2nd SOUTHERN AFRICAN HYDROGEN AND FUEL CELL CONFERENCE 2025

Design and development of metal hydride hydrogen compressors at HYSA systems based at the University of the Western Cape

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HySA Systems
Hydrogen South Africa

SAIAMC
South African Institute for Advanced Materials Chemistry
MAKING RESEARCH WORK

April 7-8, 2025

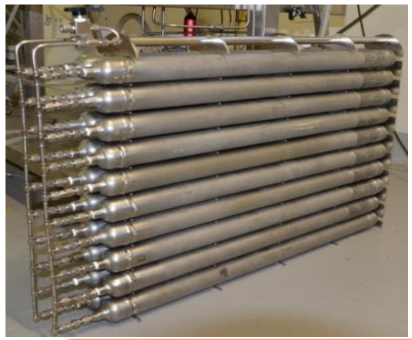
UNIVERSITY of the WESTERN CAPE

HySA Systems : RDI Activities (since 2018)

Department of Science & Innovation

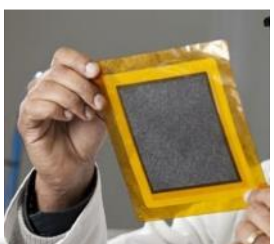
HySA Systems

MH Materials and Technologies
- H2 Storage
- H2 Compression & Refuelling



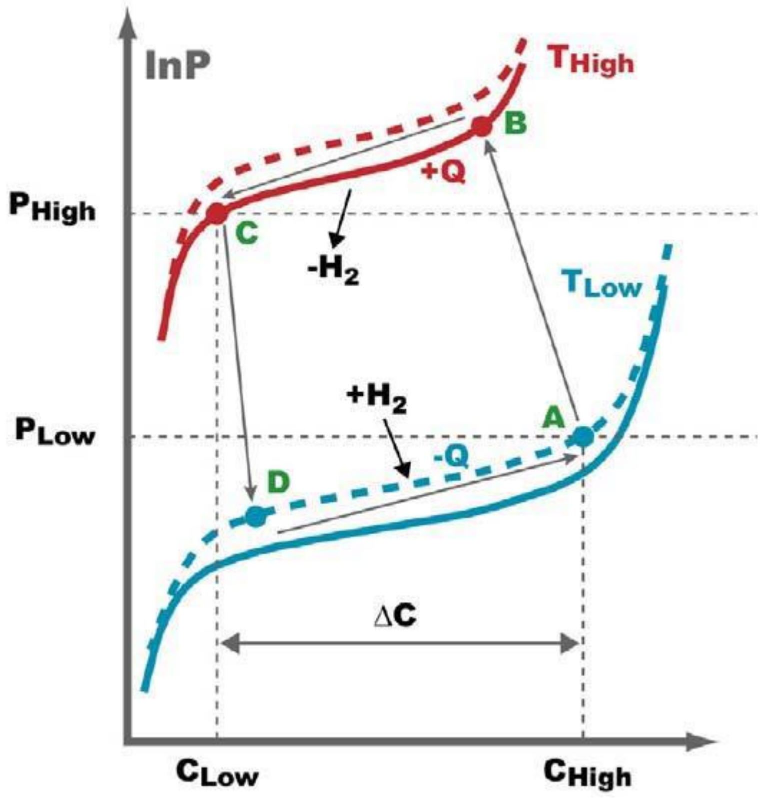
Hydrogen Fuelled Vehicles
- H2 Storage
- PEMFC Stacks
- System Integration
- System Validation
- System/Stack Modelling

Key Technologies



- High Temperature PEM Fuel Cell Stacks (>120˚C)
- HT-MEAs for HT-PEMFCs
- PEM Fuel Cell Stacks
- Solid State Hydrogen Storage (MH)
- Pd-membranes
- Power Modules for Hybrid Hydrogen Fuel Cell Vehicles

How MH compressor works



Hydrogen Concentration

The compression needs a ΔT > 70°C

-The higher the ΔT the higher the compression ratio

The Heat Transfer Fluid (HTF) can be:

- Steam
- Superheated water
- Oil
- Geothermal water
- Other

MH-H_2 Compression

Key Features

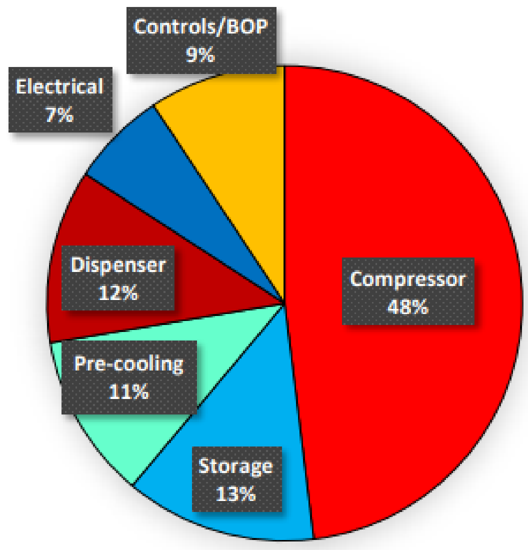
- Almost no moving parts
- low maintenance cost
- high Safety
- Silent / vibration less
- High gas purity
- Utilization of waste heat, almost no energy cost

Key Issues

- MH Materials
- MH Containers / compressor elements
- Layout and operation conditions

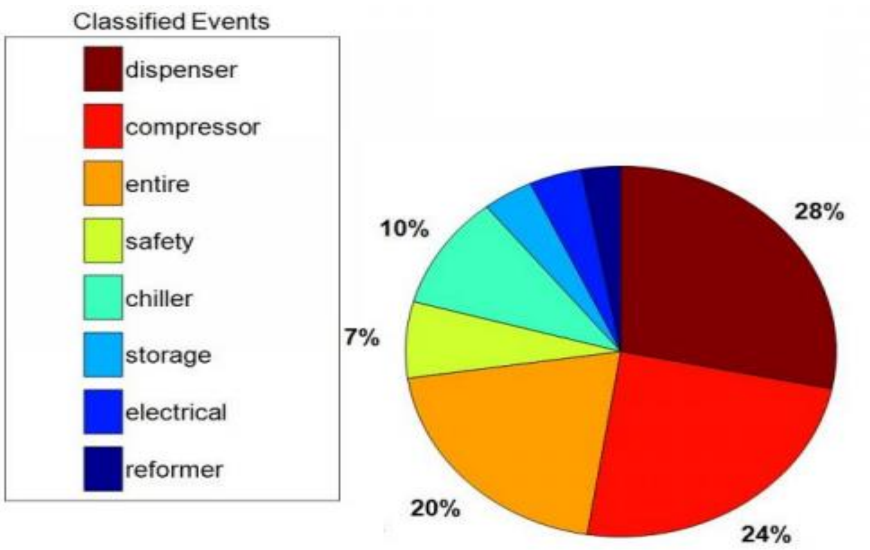
Mechanical H_2 Compressors for refuelling station cost and downtime

Compressor represents 48 % of total Station Cost



700 bar station cost distribution

Compressors are 2nd largest contributors to maintenance hours



Source: HDSAM https://hdsam.es.anl.gov/index.php?content=hd

Production of in-house MH alloys for H_2 storage & compression

Raw Materials

(RE+Ni+M1, or Ti+Zr+M2);

M1=Al, Mn, …; M2=Cr,Mn,Ni,V,Fe,…

Melting

Ingot

Annealing

Crushing & Milling

Screening

Packing

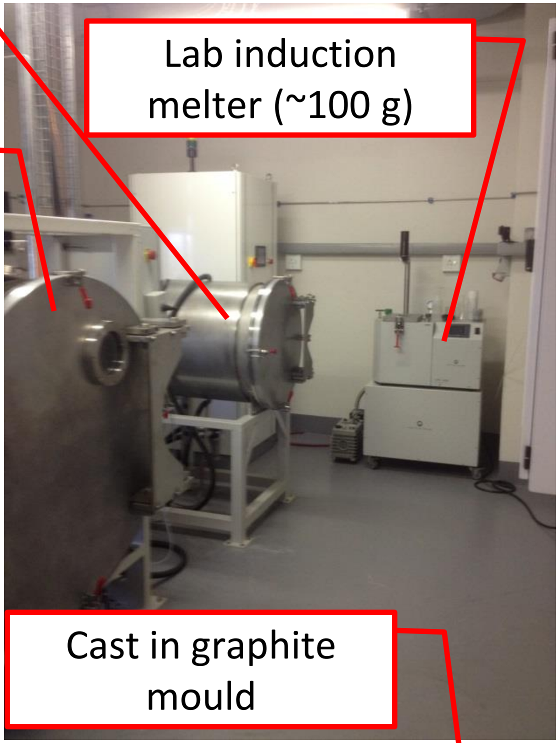
Hydrogen storage alloy powder

Implemented (~15 kg/load)

100% South African hardware

Heat treatment furnace

Induction melter (rotating chamber)



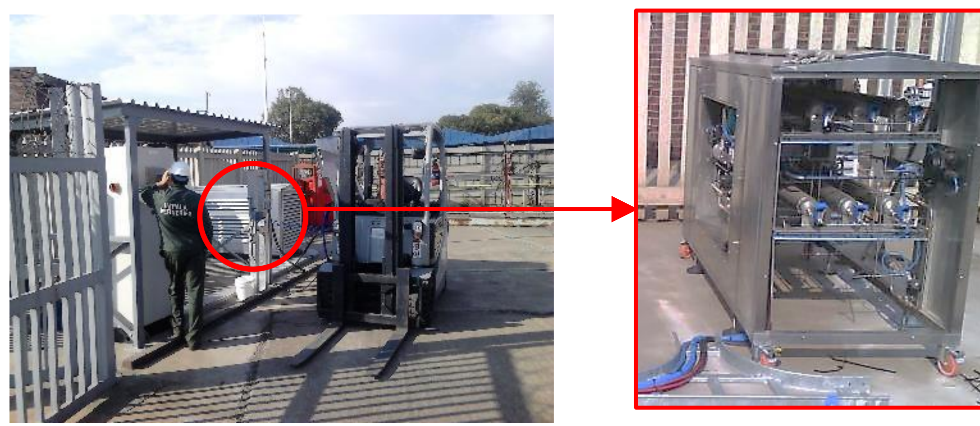
MH H_2 compression technologies developed at HySA Systems

7-200 bar 0.06 Nm^3/h MH H_2 compressor

10-200 bar 1 Nm^3/h MH H_2 compressor

- Series of industrial-scale (up to 200 bar / 15 Nm^3/h) MH H_2 compressors
- Medium-pressure (200 bar) hydrogen refuelling station with integrated MH compressor

3-200 bar 5 Nm^3 H_2/h MH H_2 compressor for industrial applications



50-200 bar 13 Nm^3 H_2/h MH H_2 compressor integrated in hydrogen refuelling station

Development of MH compressor for integration into HRS for refuelling of FC Forklift

Tests of stage 1 MH container for hydrogen compression

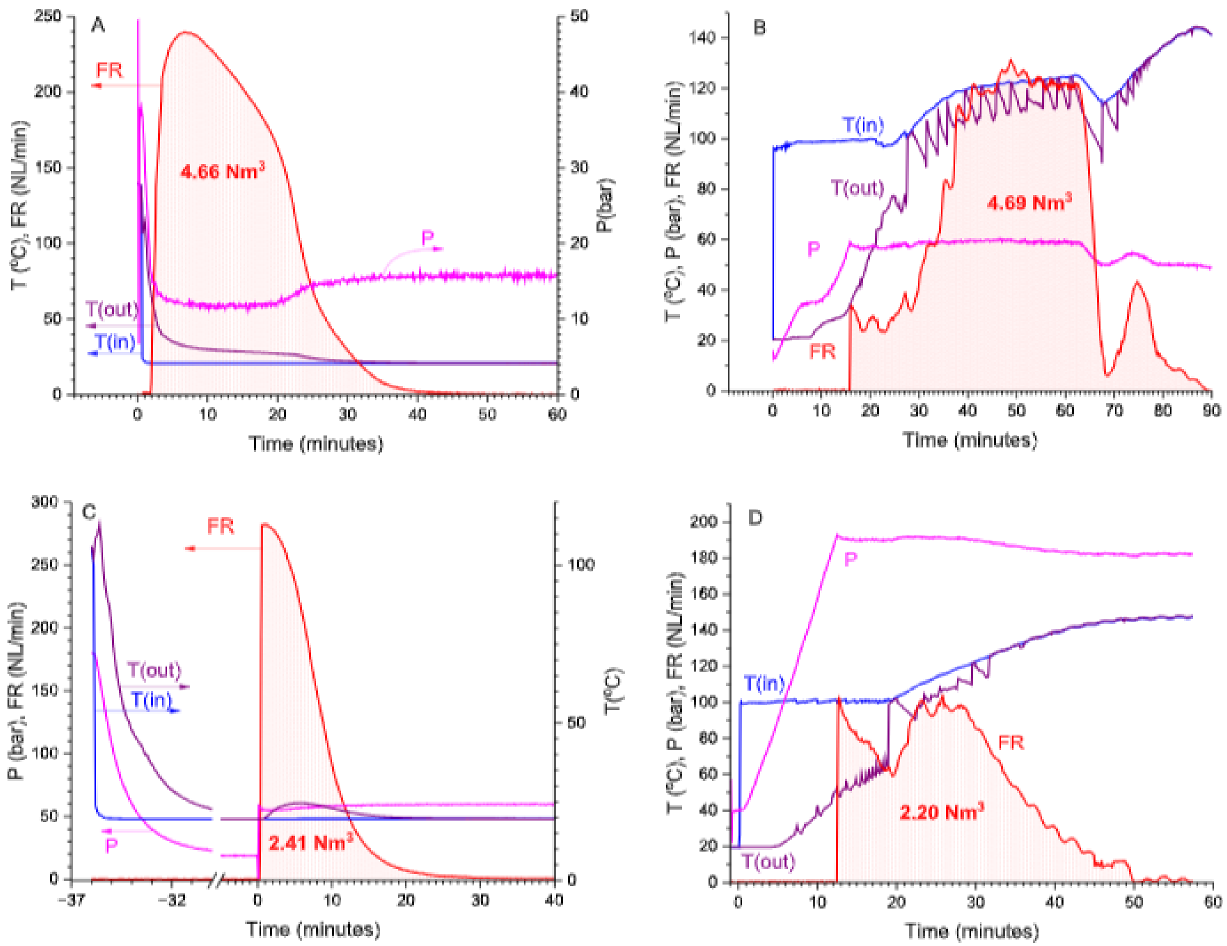
2 – Stage MH compressor

- Productivity 100 kg H_2/day (47 Nm^3/h)
- Output pressure 185 bar
- Input pressure 15 bar

Stage 1 MH container
- 2.5 m long, inner volume of 9,11 cm^3
- Maximum operating pressure 100 bar
- AB_5 –type alloy 32 kg

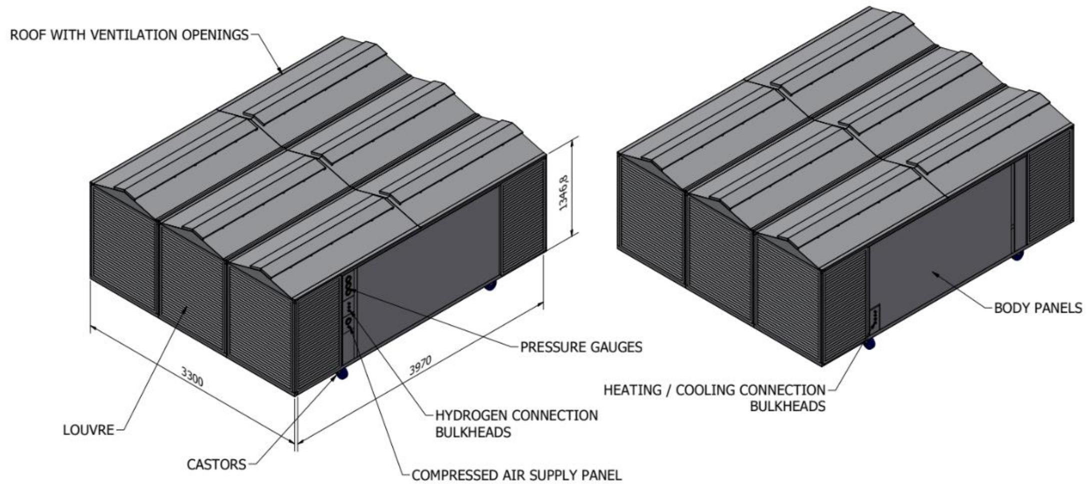
Stage 2 MH container
- 2.5 m long, inner volume of 7,81 cm^3
- Maximum operating pressure 200 bar
- AB_2 – type alloy 22 kg

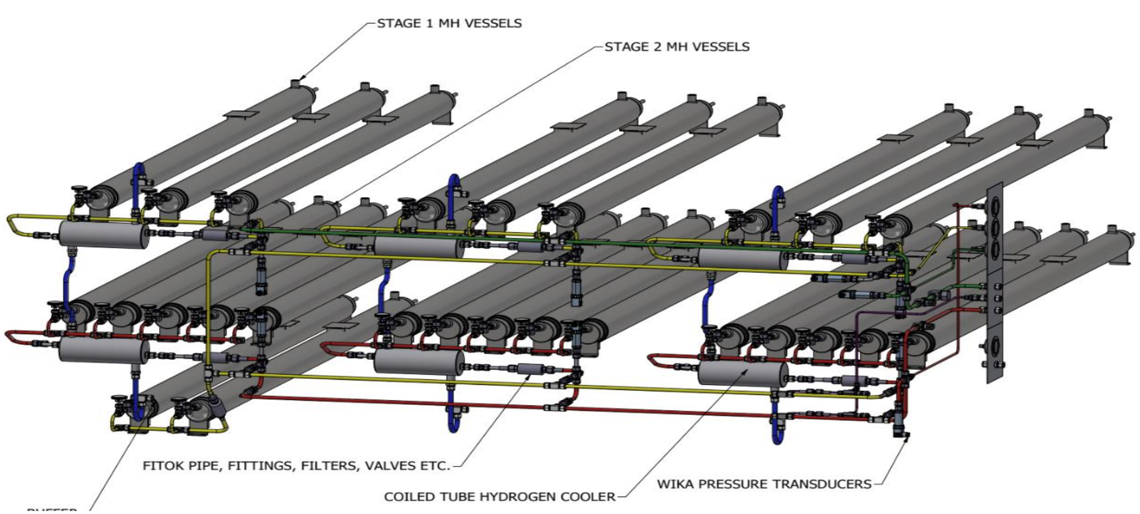
MH containers for H2 Compression
Stage 1 and 2 test results



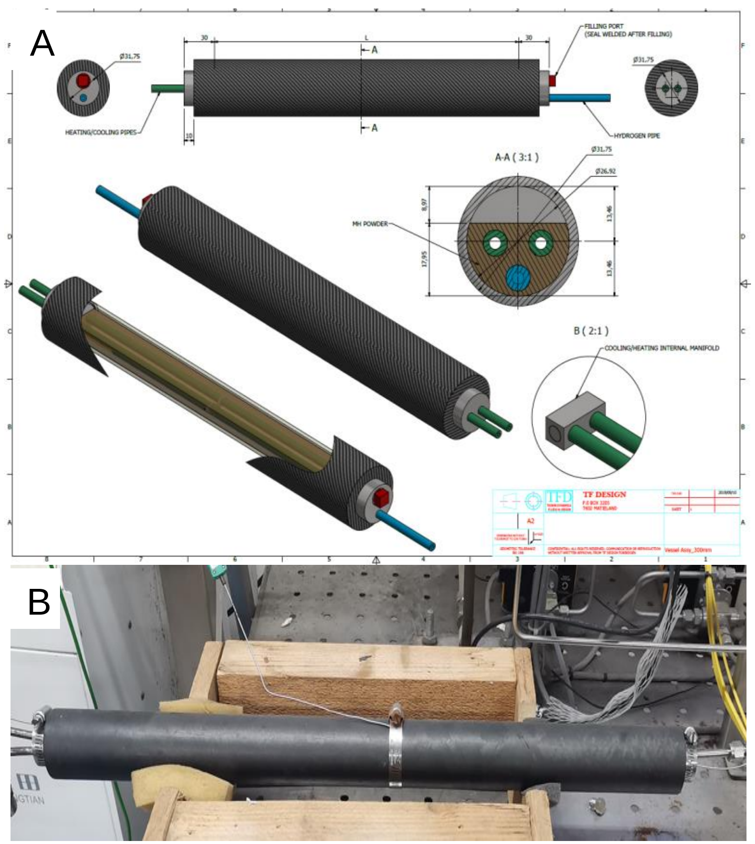
Hydrogen absorption (A,C) and desorption (B,D) performance of metal hydride containers for H2 compression in stage 1 (A,B) and stage 2 (C.D)

Concept Design for MH Compressor with productivity of 100 kg H_2/day





Design of High-Pressure Composite MH Container



High-pressure (up to 1000 bar) MH container for hydrogen compression developed by HySA Systems.

MH Container material and dimensions:

- Standard stainless steel core, with carbon wounding
- Container length: 600 mm
- Internal diameter: 26,92 mm
- Total void volume: 284,4958 ccm

High Pressure Test of Composite MH tank

- **Stage 1: pressure tests at T=23 ˚C**
    - No leaking at P=500, 1000 and 1500 bar for 5 minutes at each point;
    - Leak followed by the rupture of connection fitting between 1600 and 2000 bar; the container remained intact.
- **Stage 2: pressure tests at T=150 ˚C**
    - No leaking at P=500 and 1000 bar for 5 minutes at each point;
    - No leaking at P=1500 bar for 15 minutes;
    - Leak followed by the rupture of connection fitting between 1600 and 1900 bar; the container remained intact.

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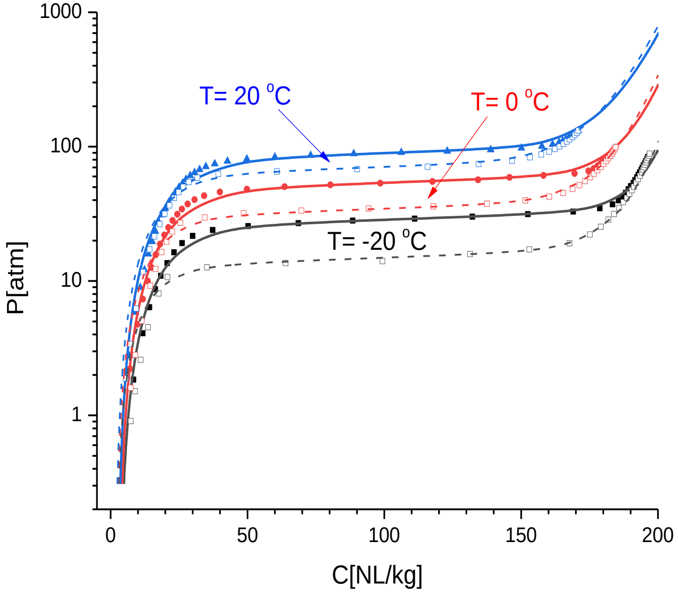
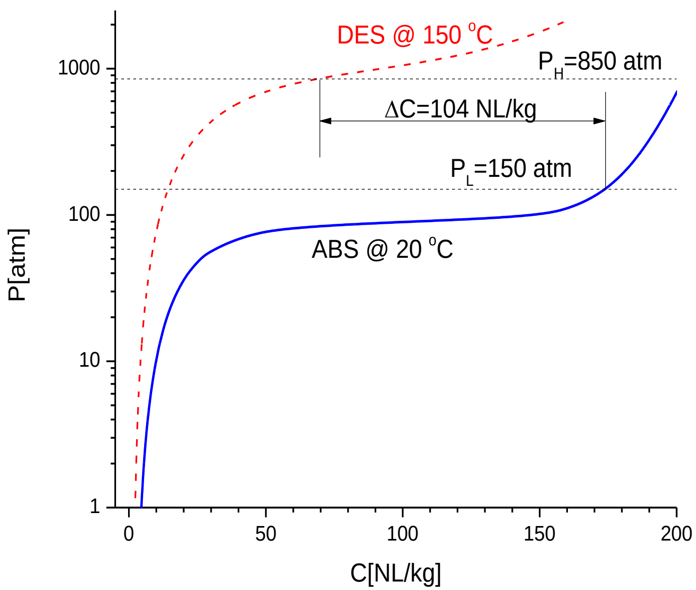
H_2 sorption studies of Ti based AB_2 MH alloy

AB_2 intermetallic (A=Ti+Zr, B= Cr+Fe+Mn+Ni)

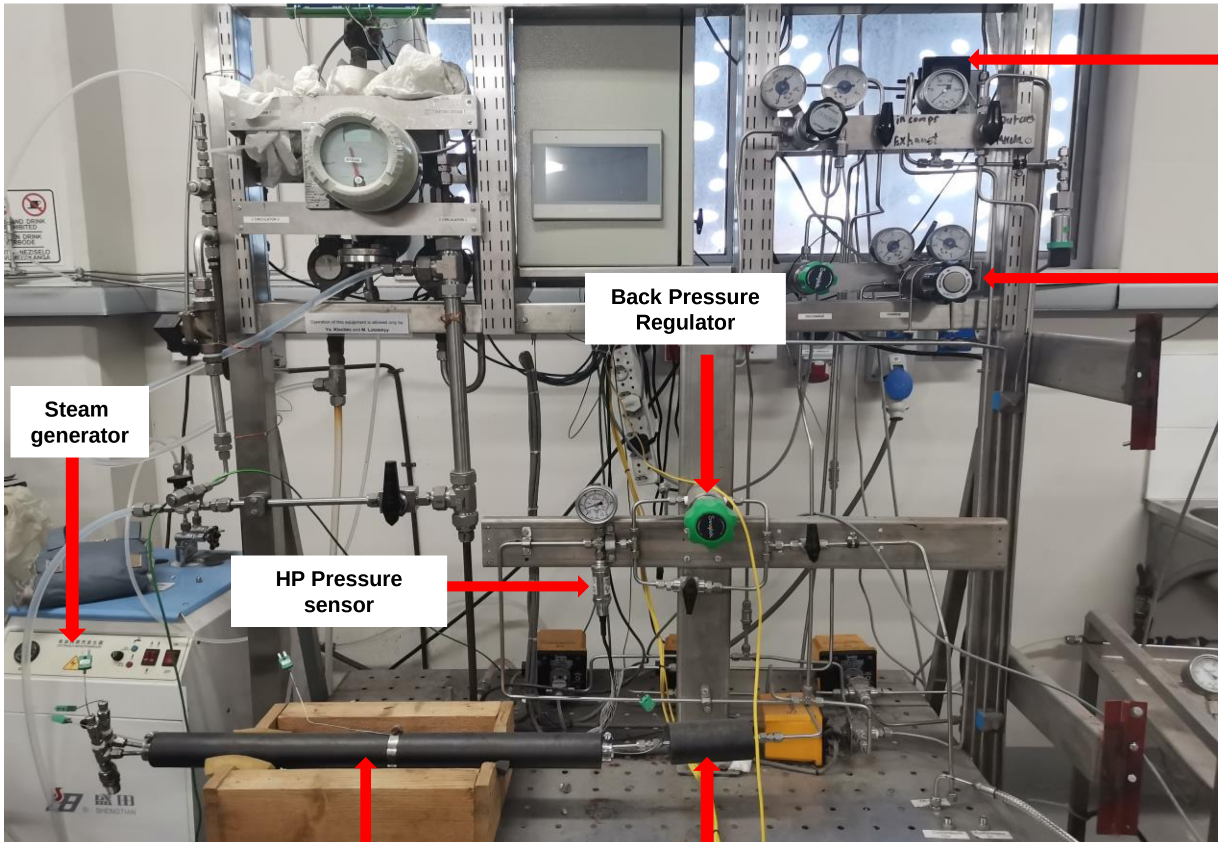


Experimental PCT data for this alloy taken in the range T= –20, 0 and 20˚C, P = 0.1 - 200 bar



Calculated isotherms of H_2 absorption at T_L = 20 ºC and H_2 desorption at T_H = 150 ºC

Experimental set-up for testing high-pressure MH Containers



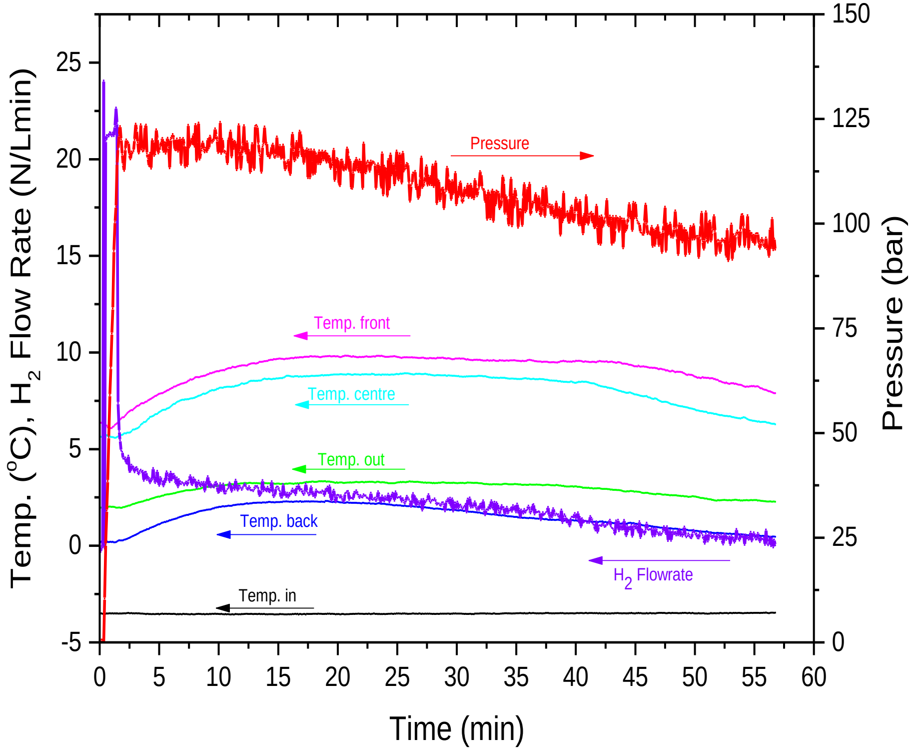
Mass flow controller

High Pressure Gas regulator

HP MH Composite Container

High-pressure filter

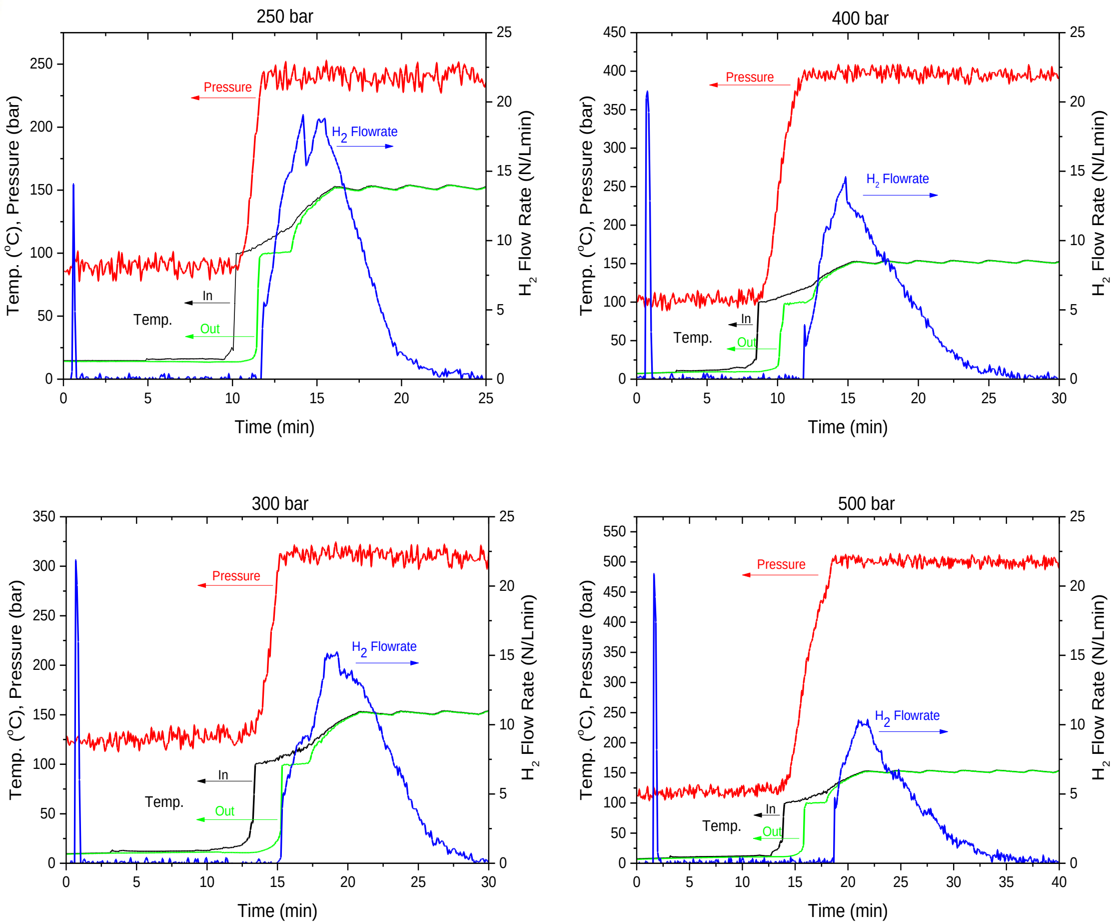
Hydrogen Absorption of Composite MH Tank



Hydrogen absorption was performed at:

- -5 °C using a cooling refrigeration bath, which circulated the cooling liquid through the MH tank.
- H_2 sorption pressure was set to 110 bar.
- Total amount of H_2 absorbed was 135 NL.

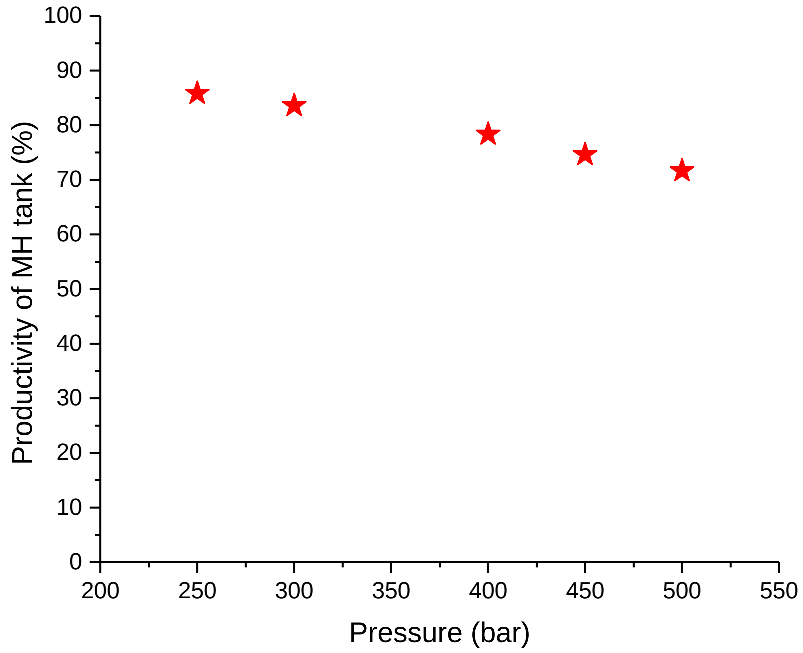
Hydrogen Desorption of Composite MH Tank at Different Backpressure Settings



H_2 Desorption of the MH tank:

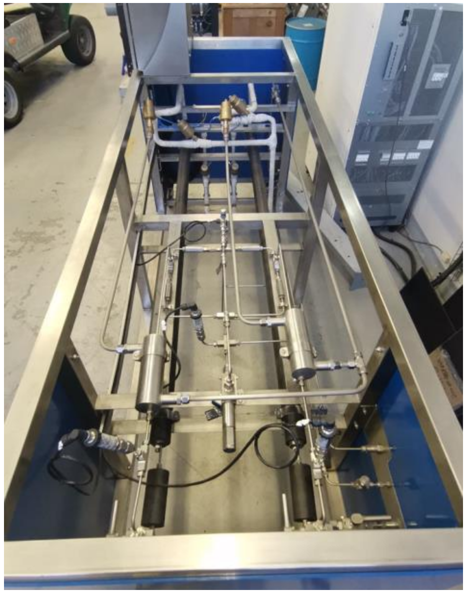
- Desorption was carried out at 150 °C.
- Backpressure regulator was used to control output pressure of the MH tank at 250, 300, 400 and 500 bar.
- The total amount of H_2 desorbed was 115, 112, 105 and 96 NL respectively.

Productivity of the Composite MH tank at different Pressures



The cycle productivity for the composite MH tank at different pressures 250, 300, 400, 450 and 500 bar was 85.82, 83.58, 78.36, 74.62 and 71.64 %

Integration of HySA Systems solutions into high-pressure hydrogen refuelling



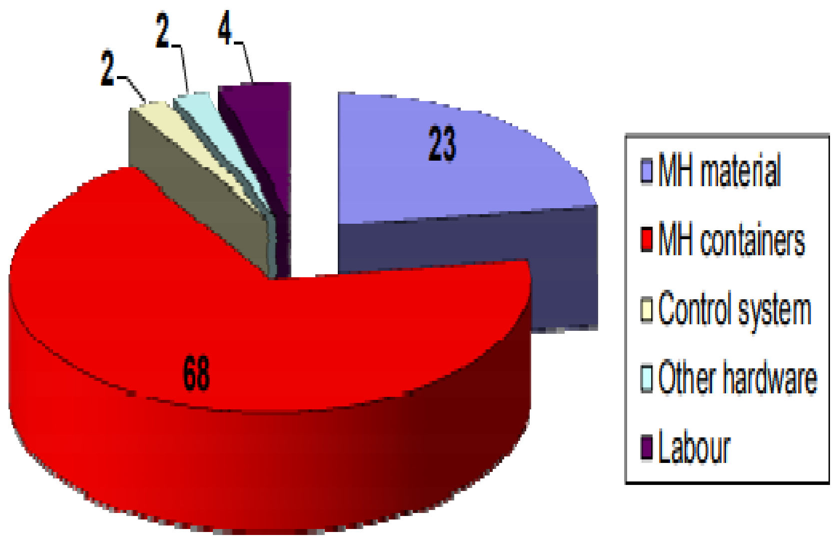
General views of the Prototype high-pressure MH H2 compressor

Prototype high-pressure MH hydrogen compressor:

- Hydrogen compression: 100 – 800+ bar
- Operating temperature range: 20–150 ˚C
- Estimated capacity: up to 1 Nm^3/h

MH-H_2 Compressor Cost Breakdown

Cost breakdown (in%) for Prototype MH compressor developed at HySA Systems



Thank you for your attention

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