Pre-normative research for safety of hydrogen driven vehicles and transport through tunnels and similar confined spaces

Fuel Cells and Hydrogen Joint Undertaking (FCH JU)
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M5.3. Internal seminar on research conclusions for use by emergency services

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Summary

The present document provides the notes of the internal seminar on research conclusions for use by emergency services. The seminar was held on the 14th September 2021 on Webex online platform. The notes report the discussion on how HyTunnel-CS research conclusions can respond to first responders' main concerns and questions in dealing with incidents involving hydrogen powered vehicles in tunnels and other confined spaces. Questions were presented by IFA representative, C. Brauner, and discussed with the General Assembly (GA) and the Executive Committee (tEC). The seminar was attended by 35 participants.

Keywords

Firefighters, first responders, intervention strategies.

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1. Participants

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2. Agenda

Tuesday, 14 September 2021, CET Time		
SEMINAR LINK HERE		
Time		**Chair**
10:00-10:10	Welcome	C. Brauner, IFA
10:10-10:40	Introduction and first responders requirements for D5.4 “Harmonised recommendations on response to hydrogen accidents”	C. Brauner, IFA
10:40-11:40	HyTunnel-CS safety strategies and recommendations as foundation for D5.4 “Harmonised recommendations on response to hydrogen accidents”	D. Makarov, UU
10:40-11:40	Introduction to D5.4 “Harmonised recommendations on response to hydrogen accidents” and proposed ToC	C. Brauner, IFA
11:40-12:00	*Break*	
12:00-13:30	Discussion of first responders needs for response to hydrogen accidents: ▪ Principles of hydrogen safety design ▪ Dealing with hydrogen releases and jet fires in confined spaces (NCSRD, DTU), part 1	C. Brauner, IFA
13:30-14:30	*Break*	
14:30-16:00	Discussion of first responders needs for response to hydrogen accidents: ▪ Dealing with hydrogen releases and jet fires in confined spaces (NCSRD, DTU), part 2 ▪ Hydrogen explosions, their prevention and mitigation (HSE) ▪ Impact of hydrogen vehicle accidents on structures (DTU)	C. Brauner, IFA
16:00-16:20	*Break*	
16:20-17:00	Discussion of first responders needs for response to hydrogen accidents: ▪ Quantitative risk assessment methodology (URS)	C. Brauner, IFA
17:00-17:30	Wrap up and closure	C. Brauner, IFA

3. Internal seminar on research conclusions for use by emergency services

The aim of the internal seminar is to review the practical application of the project research results to formulate intervention strategies and tactics for emergency services. The seminar was held on the 14th September 2021 in conjunction with HyTunnel-CS 5th progress meeting. The seminar was open to SAB and HyResponder consortium members. HyTunnel-CS GA and tEC members were invited to the seminar to actively respond to the fire services questions about hydrogen hazards and associated risks, and adapt the research outcomes in practice of emergency services. The seminar was chaired by C. Brauner. The results of the previous International workshop of emergency services (M5.2) were merged with the knowledge generated during the HyTunnel-CS pre-normative research to derive knowledge-based recommendations for emergency services on how to deal with hydrogen accidents in different underground facilities. Results of the internal seminar on research conclusions for use by emergency services will be a part of D5.4 “Harmonised recommendations on response to hydrogen accidents”, which is due in M36.

3.1.1 Introduction and first responders’ requirements for D5.4 “Harmonised recommendations on response to hydrogen accidents”

The seminar started from the main question from first responders: can the current tactics for conventional vehicle incidents still be applied to a fuel cell hydrogen vehicle (FCHV)? CB presented a review of the main firefighters’ strategies and general practices during the response to different incident scenarios. They generally can opt for a defensive or offensive attack, which will change the level of risk to firefighters.
It is highlighted that firefighters do not have much information when they arrive to the scene and may not know the type of vehicle involved into the incident, e.g. a bus completely enveloped by a fire. It would not be known if this is a hydrogen powered bus or not. Generally, the first action would be the rescue of eventual passengers in crashed vehicles. The actions and tactics of intervention could be multiple depending on the specifics of the scenario, e.g. people to be rescued, presence of electrical lines, etc.

A discussion is opened, and the following points are highlighted:

- VM: firefighters should be allowed to act as they would normally do in any case.
- VM: current onboard storages have Thermally activated Pressure Relief Devices (TPRD) to avoid rupture. Suggestion to firefighters is to contact OEM’s to have information on TPRD design and location.
- AV: the fire for a FCHV should not be treated in the same way as for a conventional one. It should be firstly identified which kind of vehicle the firefighters are dealing with, so that an intervention would not obstruct the TPRD exit. CB added that in majority of the cases they will not know anything about the vehicles involved in the accident, as shown in the example of the bus completely enveloped by flames.
- FP: smart technologies identifying the types of vehicles entering and exiting tunnels or underground car parks could give information on the involved vehicles. However, there are not requirements or standards obliging builders to implement these technologies not only for H_2, but also for CNG, LPG, electric, etc. It is remarked that data transmission to firefighters is fundamental and recommendations should highlight it.
- VM: current technology of TPRD diameter of 2 mm on onboard storages would create issues, e.g. pressure peaking phenomenon (PPP) in garages, even if not leading to rupture

of the tank. PH suggested that a solution could be to not allow FCHV to park inside garages or not allow the fire to spread through particular parking guidance. VM added that PPP should not be a problem in underground car parks due to the large volume available and open entrance doors.

- PH: if a FCHV is identified and there is no noise of a release, could robotic solutions be used to allow first responders intervention from a distance?
- CB: all fire services should be reached with this information, from those in large cities to those in small towns.

3.1.2 HyTunnel-CS safety strategies and recommendations as foundation for D5.4 "Harmonised recommendations on response to hydrogen accidents"

DM introduced the actions of HyTunnel-CS project towards the formulation of strategies and recommendations for:

- D5.4 "Harmonised recommendations on response to hydrogen accidents".
- D6.9 "Recommendations for inherently safer use of hydrogen vehicles in underground traffic systems".
- D6.10 "Recommendations for RCS".

The main focus of HyTunnel-CS project is to reduce the risks associated with FCHV incidents by changing the design of current vehicles and onboard storage systems rather than the characteristics and operational requirements of tunnels or other confined spaces. The main strategy to mitigate unignited and ignited hydrogen releases is minimizing the TPRD diameter to reduce the produced flammable cloud and thermal hazards. Discussion:

- VM: a key point is how to reflect HyTunnel-CS outcomes into recommendations for first responders and how to make them more informative.
- PH: how to apply the models currently developed for type IV tanks to type III tanks? Type III tanks should be avoided to exclude rupture eventuality. VM added that type III tanks do not have a large application for current 700 bar NWP due to the issues with cycling.
- PH noted that experiments used a detonation belt to provoke rupture, which may not be realistic. How the generated knowledge can convince first responders to intervene?

3.1.3 Discussion of first responders needs for response to hydrogen accidents

CB proceeded to the main body of the seminar, i.e. the discussion of first responders' questions on response to hydrogen incidents. Firefighters were involved in the formulation of questions prior to the meeting, which were answered and discussed by the HyTunnel-Cs consortium. The main questions (Q) are listed below in italic, along with relevant remarks from the discussion.

3.1.3.1 Principles of hydrogen safety design

Q: According to the current state of research, would it be possible to produce FCEVs in which explosion hazards in confined spaces can be practically ruled out?

VM: up to now no hydrogen tanks have exploded, so from this point of view seems that the current technology we have is safe, however, experience from CNG showed cases of explosion of tanks. It will not be possible to give yet a definitive answer to this point in D5.4.

Q: Should legislators ensure that relevant vehicle data are automatically transmitted to relevant aid organisations?

Yes, legislators should ensure it. Relevant data are:

- Type of propulsion, number of involved vehicles.

- TPRD diameter, direction of the flare, position of TPRD.
- Tank size.
- Rescue sheets indicating the actions to be undertaken.

VM added that the number of vehicles may not be essential, as we shall ensure that FCHV will not bare additional hazards than conventional vehicles. The difference is that a jet fire from a TPRD could ignite more quickly the other vehicles in its direction.

3.1.3.2 Dealing with hydrogen releases and jet fires in confined spaces

Q: Apart from the whistling noise and possible labelling of the vehicle, are there other characteristics that can be used to recognise that FCEVs are involved? Would it be possible to include these in E-call?

FP suggested the use of artificial intelligence and audio detection in confined spaces.

Q: Do small-diameter TPRDs make different noises than large-diameter TPRDs?

- VM: the noise will not be different, even explosion free in a fire TPRD less tank will make a loud noise.
- AG added that in their experiments with release diameter 0.5 and 1 mm it was not possible to distinguish the very loud produced noises, whether ignited or not. Firefighters intervening in USN tests highlighted that special equipment would be needed to communicate between them as the release was very loud. CB added this is a common problem when responding to fires in confined spaces.

Q: How can hydrogen be detected safely, i.e., without endangering the emergency services, other than with explosimeters?

- VM: during HyResponder project meetings, it was noted that even more common CH_4 detectors would react to the presence of H_2, even if not quantitatively but qualitatively.
- AG added that in the past it was discussed the idea to use paintings changing colour if in contact with H_2.

Q: How to assess if there was a release before first responders' intervention?

People attending the scene of an incident could be interviewed to check if they detected the sound/noise of H_2 releases.

Q: How can an "explosion free" tank be recognised by laymen?

VM responded the tank is not on the market yet but possibly a different colour could be used. VM specified that current tanks with a TPRD are also explosion free, therefore it is suggested to use the denomination explosion free in a fire TPRD less tank.

Q: How can I tell from the outside which type of TPRDs is involved?

This could be available only knowing which vehicle and design is involved. VM added this information is important as it affects hazard distances, however because of buoyancy in many cases we should expect distances below 10 m.

Q: How quickly does unignited hydrogen spread in an underground car park or tunnel?

If the recommendation of minimizing the TPRD diameter to not create > LFL cloud at the ceiling of an underground car parl, there should not be problems regarding spreading of the cloud, even less in a tunnel given the higher ceiling.

Q: Can hydrogen spread from top to bottom, e.g. to lower floors of an underground car park?

Generally, H_2 dispersion is affected by buoyancy, so it would tend to go from bottom to top. The only problem could be that it could be transported by ventilation.

Q: Can hydrogen in a tunnel tube spread horizontally through the cross passages into a neighbouring tube or the safety tunnel?

This could be expected in very unlikely situations. Generally, in FCHV applications as car and buses with small inventories H_2 would tend to rise up. Different situation for trains where they may have up to 100 kg of stored H_2 and releases in reduced spaces. This should be simulated.

Q: Can hydrogen accumulate in niches or side rooms?

Not if we manage to be below LFL when the jet reaches the niche.

Q: In a tunnel with a gradient: Does the hydrogen always spread upwards or in both directions?

VM: large TPRDs (e.g. 5 mm) can spread in both directions. Generally, it depends on the air stream direction, as this may affect the buoyant part of the jet where it loses momentum. However, there are as well convection and diffusion affecting dispersion.

Q: In a tunnel with a low-lying crest (i.e. for example in a tunnel that crosses under a river): Does the hydrogen also flow downwards or only upwards towards the two portals?

Hydrogen will always be mainly affected by buoyancy so it tends to go upwards. However, also in this case, there are as well convection and diffusion affecting dispersion.

Q: If released hydrogen dilutes to below the lower explosion limit: Is it correct that explosive mixtures can then no longer form?

VM: generally it is better to talk about Lower Flammability Limit (LFL), which could lead to deflagration. If a jet decays below 4% along the axis prior to reach the ceiling, even if the cloud moves beneath it, H_2 will not accumulate in higher concentrations. SG and AV noted that in their simulations in tunnels with a slope, a part of hydrogen cloud tended to get back into the jet and rise concentration above LFL due to inclination and gravity opposite to the jet direction.

Q: What is the maximum time it takes for the entire tank content of a passenger car, lorry or coach to escape completely? What is the minimum time? What is the average?

This depends on the tank inventory and TPRD size. VM added that there are available nomograms or e-laboratory to assess blowdown time for a given storage pressure, volume and TPRD size. For P=700 bar, and 2 mm TPRD the blowdown would be in the order of minutes, e.g. 5 minutes for 5 kg H_2 inventory. This would be much longer for lorries where inventories are much larger. It would affect as well if multiple TPRDs are connected together or not. CB specified that they will not have those tools in the decisional moments, thus they need a range of minimum - maximum.

Q: What is the maximum time it takes for the hydrogen to evaporate to such an extent that there is no longer any danger of explosion?

- AG noted that difference should be made between gaseous compressed hydrogen and liquid hydrogen storage systems.
- PH: it should be remarked that even after a TPRD release, there is going to be a part of H_2 left in the tank.
- AG: drones can be used but they may blow away the hydrogen they intend to measure. FP added they are testing a type that will not do so.

Q: If burning hydrogen escapes from the TPRD, is it correct that this tank will not burst then?

VM: this is 99% right if TPRD is calculated according to the fire resistance of the tank.

Q: Does it make a relevant difference whether a tunnel is equipped with longitudinal ventilation, cross ventilation or smoke extraction?

If the TPRD is designed in the way to have concentration < LFL at the ceiling, it will not have any effect.

Q: What happens when a burning "explosion free" tank is extinguished as far as this would be possible at all?

VM: experiments with extinguished fire and water on the tank showed that the TPRD less tank kept releasing. In CEA tests instead, the fire was stopped but there was no provision of water. After a while the tank stopped releasing because of contraction. Fire needed to be re-initiated to make the rest of the H_2 release. If the tank is provided with TPRD, the current bulb opening will not allow re-closing whether firefighters are extinguishing the fire or not. It is always better to try extinguishing the fire.

3.1.3.3 Hydrogen explosions, their prevention and mitigation (HSE)

Q: Can an accident with a currently approved FVCEV in a tunnel or underground car park lead to an explosion?

Yes, but it would depend on many factors and the likelihood for it to happen is very low.

Can the explosion and fire hazards be influenced by water mist?

VM noted that in his opinion the effect will be low.

What is the danger zone of an explosion in the open in front of the tunnel portals; i.e. what distance should be kept from the portals if hydrogen has been released in the tunnel?

VS will assess these distances through CFD simulations.

Q: If hydrogen has been released in a tunnel: Does the risk from explosions then decrease with increasing distance from the accident site or is it roughly the same at any distance. Or in other words: Is there a safe distance from the accident site within a tunnel tube?

This question was deferred because the discussion of the preceding questions shows a fundamental problem: many questions cannot be answered in general terms because the answer depends on many parameters. Theoretically, an answer can be given, but then only for a precisely defined situation. However, this is then of little help to responders because they are not able to collect the corresponding values under operational conditions.

Q: Can the dilution of hydrogen be accelerated by positive pressure ventilation using large fire brigade fans? (This question is superfluous if the required distances to tunnel portals or openings of underground garages are so large that fans cannot be positioned sufficiently close).

Same as with the previous question.

Q: How does the pressure wave of an explosion affect a parallel second tunnel tube or a parallel safety tunnel?

It could have an effect but smaller than in the primary tube where the explosion has happened.

Q: Does it make a difference whether the cross passages between the affected tube and the unaffected tube or the safety gallery have sliding doors or wing doors?

Doors should be designed in the way they will not be affected by the blast. Sliding doors could be damaged in the way sliding will not be possible.

3.1.3.4 Impact of hydrogen vehicle accidents on structures (DTU)

Q: How does a jet fire affect the stability of the respective structure? Would there be a difference opposed to conventional fires?

LG: jet fires have a very short duration to make an impact on the structure. The only issue is that if there is spalling there could be an effect on the steel structure beneath it. CFD/FEM studies showed that there could be concrete spalling and this could undermine the fire resistance of a ceiling if the jet fire is followed by a much longer conventional fire. In general, the singular jet fire effect is significantly lower than for conventional vehicle fires. Normal practice of fire services is to cool down the ceilings with water to avoid structural collapse.

Q: The fire resistance of a lot of tunnels is determined by the HCM and RWS curves. Some tunnels are even designed by the less severe ISO 834 curve. Is it possible to achieve temperatures that go beyond the scope of these norms? Is so, how long would these structures be able to withstand this?

How does a jet fire affect the stability of false ceilings?

LG: jet fires will extinguish very quickly. Even if there is spalling this is not itself a problem for the stability of the steel structure taking all the stresses. The spalling would be localised in the jet fire area, and the same would be for false ceiling.

Q: Can tunnels built in trough construction be brought to collapse by a jet fire (without explosion)?

LG: pre-cast tunnels may have larger moisture content. It is considered that there would not be additional risks if the material is still concrete.

Q: Is it correct that an accident with a currently registered FCEV in a tunnel or underground car park can lead to the destruction of the structure?

LG: it is unlikely. VM added that even explosion may rupture some equipment as the ventilation fans, but not provoke the collapse of the structure. Explosion would mainly be an issue for human harm.

3.1.3.5 Quantitative risk assessment methodology

Q: To what extent can the risks of FCEVs be reduced by applying safer technologies?

VM: TPRD less tanks can reduce risk to acceptable levels and could be a potential application in future, e.g. for maritime applications with storage systems in confined spaces.

PR: many factors can affect the risk level, e.g. presence of systems to identify the type of vehicles and location. URS has analysed their effect on QRA. A study showed that with video systems, the location of a fire can be defined quicker, reducing the response time.

Q: Can it be estimated what the probability of an event with conventional FCEVs is today?

PR: it is possible to apply the methodologies, but some statistics used for FCHV are those provided for gasoline and conventional vehicles.