Optimal conception of a post-combustion CO_2 capture unit with assessment of solvent degradation

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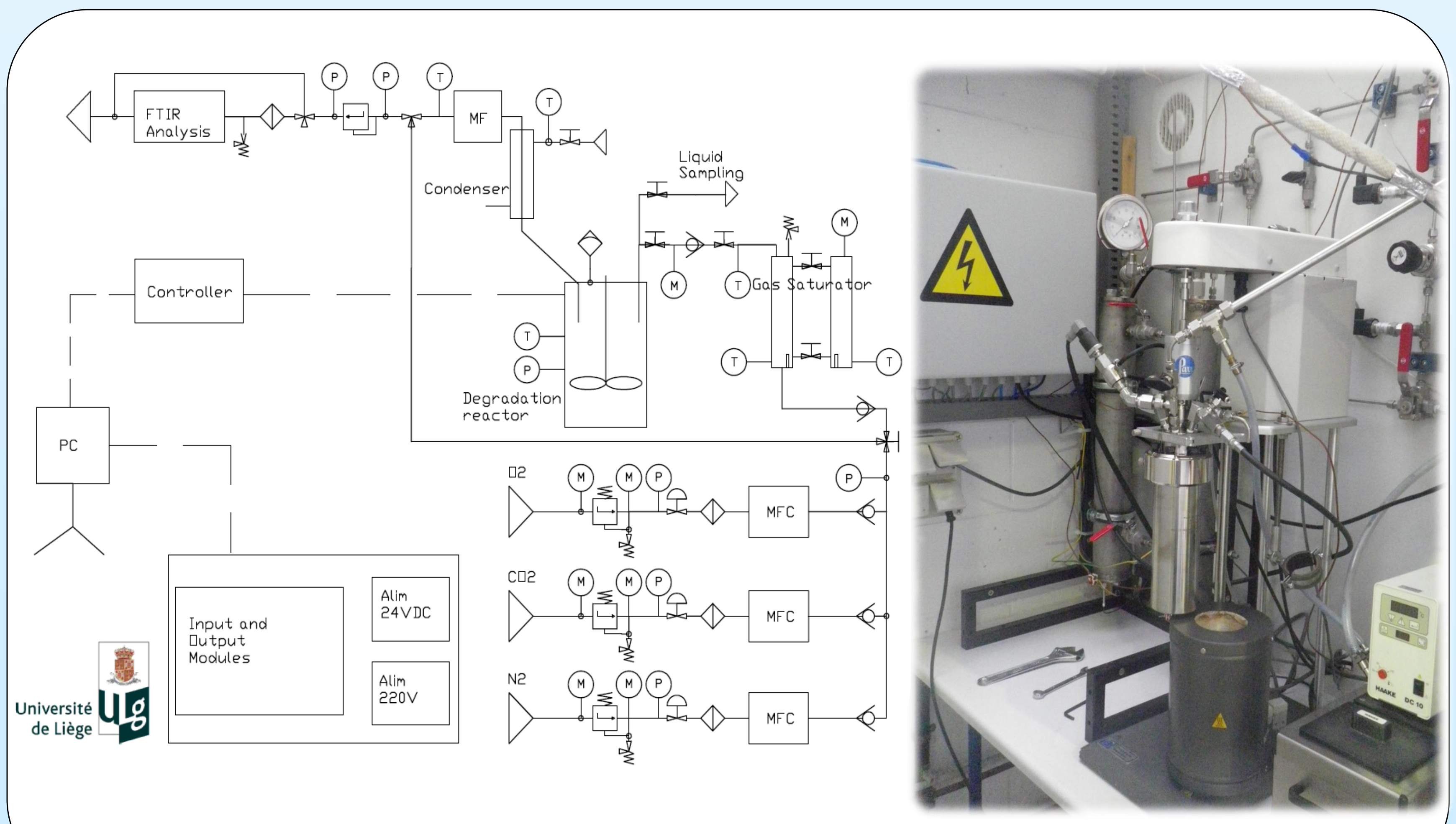
Abstract

Solvent degradation may be a major drawback for the large-scale implementation of post-combustion CO_2 capture due to amine consumption and emission of degradation products. A kinetics model describing solvent oxidative and thermal degradation has been developed based on experimental results. This model has been included into a global Aspen Plus model of the CO_2 capture process, so that optimal operating conditions can be identified to minimize both energy and environmental impacts of the process.

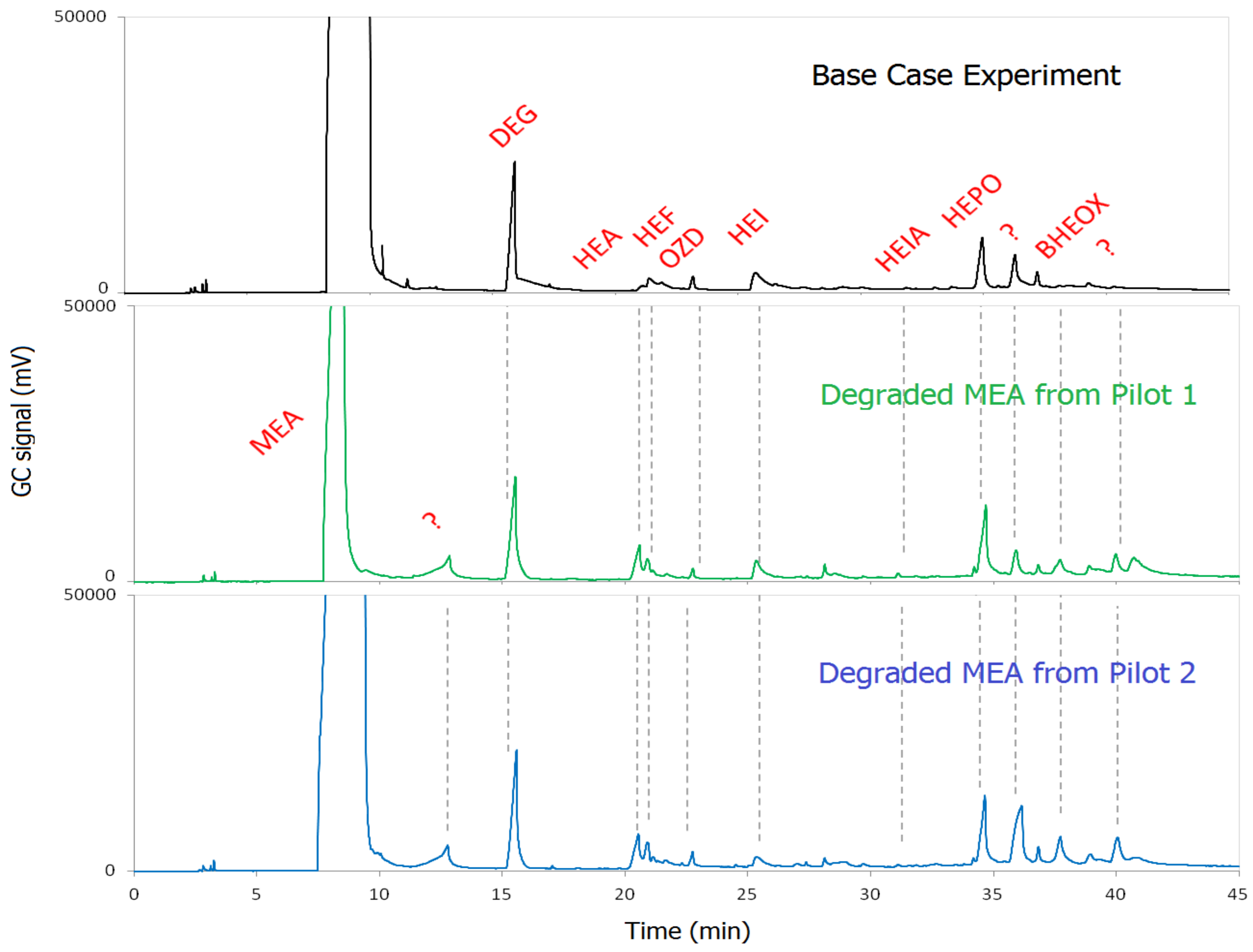
Solvent degradation

Solvent degradation reduces the process efficiency, increases corrosion, and implies additional costs for the treatment of degradation products. It may represent up to 22% of the CO_2 capture Opex[1]!

The degradation of MEA is artificially accelerated in an experimental test rig. The nitrogen mass balance can be closed within the 10% range and repeatability is demonstrated with a deviation lower than 5%. Identified degradation pathways at lab-scale are similar to pathways observed in PCCC pilot plants.



A degradation test rig has been designed and built at the University of Liège.



MEA oxidative degradation is the main pathway in pilot plants as well as in the degradation test rig.

Kinetics of the solvent degradation

The kinetics of MEA degradation has been determined by studying the influence of different operating parameters:

- Agitation rate
- Temperature
- Composition of the flue gas feed (N_2, O_2, CO_2)

Two different degradation equations have been included in an Aspen Plus model of the CO_2 capture process:

MEA oxidative degradation:

$$MEA + 1.3O_2 \rightarrow 0.6NH_3 + 0.1HEI + 0.1HEPO + 0.1HCOOH + 0.8CO_2 + 1.5H_2O$$

$$-r_{MEA} = 5.35e^{5}.e^{-\frac{41\,730}{RT}}.[O_2]^{1.46}$$

MEA thermal degradation with CO_2:

$$MEA + 0.5\ CO_2 \rightarrow 0.5\ HEIA + H_2O$$

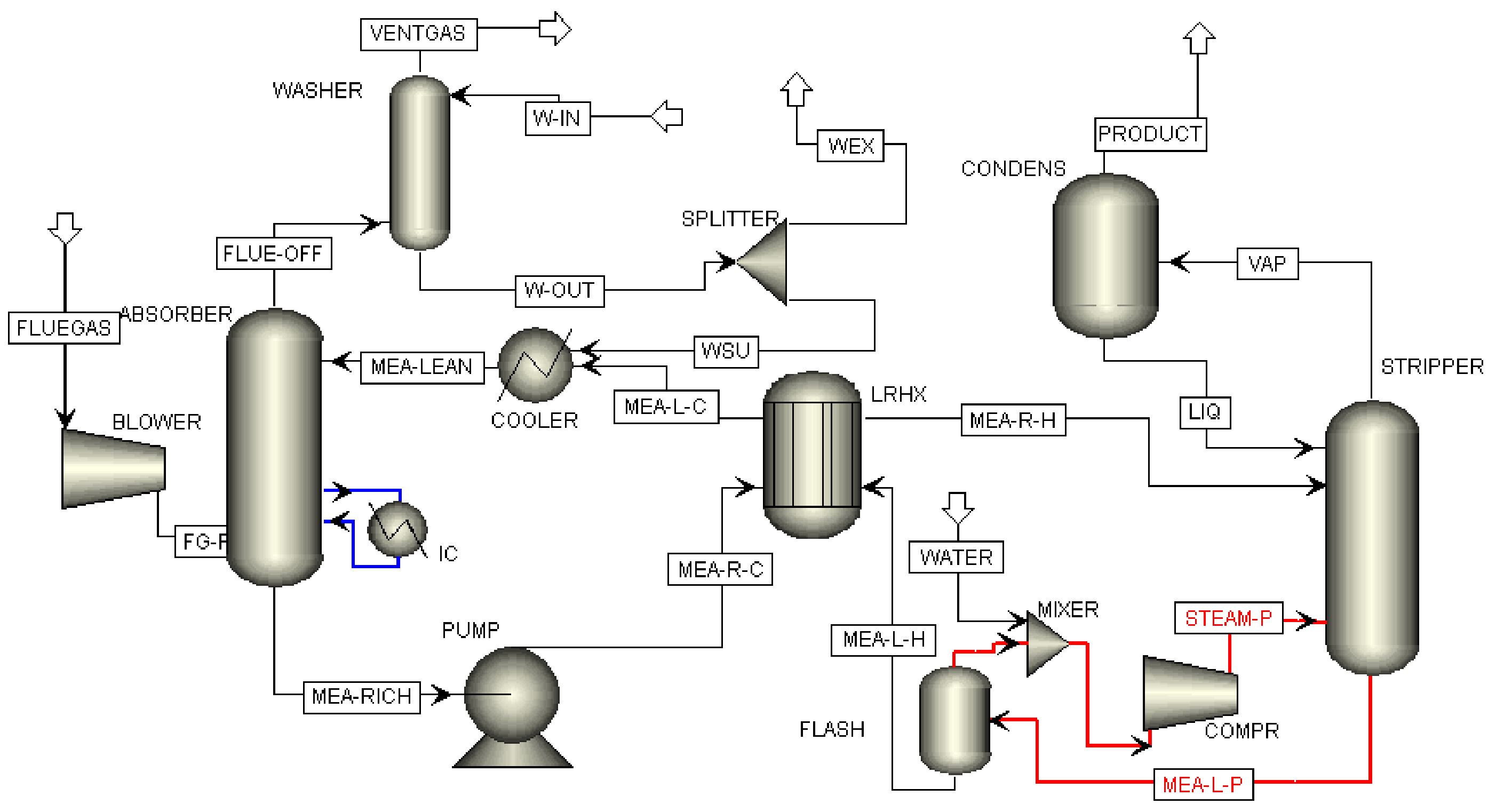
$$-r_{MEA} = 6.27e^{11}.e^{-\frac{143\,106}{RT}}.[CO_2]^{0.9}$$

Global process modeling

The global model of the CO_2 capture with assessment of solvent degradation may be used for the design of CO_2 capture plants to consider not only the process energy penalty, but also its environmental penalty which is particularly relevant for large-scale applications.

The optimized process configuration results into a MEA consumption of 78 g MEA/ton CO_2. This is lower than values reported in pilot plants, probably due to the modeling assumptions made in first approach. The model highlights that the MEA consumption is mainly related to oxidative degradation in the absorber, with ammonia as the major degradation product. The corresponding energy requirement of the CO_2 capture process is evaluated to 3.1 GJ/ton CO_2.

Finally, this model proposes an original approach for assessing solvent degradation within the modeling and design process of CO_2 capture plants.



Lean vapor compression and absorber intercooling reduce the MEA loss by 5% and the energy requirement of the process by 12%

Acknowledgements

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[1]: Abu Zahra M., 2009. Carbon dioxide capture from flue gas. PhD Thesis, TU Delft, The Netherlands.