Deliverable D2.4

Gap analysis of existing hardware used for heavy duty gaseous hydrogen vehicle refuelling

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REPORT

Disclaimer

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Acronyms, Abbreviations and Definitions

AFID	Alternative Fuels Infrastructure Directive
CHSS	Compressed Hydrogen Storage System
FC	Fuel Cell
GHG	Greenhouse Gas
GT	Gas Turbine
H_2	Hydrogen
HF	High Flow
LNG	Liquified Natural Gas
NWP	Nominal Working Pressure
OTV	On-Tank Valve
PLC	Programmable Logic Controller
SoC	State of Charge
TPRD	Thermally Activated Relief Device
UHF	Ultra High Flow

Refuelling point	Term used within the AFID to describe “a refuelling facility for the provision of any fuel (with the exception of LNG), through a fixed or a mobile installation”.

EXECUTIVE SUMMARY

The hardware used on board of hydrogen vehicles and in dispensers can influence how a vehicle refuelling protocol needs to be developed. This document looks at the key components that effect the safe fuelling of heavy duty hydrogen vehicles, whether from the perspective of the thermodynamics of the transfer of hydrogen from the refuelling station to the vehicle, from the storage of the hydrogen on board of the vehicle or from connection of the vehicle to the refuelling point. The current status for nozzles and receptacles, tanks, on-tank valves, and other elements in the refuelling line are presented and discussed. Aim is to identify those elements necessary for consideration in the development of a refuelling protocol, and other elements that need to be progressed in order to enable gaseous hydrogen fuelled heavy duty vehicles in the future.

1 INTRODUCTION

When it comes to the refuelling of hydrogen vehicles, there are some components within the systems either on board the vehicle, or in the dispensing system, that have the largest influence on how the refuelling needs to be carried out.

This document identifies some of the critical aspects of these:

- the connection devices, enabling vehicles to connect to dispensers, but also to enable control of what vehicles are able to fuel at certain dispensers, based on the flow rate, or pressure level, or information communicated from the vehicle to the station (as discussed in Deliverable D2.3[1]), and
- components on the vehicle that may lead to differing levels of heating within the vehicle tank, and therefore that must be accounted for in the design of a refuelling protocol.

[1] Deliverable D2.3 “Gap analysis of existing heavy duty gaseous hydrogen vehicle refuelling protocols” is available on the PRHYDE website at https://prhyde.eu/progress/.

2 STATE OF THE ART

2.1 Connection devices

2.1.1 Mechanical interface

The connection between the vehicle and the refuelling point is made using a nozzle / receptacle pairing to ensure compatibility and where necessary, act as a mechanical lockout device to prevent unsafe situations. The requirements for nozzle and receptacle pairings are standardised through two documents:

- **ISO 17268 – Gaseous hydrogen land vehicle refuelling connection devices**

  (at the time of writing, the latest version is that published in 2020 – see https://www.iso.org/standard/68442.html)

  EN ISO 17268 is a document published by CEN which is essentially identical to the ISO document – the EN ISO 17268: 2016 is the same as the ISO 17268: 2012, and it is expected that there will be an EN ISO 17268: 2020 to match the ISO 17268: 2020

- **SAE J2600 - Compressed hydrogen surface vehicle fuelling connection devices**

  (at the time of writing, the latest version is that published in 2015 – see https://www.sae.org/standards/content/j2600_201510/)

  SAE J2600 includes requirements for H50 components – not included in ISO 17268

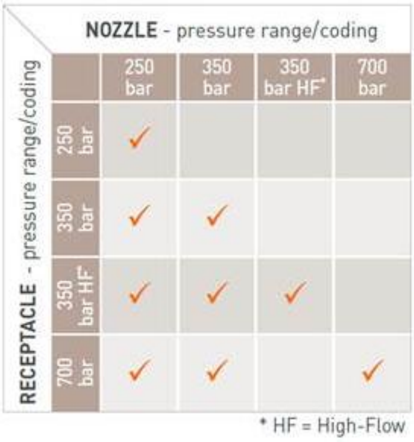
These documents are aligned with each other, albeit with some differences due to the staggering of ongoing development cycles for each, and include requirements for nozzle and receptacle pairings designed for fuelling vehicles with (a) different nominal working pressures (25, 35 and 70 MPa + 50 MPa in the case of SAE J2600) and, (b) in the case of the 35 MPa vehicles, at different flow rates *, with a "high-flow" nozzle-receptacle pairing in addition to the pairings for the other pressures. For the latter, the corresponding receptacle is defined as an "H35HF hydrogen receptacle (high flow for commercial vehicle applications)", with the critical dimensions of this incorporated into the document, as ISO TC 17268: 2020 Figure B.4.

* Note: Whilst not defined in ISO 17268, other documents, for instance, ISO 19880-1 and EN 17127 limit the fuelling protocol to a flow rate no greater than 60 g/s for the non high-flow nozzles (as these are paired with the receptacles typically used on light duty vehicles) and flow rates higher than this only permitted when the high flow nozzle is utilised. The upper limit for refuelling points using the high flow nozzle is the subject of ongoing discussion – the current EN 17127: 2018 permits only 120 g/s, a number aligned with the limit mentioned in SAE J2601-2, however ISO 19880-1 does not include this limit, and a future revision of EN 17127 is expected to remove this limit.

To enable interoperability of hydrogen refuelling points across Europe with hydrogen vehicles, the Directive 2014/94/EU on the Deployment of alternative fuels infrastructure became a legal requirement across Europe. Amongst other requirements, this introduced a legal requirement for the connection devices installed onto publicly accessible hydrogen refuelling points, including a normative reference to ISO 17268. As a result of this, as soon as they become available (a dispensation incorporated into the Commission Delegated Regulation (EU) 2019/1745 of 13 August 2019 supplementing Directive 2014/94/EU), the refuelling points at publicly accessible hydrogen refuelling stations will be required to use ISO 17268 / EN ISO 17268 compliant nozzles.

To achieve safe interoperability, higher rated receptacles can accept equally or lower rated nozzles, i.e. it is possible to refuel a vehicle with an H70 receptacle using an H35 nozzle. This ensures wider interoperability and allows for stations with an overall lower rating or performance envelope to still serve higher rated vehicles. The “high flow” version of nozzle and receptacle is a little special in that, whilst the refuelling nozzle on a H35 refuelling point for “light duty” vehicles is able to connect to a vehicle with a H35HF receptacle, the pairing prevents the transfer of hydrogen in the opposite arrangement (i.e. from an H35HF nozzle to an H35 receptacle) however, in order to protect a “light duty” vehicle from receiving hydrogen at too high a flow rate.

This is portrayed by the diagram below that indicates the compatibility of nozzles and receptacles manufactured by WEH:



RECEPTACLE - pressure range/coding \ NOZZLE - pressure range/coding	250 bar	350 bar	350 bar HF*	700 bar
250 bar	✓			
350 bar	✓	✓		
350 bar HF*	✓	✓	✓	
700 bar	✓	✓		✓

* HF = High-Flow

Figure 1: **Matrix to show the compatibility of different nozzles and receptacles, courtesy of WEH GmbH, Illertissen, Germany** (Source: https://www.weh.com/media/itoris/attachments/t/n/tn1-h2-hf-datasheet-e.pdf)

2.1.2 Communications interface

Communications between the vehicle and refuelling point enable data from the vehicle being filled to

a) be monitored / recorded by the refuelling station and

b) be utilised by the dispenser control system to define elements of the refuelling protocol.

(In the case of SAE J2601 for instance, the communicated information can allow higher target pressure, choice of CHSS category tables, controlling the refuelling up to 100% State of Charge, or stopping the refuelling if necessary. Information about communications protocols is included in PRHYDE Deliverable D2.3.)

The hardware used for communication between the vehicle and the dispenser can be wireless or wired, depending on the application:

Light duty vehicles are typically refuelled using InfraRed devices (with the communications standardized in SAE J2799, see Deliverable 2.3), with a transmitter mounted on the vehicle next to the receptacle, and a receiver on the refuelling nozzle. For heavy duty vehicle fuelling, the same technology is available, additionally manufacturers use wired connections (as explained in the 1st PRHYDE webinar by Joe Cohen or Air Products [2]), where the connection device can have a number of small pins such as the Deutch Connector or the Samtech Connector, alternatively a simpler method of connecting the vehicle to the station is being trialled by Air Products using a stereo ¼ inch cable.

NOTE: Communications hardware is not part of the PRHYDE project, wireless communications is, however, being addressed in various outside projects. In particular, the safety level of transmitted data (influences the potential usage of the data for fuelling process control) and the mechanical stability of the hardware including mis-use by the end-user are to be addressed.

[2] Presentation available on the PRHYDE website: https://prhyde.eu/wp-content/uploads/2020/05/2020-03-24_PRHYDE-15_30-Air-Products-2.pdf

2.1.3 Examples of currently available interfaces for flows >60 g/s

At the time of writing, whilst there is good supply of components for 60 g/s fuelling components, WEH are the only manufacturer of components suitable for “high flow” applications that could be identified. Their product range includes the following:

- Components on which the ISO 17268: 2020 H35HF geometry requirements are based:
  - "High flow nozzle" (available with and without IrDA communications):
    TK16 H2
  - and the corresponding receptacle:
    TN1 H2
- Additionally:
  - "Nozzle for fast filling" (no communications available):
    TK25 H2
  - and the corresponding receptacle:
    TN5 H2

Figure 2: Images of the WEH TK16 H2 & TN1 H2 (left hand side) and TK25 H2 and TN5 H2 (right hand side)
(courtesy of WEH GmbH, Illertissen, Germany)

It should be noted that the two types of nozzle / receptacle pairings are not compatible with each other, therefore vehicles using TN5 receptacles would be restricted to using specific stations with TK25 nozzles and vice versa.

Receptacle and nozzle designs on the market have different efficiencies at allowing hydrogen flow, depending on their design, diameter, and the filtering function, if included (diameter of particulate). There is no link between the interface requirements of a nozzle and the Kv[3]. The Kv or Cv value can vary widely:

- H35 receptacles on the market currently have a range of Kv values between 0.3 to 0.7.
- For reference, H70 receptacles on the market (all standard flow) currently have a range of Kv between 0.1 and 0.2.
- It is worth noting that SAE J2600 requires a minimum Cv for the receptacle of 0.35 (Kv of 0.3) unless listed otherwise in the manufacturer's literature.
- H35 nozzles on the market currently have a range of Kv values between 0.25 to 2.5.
- H70 nozzles on the market (all standard flow) currently have a range of Kv values between 0.19 and 0.5.

  Note: Where heavy duty vehicle fuelling stations use H70 components designed for light duty vehicle fuelling, this can have the consequence of higher differential pressures (pressure drop) than necessary for successful fuelling – as a result stations take approaches such as two parallel refuelling systems. Where stations designed for fuelling vehicles with large CHSS utilise "standard" nozzles, this also has the potential consequence of a light duty vehicle receiving hydrogen at a flow rate that is higher than the vehicle is designed to receive, or according to a fuelling protocol not suitable for the size of the CHSS on the vehicle, potentially leading to an unsafe scenario. (In the case of H35 systems, the H35HF nozzle acts as a mechanical lock-out to prevent this from happening).

[3] Note: Kv is the flow coefficient in metric units (m^3/h), whereas Cv is the flow coefficient in imperial units (US Gallons per minute, gpm). They are strictly equivalent and can be converted one into the other through the following relations: Kv = 0.865 Cv or Cv = 1.156 Kv.

2.2 Tanks

Tanks used in hydrogen vehicles in Europe are generally designed to be compliant with one or both of the following regulations:

I. Regulation No 134 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the approval of motor vehicles and their components with regard to the safety-related performance of hydrogen-fuelled vehicles (HFCV) [2019/795]

(for details see https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2019.129.01.0043.01.ENG)

This is the European transposition of the UN GTR No. 13 - Global Technical Regulation concerning the hydrogen and fuel cell vehicles

(for details see https://www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29glob_registry.html)

II. REGULATION (EC) No 79/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 January 2009 on type-approval of hydrogen-powered motor vehicles, and amending Directive 2007/46/EC

(for details see https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:035:0032:0046:en:PDF)

The detail supporting this Regulation is provided by COMMISSION REGULATION (EU) No 406/2010 of 26 April 2010 implementing Regulation (EC) No 79/2009 of the European Parliament and of the Council on type-approval of hydrogen-powered motor vehicles

(for details see https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:122:0001:0107:EN:PDF)

In May 2018, as part of the third and final set of actions from the Junker Commission to modernise Europe's transport system[4], it was announced that the European Regulations 79/2009/EC and 406/2010/EU will be repealed, and replaced by a revised UNECE R134.

[4] Europe on the Move: Commission completes its agenda for safe, clean and connected mobility, 17 September 2020, available online: https://ec.europa.eu/transport/modes/road/news/2018-05-17-europe-on-the-move-3_en

There are currently four different technology “types” used for pressure vessels, as described in ISO 19881 “Gaseous hydrogen — Land vehicle fuel containers“:

Table 1: Tank types in use throughout the hydrogen industry

Tank types described in ISO 19881	
Type 1	Metal container
Type 2	Container which contains a metal liner reinforced with a resin impregnated continuous filament(hoop-wrapped)
Type 3	Container which contains a metal liner reinforced with a resin impregnated continuous filament(fully-wrapped)
Type 4	Container which contains a resin impregnated continuous filament with a nonmetallic liner (all composite)
Tank type (in development) not described in ISO 19881	
Type 5	Container made of impregnated fibre, without a liner.

Additionally, although not described in ISO 19881, a Type 5 container exists. In this case, the gas permeability is limited by the composite itself.

The most common technologies used for on-board hydrogen storage are Type 3 and Type 4, although some applications with less weight constraints, such as on waterways, may use Type 1 or Type 2 pressure vessels. New vessel technologies are under development such as a Type 5 vessel (all-composite, linerless tank) or conformable tanks that have non-cylindrical shape. Any new refuelling protocol development should not prevent these future technologies from reaching the market.

The type of tank has an impact on the thermodynamic of the refuelling because the different technologies use different materials with different thermal properties. Based on a literature review, the table below shows a range of conductivity-specific heat capacities that can be found for the different part of the tank.

Table 2: Example of range of thermal properties of tanks from literature[5] and industry feedback

	λ range [W m^{-1} K^{-1}]	c_p range [J kg^{-1} K -1]	Thickness [mm]
Type 3 liner	164 - 180	896 - 1106	~3 mm
Type 4 liner	0.32 - 1.17	1600 - 2100	~5 mm
Type 3 and 4 (outer wall), Type 5 (throughout tank wall)	0.60 - 1.14	920 - 1120	10 - 35 mm

Different nominal working pressure (NWP) exist for on-board hydrogen storage, 350 bar, 500 bar and 700 bar. The market for on-board pressure vessels has developed recently, with many different pressure vessels homologated for on-board storage for road vehicles with different volume ranging from 36 L to 350 L. Storage system manufacturers can choose different architectures for a same H_2 capacity, using a small number of large tanks or a larger number of small tanks, and this architecture has an impact on the thermodynamics of the refuelling.

2.3 On-Tank valve

The on-tank valve is a key component of the on-board tank gathering several functions, including, for example, a thermally activated relief device (TPRD), filter, excess flow valve, temperature sensor, check valves etc. This device impacts the thermodynamic of refuelling through two characteristics: its Kv and the diameter of the orifice at point of injection inside the tank.

The HyTransfer project[6] has shown that the choice of injector internal diameter (i.e. altering the velocity of the gas entering the tank) at the point of injection impacts on the emergence of vertical and horizontal temperature gradients inside the tank during refuelling.

5 Monde, Masanori, et al. Estimation of temperature change in practical hydrogen pressure tanks being filled at high pressures of 35 and 70 MPa. International Journal of Hydrogen Energy. 2012, Vol. 37, 7

Igor Simonovski, Daniele Baraldi, Daniele Melideo, Beatriz Acosta-Iborra, Thermal simulations of a hydrogen storage tank during fast filling, International Journal of Hydrogen Energy, Volume 40, Issue 36, 2015, Pages 12560-12571

T. Kuroki, N. Sakoda, K. Shinzato, M. Monde, Y. Takata, Dynamic simulation for optimal hydrogen refueling method to Fuel Cell Vehicle tanks, International Journal of Hydrogen Energy, Volume 43, Issue 11, 2018, Pages 5714-5721

6 HyTransfer – Public deliverable D7.5 “Final Synthesis of the Project Findings for the Industry”, see https://www.hytransfer.eu/

Table 3: **Gas velocity criteria to ensure homogeneous gas conditions in the tank**
(Source: HyTransfer – Deliverable D7.5 "Final Synthesis of the Project Findings for the Industry")

	Short tank: $L - L_{inj} < 3*D$	Long tank: $L - L_{inj} > 3*D$
Velocity criteria to prevent from **vertical gradient**	**U > 5 m/s**	
Velocity criteria to prevent from **horizontal gradient**	**No criterion**	**U < 100 m/s** *for two third of fill from 20 to 875 bar (pressure ramp rate)*

The orientation of the injector is also known to influence this gradient, as demonstrated by HyTransfer, and earlier research[7].

On-tank valves on the market have different efficiencies at allowing hydrogen flow, depending on their design.

Table 4: **Typical technical data for OTVs (On-Tank Valves) used in the industry**

	Typical range on the market
Kv	0.1 - 0.2
Injector internal diameter	3 - 4 mm

[7] Maus, S. (2007): Modellierung und Simulation der Betankung von Fahrzeugbehältern mit komprimiertem Wasserstoff, Kapitel 8.3, VDI Verlag, Düsseldorf.

2.4 Fuelling line

More broadly, the whole fuelling line from dispenser to vehicle tank has an impact on the refuelling protocol performance.

The fuelling line can have different efficiencies at allowing hydrogen flow depending on the station and vehicle CHSS design. The Kv of the fuelling line will be impacted by the length of the line, the number of elbow and T connexions for parallel multiple tank configurations, restrictions of section, the dispenser breakaway coupling, hose, nozzle, the vehicle receptacle, etc. Other component that could significantly impact the Kv are filters.

It is worth noting that currently, there are limited, or no fuelling line products (breakaway coupling, hoses, flow meters, flow control valves, etc.) on the market to cover the needs for either high flow fuelling at 700 bar, or any fuelling at 500 bar.

The fuelling line can also have differences in thermal conductivity and thermal capacity depending on the design, impacting on the temperature of the gas entering the tank. Below are examples of maximum thermal mass hypothesis made in previous protocol development work:

- SAE maximum station thermal mass: ~5500 J/K
- HyTransfer maximum station thermal mass: ~2300 J/K
- SAE and HyTransfer maximum vehicle thermal mass: ~2600 J/k

3 Analysis / Discussion

As can be seen in the State of the Art section (Section 2) , these designs and specifications are not quite adequate to achieve the fossil parity performance[8] when it comes to heavy duty vehicles. Therefore, a new family of components, both on the refuelling assembly (breakaway, hose, nozzle, receptacle) and the station fixed equipment side (HP control valves, mass flow meters), has to be developed and fielded.

The following sections present discussions on key areas to look at for the future to facilitate heavy duty refuelling.

3.1 Pressure levels

350 bar and 700 bar applications are most common, but 500 bar applications are being considered by some companies as a potential better techno-economical trade-off. The most prevalent choice worldwide for light duty vehicles is 700 bar, while most buses and medium/heavy duty vehicle applications in Europe currently use 350 bar. All the three option are possible for HD application, depending on the needs and techno-economic trade-off. Compatibility of the pressure levels would allow for a path to use synergies between different station and vehicle designs, potentially driving down total cost of ownership (TCO) for the user, and allow for a better network coverage for higher pressure-rated vehicles at a cost of limiting range for the current refuelling.

3.2 Connectors

First developments have started to design an H70 nozzle for higher flow rates than those used for light duty vehicles, and the corresponding receptacle, hose and breakaway coupling technologies necessary, with a design working mass flow of up to 300 g/s, within a JDA for Heavy Duty FCEV hardware consortium including Toyota, Hyundai, Nikola, Air Liquide, NEL and Shell. It is anticipated that this design will be introduced to ISO 17268 at the next revision cycle to enable standardization of this critical component across industry. A key point will be to find appropriate nomenclature for the new nozzle range, indicating its compatibility with other nozzles/receptacles.

For safety reasons, the current intention is for the new H70 nozzle to be a mechanical interlock to prevent the refuelling of light duty vehicles with either H35 or H70 receptacles, also to prevent fuelling of vehicles with the H35HF receptacles.

In itself, this development is not yet adequate, as interoperable solutions for high flow nozzle and receptacle pairings at H35 and H50 need to be developed, too, along with breakaway couplings and hoses that support the flowrates.

There is also a question mark over the backward compatibility of the high flow capable H70 receptacle with other existing nozzles – it is understood that the current intention

8 For details see also Deliverables D2.1: "Performance metrics for refuelling protocols for heavy duty hydrogen vehicles", available on the PRHYDE website at https://prhyde.eu/progress/.

is that vehicles with the new H70 receptacle would not be able to use existing infrastructure that has ISO 17268 H35HF nozzles (or the alternative non-standardised WEH TK25 “fast fill” nozzles), in order to partially fuel a H70 vehicle – an approach currently possible with light duty vehicles. This approach may work for dedicated supply routes in the US where H35 is not already in use, but could create difficulties in Europe should trucks want to make use of the infrastructure to be put in for 350 bar NWP vehicles – each refuelling station with refuelling points dispensing at H35 could need two nozzles in order to service the vehicles on the road, increasing cost and complexity to HRS, or forcing them to choose which heavy duty connections to incorporate (creating a VHS / Betamax style conflict).

Discussion is needed as to whether a family of nozzles that are interoperable with the corresponding and higher pressure receptacles is required, as is the case today for light duty designs, or if it is practical for H70 heavy duty vehicles to be limited to refuelling at H70 heavy duty vehicle stations only, and not enable them to receive a partial refuelling at H35 or H50 heavy duty refuelling stations (also whether or not to allow H50 heavy duty vehicles to refuel at H35 heavy duty vehicle refuelling stations).

Freeze on is a major source of annoyance for customers in the light duty segment today on unmanned HRS. Not only does it immobilize users until the nozzle has thawed, which is a completely inacceptable situation for commercial vehicles and applications, it also poses a risk to the quality of hydrogen, as some users have been reported to start using antifreeze agents on the receptacles, with unknown potentially dangerous consequences to the fuel cell system.

Options to resolve the issues of freeze-on could be:

- elimination of pre-cooling, where possible,
- to fuel with reduced cooling (e.g. above 0°C),
- to have the protocol recognize higher design temperatures for the tank systems and adapt the fueling protocol accordingly, or
- to end the fill with a stream of non-precooled hydrogen to thaw the nozzle.

Other options should be considered too.

3.3 Tanks

Type 3 and type 4 tanks complying with EC /2009 have a design temperature range of -40°C to +85°C.

Whilst it is currently not clear whether or not the tank design temperature range will change in the future, the surveys held by PRHYDE[9] indicated that there could be a benefit to making the protocol able to work with different design temperatures of the tanks, such that the target temperature at the end of the fill could be adjusted.

[9] For details, see Deliverable D6.3 “Report on the external stakeholder engagements conducted at the start of the PRHYDE project – Surveys and Workshop 1”, available on the PRHYDE website at https://prhyde.eu/progress/.

This could be useful where there are hot ambient temperatures to allow for fast filling although this may equate to a minor loss of State of Charge (SoC) as a trade-off.

3.4 Dispenser computer

Typically, a dispenser will be controlled by a Programmable Logic Controller (PLC) installed either directly in the dispenser itself, or elsewhere in the refuelling station. The available calculation power of such a computer will influence the possibilities for the fuelling protocol, and therefore need to be considered whilst developing the fuelling protocol.

Annex

A1 Input From Workshop 1 And Surveys

A1.1 Background

In order to gather information from stakeholders external to the project, the PRHYDE consortium developed a set of surveys which interested parties were invited to complete and return to the project. Additionally, webinars were held on the 24th March and 23rd April 2020, to disseminate information about the project, but also, and equally importantly, to gather relevant information from those involved in the refuelling of heavy duty vehicles, or development of the vehicles themselves. Further information on the webinars and the surveys is available in PRHYDE Deliverables D6.3 and D6.4[10].

The section below includes summarised feedback gathered from the survey responses and, where applicable, participants of the webinars, that is relevant to hardware components critical to refuelling protocols, with analysis to be carried out as part of the development of the PRHYDE project refuelling approach.

A1.2 Connectors

Input from organisations currently involved in medium and heavy duty vehicles indicated that, for applications using high flow (some medium and heavy duty vehicles are fuelled using "standard" flow equipment as the 60 g/s limit is not an issue, or at least, is acceptable for the time being), a mixture of WEH components are used – both WEH TK16 H" & TN1 H2 and TK25 H2 and TN5 H2 nozzle/receptacle pairings.

Points made by participants of the workshops and responses to questionnaires indicate that the following points should be considered during the design of the required hardware to work with the next protocol:

- The need for a H70HF equivalent to the H35HF nozzle/receptacle pairing was raised.
- The need for H50 nozzle/receptacle pairing is also needed, in both standard and high flow.
- The development of UHF components is done in a closed group and is not accessible from the outside. Ways need to be found to reflect the needs of the wider industry at an appropriate time.
- Uncertainty that for applications such as trains and marine applications, for instance using Type 1 tanks where overheating is less of a concern, refuelling components limited to 180 g/s would be sufficient
- Different service pressure ranges need to be intercompatible with each other in the safe direction.

10 Both deliverables are available on the PRHYDE website at https://prhyde.eu/progress/.

- Concern was indicated about the lack of diversity in potential suppliers for nozzles/receptacles for heavy duty vehicles
- Concern was raised about the ability of the nozzles to be able to cope with temperatures below -25°C
- An observation was made about the weight and ease of use of the current HF nozzles available

A1.3 Other

Input from organisations currently involved in medium and heavy duty vehicles indicated the following for components other than connection devices

- Availability of / uncertainty about flow meters capable of the hydrogen flow rates anticipated for high flow refuelling applications

A1.4 Recognition

The PRHYDE consortium would like to recognise the input from external stakeholders, both as presenters at the first webinar as well as those who responded with completed surveys:

Presenters:

- Faun Umwelttechnik GmbH
- Air Products
- The CEP
- The HySpeed Project
- Honda
- Frontier Hydrogen / the CaFCP

Surveys:

- Transport for London
- Air Products
- TÜV SÜD NEL
- Audi
- Faun Umwelttechnik GmbH
- ULEMCo
- H2M
- Hexagon
- SNCF
- Maximator
- TUGraz
- Green Planet
- Colruyt Group
- McPhy
- CMB Tech
- Stottler Development, LLC
- Pitpoint
- The State of California
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- GreenGT
- Arcola Energy

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What is PRHYDE?

With funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU), the PRHYDE project is aiming to develop recommendations for a non-proprietary heavy duty refuelling protocol used for future standardization activities for trucks and other heavy duty transport systems applying hydrogen technologies.

Based on existing fuelling protocols and current state of the art for compressed (gaseous) hydrogen fuelling, different hydrogen fuelling protocols are to be developed for large tank systems with 35, 50, and 70 MPa nominal working pressures using simulations as well as experimental verification. A broad industry perspective is captured via an intense stakeholder participation process throughout the project.

The work will enable the widespread deployment of hydrogen for heavy duty applications in road, train, and maritime transport. The results will be a valuable guidance for station design but also the prerequisite for the deployment of a standardized, cost-effective hydrogen infrastructure.

Further information can be found under https://www.prhyde.eu. For feedback on the PRHYDE project or the published deliverables, please contact info@prhyde.eu.

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