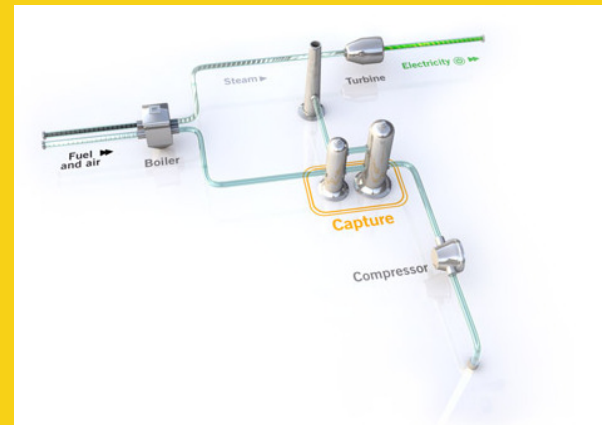




CCS FLEXIBILITY

amine-based CO₂ capture unit
dynamics for CCGT
applications



Nicola Ceccarelli
Modeling & Optimization Engineer

Disclaimer Statement

Resources: Our use of the term “resources” in this presentation includes quantities of oil and gas not yet classified as SEC proved oil and gas reserves or SEC proven mining reserves. Resources are consistent with the Society of Petroleum engineers 2P and 2C definitions.

The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate entities. In this presentation “Shell”, “Shell group” and “Royal Dutch Shell” are sometimes used for convenience where references are made to Royal Dutch Shell plc and its subsidiaries in general. Likewise, the words “we”, “us” and “our” are also used to refer to subsidiaries in general or to those who work for them. These expressions are also used where no useful purpose is served by identifying the particular company or companies. “Subsidiaries”, “Shell subsidiaries” and “Shell companies” as used in this presentation refer to companies in which Royal Dutch Shell either directly or indirectly has control, by having either a majority of the voting rights or the right to exercise a controlling influence. The companies in which Shell has significant influence but not control are referred to as “associated companies” or “associates” and companies in which Shell has joint control are referred to as “jointly controlled entities”. In this presentation, associates and jointly controlled entities are also referred to as “equity-accounted investments”. The term “Shell interest” is used for convenience to indicate the direct and/or indirect (for example, through our 23% shareholding in Woodside Petroleum Ltd.) ownership interest held by Shell in a venture, partnership or company, after exclusion of all third-party interest.

This presentation contains forward-looking statements concerning the financial condition, results of operations and businesses of Royal Dutch Shell. All statements other than statements of historical fact are, or may be deemed to be, forward-looking statements. Forward-looking statements are statements of future expectations that are based on management’s current expectations and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in these statements. Forward-looking statements include, among other things, statements concerning the potential exposure of Royal Dutch Shell to market risks and statements expressing management’s expectations, beliefs, estimates, forecasts, projections and assumptions. These forward-looking statements are identified by their use of terms and phrases such as “anticipate”, “believe”, “could”, “estimate”, “expect”, “intend”, “may”, “plan”, “objectives”, “outlook”, “probably”, “project”, “will”, “seek”, “target”, “risks”, “goals”, “should” and similar terms and phrases. There are a number of factors that could affect the future operations of Royal Dutch Shell and could cause those results to differ materially from those expressed in the forward-looking statements included in this presentation, including (without limitation): (a) price fluctuations in crude oil and natural gas; (b) changes in demand for Shell’s products; (c) currency fluctuations; (d) drilling and production results; (e) reserves estimates; (f) loss of market share and industry competition; (g) environmental and physical risks; (h) risks associated with the identification of suitable potential acquisition properties and targets, and successful negotiation and completion of such transactions; (i) the risk of doing business in developing countries and countries subject to international sanctions; (j) legislative, fiscal and regulatory developments including potential litigation and regulatory measures as a result of climate changes; (k) economic and financial market conditions in various countries and regions; (l) political risks, including the risks of expropriation and renegotiation of the terms of contracts with governmental entities, delays or advancements in the approval of projects and delays in the reimbursement for shared costs; and (m) changes in trading conditions. All forward-looking statements contained in this presentation are expressly qualified in their entirety by the cautionary statements contained or referred to in this section. Readers should not place undue reliance on forward-looking statements. Additional factors that may affect future results are contained in Royal Dutch Shell’s 20-F for the year ended 31 December, 2011 (available at www.shell.com/investor and www.sec.gov). These factors also should be considered by the reader. Each forward-looking statement speaks only as of the date of this presentation, 2nd April 2014. Neither Royal Dutch Shell nor any of its subsidiaries undertake any obligation to publicly update or revise any forward-looking statement as a result of new information, future events or other information. In light of these risks, results could differ materially from those stated, implied or inferred from the forward-looking statements contained in this presentation. There can be no assurance that dividend payments will match or exceed those set out in this presentation in the future, or that they will be made at all.

We use certain terms in this presentation, such as resources, that the United States Securities and Exchange Commission (SEC) guidelines strictly prohibit us from including in filings with the SEC. U.S. Investors are urged to consider closely the disclosure in our Form 20-F, File No 1-32575, available on the SEC website www.sec.gov. You can also obtain these forms from the SEC by calling 1-800-SEC-0330.

1.0

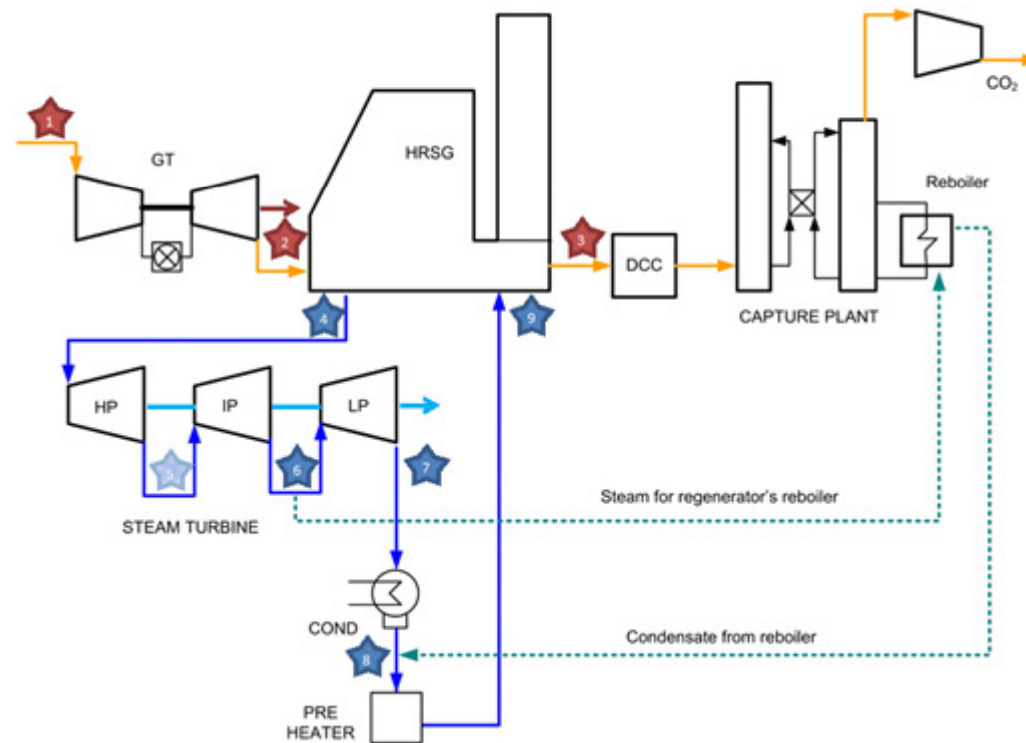
INTRODUCTION

Subtitle if required.

INTRO: CCS FLEXIBILITY - DEFINITION

■ FLEXIBILITY:

We define CCS flexibility as the capability to ensure low CO₂ electricity production across the variety of possible GT power plants in any running condition including off-design transient, such as start-up/ trip/ shutdown.



INTRO: CHALLENGES

- Process Dynamics:

Investigate and assess the dynamics associated with a CO₂ Capture unit when subject to major transients operation, as start-up and/or shutdown.

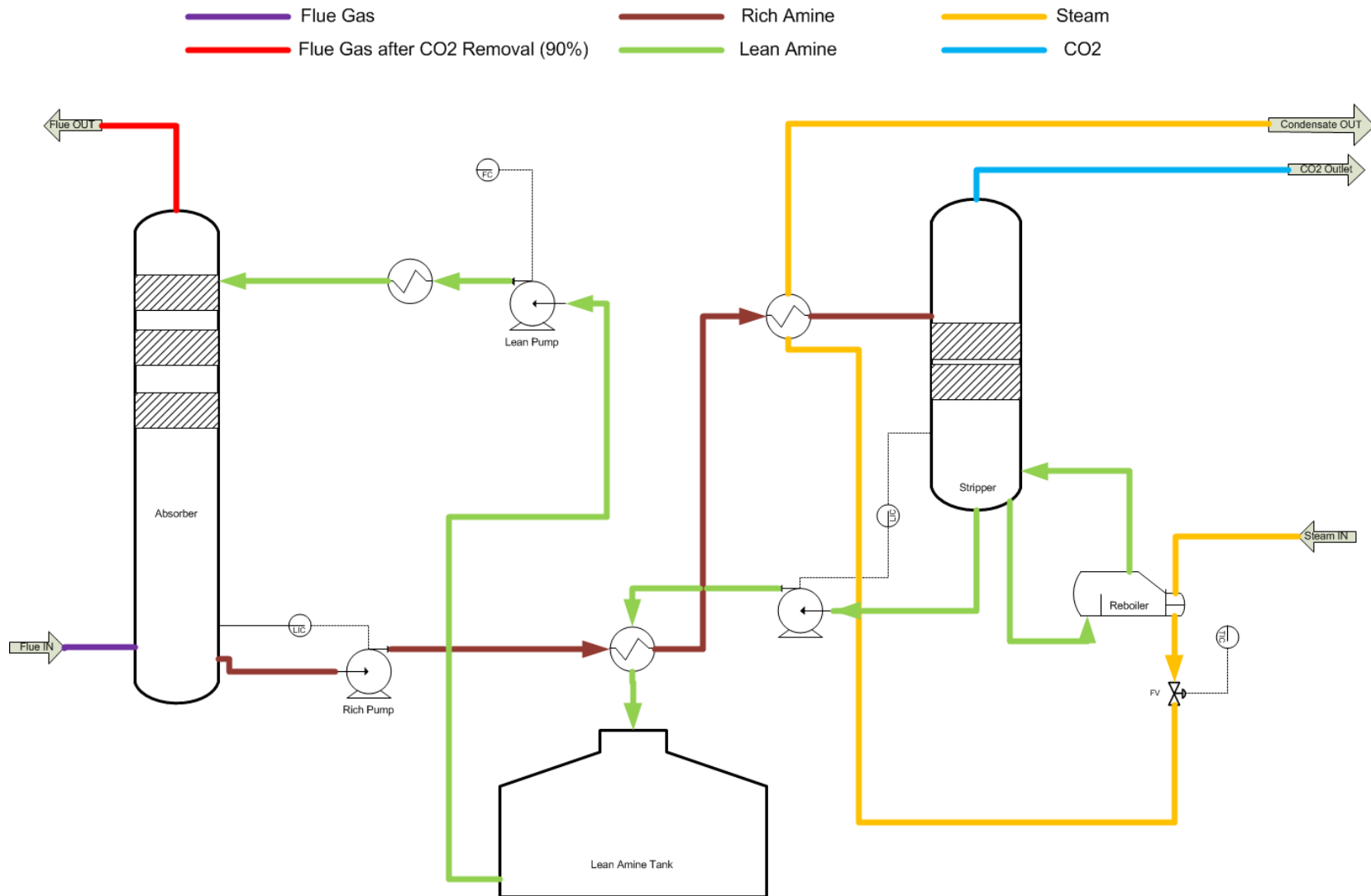
- CO₂ loss:

Quantify CO₂ emission related to CO₂ Capture unit operations.

- Unit integration:

Demonstrate the capability of delivering effective solutions for low CO₂ power production.

INTRO: CCS UNIT

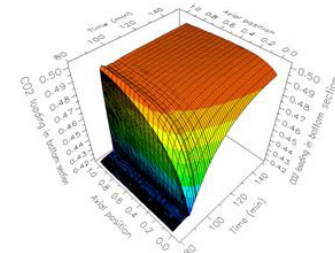
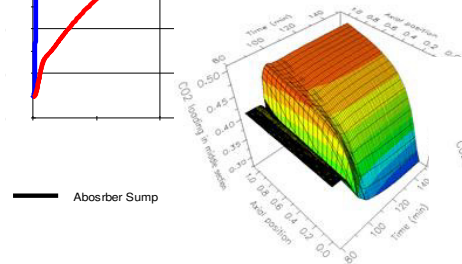
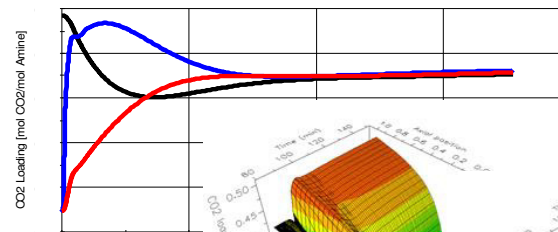
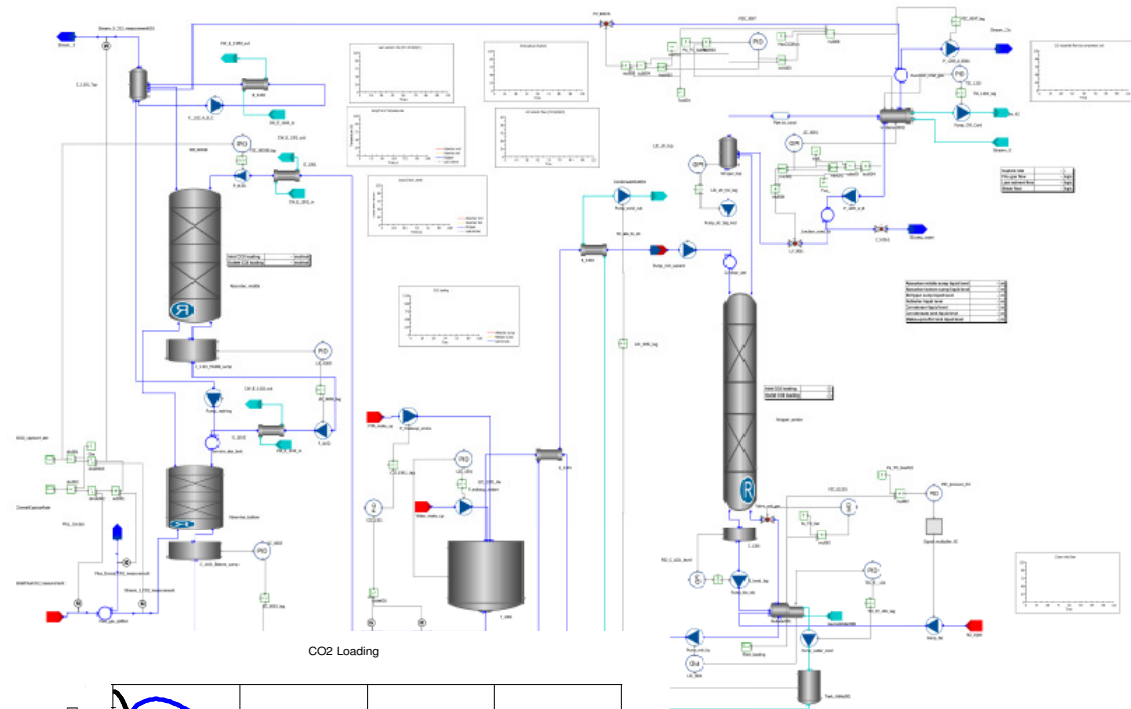


INTRO: SIMULATION PLATFORM



gSAFT

Revolutionising physical property prediction for complex fluids



INTRO: MAIN ASSUMPTIONS

- Flowsheet: [confidential] project
- Solvent: MEA vs. [confidential] Shell proprietary
- Heat losses:
 - constant overall heat transfer coefficient (for each liquid hold up)
 - wall material considered
 - ambient T: 15°C
- column: mono-dimensional
- gSAFT: diffusion vs. kinetic reaction rate
- Boundaries: Flue gas (flow), Steam (flow), CO₂ feed to compressor (flow)

3.1

RESULTS - RUN 1

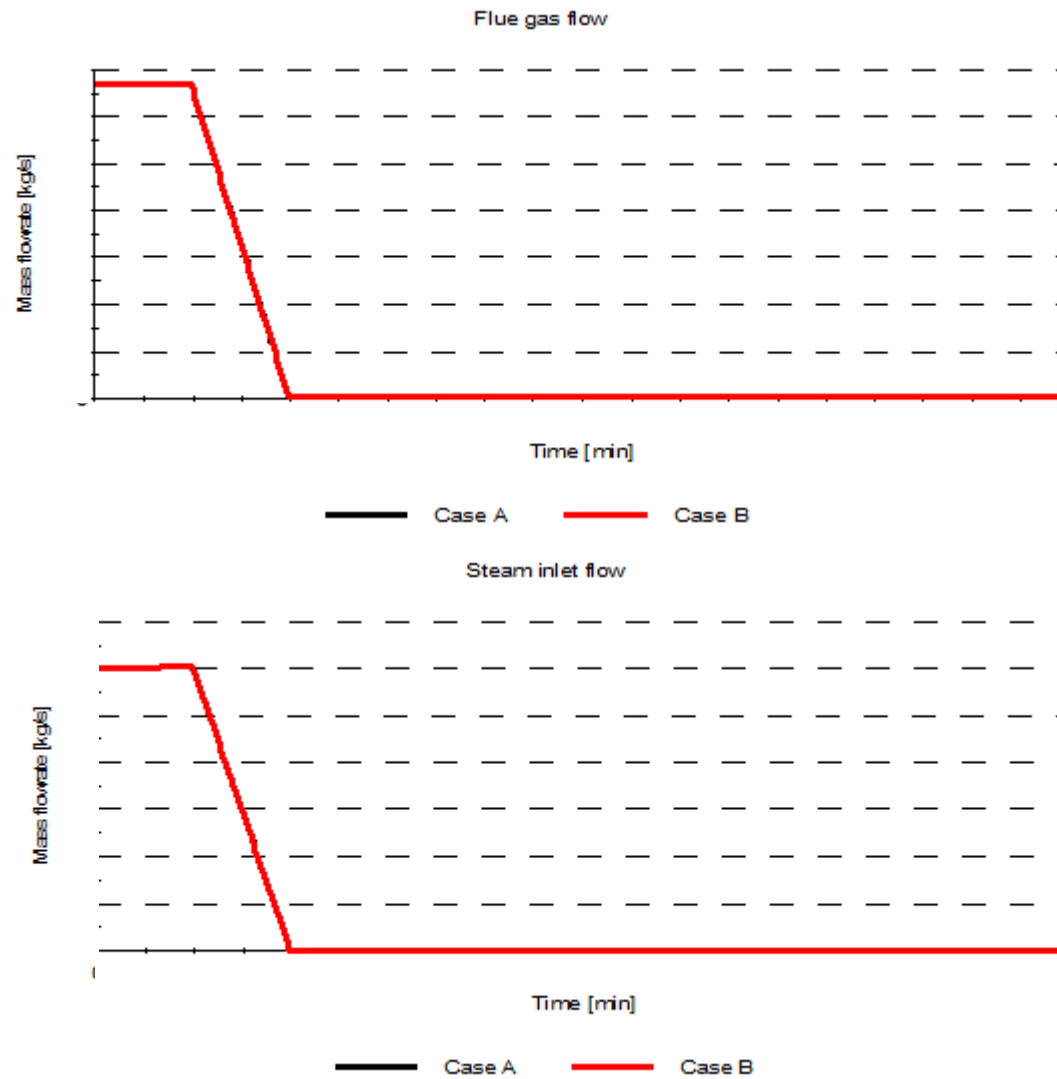
Shut Down

Case A: Full shut down

vs.

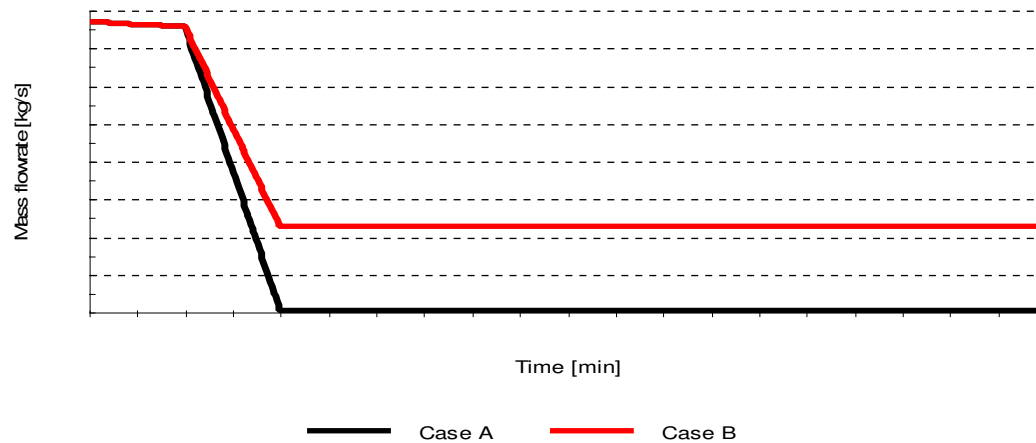
Case B: Partial recycle

RESULTS: RUN1

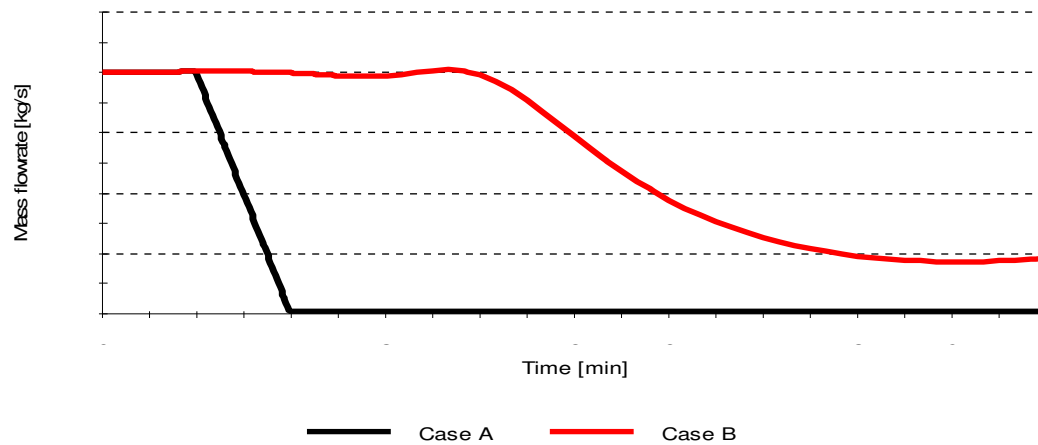


RESULTS: RUN 1

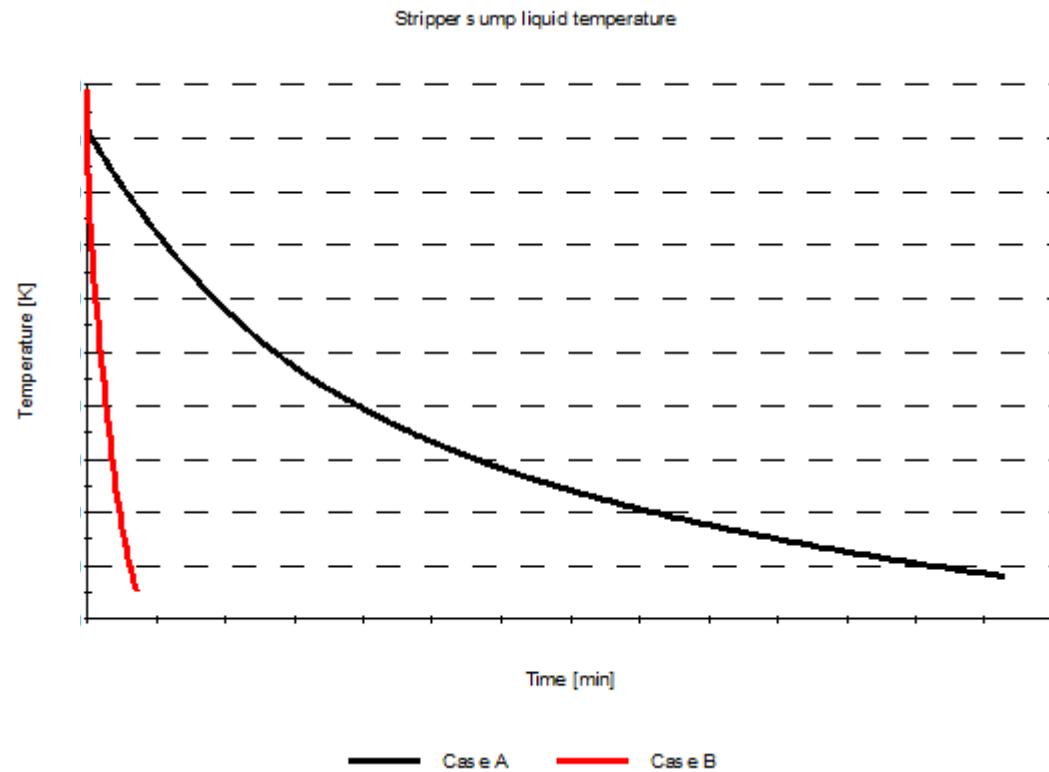
Lean Amine Pump



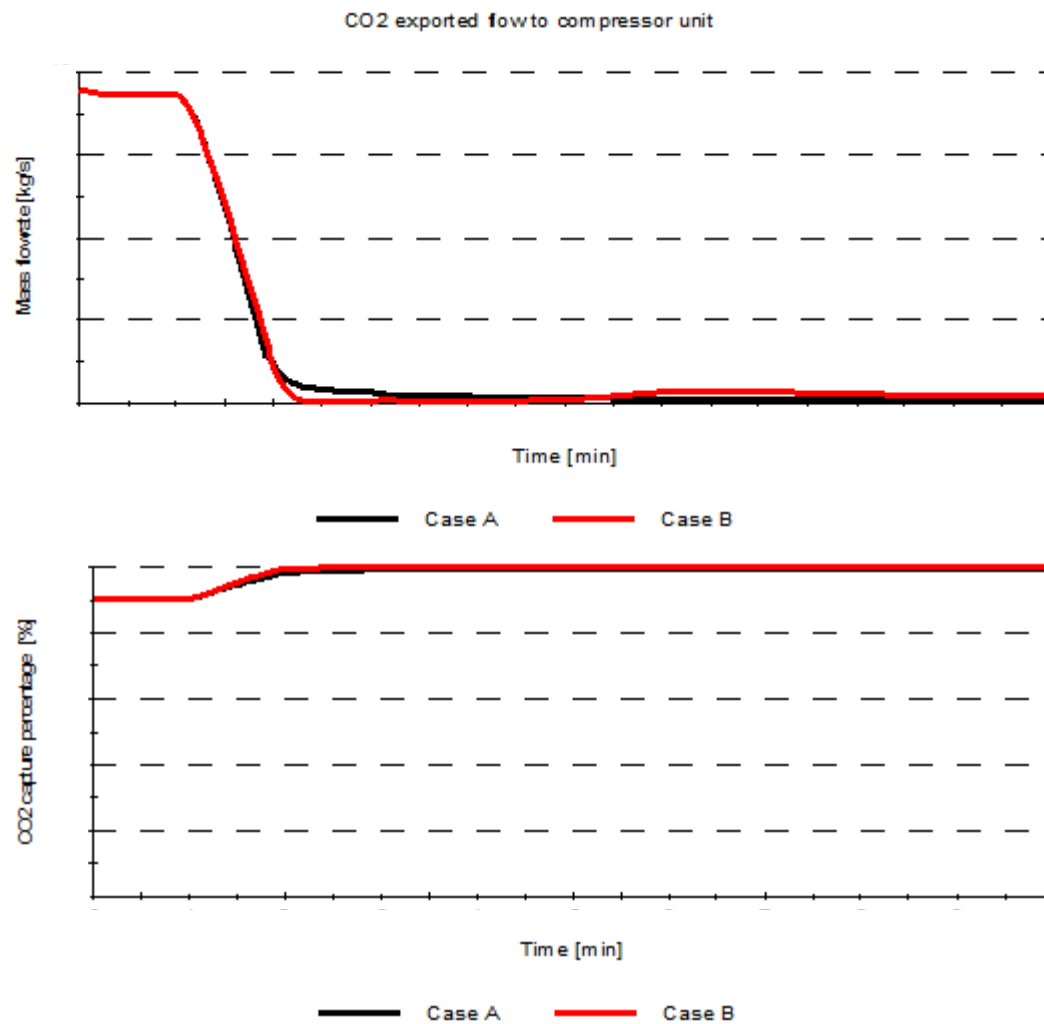
Reach Amine Pump



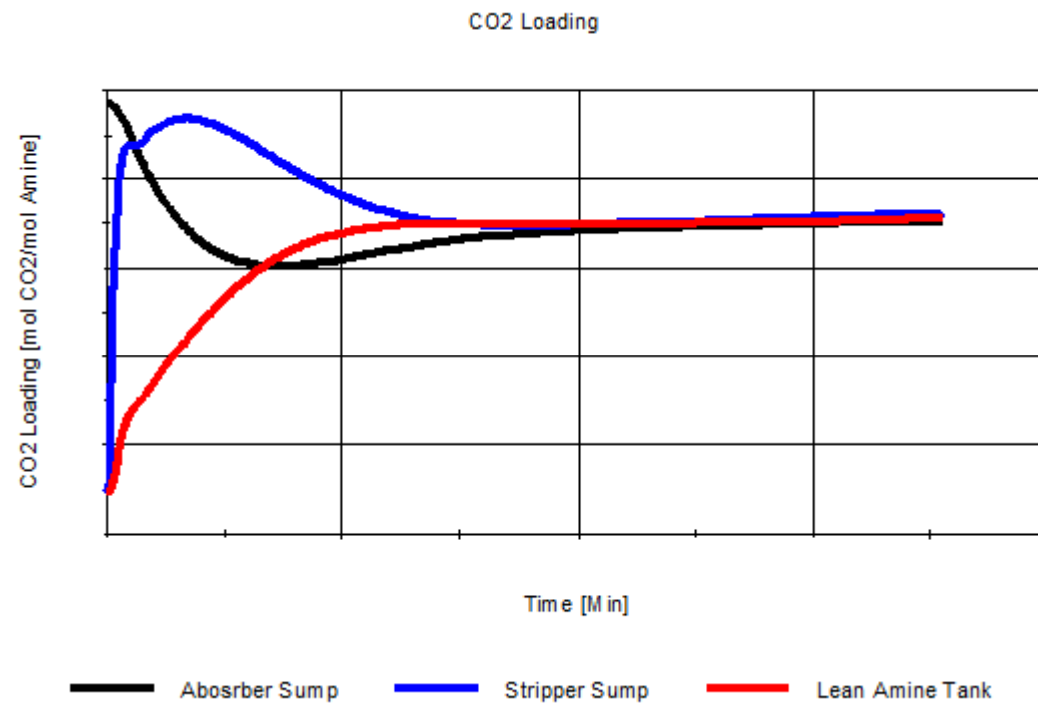
RESULTS: RUN 1



RESULTS: RUN 1



RESULTS: RUN 1



3.2

RESULTS - RUN 2

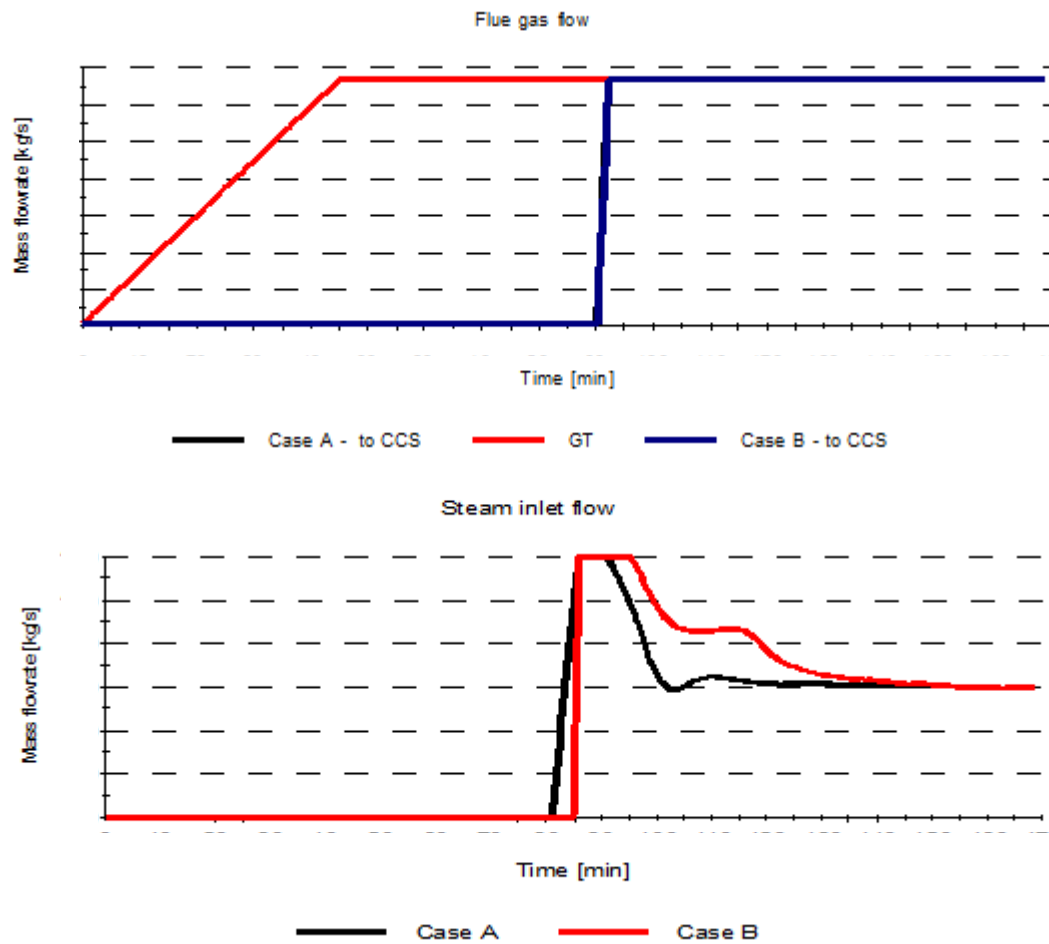
Start up

Case A: warm and blended loading

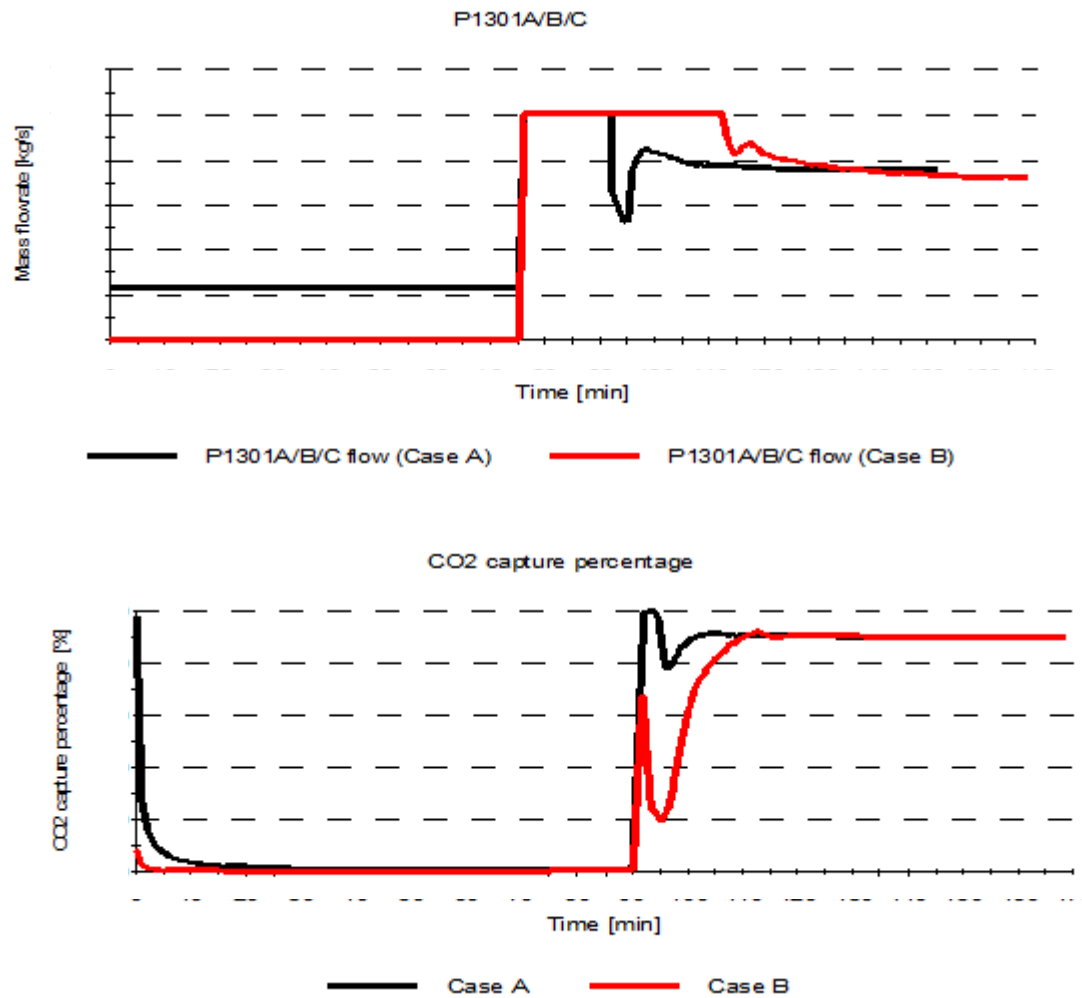
vs.

Case B: cold and saturated solvent

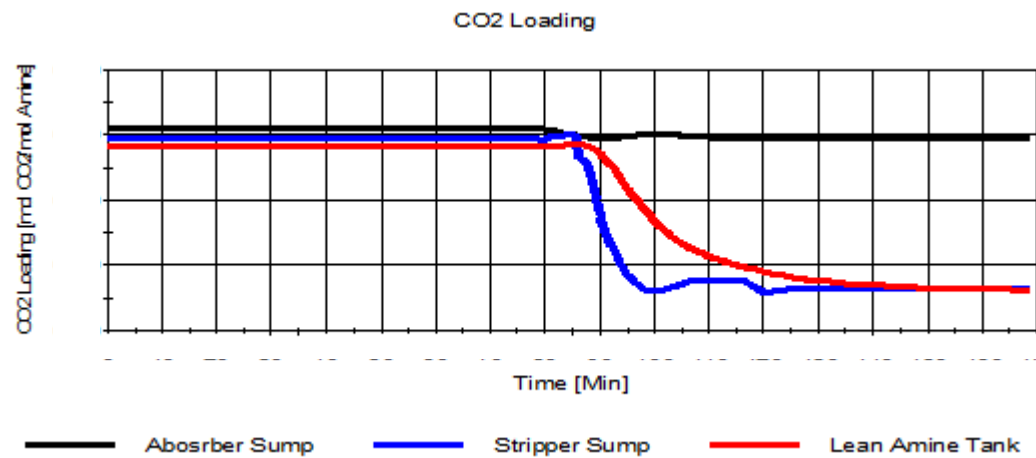
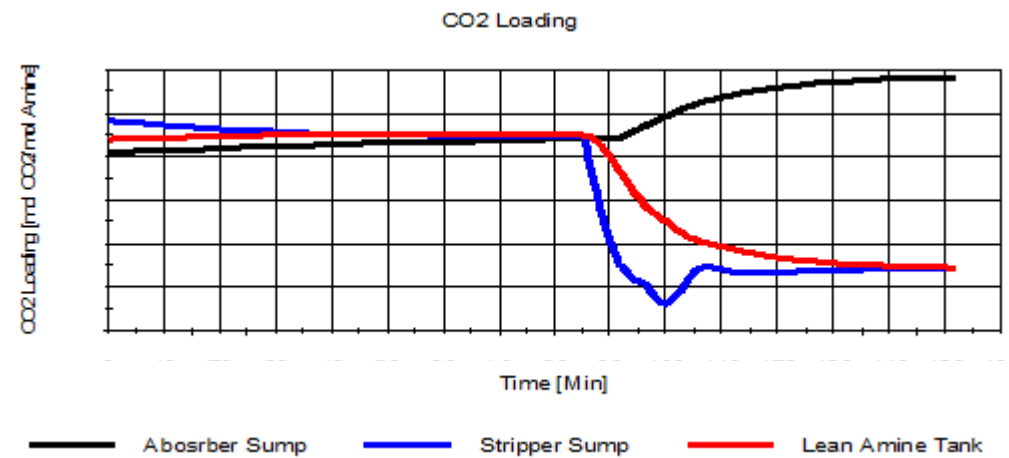
RESULTS: RUN2



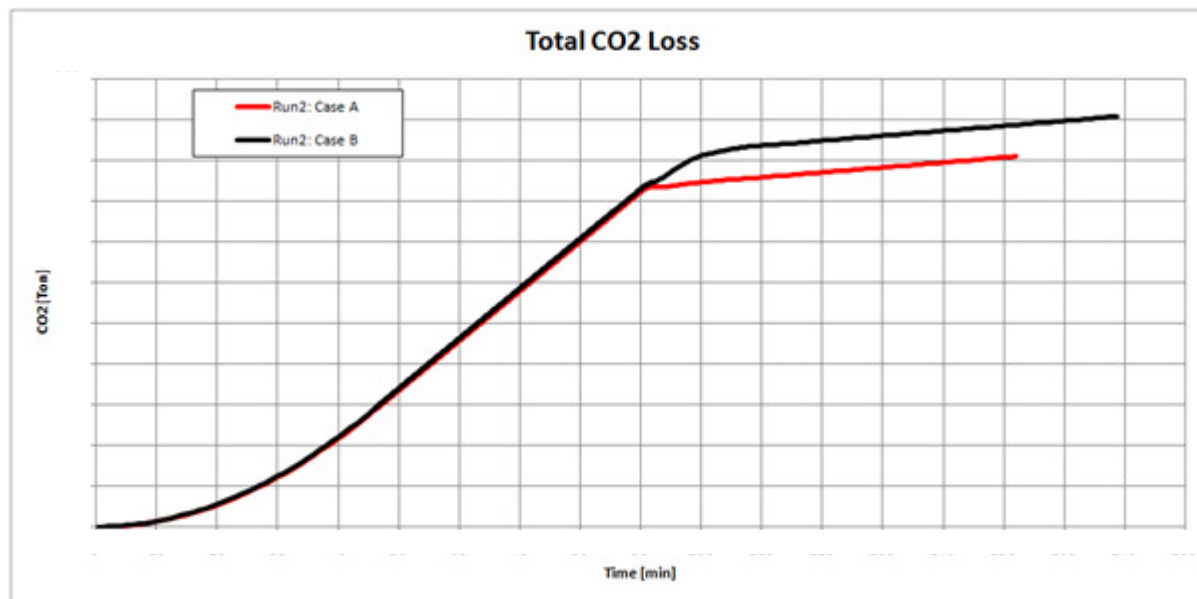
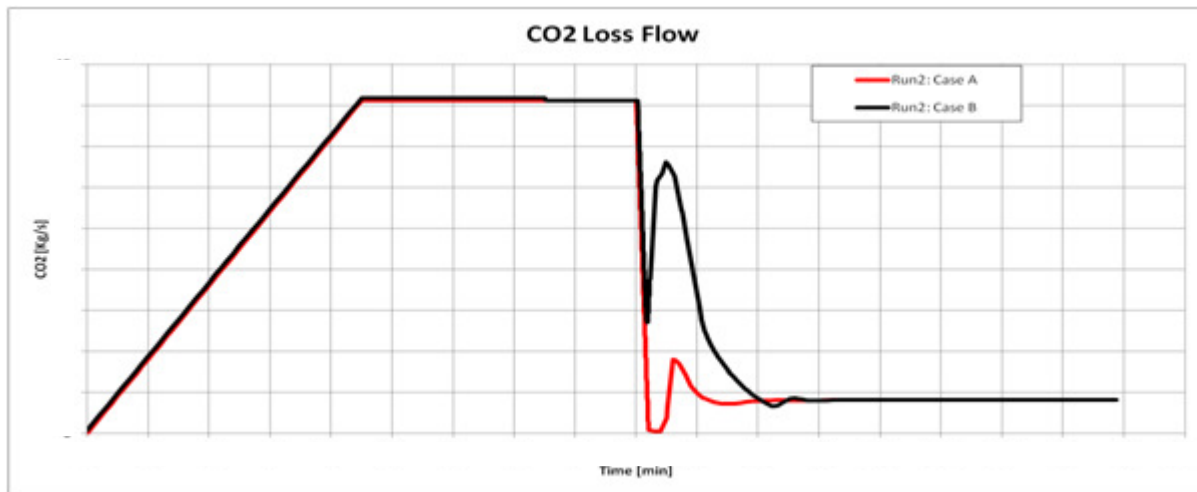
RESULTS: RUN2



RESULTS: RUN2



RESULTS: RUN2



3.3

RESULTS – RUN 3

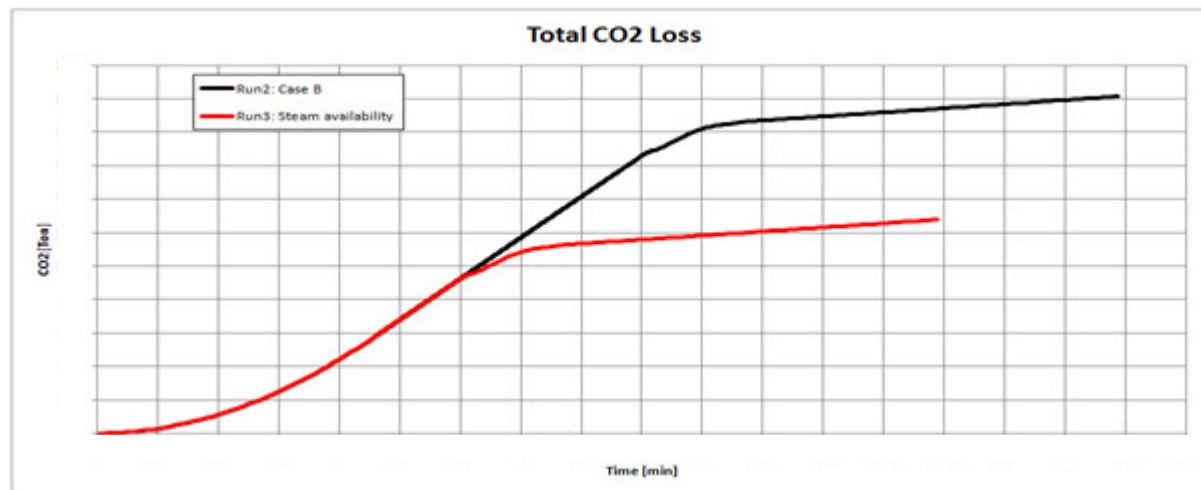
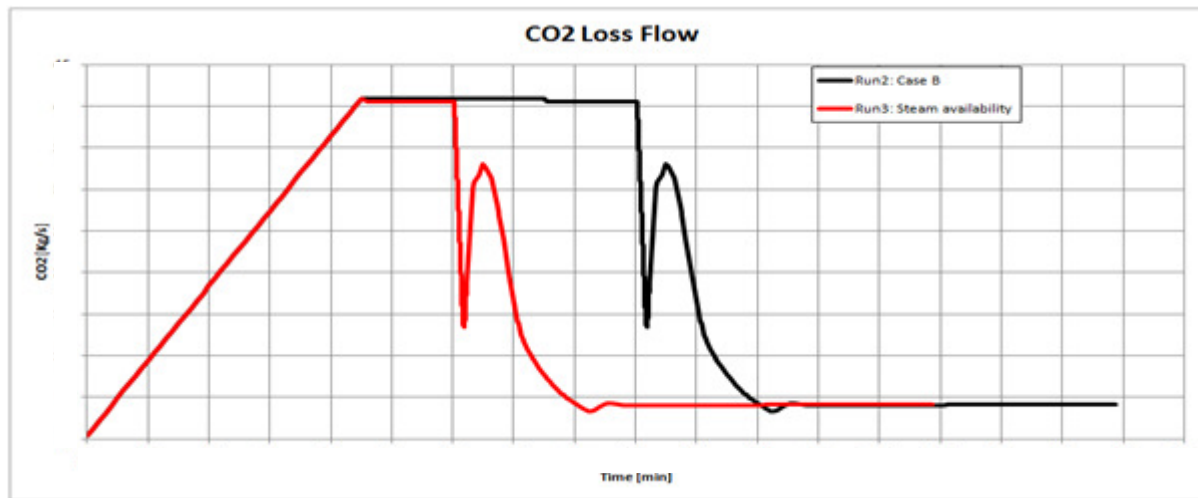
Start up

Case A: external steam available

vs.

Case B: steam from ST

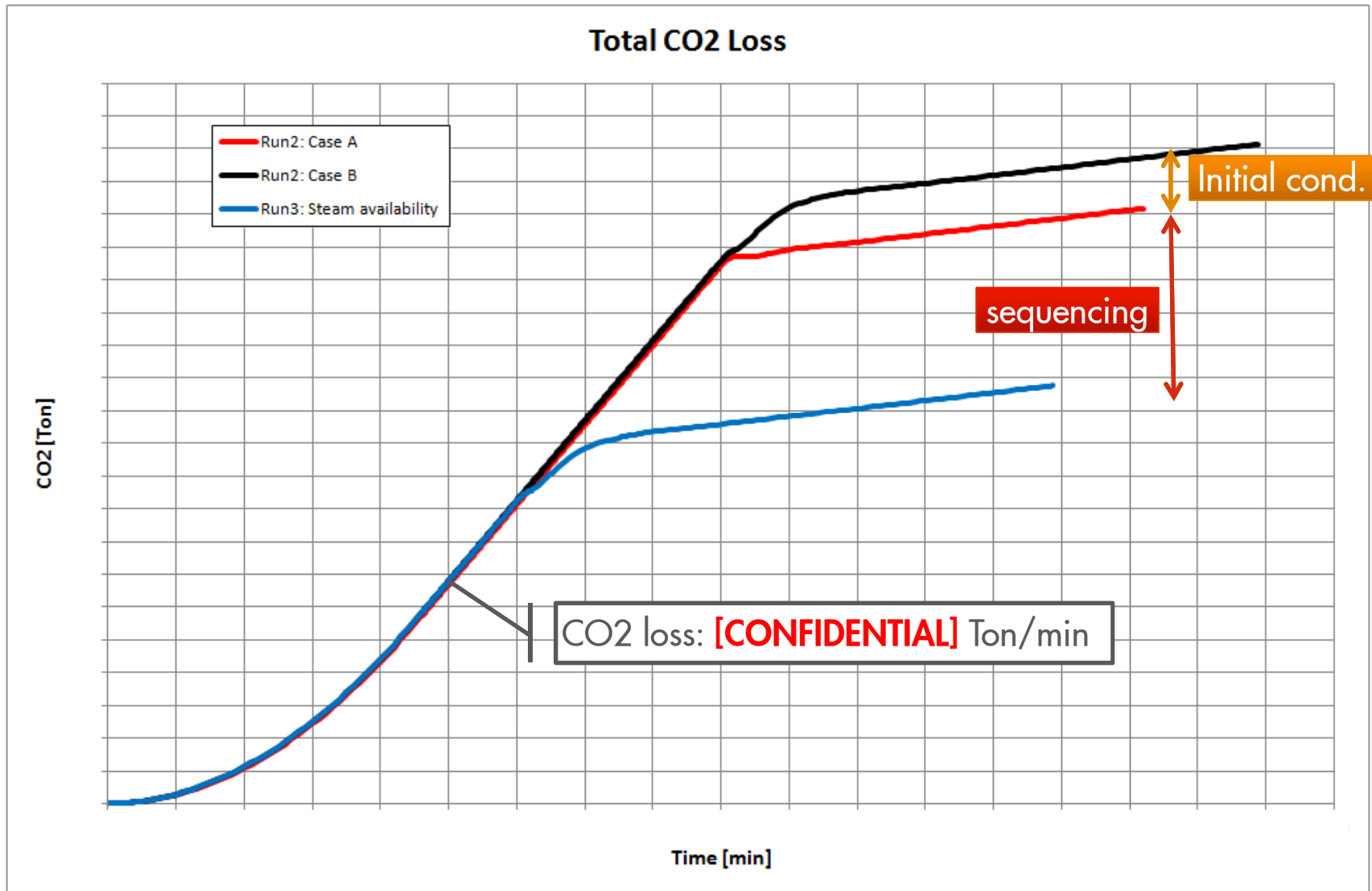
RESULTS: RUN3



CONCLUSIONS: FINDINGS

- Simulation runs show that the process itself is not the major delaying factor in achieving low CO₂ power production.
- The result confirms that the driving factors in defining capture unit performances in terms of CO₂ emissions relies in minimizing latency spent to “get ready for the unit start-up” :
 - availability of heat source for stripper column
 - availability of flue gas pre-treatment unit
 - availability of compression unit

CONCLUSIONS: FINDINGS



Q & A