HyLAW

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Horizontal Position Paper
Transport and Distribution
of
Compressed Hydrogen by Road
Quantity and Pressure Limitations

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1. Introduction and Summary

Hydrogen presents specific challenges for transportation and distribution due to its volumetric density.

Hydrogen is a gas with a very low volumetric energy density at standard temperatures and pressures, i.e. under standard conditions (1.013 bar and 0°C), hydrogen has a density of 0.0899 kg per Nm3. Therefore, it has to be to be conditioned, i.e. compressed or liquefied for storage and transportation purposes. For improvement of the volumetric energy density hydrogen is transported as a compressed gas, a cryogenic liquid, or as a chemical compound, such as a metal hydride.

At present, hydrogen is generally transported by truck in compressed gas containers or by trailer in pressurised gas cylinders or tubes, and in some cases also in liquid form in cryogenic liquid tanks. Novel materials-based storage media (metal hydrides, liquids or sorbents) are still at the R&D stage.

Compressed gaseous hydrogen (CGH2) is suitable for short to medium-distances transport in small to medium quantities, liquid hydrogen (LH2) is suitable for long-distances and bigger quantities (around 3,500 kg LH2 pro trailer)[1].

This horizontal position paper focuses on volume and pressure limitations of pressure receptacles (cylinders and tubes) for transport and distribution of compressed hydrogen by road.

At present, for transport of compressed gaseous hydrogen for short distances (100-200km) and small users are typically used single cylinders, multi-cylinder bundles or long cylindrical tubes, installed on trailers. Storage pressures range between 200 and 300 bar and a trailer can carry up to 6, 200 Nm3 of H2 for trucks subject to weight limitation of 40 tons. The quantity of hydrogen carried is relatively small (up to 550 kg depending on the number of cylinders or tubes)[2], which represents ~ 1 to 1.4 % of the total mass of the truck.

The largest high-pressure trailer developed by Linde Group can currently transport over 1,100 kg, or 13,100 Nm3 compressed hydrogen in a single trailer load. The new solution works at a higher pressure of 500 bar and uses new, lighter storage materials. However, this technology is not widely available.

At European level, it is considered that compressed gas trailer distribution will initially be the most common way to transport hydrogen from central production sites to consuming facilities. The market introduction of fuel cell electric vehicles requires a significant scale up of the compressed hydrogen trailer distribution. At the same time developing and deploying a high-capacity trailer composed of composite tanks is necessary to address both the H2 mobility market but also the industrial market to increase the volume transported so as to decrease transportation cost and CO2 emissions in a context of increasing fuel cost, and to reduce the HRS investments and ease the ramp up of first stations[3].

Current standards, regulations and safety codes have been developed for relatively small market volumes and deliveries mostly to industrial sites. These standards need to be revised and adapted, to ensure safe, efficient and low-cost hydrogen delivery at larger scales and in residential areas. The regulations have to be harmonised across Europe. Lightweight composite gas cylinders at 700 bar and higher volume tubes (up to 10,000 l) have been already developed, making possible to increase the overall payload.

Distribution of CGH2 by tube trailer becomes a much less economic option as demand rises (requiring more deliveries) and when transportation over long distances are required as more time and fuel is spent on the road. However, it can enable the transition to a low carbon economy as it is a much low-cost solution than liquefaction of hydrogen or pipeline construction.

An increase in payload of trailers would reduce the delivery frequency and the transport emissions and will limit the trailer exchanges at the refueling stations. This becomes especially important when a larger number of fuel cell vehicles are on the roads. According to the DeliverHy Project, there is a specific distance window (150-400km) and HRS size (>300kg/day) in which the overall costs for high- pressure composite trailer concepts will be lower than the state-of-the art GH2 and LH2 trailers.

2. Overview of the legal framework

There are no general requirements or limitations in the pressure or quantities of gaseous hydrogen transported by road. Nevertheless, the quantities per transport unit are restricted from one side to the accepted volumes of the

[1] SHELL Hydrogen study Energy of the future 2017, https://www.shell.com/energy-and-innovation/the-energy-future/future-transport/hydrogen/_jcr_content/par/textimage_1062121309.stream/1496312627865/46fec8302a3871b190fed35fa8c09e449f57bf73bdc35e0c8a34c8c5c53c5986/shell-h2-study-new.pdf

[2] DeliverHy - Optimisation of Transport Solutions for Compressed Hydrogen (2012-2013), http://www.deliverhy.eu/publics/LegalNotice.html

[3] http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/fch-04-2-2017.html

receptacles used and from other side – to the truck weight limitations. The high safety factors stipulated in the UN-Model Regulations on the Transport of Dangerous Goods[4], the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR)[5] and the Transportable Pressure Equipment Directive 2010/35/EU (TPED) [6] restrict the increase of payload of hydrogen trailers and the cylinder/tube volumes (450 l/3,000 l). The safety factor is the ratio between the burst pressure and the nominal fill pressure.

Current design standards for transportable pressure vessels in composite materials referenced in ADR define the application area, the maximum volume and operating pressure, some tests and a fixed safety factor (SF) of 3 for gas cylinders and tubes with composite materials. The international standards providing the technical requirements applicable to the transportable pressure vessels used for transport of compressed hydrogen are developed by ISO/TC 58 Gas Cylinders/ SC3 Cylinder design.

4. Conclusions

Current limitations on volume and working pressure of high-pressure receptacles used for hydrogen transport by road are not appropriate to deliver big quantities of hydrogen to large refuelling stations or other (industrial) users. These limitations represent a structural barrier and therefore the current standards have to be revised and changed as to allow higher vessels capacities. Having these changes adopted is a very long process involving research institutes, industry, standardisation organisations and policy makers and can only happen if a broad consensus between countries and within interest organisations will be achieved[7]. Such consensus could be reached only if the involved authorities are convinced that the technology can achieve a safety level which is at least as high as the one achieved with the current distribution technologies for hydrogen.

In order to optimise the safety factors calculation and to adopt higher volumes of the pressure vessels, a number of measures have to be undertaken. As a first step, the most relevant standards for gas cylinders (ISO 11119-X Composite gas cylinders and tubes up to 450 l) and composite tubes (ISO-11515 Refillable composite reinforced tubes of water capacity between 450 l and 3,000 l), referenced in ADR, have to be amended as to adopt a new approach to calculate safety factors for composite pressure vessels using probabilistic methods. The probabilistic approach requires a risk evaluation, based mainly on annual probabilities of failure, the quantities of hydrogen to be transported and the population density in the transport and distribution areas. The safety factors should be calculated on the base on the cylinder and tube characteristics and qualification tests performed.

Further, the water capacity and the working pressure of composite tubes have to be increased. The proposed revisions in standard ISO/DIS 17519:2018-4 Gas cylinders — Refillable permanently mounted composite tubes for transportation, allowing the use of 3,000 l tubes at 1000 bar and of 10,000 l tubes at 300 bar, currently under development, have to be adopted.

After the standards adoption, the ADR shall be updated as to allow and define new volume category of pressure receptacles (tubes from 3,000 l to 10,000 l) and refer to the revised standards. The ADR Directive and Transportable Pressure Equipment Directive shall be amended in accordance to the changes in the ADR. Finally, the national legislations of the EU Member States shall be adjusted accordingly.

5. Recommendations

Building a broad consensus between the key stakeholders for increasement of the current capacities of hydrogen receptacles in view of the revisions of the existing ISO standards for gas cylinders and composite tubes

Revision of the most important ISO standards (developed in ISO/TC58/SC3) as to increase the cylinder and tube volumes and the working pressures, as well as to optimise the safety factors specified in the ADR

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4 UN Model Regulations - UN Recommendations on the Transport of Dangerous Goods - Model Regulations (Twentieth revised edition 2017)

5 European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR 2017)

6 Directive 2010/35/EU of the European Parliament and of the Council of 16 June 2010 on transportable pressure equipment and repealing Council Directives 76/767/EEC, 84/525/EEC, 84/526/EEC, 84/527/EEC and 1999/36/EC

7 CEN- CENELEC/ Sector Forum Energy Management/Working Group Hydrogen Final Report; EUR 27641 EN, 2016