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ALIGN-CCUS: Results of the 18-month test with aqueous AMP/PZ solvent at the pilot plant at Niederaussem – solvent management, emissions and dynamic behavior

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Abstract

The ALIGN-CCUS project aims at the optimisation and cost reduction of CCUS technologies. The project consortium realises testing programs at four different amine-based post-combustion pilot plants and testing facilities: RWE Power's Innovation Centre at Niederaussem (DE), the Technology Centre Mongstad (NOR), the SINTEF pilot rig at Tiller (NOR) and the PACT facilities at Sheffield (UK).
A 13,000-hour testing campaign with 30 wt% MEA at the capture pilot plant at Niederaussem confirmed that: (i) a MEA consumption of less than 300g /t CO_2 is achievable when the degradation process can be stabilized in the linear degradation regime and, (ii) very low MEA emissions <3 mg/m³ and <10 mg/m³ even under transient operating conditions can be achieved.
Next to MEA, another long-term test with a duration of 1,5 years is carried out with the so-called CESAR1 solvent (aqueous AMP/PZ (2-Amino-2-methylpropan-1-ol, piperazine), a blend of 3.0 molar AMP (~ 26.74 wt%) and 1.5 molar PZ (~ 12.92 wt. %)). With 2.9 GJ/t_{CO2} CESAR1 has a significant lower specific energy demand for the regeneration of the solvent than 30 wt% MEA (3.5 GJ/t_{CO2}). It is a candidate to replace MEA as benchmark solvent. However, until now no long-term test with CESAR1 has been realised. The testing campaign with CESAR1 at Niederaussem comprises the analysis of the solvent performance taking into consideration factors like specific solvent regeneration energy, regeneration temperature, solvent flow rate, flue gas quality, plant design, emissions, special operational conditions and the chemistry of the solvent degradation over a period of up to 12,000 operating hours. The ALIGN-CCUS testing campaigns at Niederaussem consistently followed a holistic approach of long-term testing, comprising:
- systematic variation of the operating parameters, explicitly CO_2 capture rates between 80 and 98%,
- regular analysis of main oxidative degradation products (glycolate, acetate, formate, oxalate) and thermal degradation products (ethane-1,2-diamine (EDA), 1-Formylpiperazine (FPZ), 2-oxopiperazine (OPZ)),

- regular analysis of main dissolved metal ions (iron, nickel) and components accumulated from the flue gas (sulphur, chloride, nitrate, sulphate), to evaluate the corrosion potential of the solvent and the concentration level of potential catalysts for reactions of CESAR1 or intermediate degradation products,
- testing of solvent management strategies (solvent make-up process and dissolved oxygen removal (DORA)), to evaluate the performance of technologies for controlling the level of accumulated impurities in the solvent and the degradation rate,
- online measurement of emissions (vapour pressure driven and aerosol-based emissions, aerosol particle concentration and size distribution up- and downstream the absorber and inside the absorber column), to determine solvent losses and the release of volatile degradation products via the gas phase,
- investigation of the emissions during stable operating conditions and the transient response of the emissions to dynamic changes of the operating parameters.

The capture plant is operated in a 24/7 mode and separates CO_2 from the flue gas of a lignite-fired power plant. It was commissioned in 2009 and has meanwhile an accumulated operating time of more than 80,000 hours. As the MEA losses at the capture plant at Niederaussem are significantly lower than those reported at other facilities, it is of particular interest to compare this result with the behaviour of another solvent. Understanding the key mechanisms that are responsible for low solvent consumption and emissions ascertained in the long-term testing, and transferring this to other capture plants and solvent systems, is the pivotal idea of the ALIGN-CCUS project. The paper will present the results of this unique long-term test under conditions that can directly be transferred to commercial applications of post combustion CO_2 capture plants.

Keywords: AMP, piperazine, solvent consumption, solvent degradation, emissions, dynamic operation, pilot plant