Ammonia Cracking using Advanced Membrane Reactors

Our goal | Scale-up membrane technology to cover for industry needs

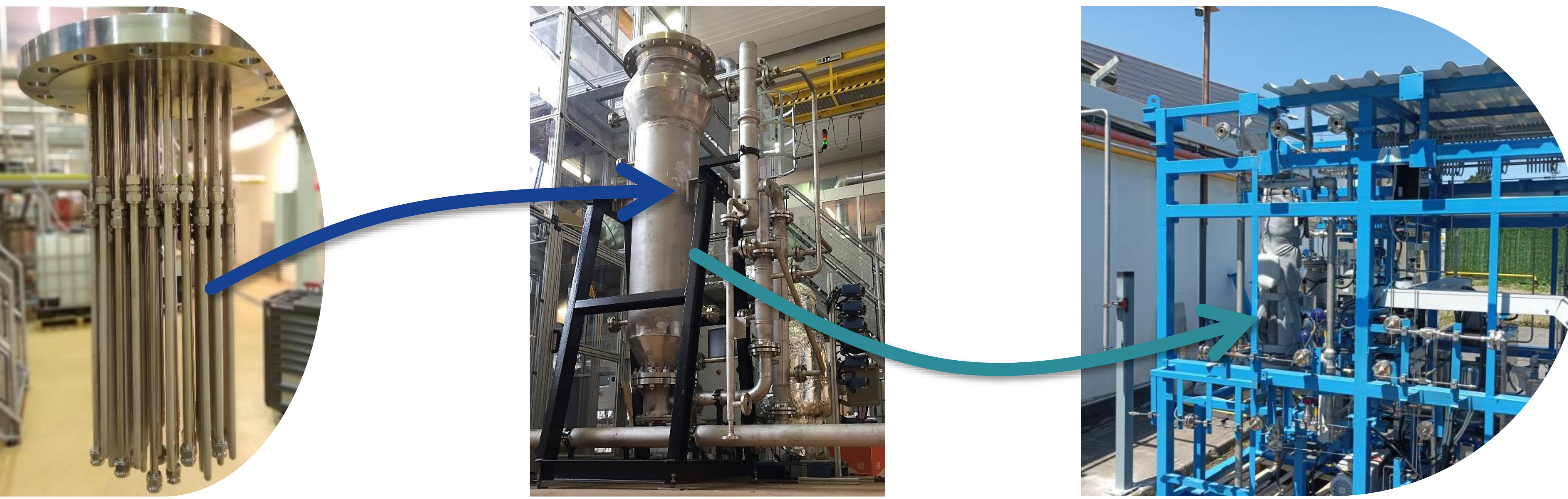
- 2,000sqm plant in Loiu, inaugurated in November 2022
- 1st world industrial palladium-alloy membrane production factory
- More than 15 years of R&D to optimize the manufacturing process
- +60 people in the team, and growing!

Advanced Membrane Reactor & Separator | High purity from carriers and blends

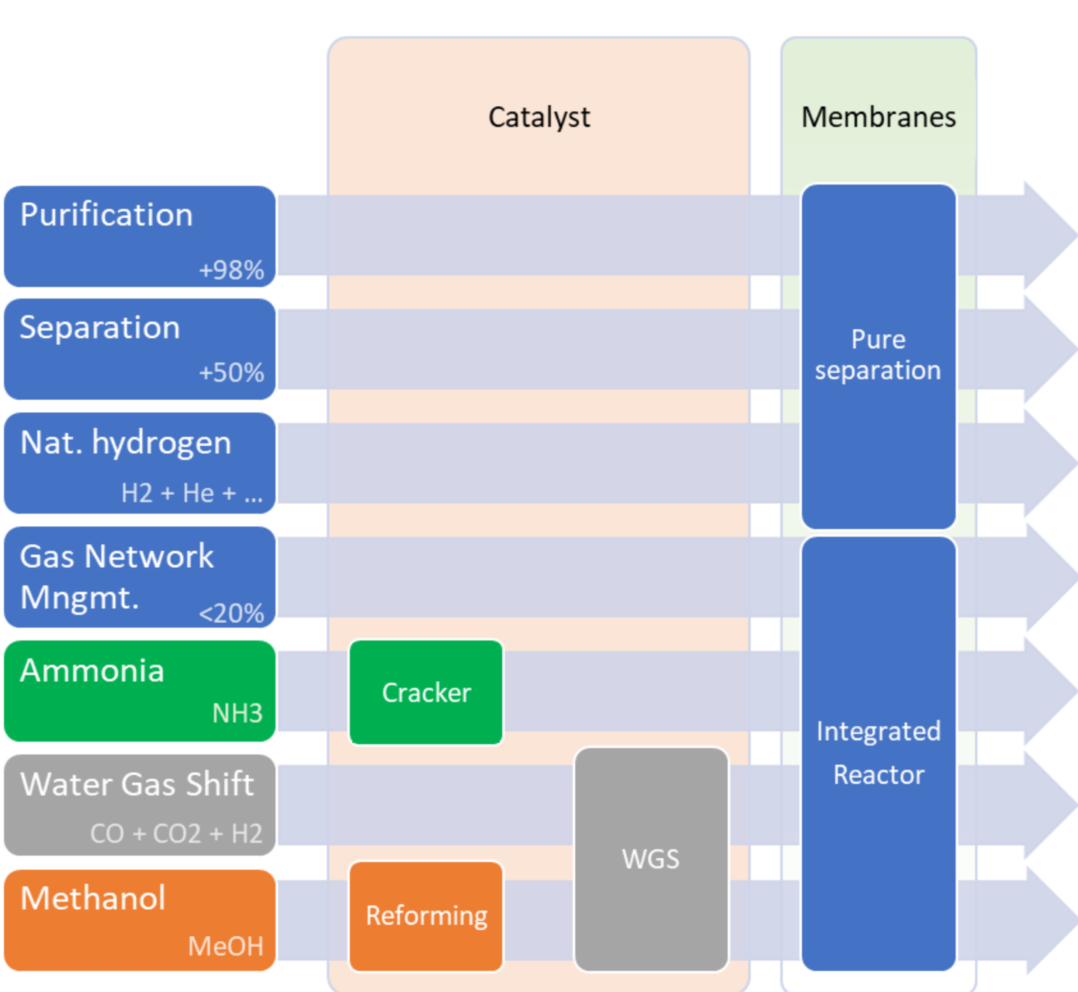
Palladium-Alloy membranes that produce **high purity hydrogen** (99.97%)…

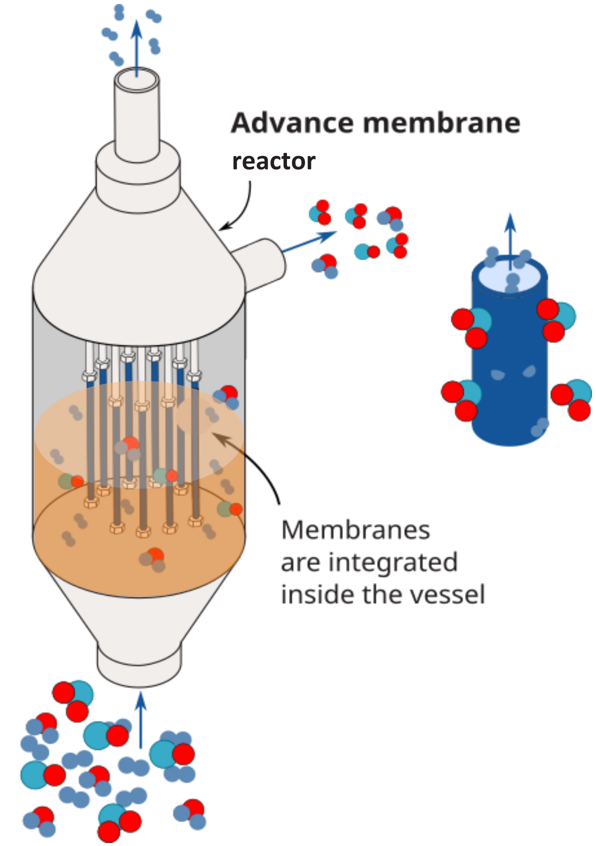
…to **efficiently recover 98% of the hydrogen** from wide variety of feedstocks…

…for **on site generation** in a reduced footprint



Applications | Advanced integrated reactor for reaction and separation





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Design & construction of Ammonia Cracker & Membrane Reactor

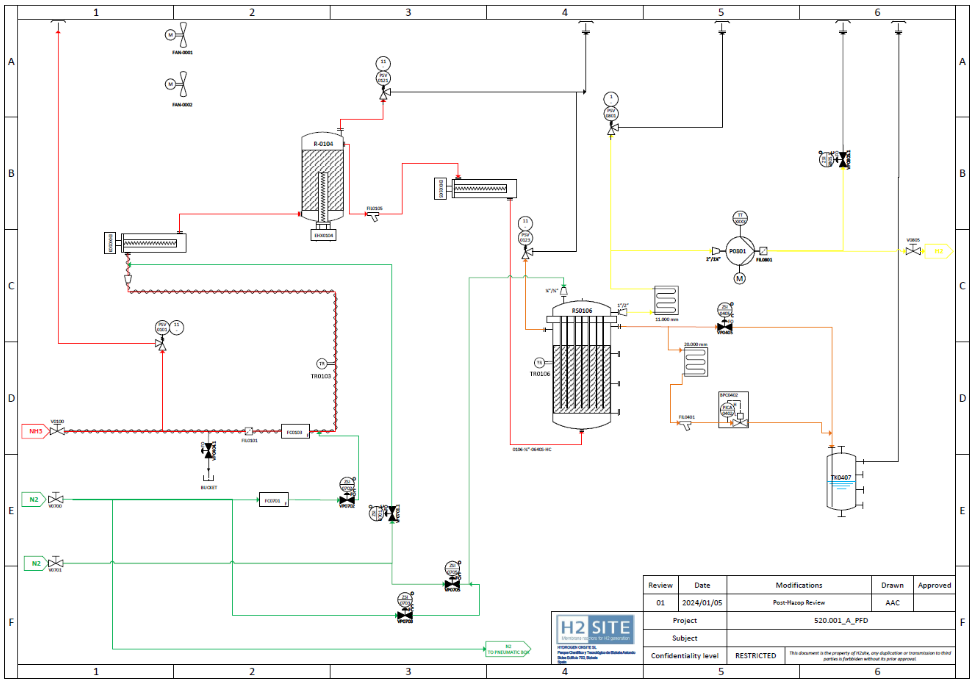
- Design of the ammonia decomposition system
- Manufacturing of hydrogen separation membranes for prototype
- Construction and commissioning of the membrane reactor prototype

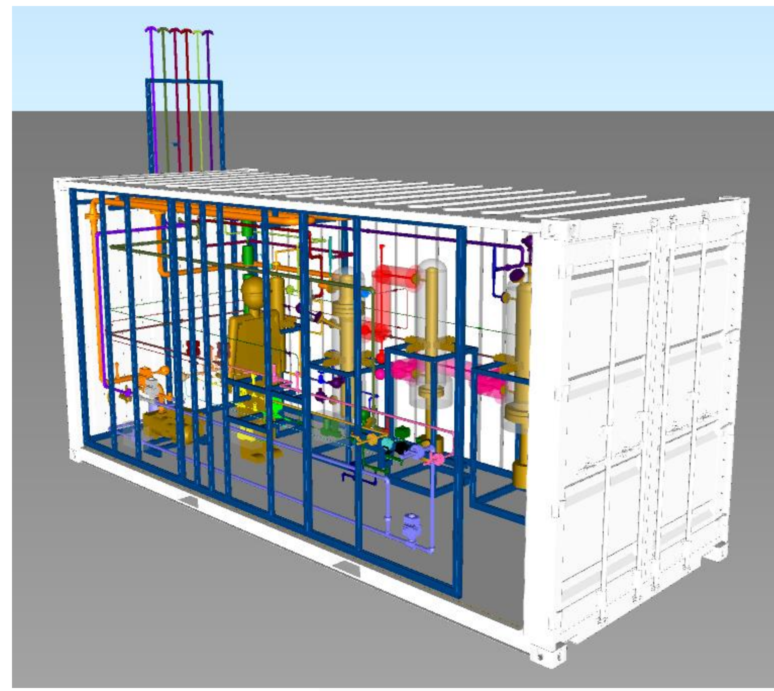
Operation of Ammonia Cracker & Membrane Reactor

- Testing and validation of the prototype by CNH2
- The equipment was installed in Fertiberia

Design of the ammonia cracker

- Designed in a 20’ HC container:
  - Plug & Play
  - Helps contain ATEX zones.





Construction of the ammonia cracker

- Main challenges:
  - Hydrogen piping & equipment requires high quality welding and thorough testing.
  - Membrane reactor needs to be accessible for membrane replacement: a manual ATEX rated hoist was installed to bring the reactor out of the container.

Construction of the ammonia cracker

- Main challenges:
  - Small bore piping and tubing cannot take the weigth of valves and instrumentation, special attention had to be paid to supports.
  - High temperatures require well designed and installed insulation.

Operation of the ammonia cracker

- CNH2 operated the cracker
- H2Site provided onsite training and remote monitorization via H2Site's remote Control Room.
- Great communication between both teams.
  - Thanks to the CNH2 team!

Operation of the ammonia cracker

- Main challenges:
  - Nitrogen pressure
  - Ammonia composition
  - Low temperature in separation
  - Daily start-up and shut down

Operation of the ammonia cracker

- Nitrogen pressure: The system was designed to work at 8-10 bar, also during heating.
  - Available nitrogen in Fertiberia is 5 bar, so in order to overcome the pressure drop of the system, Nitrogen flow had to be reduced, which made heating slower.
    - Heating was supposed to be less than 4 hours, but it took around 6.
  - This would have prevented testing, because by the time the equipment was hot it was time to shut down for the day.
    - CNH2 reorganised working hours to work longer days so that testing could be done.
- Ammonia composition and pressure:
  - There are 2 sources of ammonia nearby: low pressure pure ammonia or high pressure “top of the tank” ammonia.
  - Top of the tank ammonia contains all the volatile contaminants in the manufacturing process, with varying composition, such as CH_4, CO_2, N_2 or Ar.
  - Ammonia pressure was 7 bar in the inlet, which made the separator work at around 5 bar.

Operation of the ammonia cracker

- Low temperature in separation:
  - The heat transfer expected with pure ammonia was better than with the "top of the tank" ammonia, which implied the temperature in the membranes was around 370ºC, instead of the design 400ºC.
  - Considering that only 70% of the inlet was ammonia, and that the separator was working at 5 bar and 370ºC (instead of 8 bar and 400ºC), the Hydrogen flowrate produced was smaller than the design:

Design	Design	Operation	Simulated for operation conditions
Ammonia purity (mol%)	99,99%	60-70%	60%
Membrane temperature	400ºC	370ºC	370ºC
Membrane pressure	8 bar	5 bar	5 bar
Hydrogen flow rate	0,91 kg/h	0,21 kg/h	0,288 kg/h

Testing and validation of the ammonia decomposition prototype

Operation of the ammonia cracker

- THE ISSUE: Daily start-up and shut down
  - System is designed for 24/7 operation, but had to be operated 10/4, instead.
  - Shutdown procedure was modified to try to reduce heating time and optimise operation time:
    - This led to membrane damage.
    - NH3 entered the vacuum pump and damaged it.
  - Both the vacuum pump and the membranes had to be changed.
  - The Shutdown procedure was corrected to the original to avoid this issue from happening again.
  - The prototype was started again.

Lessons learnt

- Pressure drop thoughout the system can increase heating time if the required pressure nitrogen is not available.
- Oversizing heating capacity could compensate for temperature loss in the membrane reactor, to ensure it works under design conditions.
- Shutdown operation is critical for membrane health.
- Thermal cycles (starting and stopping everyday) reduce the purity of the hydrogen.
- Everything is easier with a motivated and willing team, such as the one we found in CNH2 and Fertiberia.
- The prototype has produced high purity hydrogen for 500 hours!

Next Steps

EUROPEAN PROJECTS

- APOLO PROJECT: NH3 cracking for marine applications
  - Already building the prototype: same footprint as ARENHA, 10 times the hydrogen production capacity
  - Will be integrated with a fuel cell to produce electricity
  - To be installed in Fertiberia.
- HERMES PROJECT: Design, construction and operation of 2 prototypes for H2 recovery in oil & gas applications.

COMMERCIAL PROJECTS

- Gas infrastructure maganement project with SNAM
  - 100 kg/day H2 separation facility in Italy.

- And much more to come!

Advanced materials and Reactors for Energy storage tHrough Ammonia

areNH₃a

Thank you for your attention

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