Safety, Codes & Standards (SCS) Program Area
Plenary Poster
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2018 Annual Merit Review and Peer Evaluation Meeting
April 29 – May 1, 2019 – Crystal City, VA
SCS Goals & Objectives

Mission: Fund R&D needed to develop science-based codes and standards, thereby enabling the safe deployment of H₂ and fuel cell technologies

Codes & Standards

- Conduct **R&D to provide critical data** and information needed to define requirements in developing codes and standards.
- Support and facilitate development of **essential codes and standards** to enable widespread deployment of hydrogen and fuel cell technologies and completion of essential regulations, codes and standards (RCS).

Safety

- Ensure that **best safety practices** underlie activities supported through DOE-funded projects.
- Enable **widespread sharing** of safety-related information resources and lessons learned with key stakeholders.
Current Strategy and Barriers

**Focus areas**

- Safety Knowledge
- Hydrogen Behavior
- Materials Compatibility
- Risk Assessment
- Detection & Sensors

**Barriers***

- Safety Knowledge: Limited access and understanding of safety data and information
- Hydrogen Behavior: Insufficient data for code revision (e.g.-large station footprints)
- Materials Compatibility: Lack of information on new materials compatibility with H$_2$
- Risk Assessment: Usage and access restrictions; Limited reliability data
- Detection & Sensors: High cost and limited commercial availability of products

**Objectives**

- Support critical stakeholders in understanding hydrogen safety best practices
- R&D to provide the science & engineering basis for the release, ignition, and combustion behavior of hydrogen across its range of use
- Establish a foundational materials understanding, which will enable and support the C&S development
- Develop tools on a scientific foundation to facilitate the assessment of the safety which can be used for various hydrogen applications
- Develop and deploy safety and fuel quality sensing technologies

* From Safety, Codes and Standards MYRD&D (June 2015)
Budget

FY 2018 Appropriation = $ 7M
FY 2019 Appropriation = $ 7M

Emphasis: R&D to enable science-based codes & standards and to support H₂ safety best practices

<table>
<thead>
<tr>
<th>Emphasis</th>
<th>% of Projects</th>
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<tbody>
<tr>
<td>Codes &amp; Standards Harmonization</td>
<td>25%</td>
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<tr>
<td>Hydrogen Behavior &amp; Risk</td>
<td>16%</td>
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<tr>
<td>Materials Compatibility R&amp;D</td>
<td>17%</td>
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<tr>
<td>Safety Resources &amp; Support R&amp;D</td>
<td>17%</td>
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<tr>
<td>Component R&amp;D</td>
<td>17%</td>
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FY 2018 Appropriation = $ 7M
FY 2019 Appropriation = $ 7M
Barrier: Limited Access and Availability of Safety Data and Information
Accomplishment: PNNL and AIChE Partner to Establish the Center for Hydrogen Safety

The CHS is a not-for-profit, global, membership organization within the American Institute of Chemical Engineers (AIChE) that promotes the safe operation, handling, and use of hydrogen and hydrogen systems across all installations and applications. The CHS identifies and addresses concerns regarding the safe use of hydrogen:

- As a sustainable energy carrier
- In commercial and industrial applications
- In hydrogen and fuel cell technologies

**Membership Benefits Include...**

- Access to the U.S. HSP for reviews and support
- Education (continuing education units [CEUs]), training, and outreach materials
- Provide leadership and facilitation of hydrogen safety issues
- Conferences and networking opportunities

[www.aiche.org/chs](http://www.aiche.org/chs)
Accomplishment: Expanded HyRAM QRA flexibility

Expanded HyRAM flexibility and availability as a research tool

- Expanded QRA flexibility in **HyRAM version 2.0** will allow for hydrogen safety analysis for new H2 technologies
  - Updated methodology enables users to alter the risk analysis for different applications
- Developing **AltRAM** to incorporate risk and physics models for CNG, LNG and propane
- Pursuing an **open source license** to expand HyRAM as a research tool
  - Will allow researchers to view and download the source code
  - Changes made by users can now be added back to HyRAM

Latest release can be found at [http://hyram.sandia.gov](http://hyram.sandia.gov)
Accomplishment: Component Failure Analysis

**Initiated Effort To Obtain Essential Component Failure Data**

- Secured two stations operators to provide field-failed components for root-cause failure analysis
- Produced project plan to analyze failed components
- Collected key failed hydrogen fueling station components for root-cause analysis
- Developed a preliminary test plan to measure leak rates from key station components

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**Field-failed 700 bar inlet valve**

**Proposed leak rate measurement system diagram**
Barrier: Insufficient Technical Data to Revise Standards
Accomplishment: Reduced Separation Distances

Pending changes to the NFPA 2 Hydrogen Technologies Code (2020 Edition) will result in reduced setback distances for gaseous hydrogen storage systems.

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<tbody>
<tr>
<td>Group 1 Exposures (lot lines, air intakes, openings, ignition sources)</td>
<td>34 (10)</td>
<td>16 (5)</td>
</tr>
<tr>
<td>Group 2 Exposures (exposed persons, parked cars)</td>
<td>16 (5)</td>
<td>13 (4)</td>
</tr>
<tr>
<td>Group 3 Exposures (buildings, flammable gas storage, combustibles, etc.)</td>
<td>14 (4)</td>
<td>13 (4)</td>
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- **Sandia National Laboratories**: Completed rigorous analysis characterizing footprint of conventional and potential future fueling station designs, and identifying technologies that can enable up to 20% reduction.


SCS001, SCS010, SCS011
Accomplishment: Demonstrated large scale release measurement capability

Measured how flame length and heat flux scale at cryogenic temperatures

- Cryogenic temperatures increase mass flow through nozzles
- For a given mass flux, heat flux increases at cryogenic temperatures
- Accurate model prediction of these behaviors is essential for QRA

Imaged hydrogen from 40 foot standoff distance in the laboratory

- Uniquely fast optics enable collection of small Raman signal

SCS010
Barrier: Usage and access restrictions; Lack of Hydrogen Knowledge by AHJs
Accomplishment: Developed Standard Permit for Hydrogen Storage

Leveraging DOE research, particularly unused R&D assets, can support major code proposals and enable advances in public safety.

- NFPA 2 Standard Permit Task Group identified hydrogen stations with gaseous/liquid storage as the key application for standard permits
  - Standard permit completed January 2019
- Task group will continue to develop standard permits for other applications based on industry and safety needs
Barrier: Lack of information on new materials compatibility with hydrogen
Accomplishment: H₂ Materials Compatibility

Performing critical materials R&D to understand material behavior in high pressure hydrogen, which will enable RCS in support of infrastructure deployment

Simple performance requirements established for SAE J2579 based on relevant design space (proposed to GTR IWG)

- Test requirements have substantially evolved to simple performance-based metrics to demonstrate suitability for application (e.g., fatigue life test conducted at room temperature only)

ASME Code Case 2938 approved


\[
\frac{da}{dN} = C \left[ \frac{1 + C_H R}{1 - R} \right] \Delta K^m
\]
Focuses of current activities include:
1) Reduce expansion of seals in hydrogen by 50%.
2) Enhance life of vessels by 50% through improved understanding of crack nucleation.
3) Enhance fracture toughness of high-strength (>950 MPa) steels by 50%.

For more information, please visit https://www.energy.gov/eere/fuelcells/h-mat-hydrogen-materials-consortium or contact h-matinfo@pnnl.gov
Barrier: High Cost and Limited Commercial Availability of Products
Accomplishment: Safety Sensors

**Objective:** Develop low cost, low power, durable, and reliable H₂ safety sensor for vehicle and infrastructure applications.

1. **Indoor Placement Study:** CFD modelling and empirical verification of indoor hydrogen releases
   - Developed preliminary guidance document for sensor placement and facility design
     - Goal: Inclusion into NFPA2

2. **Vehicle Tailpipe H₂ Emissions:** Collaboration with DOT NHTSA in support of Global Technical Regulation (GTR)
   - Performance verified in the laboratory and vehicle; Field tested on FCEV; detected hydrogen successfully
   - NREL FCEV Analyzer meets the GTR metrological requirements for compliance verification

**SCS021**

*H₂ transients in FCEV exhaust operating under load, as measured by the NREL FCEV Exhaust Analyzer*
Accomplishment: Fuel Quality and Fuel Quality Assurance

Field-demonstrated In-Line Hydrogen Contaminant Detector capable of <1ppm CO detection

- Installed in-line Hydrogen Contaminant Detector (HCD) at an existing hydrogen fueling station (H2 Frontier, Burbank CA)
  - Obtained real-world performance of the in-line analyzer
  - Demonstrated improved baseline stability
- Analyzer is capable of detecting <1ppm CO with an order of magnitude in response time (<1 minute) in a dry hydrogen stream.
Collaborations

International
- CHS – Center for Hydrogen Safety
- IPHE - International Partnership for Hydrogen & Fuel Cells in the Economy
  - 18 countries & EC, 30 projects
- IA HySAFE and ICHS
- Independent Projects (EU, Japan, Korea, etc.)

DOE-EERE Safety, Codes and Standards

Industry Partnerships & Stakeholder Associations
- Tech Teams (USCAR, energy companies- U.S. DRIVE) – GM, Ford, DOT, CaFCP, Exxon
- California Fuel Cell Partnership
- Fuel Cell and Hydrogen Energy Association (FCHEA)
- Various CDOs & SDOs (SAE, NFPA, ISO, CSA)

State & Regional Partnerships
- California Fuel Cell Partnership
- CT Center for Advanced Technology
- Massachusetts Hydrogen Coalition

National Laboratories
- LANL
- NREL
- ORNL
- PNNL
- SNL

Federal Agencies
- DOT
- NASA
- DOE-FEMP
- Interagency coordination: staff-level Interagency Working Group Assistant Secretary-level Interagency Task Force mandated by EPACT 2005.
Thank You

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