A demonstration of the STRETCHER method for ultra-high capture rates with low energy requirements

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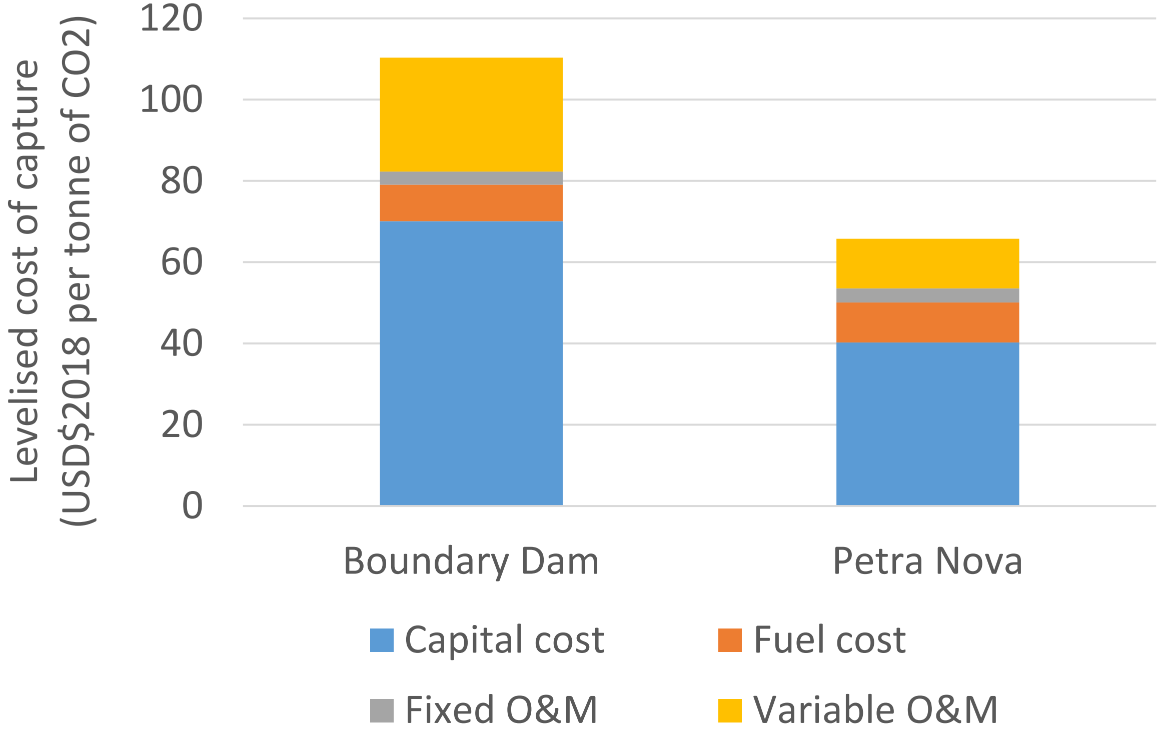
STRETCHER - System Tuning for Regenerator Efficiency and Target Capture with High Exit Rich

Based on projects funded by FCDO, DESNZ, building on previous UKCCSRC/EPSRC and University of Sheffield projects

NOTE ON THE USE OF MEA: Reported capture costs for actual PCC on coal power plants using proprietary solvents show higher variable O&M costs than additional fuel costs

(GCCSI (2019) *Global Status of CCS Report: 2019.* https://www.globalccsinstitute.com/resources/publications-reports-research/global-status-of-ccs-report-2019/)

The Global CCS Institute has reported costs for capture at the two large-scale power plant PCC projects that have been built, showing the relative weighting of different factors that have been observed in practice.



Proprietary solvents reported as being used in these projects:

Boundary Dam 3: Cansolv DC-103
https://www.carboncapturejournal.com/news/saskpower-boundary-dam-project/2775.aspx?Category=allll

Petra Nova: MHI KS-1
http://www.mhi.co.jp/technology/review/pdf/e551/e551032.pdf

'Variable O&M' costs are likely to be predominantly for solvent management and replacement. Results based on 8% discount rate, 30 years project life, 2.5 years construction time, capacity factor of 85%. Cost data normalised to 2017 values. Stated accuracy range: Boundary Dam and Petra Nova: -10% to +15%.

For Boundary Dam, which captures less than 1MtCO_2/yr, annual costs for solvent replacement alone were stated by the SaskPower chairman as $17.3M in 2015, $14.6M in 2016 (SaskPower, 2016) and reported to a government committee as $13.6M in 2017 (SaskPower, 2018), against initially-predicted costs of $5M. These solvent replacement costs would be consistent with the level of variable operation and maintenance (O&M) costs above.

SaskPower (2016) *A Word from the President on Smart Meters and Carbon Capture and Storage*, Blog on SaskPower web site, December 16, 2016.

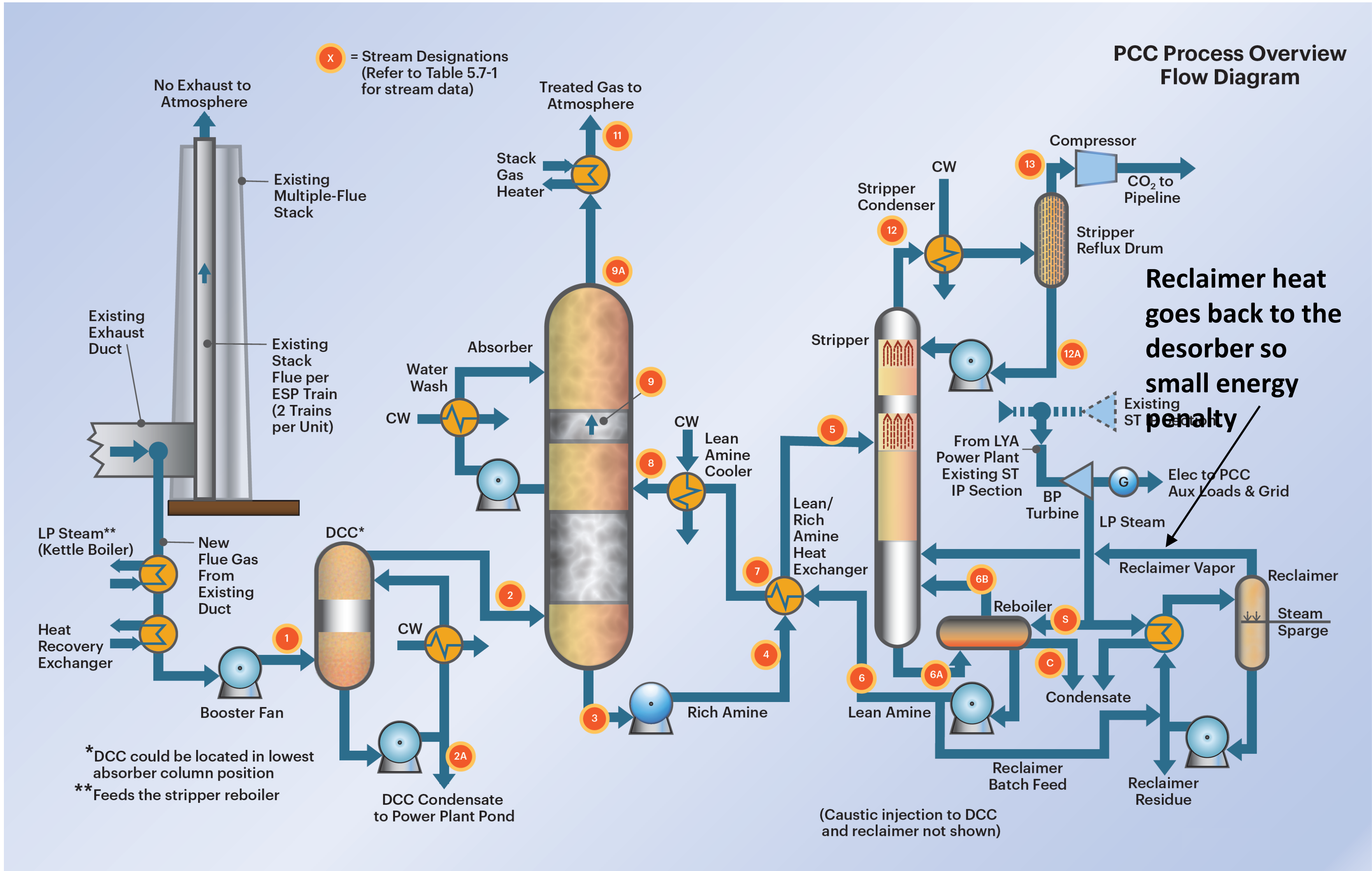
SaskPower (2018) *Letter to Herb Cox, Chairman, Standing Committee on Crown and Central Agencies, Government of Saskatchewan*. http://docs.legassembly.sk.ca/legdocs/Legislative%20Committees/CCA/Tableddocs/CCA%2061-28%20SaskPower%20Responses%20to%20questions%20raised%20at%20the%20June%2027,%202018%20meeting.pdf

NOTE ON THE USE OF MEA: MEA can be thermally reclaimed very effectively and is cheap

- Retrofit study for a brown coal power plant in Australia

Bechtel (2018) for CO2CRC, Retrofitting an Australian Brown Coal Power Station with Post-Combustion Capture, https://ukccsrc.ac.uk/wp-content/uploads/2022/10/Retrofit-Main-Report-Final-Final-in-CO2CRC-webpage.pdf

- Continuous reclaimer venting into desorber to recover thermal energy
- Typically can reclaim one inventory volume in one week to one month
- Can reject >99% of impurities in simple reclaimer with heat recovery – not possible with blends
- Reclaimer waste may be usable for SCR



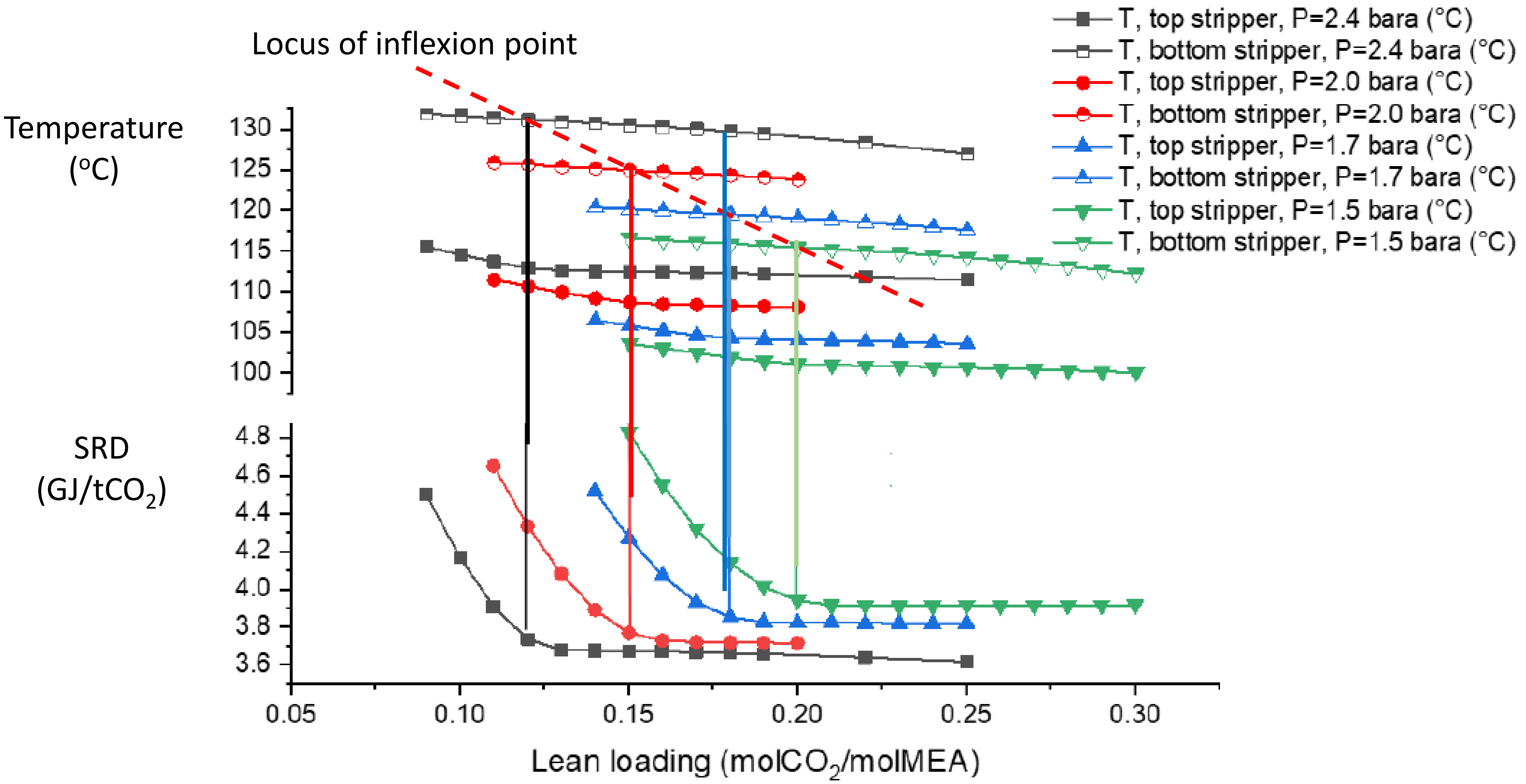
The key features of the STRETCHER method can be summarised as follows:

1. Produce the lowest possible lean loading without wasted energy for a given desorber pressure (and hence temperature range) by operating at the **desorber inflection point**.

2. Use the lean solvent flow rate that gives the optimum combination of capture rate and rich loading – and hence specific reboiler duty – for that lean loading, given the **absorber corner** constraints.

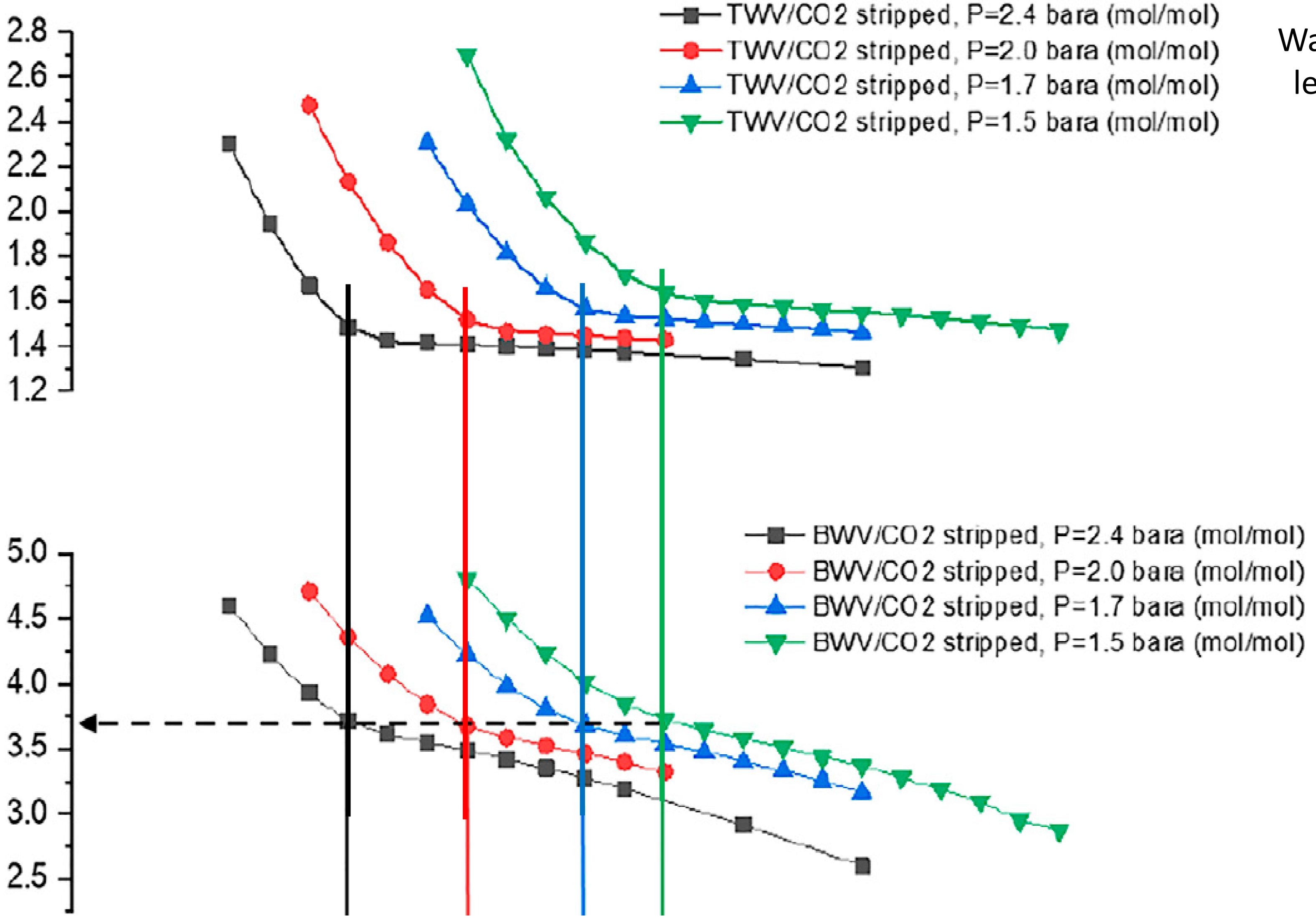
3. Use **lean and rich solvent storage** to allow the desorber and absorber to be operated with the most rapid possible feedback and so be optimised independently in the short term, while obviously still also balancing in the long term.

The inflection point occurs when the specific reboiler duty (SRD) starts to increase rapidly due to water vapour 'breakthrough'. The desorber column exit temperature starts to go up faster than the reboiler temperature



Michailos & Gibbins, 2022, https://www.frontiersin.org/articles/10.3389/fenrg.2022.866838/full

As the lean loading decreases the water vapour/CO_2 ratio out of the reboiler rises but until the inflection point all of this water vapour can be usefully condensed in the desorber packing.

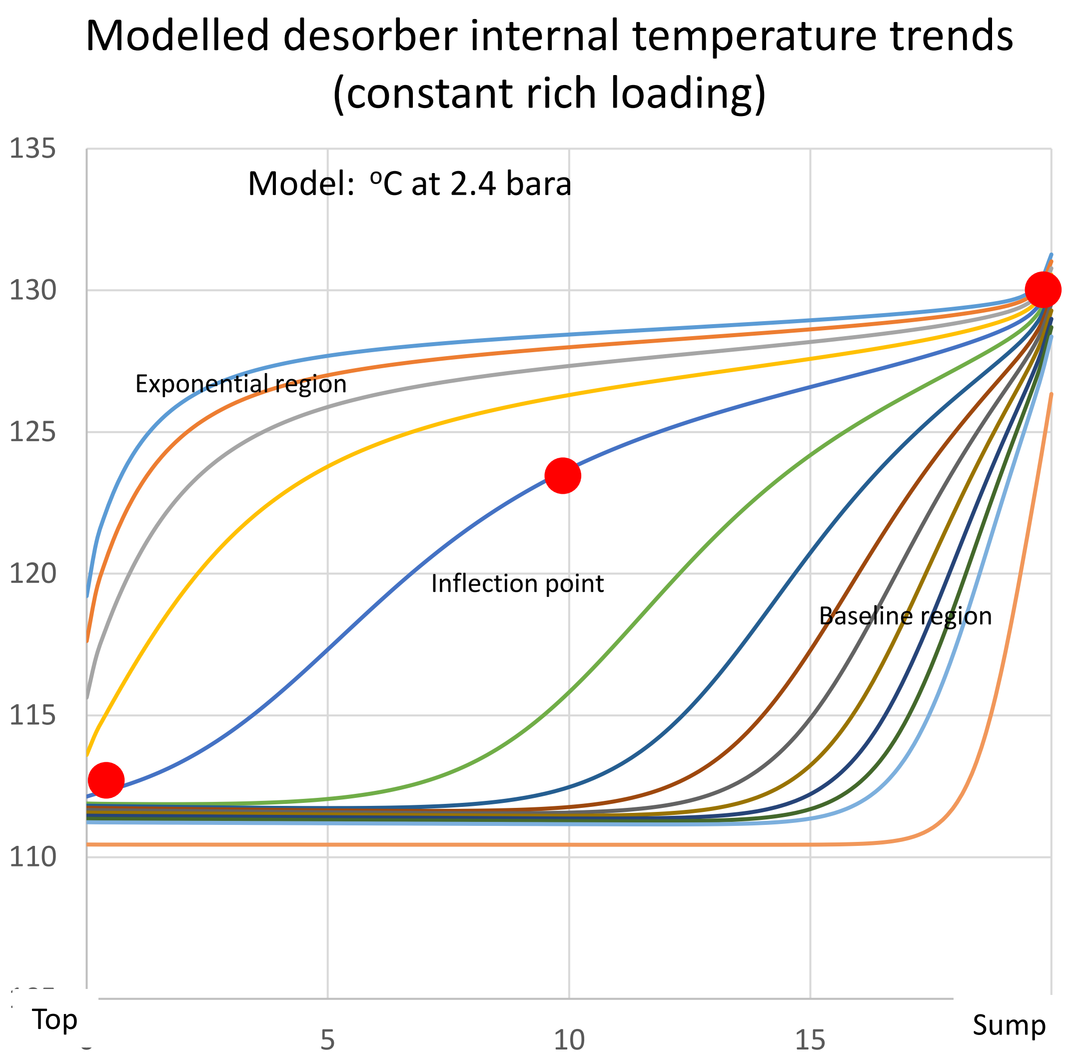


Water vapour/CO_2 ratio leaving the top of the desorber packing

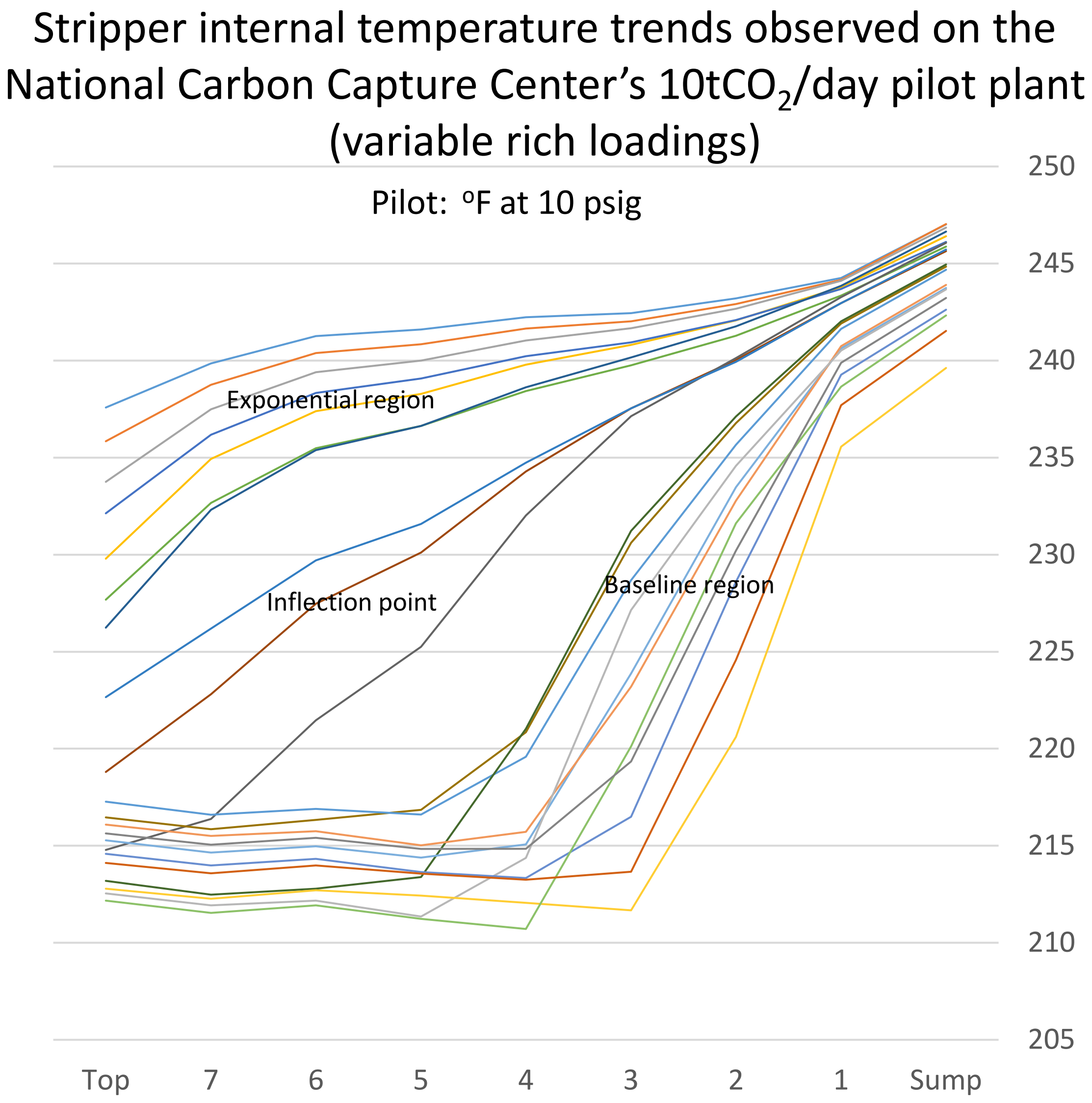
Water vapour/CO_2 ratio leaving the reboiler

Michailos & Gibbins, 2022, https://www.frontiersin.org/articles/10.3389/fenrg.2022.866838/full

The phenomena that cause the inflection point are visible in the desorber column temperature profile



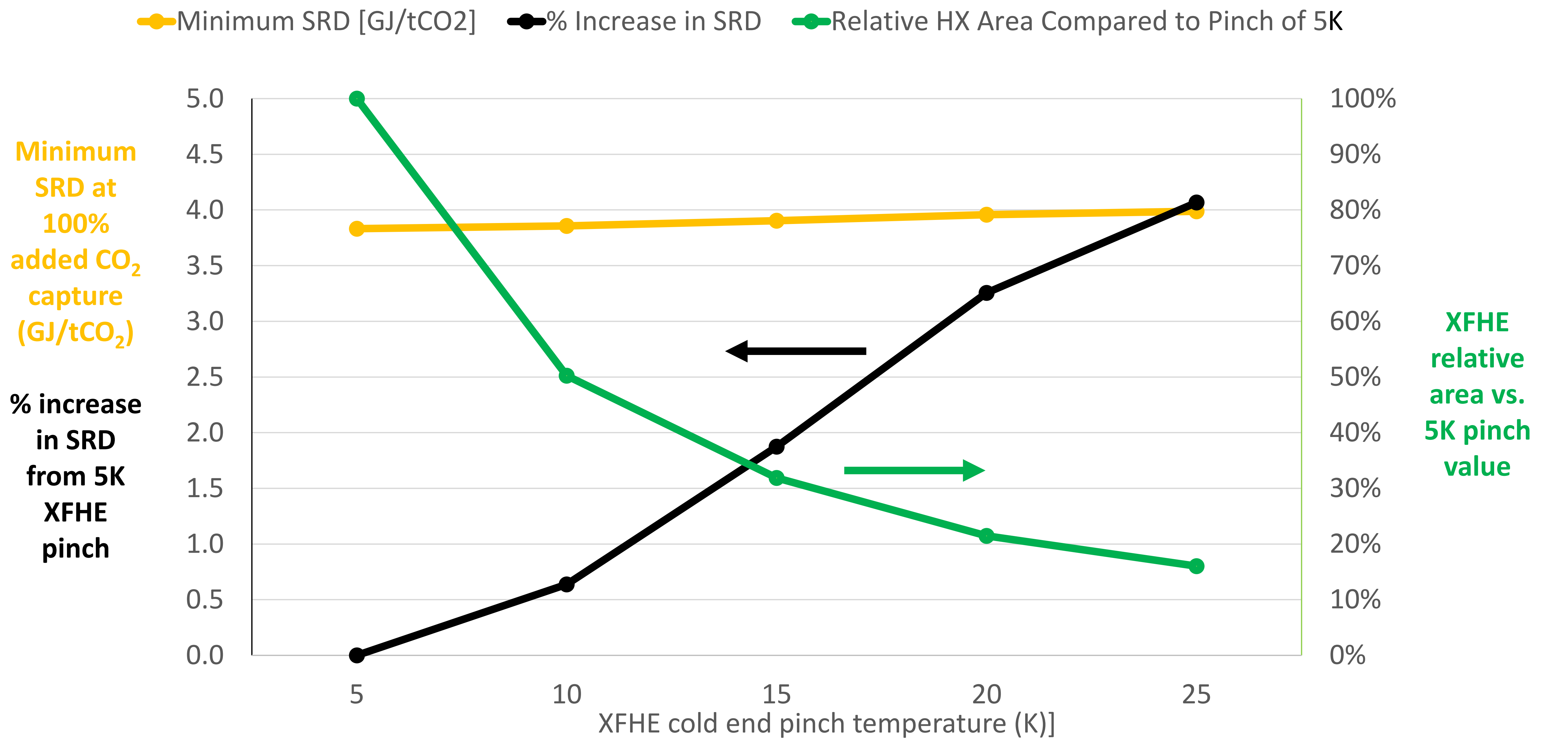
https://www.linkedin.com/pulse/stretcher-method-optimising-amine-post-combustion-capture-jon-gibbins



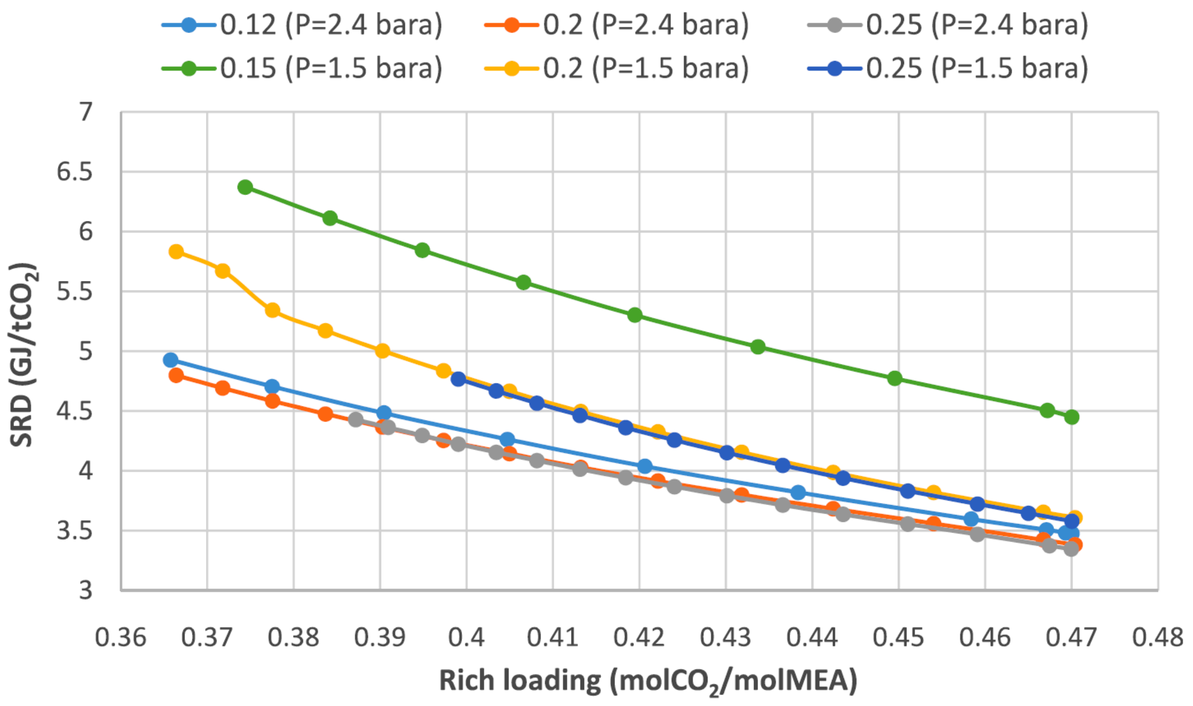
https://www.linkedin.com/pulse/amine-desorber-temperature-profile-key-optimising-net-zero-gibbins

Effect of reduced XFHE pinch at the inflection point – using the water vapour in the CO_2 to heat the rich solvent

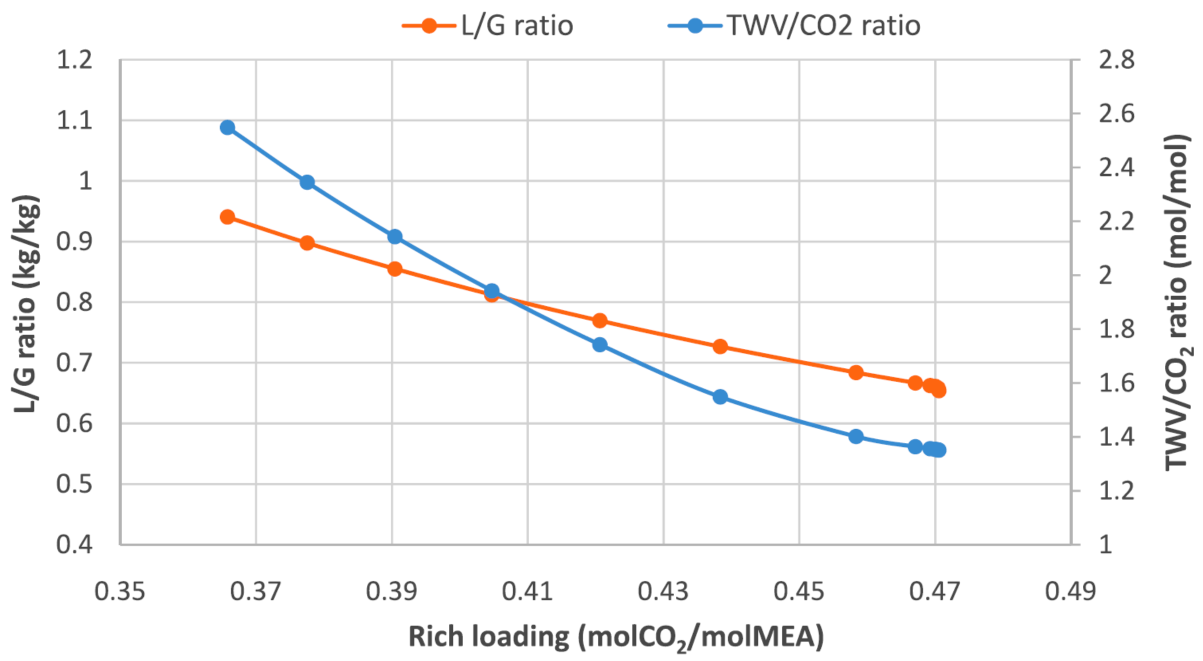
(Preliminary analysis by Joel and Mullen – data to be confirmed and extended)



SRD is insensitive to lean loadings down to the inflection point, but SRD is always sensitive to rich loading



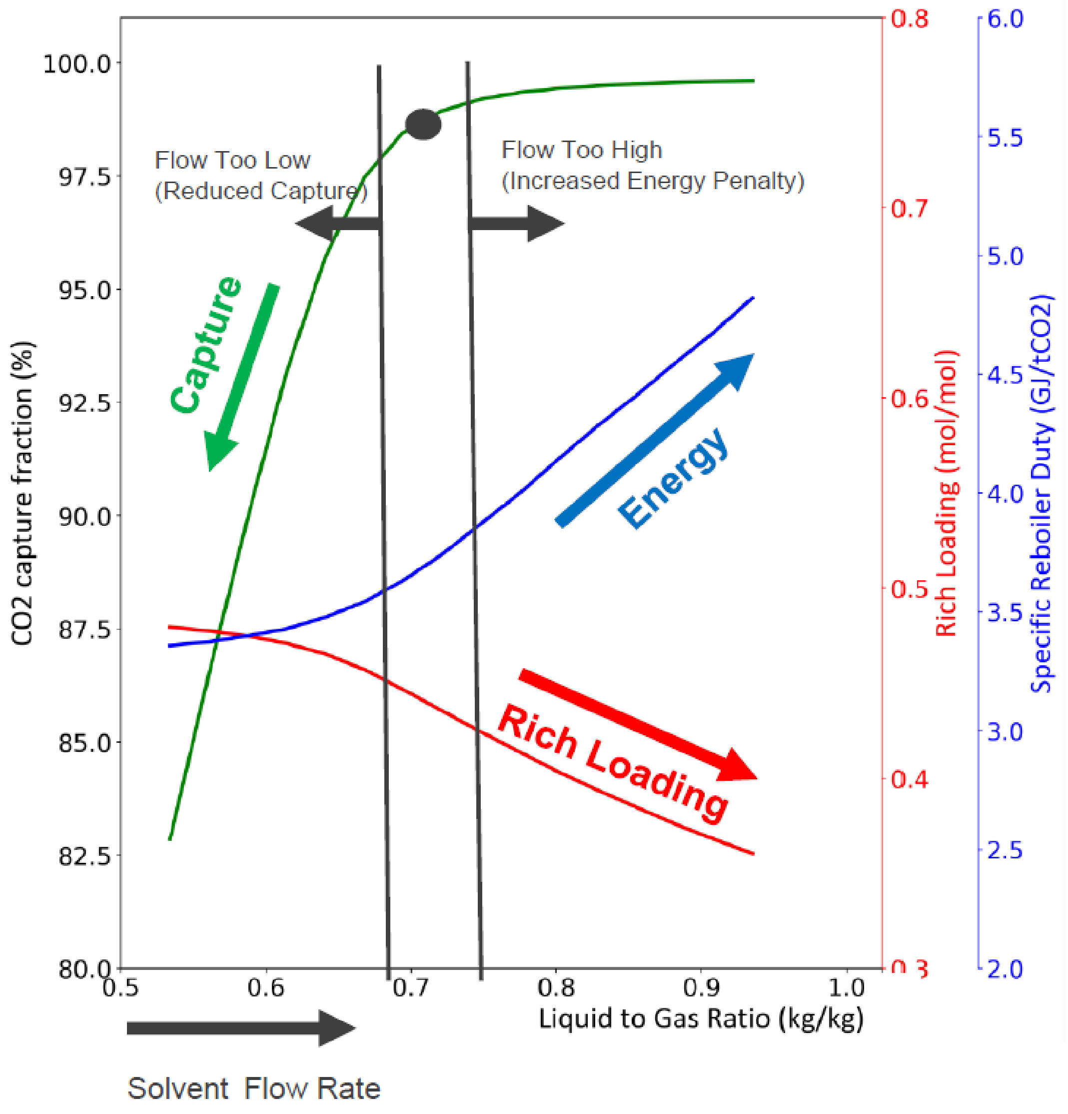
Effect of rich loading and desorber pressure on the specific reboiler duty for different lean loadings of 0.12 (only for desorber pressure of 2.4 bara), 0.15 (only for desorber pressure of 1.5 bara), 0.2 and 0.25 molCO_2/molMEA.

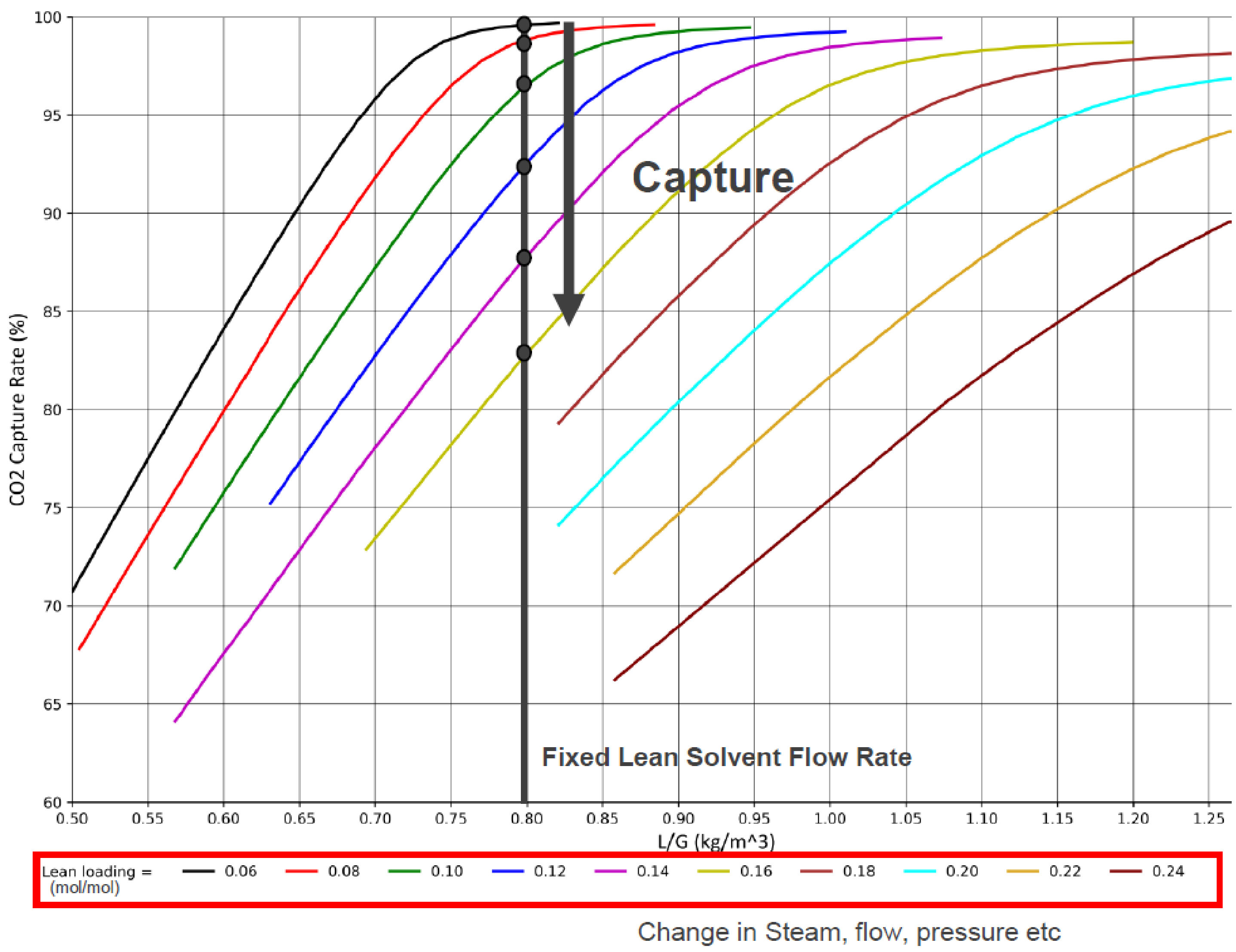


L/G ratio and TWV/CO_2 ratio as a function of rich loading. Lean loading is 0.12 molCO_2/molMEA and desorber pressure is 2.4 bara.

Michailos & Gibbins, 2022, https://www.frontiersin.org/articles/10.3389/fenrg.2022.866838/full

The absorber corner is the region where, at a given lean loading and packing height, the capture rate and SRD are co-optimised by controlling solvent flow to achieve a High Exit Rich (loading)





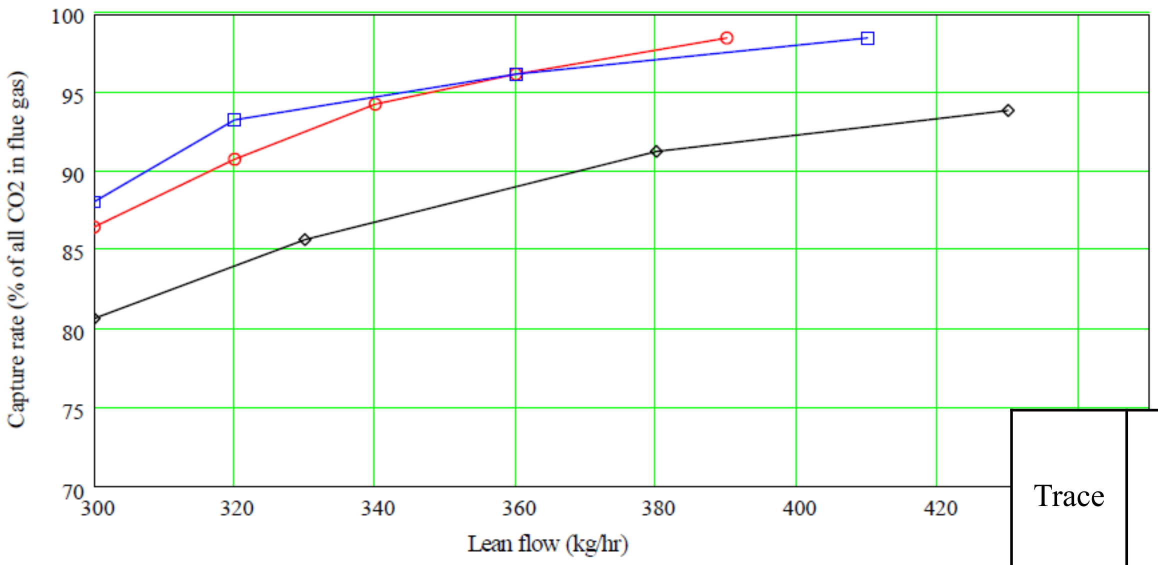
FOCUSS absorber corner test

Three absorber corner tests were undertaken at different lean loadings.

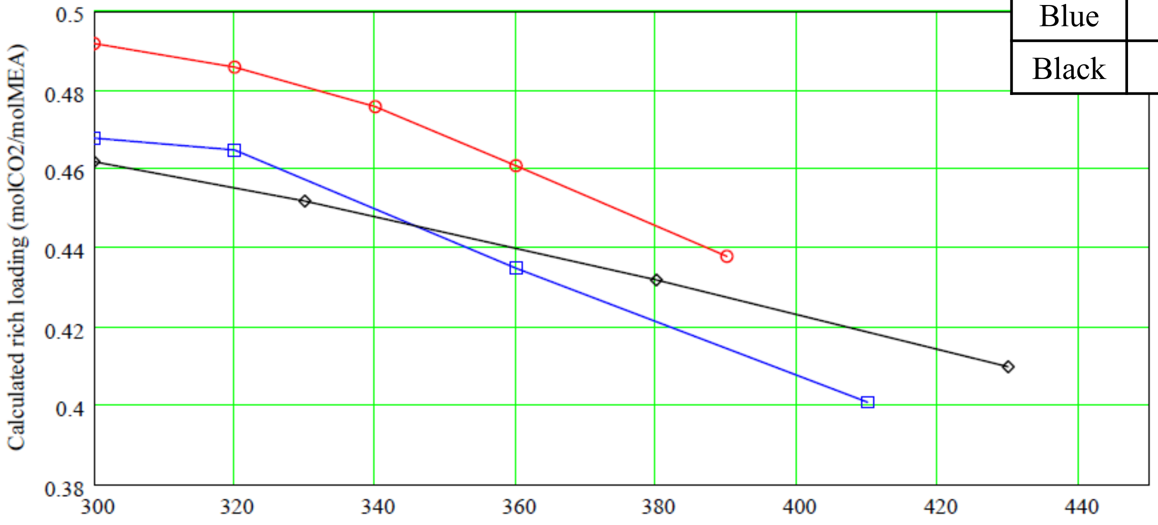
The gas flow was constant at 210 m^3/hr, the highest possible value, and the absorber inlet CO_2 concentration was adjusted to get 80-90% capture.

The lean flow was started at 300 kg/hr, the lowest controllable value, In all cases, because of the limited volume of solvent storage available.

The lean flow was then increased in 20-40 kg/hr increments with 10-15 minutes dwell time at each flow, determined by inspection of the operating parameters such as CO_2 and water concentrations in the exiting flue gas and absorber temperature profiles.



Trace	Inlet CO_2 (%v/v dry)	Lean loading ($molCO_2$ /molMEA)
Red	9.56	0.057
Blue	7.70	0.099
Black	6.06	0.183



FCDO CLEEN Project:

COGENT – Capture Operation with Greater Economy for Net-zero Targets

中英（广东）CCUS中心
UK-China (Guangdong) CCUS Centre

The University Of Sheffield. Energy Institute

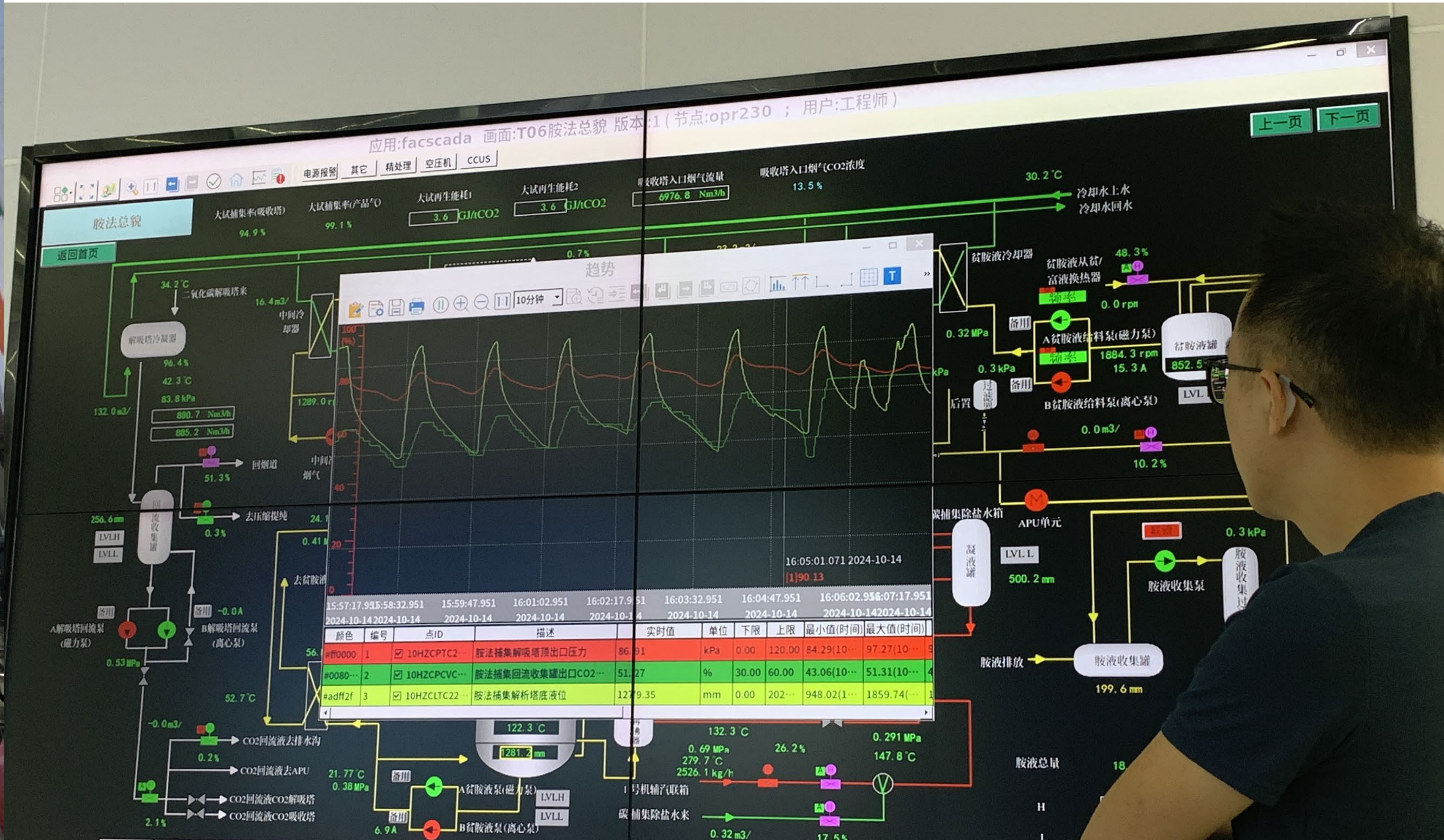
UKCCS RESEARCH CENTRE

GD UK-China CCUS Centre

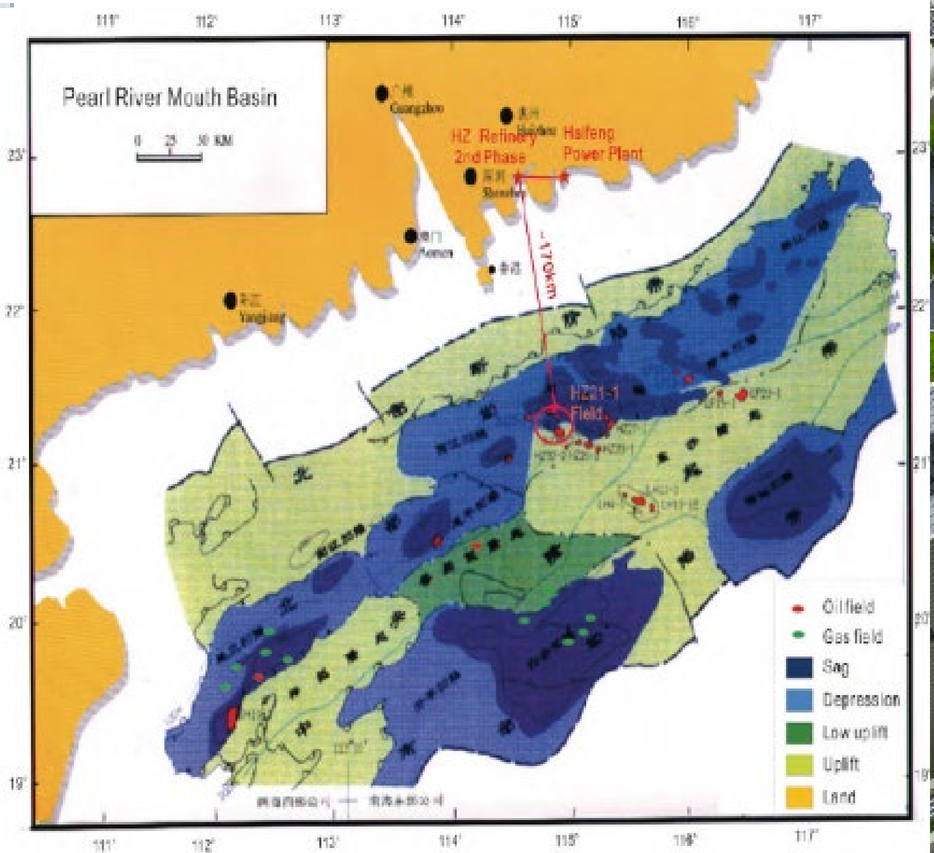
Guangdong Carbon Capture Test Platform – ~ 40tCO_2/day in tests

University of Sheffield/UKCCSRC

Project report here: https://ukccsrc.ac.uk/research/flexible-funding/flexible-funding-2021/prof-jon-gibbins-university-of-sheffield



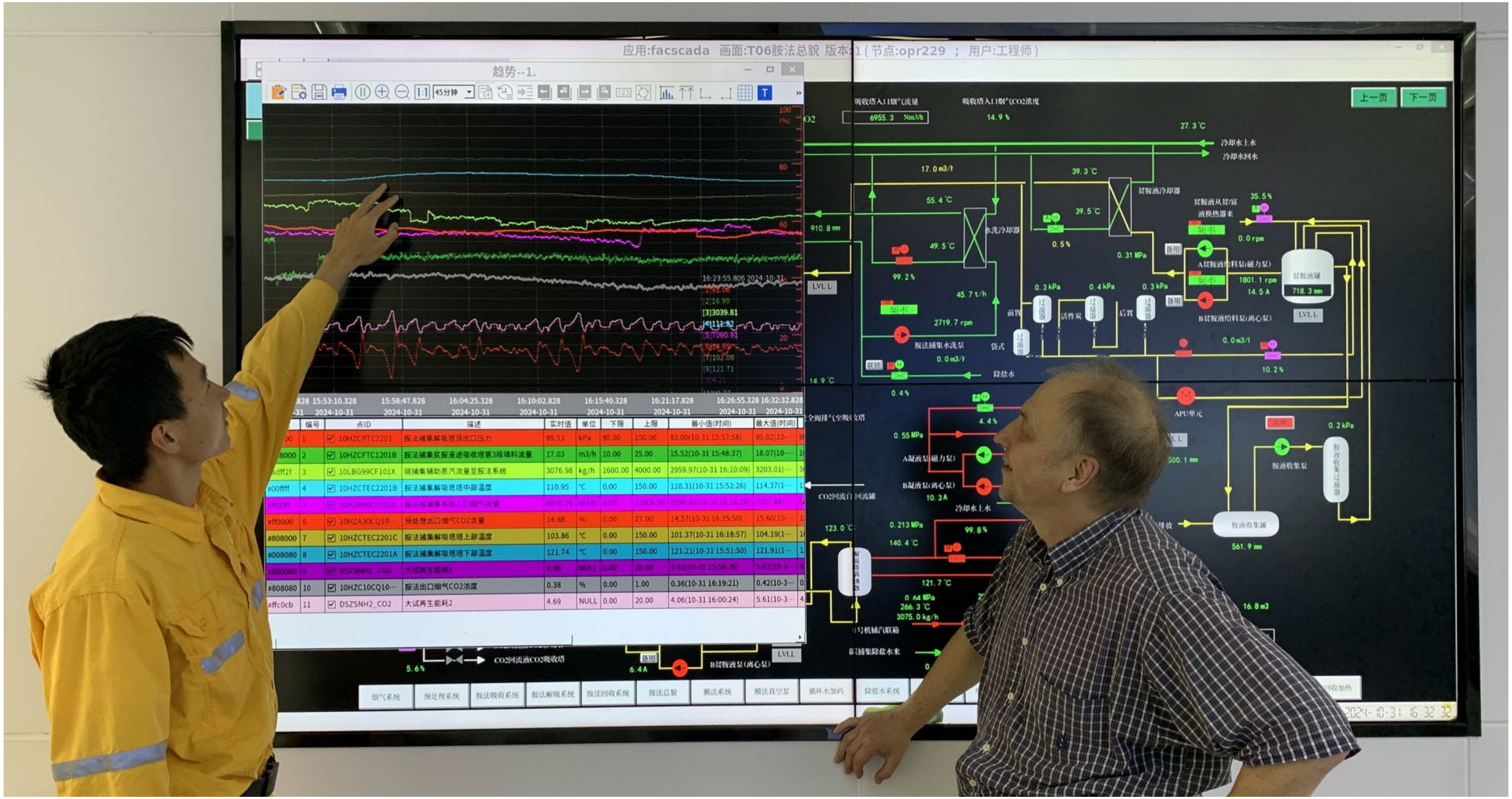

China Resources Haifeng Power Plant


Pearl River Mouth Basin
HZ Refinery 2nd Phase
Haifeng Power Plant
~170km
HZ21-1 Field
Oil field
Gas field
Sag
Depression
Low uplift
Uplift
Land

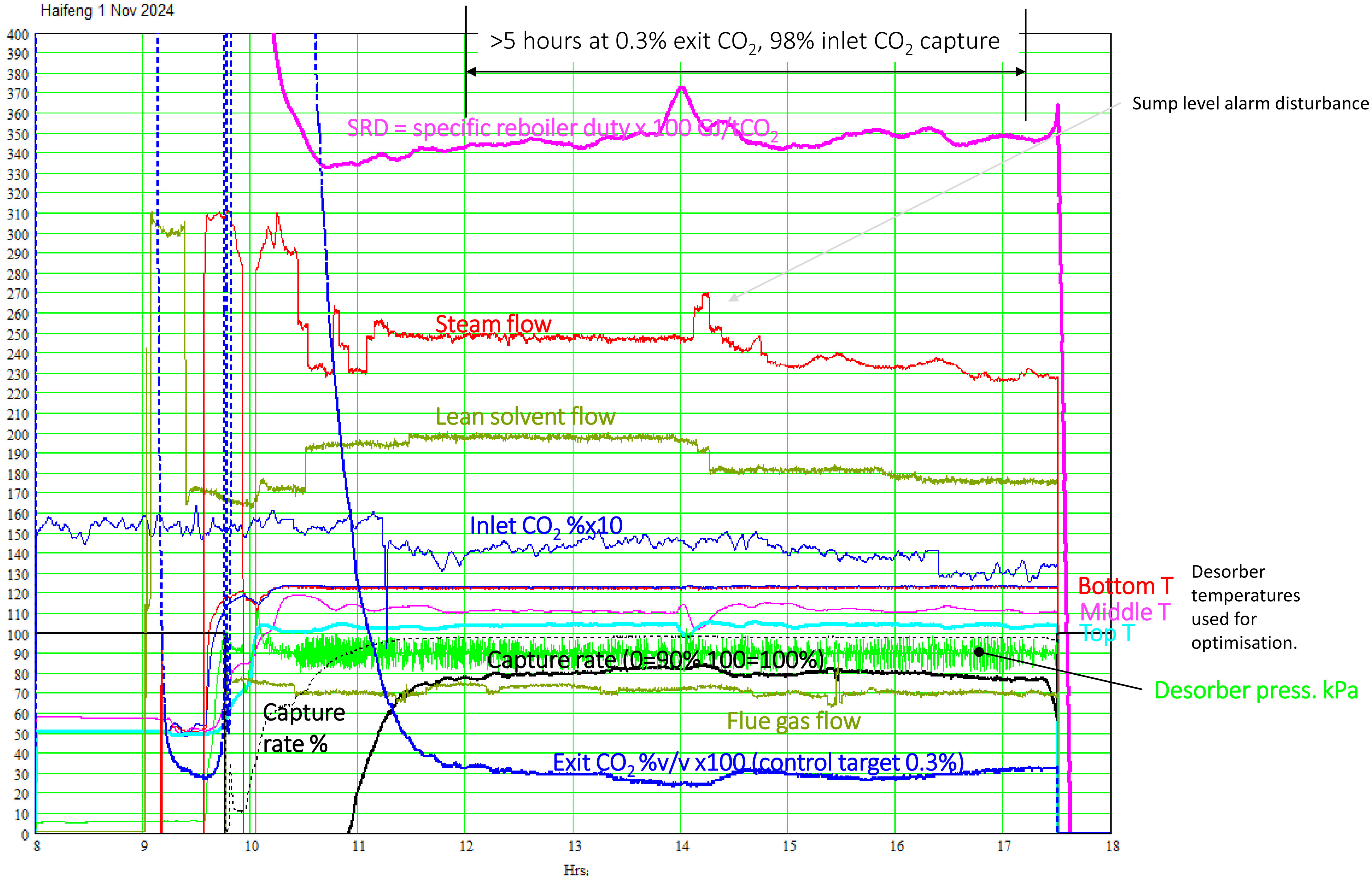

Guangdong Carbon Capture Test Platform

Visit in August 2024 to discuss the theory behind high CO2 capture rates with the Haifeng capture plant team, familiarize the GDCCUS/UKCCSRC team with the Haifeng pilot plant and plan the test campaign.

At the end of the third week of testing the team looks at the near-horizontal blue line sandwiched between two others that means this plant is operating at peak performance. China and the UK have successfully pioneered a new method that can greatly reduce, or even totally avoid, residual carbon dioxide emissions from CCS projects.



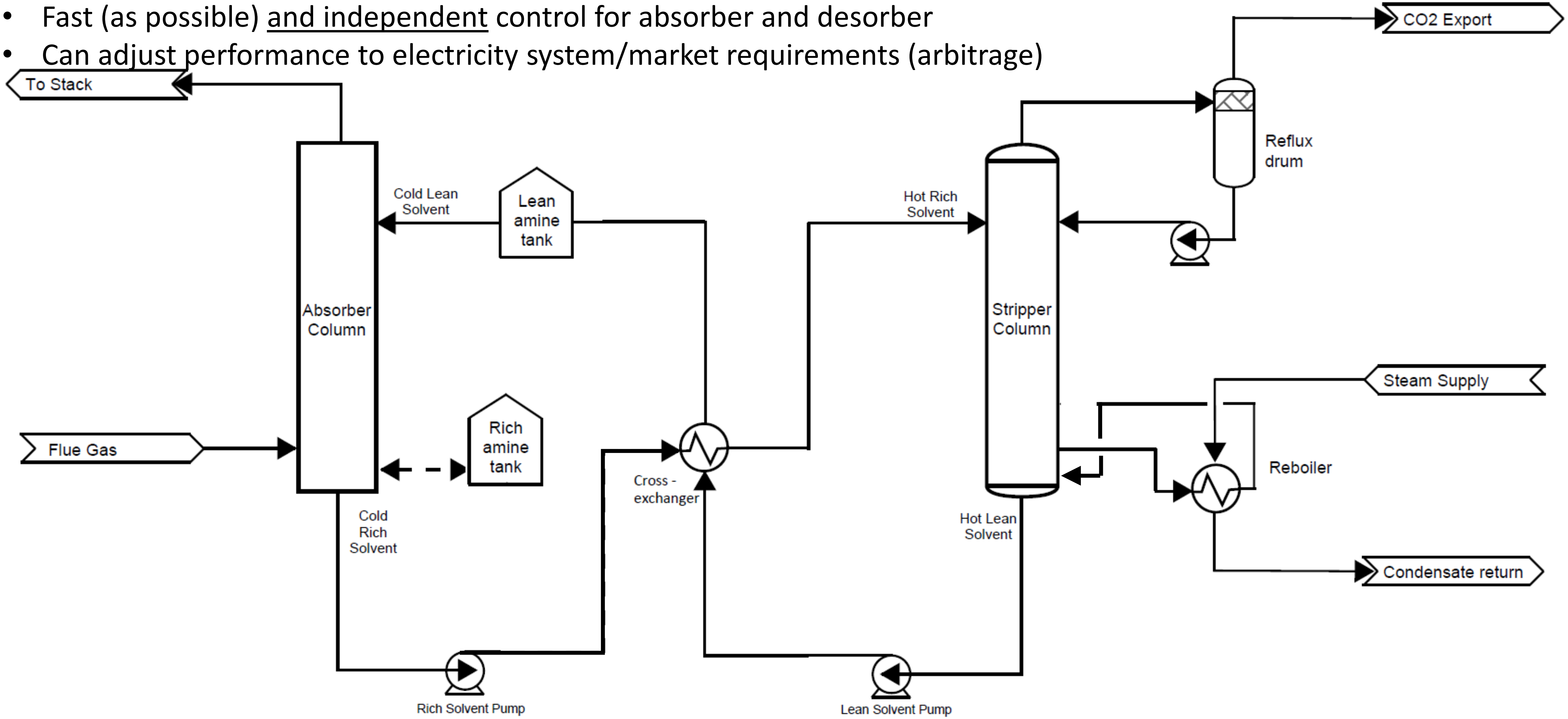
Final run on 1 Nov shows sustained capture rate of 98% of the total incoming CO_2 with no significant increase in energy consumption, due to careful process condition optimisation.



Solvent storage is useful to implement STRETCHER effectively

(as well as to maintain capture during start-stop and for market arbitrage)

- Lean solvent always passes through storage
- Rich storage acts as absorber sump extension if level rises, but may be empty
- Stripper sump also used to hold lean solvent if not lean enough
- Fast (as possible) <u>and independent</u> control for absorber and desorber
- Can adjust performance to electricity system/market requirements (arbitrage)



Next phases for COGENT and STRETCHER – contact if interested:

COGENT Phase 2 – imminent

- Add real-time lean and rich solvent loading measurement using UK-designed instrumentation and also ppm exit CO_2 measurements
- Implement reclaiming (with desorber-venting reclaimer)
- Reboiler/desorber pressure fluctuation smoothing (temperature and flow restriction)
- Maximise desorber operating pressure
- Demonstrate continuous high capture for 100 hours

COGENT Phase 3 – plans under development for 2026

- Add rich solvent storage (plant already has lean buffer tank)
- Use air dilution for low-CO_2 flue gas (gas power plant level)
- Continuous high capture during simulated CCGT stop/start and flexible operation

Longer term – Advanced Capture Exemplar (ACE) pilot with continuous reclaiming and 100% added CO_2 capture in indefinite operation