Hydrogen Fuel Safety

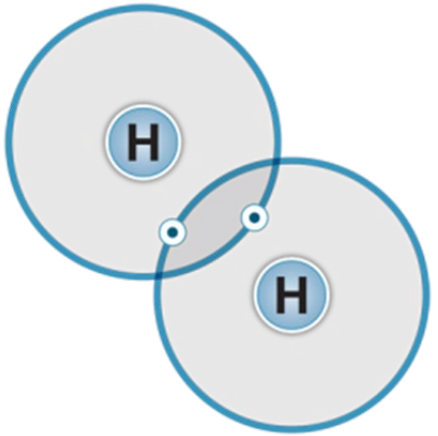
Properties, Practices, Peace of Mind

Topics Covered

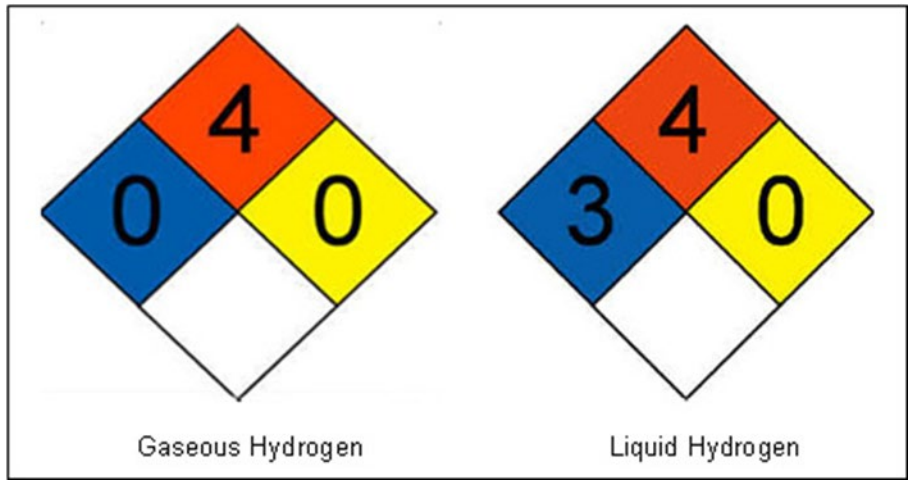
Hydrogen Basics

Safety Assurance

- Hydrogen Safety Panel
- Hydrogen Safety Codes and Standards
- Hydrogen Safety Devices and Systems
- Hydrogen Certification Procedures



Molecular Hydrogen



Gaseous Hydrogen

Liquid Hydrogen

What is Hydrogen?

- The most abundant element in the known universe
  - Makes up almost 75% of all matter
  - An energy carrier like electricity or gasoline
- The lightest and most energy dense molecule
- Not an energy source because it is not found on Earth by itself
- Must be created through,
  - Electrolysis (green hydrogen)
  - Steam methane reforming (gray hydrogen)
  - Pyrolysis (green/gray hydrogen)
- Has been used as an industrial chemical for ~150 years
  - 50 million metric tons produced annually

Hydrogen Properties and Behavior

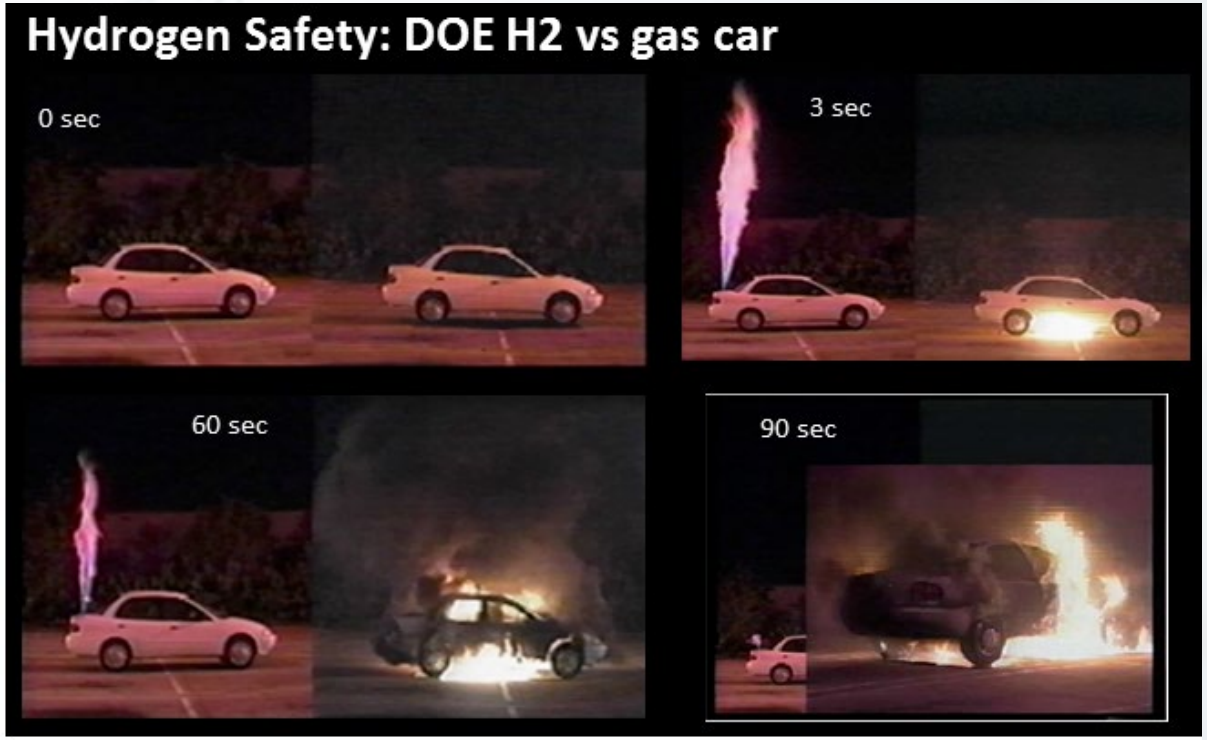
- A gas at normal atmospheric conditions conditions
- A cryogenic liquid at -427°F (-253°C)
- Rapidly disperses when released
  - Rises at a speed of 20 meters/second (66 feet/second)
- Colorless, Odorless, Non-toxic
- Flammable, Asphyxiant

Hydrogen Comparison

	Hydrogen	Natural Gas	Gasoline
Color	**No**	**No**	**Yes**
Toxicity	**None**	**Some**	**High**
Odor	**No**	**Mercaptan (Sulfur)**	**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
Spark Ignition Minimum air concentration	**4.0%**	**5.0%**	**1.4%**

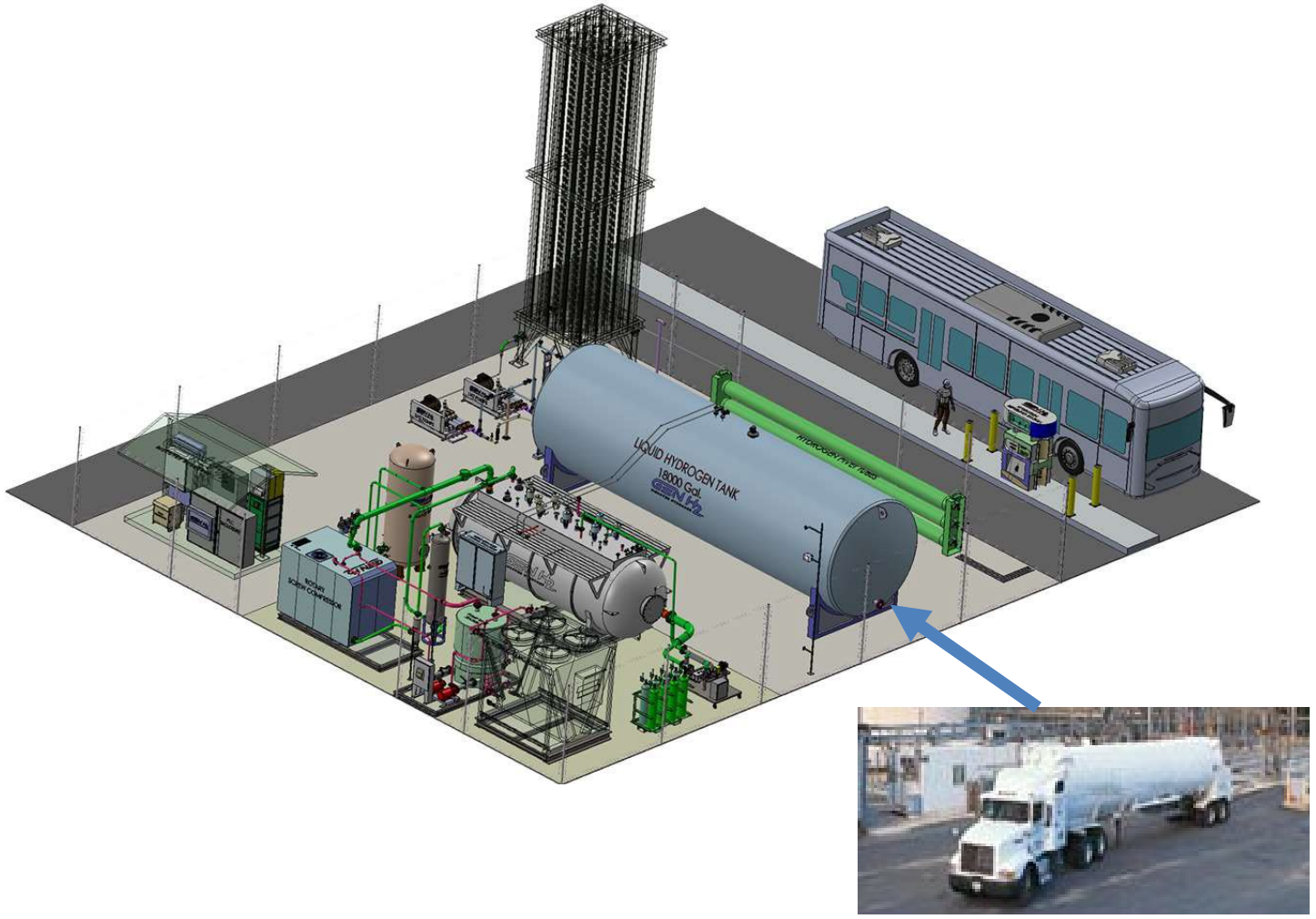
Characteristics of a Hydrogen Flame

- Smokeless
  - Burning carbon creates smoke
  - Gasoline releases carbon when it burns
- Invisible
- Approximately 4,000°F
- No radiant heat
  - Heat may not be felt until just a few inches away from the flame
  - Radiant heat from a gasoline fueled flame can be felt from a greater distance



Since the flame emits low levels of heat in the surrounding area the risk of secondary fires is lower.

Hydrogen Refueling Process



- H_2 is delivered in liquid (LH2) form and stored on-site
- Pumped through a vaporizer and converted to gaseous H_2
- Buffer storage of GH2 for smooth, consistent flow
- Automated control and safety system only flows hydrogen when all refueling protocol checks have been passed
- Automated GH2 dispenser
- Fill Pressure of 350 Bar (5,000 psi) or 700 Bar (10,000 psi)

How Safe is Hydrogen?

- Hydrogen is no more or less dangerous than any other currently used fuel
- If anything, it has some uniquely inherent safety features
  - Disperses quickly away from ground level personnel and assets
  - Lower risk of secondary fires
  - Non-toxic and non-poisonous
- Same ignition and explosion risks (at typical concentrations) as other fuels
- Long used as an industrial chemical
  - Commercially available, proven safety devices
  - Commercially available, proven storage, delivery, and handling equipment
- Established Codes, Standards, and Safety Procedures
  - Both mature and evolving

Hydrogen Safety Panel (HSP)

- Established by the US Department of Energy (DOE) office of Energy Efficiency Renewable Energy (EERE)
- Administered by the Pacific Northwest National Laboratory (PNNL)
- Develops and maintains comprehensive hydrogen safety practices
- Establishes and conducts hydrogen system safety reviews
  - Process Hazard Analysis (PHA)
  - Process Safety Analysis (PSA)
- Administers Hydrogen Tools Portal Hydrogen Tools
  - Rich repository of useful information and guidelines
- HSP members come from a broad cross-section of industry and academia

Hydrogen Code and Standards

Codes

- NFPA 1, Fire Code
- NFPA 2, Hydrogen Technologies Code
- NFPA 55, Compressed Gases and Cryogenic Fluids
- NFPA 70, National Electric Code
- OSHA 1910.103, Gaseous and Liquid Hydrogen

Standards

- ASME VIII, Boilers and Pressure Vessels
- ASME B31.3, Process Piping
- DOT MC-338, Insulated Metal Tanks for Motor Vehicles
- SAE J2601, Hydrogen Fueling Protocol

Hydrogen Safety Devices

- Pressure and temperature relief devices
- Emergency shutdown devices
- Flame and temperature detection
- Hydrogen detectors
- Vented and explosion proof enclosures
- Isolation, check, and process valves
- Fuel breakaway couplings
- Hydrogen vent stacks
- Personnel Protection Equipment (PPE)

Hydrogen Certification Procedures

Equipment Suppliers

- Understand and apply all relevant codes and standards
- Independently produce design verification and test reports
- Engage a Nationally Recognized Test Laboratory (NRTL)
  - Perform certification tests
  - Perform Process Hazard Analysis (PHS) and Process Safety Analysis (PSA)
  - Apply appropriate corrective actions
- Engage transparently with local AHJ's and community stakeholders

Test Laboratories

- Provide timely support to equipment suppliers
- Rigorously perform testing procedures, PHA, and PSA in collaboration with suppliers
- Produce Certification Test reports
- Provide equipment Listing and Labelling services

Local AHJ

- The ultimate approval authority
- Usually the local Fire Department and Building Permitting and Inspection Office
- Engage with Suppliers and Test Labs to understand hazards, codes, and safety practices
- Evaluate compliance with codes and standards
- Implement emergency response plans

References

United States Department of Energy Office of energy Efficiency and Renewable Energy

Office of Energy Efficiency & Renewable Energy | Department of Energy

H2 Tools

Home | H2tools | Hydrogen Tools

International Program on Chemical Safety

INCHEM

Fuel Cell & Hydrogen Energy Association

Fuel Cell & Hydrogen Energy Association (fchea.org)

California Fuel Cell Partnership

Home | Hydrogen Fuel Cell Partnership (h2fcp.org)