



Cryogenic Storage Vessel System for (De-)Fueling Experiments with LN2 & LH2

J. Knebel, W. Heiler, S. Gabriel, E. Torres de Ritter, A. Friedrich, T. Jordan

ELVHYS Final Project Meeting & Dissemination Conference

Jonas Knebel

14.-17.09.2026



Co-funded by
the European Union



UK Research
and Innovation

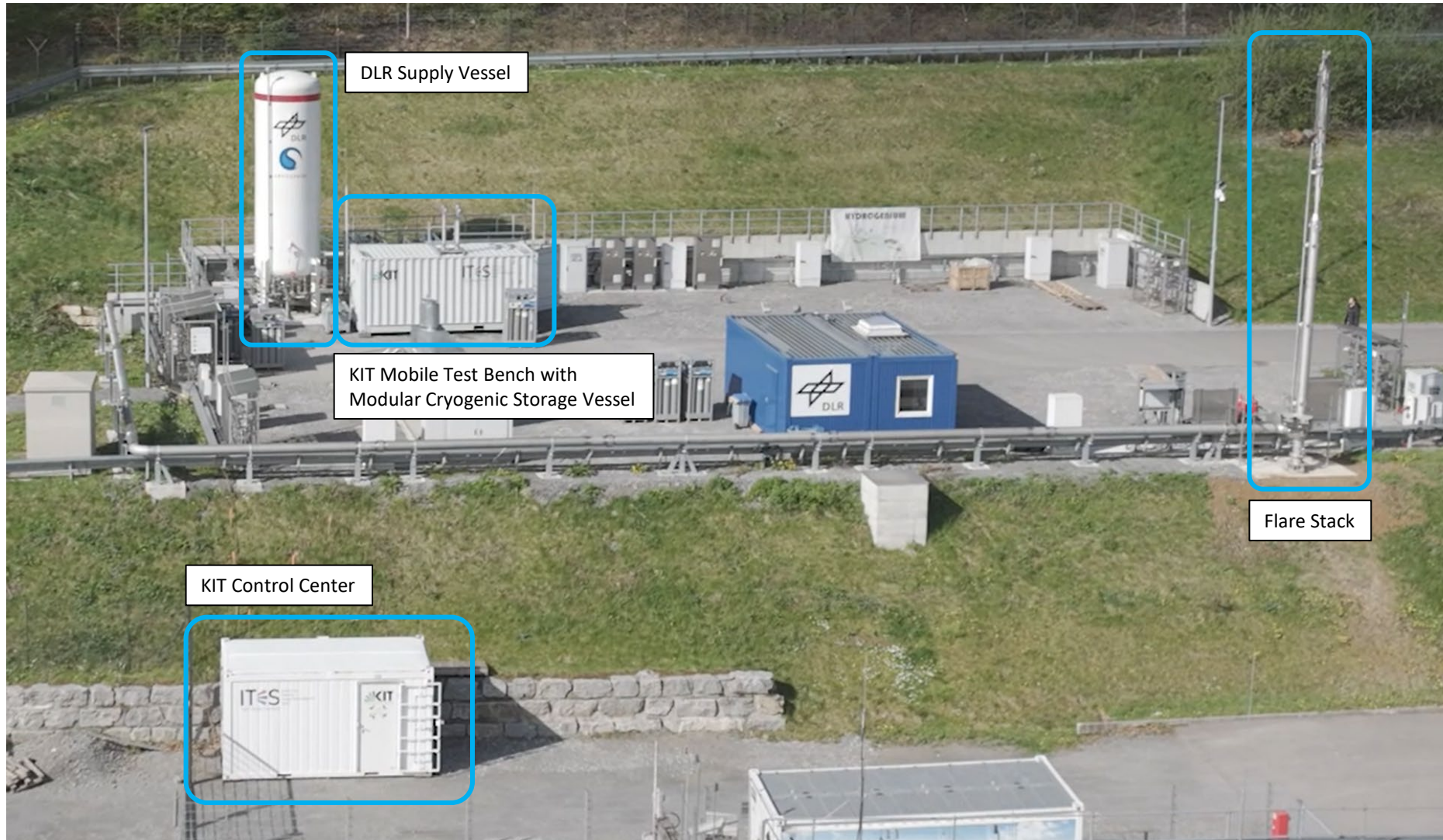
ELVHYS project No. 101101381 is supported by the Clean Hydrogen Partnership and its members. UK participants in Horizon Europe Project ELVHYS are supported by UKRI grant numbers 10063519 (University of Ulster) and 10070592 (Health and Safety Executive)

Liquid Hydrogen in Heavy-Duty Transport Application

ELVHYS Project Objectives:

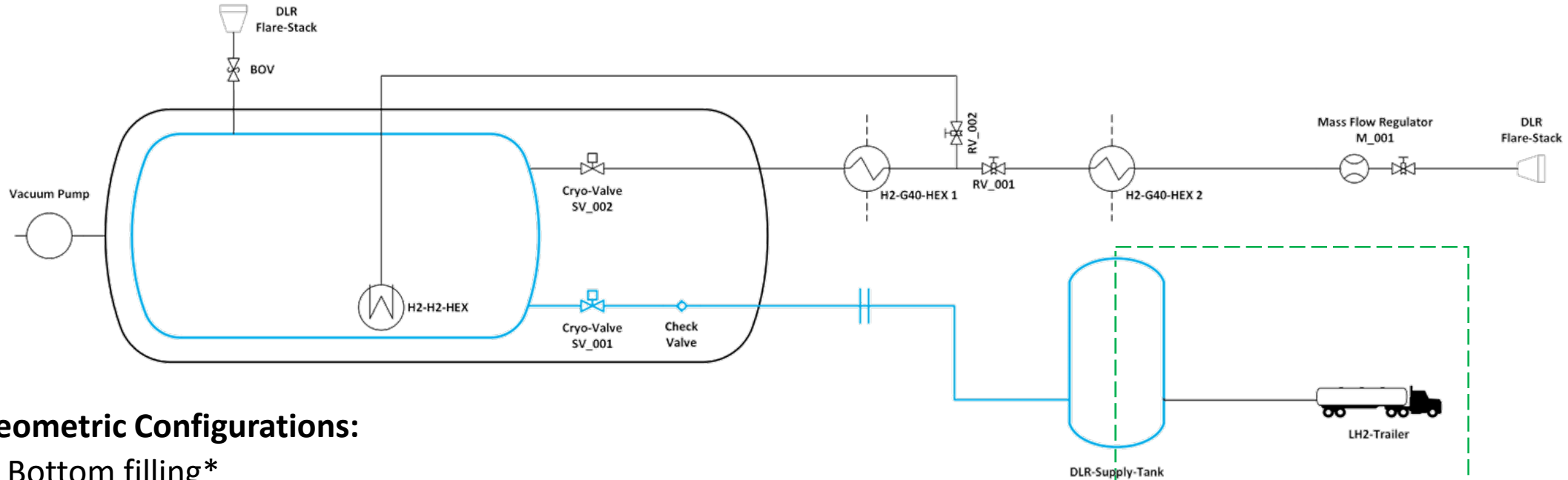
- **OBJ-4:** Support the design of the experimental setups to investigate cryogenic hydrogen transfer operations [...]
- **OBJ-5:** Successfully execute the experimental campaign addressing cryogenic hydrogen transferring operation tests for truck refuelling, ship bunkering, stationary tank filling [...]

WP 3.1: KIT Cryogenic Storage Vessel @ DLR H2CT Testing Ground



WP 3.1: Design of KIT Cryogenic Storage Vessel

Cooldown and Refueling



Geometric Configurations:

- Bottom filling*
- Top filling

Filling Mechanisms (DLR → KIT):

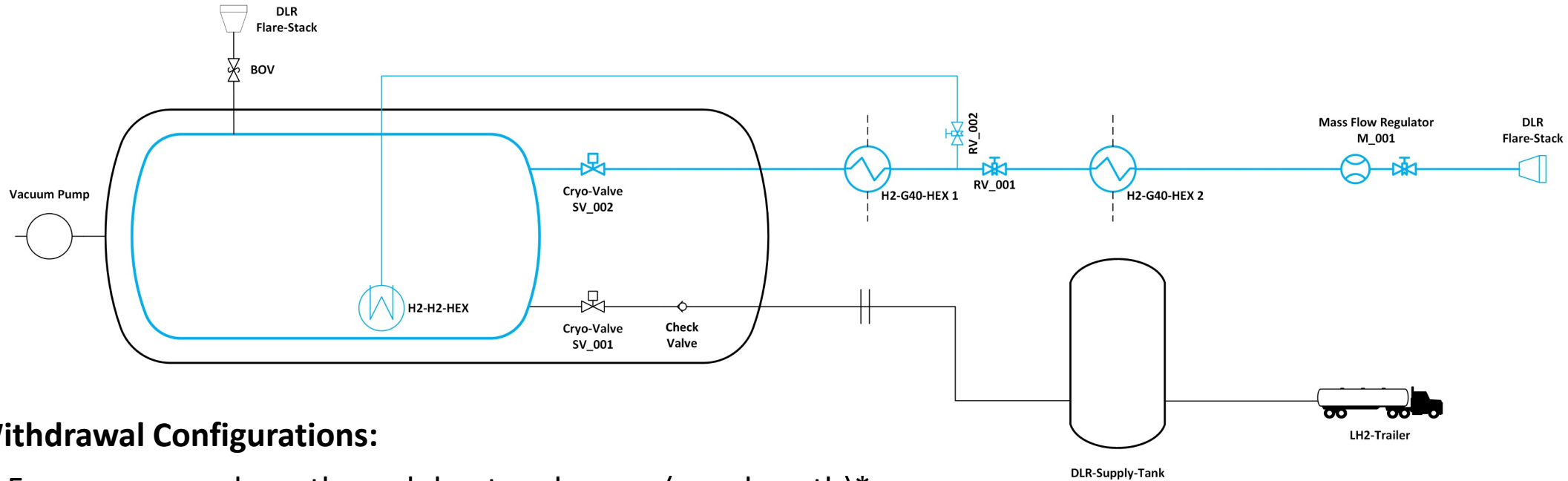
- Differential pressure*
- Cryo pump

WP-results presented by DLR

* implemented in ELVHYS-Project

WP 3.1: Design of KIT Cryogenic Storage Vessel

Venting and Supply

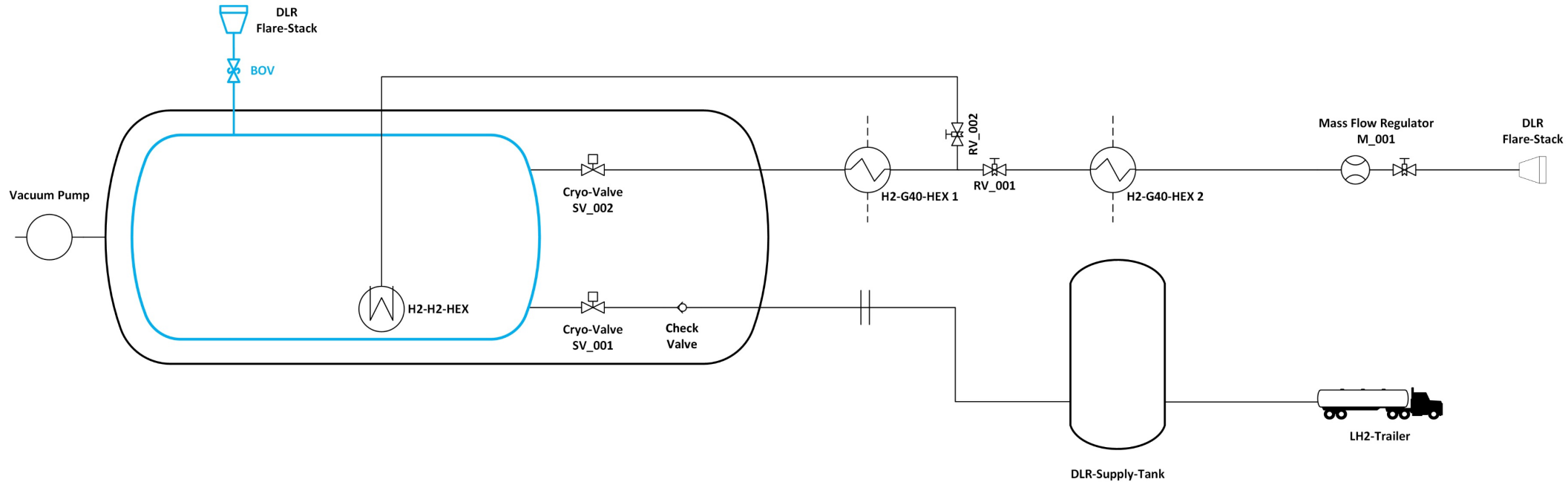


Withdrawal Configurations:

- From gaseous phase through heat exchanger (supply path)*
- From liquid phase (technically not advisable, since efficient pressure reduction is main objective for venting)
- From gaseous phase, bypassing heat exchanger (supply path), with insulated pipes (faster, since not limited by mass flow regulator)
- From gaseous phase backwards through filling line (via overridable filling check valve)

* implemented in ELVHYS-Project

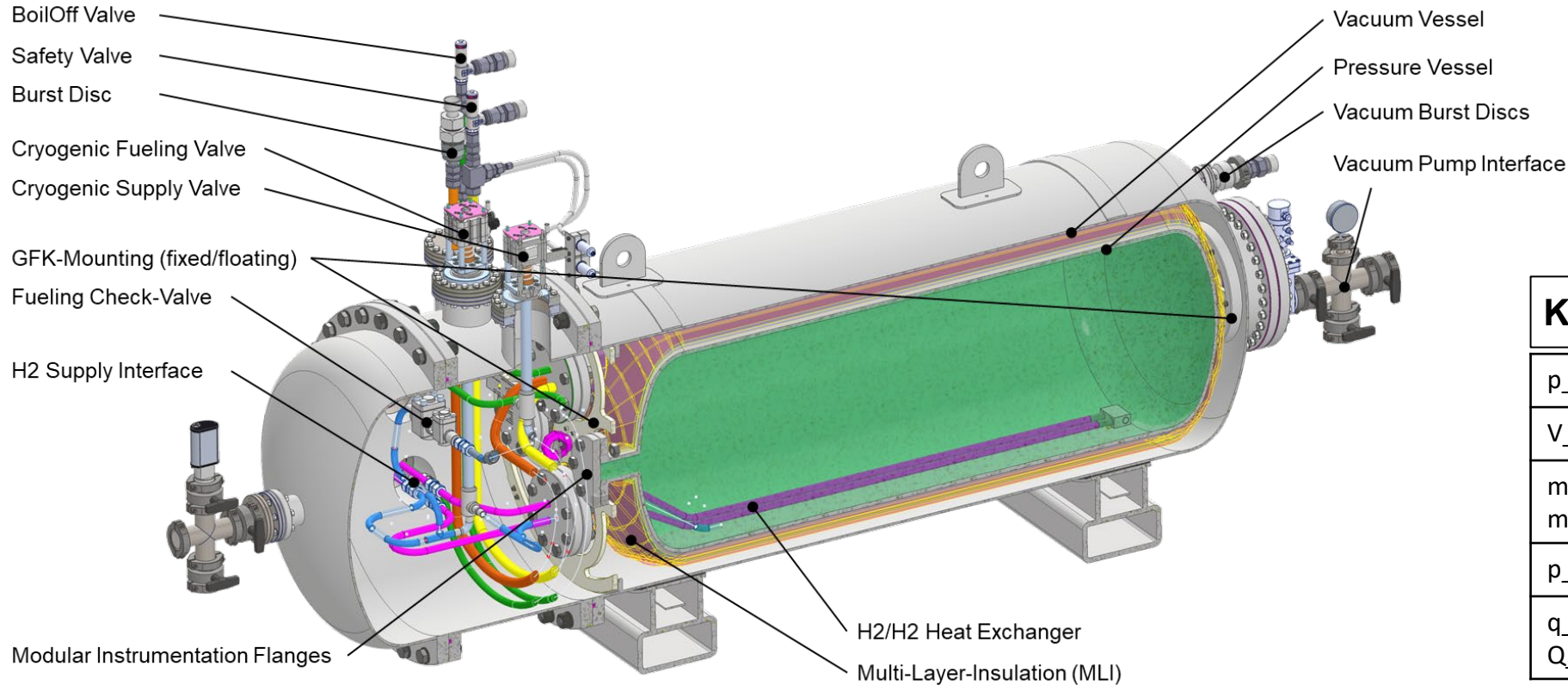
BoilOff



Behaviour during Non-Operation / Dormancy:

- Increase in system pressure due to natural heat input from environment unavoidable
- Fully passive limitation of internal pressure via boiloff-valve below primary safety device activation pressure

WP 3.1: Design of KIT Cryogenic Storage Vessel



Key Performance Data:

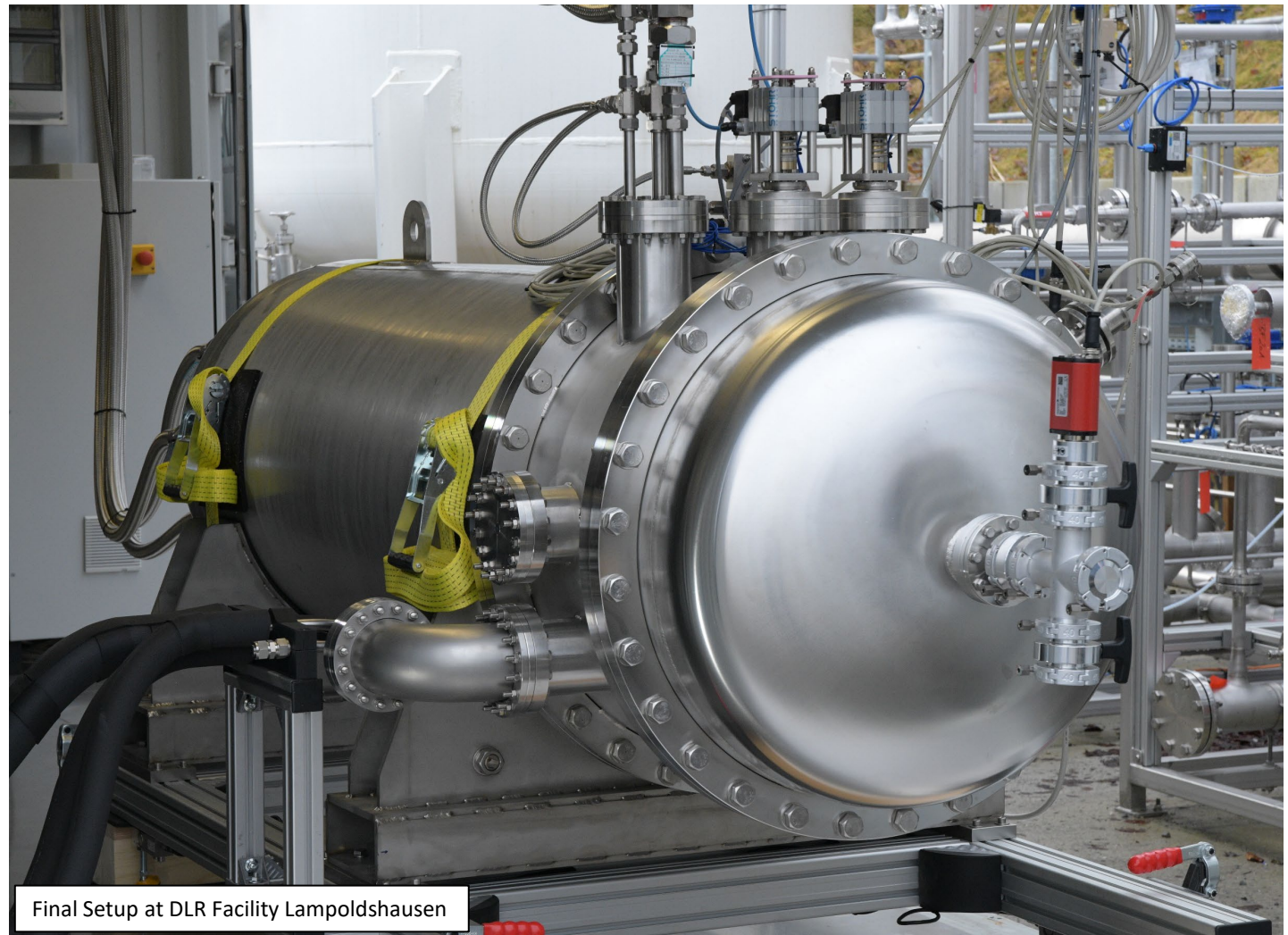
p_MAWP	25	bar(a)
V_medium	388.5	l
m_N2_inv (85%)	~ 275	kg
m_H2_inv (100%)	~ 22	kg
p_vac	~ 10 ⁻⁵	mbar
q_in (N2)	50	W
Q_in (H2)	65...100	W

MAWP = maximum allowable working pressure

Purpose of Experimental Setup:

- All modes of operation of real-world vehicle tank can be studied with increased adjustability
- Additional instrumentation and modifications can be implemented with reasonable effort between testing campaigns

WP 3.1: Hardware from Start to Finish



WP 3.1: Experimental Test Matrix

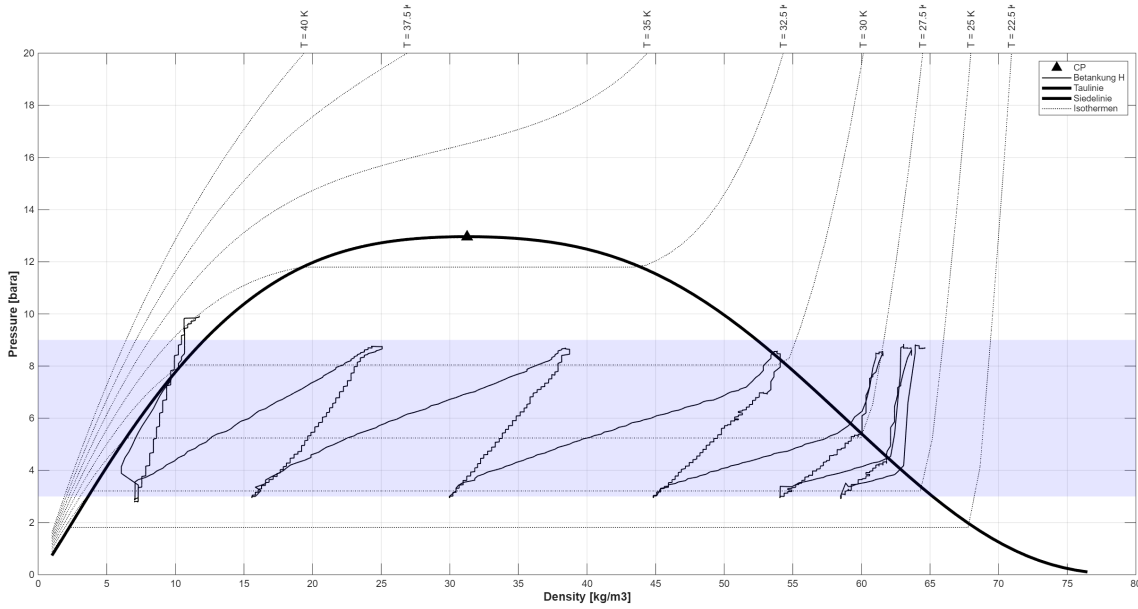


Nitrogen - LN2

Fueling					Defueling									
KIT (Fueling Start Pressure)	DLR (Station Supply Pressure)				Druckregelbereich 15...16 barg		Druckregelbereich 7...8 barg							
		8	10	12	14	ByPass-Anteil [%]		ByPass-Anteil [%]						
	2	H	J	L	N		100	75	50		100	75	50	
	4	A	B	D	F	KM-Temp [°C]	80	A			80	D		
	6	I	K	M	O		60	G			60	J		
	8	-	C	E	G		40	M			40	P		

WP 3.1: Variation of Boundary Conditions for LH2-Fueling

Fueling-Test H*: 2 ... 8 barg → $\Delta p = 6$ bar

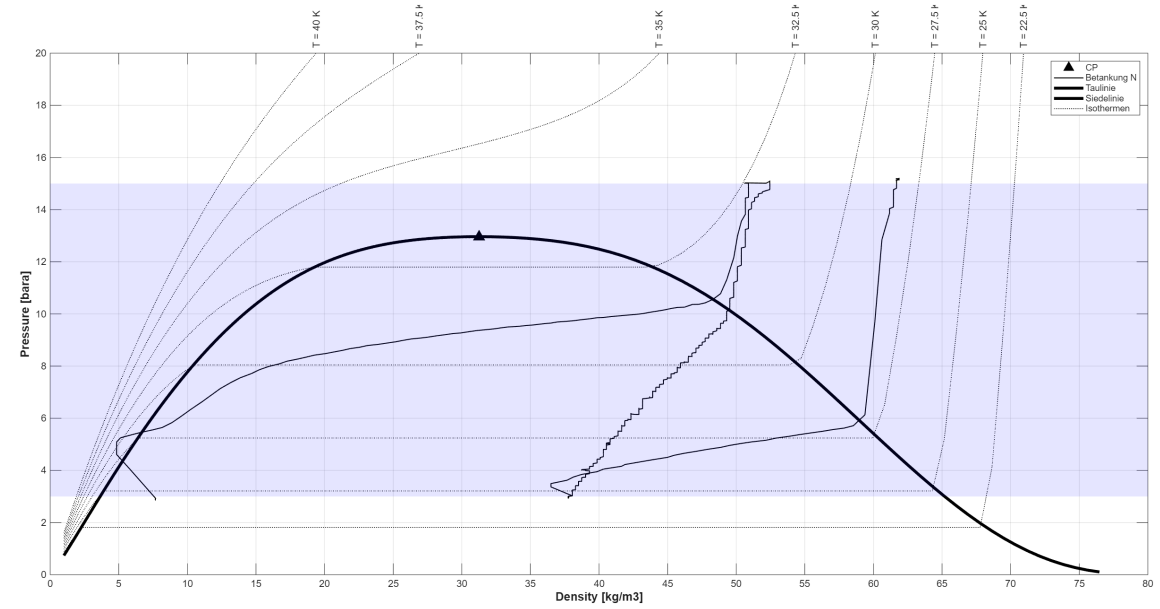


* + 4 kg/m³ density offset compensation

Key Figures for Fill-Test H

- Usable mass 22,2 kg
- Efficiency 57,6 %

Fueling-Test N**: 2 ... 14 barg → $\Delta p = 12$ bar



** + 3,2 kg/m³ density offset compensation

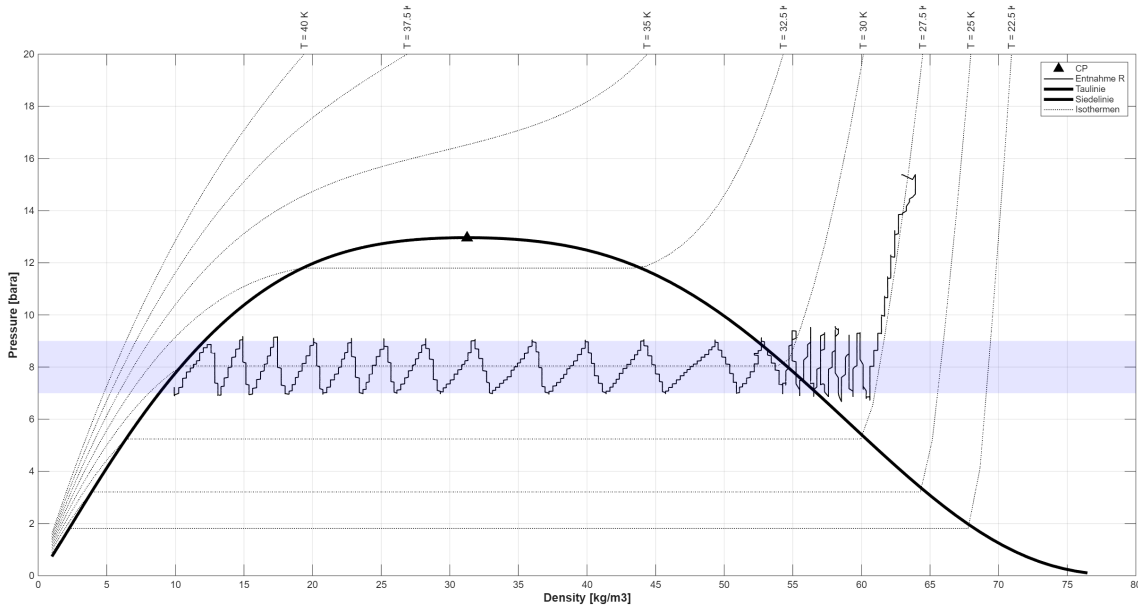
Key Figures for Fill-Test N

- Usable mass 21,0 kg
- Efficiency 80,4 %

$$\eta = \sum_i \frac{m_{fill,i}}{m_{fill,i} + m_{vent,i}}$$

WP 3.1: Variation of Boundary Conditions for LH2-Defueling (20 kg/h)

Defueling-Test R*: 6 ... 8 barg (subCP @ 12,3 barg)

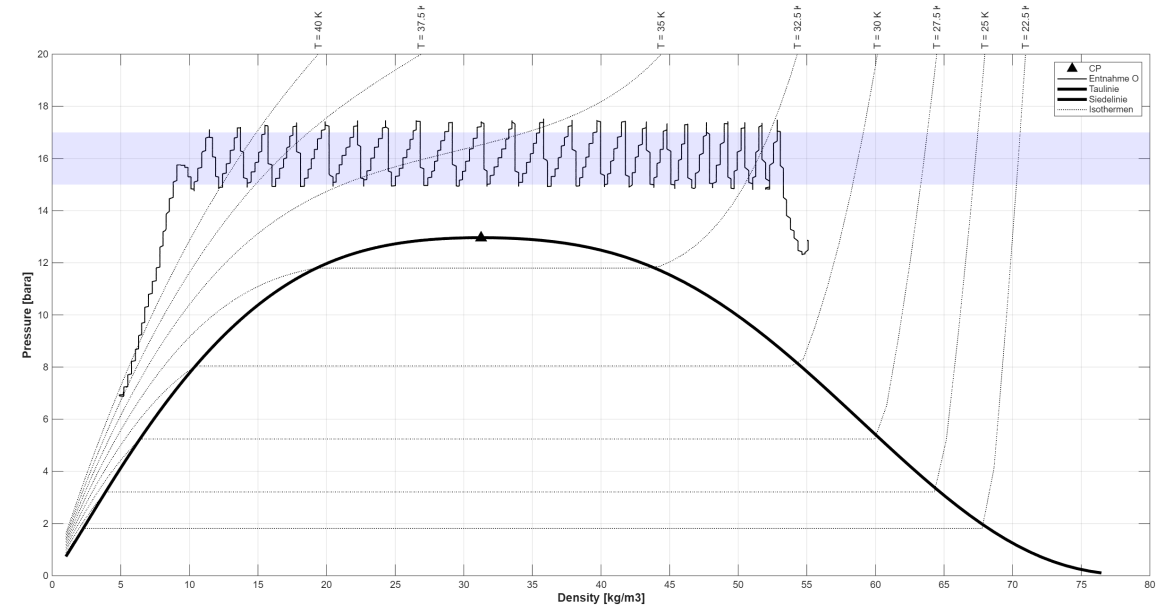


* + 4 kg/m³ density offset compensation

Key Figures for Supply-Test H

- Stable supply throughout full operating range
- Agile system response (both p▲ and p▼) within 2-phase-region

Defueling-Test O**: 14 ... 16 barg (superCP @ 12,3 barg)



** + 5 kg/m³ density offset compensation

Key Figures for Supply-Test N

- Stable supply throughout full operating range
- Very agile system response (both p▲ and p▼) with small pressure overshoots due to slow control valves

WP 3.1: Summary and Outlook

Completion of ELVHYS-Project-Objectives

- ✓ **Q1/23 – Q2/24:** Design, procurement, manufacturing, and certification of modular experimental vessel and mobile test bench environment
→ **OBJ-4 successfully completed**
- ✓ **Q3/24 – Q3/25:** Warm-commissioning @ KIT
- ✓ **Q4/25 – Q1/26:** Cold-commissioning @ DLR (in synch with first commissioning of DLR-H2CT)
- ✓ **Q1/26 – Q2/26:** Completion of planned test campaign (LN2 & LH2 fueling- & defueling-experiments)
Additionally, data for cooldown and boiloff were provided (LN2 & LH2)
→ **OBJ-5 successfully completed**

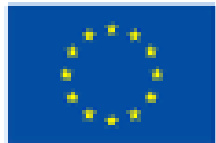
What does the future hold? (ELVHYS II?)

- Top filling configuration for study of partial condensation of warm gas phase during fueling
- Cryo pump for sLH2 filling procedure according to ISO 13984:2026 from low pressure supply vessel with constant mass flow
- Internal temperature measurement with temperature diodes
- Improved thermal insulation for feedthroughs and flexible hoses up to first H2-G40-HEX
- Optical access to pressure vessel via glass window
- Dynamic excitation of liquid inventory for thermal stratification, sloshing and wave propagation studies



Thank you for your attention

jonas.knebel@partner.kit.edu



Co-funded by
the European Union



UK Research
and Innovation

ELVHYS project No. 101101381 is supported by the Clean Hydrogen Partnership and its members. UK participants in Horizon Europe Project ELVHYS are supported by UKRI grant numbers 10063519 (University of Ulster) and 10070592 (Health and Safety Executive).

Disclaimer: Despite the care that was taken while preparing this document the following disclaimer applies: Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or Clean Hydrogen JU. Neither the European Union nor the granting authority can be held responsible for them.



Co-funded by
the European Union



UK Research
and Innovation