NREL
NATIONAL RENEWABLE ENERGY LABORATORY







Overview: NFPA 2 Hydrogen Technologies Code Requirements

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Course Outline

- Topic 1.Scope and Purpose of NFPA 2
- Topic 2. NFPA 2 Code Structure
- Topic 3. High-Pressure Gas Hazards and Risk Reduction in NFPA 2
- Topic 4. Hydrogen at NREL's Energy Systems Integration Facility (ESIF)Hydrogen Fueling Station-Evaluating Risk

Topic 1. NFPA 2 Scope and Purpose

Committee Scope:

- "This committee shall have primary responsibility for documents on the storage, transfer, production, and use of hydrogen. The use of hydrogen would include stationary, portable, and vehicular applications."
- NFPA 2 Hydrogen Technologies Code is the only document produced by the NFPA Hydrogen technologies Technical Committee

What does this mean?

- First note that this is the committee scope
- The committee must ensure that there are safety requirements for all hydrogen applications. The committee can either extract safety requirements where they already exist in another document, develop requirements where none exist but they fall under the scope of another document and submit these requirements to the appropriate document for extraction back into NFPA 2, or develop requirements and submit them to NFPA 2 where none exist and they do not fall under the scope of another document.

Topic 1. NFPA 2 Scope and Purpose

Purpose.

- "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 (GH2) form or cryogenic liquid (LH2) form"

What does this mean?

- This code addresses all aspects of hydrogen safety
- This code is structured to be the national code for hydrogen safety in the US
- Applications that the codes addresses include:
  - Hydrogen fueling stations for all types of vehicles
  - Fuel Cell Electric Vehicle (FCEV) repair facilities
  - Stationary fuel cells

Topic 2. NFPA 2 Chapter Structure

- Administration
- Referenced Publications
- Definitions
- General Fire Safety Requirements
- Performance-Based Option
- General Hydrogen Requirements
- Gaseous Hydrogen
- Liquefied Hydrogen
- Explosion Protection (reserved)
- GH_2 Vehicle Fueling Facilities
- LH_2 Fueling Facilities
- Hydrogen Fuel Cell Power Systems
- Hydrogen Generation Systems
- Combustion Applications
- Special Atmosphere Applications
- Laboratory Operations
- Parking Garages
- Repair Garages

Code moves from general requirements to specific applications

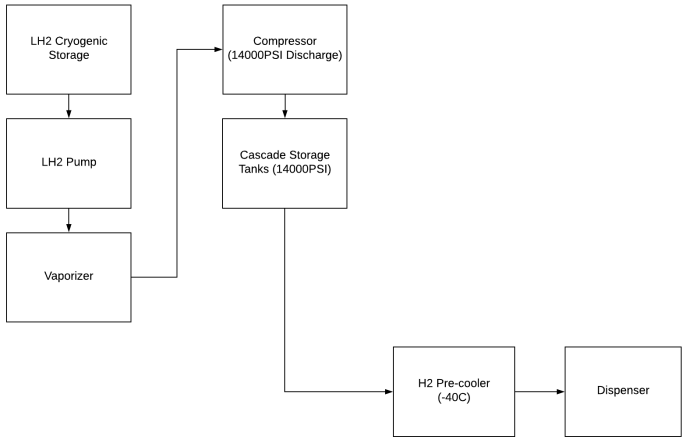
Topic 2. NFPA 2 Hydrogen Fueling Station Code Structure

Example hydrogen Fueling Station

- What requirements do a hydrogen fueling station trigger in NFPA 2? Requirements found primarily in the following chapters.
  - Chapter 4 General Fire Safety Requirements
  - Chapter 6 General Hydrogen Requirements
  - Chapter 7 Gaseous Hydrogen
  - Chapter 8 Liquefied Hydrogen
  - Chapter 10 GH_2 Vehicle Fueling Facilities

Fueling Station with Storage

LH2 Station, Trailer Liquid Supply, Cascade Fill



Location	Requirements Referenced in NFPA-2
LH2 Cryogenic Storage	Chapter 8
LH2Pump and Vaporizer	Chapter 8
Compressor	Chapter 7/10
Cascade Storage	Chapter 7
Pre-cooler	Chapter 10
Dispenser	Chapter 10

Topic 2. NFPA 2 Code Structure

Chapter 4 General Fire Safety Requirements

- Permits
- Emergency Plan
- Facility Closure Plan
- Management Plan
- Personnel Training
- Ignition Source Controls
- Signs
- Protection from Vehicular Damage

Operational Plans

- Chapter 4 requires a variety of plans to safely operate facility including:
  - What to do in the event of incidents or upset conditions
  - Identification of line management and their responsibilities
  - Safe closure
  - Personnel training

Topic 2. NFPA 2 Code Structure

Chapter 6 General Hydrogen Requirements

- Design construction
- Control areas
- Occupancy classification
- Gas rooms
- Weather protection
- Electrical equipment
- Employee alarm system
- Explosion control
- Fire protection systems
- Fire alarm systems
- GH_2 detection systems
- Ventilation
- Gas cabinets
- Cleaning and purging of piping systems

Uses Concepts from Fire Code

- Control Area. Abuilding or portion of a building or outdoor area, within which hazardous materials are allowed to be stored, dispensed, used, or handled, in quantities not exceeding the maximum allowable quantities (MAQ). [400, 2016]

- Maximum Allowable Quantity per Control Area (MAQ). A threshold quantity of hazardous material in a specific hazard class that once exceeded requires the application of additional administrative procedures, construction features, or engineering controls. [55, 2016]

Topic 2. NFPA 2 Code Structure

- **Chapter 7 Gaseous Hydrogen**

- 7.1.5 Cylinder, Containers, and Tanks
- 7.1.9 Separation from Hazardous Conditions
- 7.1.15 Piping
- 7.1.17 Venting Systems
- 7.1.18 Cathodic Protection
- 7.2 Non-bulk GH2 Systems
- 7.3 Bulk Systems including bulk storage system setbacks

Total System Safety

- Safety setback distances for bulk storage systems are located in 7.3
- These distances are one of several safety measures that ensure that systems are safe
- Safety measures include:
  - Tank design
  - Piping design
  - Component design
  - Venting

Topic 2. NFPA 2 Code Structure

Chapter 8 Liquid Hydrogen Systems

- 8.1.2 Containers
- 8.1.3.1 Piping
- 8.1.4 Pressure Relief Devices
- 8.1.5 Vent Piping
- 8.1.9 Electrical Wiring and Equipment
- 8.2 Non-Bulk Systems
- 8.3 Bulk LH_2 Systems
- 8.3.2.3.1.7 Underground Tanks

Total System Safety

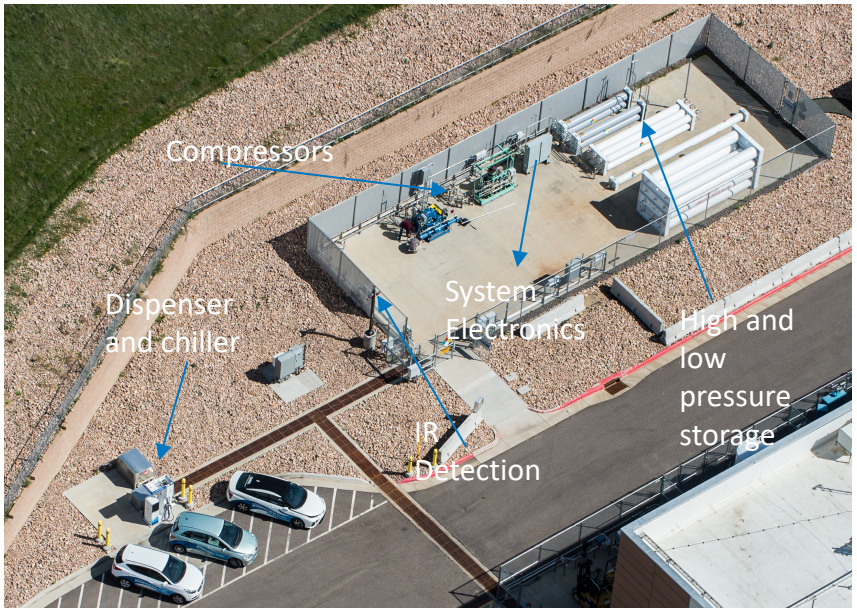
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Topic 2. NFPA 2 Code Structure

Chapter 10 GH2 Vehicle Fueling Facilities

- 10.1 Scope- note that this chapter addresses all hydrogen fueling including indoor fueling, passenger vehicle fueling and heavy-duty vehicle fueling
- 10.2 General
- 10.3 Dispensing
- 10.4 Storage

Station with gaseous hydrogen storage



Topic 3. High Pressure Gas Safety Hazards and Risk reduction Measures

Hazards	Protection Schemes	Code Sections (2016 edition)
Hydrogen acting as as simple asphyxiant as a result of a release in an enclosed space	1. Limit indoor hydrogen storage 2. Use detectors to identify releases 3. Use ventilation to ensure release can not accumulate 4. Shut down system if release detected as well as activate visual and audible alarm 5. Evacuate space in the event of alarm condition	1. 6.4.1 2. 6.12 3. 6.17 4. 10.3.1.18.1.3 and 10.3.1.17.1 5. 4.11
Hydrogen overpressure event without ignition	1. PRDS to prevent catastrophic overpressure event 2. Separate personnel from potential over pressure situations 3. Testing and maintenance to ensure pressure relief systems are functional 4. Electrical classification zones	1. 8.3.1.2.2 and 7.1.5.5 2. 4.11 3. 8.3.1.2.2 and 7.1.5.5 4. Table 7.3.2.3.1.5, Table 8.3.1.2.6, and Table 10.3.1.15.1
Hydrogen release with ignition and fire	1. Hydrogen venting to a safe location 2. No flammable materials in flame ignition area	1. 7.1.17 and 8.1.5 2. 4.12, 7.1.9.1.6, 7.1.26, 8.3.2.2.2.3, Table 8.3.2.3.1.6 (A), 10.3.1.13.9, and Table 10.3.2.3.1.4
Hydrogen release with ignition in an an enclosed or partially enclosed space resulting in an explosion	1. Limit indoor hydrogen storage to amounts such that any release would have insufficient energy to explode 2. Hydrogen storage not allowed in confined unventilated spaces	1. 6.1.1.4 and 6.1.1.5 2. 6.3

Topic 3. High Pressure Gas Safety Hazards and Risk reduction Measures

- Examples of Protection Measures
  - Fire walls
  - PRDs
  - Vent Stacks
  - Sensors
  - Equipment design – show stamp on tanks
  - Electrically classified equipment
  - Breakaway devices for dispensing hoses

Topic 3. High Pressure Gas Safety Hazards and Protection Schemes

- Fire Wall can reduce setback distance requirements for bulk hydrogen storage systems

Fire wall constructed of material that meets ASTM E136 at retail fueling station hydrogen storage pad



Module 2. High Pressure Gas Safety Hazards and Protection Schemes

Pressure Relief Device at NREL Hydrogen Infrastructure Testing and Research Facility designed per CGAS-1.3, Pressure Relief Device Standards—Part 3—Stationary Storage Containers for Compressed Gases



Topic 3. High Pressure Gas Safety Hazards and Protection Schemes

Horizontal discharge twin pipe stack at bulk liquefied hydrogen system designed per CGA G-5.5, Hydrogen Vent Systems.

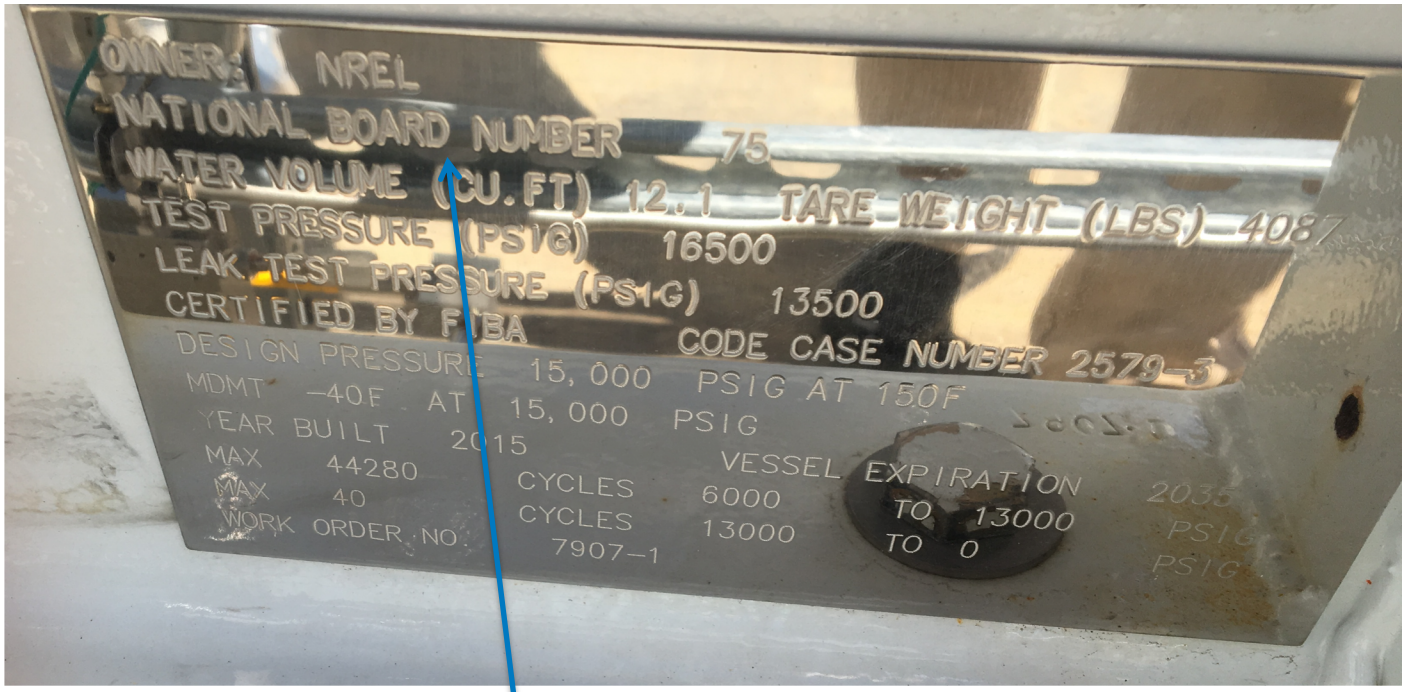


Topic 3. High Pressure Gas Safety Hazards and Protection Schemes

Chemical
sensor at hydrogen
gas compressor located at
modular hydrogen fueling
Station required 10.3.1.18.1



Topic 3. High Pressure Gas Safety Hazards and Protection Schemes



Nameplate for hydrogen storage tanks showing National Board Number at NREL Hydrogen Infrastructure Testing and Research Facility and showing leak and test pressure – required 7.1.5.1

Topic 3. High Pressure Gas Safety Hazards and Protection Schemes

Electrical classification information at chiller at NREL Hydrogen Infrastructure Testing and Research Facility for NEC Class I Division 1 environments



Topic 3. High Pressure Gas Safety Hazards and Protection Schemes

Breakaway device to prevent dispenser hose from be torn from dispenser during vehicle driveaway-required 10.3.1.8.6



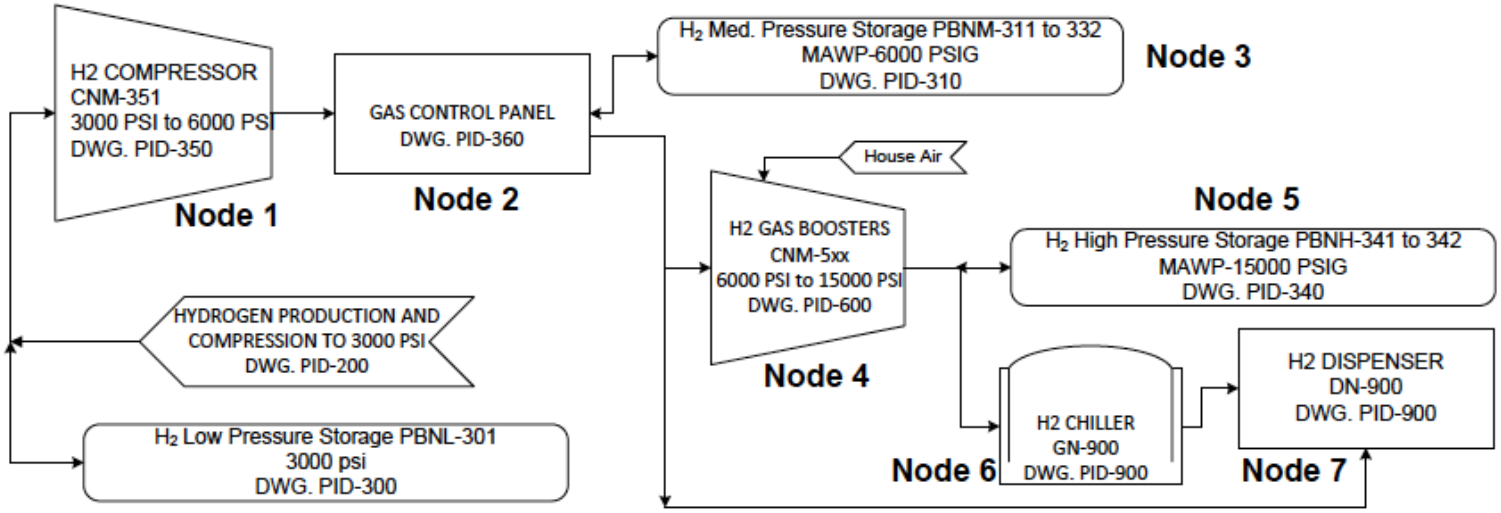
Topic 3. High Pressure Gas Safety Hazards and Protection Schemes

Infra-Red detection pointed at dispenser required under 10.3.1.18.1



Topic 4. NREL Hydrogen Fueling Station Risk Analysis

Planning for NREL High-Pressure Fueling station included qualitative risk analysis: station broken down into seven nodes and analysis done using a 1-4 scale for event severity and a 1-6 scale for event probability and undesirable outcomes at each node were identified based on defining variations at nodes. Node 8 control electronics cuts across all nodes.



Topic 4. NREL Hydrogen Fueling Station Risk Analysis

Node	Node Description	HR	MR	LR	RR	Node Total Risk
5	Compressor to Cascade Tank	0	0	7	9	23
2	Hose	0	2	3	0	12
1	Nozzle	0	0	5	1	11
4	Cascade Tanks to Dispenser	0	0	2	5	9
8	Control Electronics	0	0	2	4	8
7	Air System	0	0	0	5	5
6	Cryo Storage to Compressor	0	0	0	1	1

HR - High Risk (4)
MR - Medium Risk (3)
LR - Low Risk (2)
RR - Routine Risk
Total node risk = SUM (ranking * risk #)

Topic 4. NREL Hydrogen Fueling Station Risk Analysis

What does this analysis mean?

- Greatest risk at compressors and dispenser
- Operation of the fueling stations confirms the initial analysis with the qualifier that compressor performance has improved and current focus is on improving dispenser performance

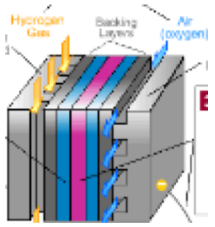
Sections that address high-risk components include the following:

- Section 7.1.21 addresses compressor requirements
- Section 10.3.1.14 address requirements for the vehicle fueling connection (nozzle)
- Section 10.3.1.8 address Hoses and hose connections

Thank You and Questions

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