DHBW Mannheim

# research cluster electrochemistry at the DHBW Mannheim

ELCH

elk

www.dhbw-mannheim.de

# Duale Hochschule Baden-Württemberg (DHBW university of cooperative education)

- The German Federal State of Baden-Wuerttemberg is one of the leading economic regions not only in Germany, but across the whole Europe.
- Home to internationally renowned corporations and thousands of successful small and medium-sized enterprises, it is known for its innovative drive and inventive spirit, as well as for a high level of productivity and low unemployment rate.
- 5,1 per cent of the Federal State's GDP is invested into research and development. This figure makes Baden-Wuerttemberg the leading innovator in comparison to other 97 regions across Europe.

DHBW Mannheim

# The campuses of the „Duale Hochschule“ Baden-Württemberg

## 12 locations in Baden-Württemberg

## 35.000 students (Mannheim 6000 students)

in Baden-Württemberg

## 6.500 lectors

experts from the industry

## 2.000 workers

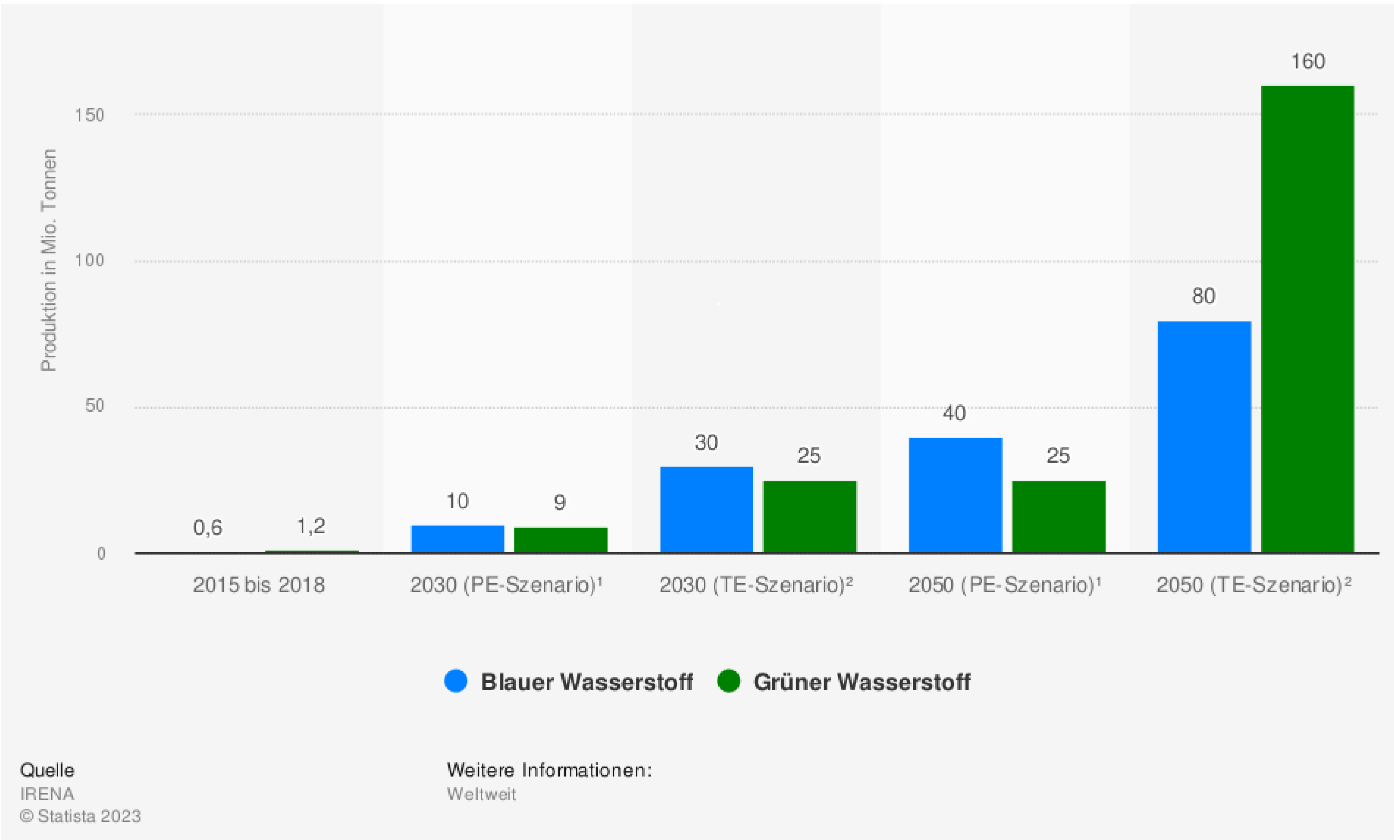
Professors and scientific and academical workers

## 9.000 strong dual partners

for excellent dual study modell

founded 1974

# Production of hydrogen worldwide from 2015-2018 and production aims till to 2050 (in million tons)



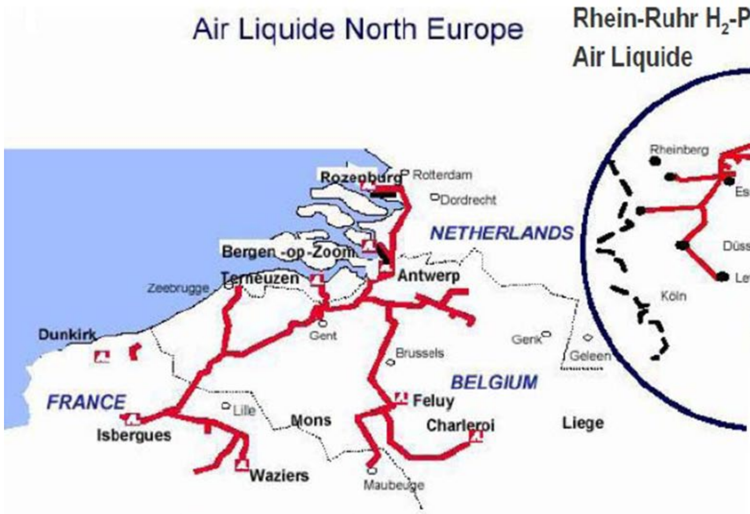

increasing consumption of hydrogen through:

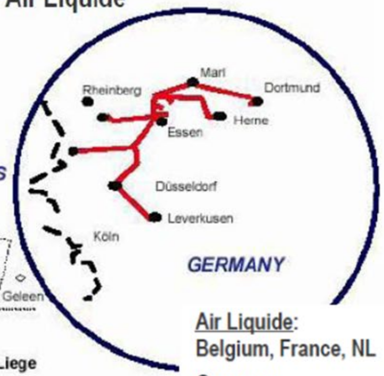
- electric mobility (fuel cells)

- gas heating (city gas mixture)

- new carbon free industrial processes e.g. steel industry

# Actual distribution of hydrogen – European pipelines and fuel stations




Rhein-Ruhr $H_2$-Pipeline, Air Liquide


Leuna $H_2$-Pipeline, **Linde**

Belgium-France-NL $H_2$-Pipeline, **Air Liquide**

Air Liquide:
Belgium, France, NL 966 km 10 MPa

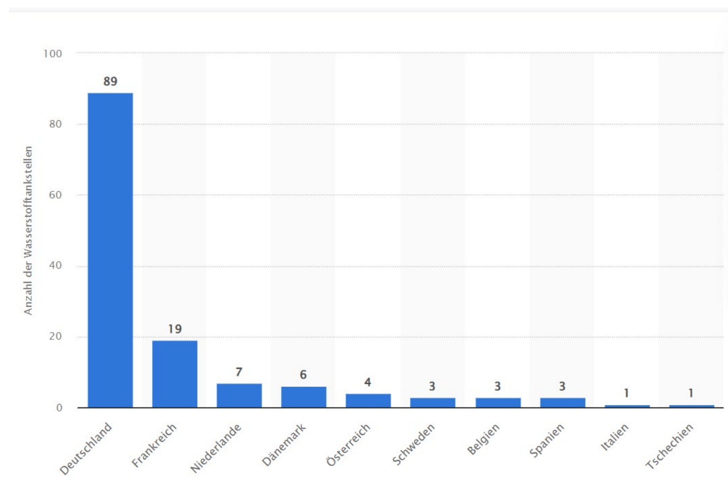
Germany:
Rhine-Ruhr Pipeline 240 km 1.1/ 2.3/ 30 MPa
[operative since 1938]
Leuna-Merseburg, Linde 100 km 2-2.5 MPa

Air Products Pipelines:
Europoort, NL 50 km

UK:
ICI Teeside 16 km 5 MPa

Sweden:
Chemical Industry 18 km 0.5-2.8 MPa

Quelle: Air Liquide




Quelle: statista

# Research Cluster Electrochemistry – ELCH at DHBW Mannheim

- Elch was founded 2016
  (Prof. Schmitz FCs from VW)
- representatives from almost all technical fields of study
- ~ 15 colleagues from DHBW MA involved
- over hundred of study works in the last years

# Research cluster electrochemistry – ELCH at DHBW Mannheim (lab with ~400 m²)

Video:
https://www.mannheim.dhbw.de/forschung-transfer/kompetenzzentren/elch

Dunz, Alexandra, Prof. Dr.
Professorin Maschinenbau

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Projektmitarbeiter Elektromobilität

Heilig, Clemens, Prof. Dr.
Studiengangsleiter, Professor Wirtschaftsingenieurwesen

Klenk, Thomas, Prof. Dr.
Studiengangsleiter, Professor Maschinenbau

Schael, Arndt-Erik, Prof. Dr.
Studiengangsleiter, Professor Chemische Technik

Schmitz, Sven, Prof. Dr.
Studiengangsleiter, Professor Mechatronik
Projektleitung EH2C

Schorer, Linda, M. Eng.
Akademische Mitarbeiterin

Schulz, Volker, Prof. Dr.
Professor Maschinenbau
Projektleitung VC-PEM
Projektleitung Pocket Rocket H2
Projektleitung Gemeinsam Theorie und Praxis

Tornow, Kai
Akademischer Mitarbeiter Elektromobilität

Wiebe, Wilhelm, Dr.- Ing.
Laboringenieur Maschinenbau


## Ansprechpersonen

Wir freuen uns über Ihre Anfrage bezüglich einer Forschungskooperation unter der E-Mail elch@dhbw-mannheim.de. Darüber hinaus können Sie selbstverständlich gern Kontakt zu den einzelnen ELCH-Mitgliedern aufnehmen:

DHBW Mannheim

# current hydrogen storage (outside the lab!)

**Hydrogen Tank**

- 24 gas cylinders
- 200 bar

**Nitrogen Tank** (cleaning gas)

- 24 gas cylinders
- 200 bar

- Continuous, scalable and peak-load 24/7 $H_2$ and $N_2$-sup

**consumption:**
~120 gas cylinders /year
(0,7 kg H2 ~ 9,5 m³/cylinder)
~100 kg/year

# Safety instructions at the hydrogen lab

Dangers:

- oxidation with extreme hot and colourless flame
- Inodourous

| Brennstoff | Wasserstoff | Methan | Propan | Benzin |
|---|---|---|---|---|
| Dichte NTP-Gas in kg/m³ | 0,0838 | 0,6512 | 1,87 | 4,4 |
| Selbstentzündungstemperatur in K | 858 | 813 | 760 | 501...744 |
| minimum ignition energy in MJ | 0,02 | 0,29 | 0,26 | 0,24 |
| Zündgrenze in Luft in Vol.-% | 4...75 | 5,3...15 | 2,1...9,5 | 1,0...7,6 |
| Flammentemperatur in Luft in K | 2318 | 2148 | 2385 | 2470 |
| Detonationsgrenze in Luft in Vol.-% | 13...65 | 6,3...14 | 2,5...8,2 | 1,1...3,3 |
| Detonationsgeschwindigkeit in m/s | 2000 | 1800 | 1850 | 1400...1700 |
| Detonationsüberdruck in kPa | 1470 | 1680 | 1825 | - |
| Lam. Verbrennungsgeschwindigkeit in m/s | 2,63 | 0,42 | 0,46 | ca. 0,45 |

# Safety instructions at the hydrogen lab

hydrogen sensors

shutdown valves in main pipes

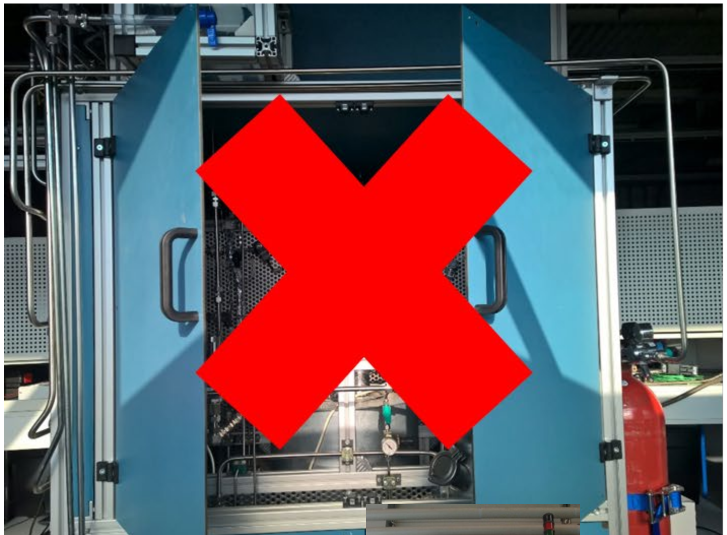


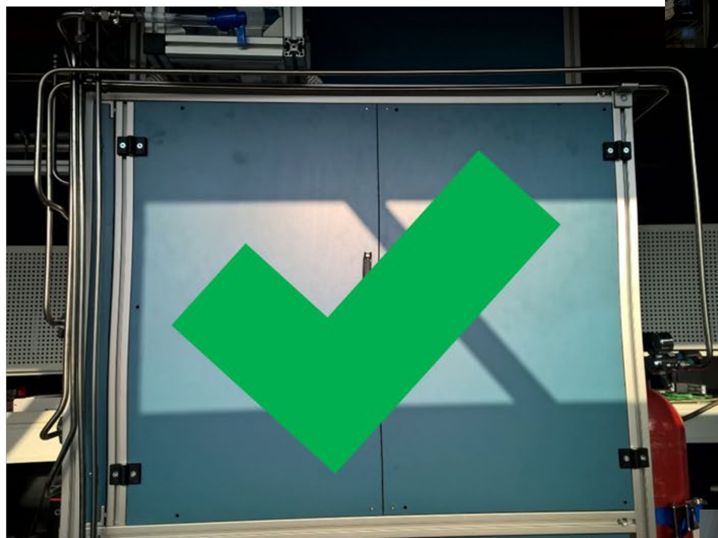

hydrogen sniffer

# Safety instructions at the hydrogen lab

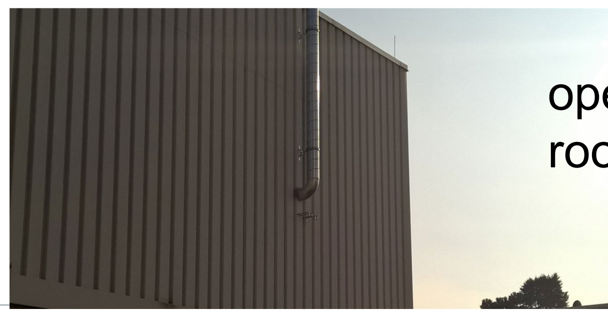
safety
instructions

housings with gas exhaust/extraction

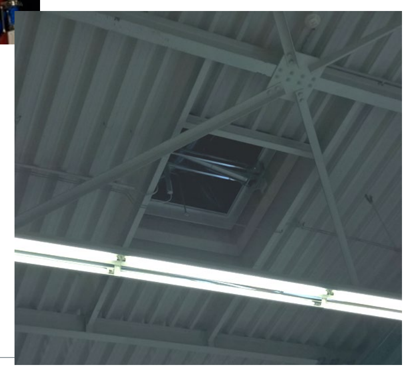




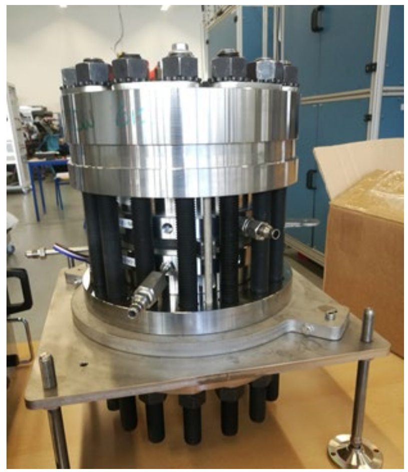
and gas alert system



opening of
roof windows



# Current lab infrastructure ~ 400 m²



## PEM Elektrolyser Proton HOGEN 40

| | |
|---|---|
| $H_2$ Production | 1 m³/h |
| Pressure | 13 bar |
| Quality $H_2$ | 99,999 % |
| Efficiency | ≈ 50 % |

## Electrochemical Compressor

| | |
|---|---|
| Inlet pressure | 3 – 10 bar |
| Outlet pressure | 100 – 400 bar |
| Temperature | 5 - 65 °C |

## Hydrogen Tank

*(projected)*

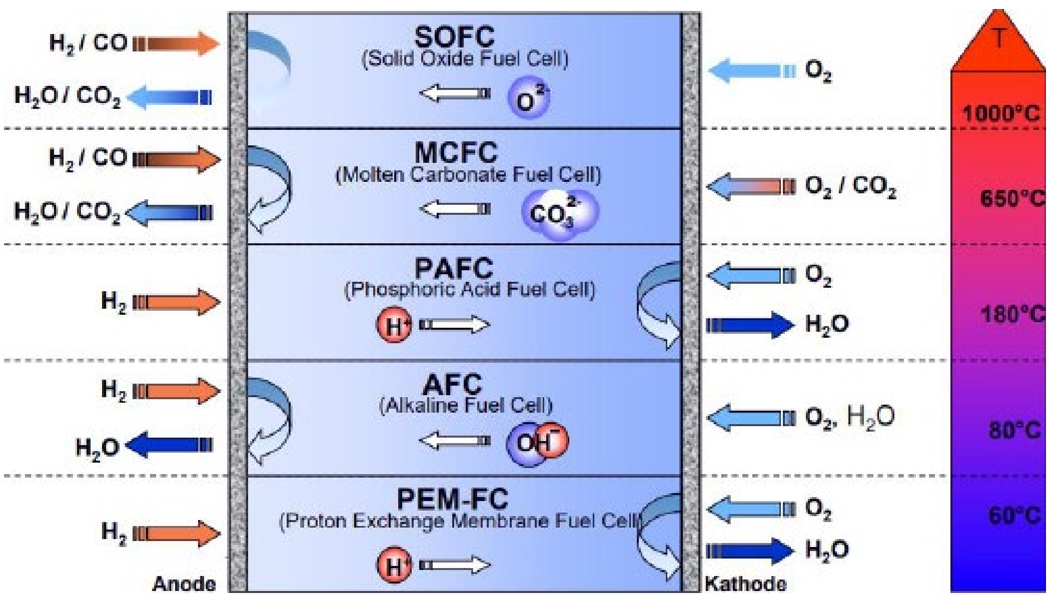
| | |
|---|---|
| Volume | 600 dm³ |
| 4 Carbon Tanks | Type 3 |
| Pressure | 441 bar |

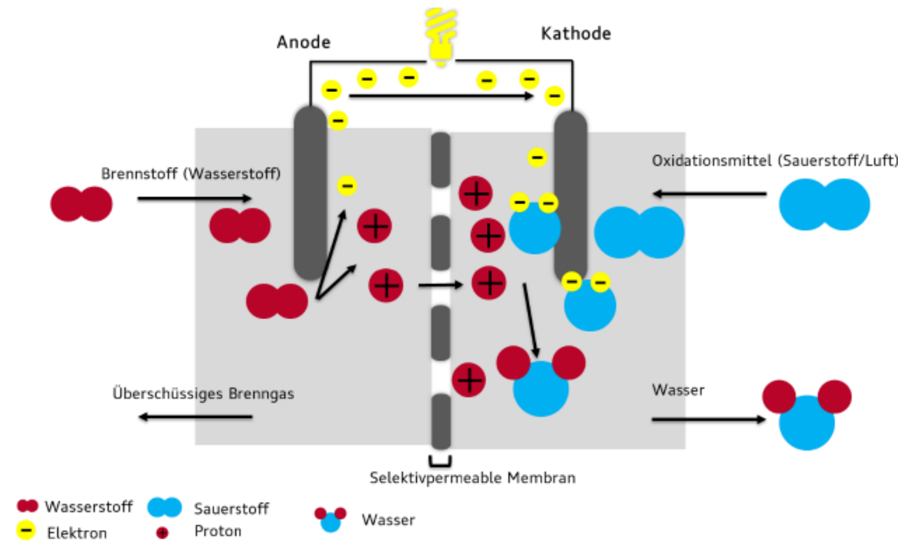
## Fuel Cell Test Rigs (PEM)

Evaluation of Fuel Cells under different conditions

| | | |
|---|---|---|
| 1 Test Rig | $U_{max}$ = 4 V; | $I_{max}$ = 100 A |
| 5 Test Rigs | $U_{max}$ = 4 V; | $I_{max}$ = 1000 A |
| 1 Test Rig | $U_{max}$ = 120 V; | $I_{max}$ = 600 A |

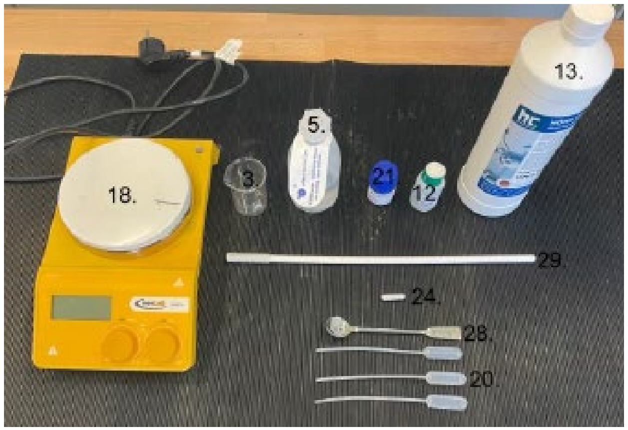
# Fuel cell types

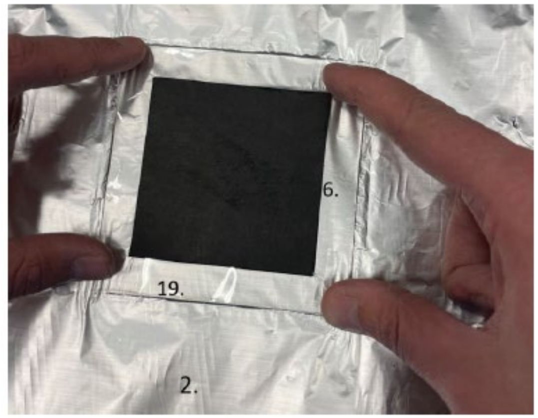


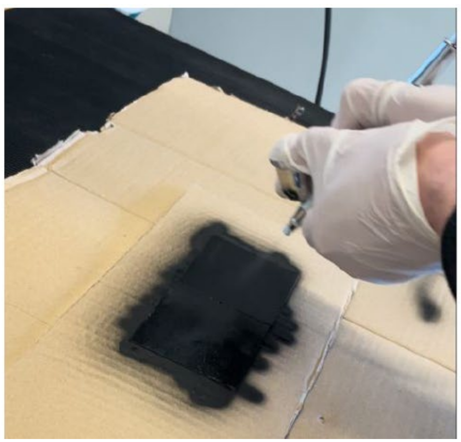



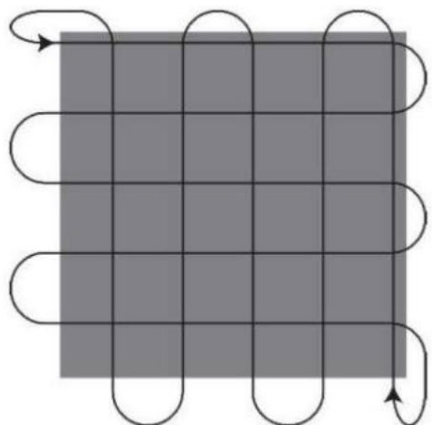

PEM-FC
based on coated nafion layer and GDL

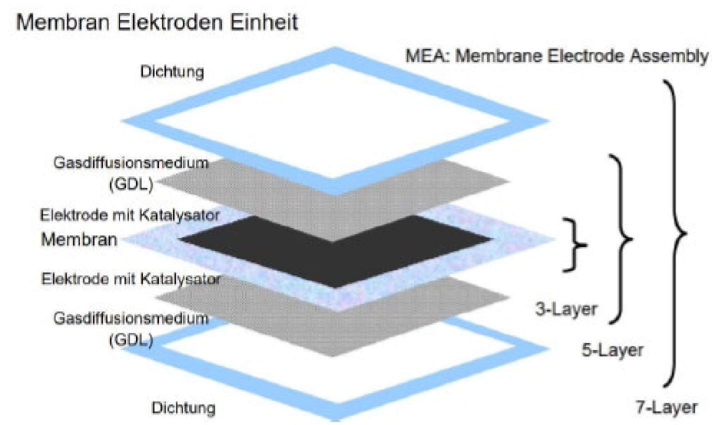
# manufacturing of own MEA prototypes







# Spectrometry (electrochemical and temperature)

**Electrochemical Workstation Zahner IM6**

- $U = \pm 4$ V / $\pm 14$ V
- $I = \pm 2{,}5$ A
- Frequenzbereich: 10 µHz - 100 kHz
- Impedanzbereich: 1 µΩ - 1 kΩ

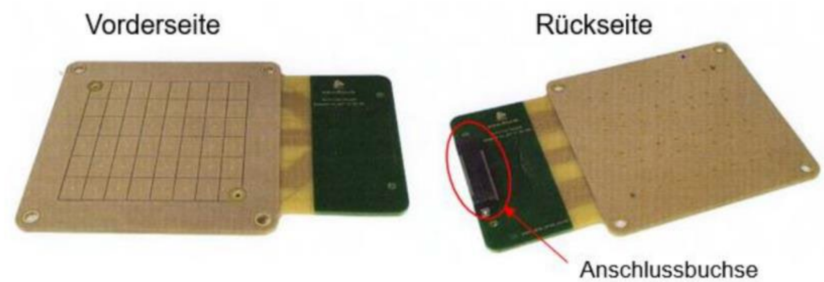
**Zahner EL1000 electronic load**

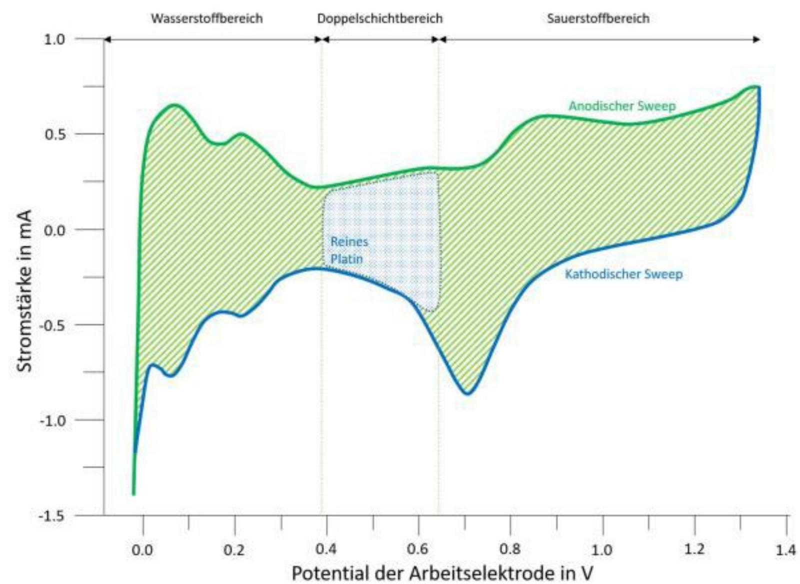
*Steuerung über Zahner IM6/Zennium Pro*

- $U = \pm 4$ V / $\pm 100$ V
- $I = \pm 2{,}5$ A / $\pm 200$ A
- Frequenzbereich: 10 µHz - 100 kHz
- Impedanzbereich: 1 µΩ - 1 kΩ

**Electrochemical Workstation Zahner Zennium Pro**

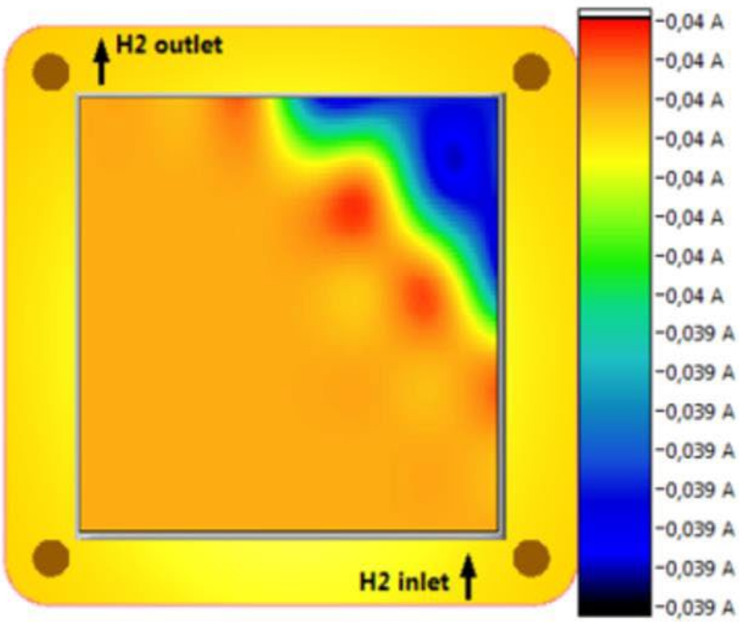
- $U = \pm 5$ V / $\pm 15$ V;
- $I = \pm 3$ A
- Frequenzbereich: 10 µHz - 100 kHz
  Impedanzbereich: 1 µΩ - 10 MΩ



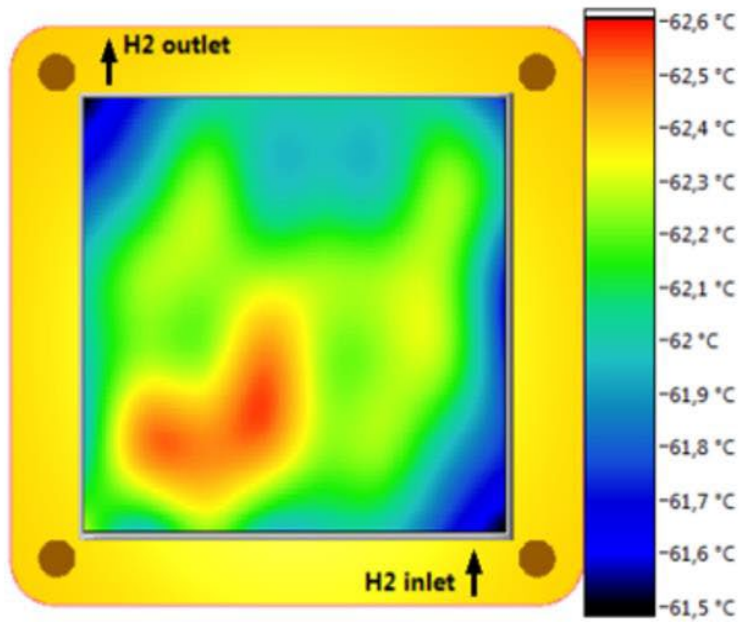



# Spectrometry (electrochemical and temperature)

Stromdichteverteilung




Temperaturverteilung



# Fuel cell test rigs (stack and system testing)



**4 HORIBA FuelCon Test Rigs**

- test object: $H_2$ fuel cells (4 cells 4V)
- maximum current: 100 A and 600 A
- hydrogen and air temperature up to 90 °C

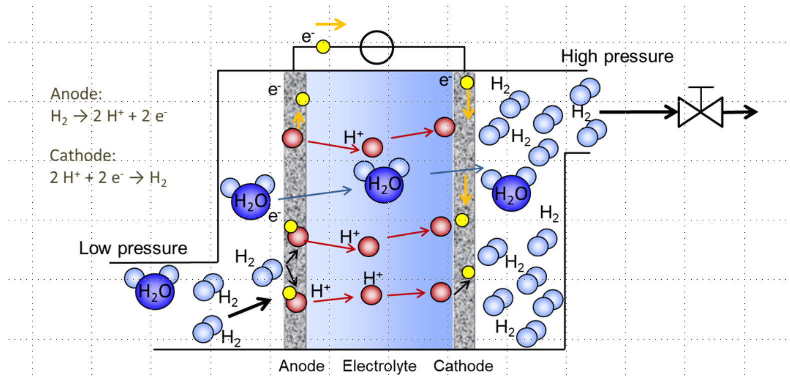
**10 kW Test Rig Kratzer**

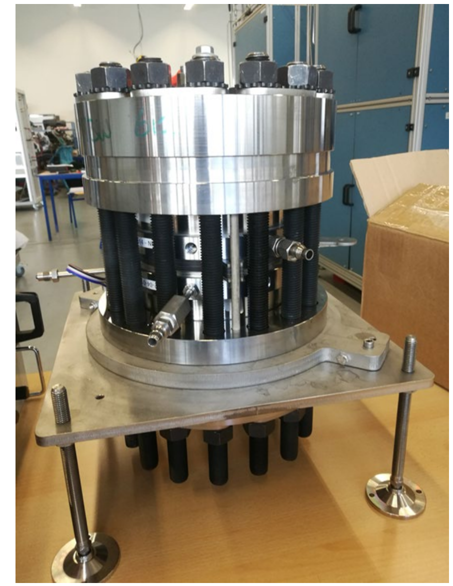
- test object: fuel cells, system components, fuel cell systems (stack 120 cells / 120 V)
- maximum power: 30 kW
- hydrogen and air temperature up to 160 °C

**2 Greenlight Innovation G100 Test Rigs**

- test objects: $H_2$-Brennstoffzellen (5 cells 5V)
- maximum current: 1000 A
- hydrogen and air temperature up to 110 °C

# Electrolyser and electrochemical hydrogen compressor



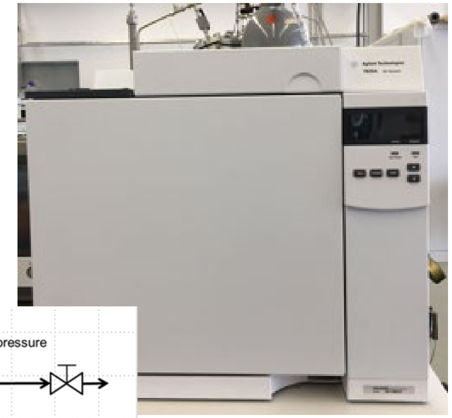



**PEM Elektrolyser**
**Proton HOGEN 40**

| | |
|---|---|
| $H_2$ Production | 1 m³/h |
| Pressure | 13 bar |
| Quality $H_2$ | 99,999 % |
| Efficiency | ≈ 50 % |

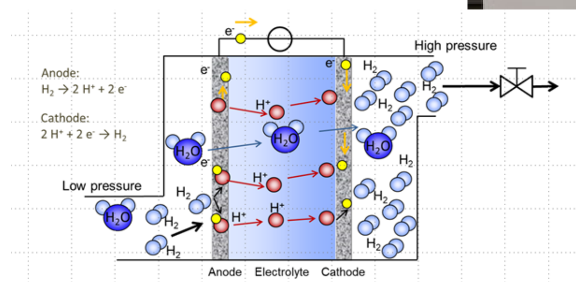
- 5 cell stack.
- Up to 400 bar cathode pressure possible (anode pressure 5-10 bar).
- At a current density of 1 A/cm² it compresses 0,4 kg $H_2$/d.

# Gas composition measurement for hydrogen analysis (EHC)



Gas chromatograph with thermal conductivity detector (TCD) and Flame Ionization Detector (FID)

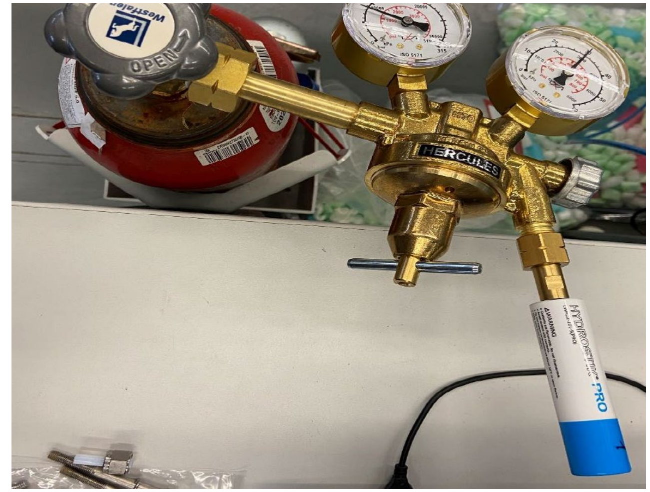
- Detectable gases depend on the separation column
- Detection limit at approx. 30 ppm

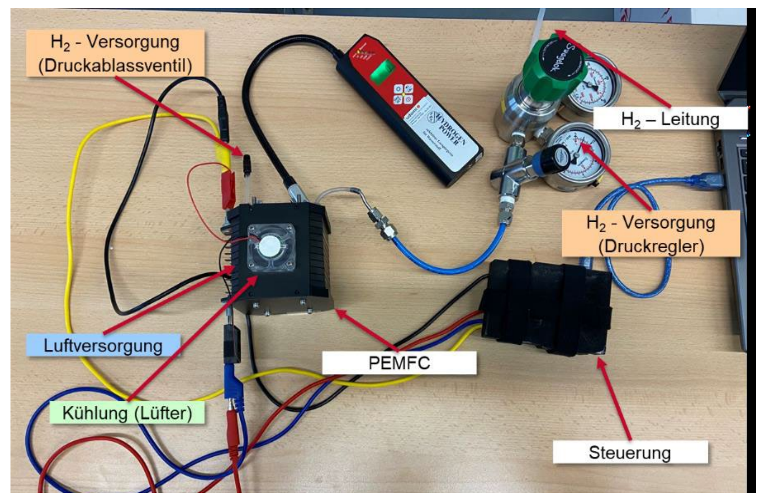



Mass Spectrometer (MS)

- Portable / no carrier gases required
- Live measurement (300 ms response time),
- Automatic sampling
- Detection limit at approx. 5 ppb,
- Component library integrated in software Integrated corrosion protection

# Hydrogen electrolyser for Horizon hydrosticks (education lab)



Geradezu achtlos verbrauchte die Menschheit fossile Energieträger in Form von Kohle, Gas oder Erdöl. Glücklicherweise gibt es auf der Erde aber nachhaltig nutzbare Energie im Übermass, die wir angesichts der Klimaveränderung auch nutzen sollten.


flugzeugen erhalten. Bei den Leichtflugzeugherstellern zeigt man sich hingegen nicht zuletzt aus finanziellen Gründen noch sehr distanziert.

Anders sieht es im universitären Bereich aus, einem Forschungsumfeld, welches weniger auf direkte finanzielle Erfolge angewiesen ist. So ist die Universität Delft in den Niederlanden mit der Firma Aero-Delft eine Partnerschaft eingegangen, um mit Studenten sowohl einen Modell-Erprobungsträger (massstabverkleinerter e-Genius) als auch eine im Umbau befindliche Sling 4 auf den Wasserstoff-Betrieb vorzubereiten. In der Phase 2 sollen im kommenden Jahr die Experimente

Im Projekt EBSAL (Entwicklung eines Brennstoffzellensystems für die allgemeine Luftfahrt) gilt es, ein Hybridsystem aus Brennstoffzellensystem, Wasserstofftank, Hochvoltbatterie, Elektromotor und Antriebssteuerung zu entwickeln, das die flugtypischen Anforderungen erfüllt und gleichzeitig sowohl bei Energie- als auch bei Leistungsdichte gegenüber verbrennungsmotorischen Antrieben wettbewerbsfähig ist. Sobald die experimentellen Untersuchungen abgeschlossen sind, soll der Antriebsstrang in einen C42 CS-ePower der Firma Comco Ikarus GmbH eingebaut werden.


https://www.mannheim.dhbw.de/aktuelles/detail/projekt-ebsal-in-der-schweizer-aerorevue



## Hydrogen BBQ

Demonstrating the utilisation of Hydrogen in cooking applications, the barbecue is capable of producing the same results as our Natural Gas and LPG range of barbecues.

# Industry and funded Projects

Experimental Evaluation of Degradation Mechanism of a Polymer Membrane Fuel Cell in automotive Application
7/2017 – 3/2021

Education Program for Electro Mobility based on Hydrogen and Fuel Cells since 1/2018

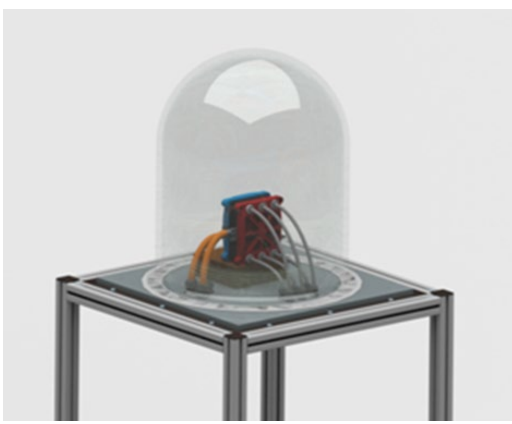
Optimisation of Proton Exchange Membrane (PEM) Fuel Cells by additive produced Gas Diffusion Layers and Flow Channels – Membrane Separator
DHBW, 3D MicroPrint GmbH, 3 year, 0.4 Mio. €, BMWi, 3/2017 – 1/2019

MEMbrane based Purification of HYdrogen System – MEMPHYS
DHBW (coordination), HyET (NL), Institute Jozef Stefan (SLO), FZ Jülich, Borit (B), Imperial College (GB), 3 years, 2 Mio. €, EU, 1/2017 – 12/2019

$H_2$ Recycling by electrochemical Compression – EH2C
Centrotherm Clean Solutions, DHBW, AZUR SPACE Solar Power, FCT Systems, Fraunhofer ISE, HyET (associated), 2 years, 2.2 Mio. €, BMWi, 4/2021 – 3/2023

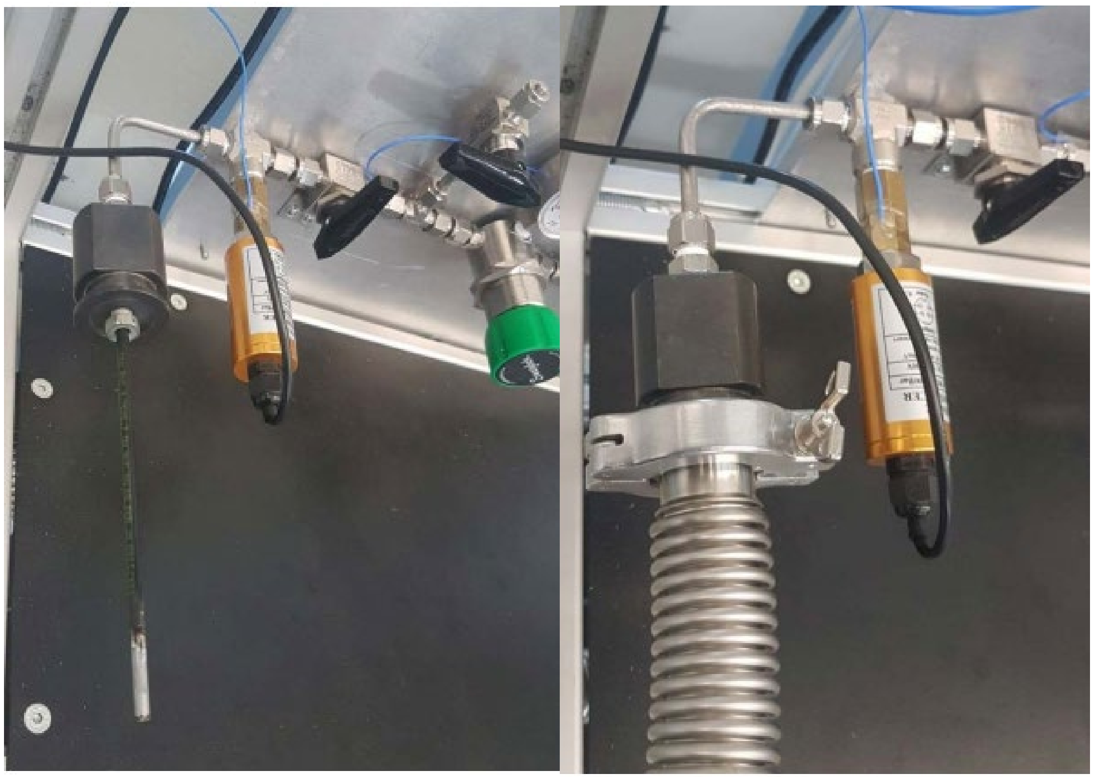
# Leak testing with Leybold mass spectrometry


- Leybold PHOENIXL 300 Helium/Hydrogen Leak Detector, detection limit Helium $10^{-10}\ \frac{\mathrm{mbar \cdot l}}{\mathrm{s}}$
- Pressure decrease procedure for testing of components
  test gases: Nitrogen, Helium, Hydrogen
  Pressures up to 200 bar



- Vacuum bell,
- d = 500 mm, h = 450 mm
- Leakage measurement in fuel cells, membranes, foils

# Tightness tests leakage measurements on components, joints, seals and membrans (permeation)



- Pressure drop method for component testing
- gases: nitrogen, helium, hydrogen and hydrogen/nitrogen 5/95 test gas
- up to 200 bar Leakage measurement on seals, fittings and gas permeability

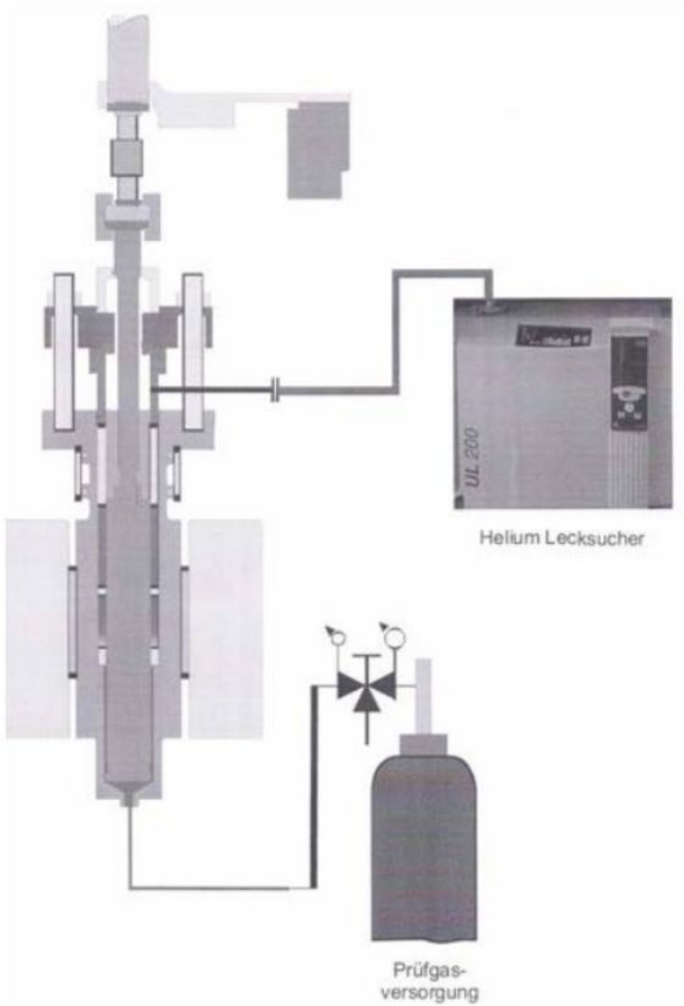
# Leak testing


- Leybold PHOENIXL 300 Helium/Hydrogen

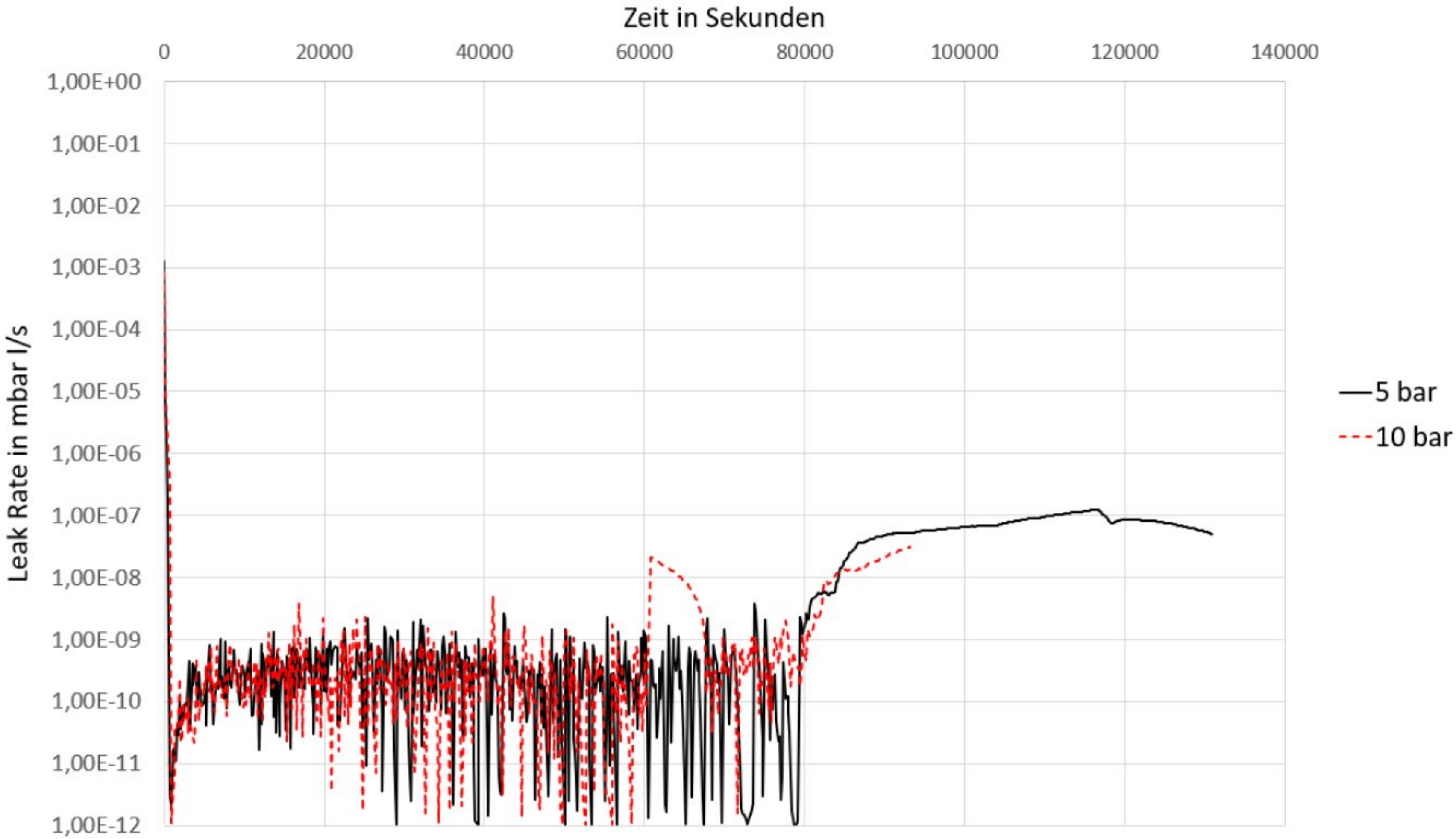
used with
amtec temes stb.freak test rig for:

- Test bench for gland packing
- D = 56 mm, d = 40 mm, h = 8 mm
- Up to 40 bar

amtec temes stb.freak test rig


UL 200
Helium Lecksucher
Prüfgas-
versorgung

**Leak Rate bei 5bar und 10 bar, Prüfmedium: Wasserstoff, 5 Packungen aus expandiertem Grafit (D1=56mm, D2=40mm, h=8mm), Vorspannung pro Bolzen = 12kN**



Thank you for your attention!!