Technische Universität Hamburg

Hydrogen Compression and Storage

- New Concepts and Innovative Approaches -

Dr. Martin Dornheim
martin.dornheim@hzg.de
Helmholtz-Zentrum Geesthacht
Hydrogen Technology Center

Magna Steyr

International Partnership for Hydrogen and Fuel Cells in the Economy

April 26th, 2017
Technische Universität Hamburg-Harburg,
Am Schwarzenberg-Campus 5

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung


Hydrogeit Verlag / www.hzwei.info / 8. Jahrgang / Juli 2008 / 7 €
DAS MAGAZIN FÜR WASSERSTOFF UND BRENNSTOFFZELLEN
HZwei
Linde
CE 0408
Linde Gas GmbH, Waschenbergerstr. 13
A 4651 Stadl-Paura
Verdichter
Typ: H2 850-20-20 HB
Ser. Nr.: TL 017 Baujahr: 2008
Max. Betriebsdruck: 900 bar
Medium: Wasserstoff 5.0
H2 GAS
StorHy: NEUE WASSERSTOFFSPEICHER FÜR FAHRZEUGE
HOCHDRUCKBETANKUNGSTECHNIK: THEORIE UND PRAXIS
Der Wasserstoff- und Brennstoffzellenmarkt kommt
IES-Modellrechnung & GermanHy-Studie

Compressed Gas Storage Tanks in Mobile Applications

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

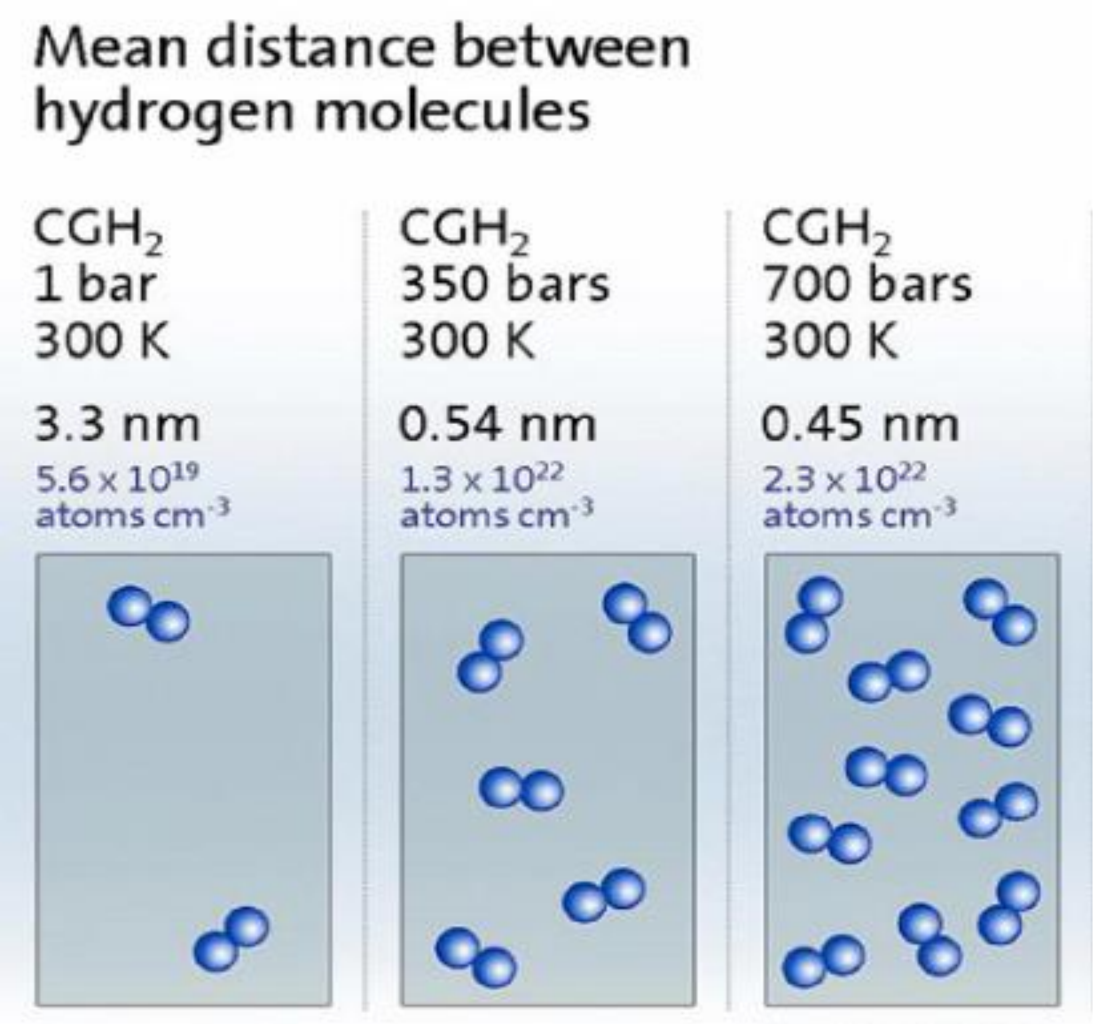
Foto: Lars Brüggemann www.larsbrueggemann.de

hydrogern train
Coradia iLint.
(Foto: dpa)

Increasing the volumetric hydrogen storage density

Wasserstoffdruckgasspeicherung

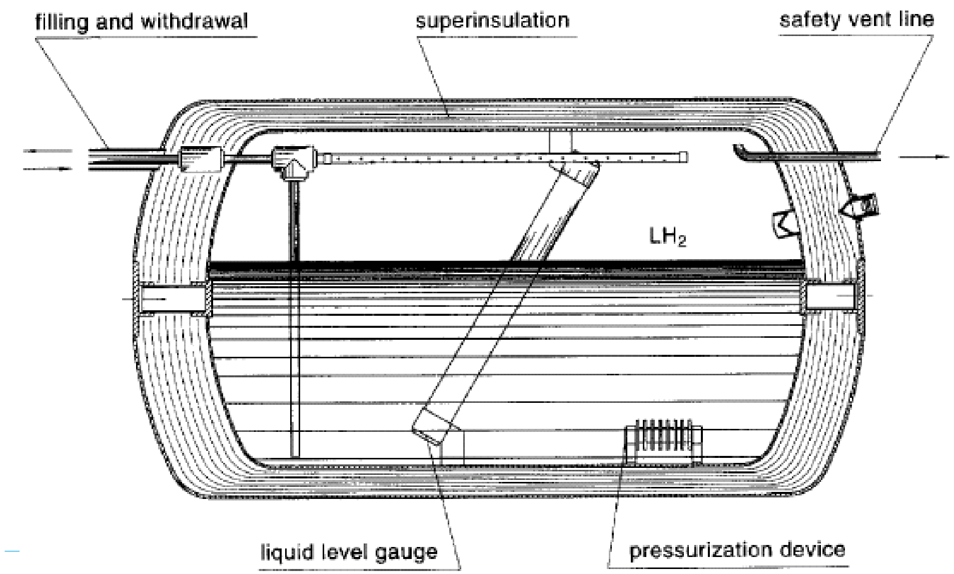
Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung



Liquid Hydrogen Storage
Flüssigwasserstoffspeicherung

Liquid Hydrogen Storage

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

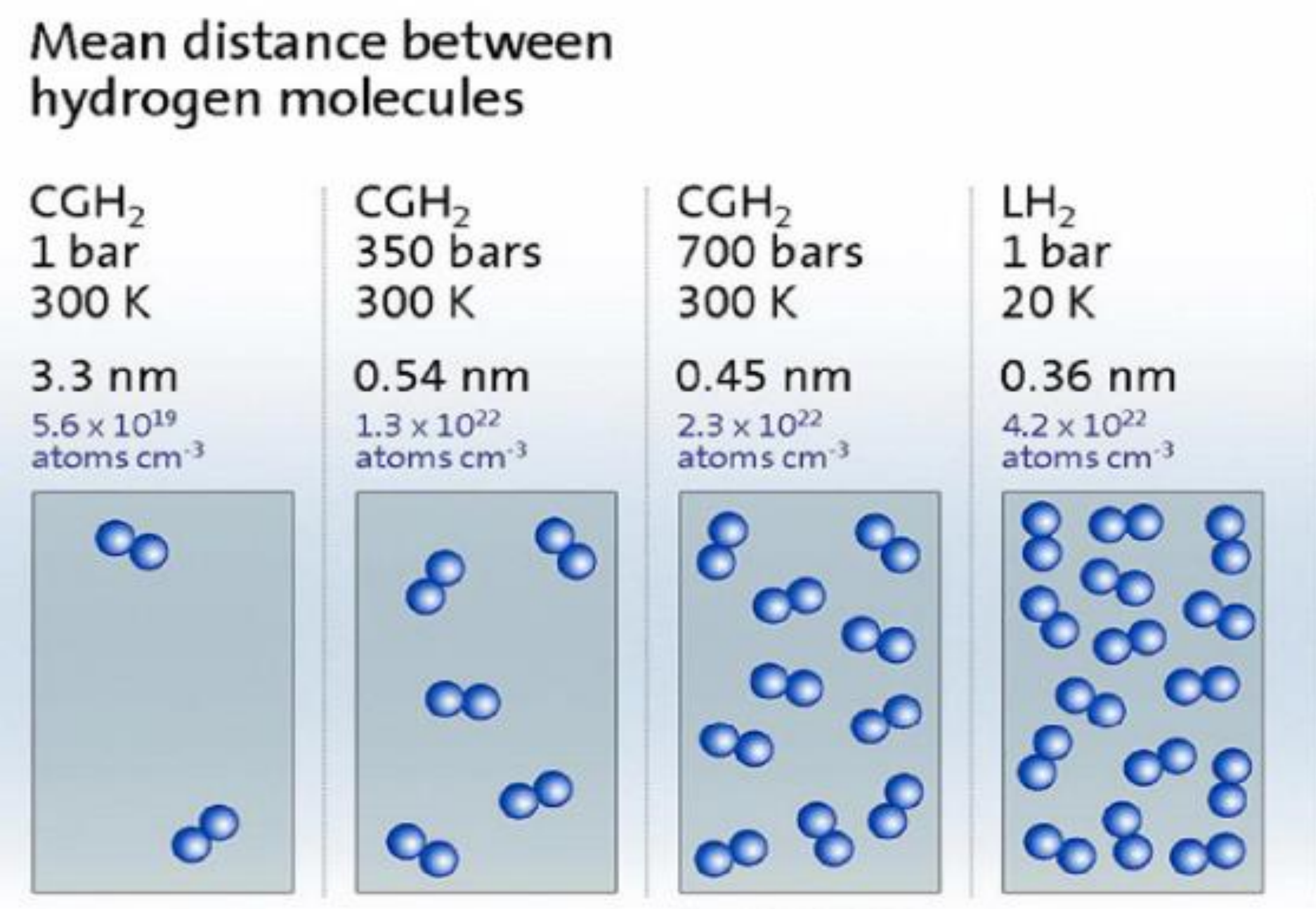


Prototyp mit Straßenzulassung: BMW 5er

Increasing the volumetric hydrogen storage density

Wasserstoffdruckgasspeicherung

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung



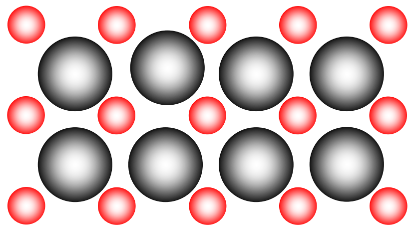
Solid Storage of Hydrogen

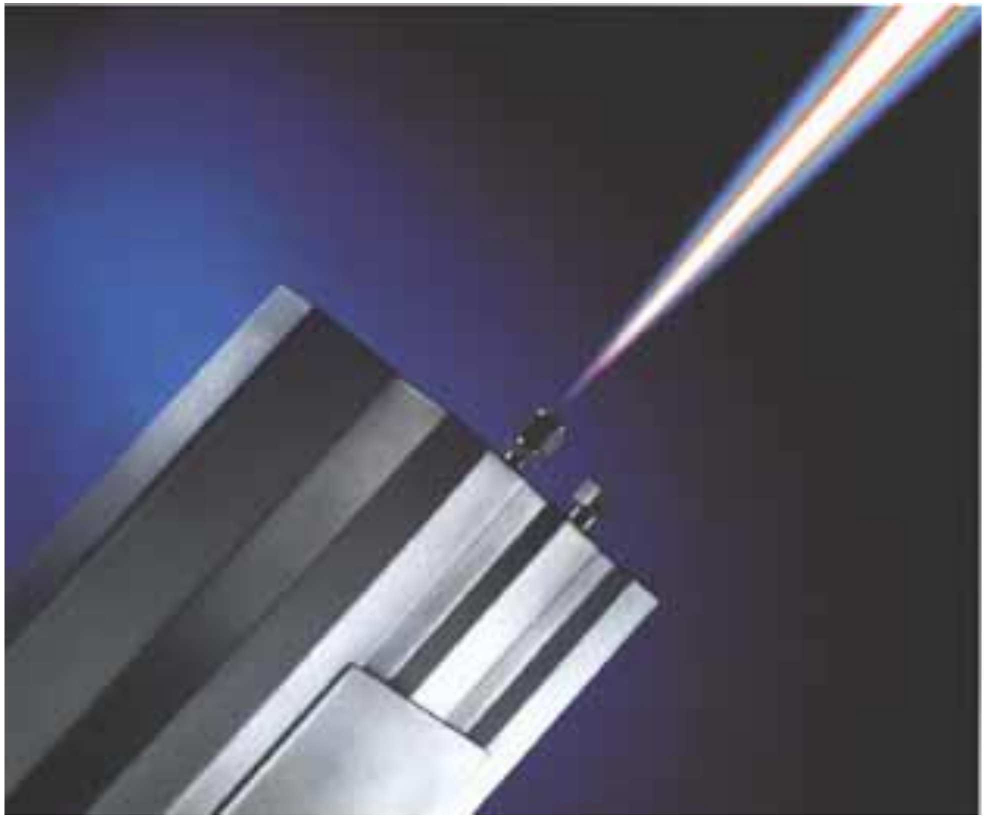
Feststoffspeicherung von Wasserstoff

Storage Alternative: Metal Hydrides

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

“solid” hydrogen
in
metal - “sponge”





extremely low volume

because of chemical bonding

high safety

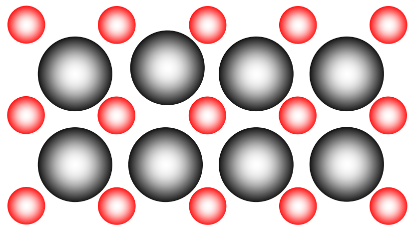
endothermal hydrogen release

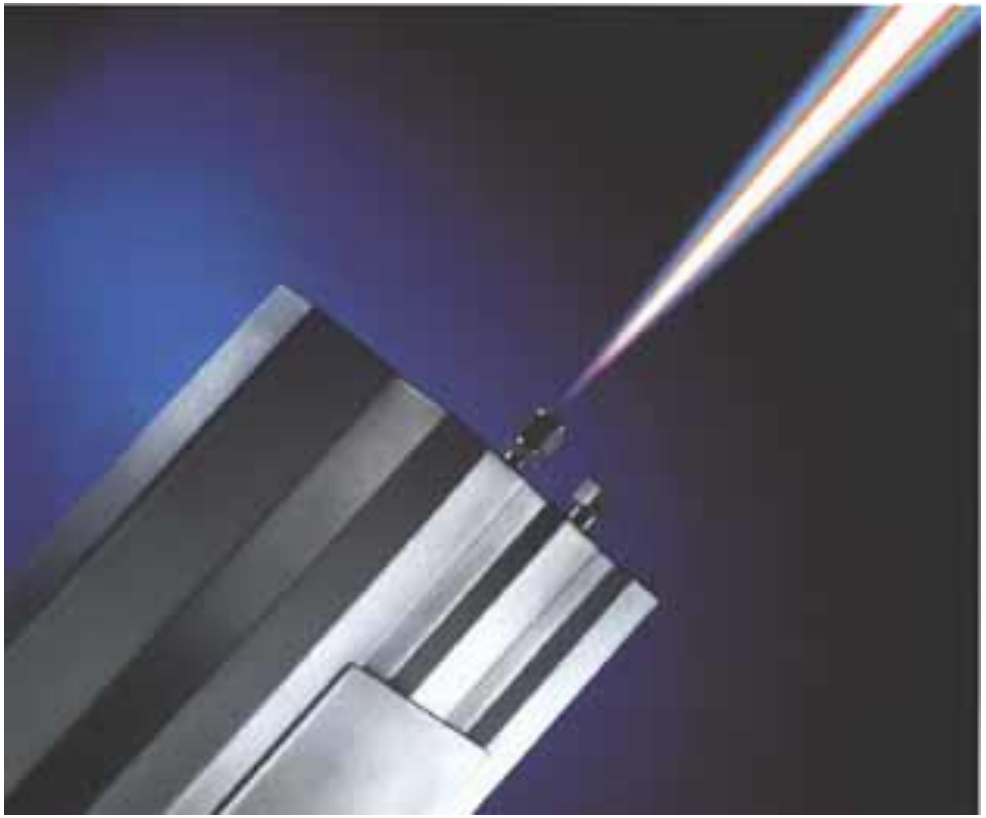
flexible vessel geometry

low pressures
moderate temperatures

Storage Alternative: Metal Hydrides

"solid" hydrogen
in
metal - "sponge"





extremely low volume

because of chemical bonding

high safety

endothermal hydrogen release

flexible vessel geometry

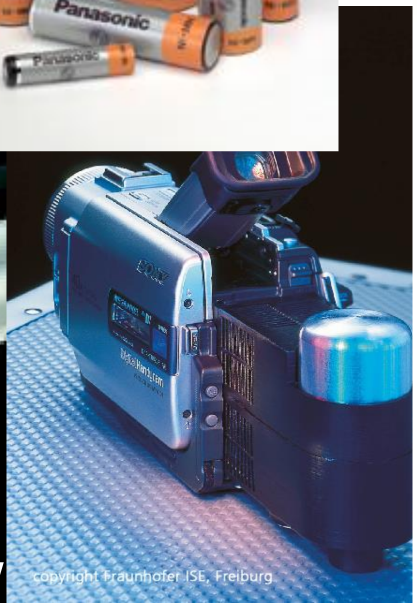
low pressures
moderate temperatures

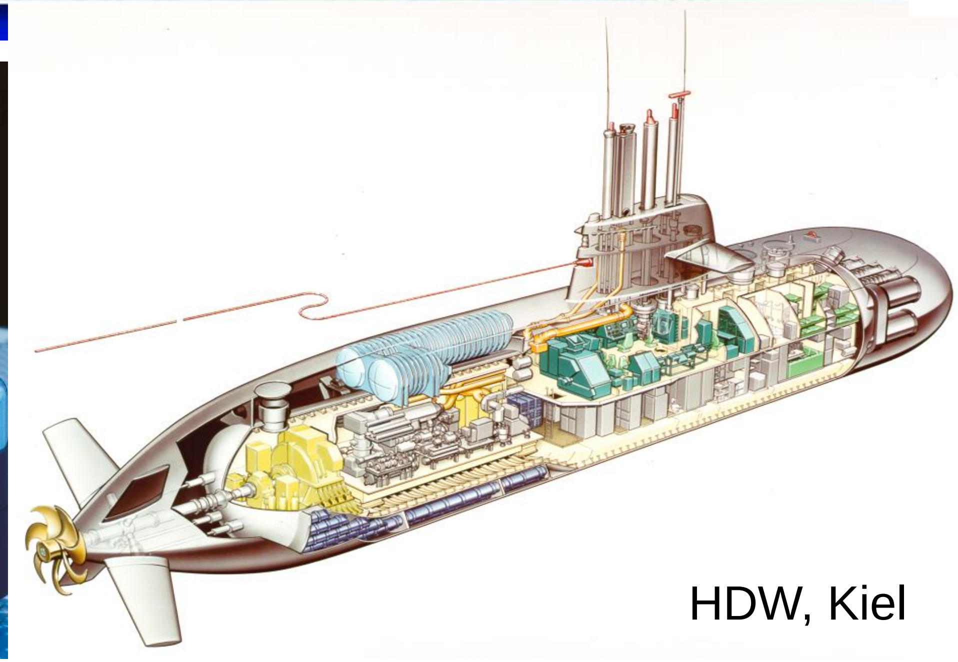
Intermetallic Hydrides - Applications

ETA-Ing

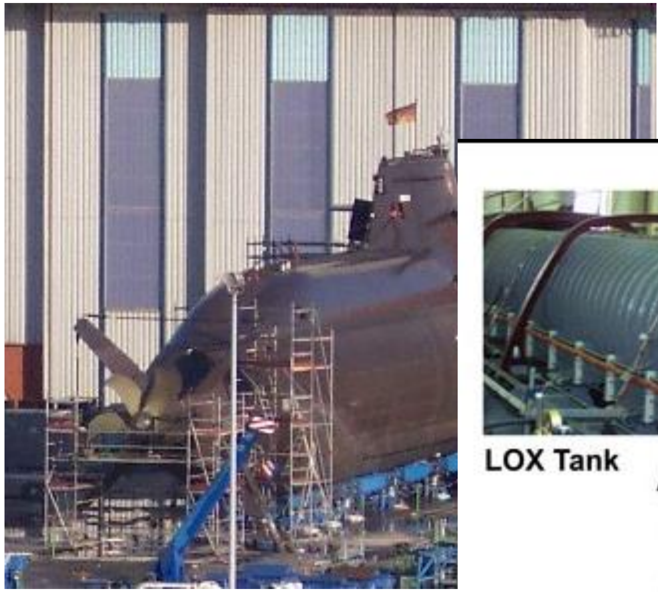
Toyota FCHV-3

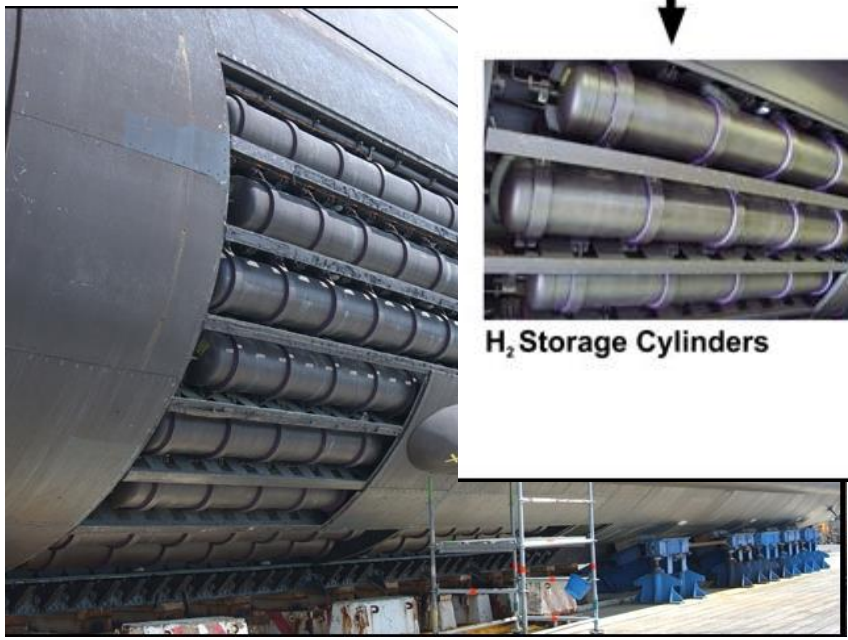

Fraunhofer ISE/ZSW

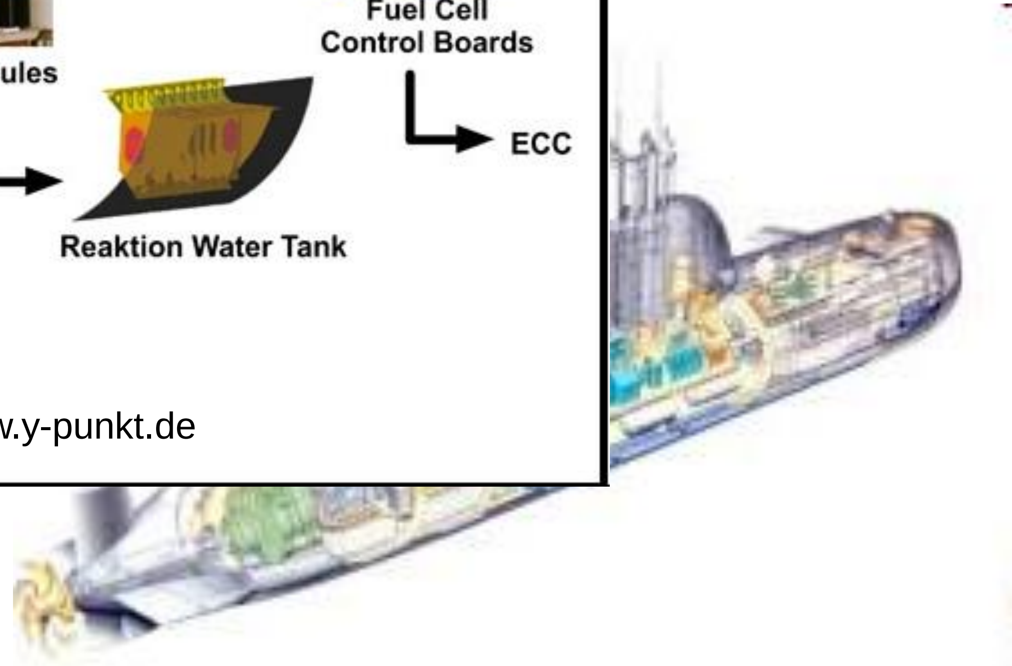


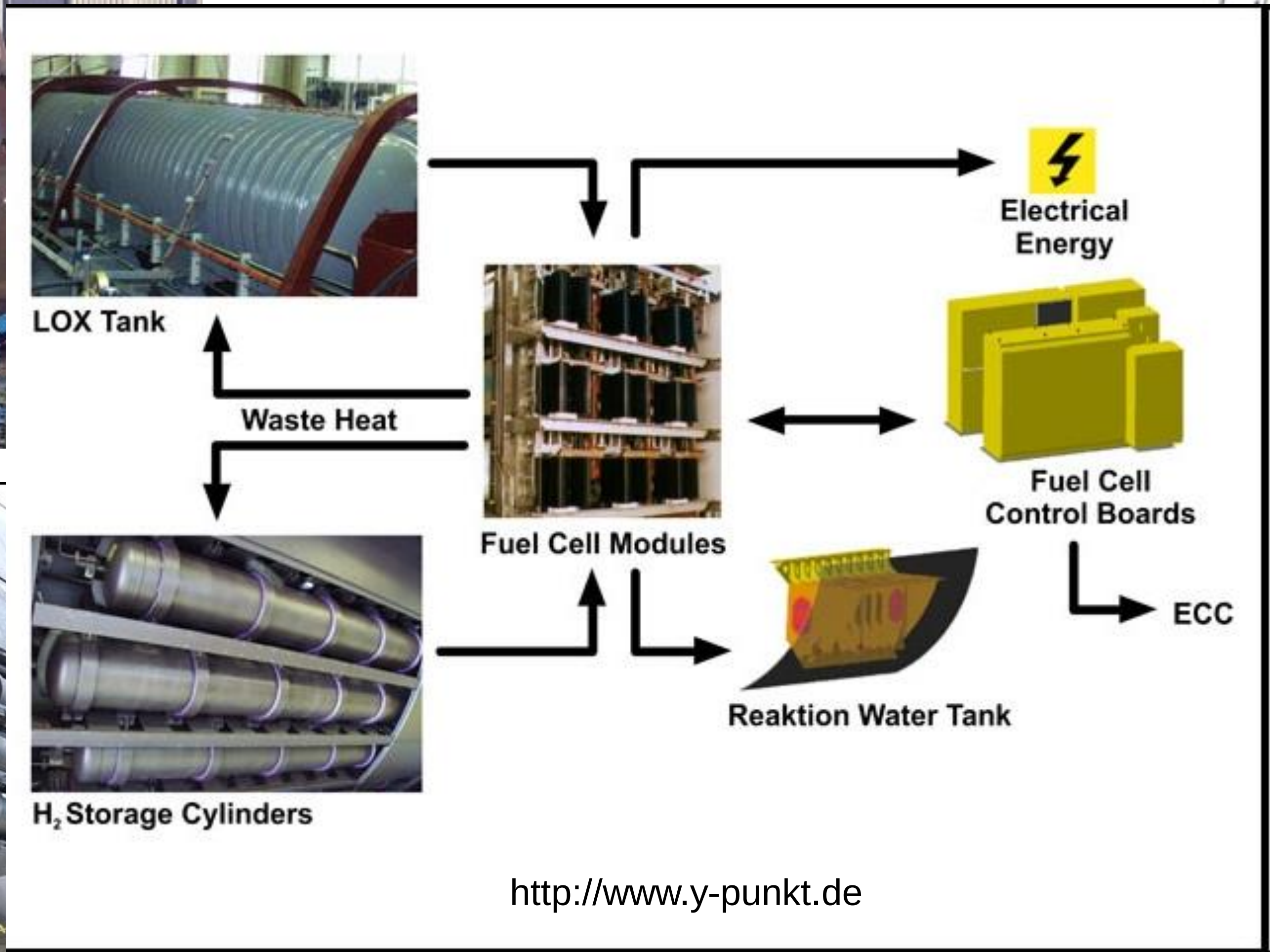

HDW, Kiel

U Boot 212 und 214 HDW

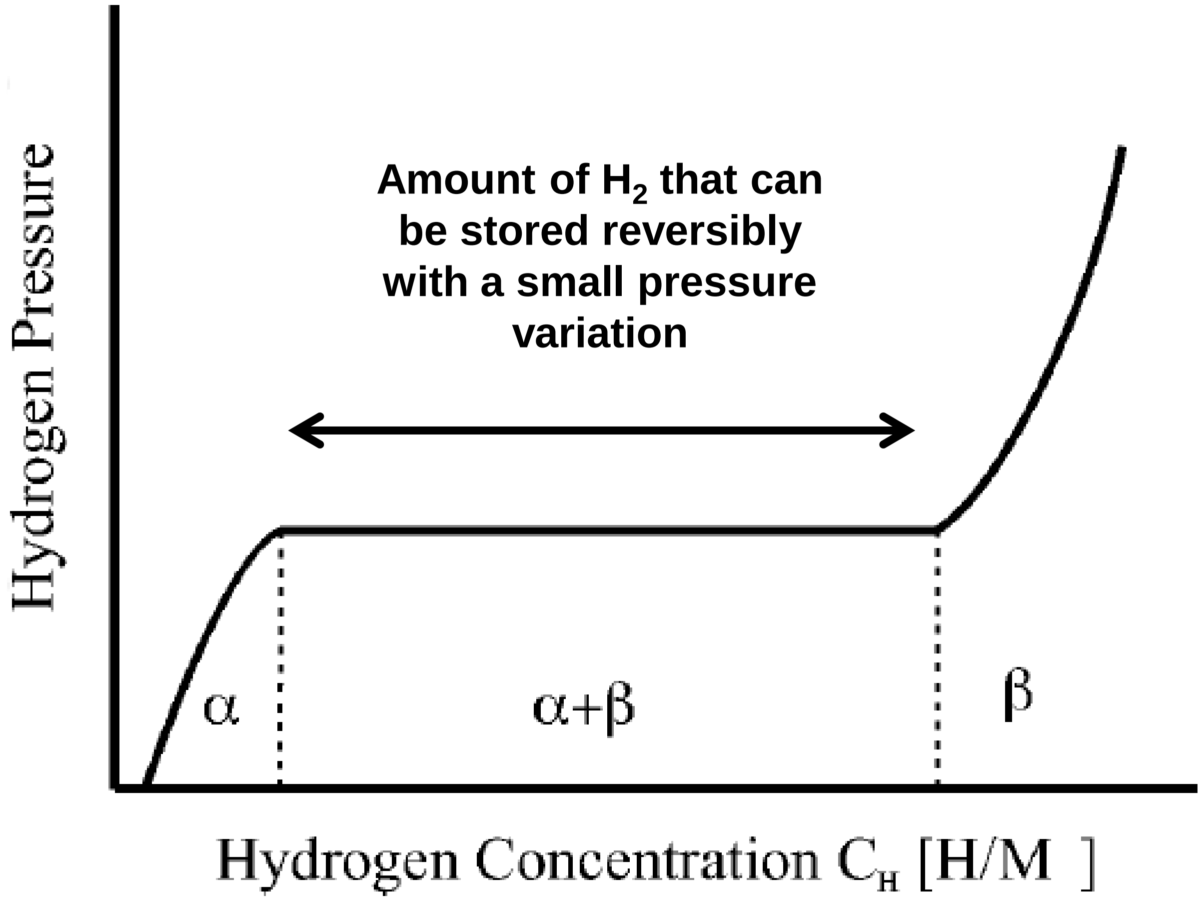








T = costant

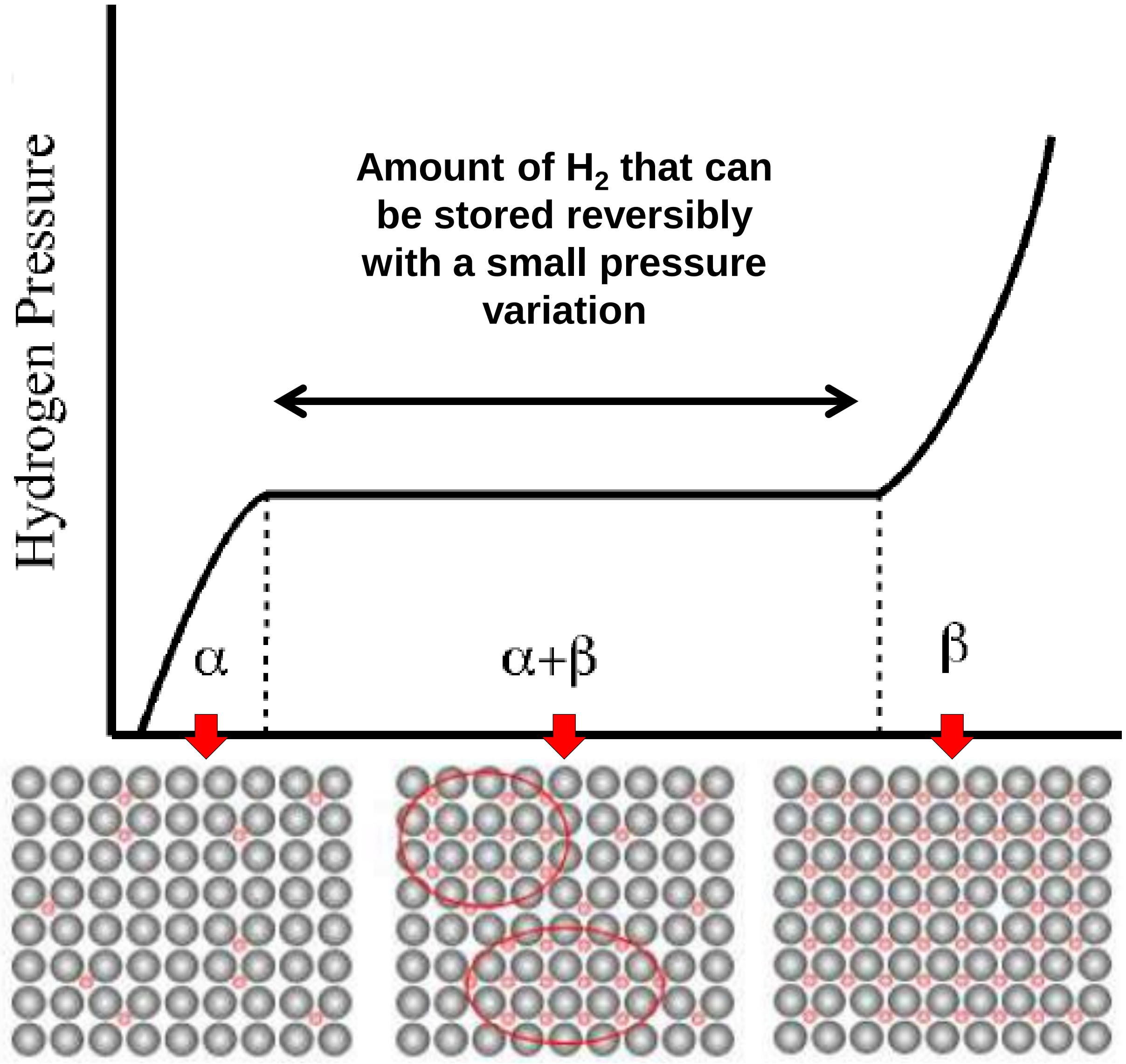


α-phase = solid solution of hydrogen in the metal matrix

β-phase = metal hydride phase

Ref: Martin Dornheim; Thermodynamics of Metal Hydrides: Tailoring Reaction Enthalpies of Hydrogen Storage Materials

15



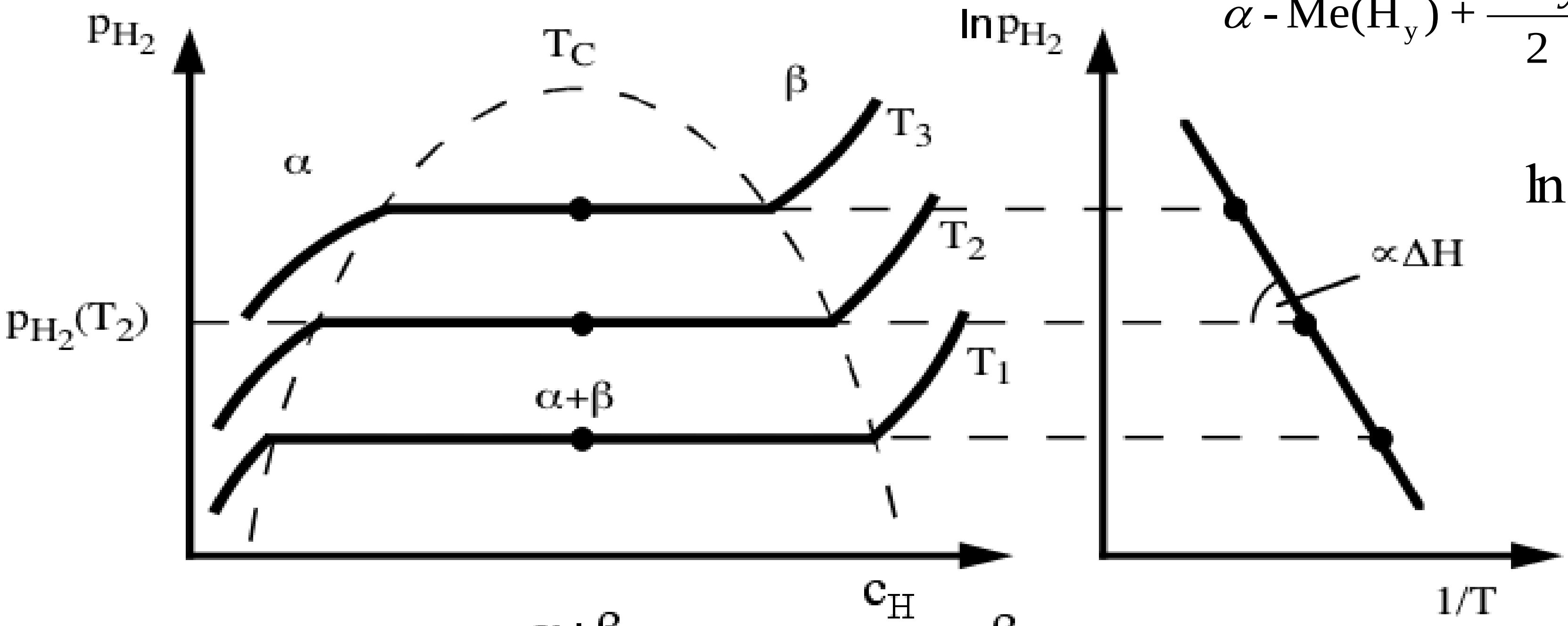
Ref: Martin Dornheim; Thermodynamics of Metal Hydrides: Tailoring Reaction Enthalpies of Hydrogen Storage Materials

16

Thermodynamics

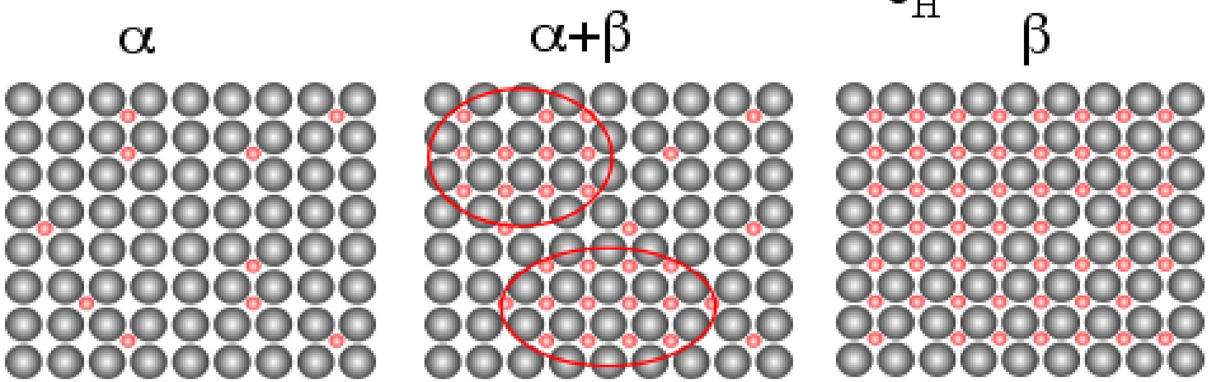
pcT-diagram

van't Hoff Plot



$$\alpha\text{-Me(H}_y) + \frac{x-y}{2}\,\mathrm{H}_2 \Leftrightarrow \beta\text{-MeH}_x + \text{heat}$$

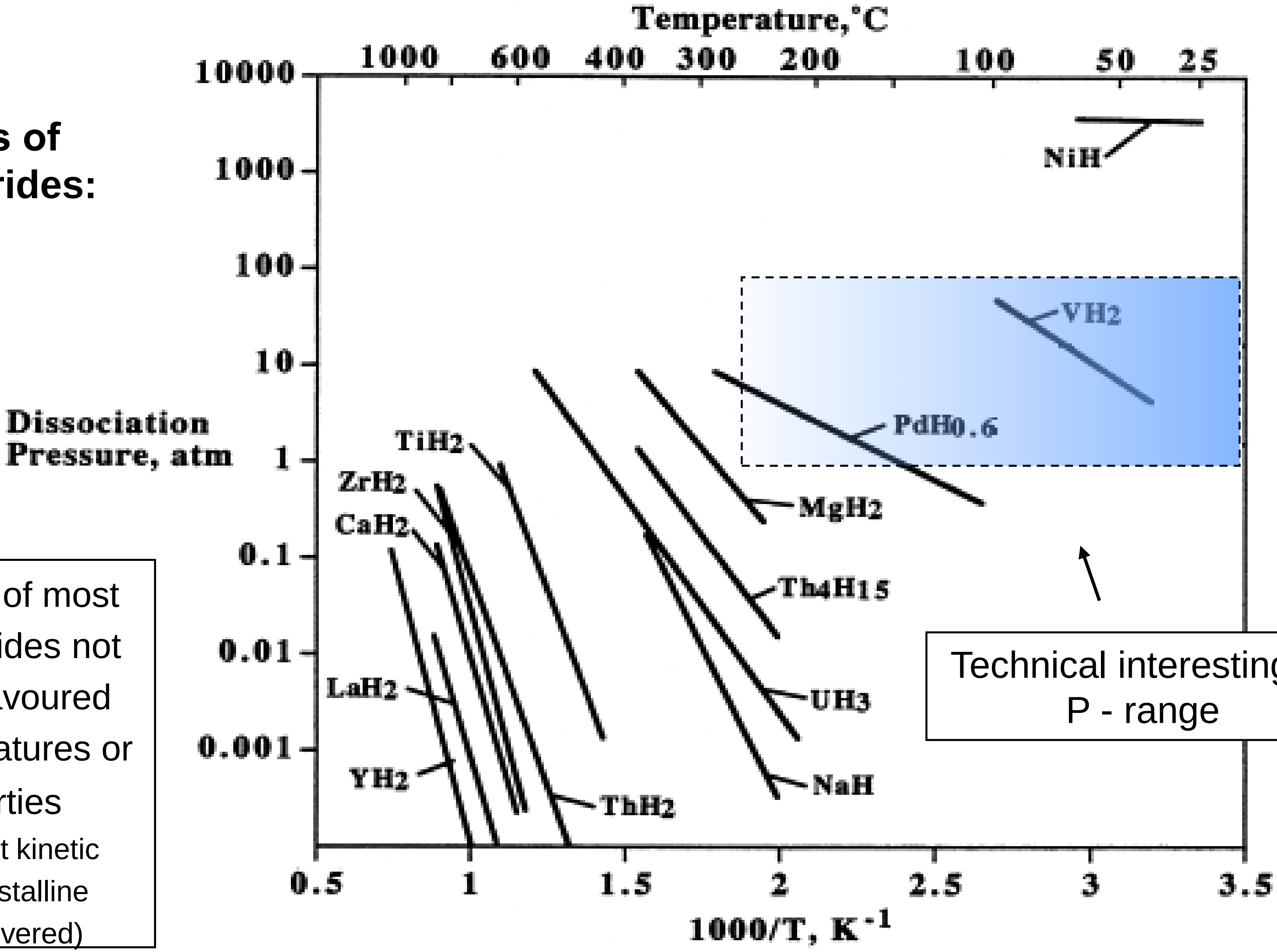
$$\ln p = \frac{\Delta H}{RT} - \frac{\Delta S}{R}$$



Limitation of Binary Metal Hydrides

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

Van't Hoff lines of elemental hydrides:



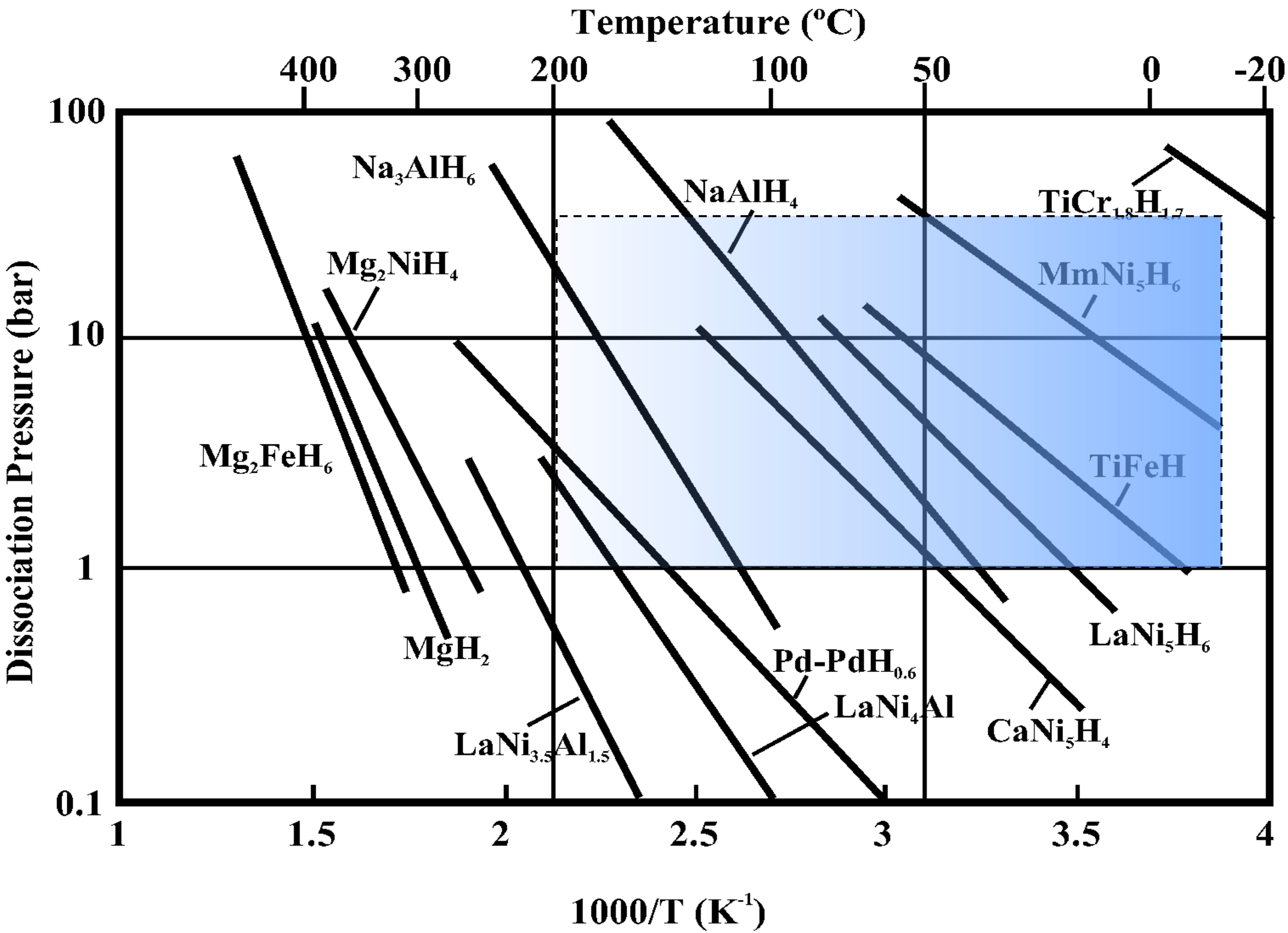
Technical interesting T-P - range

Plateau pressure of most binary metal hydrides not at the technical favoured important temperatures or bad kinetic properties

(e.g. MgH_2 before fast kinetic properties of nanocrystalline MgH_2 has been discovered)

G. Sandrock, J. Alloys Comp.,293-295 (1999) 877

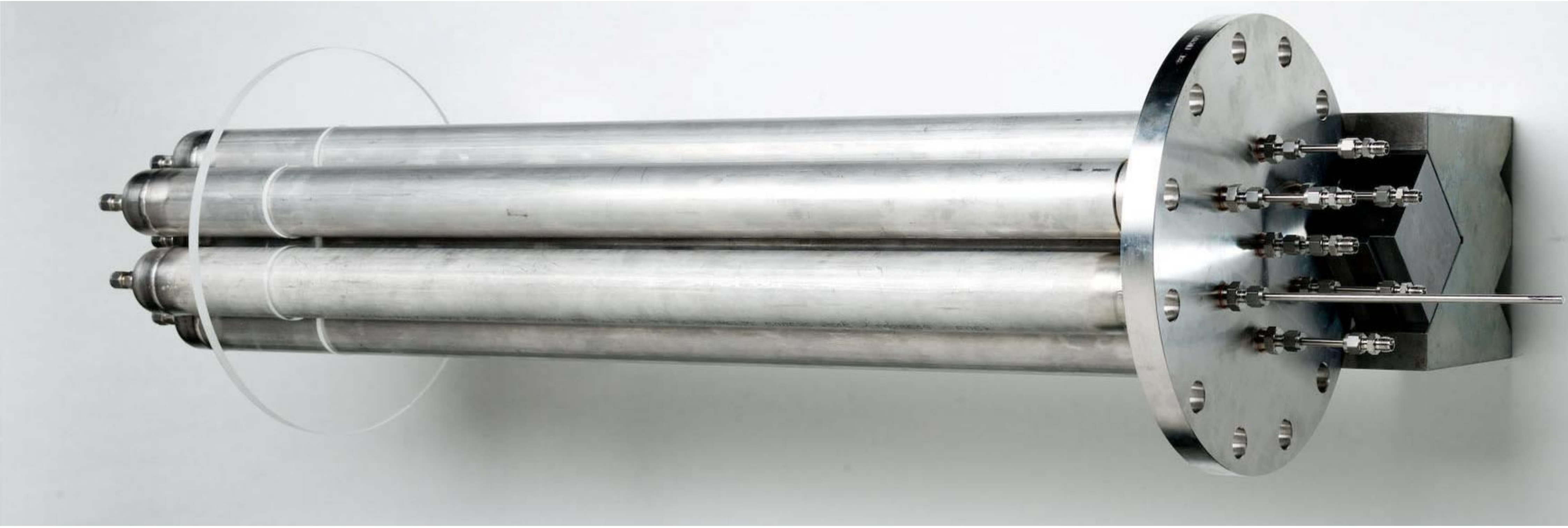
Thermodynamics



B. Bogdanovic et al., J. Alloys Comp. 302 (2000) 36

Design of a Metal Hydride Storage Tank: Tube Bundle Heat Exchanger

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

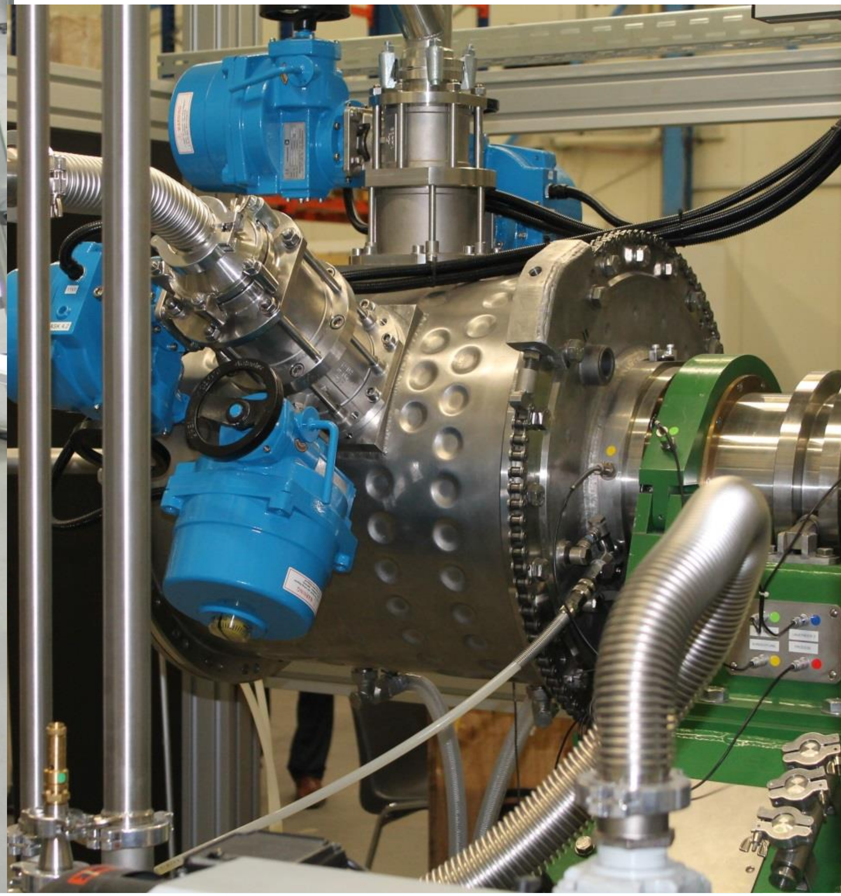


Testing of 8 kg alanate tank

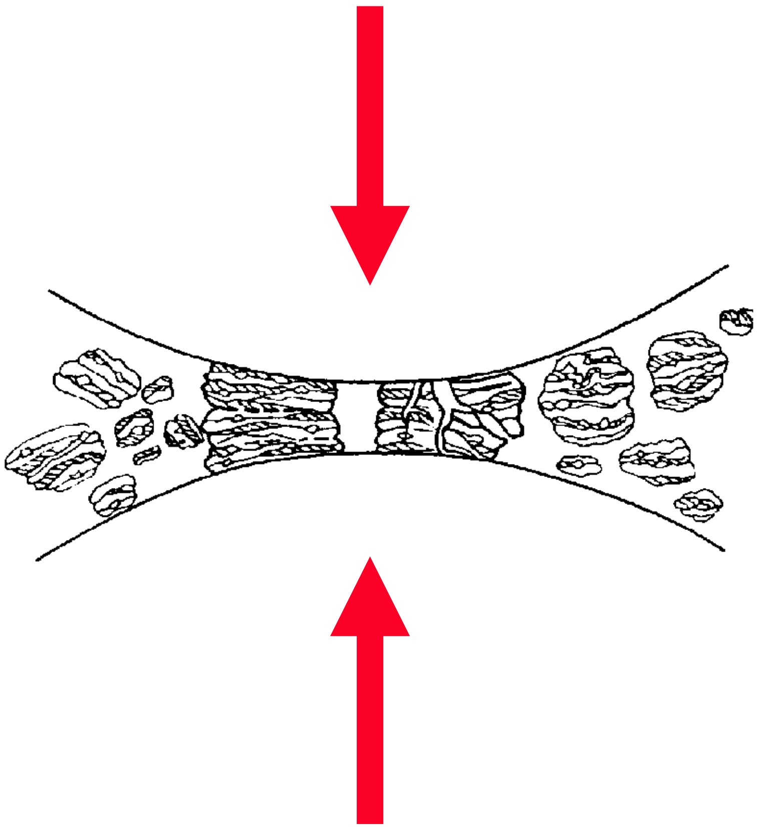
Helmholtz-Zentrum
Geesthacht
Zentrum für Material- und Küstenforschung

Hydrogen Technology Centre Olpe

Helmholtz-Zentrum
Geesthacht
um für Material- und Küstenforschung



Schema Hochenergiemahlen



Pulver & Mahlkörper in Mahlgefäß

↓

heftige Bewegung

↓

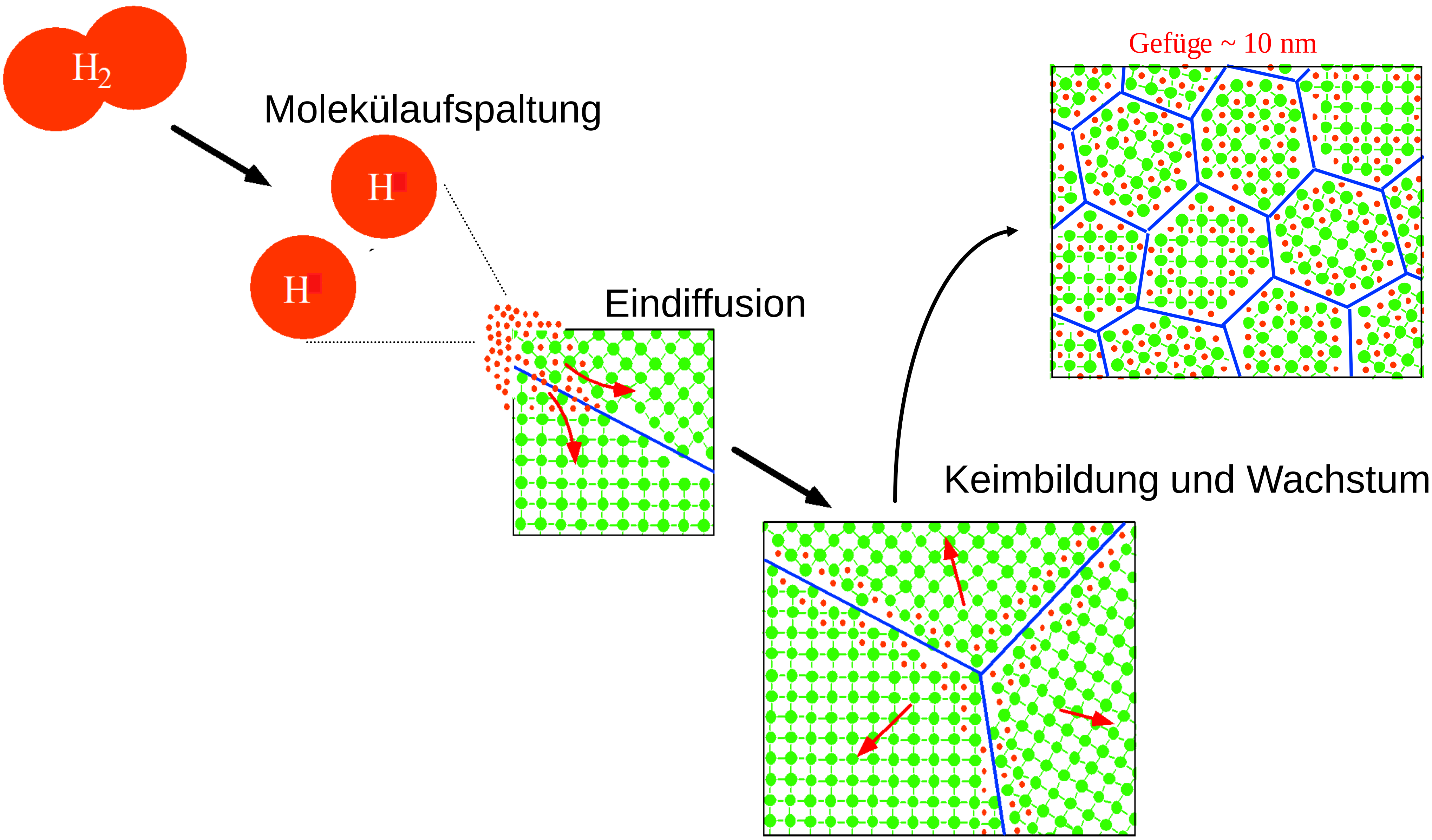
mechanische Beanspruchung

↙ ↘

Zerbrechen	plastische Verformung Kaltverschweißen

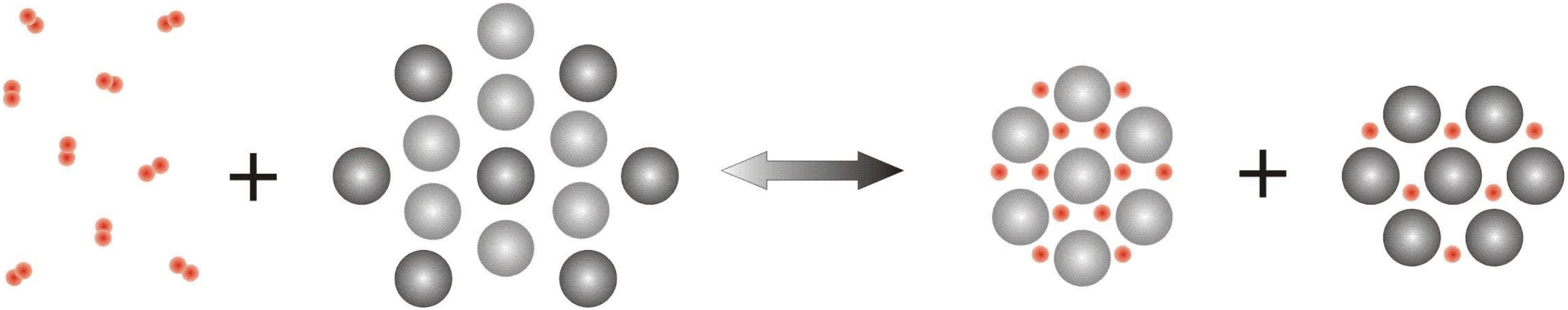
Kinetik: Einflussfaktoren

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung



Reactive Hydride Composites

Tuning thermodynamics and kinetics by combination of different high capacity hydrides:



hydrogen **stable compound** **hydride I** **hydride II**

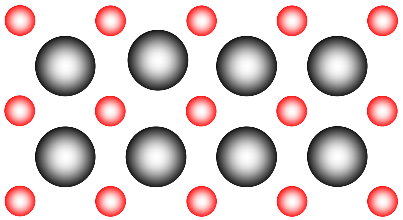
H_2 + MgB_2 + LiH ⟷ **MgH_2 + $LiBH_4$**

.

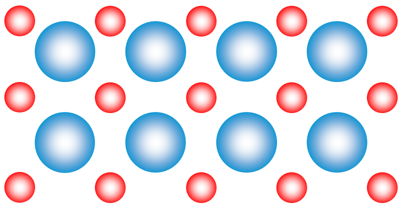
HZG European Patent, German Pub. No: DE102004/061286. 2004

world record!

Hydrogen Storage Materials:
Reactive Hydride Composites



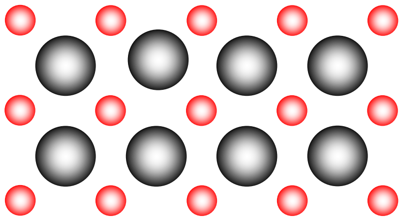
Wärme

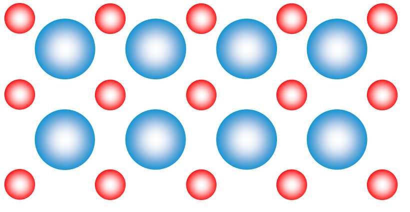


Reaktive Leichtmetall-Hydridkomposite:

Hydrogen Storage Materials: Reactive Hydride Composites

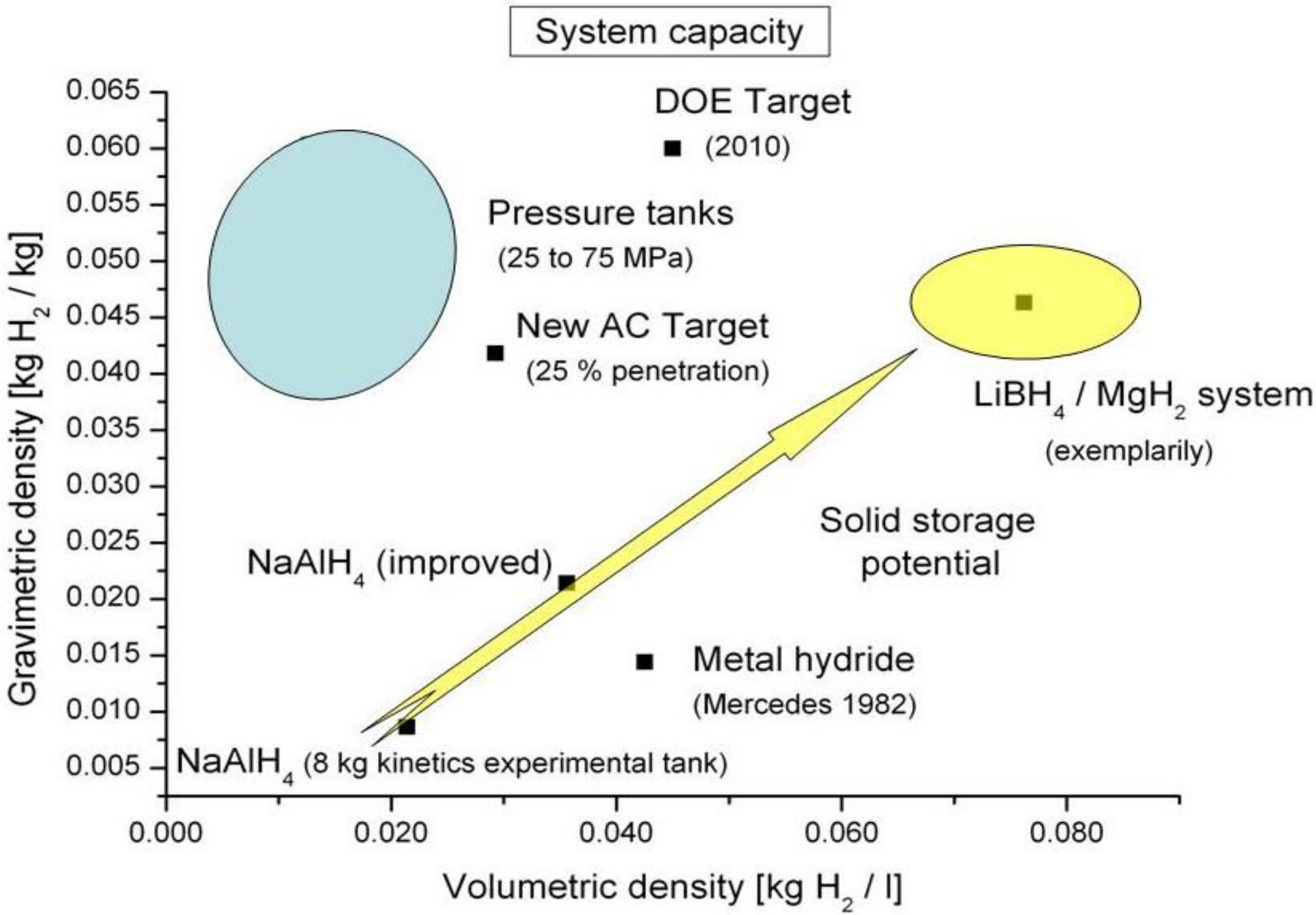
Kälte / Wasserstoffdruck





Solid storage tank system development
- Outlook -

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung



Hydrogen Compression

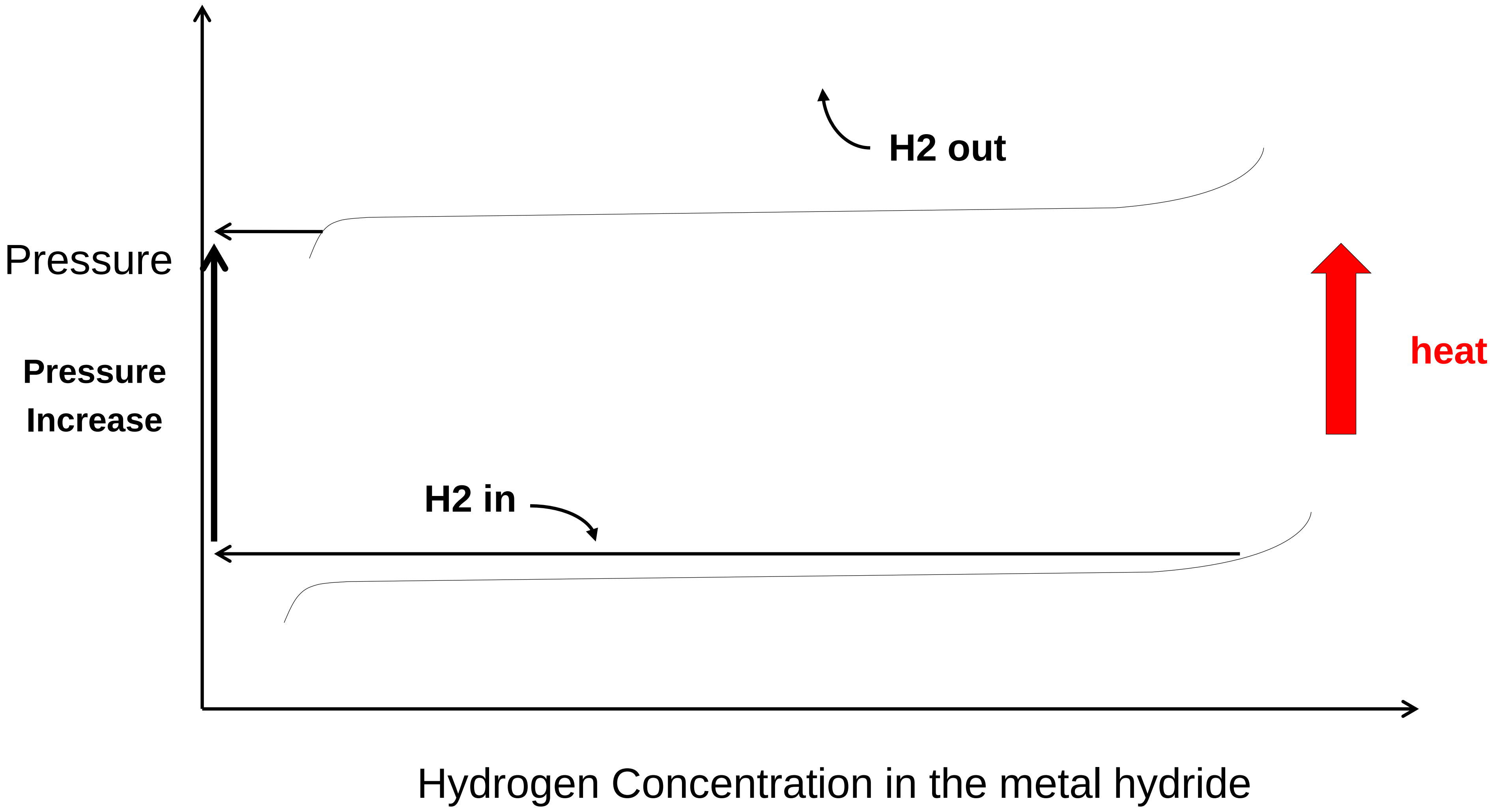
Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

Hydrogen Compressors:

- Ionic liquid piston compressor
- Electrochemical hydrogen compressor
- Hydride compressor
- Piston-metal diaphragm compressor
- Guided rotor compressor
- Linear compressor

Principle Hydrogen Compression using Metal Hydrides

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung



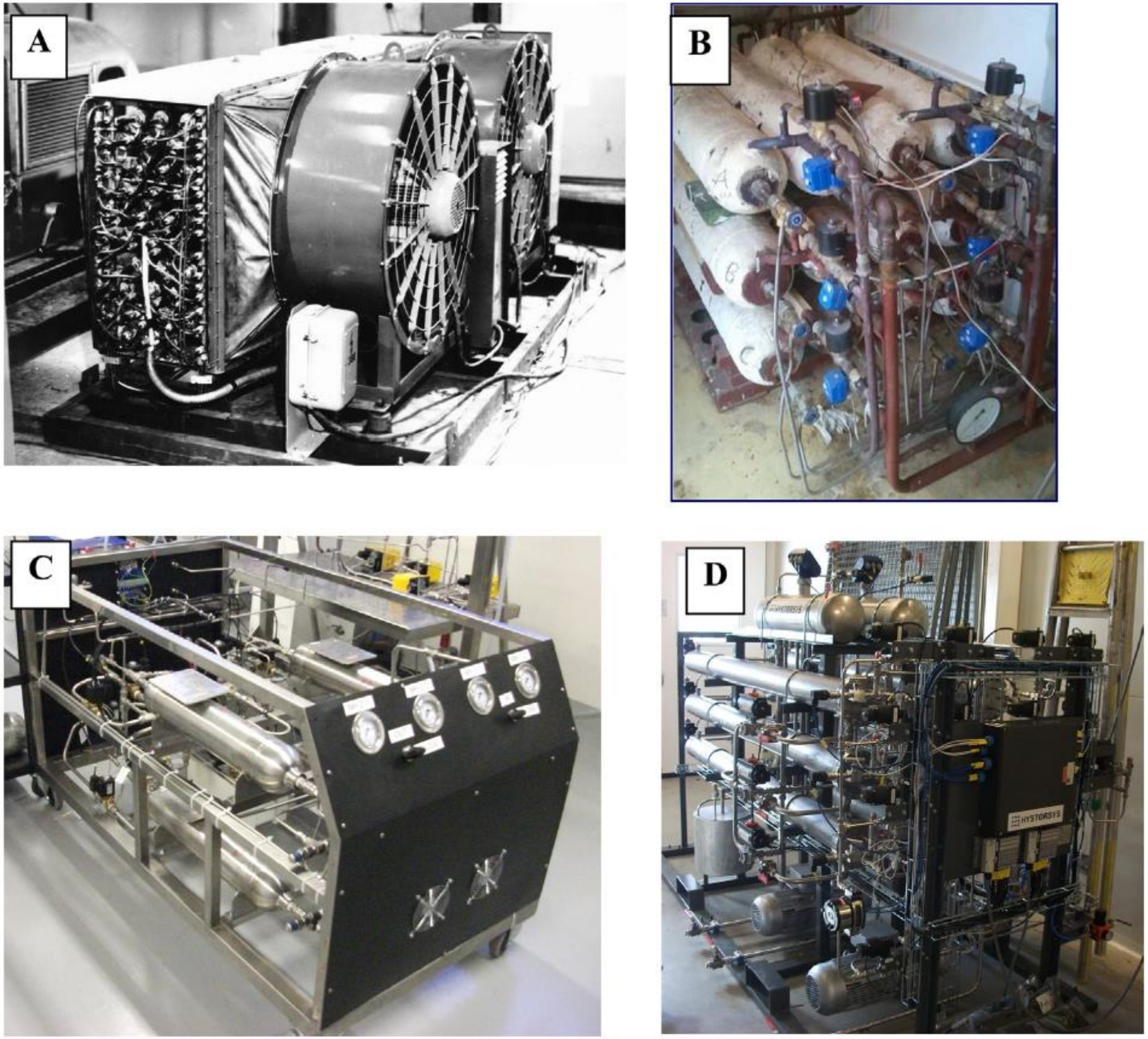
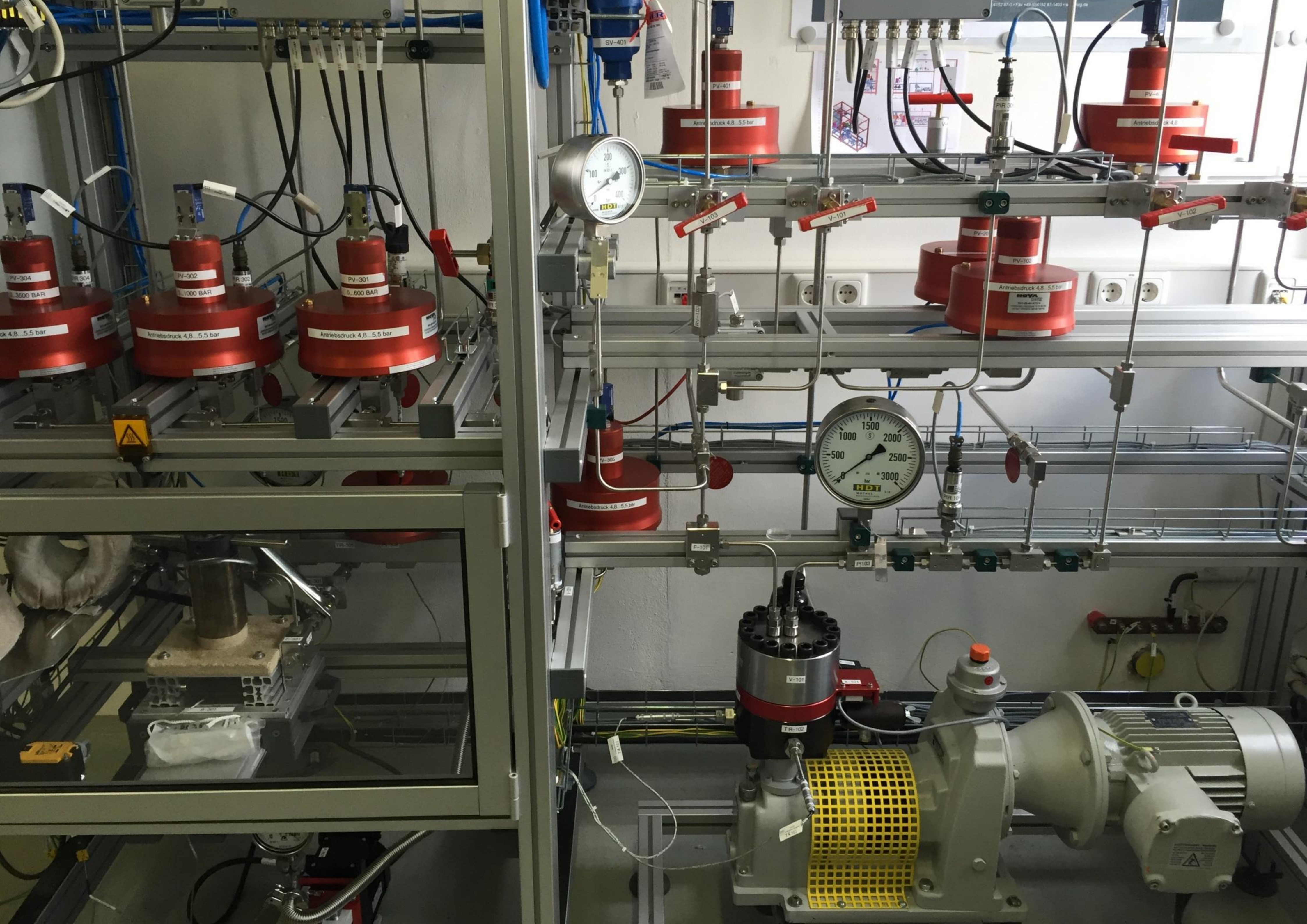


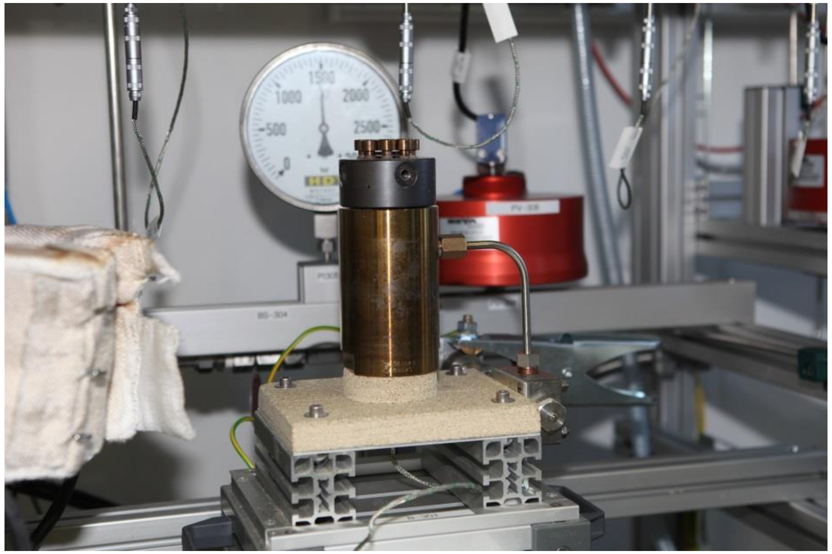
Fig. 17 – Medium-to-large scale MH compressors: A – Institute for Mechanical Engineering Problems of the National Academy of Sciences of Ukraine (1998, 3–150 bar/10 m^3/h) [141]; B – Institute of Problems of Chemical Physics/Russian Academy of Science, Special Design Engineering Bureau in Electrochemistry, Russia (2012, 2–160 bar/15 m^3/h) [58]; C – South African Institute for Advanced Materials Chemistry/University of the Western Cape (2012, 10–200 bar/1 m^3/h) [94]; D – HYSTORSYS AS, Norway (2013, 10–200 bar/10 m^3/h) [188].

HyRig 2000


SV-401
PV-401
Antriebsdruck 4,8...5,5 bar
V-103
V-101
V-102
PV-304
PIR 304
PV-302
...1000 BAR
PIR 302
PV-301
0...600 BAR
PV-305
PV-102
HDT
F-101
PI103
V-101
TIR-102

Operating Conditions: HyRig 2000

- 2000 bar, 500 °C (maximum) with pressure gauges to measure:
  - up to 500 bar
  - up to 1000 bar
  - up to 2000 bar
- Sample holder:
  - 5 kg
  - user friendly
  - fits into the large antechamber
- Unlimited samples but limited users: operational and safety considerations



34

metal hydrides

for

compact hydrogen storage

&

hydrogen compression