SEVENTH FRAMEWORK PROGRAMME

OCTAVIUS

OPTIMISATION OF CO_2 CAPTURE TECHNOLOGY ALLOWING VERIFICATION AND IMPLEMENTATION AT UTILITY SCALE

Dynamic and control of an absorber - desorber plant
Case study of the Heilbronn plant

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Background and motivation

- **The absorber – desorber plant will frequently not be at steady state because of**
  - **Various loads at the power plant – Flue gas flow and CO2 concentration**
  - **Other disturbances: Steam pressure, plant constraints, weather conditions, solvent degradation, etc**

- **Important with good control structures to optimize the plant also under transient periods**

- **First steps for control studies**
  - **Provide a good dynamic model of the plant**
  - **Validate the model with data from the plant**

Dynamic model

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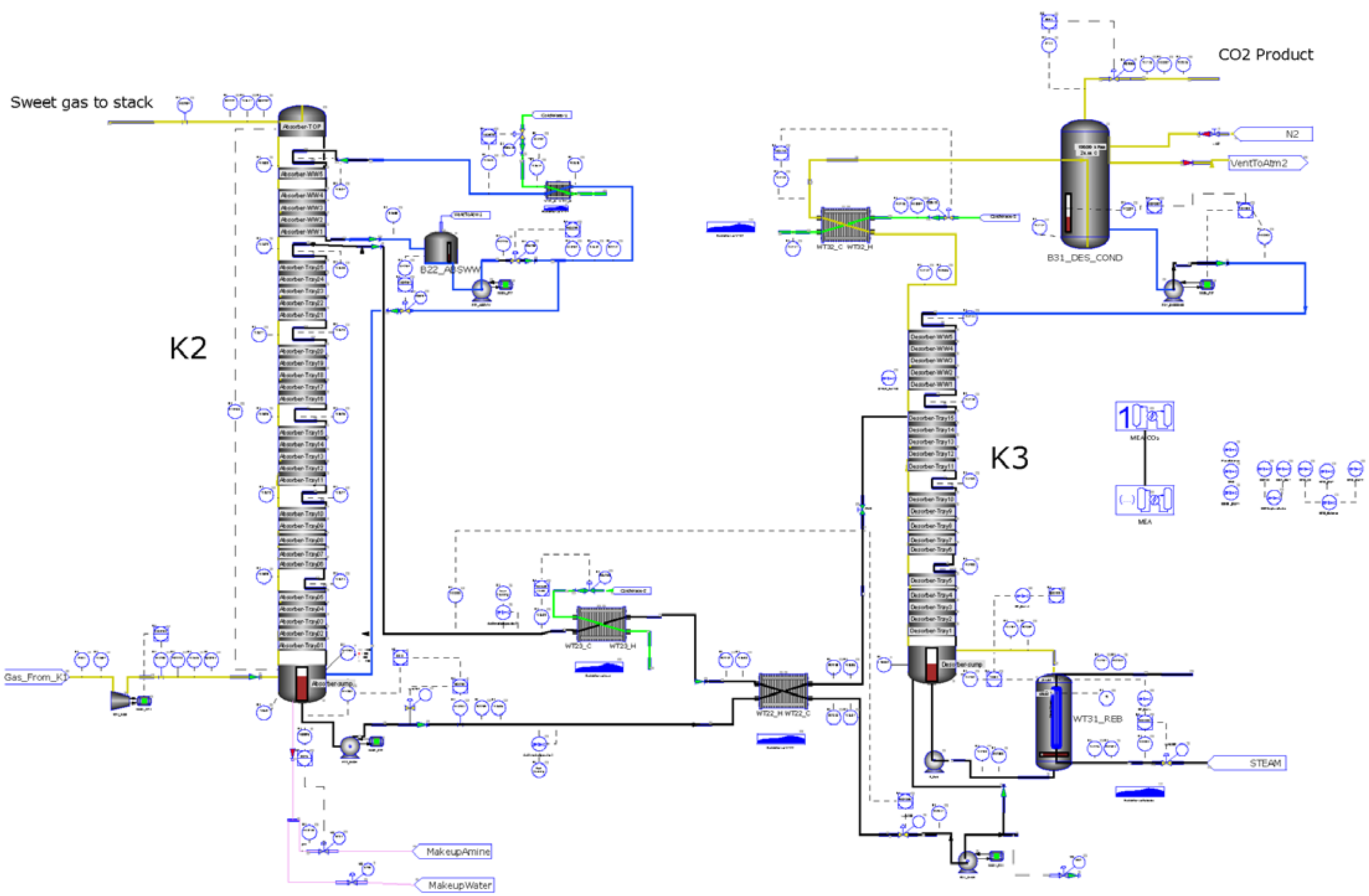
- **Dynamic models of the Brindisi and the Heilbronn plant was developed in WP 11.4 using K-Spice**
- **K-Spice is a general dynamic process simulator from Kongsberg**
  - **Extensive experience from oil and gas industries**
  - **Engineering simulators**
  - **Operative training simulators**
  - **Process safety checks**
  - **Operator procedure verification**

- **SINTEF/NTNU needed to:**
  - **Set up the process simulation flowsheet with all units and connections.**
  - **Provide dimensions and design parameters for all process units**
  - **Implement thermodynamic tables for MEA equilibrium, physical properties**
  - **Implement control structures, valve characteristics etc.**
  - **Specify inlet stream specifications and other boundary conditions**

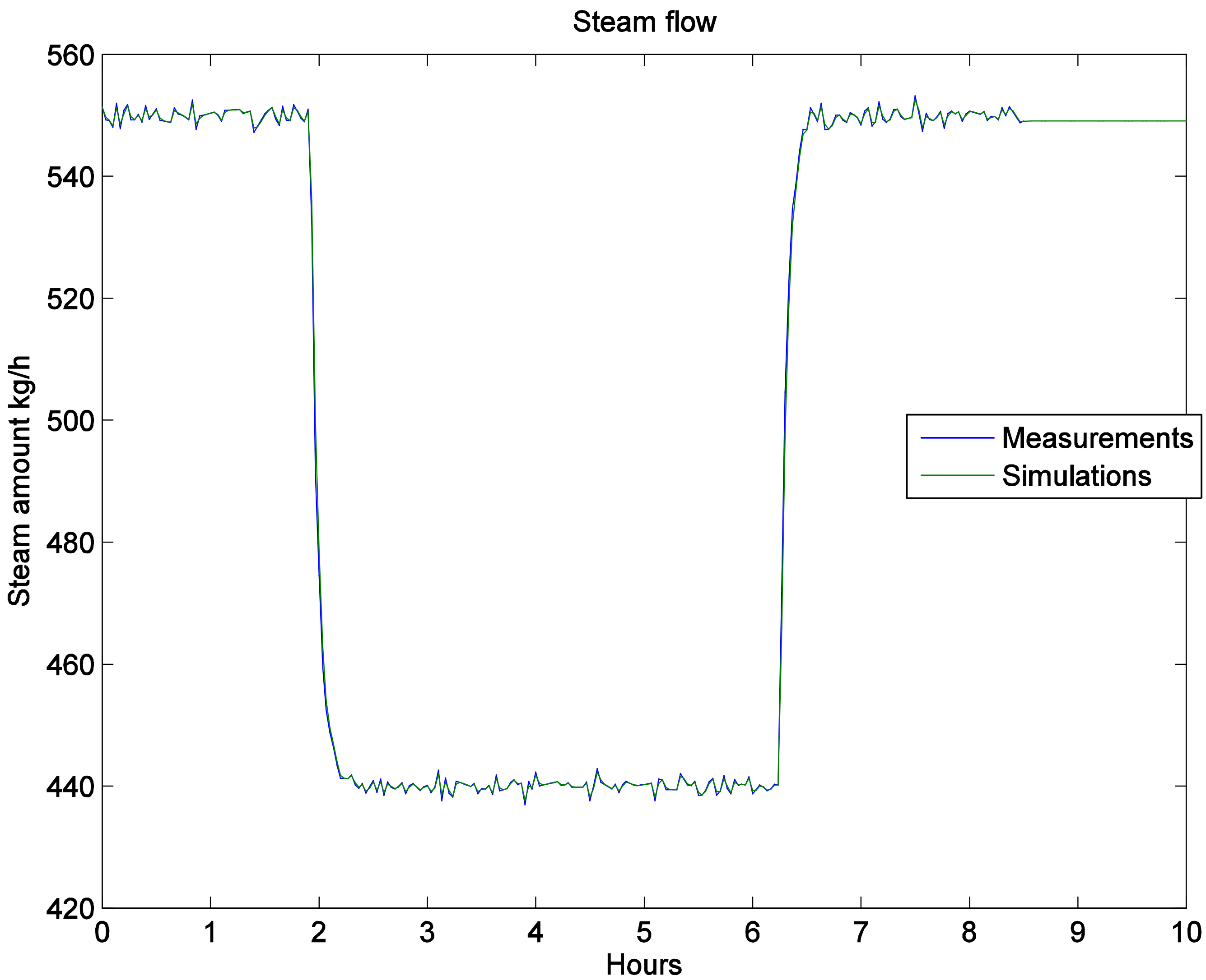
K-SPICE model for the Heilbronn pilot



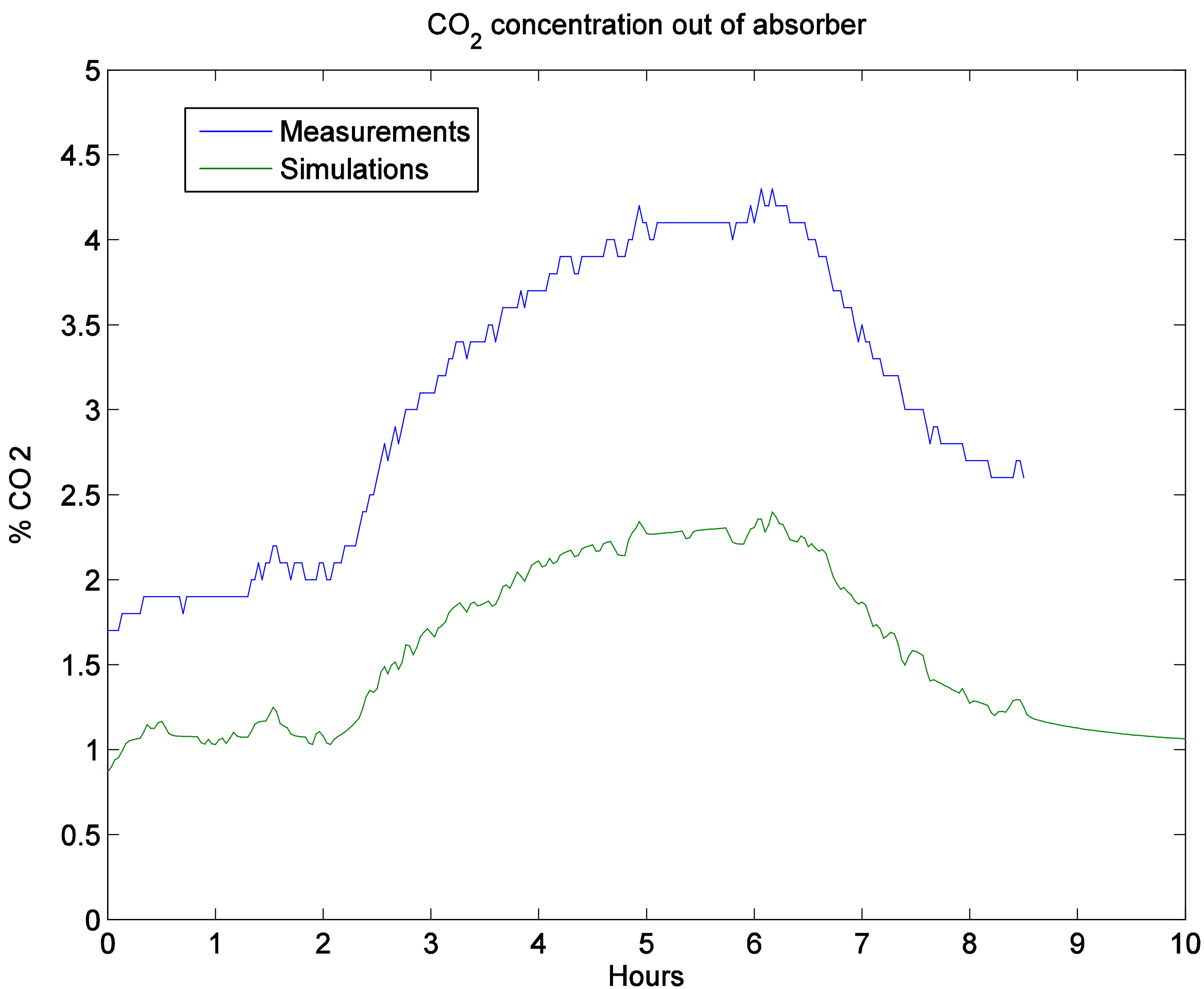
Tests performed in the campaign

1) Step in reboiler duty at liquid rate 4 m^3/h
2) Step in reboiler duty at liquid rate 6 m^3/h
3) Step in liquid circulation rate
4) Step in gas flow
5) Variation of CO2 in gas flow
6) Simultaneous step decrease of gas flow, liquid rate and reboiler duty.

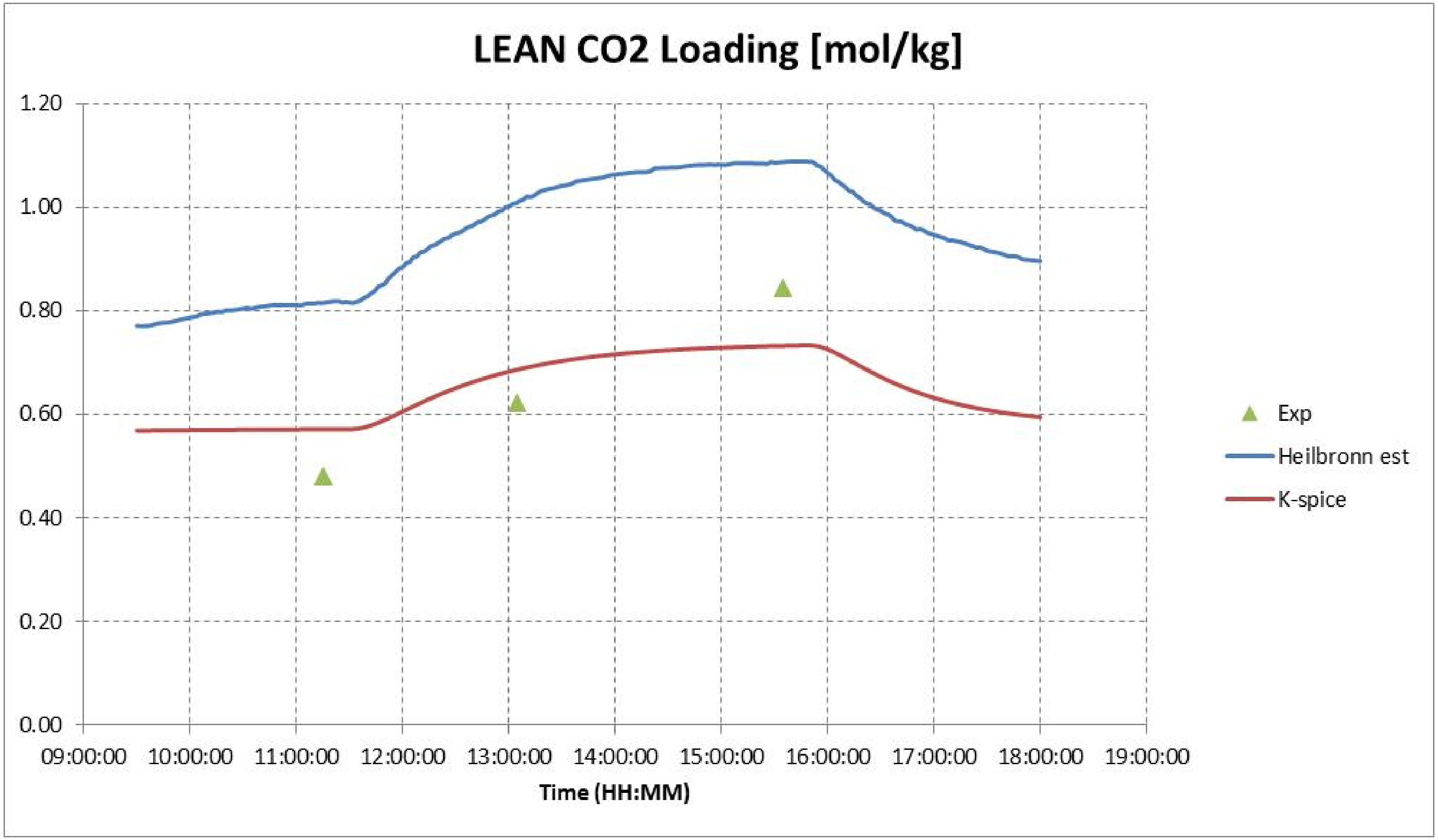
Dyn1: Step down in reboiler duty, Liq=4 m^3/h



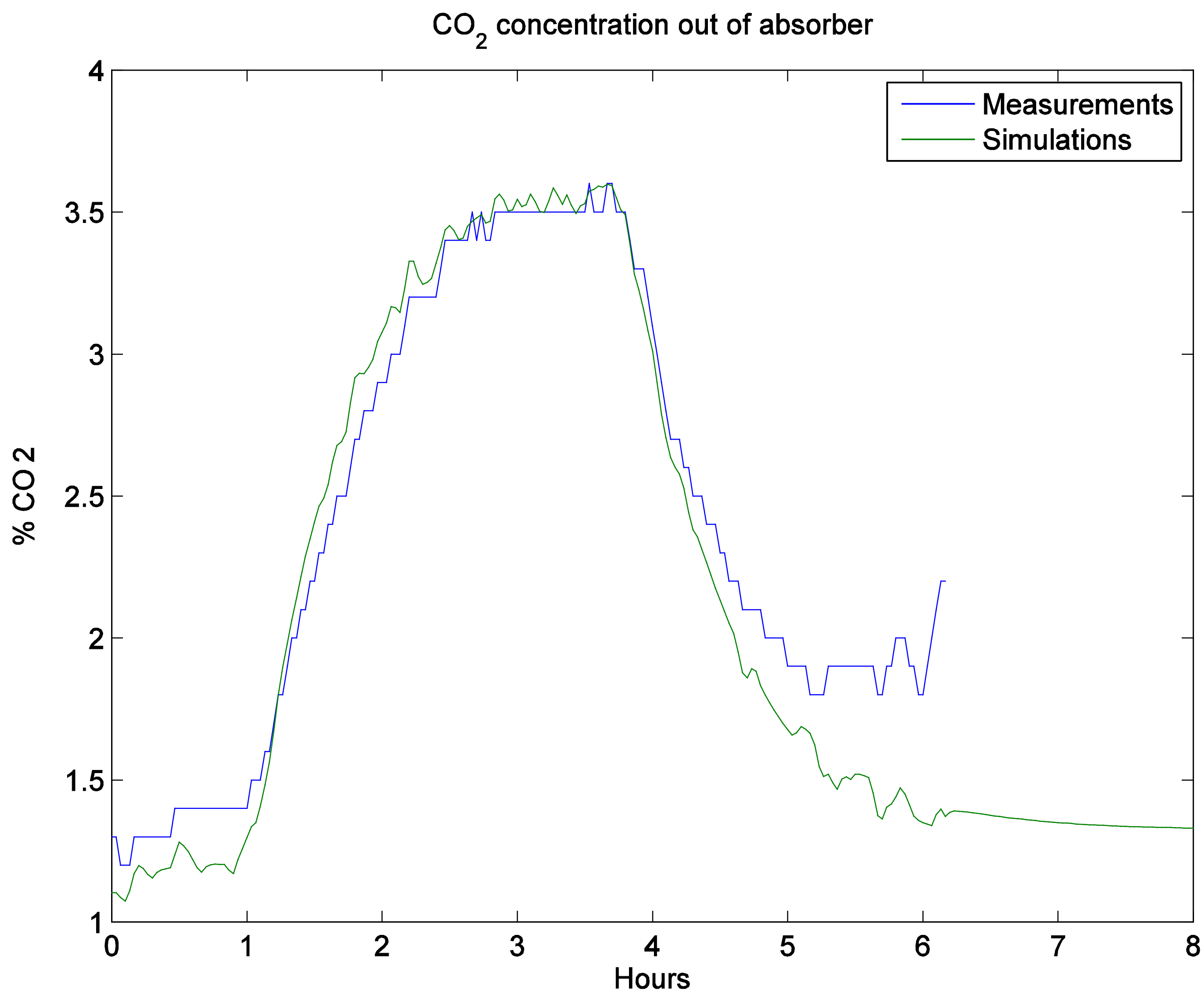
Dyn1: Step down in reboiler duty, Liq=4 m^3/h



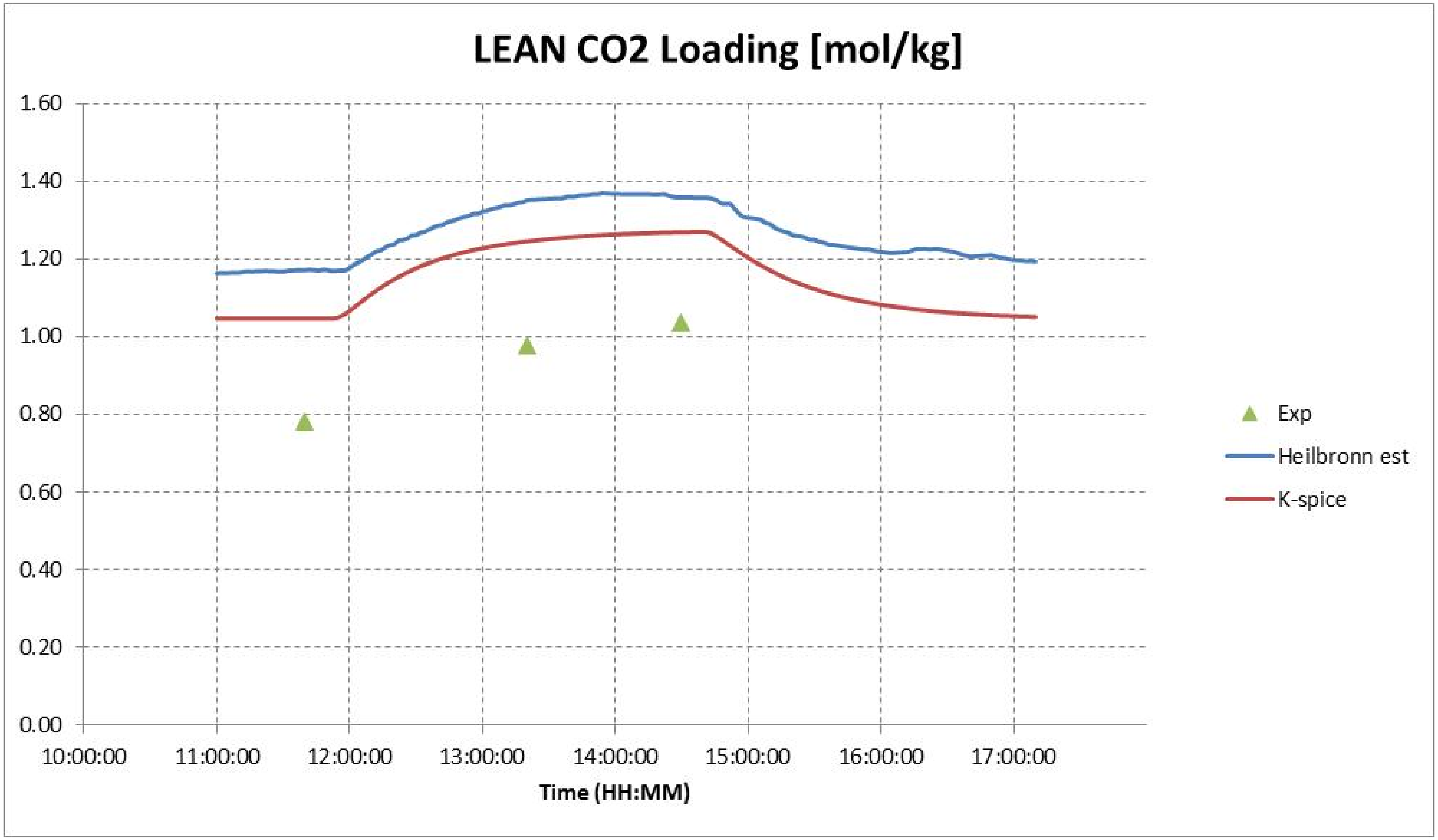
Dyn1:Step down in reboiler duty, Liq=4 m^3/h



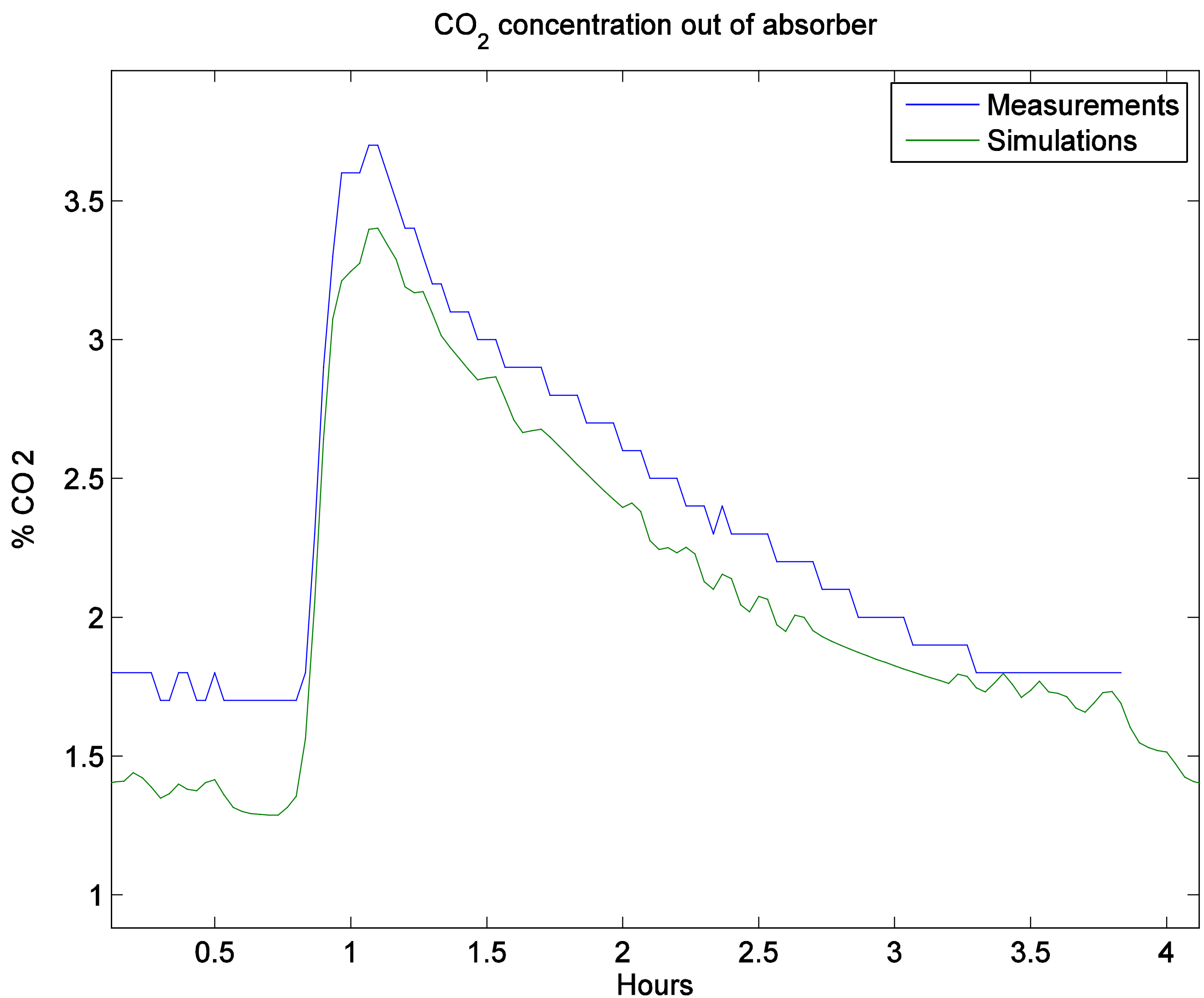
Dyn2: Step down in reboiler duty, Liq=6 m^3/h



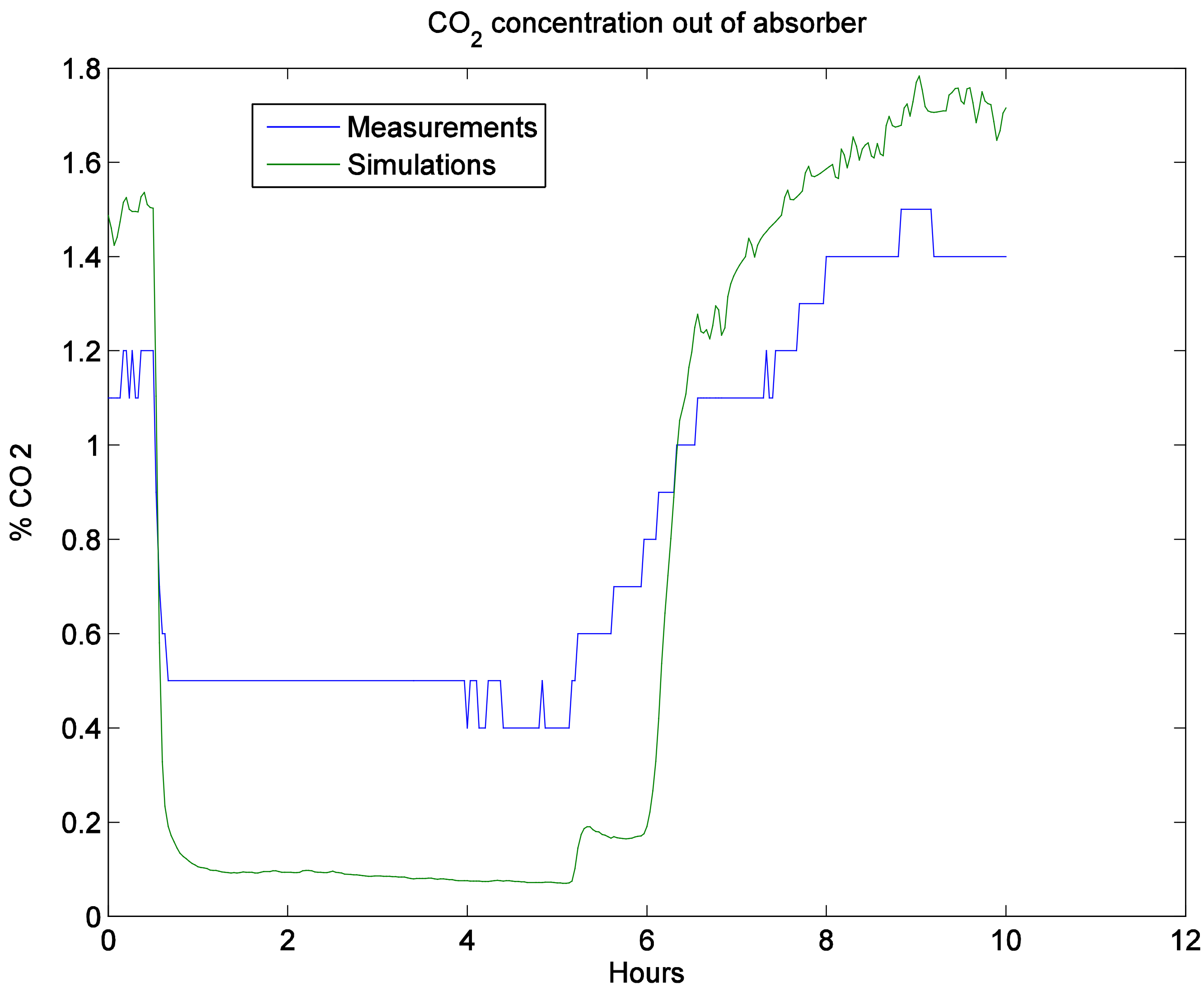
Dyn2: Step down in reboiler duty, Liq=6 m3/h



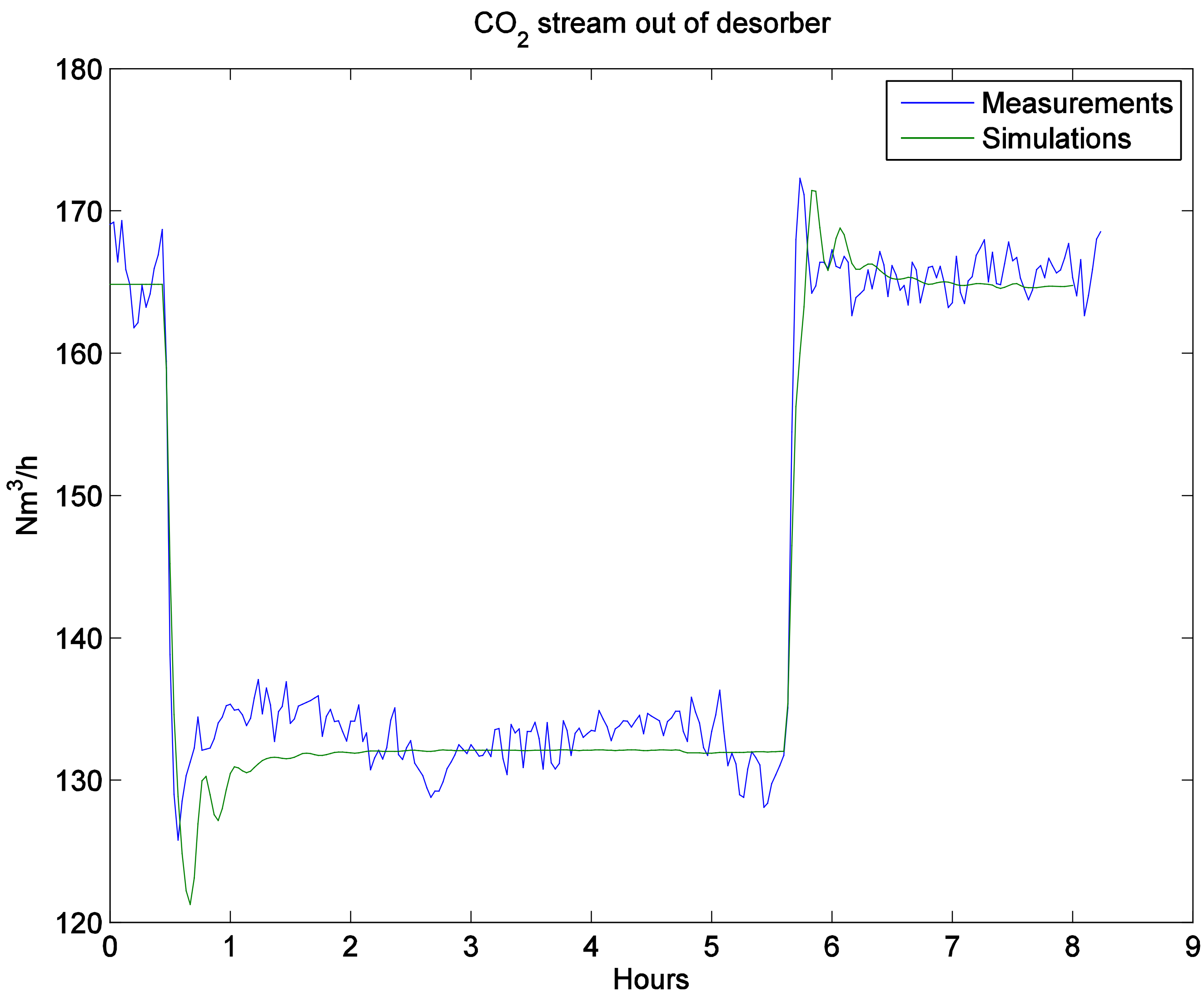
Dyn3: Step down in solvent flow rate



Dyn4: Step down in gas flow rate



Dyn6: Simultaneous decrease of flows



Dyn 6: Simultaneous decrease of flows

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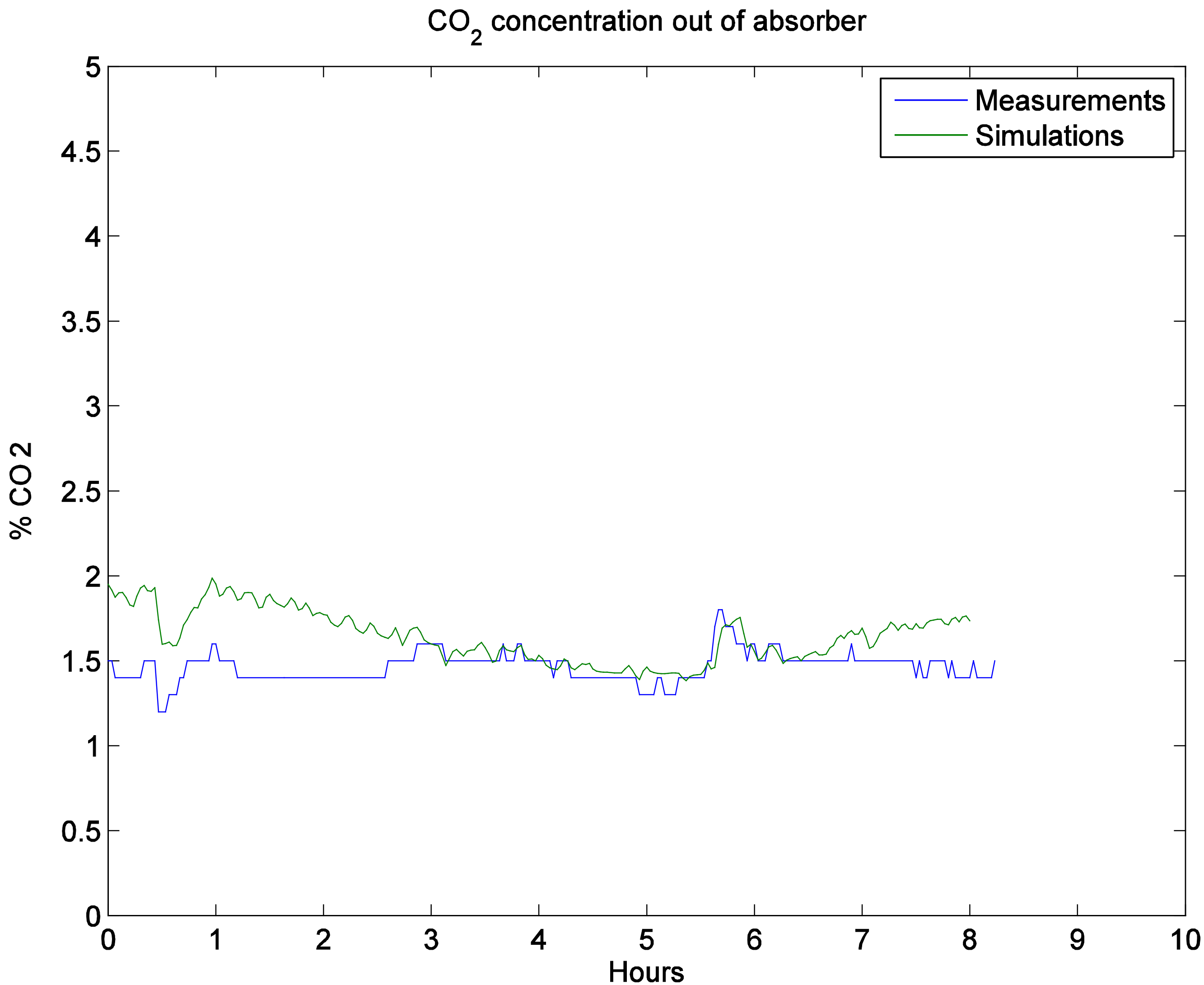
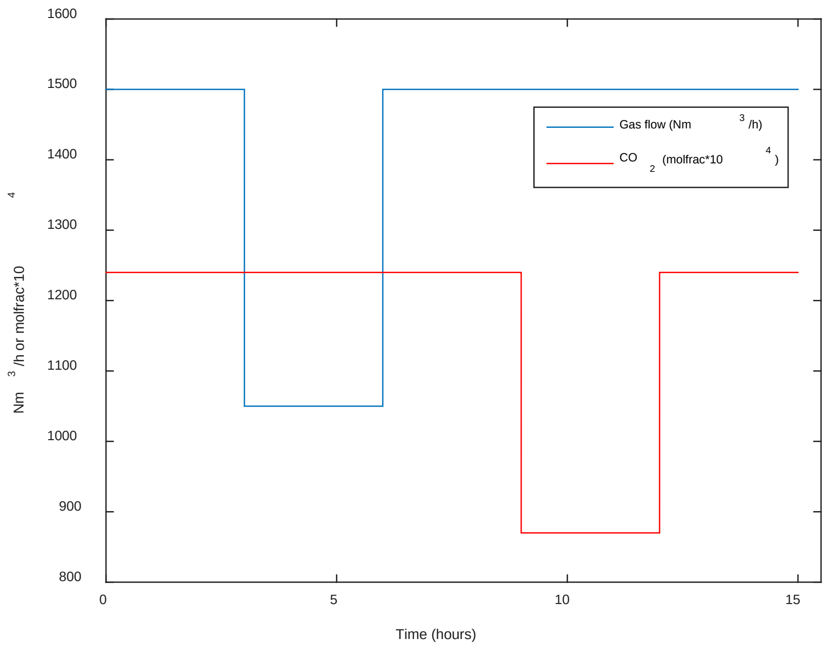


Summary of the dynamic tests

- The model is able to capture the process dynamic behavior well.
- Some steady state deviations.
- Almost no changes of the outlet CO_2 concentration when changing all variables with 20%. Ratio control seems to work well.
- Similar dynamic tests was performed at the Brindisi plant. The work was presented at GHGT-12 in Austin, Texas

Control study

- **Control objectives**
  - **90% capture rate**
  - **Minimum specific reboiler duty (SRD) in MJ/kg CO2 captured**
- **Testing step changes in flue gas flow and composition**



  - **Gas flow rate: 1500 – 1050 Nm^3**
  - **Concentration CO_2: 12.4% - 8.7%**

Two control structures tested

- **Con1: Use of ratio control (kind of feed forward control) in combination with a slow feed back control on the CO2 out of the absorber. The control structure is based on the results from the campaign.**
- **Con2: Control of the CO_2 out of absorber by lean liquid rate while keeping a temperature up in the desorber constant. This is a suggestion from the literature by Skogestad et al. on the basis of the "self optimizing control" concept.**
- **Both structures are quite simple to implement**

K-SPICE model for the Heilbronn pilot

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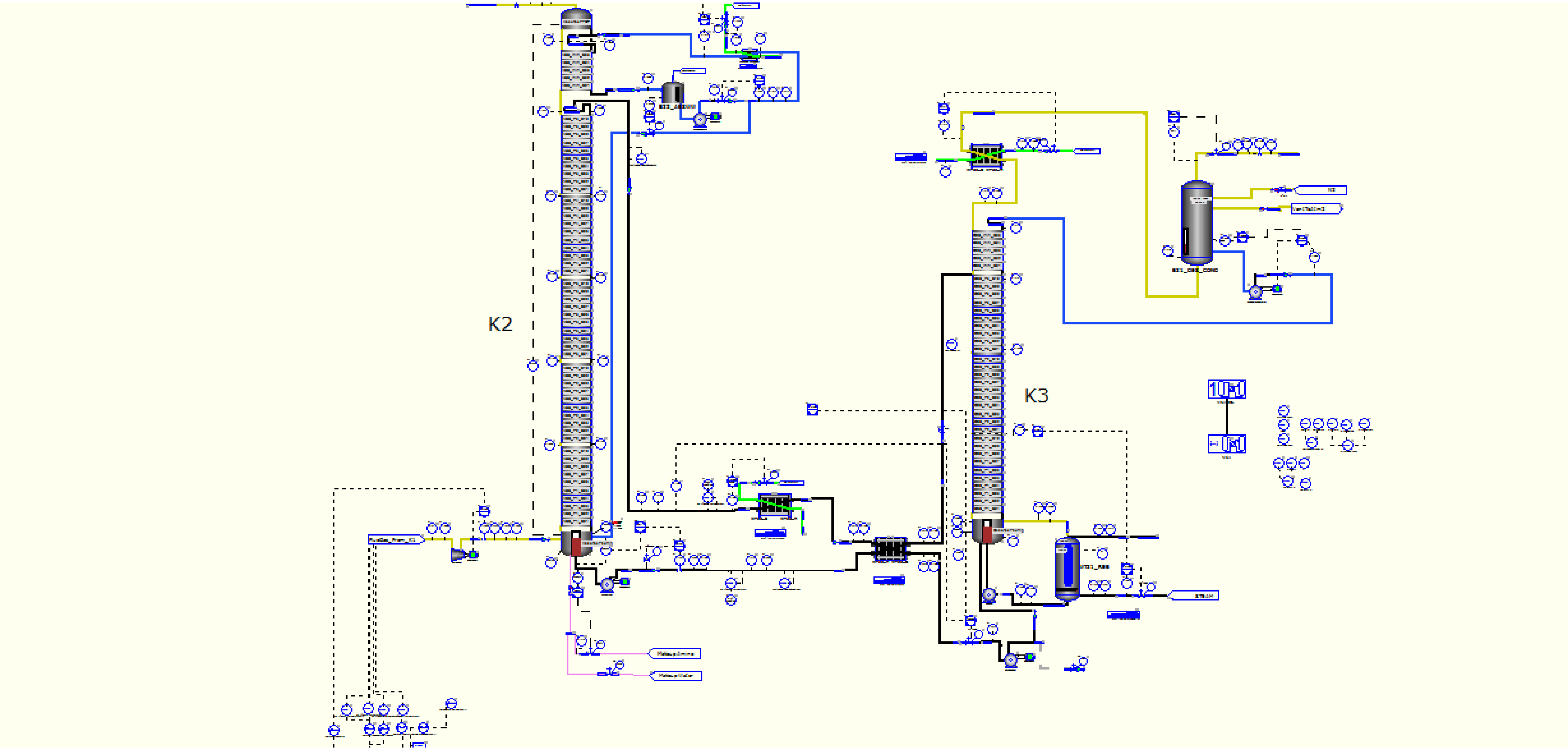

Optimal steady state as a starting point

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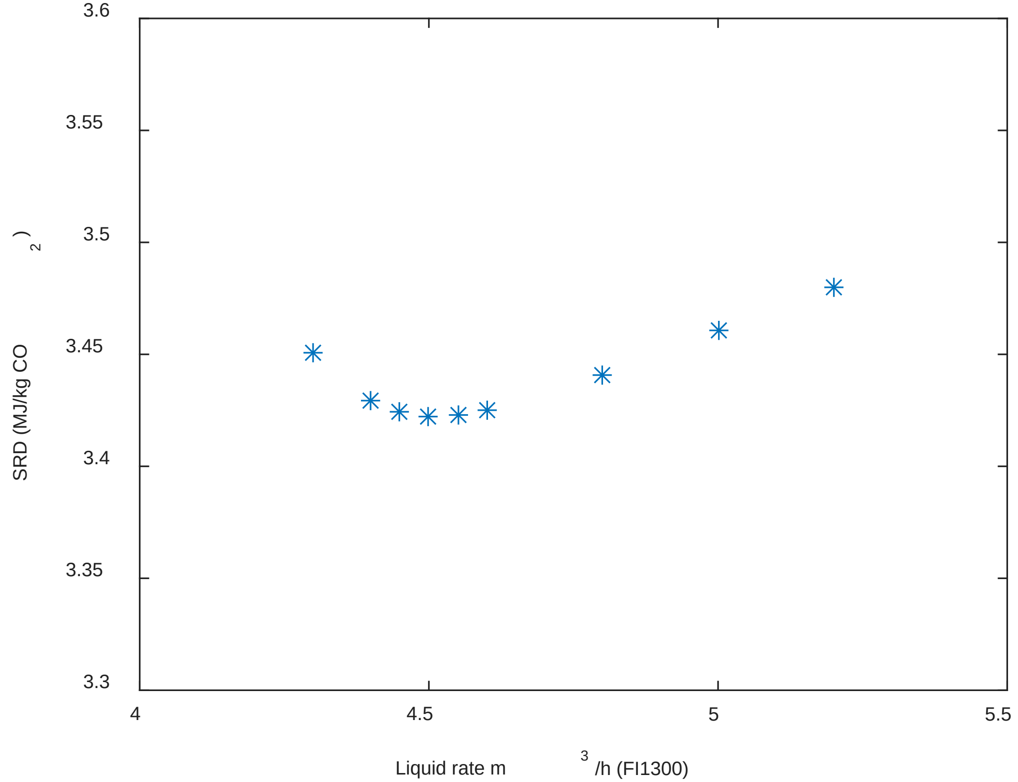
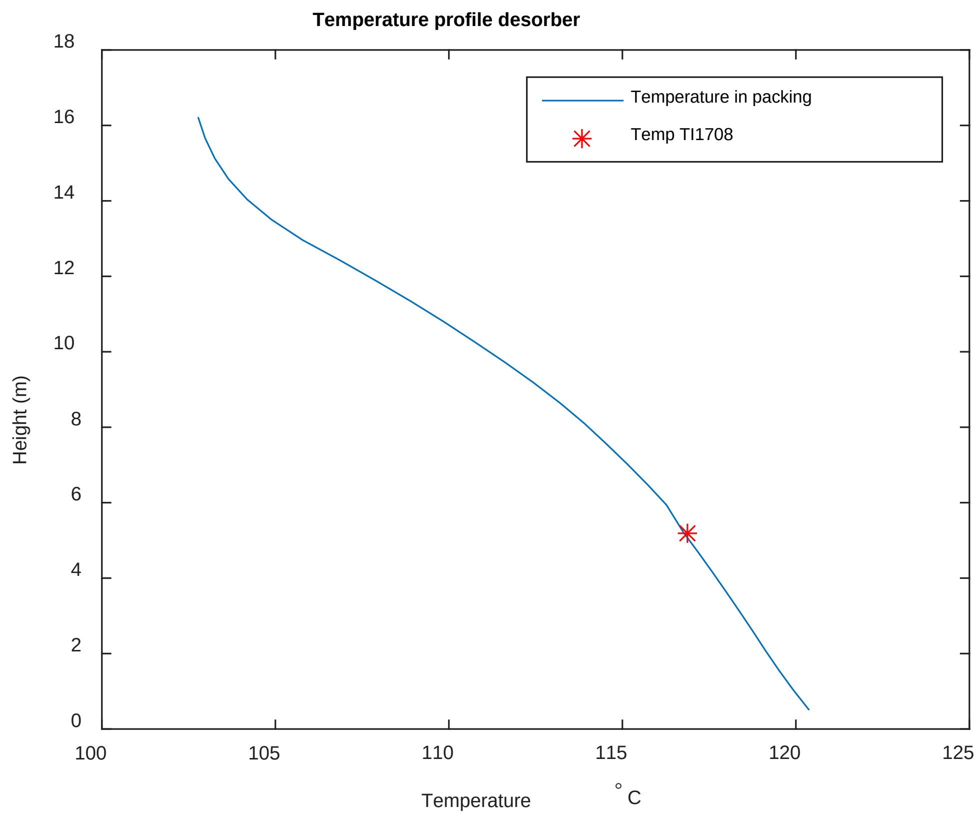


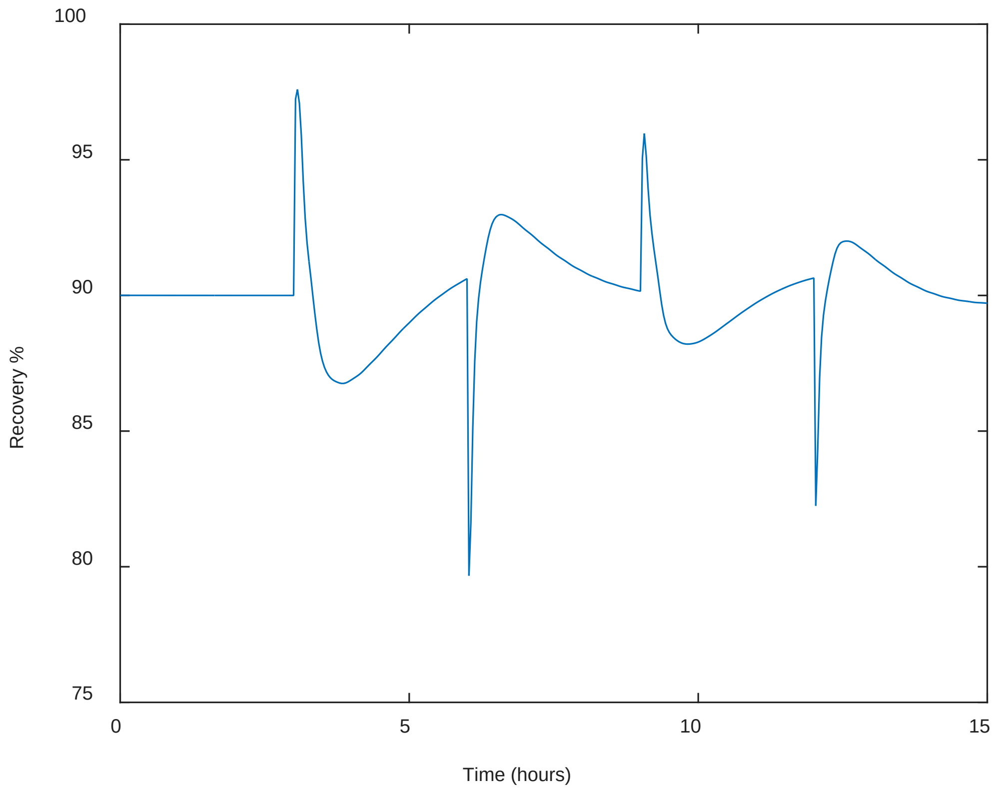
All runs 90% capture. Optimal liquid rate 4.5 m3h SRD=3.420 MJ/kg CO_2

Optimal steady state point



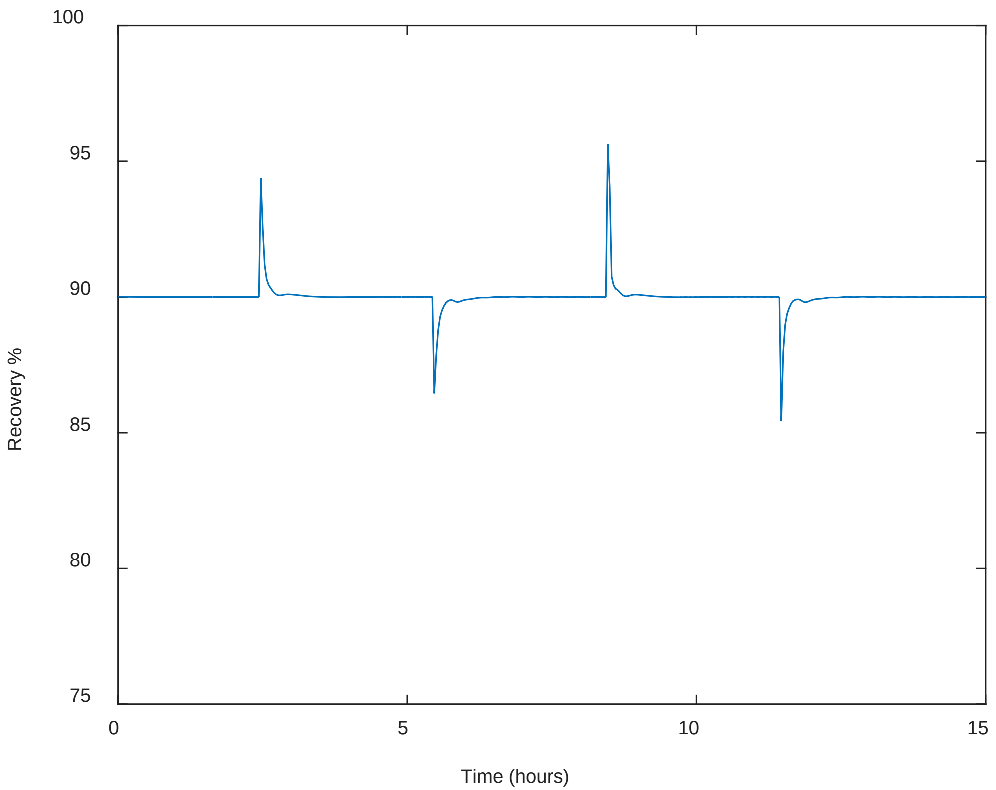
Temperature profile desorber
Con2: Keep the TI1708 between section 1 and 2 constant

Result of simulation Con1 (ratio control)



- **Reboiler duty and liquid rate proportional to the amount of CO_2 in the flue gas.**
- **A slow cascade control to keep 90% recovery by reboiler duty .**

Result of simulation Con2



- **Liquid flow to control 90% recovery.**
- **TI1708 in the desorber is kept constant by reboiler duty.**

Comparison

	Recovery %		SRD MJ/kg CO2	
	mean	std	mean	std
Con1:	90.05	1.755	3.426	0.052
Con2:	90.00	0.521	3.420	0.077

- **The mean value for recovery and SRD very similar for Con1 and Con2 and the optimal steady state case.**
- **Tighter control of the recovery with Con2**
- **Con2 should be preferred.**

Summary

- A dynamic model of the Heilbronn plant was implemented in K-Spice and tested against step responses at the plant.
- In spite of some stead state deviations, the model was able to capture the process dynamics very well.
- One may therefore assume that dynamic studies using the model will be representative for the plant.
- The plant was simulated for 15 hours with 30% steps in gas flow rate and CO_2 concentrations.
- The average specific reboiler duty (SRD in MJ/kg CO_2) over the time frame was similar and close to optimal
- However, the Con2 showed tighter control of the recovery and should be preferred.