

## A new combustion technology

At 22 minutes past five, August the 12<sup>th</sup>, 2003, the reactor system had reached operating temperature and the valves were opened for natural gas addition. This was the start-up of a new combustion technology with inherent CO<sub>2</sub> capture, chemical-looping combustion. This was the culmination of more than five years of work at Chalmers University, involving the development of methods for manufacture and testing of particles for the process, numerous applications, a search for industrial and university partners, work with reactor system design, testing in cold flow models, and two years of intensive work in the EU/CCP co-sponsored project GRACE (Grangemouth Advanced CO<sub>2</sub> Capture) together with CSIC-ICB in Zaragoza, Technical University of Vienna, Alstom Power Boilers and managed on behalf of the consortium by BP (CCP). What would happen? Work on this process was going on in Japan, US and Korea but to our knowledge the actual process had never been run continuously for any extended period of time. Would the reactor system work? Would the oxygen-carrier particles developed sustain under real operating conditions? Would the particles agglomerate, fragment, attrite or loose reactivity?

Now, after more than 100 hours of stable operation with chemical-looping operation it can be concluded not only that the process works, but also that the oxygen-carrier particles can sustain the severe conditions without noticeable chemical or physical degradation.

Chemical-looping combustion is a new technology for burning gaseous fuels, with inherent separation of CO<sub>2</sub>. Metal oxide particles are used for the transfer of oxygen from the combustion air to the fuel, thus the combustion products CO<sub>2</sub> and H<sub>2</sub>O are obtained in a separate stream.

A 10 kW prototype for chemical-looping combustion has been designed, built and run with nickel-based oxygen-carrier particles. A total operation time of more than 100 h was accomplished with the same batch of particles, i.e. without adding fresh, unused material.

A high conversion of the fuel was reached, with approximately 0.5% CO, 1% H<sub>2</sub> and 0.1% methane in the exit stream, corresponding to a fuel conversion efficiency of 99.5% based on fuel heating value. The best way to treat the unconverted fuel has not been investigated, although a possibility that should be explored is to separate this gas from the liquefied CO<sub>2</sub> and recycle it to the process.

There was no detectable leakage between the two reactor systems. Firstly, no CO<sub>2</sub> escapes from the system via the air reactor. Thus, 100% of the CO<sub>2</sub> is captured in the process. Secondly it should be possible to achieve an almost pure stream of CO<sub>2</sub> from the fuel reactor, with the possible exception of unconverted fuel, or inert compounds associated with the fuel, e.g. N<sub>2</sub>.

No decrease in reactivity or particle strength was seen during the test period. The loss of fines was small and decreased continuously during the test period, indicating that the principle mechanism is loss of fine material associated with the fresh particles. At the end of the period the fines loss, i.e. particles smaller than  $45\ \mu\text{m}$ , was calculated to be  $0.0023\%$  per hour. If this can be assumed to be a relevant measure of the steady-state attrition, it corresponds to a lifetime of the particles of  $40\ 000\ \text{h}$ . Assuming a lifetime of the particles one order of magnitude lower, i.e.  $4000\ \text{h}$ , the cost of particles in the process is estimated to be below  $1\ \text{€}/\text{ton}$  of  $\text{CO}_2$  captured.

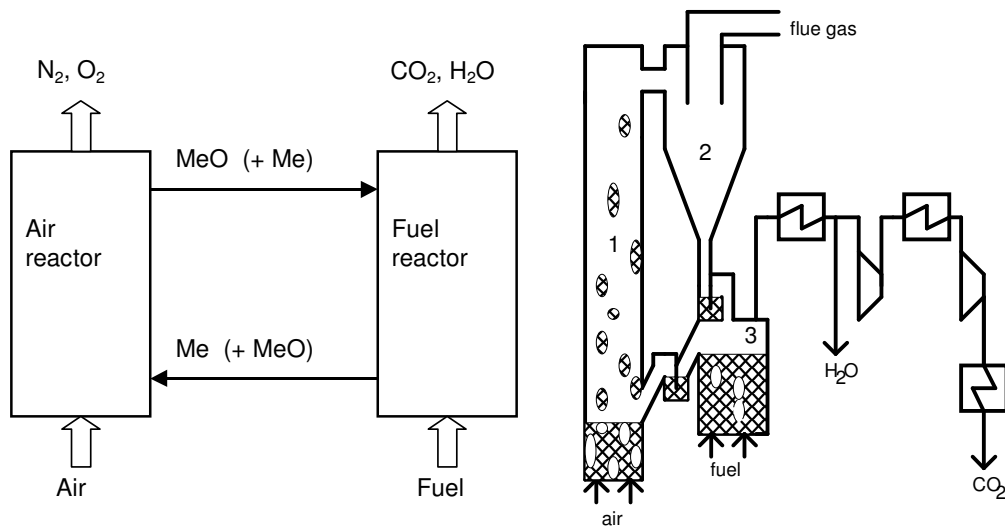


Fig. 1. Chemical-looping combustion. MeO/Me denote recirculated oxygen carrier solid material.

Fig. 2. Layout of chemical-looping combustion process, with two interconnected fluidized beds. 1) air reactor, 2) cyclone, 3) fuel reactor.



Fig. 3. Chalmers 10 kW chemical-looping combustor