IEAGHG 8th Post Combustion Capture Conference

16th to 18th September 2025 Marseille, France

Real-time Solvent Analysis for Enhanced Amine Post-Combustion Capture Performance

Aisha Ibrahim[a]*, Mathieu Lucquiaud[a], Jon Gibbins[a], Muhammad Akram[b] and Abdulaziz Gheit[b]

[a]*University of Sheffield. Sheffield. S3 7RD. UK*
[b]*Translational Energy Research Centre. Sheffield. S9 1ZA. UK*

Abstract

Amine-based post-combustion capture (PCC) is a mature and commercially viable carbon capture technology. However, optimising CO_2 removal while minimising the energy demand of solvent regeneration remains a key challenge. As global efforts toward net-zero and net-negative emissions intensify, achieving high CO_2 capture rates necessitates precise real-time monitoring of amine concentration and CO_2 loading. High capture rate operation, well above 95% and as close as practically possible to 100%, requires the desorber to be operated under conditions producing the optimum lean solvent loading at all times. This is a necessary condition so that solvent capacity in the absorber can always be supplied to match exactly flue gas conditions. This necessary condition requires rapid adjustment of solvent flow in response to real time measurement of lean loading to maintain absorber exit CO_2 concentration for high capture rates and to maximise rich loading for low energy of regeneration.

Traditional analytical techniques such as titration, spectroscopy, gas chromatography, and total inorganic carbon (TIC) analysis have been employed for solvent monitoring but present trade-offs in accuracy, precision, robustness, speed, and cost, limiting their suitability for continuous and flexible operation. Density, a well-established parameter in industrial applications, has shown promise for real-time solvent analysis. However, existing density-based approaches often assume constant solvent concentration, neglecting water losses and other dynamic process variations.

This study introduces two techniques for accurately determining amine concentration and CO_2 loading, addressing the limitations of existing methods. These approaches offer a cost-effective, reliable, and real-time solution using robust, industrially proven equipment. Additionally, they incorporate advanced data analysis and presentation methods to support informed operational decisions, enabling effective process control and optimisation of capture rates.

The first technique, a density-based method**,** leverages solvent density and temperature measurements from industrial instrumentation to enable real-time process monitoring. It integrates titration data with numerical analysis and predictive modelling to estimate solvent concentration. The inferred amine concentration, in combination with density

* Corresponding author. Tel.: +44 7442 546859, *E-mail address:* aibrahim8@sheffield.ac.uk

and temperature, facilitates continuous online CO_2 loading measurements for both lean and rich solvents through a density correlation developed using laboratory-based total inorganic carbon analysis. However, this method faces two key challenges: (1) Its reliance on titration measurements limits full real-time automation, and (2) it cannot simultaneously determine both amine concentration and CO_2 loading without an additional independent parameter.

To overcome these limitations, HAPTICS (High Accuracy Pressure Temperature for Inferential Control in Stripping) was developed. This technique infers lean loadings and solvent concentration by using solvent density, pressure, and temperature data from the stripper reboiler/sump, leveraging the equilibrium state of the solvent with vapour and CO_2. A vapour-liquid equilibrium (VLE) correlation, developed from published data relevant to reboiler conditions, links reboiler temperature, pressure, amine concentration, and CO_2 loading.

Both techniques were evaluated at the Translational Energy Research Centre (TERC) amine PCC pilot plant in Sheffield. Solvent densities and temperatures were measured using Coriolis sensors, while thermocouples and pressure sensors were installed along the stripper column and reboiler. These instruments provided extensive process data, which were used to infer amine concentration and CO_2 loading. On-site titration was also conducted to validate the accuracy of both methods by comparing their results with titration-derived values.

Figures 1 and 2 illustrate a strong correlation between inferred and titration-measured values, confirming the accuracy of both techniques. HAPTICS demonstrates an R^2 (Coefficient of Determination) of 0.948 for amine concentration and 0.982 for CO_2 loading, highlighting its reliability. However, HAPTICS requires further refinement, as some discrepancies were observed, likely due to the VLE total pressure model being based on a limited dataset. Additionally, the authors hypothesises that the use of a kettle reboiler in this study may have influenced quantitatively the results. The large internal volume of the kettle reboiler, although not detrimental to operation of the pilot plant, led to extended equilibrium times, in excess of 2hrs, which could pose challenges in scenarios requiring rapid process control.

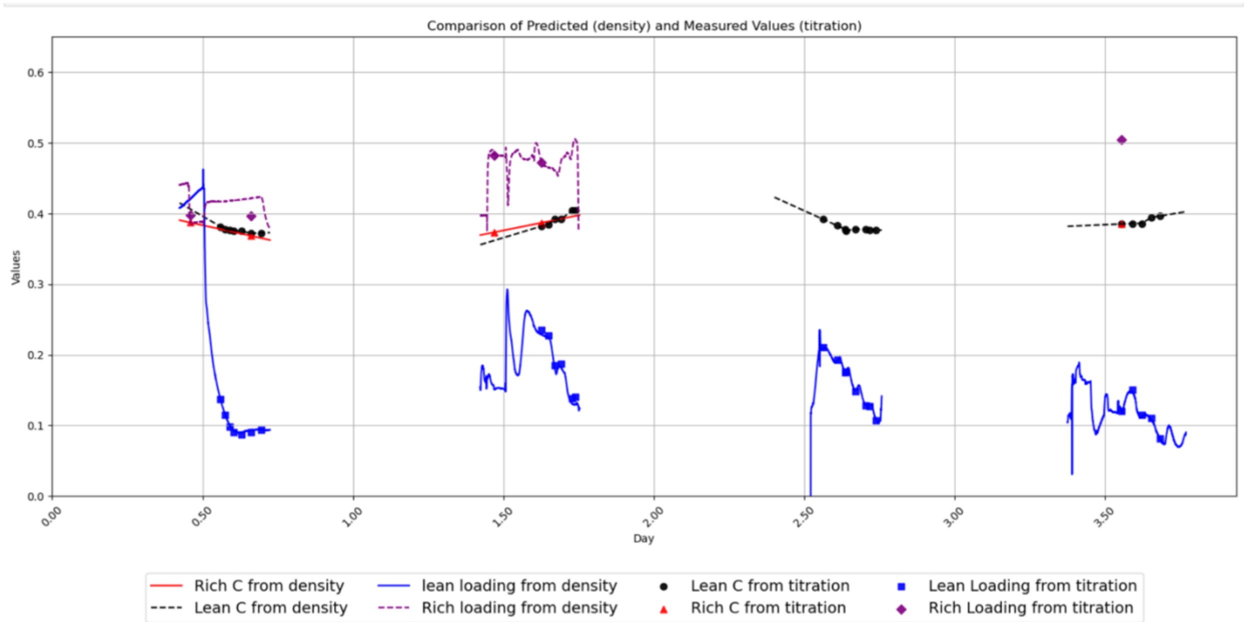

Figure 1: Titration measurements of solvent concentration and CO_2 loading alongside continuous interpolated values derived from density measurements

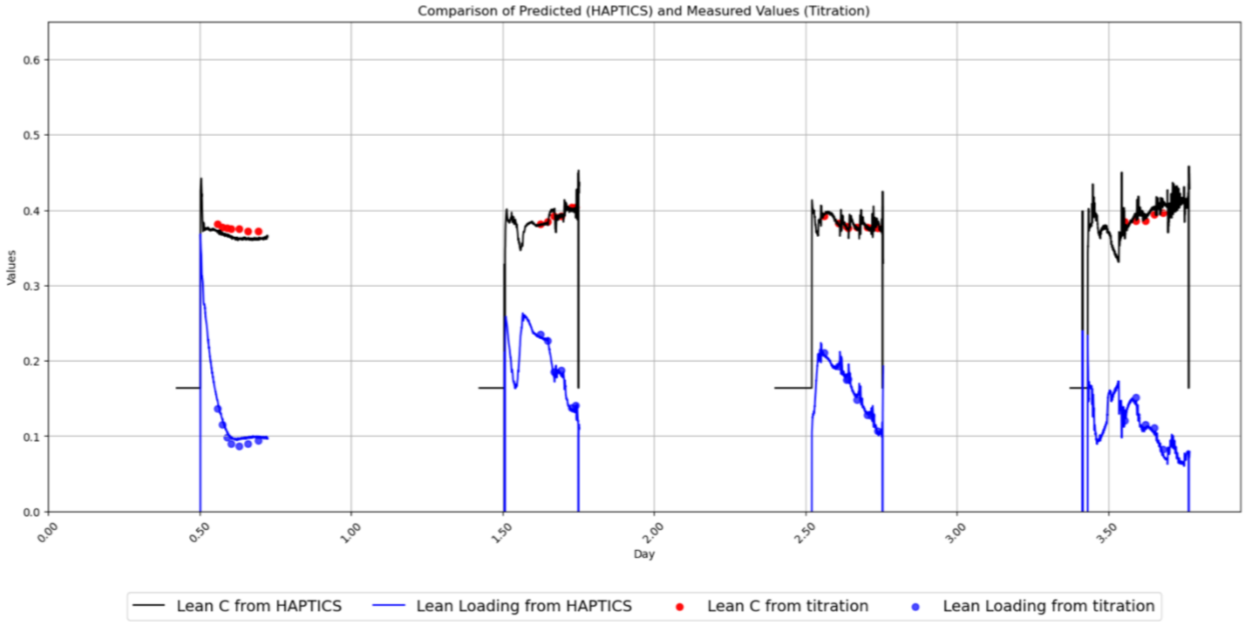

Figure 2: Titration measurements of lean solvent concentration and CO_2 loading alongside continuous values derived from HAPTICS method

Based on the findings, both techniques can be applied independently or in combination. The density-based method provides a preliminary real-time monitoring solution before the reboiler reaches equilibrium, offering an initial assessment of solvent conditions through titration-assisted analysis. Once equilibrium is established, HAPTICS offers continuous inference of solvent concentration and CO_2 loading. Future research will focus on further refining the HAPTICS total pressure model and validating these techniques under industrial conditions using once-through thermosyphon reboilers**,** the industry standard, which operate with minimal solvent volumes and achieve equilibrium more rapidly. In addition, alternative parameters will be investigated alongside density to enhance the inference of rich loadings.

In conclusion, both the density-based method and HAPTICS have been demonstrate at the 1tCO_2/day pilot scale. They demonstrate high accuracy, robustness, rapid response, and cost-effectiveness key attributes for subsequent commercial PCC implementation. This includes testing at a larger 40 tCO_2/day pilot, which would take place between the time of writing this abstract and the conference in September. The integration of these techniques provides a comprehensive solution for real-time solvent monitoring, enabling improved process control, performance optimisation, and operational efficiency, ultimately supporting the large-scale deployment of carbon capture technologies.

Keywords: amine post combustion capture; solvent analysis; density; CO_2 loadings; amine concentration;