PCCC-8

IEAGHG 8th Post Combustion Capture Conference

16th to 18th September 2025 Marseille, France

Flexibly operated capture using solvent storage (FOCUSS): Test data and application to commercial dispatchable power-plants

Daniel Mullen[1,*], Xiaomian Baxter[1], James Bowers[1], Harry Ellicott[1], Paul Kerian[1], Tom Ilett[2], Sam Atkinson[2], Mathieu Lucquiaud[3], Jon Gibbins[3]

[1]SSE Thermal, One Forbury Place, 43 Forbury Road, Reading, RG1 3JH, UK

[2]AECOM, London, Aldgate Tower, 2 Leman Street, London, E1 8FA, UK

[3]University of Sheffield, Faculty of Engineering, Sir Frederick Mappin Building, Mappin Street, Sheffield, S1 3JD, UK

Abstract

Maintaining design CO_2 capture levels throughout all operational modes is particularly relevant for Carbon Capture and Storage (CCS) power plants that are required to provide flexible and dispatchable low carbon power generation capacity and thereby support high penetration rates of intermittent renewable generation. The Flexibly Operated Capture Using Solvent Storage (FOCUSS) project is funded[*] by the UK Department for Energy Security and Net Zero (DEZNZ) and is an industry-led project managed and delivered by a consortium consisting of SSE Thermal (project lead), the University of Sheffield and AECOM. FOCUSS aims to accelerate the time to market for technology that enables amine post-combustion capture plants to achieve 95-99% CO_2 capture levels at all times, including during start-up, shut-down and other transients. It is progressing rapidly from conceptual engineering predictions to de-risked technology and new solutions to help deliver UK targets of 15-30 GW of gas power with near net-zero CO_2 emissions by 2050.

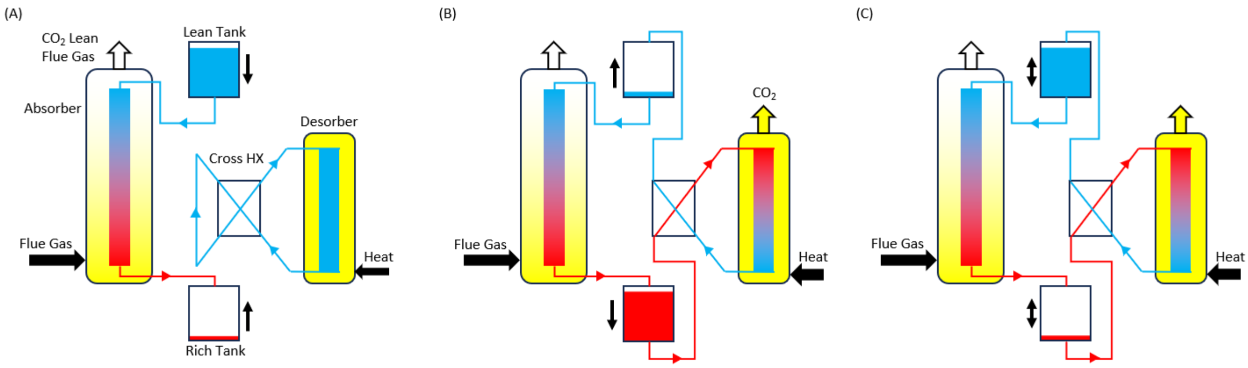

Figure 1: Illustrative diagram of Solvent Storage during start up. Lean & rich solvent in blue and red respectively while CO_2 is shown in yellow (1) CO_2 capture while desorber reaches operating conditions. (2) Rich solvent regeneration concurrently with CO_2 capture. (3) Normal operation

---

[*] FOCUSS has been awarded £515,878.00 in grant funding as part of the Department for Energy Security and Net Zero CCUS Innovation 2.0 programme, which is in turn funded through the £1 billion Net Zero Innovation Portfolio (NZIP).

Modifying the amine CO_2 capture process to utilise solvent storage in post-combustion carbon capture and storage (PCC) plants involves separating the absorption and desorption processes via two individual inline solvent holding tanks, allowing for the independent production of lean solvent and rich solvent. In this way, the desorber can always be operated under conditions that will produce the optimum lean solvent loading – or not be operated at all – while the absorber can always be supplied with the precise amounts of lean solvent required to achieve design CO_2 capture rates while also simultaneously maximising the rich loading to minimise regeneration energy requirements. In particular this approach allows high CO_2 capture rates during start-up events for combined cycle gas turbine (CCGT), with the absorber using lean solvent from storage while the solvent regeneration system reaches operational pressure and temperature. Typically, there might be of the order of 200 warm starts and 50 cold starts per year for a dispatchable CCGT power plant with CCS in a renewables-heavy electricity system and so maintaining capture rates at these times is essential to achieve high overall annual capture rates.

FOCUSS has demonstrated that the design CO_2 capture rate can be achieved throughout all operational modes, including start, stop, and transient periods, if there is sufficient stored lean solvent and that solvent inventory is appropriately managed. Incorporating solvent storage also provides additional benefits, such as the ability to promptly respond to changes in CCGT flue gas rate/composition by monitoring the absorber performance envelope and supplying adequate lean solvent to match flue gas changes without the delay caused by the desorption process. Solvent storage is also anticipated to enhance the flexibility and grid stabilisation potential of CCGTs by allowing rapid modulation of the LP steam flow rate to the reboiler – and hence providing a very fast increase or decrease in electricity output - without impacting the CO_2 capture rate.

The FOCUSS project has recently completed extensive testing using the 1 tpd amine CO_2 capture plant at the Translational Energy Research Centre (TERC) at Sheffield to demonstrate the use of solvent storage and advanced system control. Capture rates of 95 - 99+% of incoming CO_2 were achieved during all plant operational modes. Tests have also recently been conducted on a large pilot plant at 40 tpd scale showing rapid start-up using an industry-standard once-through thermosyphon reboiler configuration combined with desorber inventory circulation.

In addition to the test campaigns, this work utilises real-world data from an operational CCGT to highlight and quantify the potential for advanced CO_2 abatement during start-up using previously wasted 'early steam' and 'late steam' (Figure 2). This is steam, generated during the CCGT start-up sequence – and shutdown sequence, is not admissible for steam turbine power generation due to its inappropriate quality and equipment heating rate limitations, and is normally rejected to the condenser. Its use in the reboiler can lead to a step change in the cost of CO_2 abatement during start-up and an increase in the net thermal efficiency of the sequence by both avoiding any electricity output penalty for the use of solvent storage and also significantly reducing the solvent inventory required (Table 1).

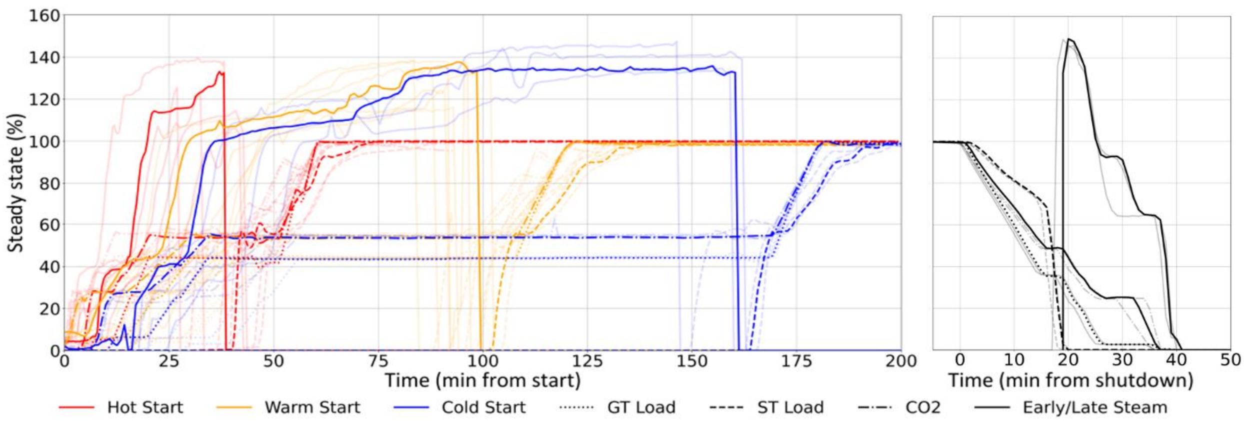

Figure 2: CCGT Startup and Shutdown Sequences

Table 1: Solvent storage requirements with and without the use of early steam, expressed as a percentage of CO_2 free solvent inventory.

Start	Without the use of Early Steam	With the use of Early Steam
Hot	89%	24%
Warm	226%	40%
Cold	344%	49%

In addition to this, practical approaches developed to achieve pipeline-quality CO_2 purity early in the startup sequence and to accommodate heating-rate restrictions on the large heat exchangers used for crossflow lean/rich heating and reboilers have been developed and will also be discussed.

Overall, the FOCUSS project has developed techniques for continuous, fully flexible amine PCC capture plant operation at the maximum design capture rates to the point where they can be included in design studies for future dispatchable CCGT power plants. We hope to share the latest key insights gained in the concluding phases of the project at PCCC8 to increase industry engagement and accelerate technology deployment rates while de-risking PCC technology.

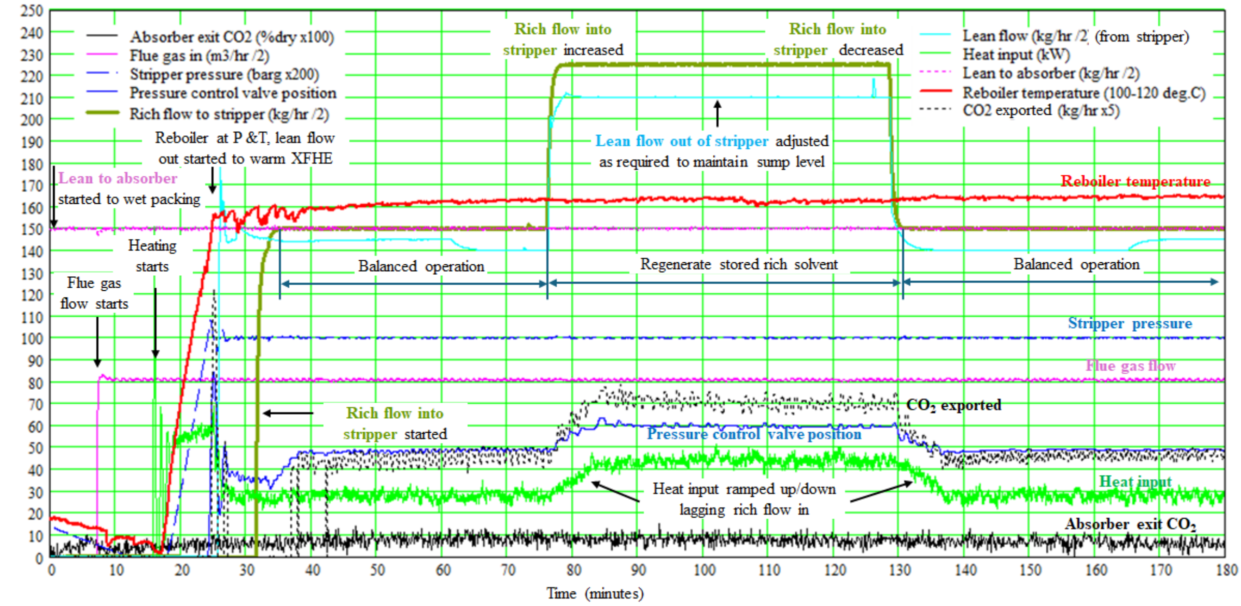

Figure 3: New data for a warm start on the TERC amine capture plant using solvent storage to achieve high capture rates throughout

Figure 4: Kettle reboiler at TERC (L) and once-through thermosyphon reboiler at Haifeng pilot (R) – it will be discussed how the type of reboiler used in pilot testing is a critical factor that is often overlooked

Keywords: Post combustion CO_2 capture; CCGT; Net Zero; Flexible amine capture; Solvent Storage; Dispatchable power generation