Sealing Solutions for Hydrogen Applications

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Agenda

01 Increasing importance of hydrogen in industrial applications

02 Challenges and difficulties in sealing hydrogen

03 Chemical resistance of gasket materials in contact with hydrogen

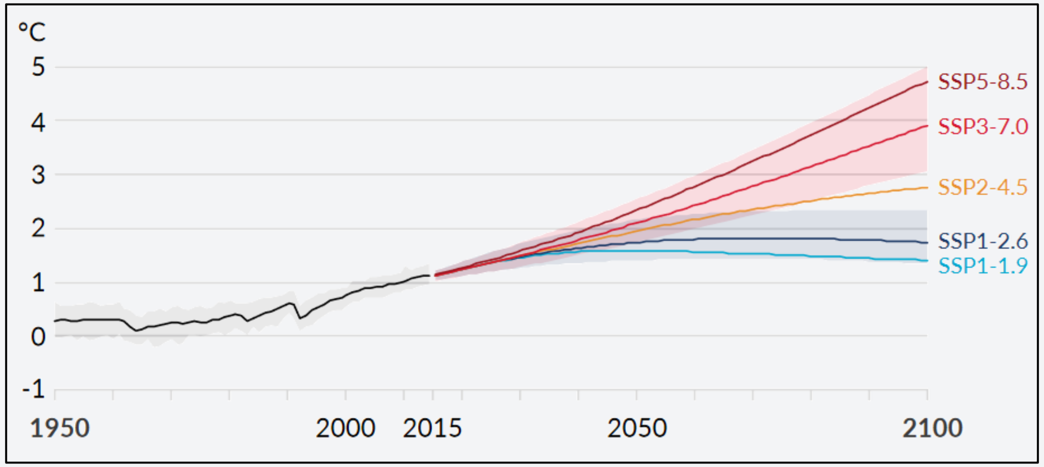
04 Hydrogen leakage tests

05 Conclusion and outlook

1. Introduction

Increasing importance of hydrogen in industrial applications

- Excerpt from the world climate report published on 09.08.21



- Significant reduction of emissions is necessary
- The importance of new, sustainable and low-emission energy sources increases
- Limited availability and increasing prices of fossil fuels further accelerate the search for alternative energy sources

[1] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis.

1. Introduction

Increasing importance of hydrogen in industrial applications

The importance of hydrogen as a potential alternative energy source is on the rise:

- H_2 can be produced with various methods (e.g. from methane or water)
- Especially green hydrogen is expected to be an important part of energy transition
  - → Production via electrolysis from water and energy from renewable source
- Other common types of hydrogen:
  - Gray hydrogen: produced from fossil fuels in steam reforming process (natural gas is converted into H_2 and CO_2 under high temperatures)
  - Blue hydrogen: equivalent to gray hydrogen, but CO_2 which is formed during production is captured and stored (CCS – carbon capture and storage)

[1] https://www.linde-gas.at/de/images/1007_rechnen_sie_mit_wasserstoff_v110_tcm550-169419.pdf

1. Introduction

Increasing importance of hydrogen in industrial applications

The importance of hydrogen as a potential alternative energy source is on the rise:

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    → Production via electrolysis from water and energy from renewable sources

- Various possibilities for hydrogen applications in industry
    - Direct application as fuel (high calorific value: 33.3 kWh/kg; crude oil: ~11.6 kWh/kg, no hazardous byproducts are formed during combustion)[1]
    - Use for energy production in fuel cells
    - Further processing or transfer into alternative storage forms, fuels or chemicals (Power-to-X)

[1] https://www.linde-gas.at/de/images/1007_rechnen_sie_mit_wasserstoff_v110_tcm550-169419.pdf

2. Sealing hydrogen

Challenges and difficulties in sealing hydrogen

- Generation, transport and usage or further processing of hydrogen require suitable sealing solutions
- Hydrogen is an extremely inflammable and potentially explosive gas

  → Leakage should be reduced to an absolute minimum!

- Problem: Hydrogen is an extremely challenging medium to seal
  - Smallest molecule (covalent radius: 31 pm; nitrogen: 71 pm)
  - Smallest density (0.09 kg/m^3, nitrogen: 1.25 kg/m^3)
  - High mobility, high diffusibility → **difficult to seal!**

2. Sealing hydrogen

Requirements for gasket materials

- Currently, official norms, specifications are being developed respectively approvals for the requirements of gasket materials in hydrogen applications

  → Frenzelit decided to perform initial in-house tests:

- Gasket materials have to be **chemically resistant** towards hydrogen
  - No material-changes caused by permanent contact with H_2

- **Leakage rates** of gasket materials should be **as low as possible**
  - Leakage measurements are usually performed with nitrogen or helium
  - So far, hardly any data for leakage measurements with hydrogen gas are available

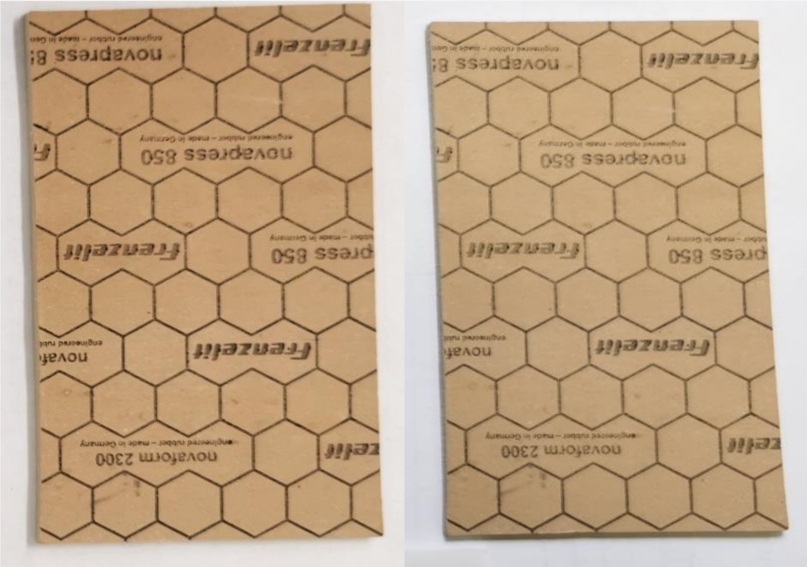
3. Chemical resistance of gasket materials

Chemical resistance towards hydrogen – test setup

- Loose storage of various fiber-based materials in hydrogen gas in an autoclave (3 bar, 6 weeks, room temperature)
- Evaluation of resistance according to:
  - Optical analysis
  - Change of weight and thickness
  - Change of length and width
  - Comparison of leakage performance before and after storage in hydrogen
- Tested materials:
  - Various fiber-based Frenzelit gasket materials

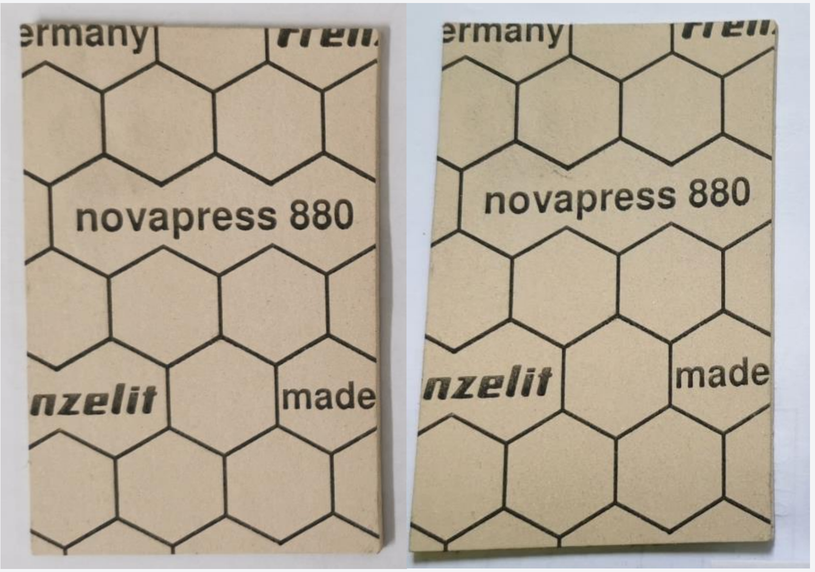
3. Chemical resistance of gasket materials

Chemical resistance towards hydrogen – optical evaluation



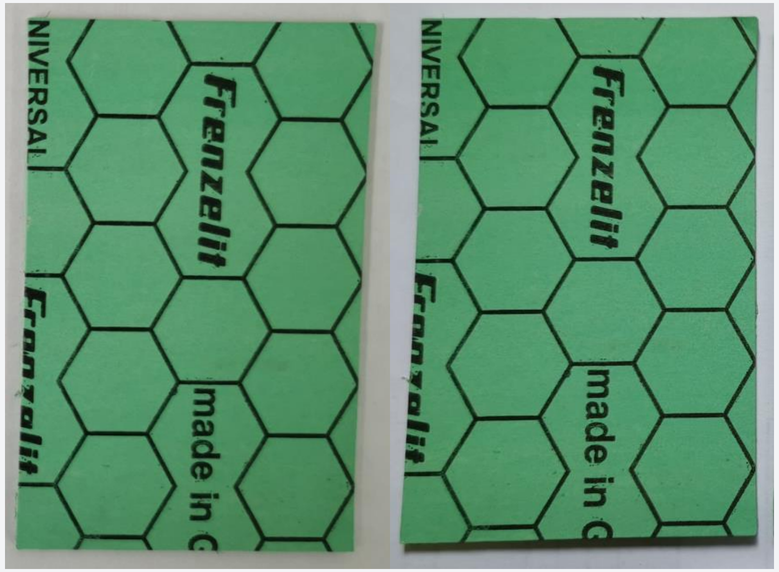
novapress® 850

before (left) und after (right) storage in H_2 for 6 weeks



novapress® 880

before (left) und after (right) storage in H_2 for 6 weeks



novapress® UNIVERSAL

before (left) und after (right) storage in H_2 for 6 weeks

→ No optical changes of the materials can be noticed

→ No damages, cracks or embrittlement can be observed

3. Chemical resistance of gasket materials

Chemical resistance towards hydrogen – change of geometry

The change of thickness, weight and sample geometry was determined based on the Carrier test process for cooling agents.

Material	Change of thickness [%]	Change of weight [%]	Change of length [%]	Change of width [%]
novapress® 850	-0,02	-0,08	0,15	0,21
novapress® 880	0,03	0,01	0,07	0,18
novapress® UNIVERSAL	0,03	-0,01	0,00	0,03

→ Only minor changes of volume and geometry can be observed

→ All changes are within the range, which is acceptable, according to the Carrier test criteria

3. Chemical resistance of gasket materials

Chemical resistance towards hydrogen – conclusion

- **No notable changes of the material properties** could be observed in context with the loose storage of gasket materials in hydrogen gas
  - No changes of optic or haptic properties of the materials could be observed
  - There were only minor changes of thickness, weight, length and broadness

→ All fiber-based materials which have been tested so far, have proven to be chemically resistant towards hydrogen

→ Many other common gasket materials, such as graphite, PTFE or mica, also show no material changes in contact with hydrogen, and can therefore be considered as resistant towards hydrogen

4. Hydrogen leakage tests

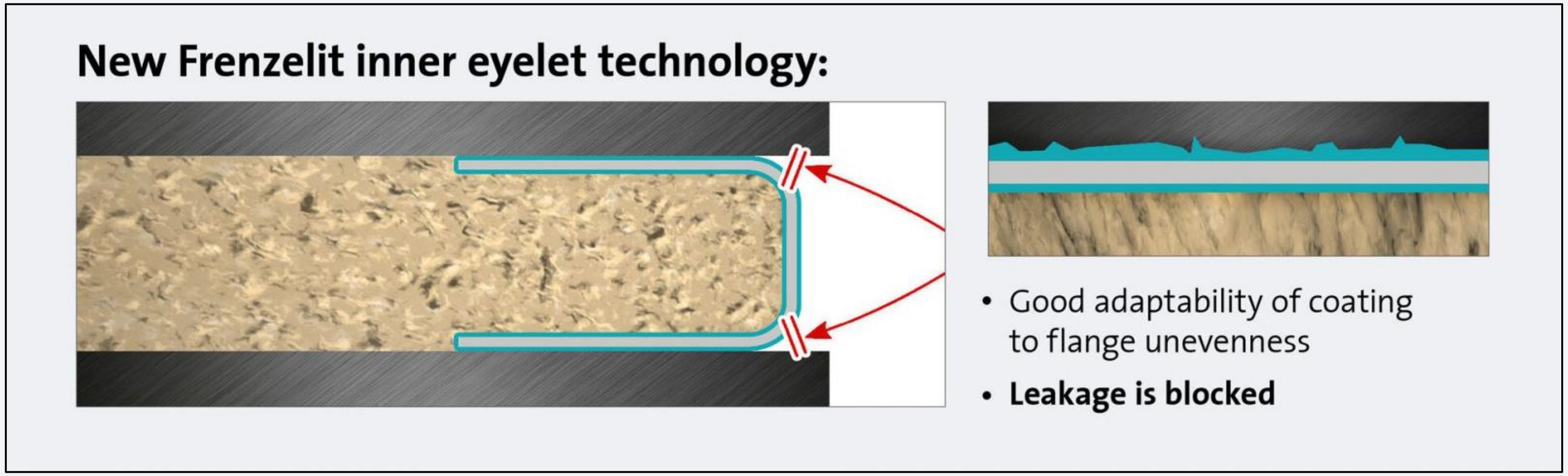
Setup of leakage test device

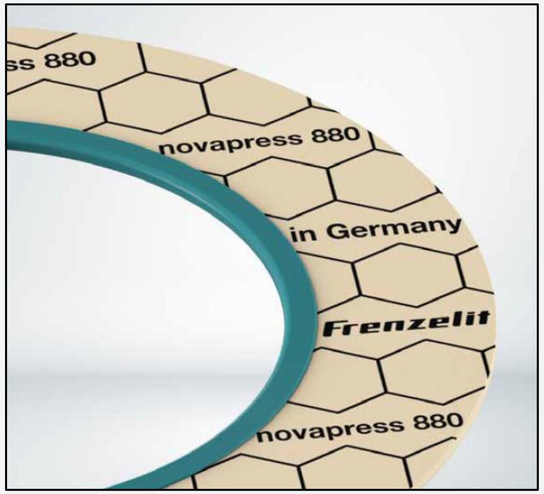
- The test device was designed based on the DIN 28090-2/1995
- Leakage tests were performed in a DN40/PN40 flange
- The leakage rate was determined via differential pressure
- Gaskets were installed with a surface pressure of 32 MPa (relaxation to 30 MPa in operation, due to inner pressure)
- An inner pressure of 40 bar hydrogen is applied, and the system is closed
- After a test time of one hour, the pressure loss in the system is determined; based on that, the leakage rate in mg/(s*m) are calculated

4. Hydrogen leakage tests

Specimens for leakage test

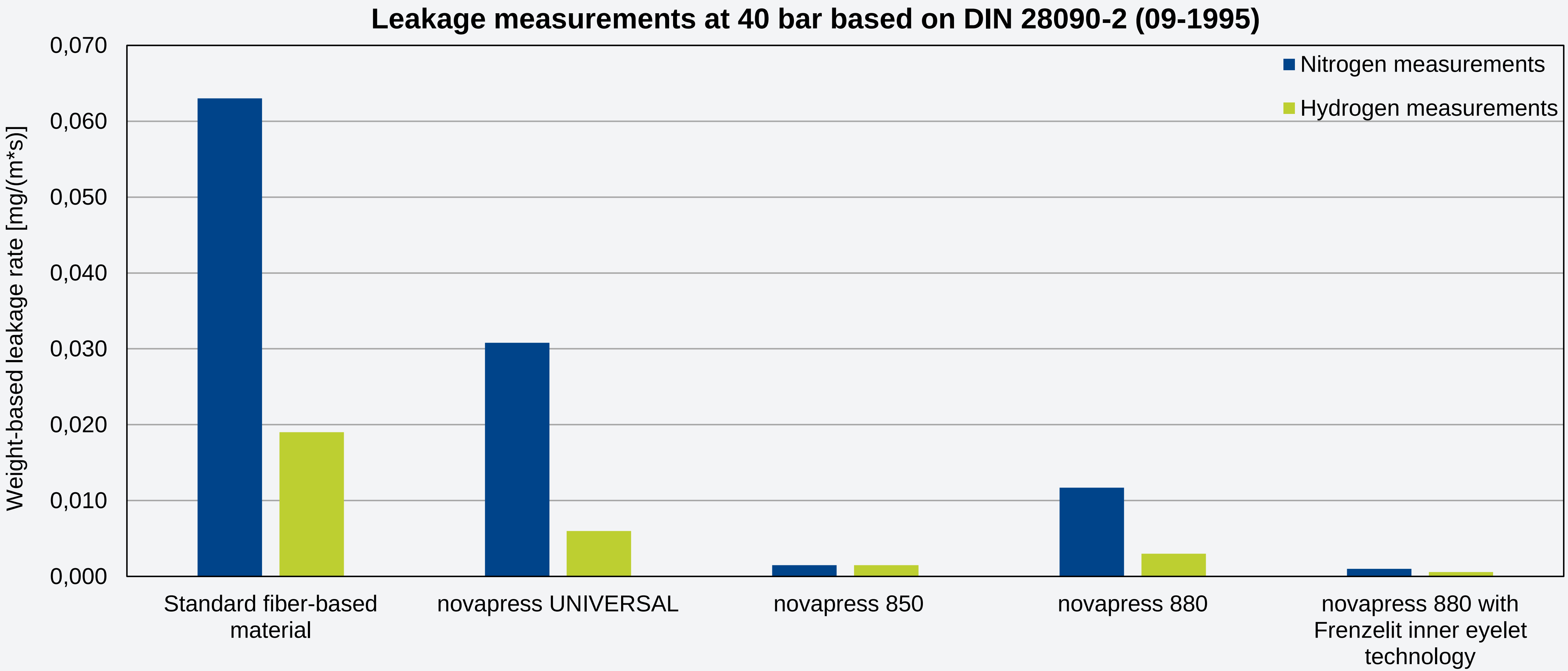
- Frenzelit gasket materials
  - Fiber-based gasket materials (novapress®)
  - Graphite gasket materials (novaphit®)
  - Frenzelit gasket materials with new inner eyelet technology





4. Hydrogen leakage tests

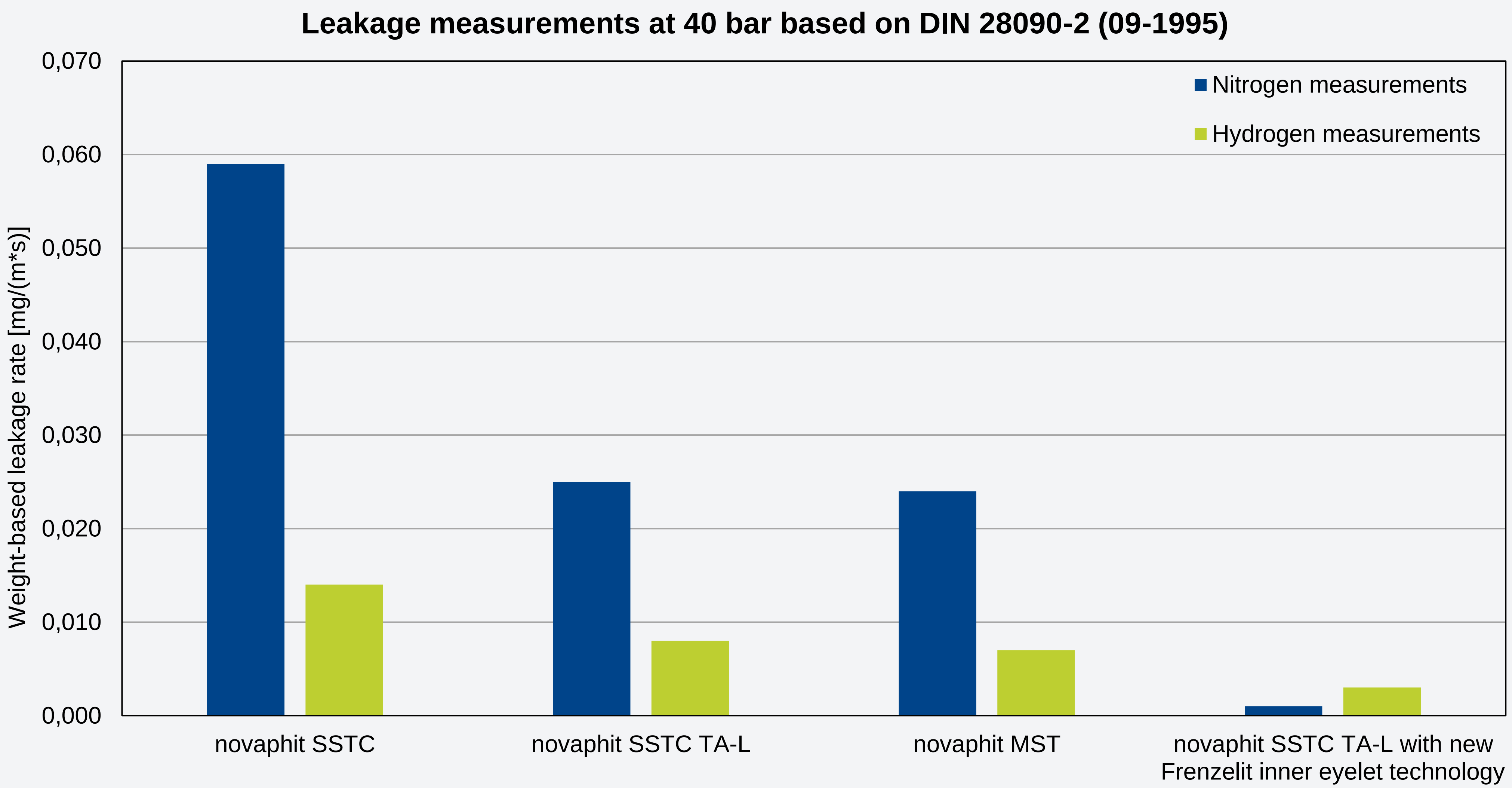
Initial results – **fiber-based gasket materials** – weight-based leakage [mg/(s*m)]



- novapress® 850 & novapress® 880 with new inner eyelet technology reach lower measurement limit

4. Hydrogen leakage tests

Initial results – **graphite gasket materials** – weight-based leakage [mg/(s*m)]



4. Hydrogen leakage tests

Initial results – hydrogen leakage of fiber-based materials

- Due to the significantly lower density of hydrogen, a lower leakage of H_2 compared to N_2 is obtained for the weight-based unit in most cases.

- Especially gasket materials, which have been designed **specifically for extremely good leakage performances**, also show good results with hydrogen.

- A direct transfer of leakage rates from nitrogen to hydrogen is apparently not possible. There seems to be no standardized conversion factor, as the leakage behavior for nitrogen and hydrogen differs strongly for different gasket materials.

5. Conclusion & Outlook

- Conclusion
  - Media resistance is not a critical issue for most common Frenzelit gasket materials

    → Common gasket materials, such as fiber-based, graphite, PTFE or mica, can be regarded as chemically resistant towards hydrogen
  - Choosing suitable gasket materials with high sealing performance is crucial for hydrogen applications → novapress® 850, novaphit® SSTC TA-L, novaphit® MST or the new Frenzelit inner eyelet technology are ideal choices
- Outlook
  - A universally valid specification for gasket materials in hydrogen applications should be pursued (e.g. similar to DVGW for gas applications)
  - For such an “hydrogen approval”, a suitable threshold value for the leakage rate has to be defined in a defined leakage unit

So erreichen Sie uns!

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