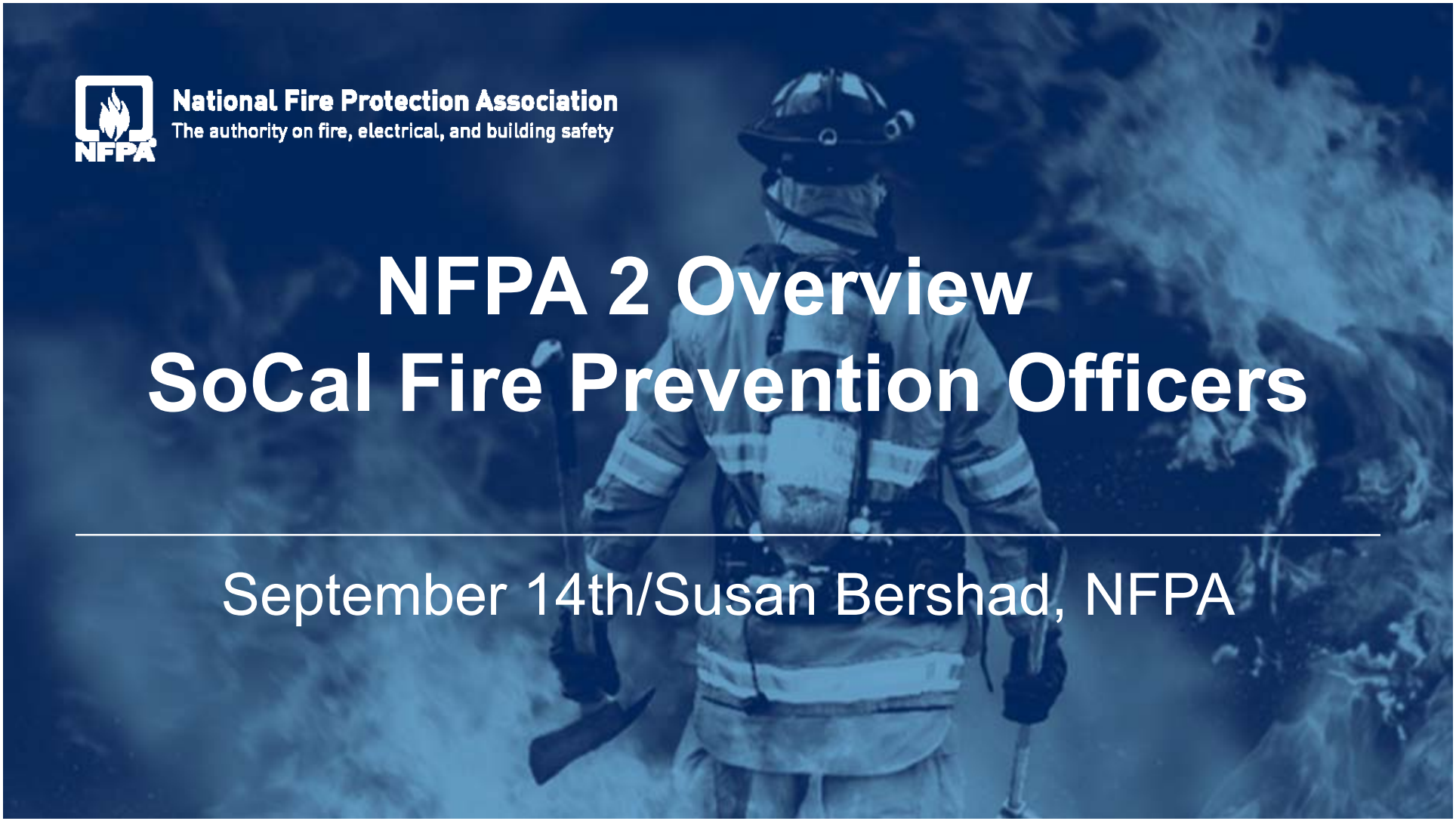

National Fire Protection Association
The authority on fire, electrical, and building safety
NFPA
NFPA 2 Overview
SoCal Fire Prevention Officers
September 14th/Susan Bershad, NFPA

Need for a National Hydrogen Code

- *With the increased interest in hydrogen being used as a vehicle fuel source, the NFPA was petitioned to develop an all-encompassing document that established the necessary requirements for hydrogen technologies*
  - Technical committee formed in 2006
  - Focus is to address all aspects of hydrogen, storage, use and handling
  - Draws from existing codes and standards
  - Identifies and fills technical gaps for a complete functional set of requirements
  - Developed for code users and enforcers
  - Structured so that it works seamlessly with building and fire codes.

California Adoption

- Current code adopts the 2011 edition of NFPA 2
- 2016 CA Fire Code adopts the 2016 edition of NFPA 2
- Effective date of January 1st, 2017
- Can be used on a case-by-case basis until then.
  - See CA OSFM IB-004

Hydrogen – Why ?

- Zero Emission Vehicle (ZEV) Mandate
- Hydrogen can be readily converted into electricity through a fuel cell (which is an energy conversion, not storage, device)
- Hydrogen is an excellent fuel for fuel cells which are used on vehicles (PEM fuel cells)
- Fuel cell vehicles have no hydrocarbon emissions
- Hydrogen can be produced from a variety of renewable energy sources such as wind power, solar power, and biomass
- Hydrogen is “flexible”- can be produced from water and electricity and converted into electricity and water
- Electrolyzer converts electricity and water to hydrogen and a fuel cell converts hydrogen and air to electricity and water

Hydrogen – Why not now?

Hydrogen infrastructure is being deployed but:

- Huge endeavor to create new infrastructure for production and distribution of hydrogen fuel
- Need to produce and distribute hydrogen in large quantities and produce more hydrogen close to the point of use
- Hydrogen fuel cell vehicles are competing against mature technology

Hydrogen Properties/Usage

- Low density means high storage pressures are required
- Pressures of 10,000 psi are used on vehicles and higher pressures are required for fueling stations
- Hydrogen can attack materials because of the small molecule size so material selection is important
- Hydrogen used in fuel cells can not be odorized because the odorants damage the platinum catalysts in fuel cells- sensors required
- When released hydrogen disperses rapidly upwards
- Safe designs should not impede dispersion

Hydrogen Properties/Usage

- Pure hydrogen burns with a nearly invisible flame and low radiant heat
- If hydrogen is released it will disperse upwards rapidly and will be in the flammable range for only a very short time (seconds to minutes)
- As a comparison a propane release will migrate downward and can be retained in below grade spaces (such as basements) in the flammable range for long periods of time
- As a comparison a gasoline release can contaminate soil and other materials for indefinite periods

Hydrogen Properties/Usage

- Liquid hydrogen usage
  - Because of gaseous hydrogen's low density there may be need for liquefied hydrogen storage
  - Liquid boils at -423 F
  - Must be really cold to stay liquid
  - Liquid density is 4.2 Lbm/ft3
  - There is more hydrogen in gallon of liquid water than in a gallon of liquid hydrogen (interesting fact)

How is Hydrogen Produced?

- Steam Reforming of Methane
  - $CH_4 + 2H_2O \longrightarrow 4H_2 + CO_2$
- Electrolytic Hydrogen Production
  - $2H_2O \longrightarrow 2H_2 + O_2$

Hydrogen Delivery

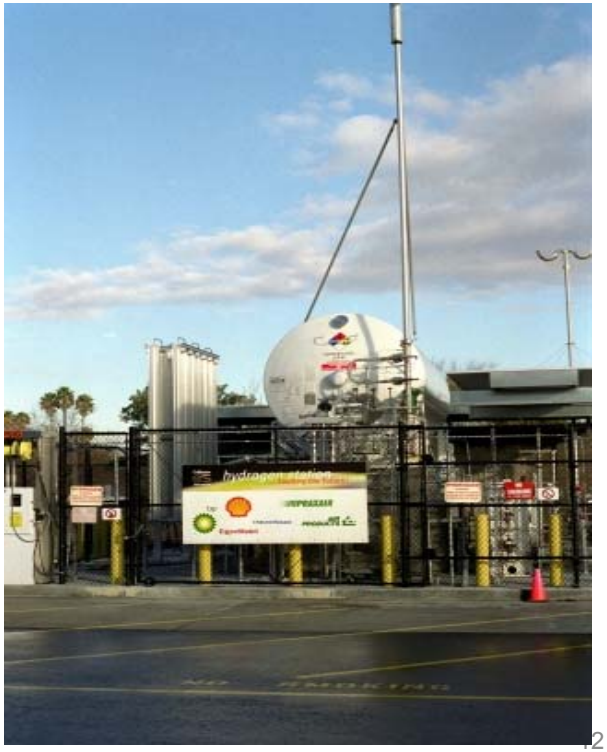
- Pipeline
  - Uncommon – only about 700 miles of pipeline in US
- High-pressure tube trailers
- Liquefied Hydrogen Trailers
- Mobile Refueler

Hydrogen Storage

- Compressed Hydrogen Gas Storage
  - 2000 psi (typical industrial)
  - 5000 psi (350 bar) fueling
  - 10,000 psi (700 bar) fueling

Hydrogen Storage

- Cryogenic Liquid Hydrogen
  - Minus 423 ^{o}F
  - Takes 30% of energy to liquefy the hydrogen
  - Insulated to minimize evaporation and boiloff.



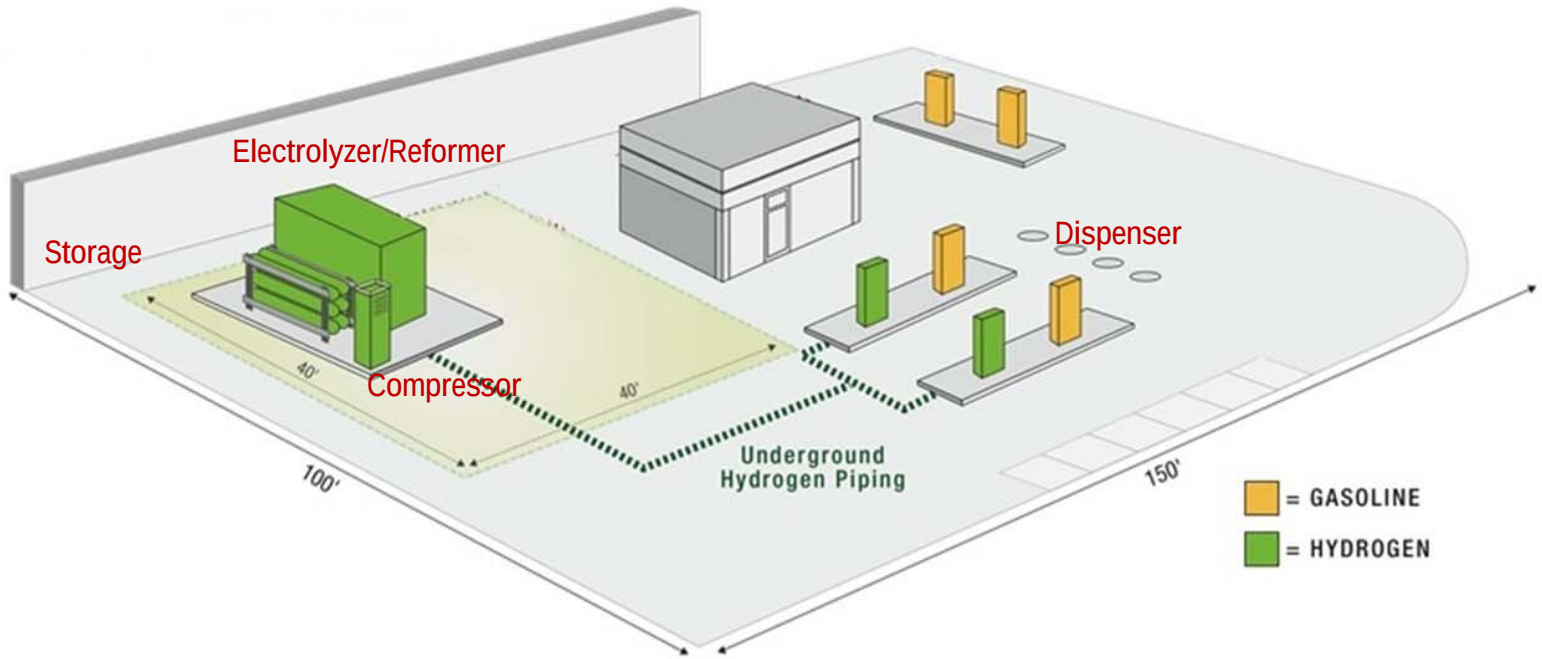
Station Concerns

- High pressure means containment is more difficult
- Hydrogen impacts materials so that materials selection is very important
- Hydrogen can not be odorized so detection systems are needed
- In bright sunlight hydrogen burns with a nearly invisible flame
- Developing retail fuel technology means equipment suppliers are limited (industrial hydrogen applications are well established)
- Developing technology also means there is limited incentive for component manufacturers to list components
- Setback distances for storage are an issue.

Hydrogen Fueling Stations

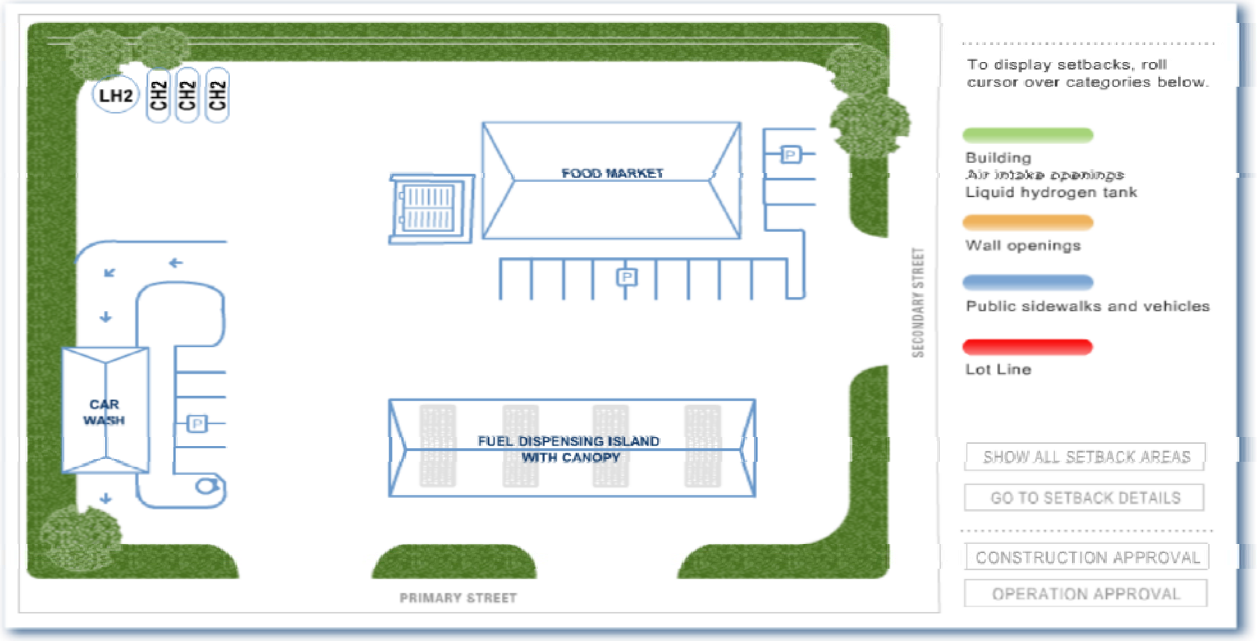
- Basic questions:
- How will the hydrogen be supplied?
- Will the station use both liquid and gaseous storage?
- What storage pressure vehicles will the station serve?
- Will the hydrogen dispenser be located at an existing fueling station?

Hydrogen Fueling Station



Example 2: H2 Delivered

fuelingstation-050609 4/11/11 1:58 PM

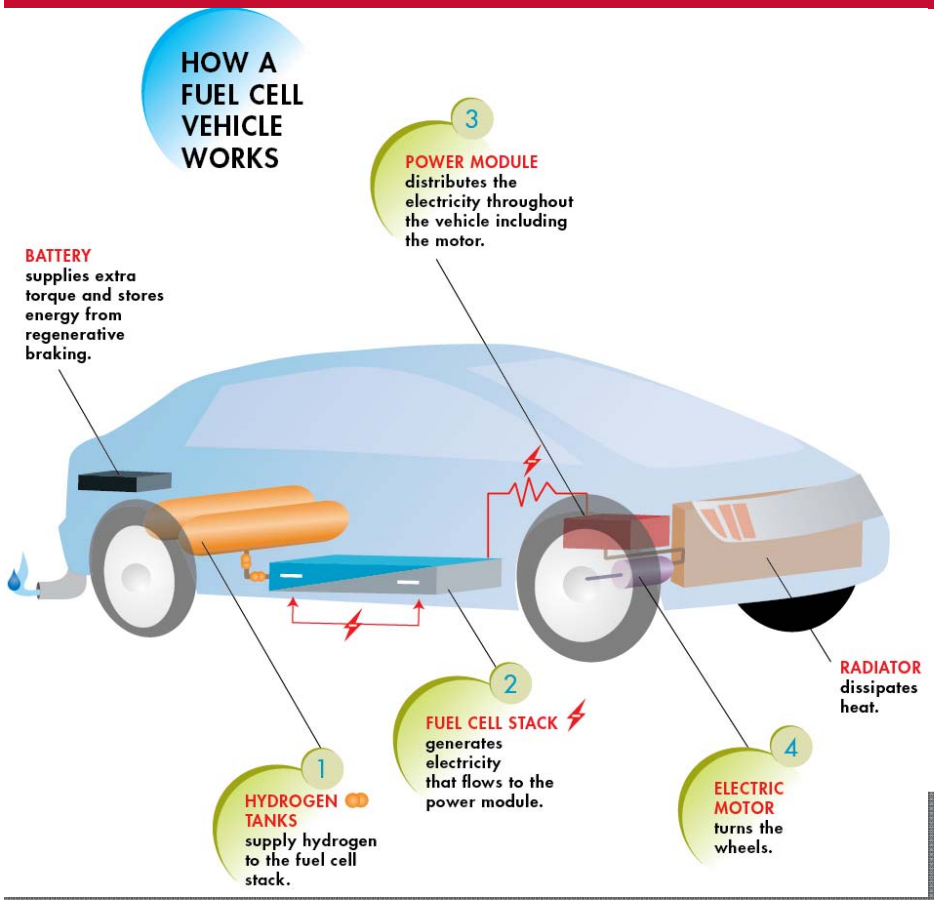


California Deployment Status

- FCEV deployment faster than expected
- Station deployment is on track.
- Energy commission investing $20M annually until CA reaches target of 100 stations
- Target areas with “connector” stations and “destination” stations.
- Demand may strip publically funded station capacity.

California Hydrogen Network –8/31/2016

- Open – Retail – 21
- Open – Non-Retail – 6
- Fully Constructed -6
- Under Construction – 3
- Approved to build – 4
- Planning approval – 2
- In permitting - 4
- Finishing permitting apps – 4
- Total - 48



Hydrogen Fuel Cell Vehicle (HFCV)—How does it work?

1. Carbon composite tanks store the gaseous hydrogen
2. The fuel cell stack converts hydrogen and air into electricity
3. The power module distributes the electricity
4. The electricity powers the motors which turns the wheels
5. The battery stores and releases electricity

Retail Public Fueling Dispenser

Retail Station Equipment - Campbell

AC Transit Fleet Fueling

Liquid Hydrogen Storage – AC Transit

AC Transit Hydrogen Equipment Enclosure

Hydrogen Equipment Enclosure – Separation Distances

Hydrogen Equipment Enclosure - Signage

Liquid Station – San Juan Capistrano

Vent Stack – Liquid Storage

NFPA 2-2016

1. Administration
2. Referenced Publications
3. Definitions
4. General Fire Safety Requirements
5. Performance-Based Option
6. General Hydrogen Requirements
7. Gaseous Hydrogen
8. Liquefied Hydrogen
9. Explosion Protection (reserved)
10. GH_2 Vehicle Fueling Facilities
11. LH_2 Fueling Facilities
12. Hydrogen Fuel Cell Power Systems
13. Hydrogen Generation Systems
14. Combustion Applications
15. Special Atmosphere Applications
16. Laboratory Operations
17. Parking Garages
18. Repair Garages

Purpose of NFPA 2

The purpose of this code shall be to provide fundamental safeguards for the generation, installation, storage, piping, use and handling of hydrogen in compressed gas (GH_2) form or cryogenic liquid (LH_2) form.

Application

- This shall apply to the production, storage, transfer and use of hydrogen in all occupancies and on all premises
- The use of hydrogen shall include stationary, portable, and vehicular infrastructure applications.
- The fundamental requirements of Chapters 1 through 8 shall apply in addition to the use-specific requirements provided in Chapters 9 through 20, as applicable

Exemption

This code shall not apply to the following

- Onboard vehicle or mobile equipment components or systems including the onboard GH_2 or LH_2 fuel supply
- Mixtures of GH_2 and other gases with a hydrogen concentration of less than 95 percent by volume when in accordance with NFPA 55, *Compressed Gasses and Cryogenic Fluids Code.*
- The storage, handling, use, or processing of metal hydride storage systems defined in Chapter 3

Objectives of Requirements – NFPA 2

- Reduce the probability of a release of hydrogen
  - Component and system material requirements
  - Operational safety requirements
- Reduce the probability of an incident in the case of a release
  - Separation distance requirements
- Reduce the severity of an incident if one were to occur.

Chapter 7 – Gaseous Hydrogen

- Requirements for gaseous fuel supply and storage systems
  - General requirements
  - Non-bulk systems– greater than MAQ and less than 5000 ft3
  - Bulk systems – greater than 5000 ft3

Chapter 7 – Gaseous Hydrogen – General Requirements

- Cylinders, containers, and tanks in accordance with DOT, Transport Canada, or ASME Boiler and Pressure Vessel Code
- Pressure relief devices designed and provided in accordance with CGA standards
- Stationary containers marked in accordance with NFPA 704
- Piping systems marked in accordance with ASME A13.1
- Hazard Identification and area warning signs posted
- Areas must be secured and guard posts installed to prevent physical damage.
- Valve provided – for bulk storage or tube trailers – not needed on individual cylinders.

Gaseous Hydrogen – General Requirements (cont.)

- General separation requirements – combustibles, sources of ignition, temperature extremes
- Unauthorized use prohibited
- Containers exposed to fire, leaking or damaged containers removed from use.
- Protected from surfaces where water may accumulate.
- All piping systems in accordance with ASME B31.3 (Section 7.1.15)
- Venting systems in accordance with CGA G-5.5
- Cathodic protection in accordance with Section 7.1.18

Hydrogen Equipment Enclosures (Section 7.1.23)

- Storage greater than 1000 scf or contains generation or processing equipment.
- If can be entered by personnel and potential existed for an oxygen-deficient atmosphere, detection and notification shall be provided
- Secured against unauthorized entry, requires two means of egress under certain conditions.
- Table 7.1.23.9.1 describes protection feature requirement based on use.

Table 7.1.23.9.1 Protection Features Based on Use

HEE or a compartment in a HEE contains:	GH_2 storage	GH_2 storage	Hydrogen generation, compression and/or processing equipment	Support equipment room (in an HEE)
Enclosure Volume:	<200 ft^3	≥200 ft^3	Not limited	Not limited
Contains or is connected to a source of hydrogen:	Yes	Yes	Yes	No
Automatic isolation from GH_2 storage	Not required	Not required	Required	Not applicable
Ventilation	Natural or mechanical	Natural for 3-walls HEE/mechanical for 4-walls HEE	Mechanical	No additional requirement
Storage compartment separation	Not applicable	Not applicable	Required	Required
Electrical equipment	Per NFPA 70, Chapter 5	Per NFPA 70, Chapter 5	Per NFPA 70, Chapter 5	Unclassified
Bonding/grounding	Required	Required	Required	Per NFPA 70
Explosion control	Not required	Required	Required	Not required
Detection	Loss of ventilation*	GH_2, Loss of ventilation*	GH_2, Fire and Loss of ventilation	GH_2 if necessary to meet the requirements of 7.1.23.10.3.1

Bulk Storage

- Separation Distances – Tables 7.3.2.3.1.1
- Based on pipe diameter, system pressure, exposure group
- Except for distances to air intakes, fire barrier walls can be used to reduce Group 1 and 2 exposures by half and eliminate Group 3 distances.
  - No more than three walls
  - No more than 2 sides at 90 degrees or no more than three at 135 degrees
  - Presents a problem for HEEs.
- Group 1 (Lot lines, air intakes, building openings, open flames/welding
  - 29 to 40 ft.
- The basis for separation distances is being reviewed by a Joint 2/55 task group for 2019 edition.

Table 7.3.2.3.1.1(a) Bulk System Separation Distances

Pressure	> 15 to ≤ 250 psig	> 250 to ≤ 3000 psig	> 3000 to ≤ 7500 psig	> 7500 to ≤ 15000 psig
Exposures Group 1 - Lot lines - Air Intakes - Operable openings - Ignition Sources	40 ft	46 ft	29 ft	34 ft
Exposures Group 2 - Exposed persons - Parked Cars	20 ft	24 ft	13 ft	16 ft
Exposures Group 3 - Non-combustible, non-fire rated construction - Combustible construction - Flammable Gas Storage - Hazardous Materials Storage - Heavy timber, coal, - Ordinary combustibles - Unopenable openings - Overhead utilities	17 ft	19 ft	12 ft	14 ft

Chapter 8 – Liquefied Hydrogen – Bulk Storage

- Greater than 39.7 gals (150 L) Hydrogen
- Provided with pressure relief devices, prevent freezing, arranged to discharge unobstructed.
- Venting in accordance with CGA 5-5
- Piping in accordance with ASME B31.12
- Containers greater than 2000 gallons equipped with automatic emergency shutoff.
- Point of fill connections must meet separation distance requirements.
- Stationary containers not installed in enclosed courts.
  - Open to the environment – requirements for encroachments by building walls

Chapter 8 – Liquefied Hydrogen

- Table 8.3.2.3.1.6 (A) in 2016 edition -
  Minimum Distance from Liquefied Hydrogen Systems to Exposures.
- Extracted from NFPA 55, basis for separation distances is being reviewed by Joint 2/55 task group
- Distances grouped by type of exposure, volume of storage
  - Distance to air intakes are 75 ft
- Some distances (lot lines, buildings, flammable storage) can be reduced by two-thirds (to not less than 5 ft) for insulated portions of the system.
- Can also be reduced through the use of fire barriers.

Chapter 10 Gaseous Hydrogen Fueling Systems

- Dispensing facilities must be certified as meeting code requirements by a qualified engineer.
- Hazard analysis must be conducted
- System components must be listed or approved.
- Storage in accordance with Chapters 6 and 7
- Hydrogen safety panel is developing hydrogen equipment certification guide
  - https://h2tools.org/sites/default/files/Hydrogen_Equipment_Certification_Guide_20151210.zip

Chapter 10 Gaseous Hydrogen Fueling Systems (cont.)

- Pressure relief devices installed on fueling transfer systems.
- Pressure gauges installed to indicate dispenser discharge pressure
- Pressure regulators installed on dispensing systems
- Fuel lines and piping systems - ASME B31.3
  - Piping as directly as possible – protected against damage.
- Hose and Hose connections – compatible with hydrogen
- Valves – listed or approved.
- System tested prior to final installation.

Chapter 10 Gaseous Hydrogen Fueling Systems (cont.)

- Maintenance in accordance with manufacturers instructions.
- Station operator develop MOC (management of change) system.
- Dispenser integrity checks required prior to fueling events.
- Dispensers using communication protocol stop fueling in the event of a communication failure
- Stop fuel automatically when reaches system pressure or activation of overpressure
- Sources of ignition not allowed within 10 ft. of any filling connection during transfer.
- Fueling nozzles listed or approved in accordance with SAE J2600

Chapter 10 Gaseous Hydrogen Fueling Systems (cont.)

- Installation of Electrical Equipment – Table 10.3.1.15.1
  - Outdoor dispenser – Class 1, Div. 2 – 5 feet
  - Indoor dispenser – Class 1, Div. 2 – 15 feet from point of transfer
  - Relief valves or vents – Class 1, Div. 1 – 5 feet, Class 2, Div. 2 – 15 feet
  - Relief valves within 15 degrees of the line of discharge – Class 1, Div. 1 – 15 feet

Chapter 10 Gaseous Hydrogen Fueling Systems (cont.)

- Installation of Emergency Shutdown equipment.
  - Manual emergency shutdown valve provided at dispensing area and at a location remote from the dispensing area.
  - Shutdown of power supply and gas supply
  - If supplying an indoor dispenser, redundant shutoff at entrance to the building.
- Canopies used to support systems
  - Type I construction
  - Operations limited to fueling
  - Constructed to prevent accumulations of hydrogen.

Chapter 10 Gaseous Hydrogen Fueling Systems (cont.)

- Outdoor Public Fueling
- Separation Distances for Outdoor Dispensing Systems – Table 10.3.2.3.1.4
  - 10 ft. for most exposures
    - Dispensing equipment to Important Building, lot line, source of ignition, street or sidewalk, railroad track.
    - Point of transfer to Important Building
  - No separation distance required between Point of Transfer and Type I or II construction with fire resistance rating of 2 hours or greater.

Mobile Refueling Requirements

10.3.3.3.5.1 Mobile refueling vehicles, temporary trailers (with or without tractors), and other means of providing vehicle refueling or onsite storage shall be subject to the same requirements as a permanent refueling or storage installation, with the exception of vessel requirements.

(A) The AHJ shall be notified before commencing operations, and permitting sought if required, under 10.3.3.3.5.

Chapters 17 and 18 – Parking and Repair Garages

- Chapters are no longer reserved in the 2016 edition
- Parking of hydrogen powered vehicles subject to the same requirements as traditional fueled vehicles
- Repair garages
  - Major and Minor repair garages
  - Requirements depend on type of work done.
  - H2 detection and special ventilation needed only for major repairs involving work on fuel tanks and and on-board fuel system

Joint NFPA 2/55 Task Group on Separation Distances

- Preparing public input for next revision cycle to change gaseous hydrogen setback distance
  - Modify assumption made in original work based on better data
- Working on liquid hydrogen set back distances
  - Developed release scenarios based on HAZOP
  - Working with Sandia on modeling and experimental verification of model
  - Research foundation working on securing industry funding.

Areas of Focus for 2019 editions

- Setback distances for GH_2 and LH_2 systems.
- Hydrogen Equipment Enclosure requirements
- Revisions to Chapter 10 Fueling based on feedback from CA deployment.
- Task Group 30A/2 TCs.