

Aaron Harris

Hydrogen Safety Panel Expert

Director of Operations & Technology, Air Liquide Hydrogen Energy US

What are the safety requirements for liquid hydrogen fueling?

Intro

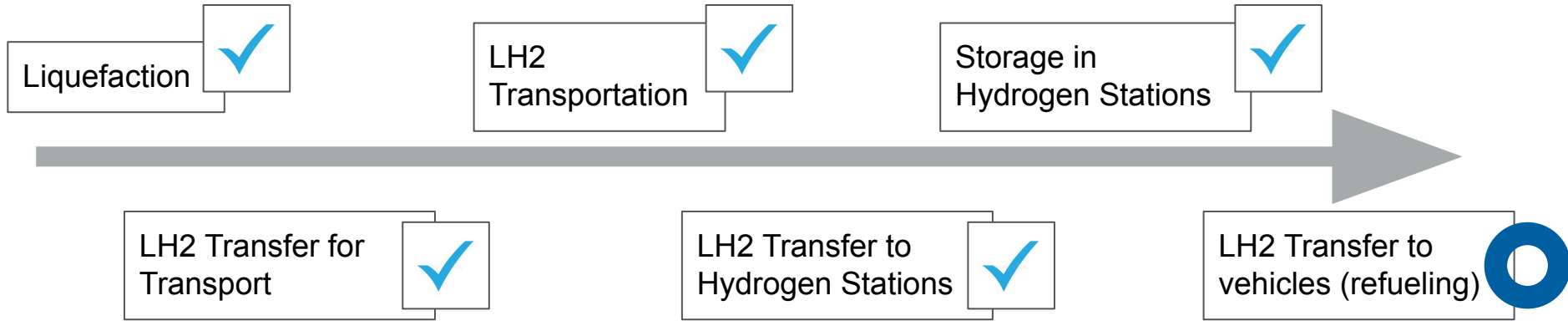
Needs assessment

Historic milestones developing the requirements for liquid hydrogen (LH2)

Future milestones in development of requirements for LH2 fueling

DOE Liquid Hydrogen Technology Workshop Feb 22-23, 2022 (virtual)

## LH2 Supply Chain regulations, codes & standards established and in practice today:



- No published standards for LH2 refueling hardware nor process control; example fueling nozzle
  - NFPA 2 Chapter 11 - 'use nozzle per the manufacturer's instructions'
  - NFPA 2 Chapter 10 - 'GH2 nozzles shall be...' *SAE J2600 Compressed Hydrogen fueling connection devices*
- Existing standards provide some guidance for the refueling facility construction and operation permitting

# Historic LH2 Pre-Normative, Normative and Regulatory Standards Development Milestones

1960- LH2 release experiments

*Reference, "Experimental Investigation of Liquid Hydrogen Hazards", Arthur D. Little, Inc.*

1968 - NASA Safety Manual

<https://ntrs.nasa.gov/citations/19750066661>

1969 NFPA 50A and 50B Tables  
OSHA regulations 29 CFR 1910.103

*(no revisions)*

*"The use of alternative approaches to distance as now embodied within the body of the code is subject to approval on a location-by-location basis."*

*- Annex G of both NFPA 2 and NFPA 55*

1967-1999 - NFPA 50B

*Standard for Liquefied Hydrogen Systems at Consumer Sites*  
Discontinued and adopted into NFPA 55 in 2004

2004 - Present NFPA 55

*Compressed Gases and Cryogenic Fluids Code*

2011-Present NFPA 2

*Hydrogen Technologies Code*

# LH2 Fueling Pre-Normative, Normative and Regulatory Standards Development Milestones

Consensus understanding of the specific hazards unique to LH2 vehicle fueling

*(Academic, Government and Industry Technical Safety Experts)*

Consensus performance objective (example: 10 kg/min)

*(Commercial and Technical Leaders)*

Consensus risk assessment

- with component reliability performance targets

*(Academic, Government and Industry Technical Experts)*

Prototype fueling hardware/controls/protocol development

- Breakaway coupling, hose, nozzle, vehicle receptacle
- Vehicle containment system standard

*(Vehicle and Station Equipment Manufacturers)*

Standard Development Process

- Publish design criteria and certification tests
- Publish serial production certification tests
- Regulatory adoption

*(Public and Private Standards Dev. Stakeholders)*

Demonstration

- Prototype production and initial protocol experience
- Validate design criteria and tests

*(Vehicle and Station Equipment Manufacturers)*

Serial Production

- Validate serial production tests

*(Vehicle and Station Equipment Manufacturers)*