The Safe Transport and Delivery of Hydrogen Webinar Q&A

Key Words: liquid, gas, vent, relief device, TPRD, rupture disc, code, standard, radiation, purge, ignition, pipeline, hose, rollover

The information in this document provides answers to the questions that were raised during the Center for Hydrogen Safety October 26th, 2022 webinar.

1. What is the difference between liquid hydrogen vents and gas in high-pressure performance?

The vent systems are quite different for gaseous (GH2) vs liquid hydrogen (LH2)

Gaseous vents are simpler in design, as they do not have to be designed for cold temperatures as LH2 vent stacks do. This affects materials of construction, expansion/contraction, supports, liquid air production, and potentially a blocked vent (frozen water, air, CO, CO2, etc.). LH2 are elevated higher in the air than gaseous (in NFPA 2 10 ft vs 25 ft)

Gaseous system may have higher reaction forces due to higher pressure.

The design of hydrogen vent systems should be completed by a qualified engineer. This can be quite complicated. Refer to codes and standards for specific requirements.

2. Have either of the presenters looked into Liquid Organic Hydrogen Carriers (LOHCs) and where that approach would be useful as an alternative to either GH2 or LH2 transport?

There have been many organizations that have been working to develop LOHC's. While they can offer benefits in transportation efficiency and safety, there are some disadvantages with needing to ship product both directions (fresh and spent) as well as additional equipment and processing energy on both ends. There are certainly applications where they might offer benefits, but they have not grown into the scale of a commercial market.

3. Are TPRDs efficient to prevent explosions in cases of external fire where the flame does not reach the TPRD temperature sensor?

One challenge with TPRD's is that they are not 100% reliable to activate in a fire situation. For example, an impinging fire might weaken a vessel wall in a localized area without warming the TPRD to the release point. There are numerous TPRD designs that attempt to expand their coverage beyond a specific point. Codes and standards have also tried to address this problem by requiring tests that anticipate a localized fire. Additional fire protection and endurance can also be built into vessels or their storage packages to overcome the limits of TPRD's.

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4. Why is there a limit for Tube trailers at 65 degrees Celsius against fuel tanks at 85 degrees Celsius? Is there a possibility of higher limits being accepted by standards in future for tube trailers?

This is a legacy of the codes and standards to which they are built. Primarily this is due to those standards originally being developed for lower pressure applications and slower fill rates where the vessels do not develop the higher temperatures present during the filling of vehicle fuel tanks. As a result, the temperatures specified in standards such as ISO 11119 and ISO 11515 only require 65 C for certain tests. Vehicle fuel tanks have required 85 C due to fast-filling, and recently there has been discussion to increase further to add inherent safety during upset conditions. This does not prevent an individual operator from specifying a higher temperature for testing.

5. For the codes and standards since there are some being developed, what are the best ways/standards you know that allow places like Manhattan to take in hydrogen truck or barge delivery?

The NYC Fire code is unique in that it explicitly prohibits liquid hydrogen delivery. This has been challenged over the years, but not successfully and will be challenging. Gaseous hydrogen is allowed and has been performed, but permitting has been difficult and it requires special approval and inspections.

6. Can you please elaborate on heat radiation of vent stacks and issues when ignited?

Location and elevation of vent stacks are intended to reduce the radiation effects on personnel to below 1577 W/m2 or 500 BTU/hr. ft 2. NFPA 2, Annex E4 has good information on radiative effects. As a comparison, peak sun radiation is ~ 1000 w/m2 for outside exposure.

For small fires, there are minimal radiative effects at the bottom of the stack. The radiation profile for large releases can be large, so best practice is to direct the flow rate vertically.

Additionally, API RP 520, can be applied to protect personnel or potentially vulnerable equipment from radiation using shielding.

7. After LH2 delivery to storage tank, do you need to purge the LH2 delivery hose with inert gas like helium before disconnecting?

This is a frequent practice that offers advantages to safety and purity but is not required and most deliveries are accomplished with warm hydrogen gas purges at the beginning and end of the fill. This has proven to be an acceptable process for trained operators wearing appropriate personal protective equipment.

8. Is vented Liquid Hydrogen less likely to ignite compared to compressed gaseous H2?

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Although it is difficult to understand the cause of ignition, past events and studies have corroborated this. In the study below almost 60% of the LH2 releases had no ignition, while only ~ 5% of the gaseous hydrogen releases had no ignition. The turbulent flow, additional friction and pressure wave associated with a high-pressure gas release increases the ignition potential.

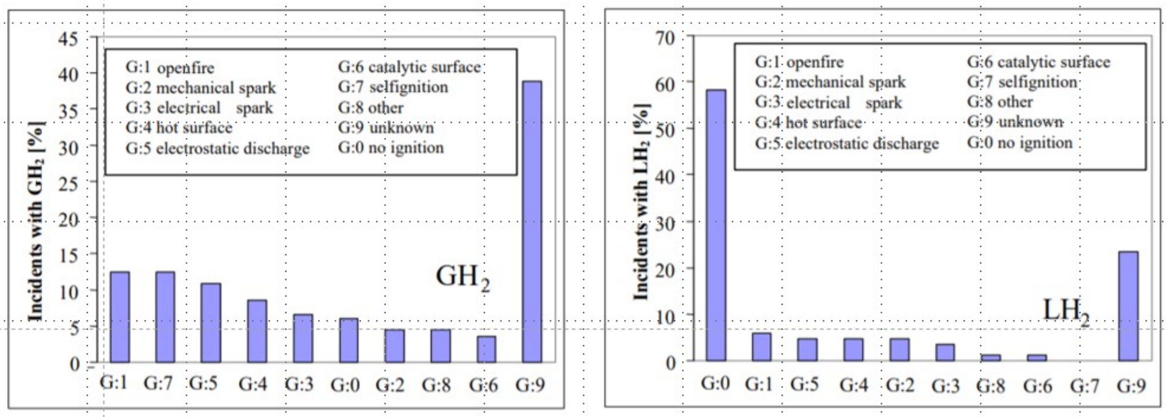

Image from: W. Breitung, Analysis Methodology for Hydrogen Behavior in Accident Scenarios 2016
Original data from: Kreiser et al. 1994

9. For LH2 trailer relief devices, do you consider rupture disc in series with PSV or in parallel?

Current practice is to install rupture discs in parallel with relief valves to offer redundancy of protection. Relief devices also must meet regulatory requirements. For example, within the US, the DOT requires compliance with CGA S1.3 with regard to type and sizing of devices.

10. When is it effective to use pipelines verses tankers or vehicles for transportation?

Pipelines can be a very cost-effective means to deliver hydrogen in large volume. There are 1000's of miles currently in operation within several pipeline networks. For example, there are extensive pipeline systems on the US Gulf Coast, within the Los Angeles basin, and in Northwest Europe. The demand in these markets is sufficient to justify the initial investment.

11. Can you elaborate on the circumstances that have led to hose failures?

Hose failures have many causes. These include:

1. Incorrect design
    a. Incorrect pressure rating
    b. Incorrect material causing permeation or hydrogen embrittlement

2. Poor construction of hoses, such as poor end crimping.
3. Pull away – no breakaway component, anti-towaway system incorrectly designed or not installed.
4. Lack of maintenance – It is recommended that a minimum, hoses are inspected annually and replaced every 3 years. More frequent maintenance may be required for high pressure hoses or hoses used very frequently.

12. Is the use of scales to fill or control use from vessels common with GH2 or LH2?

Delivery by weight is the most common and preferred method of delivering LH2. It is not commonly done for GH2 since the weight of gaseous hydrogen has traditionally been such a small percentage of the package weight.

13. Are there additional codes and standards that need to be met to be able to transport liquid hydrogen from U.S. to Canada? Example. Do the trailer components needs to have CRN's (Canadian registration numbers).

Equipment needs to be properly certified to the local regulatory body, in this case that would be Transport Canada. The use of components with CRN's will depend on the particular piece of equipment, its intended use, and the regulatory pathway. There are some differences between US DOT and Transport Canada, but generally equipment within North America has been built to meet both jurisdictions due to the overlapping production and markets.

14. LH2 rollover was mentioned as rollover due to different densities within the tank. Is that a danger?

Rollover is generally not an issue within the typical tanks used to store liquid hydrogen. The liquid level head of LH2 is very small which then helps prevent significantly higher saturation pressure at the bottom of the tank. It also helps that hydrogen is a homogeneous mix and doesn't have other constituents that tend to create a rollover situation. In addition, tanks are frequently filled with new product, which creates natural mixing.

15. The presentation mentioned an increase in roll-over events for MEGC trailers. Is there data available on these events? Are there guidelines related to CG height for MEGCs on trailers?

Unfortunately, there is not a general database of vehicle accidents. There are numerous sources of guidance for the CG as it relates to vehicle type, cargo, and length of trailer, among other parameters. Hydrogen vehicles must follow those same guidance principles.