Deliverable D6.6

Fully organized, conducted and reported workshops: objective 2 – final dissemination

Report Status: FINAL

Report Date: 14 October 2022

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Confidentiality Level: PU – Public

Acknowledgement:

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 874997. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe Research.

R E P O R T

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PRHYDE Deliverable D6.6 – Fully organized, conducted and reported workshops: objective 2 – final dissemination

Authors:

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Revision History

Revision	Revision date	Summary of changes
1	29.09.2022	Public Version (without Q&A)
2	14.10.2022	Public Version (with Q&A)
3	14.10.2022	Corrections in Q&A: Q4, Q9 and Q10

Checked by

Name	Company	Date
Nick Hart	ITM Power	29.09.2022

Approved by

Name	Company	Date
Nick Hart WP6 leader	ITM Power	30.09.2022
Christopher Kutz PRHYDE coordinator team	LBST	30.09.2022

CONTENTS

Acronyms and Abbreviations

WP	Work Package
WS	Workshop

1 INTRODUCTION

This report documents preparation and execution of the final dissemination workshop of PRHYDE. The workshop took place as a hybrid event (online and in-person at ZBT test side in Duisburg Germany.

The aim of the workshop was to disseminate final PRHYDE results with a focus on the fueling protocol concepts developed in the context of the project (WP3).

2 ENGAGEMENT THROUGH PRHYDE WORKSHOPS / WEBINARS

Several workshops have been planned for the course of the PRHYDE project.

The workshops were originally planned as in-person meeting with WebEx access to capture the widest possible range of stakeholders. Following the emergence of the COVID-19 coronavirus crisis, it was unfortunately not possible to hold the workshops in 2020 and 2021 as in person workshops, however they were held as webinars to communicate to interested stakeholders an indication of the plans of the project, and the findings of the "State of the Art" research activity.

The workshops have (/had) the following aims:

The **first workshop/webinar** planned at the start of the project, in month 3 (24th March 2020), was to ensure the widest input possible into identification of the State of the Art and to help ensure the specification of the fuelling protocols to be developed within the project will be of the most relevance to industry.

The findings from this workshop and survey contribute to the tasks of WP2 (and subsequently WPs 3-5), whilst also being a precursor for the subsequent workshops held to address Objective 2 (see Task 6.4).

The **second workshop/webinar**, held in month 4 (23rd April 2020), was an opportunity to further disseminate findings up to that time on State of the Art, and to try to get further feedback on the plans for the project.

Results of both workshops have been summarized and processed to be included in the protocol development as public deliverables D6.3[1] (workshop 1) and D6.4[2] (workshop 2) and as annex of the respective state of the art documents in WP2 (D2.3 and D2.4).

The consortium also took the opportunity to seek feedback on the planned approach for protocol development by holding a **third workshop/webinar**, held in month 12 (1st December 2020), in addition to those originally planned.

Additional stakeholder workshops took place in order to develop an understanding of what future fuelling protocols should take into consideration, and where limitations may be encountered by the current approaches / technologies on the market. The workshops were held on 2nd and 3rd December 2020 (immediately after the third workshop which took place on 1st December 2020).

Topics discussed and positions developed included:

1. What systems are anticipated in future gaseous hydrogen HD vehicles, and what could the boundary conditions be reasonably anticipated to be that the fuelling protocols of the future would need to adhere to?

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[1] Deliverable D6.3 "Report on the external stakeholder engagements conducted at the start of the PRHYDE project – Surveys and Workshop 1" is available on the PRHYDE website at https://prhyde.eu/.

[2] Deliverable D6.4 "Report on the external stakeholder engagements conducted at the start of the PRHYDE project – Workshop 2" is available on the PRHYDE website at https://prhyde.eu/.

2. What systems are currently in use on existing non-gaseous (i.e. liquid, cryo-compressed, etc) hydrogen HD vehicles, and what are the boundary conditions that fuelling protocols would need to adhere to?
3. What systems are anticipated in future non-gaseous hydrogen HD vehicles, and what could the boundary conditions be reasonably anticipated to be that the fuelling protocols of the future would need to adhere to?
4. What other constraints are anticipated for ideal future protocols (e.g. filling a train or boat in X minutes)?
5. What other considerations can be reasonably accounted for within future protocols (e.g. multiple systems being filled at the same time on the same vehicle in parallel)?
6. What capabilities of existing components on the market could influence future fuelling protocols, including those required for interoperability (for instance, is there a mechanical interlock on any existing H50 nozzle/receptacle)?
7. Where can component developments that can be reasonably anticipated to address any limitations, and where are there gaps?
8. What capabilities of other factors could influence future fuelling protocols (for instance, infrastructure to application communications)?
9. Where can developments within such other factors be reasonably anticipated to address any limitations, and where are there gaps?

Since the consortium is in the fortunate position to consist of a large cross section of stakeholders of the HD hydrogen vehicle industry, questions could be targeted towards each audience:

1. HD vehicle manufacturers / operators: road vehicles, trains, boats, off-road vehicles (e.g. mining), etc – to establish:
    a. What realistic CHSS capacities might need to be?
    b. Refuelling time constraints in the future (i.e. equivalent to the US DOE 3-5 min fill for light duty)
    c. What state (liquid/cryo-compressed / gaseous) options there are for different applications?
    d. Other considerations that affect fuelling
2. Component manufacturers – to establish:
    a. What temperature ratings are realistic for onboard storage tanks for the future?
    b. What flow capabilities are realistic for the future?
    c. How can mechanical interlocks be developed, if necessary?
    d. Other considerations that affect fuelling

3. Vehicle and HRS OEMs – to establish (in addition to above):
    a. What information needs to be transferred between the vehicle and station, and what reliability is necessary?
    b. Can simplifications be made to the calculation model that would allow for easier and more reliable data processing?

Again, many of these questions were included in the survey sent out to relevant stakeholders. Unfortunately, however, it was difficult to get as wide a variety of responses as would have been expected had face-to-face meetings been possible.

To continue with dissemination activities, a **fourth workshop/webinar** was held on 20th September 2021, directly prior to the International Conference of Hydrogen Safety (ICHS). The purpose of this workshop was to review modelling and testing performed to date, and discuss how to work with results achieved so far, in order to ensure the results generated are useful and of industrial relevance

Due to the extension of the project by nine months, the final workshops were conducted in 2022:

The **fifth workshop** (originally focus: objective 1) was conducted on 21st April 2022. Its aim was to disseminate and discuss the preliminary results from the project with external stakeholders

Note: Due to the increased ambition of the project, Objective 1 and parts of 2 have essentially been merged together, to develop a protocol that is forward looking beyond the currently available hardware / communications concepts. This workshop will, in line with the original intention, be dissemination of the current status within the project, but without being limited to what was originally described as "Objective 1" when the project was initially defined.

The **sixth and final workshop** took place at ZBT in Duisburg, Germany (further details are provided in Chapter 3 below). Due to limited capacities on site but also to prepare for potential travel restriction due to the Covid pandemic, the workshop was also broadcasted via webinar. The aim of the workshop was to disseminate final project results. Additionally, this workshop covered the proposed next steps for protocol development[3] and deployment, in line with the original intent of Objective 2.

[3] PRHYDE results will also be forwarded as input to development of ISO 19885-3. For further information, please see https://www.iso.org/committee/54560.html.

3 SIXTH AND FINAL WORKSHOP / WEBINAR (22ND SEPTEMBER 2022)

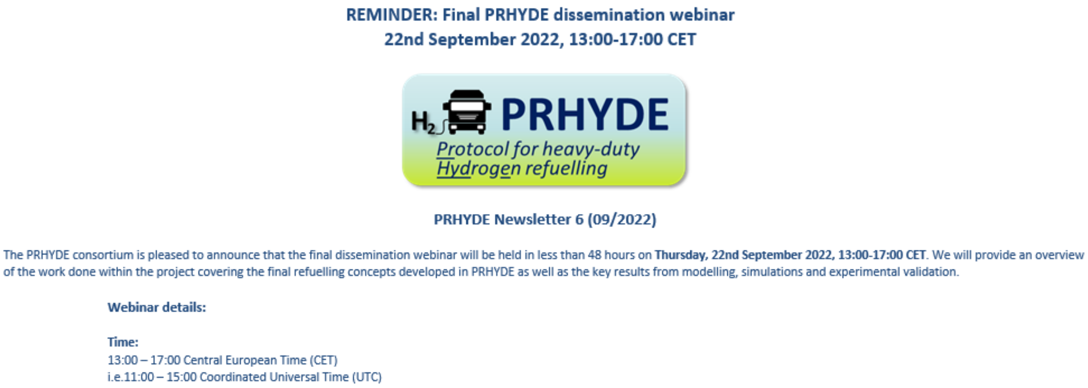
The final dissemination event of PRHYDE was held as a hybrid event (webinar and in-person workshop) at ZBT in Duisburg, Germany on 22nd September 2022 (1-5 pm CEST).

Figure 1: Workshop location

3.1 Workshop preparation

The workshop was announced via newsletter using the PRHYDE's stakeholder list and additional LinkedIn Postings (see Figures below).

In total, over 180 participants (of which 30 were present in Duisburg) followed the workshop.



REMINDER: Final PRHYDE dissemination webinar
22nd September 2022, 13:00-17:00 CET

PRHYDE Newsletter 6 (09/2022)

The PRHYDE consortium is pleased to announce that the final dissemination webinar will be held in less than 48 hours on **Thursday, 22nd September 2022, 13:00-17:00 CET**. We will provide an overview of the work done within the project covering the final refuelling concepts developed in PRHYDE as well as the key results from modelling, simulations and experimental validation.

Webinar details:

Time:
13:00 – 17:00 Central European Time (CET)
i.e.11:00 – 15:00 Coordinated Universal Time (UTC)

Figure 2: PRHYDE newsletter 6

Christopher Kutz • You
Project Manager/Consultant | Hydrogen & Renewables
2w • Edited •

How will #fuelcell #trucks be refuelled in the future? Join our final dissemination webinar of the EU-funded #PRHYDE project on protocol concepts for heavy-duty #hydrogen vehicle refuelling.
September 22, 2022 (1-5 pm CET)
Register: via email to info@prhyde.eu

Key info about the project (see also https://prhyde.eu/): since January 2020, the PRHYDE consortium has worked on the development of new fuelling concepts for gaseous HD hydrogen fuelling. The work was supplemented by a broad experimental test campaign on single tanks and further validation by applying 0D and 3D simulation models. Project results will be fed into ongoing international standardization activities.

#PRHYDE partners: Air Liquide, CEA, ENGIE, ITM Power (LSE: ITM.L), LBST Ludwig-Bölkow-Systemtechnik GmbH, Nel Hydrogen, Nikola Motor Company, Shell, Toyota Motor Corporation and Zentrum für BrennstoffzellenTechnik (ZBT) GmbH .

Co-funded by the European Union

Clean Hydrogen Partnership

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 874997. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe Research.

Figure 3: LinkedIn posting to raise awareness for the PRHYDE workshop

3.2 Agenda (22nd September 2022)

The joining instructions and the agenda is included below:

Figure 4: Webinar instructions

Final PRHYDE Webinar (Hybrid event) | 22nd September 2022

CET Timing (approx.)	Topic	Responsible
12:45 CET	**Join webinar (Note: webinar will start at 13:00 CET)**	Moderation: Martin Zerta (LBST)
13:00 CET	**Welcome**	Martin Zerta (LBST) and Christian Spitta (ZBT)
13:10 CET	**Introduction to PRHYDE**	Vincent Mattelaer (Toyota Europe)
13:25 CET	**WP3 – Protocol concept development**	Claus due Sinding (NEL) Steve Mathison (FirstElement Fuel)
14:45 CET	**Break (15 mins)**	
15:00 CET	**WP5 – Experimental validation**	Antonio Ruiz (Nikola)
15:30 CET	**WP4 – Modelling and validation**	Fouad Ammouri (Air Liquide)
16:00 CET	**Summary of key results and outlook**	Claus Due Sinding (NEL), Nick Hart (ITM), Steve Mathison (FirstElement Fuel)
16:20 CET	**Questions / Discussion**	All
16:55 CET	**Closing remarks**	Martin Zerta (LBST)
17:00 CET	*********** End of Webinar ***********	
17:15 CET …	***Lab tour (for visitors in Duisburg)***	*Christian Spitta (ZBT)*

Final PRHYDE Webinar | 22nd September 2022 www.PRHYDE.eu

Figure 5: Agenda - Final PRHYDE dissemination workshop

3.3 Documentation

Figure 6: Workshop participants at ZBT in Duisburg, Germany (Photo: ZBT/LBST)

Figure 7: Final PRHYDE dissemination workshop (Photo: LBST)

Figure 8: Lab tour at ZBT test site (Photos: LBST)

3.4 Dissemination

All presentation slides are available on the PRHYDE website (https://prhyde.eu)[4].

The slides presented during the webinar can be previewed and downloaded below:

Workshop 6: Welcome by ZBT and LBST https://lbst.de/wp-content/uploads/2022/09/1_PRHYDE_Final_Workshop_22-09-2022_Welcome_ZBT_LBST.pdf
Introduction to PRHYDE https://lbst.de/wp-content/uploads/2022/09/2_PRHYDE_Final_Workshop_22-09-2022_Introduction_PRHYDE.pdf
WP3: PRHYDE Protocol Concepts https://lbst.de/wp-content/uploads/2022/09/3_PRHYDE_Final_Workshop_22-09-2022_WP3_Protocol_Concepts.pdf
WP5: Experimental Test Campaign https://lbst.de/wp-content/uploads/2022/09/4_PRHYDE_Final_Workshop_22-09-2022_WP5_Test_Campaign.pdf
WP4: Modelling and Simulations https://lbst.de/wp-content/uploads/2022/09/5_PRHYDE_Final_Workshop_22-09_2022_WP4_Modelling.pdf
PRHYDE Summary and Outlook https://lbst.de/wp-content/uploads/2022/09/6_PRHYDE_Final_Workshop_22-09-2022_Summary_FutureWork.pdf
Q&A Session To be published as part of this document.

4 Please note: the website server had to be changed to make sure that project results are available after project end. The domain https://prhyde.eu however stays active and a redirection to the new website has been implemented.

To inform all stakeholders that the slides from the final workshop are now available online, a PRHYDE newsletter (No. 7) has been sent to all the PRHYDE stakeholders.

Final PRHYDE dissemination webinar
Slides available for downloading

PRHYDE
Protocol for heavy-duty Hydrogen refuelling

PRHYDE Newsletter 7 (09/2022)

The PRHYDE consortium herewith thank all stakeholders, who participated on the final dissemination workshop, either in-person at ZBT in Duisburg or online via webinar.
We were delighted to welcome an audience of about 180 participants (of which 30 were present in Duisburg). The slides of all presentations shown during this workshop, also those from the previous PRHYDE webinars, are now available for download at the PRHYDE website (https://prhyde.eu).

The core element of the workshop was the presentation of different fueling protocol concepts developed in the context of the PRHYDE project. While the majority of existing fueling protocols are based on worst-case assumptions, the presented PRHYDE concepts use vehicle information to optimize fueling time.

In total, four fueling concepts have been presented, namely:

- Type 2 – Static
- Type 3 – Dynamic – T_{gas} Initial
- Type 3 – Dynamic – T_{gas} Initial+
- Type 3 – Dynamic – T_{gas} Throttle

Please visit https://prhyde.eu for further information about the project and all public deliverables and further publications in the context of PRHYDE.

PRHYDE results will also be forwarded as input to development of ISO 19885-3. For further information, please see https://www.iso.org/committee/54560.html.

Please feel free to get in touch with us at info@prhyde.eu.

On behalf of the PRHYDE project consortium, and with best regards

PRHYDE coordinator team
Ludwig-Bölkow-Systemtechnik GmbH
https://en.lbst.de/

Figure 9: PRHYDE newsletter 7 (29 September 2022)

3.5 Questions and Answers (Q&A)

These questions were received during the webinar in the chat.

The answers were provided by the consortium partners and Steve Mathison (FirstElement Fuel).

#	Question / Answer from webinar Q&A
1	**Q: Will the modelling programs / macros be made publicly available for verification & review?** A: For information about the models used, please see the publication on the PRHYDE website (https://prhyde/). ICHS 2021: July 2021 – Protocol for Heavy Duty hydrogen refueling: a modeling benchmark – Arnaud Charolais, Fouad Ammouri, Elena Vyazmina, et.al. (Presentation, Article)

#	Question / Answer from webinar Q&A
2	**Q: Will you share the recording from the workshop afterwards?** A: We will provide all slides on the PRHYDE website (see Prhyde | Protocol for Heavy-duty Hydrogen Refuelling). The recording is for internal use only.

#	Question / Answer from webinar Q&A
3	**Q: How do you prove the parameters in FCV are correct?** A (Steve Mathison): This will need to be worked out in ISO WG 24. We didn't discuss this in much detail in PRHYDE. However, we envision a validation process that the vehicle OEM goes through to ensure that the t-final tables were derived and implemented on the vehicle correctly. The vehicle would then communicate to the station that it has passed this validation process (still to be determined how that will be done, e.g. self-certification or trusted third party, etc.).

#	Question / Answer from webinar Q&A
4	**Q: A very interesting approach with the dynamic refueling protocol. Has there been realized a risk analysis taking in account all possible risk scenarios (e.g. communication of wrong refueling table from the truck to the station)? If yes, will this risk analysis be published to get checked by 3rd parties?** A (Claus Due Sinding): A Risk Assessment was conducted by the PRHYDE Work Package 3 Team to assess threats unique to the new fueling concepts. With regards to communication of wrong refueling table from the truck to the station, the station can have simple “sanity checks” as safeguards, but the process of getting the refueling table into the truck also have checks to prevent wrong tables. We are working on publishing some of the Risk Assessment. It is important to notice that our Risk Assessment is a first attempt to assess the risks arising with this new approach to refuelling, so it definitely needs to be checked and worked on further.

#	Question / Answer from webinar Q&A
5	**Q: Is the intent to interpolate between the Pmin tables if Initial vehicle pressure is in between or assume the worst case of the two tables?** A (Steve Mathison): We did consider this late in the project and it is possible to do. It requires inter-table interpolation, so the interpolation would have to be done on the vehicle side. It would improve performance, so this should be considered and discussed further in ISO WG 24.

#	Question / Answer from webinar Q&A
6	**Q: Does the vehicle have to transmit all of the tables, or only the relevant table? The vehicle can detect the hot soak or not, as well as the Pmin.** A: (Vincent Mattelaer): Not really decided, but we assume that only one table is sent.

#	Question / Answer from webinar Q&A
7	**Q: What happens in Tgas Throttle with a subsequent fill?** A (Steve Mathison): A subsequent fill operates just like a non-subsequent fill. There is only one t-final table and one Pmin value based on the minimum CHSS pressure. In a subsequent fill, if the initial gas temperature is relatively high, then the PRR throttling would occur earlier in the fill (or possibly right from the beginning).

#	Question / Answer from webinar Q&A
8	**Q: Who selects the threshold gas temperature? The vehicle or the station?** A (Steve Mathison): The threshold gas temperature is calculated automatically by the station according to a formula. This formula is based on the maximum measured pressure drop between the dispenser ramp pressure and CHSS pressure, as well as a parameter "a". If the vehicle communicates this "a" parameter, then the threshold gas temperature would be influenced by the vehicle, but still calculated by the station.

#	Question / Answer from webinar Q&A
9	**Q: Does the use of SOC Taper require a higher maximum allowable pressure rating for the HRS components in the dispenser?** A (Steve Mathison): The dispenser pressure never exceeds 1.25 x NWP. It is just in the derivation of t-final that we allow the dispenser pressure to exceed 1.25 x NWP, which facilitates a shorter t-final value. Keep in mind that in the derivation of t-final, the fuel dispensing components are assumed to have a worst case flow coefficient (highest possible pressure loss). Components in the market are likely to have higher flow coefficients, lowering the pressure drop, but if it is still too high towards the end of the fill, then SOC taper reduces the PRR to achieve the SOC target. A (Nick Hart): Typically people use PRVs to control over-pressure protection, and these typically are set ~10% above the maximum operating pressure (Still, dispenser components on the market currently are typically only rated to 1.25* NWP). The new family of ISO 19880 standard now indicates the need for the rated pressure of HRS components to be at least 1.38* NWP – once components meeting this maximum allowable pressure are available, they will be suitable for both SOC Taper, and other standardised refuelling protocols such as SAE J2601, which also has “target pressure” approaching 1.25* NWP.

#	Question / Answer from webinar Q&A
10	**Q: Why does Tgas Throttle approach which has less assumptions take longer time to refuel under some circumstances?** A (Steve Mathison): Actually, simulations show that Tgas Throttle can fuel just as quickly as Tgas Initial+, however, it requires the tuning parameters to be optimized. A vehicle OEM could do this work (to optimize the tuning parameters) and communicate the best parameters to the station. Another thing to consider is that Tgas Throttle can take advantage of real world situations where the station fuel delivery components have a higher flow coefficient than the worst case assumptions and/or that they are already cold from a previous fueling. The other Type 3 dynamic fueling concepts cannot take advantage of these things as effectively. We did conduct some performance simulations which demonstrated this, but didn't include them in the presentation." When we conducted the fueling performance simulations on the PRHYDE concepts originally, for the Adaptable Tgas Throttle, I used a "general" set of parameters for "a" and "b" (both equal to 4). These general settings were found to work adequately for all CHSS analyzed (including much higher and lower liner thermal conductivities, tank surface to volume ratios, Kv values, and Tgas oscillations or noise mplitudes). However, there was no previous attempt to optimize these parameters to

	the specific CHSS under analysis. So I decided to conduct an update of the previous performance simulations where I optimized the parameters for the NREL heavy-duty vehicle simulator CHSS (seven 243.5 L Hexagon Type IV tanks). The optimized values were deemed to be a = 1 and b = 2. No noise in the Tgas was considered, but performance should be minimally impacted with reasonable oscillations (e.g. similar to those observed by the Tgas sensor 9 used in the TestNet tests). In the slides below is an abbreviated update to the performance simulations using these optimized parameters for Adaptable Tgas Throttle. Additionally, I ran the same simulations with some more realistic assumptions regarding the Kv and thermal mass of the dispenser components. Originally, these were considered worst case values. We, of course, ran some performance simulations previously where Kv was increased (thermal mass was ignored since it had very little effect). But the increase in Kv has very little impact on the Static, Tgas Initial and Tgas Initial+ concepts. So I wanted to show the improvement in fueling performance of Tgas Throttle using some more realistic assumptions regarding Kv and thermal mass. Most fuel dispensing components will not be designed at the limits of requirements for Kv and thermal mass (there is work underway currently on implementing minimum requirements into the component standards). Therefore, for these "realistic" conditions, Kv was assumed to be 25% higher than worst case and thermal mass was assumed to be 50% lower than worst case (due to a combination of the components themselves having a lower thermal mass and their likely being cold due to a previous fueling event). As you can see by the results, the fueling times using Adaptable Tgas Throttle with optimized parameters are equal to and slightly better than Tgas Initial+ under all conditions analyzed. And when realistic conditions are considered, the Adaptable Tgas Throttle fueling times are notably faster than Tgas Initial+ under most fueling conditions. So if an OEM is willing to conduct optimization on the tuning parameters "a" and "b" (and communicate these to the dispenser along with the t-final table), and also conduct good engineering on the Tgas sensor location in the tank, Tgas Throttle is likely to have the highest fueling performance of all the concepts in PRHYDE.

Slides to Question 10:

WP3/4 – Performance Simulations Update (10-4-2022)

PRHYDE-Protocol for heavy-duty hydrogen refuelling

Call Identifier FCH-04-2-2019:
Refuelling Protocols for Medium and Heavy-Duty Vehicles

PRHYDE
Protocol for heavy-duty
Hydrogen refuelling

01 JAN 2020 - 31 DEC 2021

Horizon 2020
European Union Funding
for Research & Innovation

FCH
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

www.PRHYDE.eu

Performance Simulations Matrix

2

					Scenario 1											
					Static		Tgas initial		Tgas intial+		Tgas throttle 95°C (Adaptable with General Parameters a & b = 4)		Tgas throttle 95°C (Adaptable with optimized parameters a 1 b 2)		Tgas throttle 95°C (Adaptable with optimized params a 1 b 2 & Cv 125% & thermal mass 50%)	
T_{amb}	T_{gas0}	$T_{vessel0}$	T_{fuel}	P_0	Fueling Time	Ending SOC	Fueling Time	Ending SOC	Fueling Time	Ending SOC	Fueling Time	Ending SOC	Fueling Time	Ending SOC	Fueling Time	Ending SOC
35	40	40	-21	2	9.7	97%	9.7	97%	9.7	97%	9.7	97%	9.3	97%	8.5	97%
				5	8.2		8.2		8.2		8.3		7.9		7.2	
				10	7.6		5.9		5.9		6.4		5.9		5.3	
				15	7		4.1		4.1		5		4.1		3.9	
				20	6.5		3.6		3.6		3.9		3.6		3.5	
35	30	35	-21	2	9.7		9.7		8.3		8.8		8		7.3	
				5	8.1		8.1		6.9		7.5		6.8		6.1	
				10	7.6		5.9		4.9		5.9		4.9		4.5	
				15	7		4.1		3.8		4.6		3.9		3.7	
				20	6.4		3.5		3.5		3.7		3.5		3.5	
35	20	30	-21	2	9.6		9.6		7.2		8.2		7.1		6.4	
				5	8.2		8.2		5.9		7		5.9		5.4	
				10	7.5		5.8		4.1		5.5		4.4		4.1	
				15	6.9		4		3.8		4.3		3.8		3.5	
				20	6.3		3.5		3.5		3.5		3.5		3.5	

- ❑ Simulations conducted using NREL's H2FillS model on 1705L CHSS (seven 243.5 L Hexagon Type IV tanks):
- ❑ Ambient Temperature and Tfuel chosen so that the fueling times are temperature constrained when initial pressure is low
- ❑ **Adaptable Tgas Throttle results presented in Final Webinar used "general" settings for parameters "a" & "b" (a & b = 4)**
- ❑ **To address a question raised during the Final Webinar, simulations were conducted using "optimized" settings for a & b**
- ❑ **In addition, "optimized" parameters were used along with "realistic" conditions (Cv = 125% & thermal mass = 50%)**
  - **Cv of dispenser components will typically not be worst case – assumed 25% higher than worst case**
  - **Thermal mass of dispenser components will typically not be worst case and will typically be cold from previous fills**

Performance Simulations

3

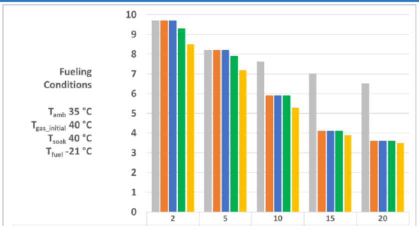
T_{amb} = 35 °C

T_{fuel} = -21 °C

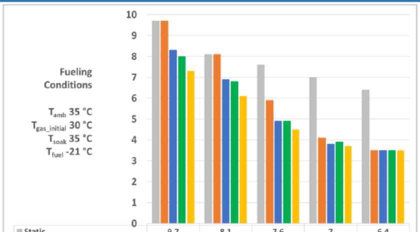
H2FillS

Performance Simulations

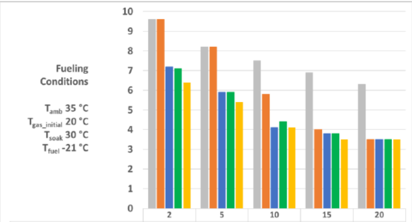
4



	2	5	10	15	20
Static	9.7	8.2	7.6	7	6.5
Tgas Initial	9.7	8.2	5.9	4.1	3.6
Tgas Initial+	9.7	8.2	5.9	4.1	3.6
Tgas Throttle Adaptable Opt Par	9.3	7.9	5.9	4.1	3.6
Tgas Throttle Adaptable Opt Par Realistic Conds	8.5	7.2	5.3	3.9	3.5



Static	9.7	8.1	7.6	7	6.4
Tgas Initial	9.7	8.1	5.9	4.1	3.5
Tgas Initial+	8.3	6.9	4.9	3.8	3.5
Tgas Throttle Adapatble Opt Par	8	6.8	4.9	3.9	3.5
Tgas Throttle Adaptable Opt Par Realistic Conds	7.3	6.1	4.5	3.7	3.5



	2	5	10	15	20
Static	9.6	8.2	7.5	6.9	6.3
Tgas Initial	9.6	8.2	5.8	4	3.5
Tgas Initial+	7.2	5.9	4.1	3.8	3.5
Tgas Throttle Adaptable Opt Par	7.1	5.9	4.4	3.8	3.5
Tgas Throttle Adaptable Opt Par Realistic Conds	6.4	5.4	4.1	3.5	3.5

Comments:

- **T_{gas} Throttle with optimized parameters** is equal to or slightly faster than Tgas Initial+ under all conditions
- **T_{gas} Throttle with optimized parameters and realistic conditions** is notably faster than Tgas Initial+ under most conditions, especially when the initial pressure is low
- **Vehicle can communicate the optimized "a" and "b" parameters to the dispenser**, along with the t-final table
- **T_{gas} Throttle should offer the highest fueling performance with the simplest approach** (only one t-final table required)
- To reap the benefits of using T_{gas} Throttle, T_{gas} Sensor location in the tank is important to minimize fluctuations in T_{gas} and to represent the bulk-average temperature

#	Question / Answer from webinar Q&A
11	**Q: What was the refuelled H2 mass for the shown tfinal values?** A (Steve Mathison): If you are referring to the performance simulations, these were based on CHSS sizes of about 1300L (52 kg) and 1700L (68 kg). The amount of mass transferred depends on the initial pressure in the CHSS.

#	Question / Answer from webinar Q&A
12	**Q: How was the table information transmitted for testing?** A (Claus Due Sinding): Excellent question! We had to work-around the fact that IrDA communication protocol cannot transmit t-final table information. So we developed the t-final tables for our Hydrogen Vehicle Dummy, and instead of storing them in the Hydrogen Vehicle Dummy, we stored them on the Station PLC. A (Alexander Kvasnicka): For testing at ZBT, our PLC programmer implemented a PLC-frontend, where we could insert the t-final tables by hand. The t-finals tables were derived per simulation for various ambient temperatures with a 5°C increment. For intermediate ambient temperatures we made a linear interpolation of the t-final tables between the adjacent tables above and below and inserted then only a single row of t-final table into the PLC.

#	Question / Answer from webinar Q&A
13	**Q: The WP5 experimental validation shows temperatures below -40°C at the end of the filling, is this in the allowed scope of the vessels?** A (Nick Hart**):** I think you are talking about some of the ZBT figures showing T_Dispenser and T_before OTV running at -40 deg C, and occasionally dropping below. Strictly speaking this wouldn't be compliant with EN 17127 for a publicly accessible station, but the tank itself wouldn't have seen these temperatures

#	Question / Answer from webinar Q&A
14	**Q: The actual tests performed were done by filling the tanks from cascade storage. Would the results be different if we used direct compression to fill the vehicle's tank?** **I understand that no, it depends only on the temperatures and the selected flow rate to the vehicle tank, is that right?** That's correct. These approaches and concepts are agnostic to station design.

#	Question / Answer from webinar Q&A
15	**Q: A periodical FCV temperature sensor maintenance is necessary, isn't it?** A (Steve Mathison): It depends on the design of the CHSS. If the temperature sensor is safety critical, it may require periodic calibration depending on the design. An alternative is to qualify the CHSS to the maximum gas temperature that could occur if the gas temperature measurement is wrong (e.g. 90 C or 95 C, depending on the value used to calculate APRRmax in the t-final derivation). In this case, the temperature sensor is not safety critical and it would be treated just like the sensors that are currently utilized on production vehicle CHSS (a fault would only affect qualify of fill).

4 CONCLUDING REMARKS

Throughout the project lifetime (January 2020 – September 2022), the Covid pandemic to a large extent prevented the originally anticipated intensive in-person interaction between project partners, and with external stakeholders.

Despite these challenges, the PRHYDE project enabled external stakeholders to follow the project progress via six webinars / workshops. The final dissemination workshop on 22nd September 2022 was held as a hybrid event. The project partners were delighted to welcome an audience of about 180 participants (of which 30 were present in Duisburg).

With that, the project successfully concluded the stakeholder interaction. Further work will continue in standardisation committees, such as ISO/TC 197/WG24, who are developing ISO 19885-3 (see https://www.iso.org/committee/54560.html), and the SAE FCEV Interface Task Force.

What is PRHYDE?

With funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU, now CHJU), 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://prhyde.eu. For feedback on the PRHYDE project or the published deliverables, please contact info@prhyde.eu.

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Members of the PRHYDE Consortium:

Further linked third partner to the project are MAN and Toyota North America.

We also thank the following companies and institutions for their contribution to the project (in alphabetical order): Bennet Pump, Daimler, FirstElement Fuel, Hexagon Purus, Honda, LifteH2, Luxfer, National Renewable Energy Laboratory (NREL), National Technology & Engineering Solutions of Sandia, LLC (NESS), Risktec, Savannah River National Laboratory (SRNL) and TÜV SÜD Rail.