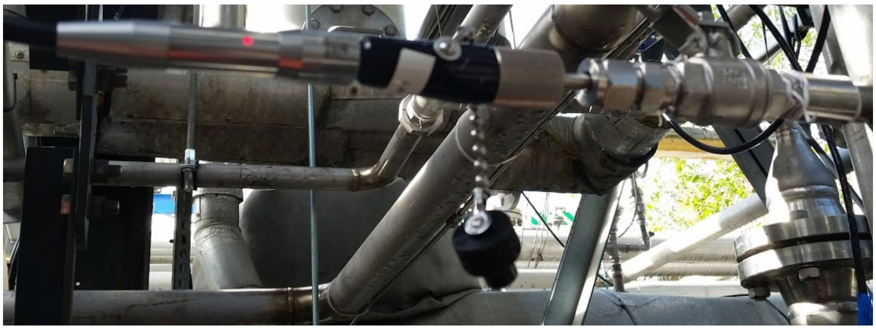
Optimizing carbon capture processes through Raman spectroscopy



In-line chemical analysis of amine process stream by a Raman immersion probe at the CO_2 capture plant facility in Sheffield, UK

Chemical absorption based on amine solvents is considered to be the most mature technology and commercially feasible method for carbon capture. USN demonstrates an implementation of a unique, fast and robust solution for in-line process monitoring and complete speciation of a CO_2 capture solvent, including CO_2 loading and amine strength. It uses a Raman Rxn2 analyzer, powered by Kaiser Raman technology, in combination with multivariate regression models.

The results

- In-line monitoring of CO_2 capture solvent quality
- Data-based decisions for process control and optimisation
- Reduction of total costs of ownership and safety risks

Customer challenges Carbon Capture, Storage and Utilization (CCUS) is gaining more attention as a mandatory solution to reduce greenhouse gas emissions from energy and industrial point source emissions. CO_2 capture by aqueous monoethanolamine (MEA) is ready for commercial deployment. The extra cost of CO_2 capture has to be optimized both by the CO_2 capture plant operator and the technology developer. A central issue of process optimization is solvent management.[1]

Our solution With the use of an Endress+Hauser Raman analyzer system, USN has validated and demonstrated a scalable Raman spectroscopic real-time monitoring solution for CO_2 capture solvent quality. It includes:

- A Raman Rxn2-785nm multi-channel analyzer and two in-line Raman probes with immersion optics, plus acquisition of raw Raman signals through proprietary software
- USN modelling competences for data treatment and prediction of solvent concentrations

University of South-Eastern Norway

The CO_2 capture group of the Faculty of Technology, Natural Sciences and Maritime Sciences at University of South-Eastern Norway (USN) embraces more than two decades of academic / industrial research history, including a state-of-the-art CO_2 laboratory (http://www.co2-lab.com). The focus is on CO_2 capture solvent management, process modelling, control, and optimization including off-line and in-line process analytics.

"Thanks to Endress+Hauser's Raman analyzer solution, we were able to share our unique and practical input for CO_2 capture plant understanding gained through in-depth process insight by in-line monitoring of CO_2 solvent."

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Endress+Hauser
People for Process Automation

PACT facility, Sheffield, UK

Application and process details The general MEA process is absorbing CO_2 in an absorber at 40 °C and stripping CO_2 from the solvent by applying heat at 120 °C in a desorber. When CO_2 is absorbed by MEA, several processes and reactions generate a pool of cations and anions which include carbonate, bicarbonate, carbamate and protonated amine. During the desorption, CO_2 absorbed by the amine is removed and CO_2-free amine is re-circulated to the absorber. Prolonged operation of the amine-based capture process causes solvent degradation and degradation products such as heat stable salts, thus reducing the capture efficiency.

Scalable approach from laboratory to process The Raman spectroscopic models for a complete ion speciation in MEA processes were first developed in the laboratory using Raman measurements of different CO_2 loaded 30 wt% MEA samples against reference measurements with NMR spectroscopy. Then, the prediction accuracy of the models was evaluated using trials at CO_2 rig at USN, which is a mini-pilot scale CO_2 capture plant.[2] Finally, its applicability was demonstrated for a large pilot scale capture operation at the Pilot-scale Advanced CO_2-capture Technology (PACT) facility near Sheffield, UK during a three-day campaign.[3] Two Raman probes with immersion optics were plugged into lean and rich amine streams during pilot campaigns, and *in situ* measurements were used for obtaining on-line concentration profiles amidst different process conditions. Further, the capability of Raman instruments for monitoring solvent degradation compounds was identified during an additional 30-day campaign at PACT.[4] The methods are also reliable for chemical analysis in other CO_2 capture solvents and mixtures in a range of concentrations.[5,6]

From process understanding to optimization Thanks to their expertise and know-how on the CO_2 capture process and the support of Endress+Hauser Raman analyzer solutions, USN has demonstrated that Raman technology can:

- Replace tedious off-line analysis (>2 hr measurement time and sample preparation) such as NMR or titration with in-line monitoring, which gives measurement results in less than one minute without human interference
- Reliably predict the total CO_2 and amine concentrations in changing process conditions
- Monitor variation of solvent quality and degradation, thus minimizing solvent loss
- Measure performance of absorber, desorber, thermal reclaiming unit, and wash water tanks
- Minimize CO_2 capture plant downtime
- Enable plant operators to optimize overall plant operation decisions

Chemical property	r^2	RMSEP*	Chemical property	r^2	RMSEP*
CO_2 loading	0.998	0.0560	Carbonate + bicarbonate	0.975	0.0437
Carbamate	0.991	0.0697	Free MEA	0.994	0.142
Carbonate	0.961	0.0058	MEAH+	0.994	0.077
Bicarbonate	0.966	0.0403			

* Root mean square error of prediction

Table 1: Summary of PLSR models for speciation[7]

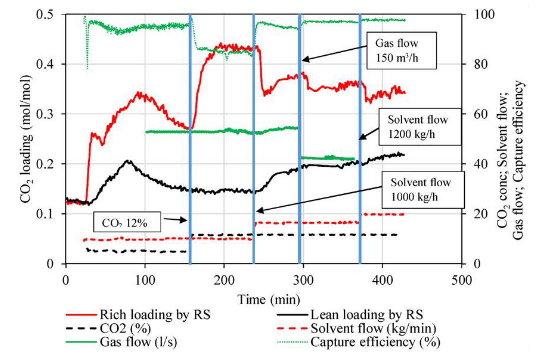

Figure 1: *In situ* prediction results at PACT CO_2 facility[3]

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