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Pilot plant testing of HS-3 solvent

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Abstract

The oil refining industry is a highly energy intensive sector, with direct CO_2 emissions typically ranging from 100 to 200 kg CO_2/tonne of crude oil, requiring urgent solutions for reducing CO_2 emissions. The Horizon 2020 REALISE project targets this sector by enabling integration of CO_2 capture and utilisation directly onsite of the existing refineries, for rapid implementation of CCUS to the oil refinery sector.

The present work is a part of the REALISE project and shows the results from a demonstration campaign which has been performed at the SINTEF CO_2Lab pilot plant, in Trondheim, Norway (Mejdell et al. 2011)

The objective has been to demonstrate the benefits of the solvent HS-3 – a blend of two amines that has been optimised within the project. A 12-week long campaign was conducted from 22nd of August to the 9th of December 2022. 91% of this period the plant was up and running, giving a total of 1802 hours' time on stream, implying that the solvent was robust and easy to run.

Altogether, 55 steady state runs were taken, and in each case, four independent measurements of the CO_2 transfer were measured: 1) The amount of CO_2 taken from the exhaust gas, 2) the amount of CO_2 absorbed in the absorber liquid, 3) the amount of CO_2 desorbed from the liquid in the stripper and 4) the amount of CO_2 leaving the top of the desorber. The deviation between these measurements was in average only 1.5%, meaning that the CO_2 mass balance was very good.

The first part of the campaign was dedicated to experimental optimization and the provision of data for modelling. The optimal L/G was found for 90% and 95% capture rates for both 5.5% and 12 % CO_2 in the flue gas. These two flue gas concentrations are typical in the oil refinery industry. An example of one of the optimization tests is shown in Figure 1. In addition, some runs at 98% and 85% capture rates were also done. The results showed that the specific reboiler duty, SRD, did not increase significantly with capture rate for the HS-3 solvent even for the 98% case.

Dynamic step response tests were also conducted to give experimental basis for validation of dynamic models. The steps were in liquid rate, reboiler duty, flow gas rate and flue gas concentration. The dynamic models were used later in the campaign for testing nonlinear model predictive control. These tests were based on the work described in Mejdell et.al. 2022.

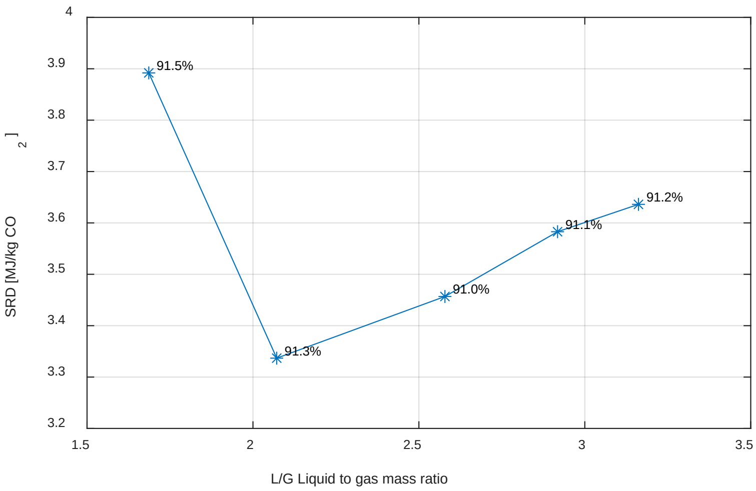

Figure 1: SRD as a function of L/G for ~90% capture rate. The attached numbers to each run are the actual measured capture rate.

After five weeks of the campaign, 20 litres of used and degraded solvent from another partner in the REALISE project was mixed in. The solvent was from TNO's mobile pilot onsite at Irving Oil Whitegate refinery in Ireland. The assumption, in this case, is that the solvent would then have a composition close to a partly reclaimed solvent from a refinery.

An important part of the campaign was to measure solvent degradation both before and after the mixing of used solvent from Ireland and these results are shown in the final presentation.

Another task was to measure the degree of emissions of solvent and solvent degradation products to the air using a varying number of water wash sections (up to 4 sections).

Finally, a unique part of the campaign was to use the CO_2 Compressor and Liquefaction Unit (CCLU) that was built in the project at Tiller. The CCLU was used to measure the impurity of amine and amine degradation products in the compressed and liquefied CO_2 product. These data are of high importance for the assessment and de-risking of CO_2 utilisation and CO_2 transport in other work packages in REALISE.

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