COSMHYC XL
INNOVATIVE H2 COMPRESSION

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Project acronym: COSMHYC XL

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COmbined hybrid Solution of Metal HYdride and mechanical Compressors for eXtra Large scale refuelling stations

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Deliverable 6.5
Public report on the hybride compressor

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PU	Public	X
PP	Restricted to other programme participants (including the FCH2 JU Services)	
RE	Restricted to a group specified by the consortium (including the FCH2 JU Services)	
CO	Confidential, only for members of the consortium (including the FCH2 JU Services)	

Table of content

Introduction

The COSMHYC-XL project aimed at developing a hybrid compression concept for HRS with a combination of a baseload Metal Hydride Compressor (MHC), enabling a high level of reliability thanks to the absence of moving parts, and a new Mechanical Compressor (MC), enabling very large flow rates.

This document presents the overall hybrid solution developed and tested in the frame of the project.

Disclaimer

This report was created within the COSMHYC XL project.

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1. Objectives of the deliverable

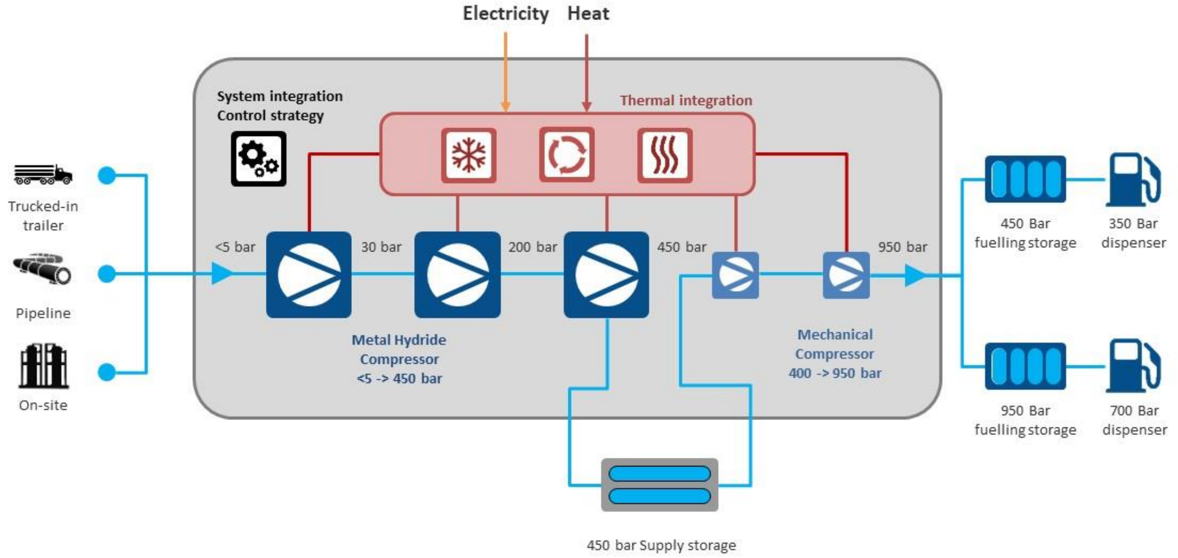
In the frame of the COSMHYC XL project, a hybrid hydrogen compression concept was developed, built and tested. This deliverable aims at introducing this hybrid concept as well as presenting the return of experience gathered during the test phase.

2. Hybrid concept developed in the frame of the project

The hybrid concept developed in the frame of the COSMHYC XL project consists of combining 2 different technologies in order to achieve an optimal compression concept for Hydrogen Refueling Stations (HRS):

- A **metal hydride compressor** (see D5.7) serving as a **base-load compressor** with a **high compression ratio** to perform the first compression stages up to **450 bar**
- A **diaphragm mechanical compressor** serving as a **booster** with a **low compression ratio** to perform the final compression stage up to **950 bar**.

The overall concept is illustrated below.

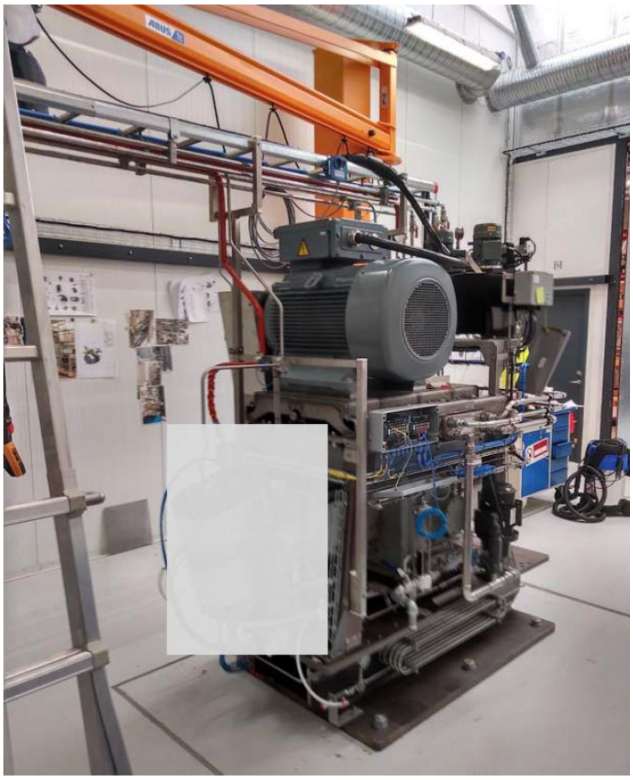


This concept enables to benefit from the advantages of both technologies:

- The metal hydride compressor is very efficient thanks to the use of waste heat, e.g. coming from the hydrogen production unit, or heat from heat pumps, and its energy consumption is not directly impacted by the inlet pressure, which makes it well adapted to low inlet pressures. In addition, it has low O&M costs and down-time thanks to the absence of moving parts, which makes it well adapted to base-load operation. Finally, it produces no noise disturbance.
- The mechanical compressor enables to reach high flow rates at a high inlet pressure, with a limited energy consumption, as its energy consumption is inversely proportional to the inlet pressure. In addition, it can easily perform starts and stops and can therefore be well adapted to an operation as a high-pressure booster.

3. Presentation of the prototypes

The mechanical prototype developed in the project is presented in the frame of the dedicated deliverable 4.6. It is illustrated below.



The metal hydride compressor prototype developed in the project is presented in the frame of the dedicated deliverable 5.7. It is illustrated below.

Both compressors were operated on separated test sites but the analysis of their performances enabled to confirm their ability to work together as a combined solution.

4. Return of experience gathered during the test phase

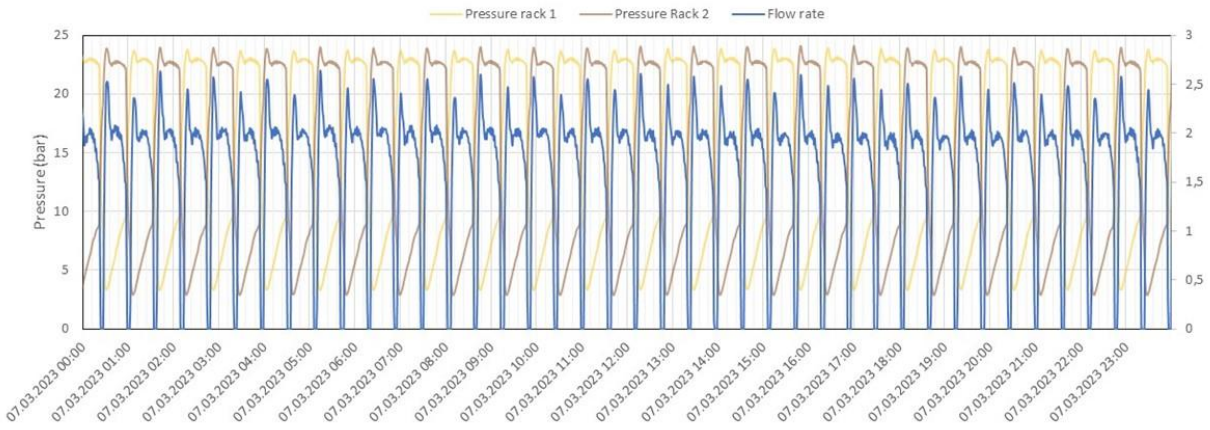
Both prototypes were tested separately on different test sites, in Denmark and Germany.

The mechanical compressor was successfully tested and enabled to demonstrate a strong increase in life time, while drastically reducing production costs at scale, as further highlighted in other deliverables.

- 2 stage & duplex configurations were tested and proved the flexibility of the technology
- Flow rates of up to 120 kg/h could be successfully demonstrated
- An outlet pressure of 950 bar could be demonstrated, with inlet pressures varying between 50 and 450 bar.

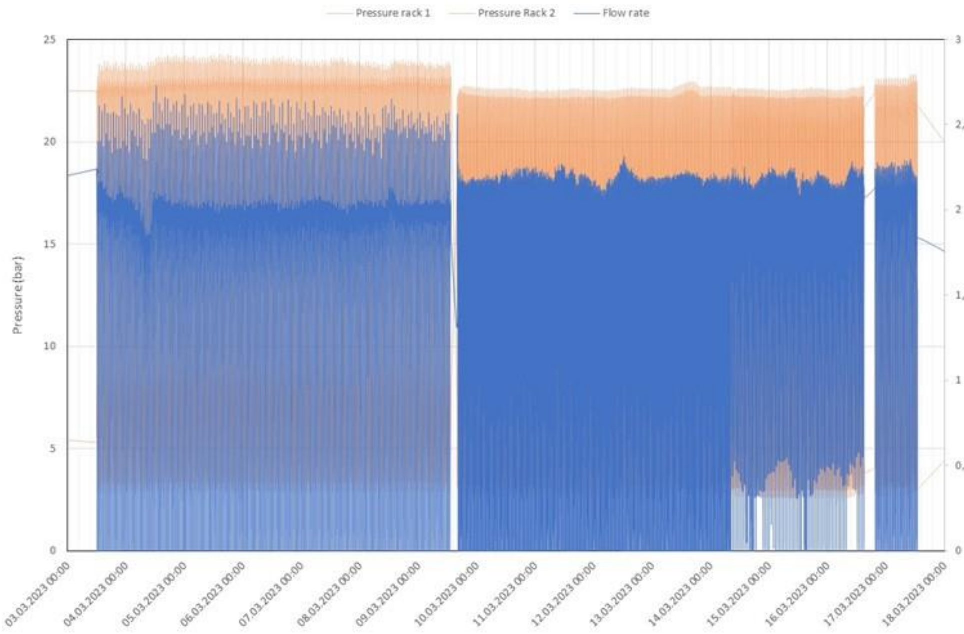
Particular attention was paid to the metal hydride compressor, as it is the most innovative part of the project:

- More than **1000 compression cycles** were performed on the compressor with either one stage or combined stages, a strong improvement compared to previous project COSMHYC. The compressor could be operated as a stand-alone machine, on a 24h/day basis, thereby proving the reliability of the overall system integration as well as the control strategy. Particular attention was paid to the reproducibility of the cycles, which proved to be very high, as can be observed below.



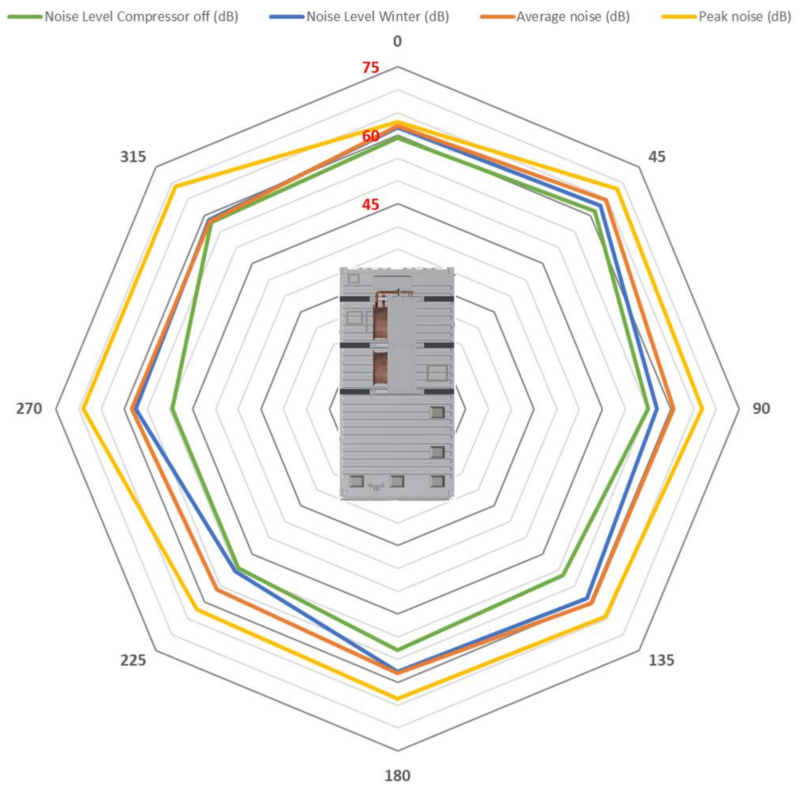
Example of day of operation of 1 stage of the compressor in automatic mode.

- **Degradation** was investigated: even if it is difficult to assess degradation under outdoor operation, due to variable climatic conditions (e.g. changes of outdoor temperature impacting the cooling temperature of the hydrides and the thermal losses), it can be stated that no degradation could be observed during the entire test phase, neither in the compression ratios obtained, nor on the flow rates. This is a highly promising result for future commercialisation. As an example, the pressure behaviour of 1 compression stage during about 2 weeks is illustrated below, and it is clearly visible that the outlet pressure is very stable (NB: short-term variations are visible on the graph and are mostly explained by climatic variations, but are not a sign of degradation, as previous pressure values recover after a while).

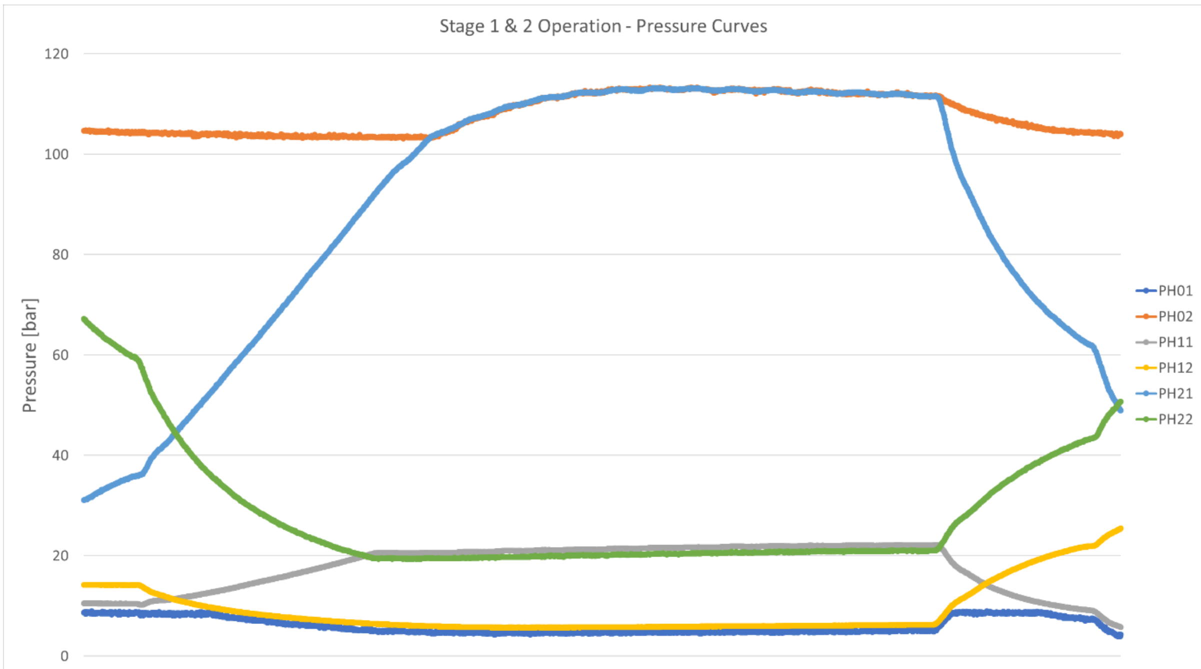


Example of 2 weeks of operation of 1 stage of the compressor in automatic mode.

- It was also possible to investigate the **noise disturbance**. The metal hydride compressor generated only 5 to 11 dB more than the environment background noise, which is very limited. In addition, most of the noise was due to the roof-mounted dry cooler, which would be present anyway in most hydrogen installations, so that the metal hydride compressor produces almost no additional noise disturbance, making it a very interesting technology in terms of social acceptance. The noise measurements are illustrated below.



- The combination of different stages was investigated. It was possible to demonstrate the capacity of the machine to effectively combine different stages to produce overall higher compression ratios. One cycle of 2 combined compression stages is illustrated below.



Example of 2 compression stages combined

One important **return of experience** is that the **definition of the service pressure** of the hydrogen components and pipes in the intermediary parts of the gas integration between different stages was identified as **a key element of stability for the system:** if the service pressure is too close from the expected nominal pressure of the lower compression stage, it may happen that the equilibrium pressure between both stages becomes in some cases higher than the service pressure, causing safety valves to open. On the other hand, defining too high service pressure induces higher costs. **Therefore, the optimal combination of cost optimisation and operation flexibility represents a major potential for improvement towards commercialisation.**

- The tests on the 3rd compression stage were affected by a significant leakage during the commissioning phase, but it was however possible to demonstrate the achievement of pressure values above 400 bar. This highlights the importance of system integration and BoP: the hydrogen industry still needs to consolidates and provide ore reliable basic components, such as fittings, sensors, flow meters etc.

- Various **flow rates** were observed depending strongly on the overall operation conditions. Average flow rates of up to 4.25 kg/h could be observed. In some peak cases (e.g. when a low-pressure bottle was placed downstream of the compressor), peak flows of up to >20 kg/h could be measured.

5. Overall conclusion

In the frame of the COSMHYC XL project, long-term tests were successfully performed on both the MHC and the MC. Regarding the MHC, more than 1000 cycles were successfully achieved.

- Overall compression ratios of more than 100 were observed, compared to 15 in the previous COSMHYC project
- No significant degradation was observed during about 1000h of operation, which is highly promising for future commercialization
- The overall system integration proved to be very reliable, confirming the strong added value of the technology in terms of maintenance costs.

The mechanical compressor demonstrated its adaptability to the combination with metal hydride compression and its adequation to the needs of a HRS.

- 2 configurations were successfully tested: 2-stage & duplex.
- Flow rates of up to 120 kg/h were successfully demonstrated.

The overall achievements of the project compared to previous project COSMHYC are summarized below.

	COSMHYC	COSMHYC XL
Stages	2	3
Compression ratio	15	>100
Operation time	~140 cycles	~1100 cycles
Cycling time	1,5 h	1h
Flow rate MHC	up to 2,2 kg/h	up to 4,25 kg/h
Short time peak flow rate MHC	7,4 kg/h	> 20 kg/h
Flow rate MC 450-> 950 bar	60 kg/h	120 kg/h

As a whole, COSMHYC XL successfully paves the way to large-scale pre-commercial demonstration, which will be done in the frame of the follow-up project COSMHYC DEMO.