POSITION PAPER

Discussion Points on HyTunnel CS Recommendation Report

Background

The three-year HyTunnel CS project culminated in the report titled Deliverable D6.9, "*Recommendations for inherently safer use of hydrogen vehicles in underground traffic systems.*" The HyTunnel CS project aimed to perform pre-normative research for the safety of hydrogen-fueled vehicles traveling through tunnels or entering confined spaces. The main objective was to compare the relative risk of hydrogen vehicles entering underground traffic systems to existing fossil fuel-powered vehicles [1]. Upon reviewing the risk assessment and research reported in this document, along with the recommendations, the Hydrogen Safety Panel (HSP) has identified several issues that warrant further consideration. It is the strong opinion of the HSP that until these concerns are resolved, these recommendations should not be used as a basis for regulatory decisions concerning fuel cell electric vehicle access to tunnels or parking garages.

HyTunnel Study Recommendation – *Limit the thermally activated pressure relief device (TPRD) orifice size on the vehicle's hydrogen storage pressure vessels*

The HyTunnel report recommends minimizing the TPRD flow rate (orifice size). This is a concern because the TPRD orifice sizes are designed to relieve pressure within the hydrogen storage vessel during a fire exposure incident. If the orifice size is significantly reduced, the gas cannot vent fast enough to compensate for the increasing pressure, which could result in a rupture. The report recommends a TPRD orifice size of 1 mm (page 26) and 0.5 mm (page 29), which range from 10% to 25% of typical TPRDs installed today and will result in significantly longer release durations. For example, the report lists release times of approximately 3 minutes for a 2 mm orifice and over 53 minutes for an orifice size of 0.5 mm. This extended-release duration could lead to catastrophic failure of a tank as well as potentially increasing the chance of damaging or igniting nearby objects exposed to the jet flame (page 41). There is an absence of analyses to evaluate orifice sizes of less than 1 mm to meet the venting and pressure relief design criteria for expected fire exposures as required by current regulations. This is a critical aspect of the hazard mitigation provided by the TPRD to prevent vessel over-pressures and failure and is notably missing from the recommendation.

One of the justifications for the smaller TPRD given in the report is the prevention of the pressure peaking phenomenon (PPP) by slowing the hydrogen release rate. However, the effect of PPP was studied in the HyTunnel project, and the report clarifies that PPP is unlikely to affect the integrity of underground parking garages with multiple entrances and exits. It would only be relevant for enclosures such as small private garages and maintenance shops with natural ventilation (page 27). This apparent contradiction is another reason for the Hydrogen Safety Panel's concern regarding this recommendation. Recent debate within the hydrogen safety community includes considering tanks without TPRDs, but this approach does not have consensus. Recommending smaller TPRD sizing without adequate evaluation of the consequences to the vessel under foreseeable external fire scenarios is premature. A thorough risk analysis comparing tanks without TPRDs, tanks with standard-size TPRDs, and tanks with TPRDs of substandard orifice sizing should be conducted for all scenarios prior to a recommendation. All stakeholders, including vehicle OEMs, vessel vendors, TPRD manufacturers, and emergency responders, should participate in this discussion.

Another reason for the smaller TPRD recommendation was to minimize the contribution of the hydrogen to the heat release rate (HRR) during a car fire. Figure 3-6 in the report shows the HRR curve for the range of TPRD orifice sizes as mimicking the shape of the HRR curve of the experimental car fire, while the HRR curve for the 2 mm orifice shows an accurate peak-shaped curve due to the tank blowdown. No explanation is given for the difference in curve shape (the HRR from any sized TPRDs will result in a peak-shaped curve) or the difference of the initiation timing. For example, it's unclear why the 1 mm orifice would activate approximately 5 minutes later than the 2 mm orifice, nor why the .5 mm is delayed a further 5 minutes. Accurate HRR curves, including the extended duration of the tank blowdown due to the smaller orifice size, need to be examined.

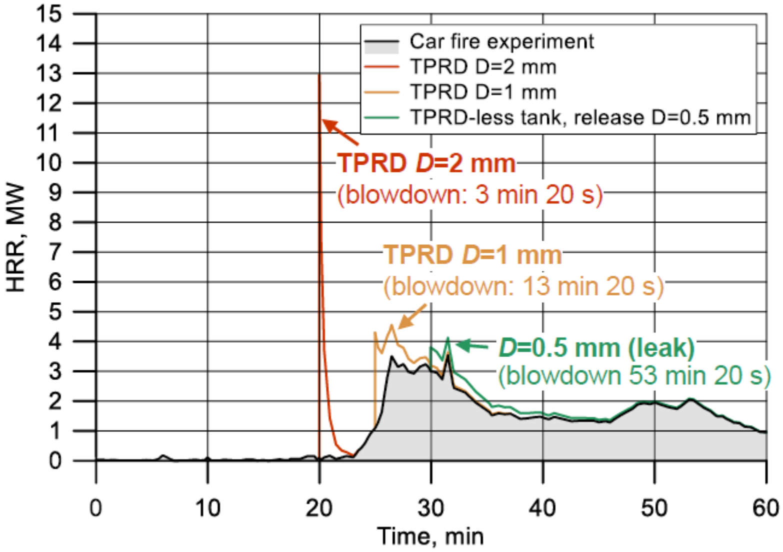

Figure 3-6. Contribution of hydrogen combustion to HRR in a passenger car fire (Okamoto et al., 2009). Example of hydrogen blowdown from 70 MPa, 62 L tank through TPRD of diameter 2 mm, 1 mm and 0.5 mm

HyTunnel Study Recommendation – *Require an "explosion free in fire self-venting tank"*

Another recommendation, made repeatedly throughout the report, focuses on a patented "explosion free in fire self-venting tank," which would leak hydrogen by melting the tank structure. This technology is new, has limited published testing, and is not part of the proposed US Vehicle Motor Safety Standards or the United Nations Global Technical Regulation (GTR) 13, which onboard vehicle vessels must pass before being approved for on-road use. Validation of the performance of these TPRD-less vessels consisted of only two experimental tests using 7.5 L prototype tanks, so very limited data is available to properly determine their performance. It is unknown if they can pass the GTR-13 tank test protocol. GTR-13 requires that vessel systems and their associated TPRDs be tested to rigorous criteria to ensure that the systems will not lead to a failure of the vessel(s) in either an impinging or engulfing fire. It is premature to recommend the new "explosion-free" tank technology for vehicles when the agencies and Codes that regulate vehicles have not proven or adopted this technology.

Also, recommending this technology is a potential conflict of interest because it could directly benefit the report's authors, who are named in the European patent [2]. This technology should be reviewed by the relevant code committees and unbiased technical experts before being proposed as a solution. There are also additional technologies that can be evaluated to reduce the TPRD instantaneous flow rate, such as multiple TPRDs and insulating vessel coatings to extend the vessel's life when exposed to fire.

HyTunnel Study quantitative risk analysis – *Erroneous assumptions*

The many inflated assumptions in the risk analyses that result in high end-state probabilities are another basis for concern, which directly leads to the conclusions in the report. One significant example within the quantitative risk analysis (QRA) is the probability of vessel rupture during a fire which is based on the assumption that 50% of TPRDs will fail to activate from a localized fire, which was taken from a source that clearly stated this assumption was just for illustrative purposes [3]. The vessel rupture probability also assumes a fire-resistance rating (FRR) of 8 minutes. This is an outdated value, and per GTR-13, all containers must be able to withstand a localized fire for a minimum of 10 minutes without rupture. This survival time is highly dependent on vessel design, and many current heavy-duty vehicle tanks have been shown to resist at least 20 minutes of fire exposure without rupture. An experimental study by JARI has shown that localized fires represent only 40% of fires, and all the fires progressed to engulfing fires within 10 minutes [4]. However, the HyTunnel-CS QRA assumes that all fires are localized (with a tank that will rupture after 8 minutes), resulting in a higher fire escalation probability. The QRA fails to consider that all fires will become engulfing, and therefore, the probability of the TPRD failure to activate should be lower. These inflated assumptions in the HyTunnel QRA artificially show an unacceptable risk level for conventional hydrogen vessels. However, more accurate assumptions would show these vessels are acceptable, even when exposed to fire conditions. More research is required to determine a realistic vessel rupture probability, including a more accurate estimation of the TPRD failure to activate on demand during a localized fire, especially given that a container has already passed the localized fire test.

Notably, the introduction suggests the QRA effort had the intent of demonstrating the risk relative to existing tunnel hazards. “The alternative hazards and associated risks prevention and reduction measures for hydrogen vehicles must ensure at least an equivalent level of safety as for fossil-fuel transport and traffic infrastructure.” No such risk comparison is provided, thereby making it impossible to make such a statement. An equivalent inflated assumption for conventional vehicles would imply that gasoline tanks have a 50% chance of failure in an accident.

Lastly, the QRA is based on analyses performed on unignited TPRD releases. The likelihood of unignited hydrogen being released through the TPRD was not considered. TPRDs are designed to release in fire scenarios, so the low probability of this gas being released into a fire event and not igniting should be evaluated. Experiments examining the credibility of this scenario need to be performed to accurately quantify this scenario. Additionally, accidental activation of TPRDs without being exposed to high-temperature conditions is a very rare event, and there should be further discussion to determine if this scenario should drive regulatory requirements and recommendations.

Conclusion

The premature and prolific publication of the above recommendations could lead to regulatory action that is not based on up-to-date data or unbiased conclusions. The HSP’s position is that the concerns identified in this position paper should be addressed prior to the HyTunnel-CS document being used for evaluating the safety of hydrogen vehicles within tunnels or as a basis for regulations or standards.

References

[1] HyTunnel CS, https://hytunnel.net/

[2] PCT International Application P119851PC00, WO 2018/149772 A1, https://patents.google.com/patent/WO2018149772A1/en

[3] Saw J.L., Flauw Y., Demeestere E.M., Naudet V., Blanc-Vannet P., Hollifield K., (2016). The EU FireComp Project and risk assessment of hydrogen composite storage applications using bow-tie analysis. In: Hazards 26, Edinburgh UK.

[4] Scheffler, G.W., et al., Establishing Localized Fire Test Methods and Progressing Safety Standards for FCVs and Hydrogen Vehicles, SAE Technical Paper, 2011