Electrolyzer Codes and Standards

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Outline

1. What are Codes and Standards
2. Examples of Relevant Codes
3. Current Codes and Standards Work
4. Resources

What are Codes and Standards

- A code is a set of rules or guidance that experts recommend others follow
  - Can be adopted into law
- Standards are detailed documents outlining how to meet code

- Codes and standards are agreed upon best practices
- Are updated or reviewed on a regularly scheduled basis
- May receive public input to identify issues and areas that need improved for the next cycle
- Intended to assist with the deployment of safe systems

Flatirons Campus Example

- Research system connected to controllable grid simulator (CGI) renewable energy generation, and battery storage
- 1.25 MW Electrolyzer
- 1 MW Fuel Cell
- 600 kg of H_2 storage at 20 MPa
- Compressor

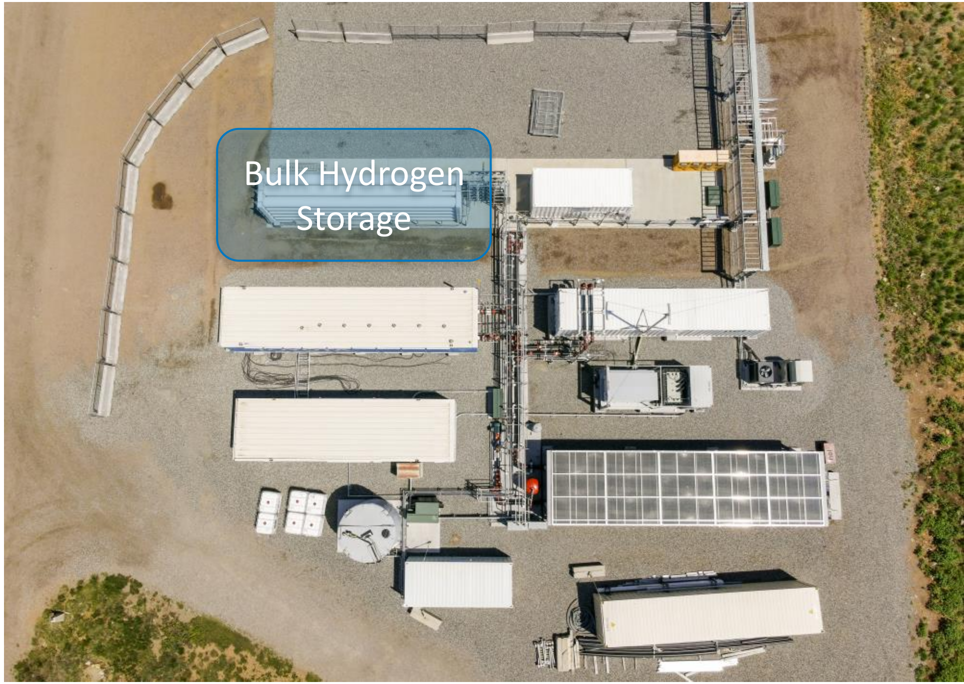
- This presentation does not provide and exhaustive list of codes and standards
- This presentation does not go into liquid hydrogen codes and standards

Facility Perspective: Codes and Standards

- International/National
  - Fire Code
  - Fuel Gas Code
  - Mechanical Code
  - Building Code
  - Electrical Code (IEC/NFPA 70)
- NFPA 2 Hydrogen Technologies Code
- NFPA 55 Compressed Gases and Cryogenic Fluids
- CGA G-5 Hydrogen
- ISO TR15916 Basic Consideration for the Safety of Hydrogen Systems
- OSHA Regulations 29 CFR 1910, Subpart H, Hazardous Materials
  - OSHA 1910.103 Hydrogen
  - OSHA 1910.119 Process Safety Management of Highly Hazardous Chemicals, Toxins and Reactives
    - Application defined by quantity threshold
- Factory Mutual Global Property Loss Prevention Data Sheets Hydrogen 7-91

Facility Perspective: Impact on Layout

- Bulk storage has the largest impact of facility size
  - NFPA 2 Hydrogen Technologies Code
- Locations of hazardous electrical classification zones guides design
  - NFPA 70
    - Can require significant effort



Electrolyzer Specific Codes and Standards (System Level)

- NFPA 2 Hydrogen Technologies Code
  - Chapter 13 Hydrogen Generation systems
    - Scope
      - 36 g/hr < Generation capacity < 100 kg/hr
      - Permanently installed hydrogen generation systems
      - References that water electrolyzers shall be listed to ISO 22734
- CSA/ANSI B22734 Hydrogen Generators using Water Electrolysis (adoptions with Canadian and U.S deviation of ISO 22734)
  - Scope
    - No generation capacity limit
    - Potential gap - high temperature electrolysis not explicitly included in the scope
    - Transport medium of aqueous base, aqueous acids, proton exchange membrane (PEM), and anion exchange membrane (AEM) included

Subsystem: Enclosures Design

- NFPA 2 Hydrogen Technologies Code
- ISO 22734 Hydrogen Generators using Water Electrolysis
- NFPA 69 Standard on Explosion Prevention Systems
- NFPA 70 National Electric Code (NEC)
- NFPA 496 Standard for Purged and Pressurized Enclosures
- NFPA 497 Recommended Practice of the Classification of Flammable Liquids, Gases, or Vapors
- IEC 60079-10-1 Explosive Atmospheres – Part 10-1: Classification of Areas- Explosive Gas Atmospheres

- Considerations
  - Air intake locations
  - Ventilation
  - Detection (GH_2 and fire)
  - Emergency isolation

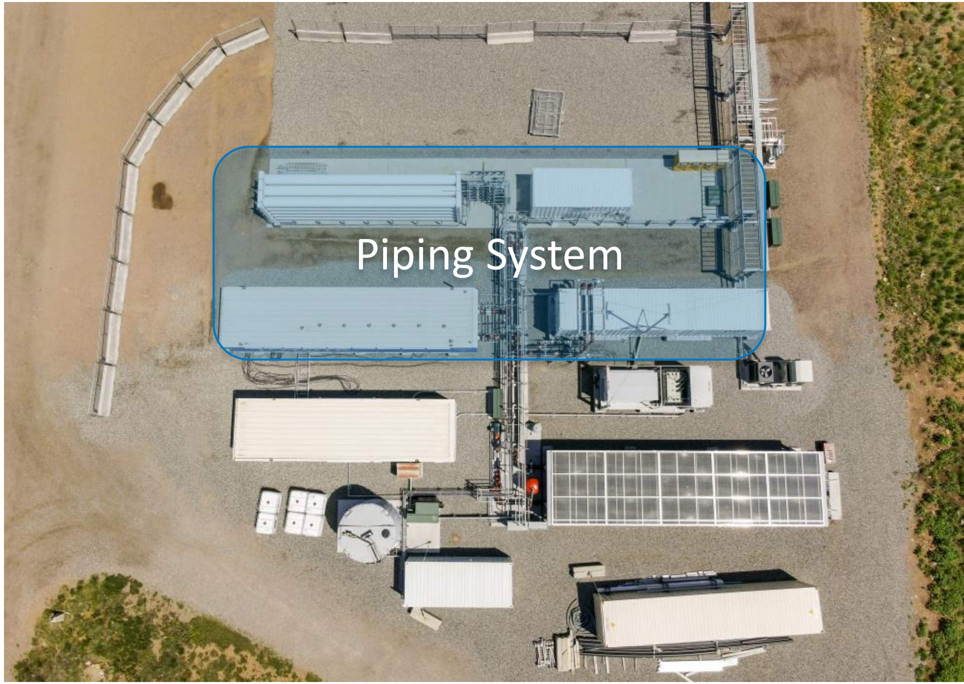
Subsystem: Hydrogen Vent System

- NFPA 2 Hydrogen Technologies Code
- CSA/ANSI 22734 Hydrogen Generators using Water Electrolysis
- CGA G-5.5 Hydrogen Vent Systems
- CGA S.1 Pressure Relief Device Standards
  - S 1.1 Part 1 - Cylinders for Compressed Gases
  - S 1.2 Part 2 - Portable Containers for Compressed Gases
  - S 1.3 Part 3 – Stationary Storage Containers for Compressed Gases

- Considerations
  - Potential for wet (saturated) gas venting
    - Freeze protection
    - Water removal

Subsystem: Piping System

- NFPA 2 Hydrogen Technologies Code
- CSA/ANSI 22734 Hydrogen Generators using Water Electrolysis
- ASME B31.3 Process Piping
- ASME B31.12 Hydrogen Piping and Pipelines
- ASME Boiler and Pressure Vessel Code
  - Separators, heat exchanges, etc.
- HGV 4.10-2012 Standard for Fittings for Compressed Hydrogen Gas and Hydrogen Rich Gas Mixtures
- CGA G-5.4-2012 Standard for Hydrogen Piping Systems at User Locations



- Considerations
  - Proper material selection for the gases and conditions
  - Equipment mechanical integrity
    - Proper installation and maintenance

Subsystem: Oxygen

- CGA G-4 Oxygen
- CGA G-4.1 Clean Equipment for Oxygen Service
- CGA P-8.7 Safe Location of Oxygen and Inert Gas Vents
- NFPA 53 Systems in Oxygen-Enriched Atmospheres
- ASTM A967 Passivation of Stainless Steels
- ASTM G65 Standards Guide for Evaluating Nonmetallic Materials for Oxygen Service
- ASTM G93 Standard Guide for Cleanliness Levels and Cleaning Methods for Materials and Equipment Used in Oxygen-Enriched Environments
- ASTM G94 Standard Guide for Evaluating Metals in Oxygen Service
- ASTM G88 Designing Systems for Oxygen Service
- ASTM G127 Guide for the Selection of Cleaning Agents for Oxygen Service
- ASTM G131 Standard Practice for Cleaning of Materials and Components by Ultrasonic Techniques
- OSHA 1910.104 Oxygen
- CSA/ANSI 22734 Hydrogen Generators using Water Electrolysis

- Considerations
  - Storage and compression of oxygen adds additional hazards
  - Material compatibility
  - Cleanliness

Subsystem: Water and Cooling

- Water quality standards determined by the manufacturer
- Cooling requirement defined by the manufacturer
- Critical components of the overall system design
- Can have a significant impact on the system size, layout, auxiliary power requirements, and operation
  - Water usage and waste requirements may be challenging for some locations

Hydrogen Quality Standards

- Hydrogen quality standard to be met depends on the end use application
  - SAE J2719 Hydrogen Fuel Quality for Fuel Cell Vehicles
  - ISO 14687 Hydrogen Fuel Quality – Product Specification
  - CGA 5.3 Commodity Specification for Hydrogen

Looking Forward

- IEEE 1547: IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
  - Currently undergoing revision process with multiple active working groups
  - Provides guidance on the integration of large systems with grid connections
    - Informs electrical utilities and regulators

- ISO TC197 Hydrogen Technologies
  - WG 32 Hydrogen Generators using Water Electrolysis
  - WG 34 Hydrogen Generators using Water Electrolysis Test Protocols and Safety Requirements
  - SC 1 Hydrogen at Scale and Horizontal Energy Systems
    - Subcommittee focusing on grid interconnects

- ASME Boiler and Pressure Vessel code has electrolyzer stack code case in development
  - Concerns about the need for this code case, impact of time and cost, and ability for stacks to meet the test requirements
  - Materials on ASME list
  - Hydrostatic or pneumatic pressure test
  - ASME approver for each stack
  - Task group on this topic starting soon

Working with AHJs

- Local AHJ's are charged with enforcing building and fire codes per their interpretation
  - Early engagement is key
  - AHJ experience and understanding of codes and the technology effects the approval process
    - Outreach and education of AHJs may help
- Selecting listed equipment (e.g. per ISO 22734 or ANSI/CSA B22734) may help with system approvals
  - NFPA 2, chapter 13 points to these standards but currently has an applicability limit of < 100 kg H_2/hr

Other Considerations

- If the system is being designed doing something new or an application being used in a new way that is potentially not captured by current codes and standards
  - For example - unique materials, abnormal pressures, high temperatures, scale, combination
  - Assess how moving into this new space could create other hazards and challenges associated with your system
  - Engineering analysis may be needed
  - Learning from other industries who may have similar experience
    - The chloralkali industry has a long track record of co-generation of H_2, NaOH, Cl_2
  - Coordination, outreach, education with AHJs
  - Performance-based vs prescriptive-based code compliance
- Technology space and codes are being developed together

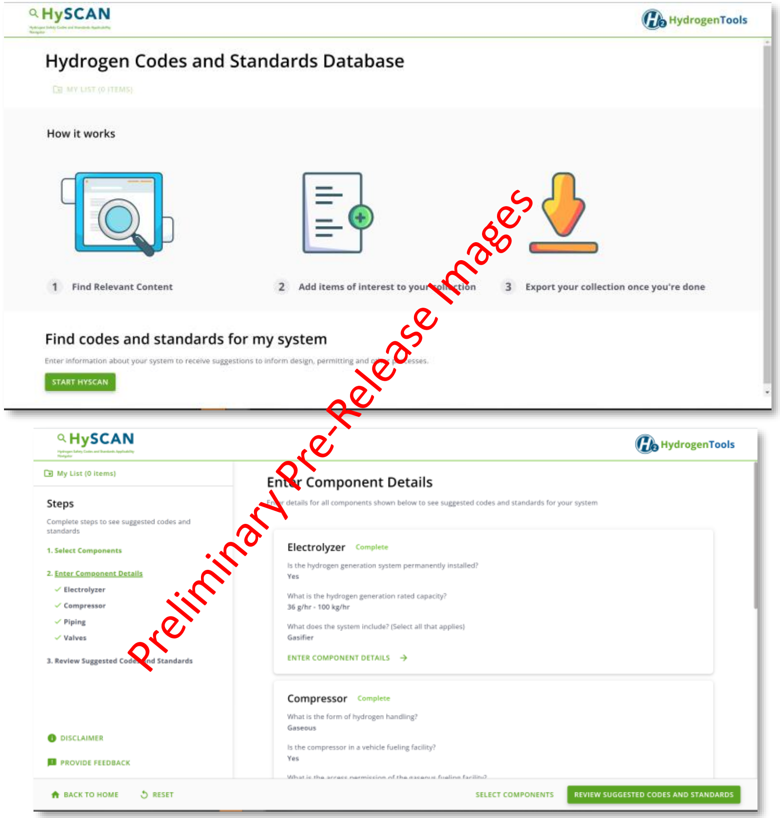
Resources

- Resource: https://h2tools.org/
  - Includes a variety of tools, lessons learned, and best practice information
    - Fuels Cells Codes and Standards Resource
      - Over 400 codes and standards related to hydrogen referenced
      - https://h2tools.org/fuel-cell-codes-and-standards?search_api_fulltext=&f%5B0%5D=application_type%3A1349
    - Safety Planning
      - https://h2tools.org/bestpractices/safety-planning
    - Lessons Learned
      - https://h2tools.org/lessons?search_api_fulltext=

The Hydrogen Safety Codes and Standards Applicability Navigator (HySCAN) Online Tool

- **Vision**: Enable hydrogen stakeholders to identify what codes and standards currently exist and may apply to their system
- **Process:**
  - Identify components in potential system of interest
  - Answer questions about those components
  - Get an informational list of potentially relevant codes and standards

HySCAN will be available soon at H2Tools.org



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