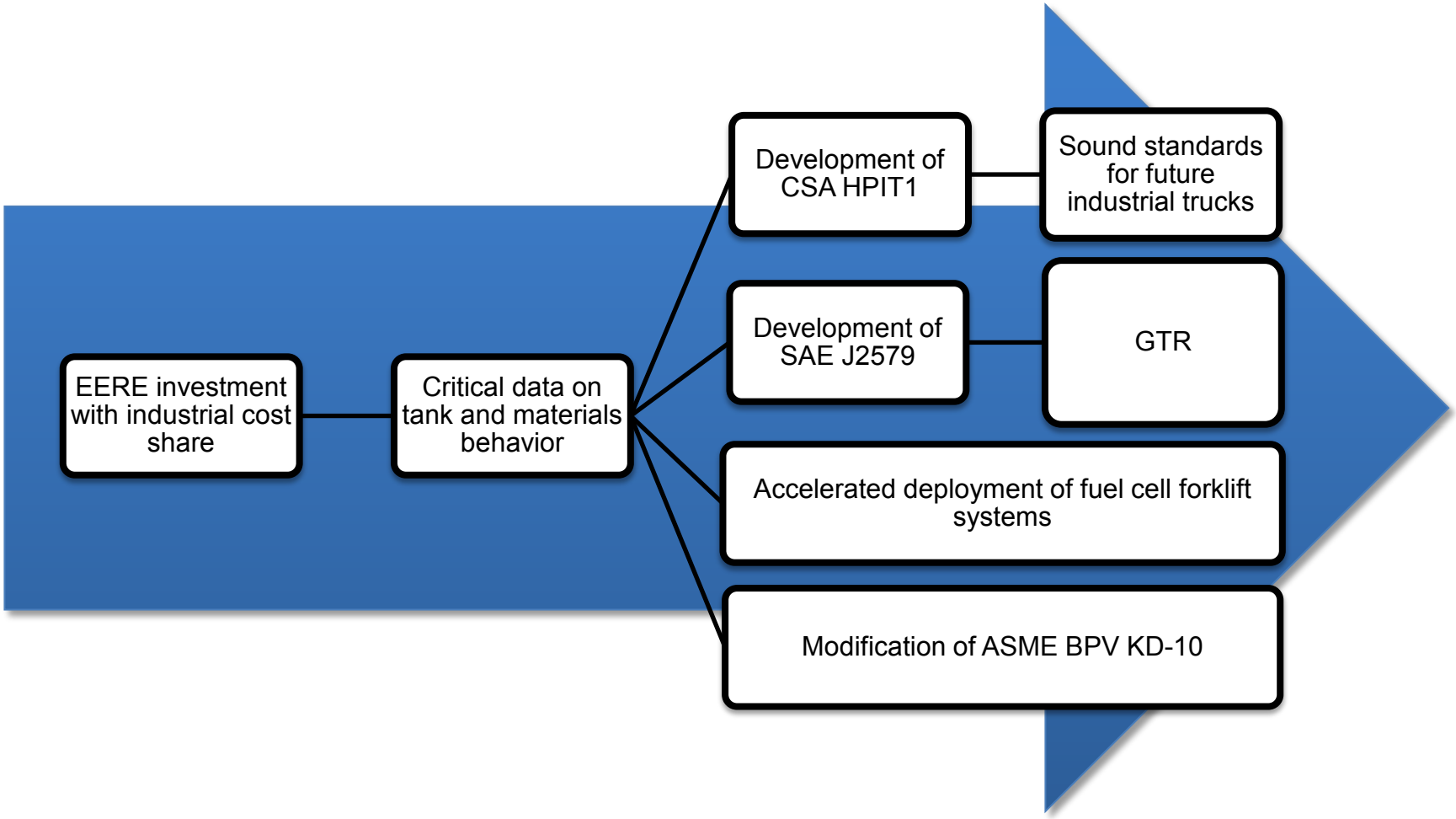
Strategic pathway for impacting standards development



Progress: Indoor Refueling

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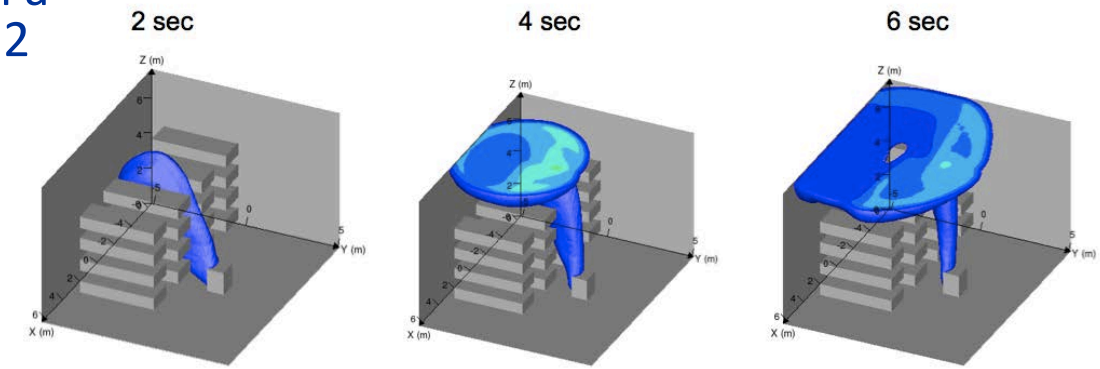
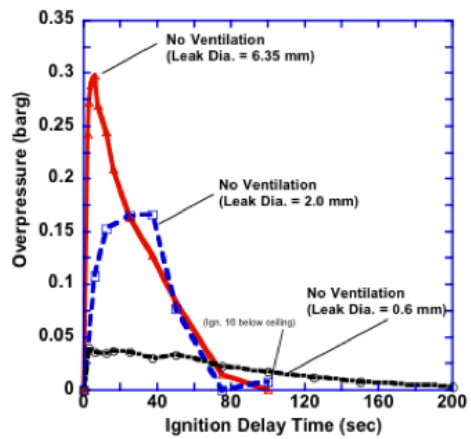
Will provide indoor releases data and analysis to advance NFPA 2 (2014 Edition)

- Evaluated H2 releases (0.8 kg) in a room-volume specified in NFPA 2
- Numerical experiments performed to understand effect of:
  - Leak size
  - Ignition delay
  - Ventilation
  - Obstacles
- Results are being incorporated into a fault-tree model of indoor refueling systems

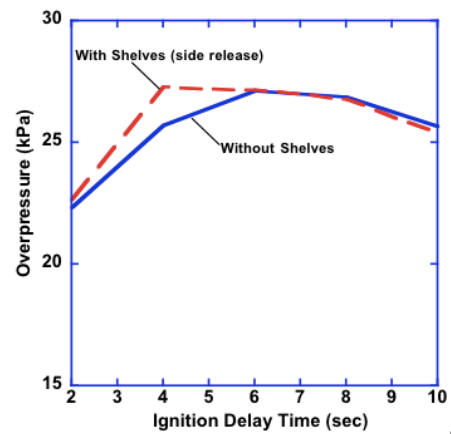
Flammable volume as a function of time for 6.35mm leak



Overpressure as a function of leak size



Overpressure with and w/o obstacles



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Progress: Releases in Semi-enclosures

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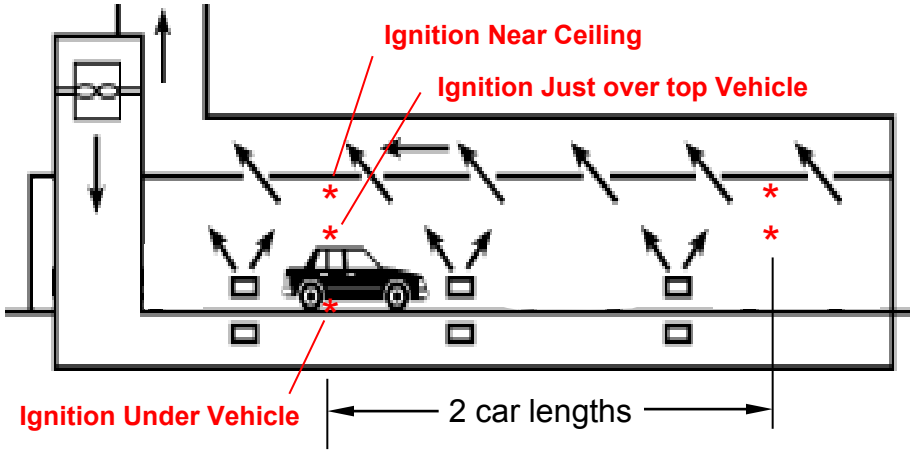
Release scenarios will allow for harmonization of NFPA 2 and NFPA 502.

- Conducted H2 releases in transversely-ventilated tunnels
- Assumed full release through the FCEV TPRD
- Numerical experiments performed to understand effect of:
  - Ignition delay
  - Ignition location
  - Ventilation

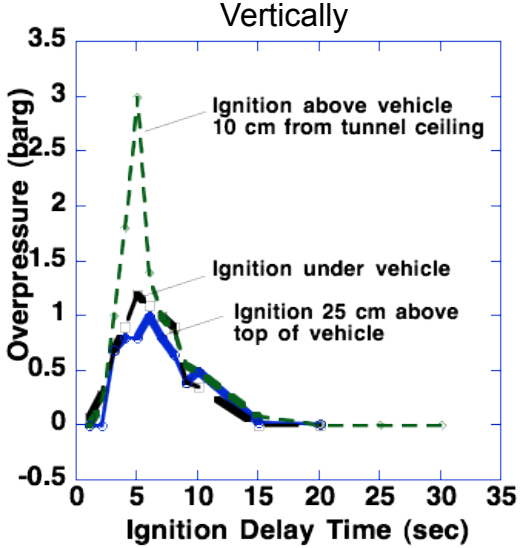
Example results:

- Overpressure lower with no tunnel ventilation
- Pressure highest when ignition occurs near ceiling
- Comparisons made to CNG: potential energy release is actually higher for CNG

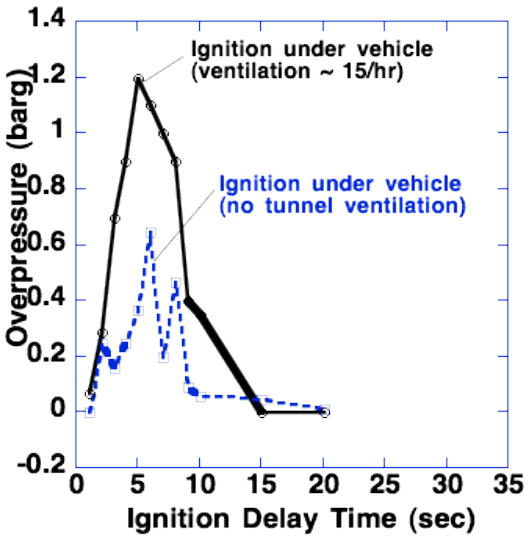
Case: Transversely-Ventilated Tunnel



Effect of Moving Ignition Point Vertically



Effect of Ventilation



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Progress: IPHE RCS WG Round Robin

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International RR Tank Test Measurement Effort Launched in FY2011

- Endorsed by the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)

- Round Robin
  - establish detailed measurement *protocol* to ensure global uniformity of test results
  - protocol will focus on validating methods of measuring relevant physics needed to execute the appropriate qualifying test sequences for high pressure composite overwrap tanks (e.g., pressure ramp rates and hold duration, temperature control, etc.)
  - Active Members: China, EC, France, U.S.

- Action Plan
  - Execute hydraulic cycling tests in the United States and China
  - Establish internationally harmonized test measurements
  - Validate test measurement for a pneumatic cycle test

Publish the RR results and make available to SDOs

Code and Standard Impact

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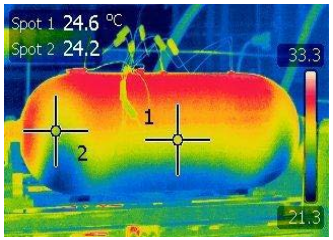
Fast-Fill Model Validation (SNL,China):



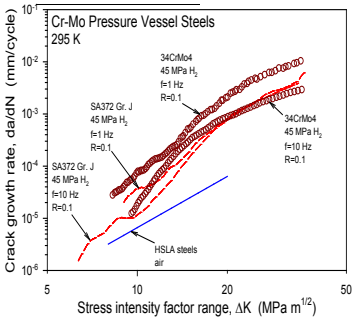
Motivation

- A variety fill models exist, some proprietary
- A generalized, validated model provides a comparative standard
- Current data may be inadequate to fully validate a model
- Current Standards (SAE 2579, GTR, EIHP)

Experimental Approach

- Perform hydrogen filling experiments at specified and relevant pressure ramp rate while the following measurements are made:
  - The transient gas pressure in the tank
  - The total enthalpy of hydrogen entering the tank
  - The transient mass flow rate of hydrogen entering the tank
  - The final uniform temperature and pressure in the tank after fill
  - The transient mass-averaged gas temperature in the tank

Materials Compatability (SNL, Japan):



- Completion of standards through committee leadership and data evaluation
  - CSA HPIT1 completed Sept. 2011
  - CSA CHMC1 (Part 1) published early 2012
  - SAE J2579 progress reported at ICHS conference Sept. 2011
  - ASME KD-10
- I^2CNER - Sandia Participation with U. of Illinois and Kyushu University
  - Leverage 40+ years in H_2 Effects on structural materials at SNL
- Evaluate effects of load-cycle frequency on fatigue crack growth rates for 7XXX aluminum alloys in high-pressure H_2
  - Results presented at ASME PVP conference July 2011

Fuel Quality (LANL):

ISO TC 197 Working Group 12

- FDIS Draft Submitted in Nov 2011
- Fuel Quality Technical Report in draft (*Target – Dec 2012)*

SAE J2719

- Hydrogen Quality Guidelines for Fuel Cell Vehicles (Published Sept 2011)

ASTM (D7653-10)

- Determination of Trace Gaseous Contaminants in Hydrogen Fuel by Fourier Transform Infrared (FTIR) Spectroscopy

Sensors (NREL, LANL, LLNL, & EC):

- Working group participation on national and international sensor test standards
  - ISO
  - UL
  - FM
- International Collaboration (NREL/JRC-IET) MOU
  - Oxygen dependence
  - Assess improvements/degradations MEMs sensor
    - Team expanded to include Univ. of Quebec
  - Hydrogen detection via oxygen displacement

Progress: Safety Training

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> 23,000 people educated through on-line and classroom courses

Hands-on Training for First Responders **Trained 710**	**1-day classroom and live-fire training for fire officials utilizing a fuel cell vehicle prop that demonstrates hydrogen and propane fires**
Basic Hydrogen Education for First Responders **Trained > 21,000**	Understanding basic hydrogen characteristics and behavior for various applications and emergency response protocol
Hydrogen Safety Training for Researcher and Technical Personnel **Trained 100**	On-line basic training on hydrogen pressure safety for researchers conducting laboratory experiments. Providing a comprehensive hands-on training on all aspects of hydrogen systems.
Code Official Training Workshop **Trained 350 (in-person) and 1000 (online)**	Workshops are designed to make information available to expedite the process for developing and permitting fuel cell and hydrogen technology projects. The target area has mostly been in Los Angeles, California.

www.hydrogen.energy.gov/firstresponders.html

Progress: Safety Knowledge Tools

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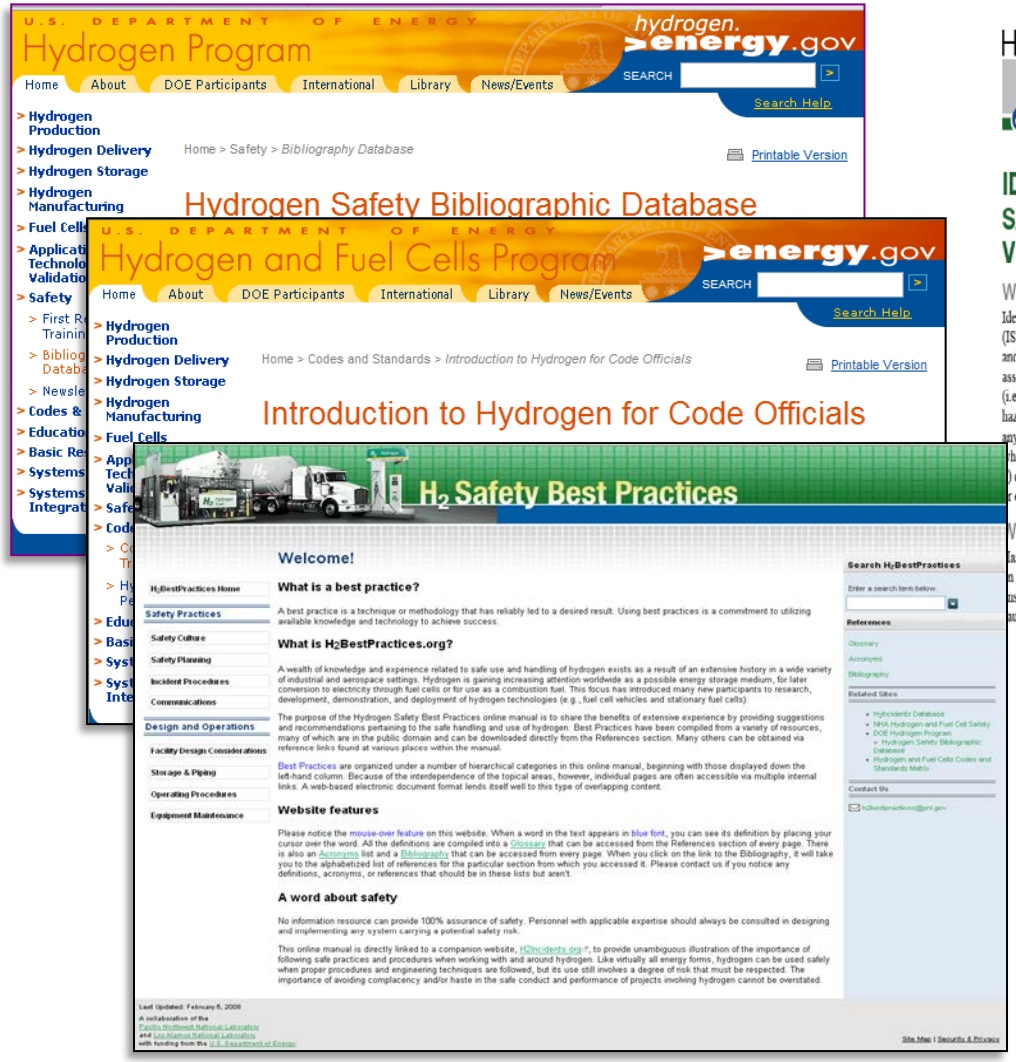

www.eere.energy.gov/hydrogenandfuelcells/codes/

- 206 Lessons Learned events in "H2Incidents.org"
- Approximately 750 entries in the Hydrogen Safety Bibliographic Database

Accomplishment

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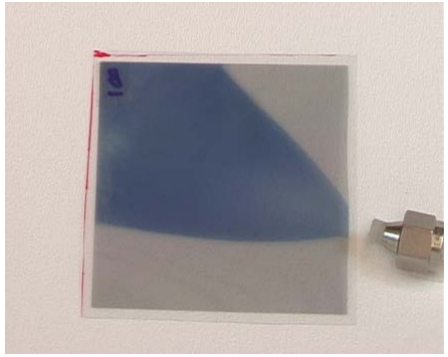
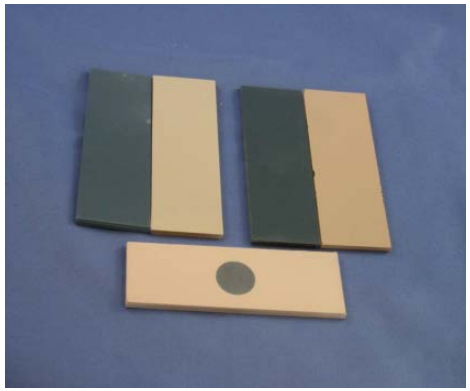
DOE's America's Next Top Energy Innovator Challenge Runner-up: Element One, Inc.

Element One has created revolutionary "smart" coatings for the detection of hydrogen that change color, either reversibly or non-reversibly, to provide both current and historical information about hydrogen leaks.

This makes it possible to produce a wide array of very low-cost, reliable sensors which can be economically deployed at all potential leak sites.





Held April 2, 2012 webinar titled
"Hydrogen leak detection – low cost distributed gas sensors"

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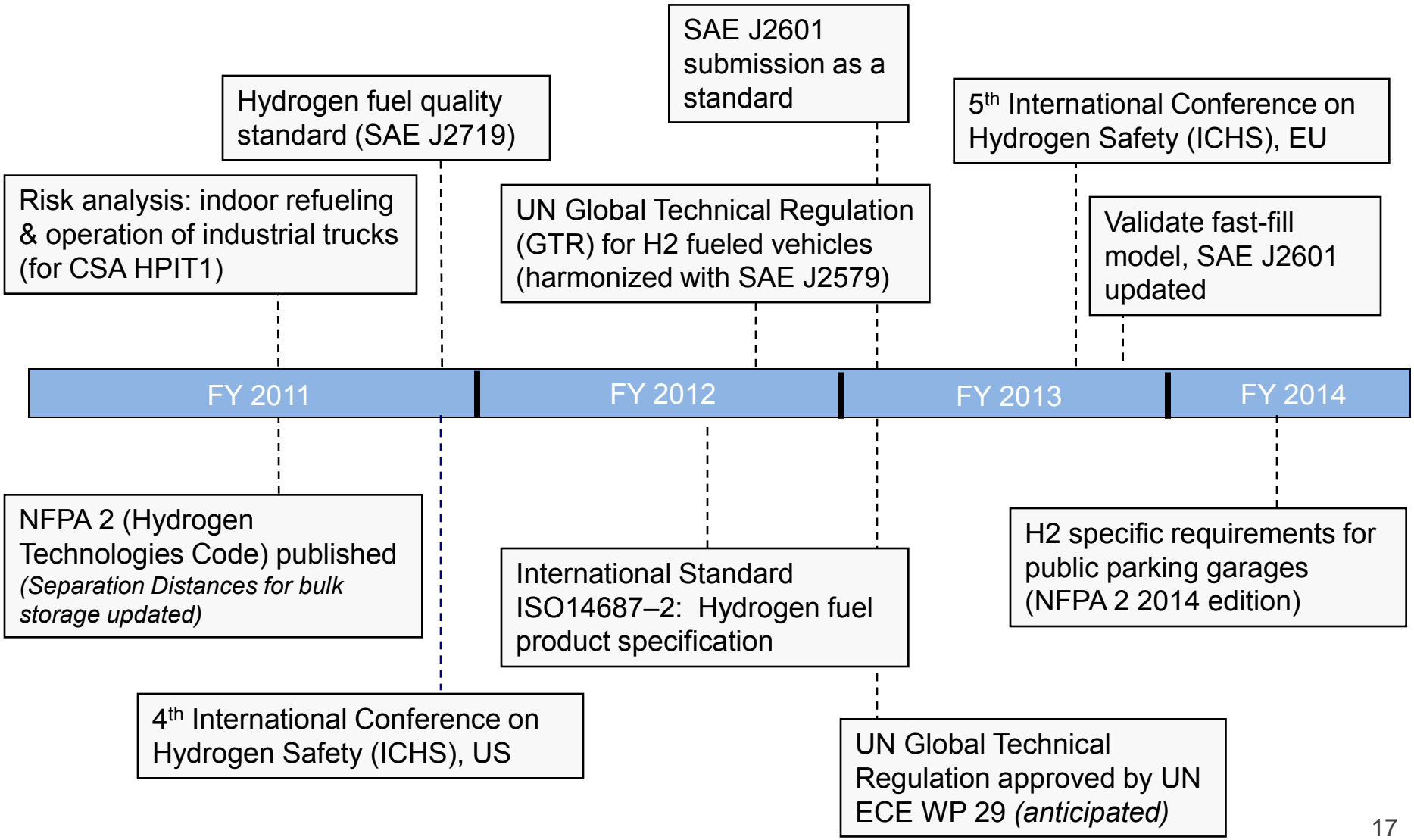
Major Roadmap Milestones



Reviewer Reminders

U.S. DEPARTMENT OF ENERGY

- Deadline to submit your reviews is **May 25th at 5:00 pm EDT.**

- ORISE personnel are available on-site for assistance.
  - **Reviewer Lab Hours:** Tuesday – Thursday, 7:30 am – 8:30 pm; Friday 7:30 am – 1:00 pm.
  - **Reviewer Lab Locations:**
    - Crystal Gateway Hotel—Rosslyn Room (downstairs, on Lobby level)
    - Crystal City Hotel—the Roosevelt Boardroom (next to Salon A)

- Reviewers are invited to a brief feedback session – at 3:45 pm today, in this room.

Session Instructions

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- This is a review, not a conference.
- Presentations will begin precisely at scheduled times.
- Talks will be 20 minutes and Q&A 10 minutes.
- Reviewers have priority for questions over the general audience.
- Reviewers should be seated in front of the room for convenient access by the microphone attendants during the Q&A.
- Please mute all cell phones and other portable devices.
- Photography and audio and video recording are not permitted.

For More Information

U.S. DEPARTMENT OF ENERGY

Safety, Codes and Standards

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Katie Randolph
Jim Alkire
Jesse Adams

Technical Support:
Kathleen O'Malley (SRA)
Jim Ohi (Consultant)
Jay Keller (Consultant)

Participating Organizations

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External Input

- Annual Merit Review & Peer Evaluation
- H2 & Fuel Cell Technical Advisory Committee
- National Academies, GAO, etc.

International

- IEA Implementing agreements
  – 25 countries
- International Partnership for Hydrogen & Fuel Cells in the Economy
  – 17 countries & EC, 30 projects

Federal Agencies

DOC NASA
DOE NIST

- *Interagency coordination through staff-level Interagency Working Group (meets monthly)*
- *Assistant Secretary-level Interagency Task Force mandated by EPACT 2005.*

DOE Hydrogen & Fuel Cells Program

State & Regional Partnerships

- California Fuel Cell Partnership
- California Stationary Fuel Cell Collaborative
- SC H_2 & Fuel Cell Alliance
- Upper Midwest Hydrogen Initiative
- Ohio Fuel Coalition
- Connecticut Center for Advanced Technology

Industry Partnerships & Stakeholder Assn's.

- Tech Teams (USCAR, energy companies- U.S. DRIVE) – GM, Ford, DOT, CaFCP, UTC
- Fuel Cell and Hydrogen Energy Association (FCHEA)
- Hydrogen Utility Group
  ~ 65 projects with 50 companies

National Laboratories

Lawrence Livermore
Los Alamos
NREL
Oak Ridge
Pacific Northwest
Sandia
Savannah River

Additional Information

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Materials and Components Compatibility

Technical Reference

Mechanical load-frame used to characterize H2 effects in materials

Objective

- Enable market transformation through development and application of standards for hydrogen components.
  1. Create materials reference guide
  2. Execute materials testing with an emphasis on steel hydrogen storage tanks
  3. Optimize materials and component test methods to reduce cost while maintaining accuracy
- Participate directly in standards development.
  1. Materials testing standards (ASME Article KD-10, SAE and CSA)
  2. Component/system design qualification standards (CSA HPIT1, CHMC1 and SAE J2579)

Benefits and Challenges

- Address need for technical data to revise standards
- Reduce the cost of materials, component and system qualification
- Develop a materials technical reference
- Develop hydrogen storage tank and component standards for portable, stationary and vehicular use

Approach

- Apply expertise and resources in materials compatibility to implement and improve standards for hydrogen components.
- Project Timeline: October 2003 – September 2015 (58% complete)
- Coordination: Standards development organizations (ASME, CSA, SAE), tank manufactures and forklift integrators (FIBA Technologies, Plug Power, Nuvera FC), DOE Pipeline Working Group and HYDROGENIUS

Key Deliverables and Milestones

- Compare cracking threshold to fracture toughness measurements for vessel steels in hydrogen
- Add/update chapters on nickel-based alloys in “Technical Reference”
- Quantify the effects of load cycle frequency on fatigue of steels in high-pressure hydrogen
- Add/update chapters on ferritic steels in “Technical Reference”
- Report on fatigue crack growth and cracking thresholds of SA372 Gr. J steel in hydrogen

Accomplishments

- Provided technical basis for update of SAE J2579 to include design qualification test (C.14) and materials tests and associated acceptance criteria (C.15)
- Enabled revision of ASME KD-10 tank standard - fracture threshold measurements of tank steels in hydrogen
- Completed materials fatigue testing to enable deployment of 100 MPa stationary tanks
- Updated “Technical Reference for Hydrogen Compatibility of Materials” and data used for materials selection in technology design and for standards development

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Quantitative Risk Assessment

Quantitative Risk Assessment helps establish requirements for hydrogen installations

Objective

- Understand the risk associated with hydrogen facilities
- Provide a safe infrastructure for the use of hydrogen through risk management
- Provide risk-informed basis for development of uniform model codes and standards

Benefits and Challenges

- Methods must be developed that accommodate sparse data
- Harmonization of codes and standards requirements allows for international deployment
- Incorporation of risk data helps avoid overly conservative code and standard requirements

Approach

- Use of Quantitative Risk Assessment (QRA) to evaluate risk, identify risk drivers and evaluate mitigation features to establish requirements
- Timeline: October 2003 – September 2015 (60%)
- Coordination: NFPA, ISO, ICC, HIPOC, Air Products

Key Deliverables and Milestones

- Complete risk assessment of indoor fuel cell material handling vehicle operations in warehouses
- Develop a consensus hydrogen ignition probability model for use in QRA
- Support NFPA 2 efforts to develop risk informed separation distance tables for LH2 facilities
- Complete risk evaluation of hydrogen refueling stations that utilize LH2, steam reformers or electroyzers

Accomplishments

- Harmonization of NFPA 55 and ISO risk assessment approach, models and data used to establish separation distances
- Risk reduction potential of barriers utilized to establish reduction factor for separation distances in NFPA-55
- Phase I work has been performed on evaluating the risk associated with indoor refueling
    - Development of approaches, models and data required in QRA
    - Experiments performed to understand phenomena, develop models and bench mark consequence models

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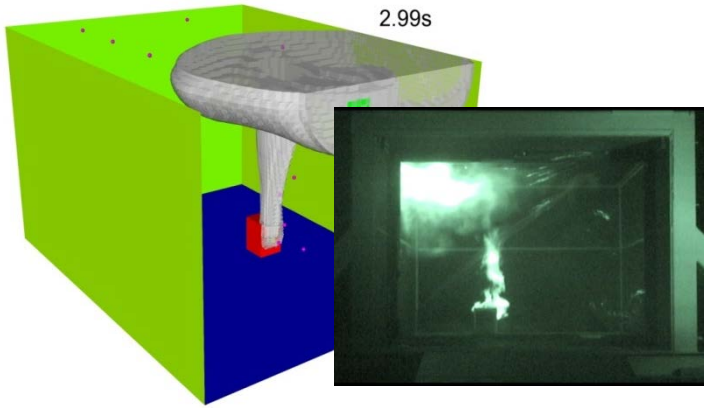
Hydrogen Release Behavior



Simulation and experimental validation of release during indoor refueling

Objective

- Provide a defensible and traceable basis for hydrogen codes and standards
- Provide advocacy and technical support for the codes and standards development process

Benefits and Challenges

- Provide expertise and technical data on hydrogen behavior and risk
- Facilitate global harmonization of RCS
- Address insufficient technical data needed to revise standards
- Reduce large footprint requirements for hydrogen fueling stations
- Facilitate safe deployment of renewable energy technologies

Approach

- Develop and validate models for hydrogen behavior to enable risk-informed decision-making for the codes and standards development process
- Project Timeline: October 2003 – September 2015 (60% complete)
- Coordination: SRI, IEA, ICC, NFPA, ISO, NHA, NIST, CTFCA, NREL

Key Deliverables and Milestones

- Understand ignition and dispersion behavior at appropriate temperature and pressure
- Develop and validate engineering models
- Evaluate risk associated with hydrogen indoor refueling
- Evaluate risk associated with small stationary APUs
- Propose risk mitigation methods and quantify risk reduction - achieved

Accomplishments

- Models validated for hydrogen releases in enclosures:
  - Tunnels
  - Warehouses
- Identified mechanism of spontaneous-ignition due to entrained particulates
- Developed the scientific-basis for separation distances in NFPA 55/2
- Harmonized NFPA and ISO framework for specifying separation distances
- Validated the use of barriers to reduce separation distances

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Hydrogen Safety Training for First Responders

A "rescue" at Sunnyvale (CA) Department of Public Safety

Objective

- Support the successful implementation of hydrogen and fuel cell technologies by providing technically accurate hydrogen safety and emergency response information to first responders.
- Continue to provide a one-day first responder training course utilizing DOE's FCEV prop at offsite first responder training centers (civilian and military).
- Continue to support the web-based awareness-level course.
- Disseminate first-responder hydrogen safety educational materials at appropriate conferences to raise awareness.

Barriers Addressed

- Lack of readily available, objective, and technically accurate information.
- Disconnect between hydrogen information and dissemination networks.
- Lack of educated trainers and training opportunities.
- Lack of hydrogen knowledge by authorities having jurisdiction.
- Lack of hydrogen safety training facilities for emergency responders.

Approach

- Reach first responders via the fuel cell electric vehicle (FCEV) prop-based course, the web-based "Introduction to Hydrogen Safety for First Responders" and outreach to the Fire Department Instructors Conference and Fire Rescue International to raise awareness of hydrogen safety training courses to the target audience.
- Project Timeline: October 2004 – Continuing
- Collaboration: California Fuel Cell Partnership, Hanford Fire Department, and Volpentest Hazardous Materials Management and Emergency Response (HAMMER) Training and Education Center

Key Deliverables and Milestones

- Provide the prop course at Defense Logistics Agency depots and other fire training centers (Summer 2011).
- Continue to update the web-based hydrogen safety course as needed.
- Target outreach opportunities.

Accomplishments

- Trained over 300 students in three FCEV prop-based courses in California in August/September 2010.
  - Rio Hondo College Fire Academy, Santa Fe Springs, CA
  - Orange County Fire Authority, Irvine, CA
  - Sunnyvale Department of Public Safety
- Held three sessions of the prop-based course at the HAMMER facility in 2009 and 2010, training ~100 participants from 18 states.
- Web-based course received 18,000 unique visitors and averages 300-400 unique visits each month from every state and many foreign countries.

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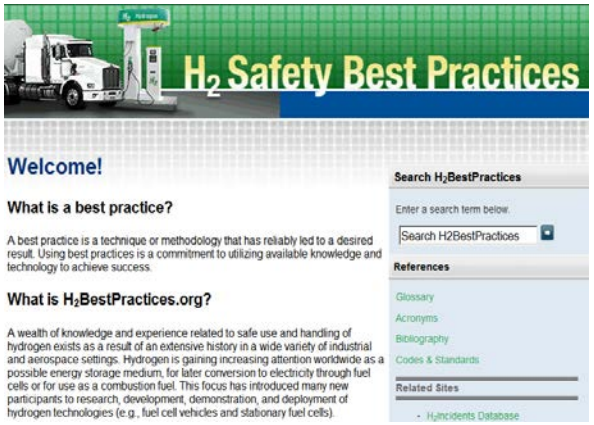
Hydrogen Safety Knowledge Tools



H_2 Safety Best Practices web site (also see H2incidents.org)

Objective

- H2 Safety Best Practices
  Capture vast knowledge base of hydrogen experience and make it publicly available.
- H2 Incident Reporting and Lessons Learned Collect information and share lessons learned from hydrogen incidents and near-misses, with a goal of preventing similar incidents from occurring in the future.

Barriers Addressed

- Limited historical database of incidents
- Proprietary data

Approach

- H2 Safety Best Practices: Best practices are compiled, new Web content is reviewed by the Hydrogen Safety Panel and PNNL experts, and approved material is posted to the Web site.
- H2 Incident Reporting and Lessons Learned: Pursue records and lessons learned for hydrogen incidents and near-miss events to add to the online database.
- Project Timeline: March 2003 – Continuing
- Collaboration: Hydrogen Safety Panel, NASA, LANL, SNL, NREL, IEA Hydrogen Implementing Agreement (HIA) Task 31 and IA HySafe

Key Deliverables and Milestones

- H2 Safety Best Practices
  1. Improve existing and add new content.
  2. Enhance Web site usability.
  3. Encourage use and respond to user questions posted on the Web site.
- H2 Incident Reporting and Lessons Learned
  1. Target to reach > 200 safety event records in FY2011.
  2. Analyze lessons learned from incidents.

Accomplishments

- H2 Safety Best Practices
  1. Enhanced best practices for outdoor storage of hydrogen cylinders.
  2. Added more information on hydrogen properties in collaboration with NASA.
  3. Updated “Hydride Storage and Handling” to cover risks related to large-scale experiments in collaboration with SNL.
- H2 Incident Reporting and Lessons Learned
  1. Currently 195 incidents recorded in the database.
  2. Created new “Lessons Learned Corner” to analyze hydrogen safety themes illustrated by database content.

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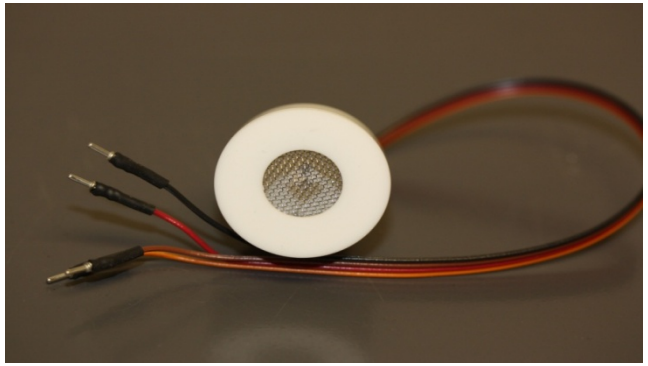
Sensor Testing



Packaged LANL/LLNL Mixed Potential Zirconia-based H_2 Sensor for Independent Testing

Objective:

- Develop a low cost, low power, durable and reliable hydrogen safety sensor for vehicle and infrastructure applications.
- Demonstration of working technology through applications of commercial and reproducible manufacturing methods and rigorous life testing results guided by materials selection, sensor design and electrochemical R&D investigation.
- Disseminate packaged prototypes to DOE laboratories and commercial parties interested in testing and fielding advanced commercial prototypes while transferring technology to industry.

Benefits and Challenges:

- Low cost sensors for hydrogen leakage needed for vehicles and pipelines.
- Potential liability issues and lack of insurability affecting the commercialization of hydrogen technologies.
- Variation in standard practice of hydrogen safety assessments.

Approach:

- Focus on the long-term testing, packaging and manufacturing protocol for the commercialization of hydrogen sensor technology.
- Evaluate alternative measurement and electrode processing methods to further improve sensor stability.
- Coordination: LANL, LLNL and ElectroScience Laboratories with BJR Sensors.

Key Deliverables and Milestones:

- Go for mode of operation and fabrication processes with critical evaluation of mass manufacturing potential.
- Multiple devices fabricated and packaged for 1st round of testing/independent validation at NREL facility.
- Application of BJR Passive Duel Technology (PDT) shows promise with near 100% rejection of cross-interference gas species tested.

Accomplishments

- Developed miniaturized, low power and robust hydrogen sensor prototype conducive to commercialization.
- Developed stable sensor response over time.
- Multiple devices fabricated and packaged showing high-degree of reproducibility device-to-device.
- Incorporation of miniature Resistance Temperature Detectors (RTD) in sensor platform to provide continuous T feedback and control point.
- Developed methods for rejection of cross-sensitivity to common interference gases tested.
- Completed long-term testing of improved electrode devices at LANL and at LLNL on separate devices.
- Completed 1st round of testing packaged H_2 safety sensors at NREL.

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Fuel Quality

Hydrogen Fuel Quality Test Apparatus

Objective:
Determine levels of constituents for the development of an ANSI and international standard for hydrogen fuel quality (ISO TC197 WG12).

Benefits and Challenges:

- Remaining Tests for Fuel Specifications:
  1. Testing critical constituents at reduced levels
  2. Reduce anode loading: .05 mg Pt/cm^2 (DOE 2015 target)
  3. Short term tests: typical vehicle operation (5-10 hours)
  4. Start/stop Fuel Cell operation
  5. Aged studies
- Critical Constituents:
  1. Lower Pt loadings may increase performance losses via surface poisoning and/or within the catalyst layer
  2. Short-term tests may help reduce the build-up of adsorbates and/or cation uptake
  3. Shut down may be to some extent be helpful as a recovering strategy (introduction of air to remove excess hydrogen)
  4. Aged fuel cells may inhibit particle growth and/or ionomer loss (similar to lowering Pt loading)

Approach:

▪Help determine levels of constituents and test these critical constituents (NH_3, CO and H_2S) at various conditions (loadings, relative humidity and concentrations) and present data at ISO WG 12 meetings.

▪Coordination: University of Hawaii/HNEI, University of Connecticut, University of South Carolina, Clemson University, SRNL, NIST, NREL and ANL

Key Deliverables and Milestones:

▪Complete testing of critical constituents at various conditions (loadings, relative humidity and concentrations).

Accomplishments

- H_2S Gore Standard MEA: Slower poisoning onset, but when accumulation occurs these results differ.
- Project produced excellent experimental and modeling results that were adopted by the international community.
- Significant progress on establishing cross contamination effects.
- Data presented at ISO WG 12 Meetings in Berlin, Germany; Seoul, Korea; and San Francisco, CA.

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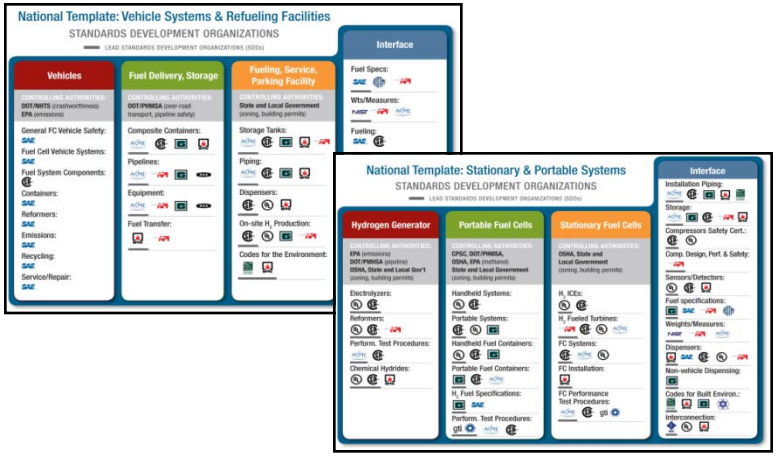
National Template



National Template Web site

Objective:

- Conduct R&D needed to establish sound technical requirements for renewable energy codes and standards with a major emphasis on hydrogen and fuel cell technologies.
- Support code development for the safe use of renewable energy in commercial, residential and transportation applications with a major emphasis on emerging fuel cell technologies.
- Advance renewable energy safety, code development and market transformation issues by collaboration with appropriate stakeholders.
- Facilitate the safe deployment of renewable energy technologies.

Benefits and Challenges:

- Consensus: achieving national agenda on codes and standards.
- Representation: government and industry support and DOE limited role.
- Technology Readiness: jurisdictional issues related to available codes and existing setback distances.

Approach:

- Support codes and standards coordination and development including coordinating involvement in technical committees and coordinating committees.
- Project Timeline: October 2002 – Continuing
- Coordination: California Fuel Cell Partnership (CaFCP), California Air Resource Board (CARB), FCHEA, SNL, LANL, ORNL, ANL, PNNL, NASA, NIST, JRC, SAE, NFPA, CSA America, ICC, CGA, ISO and IEC

Key Deliverables and Milestones:

- Publish Stationary Fuel Cell Application Codes and Standards Gap Analysis
- Direct support of several codes and standards development projects:
  1. NFPA2 Hydrogen Technologies Code
  2. ISO 14687-2 Hydrogen Fuel quality standard
  3. SAE Standards
  4. CSA Component standards

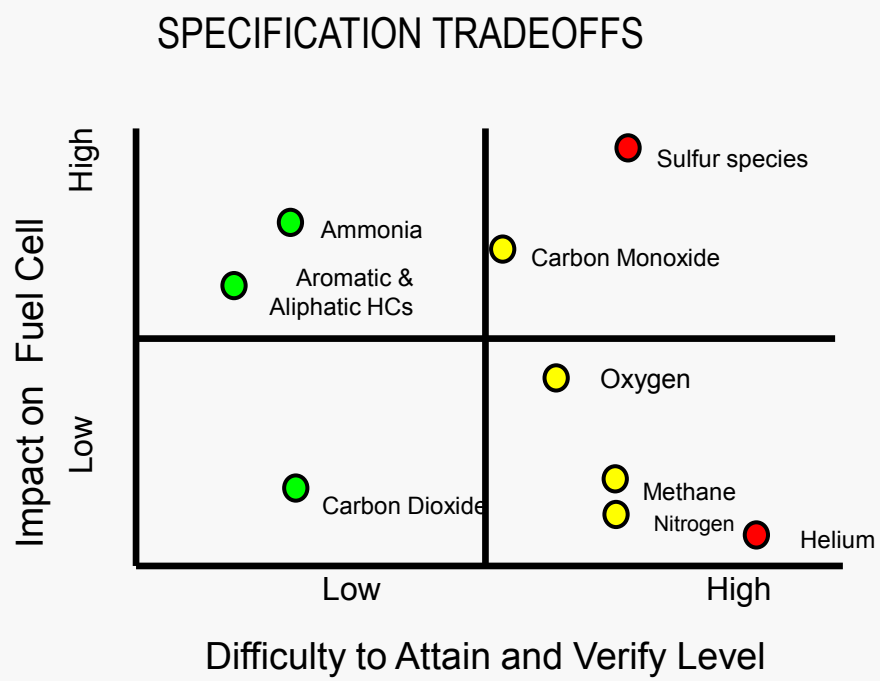
Accomplishments:

- Published Stationary Fuel Cell Application Codes and Standards Gap Analysis (October 2010)
- Direct participation on the following codes and standards committees:
  1. NFPA2 Hydrogen Technologies Code issued December 14, 2010
  2. ISO TS14687-2 Hydrogen Fuel Quality
  3. SAE J2579 Onboard Hydrogen Storage
  4. SAE J2578 General Fuel Cell Vehicle Safety
  5. SAE Fuel Cell Technical Committee
  6. CSA America H4
  7. ISO 20100 Hydrogen Fueling Stations
  8. UL2267 Fuel Cell Powered Forklifts

Progress

- Technical Specification (TS) published and harmonized with SAE J2719, Committee Draft (CD) prepared
- Draft International Standard (DIS) to be submitted to ISO TC197 Dec 2010
- Unified testing underway at LANL, HNEI, USC, Clemson-SRNL, UConn for critical contaminants
- Collaborative testing underway in Japan (JARI) and France (CEA-Liten)
- Developing standardized sampling and analytical methodologies with ASTM
- Applied ANL fuel cell stack and PSA models to support testing and to address fuel quality-fuel cost tradeoffs
- Coordinated overall approach and testing with Fuel Cell, Delivery, and Storage Tech Teams

Fuel Quality - ISO DIS 14687-2 Hydrogen Fuel Product Specification



Source: Shell Hydrogen

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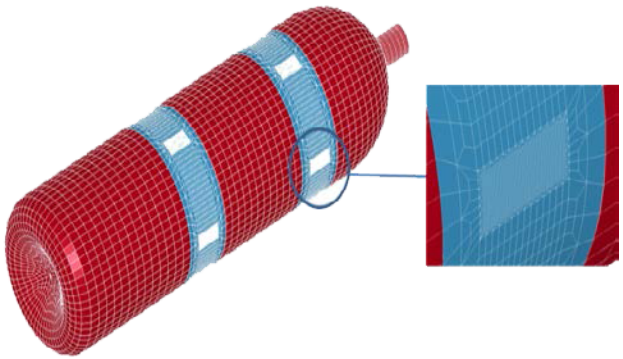
Tank Cycle-Life Testing



Structural Engineering Analysis of Cylinder

Objective

▪Provide technical basis for the development of standards defining the use of steel (type 1) storage tanks with existing defects

1.Engineering Analysis Method: validate fracture mechanics-based design approach in ASME BPVC Sec VIII, Div 3, Article KD-10

2.Performance Evaluation Method: provide data to help determine if time for crack initiation can be reliably credited in design qualification process

3.Quantify failure characteristics

▪Participate directly in standards development such as ASME, CSA HPIT1 working group and SAE J2579

Benefits and Challenges

▪Program provides the technical basis addressing this need within the scope of CSA HPIT1.

▪Hydrogen accelerates fatigue crack growth of existing defects including crack growth under cyclic stress and critical crack propagation.

▪Standards for steel hydrogen tanks that experience a large number of cycles is currently missing (CSA HPIT1).

Approach

▪Perform testing and analysis of hydrogen accelerated fatigue crack growth of existing defects to provide basis for standards development activities

▪Project Timeline: January 2010 – May 2011 (75% complete)

▪Coordination: CSA HPIT1 working group, FCHEA Fork Lift Task Force, Tank Manufactures, Norris Cylinder, Nuvera and Plug Power

Key Deliverables and Milestones

▪Complete cycling of as-manufactured tanks and tanks with engineered flaws until failure

▪Complete benchmark fatigue crack growth testing of 3 heats of 4130X

▪Quantify number of cycles for initiation and growth as well as size and distribution of engineered and “natural” defects

▪Validate structural engineering tools and existing design methodology (in particular ASME VIII.3.KD-10 and leak-before-burst criteria)

▪Communicate results to CSA HPIT1 working group and SAE J2579

Accomplishments

▪As-manufactured tanks have experienced 25,000 cycles as of Feb 2011

▪Fatigue crack growth rates have been measured for each tank material

▪Test matrix defined with input from partners (HPIT1 working group)

▪Infrastructure has been developed for accelerated qualification test method development