Novel flat sheet gas separation membrane modules – design, prototype development and operation

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A variety of challenges is associated with the emerging field of membrane-based post-combustion CCS technologies. Simultaneous high performance, high selectivity and high durability under the rather harsh operating conditions of flue gas has proven notoriously complicated to combine in one membrane material. Additionally, for practical and economical purposes, membranes that do approximate this set of targets need upscalable production technology as well as a resulting low price per unit area.

A critical success parameter seemingly less in the limelight of (gas separation) R&D attention is the <u>membrane module</u>. Simply put, the module enables the very functioning of the membrane in the target application, and aims to provide the best operation conditions for given gas composition, pressures, etcetera, while interfacing with the application's process. Independent of the exact nature of membranes, especially hollow fibre modules and spiral wound modules are understandably popular, mostly for reasons of packing density and maturity (proven and optimised operation). However, especially for the experimental new materials slowly coming to fruition in demanding CCS membrane research, such modules might not be suitable and other designs might be required, of which hardly any are applicable for (CCS) gas separation applications. Reasons for <u>novel flat sheet gas separation modules</u> can be that new materials cannot be produced yet or at all as hollow fibres or spiral-windable sheets, that such production would be too time- or cost-intensive, or that accessibility and replacement of membranes is key (e.g. while working with experimental installations and materials).

This paper describes the criteria for, design and development of, and operational experiences with <u>two novel flat sheet gas separation membrane modules</u>. The direct purpose of these membrane modules is to serve as CCS post-combustion membranes, specifically and firstly for the promising high-performance fixed site carrier membranes developed in the EC-FP6 NanoGLOWA[†] project, but a wider range of applicability exists.

Design criteria for the first version of the module included easy access to and replaceability of membranes, versatility in applicable pressures, suitable gas flows for separation, drainage and obviously durability and leak-tightness. In international cooperation with universities, institutes and industry, a practical design compromise was achieved and subsequently constructed. Preliminary testing led to *design enhancements*, after the module was approved for several months of rigourous operation experiments, yielding excellent membrane and module performance results. A second round of design enhancements preceded *real-life application testing* in a coal-fired power plant, again very successfully. A wealth of experience was gathered, which was incorporated in a *scaled-up design* for industrial pilot testing, suitable for roughly 40x more membrane area. In such a design, to be commissioned early 2011, many optimisations have been included, e.g. with respect to sealing issues, flow patterns, packing density and accessibility for sensors. Planned improvements remaining for *future non-prototype versions* are e.g. packing density increase, weight reduction, and CFD-simulated flow optimisation.

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† *EU FP6 Integrated Project NanoGLOWA, a five-year project focusing on research and development of five fundamentally different types of CO_2-selective membranes (and modules and pilot installations) for post-combustion carbon capture at coal-fired power plants.*