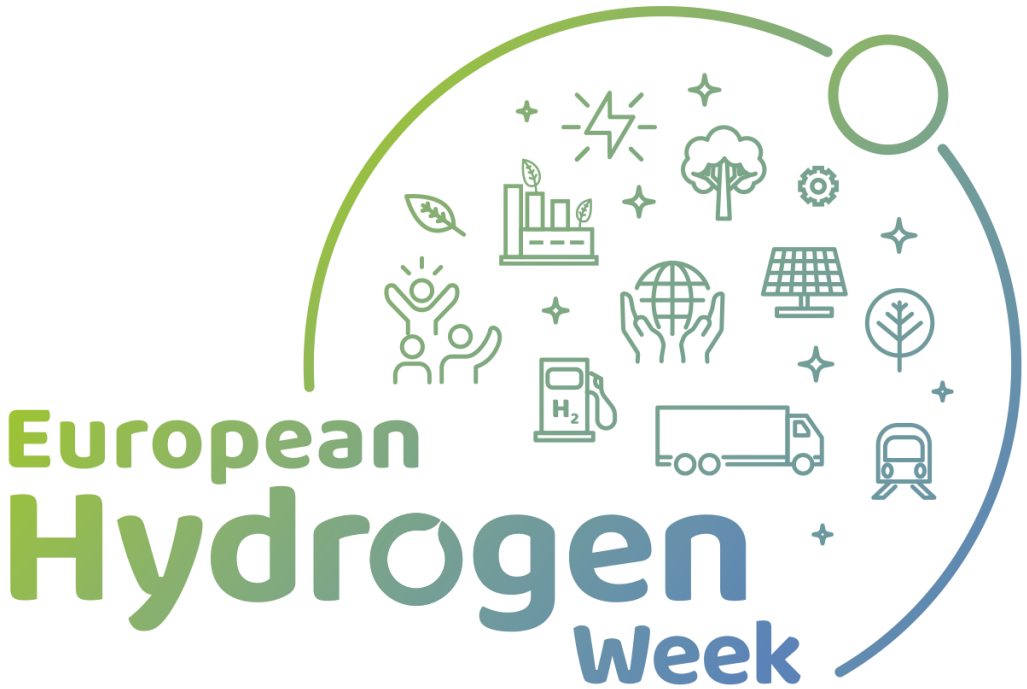
PRHYDE

Protocol for Heavy-Duty Hydrogen Refuelling



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#EUResearchDays
#PRD2022
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Background

LDV

(tank sizes 2 to 10 kg)

Protocol?	✓	(SAE J2601)
Fast fuelling?	✓	(3 to 5 minutes)
Hardware?	✓	(max. 60 g/s)

GAP

HDV

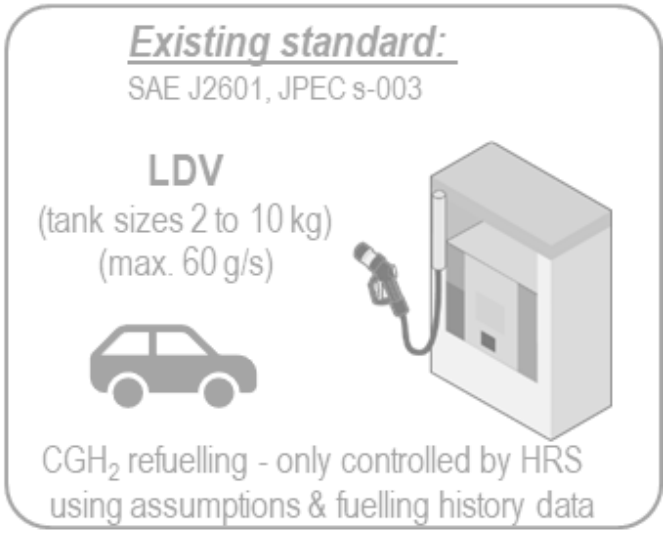
(tank sizes 10 to 100 kg)

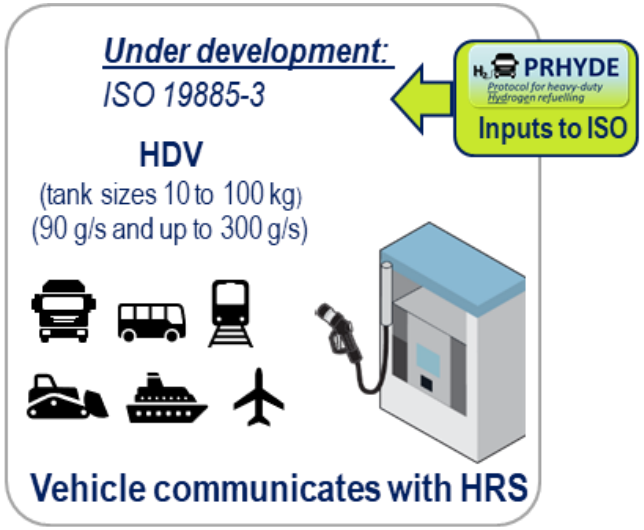
Protocol?	~	(JPEC S-0003 – Only for max 60 g/s))
Fast fuelling?	✗	(JPEC S-0003 – 10 to 45 minutes)
Hardware?	✗	(90 g/s and 300 g/s under development)

Current protocols are too limited or not existing for heavy duty fuelling

European Hydrogen Week

A new international standard has to be developed for H_2 refuelling as existing ones are not sufficient for heavy duty vehicles





A new international standard should to be developed to define specific conditions for efficient & safe H_2 refuelling of HDV.

- **ISO TC 197 WG 24 (TF 3)** has started to prepare a specific standard for HDV H2 refuelling in 01/2022.
- The **PRHYDE project** (01/20 – 09/22), EU-funded with international partners and cooperation (i.e. from the US), **provides inputs & support to the ISO group** and H_2 technology developers to accelerate this protocol development.

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The PRHYDE project provides the new concept & methodology for high performance H_2 refuelling of HDV (35/50/70 MPa)

PRHYDE approach:

The **PRHYDE H_2 HDV refuelling concept & methodology** targets to optimise

- the refuelling time,

- the filling up to maximum tank capacity and

- the energy efficiency by reducing demand for pre-cooling requisite.

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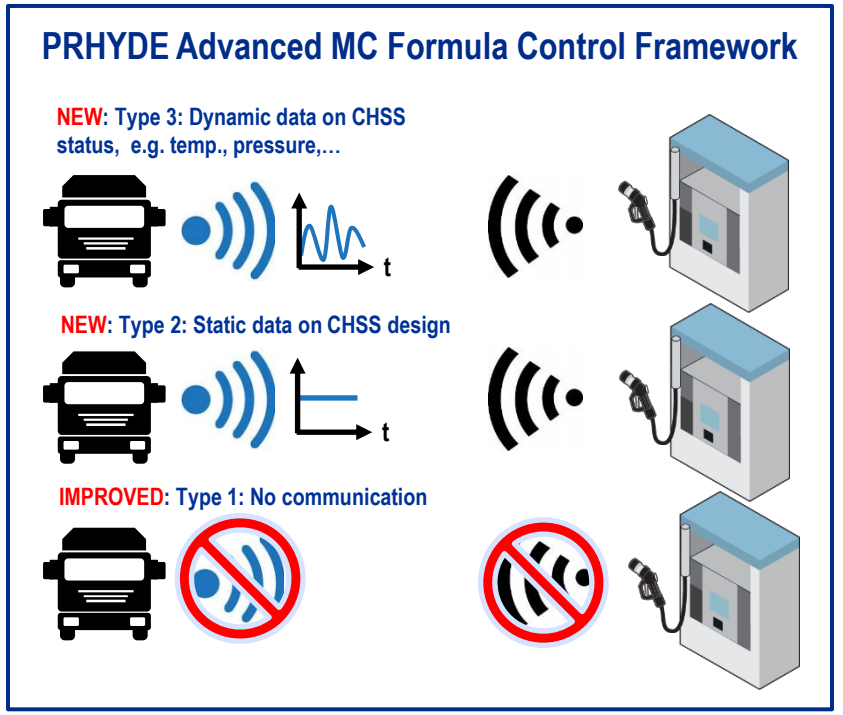
The PRHYDE project provides the new concept & methodology for high performance H_2 refuelling of HDV (35/50/70 MPa)

PRHYDE approach:

The new H_2 refuelling approach comprises three technical concepts for refuelling (*protocol types*):

- NEW: **High performance refuelling (*type 3*)**: the vehicle provides information to the HRS (dynamic data on the H_2 storage system conditions)
- NEW: **Optimised static refuelling (*type 2*)**: the vehicle provides static data only to the HRS (real CHSS values but no actual performance data, e.g. temp., pressure,…)
- IMPROVED: **Non-communication refuelling (*type 1*)**: Most conservative values for safe refuelling (used as a fall-back option, if no communication is available)



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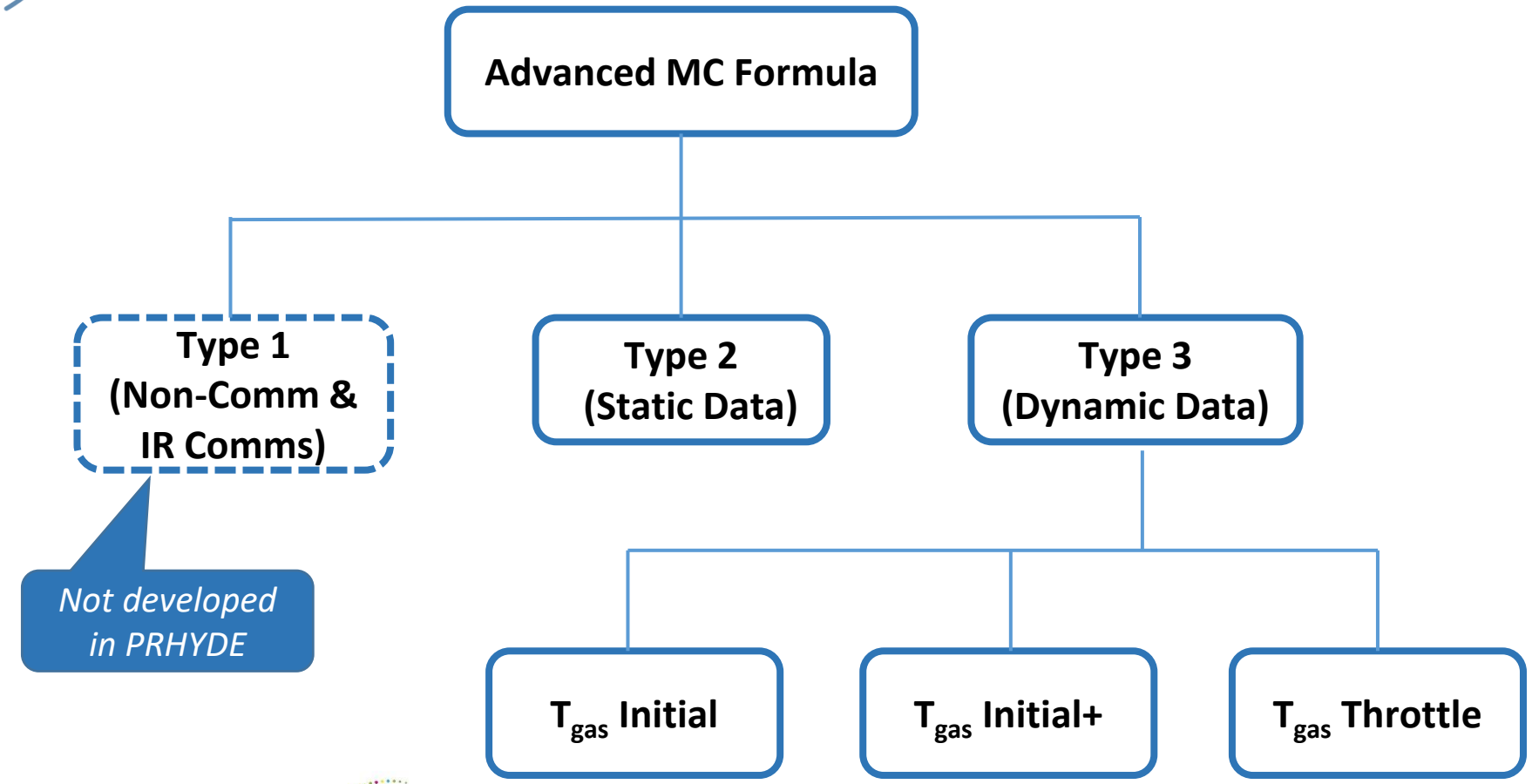
PRHYDE Advanced MC Formula Control Framework



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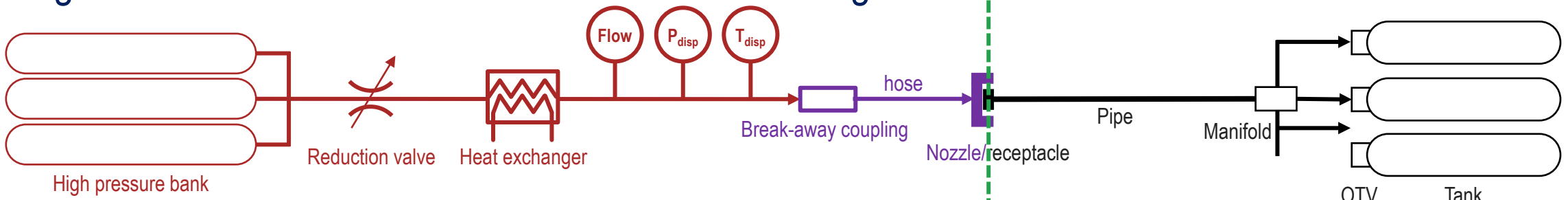
Current SAE J2601 Fuelling Protocol Principle

The station takes full responsibility.
Using most conservative values slows down the fuelling



HRS supplier has impact in order to create good fuelling

Known, but protocol takes most conserative values

Unknown. Protocol will use most conservative values for each individual component, number of tanks, size of tank etc...

PRHYDE will eliminate the use of most conservative values for this part.

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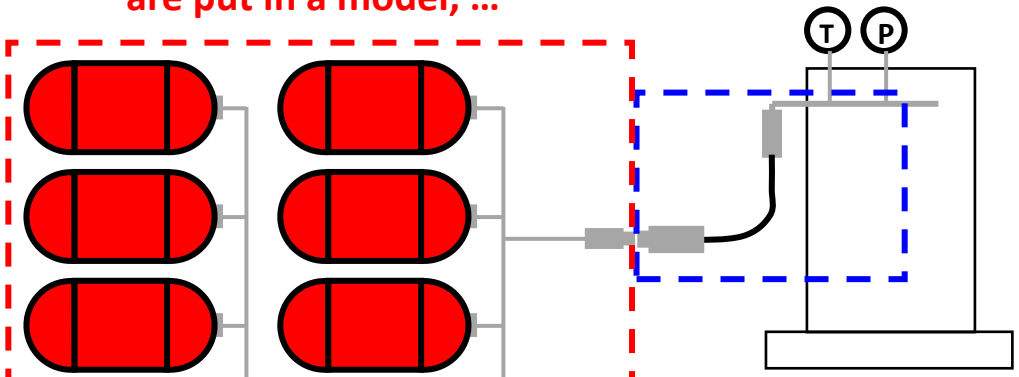
OEM Tank Assembly Values are stored as a t_{final} table

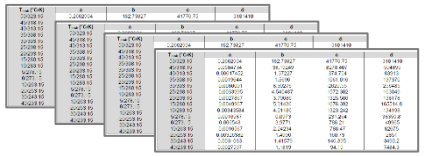
Actual CHSS Design & thermophysical properties are put in a model, …

… together with assumptions for dispenser components



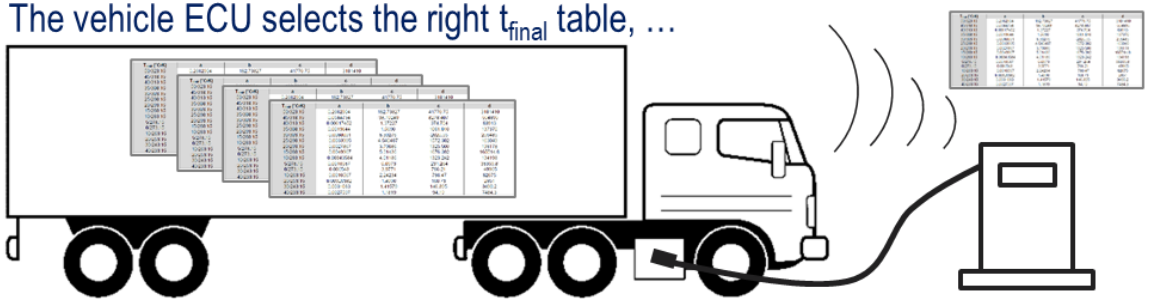
MODEL

A set of t-final tables are produced and stored in vehicle ECU



The vehicle ECU selects the right t_{final} table, …

… and sends it to the station



Example of a t-final table

t-final table format: MAT values every 2 °C and ambient temperature values every 5 °C

T_{amb} \ MAT	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0	2	4	46	48	50
50	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
45	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
40	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
35	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
30	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
25	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	08.4	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
20	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
15	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
10	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
5	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
0	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
-10	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
-20	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
-30	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m
-40	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m	mm.m

Format = mm.m

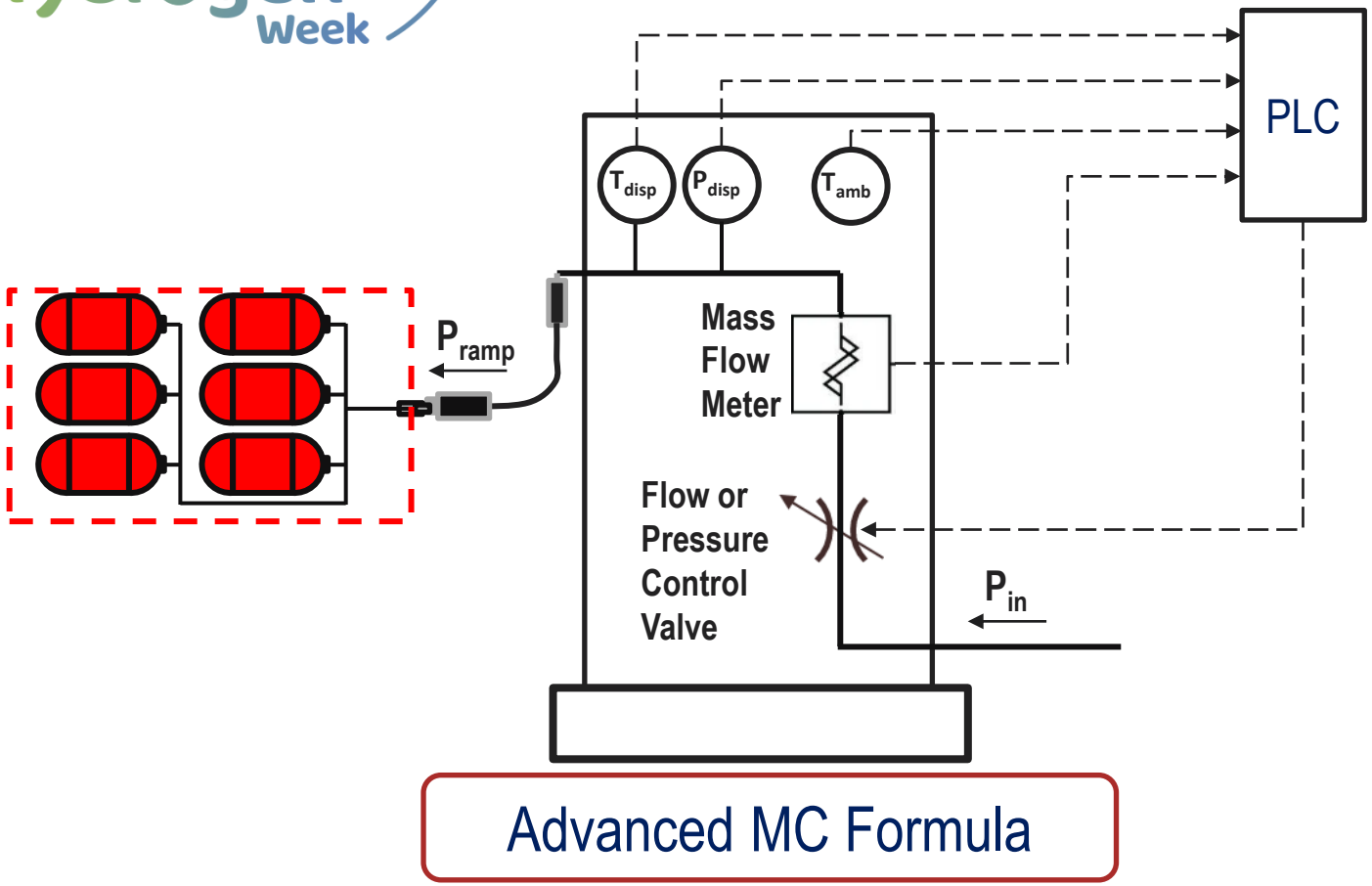
This indicates the t_{final} value in minutes

Example:

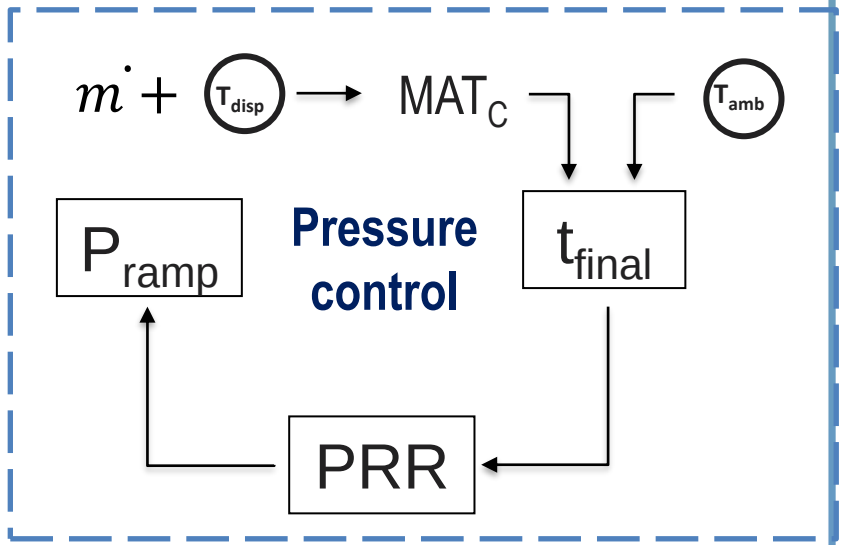
MAT = -14°C, T_{amb} = 25°C

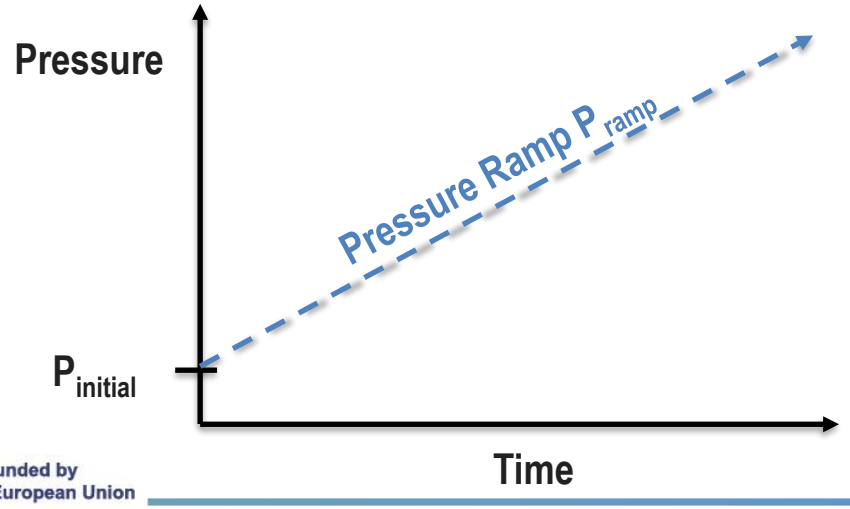
→ t_{final} = 08.4

Basic fuelling control for all PRHYDE concepts



Advanced MC Formula





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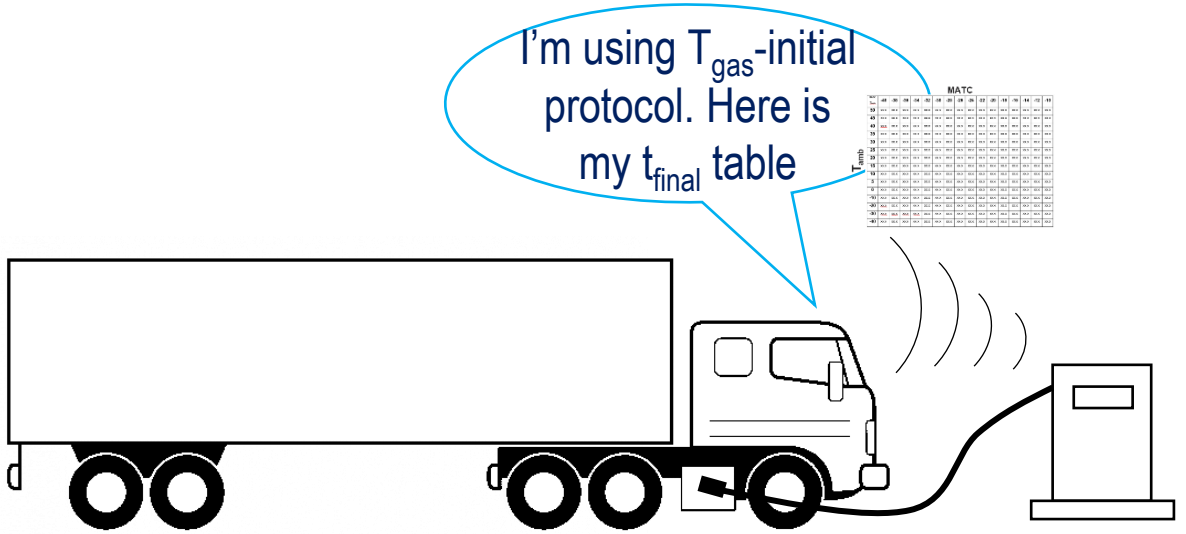
The four PRHYDE Fuelling Concepts

The vehicle will decide which protocol to use. It is the choice of the OEM.

1. Type 2 – Static
2. Type 3 – Dynamic – T_{gas} Initial
3. Type 3 – Dynamic – T_{gas} Initial+
4. Type 3 – Dynamic – T_{gas} Throttle

If the vehicle is not sending any table or protocol, then a most conservative t_{final} table, stored in the dispenser will be used.



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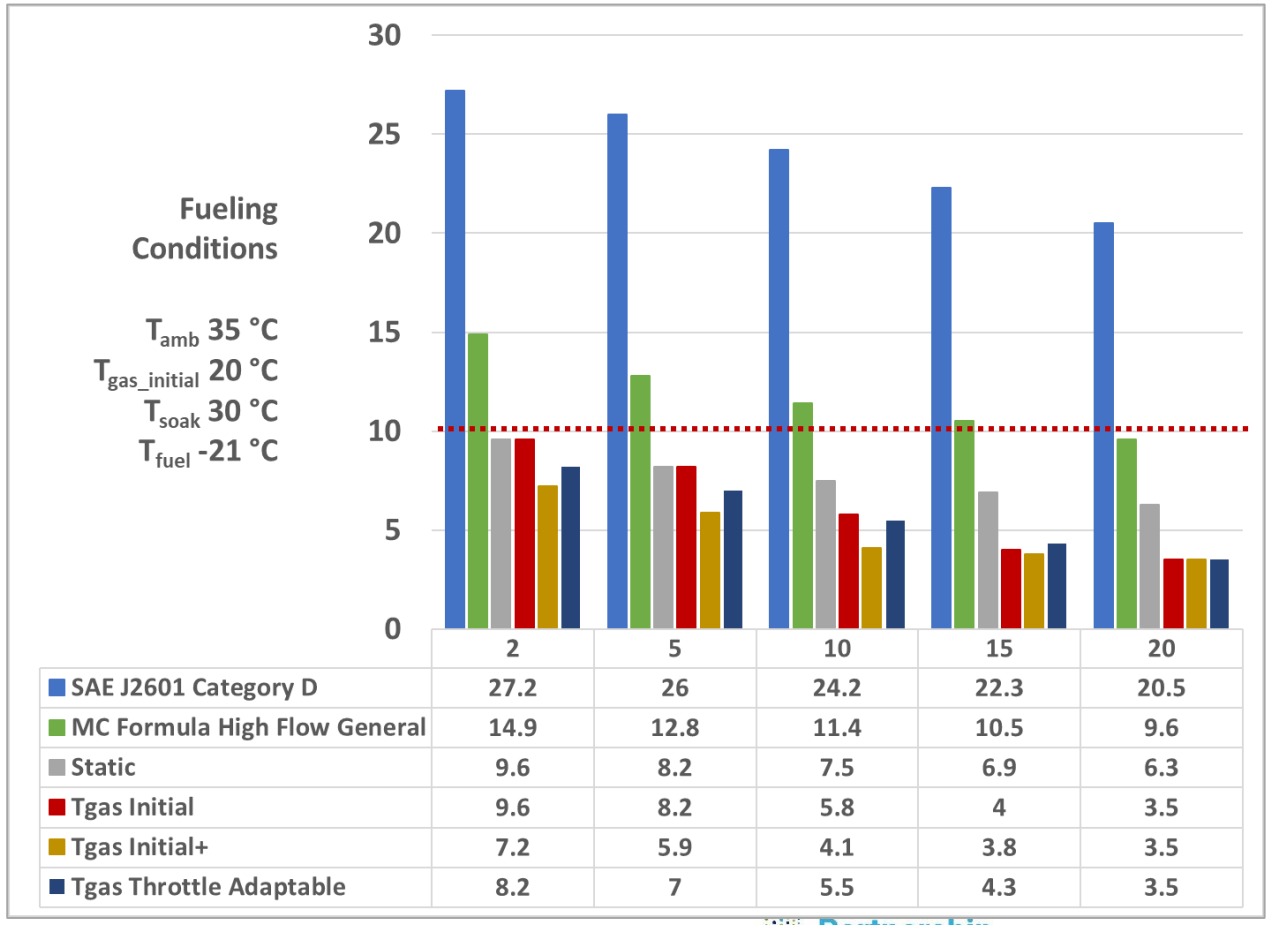
Simulations and testing



	2	5	10	15	20
SAE J2601 Category D	27.2	26	24.2	22.3	20.5
MC Formula High Flow General	14.9	12.8	11.4	10.5	9.6
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	8.2	7	5.5	4.3	3.5

Date (mo./yr.)	Fill Mass (kg)	Time (mins)	Average Mass Flow Rate (Kg/min)
08/2022	61.5	4.7	13.2
08/2022	78.7	6	13.1

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Heavy-duty hydrogen refuelling: PRHYDE

Members of the PRHYDE Consortium:

Air Liquide creative oxygen · cea LE RIPAULT · ludwig bölkow systemtechnik · ENGIE Lab CRIGEN · ITM POWER Energy Storage | Clean Fuel · nel · NIKOLA · ZBT

PRHYDE — Protocol for heavy-duty Hydrogen refuelling

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- Project lifetime: January 2020 - September 2022
- For further information, see www.prhyde.eu
- Acknowledgment:
  - Linked third partners: MAN and Toyota North America.
  - We also thank the following companies and institutions for their contribution to the project (in alphabetical order):
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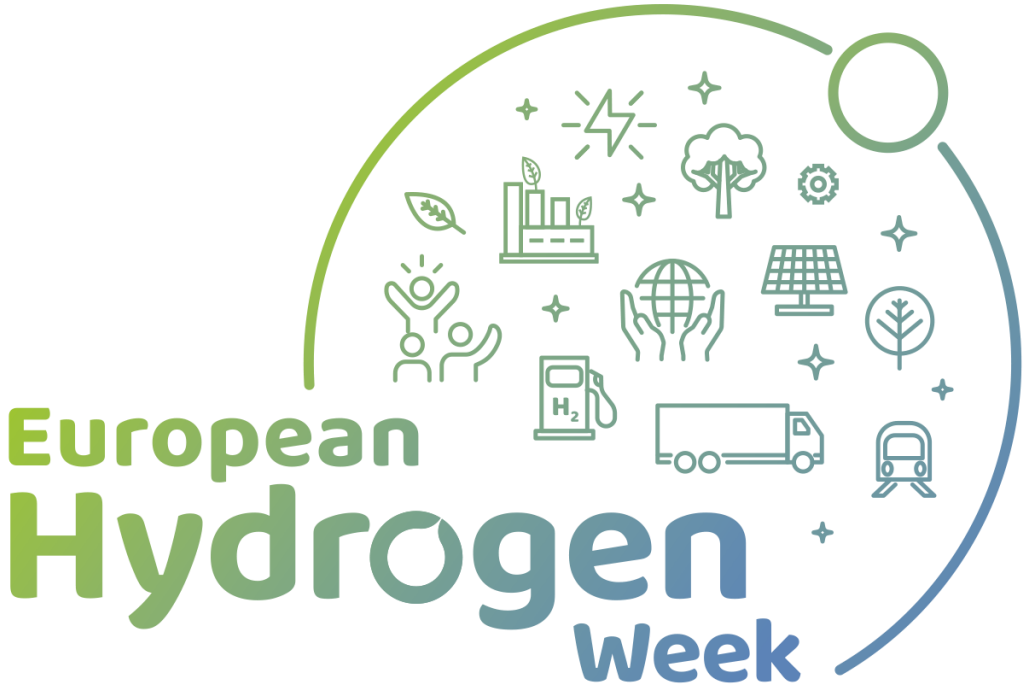

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