Delivering clean hydrogen fuel from ammonia using metal membranes

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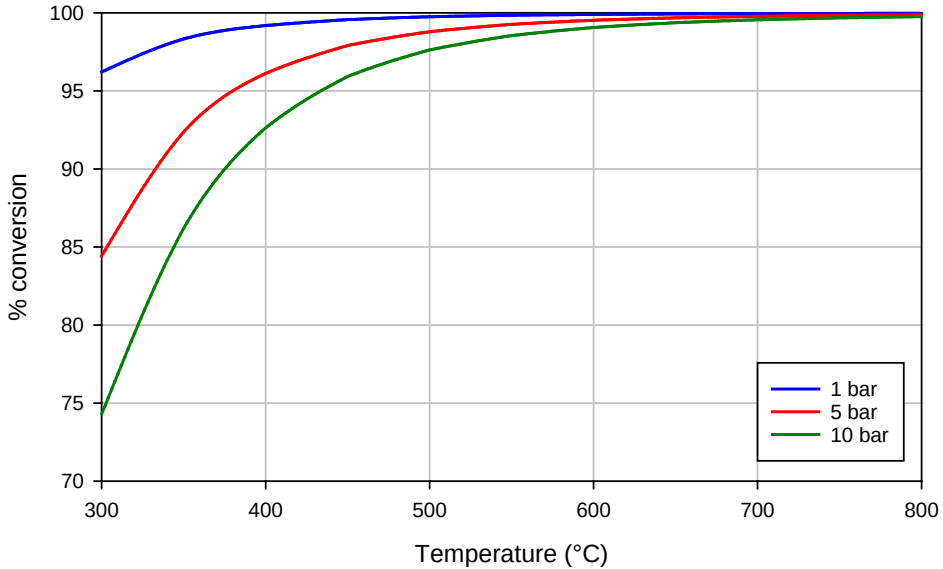
Renewable Ammonia Export

H_2

N_2

- Power generation: Combustion (internal combustion engine or turbine)
- Power generation: Direct conversion (High-temperature fuel cell)
- H_2 production: Decomposition and H_2 purification
- Hybrid H_2 and power systems

Ammonia decomposition



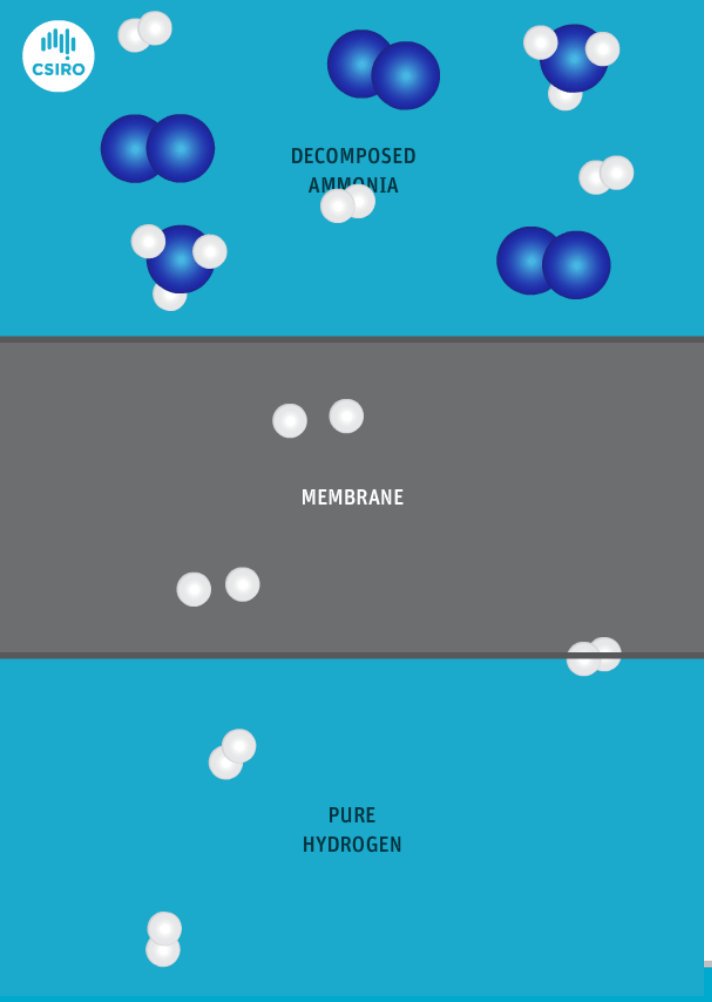
ISO14687-3 (stationary):
50% non-H_2 species, 100 ppbv NH_3

ISO14687-2 (mobile):
300 ppmv non-H_2 species, 100 ppbv NH_3

100 ppbv NH_3 = 99.99998% conversion

* Use a scrubber or membrane or both

Vanadium-based membranes for H_2 purification



High pressure

Feed-side catalyst

V or V-alloy core

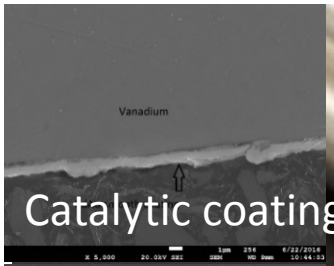
Permeate-side catalyst

Low pressure

Our design philosophy:

- Minimise materials costs (minimise use of palladium)
- Use scalable manufacturing techniques (metal tube extrusion and electroplating)
- Prioritise purity over flux (to meet ISO14687 for PEM fuel cells)

CSIRO's membrane technology



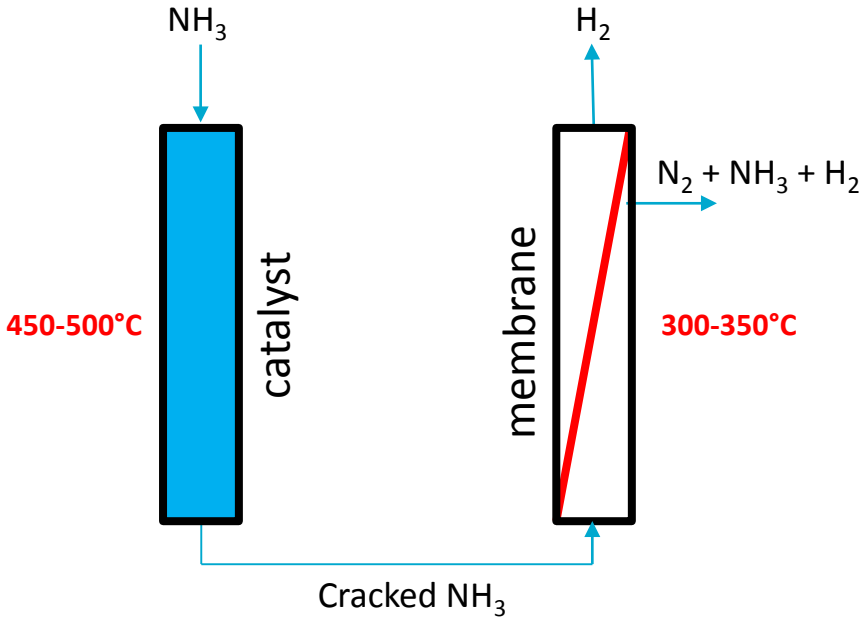
Catalytic coating

Multi-tube module

10 mm diameter
0.2 mm thick
500mm long
Self-supporting (no porous support structure which minimises cost)

Cracking system configuration

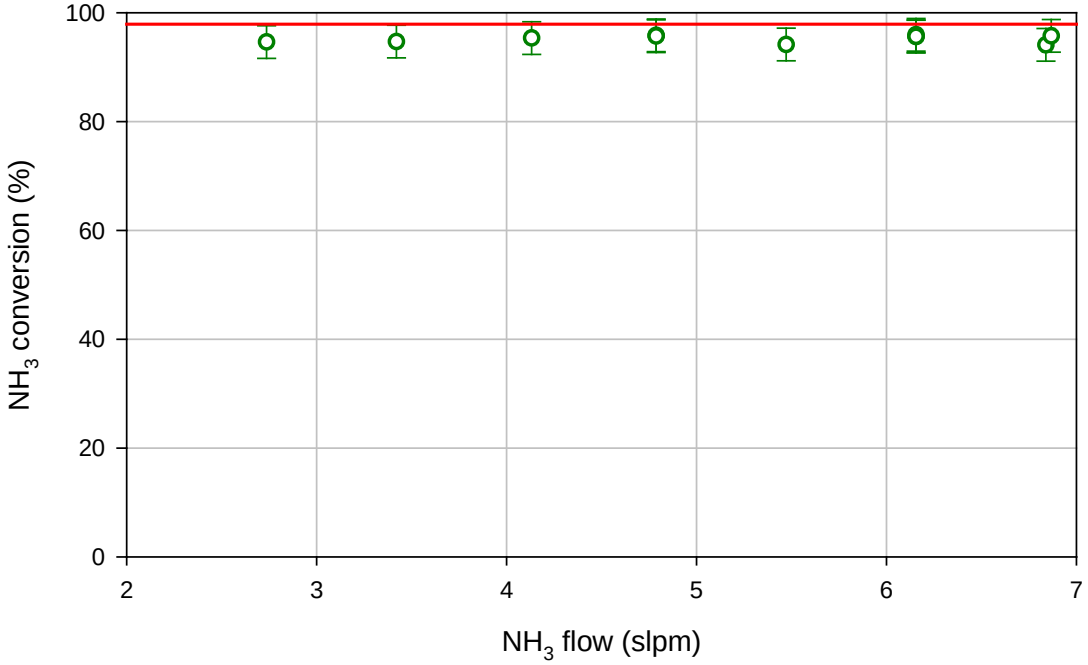
1.5mm diam. granular catalyst: 0.5 wt% Ru layer on Al_2O_3 support



500 mm membrane

Single-tube prototype

NH_3 conversion (150g catalyst loading, 450°C, 5 bar(a) with downstream membrane)

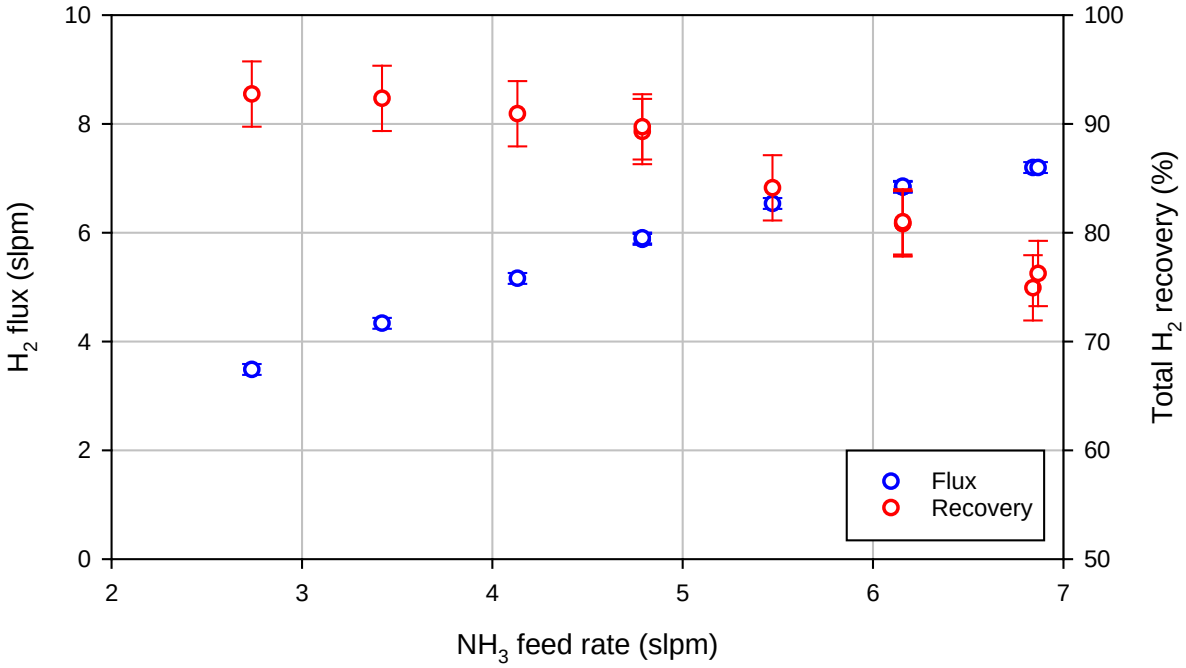


Near-equilibrium NH_3 conversion at 450˚C

NH_3 decomposition rate is inhibited by H_2 ($P_{H2}^{-0.42}$)

Single-tube prototype

H_2 flux and recovery (150g catalyst loading, 450°C, 5 bar(a) with downstream membrane)



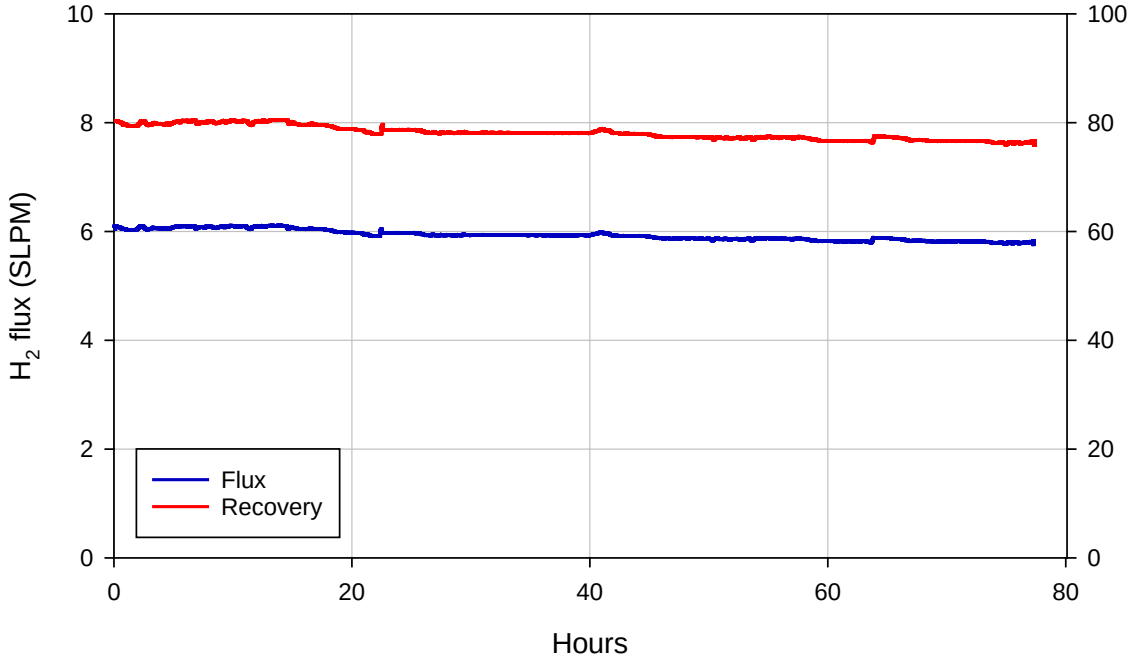
H_2 production rate is inversely proportional to H_2 recovery

Can vary yield/flux for specific applications:

- Stand-alone with waste heat
  Stand-alone with self-heating
- Hybrid cracker/combustion

Single-tube prototype

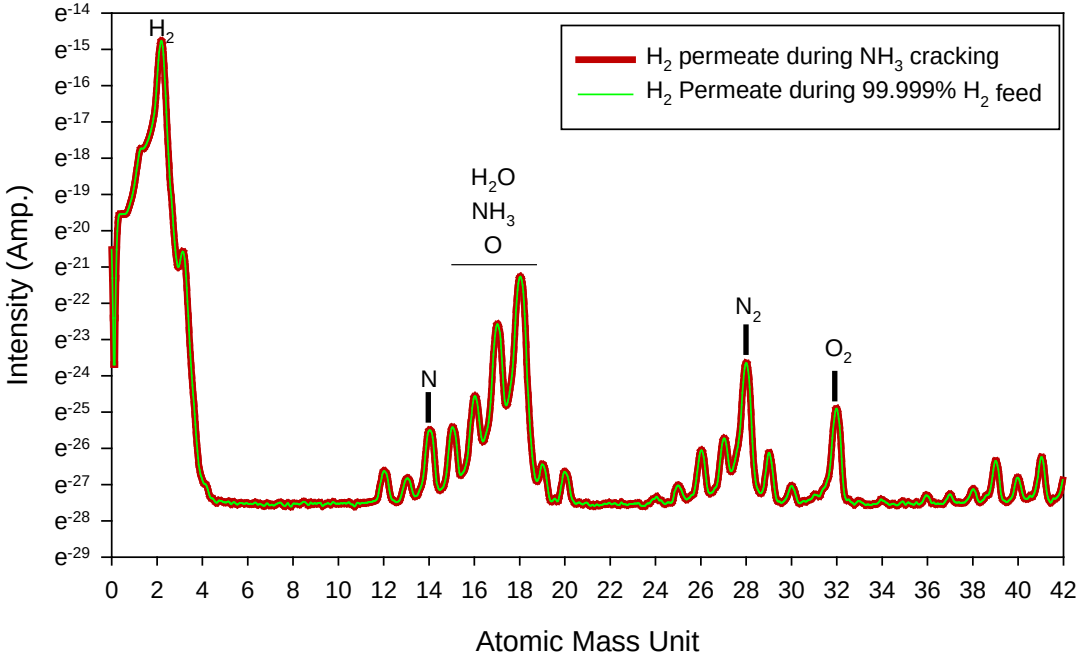
H_2 flux and recovery (5.0 slpm NH_3, 150g catalyst loading at 450°C with membrane)



- Stable performance over 80 hours at 80% total H recovery
- energy content of retentate ≅ enthalpy requirement for cracking

Single-tube prototype

Mass spectrum of permeate stream with different feed gas compositions



No enrichment of N_2 or NH_3 in H_2 permeate during NH_3 cracking: ISO14687 met

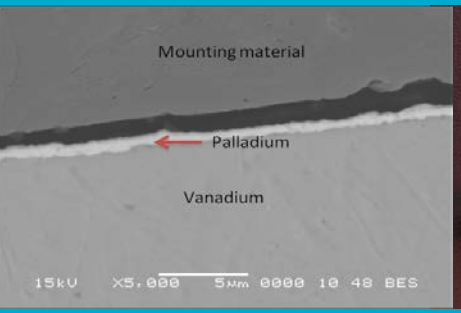
Multi-tube pilot plant

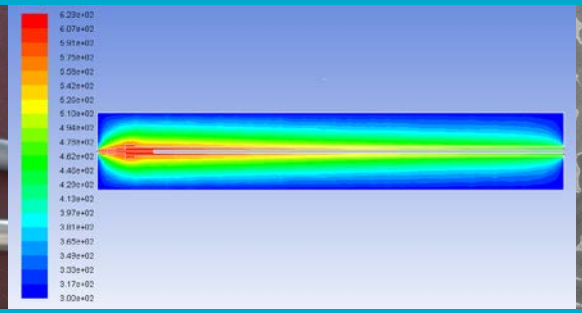
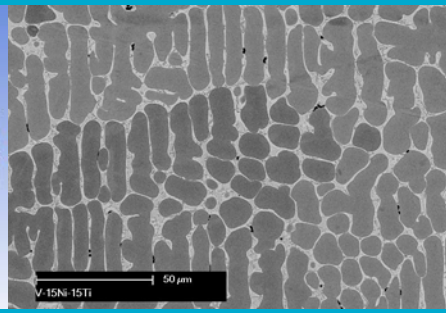
- Membrane area 0.3 m^2 (19 x 50 cm tubes ≈ 120 slpm ≈ 15 kg/day at 80% yield)
- H_2 to be compressed and dispensed into FCEVs in Australia

Summary

- Australia is at the forefront of renewable ammonia export
- CSIRO's technology can deliver FCEV-grade H_2 from ammonia
- We're rapidly scaling this technology towards to 15 kg H_2 per day and beyond, with demonstrations planned in Australia and Asia

- Acknowledgement: Science and Industry Endowment Fund



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