Chalmers' 100 kW chemical-looping combustor for solid fuels

A 100 kW chemical-looping combustor was designed, built and operated at Chalmers University in the European ECLAIR project coordinated by ALSTOM. The commissioning testing started in December 2010 and first short successful operation with solid fuels was accomplished in August 2011. A number of improvements on the system were implemented along with further testing, and a major testing campaign was run in April-June 2012.

The key components of the unit are two interconnected fluidized-bed reactors, the air reactor and the fuel reactor, Fig. 1. The circulation of oxygen carrier between the two fluidized bed reactors means that the technology used has large similarities to normal circulating fluidized bed combustion. Ideally, the costs could also be quite similar, giving a potential of dramatically reducing the costs of CO_2 capture.

The use of solid fuels in CLC offers additional challenges as compared to gaseous fuels. In order to reach high CO_2 capture, the char needs to be gasified in the fuel reactor and to avoid that it follows the circulating bed material to the air reactor. To this end a so-called carbon stripper has been implemented in the stream between the fuel and air reactors. Another challenge is to reach high conversion of the gas, i.e. volatiles and syn-gas, generated by the solid fuel in the fuel reactor. Because the ash present in most solid fuels is likely to reduce the lifetime of the oxygen carrier, the use of low-cost oxygen carriers is desired for solid fuels. Fortunately, a number of low-cost oxygen carriers based on iron or manganese show high reactivity towards the major part of the gases generated by solid fuel, i.e. CO/H_2.

Operation of the 100 kW CLC unit was typically made at temperatures of 1000°C in the air reactor and 970°C in the fuel reactor, and the oxygen carrier used was a low-cost natural ore, ilmenite. CO_2 capture was typically 98-99% indicating very little loss of char to the air reactor. The high flexibility of the unit allowed for operation with large variations of solids inventory in the fuel reactor as well as of the global circulation. The latter had little effect on the performance in contrast to the former. Thus, the gas conversion in the fuel reactor varied between 74 and 84% mainly as a function of the solids inventory in the fuel reactor. The data indicate that even higher conversion could be reached by increasing the solids inventory. An 84% gas conversion means that 16% of the oxygen needed for full combustion is missing. The two main options to reach full gas conversion are

- oxygen polishing, i.e. adding oxygen to the gases exiting the fuel reactor
- combustible recycling, i.e. separating the combustible gases as the CO_2 is liquified and introducing them into the fuel reactor.

There should be several ways to improve the gas conversion further, e.g. higher solids inventory, different reactor design and more reactive oxygen carrier.

The operation was smooth and all major operational difficulties were associated with external functions such as fuel feeding, gas sampling for analyses and steam supply for fluidization. In summary it can be concluded that the technology seems to work quite well, although there are options for further improvement.

The detailed results are reported in a number of papers as well as in the PhD thesis of Pontus Markström, available at http://www.entek.chalmers.se/~anly/co2/co2publ.htm (nr 182)

Moreover, a film showing how the reactor system works, using a perspex glass cold-flow model, can be seen at http://www.entek.chalmers.se/~anly/co2/CFM.htm.

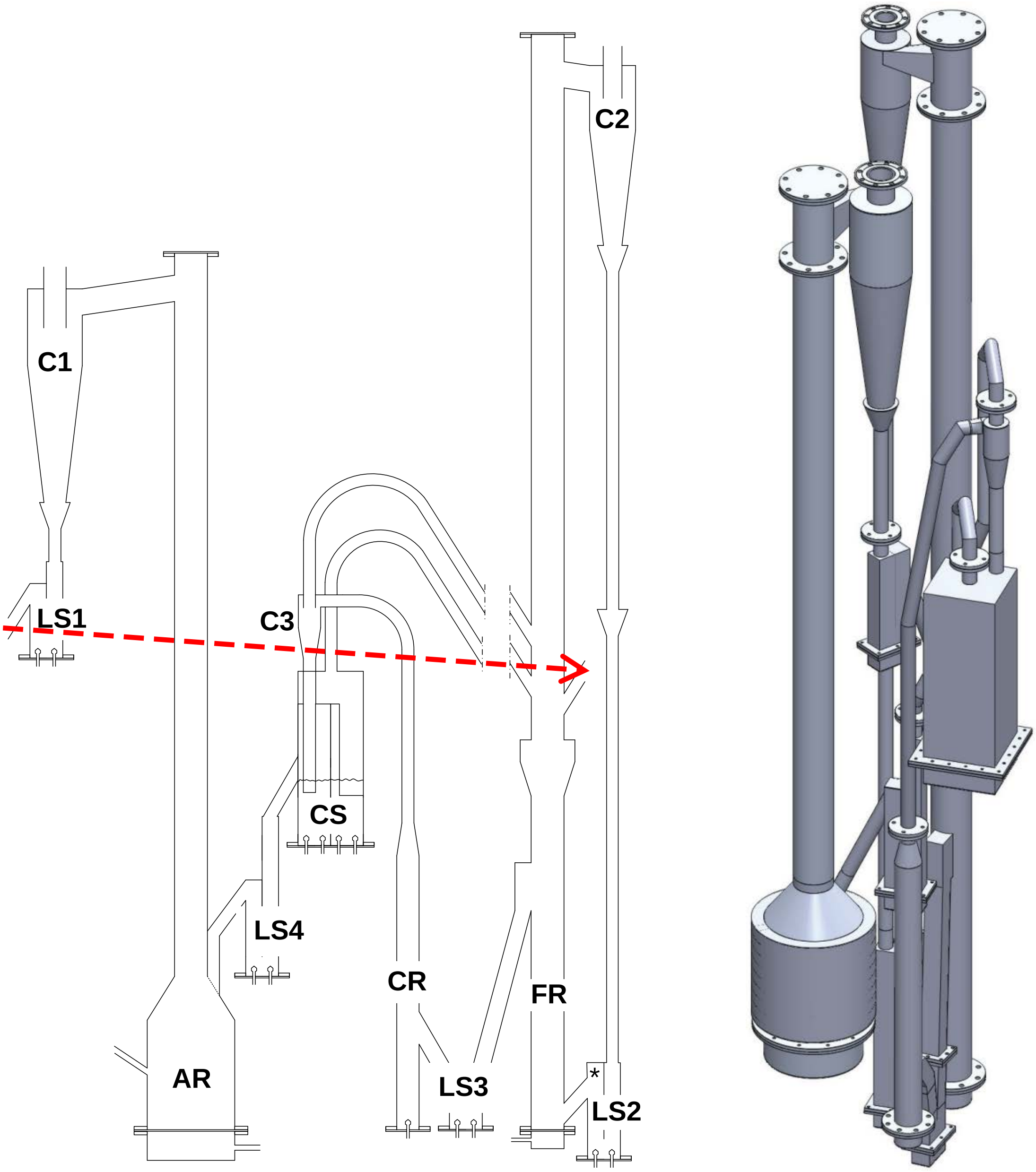
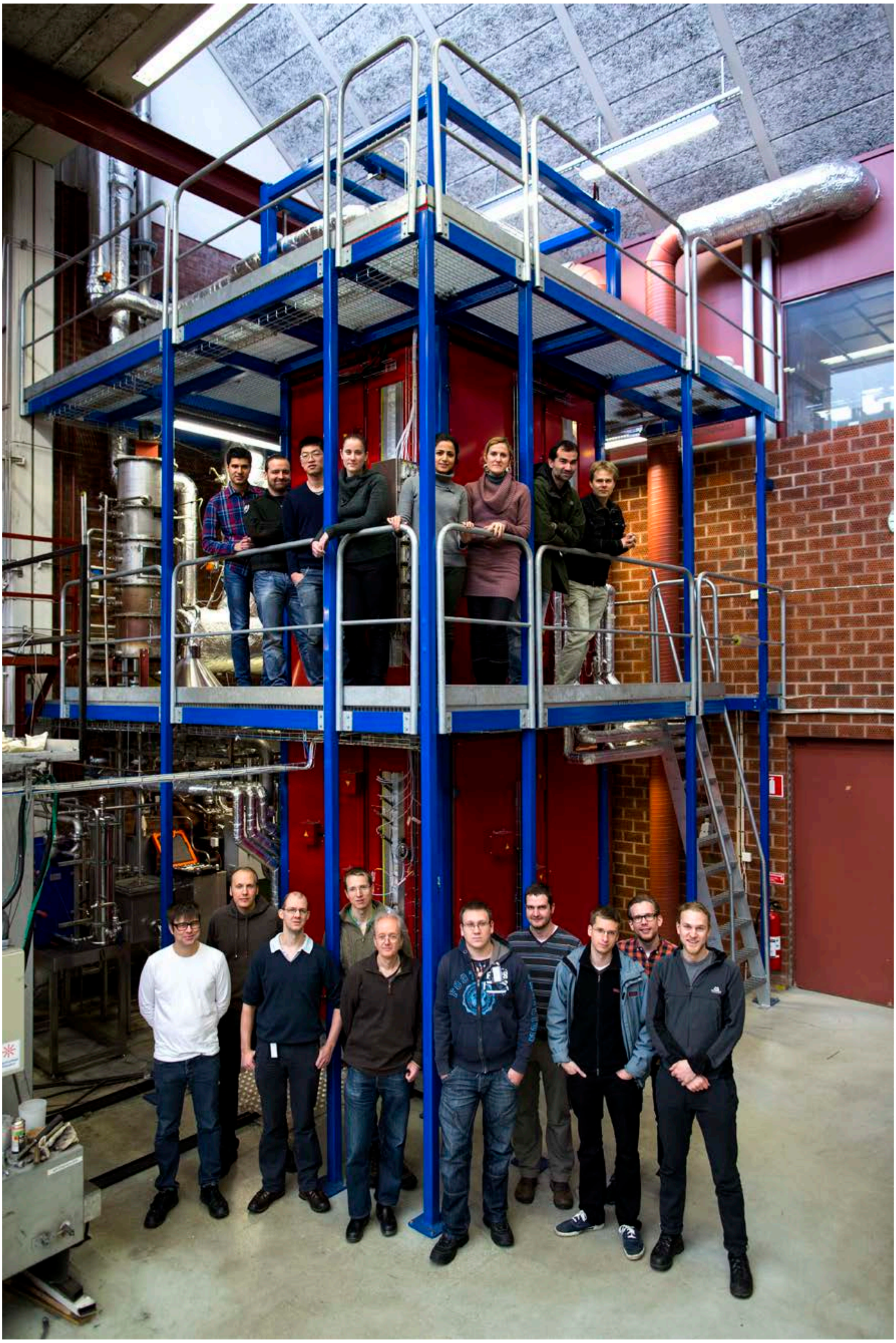


Fig. 1. Left: 100 kW reactor system in unfolded two-dimensional view. AR = air reactor, FR = fuel reactor, CR = circulation riser, CS = carbon stripper, LS = loop seal, C = cyclone . Right: reactor system of 100 kW in 3-D view.


Chalmers' CLC group in front of 100 kW chemical-looping combustor for solid fuels