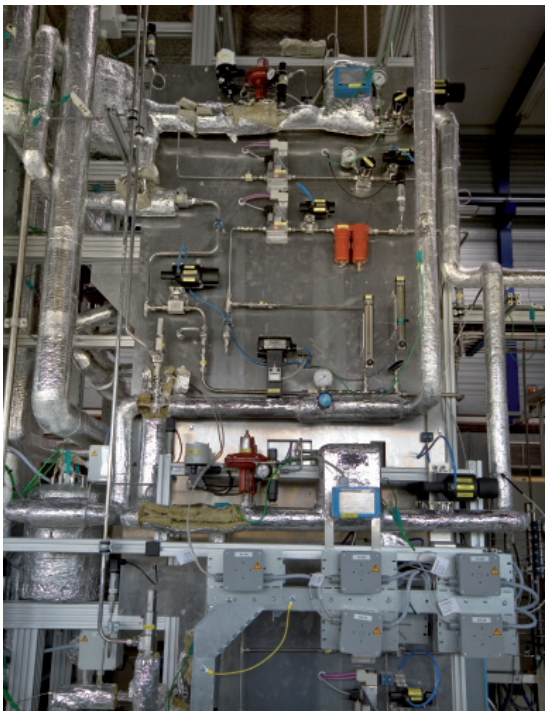
A New Experimental Unit for Demonstrating Pre-Combustion CO_2 Capture

A novel technology for capturing CO_2 in natural-gas fired power plants is being developed at ECN. This technology is particularly attractive for decarbonising gas turbine fuel, and hence provides opportunities for power generation with low CO_2 emissions, high power efficiency, and potentially lower cost of capturing CO_2 for storage. In collaboration with Air Products, ECN have designed and constructed an experimental unit. The unit will demonstrate continuous CO_2 capture and will generate process data that is needed to quantify industrial-scale performance and the effect on power production plants.

The unit consists of six reactors, each six meters tall. The reactors contain beds of pellets that catalyse chemical reaction and adsorb CO_2. By switching valves the reactors are operated in cycles of CO_2 -adsorption and desorption. Since at any time there is always at least one reactor in adsorption mode and at least one reactor in desorption mode, a continuous production is obtained. Design, engineering, construction, and commissioning of the unit took less than one year.

Advantages of the technology include high carbon recovery rates exceeding 90%, considerable saving of investment costs for heat exchanging equipment, and high efficiency since the decarbonised fuel is produced without noticeable loss of compression energy. The technology is developed for natural-gas fired power plants, but it has also potential in coal gasification plants and in industrial H_2 production plants.

Frontal view of the experimental unit, showing three reactors



Feed section for supplying, mixing and heating gases and steam

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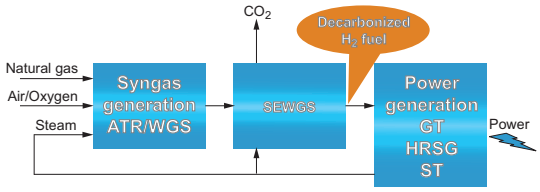
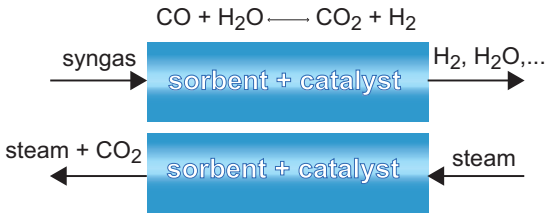


Power production with CO_2 capture by SEWGS. Power is generated by gas turbines (GT) and steam turbines (ST), heat is recovered for steam generation (HRSG). Steam is needed for autothermal reforming and water gas shift (ATR/WGS), and for CO_2 removal by SEWGS.



SEWGS principle: (upper) adsorption and reaction at high pressure (lower) desorption at low pressure

The Process

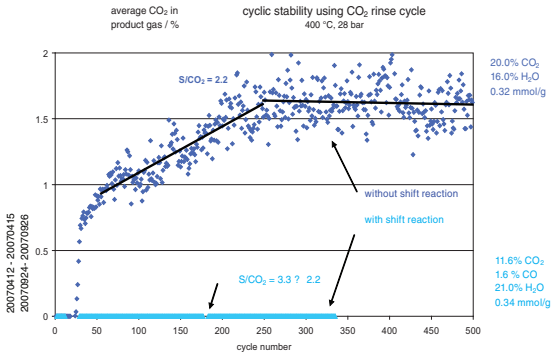
The Sorption Enhanced Water Gas Shift process (SEWGS) is a technology that combines the water-gas shift reaction with CO_2 capture at high temperature. The feed to the SEWGS unit is syngas, which is produced by reforming and high temperature shift. The products are a pure CO_2 stream at low pressure and a H_2-rich stream at high pressure and high temperature. The CO_2 can be compressed and transported to a suitable storage location, e.g. geological formations.

In a reactor CO is converted with H_2O to CO_2 and H_2 (water-gas shift reaction). Simultaneously, CO_2 is removed from the gas by sorption on a promoted hydrotalcite-like material. The sorbent is regenerated by purging countercurrently with steam at low pressure. Since adsorption of CO_2 is thermodynamically favored at high pressure and desorption at low pressure, parallel reactors are operated in pressure swing cycles.

The SEWGS development

Sorbent material, hydrotalcites, can be used in the sorption enhanced water gas shift based capture system. The experiments with the SEWGS single column proofed good long term stability of the hydrotalcite sorbents for CO_2 capture. In 2007 combined WGS and CO_2 capture experiments in the single column unit (column is filled with mixture of WGS catalyst and CO_2 sorbent) also confirmed the technical feasibility of the SEWGS process for pre combustion CO_2 capture.

In 2008, continuous SEWGS experiments have been performed on the multi column SEWGS test rig. A so so-called CO_2 rinse cycle was tested. CO_2 rinse means that CO_2 at 30 bar is used to remove the gas from a reactor that is saturated with CO_2 at the end of the hydrogen production step of the cycle. This cycle yielded a relatively pure hydrogen product, which means a high CO_2 capture ratio.



CO_2 slip in product gas during operation of SEWGS-1 without (dark blue line) and combined water gas shift(light blue line). The combined water gas shift CO_2 capture experiments show nearly 100% CO conversion at 400°C, while capturing/absorbing almost all CO_2. After 300 cycles steady state is attained and CO_2 slip is still negligible.

Finally, the SEWGS technology is also promising for application in coal gasification combined cycles (IGCC). In the EOS LT CAPTECH consortium, ECN and KEMA have shown that the sorbents of choice (promoted hydrotalcites) are capable of capturing CO_2 in presence of hydrogen sulphide. H_2S also adsorbed on the material and was also desorbed in the regeneration step of the cycle. Multiple cycles were performed and no degeneration of the sorbent was observed.

Outlook

The EU FP7 project CAESAR will take forward the SEWGS development into the next phase of pilot plant design. Furthermore, other applications, such as coal gasification plants (IGCC) and blast furnaces will be investigated in the experimental unit. Project participants are: Air Products, BP, ECN, SINTEF and Poly Tecnico di Milano.

CO_2 Capture Project

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