Final Action Report

Permitting Hydrogen Fueling Stations and Hydrogen Fuel Cell Backup Power for Wireless Telecommunications Sites Workshop

California State University

August 25 & 26, 2008
Los Angeles, California

Prepared by

The National Association of State Fire Marshals

with the assistance of

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TABLE OF CONTENTS

Table of Contents

SECTION 1

Executive Summary

1. Executive Summary

The overall objective of the workshop was to present “case studies” for a selected number of hydrogen motor-fueling station configurations and back-up power for telecommunication sites to an invited group of fire and building code officials that shows how their existing codes and standards, or engineering solutions based on the codes (“alternative methods”), have been or can be applied to permit construction of a hydrogen motor-fueling station in a rigorous but timely manner. Additionally a goal was to have this group develop their own permit processing guide identifying the pathway and application they would take in their jurisdiction and what codes and standards would apply.

To summarize the project:

- The workshop was hosted as a stand alone activity.
- The workshop built on experiences of the previous workshops via teleconference coordination and discussion.
- Building code, fire code and electrical code officials from the Los Angeles County area participated in the workshop.
- An overview of hydrogen and hydrogen safety as compared to other fuel gases was provided.
- Participants were broken down into teams equally divided so to have various expertise on each breakout team.
- Each team was assigned construction plans involving a service station and also plans involving telecommunications sites.
- Upon completion of their work, each team gave a verbal report on the results of their reviews which was followed by comments from any team that used the same plan for their review. General discussion followed.
- Issues were identified and discussed dealing with an understanding of how to apply the codes and standards and existing code language.
- Participants were overwhelmingly positive in their comments and the valuable educational opportunity.

The goals of the project were met. Participants were provided with a better understanding of how to apply the codes and referenced standards to a hydrogen motor-fueling facility permit application and they indicated they had an increased level of comfort with the topic. In addition, feed back from the participants provided guidance on content to include in future workshops along with areas within the existing code language that may need modification to clarify technical requirements.

Workshop Sponsors

National Association of State Fire Marshals

US Department of Energy

National Renewable Energy Laboratory

The California Fuel Cell Partnership

US Fuel Cell Council

General Motors

Plug Power, Inc.

ReliOn, Inc.

Workshop Facilitators

National Association of State Fire Marshals

Project Development

SECTION 2

2. Project Development

The success of any project rests on establishing clear goals, assigning responsibilities, setting timelines for completion of assignments, and verifying follow through.

The development phase of the project presents its own challenges through the involvement of agencies and firms with office locations scattered around the country and individuals that are highly mobile on a day to day basis. Face to face meetings during the planning and development phase were limited and alternate means of communications was a necessity.

Project development was accomplished via teleconferences and effective use of electronic communications such as e-mail exchange of messages and documents.

The initial project conference call was held on July 22nd. Representatives of NREL, NASFM, CaFCP and industry discussed the workshop that had recently been completed, and participation for the next workshop to be held in the Los Angeles, California area with dates of August 25 and 26.

The discussion agenda was:

Draft Agenda
Workshop on Permitting Hydrogen Fueling Stations and
Hydrogen Fuel Cell Backup Power for Wireless Telecommunication Sites

California State University
Los Angeles, CA
August 25-26, 2008

August 25 (Monday)

10:30 Registration

11:00 Welcome — The Governator and Jamie Lee Curtis

11:15 Background, objectives of workshop — Antonio Ruiz, U.S. DOE

11:30 Introductions, agenda, structure of workshop — Jim Narva, NASFM (Go around room intros)

11:45 Get Lunch & Return for working lunch

12:15 Hydrogen Fuel & Fuel Cells Overview — Kathy Haq, National Fuel Cell Research Center (Melanie to Contact)

12:45 Hydrogen Safety — Carl Baust, (Carl to Contact)

1:15	Emergency Response & Safety Systems	Jennifer Hamilton, CaFCP
1:45	Hydrogen Fueling Stations & Transportation	Bill Elrick, CaFCP & Alex Keros, GM (add planned HFS to discussion)
2:15	Break	
2:30	Hydrogen Fuel Cells for Back-up Power at Wireless Telecommunication Sites	Paul Buehler, Plug Power Mike Maxwell or Mark Cohen, ReliOn
3:15	Permitting Hydrogen Facilities Springs and ICC & NFPA 52 Pathways Introduce Permitting Website	Richard Kallman, City of Santa Fe Chair of the DOE Hydrogen Safety Panel
4:00	Q/A, discussion	NASFM
4:15	Break Breakout Group Assignments Group Discussions & Goal Pathway	 Bill Elrick, CaFCP Group Facilitators
5:00	Adjourn	

<u>August 26 (Tuesday)</u>

(NASFM TO COORDINATE)

Breakfast	
Breakout session 2	
Cal State HFS Site Tour	
Breakout session 3	
Lunch	
Plenary for report outs	
Summary, next steps	Jim Narva
Adjourn workshop	Antonio Ruiz

Needs Identified So Far:
4 Laptops with internet access for breakout sessions
1 Laptop with internet, projector, and screen for presentations

As a result of this teleconference the following parameters were identified and discussed.

- The overall objective of the workshop is to present "case studies" for a selected number of HRS and back-up power for telecommunication site configurations to an invited group of fire, building, and electrical code officials that shows how existing codes and standards or engineering solutions based on the latest codes ("alternative methods") have been or can be applied to permit HRS in a rigorous but timely manner and to have this group review and develop permitting guides for their jurisdictions. The targeted locals would be from the Los Angeles County area.

- The fire and building code officials will be invited by NASFM. CaFCP will identify those to be invited.

- The case studies can include existing, planned, and “hypothetical” installations. The case studies should demonstrate the logic and concept of the configurations and how safety is built into the design in relation to the existing site improvements.

- At the workshop, teams will be formed to review several case studies each. The teams will be asked to evaluate the application of codes and standards to the examples presented in each case study and to draft a guide that identifies what path an application would take through the approval agencies in their jurisdiction and what codes and standards would be applied. Each team will review more than one type of case study to provide experience with both a HFS and a telecommunications site.

- Two keys issues to address with the workshop is how the codes and standards apply and in which order in their jurisdiction, (which will deal with the logic and design principals); and we also want the participants to become familiar with and apply the DOE/NREL Hydrogen Permitting Website and other resources.

The Workshop

SECTION 3

3. The Workshop

The agenda for the workshop was as follows:

Permitting Hydrogen Fueling Stations and Hydrogen Fuel Cell Backup Power for Wireless Telecommunication Sites Workshop

California State University, Los Angeles, CA
August 25 – 26, 2006

AGENDA

DAY ONE: MONDAY, AUGUST 25, 2008

10:30 a.m. – 11:00 a.m.	**Registration**
11:00 a.m. – 11:15 a.m.	**Welcome** *Mike Kashuba, Air Resources Board*
11:15 a.m. – 11:35 a.m.	**Workshop Background and Objectives** *Antonio Ruiz, US Department of Energy*
11:35 a.m. – 11:45 a.m.	**Workshop Structure, Introductions and Agenda** *Jim Narva, NASFM*
11:45 a.m. – 12:45 a.m.	**Working Lunch – Hydrogen Fuel and Safety, Fuel Cells Overview** *Anthony Androsky, US Fuel Cell Council*
12:45 p.m. – 1:15 p.m.	**Emergency Response and Safety Systems** *Jennifer Hamilton, California Fuel Cell Partnership*
1:15 p.m. – 2:15 p.m.	**Hydrogen Fueling Stations and Transportation** *Bill Elrick, California Fuel Cell Partnership; Alex Keros, General Motors,* and *Carl Baust, OCFA*
2:15 p.m. – 2:30 p.m.	**Break**
2:30 p.m. – 3:15 p.m.	**Hydrogen Fuel Cells for Back-up Power at Wireless Telecommunication Sites** *Paul Buehler, Plug Power* and *Mike Maxwell, ReliOn*
3:15 p.m. – 4:00 p.m.	**Permitting Hydrogen Facilities, ICC and NFPA 52 Pathways and Introduction of Permitting Website** *Jim Glew, City of Santa Monica* and *Ken Kraus, City of Los Angeles Fire Department*
4:05 p.m. - 4:15 p.m.	**Break**

4:14 p.m. – 5:00 p.m.	**Q/A, Discussion, Breakout Group Assignments, and Breakout Session Goals** *Jim Narva, NASFM, Carl Rivkin, NREL, and Group Facilitators*

DAY TWO: TUESDAY, AUGUST 26, 2008

8:00 a.m. – 8:30 a.m.	**Continental Breakfast**
8:30 a.m. – 9:45 a.m.	**Breakout session**
9:45 a.m. – 10:30 a.m.	**California State HFS Site Tour**
10:30 a.m. – Noon	**Breakout session**
Noon – 1:00 p.m.	**Lunch**
1:00 p.m. – 2:40 p.m.	**Plenary Session for Report Outs** *Group Facilitators*
2:40 p.m. – 2:50 p.m.	**Summary and Next Steps** *Jim Narva, NASFM*
3:00 p.m.	**Adjourn Workshop** *Carl Rivkin, NREL*

The primary goals of the workshop were

- Provide the participants with background on hydrogen such as its chemical properties and uses with comparisons to other flammable gases.

- Provide a hydrogen safety overview and information for emergency responders.

- Familiarize participants with examples of hydrogen motor fueling station projects and telecommunication back up power installations that have been implemented in the United States.

- Familiarize participants with the codes and standards and the processes that have been utilized by local/state officials to permit the projects.

- Provide workshop participants with the opportunity to conduct “Virtual Permittings” of projects that have already been permitted to get a handle on how they would process the permitting, given available information about the projects and available codes and standards.

- Have the participants develop local permitting pathway guides for their use.

- Identify critical issues associated with the permitting process that need to be addressed by the Department of Energy, in order to facilitate the permitting process (i.e., make it efficient, both in terms of time and expense).

- Provide participants with the opportunity to articulate codes and standards gaps or conflicts (if any) that need to be addressed.

- Raise the comfort level of the code official so that when they are presented with an application to construct a hydrogen motor fueling station in their jurisdiction.

An introduction to issues that can develop when applying codes and standards to projects utilizing hydrogen as an energy source, presentations were done on the use of stationary hydrogen fuel cells as a back up power supply at telecommunications equipment sites and on hydrogen as a motor fuel. The presentations were used as an avenue to identify the path a code official should take when applying the California edition of the International Building Codes along with related codes and standards and as an introduction to the properties of hydrogen as compared to other fuel gases commonly in use.

For the breakout sessions the participants were broken down into teams. Each team was assigned a motor fueling station and a telecommunications site review projects. This ensured that there would be sufficient diverse scenarios for the allotted times and that the participants would be exposed to plans covering both HFS and telecommunication installations.

The resources provided to each team included the following:

A set each of:

- International Code Council I-Codes
  - International Building Code
  - International Fire Code

- National Fire Protection Association
  - NFPA 853 Stationary Hydrogen Fuel Cells
  - NFPA 55 Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks 2006 edition
  - NFPA 70 National Electrical Code
  - NFPA 52 Standard for Motor Vehicle Service Stations

- Online access was provided to the DOE/NREL Hydrogen Permitting Website

Along with:

- A set of Site Layout Plans
- Note Pad Easel, Review Report Forms, Evaluation Forms, Pens and Scales

The Results

SECTION 4

4. The Results

The manner in which the teams were selected ensured that individuals had diverse qualifications and were diverse from the standpoint of regional influences on application of codes and standards. The workshop would be the first time they had worked with each other applying the code.

Teams can have a tendency to begin with a slightly disorganized or a shotgun approach to the plans with team's members picking up the different codes and standards and identifying issues to be addressed. It is a fairly common approach to dealing with hydrogen installations because most guidance documents simply list all of the codes and standards that may apply without providing a matrix of the path that should be followed to properly apply the technical requirements of the codes and standards. This approach also occurs because it is not uncommon to have a building code, fire code, mechanical code and/or electrical code official simultaneously reviewing their portions of an application to complete a review process.

However, because this workshop involved each official developing their own permitting guide the team members coalesced and agreed that the codes and standards needed to be applied in an orderly manner starting with the land use approval process then the building code and followed by the fire code. The fuel gas code and referenced standards would be applied subsequent to these two documents. This process was helped by the availability of the "Michigan Guide Boilerplate" document and the California version of the I-Code Path matrix that visual depicts the path through the various codes.

The structured approach ultimately applied by the separate teams wherein sections of the building code were noted with a path to a reference led all of the teams to identify loop backs wherein the code language pointed to another code section, only to find the referenced code section pointed back to the starting point. Some of these issues were pointed out in the introductory presentations.

Ultimately the teams did an excellent job of reviewing the assigned plans in a collaborative manner. Only minimal guidance was provided by the workshop facilitators. Reporting of results was thorough and well documented by all four teams, although none of the teams came out of the exercise with a customized code "pathway" for their jurisdiction.

Each team's final analysis and presentation included explanations on how they made their decisions, why they made the decisions they did, and what path took them to the next section of the code or to a referenced standard.

At the end of the workshop each participant was asked to complete an evaluation form. The evaluation asked the participants to rank their responses to four questions concerning expectations, increase in comfort level, increased understanding and whether or not they would recommend others to attend a similar workshop. In addition they were asked to share what they liked or disliked about the workshop and to provide recommendations for improvements.

The rankings provided by the participants were overwhelmingly positive and all those that commented responded that they would recommend participation in similar workshops to their peers.

Summary

S E C T I O N 5

5. Summary

The workshop was a success both from the standpoint of providing code officials with an understanding of how to apply the various codes and standards to an application to build a hydrogen motor-fuel station or a back up power installation for a telecommunications site, and in having the codes and standards methodically applied to a project in a manner that identified areas of concern that needed to be addressed. For code officials to feel comfortable dealing with these types of applications they need to believe they have an adequate knowledge of the issues involved and they need to be assured that the existing codes and standards adequately address safety in an effective manner.

This workshop gave a different assignment to the code officials present, i.e., they were asked to develop a permitting guide for their own jurisdiction that identified the agencies an application needed to be approved by, the order that application would move through those agencies and what codes and standards would be applied in that process. The purpose was to provide the participants with a tool to take back to their jurisdictions and apply should an application be made for the use of hydrogen as a fuel in their jurisdiction.

For the workshop to have been the success it was, all involved in the preparation had to perform their functions in an effective and timely manner. The management of the invitations, travel and accommodations for those attending, and scheduling of the facility for meeting rooms and refreshments are as important as the information gathering, material preparation and presentation of the workshop itself.

A failure of any one component, whether it was the lack of a room, missing or inaccurate piece of information, or the functioning of the workshop itself affects the experience of the participant and their assessment of the workshop as a whole.

When a team is assembled and contracted to develop and present a workshop it must include and agency or organization that has a proven track record organizing an event that includes travel, accommodations and leasing of conference space. When the participants arrive for the workshop everything must be organized and ready to go. Technical assistance must be available before and during the activity to address any audio visual equipment issues that come up.

The team must include firms, individuals or agencies familiar with the targeted topic to provide valid information and resources for use in the workshop. To be effective the information must be current, technically accurate and in a form that allows it to be understood and have a professional appearance.

And the team must include experienced educational presenters to develop the material and present or facilitate the workshop. Many otherwise well prepared presentations have failed when the presenter did not have the ability to communicate effectively with the audience.

The code officials that were invited to attend this workshop were all experienced in their field of endeavor. All are knowledgeable about codes and standards. Because of their backgrounds they were a challenging audience; one that requires a high content level and a high level of accuracy. They have the ability to immediately pick up on flaws, incorrect information or if a presenter is not being entirely open with their information.

Because the participants had such a high level of knowledge and experience, their positive response to the workshop and the information provided documents the quality and value of the workshop for the purpose of educating code officials on the topic of hydrogen motor-fuel stations and the safe use of hydrogen in general.

APPENDICES

Appendices
A-H

Permitting Hydrogen Fueling Stations and Hydrogen Fuel Cell Backup Power for Wireless Telecommunication Sites Workshop

California State University, Los Angeles, CA
August 25 – 26, 2006

FINAL ATTENDANCE LIST

Name	Title	Company
Alex Keros	Sr. Project Engineer	General Motors
Awet Teame	Fire Inspector	Beverly Hills Fire Department
Anthony Androsky	Deputy Executive Director	US Fuel Cell Council
Bill Elrick	Program Manager	California Fuel Cell Partnership
Bob Coale	SPECIAL PROJECTS MANAGER	Gladstien, Meandrose & Associates
Carl Rivkin	Senior Project Leader II	NREL
Carlos Urrutia	Member LACCD Energy Team	Los Angeles Community College District
Cecilia Kim	Plan Check Inspector	Beverly Hills Fire Department
Chad Blake	Sr. Project Leader	NREL
Chrishawn Morgan-Price		NASFM

David Blekhman		California State University, LA
David Kantor	Project Manager	CALSTART
Dirk Drossel	Fire Inspector	Burbank Fire Department
Douglas Myers	Sr. Plans Examiner	Pasadena Fire Department
Dr. Ray Shackelford	Professor Fire Protection Administration	California State University, LA
Eddie Vasquez	Fire and Life Safety Officer II	Department of General Services - Division of the State Architect, San Diego / Riverside Satellite Office
Frank J. Ledesma	Fire Captain	Los Angeles County Fire Department
Heather Drummond		Pasadena Fire Dept
Ikuya Yamashita		Honda R&D Americas
James Weckerle	HazMat Specialist	Pasadena Fire Dept
Jennifer Hamilton	Safety Officer	California Fuel Cell Partnership
Jim Glew	Fire Marshal	Santa Monica Fire Department
Jim Narva		NASFM
Joe McElvaney	Consultant	The DiCristina Group
John Johns		California State University, LA

Jon Bullock	Fire Inspector	Los Angeles City Fire Department
Jonathan Graham	Consultant	The DiCristina Group
Jordan McRobie	Regional Coordinator	California Fuel Cell Partnership
Jorge Martinez	Safety Analyst	City of Burbank
Ken Kraus		Los Angeles City Fire Department
Kevin Brady		California State University, LA
Mario Gonzales	Fire Inspector	Los Angeles County Fire Department
Mark Hedglin	Transportation Engineering - Mechanical	California Department of Transportation
Matt McClory	Advanced Technology Vehicles	Toyota Technical Center
McKinley Addy		California Energy Commission
Melanie Caton	Project Leader	NREL
Mike Kashuba	Staff Air Pollution Specialist	ARB
Mike Maxwell	Director of Applications Engineering	ReliOn, Inc.
Paul Buehler	Technical Consultant	Plug Power
Richard Kallman	Environmental Protection Specialist	City of Santa Fe Springs Department of Fire Rescue

Robert Burgess	Senior Engineer, Hydrogen Technologies & System Center	NREL
Sarab Singh	Facilities Planner/ Project Manager	California State University, LA
Steve Mathison		Honda R&D Americas
Steven W. Hoffman	Western Region Project Manager	Air Products and Chemicals, Inc
Virgil Seaman	Professor - Dept. Technology	California State University, LA

Permitting Hydrogen Fueling Stations and Hydrogen Fuel Cell Backup Power for Wireless Telecommunication Sites

DOE/CaFCP/NASFM Workshop
California State University
August 25 & 26, 2008

Antonio Ruiz
Technology Development Manager
U.S. Department of Energy
Hydrogen Program

DOE Hydrogen Safety, Codes and Standards Program Objectives

- Establish requirements for hydrogen codes and standards based on scientific data, modeling, and analysis
- Implement consensus national agenda on domestic and international codes and standards for hydrogen systems in commercial, residential, and transportation applications
- Facilitate permitting of retail hydrogen fueling stations and fuel cell installations for backup power in the US through education and outreach to state/local code officials
  - priority for FreedomCAR and Fuel Partnership and Hydrogen Technical Advisory Committee
  - need efficient, cost-effective permitting process based on collaboration among code officials, industry, and other key stakeholders

Jonathan4

Background: HFS Permitting Workshop

(Sacramento, February 1, 2007)

- Invited fire/building code officials, HFS developers from states where HFS located or likely to be located
- Perspectives of hydrogen fueling station (HFS) developers and code officials on permitting experience (case studies)
  - Shared lessons learned
    - Shell Benning Road HFS (Washington, DC, Office of Fire Marshall)
    - NextEnergy energy station (Michigan Dept. Environmental Quality)
    - Chevron AC Transit HFS (Oakland Fire Prevention Bureau)
- Key issues and barriers to timely and cost-effective permitting of HFS identified
- Recommendations to DOE on how it can facilitate permitting process for HFS
- Feedback on proposed DOE initiative

Background: HFS Permitting

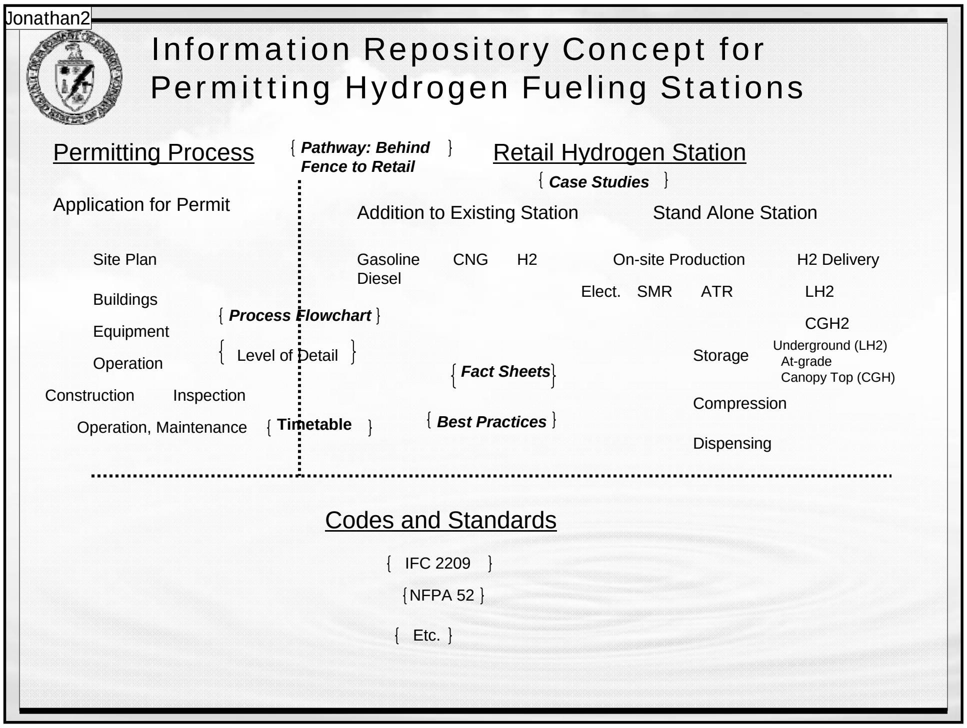
- Key Recommendations to DOE
  - Develop Information Repository for HFS with validated,"3rd party" data and information
  - Identify applicable codes & standards (specific safety requirements) and make them more accessible to permitting officials
  - Develop detailed Process Flowchart for permitting HFS
  - Develop Template for code officials to navigate permitting process
  - Note best practices for application of codes and standards for HFS
  - Develop fact sheets on hydrogen technologies/HFS equipment for permitting officials
  - Develop permitting pathway from "behind the fence" stations to retail stations
- Proceedings/presentations posted on NHA website (www.hydrogenandfuelcellsafety.info)

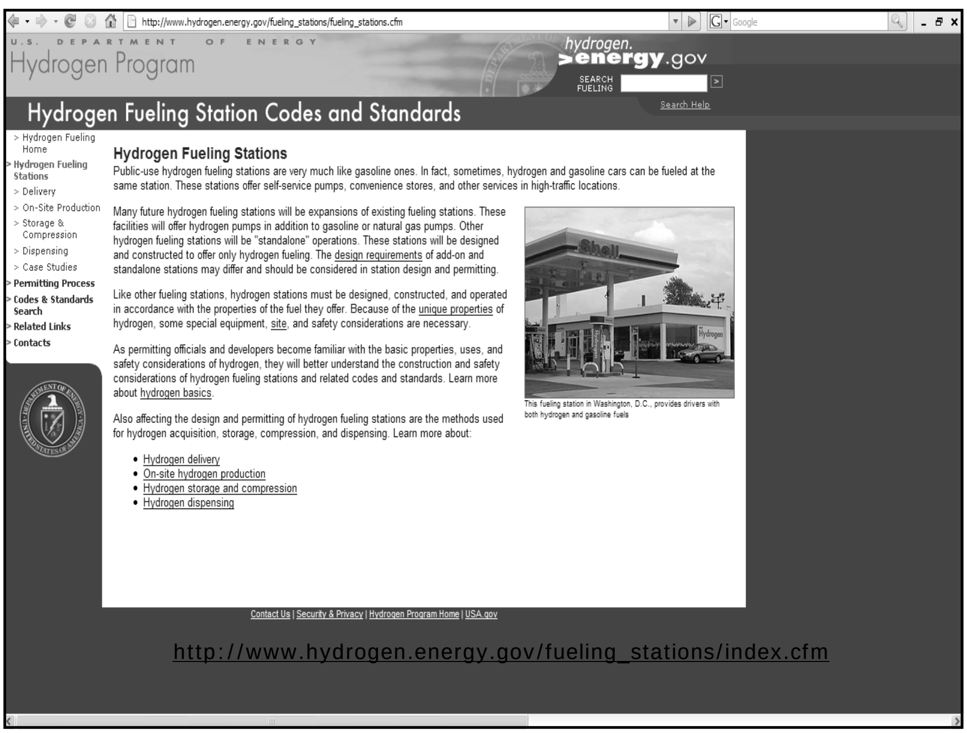
Permitting H2 Fueling Stations and Fuel Cell Installations: DOE Initiative

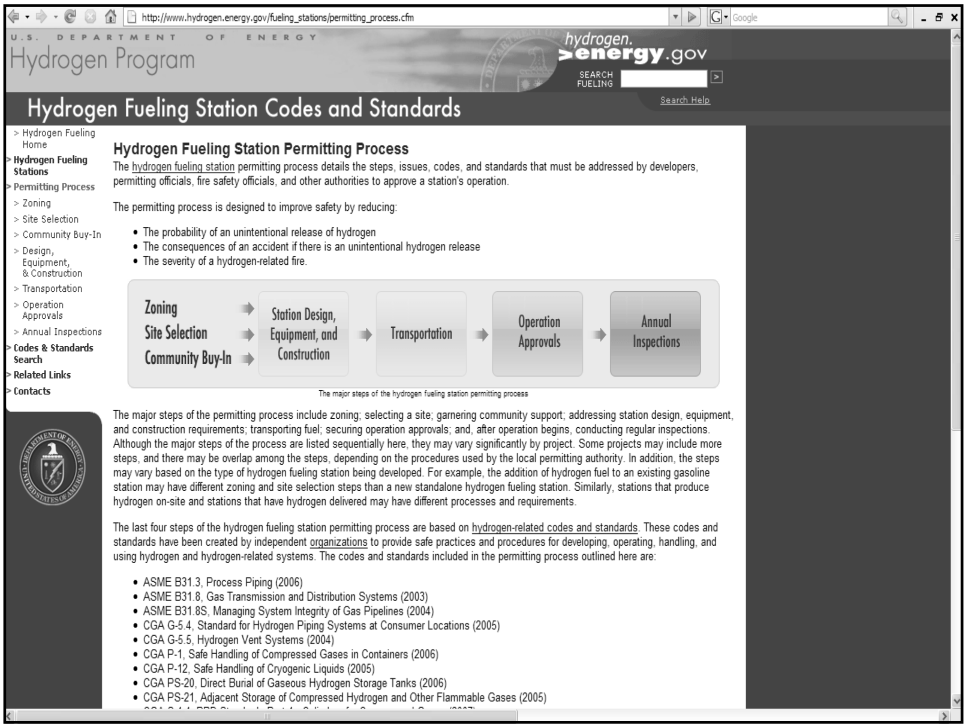
- Information Toolkit
  - Fact sheet(s)
    - basic information on hydrogen and FC installations (examples, codes/standards typically used, information sources)
  - Network chart
    - contact list of code officials whose jurisdictions have issued permits for hydrogen and FC installations
  - Flowchart of permitting requirements
    - web-based map to “navigate” requirements with database of key standards and codes
  - Permitting Compendium
    - web-based information source and database
- Education-outreach workshops for code officials
  - National workshops with NASFM and NCSBCS (planned)
    - vet case studies, C&S permitting process, information tools
  - Workshops in key regions
    - locations where industry will focus H_2 infrastructure development and hydrogen vehicle and fuel cell deployment

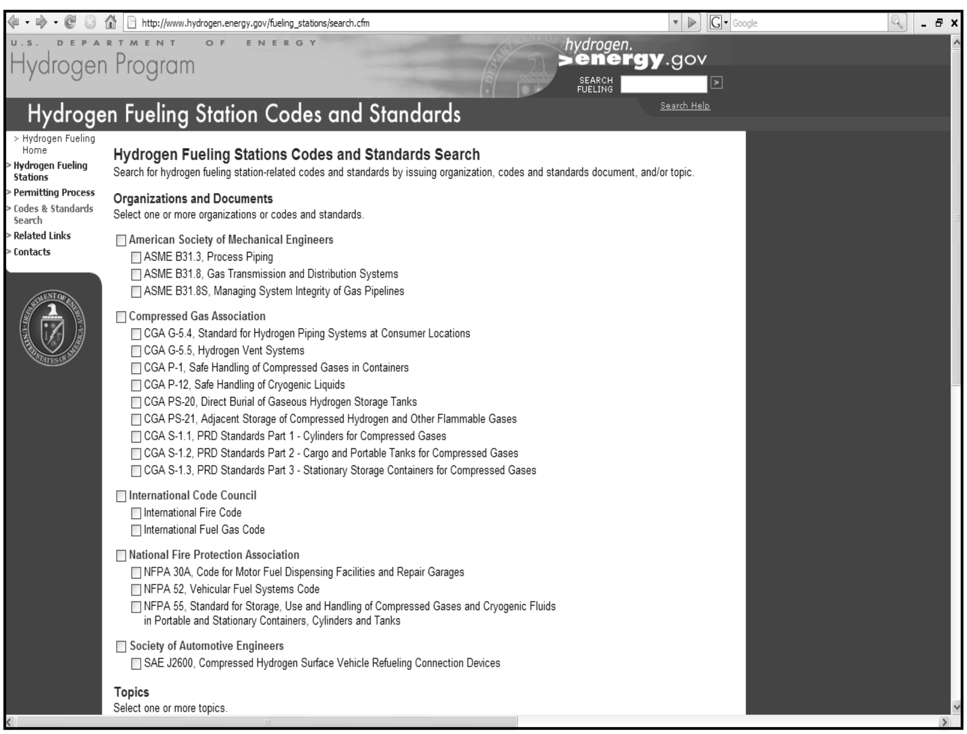
DOE/CaFCP/NASFM Workshop

- Objectives
  - Invite key fire and building code officials
    - present case studies
      - H2 stations and fuel cell installations permitted/permitting underway
      - codes/standards applied
    - review and discussion by permitting officials of case studies
    - recommendations to DOE on facilitating permitting process
  - Show information repository concept
    - web-based tools to “navigate” requirements with database of key standards and codes
    - recommendations to DOE on initiative and other steps
- Acknowledgements
  - CaFCP, NASFM, USFCC, Shell, GM, Plug Power, ReliOn
  - Mike Kashuba, Jim Narva, Chrishawn Morgan-Price, Allison Crowley, Carl Baust, Jim Glew, Ken Kraus


Jonathan2
Information Repository Concept for
Permitting Hydrogen Fueling Stations
Permitting Process
{ Pathway: Behind Fence to Retail }
Retail Hydrogen Station
{ Case Studies }
Application for Permit
Addition to Existing Station
Stand Alone Station
Site Plan
Gasoline Diesel
CNG
H2
On-site Production
H2 Delivery
Elect.
SMR
ATR
LH2
Buildings
{ Process Flowchart }
Equipment
CGH2
Operation
{ Level of Detail }
{ Fact Sheets }
Storage
Underground (LH2)
At-grade
Canopy Top (CGH)
Construction
Inspection
Compression
Operation, Maintenance
{ Timetable }
{ Best Practices }
Dispensing
Codes and Standards
{ IFC 2209 }
{ NFPA 52 }
{ Etc. }


http://www.hydrogen.energy.gov/fueling_stations/fueling_stations.cfm
U.S. DEPARTMENT OF ENERGY
Hydrogen Program
hydrogen.
energy.gov
SEARCH FUELING
Search Help
Hydrogen Fueling Station Codes and Standards
> Hydrogen Fueling Home
> Hydrogen Fueling Stations
> Delivery
> On-Site Production
> Storage & Compression
> Dispensing
> Case Studies
> Permitting Process
> Codes & Standards Search
> Related Links
> Contacts
Hydrogen Fueling Stations
Public-use hydrogen fueling stations are very much like gasoline ones. In fact, sometimes, hydrogen and gasoline cars can be fueled at the same station. These stations offer self-service pumps, convenience stores, and other services in high-traffic locations.
Many future hydrogen fueling stations will be expansions of existing fueling stations. These facilities will offer hydrogen pumps in addition to gasoline or natural gas pumps. Other hydrogen fueling stations will be "standalone" operations. These stations will be designed and constructed to offer only hydrogen fueling. The design requirements of add-on and standalone stations may differ and should be considered in station design and permitting.
Like other fueling stations, hydrogen stations must be designed, constructed, and operated in accordance with the properties of the fuel they offer. Because of the unique properties of hydrogen, some special equipment, site, and safety considerations are necessary.
As permitting officials and developers become familiar with the basic properties, uses, and safety considerations of hydrogen, they will better understand the construction and safety considerations of hydrogen fueling stations and related codes and standards. Learn more about hydrogen basics.
Also affecting the design and permitting of hydrogen fueling stations are the methods used for hydrogen acquisition, storage, compression, and dispensing. Learn more about:
Hydrogen delivery
On-site hydrogen production
Hydrogen storage and compression
Hydrogen dispensing
Shell
Hydrogen
This fueling station in Washington, D.C., provides drivers with both hydrogen and gasoline fuels
Contact Us | Security & Privacy | Hydrogen Program Home | USA.gov
http://www.hydrogen.energy.gov/fueling_stations/index.cfm


http://www.hydrogen.energy.gov/fueling_stations/permitting_process.cfm
U.S. DEPARTMENT OF ENERGY
Hydrogen Program
hydrogen.energy.gov
SEARCH FUELING
Search Help
Hydrogen Fueling Station Codes and Standards
> Hydrogen Fueling Home
> Hydrogen Fueling Stations
> Permitting Process
> Zoning
> Site Selection
> Community Buy-In
> Design, Equipment, & Construction
> Transportation
> Operation Approvals
> Annual Inspections
> Codes & Standards Search
> Related Links
> Contacts
Hydrogen Fueling Station Permitting Process
The hydrogen fueling station permitting process details the steps, issues, codes, and standards that must be addressed by developers, permitting officials, fire safety officials, and other authorities to approve a station's operation.
The permitting process is designed to improve safety by reducing:
• The probability of an unintentional release of hydrogen
• The consequences of an accident if there is an unintentional hydrogen release
• The severity of a hydrogen-related fire.
Zoning
Site Selection
Community Buy-In
Station Design, Equipment, and Construction
Transportation
Operation Approvals
Annual Inspections
The major steps of the hydrogen fueling station permitting process
The major steps of the permitting process include zoning; selecting a site; garnering community support; addressing station design, equipment, and construction requirements; transporting fuel; securing operation approvals; and, after operation begins, conducting regular inspections. Although the major steps of the process are listed sequentially here, they may vary significantly by project. Some projects may include more steps, and there may be overlap among the steps, depending on the procedures used by the local permitting authority. In addition, the steps may vary based on the type of hydrogen fueling station being developed. For example, the addition of hydrogen fuel to an existing gasoline station may have different zoning and site selection steps than a new standalone hydrogen fueling station. Similarly, stations that produce hydrogen on-site and stations that have hydrogen delivered may have different processes and requirements.
The last four steps of the hydrogen fueling station permitting process are based on hydrogen-related codes and standards. These codes and standards have been created by independent organizations to provide safe practices and procedures for developing, operating, handling, and using hydrogen and hydrogen-related systems. The codes and standards included in the permitting process outlined here are:
• ASME B31.3, Process Piping (2006)
• ASME B31.8, Gas Transmission and Distribution Systems (2003)
• ASME B31.8S, Managing System Integrity of Gas Pipelines (2004)
• CGA G-5.4, Standard for Hydrogen Piping Systems at Consumer Locations (2005)
• CGA G-5.5, Hydrogen Vent Systems (2004)
• CGA P-1, Safe Handling of Compressed Gases in Containers (2006)
• CGA P-12, Safe Handling of Cryogenic Liquids (2005)
• CGA PS-20, Direct Burial of Gaseous Hydrogen Storage Tanks (2006)
• CGA PS-21, Adjacent Storage of Compressed Hydrogen and Other Flammable Gases (2005)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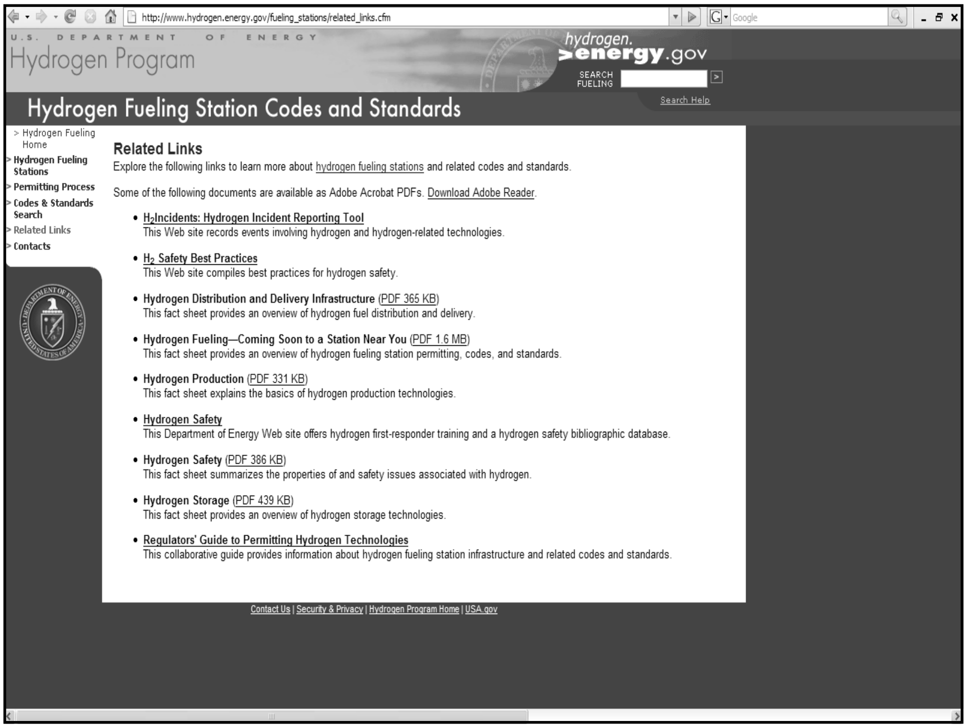
U.S. DEPARTMENT OF ENERGY
Hydrogen Program
hydrogen.energy.gov
SEARCH FUELING
Search Help
Hydrogen Fueling Station Codes and Standards
> Hydrogen Fueling Home
> Hydrogen Fueling Stations
> Permitting Process
> Codes & Standards Search
> Related Links
> Contacts
Hydrogen Fueling Stations Codes and Standards Search
Search for hydrogen fueling station-related codes and standards by issuing organization, codes and standards document, and/or topic.
Organizations and Documents
Select one or more organizations or codes and standards.
American Society of Mechanical Engineers
ASME B31.3, Process Piping
ASME B31.8, Gas Transmission and Distribution Systems
ASME B31.8S, Managing System Integrity of Gas Pipelines
Compressed Gas Association
CGA G-5.4, Standard for Hydrogen Piping Systems at Consumer Locations
CGA G-5.5, Hydrogen Vent Systems
CGA P-1, Safe Handling of Compressed Gases in Containers
CGA P-12, Safe Handling of Cryogenic Liquids
CGA PS-20, Direct Burial of Gaseous Hydrogen Storage Tanks
CGA PS-21, Adjacent Storage of Compressed Hydrogen and Other Flammable Gases
CGA S-1.1, PRD Standards Part 1 - Cylinders for Compressed Gases
CGA S-1.2, PRD Standards Part 2 - Cargo and Portable Tanks for Compressed Gases
CGA S-1.3, PRD Standards Part 3 - Stationary Storage Containers for Compressed Gases
International Code Council
International Fire Code
International Fuel Gas Code
National Fire Protection Association
NFPA 30A, Code for Motor Fuel Dispensing Facilities and Repair Garages
NFPA 52, Vehicular Fuel Systems Code
NFPA 55, Standard for Storage, Use and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders and Tanks
Society of Automotive Engineers
SAE J2600, Compressed Hydrogen Surface Vehicle Refueling Connection Devices
Topics
Select one or more topics.



Jonathan3

Next Steps

- DOE-NASFM workshop results
  - Post presentations and notes
  - Summarize recommendations from breakout sessions
  - Incorporate recommendations into DOE initiative
- DOE regional workshops
  - Similar purpose, agenda, format as DOE-NASFM workshop
  - Areas of focus by HFS developers, auto OEMs, telecom industry, fuel cell manufacturers
  - Emphasize regional/local permitting issues
- HFS Permitting Website
  - Launched in February 2008
- H2 Fuel Cell/Telecom Permitting Website
  - Launch June 2008

Thank You!

www.hydrogen.energy.gov

Antonio Ruiz
antonio.ruiz@ee.doe.gov
(202) 586-0729

Hydrogen

Properties – Generation – Distribution - Uses

PRESENTATION FOR

US BUILDING OFFICIALS

US CODE OFFICIALS

US FIRE MARSHALS

1

Hydrogen Facts

- Hydrogen (H) is the first element in the periodic table of elements. It consists of one proton and one electron.
- Molecular hydrogen (H_2) is a small, simple molecule consisting of two protons and two electrons.
- Hydrogen is not commonly found in its pure form on Earth since it readily combines with other elements.

2

Hydrogen Properties

US Fuel Cell Council

Physical Constants

H_2 Molecular weight	2
Density (70°F, 1 atm)	0.00521 lbm/ft^3
Specific Gravity (70°F, 1 atm)	0.0696 (~$^1/_{14}$ of air)
Boiling point	-423°F (~37 R)
Melting point	-435°F (~25 R)
Energy Content (Lower Heating Value at 70°F, 1 atm)	51,555 Btu/lbm 268.6 Btu/ft^3

Sources: CGA G-5, Hydrogen, 6th Edition; 2005

3

Hydrogen Properties

US Fuel Cell Council

Hydrogen has some interesting physical properties:

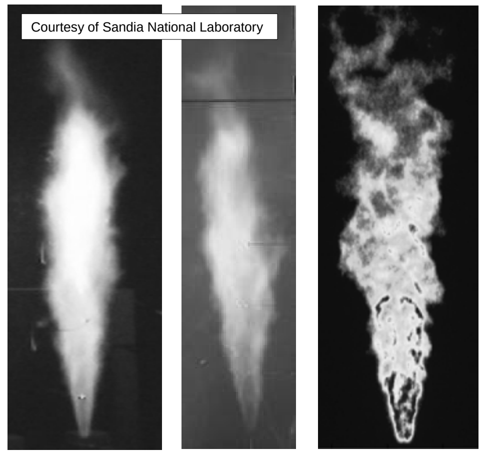
- Non-toxic
- Asphyxiant
- Odorless and Tasteless
- *Burns with a pale-blue, almost-invisible flame (DOE)*
- Burning hydrogen produces no carbon dioxide, particulate, or sulfur emissions. It can produce nitrous oxide (NOX) emissions under some conditions. (DOE)

4

Hydrogen Properties

- A pure hydrogen flame is a pale blue color and is difficult to see in sunlight.
- Impurities in the air reacting with the hydrogen may make the flame more visible

Visible IR UV



30 msec exposures 100 μsec exposure

5

Hydrogen Properties

Some Hydrogen properties present a challenge:

- Easily ignited
- Wide flammability and explosive ranges
- Permeable through many materials
- Hydrogen can cause embrittlement of some metals.
- Some polymers are not compatible with hydrogen.
- *Low energy content (by volume)*
- *Low emissivity ("almost invisible flame" and low radiant heat transfer)*

6

Hydrogen Properties

US Fuel Cell Council

Some Hydrogen properties make it easier to work with:

- *Low energy content (by volume)*
- *Low emissivity (low radiant heat transfer)*
- Highly diffusible (disperses quickly)
- Very buoyant
- Easily managed by ventilation

7

Hydrogen Properties

US Fuel Cell Council

***One of the uses of hydrogen is as a fuel gas*.**

As with other fuel gases, *it is to be respected but not feared!*

Hydrogen is similar to but not identical with other fuel gases.

DOE maintains a source of hydrogen incident data at www.h2incidents.org .

Hydrogen Safety updates and information can be found at www.hydrogensafety.info .

The next few slides compare hydrogen to other common fuel gases.

8

Hydrogen Properties

US Fuel Cell Council

	Hydrogen	Natural Gas	Gasoline
	4 / 0 / 0	4 / 1 / 0	3 / 1 / 0
Color	No	No	Yes
Toxicity	None	Some	High
Odor	Odorless	Mercaptan	Yes
Buoyancy Relative to Air	14X Lighter	2X Lighter	3.75X **Heavier**
Diffusivity Relative to Gasoline	~20X Gasoline	~5x Gasoline	0.2cm3/sec
Energy by Weight	2.8X **>** Gasoline	~1.2X **>** Gasoline	43 MJ/kg
Energy by Volume	4X to 10X**<** Gasoline	1.5X **<** Gasoline	120 MJ/Gallon

Hydrogen Properties

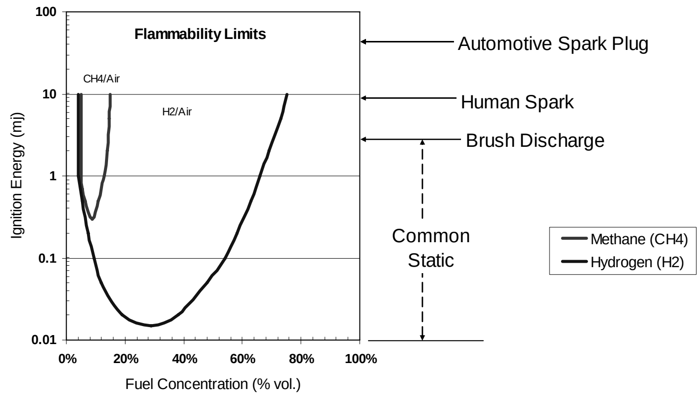
US Fuel Cell Council

	Hydrogen	Natural Gas	Gasoline
	4 / 0 / 0	4 / 1 / 0	3 / 1 / 0
Flammability in air (LFL – UFL)	4.1% - 74%	5.3% - 15%	1.4% - 7.6%
Explosive limits in air (LEL – UEL)	18.3% - 59%	5.7% - 14%	1.4% - 3.3%
Fuel/Air Stoichiometry (complete combustion)	29%	9%	2%
Auto Ignition Temperature (F)	968	1166	437
Flame temperature (F)	3700	3400	4000
Radiant Heat Transfer From Flame	1/10 Gasoline	~ Gasoline	Gasoline

Anthony Androsky
US Fuel Cell Council

Hydrogen Properties

Ignition Energy as a function of Mixture



Air Products Presentation dates 1998 June 12, p. 12

11

Hydrogen Properties

Sources for information on hydrogen properties used in slides 9-12:

- Bulletin 503, US Bureau of Mines, Limits of Flammability of Gases and Vapor; Coward and Jones 1952
- Bulletin 627, US Bureau of Mines, Flammability Characteristics of Combustible of Gases and Vapor; Zabetakis,1965
- CGA G-5, Hydrogen, 6th Edition, 2005
- Engineering Manual, 2nd Edition; Robert. H. Perry, 1967
- NFPA 497, Recommended Practice for the Classification of Flammable Liquids, Gases or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas; 1997
- NASA NSS 1740.16, Safety Standard for Hydrogen and Hydrogen Systems

12

Hydrogen Generation

US Fuel Cell Council

- Hydrogen can be generated at a central plant or locally at the point of use. It can be generated by a number of methods. Some of these methods include:
  - Reforming of Hydrocarbon Fuels
  - Splitting of water using electricity (electrolysis)
  - Gasification of fossil fuels (e.g. coal)
- The most common method of generating hydrogen is steam methane reforming (SMR) of natural gas. Steam methane reforming accounts for 95% of the hydrogen produced in the U.S. (DOE).
- The most common methods for the local point-of-use generation of hydrogen are:
  - Steam methane reforming
  - Electrolysis

13

Transport to Site

US Fuel Cell Council

Hydrogen can be generated on-site (distributed generation) or at a remote location (central generation) and transported.

- Hydrogen generated on-site for use on-site is typically stored as a compressed gas since liquefaction is not needed and liquefaction is costly.

- Hydrogen generated off-site may be delivered as a liquid or as a gas depending upon the economies of transportation and liquefaction. Delivery is typically based on the method of storage.

14

On-site Storage

US Fuel Cell Council

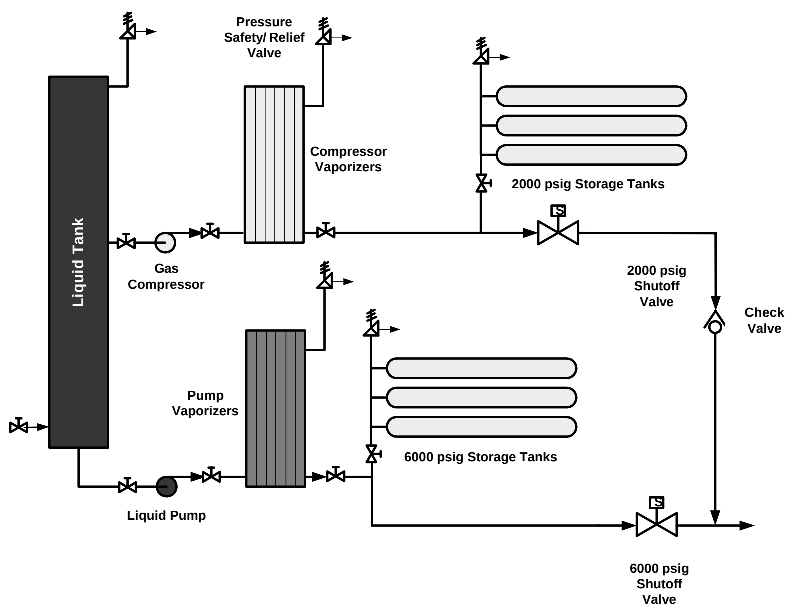
Liquid Storage

- Hydrogen is stored at very low temperatures (–) 423°F
- Each major component typically has isolation valves.
- Each major component with significant inventory has a pressure actuated safety relief valve.

15

On-Site Storage

US Fuel Cell Council



16

On-site Storage

US Fuel Cell Council

Liquid Storage

- Major components are typically designed per the ASME Boiler and Pressure Vessel Code
- Piping is designed per the appropriate ASME piping code (B31.1, B31.3, B31.12). The decision to use a particular design standard is made based on prior experience and precedent within the particular industry doing the design. All of these standards provide conservative designs that are practically interchangeable.
- NFPA 55 (was NFPA 50B) or the International Fire Code Chapter 34 is usually followed for liquid storage sites.

17

On-site Storage

US Fuel Cell Council

Liquid Storage

- The Compressed Gas Association has a number of well written guidelines and recommended practices. Examples include:
  - CGA G5.4 - Hydrogen Piping Systems at Customer Sites
  - CGA G5.5 - Hydrogen Vent Systems
  - CGA H3 - Cryogenic Hydrogen Storage

18

On-site Storage

US Fuel Cell Council

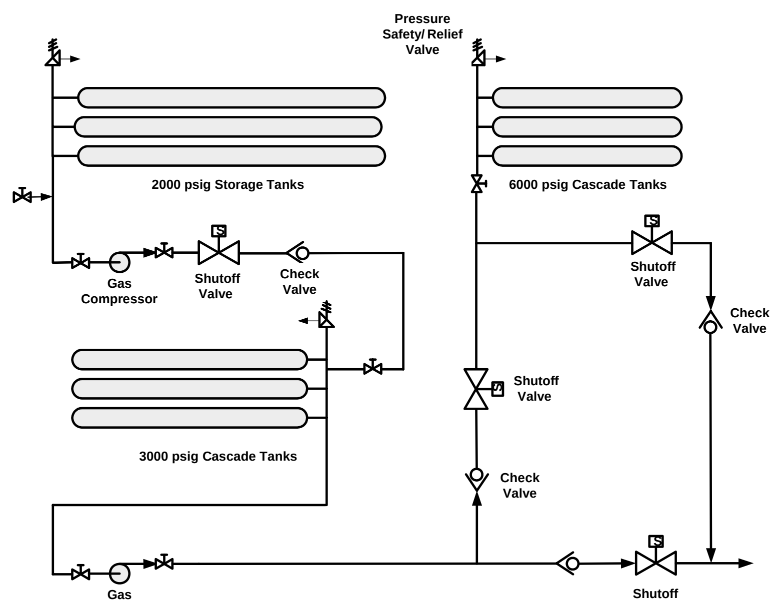
Gaseous Storage.

- Each major component typically has isolation valves.
- Each major component with relatively large inventory typically has a pressure actuated safety relief valve.
- Several pressure stages may exist.

19

On-Site Storage

US Fuel Cell Council



20

Anthony Androsky
US Fuel Cell Council

On-site Storage

Gaseous Storage.

- Major components are typically designed per the ASME Boiler and Pressure Vessel Code
- Piping is designed per the appropriate ASME piping code (B31.1, B31.3, B31.12). The decision to use a particular design standard is made based on prior experience and precedent within the particular industry doing the design. All of these standards provide conservative designs that are practically interchangeable.
- NFPA 55 (was NFPA 50A) or the International Fire Code Chapter 35 is usually followed for gaseous storage sites.

21

On-site Storage

Gaseous Storage.

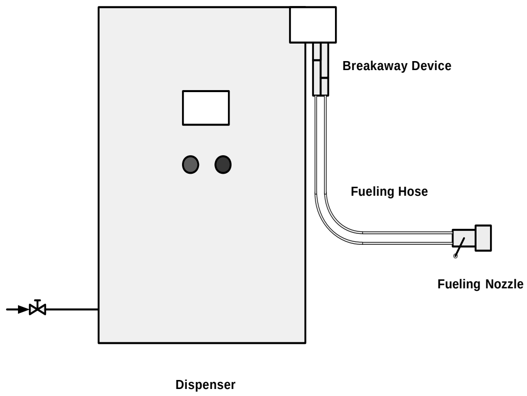
- The Compressed Gas Association has a number of well written guidelines and recommended practices. Examples include:
  - CGA G5.4 - Hydrogen Piping Systems at Customer Sites
  - CGA G5.5 - Hydrogen Vent Systems
  - CGA G5.6 - Hydrogen Pipeline Systems

22

US Fuel Cell Council

Dispenser

A dispenser system consists of four major components:



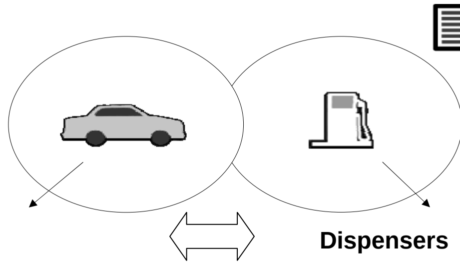
Dispenser

Breakaway Device

Fueling Hose

Fueling Nozzle

US Fuel Cell Council



Vehicles

- SAE J2578 – Vehicle Safety
- SAE J2600: 35 MPa Receptacle
- SAE J2601 Draft: – Communication & Targets
- SAE J2799: 70MPa Nozzle Report
- SAE J2719 & ISO/TS 14687-2:2008: Hydrogen Quality

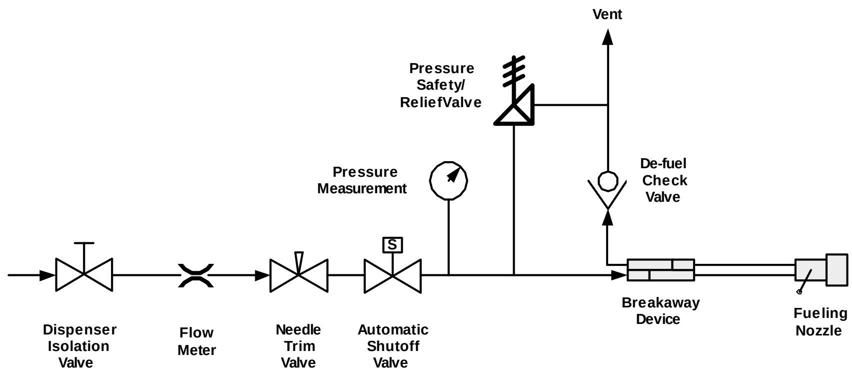
Dispensers

- CSA HGV 4.1 Draft – Hydrogen Dispensers
- SAE J2600: 35 MPa Nozzle
- CSA HGV 4.3: Draft – Dispenser Communication via SAE J2601
- HGV 4.2 Draft – Hose and Hose Assemblies
- SAE J2719 & ISO/TS 14687-2:2008: Hydrogen Quality
- HGV4.4 Draft– Breakaway Devices
- Local and State Regulations:
    - Dispenser Accuracy, Grounding, PRV Setting, Permits

Anthony Androsky
US Fuel Cell Council

Dispenser

US Fuel Cell Council



25

Vehicle Storage

US Fuel Cell Council

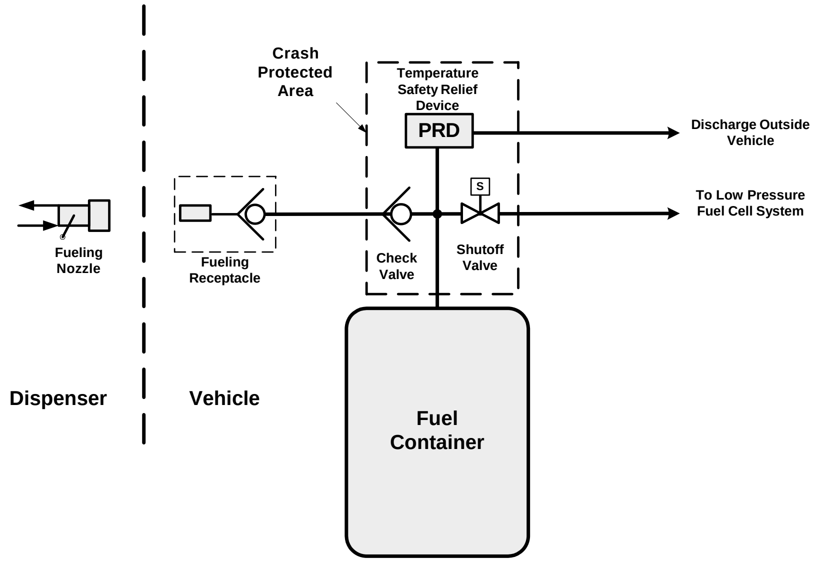
SAE and CSA are presently addressing storage on the vehicle. Storage is at 350 bar (5000 psi) or 700 bar (10,000 psi).

The storage system is relatively simple.

- Check Valve(s)
- Tank
- Shut off Valve
- Temperature Activated Pressure Relief Valve (PRD)

26

Dispenser



27

Hydrogen Fueling Stations

Designed using one or more of the following:

- NFPA 52
- International Fire Code Chapter 22
- ASME Boiler and Pressure Vessel Code
- ASME B31.1, B31.3, B31.12
- NFPA 55

Storage may be liquid or gaseous hydrogen.

Dispensing can be liquid or gaseous.

Permitting guidance can be found here:
http://www.hydrogen.energy.gov/fueling_stations/permitting_process.cfm

28

Fueling Stations

US Fuel Cell Council

Hydrogen Fueling Station in
Oakland, California
Courtesy of Chevron

Hydrogen Fueling Station in
Washington, DC
Courtesy of General Motors

29

Fuel Cells

US Fuel Cell Council

What is a fuel cell?

A fuel cell generates electricity efficiently and cleanly without combustion. A chemical reaction between a fuel supply and oxygen produces direct current electricity inside the fuel cell. The fuel cell will stop running when the fuel supply is depleted or shut off.

Fuel cells on the space shuttle use bottled oxygen and hydrogen as fuel and make water for the astronauts to drink. For our systems, oxygen from the air is used.

30

Fuel Cells

US Fuel Cell Council

What parts make up a fuel cell?

A fuel cell, like a battery, is a string of cells. Each cell consists of:

- an anode electrode
- an anode fuel distributor
- an electrolyte
- a cathode electrode
- a cathode fuel distributor
- a heat removal device

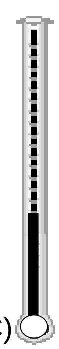
A fuel cell needs fuel to run. Fuel can be provided in many ways, and is fed to the fuel cell in order for the chemical reaction to take place, which provides electricity.

31

US Fuel Cell Council

Fuel Cell Technologies

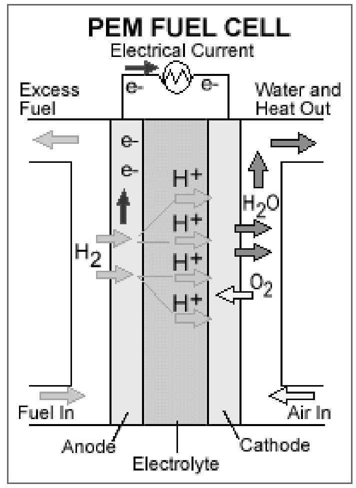
Type	Efficiency	Operating Temp.
Solid Oxide	45-65%	~1500°F (~800°C)
Molten Carbonate	50%	~1200°F (~650°C)
Phosphoric Acid	40%	~400°F (~200°C)
Alkaline	50-60%	~180°F (~ 80°C)
Direct Methanol	40%	Up to180°F (80°C)
Proton Exchange Membrane (PEM)	40%	Up to 240°F (120°C)



32

PEM Fuel Cells

PEM cells are being commercialized and typically operate between ambient room temperature and 250ºF (120ºC).



Courtesy of DOE

33

Fuel Cell Vehicles

Courtesy of General Motors and US Postal Service

Courtesy of Ballard

Courtesy of Hydrogenics

Courtesy of DaimlerChrysler

34

US Fuel Cell Council

Light Commercial/Backup Utilizing H2 Storage

Outdoor installation of power plant and fuel supply
Courtesy of Plug Power

Telecommunications backup power
Courtesy of ReliOn

Extended run backup power for telecommunications
Courtesy of IdaTech

Indoor Rack mounted installation of power plant without fuel supply
Courtesy of UTC Power

35

US Fuel Cell Council

24 x 7 Reliable Large Industrial Scale Fuel Cell Power

Sierra Nevada Brewery
Chico, California
Courtesy of FuelCell Energy

- 1MW (250kW x 4) Net Output
- Runs on a blend of digester gas and natural gas
- Connected in parallel with electric grid
- Provides 95% of the electrical requirements for the brewery
- Heat recovery provides about 65% of the hot water/steam requirements

36

Micro / Portable Applications

Angstrom Power Cell Phones
Courtesy of Angstrom Power

Jadoo Power System
Courtesy of Jadoo Power

37

Installation

What product standards exist for fuel cells?

- Stationary Fuel Cells are built and listed to ANSI/CSA FC1.
- Portable Fuel Cells have been listed to ANSI/CSA FC3.
- Micro Fuel Cells have been listed to UL 2265A and UL 2265C.
- International Civil Aviation Organization Technical Instructions and the relevant country regulations for aircraft passenger carry-on. require certification to IEC 62282-6-1.
- Fork Truck Fuel Cells are built and listed to UL 2267.
- International product standards are also published.

Refer to the following websites for details and status:

- www.usfcc.com/about/standards.html
- www.hydrogen.gov/regulations
- www.fuelcellstandards.com
- www1.eere.energy.gov/hydrogenandfuelcells/

38

Installation

US Fuel Cell Council

What model code requirements exist for fuel cells?

In all cases, the regulations in force at the installation site and the local building officials have the final say on all requirements.

For model codes, the ICC uses the rule set from NFPA (harmonized between both) as indicated by IMC-2006 Section 924. This section indicates that the fuel cell is to be tested to ANSI FC-1 and installed to NFPA 853.

NFPA 853 specifically deals with physical positioning, fuel safety, ventilation, exhaust and fire protection. The electrical connections are addressed by reference to NFPA 70 article 692. H2 storage is addressed by reference to NFPA 55.

Air intake and ventilation exhausts are addressed by ANSI FC-1 (for small units) or NFPA 211 (for large custom installations) and NFPA 853.

More information is available from the National Association of State Fire Marshals www.nasfmhydrogen.com/ and www. Fuelcellstandards.com

39

US Fuel Cell Council

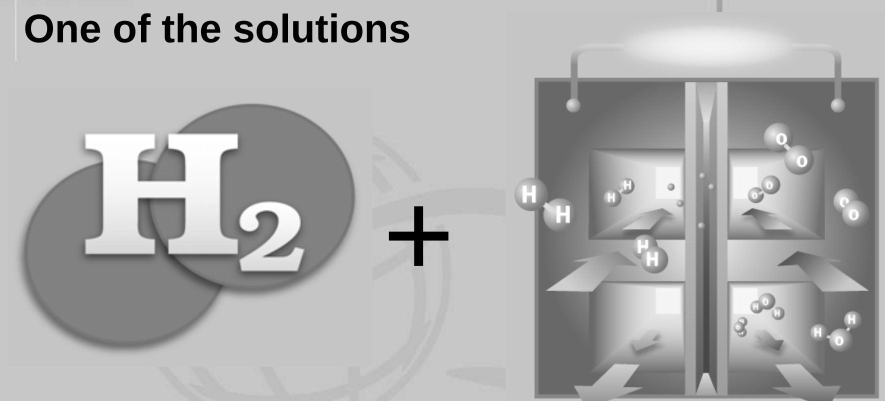
US Fuel Cell Council
1100 H St, NW
Suite 800
Washington, DC 20005
T. 202.293.5500
F. 202.785.4313
www.usfcc.com

40

Hydrogen Safety

Jennifer Hamilton
Safety Officer
CSULA, August 25, 2008

One of the solutions



- Improved vehicle performance
- Energy independence
- Zero-emission transportation
- Reduced greenhouse gases

Why hydrogen?

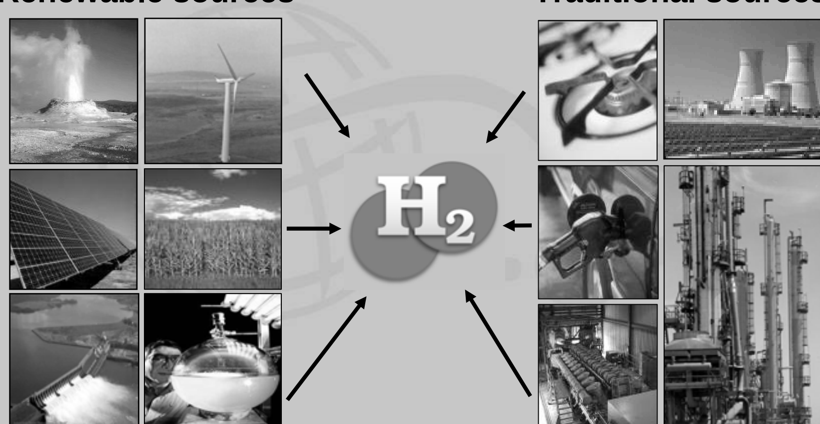
Hydrogen is the most abundant element in the universe

- Is an excellent energy carrier
- Nonpolluting
- Economically competitive
- As safe as gasoline
- Used safely for over 50 years
- Produced in any country from a variety of energy sources

California Fuel Cell Partnership

Where do we get H_2?

Renewable sources **Traditional sources**



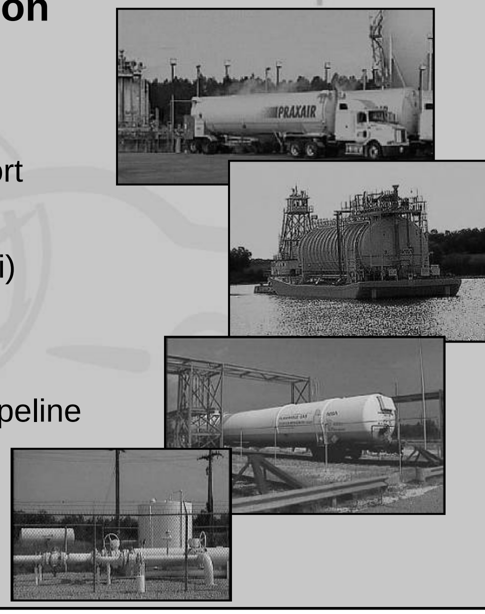
Solar, wind, geothermal, hydro, biomass, algae

Natural gas, methane, gasoline, nuclear, coal

Hydrogen distribution

DOT approved…

- Cryogenic liquid transport
  - -423°F (-253°C)
  - Low pressure (<100 psi)
- Pressurized gas trailers
  - Approx. 2,000psi
- Truck, rail, barge and pipeline



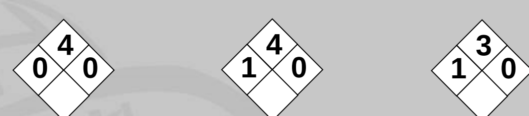
Gas properties & characteristics

- Displaces O2 (Asphyxiant)
- Burns with a pale blue flame
  - – near invisible in daylight (<u>can see what it burns</u>)
  - – 1/10th radiant heat of gasoline fire

Comparison of properties

	Hydrogen	Natural Gas	Gasoline
Color	No	No	Yes
Toxicity	None	Some	High
Odor	Odorless	Mercaptan	Yes
Buoyancy Relative to Air	14X Lighter	2X Lighter	3.75X Heavier
Energy by Weight	2.8X **>** Gasoline	~1.2X **>** Gasoline	43 MJ/kg
Energy by Volume	4X **<** Gasoline	1.5X **<** Gasoline	120 MJ/Gallon

Comparison of flammability



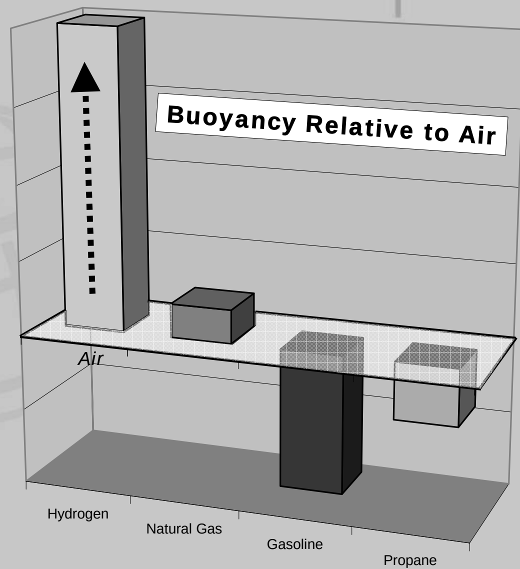
	Hydrogen	Natural Gas	Gasoline
Flammability in air (LFL – UFL)	4.1% - 74%	5.3% - 15%	1.4% - 7.6%
Explosive limits in air (LEL – UEL)	18.3% - 59%	5.7% - 14%	1.4% - 3.3%
Most easily ignited mixture in air	29%	9%	2%
Flame temperature (°C)	2045	1875	2197

California FUEL CELL PARTNERSHIP

How fast does it rise?

"Hydrogen rises 2 times faster than helium and 6 times faster than natural gas, at a speed of almost 45 mph (20m/s)."

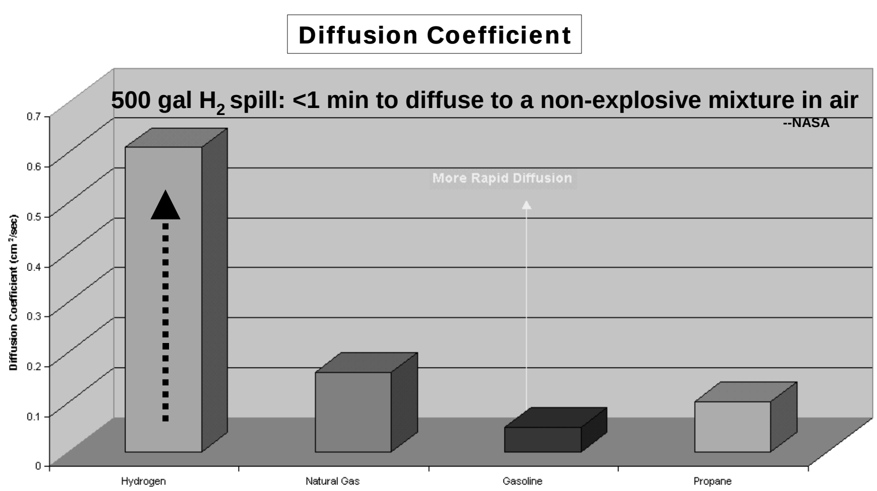
--National Hydrogen Association; Hydrogen Safety Fact Sheet



Courtesy of Ballard

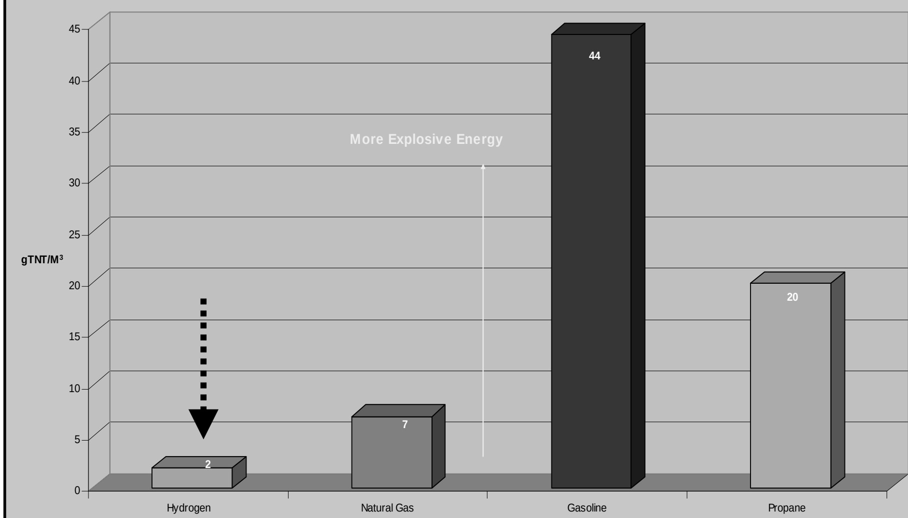
California FUEL CELL PARTNERSHIP

How quickly does it disperse?



Courtesy of Ballard

How explosive is it?



Courtesy of Ballard

Other resources for hydrogen safety

- US DOE hydrogen safety http://www.hydrogen.energy.gov/safety.html
- Hydrogen Best Practices http://h2bestpractices.org/
- National Hydrogen Association http://www.hydrogenandfuelcellsafety.info/

- CaFCP ER Website - www.er.cafcp.org

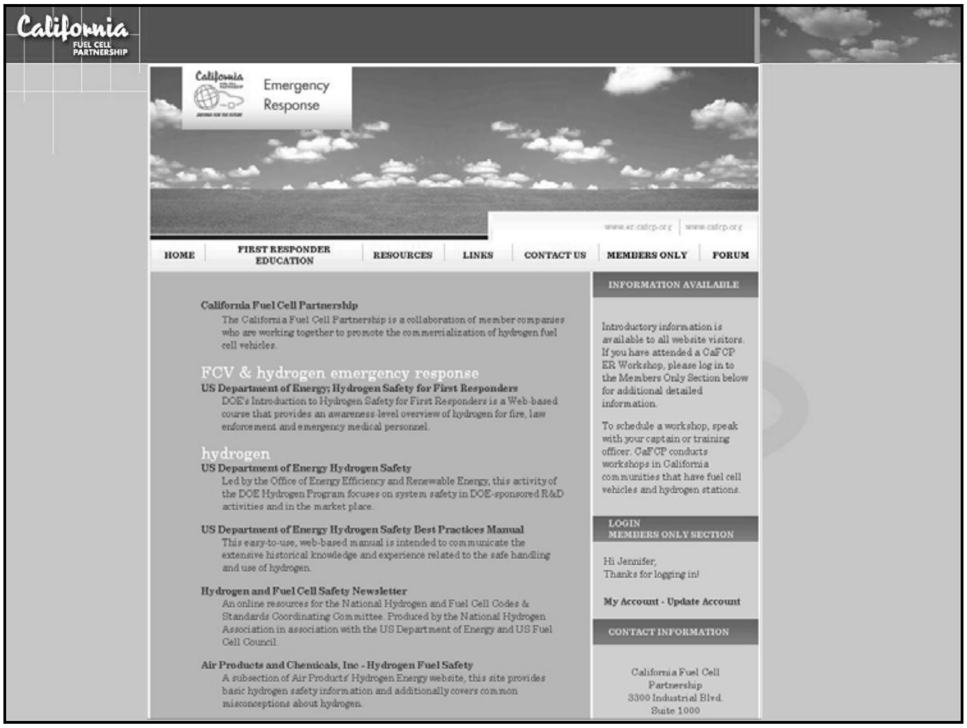
Hydrogen Vehicle Fire Department Concerns

Carl Baust, P.E., SET
Orange County (CA) Fire Authority

Cal State LA
Los Angeles, California
August 25, 2008

Purpose: Illustrate Fire Safety Aspects of H2 Vehicles and Stations

- **Basic Concepts**
- **Regulator Issues**
- **Responder Awareness**


California
FUEL CELL PARTNERSHIP
Emergency Response
www.er.cafcp.org
www.cafcp.org
HOME
FIRST RESPONDER EDUCATION
RESOURCES
LINKS
CONTACT US
MEMBERS ONLY
FORUM
California Fuel Cell Partnership
The California Fuel Cell Partnership is a collaboration of member companies who are working together to promote the commercialization of hydrogen fuel cell vehicles.
FCV & hydrogen emergency response
US Department of Energy; Hydrogen Safety for First Responders
DOE's Introduction to Hydrogen Safety for First Responders is a Web-based course that provides an awareness-level overview of hydrogen for fire, law enforcement and emergency medical personnel.
hydrogen
US Department of Energy Hydrogen Safety
Led by the Office of Energy Efficiency and Renewable Energy, this activity of the DOE Hydrogen Program focuses on system safety in DOE-sponsored R&D activities and in the market place.
US Department of Energy Hydrogen Safety Best Practices Manual
This easy-to-use, web-based manual is intended to communicate the extensive historical knowledge and experience related to the safe handling and use of hydrogen.
Hydrogen and Fuel Cell Safety Newsletter
An online resources for the National Hydrogen and Fuel Cell Codes & Standards Coordinating Committee. Produced by the National Hydrogen Association in association with the US Department of Energy and US Fuel Cell Council.
Air Products and Chemicals, Inc - Hydrogen Fuel Safety
A subsection of Air Products' Hydrogen Energy website, this site provides basic hydrogen safety information and additionally covers common misconceptions about hydrogen.
INFORMATION AVAILABLE
Introductory information is available to all website visitors. If you have attended a CaFCP ER Workshop, please log in to the Members Only Section below for additional detailed information.
To schedule a workshop, speak with your captain or training officer. CaFCP conducts workshops in California communities that have fuel cell vehicles and hydrogen stations.
LOGIN
MEMBERS ONLY SECTION
Hi Jennifer,
Thanks for logging in!
My Account - Update Account
CONTACT INFORMATION
California Fuel Cell Partnership
3300 Industrial Blvd.
Suite 1000

Basic Concepts

"Comparing hydrogen safety against conventional fuels yields no clear cut answers…hazards are far more influenced by circumstances than for other fuels."

1976 Stanford Research Institute Study

Basic Concepts

- **H2 Basics -** Wide Flammability Range, Low Ignition Energy, No Odor, Burns Invisibly*
  - **Energy Content: 60,958 Btu/lb (Highest)**
  - **Flammability limits: 4.1% -74% (Widest)**
  - **Explosion limits: 18.3% -59% (Widest)**
- **Today -** Industrial Processes and Specialty Applications
- **Tomorrow? -** Potential Production At Fuel Stations, Industries and Homes

***Attribute of non-carbon alternative fuels**

Basic Concepts

Property	Gasoline	Methane	Hydrogen
Flammability Limits In Air (vol	1.0 - 7.6	5.3 - 15.0	4.0 - 75.0
Ignition Energy In Air (Mj)	0.24	0.29	0.02
Ignition Temperature (°C)	228 - 471	540	585
Flame Temperature In Air (°C)	2197	1875	2045
Explosion Energy (g-TNT/kJ)	0.25	0.19	0.17
Flame Emissivity (%)	34 - 43	25 - 33	17 - 25

Basic Concepts

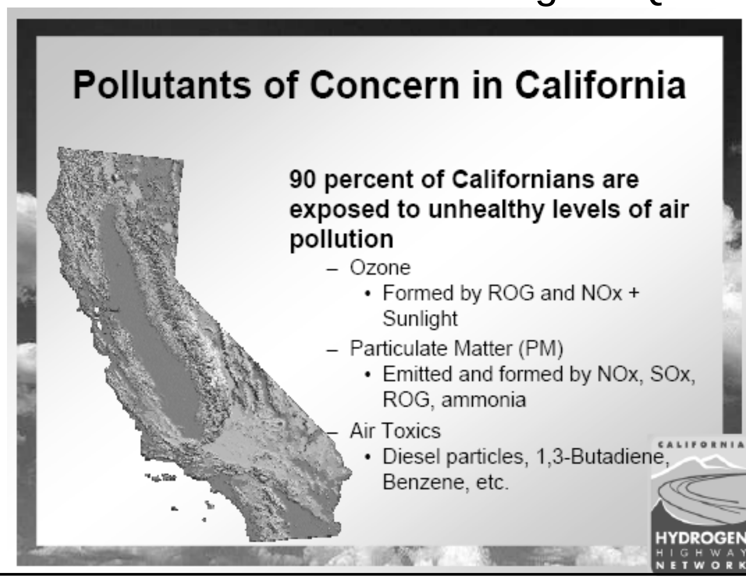
- **Large Experiment** – 1936 - Germany's Concern With An Imported Oil Supply

(About 1,000 Vehicles)

H2 is used in internal combustion engines

Basic Concepts

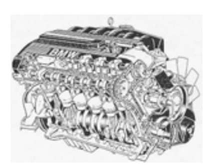
- **California Focus** – Worsening Air Quality



Basic Concepts

- **H2 Vehicles –** Fuel Cell, Hybrid and Internal Combustion Power Plants



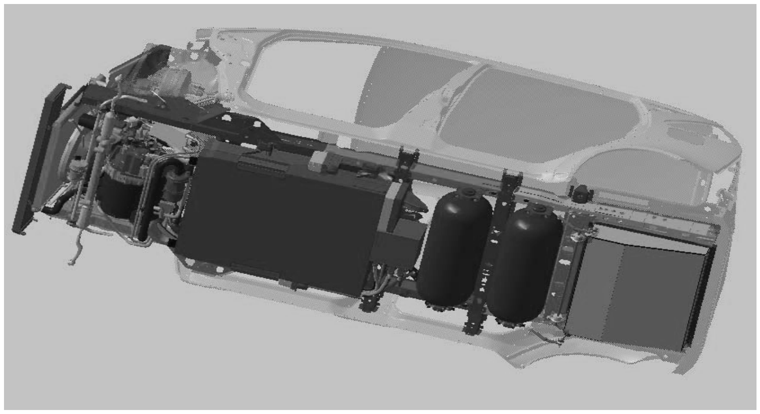


Maximum range is approximately 280 miles

H2 vehicles require H2 stations

Basic Concepts

- **Storage –** Gas Predominates



5,000 PSI is typical
10,000 PSI is in development
15,000 PSI Is being researched

Basic Concepts

- **Range –** Pushing Increased Storage

VOLUME | **WEIGHT**

8.4 gallons of gasoline = 990,000 BTUs of energy = 8.2 kilograms of hydrogen

Gasoline
49 lbs Fuel
60 lbs Fuel & Containment

Methanol
2.19 ft^3
105 lbs Fuel
125 lbs Fuel & Containment

Hydrogen Metal Hydride
12 ft^3
18 lbs Fuel
1,700 lbs Fuel & Containment

Hydrogen Gas at 3,600 PSI
17 ft^3
18 lbs Fuel
630 lbs Fuel & Containment

Hydrogen Gas at 5,000 PSI
13 ft^3
18 lbs Fuel
450 lbs Fuel & Containment

Liquid Hydrogen
18 lbs Fuel
161 lbs Fuel & Containment

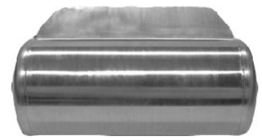
Legend:
Fuel Weight | Containment Weight
Total Weight

Basic Concepts

- Vehicle And Stationary Storage Tanks

Composite  **HP GH2**

Metal Hydride  **LP GH2**

Cryogenic  **LH2**

Vehicle storage affects H2 station design

Basic Concepts

- California Network Development

24 Stations Operating
14 Stations Planned
175 Fuel Cell Vehicles Operating
35 ICE Vehicles Operating

Regulator Issues

- **Community Selection –** Based On Air Pollution, Network Potential and Local Desires

Planning proposals have been well received

Stations are restricted access; city yards, research facilities and universities

Regulator Issues

Commercial Availability

Gasoline & Hydrogen Siting Comparison

Issue	Gasoline	Hydrogen
Time to Permit	3 months – 2 years	1 year – undefined
Zoning	Permitted / Restricted	Undefined
Design	Standard / Common Use	Custom Engr'd / One-Off
Effort to Site	.1 – .25 MY	1 – 2+ MY
NIMBY	Exception	Rule

"Hydrogen literacy" is reducing permitting difficulties

Regulator Issues

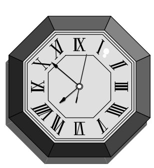
- **Building Department –** Reviews Structural, Mechanical, Electrical, etc., Applications

"Don't issue permits until we get fire approval!"

The fire department is designated the lead agency

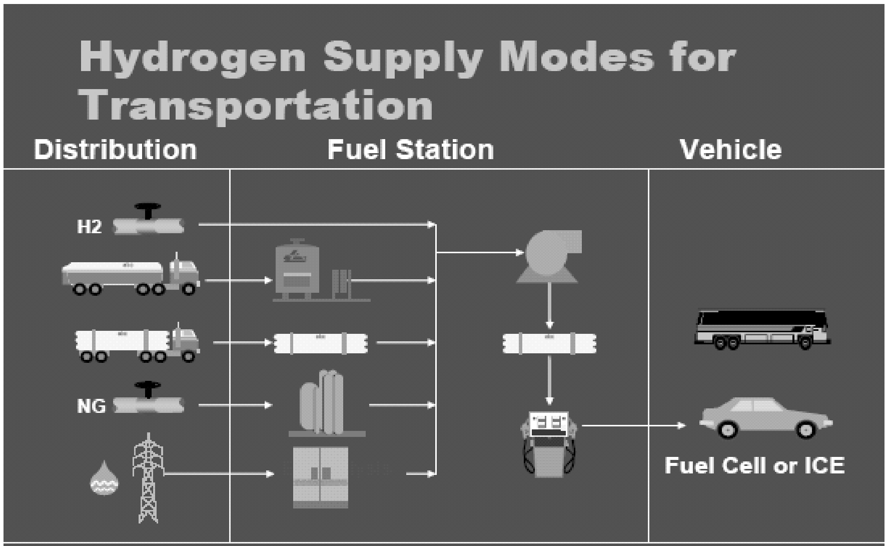
Regulator Issues

- **Fire Marshal –** Has Primary Responsibility For H2 Station Safety



An <u>early</u> meeting with the fire marshal is essential for a unified compliance strategy

Regulator Issues



Fuel is derived from a variety of sources / methods

Regulator Issues

- **H2 Stations** - Varied Considerations:

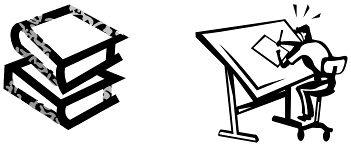
GH2? LH2? Delivered?
Electrolyzer? Gas Reforming?

Non-standardized designs complicate approvals

Regulator Issues

- **Commercial vs. Industrial –** Minimal Experience In Hydrogen Energy


- **Project Review -** New Regulations



H2 stations are storage <u>and</u> may be production facilities

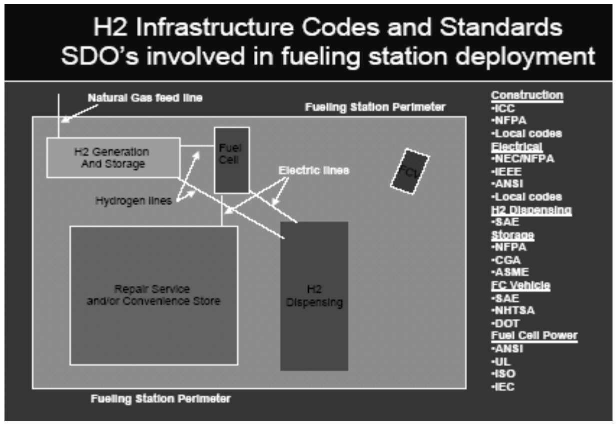
Regulator Issues

- **Related Experience –** LNG/CNG Provides Similar Challenges


OCFA is a pioneer in permitting landfill gas as a bus fuel

Regulator Issues

- **Codes & Standards Are In Progress**



Industrial clearances are difficult for H2 stations

Regulator Issues

- **Codes & Standards –** H2 Station Specific Provisions Are Arriving

Stations have used industrial-based standards
Recent installations are designed to International Codes and NFPA 52-2006

Regulator Issues

- H2 Codes & Standards -
  NFPA 52-2006 Revised For Hydrogen!

NFPA 52 Vehicle Fuel Systems Code
CSA America NGV2 Standards for Hydrogen Vehicle Fuel Containers
CSA America HGV 3 Fuel System Components for Hydrogen Gas Powered Vehicles
CSA America HGV 4 Series for Fuel Dispensing Equipment and Components
CSA America HPRD1 Basic Requirements for Pressure Relief Devices for Compressed H2 Vehicle Fuel Containers

Regulator Issues

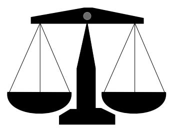
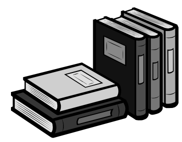
- H2 Codes & Standards

Hydrogen Transportation, Storage & Distribution
NFPA 55 Storage, Use and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders and Tanks.
ASME Hydrogen Standards Development Activity "piping and pipelines" "storage and transportation tanks"
ASME B31 Series Piping and Pipelines
ASME BPVC Boiler and Pressure Vessel Code
CGA Publication G5.4 Hydrogen Piping Systems at Consumer Sites

Multiple technologies are involved in H2 stations

Regulator Issues

- **California Fire Code –** 2007 CFC Specifically Recognizes H2 Stations

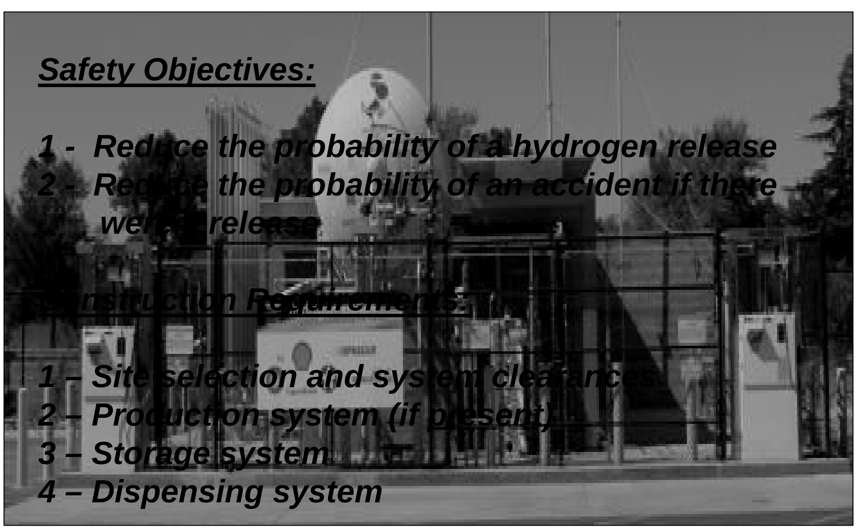



Section 2209.1 <u>General</u>

"Hydrogen motor fuel-dispensing and generation facilities shall be in accordance with this section and Chapter 35."

Regulator Issues

- **Basic Review Goals -**



<u>Safety Objectives:</u>

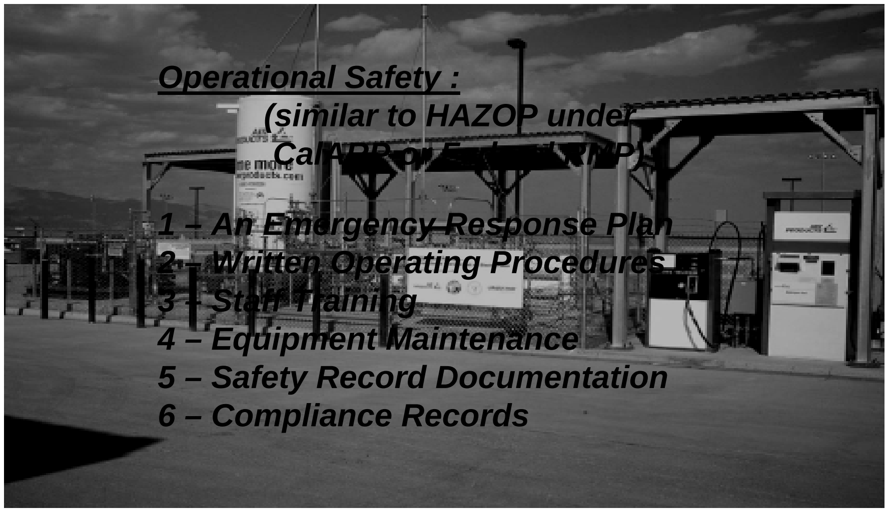
1 - Reduce the probability of a hydrogen release
2 - Reduce the probability of an accident if there were a release

<u>Construction Requirements:</u>

1 – Site selection and system clearances
2 – Production system (if present)
3 – Storage system
4 – Dispensing system

Regulator Issues

- **Basic Review Goals -**

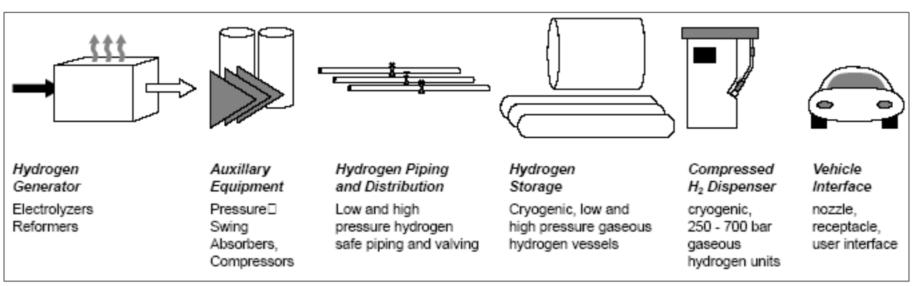


Operational Safety :
(similar to HAZOP under CalARP or Federal RMP)

1 – An Emergency Response Plan
2 – Written Operating Procedures
3 – Staff Training
4 – Equipment Maintenance
5 – Safety Record Documentation
6 – Compliance Records

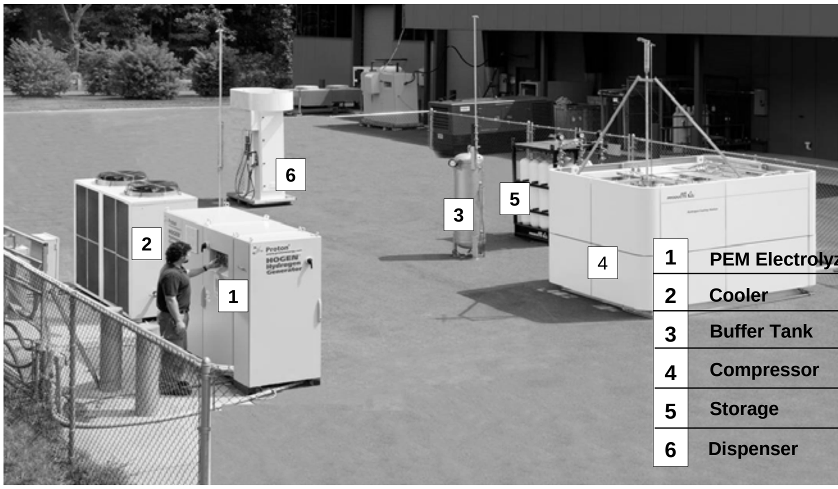
Regulator Issues

- **Plan Submittals –** Must Be Descriptive Of The Process



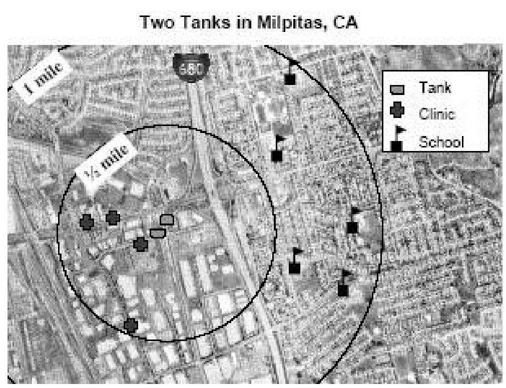
Regulator Issues

- **Plan Submittal –** Graphics Enhance The Examiner's Understanding



Regulator Issues

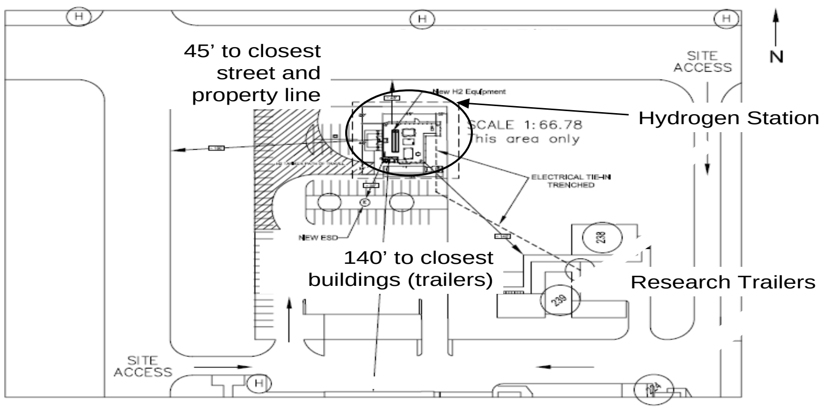
- **Plan Submittals –** A Gas Dispersion Model May Be Required



Risk evaluation affects requirements

Regulator Issues

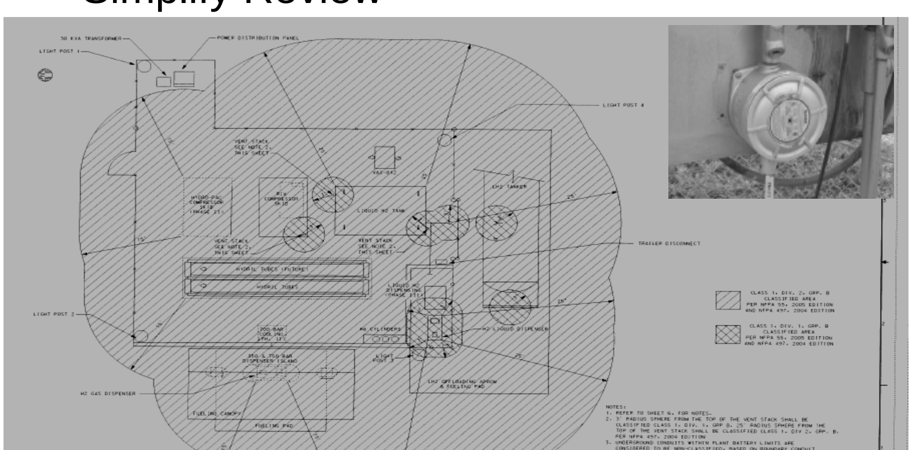
- **Plan Submittal –** Clearly Labeled Plans Simplify Review



Site Clearances

Regulator Issues

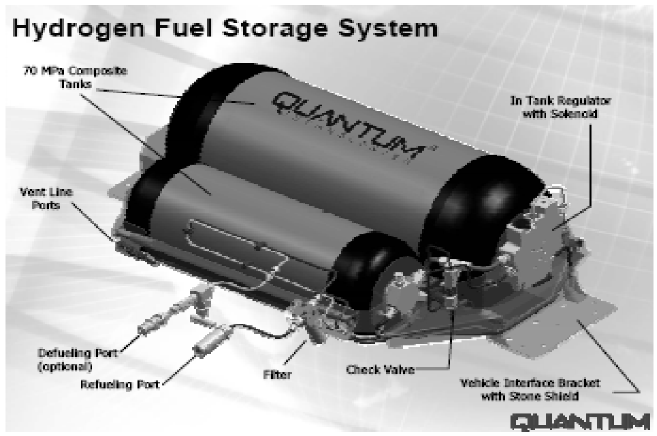
- **Plan Submittal –** Clearly Labeled Plans Simplify Review



Electrical Clearances

Regulator Issues

- **Equipment Approvals –** Specific Agency Standards Must Be Met



Composite tanks are only approved for vehicular storage

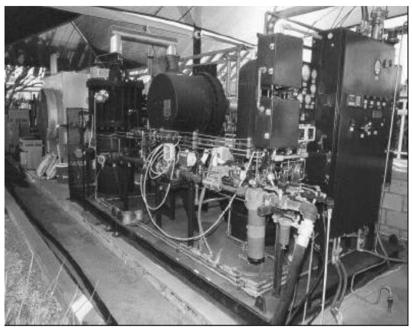
Regulator Issues

- **Equipment Approvals –** Special Equipment Requires Documentation

Cryogenic storage illustrates varied fuel types

Regulator Issues

- **Equipment Approvals –** Reformers And Electrolyzers Must Be Labeled



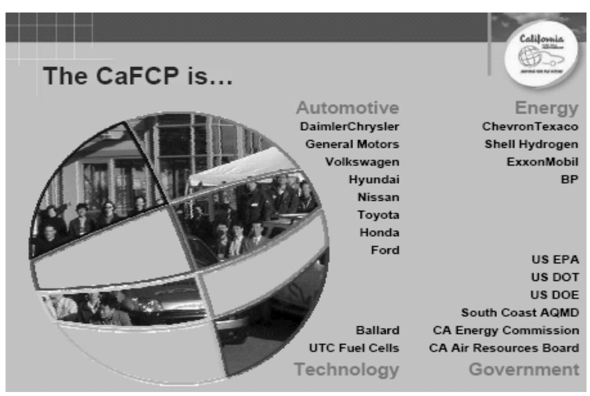
REFORMER

ELECTROLYZER

Third party (NRTL) approval by either testing or field evaluation

Responder Awareness

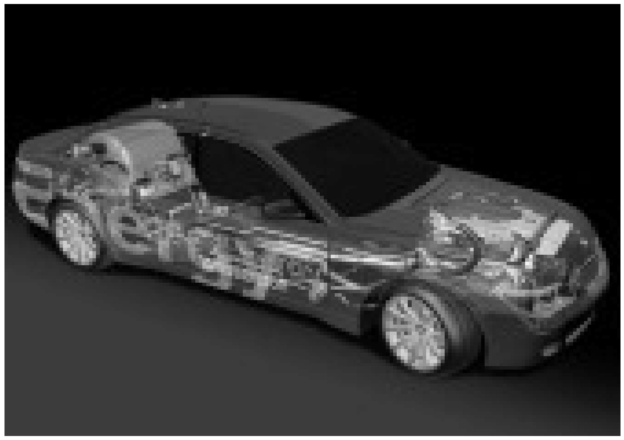
- **Emergency Responder Training -** Provided By Industry And Government



The California Fuel Cell Partnership conducts outreaches

Responder Awareness

- **Emergency Responder Training -**



BMW is an individual automaker offering safety instruction

Responder Awareness

- **Emergency Responder Training -**

H2 Fuel Cell busses are also operating

Responder Awareness

- ✠ **Emergency Responder Training -**

H2 Fire Gasoline Fire

Thermal Imaging use should be standard procedure in <u>any hydrogen vehicle incident</u>

Responder Awareness

- ✠ **Emergency Responder Training -**

H2 Fire Gasoline Fire

<u>Distance</u> and hose steams on surrounding exposures are appropriate

Responder Awareness

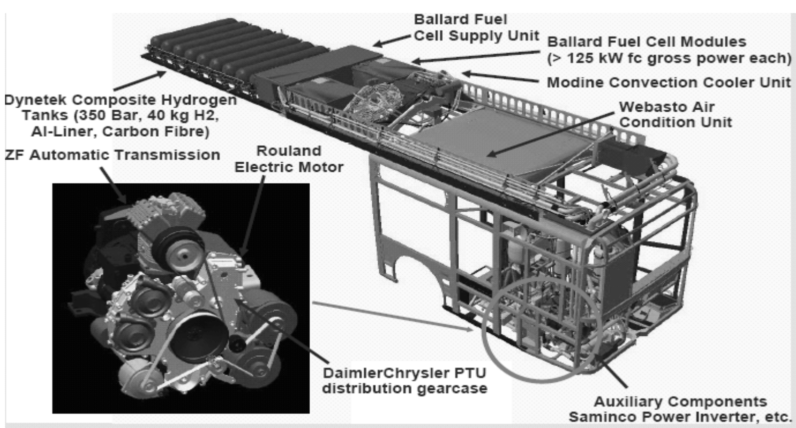
✠ Emergency Responder Training -

Generalized Non-Fire Collision Response:

1 – Place transmission in PARK
2 – Turn ignition key off and remove key
3 – Disconnect negative battery terminal
4 – Push emergency shut-down button and/or close fuel valve

Responder Awareness

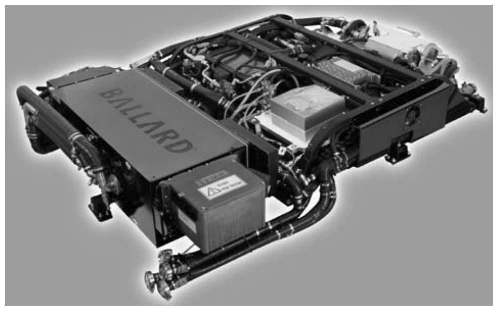
✠ Emergency Responder Training -



Knowledge of vehicle fuel and power systems is vital for an appropriate response

Responder Awareness

✠ Emergency Responder Training -



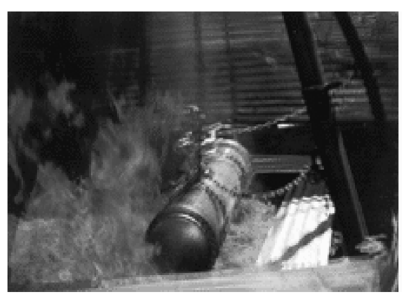
Vehicle Fuel Cell Stack and Accessory Components

H2 vehicles have high-voltage electrical power distribution systems

Responder Awareness

✠ Emergency Responder Training -

Bullet Puncture



Fire Resistance

Liquid hydrogen tank construction is robust

A cryogenic release response involves distance and total protection against frostbite and freezing tissue.

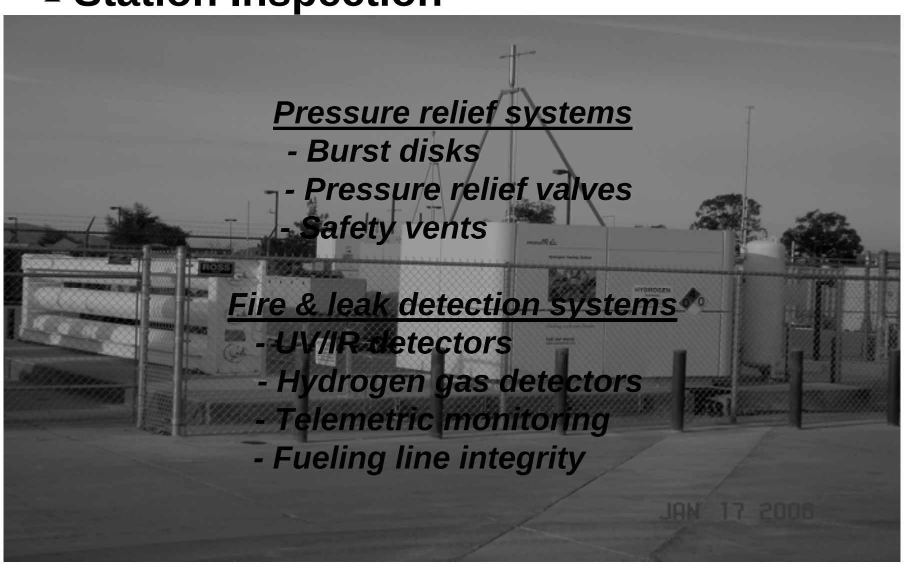
Responder Awareness

- Emergency Responder Training -

A CNG tank explosion reinforces the distance concept

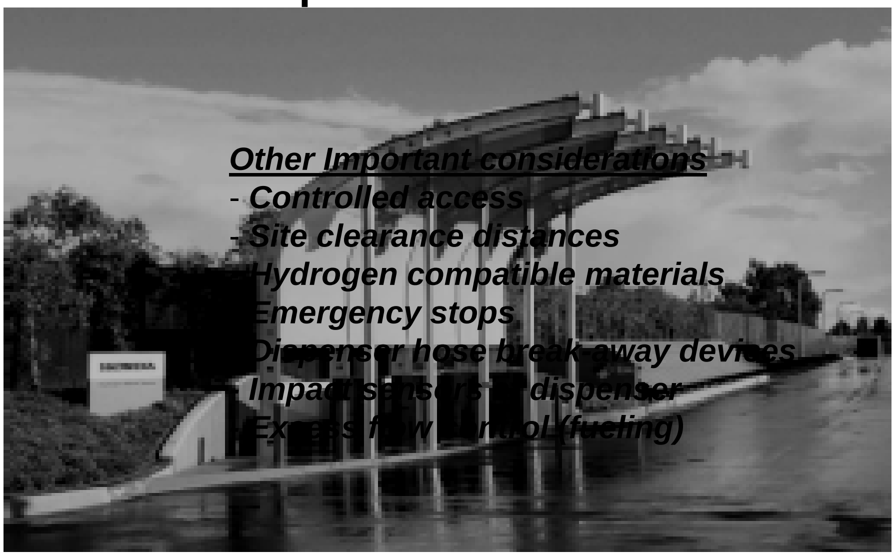
Responder Awareness

- Station Inspection -



Responder Awareness

- **Station Inspection -**



Other Important considerations
- ***Controlled access***
- ***Site clearance distances***
- ***Hydrogen compatible materials***
- ***Emergency stops***
- ***Dispenser hose break-away devices***
- ***Impact sensors on dispenser***
- ***Excess flow control (fueling)***

Responder Awareness

- **Station Inspection –** Gaseous Refueling Protocols Are Sophisticated

Winner Of The SAE J2600 Nozzle Standard

Responder Awareness

- **Station Inspection –** Pressure!

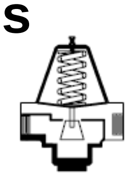
Compressed Gases are All Around Us

Applications	Service Pressures (psi)
Industrial gas	6,000
Fireman's breathing tank	4,500
Paintball propellant	4,500
Natural gas vehicle storage	3,600
Scuba tanks	3,300
Medical	3,000
Aircraft oxygen and emergency slides	3,000
Beverage	1,800
Nitrous Oxide (automotive)	1,200
Fire extinguishers	240

Composite tanks rated at 15,000 PSI are in development

Responder Awareness

- **Station Inspection –** Pressure!!

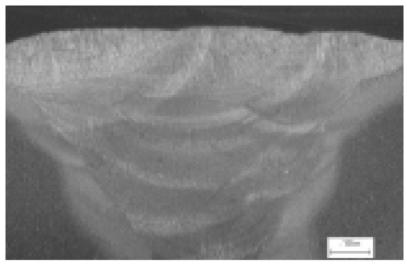


Third party examination is standard

ASME B31.3 sets criteria for process piping

Responder Awareness

✠ **Station Inspection –** Pressure!!!



Welded Pipe Joint

- **Fatigue Crack Growth**
  - Accelerated da/dN is significant even at low H2 pressures.
  - Cyclic stress sources are not significant in pipelines, but do exist: pressure variation, pressure modulating devices, vibration from nearby equipment etc.

Increased vehicle volume may affect containment integrity

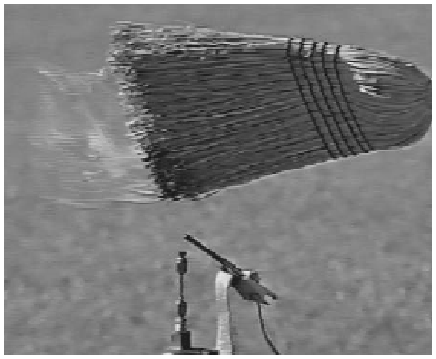
Responder Awareness

✠ **Station Inspection –** Pressure!!!!

ASME Boiler & Pressure Vessel Code stipulates tank criteria

Responder Awareness

- **Lessons –** Responder Perception



Corn brooms are sometimes used by emergency response personnel to detect hydrogen flames.

Education and training instill confidence

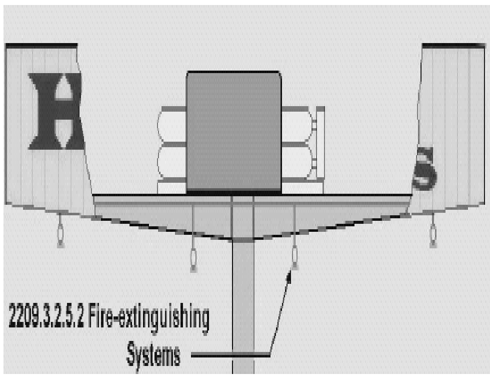
Responder Awareness

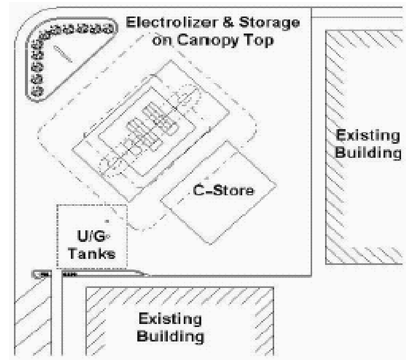
- **Lessons –** Refueling Demonstrations

"Temporary" storage involves protection and dispersal considerations

Responder Awareness

✠ **Lessons –** Canopy Storage





Composite light weight tanks are not ASME rated

CalOSHA has continuing exclusive jurisdiction

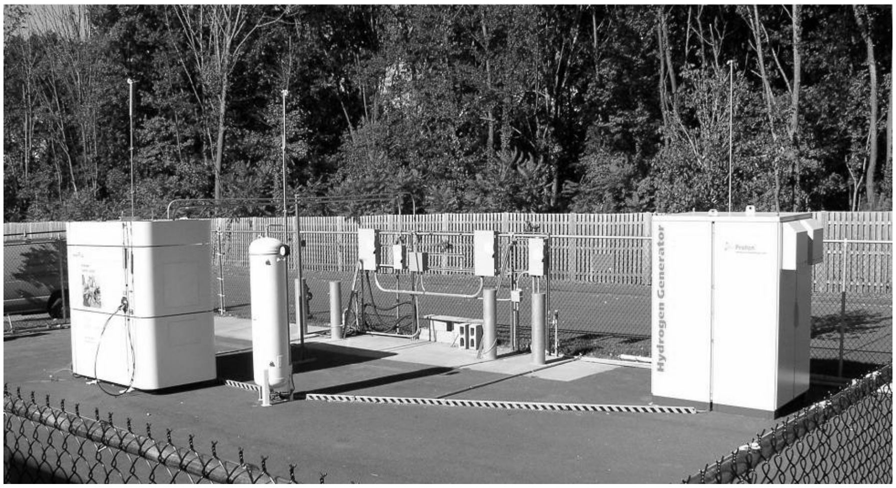
Responder Awareness

✠ **Lessons –** Fire Suppression

Sprinklers or nozzles are rare

Responder Awareness

✠ **Lessons –** Detection Placement



Open arrangements may negate flame detection

Responder Awareness

✠ **Lessons –** Operational History

Case Study: CaFCP HQ Station
West Sacramento, CA

- ✓ Over 5,200 fills since 2000
- ✓ No major incidents
- ✓ Used by 8 car companies
- ✓ Bus refueling
- ✓ Multiple nozzle models used

Cryogenic Liquid Hydrogen Storage (up to 20 cars/day)

Station safety records have been very good

Responder Awareness

- Lessons – Varied Applications

APC InfraStruXure UPS with Integrated Fuel Cell

H2 UPS

H2 FUEL CELLS

RESIDENTIAL CNG

Gaseous fuel experience is increasing

Responder Awareness

A New Energy Consciousness Is Coming!

Thank You

A Legacy of Challenge and Caution

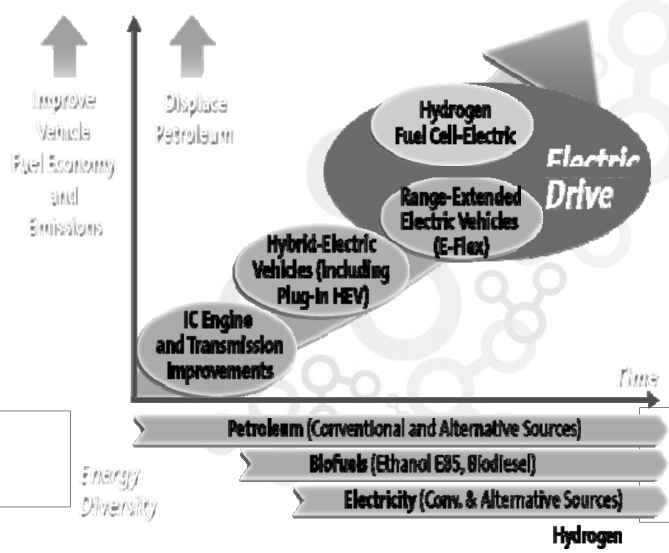
Chevrolet Equinox Fuel Cell Electric Vehicle and Project Driveway

EQUINOX FUEL CELL

Alex Keros
Fuel Cell Activities- Western Region

GM

GM's Advanced Propulsion Technology Strategy



GM

Project Driveway Program Overview

Equinox Fuel Cell is a fully-functional, distinctively-styled, 4-passenger crossover, with all the safety features of the 5-star production Equinox

- 110 Equinox Fuel Cell Vehicles fielded globally
  - Deployment plan based on 110 vehicles globally
- U.S. deployments in three locations
  - California (LA, Sacramento)
  - Greater New York City metro area
  - Washington D.C.
  - Other global deployments planned for Germany, China, Korea, Japan
- Deployment began in Sept. 2007 & runs through end of 2011
- U.S. deployment includes five target driver groups
  - Media, Public Policy, Celebrities/Influentials, B2B and mainstream driver
  - 3 to 30-month deployments, depending on driver group
- Comprehensive feedback on all elements of customer experience

3

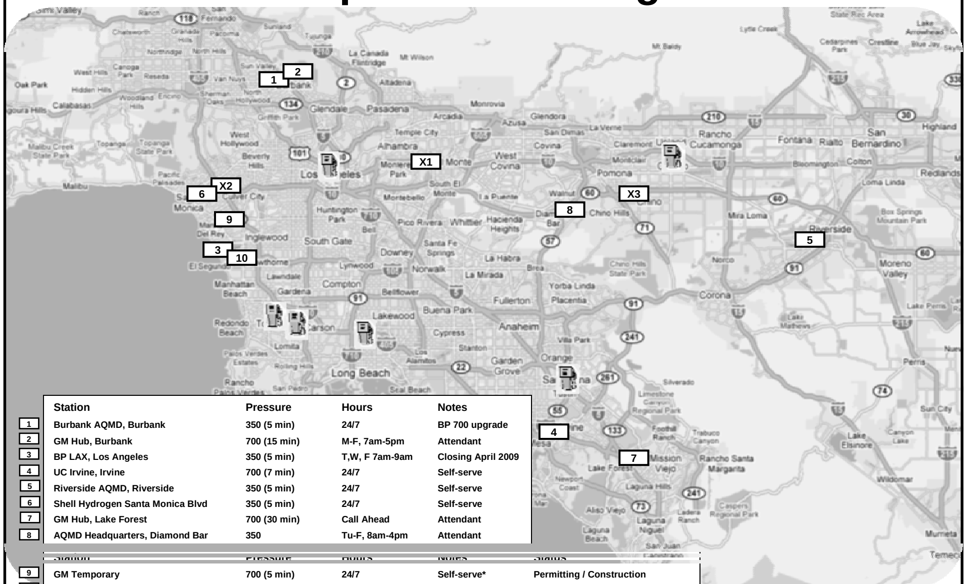
Project Driveway:
Hydrogen Infrastructure Overview

GM Confidential

4

Alex Keros
Fuel Cell Activities- Western Region

Metropolitan Los Angeles



	Station	Pressure	Hours	Notes
1	Burbank AQMD, Burbank	350 (5 min)	24/7	BP 700 upgrade
2	GM Hub, Burbank	700 (15 min)	M-F, 7am-5pm	Attendant
3	BP LAX, Los Angeles	350 (5 min)	T,W, F 7am-9am	Closing April 2009
4	UC Irvine, Irvine	700 (7 min)	24/7	Self-serve
5	Riverside AQMD, Riverside	350 (5 min)	24/7	Self-serve
6	Shell Hydrogen Santa Monica Blvd	350 (5 min)	24/7	Self-serve
7	GM Hub, Lake Forest	700 (30 min)	Call Ahead	Attendant
8	AQMD Headquarters, Diamond Bar	350	Tu-F, 8am-4pm	Attendant

	Station	Pressure	Hours	Notes	Status
9	GM Temporary	700 (5 min)	24/7	Self-serve*	Permitting / Construction
10	Clean Energy LAX	700 (5 min)	24/7	Self-serve*	Construction
X1	Rosemead Chevron	350 (5 min)			Access/Liability terms
X2	Santa Monica AQMD	350 (5 min)			Access terms
X3	Chino Chevron	350 (5 min)			Access/Liability terms

Hydrogen Infrastructure

- Comprehensive Program extends from vehicles to fueling to facilities
  - Holistic integration of Project Driveway with stakeholders allows for data transfer
    Result: Technology/market benefits when experienced is shared—City Officials, FR's, Industry, etc.

- Station access and accessibility barriers remain a concern
  - Select operators will not provide access/provide impracticable liability terms
    Result: Limits an already small network and adds pressure on accessible stations
  - In most cases, market/retail-like execution is missing (*but transitioning*)
    - Select stations: Require personal protective equipment, call-ahead/9-5 hours, training events
      Results: Drivers wearing Nomex, no weekend access, on-going appt coordination

"Real-world" effect on participants/drivers communicated to GM.
Example: After a station operator transitioned from supervised fills to 24/7 access, the amount of fueling (miles driven) nearly doubled each week.

Hydrogen Infrastructure

- Continuous effort to provide infrastructure support for vehicles
  - Constant balance of existing fuel supply, GM deployment, & additional OEM demand
    Result: Necessary to design stations for growth
  - With limited stations, the importance of each station rises
    Result: Station unavailability is arduous
- GM Experience: Fueling equipment to augment existing infrastructure
  - GM is managing the installation and operation of multiple fueling (700bar) systems
    - Permitting and Construction continues to be an unpredictable process
      Result: 8-Month vs. 6-Week permitting phases
  - Burbank Example: Engaged City officials early on regarding Facility and Fueling
    - Permitting focused on collaboration between GM and City's needs
      Result: World class facility (H2/Fire Detection System) and 700bar Fueling ,
      Result: City officials are knowledgeable advocates
  - Los Angeles Example: Clear plan defined for integration of fueling into existing station
    - Collaboration with organizations who understood process, leverage points, dialog with officials
      Result: Permitting time reduced dramatically , No surprises for either side, state-of-the-art fueling facility
  - Additional experiences in Los Angeles and New York areas

Station permitting/installation does not need to be cumbersome for either party.
Significant learning for City stakeholders as well as GM (industry).

Thank You.

Alex Keros
Sr. Project Engineer, Hydrogen Infrastructure
alexander.keros@gm.com, 310-257-3756

EQUINOX FUEL CELL

Applying Codes and Standards Systematically

P.J. Buehler – Plug Power
Mike Maxwell - ReliOn
25 August 2008

Where We Stand Today

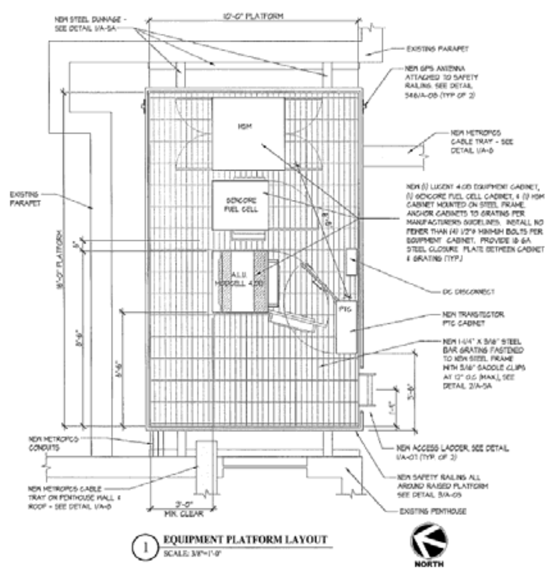
- We now have a path through the I-Codes.
  - Available to all.
  - Endorsed by HELP and SBCC.
  - Linked on Plug Power, HELP and SBCC websites.
    - http://www.nasfmhydrogen.com/documents/I-CodePathFuelCell.pdf
    - http://www.saferbuildings.org/docs/training/I-CodePathFuelCell.pdf

Progress with AHJs

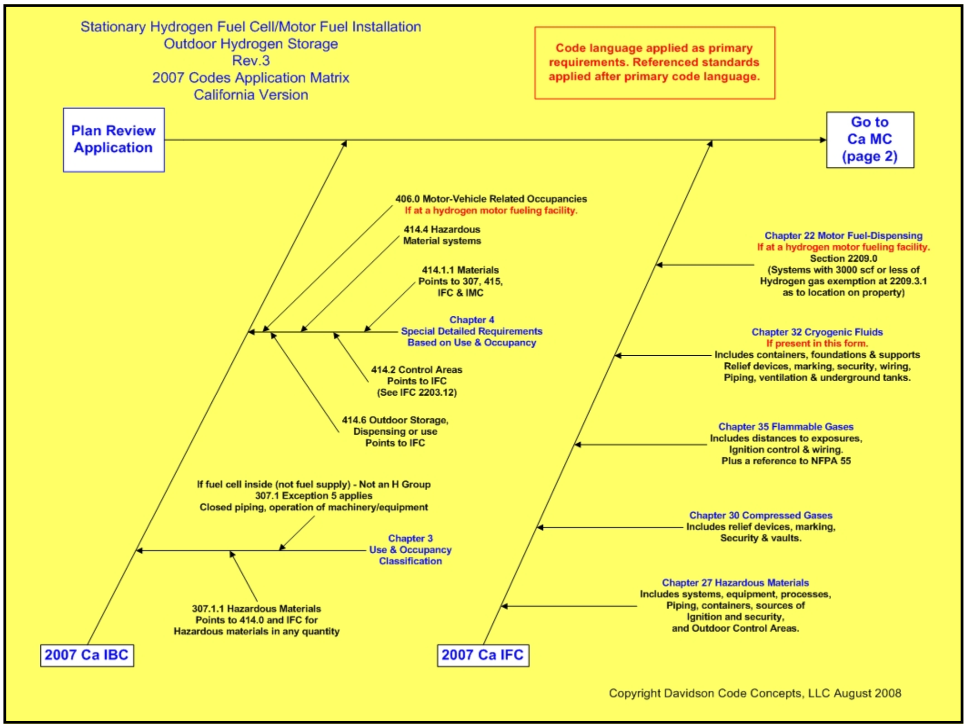
- Clear and concise rules have allowed for painless permitting since June 2007.
  - Massachusetts
  - New York
  - California
  - Rhode Island
  - New Hampshire
  - New Mexico
  - North Carolina
  - Houston, Texas

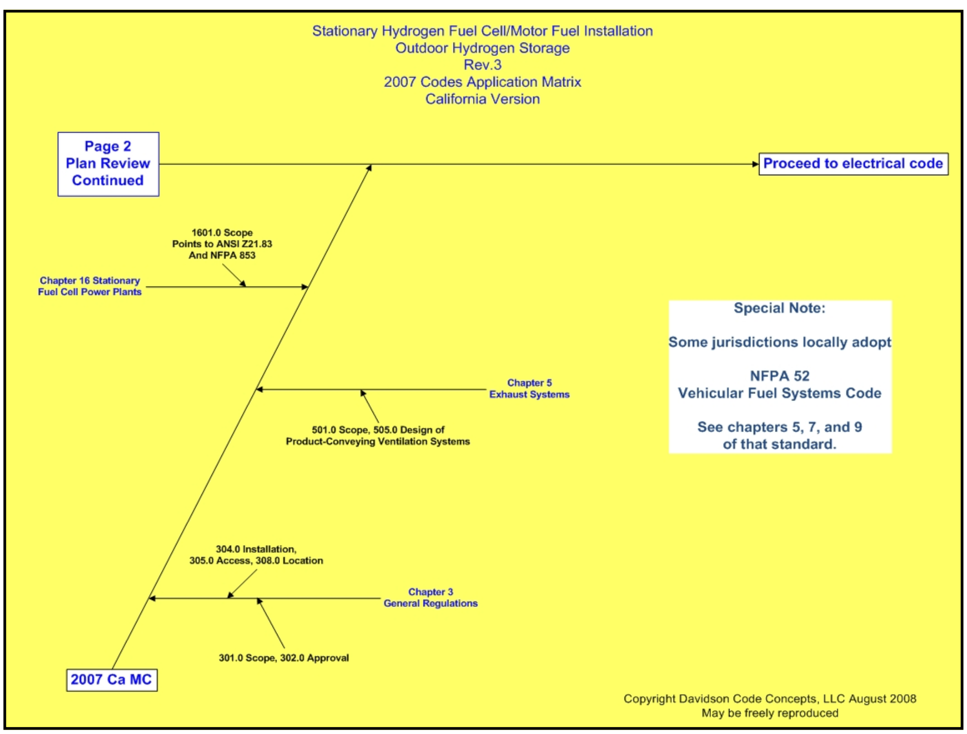
New Opportunities

- New York City



Applying Codes and Standards Systematically





P.J. Buehler – Plug Power

Mike Maxwell - ReliOn

Referenced Standards?

- NFPA 853 Standard for the Installation of Stationary Fuel Cell Power Systems
- NFPA 55 Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks
- ANSI/CSA America FC 1

Others

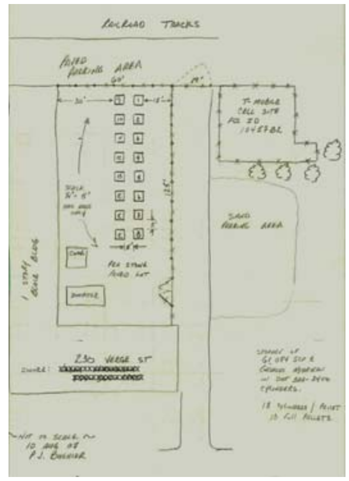
- NFPA 70 NEC
- NFPA 54 ANSI Z223.1–2006 National Fuel Gas Code

How It's Done

- Engineer follows published codes in the design process.
  - Then applies referenced standards.
- Engineer submits plans which meet the setback distances relevant to that jurisdiction.
- AHJ has an easier time reviewing the permit.
  - Has path through the codes showing relevant distances.
  - Can easily match design with codes.
- Permit is issued quickly or on the spot!

Designs Which Were Approved Quickly

No permit required. Electrical inspection at completion of work for power and grounding.



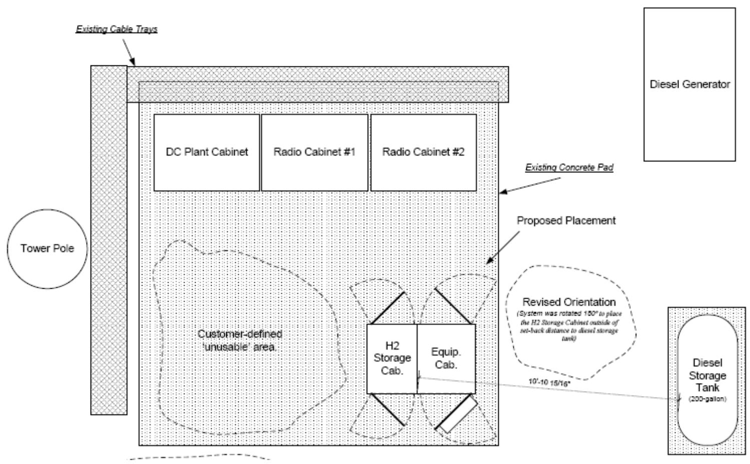
Permit issued “on-the-spot”.

How It’s Done (the hard way)

- Original site plan oriented the fuel cell cabinet and fuel storage cabinet to so the fuel cell front panels faced the outside of the pad
- This plan was rejected by the AHJ because the fuel storage cabinet violated the setback distance to an existing diesel storage tank
- The plan was modified by simply re-orienting the cabinets by 180°, placing the fuel storage cabinet outside of the required setback
- The plan was approved.
- Knowledge of setbacks would have saved 1 week off the siting schedule with a trivial re-orientation

Applying Codes and Standards Systematically

Minor change in orientation solves siting restriction



Don't Even Think About it Here!
(Yes, this is a real proposed location)

P.J. Buehler – Plug Power
Mike Maxwell - ReliOn

Listed and approved fuel consuming appliances

A stationary hydrogen fuel cell is a listed and approved fuel consuming appliance

Questions?

Moving from cylinder replacement to on-site refueling

Simpler, safer, more reliable

U.S. DOE/NREL, CaFCP & NASFM
Hydrogen Permitting Workshop

Mike Maxwell
ReliOn, Inc.
August 25, 2008

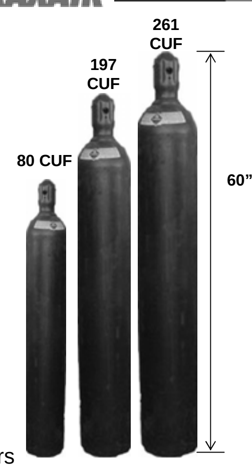
Hydrogen Storage / Delivery – Current Model

Advantages of Current Model:

- Large distribution infrastructure
  - 3000 + locations in the US
- Proven technology
  - Standards established for siting & delivery
- Hydrogen available in compressed cylinders
  - Certified containers
  - Capacity / run time dependent on tank size and pressure

Limitations of Current Model:

- Labor intensive to exchange heavy cylinders
  - Weight & size ~ 140 lb. each
- Residual hydrogen "lost" in exchange
- Limited scale for extended run times
  - More run time = more cylinders
  - 200 kW-hr ➔ 24 Cylinders; 300 kW-hr ➔ 36 Cylinders



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Hydrogen Development Goals

Hydrogen storage/delivery development goals:
- Maintain reliability and ensure commercial readiness
- Refill vs. cylinder exchange
  - Utilize hydrogen mobile refueler and deliver to fixed storage (propane model)
  - Mitigate labor of cylinder exchange
- Higher volume refillable storage system
  - Telcos require >48 hours run-time to allow re-fueling multiple sites during long widespread outages.
  - Example: ~35 scf/kWhr; 7000 scf = 200 kW-hr of hydrogen energy storage
    - ~ 50 hrs of runtime @ 4kW
    - ~ 34 hrs of runtime @ 6kW

Why focus on compressed gas development vs. fuel processors?
- High reliability, low maintenance
- Independent of system power requirements (scalable)
- Infinite storage time (no fuel degradation)
- No environmental spill hazard
- No air emissions
- No waste product

3

Advantages of refill vs. exchange

- Refilling offers several advantages over cylinder exchange
- Cylinder exchange requires:
  - disconnecting and reconnecting cylinders; every connection cycle is a chance for a leak, and damage to cylinder valve
  - Moving and maneuvering heavy tanks; difficult access even in outdoor installations (gravel/dirt, above-ground conduit, etc.)
  - Inefficient volumetric storage (cylinders can't be closely packed because access is required)
  - Cylinders exchanged by lay persons
- Refilling offers:
  - Single connection point designed for refueling
  - Maneuvering a hose vs. cylinders
  - Denser storage volume
  - Trained personnel/operators
  - Already a standard method at volume H_2 consumers (hydrogenation, semiconductor, metal treatment)
  - Already validated for propane
    - Propane = 2520 Btu/scf
    - H_2 = 270 Btu/scf

4

Storage allowances for Infrastructure Fuels

Fuel Type	Allowable onsite Storage Quantity/ BTU	References/Special Conditions
Diesel	275 gallons 139,000 BTUs/gallon **38,225,000 BTUs/site**	NFPA 30 Flammable Liquids Code 2006, Table 4.3.2.1.1(a) and (b) : 2.5 ft to exposures
Gasoline	275 gallons 124,000 BTUs/gallon **34,100,000 BTUs/site**	NFPA 30 Flammable Liquids Code 2006; Table 4.3.2.1.1(a) and (b) : 2.5 ft to exposures
LPG	1200 gallons 91,600 BTUs/gallon **109,120,000 BTUs/site**	2006 IFC Table 3804.3 : 10ft to exposures, 10 foot minimum between fill connection & vent from liquid-level gauge to external source of ignition (air conditioner), direct vent appliances, or mechanical ventilation air intake.
Hydrogen	3500cuft 270 BTUs/cu. ft. **945,000 BTUs/site**	2006 IFC Table 3504.2.1 0 ft for >=2 hour construction/no openings within 25 ft; 5 ft otherwise to non-rated construction, public streets, alleys & ways, lot lines and other storage areas

Allowable Hydrogen on site storage is at least one order of magnitude lower than other fuels by BTU content.

5

2006 IFC 3005.7 Transfer.

Transfer of gases between containers, cylinders and tanks shall be performed by qualified personnel using equipment and operating procedures in accordance with CGA P-1.

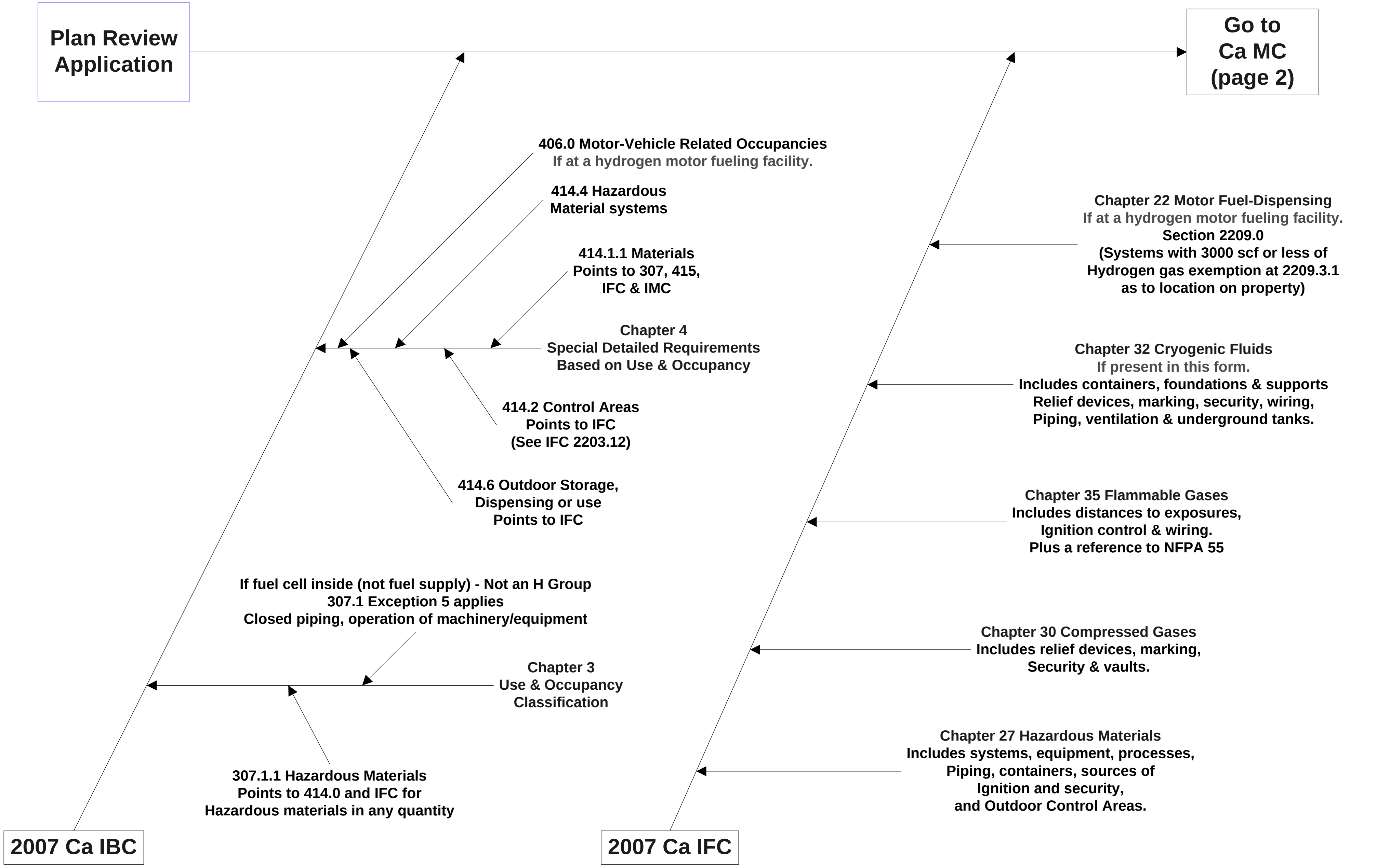
Exception: Fueling of vehicles with compressed natural gas (CNG).

Discussion/Questions

6

Stationary Hydrogen Fuel Cell/Motor Fuel Installation
Outdoor Hydrogen Storage
Rev.3
2007 Codes Application Matrix
California Version

Code language applied as primary requirements. Referenced standards applied after primary code language.



Stationary Hydrogen Fuel Cell/Motor Fuel Installation
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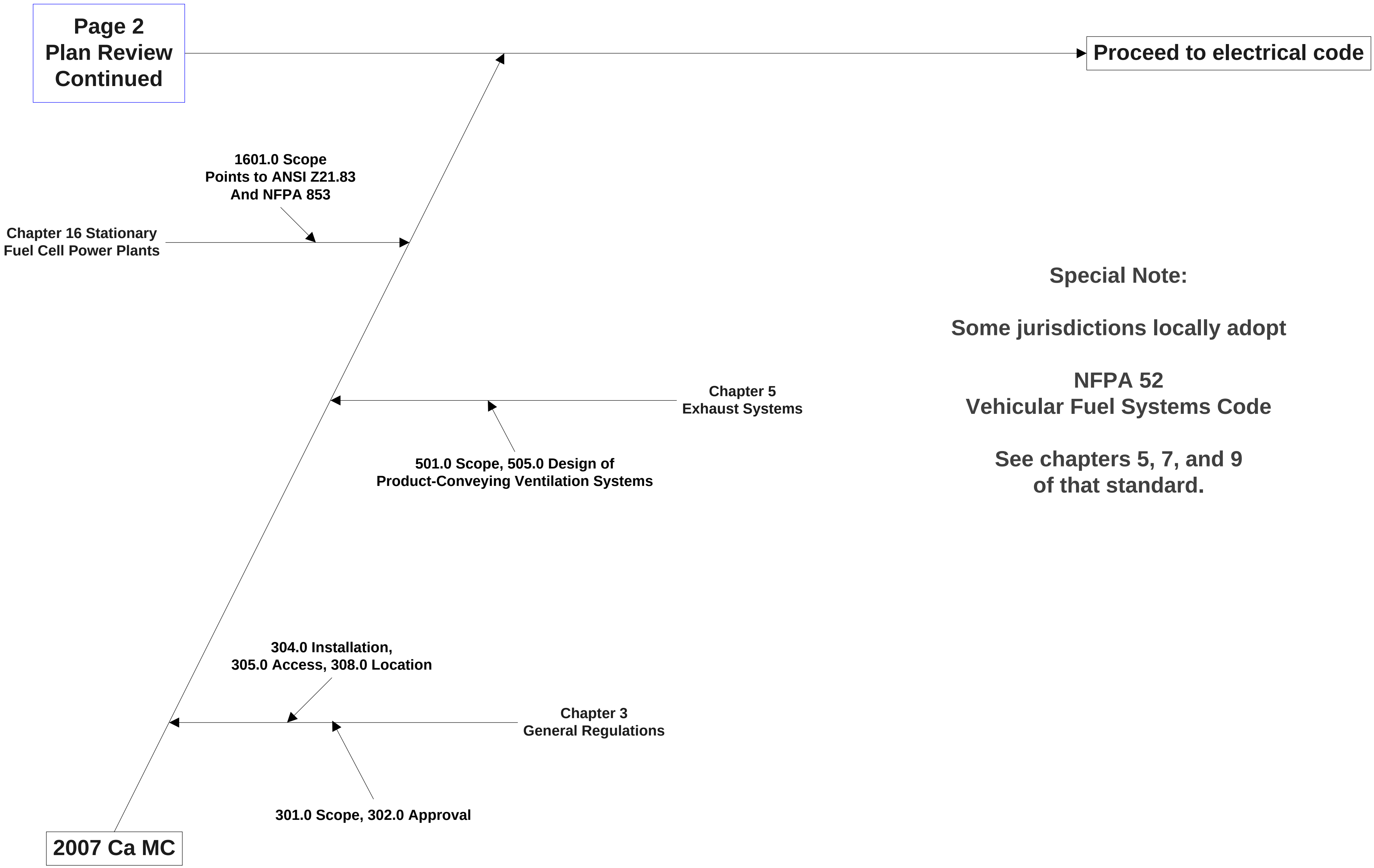


Special Note:

Some jurisdictions locally adopt

NFPA 52
Vehicular Fuel Systems Code

See chapters 5, 7, and 9
of that standard.

City of Santa Monica

Hydrogen Facility 2500 Michigan Avenue

Dispenser

Hydrogen stacked over CNG Tanks

Electrolyzer Generator

City of
Santa Monica

Renewable Hydrogen High Pressure Storage

Each Series 200 system includes one modular 3-pack of buffer storage vessels. The purpose of this storage is to provide a buffer between the compressor discharge and the hydrogen demand
from the vehicles. A majority of the fill is provided by the storage system, minimizing compressor size and horsepower requirement.

It also allows the compressor to run for longer periods and for fewer cycles, thereby improving reliability and decreasing maintenance costs. Storage also serves to significantly reduce the gas temperature from the discharge of the compressor resulting in better fill efficiency.

Additional features of the buffer storage:

- Three vessels with 20.6 cubic feet water volume each for a total of 61.8 cubic feet of water volume
- Maximum allowable working pressure of 7777 psig
- Operating pressure of 6350 psig
- Total storage at operating pressure of 50 kilograms of hydrogen gas
- SA 372, Grade J, Class 70 vessel material
- Storage vessel design compliant with ASME boiler and pressure vessel code, section VIII
- Designed to meet Zone 4 seismic classification

Renewable Hydrogen Metallic Diaphragm Compressor

Compressors and pumps of this type are used in applications ranging from vacuum to pressures up to 60,000 psig (4,100 bar). Because of the large surface areas and masses and the use of water-cooled heads, PDC's metallic diaphragm compressors achieve higher compression ratios than conventional units.

In specific cases, compression ratios as high as one hundred to one are possible.

Each Series 200 system includes

- one compressor system with a PDC diaphragm compressor, model PDC-3-1000-6000.
- The unit is suitable for suction pressures of 200 psig and capable of operating with discharge pressures of up to 7000 psig.

Additional feature of the compressor:

- Closed loop water cooling system for lower operating temperatures
- Electric drive motor
- No air or nitrogen utilities required for operation

The compressor skid also houses all circuit breakers, motor starters, motor overloads, control relays, and electric solenoid valves. In addition, the compressor skid also houses a control panel (PLC) used for compressor control. This control panel is the primary control for the hydrogen compression and storage system. It also interfaces with the on-site production, emergency shutdown systems, and dispenser.

Renewable Hydrogen Generator - Electrolyzer

The hydrogen supply system is designed and Manufactured by Proton Energy System

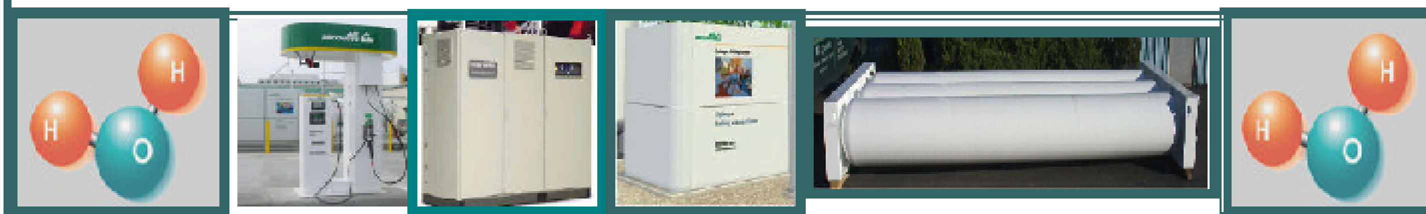
- Net Production Rate: 6 normal cubic meters per hour (200 standard cubic feet per hour)
- Purity: 99.999% hydrogen
- Maximum Discharge Pressure: 218 psig maximum

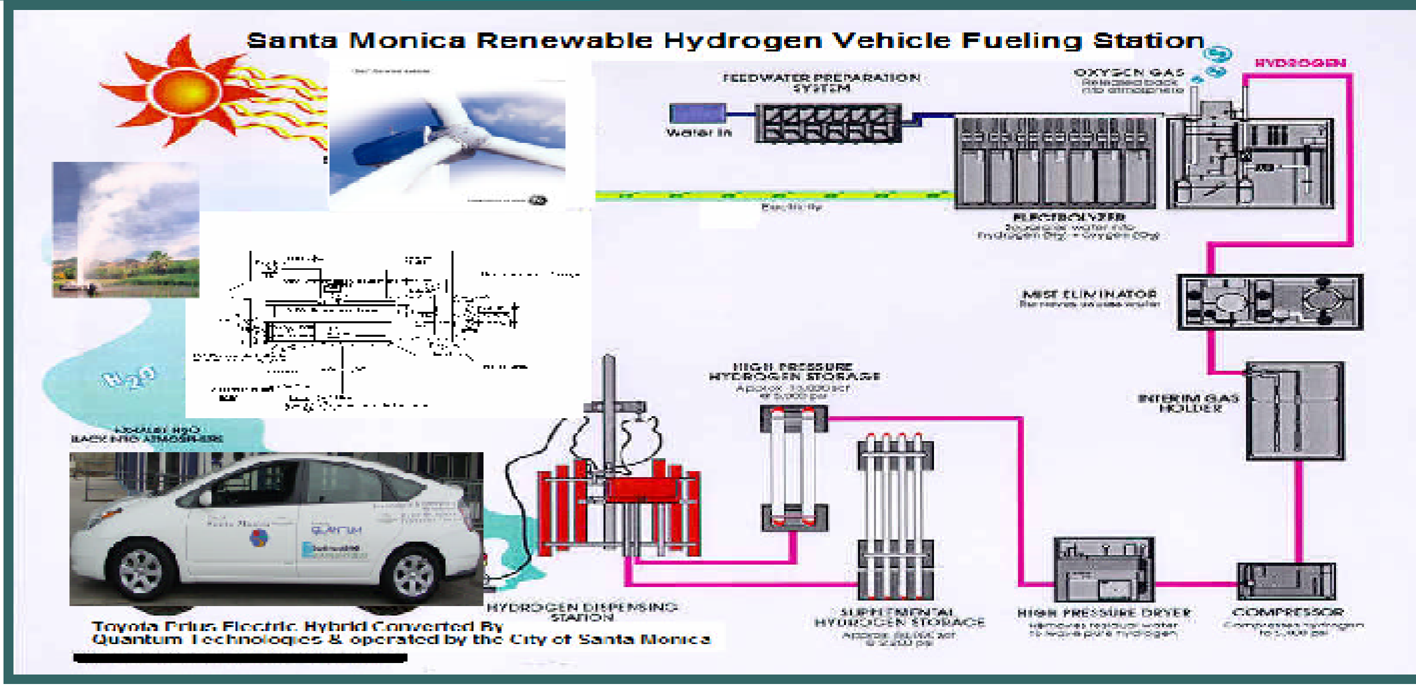
The system includes:

- Proton’s HOGEN® 240 Electrolyzer
- 51.45 kw/h power requirement
- Full automation with push button start/stop and emergency stop
- Auto calibration of the hydrogen detector
- Moisture detector that checks the hydrogen for moisture breakthrough, indicating a problem with the PSA drier
- External DI water supply system that will deliver the quantity and quality of pure water needed to ensure optimum performance
- Heated purge that allows the operation of the unit from –15? C/5? F to 5?C/41? F
- Remote access capable via Ethernet for remote monitoring and diagnostics
- External filter with shroud

City of Santa Monica

Renewable Hydrogen Project Process Flow Chart





Hydrogen Myths

Myth #1:
"The Hindenberg" Myth.

There has been a myth handed down for years that the Hindenberg Disaster was caused by hydrogen igniting. This has been proven false.

What really caused the loss of life was the diesel fuel igniting and then spreading to the cover that was not flame proofed, and composed of powdered aluminum cellulose acetate butyrate dopant (as per NASA), an extremely explosive component of rocket fuel.

Of all the deaths there were, none due to hydrogen burns. All the deaths were caused by either diesel fuel burns or from people jumping to their deaths. Besides, that was a poor use of hydrogen, and was abandoned in the future for helium, a non-combustible inert gas.

The Challenger Space Shuttle and the H-bomb

Many people incorrectly associate hydrogen fears with the vividly haunting images of the 1986 Challenger Space Shuttle explosion or the detonation of a hydrogen bomb. Experts agree that the Challenger catastrophe was not caused by hydrogen.

And an H-bomb employs tritium, a fundamentally different form of hydrogen, to replicate the same process by which the sun generates energy. This occurs at astronomical temperatures and pressures where nuclear rather than chemical reactions take place.

"Hydrogen vs. Liquid Hydrocarbons"

Actually hydrogen would be safer in a vehicle accident than gasoline, propane, or even natural gas, because hydrogen is significantly lighter than air and would dissipate in the open air quicker than any of the fossil fuels. Gasoline would remain on the ground in a liquid form, creating a significant fire hazard. Propane, being heavier than air, would float at ground level creating a potentially highly explosive fuel bomb type explosion. Even if the hydrogen did ignite, the people in the area around the incident would not be burned.

Because it is so light, hydrogen disperses and floats skyward when leaked - it won't pool or soak into clothing like gasoline, just waiting to ignite. (Spilled hydrogen won't soak into the earth and pollute ground water either, or cause an environmental disaster like the Exxon Valdez).

But what if the hydrogen does somehow ignite in a car? Tests conducted at the College of Engineering at Miami University aimed to find this out. 3000 cubic feet per minute of hydrogen was leaked from a vehicle tank and set alight. Over the course of the burn, temperature sensors inside the vehicle did not measure an increase of more than 1 or 2 degrees centigrade anywhere inside the vehicle. The temperature of the surface of the outside of the vehicle did not climb above that of a vehicle sitting in the sunshine!

One might shrug their shoulders and say "So What? However, when a carbon-based fuel like gasoline burns, glowing hot soot particles transfer the heat to its surroundings – potentially including you. But because hydrogen contains no carbon, it burns cleanly without a residue of hot soot, producing little radiant energy. This means that a victim would have to be practically in the flame in order to get burned.

Pressurized hydrogen tanks are made to withstand enormous impacts, and fail gracefully, if at all. Some fear that a hydrogen tank has the potential to explode, and that is possible. But these critics often overlook the greater explosive potential of the gas tanks in their very own cars.

Many real-life tests have demonstrated the safety of pressurized hydrogen storage.
Simulated 55 mph crash tests left the car totaled, but the hydrogen tank intact.
To prove the safety of its hydrogen vehicles, BMW tested its hydrogen tanks in a series of accident simulations that included collision, fire and tank ruptures. In all cases, the hydrogen cars fared as well as conventional gasoline vehicles. And hydrogen-fueled cars are designed to preclude the possibility of leaked hydrogen collecting within the vehicle.

Handling Hydrogen

From the perspective of safety, storing and transporting hydrogen safely is very similar to handling natural gas or propane, which are currently piped all over the world to industries and homes. A safe hydrogen infrastructure will include a system of detectors to pinpoint leaks, alarms in order notify of leakage, and a system of cut-off points, all of which will be regularly tested. Five percent of natural gas is already reformed to produce hydrogen for industrial use in petrochemical production, food processing, and microchip manufacture and for spacecraft fuel. These industries have already resolved the safety issues around the storage and transportation of hydrogen.

APPLICATION FOR INSTALLATION OF HYDROGEN STORAGE SYSTEMS

This information is required under XXXXXX California Compiled Laws Annotated

INSTRUCTIONS: The item numbers are referenced in the attached typical installation of a Hydrogen Storage Tank. The system must be in compliance with the Storage and Handling of Liquefied and Gaseous Hydrogen (H2) Rules. The manufacturer and part number must be indicated next to the appropriate item. Please direct any questions to XXX at XXX or e-mail at XXX. For detailed instructions, see Page 7.

FACILITY NAME	NEW ASSIGNED CONTAINER NUMBER(S)		**FACILITY ID NUMBER**
FACILITY STREET ADDRESS (PO BOX NOT ACCEPTABLE)	CONTACT PERSON, TRAINED		AREA CODE & TELEPHONE NUMBER ( ) --
CITY	COUNTY	STATE MI	ZIP CODE
OWNER NAME	OWNER ADDRESS		AREA CODE & TELEPHONE NUMBER ( ) --
CITY	STATE		ZIP CODE
SUBMITTER'S NAME/COMPANY	STREET ADDRESS		AREA CODE & TELEPHONE NUMBER ( ) --
CITY	STATE		ZIP CODE

SECTION I **The following section applies to <u>container</u> installations of the H2 Rules.**

ITEM	DESCRIPTION	MANUFACTURER & PART NO.	ITEM	DESCRIPTION	MANUFACTURER & PART NO.
1.	**CONTAINER LOCATION:** Section 3-2.2 & Table 3-2.2: To buildings, property lines, roadways, railways, adjacent flammable or combustible liquid and LPG tanks. Away from overhead power lines.		5.	**CONTAINER SUPPORTS/ FOUNDATIONS:** Section 2-1.2:Firm foundation of noncombustible material, substantial supports. Foundation/supports in contact with cryogenic fluid must withstand temperature effects.	
2.	**CONTAINER DESIGN/ CONSTRUCTION:** Section 2-1: Title 49 CFR, and ASME standards; Dimension & capacity. Underground: ASME vacuum jacket; burial depth, Back fill material.		6.	**PIPE SUPPORTS:** Part 2, Section 2-3.1.2: Constructed of non-combustible material. Part 3, Section 2-3.4: Protection from cryogenic exposure.	
3.	**CORROSION PROTECTION:** Section 2-1.2: Container must be protected against corrosion. Section 2-1.8: Composite containers must be protected from UV radiation. Section 5: Underground containers must be protected from corrosion.		7.	**HOSE/PIPING MATERIAL:** Section 2.3: No cast-iron, no aluminum with liquid H_2, protected against corrosion, suitable for pressures & temperatures, supported and protected against corrosion & physical damage, must conform to ASME B31.3 Marked with product and flow direction. Section 2-3.10: Underground must be at proper depth, & vacuum jacketed.	
4.	**COMPRESSOR, GAS PROCESSING EQUIPMENT** Part 2, Section 1-8.1, 2-7.1 & Part 3, Section 1-5.1, 2-9.1: Size of compressor, psig and scfm. Listed and approved. Section 2-10 Gauge on each discharge.		8.	**NORMAL VENTS:** Section 2.2: Steel aboveground. Relieve excessive internal pressure. Terminate outdoors. Sign warning not to spray water in vent opening. Vents terminate outdoors.	

(Continued on Page 2)

APPLICATION FOR INSTALLATION OF HYDROGEN STORAGE SYSTEMS

(Continued from Page 1)

ITEM	DESCRIPTION	MANUFACTURER & PART NO.	ITEM	DESCRIPTION	MANUFACTURER & PART NO.
9.	**CONTAINER VALVES** Part 2, Section 2-4.8 Independent fill line must have backflow check valve as close as practical to container to prevent uncontrolled/accidental release.		15.	**OVERFILL PROTECTION** Part 3, Section 2-1.8: Approved means to prevent overfill of container.	
10.	**PRESSURE RELIEF:** Section 2-2, 7-2.8: Installed per ASME standards. Arranged to discharge upward & unobstructed. Designed & located to prevent moisture and freezing. Gaseous service shall not have manual relief.		16.	**Anchorage** Section 2-1.2: Anchorage in areas subject to buoyant forces; each container shall be safeguarded against movement by anchoring or other secure means.	
11.	**MARKING:** Section 6-3.1: Area shall be marked “No Open Flames” “Nonodorized Flammable Gas.” Storage site shall be fenced & posted “Liquefied Hydrogen Flammable Gas No Smoking – No Open Flames,” or according to NFPA 704.		17.	**UNLOADING/ LOADING RISER LOCATION:** Section 3-2.3: Fixed piping, between riser & container and master shutoff and check valves. Separation per Table 3-2.2. Section 2-3.8: Backflow check valve at container Section 2-7: Static protection. Section 5-1: ESD in pipe transfer within 10’ of hose/arm for lines 3” or more diameter.	
12.	**FIRE PROTECTION AND IDENTIFICATION:** Part 2, Section 2-5, & Part 3, Section 2-1.3: Labeled 3” letters, "Gaseous Hydrogen-Flammable Gas,” “Liquefied Hydrogen-Flammable Gas”.		18.	**VACUUM/LIQUID LEVEL MONITORING:** Part 3, Section 2-1.9: Means to indicate vacuum degradation within the vacuum jacket of underground container.	
13.	**PHYSICAL PROTECTION:** Sections 2-1.5 & 2-1.6: Guard posts must be in accordance with section specifications, or other means to protect system from vehicular damage. Section 2-4.3: Protect system against tampering. Section 3-1.9: Aboveground system must be fenced & posted.		19.	**EMERGENCY SHUTOFF VALVES:** Section 2-4: Auto-fire valve located at building where pipe enters, & in piping to equipment. Section 3-2.3: Emergency shutoff. Manually operated in path of egress Part 3, Section 2-2.12: Not between pressure relief and device or containers unless locking type. Section 2-4.4: Auto shutoff in liquid withdrawl line as close as practical to container.	
14.	**VAPORIZER:** Part 3, Section 2-6: Anchored, low temperature shutoff in discharge piping, relief valve on heated vaporizer. Monitor outlet temperatures.		20.	**CANOPY:** Section 4-5: The lowest elevation of the roof or canopy shall not be less than 4 feet (1.8 meters) from the top of the container. Vent(s) extended through the roof or canopy. Constructed to not allow vapors to accumulate under the canopy or roof. Constructed of noncombustible materials.	

APPLICATION FOR INSTALLATION OF HYDROGEN STORAGE SYSTEMS

SECTION II **The following section applies to hydrogen motor vehicle fueling.**

ITEM	DESCRIPTION	MANUFACTURER & PART NO.	ITEM	DESCRIPTION	MANUFACTURER & PART NO.
1.	**TYPE OF DISPENSING STATION**: Attended, Unattended, self-service, inside building, marina service station.		7.	**HAZARD ANALYSIS:** Section 7-2: Emergency plan designed by a qualified H_2 engineer.	
2.	**LOCATION OF DISPENSER:** Sections 3-4 & 7-2: Minimum 10 feet from property lines, building, 20 feet from fixed source of ignition, not under power line. Within 100 feet of emergency shutoff switch. Protected from collision, secured in place. In clear view of attendant.		8.	**EMERGENCY BREAKAWAY DEVICE:** Section 3-5 & 5-1: Installed on each hose that dispenses a liquid into motor vehicles. Designed to retain liquid on both sides of the breakaway point.	
3.	**DISPENSING DEVICE:** Section 2-12: Must be listed and identified as to product it dispenses. Section 7-2.5: Equipped to allow control of flow. Section 3-4: Protect against collision. Securely bolt in place.		9.	**FIRE EXTINGUISHER:** Part 2, Section 6-4 & Part 3, Section 6-3: At least one listed 40-BC or two 20-BC within 75 feet of dispensers, fill pipes, and dispensing area.	
4.	**BONDING:** Part 2, Section 5-5 & Part 3, Section 5-4: Static protection between dispenser and vehicle. Transfer surface must be concrete with resistivity not exceeding API-RP 2003, or connection is in continuous metallic contact.		10.	**PHYSICAL PROTECTION:** Section 3-4 & 7-2.2: Secure against unauthorized use and vehicular collision. Section 7-2.3: check valve or pressure regulating valve under the dispenser. Device in liquid service to prevent internal/external icing.	
5.	**EMERGENCY SHUTOFF DEVICE:** Section 7-6: ESD or electric disconnect must be at least 10 feet and not more than 100 feet from dispensing area, along means of egress. Shall shut down all pumps & compressors, fuel supply, transfer equipment.		11.	**SIGNS:** Section 7-2: Warning signs posted: "No Smoking," "No Open Flames," "Stop Motor." "No filling of portable containers in or on a motor vehicle. Non-Odorized Flammable Gas, Cryogenic Liquid or Cold Gas, in 3" red letters on white background. Remain in attendance outside of the vehicle in view of the nozzle." Section 5-1.9: Dispensing instructions posted.	
6.	**DISPENSING NOZZLE:** Section 7-2: Automatic stop flow at temperature-corrected pressure. Shall prevent escape of H_2. Section 5-1.8: Must have interlock or self-closing ends.				

APPLICATION FOR INSTALLATION OF HYDROGEN STORAGE SYSTEMS

(In addition to requirements from Page 3)

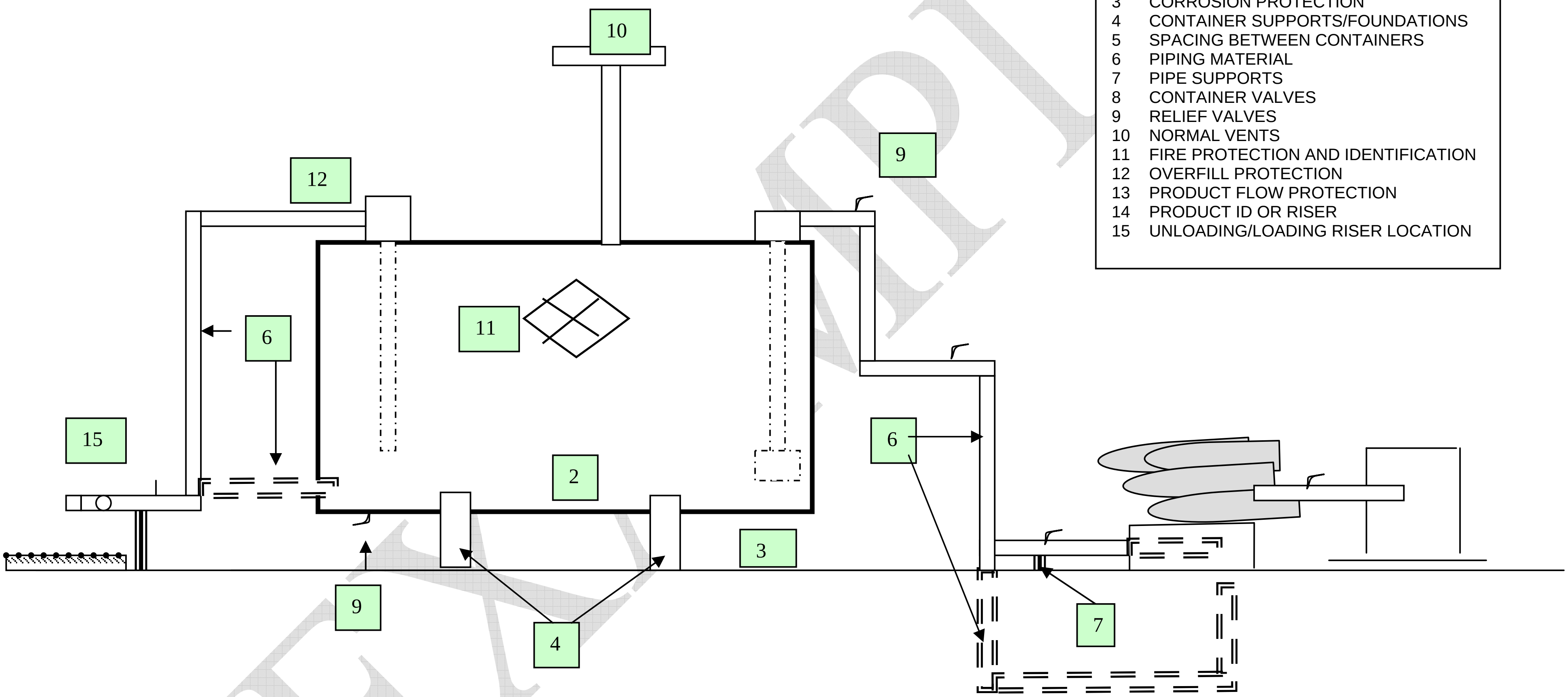
SECTION III **The following section applies to <u>indoor</u> hydrogen motor vehicle fueling, must have prior approval from department.**

ITEM	DESCRIPTION	MANUFACTURER & PART NO.	ITEM	DESCRIPTION	MANUFACTURER & PART NO.
1.	**VENTILATION** Section 4-2: Vent to outdoors, inlet within 18" of floor on exterior wall, outlet at high point in exterior wall or roof.		5.	**SIGNS** Section 4-3.8: At access doors, "No Smoking, Non-Odorized Flammable Gas, No Open Flames", 1" red letters on white background.	
2.	**ROOM CONSTRUCTION** Section 4-3.1: At least 2 hour fire rating with at least one exterior wall.		6.	**DETECTION SYSTEM** Section 4-3.9: Dispenser must have gas/leak/fire detection system.	
3.	**AUTO VALVE** Section 4-6.1: Auto valve between storage & dispensing which closes when ESD is activated or loss of power.		7.	**MANUAL SHUTOFF VALVE** Section 4-6.2: Manual shutoff valve must be upstream of breakaway unless dispenser has self-closing valve. Valve must close when power is cutoff or ESD activated.	
4.	**SPACING** Section 4-7.6: Spacing between vehicle fueling appliances must be at least 3'. No manifolding.		8.	**STATIC PROTECTION** Section 4-8.2: Must be in place at load/unload riser location.	

TYPICAL INSTALLATION OF

HYDROGEN STORAGE SYSTEM

(Numbers corresponds to the item numbers on the application)



PART I – ITEMS

1. CONTAINER LOCATION
2 CONTAINER DESIGN/CONSTRUCTION
3 CORROSION PROTECTION
4 CONTAINER SUPPORTS/FOUNDATIONS
5 SPACING BETWEEN CONTAINERS
6 PIPING MATERIAL
7 PIPE SUPPORTS
8 CONTAINER VALVES
9 RELIEF VALVES
10 NORMAL VENTS
11 FIRE PROTECTION AND IDENTIFICATION
12 OVERFILL PROTECTION
13 PRODUCT FLOW PROTECTION
14 PRODUCT ID OR RISER
15 UNLOADING/LOADING RISER LOCATION

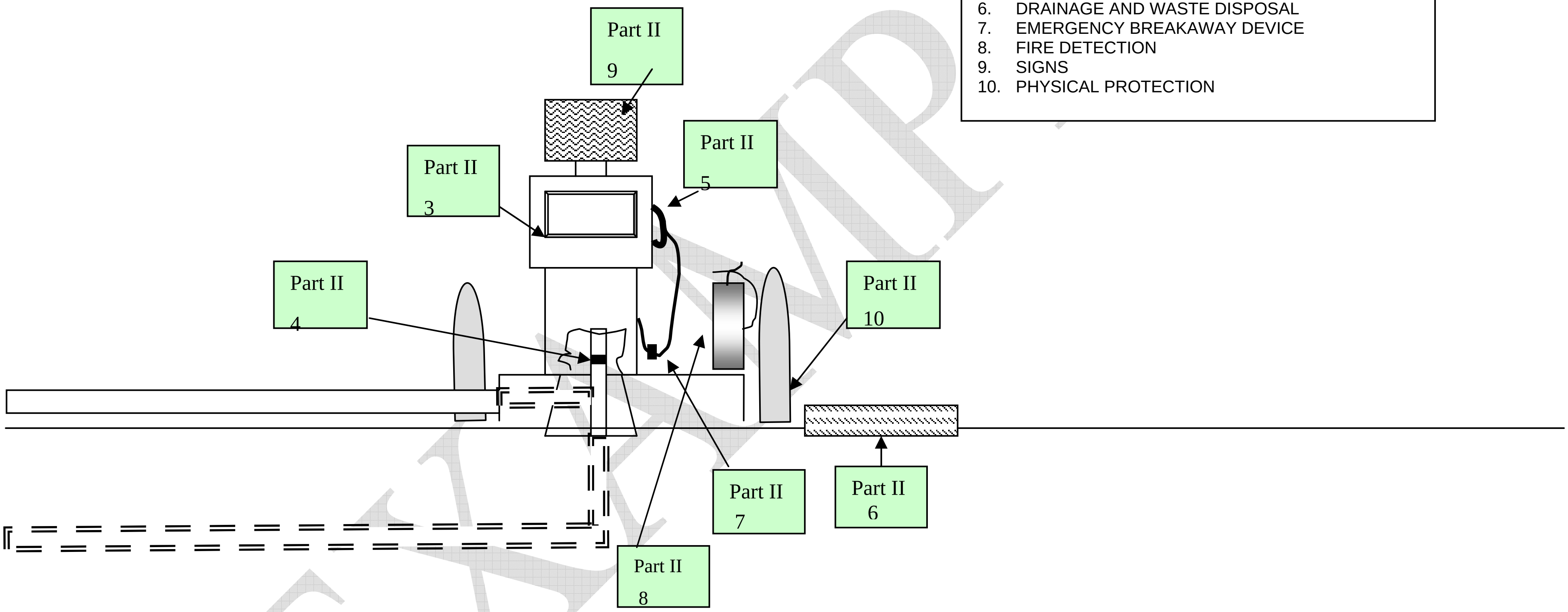
TYPICAL INSTALLATION OF

HYDROGEN DISPENSING SYSTEM

(Numbers corresponds to the item numbers on the application)

PART II – ITEMS

1. TYPE OF FACILITY
2. LOCATION OF DISPENSER
3. DISPENSING DEVICE
4. EMERGENCY SHEAR/FIRE VALVE
5. DISPENSING NOZZLE
6. DRAINAGE AND WASTE DISPOSAL
7. EMERGENCY BREAKAWAY DEVICE
8. FIRE DETECTION
9. SIGNS
10. PHYSICAL PROTECTION



A plan review must be completed on any hydrogen storage container system of 400 scf or more, where less than 400 scf systems are less than 5 feet apart, or any container filling location. A request for plan review must include:

1) Size of proposed container(s). The material of construction, the dimension, and the **capacity** of each container.
2) Type of venting, pressure relief, and compressor size.
3) A completed parts and materials list for each container with vent manufacturer, model number and flow rate (gpm, SCFH) as appropriate.
4) A plot map showing all of the following information within 100 feet of the proposed system:
   a) Location of **buildings**, public **roadways**, railroad mainlines, public sidewalks, and **property lines**.
   b) Overhead power lines.
   c) **Proposed** location of the **container**(s) and **loading/unloading** risers.
   d) Location of all **existing** tanks, above and under ground, storing flammable/combustible liquids or gases.
   e) Location of all fuel dispensers and canopy footings.

4) A separate piping diagram for each container with pipe, vent and valve specification identified on the diagram. Include manufacturer and model numbers where appropriate.
5) Section II shall be completed for motor fueling facilities.
6) Each installation of 26,000 scf gaseous storage capacity, or increment thereof, shall be considered a container.
7) A plan review fee of $203 (checks made payable to the State of Michigan) **per** container.

   Send the application to:
   DEQ OFFICE OF FINANCIAL MANAGEMENT
   REVENUE CONTROL UNIT
   PO BOX 30657
   LANSING, MI 48909
8) Physical address for overnight deliveries:

   MDEQ-WHMD
   Revenue Control Unit 5th Floor
   Constitution Hall
   525 West Allegan
   Lansing, Michigan 48933

The facility cannot be operated without approval from the Waste and Hazardous Materials Division. If you have any additional questions concerning this matter, please contact the Storage Tank Unit at 517-335-7211, or e-mail DEQ-STD-TANKS@michigan.gov.

NREL National Renewable Energy Laboratory
A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Innovation for Our Energy Future
1617 COLE BLVD.
GOLDEN, CO 80401-3393
(303) 275-3000

Permitting Hydrogen Fueling Stations

and

Hydrogen Fuel Cell Back-up Power for Wireless Telecommunications Sites Workshop

Review Path Form

Your Jurisdiction Name: ____

What agencies and in what order would an application have to be submitted to for approval in your jurisdiction?

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What codes would have to be complied with at each agency?