PCCC-8

Real-time solvent analysis for enhanced amine post-combustion capture performance

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Background: Ultra-high amine PCC

Post-Combustion Capture (PCC) is a mature technology, often thought to require specialised solvents to achieve 100% fossil fuel capture . However, research demonstrates that this is achievable using MEA with only a minimal energy penalty for CCGT (Michailos and Gibbins , 2022 & Gibbins, 2022).

Achieving high capture rate with minimum energy penalty

why?

- Achieve net zero by capturing 100% added CO_2
- More desirable to capture the extra % with PCC than using CDR alternatives if cheaper

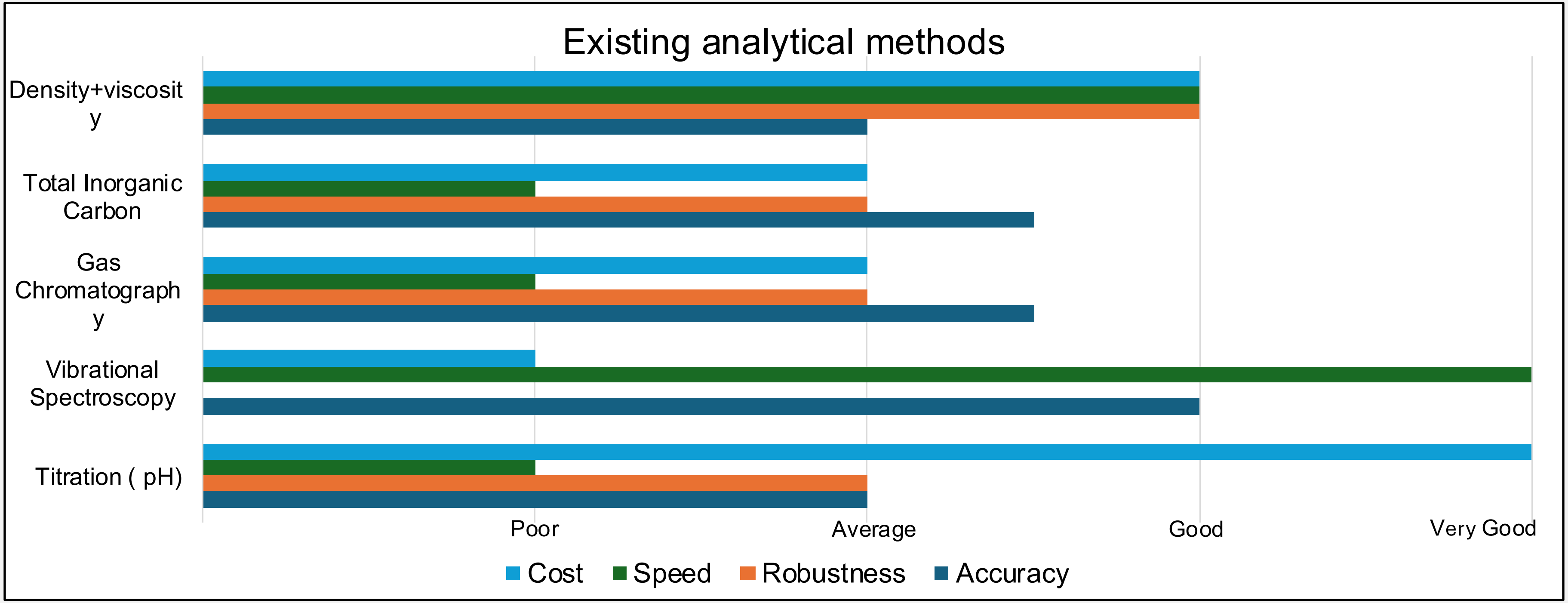
How?

- Achieve lowest possible lean loading at given reboiler pressure
- Optimise lean flow to absorber to achieve highest possible rich loading
- Leverage lean and rich storage to optimise absorber and stripper performance independently

What to do?

- Monitor process parameters: Temperature, pressure, flow
- **Real time monitoring of solvent concentration and loading (rich & lean)**

Existing analytical methods for solvent monitoring



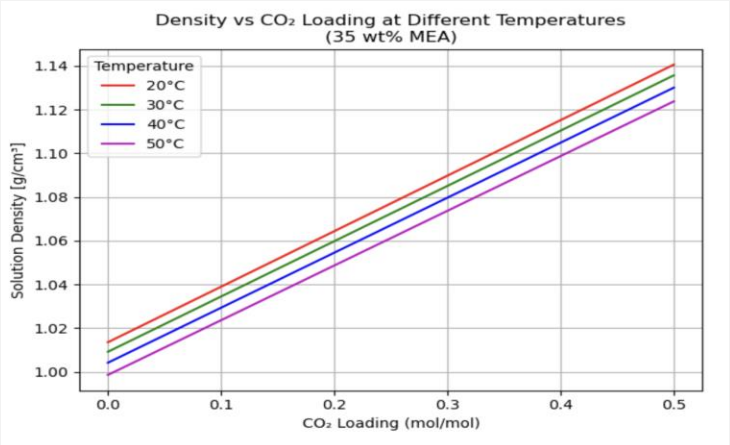
Objective:

❖ **Develop real-time solvent monitoring techniques that are accurate, robust, fast, and cost-effective using standard, commercially available instruments commonly found in commercial plants**

Theory: Density method

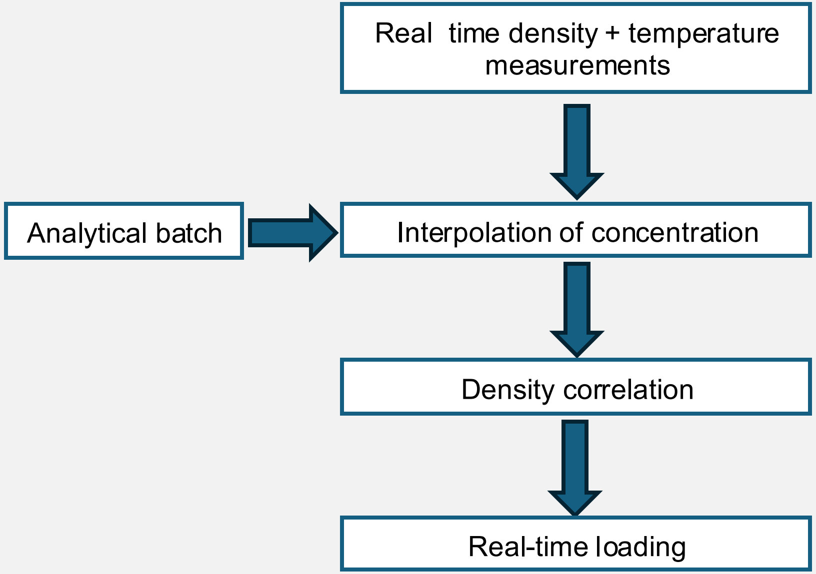
- **Weiland Correlation (Weland et al, 1998) :** Relates solvent density to amine concentration, CO_2 loading, and temperature. **:** Based on experimental + literature data; captures solvent behaviour across a wide range of conditions

- **The Challenge:** Density = f(Temperature, Concentration, Loading). We can measure Density and Temperature in real-time, but that still leaves two unknowns. To find the Loading, we must first know the Concentration



- **Accurate density measurement is essential** – a change of 0.01 mol/mol in loading results in a density change of only 0.0026 g/cm³

- **Precise temperature measurement improves predictions** –1°C change in temperature results in a density change of only 0.00067 g/cm³.

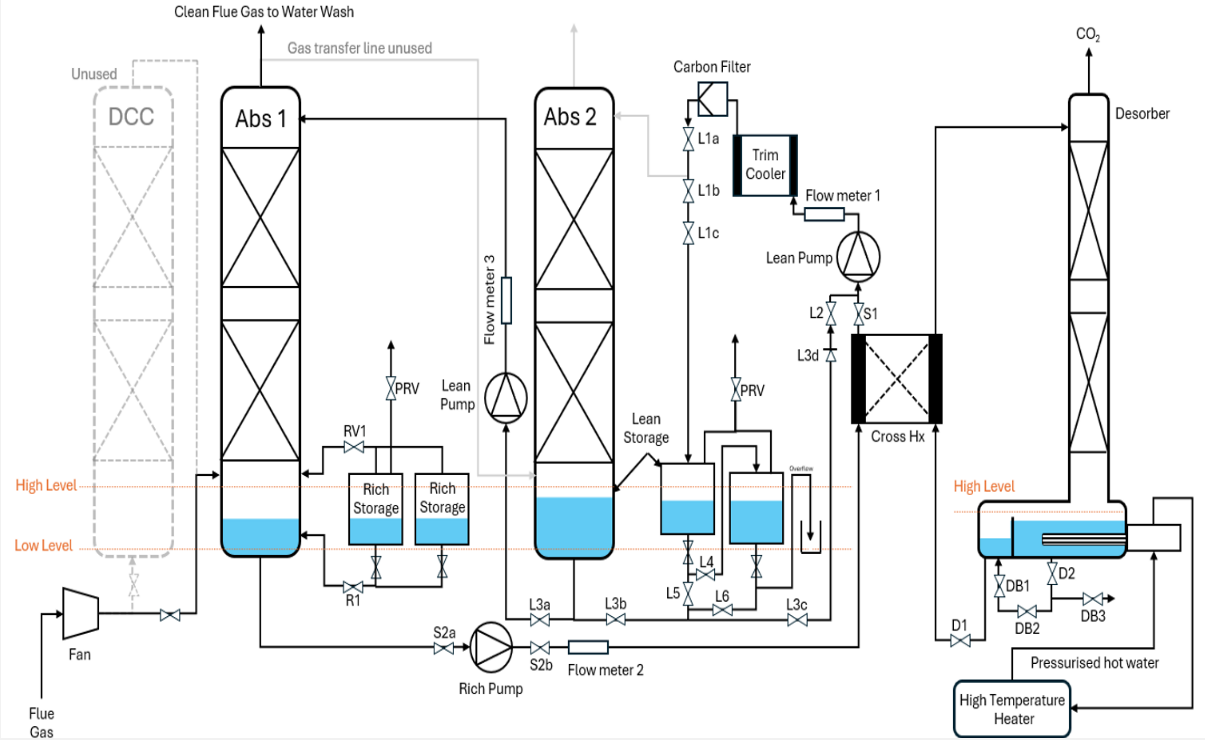


Methodology

Field study: Methodology

❖ **Aim of the test**: illustrate and verify the methods for calculating solvent loading and concentration

The test was conducted as part of the FOCUSS Project, funded by UK DESNZ and supported by SSE Thermal, AECOM, and the University of Sheffield.



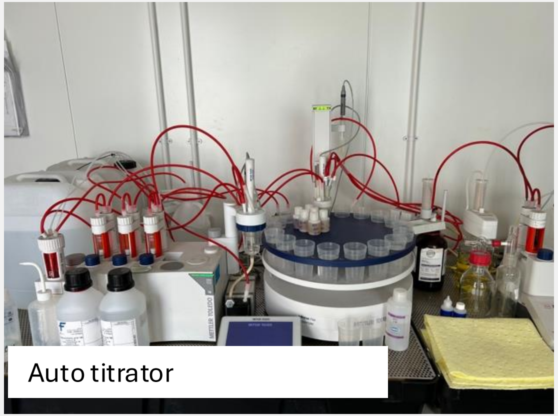
Revised EIC plant layout: 1tCO2/day pilot scale

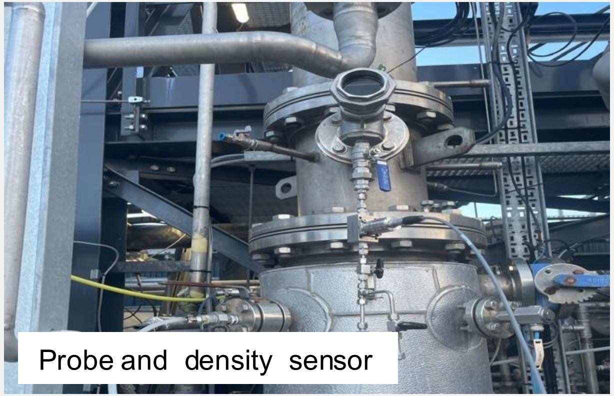
All plant data

Calibrate the density correlation

Loading calculated (The real-time result)

Field study: EIC pilot plant testing





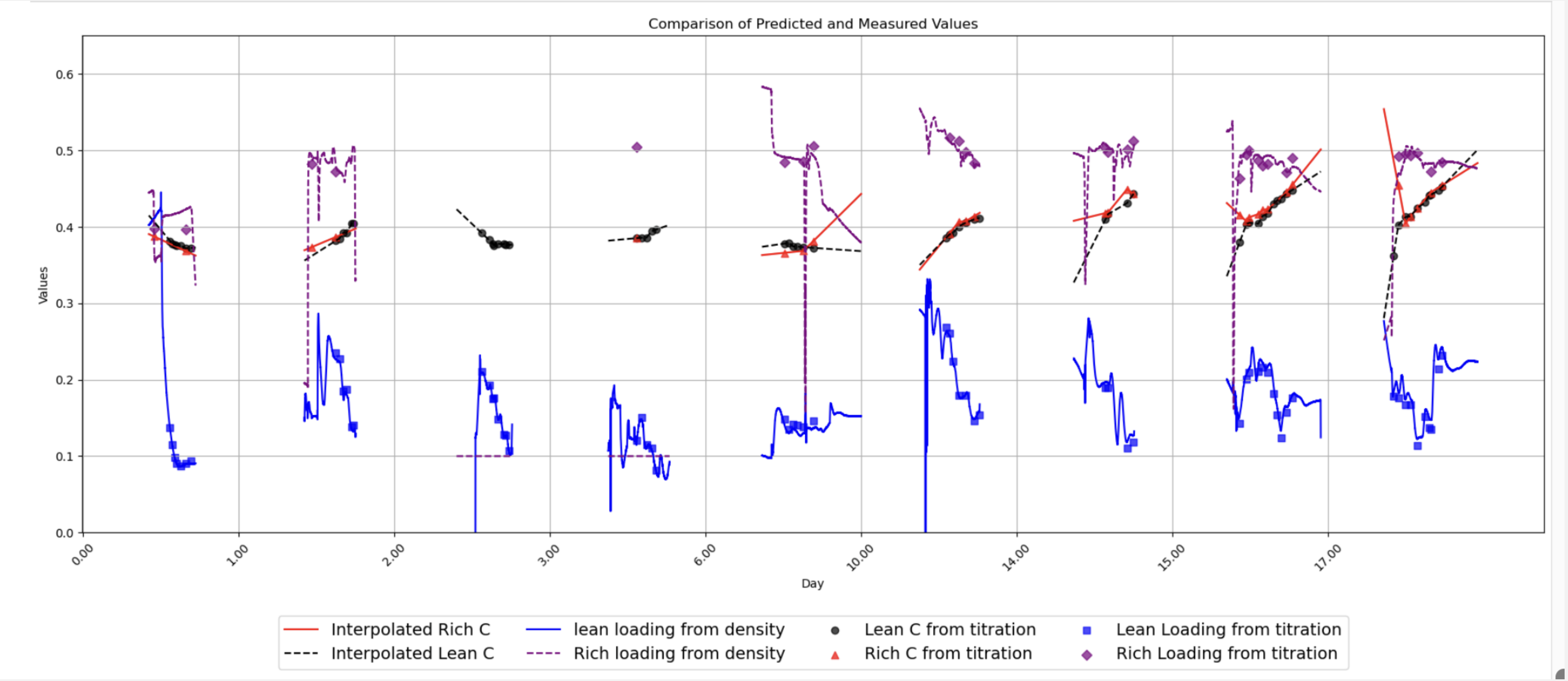
Flow Measurement
- 3 × Coriolis flowmeters
- Density sensor

Pressure Measurement
- Pressure sensor

Temperature Measurement
- RTDs – reboiler & stripper temperature profile
- 1 × Thermocouple – stripper temperature

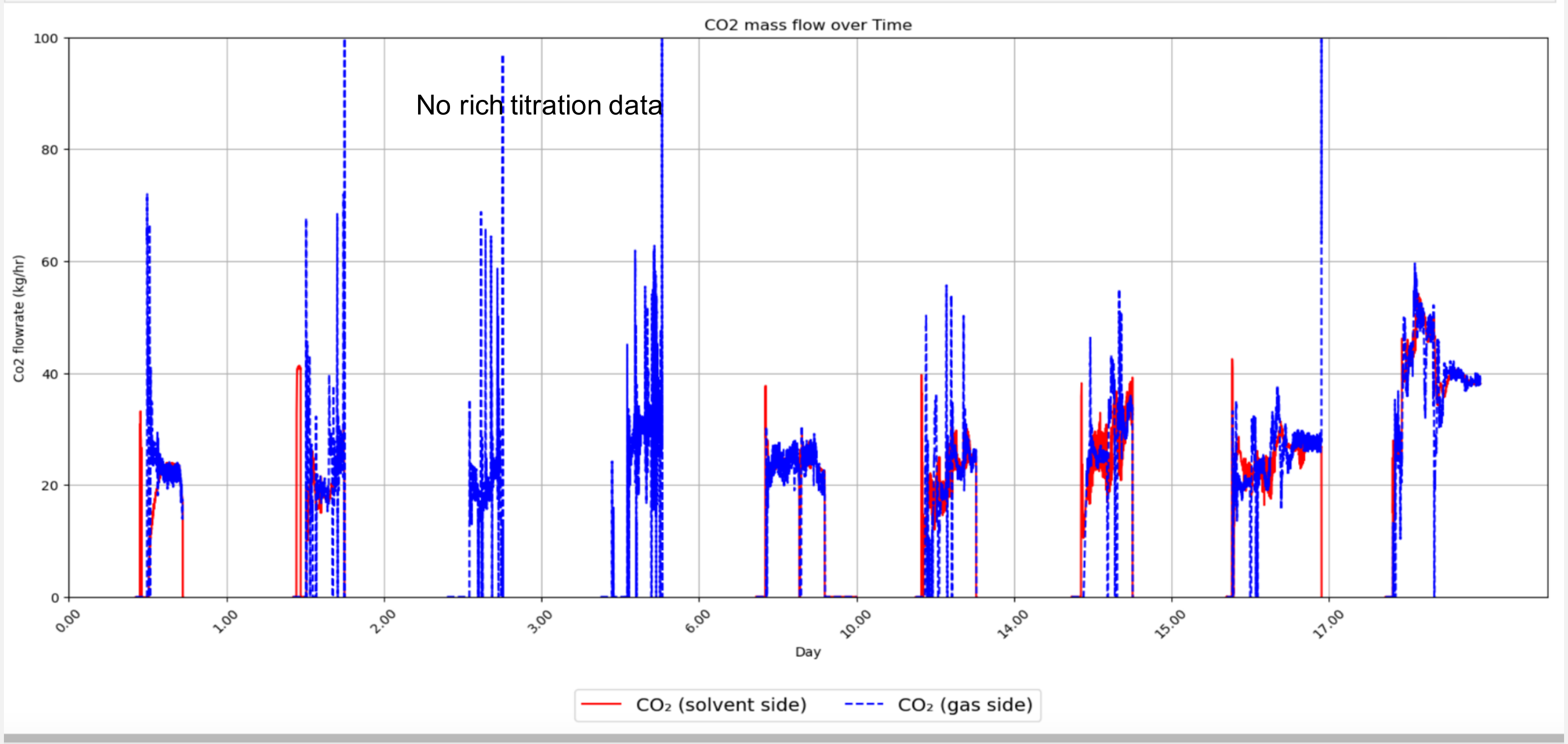
Analytical Equipment
- Auto titrator

Results: Density method



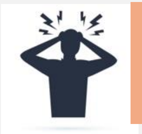
✓ Strong agreement between predicted (density) and measured (titration) values

Results: Mass balance



Conclusion: Strong agreement between gas-side (the vortex flowmeter) and solvent-side CO_2 flow (using the real-time concentration and loading) measurements validates the accuracy of our real-time calculations.

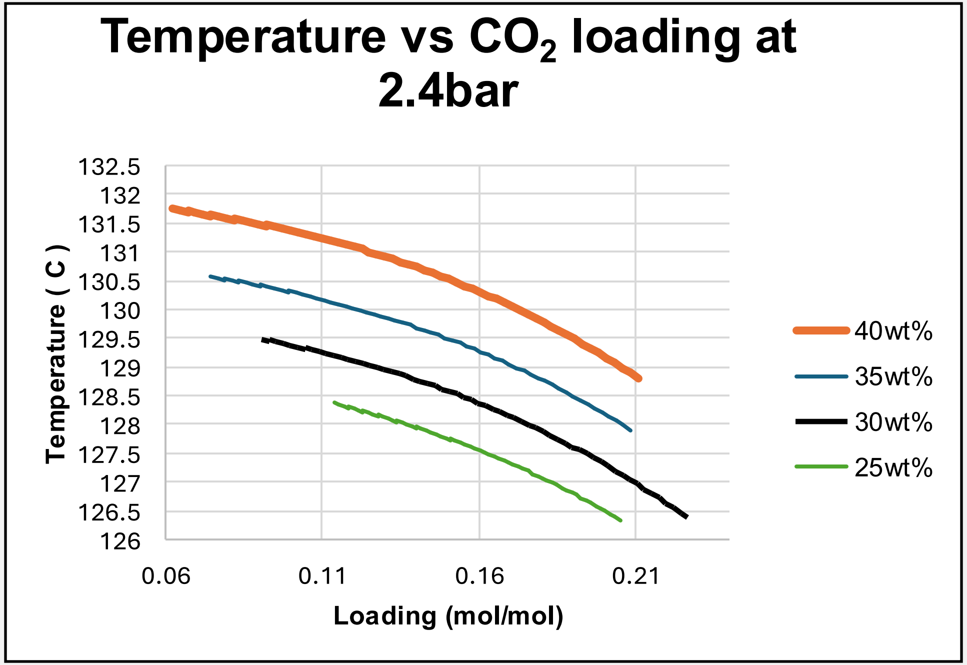
Theory: Tuneable VLE



Challenge: What if no titration data is available to calibrate the density method?

Solution: Develop a second, independent model using reboiler Vapor-Liquid Equilibrium (VLE) to create a self-calibrating system

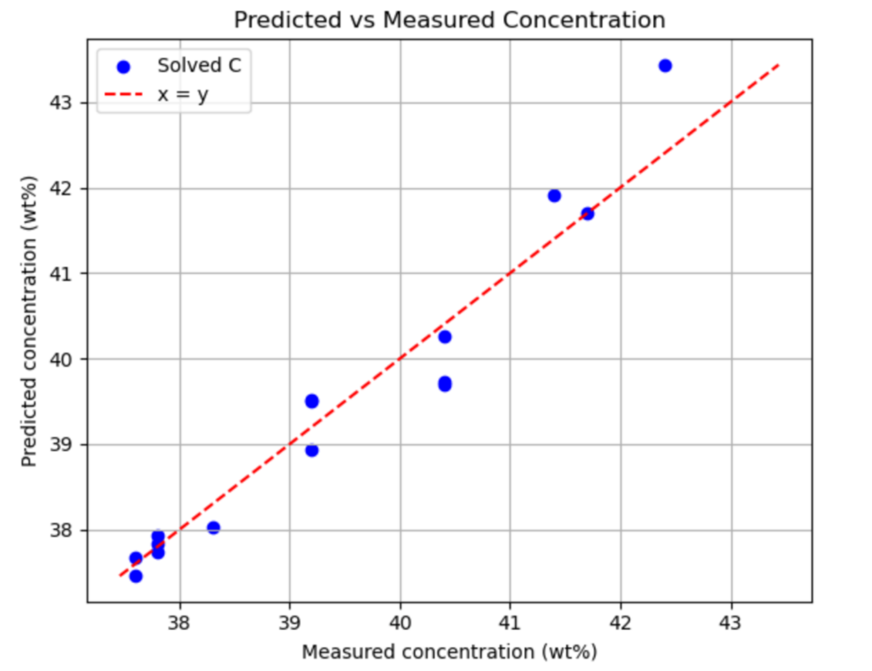
- **Absolute loading from equilibrium data** – determined using temperature & pressure at reboiler equilibrium (lean solvent + vapor).
- **Model insight** – Aspen CCSI model shows the relationship **between temperature**, **CO_2 loading**, and **MEA concentration (wt%)** at 2.4 bar.
- **High sensitivity** – a 0.5 °C shift (e.g., 130.5 → 130.0 °C) causes a significant change in CO_2 loading → precise temperature measurement is critical.
- **Testing needs** – simple empirical formulas required, but limited experimental data at relevant T & P.
- A fitted VLE model was developed – 3 variables



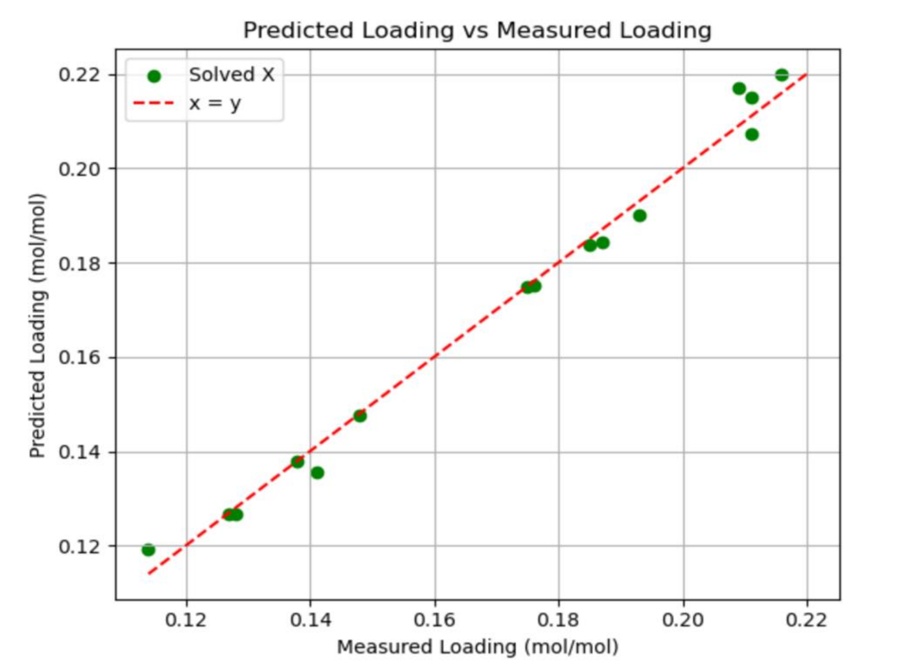
Aspen CCSI Model

HAPTICS: High Accuracy Pressure & Temperature for Inferential Control in stripping

❖ **The Breakthrough:** We combine the Density and VLE models. With two equations, we can simultaneously solve for our two unknowns: **Concentration and Loading**, without requiring any titration. However, only works at reboiler equilibrium.



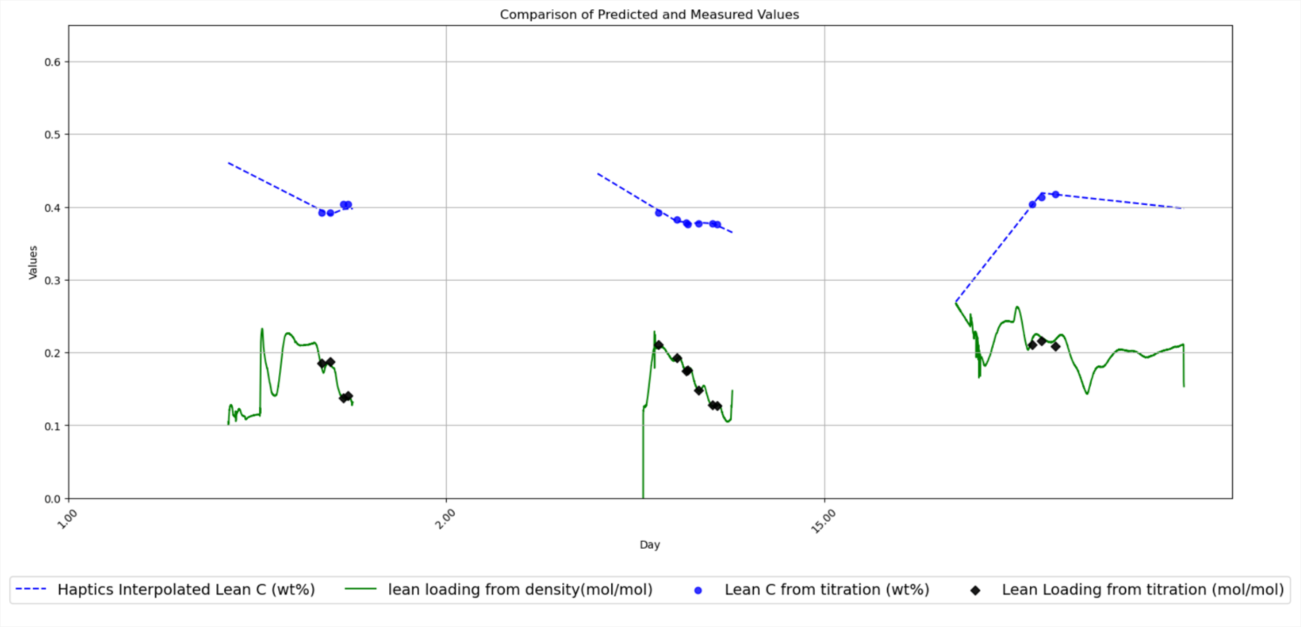
Root mean square errors: 0.4241



Root mean square errors: 0.0035

Real-time monitoring with HAPTICS

Haptics is valid only at equilibrium. Once concentration and loading are determined from Haptics, concentration can be interpolated, and the density method can then be applied to calculate loading



- **Strong correlation** between methods and titration
- **Challenge:** Pilot kettle reboiler took long to stabilise
- **Future Outlook:** Commercial ones through thermosyphon reboiler are expected to reach equilibrium faster

Conclusion and future work:

- ✓ **Density method vs. titration** – strong agreement, but batch analytical methods still needed for amine concentration calibration.
- ✓ **HAPTICS predictions** – good correlation with titration data, though only valid once equilibrium is reached.
- ✓ **Complementary Use:** Both techniques can be combined to strengthen reliability
- ✓ **Data limitations** – insufficient data to develop a full VLE total pressure model at target loadings and temperatures.
- ✓ **Pilot plant reboiler** – kettle design is simple but slow to stabilise, consistent with test observations.

- ❖ **Industrial validation** – test HAPTICS and density methods under industrial conditions using OTTS reboilers at a larger 40 tCO_2/day pilot.
- ❖ **Rich Loading via Density** – complementary/backup method for absorber corner tests/when CO_2 sensors reach their detection limits
- ❖ **Enhanced density method** – integrate additional physicochemical parameters to enable real-time inference of both concentration and loading.
- ❖ **Temperature profiling** – explore reboiler temperature profiles & density as a tool for predicting lean loadings at ultra-high capture levels.
- ❖ **Reclaiming Stages:** Apply density as an indicator to track different stages of the reclaiming process.

Acknowledgements

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