TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

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Hydrogen Permeability Testing of Fibre Reinforced Thermoplastics under Cryogenic Conditions – Validation of a Test Rig Concept

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C3Or3B-03

Fibre Reinforced Thermoplastics (FRT) as Construction Materials in Cryogenic Engineering

[1]

- **LH_2 as sustainable fuel for certain mobile applications**
  - Cryogenic LH_2 on-board systems

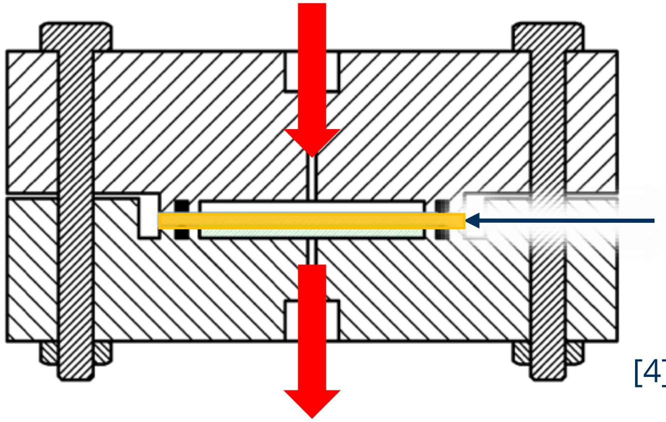
[2]

- **Stainless steel as conventional construction material**
  - Increasing need for lightweight engineering
  - FRT as alternative construction materials
- **High vacuum insulation required**
  - Hydrogen permeation through FRT as challenge
  - Qualification of H_2/FRT permeation necessary

[3]

Comparison of Permeability Test Rig Concepts – Conventional Setup

- **Specimen:** Flat Disc
- **Permeation Cell:** Specimen disc fixed between two flanges
- **High pressure chamber:** Pressurised side of the cell
- **Low pressure chamber:** Evacuated side of the cell

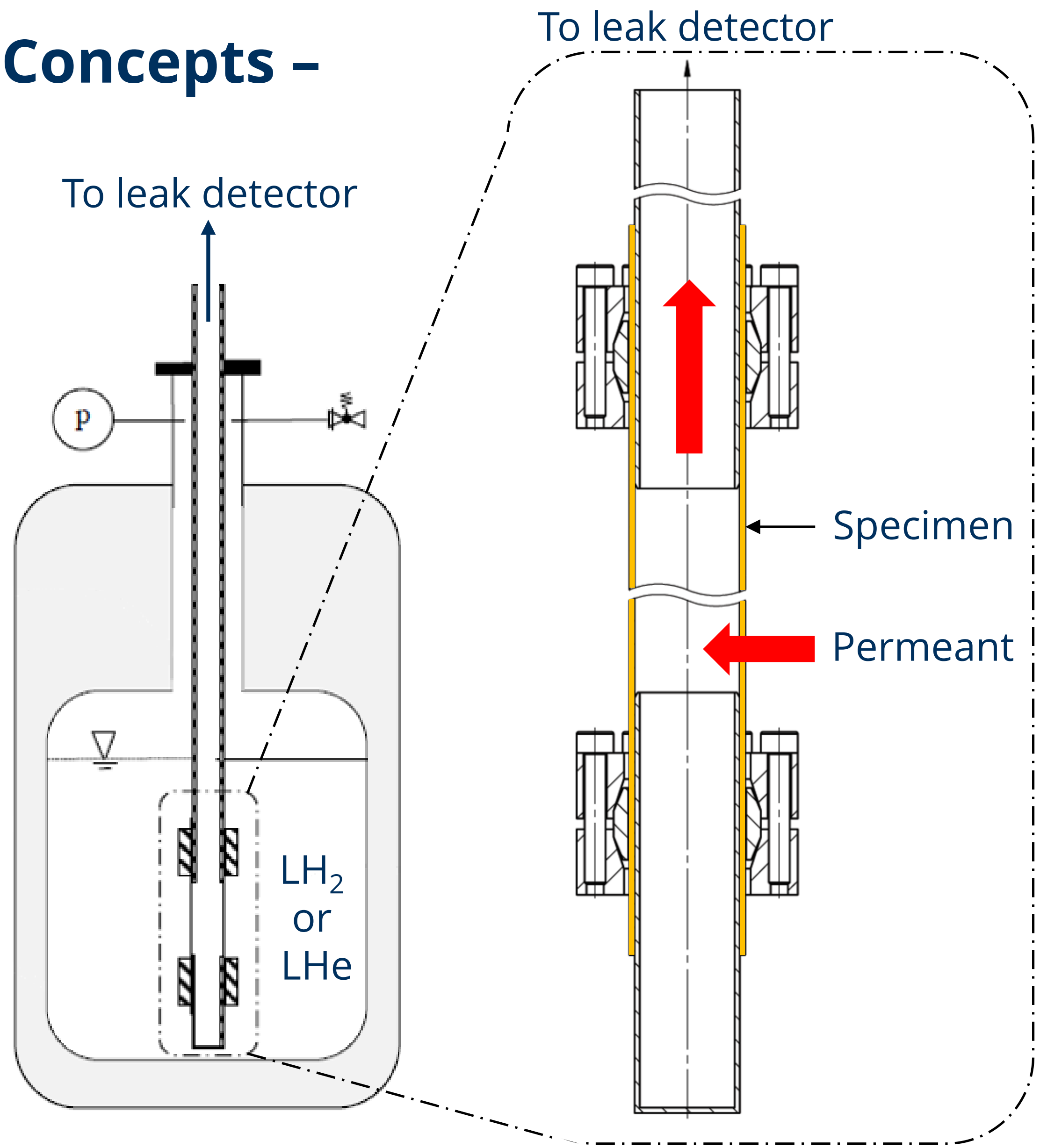


Why is there a need for a novel test rig setup?

- Conventional setup is difficult to adapt to cryogenic conditions.
- Specimens should be close to real FRT applications (e.g. fuel tanks, pipes)

Comparison of Permeability Test Rig Concepts – Novel Setup

- **Specimen:** Cylindrical Pipe
- **Permeation Cell:** Specimen pipe connected to two impermeable metallic pipe segments
- **High pressure chamber:** Encasement around cell
- **Low pressure chamber:** Inside of specimen pipe



Advantages

- Measurement of curved structures is possible.
- Permeable surface area can be adjusted by pipe length.

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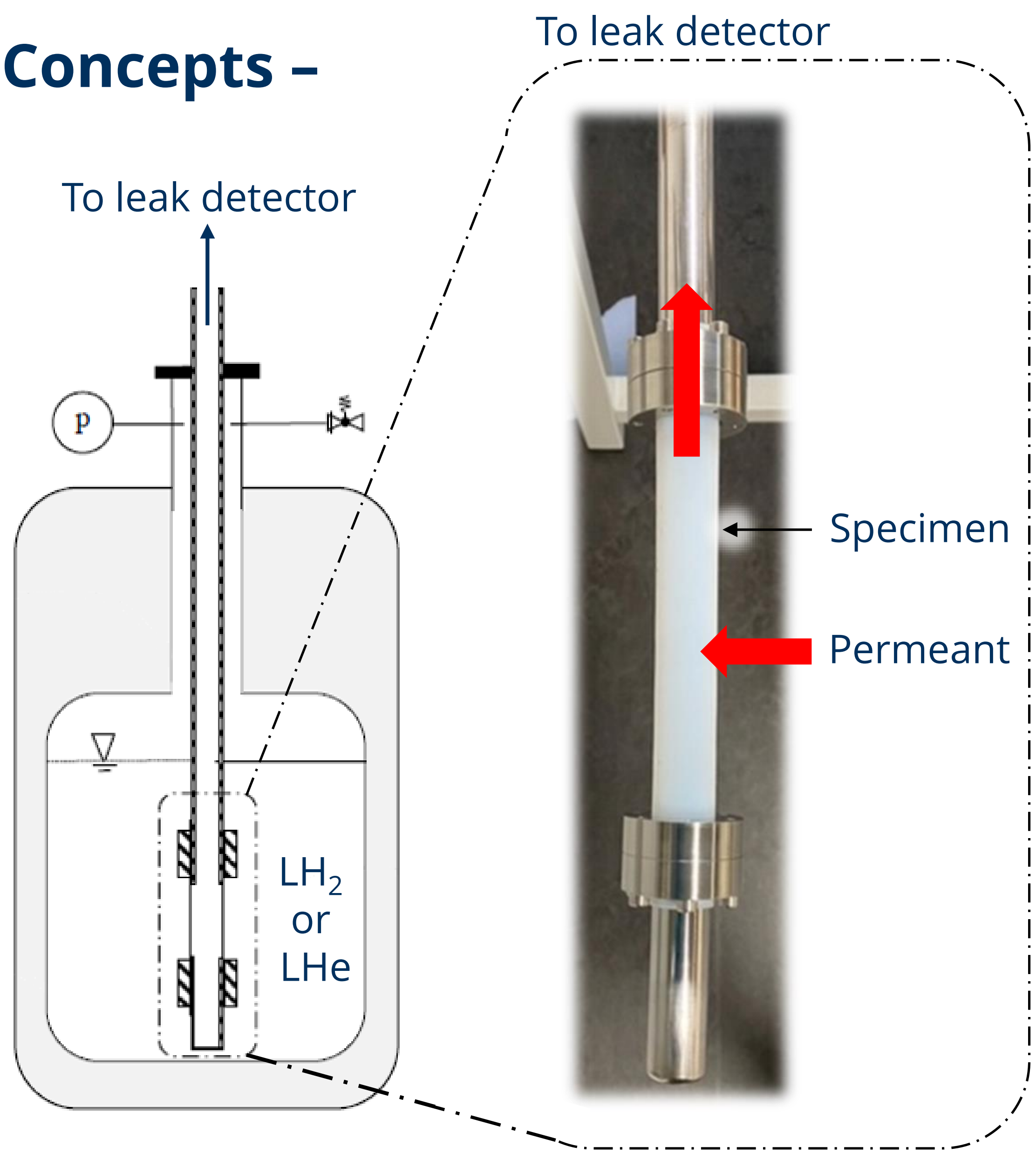
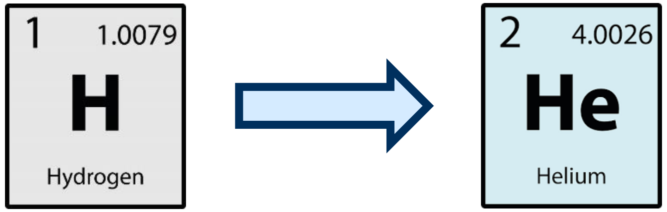


Advantages

- Measurement of curved structures is possible.
- Permeable surface area can be adjusted by pipe length.

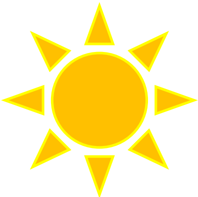
Validation Experiments – Substitutions

- **He-4 as permeant instead of H_2**
  - ➢ Simple experiments without huge safety precautions
  - ➢ Results are comparable as substances are similar in size



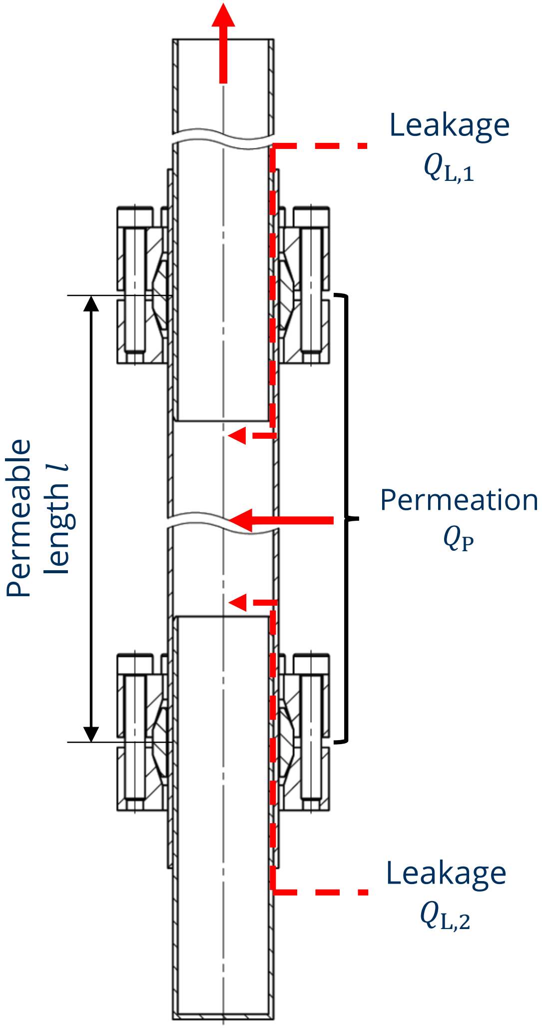
- **PTFE as subsitute polymer instead of FRT**
  - ➢ Literature data on He permeation through PTFE is abundant
  - ➢ Little data available on specific FRT

- **First validation at room temperature**
  - ➢ Little data available at cryogenic temperature

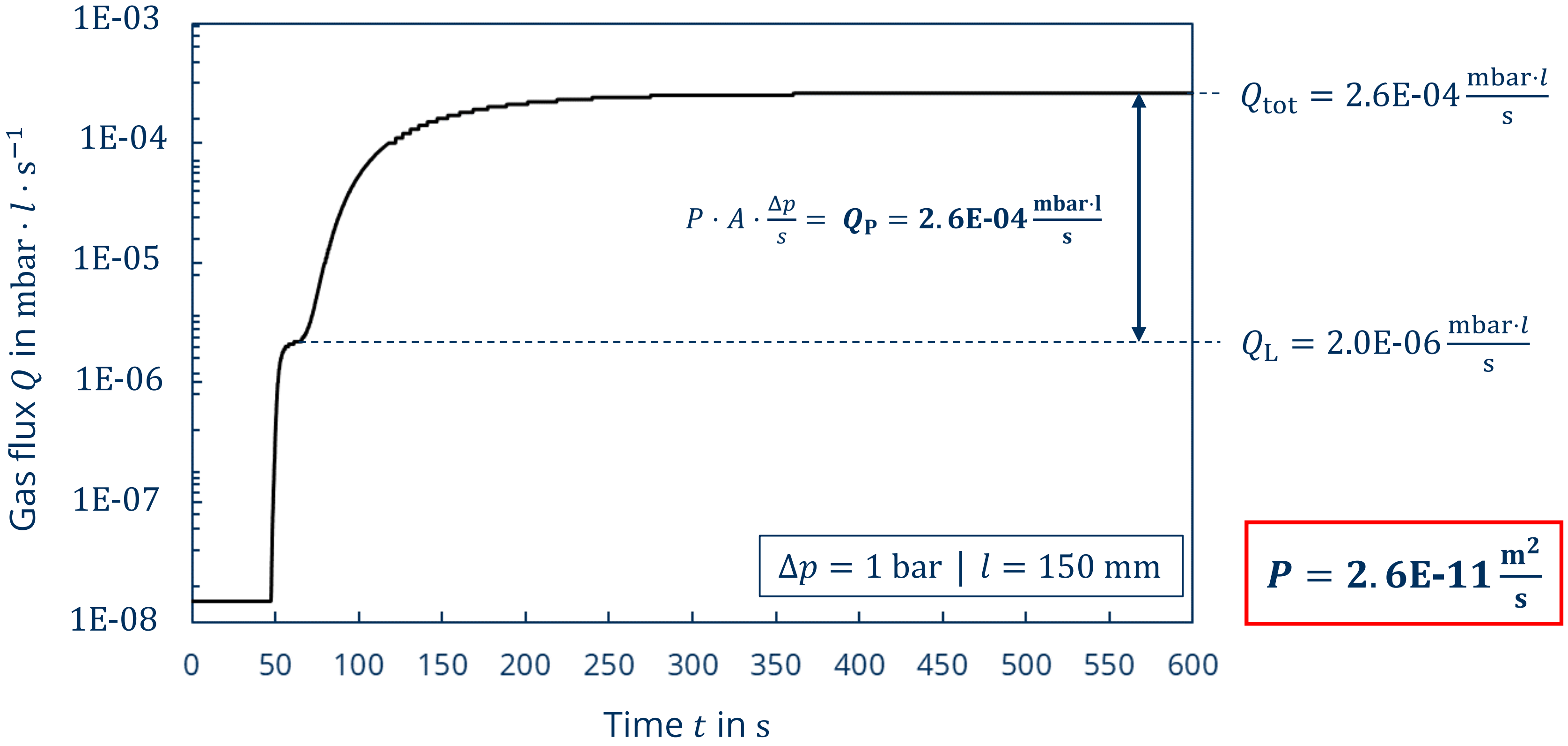


- **Experiments at cryogenic temperature**
  - ➢ Still ongoing

Validation Experiments – Measuring He/PTFE Permeability



Pressurisation → Leakage → Steady State Permeation → Calculate Permeability



$$\boldsymbol{P = 2.6\text{E-}11 \frac{m^2}{s}}$$

Validation Experiments – Results and Conclusion

Nr.	T (°C)	l (mm)	Δp (bar)	$Q_{tot}/10^{-4}$ $(\mathrm{mbar \cdot l \cdot s^{-1}})$	$Q_L/10^{-5}$ $(\mathrm{mbar \cdot l \cdot s^{-1}})$	$Q_P/10^{-4}$ $(\mathrm{mbar \cdot l \cdot s^{-1}})$	$P/10^{-11}$ $(\mathrm{m^2 \cdot s^{-1}})$
1	28.3	100	2.1	4.4	1.0	4.3	3.1
2	26.0	100	1.9	3.8	1.6	3.6	2.9
3	28.9	100	2.1	4.3	0.6	4.2	3.0
4	22.0	150	1.0	2.6	0.2	2.6	2.6
5	28.6	150	2.1	8.2	0.3	8.2	3.9
							Ø 3.1

- PTFE with wide variation in material properties.
- Literature reports values of P between 10^{-10} and 10^{-11} $\mathrm{m^2 \cdot s^{-1}}$ [5,6].

> **Proposed test rig is validated at room temperature for homogeneous thermoplastics.**

Thank you for your attention.

References

[1] Daimler Truck 2023 Entwicklungsmeilenstein erreicht: Daimler Truck testet Brennstoffzellen-Lkw mit Flüssigwasserstoff *https://media.daimlertruck.com/marsMediaSite/de/instance/ko/Entwicklungsmeilenstein-erreicht-DaimlerTruck-testet-Brennstoffzellen-Lkw-mit-Fluessigwasserstoff.xhtml?oid=51975637* (accessed on 02/07/2023)

[2] Airbus 2023 ZEROe – Towards the world's first hydrogen-powered commercial aircraft *https://www.airbus.com/en/innovation/low-carbon-aviation/hydrogen/zeroe* (accessed on 02/07/2023)

[3] Hydrogen Energy Supply Chain Project 2023 The Suiso Frontier *https://www.hydrogenenergysupplychain.com/supply-chain/the-suiso-frontier/* (accessed on 02/07/2023)

[4] DIN EN ISO 11114-5:2022-05, Gasflaschen – Verträglichkeit von Werkstoffen für Gasflaschen und Ventile mit den in Berührung kommenden Gasen – Teil 5: Prüfverfahren zur Bewertung der Kunststoffinnenbehälter (ISO 11114-5:2022)

[5] Weston G F 1975 Materials for ultrahigh vacuum *Vacuum* **25** pp 469–84

[6] AGC Inc. 2002 Physical properties of Fluon® unfilled and filled PTFE *Technical Service Note F12/13*