

The MEMCAP Process Development Unit

Testing of membrane separators and reactors for CO₂ capture

The MEMCAP facility is a process development unit (PDU) for testing membrane separators and reactors that can be implemented in power plants with CO₂ capture. Typically, it has a capacity of 8 tubular membranes of 50 cm long, and can be operated up to 40 bar and 600°C. The PDU will demonstrate the feasibility of membrane reactors at a bench scale size. It will be used for testing of reactor concepts, and the study of membrane and catalyst characteristics.

The facility

The PDU can supply gas mixtures with a varying composition and flowrate at high pressure. These are heated and then fed to the membrane reactor. In the membrane reactor hydrogen is produced and immediately separated from the other gases by the membrane. The MEMCAP PDU produces two product streams: a hydrogen product and a stream with the components that are not separated by the membrane, which is a CO₂-rich product. The products gas streams are cooled and water is removed. Gas analysis is performed on all feed and product streams. It is even possible to analyse the product streams of the individual tubes of the membrane reactor. The facility allows for exchange of membrane reactors so different reactors and reactor concepts can be tested.

Key features

Gas supply	CH ₄ , CO, H ₂ , CO ₂ , N ₂ , steam
Max Pressure	35 bar
Max Temperature	600°C
Membranes	H ₂ selective membranes
Max	8 membranes of 50 cm length
Max.Capacity	25 kW H ₂
Reactions	Steam methane reforming or Water-gas shift
Operation	Fully automatic



The concept

Membrane reactors allow for conversion of natural gas into two separate streams of H₂ (for power production) and CO₂ (for underground storage). The conversion is done catalytically through steam reforming and/or the water-gas shift reaction.



Unit Hydrogen and Clean Fossil Fuels

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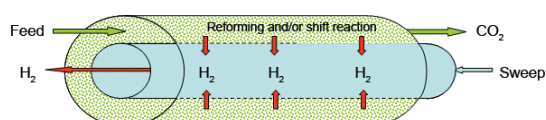


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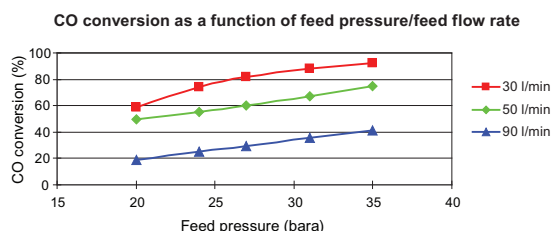
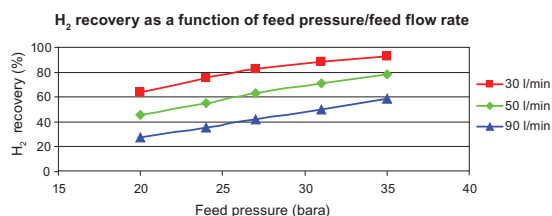
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Parallel to the reaction hydrogen is removed from the reaction zone by Palladium(-alloy) hydrogen selective membranes. Separation is improved by using a sweep stream. When implemented into a power plant, the advantage of this concept is that H_2/CO_2 separation is done at high temperature, thus limiting heat transfer costs and improving the efficiency of the power plant. Also the selective removal of hydrogen shifts the equilibrium of the reactions towards high conversion allowing for high conversions at more favorable temperatures, which also reduces the costs.



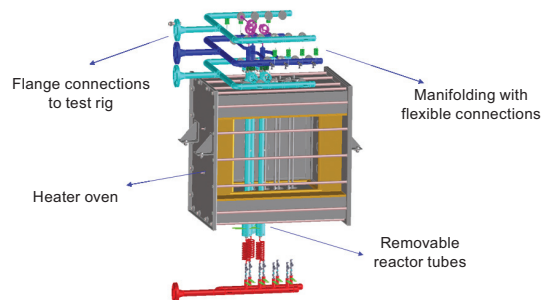
Membrane reactor test results

The multi tube membrane reactor with 3 Pd membrane successfully demonstrated the operation for membrane-water gas shift reaction using auto thermal reformer + shift derived feed gas. In the shift test, the CO conversion and H_2 recovery were both investigated under different feed pressures and feed flow rates. The figure below show CO conversion and H_2 recovery as function of the feed pressure and the feed flow.



Membrane reactor construction

The current design of the membrane reactor is derived from an envisaged full scale steam methane reformer type reactor with membranes inserted into the reactor tubes. Heating is done by radiating electrical elements, mimicking radiant burners. The reactor is also suitable for conducting adiabatic membrane water-gas shift reaction experiments and membrane separation tests.



Outlook

In the three years EU, FP7 project CACHET-II the test unit will be used for the further development of the Pd membrane reactors for pre combustion CO_2 capture. Besides, in the Dutch national CATO₂ programme, the MEMCAP unit is used in a benchmark test of Pd-based membranes of several different developers/vendors. The membranes will be tested following a test protocol using gas mixtures representative for industrial processes with CO_2 capture.



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