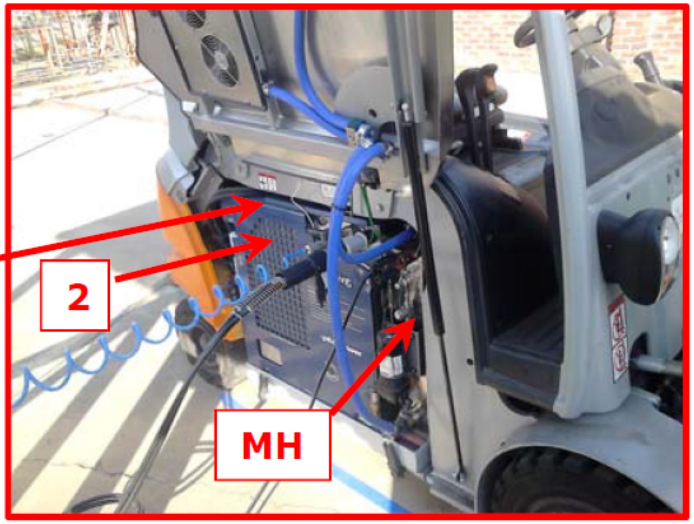
HORIZON 2020

M.Lototskyy
HYDRIDE4MOBILITY
Project concept, plan and collaboration, milestones and deliverables



IFE: kick-off meeting HYDRIDE4Mobility

February 23, 2018

Project Goal and Challenges

An ultimate goal of this project is the development of hydrogen energy systems with improved efficiency, based on the advances in hydrogen storage and compression technologies for promising niche applications: hydrogen fuelled utility vehicles (forklifts) and systems for their refuelling for industrial customers.

In order to achieve the stated goal, solutions for several technical challenges associated with the following areas of activities are required:

- Compact and efficient on-board storage of hydrogen fuel and its uninterrupted supply at the required pressures and flow rates.
- Fast refuelling; safe, reliable and inexpensive hydrogen refuelling infrastructure.
- Optimisation of the efficiency of Balance-of-Plant (BoP) and integration of the on-board power modules comprising MH hydrogen storage and fuel cells.

MH for FC forklifts: Motivation

CGH2 | **MH**

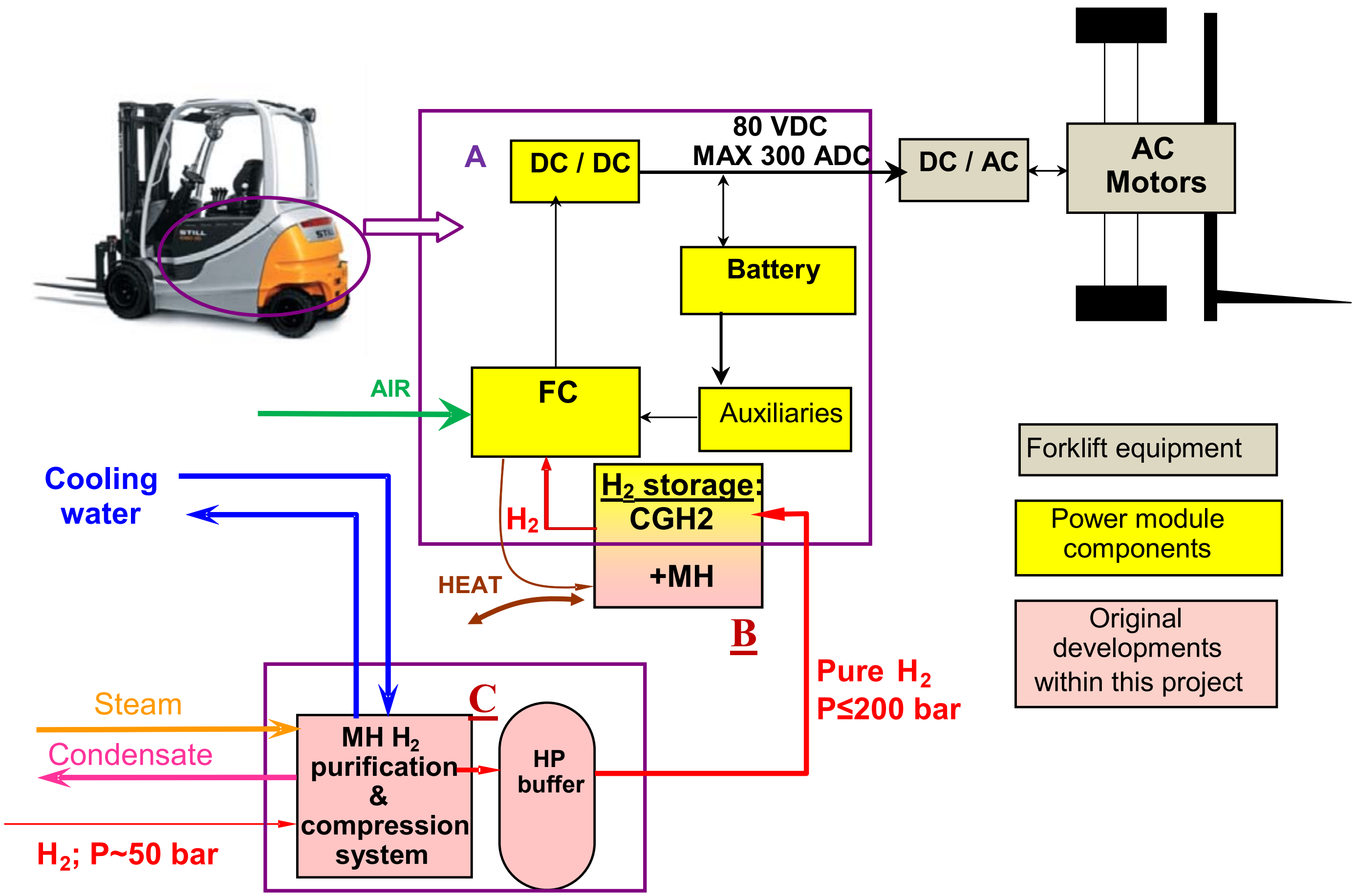
CGH2

- Approved technology, prototypes available (Plug Power, H2Logics, Proton Motor, PearlHydrogen);
- Fast refuelling;
- Safety and refuelling infrastructure (filling H_2 pressure ~350 bar);
- Space constrains;
- Additional counterbalance required (forklift operation safety).

MH

- Compact + heavy: intrinsic solution of the counterbalance problem;
- Safety (lower standby H_2 pressure);
- Simpler refuelling infrastructure (filling H_2 pressure <200 bar);
- Limitations of charge / discharge rates (heat transfer issues).

Background (UWC+ Implats): System Concept

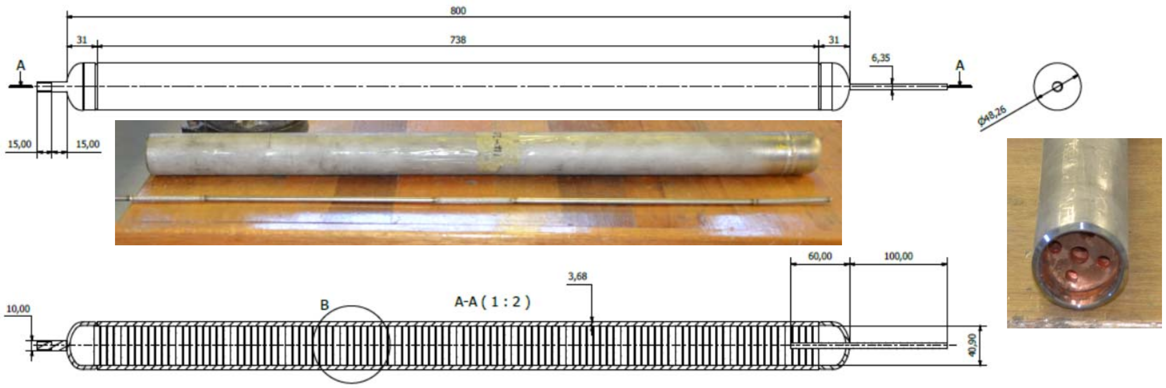


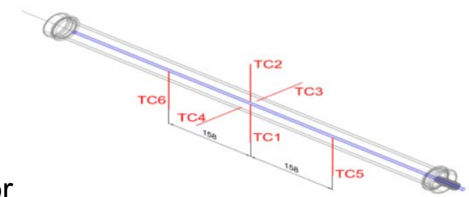
- STILL RX-60-30 electric forklift, 3 ton lifting capacity, 80 VDC bus voltage.
- Commercial on-board fuel cell power module (**A**; GenDrive 1000 160X-80CEA / Plug Power) replacing the forklift battery and equipped with:
  - built-in CGH2 hydrogen storage system and
  - MH hydrogen storage extension tank (**B**).
- Stationary hydrogen refuelling system (**C**) consisting of a low-pressure H_2 supply and a MH hydrogen compressor.

IMPLATS Distinctly Platinum

HySA Systems Hydrogen South Africa

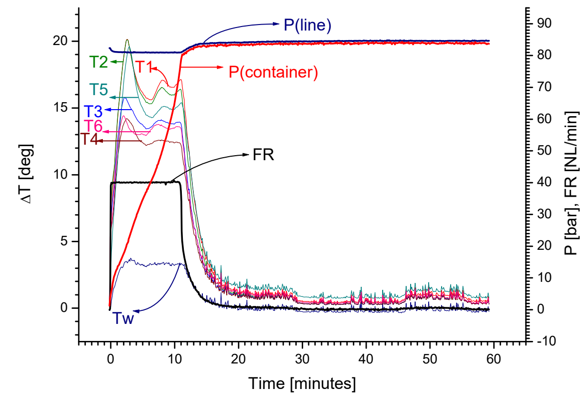
MH container (H storage)



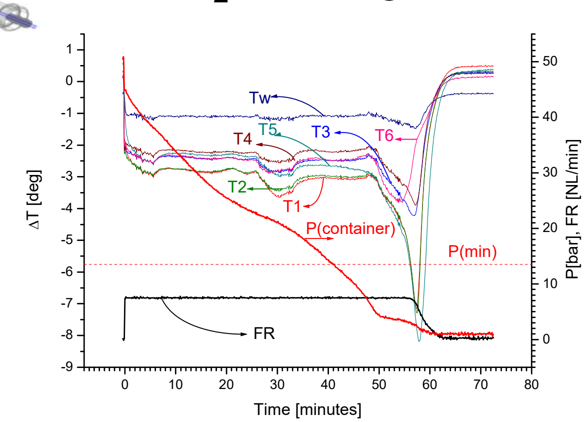


- Advanced solutions including:
  - Cylindrical SS container with transversal Cu fins; external water heating / cooling;
  - Additives to main MH material (powder mixture or compact).
- Validated by the modelling & tests of a prototype MH container.
- H storage capacity > 500 NL.
- Charge time <15 minutes @ $P(H_2)$>80 bar and T_0=30°C.

H_2 charge



H_2 discharge



THERMODYNAMICS FLUIDS & DESIGN

HySA Systems
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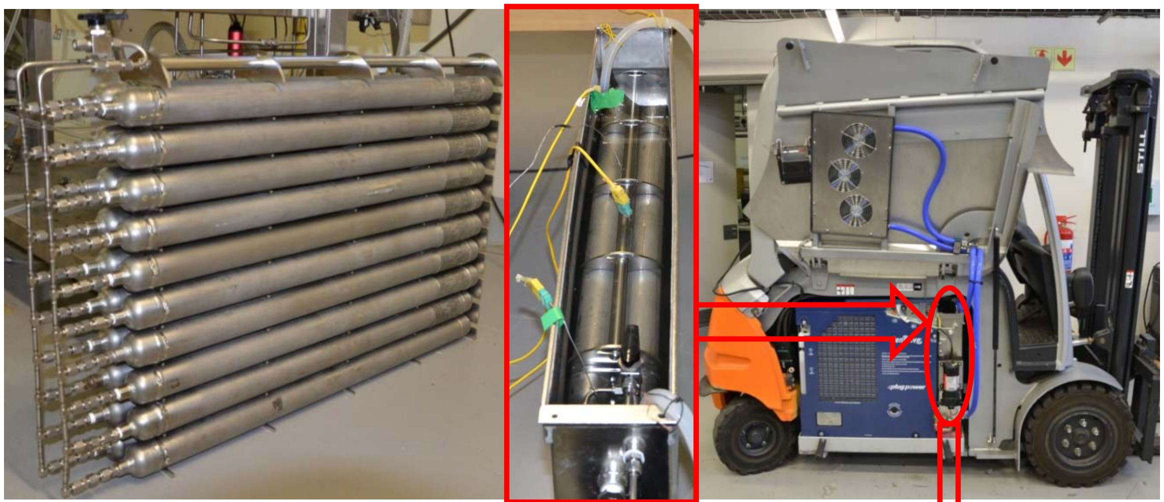
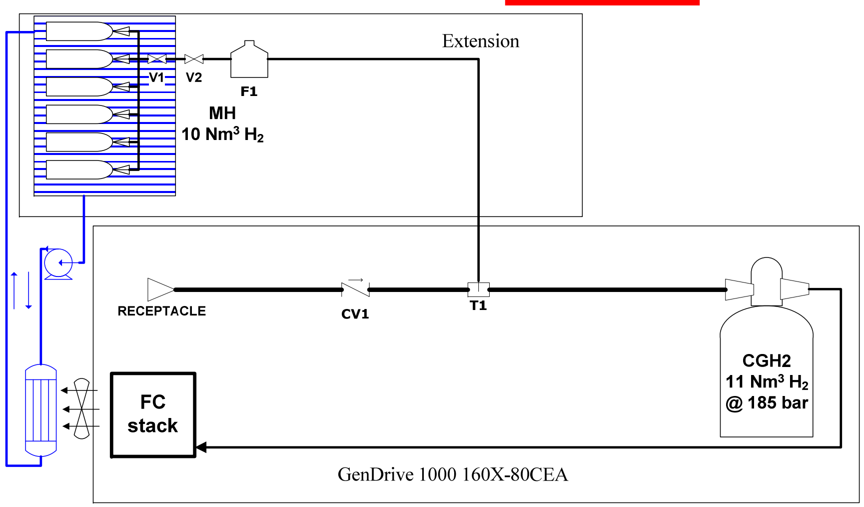
MH H storage tank





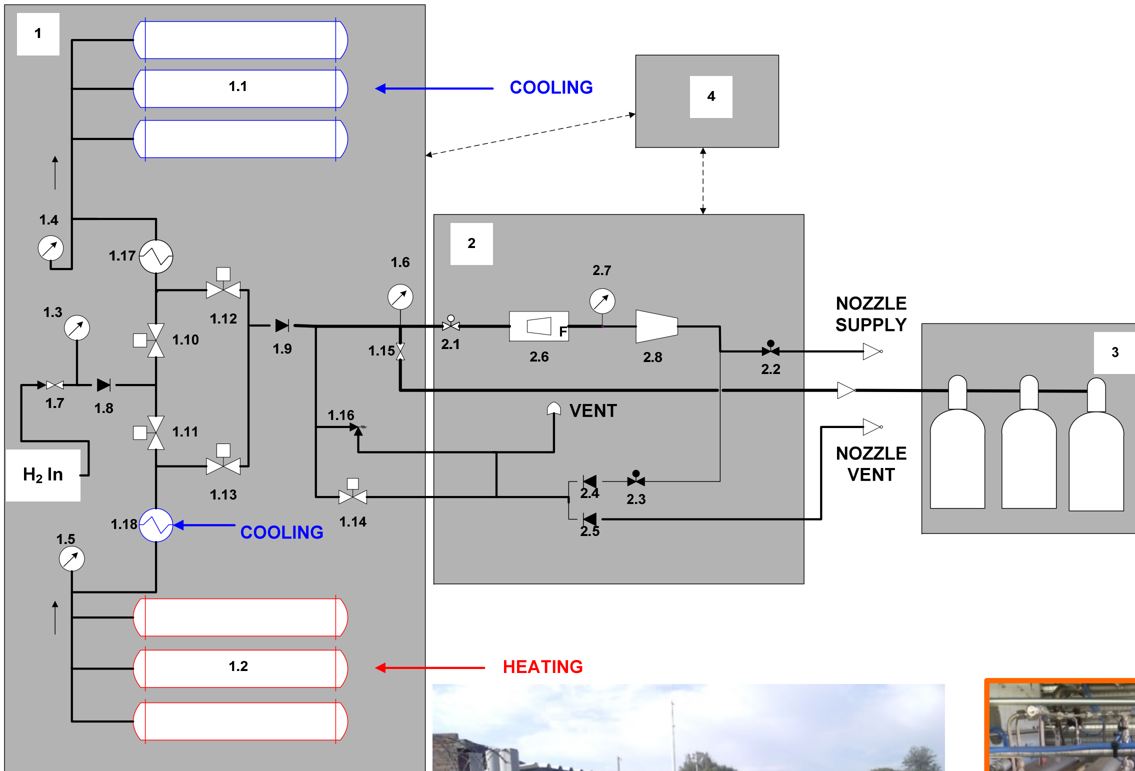
- Assembly of 20x MH containers connected in parallel to gas manifold.
- The assembly is submersed in external water / glycol tank providing thermal control during the charge (cooling with ambient air) and discharge (heating from the FC stack).
- Dimensions 950 (L) x 120 (W) x 700 (H) mm; weight ~200 kg.
- The tank is fitted in the forklift in the space remaining vacant after the installation of the GenDrive power module.
- The total weight of the power module and the extension tank is ~1800 kg that provides sufficient counter-balance for the safe forklift operation when lifting up to 3 tons.
- Only minor changes in high-pressure H_2 system of the GenDrive power module.
- 21 Nm^3 H_2 total capacity at charge pressure of 185 bar (for CGH2 only ~19 Nm^3 @ 350 bar).

IMPALA PLATINUM

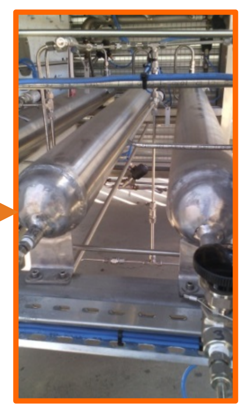
TFD THERMODYNAMICS FLUIDS & DESIGN

HySA Systems Hydrogen South Africa

Refuelling system



1 – MH compressor
2 – H_2 dispenser
3 – buffer
4 – control system



- H_2 dispensing at P=185 bar.
- Maintaining high H_2 pressure (200 bar) for the dispensing system by the integrated thermally driven MH H_2 compressor.
- Use services available at the customer's site:
  - Pipeline H_2 (50-60 bar);
  - Low-grade steam (~140 °C);
  - Cooling water (15-20 °C);
  - Compressed air (5.5-7.5 bar);
  - Electric power (< 1 kW).
- Certified for the operation in the industrial environment.

- **Refuelling time:**
  - **Complete in 15 min**
  - **83% in 6 minutes**

IMPALA PLATINUM

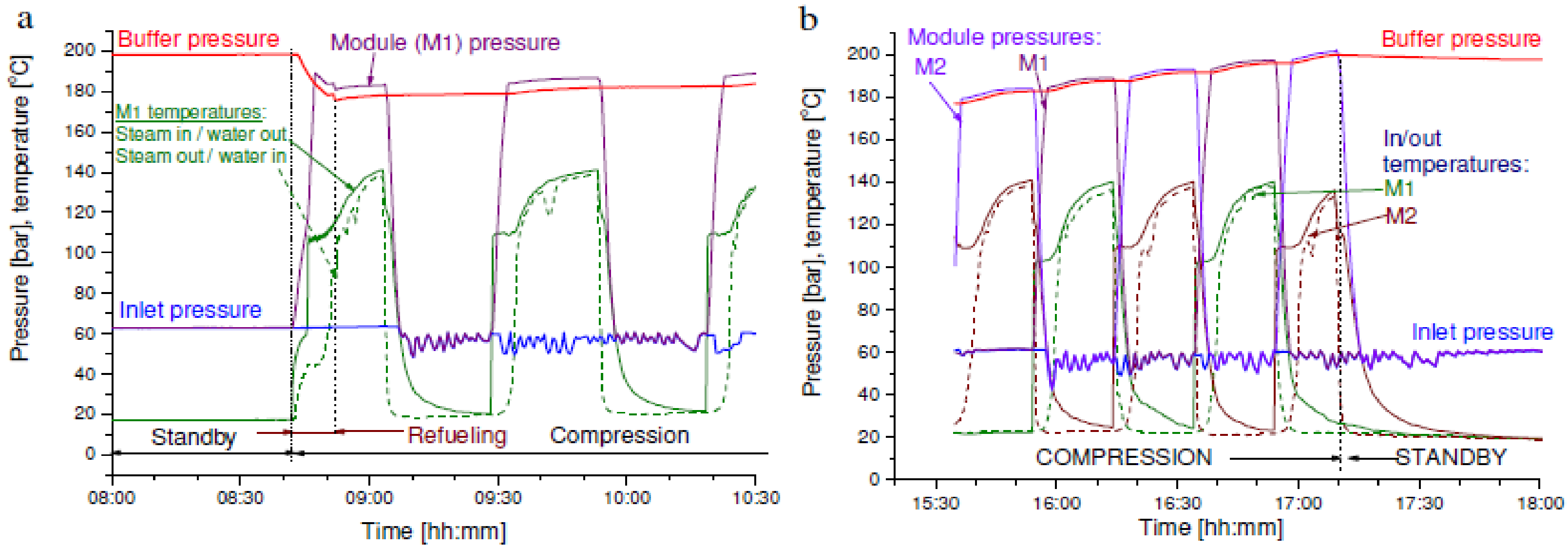
HySA Systems Hydrogen South Africa

TFD THERMODYNAMICS FLUIDS & DESIGN

The equipment (forklift and hydrogen refuelling station) was commissioned at the site of industrial customer (Impala Platinum refineries, Springs) in September 2015 and is in uninterrupted operation since that time

Officially launched by the DST Minister of South Africa on March 31 2016

MH compressor of the refuelling system: test results



- 50 – 200 bar, 7 – 12 Nm^3/h
- In permanent 24/7 operation since October 2015; ~2400 operation hours (5000 ABS/DES cycles) accumulated so far
- Identified malfunctions mainly result in the drop of compressor’s productivity and, sometimes, drop in the buffer pressure to 130–150 bar:
  - Contamination of pipelines with very fine powder of the MH material – addressed;
  - Malfunctions of the control system due to failures of electric components and errors of pressure sensors used for a feedback in the control of gas valves – addressed;
  - Slow decrease of the productivity possibly caused by the accumulation of gas impurities in the system – addressed (periodic purge & regeneration).

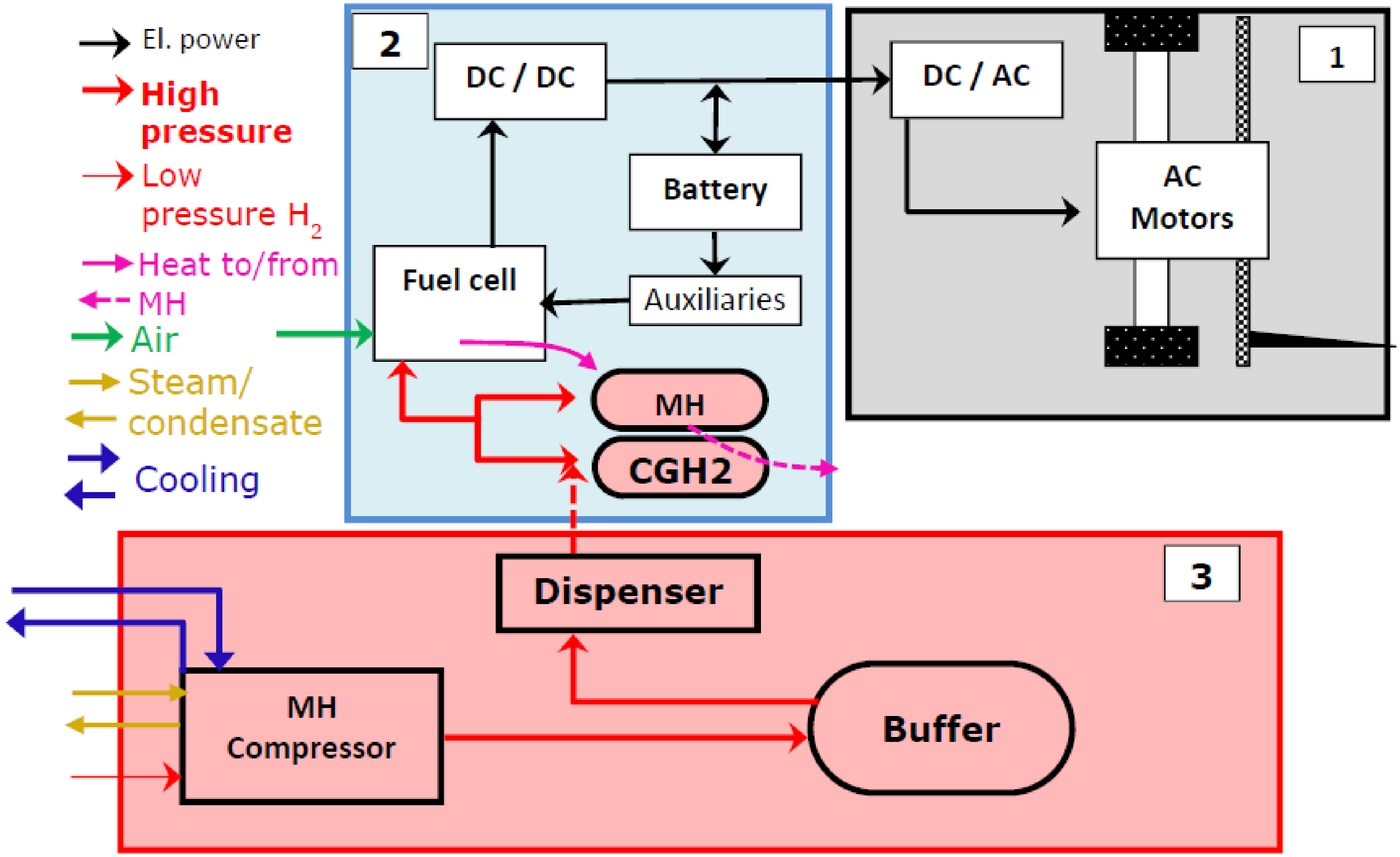
HySA Systems Hydrogen South Africa

IMPALA PLATINUM

Major remaining problems

- Necessity to further increase the useable hydrogen storage capacity and to further shorten the refuelling time using a lower refuelling pressure;
- High cost of the MH extension tank, mainly due to the high cost of the individual MH container and, to a lesser extent, the high cost and restricted availability of the MH materials;
- Necessity to improve the hydrogen refuelling system, first of all, by improving the MH hydrogen compressor resulting in a decrease of the input pressure and heating temperature, as well as increase of the hydrogen supply productivity at a required level of H_2 pressure and H_2 supply rate, and system reliability.

General system concept



1 – forklift chassis
2 – fuel cell power module with integrated MH H storage
3 – H_2 refuelling system

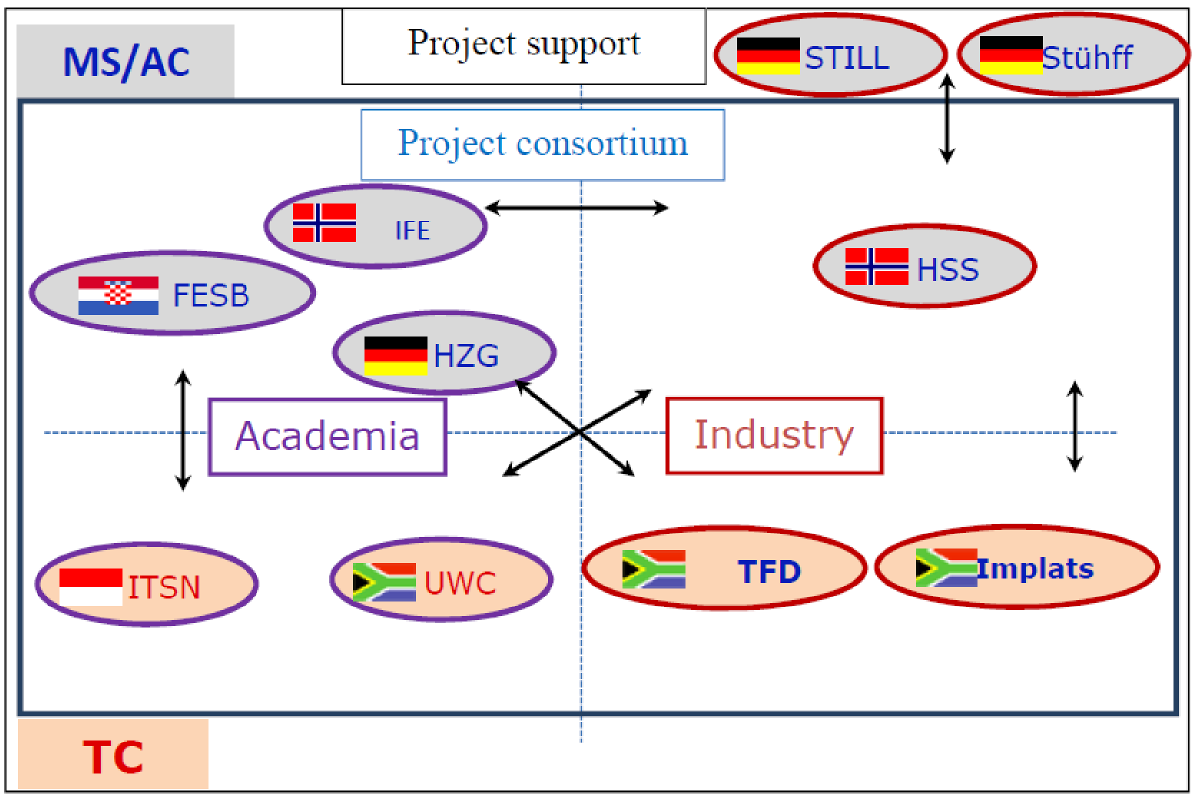
Scope of activities

- WP1: Development and characterisation of advanced MH materials for hydrogen storage and compression
- WP2: Development of cost efficient MH containers with a focus on their mass production
- WP3: Integration of MH containers comprising advanced MH materials
- WP4: System integration
- WP5: Implementation of the developed materials and systems

Success in fulfilment of these works requires a multi-disciplinary approach which involves competence in several different fields including materials and systems for hydrogen storage, manufacturing and integration of the fuel cell power modules, manufacturing of the utility vehicles, as well as identifying the customers of the hydrogen fuelled utility vehicles and refining their specifications to the systems.

Project consortium

The consortium members belong to different academic and non-academic institutions located both inside and outside the EU, and it is envisaged that the strengthening of existing links and establishing new collaborative links between the different institutions will be crucial for the success.



Partner institutions:

- Institutt for Energiteknikk (**IFE**), NO;
- Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung GmbH (**HZG**), DE;
- University of Split via Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture (**FESB**), HR;
- Hystorsys AS (**HSS**), NO;
- University of the Western Cape (**UWC**), via HySA Systems Centre of Competence, ZA;
- Institut Teknologi Sepuluh Nopember, Surabaya (**ITSN**), ID;
- TF Design (Pty) Ltd. (**TFD**), ZA;
- Impala Platinum Ltd. (**Implats**), ZA.

Plan and collaboration

WP1: <u>IFE</u>, HZG, UWC, ITSN (Month 1 – Month 36)

1.1. On the basis of experimental studies of composition – structure – hydrogen sorption properties relationships (IFE, HZG, ITSN), and target specifications for hydrogen storage and compressor applications (UWC), target recipes for the advanced MH materials will be drawn;

1.2. Influence of effects of up-scaled production and impurities on the properties of the developed materials will be studied (UWC, IFE) and their manufacturing technology will be optimised (UWC).

WP2: <u>HZG</u>, IFE, HSS, TFD, UWC (Month 4 – Month 42)

2.1. Design of advanced MH containers for on-board hydrogen storage applications (UWC, HZG, IFE);

2.2. Design of advanced MH containers for hydrogen compression applications (HSS, HZG, UWC);

2.3. Optimisation of manufacturing technology of the MH containers with a focus on lowering manufacturing cost (TFD);

2.4. Construction and building of advanced hydrogen storage containers for prototype MH hydrogen storage and the hydrogen compression systems (TFD)

WP3: <u>HSS</u>, HZG, TFD, UWC, ITSN (Month 7 –Month 42)

3.1. Design of advanced tanks for on-board hydrogen storage (HZG, UWC, TFD, ITSN);

3.2. Design of advanced MH compressor for the H2 refuelling stations (HSS, HZG, UWC, TFD);

3.3. Construction and building of advanced hydrogen storage tanks for prototype fuel cell utility vehicles (HSS, TFD);

3.4. Construction and building of advanced MH compressor for prototype hydrogen refuelling station (HSS, TFD)

Plan and collaboration (2)

WP4: FESB, IFE, HSS, UWC, Implats (Month 6 –Month 48)

4.1. Development and optimization of system design (FESB, UWC) in terms of overall efficiency, complexity, waste heat utilization and durability. Investigation of possibilities for simplifying system by avoiding certain BoP components, particularly expensive external humidifiers and instead using water and heat produced in fuel cell for internal humidification of reactants.

4.2. Development of advanced heat management concept in order to maximize utilisation of system waste heat for thermal management of hydrogen desorption from MH storage tanks (FESB, UWC)

4.3. Optimisation of hydrogen refuelling stations with integrated MH compressors (HSS, UWC)

4.4. Optimisation of system solutions for FC powered material handling units with MH hydrogen storage for industrial customers (Implats)

WP5: FESB, Implats, UWC, HSS (Month 8 –Month 48)

5.1. Analysis of on-site operation of the prototype vehicle and its refuelling station at the site of industrial customer in South Africa (Implats, UWC, FESB, HSS)

5.2. Identification of European industrial customers for hydrogen fuelled utility vehicles and stations for their refuelling comprising MH (FESB, HSS)

5.3. Techno-economic assessment for hydrogen fuelled utility vehicles and stations for their refuelling comprising MH (FESB, HSS, Implats, UWC)

5.4. Establishment of joint-venture company involved in the manufacturing of hydrogen fuelled utility vehicles and their refuelling stations for industrial customers (HSS, Implats, FESB, UWC)

Scientific deliverables

#	Title	WP	Lead Beneficiary	Due Date
1.1	Basic recipes of the MH materials	1	IFE	12
3.1	Design / specifications of advanced hydrogen storage tank	3	HSS	18
2.1	Prototype of advanced MH container for on-board hydrogen storage	2	HZG	18
1.2	Technological features and updated recipes of MH materials	1	IFE	24
2.2	Prototype of advanced MH container for H2 compression	2	HZG	24
4.1	Optimal design and operational concept of fuel cell powered module with advanced thermal management for waste heat utilization in MH hydrogen storage tanks	4	FESB	24
5.1	Specification to the product line and identification of the OEM's and customers	5	FESB	30
3.3	Design / specifications of advanced MH compressor	3	HSS	30
5.2	Techno-economic assessment	5	FESB	36
4.2	Optimal design and specification of hydrogen refuelling station with integrated MH compressor	4	HSS	42

Milestones

#	Title	WP	Lead Beneficiary	Due Date
1	First prototype of advanced hydrogen storage tank	3 (3.2)	HSS	24
2	Manufacturing of MH containers for on-board hydrogen storage	2 (2.3)	HZG	30
3	Sufficient delivery of MH materials from up-scaled production for the prototype systems to be developed within the project	1 (1.3)	IFE	36
4	Manufacturing of MH containers for H2 compressor	2 (2.4)	HZG	42
5	First prototype of advanced MH compressor	3 (3.4)	HSS	42
6	Integration of fuel cells and MH hydrogen storage and its BoP components in power modules	4 (4.3)	FESB	48
7	Establishment of joint-venture company	5 (5.3)	FESB	48
8	Final report	6 (6.4)	IFE	48

Thank you for listening!

mlototskyy@uwc.ac.za

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