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First Process Results and Operational Experience with CESAR1 Solvent at TCM with High Capture Rates (ALIGN-CCUS Project)

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Abstract

ALIGN-CCUS (Accelerating Low CarboN Industrial Growth through Carbon Capture Utilisation and Storage) is a project from the first ERA-NET Co-fund ACT program. In this program nine European countries, together with the European Union Horizon 2020 program are joining forces for research and innovation actions. The ALIGN consortium involves 31 partners from industry, research and academia and has considerable involvement of industrial companies and an enterprise organization. The ALIGN-CCUS (ALIGN) project aims to accelerate the transition of current industry and power sectors into a future of continued economic activity and low-carbon emissions, in which carbon capture, utilization and storage (CCUS) plays an essential role. For the optimization and cost reduction of post-combustion capture (PCC) technology, the consortium realizes testing programs at four different pilot plants and testing facilities: the Technology Centre Mongstad (NOR), the SINTEF pilot rig at Tiller, Trondheim (NOR), RWE's Coal Innovation Centre at Niederaussem (DE) and the PACT facilities at Sheffield (UK). Collaboration of TCM with ALIGN CCUS project is significant in bridging the knowledge gaps, and reducing HSE, technical and financial risks of technology deployment at large scale.

Technology Center Mongstad (TCM) is located next to the Equinor refinery at Mongstad which is the source of the flue gas supplied to TCM. The ALIGN-CCUS test campaign at TCM started in September 2019 with combined cycle gas turbine (CCGT) flue gas. The main objective of this campaign is to investigate the performance on an advanced aqueous amine solvent. CESAR1 solvent has been selected for its low energy requirement [1,2], higher stability and lower corrosivity [3] compared to monoethanolamine (MEA). CESAR1 is a blend of 27wt% AMP (2-Amino-2-methylpropan-1-ol) and 13wt% piperazine. This solvent was selected in the frame of the European Union project CESAR [4]. The IEAGHG has recently chosen CESAR 1 as their new benchmark solvent.

The TCM test campaign aims at demonstrating operability of CESAR1 solvent at large scale with a real flue gas with a focus on emission control and monitoring, and solvent consumption. By the end of 2019, the amine plant has been operated for more than 1100 hours with CCGT flue gas. This paper describes in the first part the parametric

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testing performed in different configurations of the amine plant. Optimum performances were determined by varying the liquid to gas ratio at capture rates from 85% up to 98%. The absorber was operated with 12, 18 or 24m of packing. The optimum results are compared to MEA from TCM owners MEA campaigns [5,6]. Initial assessment of performance shown in Figure 1 indicates that SRD lower than 3.2 GJ/t_{CO2} may be achievable. Stripper pressure effect towards solvent performance was also assessed during the parametric testing and CESAR1 solvent showed potential to be operated at higher pressure. This means potential Capex and Opex savings for CO_2 compression step.

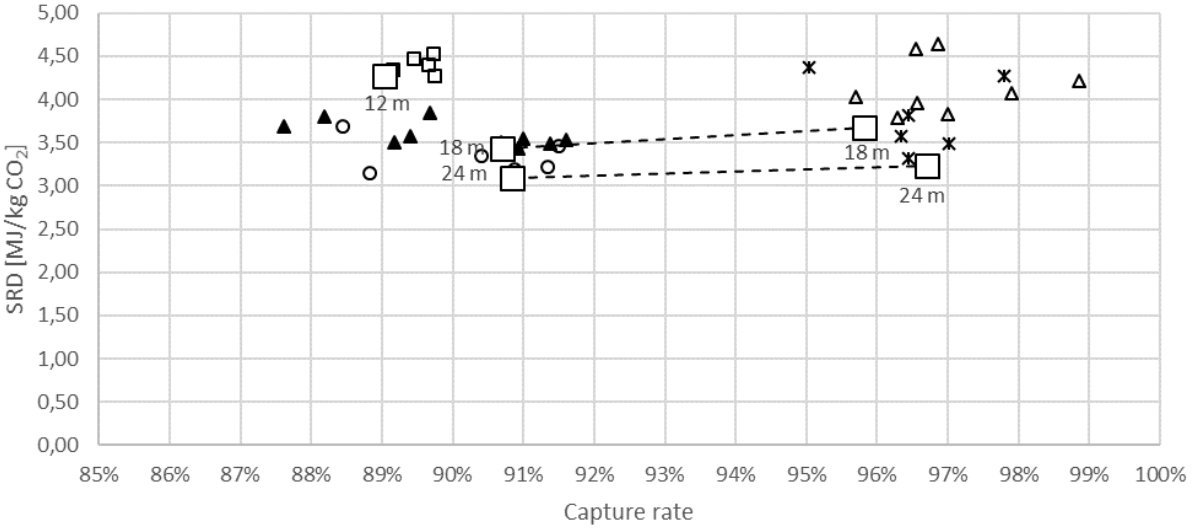

Figure 1: SRD plotted versus capture rate for five test series at captures around 90 and >95%. Absorber packing height of 24, 18 and 12 meters were utilised. Lowest achieved SRD value within each test series are shown as larger squares. Dashed lines indicate trends going from 90 to >95% capture at same packing height. Plots are based on initial assessment of the data and will be further investigated.

The second part of this paper describes TCM operational experience with CESAR1 solvent including transient phases like start-up. As the CESAR1 solvent has been known to precipitate at high CO_2 loadings and at low temperatures [7,8,9], TCM Operations did several measures prior to the ALIGN-CCUS campaign in order to avoid precipitation, including lab experiments. The results were used for evaluating type of solvent supply (pre-mixed or pure components) and to indicate limits for plant operation. As a result of these tests it was decided to order the solvent pre-mixed. A set of operational guidelines was also prepared in order to safely fill the amine storage tanks and start the plant in a safe mode, avoiding precipitation. The solvent concentration, measured daily, decreased more than expected during the first tests of the campaign and was further reduced while water was boiled off to increase the concentration. While troubleshooting, looking for both external and internal leaks in the plant and checking lab analysis, increasing differential pressure in the absorber packing was observed over the next set of optimization tests. Precipitation was suspected, and measures were put into place in order to attempt to reverse it. Stop of flue gas flow and high solvent temperature and circulation rate were proven to be highly effective, measurable both by the decreased differential pressure and the increased amine concentration. For further operation the flue gas inlet temperature has been increased as a mitigating action to prevent precipitation. This issue did not affect the solvent quality which has been monitored over the test campaign. Iron content was measured on daily basis and corrosion coupons were placed in four locations of the amine plant: in hot and cold lean amine and in hot and cold rich amine. The degradation products have remained low during the first phase of the test campaign. The good solvent quality was confirmed by low emissions.

To gain more knowledge on precipitation of the solvent in an amine plant of this size, additional testing time has been allocated to the ALIGN-CCUS campaign with the CESAR1 solvent with the specific purpose of finding the limits for precipitation at different operational setup. The risk is carefully evaluated and a set of handles for

operation are in place in case precipitation is suspected. The TCM amine plant is equipped with differential pressure measurements and several temperature transmitters inside the packing, density transmitters at both lean and rich solvent flows and has the option to vary the packing height between 12, 18 and 24m. This provides a solid basis for performing thorough precipitation testing. By identifying limits and demonstrating handles for reversal, the overall risk of precipitation of full-scale operation with the CESAR1 solvent could be reduced significantly.

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Keywords: Post combustion carbon capture; absorption; AMP; Piperazine

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